PORTLAND HARBOR RI

APPENDIX G
BASELINE ECOLOGICAL RISK ASSESSMENT
ATTACHMENT 6
TOXICITY TEST RESULTS AND INTERPRETATION

DRAFT

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Prepared for
The Lower Willamette Group

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1.0 INTRODUCTION

In the US Environmental Protection Agency's (EPA's) Problem Formulation (Attachment 2) to the baseline ecological risk assessment (BERA), EPA provided an approach for assessing sediment toxicity to benthic invertebrates using laboratory toxicity tests and two predictive models. Toxicity test interpretation was modified to incorporate a reference envelope approach recommended by MacDonald and Landrum (2008) following EPA's request for an independent review and additional negotiations between EPA and the Lower Willamette Group (LWG).

This attachment presents the results of toxicity tests using *Chironomus dilutus* and *Hyalella azteca*, an evaluation of the mortality and growth endpoints, and a summary of the reference envelope approach used to interpret the toxicity test responses. The MacDonald Environmental and Landrum report is provided as a supplement to this attachment.

2.0 TOXICITY TEST RESULTS

Results of the toxicity tests performed with *Chironomus dilutus* and *Hyalella azteca,* including the outcome of statistical comparisons between test samples and negative control samples, are presented in Tables 2-1 and 2-2, respectively. The location of sampling stations, either within the Study Area or within the upriver reach (river mile [RM] 15.4 to RM 25.5) is also noted.

Table 2-1. Results of the 10-Day *Chironomus* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
D1-1	Yes	15.0	21.3	0.89	0.82	No	No
D2	Yes	15.0	8.8	0.89	0.99	No	No
G007-1	Yes	15.0	28.8	0.58	0.52	Yes	No
G009	Yes	15.0	17.5	0.58	0.61	No	No
G010	Yes	15.0	18.8	0.58	0.55	No	No
G011	Yes	15.0	22.5	0.58	0.67	No	Yes
G015	Yes	15.0	11.3	0.58	0.65	No	Yes
G017	Yes	15.0	35.0	0.58	0.51	No	No
G019	Yes	15.0	15.0	0.58	0.69	No	Yes
G020	Yes	15.0	13.8	0.85	0.87	No	No
G024	Yes	15.0	17.5	0.85	0.89	No	No
G025	Yes	15.0	18.8	0.85	1.00	No	No
G026	Yes	15.0	18.8	0.58	0.58	No	No
G027	Yes	15.0	12.5	0.85	1.05	No	Yes
G033	Yes	15.0	18.8	0.85	0.80	No	No
G034	Yes	15.0	16.3	0.85	1.00	No	No
G035	Yes	15.0	11.3	0.85	0.86	No	No
G038	Yes	5.0	0.0	0.84	1.03	Yes	Yes
G060	Yes	15.0	12.5	0.58	0.69	No	Yes
G061	Yes	15.0	12.5	0.85	0.87	No	No
G062	Yes	15.0	22.5	0.85	0.81	No	No
G064	Yes	15.0	16.3	0.58	0.65	No	Yes
G066	Yes	15.0	10.0	0.58	0.67	No	Yes

Table 2-1. Results of the 10-Day *Chironomus* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G067	Yes	15.0	10.0	0.85	0.96	No	No
G073	Yes	15.0	16.3	0.85	0.92	No	No
G074	Yes	15.0	12.5	0.85	1.03	No	Yes
G077	Yes	10.0	20.0	0.84	0.75	Yes	No
G078	Yes	15.0	17.5	0.85	0.87	No	No
G079	Yes	15.0	18.8	0.85	0.84	No	No
G080	Yes	15.0	15.0	0.85	0.95	No	No
G082	Yes	10.0	13.8	0.84	0.93	No	No
G083	Yes	15.0	10.0	0.85	0.98	No	No
G085	Yes	15.0	40.0	0.85	0.32	Yes	Yes
G086	Yes	10.0	26.3	0.84	0.68	Yes	Yes
G088	Yes	10.0	41.3	0.84	0.55	Yes	Yes
G089	Yes	15.0	41.3	0.85	0.51	Yes	Yes
G090	Yes	10.0	25.0	0.84	0.55	Yes	Yes
G091	Yes	10.0	28.8	0.84	0.63	No	No
G092	Yes	15.0	100.0	0.85	100% mortality	Yes	Yes
G093	Yes	5.0	6.3	1.02	0.79	No	Yes
G096	Yes	10.0	21.3	0.84	0.77	Yes	No
G099	Yes	10.0	30.0	0.84	0.61	No	Yes
G103	Yes	10.0	27.5	0.84	0.69	Yes	Yes
G105	Yes	10.0	38.8	0.84	0.51	Yes	Yes
G106	Yes	10.0	13.8	0.84	0.78	No	No
G109	Yes	10.0	21.3	0.84	0.63	No	Yes
G111	Yes	15.0	26.3	0.85	0.80	No	No
G112	Yes	10.0	16.3	0.84	0.70	No	Yes
G117	Yes	10.0	63.8	0.84	0.15	Yes	Yes
G121	Yes	10.0	25.0	0.84	0.70	No	No
G122	Yes	10.0	28.8	0.84	0.59	Yes	Yes

Table 2-1. Results of the 10-Day *Chironomus* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G123	Yes	5.0	21.3	0.84	0.77	Yes	No
G124	Yes	7.5	16.3	0.90	0.92	Yes	No
G127	Yes	10.0	17.5	0.97	1.10	No	No
G130	Yes	10.0	12.5	0.97	1.10	No	No
G133	Yes	10.0	26.3	0.97	0.99	Yes	No
G136	Yes	10.0	13.8	0.97	1.05	No	No
G139	Yes	10.0	12.5	0.97	1.25	No	Yes
G142	Yes	10.0	21.3	0.97	1.18	No	Yes
G147	Yes	10.0	21.3	0.97	1.05	No	No
G155	Yes	5.0	11.3	0.84	0.61	No	Yes
G157	Yes	5.0	53.8	0.84	0.12	Yes	Yes
G160	Yes	5.0	58.8	0.84	0.16	Yes	Yes
G161	Yes	5.0	30.0	0.84	0.25	Yes	Yes
G163	Yes	5.0	2.5	0.84	0.84	No	No
G164	Yes	10.0	12.5	0.84	0.87	No	No
G166	Yes	5.0	5.0	0.84	0.82	No	No
G170	Yes	10.0	7.5	0.97	1.19	No	Yes
G172	Yes	10.0	16.3	0.97	0.91	No	No
G176	Yes	10.0	65.0	0.97	0.20	Yes	Yes
G178	Yes	10.0	18.8	0.84	0.81	Yes	No
G179	Yes	10.0	71.3	0.97	0.19	Yes	Yes
G180	Yes	10.0	17.5	0.84	0.70	No	Yes
G182	Yes	10.0	8.8	0.97	1.24	No	Yes
G184	Yes	10.0	12.5	0.97	1.15	No	Yes
G187	Yes	10.0	32.5	0.97	0.83	Yes	No
G197-1	Yes	13.8	15.0	1.06	1.11	No	No
G198	Yes	5.0	0.0	0.84	0.84	Yes	No
G199	Yes	5.0	5.0	0.84	0.85	No	No
G200	Yes	5.0	10.0	1.02	0.98	No	No

Table 2-1. Results of the 10-Day *Chironomus* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G202	Yes	5.0	3.8	0.84	0.90	No	No
G203-1	Yes	15.0	17.5	0.58	0.58	No	No
G204	Yes	5.0	8.8	0.84	0.75	No	Yes
G205	Yes	6.3	11.3	0.97	1.17	No	Yes
G206	Yes	5.0	6.3	1.02	0.93	No	Yes
G207	Yes	5.0	13.8	0.84	0.74	Yes	Yes
G209	Yes	5.0	5.0	0.84	0.95	No	Yes
G210	Yes	5.0	33.8	1.02	0.63	Yes	Yes
G212-1	Yes	6.3	13.8	0.97	0.97	No	No
G213	Yes	5.0	5.0	1.02	0.85	No	Yes
G220	Yes	15.0	17.5	0.58	0.57	No	No
G221	Yes	15.0	13.8	0.58	0.63	No	No
G227	Yes	10.0	18.8	0.97	1.07	No	No
G228	Yes	10.0	3.8	0.97	1.23	No	Yes
G230	Yes	10.0	17.5	0.97	1.16	No	Yes
G231	Yes	5.0	3.8	0.84	1.00	No	Yes
G232	Yes	8.8	7.5	0.80	1.08	No	Yes
G234	Yes	5.0	5.0	0.84	0.90	No	No
G235	Yes	10.0	16.3	0.84	0.67	No	Yes
G240	Yes	10.0	15.0	0.97	1.14	No	Yes
G242	Yes	10.0	17.5	0.97	1.07	No	No
G244	Yes	5.0	2.5	0.84	0.99	No	Yes
G245	Yes	10.0	13.8	0.97	1.12	No	Yes
G247	Yes	5.0	3.8	0.84	0.91	No	No
G254	Yes	5.0	8.8	0.84	0.74	No	Yes
G260	Yes	8.8	7.5	0.87	1.09	No	Yes
G263	Yes	8.8	17.5	0.80	0.76	Yes	No
G264	Yes	8.8	51.3	0.80	0.22	Yes	Yes
G267	Yes	8.8	6.3	0.80	0.89	No	Yes

