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LETTER OF TRANSMITTAL

SLR International Corp.
Building H, Suite 150 22122 20th Ave SE | Bothell, WA 98021 | Phone 425.402.8800 | Fax 425.402.8488

To: Mr. David South
Washington Department of Ecology
3190 160th Avenue SE
Bellevue, Washington 98008-5452

Date: April 20, 2004

Project #: 001.0153.00001

Re: 2003 Sediment Sample Results, Unocal Edmonds Terminal

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COMMENTS:

Per your request, attached are three copies of the reports pertaining to the 2003 sediment sampling activities at the above-referenced site. The reports include: 1) Integral Consulting's (Integral's) memorandum dated February 24, 2004, 2) STL Seattle's laboratory reports (chemical analyses), and 3) AMEC's laboratory report (bioassay testing). These reports were included in Maul Foster & Alongi's *Data Submittal for 2003 Additional Lower Yard Assessment Activities*, dated March 2, 2004. Integral's memorandum describes their evaluation of the chemical and bioassay testing results, and presents conclusions regarding the source(s) of toxicity. At the time of their memorandum, Integral was unaware that sample US-05 (a sample that failed at least one of the toxicity tests) was located near a Terminal stormwater outfall. After finding out that US-05 was located near an outfall, Integral concluded that the two Terminal stormwater outfalls are the sources of toxicity at samples US-05 and US-07 (as stated in the Draft FS Report). If you have any questions, please call me at (425) 402-8800.

See paper copy in Central Files for items 2 and 3

cc: Mark Brearley, Unocal (transmittal only)

By: Mike Staton

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Integral Consulting, Inc.
1500 112th Avenue NE
Suite 101
Bellevue, WA 98004

telephone: 425.451.3823
facsimile: 425.451.3824
www.integral-corp.com

MEMORANDUM

To:	Mike Staton
From:	Linda Mortensen and Les Williams
Date:	February 24, 2004
Subject:	Sediment Bioassay Results for Unocal Site in Edmonds, WA
Project No.:	C0780102

This memorandum summarizes sediment bioassay results conducted by AMEC laboratory on sediments collected in October 2003 within Willow Creek at the Unocal Edmonds Bulk Fuel Terminal in Edmonds, Washington (AMEC 2004). The sediment bioassay tests conducted included a 10-day amphipod (*Eohaustarius estuaris*) test, a 48-hr larvae bivalve test (*Mytilus galloprovincialis*), and a juvenile polychaete (*Neanthes arenaceodentata*) test. All tests followed Puget Sound Estuary Program (PSEP) testing protocols (PSEP 1995).

Results for all three test species are contained in Table 1 (amphipod), Table 2 (bivalve), and Table 3 (polychaete). This memorandum evaluates four aspects of the test results:

- Evaluation of test quality and acceptability based on performance standards and test method guidelines on quality assurance/quality control (QA/QC)
- Evaluation of sediment station pass/fail based on Sediment Management Standards (SMS) criteria
- Comparison of current and historical bioassay test results
- Evaluation of sediment station failure relative to petroleum hydrocarbon concentrations and other analyte concentrations in sediment.

1. Evaluation of Test Quality and Acceptability

Performance standards for test acceptability are specified in the PSEP test guidelines (PSEP 1995) and in Washington State Department of Ecology (Ecology) Sediment Management Standards (SMS) standards (WAC 173-204; Ecology 1995). Performance standards specific to the negative control and the reference stations are summarized in Table 4. QA/QC checklists for each test species are contained in Appendix A.

In the 10-day amphipod (*Eohaustorius estuarius*) test the performance standards for the control were satisfied, however the reference station criterion was not met based on the five test replicates. If, however, survival in the surrogate (sixth) replicates were included in the mean survival estimate, than survival in reference station US-12 does pass the performance standard criterion. The surrogate replicate is identical to the other replicates at each test concentration and it is the test replicate that is exclusively used for water quality measurements.

In the 48-hour bivalve (*Mytilus galloprovincialis*) larvae test the performance standards for the control were satisfied and the reference station criterion was met for one of the stations (US-12), but not for the other reference station (US-15).

In the 20-day polychaete (*Neanthes arenaceodentata*) test the performance standards for the control survival and growth were satisfied. Although a growth guideline of 0.72mg/ind/day for the negative control is indicated in the SMS standards (WAC-173-204-315(2)(d); Ecology 1995), a more recent SMS clarification paper on the growth endpoint for this species indicates that only control growth rates below 0.38 mg/ind/day will be considered to be an SMS failure (Kendall 1996). Growth in both reference station samples was greater than growth in the control and both samples passed the performance standard.

Performance standards related to the positive control (reference toxicant tests) indicated that each of the test species were of acceptable health for testing purposes. The calculated concentrations at which 50 percent of the test organisms died (the LC50s) were within the confidence interval of historical LC50s using the same test species and reference toxicant (Appendix A).

Overall aspects of the test quality including sample handling, test initiation conditions, and water quality monitoring were found to be acceptable for each test species (Appendix A).

2. Evaluation of Site Station Results Compared to SMS Criteria

Biological effects criteria under SMS are specified for both Sediment Quality Standards (SQS) and Cleanup Screening Levels (CSLs) in the SMS standards (Ecology 1995). These criteria for each of the three tests are summarized in Table 5. Reference station US-12 was used for comparison to site results in all three tests. Additionally, reference station US-15 was used for comparison to site results for the polychaete test because this was the only species where station US-15 passed the performance standards.

