APPENDIX AA
MVS MODELING VERIFICATION REPORT (SUNDANCE)

Palos Verdes Shelf Technical Memorandum

Prepared by ICF, Inc. and Sundance Environmental and Energy Specialists, LTD

Final – November 21, 2017

Mass and Volume-Averaged Concentrations of Chemicals and Chemical Grouping from the 2013 Palos Verdes Shelf Sediment Sampling Program

1.0 INTRODUCTION

As directed by ICF, Inc., Sundance Environmental and Energy Specialists, Ltd. (Sundance) conducted three-dimensional (3D) geostatistical analysis of Palos Verdes (PV) Shelf analytical data from sediment samples obtained from sediment cores collected in 2013 for the U.S. Environmental Protection Agency (EPA) Region 9. Specifically, within the 2013 PV Shelf effluent-affected (EA) sediment bed, the spatial distribution of various forms of 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane (DDT); 1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene (DDE); 1,1-dichloro-2,2-bis(p-chlorophenyl)ethane (DDD): 1-chloro-2,2-bis(p-chlorophenyl)ethylene (DDMU); and unsym-bis(p-chlorophenyl)ethylene (DDNU) as follows: and , o,p'-DDD, p,p'-DDD, o,p'-DDE, p,p'-DDE, o,p'-DDT, p,p'-DDT, p,p'-DDMU, p,p'-DDNU, total DDT, total DDT compounds, and total polychlorinated biphenyls (PCBs). The data used in the analysis were not normalized for total organic carbon (TOC). The concentrations of these chemicals were individually modeled to estimate mass and volume-averaged concentrations of each of these chemicals and chemical groupings. Mass (kg) and volume-averaged concentrations (µg/kg) were estimated for each of these chemicals and chemical groupings in the 0 centimeter (cm) – 8 cm top layer of the EA bed, the 8 cm to the bottom of the EA bed, and the entire EA sediment bed.

The technical memorandum is organized as follows: Section 1.0 is the introduction; Section 2.0 discusses the data; Section 3.0 presents the methodology; Section 4.0 presents the results; and Section 5.0 lists the references.

2.0 2013 PV SHELF SEDIMENT DATA

Figure 1 shows the map locations of the 69 PV Shelf sediment cores obtained in 2013. All core locational descriptions are in meters (m) and their geographic projection is NAD83 UTM Zone 11N. The laboratory results from physical and chemical analyses of the cores were reported for 2 cm increments of core from 0 cm to 8 cm and then in 4 cm increments of core from 8 cm to the bottom of the core.

2.1 PV Shelf 2013 EA Sediment Bed

The footprint of the 2013 PV Shelf EA sediment bed and, thus, the horizontal extent of the 3D domain of the geostatistical analyses were defined as the polygon shown in Figure 2. The footprint area of the 2013 EA sediment bed is approximately 33 square kilometers (km^2). The overall sediment bed dimensions were defined in a manner that allows reasonable comparison of 2013 sediment sample analyses to chemical mass estimates from 1992 and 2009. Figure 3 shows the 2013 PV Shelf EA sediment bed footprint in comparison to the 2009 EA sediment bed footprint.

The bottom depth of each sediment core was used to define the vertical extent, or thickness (<1m), of the EA sediment bed. Within the EA sediment bed domain the sea floor elevation varies more than 100 m. Figure 4 show this variation with the water column above the seabed, the 0 cm – 8 cm sediment layer, and the 8 cm to bottom of core sediment layer exaggerated in the vertical dimension. However, according to and in keeping with previous PV Shelf sediment geostatistical analyses "the deposition of sediment in layers over time is a greater relational factor than the absolute measured elevation of samples. Therefore, all geologic data were referenced to depth in the sea floor bed rather than to sea level, to allow the kriging algorithms to fit the chemical data and depositional process most effectively"

(USEPA 2013; Sundance 2012). Figure 5 shows the 0 cm – 8 cm sediment bed and the 8 cm – to bottom of core sediment bed with the top of the seabed referenced to zero elevation. Figure 5 presents the full domain for the geostatistical analysis of the 2013 PV Shelf sediment data.

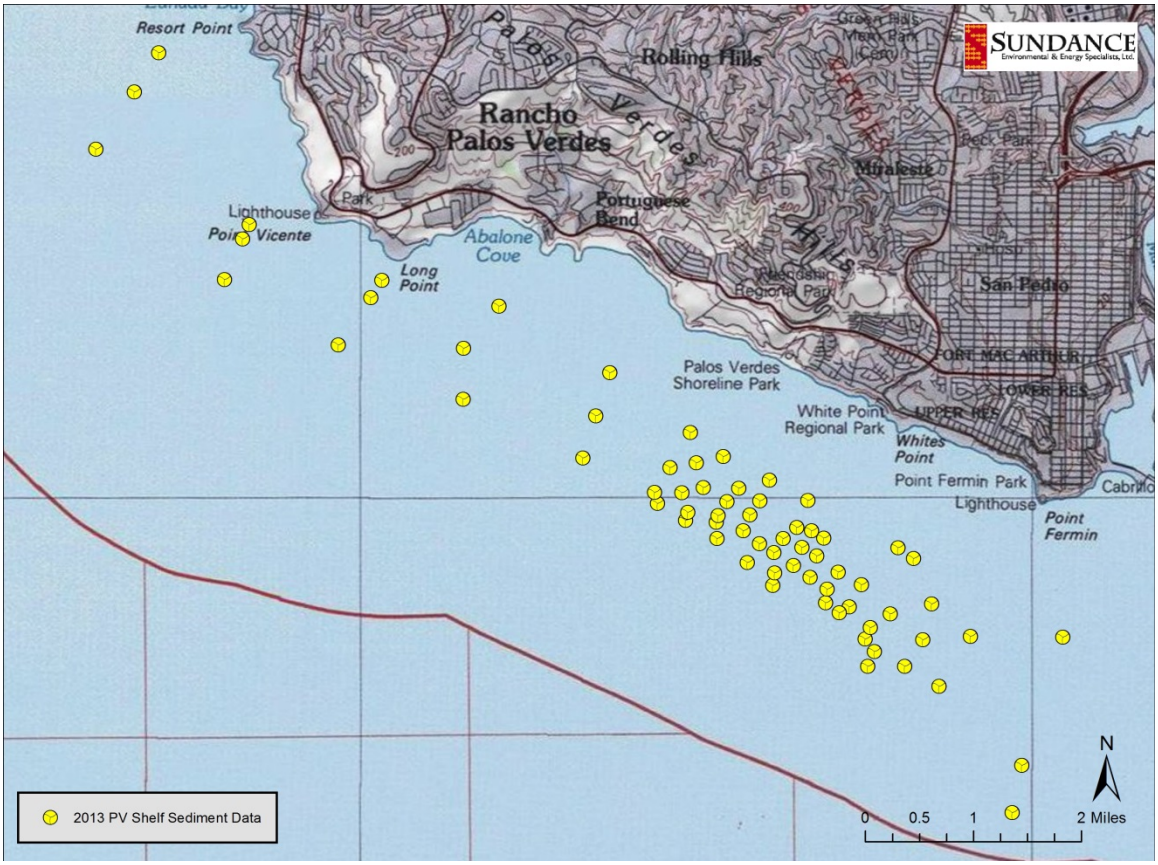

Figure 1. Location of 2013 PV Shelf sediment cores.

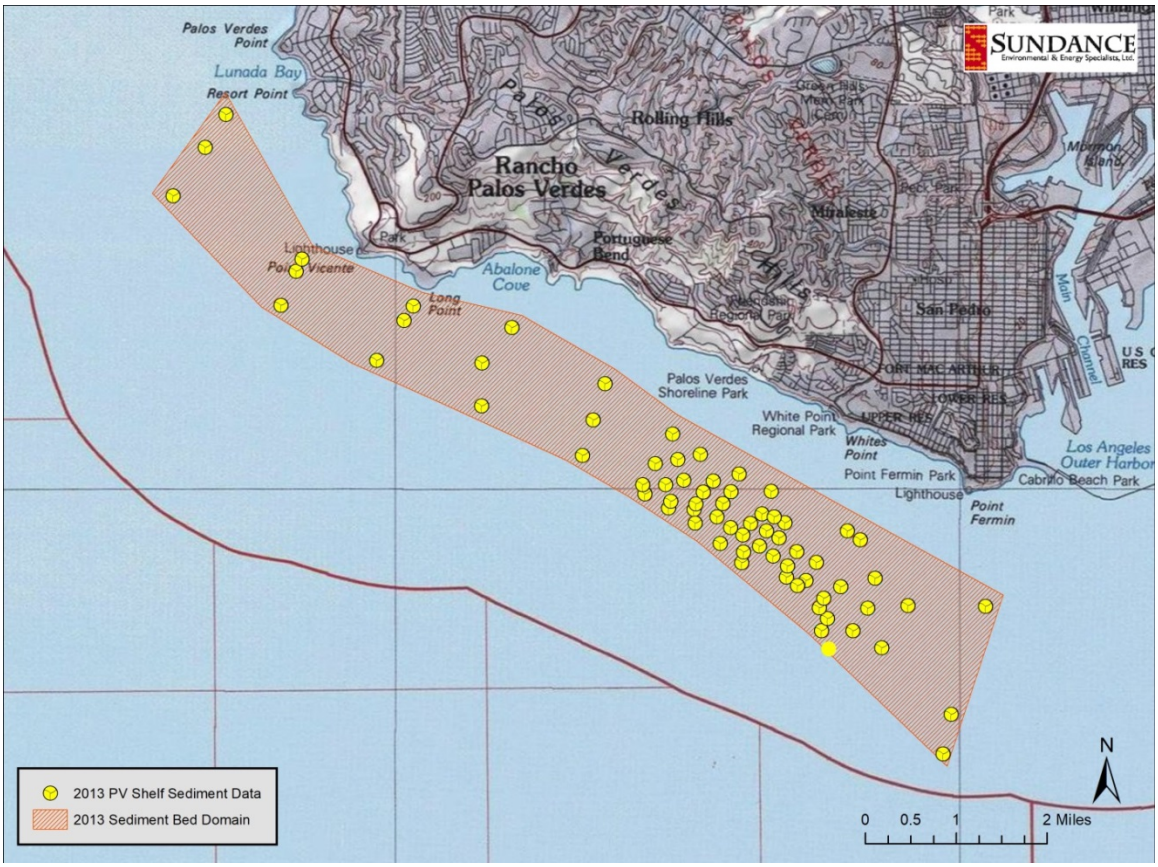

Figure 2. 2013 PV Shelf EA sediment bed domain.

