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Zinc Accumulation in the Upper Waitemata Harbour – Benefits of Source Control

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Zinc Accumulation in the Upper Waitemata Harbour – Benefits of Source Control

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1 Executive Summary

Predictions have been made of zinc, copper and PAH (polycyclic aromatic hydrocarbon) accumulation in bed sediments of the Upper Waitemata Harbour (UWH) for 50 and 100 years into the future under a number of development scenarios.

In this follow-up investigation, we determine the environmental benefits in the UWH associated with a range of zinc source control options that might be implemented in the catchment.This was achieved by re-running the USC-2 model over the 100-year timeframe with zinc loads modified to reflect six source control options. In effect, each source control option is applied to the development #1 scenario. This is the "benchmark" scenario used to date in the UWH study; it features projected (realistic) development and stormwater treatment in the catchment.

The results are shown by:

(1) Plots of how the zinc concentrations in estuary bed sediments are predicted to change over the next 100 years.

(2) Tabulations of times to Environmental Response Criteria (ERC) sediment-quality "traffic light" exceedance.

(3) Circle diagrams depicting the reduction in mass of zinc deposited in the harbour achieved by the source control options.

(4) Plots of "concentration trajectories". These show how much source control reduces the rate of contaminant buildup relative to development #1 scenario, and also how much source control reduces the absolute contaminant buildup, again relative to development #1 scenario.

The results show that the potential benefits in terms of zinc concentration in harbour sediments that would result from source control (i.e., reducing the amount of zinc in roof run-off) would greatly exceed the benefits achievable by the implementation of stormwater treatment only in new developments. The combination of source control in both existing and new developments and stormwater treatment in new developments would achieve the greatest benefit.

2 Introduction

Using the USC-2 model, predictions have been made of zinc, copper, polycyclic aromatic hydrocarbon (PAH) and organochlorine pesticide accumulation in bed sediments of the Upper Waitemata Harbour (UWH) for 50 and 100 years into the future under a number of development scenarios. The methods used to make the predictions are reported in Green et al. (2004a). The results are reported in Green et al. (2004b), Green et al. (2004c) and Green et al. (2004d). A summary of the study is presented in Green et al. (2004e).

Figure 2.1 shows the subestuaries into which the UWH was divided for the purposes of the study.

Table 2.1 shows the scenarios investigated to date in the UWH contaminant study. For each scenario, a plot of contaminant buildup over the next 50 and 100 years was created, and times to ERC (Environmental Response Criteria) sediment-quality "traffic light" exceedance were tabulated.

The aim of the analysis presented herein is to determine the environmental benefits in the UWH associated with a range of zinc source control options that might be implemented in the catchment.This was achieved by re-running the USC-2 model over the 100-year timeframe with zinc loads modified to reflect a range of source control options. In effect, each source control option is applied to the development #1 scenario. This is the "benchmark" scenario used to date in the UWH study; it features projected (realistic) development and stormwater treatment in the catchment.

A number of scenarios are investigated in this analysis.

The proposed extent of future residential, commercial and industrial developments in the harbour subcatchments is the same for all scenarios, but each scenario has a different mixture of stormwater treatment and source control:

- The development #1 scenario is the same as the development #1 scenario shown in Table 2.1, which has been previously investigated in the UWH contaminant study. This has realistic (projected) stormwater treatment, as described in the results reports listed above.
- The zero stormwater treatment scenario is the same scenario that was used in the definition of the response envelope (see Table 2.1).
- There are six new source control options (Table 2.2). The origin of these source control options is explained below. Note that source control option #2 in fact includes only stormwater treatment (biomedia filtration), whereas the other 5 source control options include only source control (roof materials).

The development #1 scenario treats both metals and sediment in road run-off from unkerbed through-roads as being attenuated by natural processes, such as trapping in roadside vegetation. Incorporation of these processes in the model correctly dealt with the metals, but inadvertently resulted in the sediment retention being applied to other urban sources of sediment. This error was relatively small. Nevertheless, we have contrived here a "revised development #1 scenario" in which this (small) error has been corrected. The effect of this is to correctly retain metals in road run-off but to allow a little more sediment to reach the harbour.

The data used here for the effectiveness of the source control options originated from an investigation being underaken by NIWA for the ARC into the sources of metals in urban catchments (Timperley et al. 2005). This investigation involves combining the results of studies on the total catchment loads of metals in urban stormwater, metals in roof run-off and metals in road run-off. The early results from this investigation showed that roofs account for at least 75% of the zinc in stormwater from commercial and industrial landuses and for about 40% in stormwater from residential landuses. These values were used for the model runs described here. The metal sources investigation is now close to completion and has confirmed that the earlier values used for the modelling were appropriate.

Figure 2.1:

Subestuaries into which the UWH was divided for the purposes of the study.

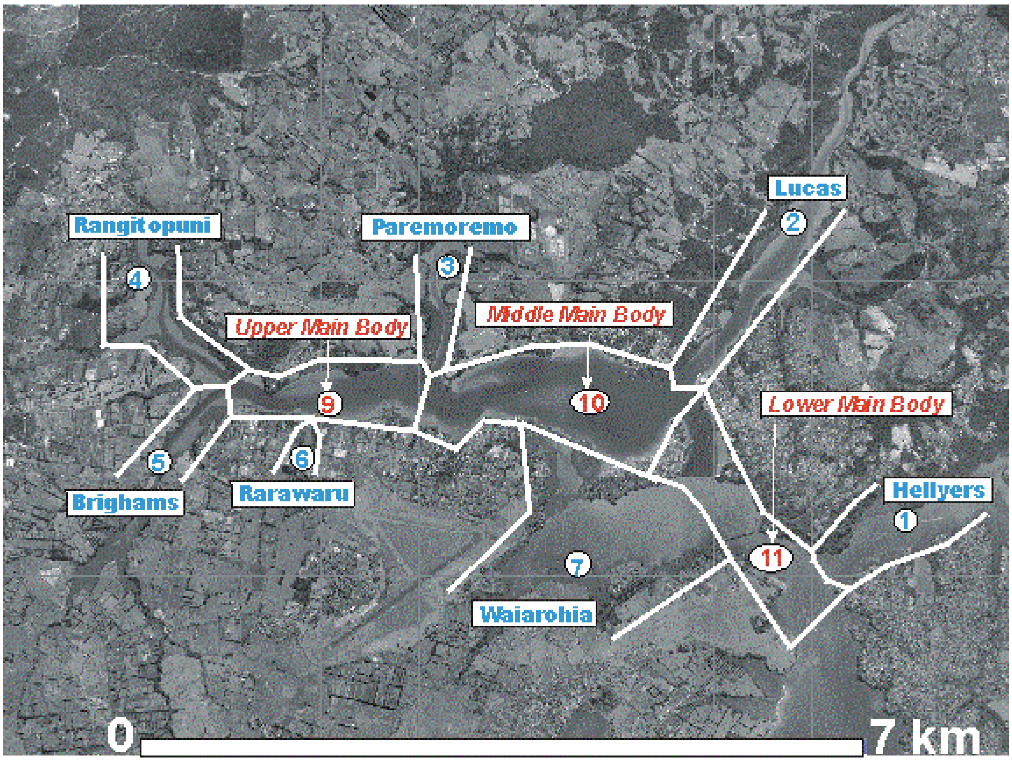

Table 2.1:

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, benchmark simulation.	Projected (realistic). *Each TA provided information describing projected land use change.*	Projected (realistic). *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 (realistic). *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.

Table 2.2:

Source control options investigated in this study (SC = source control, SWT = stormwater treatment).

Control option	Apply to:	Source Controls	Stormwater Treatment	Effects on zinc loads
#1	New residential, industrial and commercial developments.	No roof materials that leach substantial amounts of zinc, i.e., • No galvanised steel • No zinc-alum steel unless coated and maintained with a permanent non-zinc-leaching sealer. • No zinc-leaching paints.	Realistic treatment: 50% retention of zinc for all new developments (with modified treatment of road run-off)	Reduce zinc loads from new industrial and commercial developments by 87.5% (75% SC, 12.5% SWT). Reduce zinc loads from new residential developments by 70% (40% SC, 30% SWT).
#2	As for #1			
	Existing industrial and commercial developments.	Treat roof runoff with biomedia filtration implemented over next 15 years	No treatment	Reduce zinc loads from existing industrial and commercial developments by increasing amounts reaching 70% in 15 years time.
#3	As for #1			
	Existing industrial and commercial developments	Replace roof materials that leach substantial amounts of zinc over next 15 years, i.e., • Galvanised steel • Zinc-alum steel unless coated and maintained with a permanent non-zinc-leaching sealer. • Zinc-leaching paints.	No treatment	Reduce zinc loads from existing industrial and commercial developments by increasing amounts reaching 75% in 15 years time.
#4	As for #1			
	Existing industrial and commercial developments.	Replace roof materials that leach substantial amounts of zinc over next 50 years, i.e., • Galvanised steel • Zinc-alum steel unless coated and maintained with a permanent non-zinc-leaching sealer. • Zinc-leaching paints.	No treatment	Reduce zinc loads from existing industrial and commercial developments by increasing amounts reaching 75% in 50 years time.
#5	As for #3			
	Existing residential developments	Replace roof materials that leach substantial amounts of zinc over next 15 years, i.e., • Galvanised steel • Zinc-alum steel unless coated and maintained with a permanent non-zinc-leaching sealer. • Zinc-leaching paints.	No treatment	Reduce zinc loads from existing residential developments by increasing amounts reaching 40% in 15 years time.
#6	As for #3			
	Existing residential developments	Replace roof materials that leach substantial amounts of zinc over next 50 years, i.e., • Galvanised steel • Zinc-alum steel unless coated and maintained with a permanent non-zinc-leaching sealer. • Zinc-leaching paints.	No treatment	Reduce zinc loads from existing residential developments by increasing amounts reaching 40% in 50 years time.

3 Results

The results are shown by:

(1) Plots of how the zinc concentrations in estuary bed sediments are predicted to change over the next 100 years under each scenario.

- Figure 3.1 shows zinc buildup in the surface (bioturbated) layer of estuary bed sediments over the next 100 years under each development scenario and for each subestuary of the UWH. These are total-sediment zinc concentrations.

(2) Tabulations of times to ERC traffic light exceedance.

- Table 3.1 shows times to ERC traffic light exceedance for each scenario.

(3) Circle diagrams depicting the reduction in mass of zinc deposited in the harbour achieved by the source control options.

- Figure 3.2 shows circle diagrams depicting the reduction in mass of zinc deposited in the harbour achieved by the source control options, relative to the development #1 scenario.

(4) Plots of "concentration trajectories". These show how much source control reduces the rate of contaminant buildup relative to development #1 scenario, and also how much source control reduces the absolute contaminant buildup, again relative to development #1 scenario.

- Figure 3.3 shows "concentration trajectories".

Figure 3.1:

Predicted zinc buildup in estuary bed sediments of the Hellyers and Lucas subestuaries over the next 100 years under each scenario. These are total-sediment zinc concentrations.

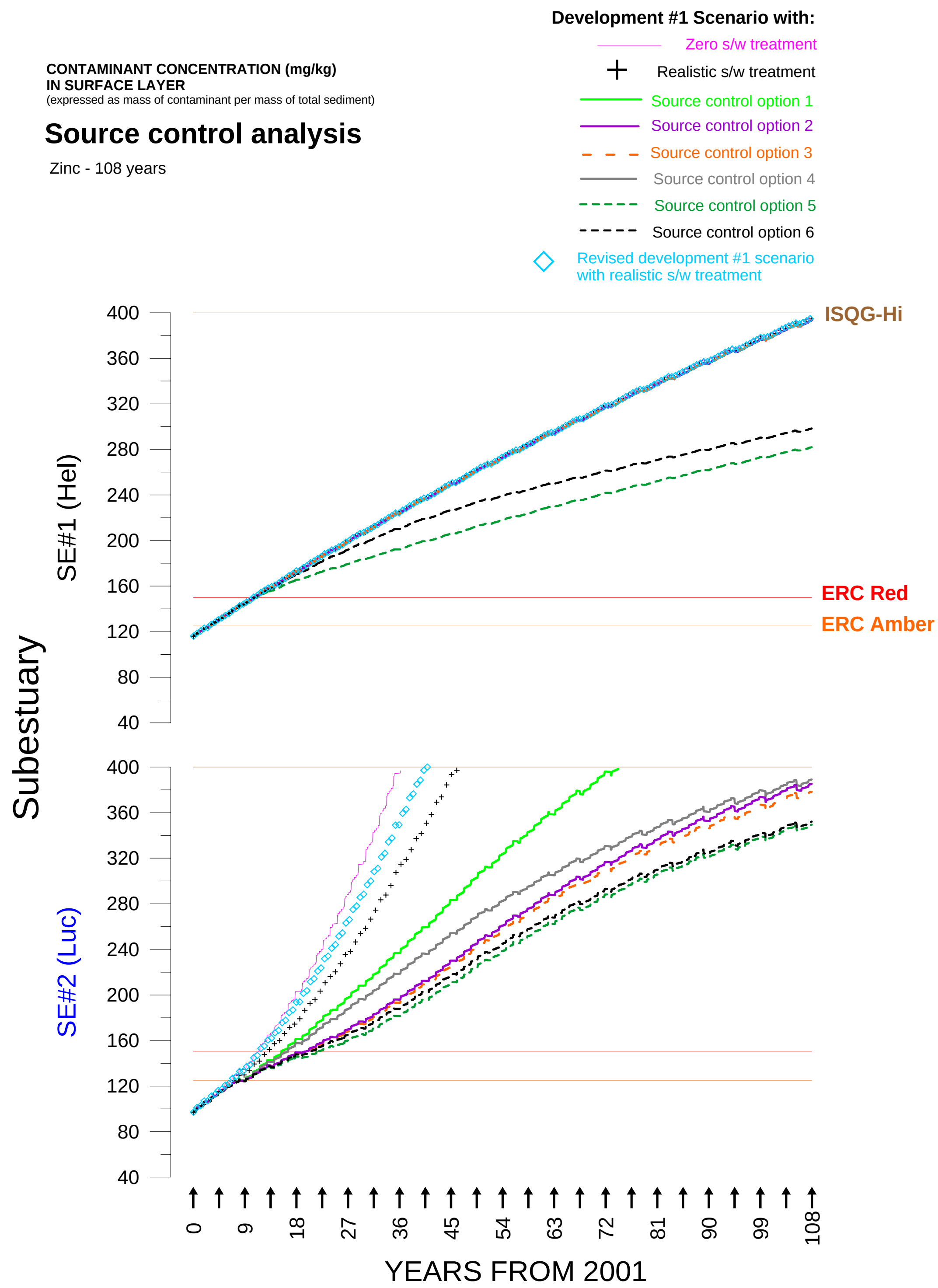

Figure 3.1:

[Continued] Predicted zinc buildup in estuary bed sediments of the Paremoremo and Rangitopuni subestuaries over the next 100 years under each scenario. These are total-sediment zinc concentrations.