Results of the comparison of site station results to SMS biological criteria are presented in Table 6. The chronic polychaete test had no exceedances of SMS biological criteria using either of the reference stations. The amphipod test had two stations with CSL category exceedances (at US-05 and US-07). The bivalve larvae test had one station with a CSL category exceedance (at US-07). For sediment stations to be a concern based on SMS biological criteria exceedances there need to be at least two SQS exceedances or one CSL exceedance (Ecology 1991). As summarized in Table 7, stations US-05 and US-07 are stations of concern.

3. Comparison of Current Bioassay Test Results with 1995 Bioassay Test Results
Table 8 provides a comparison of historical (1995) and current sediment bioassay results. In 1995, as part of a site Remedial Investigation (RI), sediment bioassays were conducted at 15 locations within Willow Creek. As compared to SMS criteria, 1995 test results showed three SQS failures and two CSL failures. These results summarized by station include:

- US-05: CSL amphipod failure
- US-08: SQS bivalve larvae development failure
- US-09: SQS polychaete failure
- US-13: SQS polychaete failure
- US-15: CSL bivalve larvae development failure

Sediment samples collected in 2003 from Willow Creek targeted the same sampling areas. The objective of conducting further bioassay testing on Creek sediments was to determine current conditions and, if toxicity was found, to relate bioassay test results to a chemical gradient. Petroleum hydrocarbons are the class of chemicals of concern at the former fuel transfer facility and chemical testing of the sediment focused on defining a range of petroleum hydrocarbon concentrations through a number of analytical techniques including analyses for: polycyclic aromatic hydrocarbons (PAHs), extractable petroleum hydrocarbons (EPH), and three total petroleum hydrocarbons (TPH) fractions – diesel, motor oil, and gasoline.

Sample stations selected for bioassay testing in 2003 attempted to capture a petroleum gradient within the creek, and focused on the area at and downstream of station US-7 which is the source of site stormwater discharge. Stations selected for re-analysis included: US-03, US-04, US-05, US-07, US-12, and US-15. The two upstream stations were re-tested to characterize toxicity in areas presumed to not be impacted by site stormwater. These reference stations were used for making SMS criteria decisions about bioassay performance. Test results from 2003 were:

- US-03: no toxicity
- US-04: no toxicity
- US-05: CSL amphipod failure
- US-07: CSL amphipod failure and CSL bivalve larvae development failure
- US-12: no toxicity
- US-15: reference station performance failure for amphipods and bivalves

These results suggest that the site stormwater runoff and nearby chemical deposition may have caused the observed toxicity. However, the poor performance in station US-15 suggests that there are other natural or anthropogenic sources that are also causing toxicity. Other anthropogenic sources may include road runoff to the creek, or discharge to the creek by the fish hatchery. Alternatively, natural conditions and characteristics of the sediment (e.g., sediment grain size, total organic carbon (TOC), pore water salinity (see Appendix A)) may be resulting in bioassay failure.

4. Comparison of Bioassay Results to Sediment Chemical Concentrations

All 2003 sediment chemical data and 1995 and 2003 sediment bioassay data are summarized in Table 9. As previously mentioned, analytical and biological testing decisions focused on petroleum hydrocarbons as the principle class of site-related chemicals. The 2003 bioassay test failures at stations US-05 (amphipod) and US-07 (amphipod and bivalve larvae) appear to be unrelated to hydrocarbon concentrations based on either a bulk dry weight or organic carbon normalized basis and there is a lack of spatial correlation between toxicity and locations where these substances are elevated (Appendix B). Hydrocarbons have the potential to preferentially bind to sediment organic carbon, which in turn has the potential for reducing hydrocarbon toxicity because of reduced bioavailability. Based on the biological test results we would expect to see the highest chemical concentrations in station US-07 and the next highest chemical concentrations in station US-05. As compared to the other stations tested, station US-07 had the highest concentrations of HPAHs and TPH gasoline (on both an organic carbon normalized and non-normalized basis) (Table 9, Appendix B). Station US-05 had the second highest concentration of TPH gasoline concentration on an organic carbon normalized basis, but on a non-normalized basis both US-03 and US-04 had TPH gasoline concentrations greater that US-05.

Further, it appears from these results that bioassay response was not related to TPH diesel or motor oil concentrations given that diesel and motor oil were not detected in station US-05 and were detected at their highest concentrations in station US-04 where there were no adverse biological effects noted for any species. EPH fraction concentrations also do not correlate with observed toxicity.

Regarding sediment concentrations of other chemicals besides petroleum hydrocarbons, a screening against SMS criteria indicated only one chemical exceedance – an SQS exceedance at station US-07 for total PCBs. While PCB concentrations in this sample may have contributed to toxicity, toxicity at the other stations can not be explained by PCB concentrations because they were not detected when analyzed. It is also possible that metals concentrations in the creek contributed to the observed toxicity. Although no metals concentrations exceeded marine SMS standards, as compared to freshwater consensus-based sediment criteria (MacDonald et al. 2000), exceedances for arsenic, chromium, lead, mercury, and zinc were noted. These exceedances, shown in Table 10 and presented graphically in Appendix B, indicate that in general metals concentrations are higher in upstream locations as compared to downstream locations. Potentially, elevated arsenic and lead concentrations contributed to the observed toxicity on station US-15. All of the other bioassay stations tested did not show metals exceedances.