Table 2-1. Results of the 10-Day *Chironomus* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G268	Yes	8.8	12.5	0.87	0.94	No	No
G269	Yes	8.8	31.3	0.80	0.33	Yes	Yes
G270-1	Yes	15.0	37.5	0.58	0.32	Yes	Yes
G273	Yes	7.5	13.8	0.90	0.65	No	Yes
G274	Yes	6.3	32.5	0.97	0.42	Yes	Yes
G276	Yes	8.8	25.0	0.80	0.63	Yes	Yes
G277	Yes	7.5	11.3	0.90	0.92	No	No
G278	Yes	8.8	37.5	0.80	0.45	Yes	Yes
G280	Yes	7.5	10.0	0.90	0.89	No	No
G282	Yes	5.0	10.0	1.02	0.91	No	Yes
G283	Yes	8.8	96.3	0.80	0.01	Yes	Yes
G284	Yes	8.8	8.8	0.80	0.77	No	No
G288	Yes	8.8	100.0	0.87	100% mortality	Yes	Yes
G292	Yes	8.8	17.5	0.87	0.93	No	No
G294-1	Yes	15.0	100.0	0.58	100% mortality	Yes	Yes
G295	Yes	7.5	6.3	0.90	0.93	No	No
G296	Yes	6.3	7.5	0.97	1.00	No	No
G298	Yes	8.8	100.0	0.87	100% mortality	Yes	Yes
G301	Yes	8.8	7.5	0.87	0.96	No	Yes
G302	Yes	8.8	100.0	0.87	100% mortality	Yes	Yes
G303	Yes	6.3	11.3	0.97	1.02	No	No
G308	Yes	8.8	35.0	0.87	0.53	Yes	Yes
G311-1	Yes	15.0	86.3	0.58	0.01	Yes	Yes
G315	Yes	8.8	13.8	0.87	0.89	No	No
G316	Yes	8.8	12.5	0.87	0.98	No	Yes
G318	Yes	8.8	12.5	0.87	0.83	No	No

Table 2-1. Results of the 10-Day *Chironomus* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G320	Yes	8.8	38.8	0.87	0.52	Yes	Yes
G321	Yes	13.8	16.3	1.06	0.84	No	No
G323	Yes	8.8	11.3	0.87	1.08	No	Yes
G324-1	Yes	15.0	27.5	0.58	0.64	No	No
G327	Yes	8.8	17.5	0.87	0.43	No	Yes
G329	Yes	13.8	5.0	1.06	1.16	Yes	No
G331	Yes	8.8	5.0	0.87	0.99	No	Yes
G333	Yes	8.8	13.8	0.87	0.95	No	No
G334	Yes	15.0	6.3	0.58	0.59	Yes	No
G335	Yes	8.8	13.8	0.87	0.88	No	No
G336	Yes	8.8	18.8	0.87	0.91	Yes	No
G339	Yes	8.8	22.5	0.80	0.54	Yes	Yes
G342	Yes	7.5	12.5	0.90	0.90	No	No
G345-1	Yes	15.0	17.5	0.58	0.53	No	Yes
G346	Yes	7.5	10.0	0.90	0.95	No	No
G347	Yes	7.5	13.8	0.90	0.83	No	No
G348	Yes	8.8	36.3	0.87	0.52	Yes	Yes
G350	Yes	8.8	12.5	0.87	0.85	No	No
G351	Yes	5.0	3.8	1.02	0.92	No	Yes
G352	Yes	7.5	12.5	0.90	0.91	No	No
G353-1	Yes	13.8	8.8	1.06	1.09	No	No
G355	Yes	6.3	12.5	0.97	0.85	No	Yes
G359	Yes	13.8	27.5	1.06	0.85	No	No
G360	Yes	6.3	52.5	0.97	0.42	Yes	Yes
G362-1	Yes	5.0	12.5	1.02	0.89	No	Yes
G364	Yes	7.5	15.0	0.90	0.76	No	Yes
G366	Yes	5.0	100.0	1.02	100% mortality	Yes	Yes
G367	Yes	6.3	5.0	0.97	0.98	No	No

Table 2-1. Results of the 10-Day *Chironomus* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G368	Yes	7.5	88.8	0.90	0.04	Yes	Yes
G371	Yes	5.0	60.0	1.02	0.45	Yes	Yes
G372-1	Yes	13.8	3.8	1.06	1.03	Yes	No
G376	Yes	6.3	8.8	0.97	0.97	No	No
G377	Yes	5.0	6.3	1.02	1.05	No	No
G380	Yes	5.0	10.0	1.02	1.05	No	No
G382	Yes	7.5	11.3	0.90	0.98	No	No
G383	Yes	7.5	11.3	0.90	1.00	No	No
G384-1	Yes	13.8	17.5	1.06	0.91	No	No
G385	Yes	6.3	10.0	0.97	0.97	No	No
G386	Yes	8.8	6.3	0.80	0.99	No	Yes
G387	Yes	13.8	15.0	1.06	1.05	No	No
G389	Yes	6.3	21.3	0.97	0.92	Yes	No
G390	Yes	13.8	25.0	1.06	0.49	No	Yes
G392	Yes	7.5	7.5	0.90	0.74	No	Yes
G393	Yes	5.0	6.3	1.02	0.91	No	Yes
G396	Yes	7.5	16.3	0.90	0.86	Yes	No
G398	Yes	13.8	8.8	1.06	1.19	No	No
G401	Yes	5.0	6.3	1.02	0.94	No	Yes
G403	Yes	5.0	8.8	1.02	0.97	No	No
G405	Yes	7.5	13.8	0.90	0.99	No	No
G408	Yes	6.3	12.5	0.97	1.03	Yes	No
G409	Yes	7.5	5.0	0.90	0.95	No	No
G413	Yes	5.0	6.3	1.02	1.07	No	No
G415	Yes	5.0	2.5	1.02	0.92	No	Yes
G416	Yes	6.3	6.3	0.97	0.90	No	No
G417	Yes	5.0	3.8	1.02	1.03	No	No
G420	Yes	7.5	11.3	0.90	0.93	No	No
G425	Yes	7.5	10.0	0.90	1.04	No	Yes

Table 2-1. Results of the 10-Day *Chironomus* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G426	Yes	7.5	6.3	0.90	0.90	No	No
G430	Yes	5.0	7.5	1.02	1.04	No	No
G437	Yes	5.0	2.5	1.02	0.97	No	No
G441	Yes	13.8	12.5	1.06	1.11	No	No
G444	Yes	13.8	10.0	1.06	0.98	No	No
G445	Yes	13.8	11.3	1.06	0.77	No	Yes
G450-1	Yes	13.8	25.0	1.06	0.90	No	No
G453	Yes	8.8	95.0	0.80	0.00	Yes	Yes
G454	Yes	8.8	12.5	0.80	0.96	No	Yes
G455	Yes	13.8	33.8	1.06	0.47	Yes	Yes
G456	Yes	8.8	6.3	0.80	0.85	No	No
G457	Yes	8.8	11.3	0.80	0.87	No	No
G458	Yes	13.8	11.3	1.06	1.10	No	No
G461	Yes	8.8	12.5	0.80	0.94	No	Yes
G467	Yes	8.8	11.3	0.80	1.08	No	Yes
G468	Yes	8.8	20.0	0.80	0.84	Yes	No
G469	Yes	13.8	21.3	1.06	0.89	No	No
G473	Yes	8.8	7.5	0.80	0.99	No	Yes
G474	Yes	13.8	11.3	1.06	1.15	No	No
G477	Yes	8.8	13.8	0.80	0.93	No	Yes
G480	Yes	8.8	10.0	0.80	0.76	No	No
G492-1	Yes	13.8	10.0	1.06	1.15	No	No
G497	Yes	13.8	12.5	1.06	1.04	No	No
G612-1	Yes	12.5	8.8	0.79	0.74	No	Yes
G613	Yes	11.3	10.0	0.71	0.72	No	No
G622	Yes	12.5	23.8	0.79	0.68	No	No
G623	Yes	12.5	12.5	0.79	0.73	No	No
G625	Yes	12.5	4.3	0.79	0.70	No	No
G628	Yes	12.5	13.8	0.79	0.72	No	No

Table 2-1. Results of the 10-Day *Chironomus* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G637-1	Yes	12.5	15.0	0.79	0.76	No	No
G638	Yes	12.5	6.3	0.79	0.80	No	No
G643	Yes	12.5	15.7	0.79	0.62	No	Yes
G648	Yes	12.5	10.0	0.79	0.72	No	No
G653	Yes	12.5	11.3	0.79	0.67	No	Yes
G654	Yes	12.5	31.3	0.79	0.38	No	Yes
G656	Yes	11.3	18.8	0.71	0.63	No	No
G663	Yes	12.5	17.5	0.79	0.60	No	Yes
G665	Yes	12.5	17.5	0.79	0.76	No	No
G670	Yes	11.3	20.0	0.71	0.77	No	No
G671	Yes	12.5	2.5	0.79	0.76	Yes	No
G672	Yes	11.3	32.5	0.71	0.57	Yes	Yes
G674	Yes	12.5	13.8	0.79	0.71	No	Yes
G675	Yes	11.3	12.5	0.71	0.78	No	No
G683	Yes	12.5	11.3	0.79	0.70	No	Yes
G684-1	Yes	11.3	11.3	0.71	0.70	No	No
G685	Yes	12.5	8.8	0.79	0.76	No	No
G689	Yes	12.5	55.0	0.79	0.35	Yes	Yes
G693	Yes	12.5	13.8	0.79	0.66	No	Yes
G694	Yes	12.5	10.0	0.79	0.56	No	Yes
G700	Yes	12.5	12.5	0.79	0.69	No	Yes
G707	Yes	12.5	11.3	0.79	0.72	No	No
G711	Yes	12.5	12.5	0.79	0.74	No	No
G713	Yes	12.5	16.3	0.79	0.69	No	Yes
G718	Yes	12.5	11.3	0.79	0.67	No	Yes
G722	Yes	12.5	7.5	0.79	0.69	No	Yes
G736	Yes	12.5	7.5	0.79	0.79	No	No
G737	Yes	12.5	18.8	0.79	0.68	No	Yes
G740	Yes	11.3	15.0	0.71	0.74	No	No