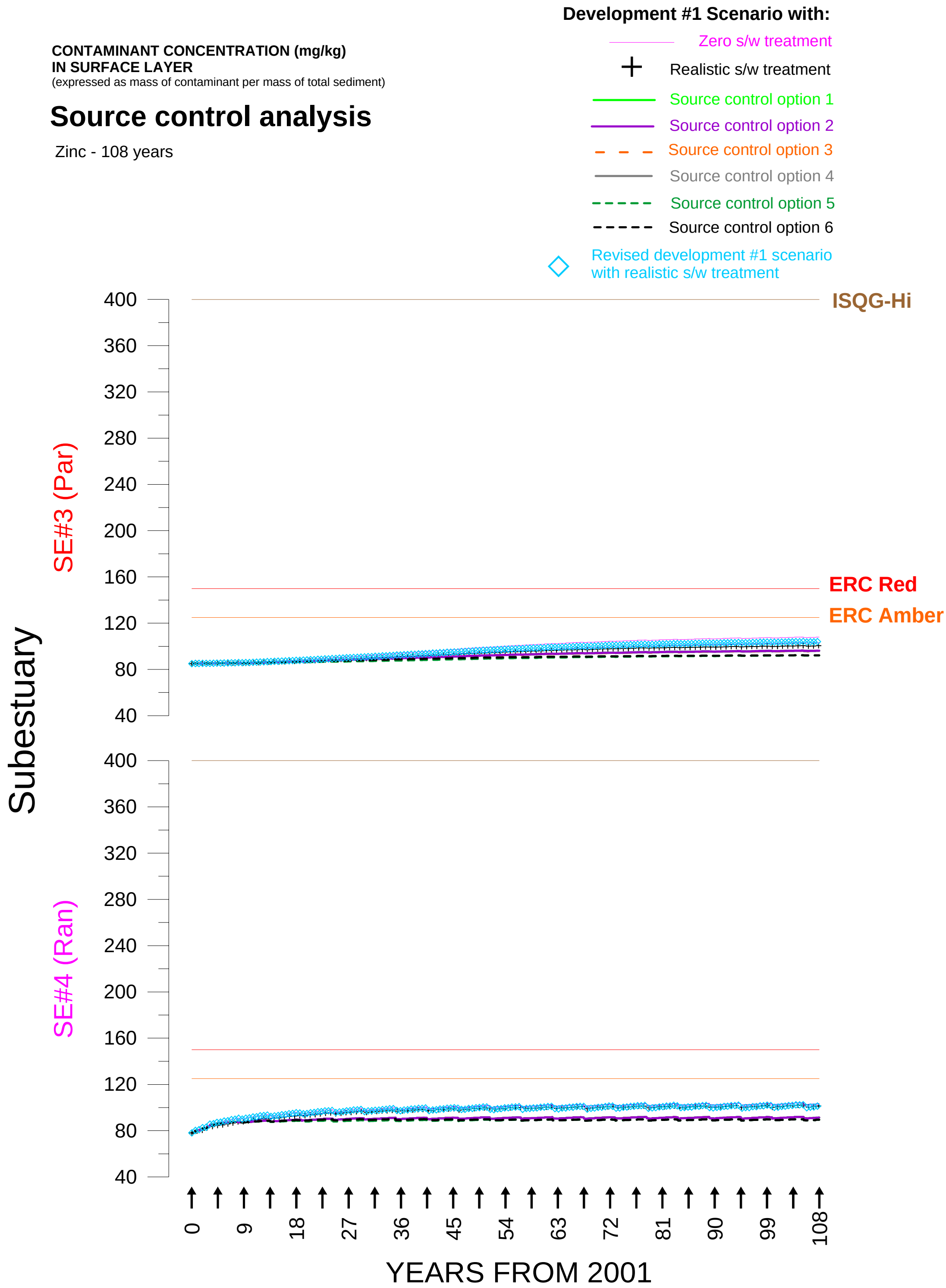

Figure 3.1:

[Continued] Predicted zinc buildup in estuary bed sediments of the Brighams and Rarawaru subestuaries over the next 100 years under each scenario. These are total-sediment zinc concentrations.

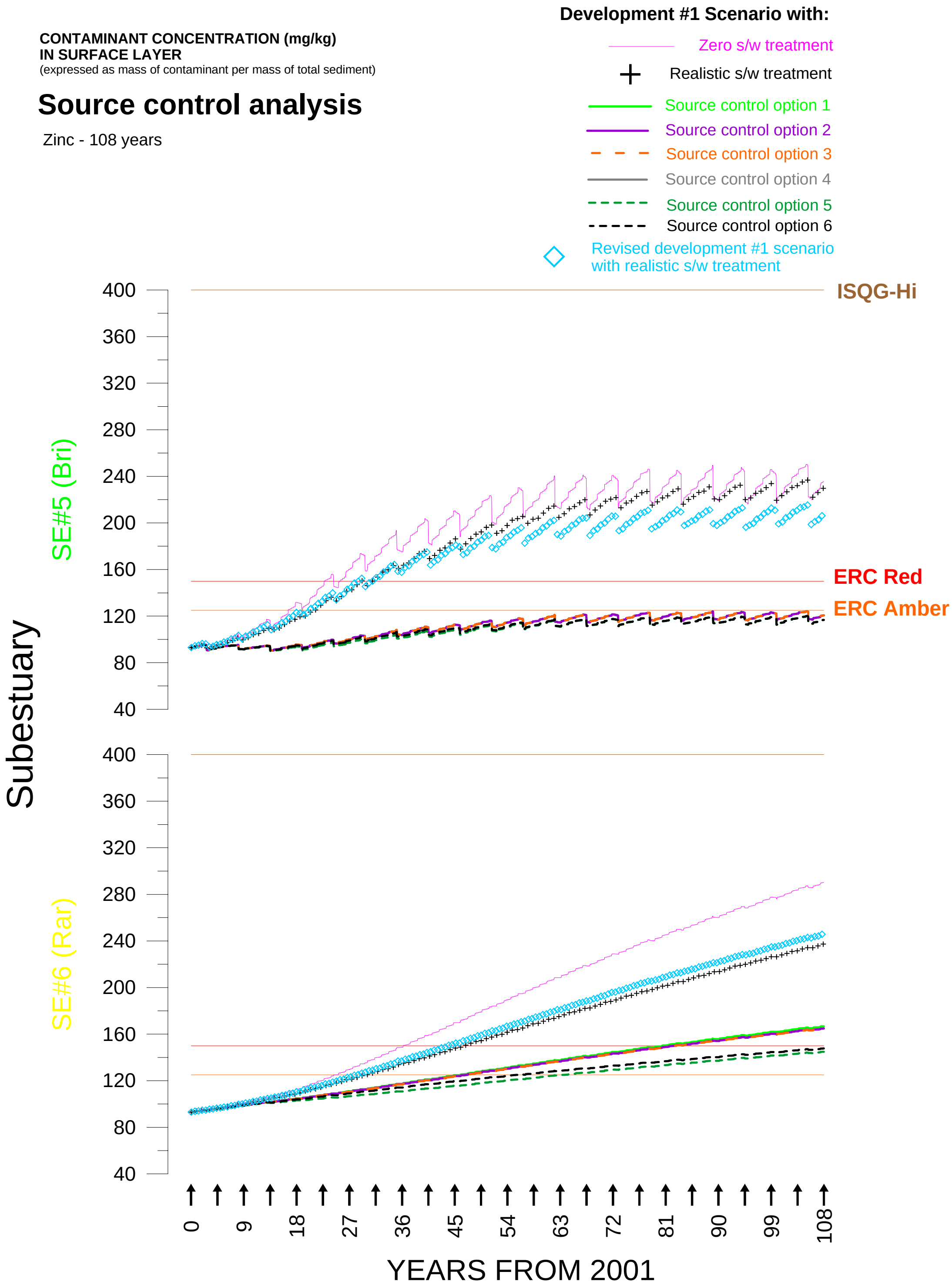

Figure 3.1:
[Continued] Predicted zinc buildup in estuary bed sediments of the Waiarohia and Upper Main Body subestuaries over the next 100 years under each scenario. These are total-sediment zinc concentrations.

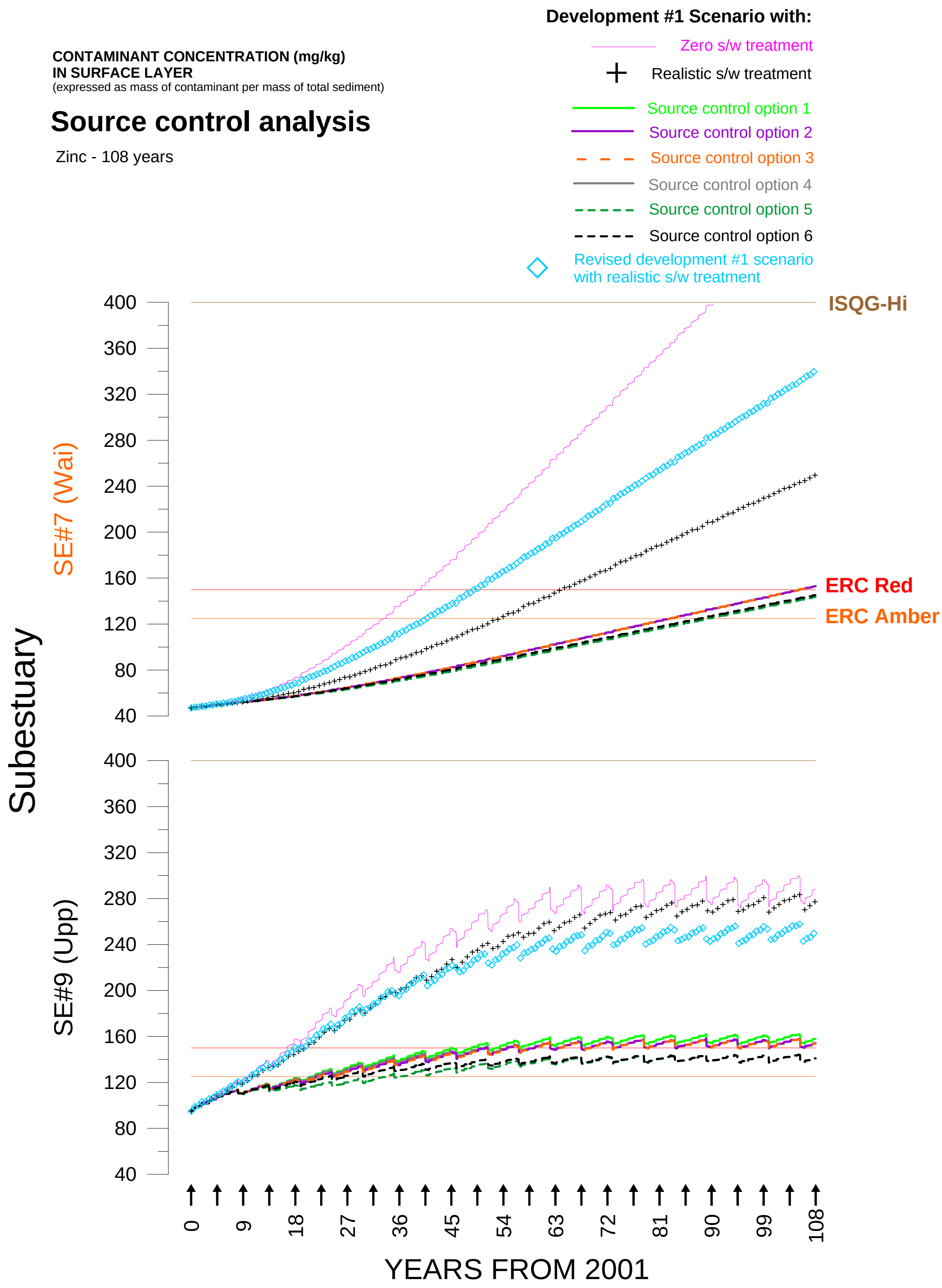

Figure 3.1:

[Continued] Predicted zinc buildup in estuary bed sediments of the Middle Main Body and Lower Main Body subestuaries over the next 100 years under each scenario. These are total-sediment zinc concentrations.