4. Conclusions and Recommendations

Reference station performance for both the amphipod and bivalve tests was in general acceptable for all three test species at station US-12, but was poor for the amphipods and bivalve larvae at station US-15, the most upstream station. The cause of toxicity at station US-15 is not known, although more petroleum hydrocarbons and metals were detected in station US-15 than in station US-12. These samples were collected in upstream areas away from likely site sources, however, it would have been more meaningful to collect reference sediment from Ecology approved reference stations as was done for the prior bioassay testing event. The intent of a testing a reference station is to provide a comparative bioassay response in a sediment that has similar grain size, organic carbon, and other habitat characteristics but no contamination. Stations US-12 and US-15 differed fundamentally from the other stations tested in terms of organic carbon content – both stations has higher organic carbon levels as noted on Table 8. It is not known the degree to which matrix (grain size and organic carbon) interferences contributed to toxicity. Ammonia and sulfide are also confounding factors in sediment toxicity. Concentrations of ammonia and sulfide in sediment porewater are provided in Table 9. In a recent SMS clarification paper (Barton 2002) an ammonia threshold of 30 mg/L was indicated as a concentration above which there may be concern for toxicity to the amphipod *Eohaustorius estuarius*. Interstitial ammonia concentrations in the samples tested ranged from < 1 mg/L to 14.1 mg/L. These data suggest that toxicity from ammonia was not a confounding factor in the amphipod test. Given that station US-07 did not have the highest ammonia concentration it is also unlikely that ammonia is a confounding factor for the bivalve test. Interstitial sulfide concentrations in samples tested ranged from < 0.5 mg/L to 1.0 mg/L - the highest concentration measured was at station US-03. Because there were no adverse effects for any of the test species at the station with the highest sulfide concentration, it is unlikely that sulfide concentrations influenced the toxicity observed at stations US-05 and US-07.

Given that bioassay SMS failures were limited to two stations with very different hydrocarbon concentrations further dilution testing at either station is not recommended. Remedial options or monitoring should be considered for stations US-05 and US-07 where CSL bioassay failures occurred.

5. References

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Ecology. 1996. Sediment Management Standards Marine Bioassays. Task II: Recommended Quality Assurance and Quality Control Deliverables. Publication No. 96-314. Washington State Department of Ecology. March.

Ecology. 1995. Chapter 173-204 WAC Sediment Management Standards. Washington State Department of Ecology. December 29.

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Kendall, D. 1996. Neanthes 20-day Growth Bioassay – Further Clarification on Negative Control Growth Standard, Initial Size, and Feeding Protocol. PSDDA/SMS Clarification Paper.

MacDonald, D.D, C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Archives of Environmental Contamination and Toxicology 39:20-31.

PSEP. 1995. Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments. Puget Sound Estuary Program. July.

Table 1. Results of 10-day Amphipod (*Eohaustarius estuaris*) Test

Site	Replicate [1]	Survival: Number Alive	Survival: % Survival	Survival: Mean % Survival	Reburial: Number Reburied	Reburial: % Reburial	Reburial: Mean % Reburial
Control	1	17	85	94	17	85	94
	2	19	95		19	95	
	3	20	100		20	100	
	4	19	95		19	95	
	5	19	95		19	95	
	Surrogate	19	95		19	95	
US-03	1	14	70	66	14	70	66
	2	15	75		15	75	
	3	15	75		15	75	
	4	14	70		14	70	
	5	9	45		9	45	
	Surrogate	12	60		12	60	
US-04	1	15	75	67	15	75	66
	2	13	65		12	60	
	3	16	80		16	80	
	4	8	40		8	40	
	5	12	60		12	60	
	Surrogate	16	80		16	80	
US-05	1	8	40	39	8	40	39
	2	7	35		7	35	
	3	6	30		6	30	
	4	8	40		8	40	
	5	11	55		11	55	
	Surrogate	7	35		7	35	
US-07	1	8	40	34	8	40	29
	2	11	55		10	50	
	3	4	20		4	20	
	4	2	10		0	0	
	5	9	45		9	45	
	Surrogate	7	35		4	20	
US-12	1	13	65	78	13	65	77
	2	15	75		15	75	
	3	12	60		12	60	
	4	18	90		16	80	
	5	16	80		16	80	
	Surrogate	20	100		20	100	
US-15	1	16	80	73	16	80	71
	2	15	75		15	75	
	3	14	70		13	65	
	4	14	70		14	70	
	5	13	65		12	60	
	Surrogate	15	75		15	75	

[1] Surrogate replicates are identical to the other replicates, but were specifically used for water quality measurements.

Table 2. Results of the Bivalve Larvae (*Mytilus galloprovincialis*) Test

Site	Replicate	Final Number Normal	Mean Number Normal	Mean % Normal [1]	Mean % Mortality	Control Normalized Mean % Normal [2]	Control Normalized Mean % Mortality
	1	265					
	2	298					
Control	3	332	293	93	7		
	4	292					
	5	276					
	1	250					
	2	228					
US-03	3	236	231	73	27	79	21
	4	228					
	5	211					
	1	280					
	2	256					
US-04	3	264	252	80	20	86	14
	4	207					
	5	253					
	1	210					
	2	260					
US-05	3	186	219	69	31	75	25
	4	237					
	5	201					
	1	165					
	2	94					
US-07	3	143	127	40	60	43	57
	4	119					
	5	113					
	1	189					
	2	203					
US-12	3	166	200	63	37	68	32
	4	201					
	5	241					
	1	100					
	2	92					
US-15	3	111	86	27	73	30	70
	4	73					
	5	56					