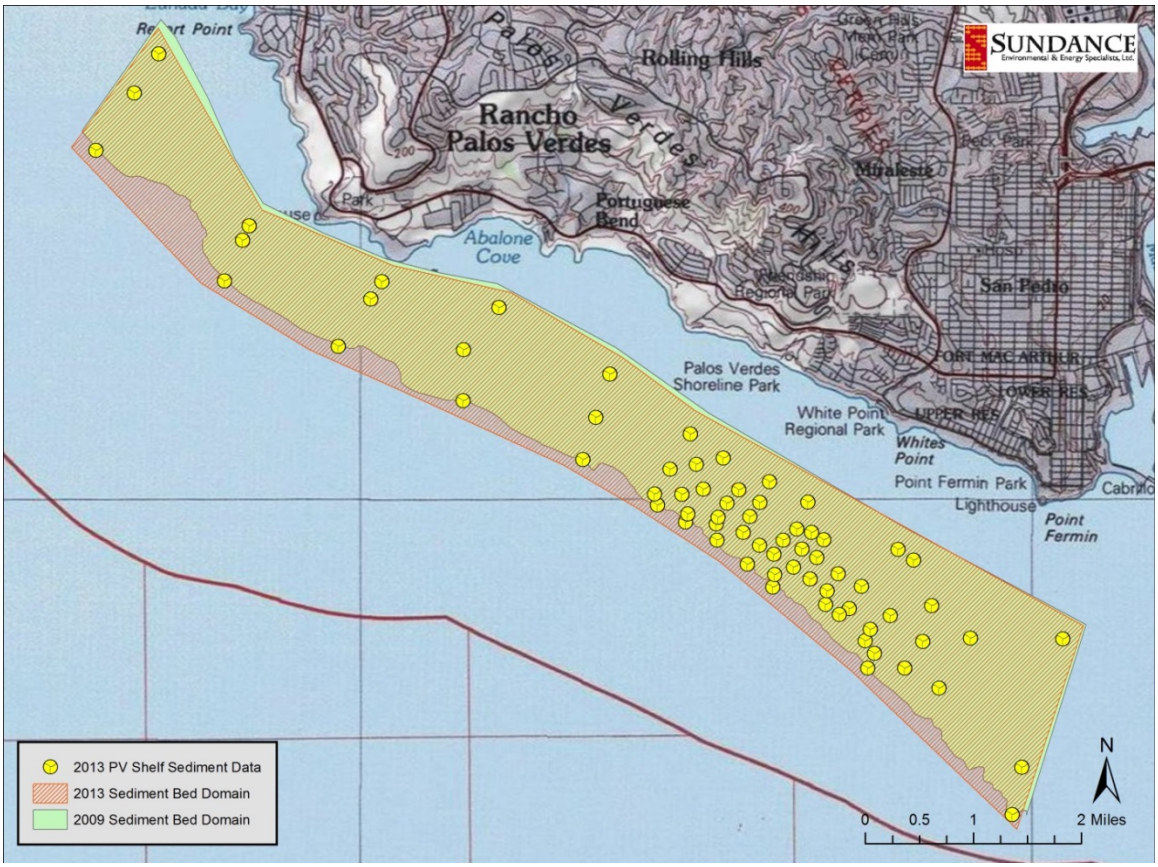

Figure 3. Comparison of 2013 PV Shelf EA sediment bed domain to the 2009 EA sediment bed domain.

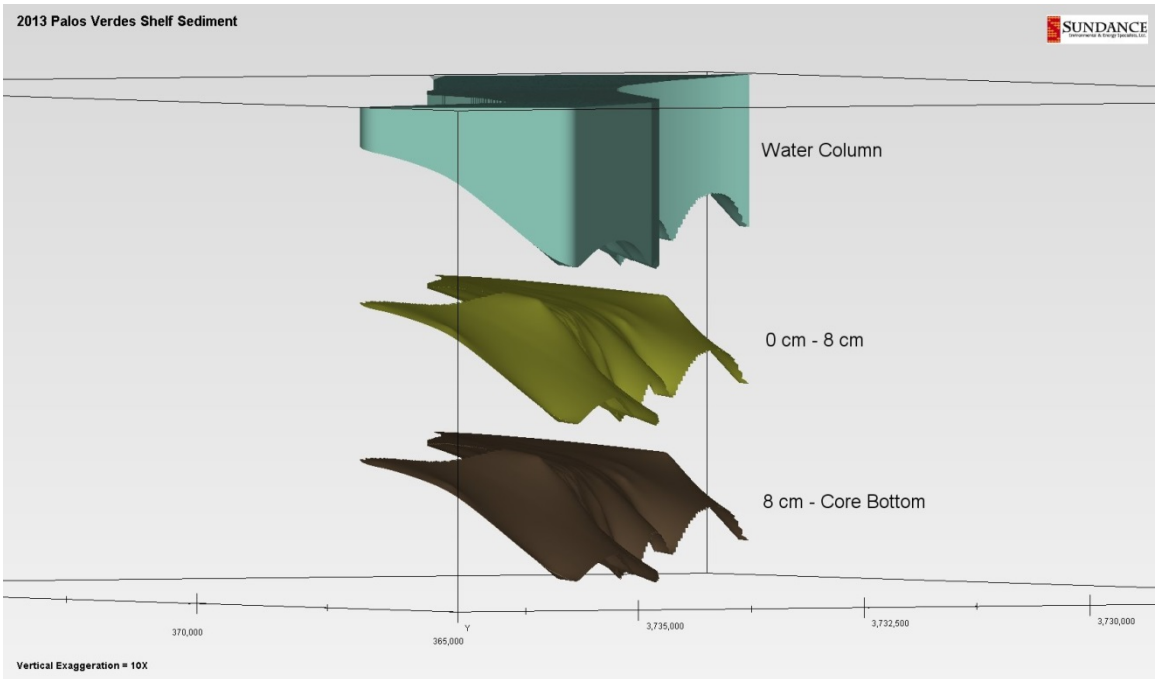

Figure 4. 3D rendering of the water column, 0 cm – 8 cm layer, and 8 cm to bottom of core layer. Note the 10:1 vertical exaggeration.

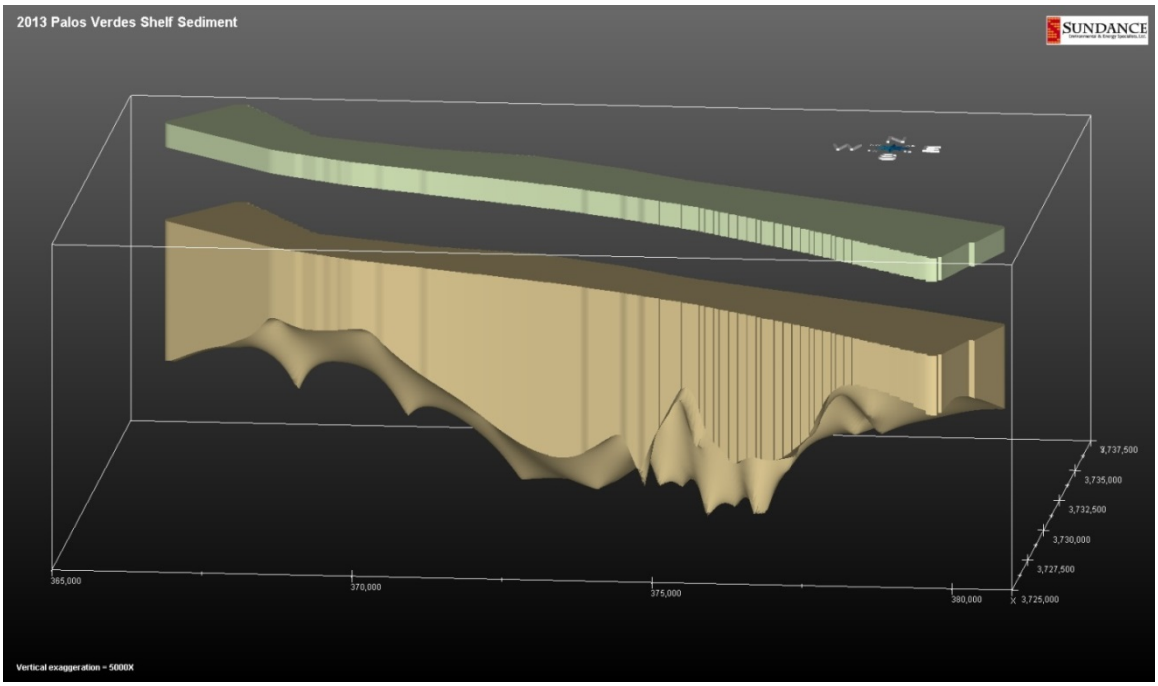

Figure 5. 3D rendering of the PV Shelf 0 cm – 8 cm and 8 cm – bottom of core sediment layers. Note that in composite the total thickness of these layers is less than 1m. The vertical exaggeration of the image is 5000:1.