Table 2-1. Results of the 10-Day *Chironomus* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G741	Yes	11.3	11.3	0.71	0.76	No	No
G744	Yes	11.3	25.0	0.71	0.70	No	No
G745	Yes	11.3	10.0	0.71	0.74	No	No
G746	Yes	11.3	22.5	0.71	0.68	Yes	No
G750	Yes	11.3	22.5	0.71	0.66	No	No
G751	Yes	11.3	15.0	0.71	0.74	No	No
G752	Yes	11.3	21.3	0.71	0.73	No	No
G755	Yes	11.3	15.0	0.71	0.81	No	No
G756	Yes	11.3	23.8	0.71	0.73	No	No
G763	Yes	11.3	13.8	0.71	0.88	No	Yes
G766	Yes	11.3	15.0	0.71	0.80	No	No
G767	Yes	11.3	8.8	0.71	0.76	No	No
G769	Yes	11.3	20.0	0.71	0.73	No	No
G772	Yes	11.3	13.8	0.71	0.89	No	Yes
G775	Yes	11.3	8.8	0.71	0.91	No	Yes
G776	Yes	11.3	8.8	0.71	0.94	No	Yes
G777	Yes	11.3	17.5	0.71	0.67	No	No
G778	Yes	11.3	28.8	0.71	0.62	No	No
G779	Yes	11.3	22.5	0.71	0.71	No	No
G780	Yes	11.3	13.8	0.71	0.82	No	No
G781	Yes	11.3	15.0	0.71	0.73	No	No
G785[b]	No	12.5	13.8	0.79	0.86	No	Yes
G785a[b]	No	11.3	17.5	0.71	0.77	No	No
G786[b]	No	12.5	12.5	0.79	0.80	No	No
G786a[b]	No	11.3	18.8	0.71	0.67	No	No
G787[b]	No	12.5	12.5	0.79	0.67	No	Yes
G787a[b]	No	11.3	30.0	0.71	0.57	Yes	Yes
G788[b]	No	12.5	10.0	0.79	0.65	No	Yes
G788a[b]	No	11.3	16.3	0.71	0.63	No	No

Table 2-1. Results of the 10-Day *Chironomus* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
U1C-1	No	15.0	5.0	0.89	1.11	Yes	Yes
U1C-2	No	15.0	11.3	0.89	1.05	No	Yes
U1C-3	No	15.0	6.3	0.89	1.05	No	Yes
U2C-1	No	15.0	11.3	0.89	1.18	No	Yes
U2C-2	No	15.0	10.0	0.89	1.03	No	Yes
U2C-3	No	15.0	11.3	0.89	1.04	No	Yes
U3C-1	No	15.0	10.0	0.89	1.15	No	Yes
U3C-2	No	15.0	11.3	0.89	1.14	No	Yes
U3C-3	No	15.0	3.8	0.89	1.20	Yes	Yes
U4Q-1	No	15.0	6.3	0.89	1.01	No	Yes
U4Q-2	No	15.0	6.3	0.89	1.16	No	Yes
U4Q-3	No	15.0	8.8	0.89	1.00	No	No
U5Q-1	No	15.0	12.5	0.89	1.00	No	No
U5Q-2	No	15.0	22.5	0.89	0.89	No	No
U5Q-3	No	15.0	6.3	0.89	1.05	No	Yes
U6TOC-1	No	15.0	5.0	0.89	1.02	Yes	Yes
U6TOC-2	No	15.0	12.5	0.89	1.06	No	Yes
U6TOC-3	No	15.0	11.3	0.89	0.97	No	No

[a] Statistically different from the negative control response (one-tailed test, $p < 0.05$). Note that the test growth response was considered significantly different from control without the performance of the statistical test, in which all organisms died.

[b] Toxicity testing of the sediment samples from stations G785, G786, G787, and G788 was performed twice (as reference sediments).

Table 2-2. Results of the 28-Day *Hyalella* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
D1-1	Yes	3.8	0.0	0.37	0.24	No	Yes
D2	Yes	3.8	3.8	0.37	0.32	No	Yes
G007-1	Yes	0.0	2.5	0.26	0.17	No	Yes
G009	Yes	0.0	8.8	0.26	0.25	Yes	No

Table 2-2. Results of the 28-Day *Hyalella* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G010	Yes	0.0	3.8	0.26	0.19	Yes	Yes
G011	Yes	0.0	2.5	0.26	0.27	No	No
G015	Yes	0.0	6.3	0.26	0.19	No	Yes
G017	Yes	0.0	5.0	0.26	0.20	Yes	Yes
G019	Yes	0.0	8.8	0.26	0.39	Yes	Yes
G020	Yes	2.5	2.5	0.32	0.24	No	Yes
G024	Yes	2.5	6.3	0.32	0.18	No	Yes
G025	Yes	2.5	3.8	0.32	0.53	No	Yes
G026	Yes	0.0	3.8	0.26	0.20	Yes	Yes
G027	Yes	2.5	5.0	0.32	0.29	No	No
G033	Yes	2.5	6.3	0.32	0.21	No	Yes
G034	Yes	2.5	1.3	0.32	0.26	No	Yes
G035	Yes	2.5	6.3	0.32	0.26	No	No
G038	Yes	3.8	1.3	0.31	0.32	No	No
G060	Yes	0.0	3.8	0.26	0.25	Yes	No
G061	Yes	2.5	2.5	0.32	0.20	No	Yes
G062	Yes	2.5	2.5	0.32	0.23	No	Yes
G064	Yes	0.0	5.0	0.26	0.25	Yes	No
G066	Yes	0.0	8.8	0.26	0.27	Yes	No
G067	Yes	2.5	1.3	0.32	0.23	No	Yes
G073	Yes	2.5	8.8	0.32	0.30	No	No
G074	Yes	2.5	7.5	0.32	0.26	No	Yes
G077	Yes	5.0	3.8	0.28	0.24	No	No
G078	Yes	2.5	21.3	0.32	0.22	Yes	Yes
G079	Yes	2.5	12.5	0.32	0.23	Yes	Yes
G080	Yes	2.5	5.0	0.32	0.30	No	No
G082	Yes	5.0	6.3	0.28	0.29	No	No
G083	Yes	2.5	10.0	0.32	0.18	Yes	Yes
G085	Yes	2.5	20.0	0.32	0.22	Yes	Yes
G086	Yes	5.0	3.8	0.28	0.28	No	No

Table 2-2. Results of the 28-Day *Hyalella* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G088	Yes	5.0	5.0	0.28	0.24	No	No
G089	Yes	2.5	7.5	0.32	0.21	No	Yes
G090	Yes	5.0	5.0	0.28	0.27	No	No
G091	Yes	5.0	6.3	0.28	0.30	No	No
G092	Yes	2.5	100.0	0.32	100% mortality	Yes	Yes
G093	Yes	1.3	7.5	0.43	0.32	Yes	Yes
G096	Yes	5.0	5.0	0.28	0.27	No	No
G099	Yes	5.0	1.3	0.28	0.27	No	No
G103	Yes	5.0	3.8	0.28	0.25	No	No
G105	Yes	5.0	2.5	0.28	0.33	No	No
G106	Yes	5.0	7.5	0.28	0.26	No	No
G109	Yes	5.0	2.5	0.28	0.25	No	No
G111	Yes	2.5	5.0	0.32	0.22	No	Yes
G112	Yes	5.0	6.3	0.28	0.26	No	No
G117	Yes	5.0	17.5	0.28	0.25	Yes	Yes
G121	Yes	5.0	5.0	0.28	0.27	No	No
G122	Yes	5.0	0.0	0.28	0.22	Yes	Yes
G123	Yes	3.8	13.8	0.31	0.18	Yes	Yes
G124	Yes	1.3	6.3	0.32	0.24	No	Yes
G127	Yes	11.3	1.3	0.31	0.27	Yes	Yes
G130	Yes	11.3	2.5	0.31	0.32	Yes	No
G133	Yes	11.3	7.5	0.31	0.27	No	Yes
G136	Yes	11.3	12.5	0.31	0.26	No	Yes
G139	Yes	11.3	6.3	0.31	0.31	No	No
G142	Yes	11.3	6.3	0.31	0.37	No	Yes
G147	Yes	11.3	10.0	0.31	0.30	No	No
G155	Yes	3.8	3.8	0.31	0.20	No	Yes
G157	Yes	3.8	51.3	0.31	0.13	Yes	Yes
G160	Yes	3.8	21.3	0.31	0.22	Yes	Yes

Table 2-2. Results of the 28-Day *Hyalella* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G161	Yes	3.8	32.5	0.31	0.18	Yes	Yes
G163	Yes	3.8	5.0	0.31	0.30	No	No
G164	Yes	5.0	2.5	0.28	0.28	No	No
G166	Yes	3.8	15.0	0.31	0.25	Yes	Yes
G170	Yes	11.3	8.8	0.31	0.25	No	Yes
G172	Yes	11.3	12.5	0.31	0.26	No	Yes
G176	Yes	11.3	41.3	0.31	0.19	Yes	Yes
G178	Yes	5.0	3.8	0.28	0.28	No	No
G179	Yes	11.3	86.3	0.31	0.06	Yes	Yes
G180	Yes	5.0	3.8	0.28	0.30	No	No
G182	Yes	11.3	7.5	0.31	0.32	No	No
G184	Yes	11.3	6.3	0.31	0.28	No	No
G187	Yes	11.3	10.0	0.31	0.24	No	Yes
G197-1	Yes	10.0	8.8	0.30	0.31	No	No
G198	Yes	3.8	2.5	0.31	0.27	No	Yes
G199	Yes	3.8	11.3	0.31	0.26	Yes	Yes
G200	Yes	1.3	3.8	0.43	0.28	No	Yes
G202	Yes	3.8	3.8	0.31	0.27	No	Yes
G203-1	Yes	0.0	6.3	0.26	0.19	Yes	Yes
G204	Yes	3.8	2.5	0.31	0.23	No	Yes
G205	Yes	5.0	3.8	0.41	0.29	No	Yes
G206	Yes	1.3	0.0	0.43	0.31	No	Yes
G207	Yes	3.8	11.3	0.31	0.25	No	Yes
G209	Yes	3.8	3.8	0.31	0.37	No	Yes
G210	Yes	1.3	68.8	0.43	0.12	Yes	Yes
G212-1	Yes	5.0	5.0	0.41	0.30	No	Yes
G213	Yes	1.3	7.5	0.43	0.29	Yes	Yes
G220	Yes	0.0	6.3	0.26	0.20	Yes	Yes
G221	Yes	0.0	3.8	0.26	0.28	No	No
G227	Yes	11.3	6.3	0.31	0.32	No	No