Initial density = 315 per 10 mL

[1] number normal divided by initial density

[2] Number normal in test station divided by number normal in control

Table 3. Results of the 20-day Polychaete (*Neanthes arenaceodentata*) Test

		Survival			Growth			
Site	Replicate	Number Alive	% Survival	Mean % Survival	Final Weight per Organism (mg)	Final Growth per Organism (mg) [1]	Mean Growth per Organism (mg)	Mean Growth per Organism per Day (mg/day)
Control	1	4	80	96	16.67	14.29	12.58	0.63
	2	5	100		14.09	11.70		
	3	5	100		14.06	11.68		
	4	5	100		15.01	12.63		
	5	5	100		15.00	12.62		
US-03	1	5	100	92	15.28	12.90	13.11	0.66
	2	5	100		14.89	12.51		
	3	4	80		18.83	16.44		
	4	4	80		13.97	11.58		
	5	5	100		14.48	12.10		
US-04	1	5	100	100	14.72	12.33	12.89	0.64
	2	5	100		11.93	9.54		
	3	5	100		17.28	14.89		
	4	5	100		13.76	11.37		
	5	5	100		18.70	16.32		
US-05	1	5	100	100	17.09	14.71	13.94	0.70
	2	5	100		18.03	15.64		
	3	5	100		11.34	8.95		
	4	5	100		16.00	13.62		
	5	5	100		19.18	16.80		
US-07	1	5	100	96	16.57	14.19	13.26	0.66
	2	5	100		17.74	15.35		
	3	4	80		18.47	16.09		
	4	5	100		14.01	11.63		
	5	5	100		11.44	9.06		
US-12	1	5	100	100	16.18	13.80	14.20	0.71
	2	5	100		14.25	11.86		
	3	5	100		19.00	16.62		
	4	5	100		19.92	17.53		
	5	5	100		13.57	11.19		
US-15	1	5	100	96	14.63	12.25	15.15	0.76
	2	5	100		17.90	15.52		
	3	5	100		16.55	14.17		
	4	4	80		14.77	12.38		
	5	5	100		23.84	21.46		

Mean initial weight per organism was 2.38 mg

[1] final weight minus initial weight

Table 4. Performance Standards for Control and Reference Sediment Biological Test Results

Test	Standard [1]	Result	Standard Met?
10-day amphipod (*Eohaustorius estuarius*)	Control mean survival ≥ 90%	94%	yes
	Control replicate survival ≥ 80%	85-100%	yes
	Reference mean survival ≥ 75%	78% (US-12)*; 73% (US-15)*	yes (US-12)*; no (US-15)*
48-hour bivalve (*Mytilus galloprovincialis*)	Control mean effective mortality < 30%	7%	yes
20-day polychaete (*Neanthes arenaceodentata*)	Control mean survival ≥ 90%	96%	yes
	Control mean growth ≥ 0.72 mg dw/ind/day	0.63 mg dw/ind/day	yes [2]
	Reference mean growth ≥ 80% of the control	113% (US-12); 120% (US-15)	yes

* Includes surrogate replicate results
dw = dry weight
ind = individual

[1] Sources of standards: PSEP 1995 and Ecology 1995 (WAC 173-204-315) as modified per Sediment Management Annual Review Meetings (SMARM).

[2] The SMS standards (WAC 173-204-315(2)(d)) indicate that control sediments exhibiting growth below 0.72 mg/ind/day may be approved by the department on a case-by-case basis. Also, a SMARM meeting clarification paper on the growth endpoint for the polychaete test suggests that control growth rates below 0.38 mg/ind/day are considered a QA/QC failure.

Table 5. SMS Sediment Bioassay Biological Effects Criteria

Sediment Bioassay Test	Test Type	SMS Biological Effects Criteria: SQS (WAC 173-204-320(3))	SMS Biological Effects Criteria: CSL (WAC 173-204-420(3)(c))
10-day Amphipod	acute	The test sediment has statisitcally (t-test, $p \leq 0.05$) higher mean mortality as compared to the reference sediment and test sediment mean mortality is > 25%.	The test sediment has statisitcally (t-test, $p \leq 0.05$) higher mean mortality as compared to the reference sediment and test sediment mean mortality is > 30%.
48-hr Bivalve Larvae	acute	The test sediment has a mean survivorship of normal larvae that is statistically (t-test, $p \leq 0.05$) less than survivorship of normal larvae in the reference station and test sediment mean survivorship of normal larvae is < 85% of the mean normal survivorship in the reference sediment.	The test sediment has a mean survivorship of normal larvae that is statistically (t-test, $p \leq 0.05$) less than survivorship of normal larvae in the reference station and test sediment mean survivorship of normal larvae is < 70% of the mean normal survivorship in the reference sediment.
20-day Polychaete	chronic	The test sediment mean individual growth rate is statistically (t-test, $p \leq 0.05$) less than the reference sediment mean individual growth rate and the test sediment mean individual growth rate is < 70% of the reference sediment mean individual growth rate.	The test sediment mean individual growth rate is statistically (t-test, $p \leq 0.05$) less than the reference sediment mean individual growth rate and the test sediment mean individual growth rate is < 50% of the reference sediment mean individual growth rate.