2.2 PV Shelf 2013 Analytical Data

The 2013 PV Shelf analytical data include location identification (ID), sample ID, XY location coordinates (m), core interval, parameter label, preferred name, parameter value, EPA flags, units, method detection limit (MDL), reporting limit (RL), wet bulk density, specific gravity, and calculated dry bulk density. For all sediment cores combined there are a total of 1020 discrete core intervals and thus 1020 parameter values for each chemical and grouping of chemicals plus moisture content and TOC. All chemical and chemical groupings concentration data were reported as µg/kg. This unit of measure was maintained throughout the analyses. Dry bulk density was reported as grams per cubic centimeter (g/cm^3). This unit of measure was also maintained throughout the analyses. Mass of each chemical and chemical grouping was calculated as kg according to the following general formula.

$$Mass\ (kg) = Concentration\left(\frac{\mu g}{kg}\right) \times Dry\ Bulk\ Density\ \left(\frac{g}{cm^3}\right) \times Volume\ (m^3) \times 10^{-6} \qquad (1)$$

Only Sample Code N (Normal) data were included in the analyses. For parameter values that were reported as uniquely zero the value input for processing was 0.001. However, during post processing of results all computed concentrations less than 10% of the minimum detection limit were set to 10% of the minimum detection limit. Given the overwhelmingly high concentrations observed for all chemicals and chemical groupings the values assigned to reported zero concentrations have a negligible effect on the resulting mass estimates.

3.0 METHODOLOGY

All computations and 3D visualizations were performed using C Tech Development Corp. (C Tech) Earth Volumetric Studio (EVS) version 2017.5 software. EVS is a recently released new product that replaces

Mining Visualization System (MVS) which was used in previous PV Shelf sediment geostatistical analyses. EVS has many improvements and enhancements over MVS, particularly the ability to customize the geostatistical parameterization within the variogram setup.

3.1 Key Computational Input Parameters

The calculated mass of any chemical or chemical grouping is sensitive, to varying degrees, to several input parameters. The impact of each of the following input parameters on calculated chemical mass was evaluated.

Max-gap (maximum gap) is the maximum distance allowed between samples for kriging. It applies to continuous vertical intervals (for example, 2 cm core sample). Max-gap establishes how many discrete point concentration values are employed to represent the reported value for the entire vertical interval. If the interval length is less than max-gap one value is placed in the center of the interval. If the interval is longer than max-gap two or more equally spaced values are distributed within the interval. Sundance (2012) performed a detailed sensitivity analysis comparing the resulting mass estimates from 1992 PV Shelf sediment data by varying max-gap while keeping all other parameters equal. The outcome of this exercise indicated that the differences in computed mass among the varying max-gap values was very small (tens of kg out of ~40,000 kg). Therefore, given the relative insensitivity of mass calculations to max-gap the value used for previous Sundance (2012) PV Shelf sediment analyses was used in this study. This value is 1 cm which means that for a 2 cm core interval a concentration value is set at the top, the middle, and bottom of each 2 cm interval. Using the same max-gap value as previous studies facilitates comparison of these results to previous studies.

Variogram parameters (that is, range, sill, and nugget) influence the kriged spatial distribution of concentrations and therefore the mass calculations. Within the MVS software used in previous PV Shelf sediment data analyses these key variogram parameters were determined by an “expert system” C Tech used to fit the experimental variogram to the data. Within EVS the user can customize the experimental variogram and bypass the expert system. As discussed below a validation exercise was conducted to compare the mass results obtained from customized variography versus automatic setting of variogram parameters.

Adaptive gridding further subdivides the initial 3D grid to place a kriging node at the input location of each data sample. Kriging is an exact interpolator and as such adaptive gridding guarantees that the kriged estimates include exactly the entire sample input data which improves accuracy over non-adaptive gridding. However, adaptive gridding increase computational overhead as the final kriged grid is larger than the initial input grid.

Horizontal to vertical (H:V) anisotropy has a major effect on the resulting mass calculation. This is especially true in this study due to the nature of the domain. The horizontal extent of the domain is several orders of magnitude greater than the vertical extent which is less than 1 m. Consequently, the amount of mass of a chemical is far more dependent on the horizontal spreading of the chemical than its vertical distribution. Further, given the longshore currents it is likely that the chemicals are spread horizontally in the upper layers of the sediment (Murry, et al. 2002). USEPA (2011) used the single value of 2000 for H:V anisotropy in their analysis of 2009 PV Shelf sediment data. Sundance (2012) demonstrated the sensitivity of mass calculations to H:V in their analysis 1992 and 2009 PV Shelf sediment data by calculating chemical masses resulting from H:V anisotropy of 500:1, 1000:1, 2000:1, and 5000:1. Sundance (2012) concluded from this analysis that, given the wide range of resulting mass

estimates due to varying H:V anisotropy, that one estimate of mass based a single H:V anisotropy does not reliably represent mass. Rather, Sundance (2012) reported mass for 1992 p,p'-DDE as an ensemble of four estimates based on the four different H:V anisotropy values used for the mass calculations. This approach was also employed in the calculation of the mass of chemicals and chemical groupings resulting from the 2013 PV Shelf sampling.

3.2 Software Validation

Previous PV Shelf chemical mass estimates (Sundance 2012; USEPA 2013) were obtained using C Tech's MVS software. As noted above C Tech's newer software, EVS, was used to calculate chemical mass and volume-averaged concentrations from the 2013 sediment samples. Therefore, to validate EVS and assure comparison of the results of analyses of 2013 PV Shelf sediment data to previous results is valid, C Tech's EVS software was used to analyze the 1992 PV Shelf sediment MVS data sets for p,p'-DDE. Further, MVS was updated several versions since the version used by Sundance (2012) to analyze the 1992 PV Shelf sediment data. Table 1 shows the results of this exercise and confirms the suitability of EVS for 2013 PV Shelf sediment data analyses. Column "a" shows the range of H:V anisotropies over which 1992 p,p'-DDE mass estimates were made. Column "b" lists the original mass calculations reported in Sundance (2012). Column "c" lists, over the range of H:V anisotropies, the mass estimates based on applying the latest version of MVS (9.94). These mass estimates are in very close agreement to the original mass estimates based on Sundance (2012) MVS analyses (column "b"). Columns "d" and "e" contain the results from applying EVS version 2017.5 to the same 1992 p,p'-DDE PV Shelf sediment data. Column "d" contains the EVS results using the autofit option (expert system) variography (as was the case for all MVS-based mass estimates) and column "e" is the EVS results after applying customized variography. For the EVS-based 1992 p,p'-DDE mass estimates the values of the geostatistical parameters are provided in column "f". The results from both autofit and custom EVS applications are also in good agreement with the MVS-based mass estimates for 1992 p,p'-DDE thus validating the use of EVS 2017.5 for application to 2013 PV Shelf sediment data analyses.

Table 1. Results of MVS – EVS software benchmarking against 1992 PV Shelf p,p'-DDE sediment data.

a	b	c	d	e	f
Anisotropy (H:V)	Original 2011 Calculation of Mass Estimates via MVS, kg	2017 Calculation of Mass Estimates via MVS9.94, kg	2017 Calculation of Mass Estimates via EVS 2017.5 (autofit variography), kg	2017 Calculation of Mass Estimates via EVS 2017.5 (customized p,p'-DDE variography), kg	Geostatistical Parameters
500	26,354	26,267	25,801	24,095	
1000	28,245	28,163	27,674	26,035	
2000	31,545	31,456	30,933	29,165	
5000	37,235	37,132	36,741	34,420	
			Spherical	Exponential	Variogram Model
			5,414.00	850.00	Range
			0.28	0.24	Sill
			0.00	0.00	Nugget

3.3 2013 EA Sediment Bed Domain

The starting 2D domain footprint was established as the convex hull of the X,Y locations of the set of 2013 PV Shelf sediment cores with a 2% boundary offset to ensure that all samples were fully within the domain boundaries. Once the convex hull was determined including the 2% offset the domain was masked using the polygon shown in Figure 2 to fix the final 2D domain to this polygon. Table 2 contains the horizontal dimensions of the grid wherein the grid cell size is 100 m X 100 m with a total surface area of approximately 33 km^2. The vertical extent of the 3D domain was constructed as 0 m (sediment surface) to the surface represented by the kriged bottom of the 2013 PV Shelf sediment cores.

Table 2. 2013 EA sediment bed domain parameters.

Parameter	Value	Unit
Easting (X) minimum	365,797	meter
Easting (X) maximum	380,559	meter
Easting (X) extent	14,762	meter
Easting (X) resolution	148	#
Avg. Easting (X) cell width	100	meter
Northing (Y) minimum	3,725,269	meter
Northing (Y) maximum	3,736,948	meter
Northing (Y) extent	11,679	meter
Northing (Y) resolution	116	#
Avg. Northing (Y) cell width	100	meter
Surface area	33.2	sq. km
Total soil volume	1.63×10^7	$meter^3$

3.4 Geostatistical Analysis of 2013 PV Shelf Sediment Analytical Data

The chemical, chemical groupings and dry bulk density analytical data were 3D kriged within the EA sediment bed domain. Figure 6 shows an example (p,p'-DDE) 3D sediment core spatial distribution within the EA sediment bed domain. The starting vertical grid resolution was 84 which results in a vertical grid cell size ≤ 1 cm. However, the grid was further modified (that is, made denser) with adaptive gridding around each data point. The EA sediment bed computational domain has a total volume of 1.63×10^7 m^3. The domain was subsequently separated into two layers as shown in Figure 5 representing the sediment bed from 0 cm – 8 cm and 8 cm – bottom of the sediment cores. Mass and volume-averaged concentration estimates were calculated for the entire 2013 EA sediment bed domain and separately for these two discrete layers.