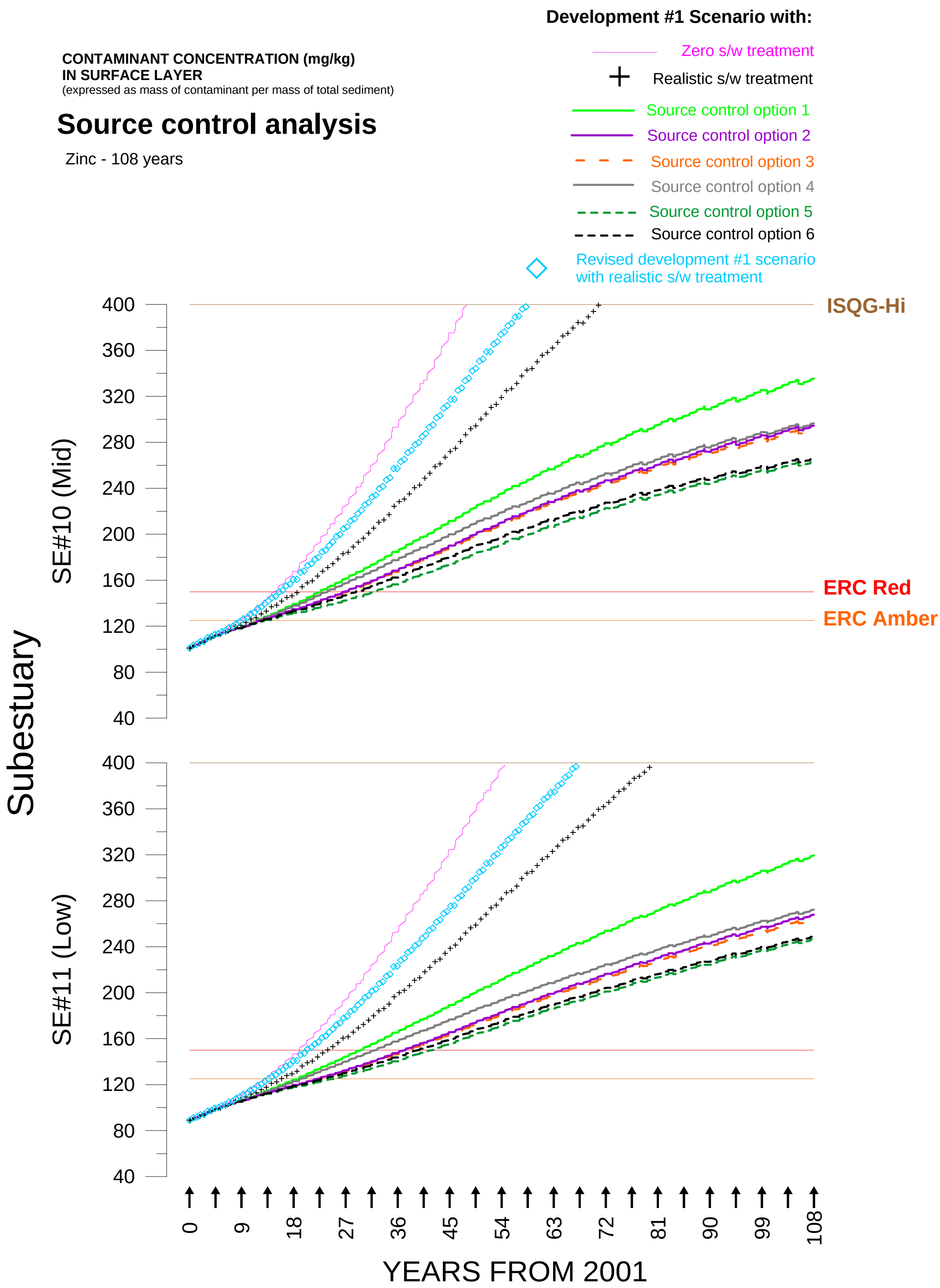

Table 3.1:

Times for total-sediment zinc concentrations to exceed ERC traffic light thresholds. “>” signifies traffic light is not exceeded within 108 years.

Subestuary	Zero s/w treatment	Development #1	Source control option 1	Source control option 2	Source control option 3	Source control option 4	Source control option 5	Source control option 6	Revised Development #1
Years to ERC Amber (125 mg/kg)									
1=Hellyers	3.1	3.1	**3.1**	3.1	**3.1**	3.1	**3.1**	**3.1**	**3.1**
2=Lucas	6.8	7.2	**8.0**	8.0	**8.0**	8.0	**8.0**	**8.0**	**6.8**
3=Paremoremo	>	>	**>**	>	**>**	>	**>**	**>**	**>**
4=Rangitopuni	>	>	**>**	>	**>**	>	**>**	**>**	**>**
5=Brighams	16.6	21.1	**>**	>	**>**	>	**>**	**>**	**20.3**
6=Rarawaru	25.2	30.1	**46.0**	47.3	**47.3**	46.5	**63.5**	**55.8**	**28.1**
7=Waiarohia	33.6	53.4	**82.8**	82.8	**82.8**	82.8	**89.1**	**87.9**	**40.5**
9=Upper main body of UWH	10.4	10.5	**20.8**	22.0	**22.0**	21.5	**33.8**	**23.9**	**10.4**
10=Middle main body of UWH	9.2	10.4	**11.7**	12.4	**12.4**	11.7	**12.9**	**12.9**	**9.2**
11=Lower main body of UWH	12.9	15.9	**18.9**	22.0	**22.7**	19.2	**25.2**	**23.0**	**14.0**
Years to ERC Red (150 mg/kg)									
1=Hellyers	10.5	10.5	**10.5**	10.5	**10.5**	10.5	**11.1**	**10.8**	**10.5**
2=Lucas	11.4	12.9	**15.4**	19.4	**19.8**	16.3	**21.5**	**20.3**	**11.7**
3=Paremoremo	>	>	**>**	>	**>**	>	**>**	**>**	**>**
4=Rangitopuni	>	>	**>**	>	**>**	>	**>**	**>**	**>**
5=Brighams	22.7	28.9	**>**	>	**>**	>	**>**	**>**	**28.8**
6=Rarawaru	36.2	46.5	**80.4**	82.8	**82.8**	81.8	**>**	**>**	**43.6**
7=Waiarohia	39.4	64.4	**105.3**	105.3	**105.3**	105.3	**>**	**>**	**48.7**
9=Upper main body of UWH	16.6	20.1	**48.5**	50.9	**54.8**	50.3	**>**	**>**	**17.8**
10=Middle main body of UWH	14.7	18.9	**22.7**	26.9	**27.5**	23.9	**32.3**	**28.8**	**15.5**
11=Lower main body of UWH	19.0	23.9	**29.7**	37.4	**37.5**	32.3	**42.0**	**39.7**	**20.3**

Figure 3.2:
Circle diagrams depicting the reduction in mass of zinc deposited in the harbour achieved by the source control options, relative to the development #1 scenario.

Read across each line to see where in the harbour zinc generated in each subcatchment gets deposited. The symbols at the end of each line are proportional to the total load of zinc from each subcatchment deposited in the harbour. Read up each column to see where zinc deposited in each subestuary comes from.

The solid, black symbols represent the development #1 scenario. The open, coloured circles represent the source control option.

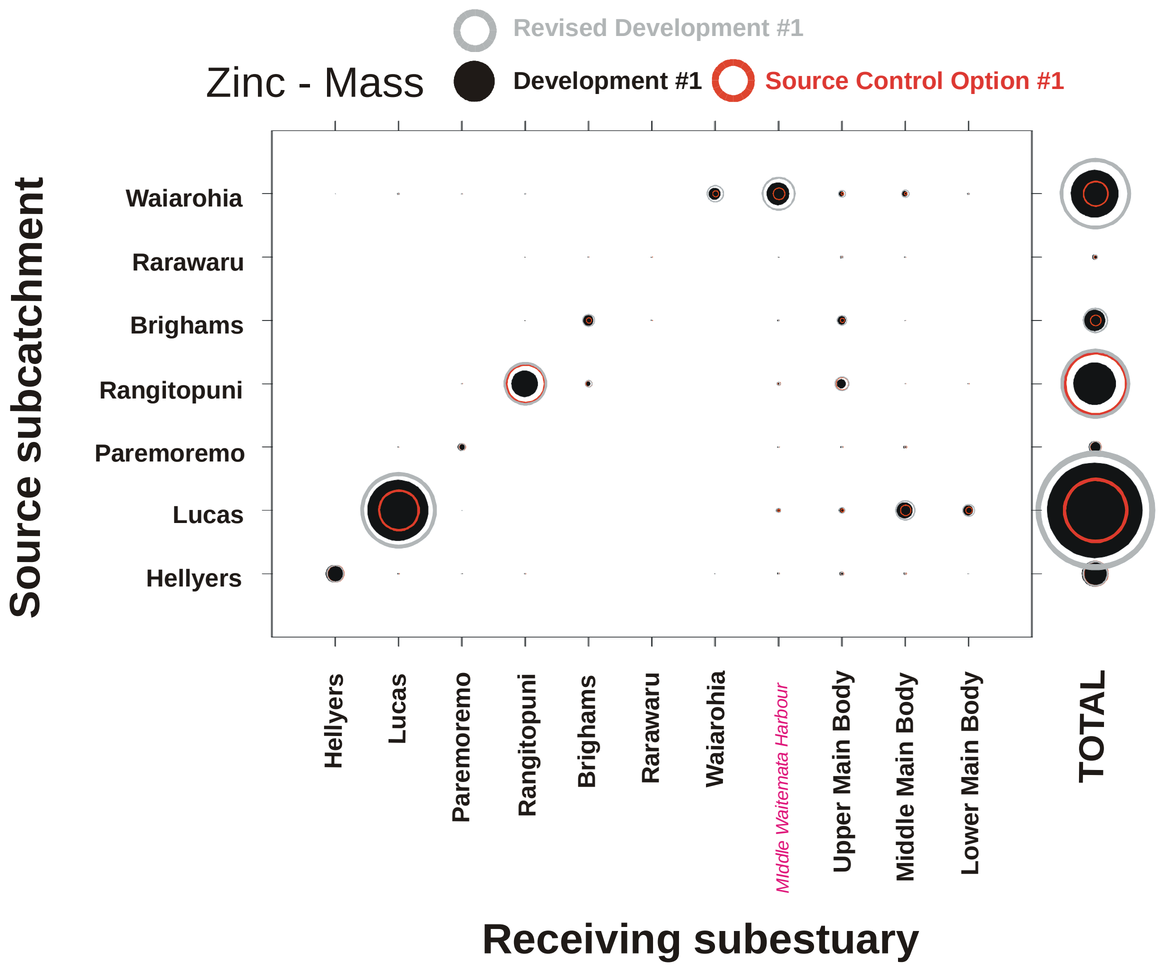

Figure 3.2:
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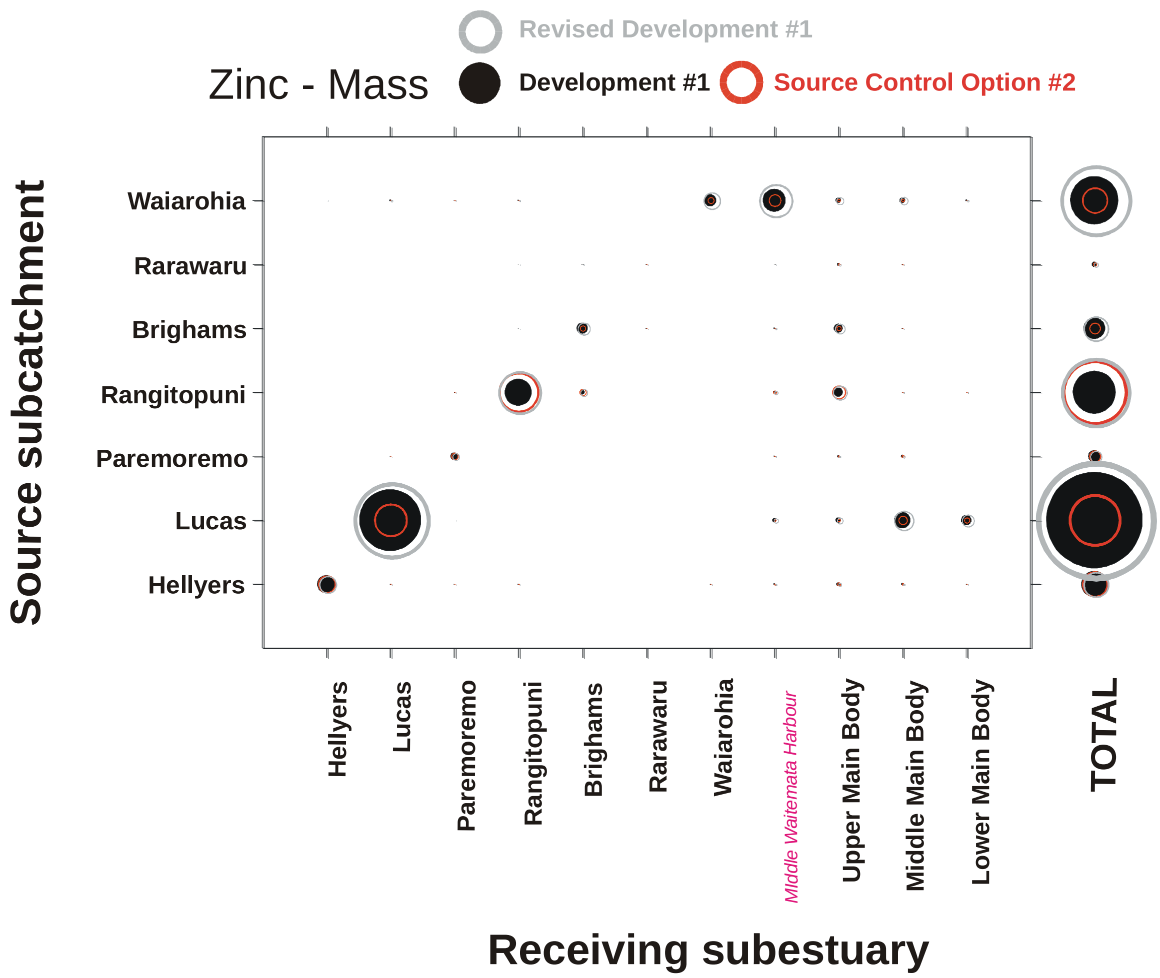