Source of biological effects criteria is Ecology 1995 SMS Standards (WAC 173-204)
SQS - sediment quality standards
CSL - cleanup screening levels

Table 6. Unocal Preliminary Sediment Bioassay Results Compared to SMS Criteria

Sediment Station	Endpoint	Result	Distribution (Shapiro-Wilk's)	Significance [2] (t-test, $p<0.05$)	SMS Comparison [3] SQS	CSL
10-Day Amphipod (*Eohaustorius estuarius*)						
US-03	Mean Survival (%) [1]	66	Normal ($p>0.05$)	none ($p>0.05$)	pass	pass
US-04		67	Normal ($p>0.05$)	none ($p>0.05$)	pass	pass
US-05		39 CUL	Normal ($p>0.05$)	yes ($p<0.001$)	fail	fail
US-07		34 CUL	Normal ($p>0.05$)	yes ($p=0.001$)	fail	fail
US-12 (reference)		78	Normal ($p>0.05$)	--	--	--
US-15 (reference)		73	Normal ($p>0.05$)	--	--	--
48-Hour Bivalve Larval Development (*Mytilus galloprovincialis*)						
US-03	Mean Normal (%)	73	Normal ($p>0.05$)	none ($p>0.05$)	pass	pass
US-04		80	Normal ($p>0.05$)	yes ($p=0.017$)	pass	pass
US-05		69	Normal ($p>0.05$)	none ($p>0.05$)	pass	pass
US-07		40	Normal ($p>0.05$)	yes ($p=0.003$)	fail	fail
US-12 (reference)		63	Normal ($p>0.05$)	--	--	--
US-15 (reference)		27	Normal ($p>0.05$)	--	--	--
20-Day Polychaete (*Neanthes arenaceodentata*)						
US-03	Mean Growth/Individual (mg)	13.11	Normal ($p>0.05$)	none ($p>0.05$)	pass	pass
US-04		12.89	Normal ($p>0.05$)	none ($p>0.05$)	pass	pass
US-05		13.94	Normal ($p>0.05$)	none ($p>0.05$)	pass	pass
US-07		13.26	Normal ($p>0.05$)	none ($p>0.05$)	pass	pass
US-12 (reference)		14.20	Normal ($p>0.05$)	--	--	--
US-15 (reference)		15.15	Normal ($p>0.05$)	--	--	--

[1] Calculated including the surrogate (6th) replicate at all stations

[2] For both the amphipod and bivalve tests comparisons were made to reference station US-12 and for the polychaete test comparisons were made to both reference stations.

[3] Based on the criteria outlined in Table 5

Table 7. Determination of Stations of Concern Based on Compliance with SMS

	SQS Comparisons				CSL Comparisons				
Sediment Station	Amphipod Survival (%)	Larval Normality (%)	Polychaete Growth (mg/d)	SQS Failures	Amphipod Survival (%)	Larval Normality (%)	Polychaete Growth (mg/d)	CSL Failures	Station of Concern? [1]
US-03	pass	pass	pass	none	pass	pass	pass	none	no
US-04	pass	pass	pass	none	pass	pass	pass	none	no
US-05	pass	pass	pass	1	fail	pass	pass	1	yes
US-07	pass	pass	pass	2	fail	fail	pass	2	yes

[1] Stations are of concern if there are two SQS failures or one CSL failure based on Ecology (1991).

Table 8. Comparison of Current and Historical Bioassay Results

	10-Day Amphipod (*Eohaustorius estuarius*)		48-Hr Bivalve Larval Development (*Mytilus galoprovincialis*)		20-Day Polychaete (*Neanthes arenaceodentata*)	
	Mean Survival (%) [1]		Mean Normal (%)		Mean Growth/Individual (mg)	
Station	2003	1995	2003	1995	2003	1995
US-01-1003	NA	94	NA	67	NA	12.18
US-02-1003	NA	96	NA	67	NA	7.52
US-03-1003	66	80	73	55	13.11	7.38
US-04-1003	67	92	80	76	12.89	9.1
US-05-1003	39 [CSL]	54 [CSL]	69	61	13.94	8.32
US-06-1003	NA	92	NA	77	NA	7.16
US-07-1003	34 [CSL]	93	40 [CSL]	70	13.26	7.24
US-08-1003	NA	94	NA	54 [SQS]	NA	8.04
US-09-1003	NA	78	NA	62	NA	5.46 [SQS]
US-10-1003	NA	86	NA	70	NA	9.12
US-11-1003	NA	95	NA	78	NA	7.48
US-12-1003	78	81	63	68	14.20	8.88
US-13-1003	NA	82	NA	64	NA	5.96 [SQS]
US-14-1003	NA	90	NA	75	NA	6.78
US-15-1003	73	96	27	45 [CSL]	15.15	8.24

[SQS] indicates that the result meets the criteria for a SQS "hit" as compared to reference station performance.

[CSL] indicates that the result meets the criteria for a CSL "hit" as compared to reference station performance.

Table 9. Summary of Bioassay Results and Detected Chemicals with SMS Criteria in Unocal Sediment