Each chemical or chemical grouping was 3D kriged resulting in an independent interpolated estimate of the chemical or chemical grouping concentration at every grid node in µg/kg. In like fashion, the dry bulk density was 3D kriged resulting in independent interpolated estimate of dry bulk density at every grid node in g/cm^3. Using internal software node computation capabilities, Equation 1 was applied to the chemical concentration and dry bulk density interpolated results to estimate mass.

Ordinary three-dimensional kriging was applied to the 2013 PV Shelf chemical and dry bulk density sediment data. For each chemical or chemical grouping a custom variogram was fitted to the data set. All data points were used in each kriging computation thus avoiding the requirement to establish a search radius and the number of points to include within that reach.

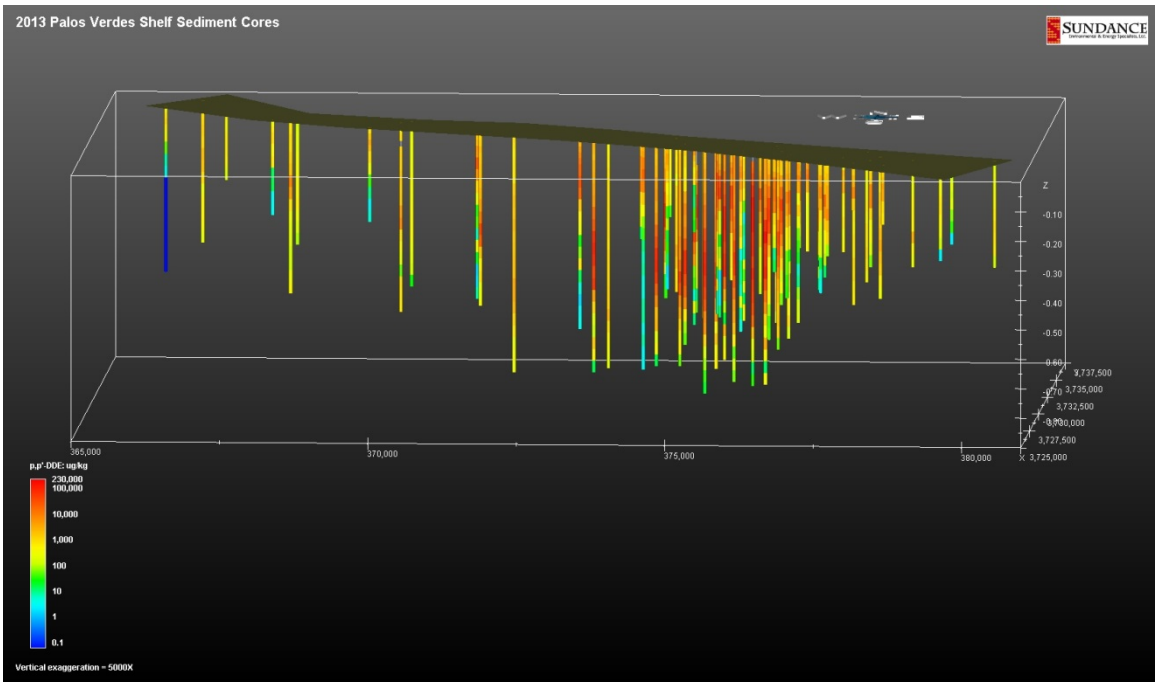

Figure 6. 3D spatial distribution of the 2013 PV Shelf p,p'-DDE sediment data within the EA sediment bed. Note the vertical exaggeration of the image is 5000:1.

4.0 RESULTS

This section discusses the summarized and detailed results of the data analysis, the uncertainty analysis, and the comparison of the 2009 and 2013 data.

4.1 Summary

Table 3 presents an overall summary of the mass (kg) and volume-averaged concentration (ug/L) of each chemical and chemical grouping. As discussed above the estimated mass based on kriging the concentration and dry bulk density is highly sensitive to the value of horizontal to vertical anisotropy used in the geostatistical analysis. Consequently, the mass and volume-averaged concentration for each chemical and chemical grouping was estimated for four values of H:V anisotropy, namely 500:1, 1000:1, 2000:1, and 5000:1. In the summary table (Table 3) the average mass and average volume-averaged concentration resulting from the four discrete H:V anisotropy estimates for each chemical and chemical grouping is shown. The full details of each chemical and chemical grouping mass and volume-averaged concentration by varying H:V anisotropy are presented following the summary.

Table 3. Summary results for chemical and chemical group mass and average concentration.

Chemical or Chemical Grouping	0 cm - 8 cm Avg. Mass (kg)	8 cm - Core Bottom Avg. Mass (kg)	Total Avg. Mass (kg)	0 cm - 8 cm Avg. Conc. (ug/kg)	8 cm - Core Bottom Avg. Conc. (ug/kg)	Total Avg. Conc. (ug/kg)
p,p'-DDE	2936	19837	22773	1134	1501	1443
o,p'-DDE	539	3993	4532	210	305	290
p,p'-DDD	341	2347	2688	138	189	181
o,p'-DDD	62	512	574	25	41	38
p,p'-DDT	227	1779	2006	89	140	132
o,p'-DDT	3	54	57	1.4	4.8	4.2
p,p'-DDMU	1252	10994	12246	499	831	779
p,p'-DDNU	93	756	849	37	56	53
Total DDT	3851	33823	37674	1526	2694	2511
Total DDT Compounds	5291	46601	51892	2100	3656	3412
Total PCB	466	3648	4114	185	283	268

4.2 Detailed Results for Individual Chemicals and Chemical Grouping

The detailed mass and volume-averaged concentration estimates for each chemical and chemical grouping follow in the order presented in Table 3. The geostatistical parameters employed in each chemical and chemical grouping geostatistical analysis are presented in tabular form followed by the mass and volume-averaged concentration for each H:V anisotropy value. Finally, the tabular results are shown graphically for each chemical and chemical grouping.

p,p'-DDE

Table 4. Geostatistical parameters for 2013 PV Shelf p,p'-DDE analysis.

Analyte	2013 p,p'-DDE	Unit
Xmin	365,797	meters
Xmax	380,559	meters
X length	14,762	meters
X resolution	148	#
X cell width	100	meters
Ymin	3,725,397	meters
Ymax	3,736,948	meters
Y length	11,551	meters
Y resolution	116	#
Y cell length	100	meters
Zmin	-0.838	meters
Zmax	0	meters
Z length	0.838	meters
Z resolution	84	#
Z cell length	0.01	meters
Adaptive gridding	Yes	N/A
Proportional gridding	Yes	N/A
Anisotropy ratio to 1	500, 1000, 2000, 5000	Horizontal to vertical
Minimum sample interval	0.02	meters
Maximum sample interval	0.04	meters
Analyte minimum	0.00	ug/kg
Analyte maximum	230000.00	ug/kg
Max-gap	0.01	meters
Preclip minimum	0.00	ug/kg
Preclip maximum	1.00E+09	ug/kg
Postclip minimum	0.01	ug/kg
Postclip maximum	10000000.00	ug/kg
LT multiplier	0.10	#
Detection limit	0.06	ug/kg
Variogram Type (Optimized)	Exponential	N/A
Range	1100.00	meters
Sill	0.33	N/A
Nugget	0.28	N/A

Table 5. Detailed mass and volume-averaged concentration for 2013 PV Shelf p,p'-DDE.

Anisotropy	Mass (0 cm - 8 cm) kg	Mass (below 8 cm) kg	Total Mass kg	Avg. Conc. (0 cm - 8 cm) ug/kg	Avg. Conc. (below 8 cm) ug/kg	Avg. Conc. Total Vol. ug/kg
500	3,088	12,777	15,866	1,200	907	953
1000	2,916	17,677	20,594	1,123	1,324	1,292
2000	2,817	22,916	25,733	1,083	1,768	1,660
5000	2,920	25,978	28,898	1,128	2,005	1,868
Average	2,936	19,837	22,773	1,134	1,501	1,443