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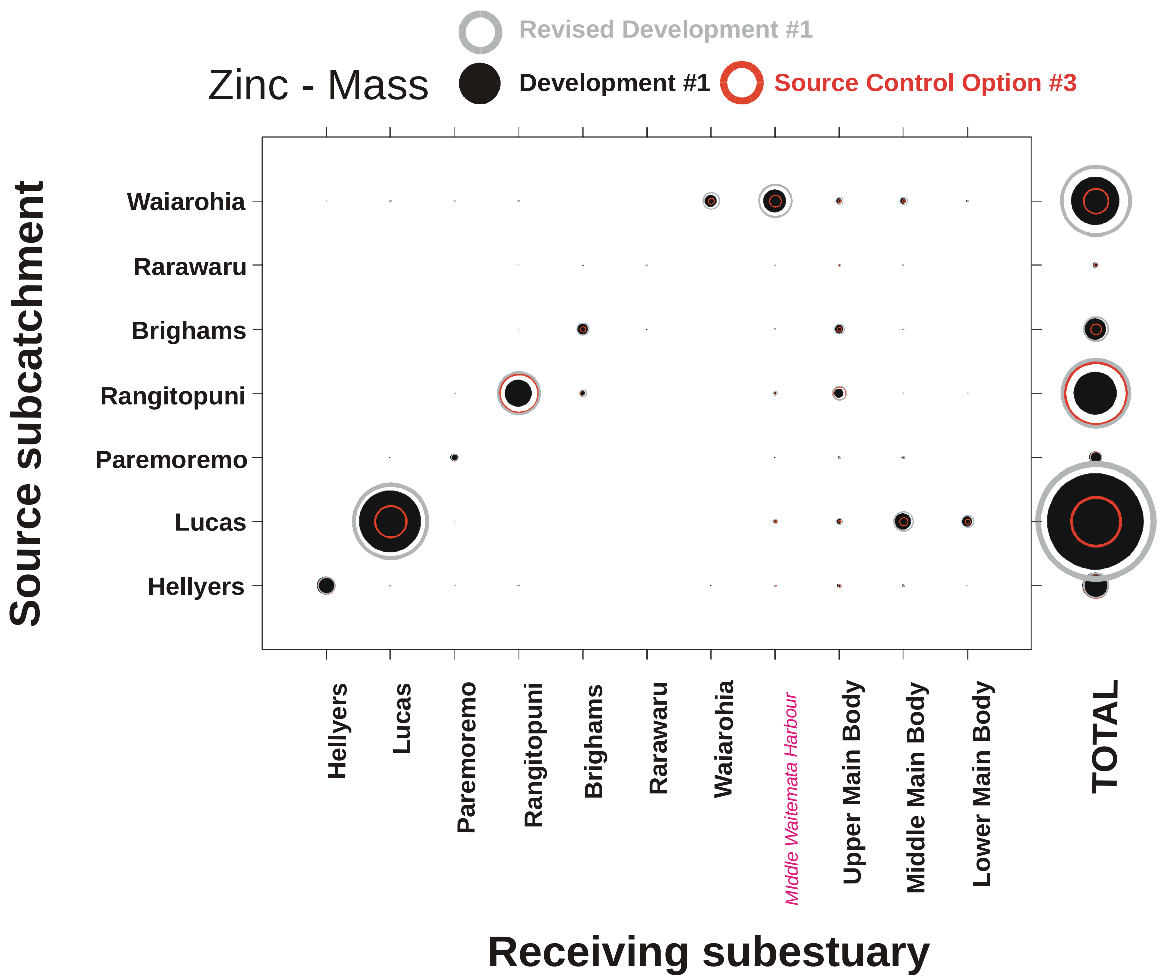

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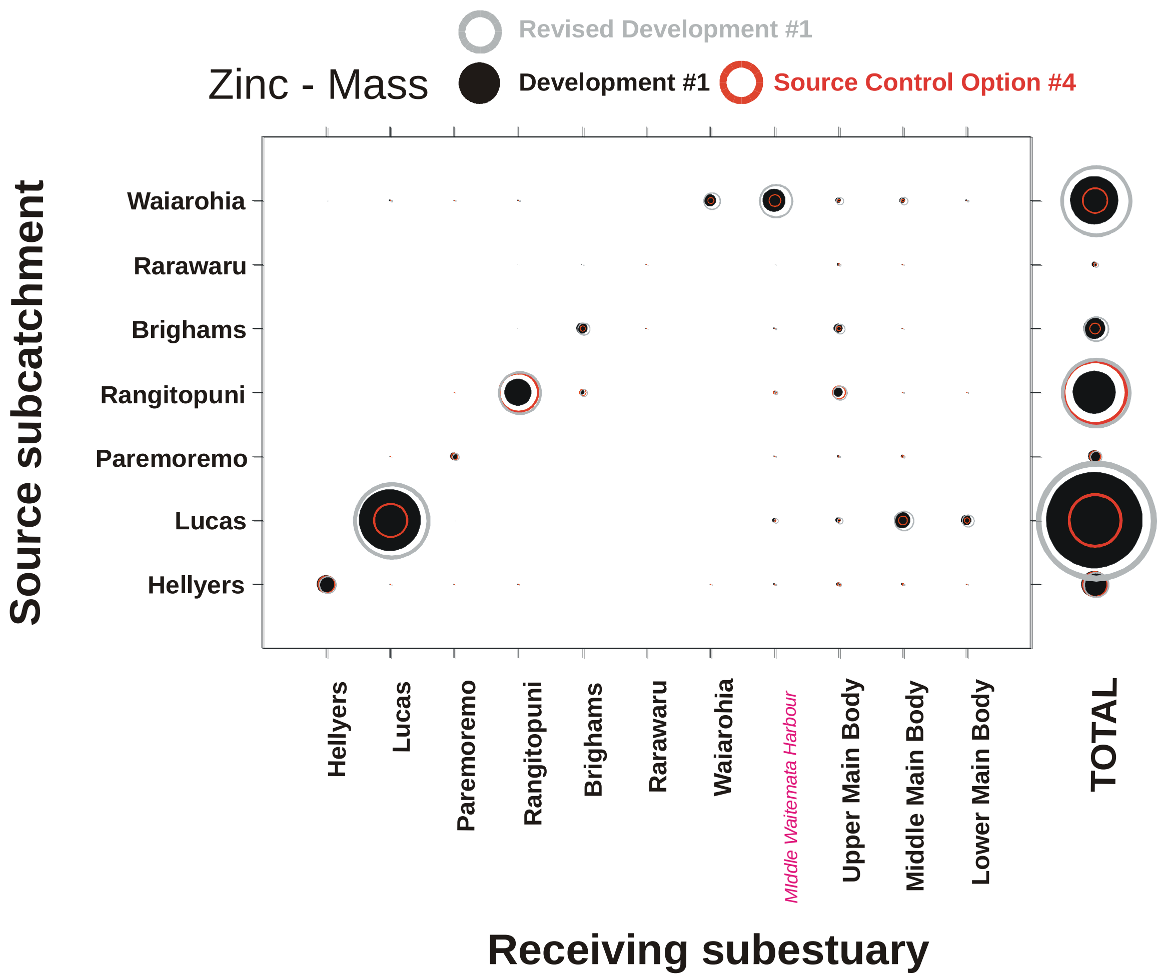

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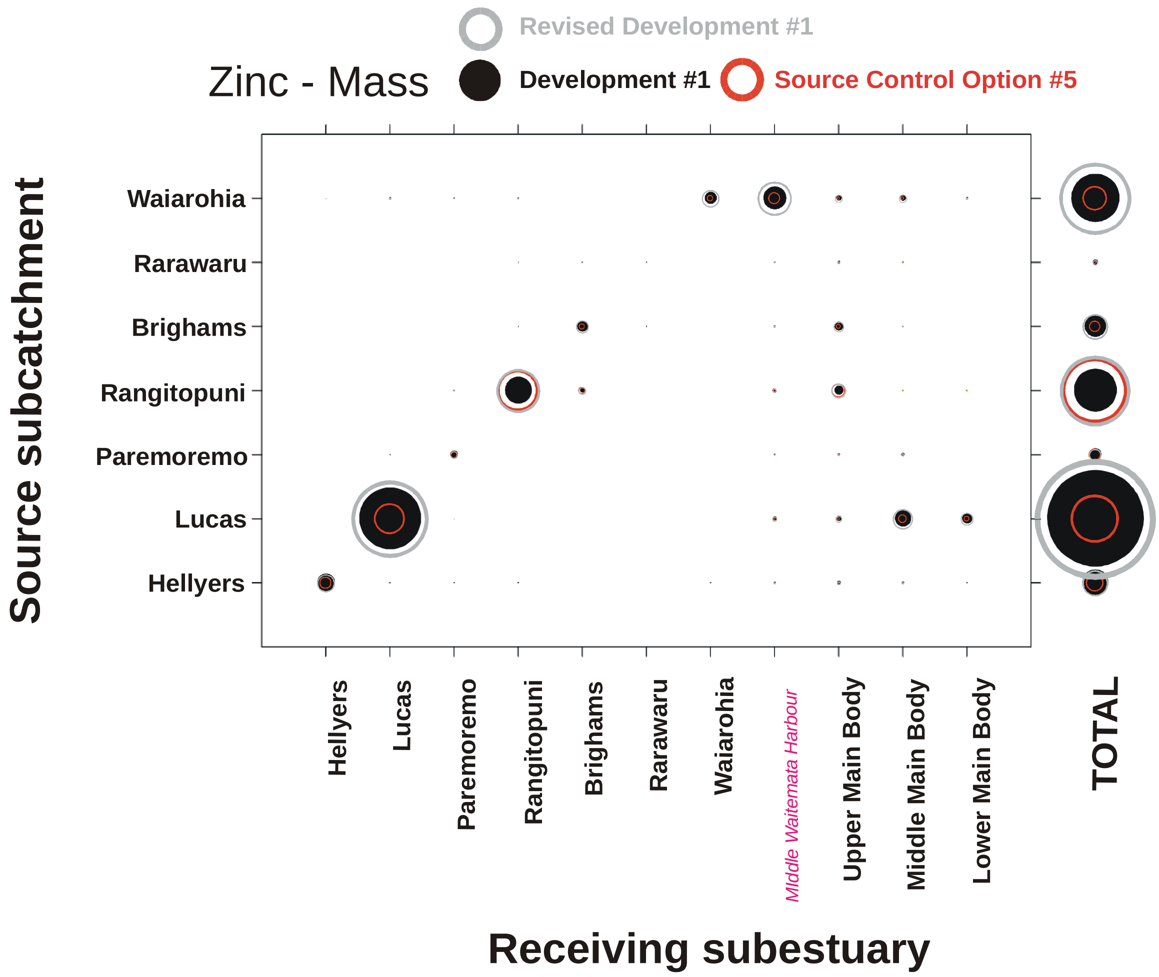

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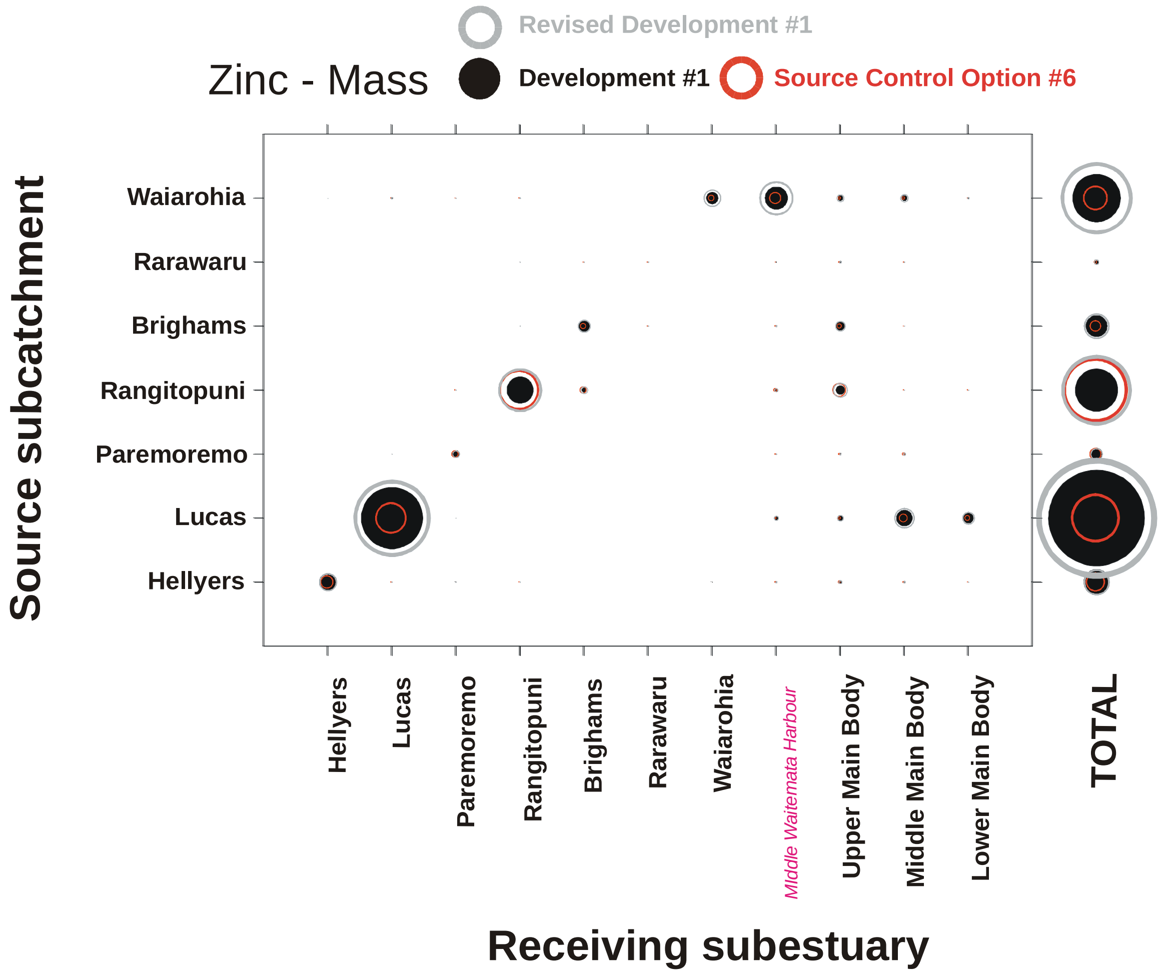