Table 2-2. Results of the 28-Day *Hyalella* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G228	Yes	11.3	5.0	0.31	0.29	No	No
G230	Yes	11.3	3.8	0.31	0.27	Yes	No
G231	Yes	3.8	7.5	0.31	0.27	No	Yes
G232	Yes	11.3	8.8	0.31	0.29	No	No
G234	Yes	3.8	8.8	0.31	0.28	No	No
G235	Yes	5.0	5.0	0.28	0.25	No	No
G240	Yes	11.3	7.5	0.31	0.25	No	Yes
G242	Yes	11.3	7.5	0.31	0.27	No	Yes
G244	Yes	3.8	6.3	0.31	0.28	No	Yes
G245	Yes	11.3	7.5	0.31	0.20	No	Yes
G247	Yes	3.8	2.5	0.31	0.25	No	Yes
G254	Yes	3.8	6.3	0.31	0.26	No	Yes
G260	Yes	5.0	5.0	0.24	0.28	No	No
G263	Yes	11.3	5.0	0.31	0.24	No	Yes
G264	Yes	11.3	21.3	0.31	0.23	No	Yes
G267	Yes	11.3	13.8	0.31	0.19	No	Yes
G268	Yes	5.0	7.5	0.24	0.19	No	Yes
G269	Yes	11.3	17.5	0.31	0.24	No	Yes
G270-1	Yes	0.0	7.5	0.26	0.18	Yes	Yes
G273	Yes	1.3	30.0	0.32	0.18	Yes	Yes
G274	Yes	5.0	83.8	0.41	0.06	Yes	Yes
G276	Yes	11.3	7.5	0.31	0.21	No	Yes
G277	Yes	1.3	8.8	0.32	0.23	No	Yes
G278	Yes	11.3	6.3	0.31	0.28	No	No
G280	Yes	1.3	6.3	0.32	0.20	Yes	Yes
G282	Yes	1.3	6.3	0.43	0.30	No	Yes
G283	Yes	11.3	98.8	0.31	0.00	Yes	Yes
G284	Yes	11.3	11.3	0.31	0.22	No	Yes
G288	Yes	5.0	100.0	0.24	100% mortality	Yes	Yes

Table 2-2. Results of the 28-Day *Hyalella* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G292	Yes	5.0	12.5	0.24	0.23	No	No
G294-1	Yes	0.0	100.0	0.26	100% mortality	Yes	Yes
G295	Yes	1.3	11.3	0.32	0.19	Yes	Yes
G296	Yes	5.0	6.3	0.41	0.22	No	Yes
G298	Yes	5.0	100.0	0.24	100% mortality	Yes	Yes
G301	Yes	5.0	7.5	0.24	0.21	No	Yes
G302	Yes	5.0	98.8	0.24	0.00	Yes	Yes
G303	Yes	5.0	8.8	0.41	0.26	No	Yes
G308	Yes	5.0	21.3	0.24	0.17	Yes	Yes
G311-1	Yes	0.0	38.8	0.26	0.19	Yes	Yes
G315	Yes	5.0	7.5	0.24	0.20	No	Yes
G316	Yes	5.0	3.8	0.24	0.26	No	No
G318	Yes	5.0	1.3	0.24	0.23	No	No
G320	Yes	5.0	6.3	0.24	0.20	No	Yes
G321	Yes	10.0	11.3	0.30	0.21	No	Yes
G323	Yes	5.0	12.5	0.24	0.25	Yes	No
G324-1	Yes	0.0	6.3	0.26	0.22	Yes	No
G327	Yes	5.0	11.3	0.24	0.19	Yes	Yes
G329	Yes	10.0	1.3	0.30	0.32	Yes	No
G331	Yes	5.0	7.5	0.24	0.25	No	No
G333	Yes	5.0	2.5	0.24	0.26	No	No
G334	Yes	0.0	7.5	0.26	0.23	Yes	Yes
G335	Yes	5.0	8.8	0.24	0.21	No	Yes
G336	Yes	5.0	7.5	0.24	0.20	No	Yes
G339	Yes	11.3	7.5	0.31	0.24	No	Yes
G342	Yes	1.3	6.3	0.32	0.21	No	Yes
G345-1	Yes	0.0	5.0	0.26	0.20	No	Yes
G346	Yes	1.3	5.0	0.32	0.17	No	Yes
G347	Yes	1.3	7.5	0.32	0.20	Yes	Yes

Table 2-2. Results of the 28-Day *Hyalella* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G348	Yes	5.0	8.8	0.24	0.23	No	No
G350	Yes	5.0	7.5	0.24	0.21	No	No
G351	Yes	1.3	1.3	0.43	0.26	No	Yes
G352	Yes	1.3	3.8	0.32	0.22	No	Yes
G353-1	Yes	10.0	3.8	0.30	0.26	No	Yes
G355	Yes	5.0	3.8	0.41	0.34	No	Yes
G359	Yes	10.0	7.5	0.30	0.21	No	Yes
G360	Yes	5.0	43.8	0.41	0.22	Yes	Yes
G362-1	Yes	1.3	8.8	0.43	0.33	Yes	Yes
G364	Yes	1.3	10.0	0.32	0.20	Yes	Yes
G366	Yes	1.3	67.5	0.43	0.13	Yes	Yes
G367	Yes	5.0	3.8	0.41	0.34	No	Yes
G368	Yes	1.3	82.5	0.32	0.10	Yes	Yes
G371	Yes	1.3	61.3	0.43	0.20	Yes	Yes
G372-1	Yes	10.0	8.8	0.30	0.24	No	Yes
G376	Yes	5.0	3.8	0.41	0.29	No	Yes
G377	Yes	1.3	5.0	0.43	0.29	No	Yes
G380	Yes	1.3	10.0	0.43	0.38	Yes	Yes
G382	Yes	1.3	8.8	0.32	0.19	Yes	Yes
G383	Yes	1.3	3.8	0.32	0.29	No	Yes
G384-1	Yes	10.0	11.3	0.30	0.23	No	Yes
G385	Yes	5.0	7.5	0.41	0.32	No	Yes
G386	Yes	11.3	2.5	0.31	0.21	Yes	Yes
G387	Yes	10.0	7.5	0.30	0.22	No	Yes
G389	Yes	5.0	15.0	0.41	0.30	No	Yes
G390	Yes	10.0	97.5	0.30	0.00	Yes	Yes
G392	Yes	1.3	5.0	0.32	0.21	No	Yes
G393	Yes	1.3	5.0	0.43	0.34	No	Yes
G396	Yes	1.3	18.8	0.32	0.21	Yes	Yes
G398	Yes	10.0	15.0	0.30	0.17	No	Yes

Table 2-2. Results of the 28-Day *Hyalella* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G401	Yes	1.3	3.8	0.43	0.26	No	Yes
G403	Yes	1.3	3.8	0.43	0.34	No	Yes
G405	Yes	1.3	10.0	0.32	0.29	Yes	No
G408	Yes	5.0	12.5	0.41	0.31	No	Yes
G409	Yes	1.3	6.3	0.32	0.23	No	Yes
G413	Yes	1.3	1.3	0.43	0.37	No	Yes
G415	Yes	1.3	8.8	0.43	0.31	Yes	Yes
G416	Yes	5.0	5.0	0.41	0.25	No	Yes
G417	Yes	1.3	5.0	0.43	0.34	No	Yes
G420	Yes	1.3	2.5	0.32	0.26	No	Yes
G425	Yes	1.3	0.0	0.32	0.28	No	No
G426	Yes	1.3	7.5	0.32	0.22	No	Yes
G430	Yes	1.3	3.8	0.43	0.40	No	No
G437	Yes	1.3	6.3	0.43	0.33	No	Yes
G441	Yes	10.0	7.5	0.30	0.25	No	Yes
G444	Yes	10.0	10.0	0.30	0.22	No	Yes
G445	Yes	10.0	15.0	0.30	0.17	No	Yes
G450-1	Yes	10.0	5.0	0.30	0.23	No	Yes
G453	Yes	11.3	96.3	0.31	0.01	Yes	Yes
G454	Yes	11.3	8.8	0.31	0.25	No	Yes
G455	Yes	10.0	17.5	0.30	0.22	No	Yes
G456	Yes	11.3	8.8	0.31	0.23	No	Yes
G457	Yes	11.3	22.5	0.31	0.21	No	Yes
G458	Yes	10.0	8.8	0.30	0.21	No	Yes
G461	Yes	11.3	12.5	0.31	0.22	No	Yes
G467	Yes	11.3	12.5	0.31	0.26	No	No
G468	Yes	11.3	8.8	0.31	0.17	No	Yes
G469	Yes	10.0	5.0	0.30	0.25	No	Yes
G473	Yes	11.3	10.0	0.31	0.24	No	Yes
G474	Yes	10.0	8.8	0.30	0.27	No	No

Table 2-2. Results of the 28-Day *Hyalella* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G477	Yes	11.3	3.8	0.31	0.26	No	Yes
G480	Yes	11.3	10.0	0.31	0.30	No	No
G492-1	Yes	10.0	3.8	0.30	0.24	No	Yes
G497	Yes	10.0	8.8	0.30	0.24	No	Yes
G612-1	Yes	10.0	7.5	0.17	0.09	No	Yes
G613	Yes	0.0	11.3	0.20	0.13	Yes	Yes
G622	Yes	10.0	12.5	0.17	0.11	No	Yes
G623	Yes	10.0	15.0	0.17	0.11	No	Yes
G625	Yes	10.0	5.0	0.17	0.11	No	Yes
G628	Yes	10.0	8.8	0.17	0.10	No	Yes
G637-1	Yes	10.0	8.8	0.17	0.10	No	Yes
G638	Yes	10.0	12.5	0.17	0.10	No	Yes
G643	Yes	10.0	10.0	0.17	0.11	No	Yes
G648	Yes	10.0	10.0	0.17	0.10	No	Yes
G653	Yes	10.0	16.3	0.17	0.10	No	Yes
G654	Yes	10.0	13.8	0.17	0.12	No	Yes
G656	Yes	0.0	12.5	0.20	0.14	Yes	Yes
G663	Yes	10.0	10.0	0.17	0.10	No	Yes
G665	Yes	10.0	12.5	0.17	0.10	No	Yes
G670	Yes	0.0	13.8	0.20	0.14	Yes	Yes
G671	Yes	10.0	13.8	0.17	0.09	No	Yes
G672	Yes	0.0	11.3	0.20	0.12	Yes	Yes
G674	Yes	10.0	15.0	0.17	0.10	No	Yes
G675	Yes	0.0	12.5	0.20	0.14	Yes	Yes
G683	Yes	10.0	1.3	0.17	0.11	Yes	Yes
G684-1	Yes	0.0	6.3	0.20	0.14	Yes	Yes
G685	Yes	10.0	6.3	0.17	0.10	No	Yes
G689	Yes	10.0	8.8	0.17	0.12	No	Yes
G693	Yes	10.0	10.0	0.17	0.10	No	Yes
G694	Yes	10.0	3.8	0.17	0.10	No	Yes