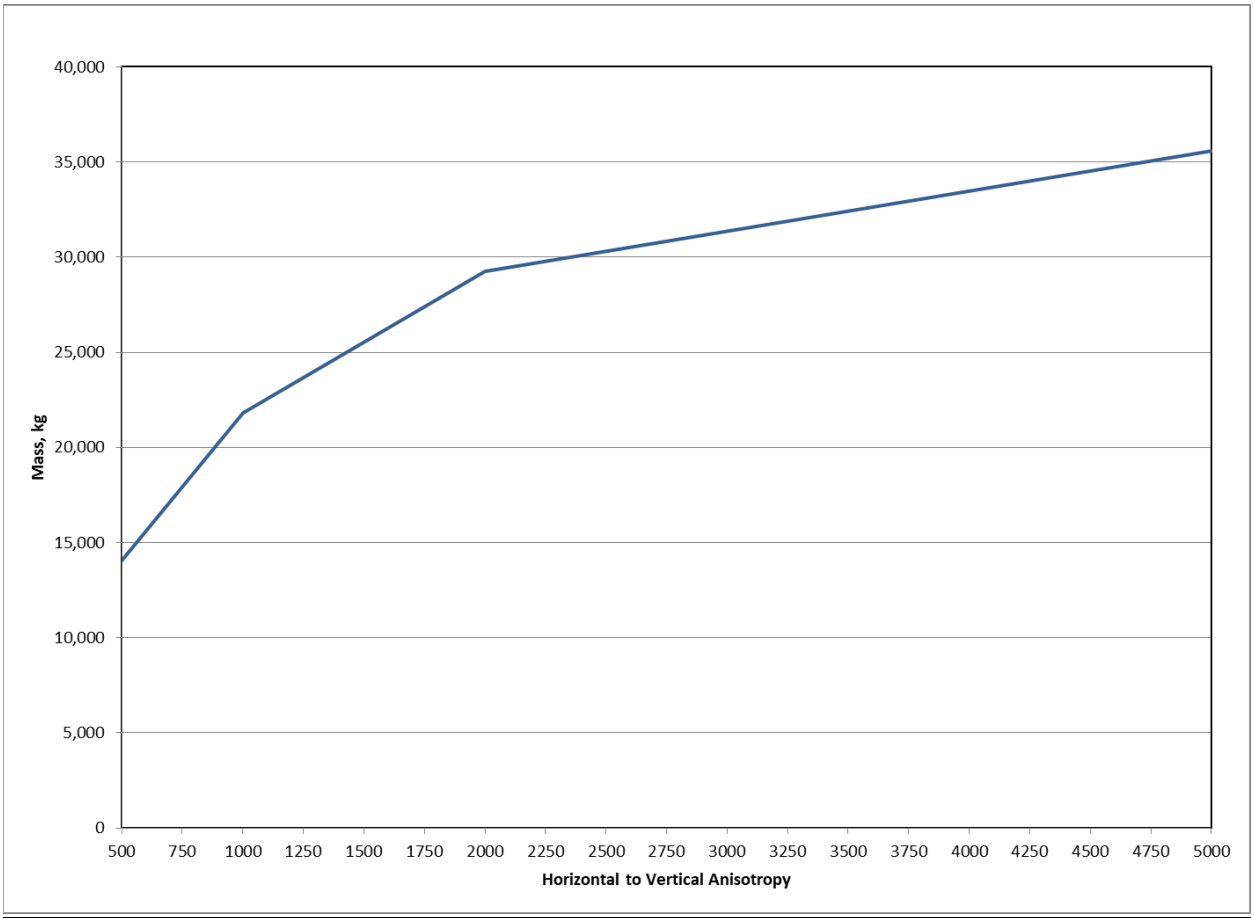

Figure 7. 2013 PV Shelf total p,p'-DDE mass vs. H:V anisotropy.

o,p'-DDE

Table 6. Geostatistical parameters for 2013 PV Shelf o,p'-DDE analysis.

Analyte	2013 o,p'-DDE	Unit
Xmin	365,797	meters
Xmax	380,559	meters
X length	14,762	meters
X resolution	148	#
X cell width	100	meters
Ymin	3,725,397	meters
Ymax	3,736,948	meters
Y length	11,551	meters
Y resolution	116	#
Y cell length	100	meters
Zmin	-0.838	meters
Zmax	0	meters
Z length	0.838	meters
Z resolution	84	#
Z cell length	0.01	meters
Adaptive gridding	Yes	N/A
Proportional gridding	Yes	N/A
Anisotropy ratio to 1	500, 1000, 2000, 5000	Horizontal to vertical
Minimum sample interval	0.02	meters
Maximum sample interval	0.04	meters
Analyte minimum	0.00	ug/kg
Analyte maximum	41000.00	ug/kg
Max-gap	0.01	meters
Preclip minimum	0.00	ug/kg
Preclip maximum	1.00E+09	ug/kg
Postclip minimum	0.004	ug/kg
Postclip maximum	10000000.00	ug/kg
LT multiplier	0.10	#
Detection limit	0.04	ug/kg
Variogram Type (Optimized)	Exponential	N/A
Range	1000.00	meters
Sill	0.53	N/A
Nugget	0.35	N/A

Table 7. Detailed mass and volume-averaged concentration for 2013 PV Shelf o,p'-DDE.

Anisotropy	Mass (0 cm - 8 cm) kg	Mass (below 8 cm) kg	Total Mass kg	Avg. Conc. (0 cm - 8 cm) ug/kg	Avg. Conc. (below 8 cm) ug/kg	Avg. Conc. Total Vol. ug/kg
500	559	2450	3009	219	175	182
1000	529	3511	4040	206	266	256
2000	519	4637	5156	202	361	336
5000	551	5373	5924	215	418	387
Average	539	3993	4532	210	305	290

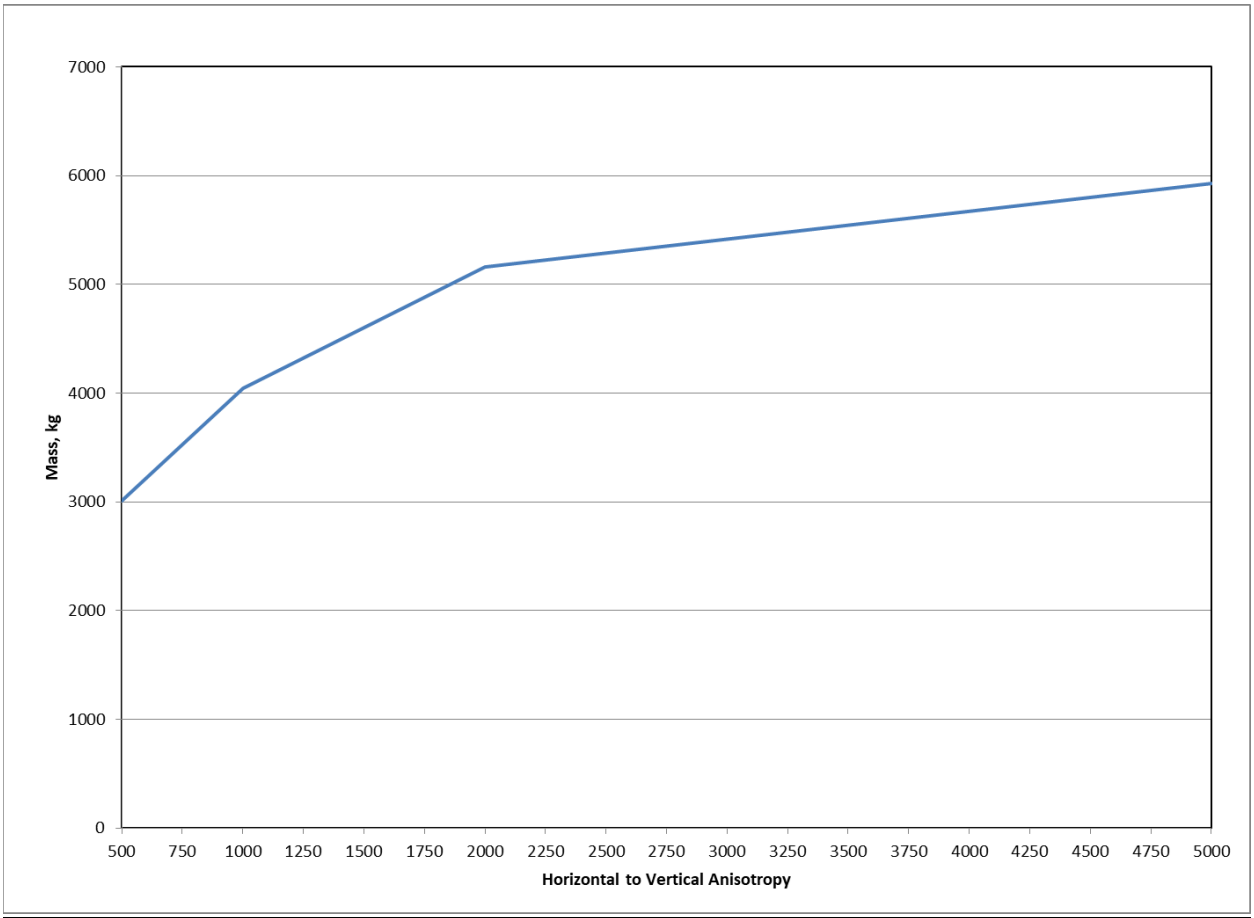

Figure 8. 2013 PV Shelf total o,p'-DDE mass vs. H:V anisotropy.

p,p'-DDD

Table 8. Geostatistical parameters for 2013 PV Shelf p,p'-DDD analysis.

Analyte	2013 p,p'-DDD	Unit
Xmin	365,797	meters
Xmax	380,559	meters
X length	14,762	meters
X resolution	148	#
X cell width	100	meters
Ymin	3,725,397	meters
Ymax	3,736,948	meters
Y length	11,551	meters
Y resolution	116	#
Y cell length	100	meters
Zmin	-0.838	meters
Zmax	0	meters
Z length	0.838	meters
Z resolution	84	#
Z cell length	0.01	meters
Adaptive gridding	Yes	N/A
Proportional gridding	Yes	N/A
Anisotropy ratio to 1	500, 1000, 2000, 5000	Horizontal to vertical
Minimum sample interval	0.02	meters
Maximum sample interval	0.04	meters
Analyte minimum	0.00	ug/kg
Analyte maximum	69000.00	ug/kg
Max-gap	0.01	meters
Preclip minimum	0.00	ug/kg
Preclip maximum	1.00E+09	ug/kg
Postclip minimum	0.005	ug/kg
Postclip maximum	10000000.00	ug/kg
LT multiplier	0.10	#
Detection limit	0.05	ug/kg
Variogram Type (Optimized)	Exponential	N/A
Range	1200.00	meters
Sill	0.90	N/A
Nugget	0.075	N/A

Table 9. Detailed mass and volume-averaged concentration for 2013 PV Shelf p,p'-DDD.