Year	Analyte	SQS	CSL	SMS Units	US-01-1003	US-02-1003	US-03-1003	US-04-1003	US-05-1003	US-06-1003	US-20-1003 (US-06 Dup)	US-07-1003	US-08-1003	US-09-1003	US-21-1003 (US-09 Dup)	US-10-1003	US-11-1003	US-12-1003	US-13-1003	US-14-1003	US-15-1003	US-16-1003
2003	10-Day Amphipod	Mean Survival (%) [1]			NA	NA	66	67	39 [CSL]	NA	NA	34 [CSL]	NA	NA	NA	NA	NA	78	NA	NA	73	NA
1995	(*Eohaustorius estuarius*)				94	96	80	92	54 [CSL]	92	NA	93	94	78	NA	86	95	81	82	90	96	NA
2003	Bivalve Larval Development	Mean Normal (%)			NA	NA	73	80	69	NA	NA	40 [CSL]	NA	NA	NA	NA	NA	63	NA	NA	27	NA
1995	(Mytilus galloprovincialis)				67	67	55	76	61	77	NA	70	54 [SQS]	62	NA	70	78	68	64	75	45 [CSL]	NA
2003	20-Day Polychaete	Mean Growth/Individual (mg)			NA	NA	13.11	12.89	13.94	NA	NA	13.26	NA	NA	NA	NA	NA	14.20	NA	NA	15.15	NA
1995	(Neanthes arenaceodentata)				12.18	7.52	7.38	9.1	8.32	7.16	NA	7.24	8.04	5.46 [SQS]	NA	9.12	7.48	8.88	5.96 [SQS]	6.78	8.24	NA
SVOCs (mg/kg oc)																						
	2-Methylnaphthalene	38	64	mg/kg oc	9.26 U	1.66 J	1.16 U	1.41 U	0.37 U	1.32 U	0.10 U	1.47 U	0.18 U	0.06 U	7.58 U	0.08 U	0.17	0.07 U	0.10 U	0.26	0.08 U	0.07 U
	bis(2-Ethylhexyl)phthalate	47	78	mg/kg oc	92.58 U [B]	NA	NA	7.78	NA	NA	NA	21.87	NA	NA	NA	1.90	NA	NA	1.38	NA	2.53	NA
	Butylbenzylphthalate	4.9	64	mg/kg oc	92.58 U [B]	NA	NA	7.04 U [A]	NA	NA	NA	7.33 U [A]	NA	NA	NA	0.41 U	NA	NA	0.49 U	NA	1.24	NA
	Di-n-butylphthalate	220	1700	mg/kg oc	37.08 U	NA	NA	9.26	NA	NA	NA	5.85 U	NA	NA	NA	0.33 U	NA	NA	0.40 U	NA	0.54	NA
PAHs (mg/kg oc)																						
	Acenaphthene	16	57	mg/kg oc	3.71 U	1.42 U	0.46 U	6.07	0.15 U	0.53 U	0.04 U	0.59 U	0.07 U	0.25	3.03 U	0.03 U	0.70	0.07	0.08	0.04 U	0.06	0.03 U
	Acenaphthylene	66	66	mg/kg oc	4.35	1.42 U	0.46 U	0.56 U	0.15 U	0.53 U	0.25	0.59 U	0.07 U	1.03	3.03 U	0.08	3.65	0.10	0.08	0.08 J	0.03 U	0.07
	Anthracene	220	1200	mg/kg oc	3.71 U	1.42 U	0.46 U	9.81	0.26 J	0.88 J	1.30	0.59 U	0.07 U	1.52	3.03 U	0.03 U	3.39	0.03 U	0.08	0.20	0.11	0.04 J
	Fluorene	23	79	mg/kg oc	3.71 U	1.42 U	0.46 U	9.32	0.15 U	0.53 U	0.04 U	0.59 U	0.07 U	0.02 U	3.03 U	0.03 U	0.54	0.03 U	0.04 U	0.21	0.10	0.03 U
	Naphthalene	99	170	mg/kg oc	9.26 U	1.42 U	0.46 U	0.56 U	0.19 J	0.53 U	0.04 U	0.59 U	0.07 U	0.02 U	3.03 U	0.03	0.32	0.03 U	0.04 U	0.07 J	0.03 U	0.03 U
	Phenanthrene	100	480	mg/kg oc	3.71 U	1.42 U	1.45	34.07	0.75	0.53 U	0.53	0.59 U	0.07 U	0.24	3.03 U	0.04	4.26	0.03 J	0.21	1.08	0.47	0.05
	calculated LPAH [1]	370	780	mg/kg oc	4.35	1.66	1.45	59.28	1.20	0.88	2.08	0.58 U	0.18 U	3.04	7.58 U	0.15	13.01	0.20	0.46	1.90	0.73	0.16
	Benzo(a)anthracene	110	270	mg/kg oc	9.26 U	1.42 U	0.46 U	0.56 U	0.15 U	0.53 U	1.34	12.47	0.07 U	5.22 D10	3.03 U	0.03 U	5.68	0.03 U	0.34	0.04 U	0.03 U	0.03 U
	Benzo(a)pyrene	99	210	mg/kg oc	9.26 U	1.42 U	2.68	0.56 U	0.73	0.53 U	0.79	4.91	0.07 U	2.73	3.03 U	0.03 U	6.52	0.03 U	0.37	0.04 U	0.30	0.03 U
	Benzo(g,h,i)perylene	31	78	mg/kg oc	3.71 U	1.42 U	NA	0.56 U	NA	0.53 U	0.04 U	5.69	NA	1.11	3.03 U	0.03 U	3.17	0.03 U	0.04 U	0.04 U	0.03 U	0.03 U
	Benzofluoranthenes	230	450	mg/kg oc	7.39 U	1.42 U	3.54	1.12 U	1.36	1.06 U	0.08 U	11.27	0.15 U	2.85	6.06 U	0.06 U	7.65	0.06 U	0.67	0.08 U	0.60	0.05 U
	Chrysene	110	460	mg/kg oc	9.47	1.42 U	3.08	5.43	1.36	0.53 U	1.07	18.40	0.07 U	3.86	49.74	0.03 U	5.74	0.03 U	0.34	0.59	0.03 U	0.03 U
	Dibenz(a,h)anthracene	12	33	mg/kg oc	9.26 U	1.42 U	0.46 U	0.56 U	0.15 U	0.53 U	0.04 U	0.59 U	0.07 U	0.29	3.03 U	0.03 U	0.68	0.03 U	0.04 U	0.04 U	0.03 U	0.03 U
	Fluoranthene	160	1200	mg/kg oc	7.27	1.42 U	3.84	3.94	1.57	2.87	1.25	7.20	0.18 U	1.15	7.58 U	0.10	5.52	0.10 J	0.73	0.27	0.55	0.12 J
	Indeno(1,2,3-cd)pyrene	34	88	mg/kg oc	9.26 U	1.42 U	1.70	0.56 U	0.52	0.53 U	0.04 U	2.26	0.07 U	0.80	3.03 U	0.03 U	2.81	0.03 U	0.04 U	0.04 U	0.28	0.03 U
	Pyrene	1000	1400	mg/kg oc	9.11	1.42 U	4.60	11.23	1.98	3.69	1.98	11.53	0.07 U	1.93	105.64	0.03 U	8.00	0.09	0.68	0.60	0.63	0.15
	calculated HPAH [1]	960	5300	mg/kg oc	25.86	1.42 U	19.45	20.60	7.52	6.57	6.43	73.73	0.15 U	19.93	155.38	0.10	45.76	0.20	3.14	1.46	2.36	0.27