Table 2-2. Results of the 28-Day *Hyalella* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G700	Yes	10.0	10.0	0.17	0.10	No	Yes
G707	Yes	10.0	16.3	0.17	0.10	No	Yes
G711	Yes	10.0	12.5	0.17	0.10	No	Yes
G713	Yes	10.0	6.3	0.17	0.10	No	Yes
G718	Yes	10.0	8.8	0.17	0.11	No	Yes
G722	Yes	10.0	13.8	0.17	0.10	No	Yes
G736	Yes	10.0	11.3	0.17	0.11	No	Yes
G737	Yes	10.0	16.3	0.17	0.10	No	Yes
G740	Yes	0.0	13.8	0.20	0.16	Yes	Yes
G741	Yes	0.0	11.3	0.20	0.13	Yes	Yes
G744	Yes	0.0	10.0	0.20	0.14	Yes	Yes
G745	Yes	0.0	10.0	0.20	0.14	Yes	Yes
G746	Yes	0.0	8.8	0.20	0.14	Yes	Yes
G750	Yes	0.0	16.3	0.20	0.13	Yes	Yes
G751	Yes	0.0	10.0	0.20	0.17	Yes	Yes
G752	Yes	0.0	15.0	0.20	0.13	Yes	Yes
G755	Yes	0.0	12.5	0.20	0.14	Yes	Yes
G756	Yes	0.0	20.0	0.20	0.15	Yes	Yes
G763	Yes	0.0	7.5	0.20	0.16	Yes	Yes
G766	Yes	0.0	10.0	0.20	0.15	Yes	Yes
G767	Yes	0.0	6.3	0.20	0.16	Yes	Yes
G769	Yes	0.0	8.8	0.20	0.16	Yes	Yes
G772	Yes	0.0	7.5	0.20	0.16	Yes	Yes
G775	Yes	0.0	10.0	0.20	0.14	Yes	Yes
G776	Yes	0.0	16.3	0.20	0.14	Yes	Yes
G777	Yes	0.0	22.5	0.20	0.17	Yes	No
G778	Yes	0.0	8.8	0.20	0.16	Yes	Yes
G779	Yes	0.0	16.3	0.20	0.15	Yes	Yes
G780	Yes	0.0	3.8	0.20	0.19	No	No
G781	Yes	0.0	13.8	0.20	0.13	Yes	Yes

Table 2-2. Results of the 28-Day *Hyalella* Sediment Toxicity Test

Station	Study Area?	Mortality (%)		Biomass (mean mg/individual)		Significantly Different?[a]	
		Control	Test	Control	Test	Mortality	Growth
G785[b]	No	10.0	3.8	0.17	0.11	No	Yes
G785a[b]	No	0.0	15.0	0.20	0.13	Yes	Yes
G786[b]	No	10.0	18.8	0.17	0.11	Yes	Yes
G786a[b]	No	0.0	15.0	0.20	0.15	Yes	Yes
G787[b]	No	10.0	7.5	0.17	0.10	No	Yes
G787a[b]	No	0.0	8.8	0.20	0.12	Yes	Yes
G788[b]	No	10.0	11.3	0.17	0.13	No	Yes
G788a[b]	No	0.0	10.0	0.20	0.15	Yes	Yes
U1C-1	No	3.8	7.5	0.37	0.40	No	No
U1C-2	No	3.8	3.8	0.37	0.37	No	No
U1C-3	No	3.8	7.5	0.37	0.38	No	No
U2C-1	No	3.8	3.8	0.37	0.38	No	No
U2C-2	No	3.8	3.8	0.37	0.38	No	No
U2C-3	No	3.8	5.0	0.37	0.43	No	Yes
U3C-1	No	3.8	2.5	0.37	0.33	No	Yes
U3C-2	No	3.8	2.5	0.37	0.33	No	Yes
U3C-3	No	3.8	2.5	0.37	0.33	No	Yes
U4Q-1	No	3.8	5.0	0.37	0.28	No	Yes
U4Q-2	No	3.8	3.8	0.37	0.27	No	Yes
U4Q-3	No	3.8	3.8	0.37	0.28	No	Yes
U5Q-1	No	3.8	2.5	0.37	0.33	No	No
U5Q-2	No	3.8	1.3	0.37	0.36	No	No
U5Q-3	No	3.8	5.0	0.37	0.34	No	Yes
U6TOC-1	No	3.8	1.3	0.37	0.25	No	Yes
U6TOC-2	No	3.8	6.3	0.37	0.31	No	Yes
U6TOC-3	No	3.8	5.0	0.37	0.20	No	Yes

[a] Statistically different from the negative control response (one-tailed test, $p < 0.05$). Note that the test growth response was considered significantly different from control without the performance of the statistical test, in which all organisms died.

[b] Toxicity testing of the sediment samples from stations G785, G786, G787, and G788 was performed twice (as a reference sediment).

3.0 EVALUATION OF TOXICITY TEST ENDPOINTS

During negotiations between EPA and LWG, two decisions were reached regarding the treatment of toxicity test endpoints. First, it was decided that the growth endpoint for both sediment toxicity tests would be represented by final biomass and calculated as the mean final weight of surviving organisms at the end of the test. This decision acknowledged that the growth endpoint was not independent of survival and the final weight was a way to combine the growth and survival endpoints. Second, it was agreed that the four endpoints would not be pooled either in the interpretation of the sediment toxicity tests or in the development of predictive models. Both EPA and LWG agreed that each endpoint may provide unique information that can be used in the risk assessment of benthic invertebrates, development of the predictive models, and derivation of site-specific toxicity thresholds.

4.0 REFERENCE ENVELOPE APPROACH

As negotiated with EPA, toxicity test results were compared to a numeric threshold representing toxicity test responses from the upriver reach, according to the reference envelope approach presented in MacDonald and Landrum (2008). This section presents the derivation of reference toxicity thresholds, including reference station selection criteria (Section 4.1), identification of stations that met those criteria (Section 4.2), and derivation of percentiles used in the establishing the low and high- toxicity thresholds (Section 4.3).

4.1 SELECTION OF STATIONS FOR THE REFERENCE ENVELOPE

MacDonald and Landrum (2008) recommended that stations and samples considered for inclusion in the reference envelope meet six criteria:

1. Each sediment toxicity test should meet standard performance criteria, including an evaluation of potential interference from ammonia and sulfides.

2. All measured metals, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs) occur at concentrations below conservative sediment quality guidelines (SQGs).

3. Mean PEC-Q_{dw} < 0.1.[1]

4. $\sum$ESB-TU_{PAHs} < 0.1.[2]

5. $\sum$ (AVS/SEM)/f_{oc} < 130 µmol/g.[3]

6. Control-adjusted response rate should not exceed the minimum significant difference (MSD) for each toxicity test endpoint; or in the absence of MSD values, the control-adjusted response rate should not exceed the Tier II levels applied in the National Sediment Inventory (EPA 2004).

This list of criteria was revised because not all the information needed to evaluate the above criteria had been collected in Portland Harbor, and EPA and LWG agreed that stations for the reference envelope should be selected from the BERA dataset. Decision rules for inclusion in the reference dataset were revised to the following five criteria:

1. Each sediment toxicity test to be considered should meet standard performance criteria, including an evaluation of potential interference from ammonia.

[1] PEC – probable effects concentration

[2] ESB – equilibrium partitioning sediment benchmark; TU – toxic unit

[3] AVS/SEM – Acid volatile sulfide/simultaneously extracted metals

2. All measured metals, PAHs, and PCBs occur at concentrations below the lowest value of Regional Sediment Evaluation Team (RSET) screening level 1 (SL1) or PEC.

3. Mean PEC-Q_{dw} < 0.1.

4. $\sum$ESB-TU_{PAHs} < 0.1.

5. Control-adjusted response rate should not exceed the Tier II levels applied in the National Sediment Inventory (EPA 2004).

AVS/SEM could not be evaluated for Portland Harbor sediments because these chemical analyses had not been performed. Hence, the availability and thereby the toxicity of metals was not fully assessed in the reference envelope approach.

4.1.1 Toxicity Test Acceptability Criteria

Two of the five criteria addressed the acceptability of the sediment toxicity tests. All of the toxicity tests conducted in Portland Harbor complied with the acceptability criteria described in the American Society for Testing and Materials (ASTM 2003) and EPA (2000) methods for freshwater toxicity tests:

- *Chironomus* mortality < 30% in the negative control
- *Hyalella* mortality < 20% in the negative control
- Minimum mean weight of 0.48 mg ash-free dry weight for surviving *Chironomus* in the negative control
- Water quality parameters, including ammonia, within the specified ranges
- Results of the concurrent positive reference toxicity tests within two standard deviations of the mean

Tests were conducted according to required experimental designs. For the evaluation of potential interference by ammonia in the bulk sediments, concentrations were compared to the thresholds provided by the US Army Corps of Engineers (USACE) in *Dredged Material Evaluation and Disposal Procedures* (USACE et al. 2008)[4]; no other document that provided toxicity thresholds for bulk sediment ammonia concentrations was identified. The total ammonia concentrations measured in the overlaying water at test initiation and termination ranged between < 0.1 and 1.9 mg/L. These concentrations were well below the ammonia thresholds of 15 to 60 mg/L for marine amphipods provided by EPA and USACE (Barton 2002).

[4] The criteria were based on sediment toxicity test with *Neanthes* and were as follow: < 115 mg/kg no effect; >230 mg/kg minor effects; > 400 mg/kg major effects. Stations included in the reference envelope met the criterion for no effects.

The reference envelope stations were selected from the group of stations that did not exceed the Tier II levels applied in the National Sediment Inventory (EPA 2004). These criteria specified that the control-adjusted mortality rate should be < 25% (calculated as test mortality - control mortality) and that the control-adjusted growth should be > 70% (calculated as [test final biomass/control final biomass]*100).