Anisotropy	Mass (0 cm - 8 cm) kg	Mass (below 8 cm) kg	Total Mass kg	Avg. Conc. (0 cm - 8 cm) ug/kg	Avg. Conc. (below 8 cm) ug/kg	Avg. Conc. Total Vol. ug/kg
500	330	1433	1763	136	111	115
1000	321	2123	2444	131	170	164
2000	335	2699	3034	135	220	207
5000	377	3134	3511	151	255	239
Average	341	2347	2688	138	189	181

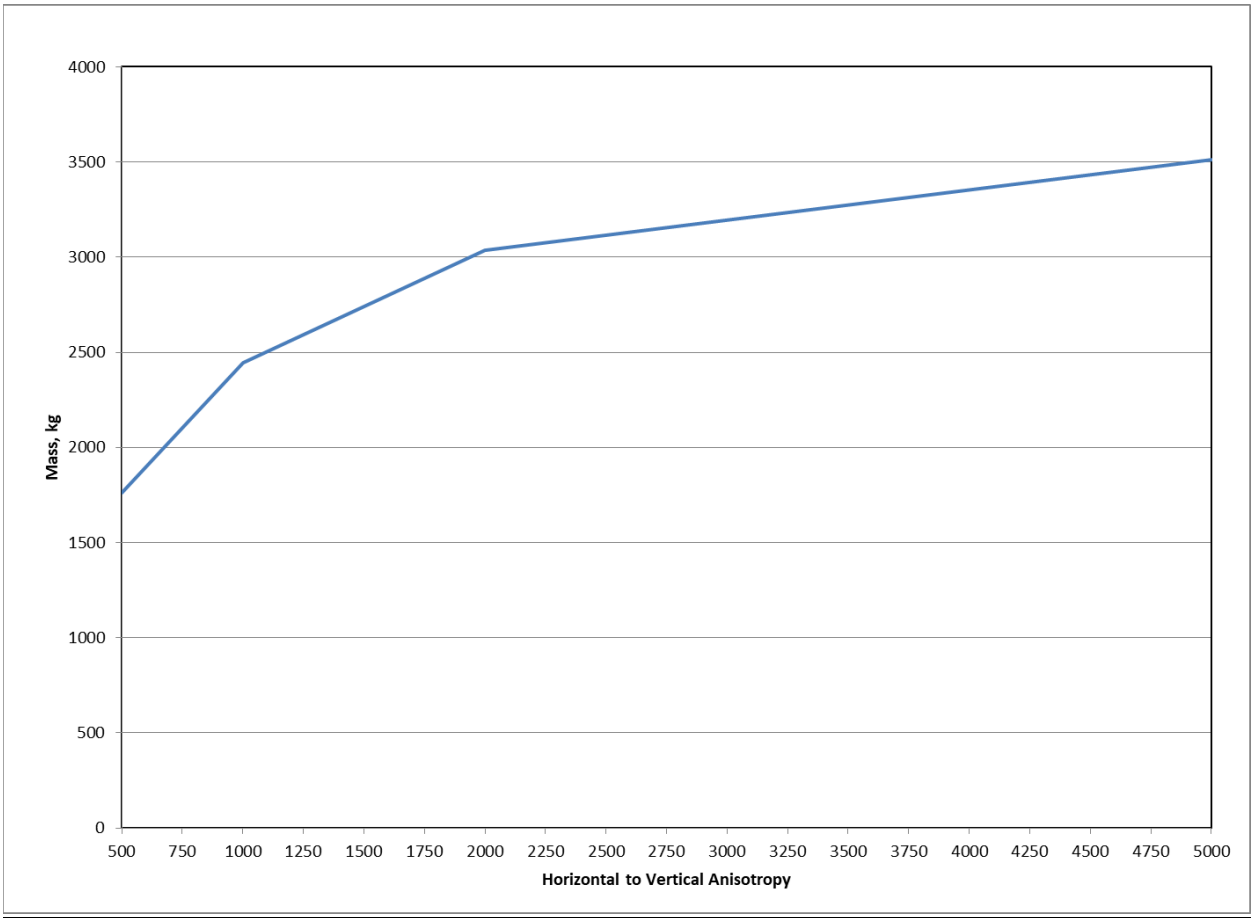

Figure 9. 2013 PV Shelf total p,p'-DDD mass vs. H:V anisotropy.

o,p'-DDD

Table 10. Geostatistical parameters for 2013 PV Shelf o,p'-DDD analysis.

Analyte	2013 o,p'-DDD	Unit
Xmin	365,797	meters
Xmax	380,559	meters
X length	14,762	meters
X resolution	148	#
X cell width	100	meters
Ymin	3,725,397	meters
Ymax	3,736,948	meters
Y length	11,551	meters
Y resolution	116	#
Y cell length	100	meters
Zmin	-0.838	meters
Zmax	0	meters
Z length	0.838	meters
Z resolution	84	#
Z cell length	0.01	meters
Adaptive gridding	Yes	N/A
Proportional gridding	Yes	N/A
Anisotropy ratio to 1	500, 1000, 2000, 5000	Horizontal to vertical
Minimum sample interval	0.02	meters
Maximum sample interval	0.04	meters
Analyte minimum	0.00	ug/kg
Analyte maximum	21000.00	ug/kg
Max-gap	0.01	meters
Preclip minimum	0.00	ug/kg
Preclip maximum	1.00E+09	ug/kg
Postclip minimum	0.009	ug/kg
Postclip maximum	10000000.00	ug/kg
LT multiplier	0.10	#
Detection limit	0.09	ug/kg
Variogram Type (Optimized)	Exponential	N/A
Range	1000.00	meters
Sill	1.18	N/A
Nugget	0.320	N/A

Table 11. Detailed mass and volume-averaged concentration for 2013 PV Shelf o,p'-DDD.

Anisotropy	Mass (0 cm - 8 cm) kg	Mass (below 8 cm) kg	Total Mass kg	Avg. Conc. (0 cm - 8 cm) ug/kg	Avg. Conc. (below 8 cm) ug/kg	Avg. Conc. Total Vol. ug/kg
500	57	268	325	23	20	21
1000	56	448	504	22	36	34
2000	60	616	676	24	50	46
5000	72	718	791	29	58	53
Average	62	512	574	25	41	38

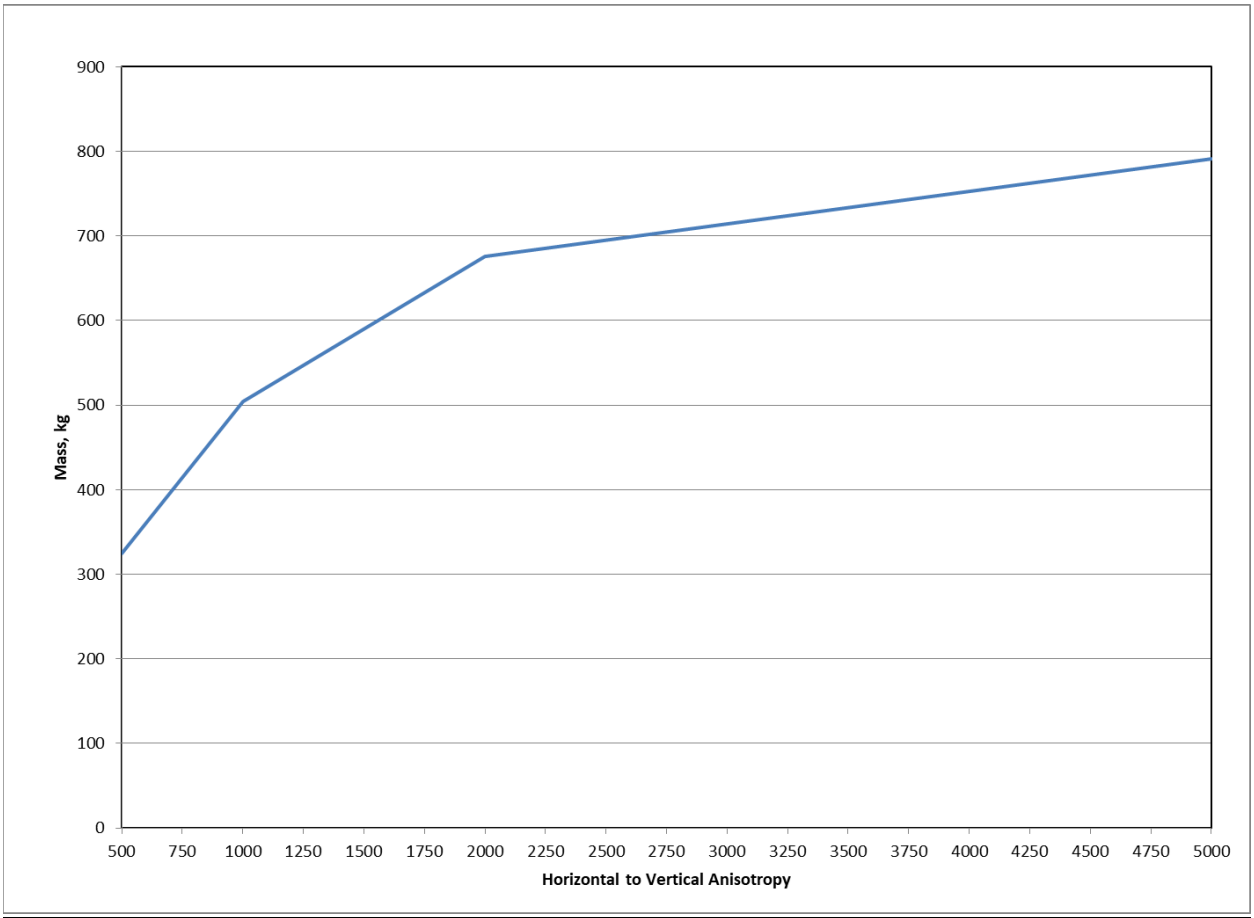

Figure 10. 2013 PV Shelf total o,p'-DDD mass vs. H:V anisotropy.

p,p'-DDT

Table 12. Geostatistical parameters for 2013 PV Shelf p,p'-DDT analysis.