EPH (mg/kg)																						
	C10-C-12 Aliphatics	--	--	--	< 5	< 5	< 5	< 5	NA	< 10.9	NA	< 10.0	NA	< 30.9	NA	< 29.2	NA	NA	< 20.9	NA	< 26.9	< 24.9
	C12-C-16 Aliphatics	--	--	--	< 5	< 5	5.96	10.70	NA	< 10.9	NA	60.80	NA	< 30.9	NA	< 29.2	NA	NA	< 20.9	NA	< 26.9	< 24.9
	C16-C-21 Aliphatics	--	--	--	< 5	< 5	10.20	40.00	NA	23.20	NA	110.00	NA	71.90	NA	< 29.2	NA	NA	< 20.9	NA	< 26.9	< 24.9
	C21-C-34 Aliphatics	--	--	--	16.40	< 5	28.90	107.00	NA	40.40	NA	56.10	NA	151.00	NA	< 29.2	NA	NA	< 20.9	NA	< 26.9	< 24.9
	Total EPH Aliphatics				16	0	45	158	NA	64	NA	227	NA	223	NA	0	NA	NA	0	NA	0	0
	C10-C-12 Aromatics	--	--	--	< 5	< 5	< 5	< 5	NA	< 10.9	NA	< 10.0	NA	< 30.9	NA	< 29.2	NA	NA	< 20.9	NA	< 26.9	< 24.9
	C12-C-16 Aromatics	--	--	--	< 5	< 5	< 5	< 5	NA	< 10.9	NA	< 10.0	NA	< 30.9	NA	< 29.2	NA	NA	< 20.9	NA	< 26.9	< 24.9
	C16-C-21 Aromatics	--	--	--	< 5	< 5	10.10	33.30	NA	15.80	NA	80.40	NA	52.20	NA	< 29.2	NA	NA	< 20.9	NA	< 26.9	< 24.9
	C21-C-34 Aromatics	--	--	--	22.10	< 5	50.60	158.00	NA	46.40	NA	61.80	NA	181.00	NA	< 29.2	NA	NA	< 20.9	NA	< 26.9	< 24.9
	Total EPH Aromatics				22	0	61	191	NA	62	NA	142	NA	233	NA	0	NA	NA	0	NA	0	0
	Total EPH				39	0	106	349	NA	126	NA	369	NA	456	NA	0	NA	NA	0	NA	0	0
TPH (mg/kg)																						
	#2 Diesel	--	--	--	378 X1	54.70	215 X1	1470 X1	16.2 U	180 X1	302 X1	598 X1	22.4 U	191 X1	256 X1	57 U	24.9 U	32.3 U	71.8 J	27.9 J	47.4 J	81.4 U
	Motor Oil	--	--	--	1820.00	344.00	1120.00	5480.00	32.4 U	353 X1	555 X1	325.00	44.8 U	492 X1	627 X1	270 X2	110 X2	64.6 U	490 X2	47.7 J	362.00	470 X2
	Gasoline	--	--	--	2.42	5.25 U	8.52	9.76	4.85	8.12	5.22	59.10	17.10	15.80	15.7 U	11.90	8.04 U	10.7 U	10.90	7.83 U	14.3 U	24.7 U
	Total TPH				2,200	399	1,344	6,960	5	541	862	982	17	699	883	282	110	0	573	76	409	470
TPH (mg/kg oc)																						
	#2 Diesel	--	--	--	90000 X1	4307	9598 X1	90741 X1	3115 U	6102 X1	8366 X1	39867 X1	1514 U	2108 X1	3282 X1	703 U	803 U	597 U	860 J	955 J	642 J	532 U
	Motor Oil	--	--	--	433333	27087	50000	338272	6231 U	11966 X1	15374 X1	21667	3027 U	5430 X1	8038 X1	3329 X2	3548 X2	1194 U	5868 X2	1634 J	4905	3072 X2
	Gasoline	--	--	--	576.00	413 U	380.00	602.00	933.00	275.00	145.00	3940.00	1155.00	174.00	201 U	147.00	259 U	198 U	131.00	268 U	194 U	161 U
	Total TPH				523,909	31,394	59,978	429,615	933	8,343	23,885	65,474	1,155	7,712	11,320	3,476	3,548	0	6,859	2,589	5,547	3,604
SVOCs (ug/kg)																						
	3-&4-Methylphenol	670	670	ug/kg	309 U	NA	NA	182 U	NA	NA	NA	176 U	NA	NA	NA	52.7 U	NA	NA	66.1 U	NA	84.8 J	NA
	Phenol	420	1200	ug/kg	155 U	NA	NA	91.1 U	NA	NA	NA	87.8 U	NA	NA	NA	26.4 U	NA	NA	33 U	NA	41.4 J	NA
PCBs (mg/kg oc)																						
	calculated Total PCBs [1]	12	65	mg/kg oc	2.80 U	NA	NA	0.94 U	NA	NA	NA	32.27 [SQS]	NA	NA	NA	0.50 U	NA	NA	0.56 U	NA	0.50 U	NA
Metals (mg/kg)																						
	Arsenic	57	93	mg/kg	2.08	4.24	6.22	3.4	1.47 J	12.2	12.2	2.99	4.81	10.8	12.4	20.7	3.79 J	7.55	12	4.53	12	36.9
	Chromium	260	270	mg/kg	15.3	NA	NA	21.4	NA	NA	NA	15.9	NA	NA	NA	35.2	NA	NA	49.5	NA	21.6	NA
	Copper	390	390	mg/kg	10.4	12.7	21.3	7.58	2.24 J	17.8	16.7	12.1	19.8	19	20.2	24.7	10.2	21	27.3	22.1	17.3	58.7
	Lead	450	530	mg/kg	11.7	6.25	10.4	5.91	1.32 U	67.4	69.1	21	1.84 J	48.7	55.6	23.8	18.3	11.1	49.6	7.68	73.4	262
	Mercury	0.41	0.59	mg/kg	0.0113 U	NA	NA	0.0682 B1	NA	NA	NA	0.0664 B1	NA	NA	NA	0.162 B1	NA	NA	0.189 B1	NA	0.128 B1	NA
	Zinc	410	960	mg/kg	37.9	34	48.4	31.5	11.4	80.2	77.4	78.9	35.8	86.1	99.4	42.8	43.1	45	121	40.2	102	378
Conventionals																						
	Ammonia Nitrogen (mg/kg)	--	--	--	19.40	NA	NA	88.80	NA	NA	NA	94.20	NA	NA	NA	661.00	NA	NA	945.00	NA	564.00	NA
	ammonia (mg/L) [3]				NA	NA	5.50	4.80	1 U	NA	NA	4.30	NA	NA	NA	NA	NA	5.60	NA	NA	14.10	NA
	sulfide (mg/L) [3]				NA	NA	1.00	0.5 U	0.5 U	NA	NA	0.85	NA	NA	NA	NA	NA	0.5 U	NA	NA	0.5 U	NA
--	TOC (%)	--	--	--	0.42	1.27	2.24	1.62	0.52	2.95	3.61	1.50	1.48	9.06	7.80	8.11	3.10	5.41	8.35	2.92	7.38	15.30