4.1.2 Chemistry Acceptability Criteria

The remaining three criteria addressed the acceptable sediment chemical quality of the reference stations. Two sets of conservative SQGs, the RSET Interim SL1 (RSET 2006) and the PEC (MacDonald et al. 2000), were used in the screening process; all measured concentrations had to be lower than the two SQGs (Table 4-1).

Table 4-1. SQG Selection Based on RSET Interim SL1 and PEC

Chemical	SL1	PEC
Metals (mg/kg dw)		
Arsenic	**20**	33
Cadmium	**1.1**	4.98
Chromium	**95**	111
Copper	**80**	**149**
Lead	340	**128**
Mercury	**0.28**	1.06
Nickel	60	**48.6**
Silver	**2.0**	NG
Zinc	**130**	459
Butyltins (µg/kg dw)		
TBT	**75**	NG
PAHs (µg/kg dw)		
2-methylnaphthalene	470	NG
Acenaphthylene	470	NG
Acenaphthene	1,100	NG
Anthracene	1,200	**845**
Benz(a)anthracene	4,300	**1,050**
Benzofluoranthenes (b+k)	600	NG
Benzo(g,h,i)perylene	4,000	NG
Benzo(a)pyrene	3,300	**1,450**
Chrysene	5,900	**1,290**
Dibenzo(a,h)anthracene	**800**	NG
Fluoranthene	11,000	**2,230**

Table 4-1. SQG Selection Based on RSET Interim SL1 and PEC

Chemical	SL1	PEC
Fluorene	1,000	**536**
Indeno(1,2,3-c,d)pyrene	**4,100**	NG
Naphthalene	**500**	561
Phenanthrene	6,100	**1,170**
Pyrene	8,800	**1,520**
Total LPAH	**6,600**	NG
Total HPAH	**31,000**	NG
Total PAH	NG	**22,800**
Phthalates (µg/kg dw)		
Dimethyl phthalate	**46**	NG
Butyl benzyl phthalate	**260**	NG
Bis(2-ethylhexyl) phthalate	**220**	NG
Di-n-octyl phthalate	**26**	NG
VOCs (µg/kg dw)		
Dibenzofuran	**400**	NG
Total PCBs (µg/kg dw)		
Total PCBs	**60**	676
Pesticides (µg/kg dw)		
Dieldrin	NG	**61.8**
Endrin	NG	**207**
gamma-Hexachlorocyclohexane	NG	**4.99**
Heptachlor epoxide		**16**
DDD	**9**[a]	28
DDE	**16**[a]	31.3
DDT	**34**[a]	62.9
Total chlordane	NG	**17.6**
Total DDx	NG	**572**

[a] Marine SL1 value is from RSET. RSET has no freshwater SQGs for DDD, DDE, or DDT.

DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
dw – dry weight
NG – no guideline
PAH – polycyclic aromatic hydrocarbon
PEC – probable effects concentration
PCB – polychlorinated biphenyl
RSET – Regional Sediment Evaluation Team
SL1 – screening level 1
SQG – sediment quality guideline
TBT – tributyltin
Total DDx – sum of all six DDT isomers (2,4′-DDD, 4,4′-DDD, 2,4′-DDE, 4,4′-DDE, 2,4′-DDT and 4,4′-DDT)
VOC – volatile organic compound

Bold identifies selected SQGs.

The mean PEC-Q_{dw} and the $\sum$ESB-TU_{PAHs} were derived in accordance with methods described by Long et al. (2006) and EPA (2003), respectively. Stations included in the reference envelope had to have a mean PEC-Q_{dw} < 0.1 and a $\sum$ESB-TU_{PAHs} < 0.1.

4.2 SELECTED STATIONS FOR THE REFERENCE ENVELOPE

Data available for the reference envelope evaluation within the upriver reach (RM 15.4 to RM 25.5) were collected during Round 2 and 3 and consisted of sediment samples collected at 22 stations. Sediment samples collected at four stations were tested with toxicity tests twice because they were included as reference stations. Table 4-2 presents the toxicity test results for the selected 18 stations that met the chemical criteria. Sixteen of these stations were located in the upriver reach. The remaining two stations were included per the request of EPA and were located in the upper segment of the Study Area (RM 10.6 and RM 11.2).

Table 4-2. Toxicity Test Results for the Selected Reference Stations

Station ID	*Chironomus dilutus*						*Hyalella azteca*					
	Mortality (%)		Growth (mean mg/ individual)		Mortality Relative to Control (%)	Growth Relative to Control (%)	Mortality (%)		Growth (mean mg/ individual)		Mortality Relative to Control (%)	Growth Relative to Control (%)
	Control	Test	Control	Test			Control	Test	Control	Test		
G766	11.25	15.00	0.71	0.80	3.8	113	0.00	10.00	0.20	0.15	10.0	75
G767	11.25	8.75	0.71	0.76	-2.5	107	0.00	6.25	0.20	0.16	6.3	80
G786a	11.25	18.75	0.71	0.67	7.5	94	0.00	15.00	0.20	0.15	15.0	75
G788	12.50	10.00	0.79	0.65	-2.5	82	10.00	11.25	0.17	0.13	1.3	77
G788a	11.25	16.25	0.71	0.63	5.0	89	0.00	10.00	0.20	0.15	10.0	75
U1C-1	15.00	5.00	0.89	1.11	-10	125	3.75	7.50	0.37	0.40	3.8	108
U1C-2	15.00	11.25	0.89	1.05	-3.8	118	3.75	3.75	0.37	0.37	0.0	100
U2C-1	15.00	11.25	0.89	1.18	-3.8	133	3.75	3.75	0.37	0.38	0.0	103
U2C-3	15.00	11.25	0.89	1.04	-3.8	117	3.75	5.00	0.37	0.43	1.3	116
U3C-1	15.00	10.00	0.89	1.15	-5.0	129	3.75	2.50	0.37	0.33	-1.3	89
U3C-2	15.00	11.25	0.89	1.14	-3.8	128	3.75	2.50	0.37	0.33	-1.3	89
U3C-3	15.00	3.75	0.89	1.20	-11	135	3.75	2.50	0.37	0.33	-1.3	89
U4Q-1	15.00	6.25	0.89	1.01	-8.8	114	3.75	5.00	0.37	0.28	1.3	76
U4Q-2	15.00	6.25	0.89	1.16	-8.8	130	3.75	3.75	0.37	0.27	0.0	73
U4Q-3	15.00	8.75	0.89	1.00	-6.3	112	3.75	3.75	0.37	0.28	0.0	76
U5Q-1	15.00	12.50	0.89	1.00	-2.5	112	3.75	2.50	0.37	0.33	-1.3	89
U5Q-2	15.00	22.50	0.89	0.89	7.5	100	3.75	1.25	0.37	0.36	-2.5	97
U5Q-3	15.00	6.25	0.89	1.05	-8.8	118	3.75	5.00	0.37	0.34	1.3	92

ID – identification

4.3 DERIVATION OF DISTRIBUTION PERCENTILES

A reference envelope represents a normal range of responses that would be expected in sediments exclusive of site-related contaminants and sources. These reference ranges are typically calculated to capture 95% of the variability in the reference responses. The distribution that best fit the control-adjusted mortality and growth results for each test organism in the 18 reference stations and each distribution's parameters and percentiles were computed using @Risk software (Table 4-3). The 95th percentiles for the two control-adjusted mortality endpoints (treatment-control mortality) were 8.1 and 13.3% for *Chironomus* and *Hyalella*, respectively. The 5th percentiles for the two control-adjusted growth endpoints (treatment growth/control growth) were 88.7 and 67.1%, which provide thresholds of 11.3 and 32.9% for *Chironomus* and *Hyalella*, respectively.

Table 4-3. @Risk Fit Statistics for the Four Endpoints

	Endpoint and Distribution			
Parameters	***Chironomus* Mortality Lognorm**	***Chironomus* Growth Weibull**	***Hyalella* Mortality LogLogistic**	***Hyalella* Growth LogLogistic**
Distribution Statistics				
Minimum	-0.1661	0	-0.0285	0
Maximum	+Infinity	+Infinity	+Infinity	+Infinity
Mean	-0.0316	1.1445	0.0291	0.8718
Mode	-0.0636	1.1911	-0.00872	0.8493
Median	-0.0432	1.1599	0.00705	0.8615
Std. Deviation	0.0598	0.1417	+Infinity	0.1358
Skewness	1.4233	-0.6246	+Infinity	0.7761
Kurtosis	6.8057	3.5372	+Infinity	5.7534
Percentiles				
5%	-0.105	0.8869	-0.0207	0.6714
10%	-0.0948	0.9552	-0.017	0.7153
15%	-0.087	0.9988	-0.014	0.7439
20%	-0.0802	1.032	-0.0111	0.7661
25%	-0.0739	1.0594	-0.00831	0.785
30%	-0.0678	1.0831	-0.00552	0.8019
35%	-0.0618	1.1044	-0.00265	0.8176
40%	-0.0558	1.124	0.000352	0.8325
45%	-0.0496	1.1423	0.00356	0.847
50%	-0.0432	1.1599	0.00705	0.8615

Table 4-3. @Risk Fit Statistics for the Four Endpoints

	Endpoint and Distribution			
Parameters	***Chironomus* Mortality Lognorm**	***Chironomus* Growth Weibull**	***Hyalella* Mortality LogLogistic**	***Hyalella* Growth LogLogistic**
55%	-0.0365	1.1769	0.0109	0.8763
60%	-0.0293	1.1937	0.0153	0.8916
65%	-0.0214	1.2106	0.0204	0.9079
70%	-0.0126	1.2278	0.0265	0.9256
75%	-0.00245	1.2458	0.0341	0.9455
80%	0.0096	1.2651	0.0441	0.9688
85%	0.0248	1.2867	0.0583	0.9978
90%	0.0457	1.3127	0.0817	1.0377
95%	0.0811	1.3488	0.1334	1.1055

The percentiles were used to establish the low and high thresholds:

- Low toxicity thresholds for the control-adjusted mortality endpoints were derived by adding 10% to the 95th percentile values (e.g., *Chironomus* treatment – control mortality low threshold: 8.1% + 10% = 18.1%). That is, if *Chironomus* treatment minus control mortality in a sample was > 18.1%, the low toxicity threshold was exceeded and the sample was outside the reference envelope.
- Low toxicity thresholds for the growth endpoints were derived by first subtracting 10% from the 5th percentile values (e.g., *Chironomus* treatment/control growth low threshold: 88.7% - 10% = 78.7%; and if *Chironomus* treatment/control growth is < 78.7%, the sample is outside the reference envelope). To convert the growth threshold to a magnitude similar to the mortality threshold, the low toxicity threshold was subtracted from 100% (e.g., 100% - 78.7% = 21.3%), and any sample with treatment/control growth greater than 21.3% was considered within the reference envelope treatment/control growth range.