Analyte	2013 p,p'-DDT	Unit
Xmin	365,797	meters
Xmax	380,559	meters
X length	14,762	meters
X resolution	148	#
X cell width	100	meters
Ymin	3,725,397	meters
Ymax	3,736,948	meters
Y length	11,551	meters
Y resolution	116	#
Y cell length	100	meters
Zmin	-0.838	meters
Zmax	0	meters
Z length	0.838	meters
Z resolution	84	#
Z cell length	0.01	meters
Adaptive gridding	Yes	N/A
Proportional gridding	Yes	N/A
Anisotropy ratio to 1	500, 1000, 2000, 5000	Horizontal to vertical
Minimum sample interval	0.02	meters
Maximum sample interval	0.04	meters
Analyte minimum	0.00	ug/kg
Analyte maximum	84000.00	ug/kg
Max-gap	0.01	meters
Preclip minimum	0.00	ug/kg
Preclip maximum	1.00E+09	ug/kg
Postclip minimum	0.006	ug/kg
Postclip maximum	10000000.00	ug/kg
LT multiplier	0.10	#
Detection limit	0.06	ug/kg
Variogram Type (Optimized)	Exponential	N/A
Range	1100.00	meters
Sill	1.55	N/A
Nugget	0.320	N/A

Table 13. Detailed mass and volume-averaged concentration for 2013 PV Shelf p,p'-DDT.

Anisotropy	Mass (0 cm - 8 cm) kg	Mass (below 8 cm) kg	Total Mass kg	Avg. Conc. (0 cm - 8 cm) ug/kg	Avg. Conc. (below 8 cm) ug/kg	Avg. Conc. Total Vol. ug/kg
500	254	1024	1277	101	77	81
1000	212	1587	1799	83	125	118
2000	204	2072	2276	79	165	152
5000	239	2435	2674	93	192	177
Average	227	1779	2006	89	140	132

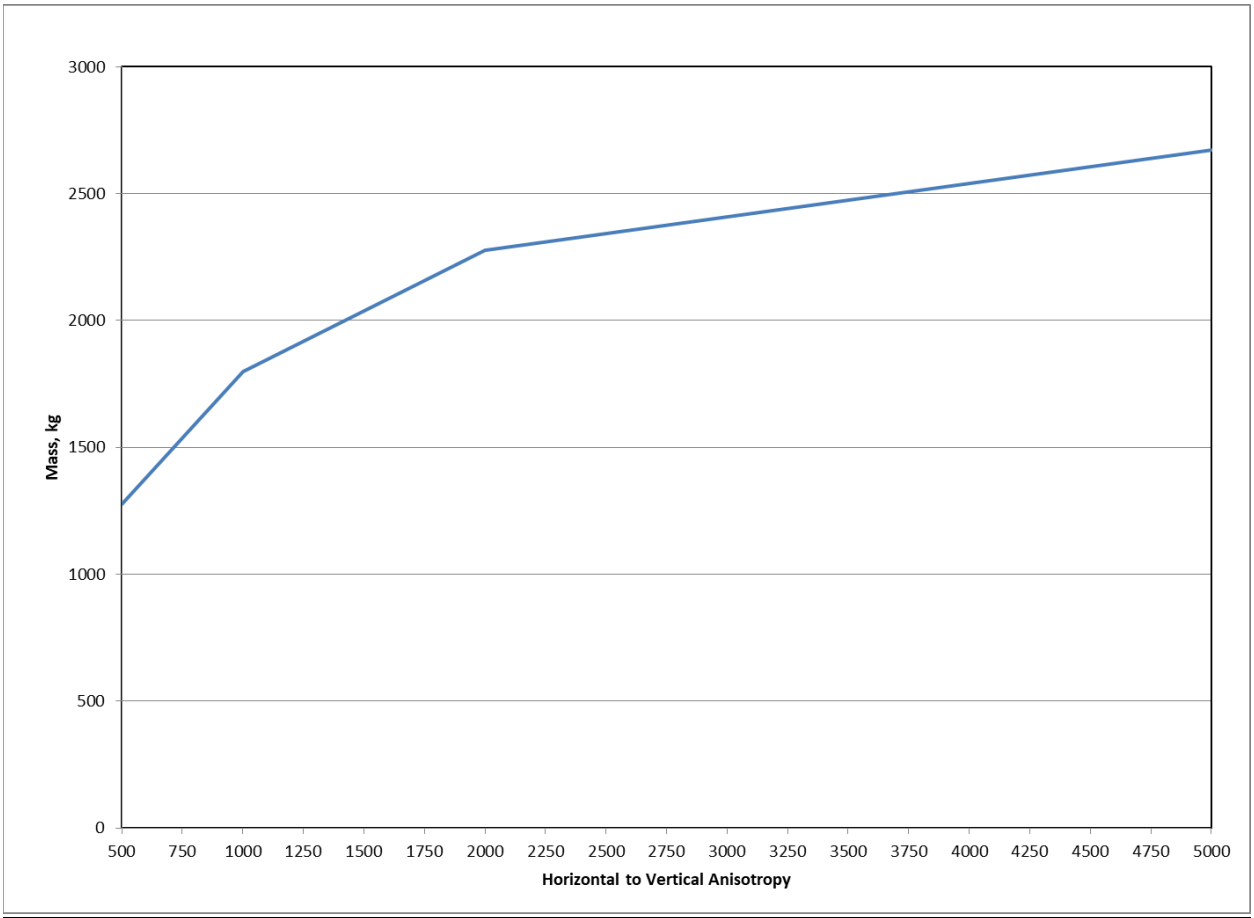

Figure 11. 2013 PV Shelf total p,p'-DDT mass vs. H:V anisotropy.

o,p'-DDT

Table 14. Geostatistical parameters for 2013 PV Shelf o,p'-DDT analysis.

Analyte	2013 o,p'-DDT	Unit
Xmin	365,797	meters
Xmax	380,559	meters
X length	14,762	meters
X resolution	148	#
X cell width	100	meters
Ymin	3,725,397	meters
Ymax	3,736,948	meters
Y length	11,551	meters
Y resolution	116	#
Y cell length	100	meters
Zmin	-0.838	meters
Zmax	0	meters
Z length	0.838	meters
Z resolution	84	#
Z cell length	0.01	meters
Adaptive gridding	Yes	N/A
Proportional gridding	Yes	N/A
Anisotropy ratio to 1	500, 1000, 2000, 5000	Horizontal to vertical
Minimum sample interval	0.02	meters
Maximum sample interval	0.04	meters
Analyte minimum	0.00	ug/kg
Analyte maximum	3200.00	ug/kg
Max-gap	0.01	meters
Preclip minimum	0.00	ug/kg
Preclip maximum	1.00E+09	ug/kg
Postclip minimum	0.007	ug/kg
Postclip maximum	10000000.00	ug/kg
LT multiplier	0.10	#
Detection limit	0.07	ug/kg
Variogram Type (Optimized)	Exponential	N/A
Range	800.00	meters
Sill	2.30	N/A
Nugget	0.320	N/A

Table 15. Detailed mass and volume-averaged concentration for 2013 PV Shelf o,p'-DDT.

Anisotropy	Mass (0 cm - 8 cm) kg	Mass (below 8 cm) kg	Total Mass kg	Avg. Conc. (0 cm - 8 cm) ug/kg	Avg. Conc. (below 8 cm) ug/kg	Avg. Conc. Total Vol. ug/kg
500	2.6	23.6	26.2	1.1	2.0	1.9
1000	2.5	48.2	50.7	1.1	4.3	3.8
2000	3.1	65.8	68.9	1.3	5.9	5.1
5000	5.3	78.7	84.1	2.1	6.9	6.1
Average	3	54	57	1.4	4.8	4.2