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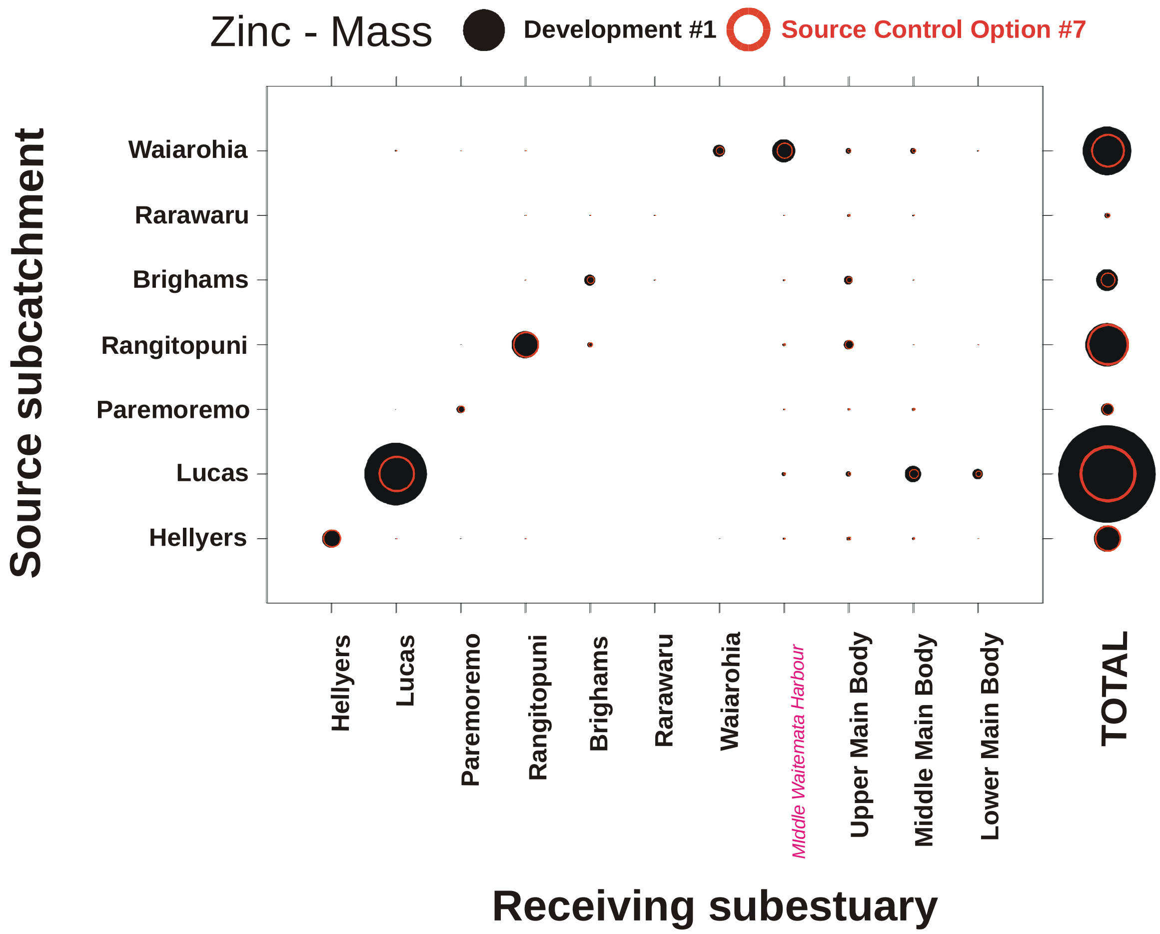

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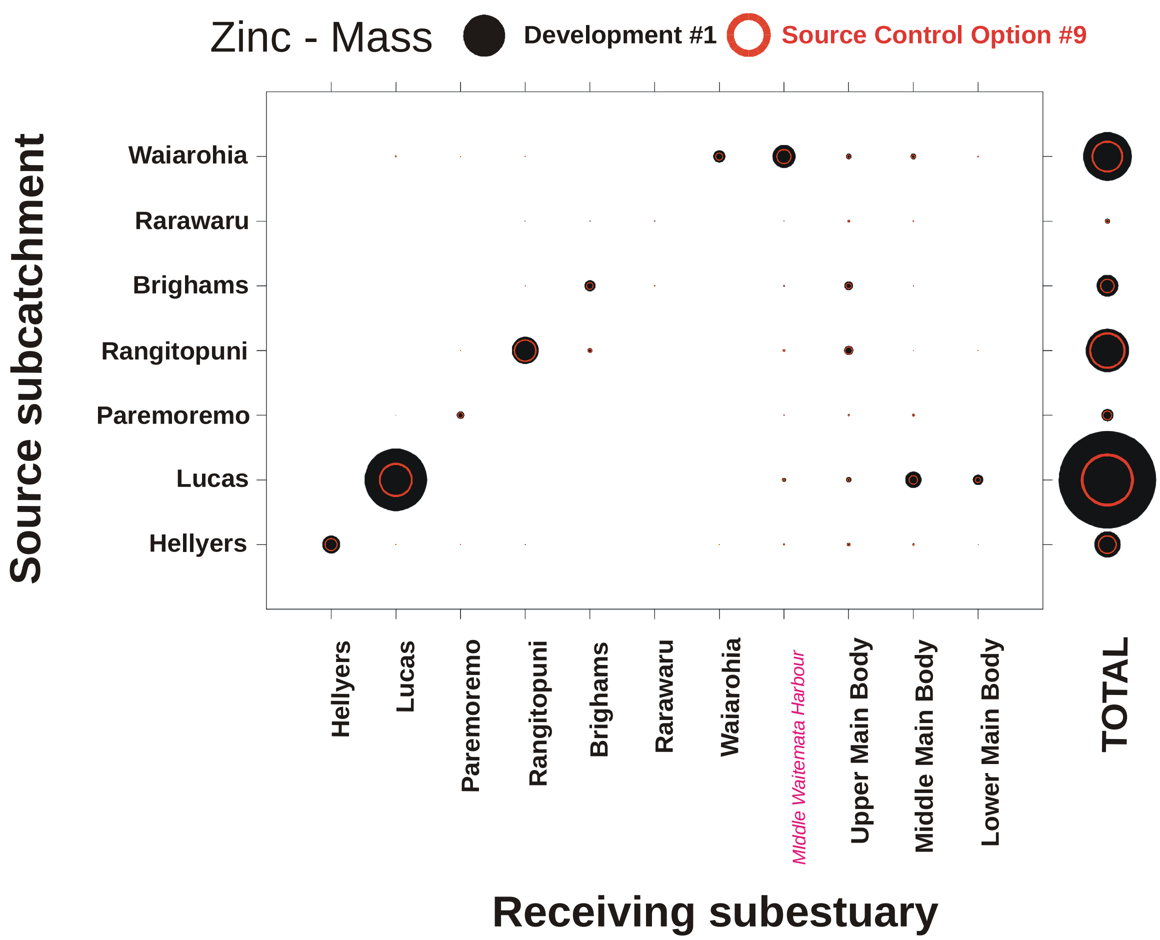
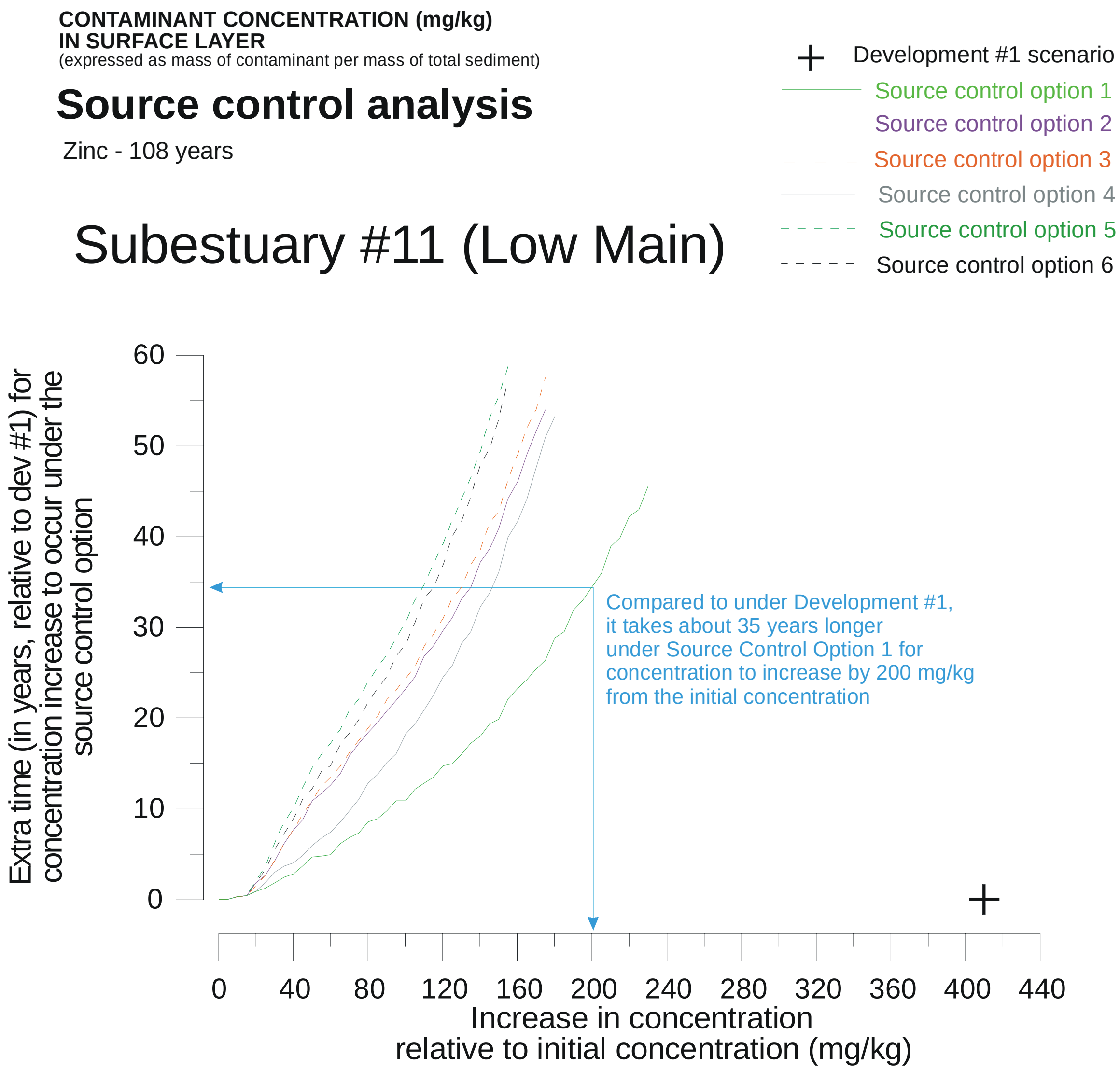


Figure 3.3:

Concentration trajectory. These first two panels show how to read the concentration trajectory plots. The following panels show the actual concentration trajectory plots.

1. HOW MUCH DOES SOURCE CONTROL SLOW THE RATE OF CONTAMINANT BUILDUP?

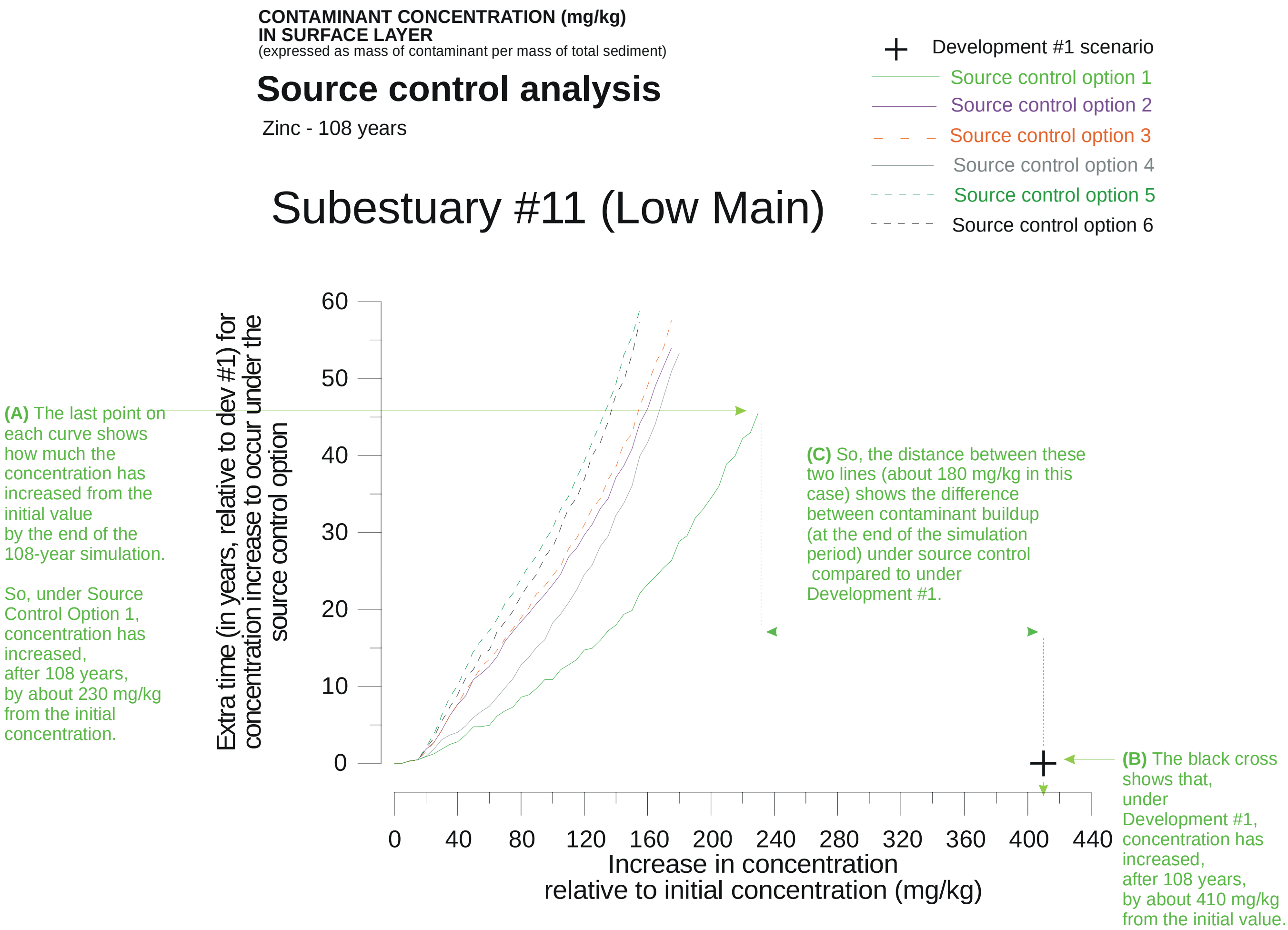


So, the steeper the plot rises, the slower the buildup of contaminant under source control compared to under development #1

Figure 3.3:

Concentration trajectory. These first two panels show how to read the concentration trajectory plots. The following panels show the actual concentration trajectory plots.