A similar process was performed for the high toxicity thresholds by adding or subtracting 20% instead of 10% from the 95th and 5th percentile values. The toxicity thresholds are presented in Table 4-4. A sediment sample was classified as a "hit" if the response was significantly different from the negative control and the response exceeded the respective threshold.

Table 4-4. Biological Effects Levels Based on the Reference Envelope

Test and Endpoint	Reference Thresholds[a]	Low Toxicity Threshold (%)[b]	High Toxicity Threshold (%)[b]
Chironomus dilutus mortality	8.1	18.1	28.1
Chironomus dilutus growth	11.3	21.3	31.3
Hyalella azteca mortality	13.3	23.3	33.3
Hyalella azteca growth	32.9	42.9	52.9

[a] The thresholds were based on the 95th percentile for the control-adjusted mortality endpoints and the 5th percentile for the control-adjusted growth endpoints.

[b] The test response also had to be statistically different from the negative control response (one-tailed test, $p < 0.05$) to consider the sediment as having an adverse effect.

5.0 RELIABILITY ANALYSIS OF THE FPM

The selection of the SQGs from the floating percentile model (FPM) involved a series of model runs and subsequent reliability analyses. The reliability analyses are all coded into the current version of the FPM software (Anderson 2008), which was used for the BERA.

The best performing set of SQGs for each endpoint and toxicity threshold was selected by selecting the model run for each endpoint with the best overall reliability rate and the most balanced false positive and false negative rates. Each of these best-performing sets of SQGs for each endpoint met all the reliability criteria, with false negative ranging from 5 to 20%, false positive rates ranging from 4 to 20%, overall reliabilities > 80%, and predicted no-hit reliability ranging from 96 to 100% (Table 5-1). Next, for each chemical, the lowest low and high SQG were selected as the low or high SQG for the chemical (Table 5-2).

Table 5-1. Reliability Results for Initial Endpoint-Specific FPM Runs

	Reliability Parameters						
Endpoint by Toxicity Threshold	**% False Negatives**	**% False Positives**	**% Sensitivity**	**% Efficiency**	**% Predicted Hit Reliability**	**% Predicted No-Hit Reliability**	**% Overall Reliability**
Low Toxicity Thresholds							
Chironomus mortality	19	19	81	81	38	97	81
Chironomus growth	19	20	81	80	45	96	81
Hyalella mortality	5.0	13	95	88	36	100	88
Hyalella growth	19	15	82	85	35	98	84
High Toxicity Thresholds							
Chironomus mortality	17	7.4	83	93	50	98	92
Chironomus growth	20	12	80	89	48	97	87
Hyalella mortality	5.9	4.4	94	96	57	100	96
Hyalella growth	6.7	4.0	93	96	56	100	96

FPM – floating percentile model

Table 5-2. First Set of FPM SQGs

Chemical	Selected SQGs	
	Low Toxicity Thresholds	**High Toxicity Thresholds**
Metals (mg/kg dw)		
Arsenic	22.9	NC
Cadmium	0.71	3.51
Copper	562	562
Lead	179	179
Mercury	0.235	0.407
Silver	1.72	1.72
PAHs (µg/kg)		
Sum of 34 ESB PAHs (unitless)	1.2	14
Total benzofluoranthenes	6,200	53,000
Total HPAHs	610,000	610,000
Total LPAHs	2,300	33,000
Total PAHs	330,000	330,000
SVOCs (µg/kg)		
Benzyl alcohol	36	36
Carbazole	1,100	1,100
Phenols (µg/kg)		
4-Methylphenol	96	125
Phenol	120	120
Phthalate (µg/kg)		
Diethyl phthalate	120	NC
PCBs		
Total PCB Congeners (pg/g)	12,500,000	12,500,000
Total PCBs (µg/kg)	500	3,500
Pesticides (µg/kg)		
delta-Hexachlorocyclohexane	1.29	2.35
Dieldrin	21.5	21.5
Endrin	20.8	20.8
Endrin ketone	8.5	8.5
Sum DDD	114	114
Sum DDE	906	906
Sum DDT	8,110	8,110
Total DDx	11,500	11,500
TPHs (mg/kg)		
PYO-PTO	15,000	22,000
Conventionals		

Table 5-2. First Set of FPM SQGs

Chemical	Selected SQGs	
	Low Toxicity Thresholds	**High Toxicity Thresholds**
Ammonia (mg/kg)	171	276
Sulfide (mg/kg)	38.5	38.5
Total organic carbon (%)	2.7	13
Total % fines	84.4	NC

DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
ESB – equilibrium partitioning sediment benchmark
HCH – hexachlorocyclohexane
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
NC – not calculated (FPM SQG could not be calculated because the chemical's toxicity threshold exceeds the maximum concentration in the dataset
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PTO – petrogenic (petroleum compound)
PYO – pyrogenic (petroleum compound)
SVOC – semivolatile organic compound
Total DDx – sum of all six DDT isomers (2,4′-DDD, 4,4′-DDD, 2,4′-DDE, 4,4′-DDE, 2,4′-DDT and 4,4′-DDT)
TPH – total petroleum hydrocarbons

The low and high sets of endpoints performed as shown in Table 5-3 for the individual endpoints.

Table 5-3. Endpoint-Specific Error and Reliability Rates Using Initial Low and High Sets of SQGs

Endpoint by Toxicity Thresholds	Reliability Parameters						
	% False Negatives	**% False Positives**	**% Sensitivity**	**% Efficiency**	**%Predicted Hit Reliability**	**% Predicted No-Hit Reliability**	**Overall Reliability**
Low Toxicity Thresholds							
Chironomus mortality	19	36	81	64	25	96	66
Chironomus growth	15	33	85	67	34	96	70
Hyalella mortality	15	38	85	62	14	98	63
Hyalella growth	15	37	85	63	19	98	65
Pooled low toxicity	18	37	82	64	37	93	67
High Toxicity Thresholds							
Chironomus mortality	17	13	83	87	36	98	86
Chironomus growth	23	11	77	88	48	97	87
Hyalella mortality	5.9	38	94	62	13	99	64
Hyalella growth	6.7	15	93	85	25	100	85
Pooled high toxicity	22	11	78	89	49	97	87

Note: Minimum SQGs are across individual endpoints.

SQG – sediment quality guideline

Seventeen chemicals were removed from the initial list of 36 sediment quality values (SQGs) (Table 5-4). Chemicals were removed from the initial lists for any of the following reasons:

- The SQG for the chemical was equal to the maximum concentration observed in the Study Area.
- The maximum no-hit concentration was higher than the maximum hit concentration.
- Removal caused no change in any of the overall error and reliability rates (tested through trial and error) or SQGs for other chemicals (indicated that the chemical was redundant and correlated with other chemicals).

Table 5-4. Chemicals Removed from Initial Set of SQG Chemicals and Reason for Removal

Chemical	Reason for Removal
4-Methylphenol	Both lists: max no hit > max hit
Antimony	Both lists: SQG > max and max no hit > max hit
Arsenic	High list: SQG > max and max no hit > max hit; removal from low list does not affect false negative rate
Chromium	High list: SQG > max, and max no hit > max hit; removal from low does not change error/reliability rates or other SQGs
Dibutyltin ion	Both lists: SQG > max and max no hit > max hit
Diethyl phthalate	High list: SQG > max, and high risk max no hit > max hit; removal from low list does not affect false negative rate
Lead	Both lists: max no hit > max hit
PYO-PTO	Both lists: does not change error/reliability rates or other SQGs
Sum DDD	Redundant with total DDx, and total DDx is TRV
Sum DDE	Redundant with total DDx, and total DDx is TRV
Sum DDT	Redundant with total DDx, and total DDx is TRV
Sum of 34 ESB PAHs	Both lists: redundant with other PAHs; high list: no effect on final model; low list: removal changes threshold for LPAHs
Total % fines	Both lists: max no hit > max hit
Total chlordane	Both lists: SQG > max, and max no hit > max hit
Total organic carbon	Both lists: no effect on final model
Total PAHs	Both lists: no effect on final model

Table 5-4. Chemicals Removed from Initial Set of SQG Chemicals and Reason for Removal

Chemical	Reason for Removal
Total PCB congeners	Both lists: duplicative of total PCBs, and no effect on model
Zinc	Low list: no hit > hit; no effect on high list

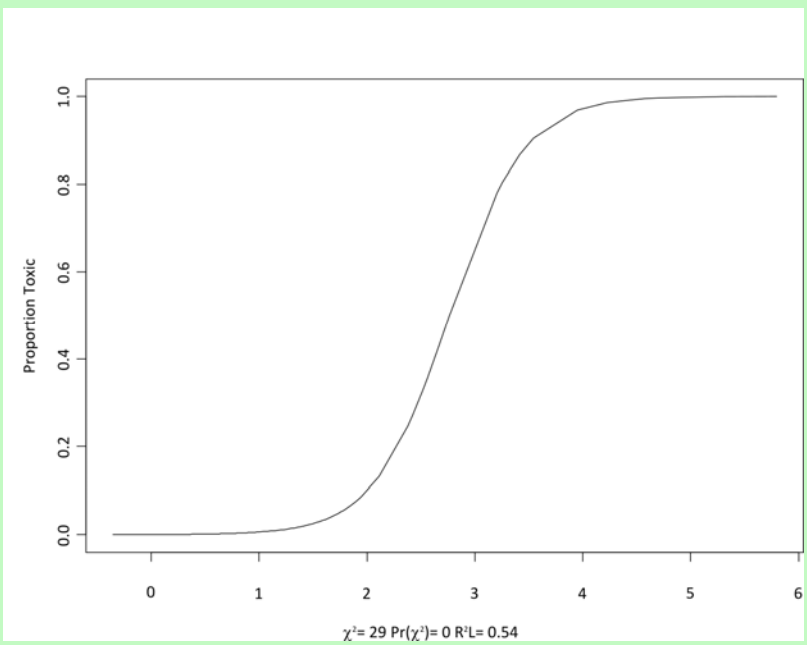
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
ESB – equilibrium partitioning sediment benchmark
HPAH – high-milecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PYO – pyrogenic (petroleum compound)
PTO – petrogenic (petroleum compound)
Total DDx – sum of all six DDT isomers (2,4′-DDD, 4,4′-DDD, 2,4′-DDE, 4,4′-DDE, 2,4′-DDT and 4,4′-DDT)
TRV – toxicity reference value

6.0 THE LOGISTIC REGRESSION MODEL

The logistic regression model (LRM) approach estimates a functional curve relationship between concentrations of a chemical and the proportion of toxicity detected in the sediment toxicity tests (Field et al. 2002). This enables users to select the specific probability of effects based on a risk management decision that corresponds to their specific assessment objective.