Notes:
Bold font indicates detected concentrations
NA = not analyzed
-- = not applicable
SMS criteria for 4-Methylphenol were applied to data for 3-&4-Methylphenol
[1] It was assumed that non-detects were equal to zero except where all individual compounds were non-detect in which case the highest DL was assumed to be the concentration as per WAC 173-204-320(2)(b)(i) and (ii)
SQS = concentration exceeds SQS
CSL = concentration exceeds CSL
A = detection limit exceeded SQS
B = detection limit exceeded CSL

Table 10. Summary of Detected Chemicals with SMS Criteria in Unocal Sediment

Analyte	Arsenic	Chromium	Copper	Lead	Mercury	Zinc
TEC	9.79	43.4	31.6	35.8	0.18	121
PEC	33	111	149	128	1.06	459
US-01-1003	**2.08**	**15.3**	**10.4**	**11.7**	0.0113 U	**37.9**
US-02-1003	**4.24**	NA	**12.7**	**6.25**	NA	**34**
US-03-1003	**6.22**	NA	**21.3**	**10.4**	NA	**48.4**
US-04-1003	**3.4**	**21.4**	**7.58**	**5.91**	**0.0682 B1**	**31.5**
US-05-1003	**1.47 J**	NA	**2.24 J**	1.32 U	NA	**11.4**
US-06-1003	**12.2**	NA	**17.8**	**67.4**	NA	**80.2**
US-20-1003 (US-06 Dup)	**12.2**	NA	**16.7**	**69.1**	NA	**77.4**
US-07-1003	**2.99**	**15.9**	**12.1**	**21**	**0.0664 B1**	**78.9**
US-08-1003	**4.81**	NA	**19.8**	**1.84 J**	NA	**35.8**
US-09-1003	**10.8**	NA	**19**	**48.7**	NA	**86.1**
US-21-1003 (US-09 Dup)	**12.4**	NA	**20.2**	**55.6**	NA	**99.4**
US-10-1003	**20.7**	**35.2**	**24.7**	**23.8**	**0.162 B1**	**42.8**
US-11-1003	**3.79 J**	NA	**10.2**	**18.3**	NA	**43.1**
US-12-1003	**7.55**	NA	**21**	**11.1**	NA	**45**
US-13-1003	**12**	**49.5**	**27.3**	**49.6**	**0.189 B1**	**121**
US-14-1003	**4.53**	NA	**22.1**	**7.68**	NA	**40.2**
US-15-1003	**12**	**21.6**	**17.3**	**73.4**	**0.128 B1**	**102**
US-16-1003	**36.9**	NA	**58.7**	**262**	NA	**378**

Bold font indicates detected concentrations

TEC	consensus-based threshold effect concentration (MacDonald et al. 2000)
PEC	consensus-based proable effect concentration (MacDonald et al. 2000)
[shaded]	concentration exceeds TEC