2. HOW MUCH DOES SOURCE CONTROL REDUCE THE ABSOLUTE CONTAMINANT LEVEL BY THE END OF THE SIMULATION PERIOD?



So, the further the black cross is from the end of the plot, the more source control reduces the absolute level of contamination compared to Development #1

Figure 3.3:

[Continued] Concentration trajectory, Hellyers. See the first two panels for how to read this plot.

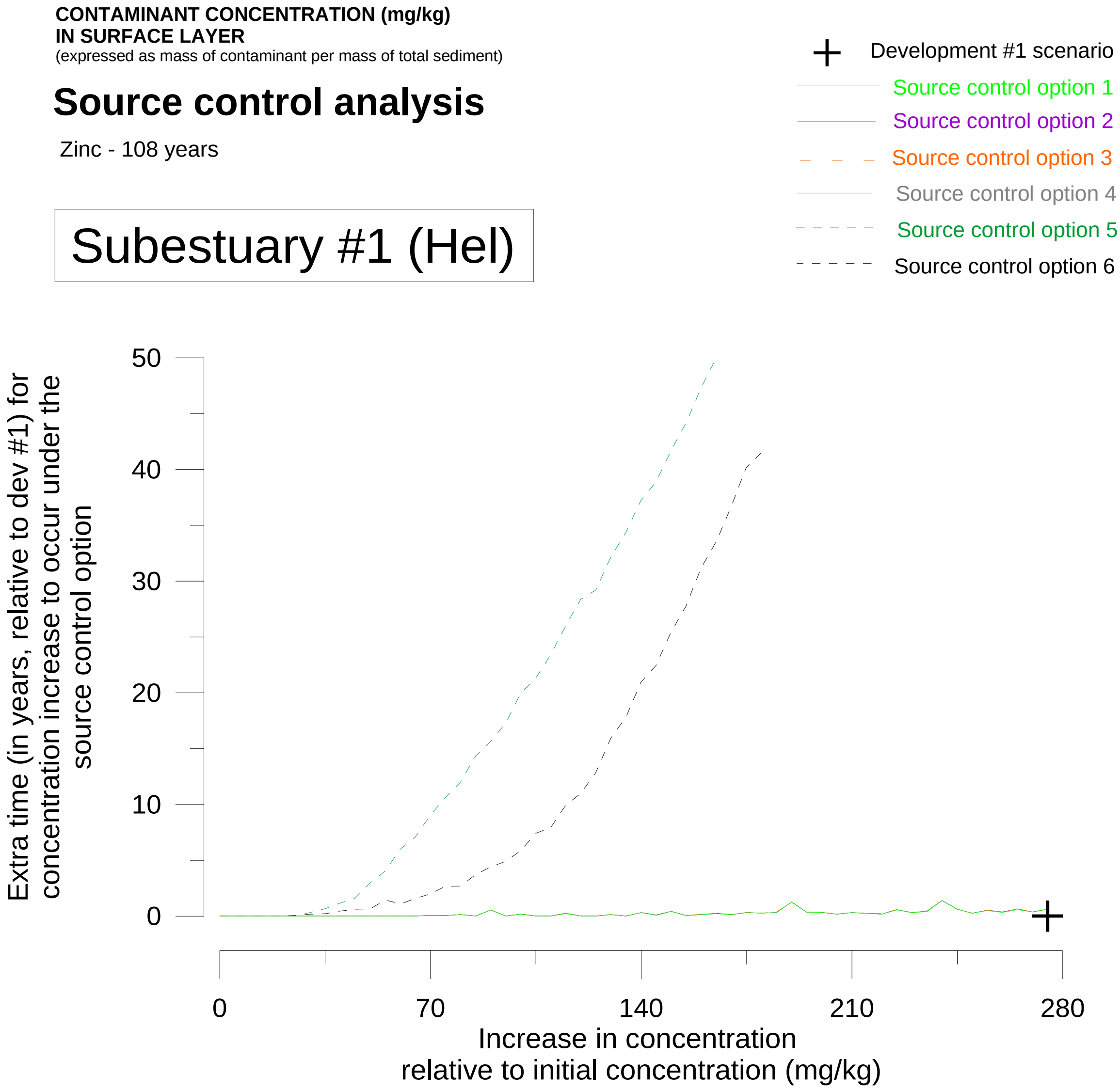


Figure 3.3:

[Continued] Concentration trajectory, Lucas. See the first two panels for how to read this plot.

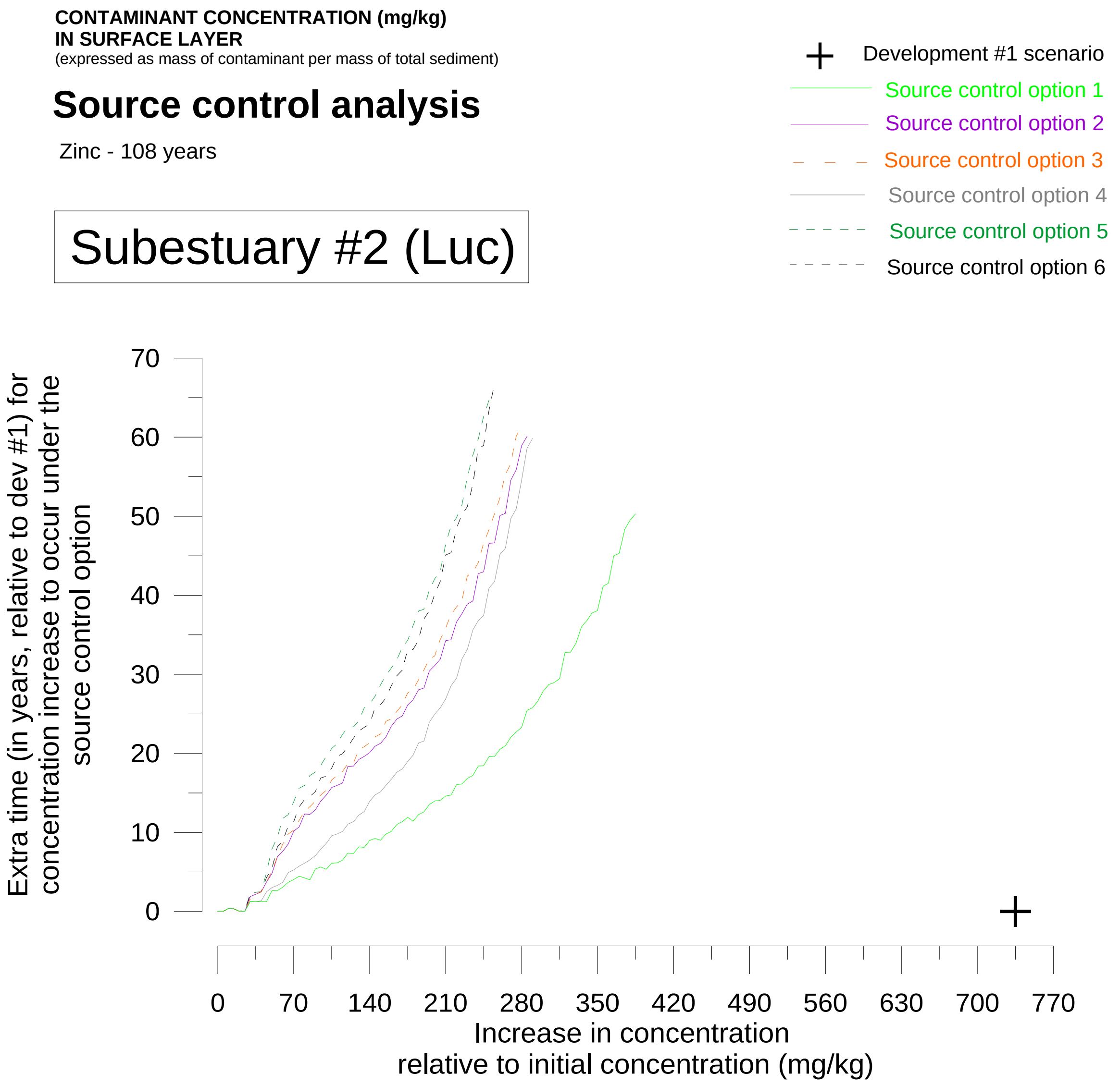


Figure 3.3:

[Continued] Concentration trajectory, Paremoremo. See the first two panels for how to read this plot.

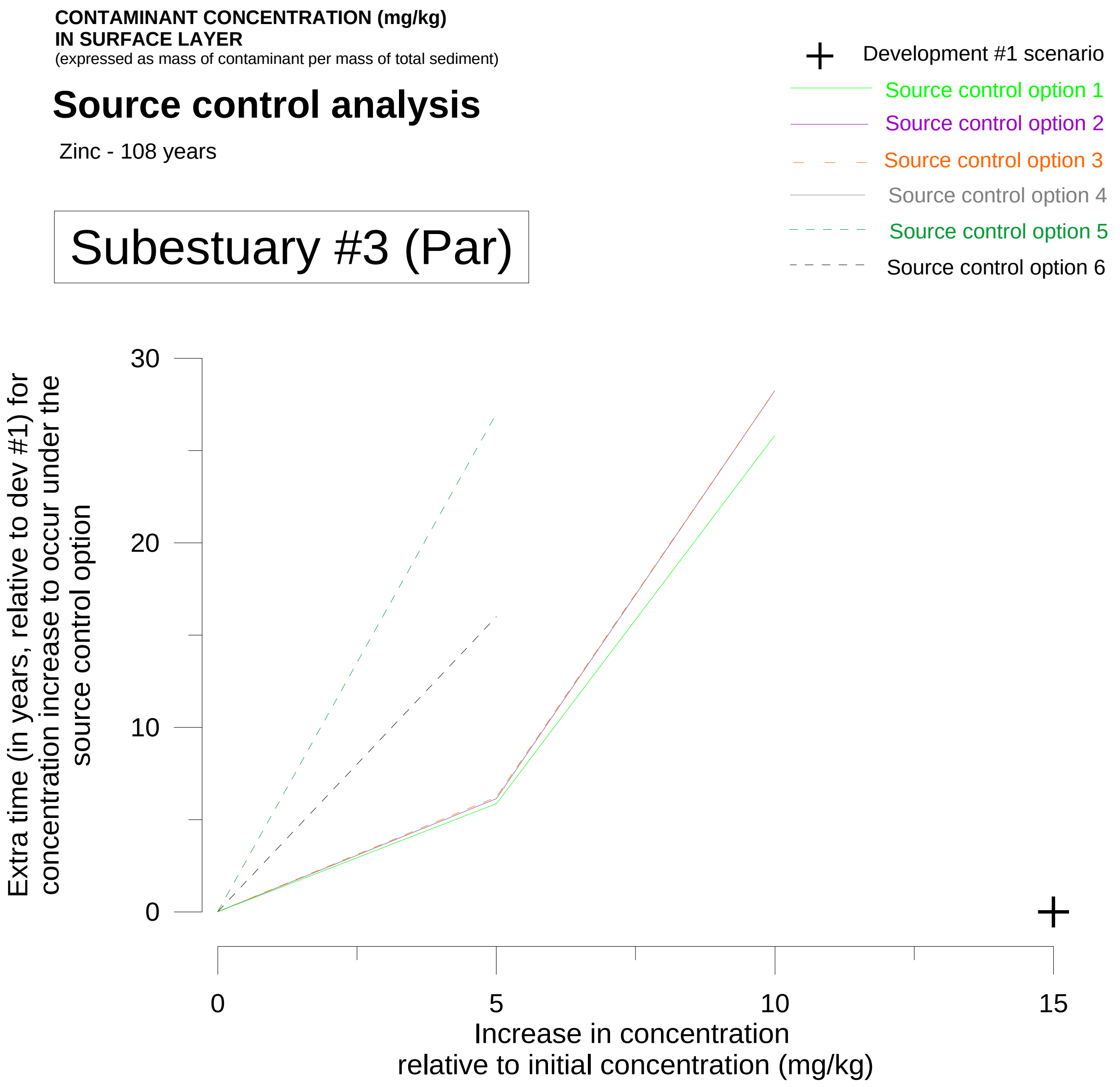


Figure 3.3:

[Continued] Concentration trajectory, Rangitopuni. See the first two panels for how to read this plot.