Logistic Regression Model

The LRM approach was developed as an alternative to the threshold methods used for SQG derivation. The chemistry data were divided into three categories for each selected chemical: 1) non-toxic samples, 2) toxic samples with chemical concentrations greater than the mean concentration in the non-toxic samples, and 3) toxic samples with chemical concentrations lower than the mean concentration in the non-toxic samples. The designation as toxic was based on the reference envelope approach. Toxic samples that had concentrations less than the mean concentration for the non-toxic samples were identified and excluded from the LRM fit for that chemical endpoint. An LRM using the screened chemistry data relating toxicity to $\log_{10}$ concentration was applied. Goodness of fit and other information useful in assessing the model were compiled, and models with poor fit or insufficient data were excluded from further consideration.



A multiple-chemical model was constructed to predict the probability of a toxic effect from the mixture of chemicals detected in a sample. Each sample had a set of concentrations for the full suite of chemical results reported for that sample, and each of these concentrations had an associated probability of toxicity (p) predicted from the individual chemical models. The maximum value among these individual predictions of toxicity was used as the single best prediction of a toxic effect for each sample.

A suite of individual LRMs were fitted to each chemical after the elimination of the chemicals in Table 6-5 in Section 6.0 of the BERA. Each individual model was reviewed, and all chemicals with a poorly fitted model or insufficient data were omitted from the LRM development process. These were models that had Chi-square p-values greater than 0.01, R^2_L values less than 0.20, fewer than five toxic samples retained in the screened

dataset, or higher concentrations that were not associated with toxicity. For each toxicity test endpoint, individual chemical models were scored based on predictive performance for the BERA dataset. The best suite of chemical models for each toxicity test endpoint was retained; this process did not restrict the final suite to the same list of chemicals for each toxicity test endpoint. Table 6-1 presents the chemicals retained in the LRM for one or more toxicity test endpoint.

Table 6-1. Chemicals Included in the Logistic Regression Model

Chemical	Number of Detections	Chemical	Number of Detections
Metals			
Cadmium	291	Mercury	289
Lead	293	Silver	293
PAHs			
2-Methylnaphthalene	272	Fluoranthene	285
Acenaphthene	274	Fluorene	271
Acenaphthylene	274	Indeno(1,2,3-c,d)pyrene	281
Anthracene	275	Naphthalene	232
Benzo(a)anthracene	281	Phenanthrene	282
Benzo(a)pyrene	281	Pyrene	285
Benzo(b)fluoranthene	280	Sum of 34 ESB PAHs	288
Benzo(g,h,i)perylene	282	Total benzoflouranthenes	280
Benzo(k)fluoranthene	277	Total HPAHs	287
Chrysene	278	Total LPAHs	283
Dibenzo(a,h)anthracene	281	Total PAHs	288
SVOCs			
Carbazole	205	Dibenzofuran	265
Phthalates			
Dibutyl phthalate	44		
PCBs			
Aroclor 1254	218	Total PCBs	231
Aroclor 1260	149	Total PCBs Aroclors	231
Pesticides			
2,4′-DDD	231	Endrin ketone	70
2,4′-DDE	108	beta-HCH	192
4,4′-DDD	274	delta-HCH	52

Table 6-1. Chemicals Included in the Logistic Regression Model

Chemical	Number of Detections	Chemical	Number of Detections
4,4′-DDE	269	Sum DDD	280
alpha-Endosulfan	56	Sum DDE	269
cis-Chlordane	154	Total DDx	285
Endrin	31	Total chlordane	235
TPH			
PTO-PYO	41		
Conventionals			
Sulfides	240		

DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
ESB – equilibrium partitioning sediment benchmark
HCH – hexachlorocyclohexane
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PTO – petrogenic (petroleum compound)
PYO – pyrogenic (petroleum compound)
SVOC – semivolatile organic compound
Total DDx – sum of all six DDT isomers (2,4′-DDD, 4,4′-DDD, 2,4′-DDE, 4,4′-DDE, 2,4′-DDT and 4,4′-DDT)
TPH – total petroleum hydrocarbons

In the *Comprehensive Round 2 Site Characterization Summary and Data Gaps Analysis Report* (Integral et al. 2007), total petroleum hydrocarbons (TPHs) were identified as being correlated with the detected toxicity in the toxicity tests. The TPH data were later reclassified into pyrogenic (PYO) compounds, petrogenic (PTO) compounds, and other petroleum hydrocarbons; and subsequent analysis determined that PYO and PTO compounds were correlated with the detected toxicity. Because the inclusion of chemicals with good correlations to toxicity in a combined model can mask correlations between toxicity and other chemicals, the best-fitted model for PYO and PTO compounds was retained as a separate model. All the other chemicals were combined into a multiple-chemical model, in which the maximum probability of toxicity (max_p) across all chemicals was calculated. As specified in EPA's Problem Formulation (Attachment 2) the two probability (Pr) values of 0.4 and 0.6 were selected as the thresholds to predict non-toxic and toxic sediment samples, respectively.

The reliability of the LRM was evaluated using the following seven reliability parameters:

- **False negatives rates –** Incorrectly predicted no-hits/total hits

- **False positives rates –** Incorrectly predicted hits/total no-hits
- **Sensitivity –** Correctly predicted hits/total hits
- **Efficiency –** Correctly predicted no-hits/total no-hits
- **Predicted hit reliability –** Correctly predicted hits/total predicted hits
- **Predicted no-hit reliability –** Correctly predicted no-hits/total predicted no-hits
- **Overall reliability –** Correctly predicted sampling locations (correctly predicted hits + correctly predicted no-hits)/ total sampling locations

The reliability goals for the set of SQGs presented in the draft Washington State freshwater guidelines were adopted (Avocet 2003); both false negative and false positive rates should be below 20%, and the overall reliability should be above 80%. In addition, predicted no-hit reliability should be above 90% in order to have greater confidence in defining a sampling location as having no adverse effects (Avocet 2003).

None of the LRMs passed the reliability analysis (Tables 6-2 and 6-3). In an attempt to improve LRM reliability by eliminating a potentially important confounding factor, the reliability of the LRMs for non-petroleum chemicals was calculated based on the complete 293 sampling location BERA dataset (Table 6-3). TPH and individual petroleum compounds were removed from this analysis because of a suspicion that their reliability was low. This suspicion was confirmed when the reliability for the LRMs based only on TPH alone was calculated for the 41 sampling locations with TPH measurements (Table 6-2). All of the sampling locations that were predicted to be toxic based on TPH were also predicted to be toxic based on another chemical in the non-petroleum chemical set, so having separate predictions for TPH alone and for non-petroleum chemicals did not help to improve reliability.

The Pr thresholds for toxicity used in these LRM predictions were 0.4 and 0.6, as specified by EPA in the Problem Formulation (Attachment 2). Because the majority of the LRMs failed the criterion for the false negative rate, the Pr thresholds were lowered until this criterion was met. By making this adjustment, all LRMs either failed to meet the other acceptability criteria or the Pr threshold was so low (≤ 20%) that it did not provide a reasonable separation between toxic and non-toxic samples.

The low Pr thresholds resulted from trying to simultaneously keep both error rates below 20%. The dataset includes a number of low-concentration toxic sampling locations that drive the toxicity threshold down. Because there are so few toxic sampling locations, each sampling location contributes substantially to the error percentage and to the ultimate toxicity threshold needed to achieve the target error rates. Based on this reliability analysis, no site-specific SQGs suitable for predicting adverse effects to benthic invertebrates in the Study Area could be derived using the LRMs; Hence the LRM was not used to predict adverse effects to the benthic community in the benthic risk assessment.

Table 6-2. LRM Reliability Results for Petrogenic and Pyrogenic Petroleum Compounds

	Reliability Parameters						
Endpoint by Toxicity Thresholds	**% False Negatives**	**% False Positives**	**% Sensitivity**	**% Efficiency**	**% Predicted Hit Reliability**	**% Predicted No-Hit Reliability**	**Overall Reliability**
Low Toxicity Thresholds							
Chironomus mortality	22	4	67	87	92	83	78
Chironomus growth	36	4	64	93	90	83	83
Hyalella mortality	45	3	55	93	86	85	83
Hyalella growth	42	7	50	93	75	84	80
High Toxicity Thresholds							
Chironomus mortality	35	11	61	78	88	64	68
Chironomus growth	22	4	67	87	92	83	78
Hyalella mortality	57	4	43	93	86	76	76
Hyalella growth	53	8	40	92	75	75	73

LRM – logistic regression model

Table 6-3. LRM Reliability Results for Non-Petroleum Chemicals

Endpoint by Toxicity Threshold	Reliability Parameters						
	% False Negatives	% False Positives	% Sensitivity	% Efficiency	% Predicted Hit Reliability	% Predicted No-Hit Reliability	Overall Reliability
Low Toxicity Thresholds							
Chironomus mortality	33	10	63	81	56	93	78
Chironomus growth	38	7	51	89	53	94	85
Hyalella mortality	63	3	30	93	53	94	87
Hyalella growth	45	3	45	93	56	97	89
High Toxicity Thresholds							
Chironomus mortality	34	7	54	89	53	95	85
Chironomus growth	46	3	50	92	63	96	89
Hyalella mortality	47	1	47	96	70	97	93
Hyalella growth	35	3	59	93	59	98	91

LRM – logistic regression model

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