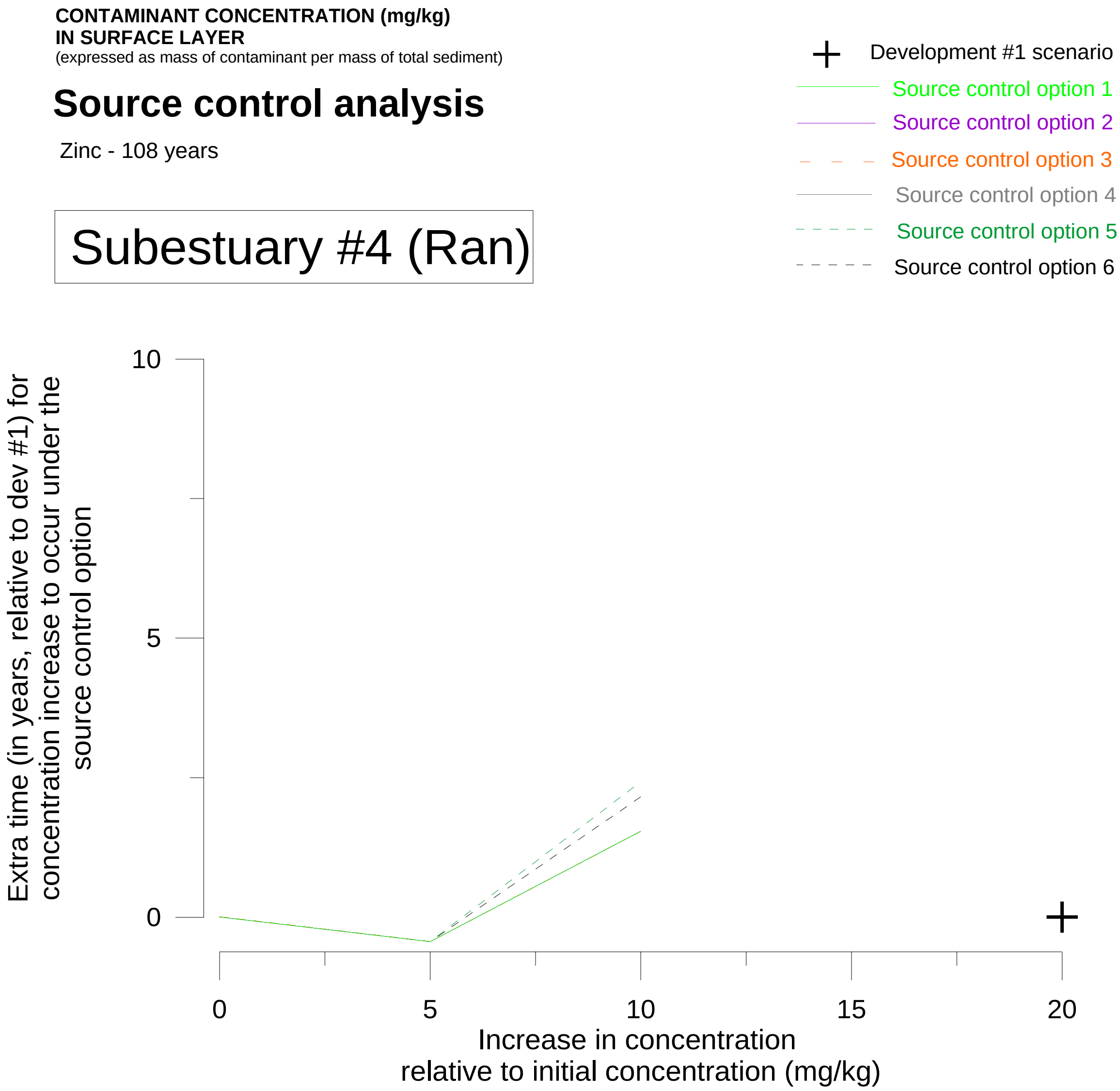


Figure 3.3:
[Continued] Concentration trajectory, Brighams. See the first two panels for how to read this plot.

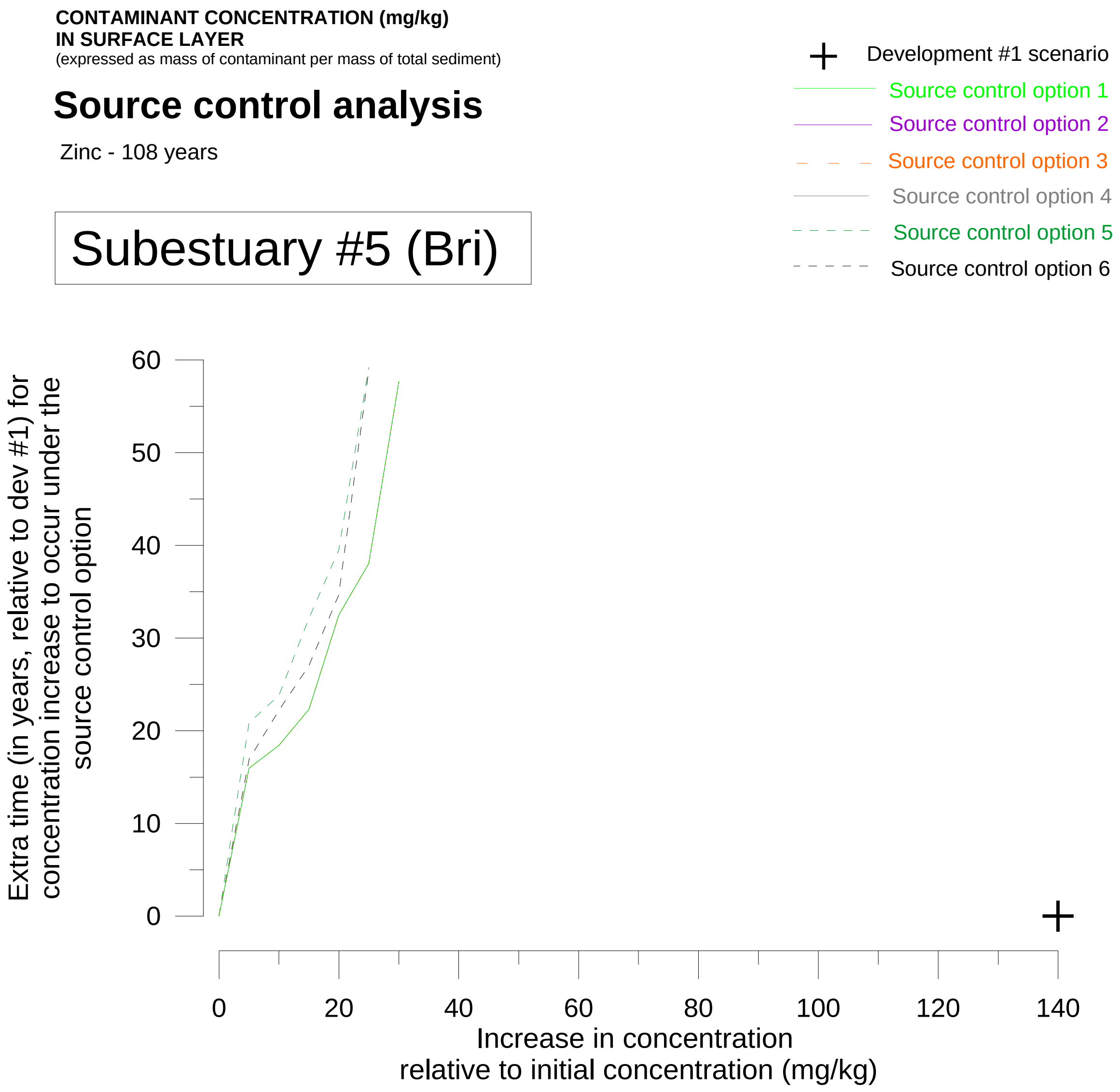


Figure 3.3:

[Continued] Concentration trajectory, Rarawaru. See the first two panels for how to read this plot.

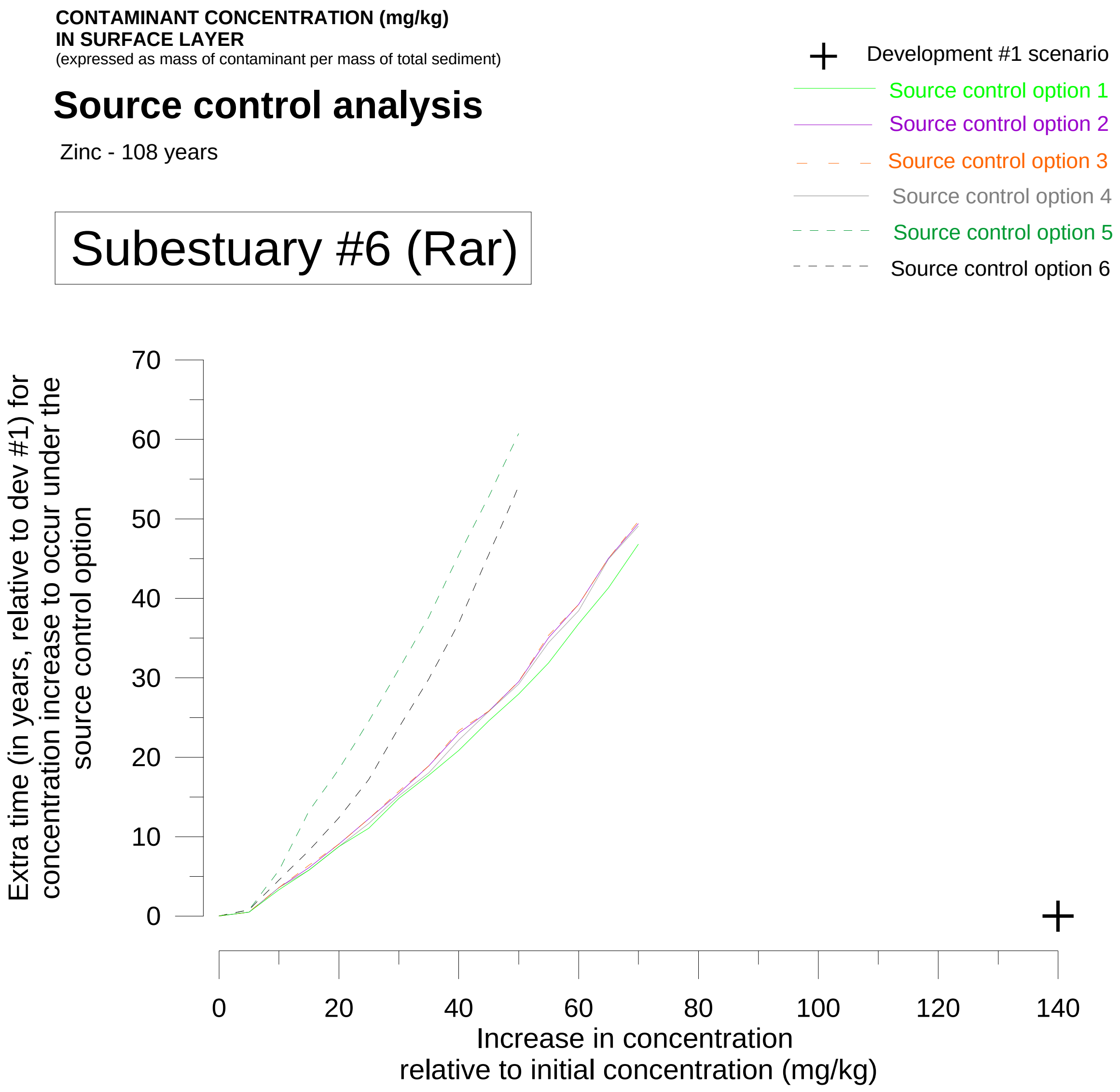


Figure 3.3:

[Continued] Concentration trajectory, Waiarohia. See the first two panels for how to read this plot.

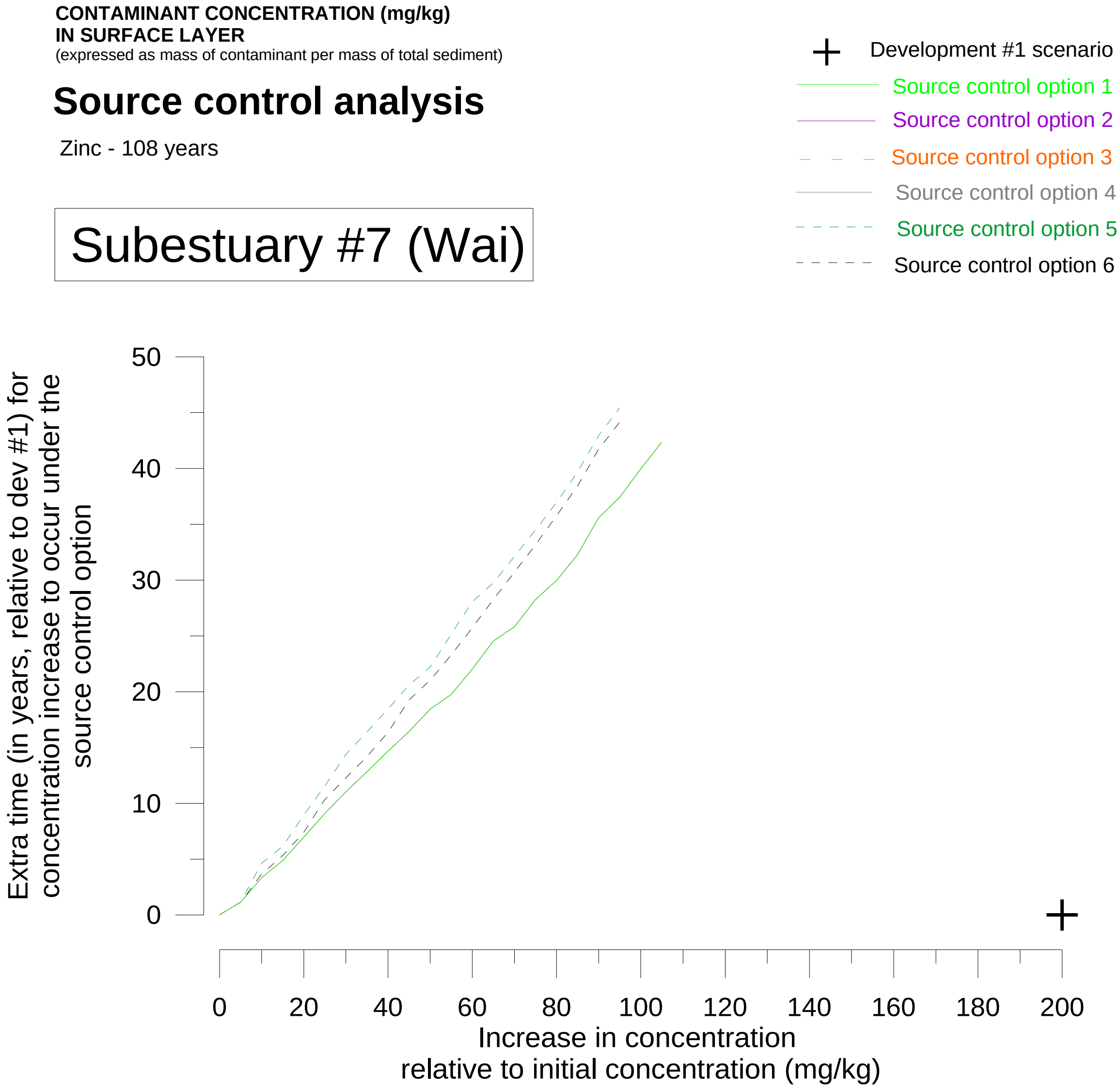


Figure 3.3:

[Continued] Concentration trajectory, Upper Main Body. See the first two panels for how to read this plot.

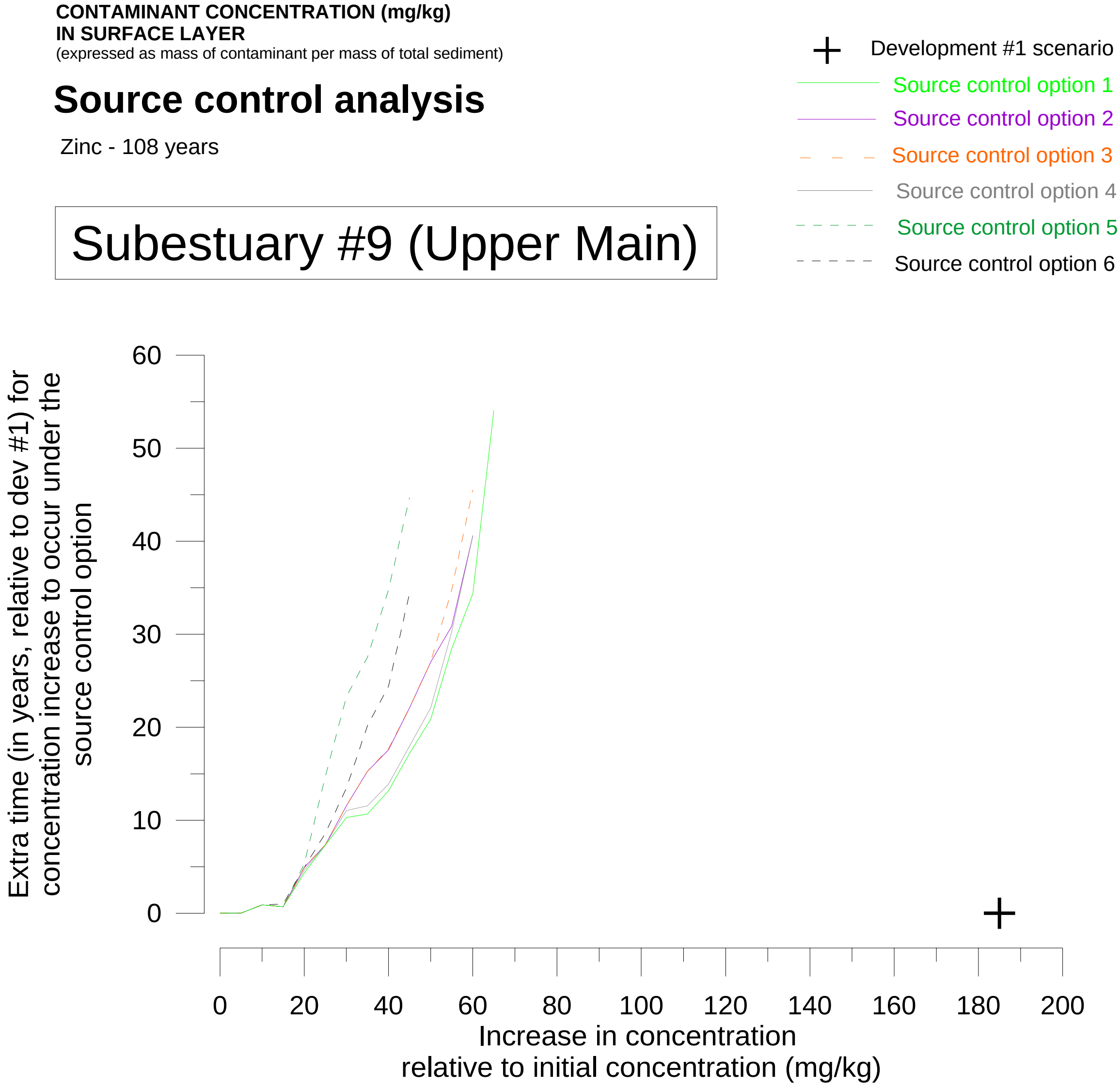


Figure 3.3:

[Continued] Concentration trajectory, Middle Main Body. See the first two panels for how to read this plot.

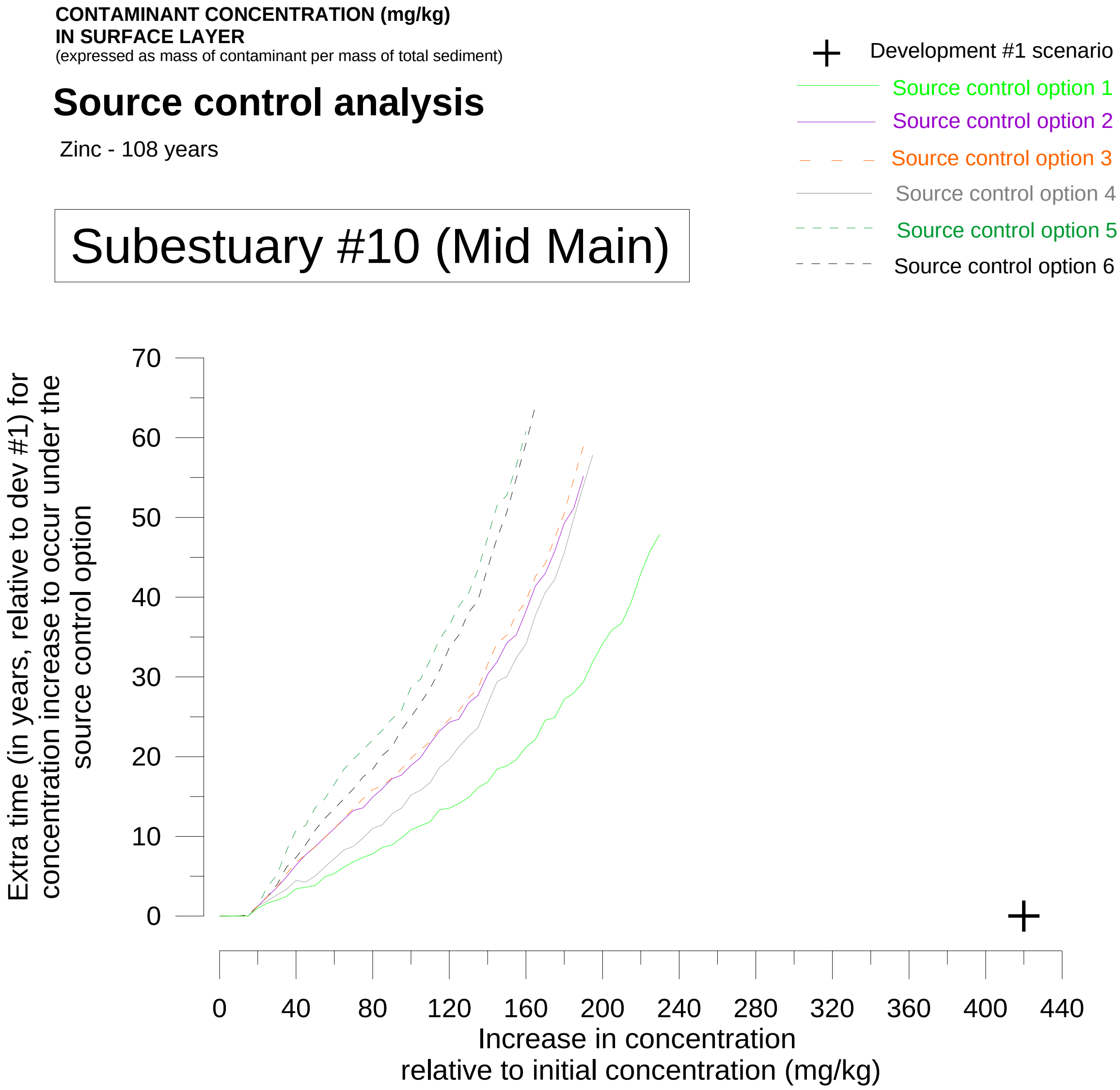
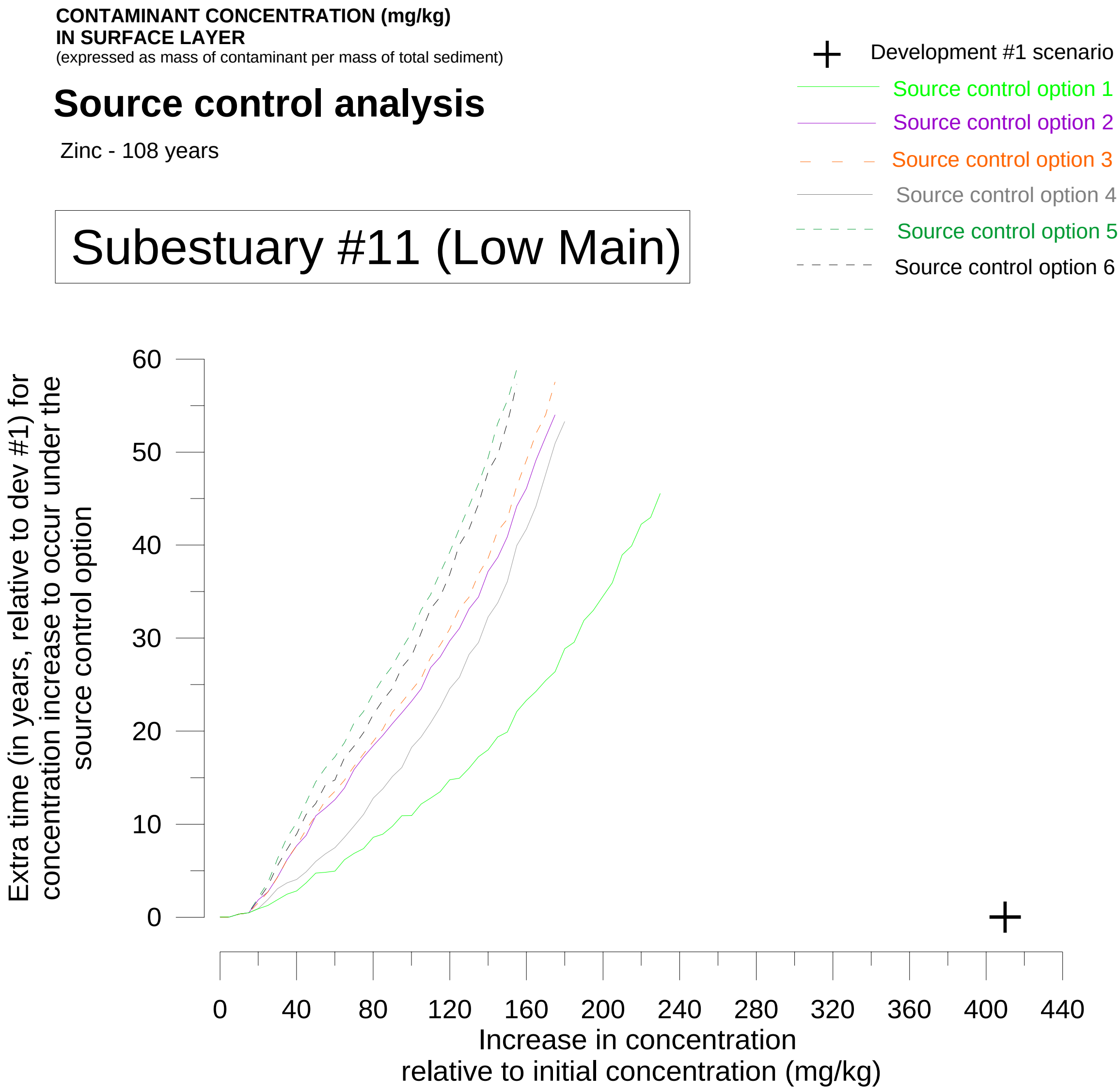


Figure 3.3:

[Continued] Concentration trajectory, Lower Main Body. See the first two panels for how to read this plot.



4 Discussion

The results show that the potential benefits in terms of zinc concentration in harbour sediments that would result from source control (i.e., reducing the amount of zinc in roof run-off) would greatly exceed the benefits achievable by the implementation of stormwater treatment only in new developments. The combination of source control in both existing and new developments and stormwater treatment in new developments would achieve the greatest benefit.

5 References

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