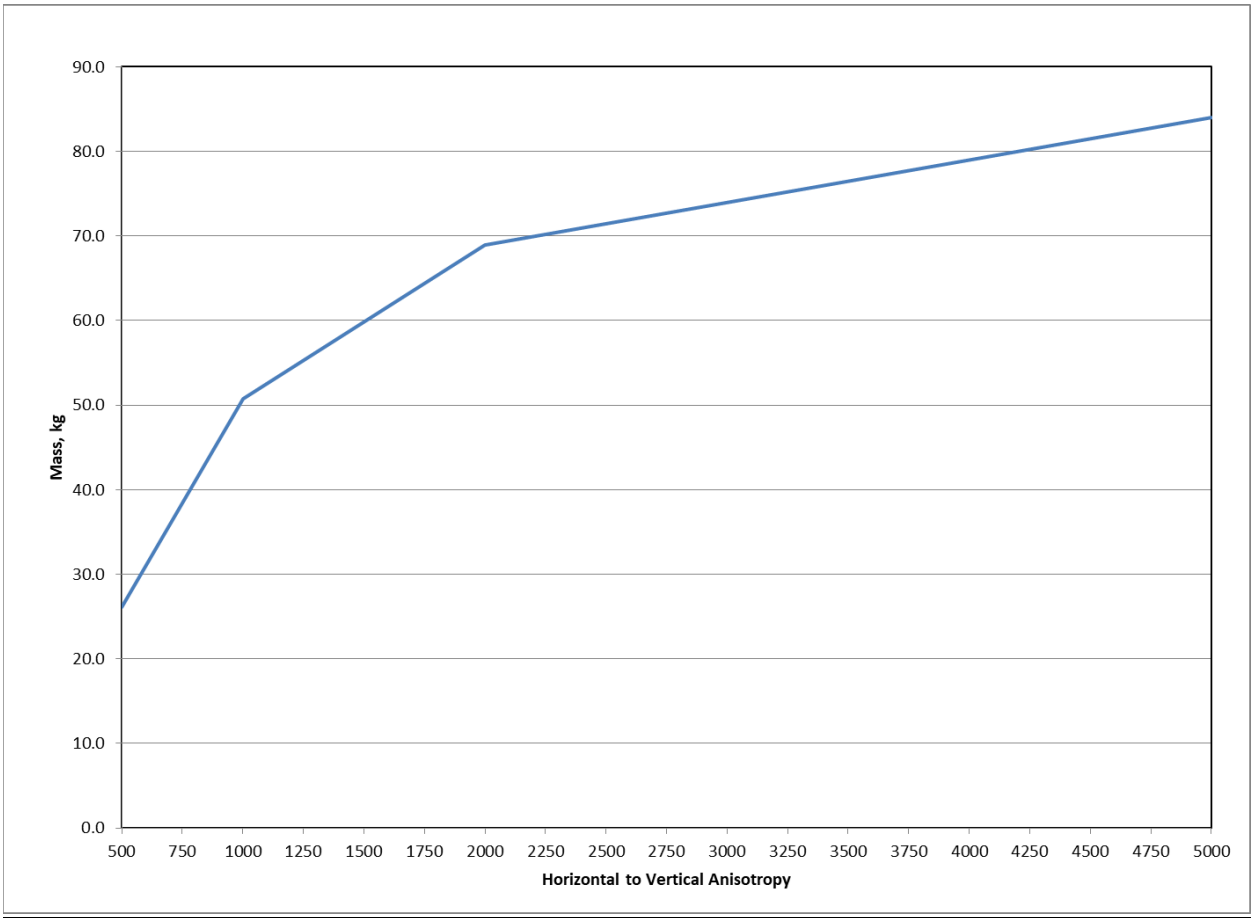

Figure 12. 2013 PV Shelf total o,p'-DDT mass vs. H:V anisotropy.

p,p'-DDMU

Table 16. Geostatistical parameters for 2013 PV Shelf p,p'-DDMU analysis.

Analyte	2013 p,p'-DDMU	Unit
Xmin	365,797	meters
Xmax	380,559	meters
X length	14,762	meters
X resolution	148	#
X cell width	100	meters
Ymin	3,725,397	meters
Ymax	3,736,948	meters
Y length	11,551	meters
Y resolution	116	#
Y cell length	100	meters
Zmin	-0.838	meters
Zmax	0	meters
Z length	0.838	meters
Z resolution	84	#
Z cell length	0.01	meters
Adaptive gridding	Yes	N/A
Proportional gridding	Yes	N/A
Anisotropy ratio to 1	500, 1000, 2000, 5000	Horizontal to vertical
Minimum sample interval	0.02	meters
Maximum sample interval	0.04	meters
Analyte minimum	0.00	ug/kg
Analyte maximum	59000.00	ug/kg
Max-gap	0.01	meters
Preclip minimum	0.00	ug/kg
Preclip maximum	1.00E+09	ug/kg
Postclip minimum	0.004	ug/kg
Postclip maximum	10000000.00	ug/kg
LT multiplier	0.10	#
Detection limit	0.04	ug/kg
Variogram Type (Optimized)	Exponential	N/A
Range	860.00	meters
Sill	0.58	N/A
Nugget	0.000	N/A

Table 17. Detailed mass and volume-averaged concentration for 2013 PV Shelf p,p'-DDMU.

Anisotropy	Mass (0 cm - 8 cm) kg	Mass (below 8 cm) kg	Total Mass kg	Avg. Conc. (0 cm - 8 cm) ug/kg	Avg. Conc. (below 8 cm) ug/kg	Avg. Conc. Total Vol. ug/kg
500	914	5996	6911	357	429	418
1000	1099	9245	10344	434	690	650
2000	1321	12675	13996	526	967	898
5000	1675	16057	17733	679	1238	1151
Average	1252	10994	12246	499	831	779

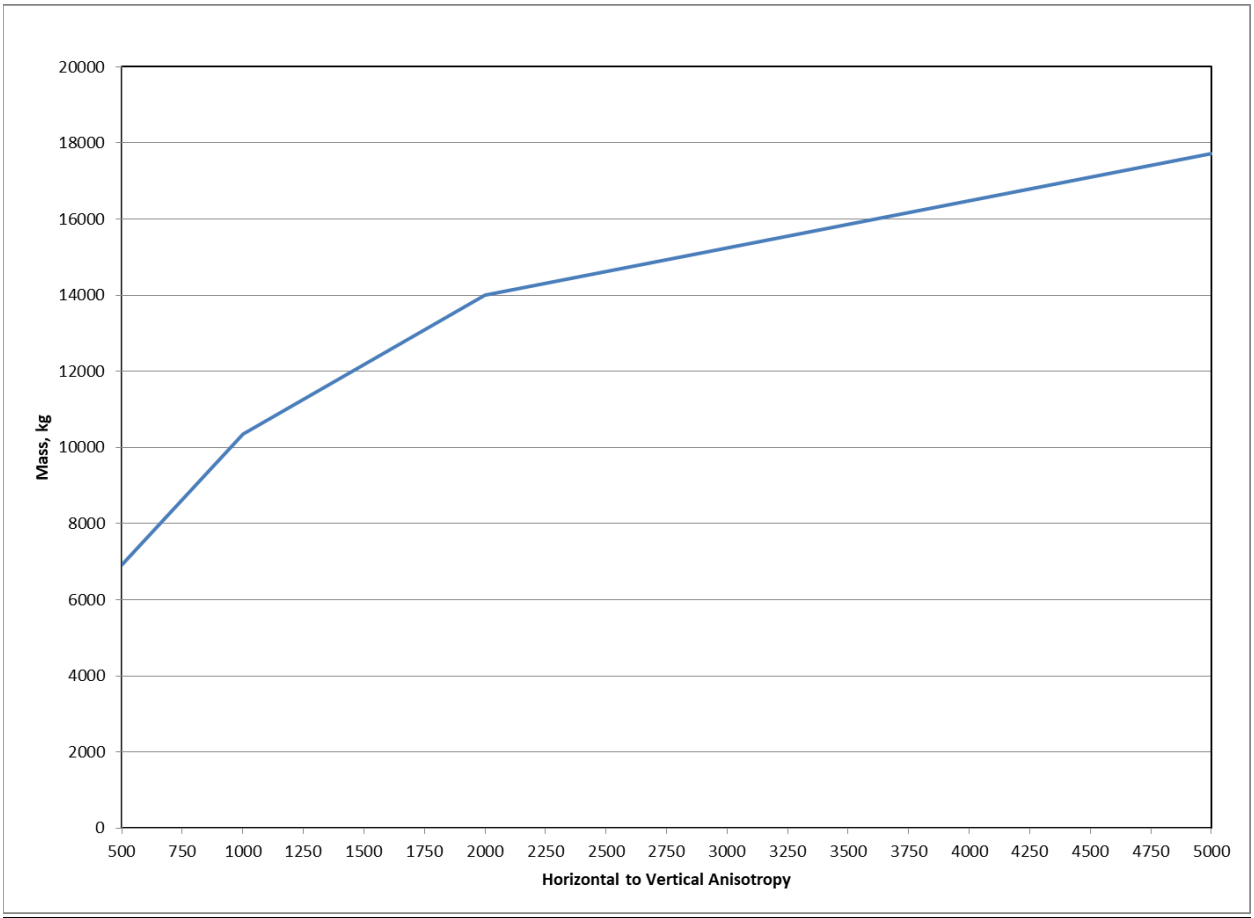

Figure 13. 2013 PV Shelf total p,p'-DDMU mass vs. H:V anisotropy.

p,p'-DDNU

Table 18. Geostatistical parameters for 2013 PV Shelf p,p'-DDNU analysis.

Analyte	2013 p,p'-DDNU	Unit
Xmin	365,797	meters
Xmax	380,559	meters
X length	14,762	meters
X resolution	148	#
X cell width	100	meters
Ymin	3,725,397	meters
Ymax	3,736,948	meters
Y length	11,551	meters
Y resolution	116	#
Y cell length	100	meters
Zmin	-0.838	meters
Zmax	0	meters
Z length	0.838	meters
Z resolution	84	#
Z cell length	0.01	meters
Adaptive gridding	Yes	N/A
Proportional gridding	Yes	N/A
Anisotropy ratio to 1	500, 1000, 2000, 5000	Horizontal to vertical
Minimum sample interval	0.02	meters
Maximum sample interval	0.04	meters
Analyte minimum	0.00	ug/kg
Analyte maximum	4100.00	ug/kg
Max-gap	0.01	meters
Preclip minimum	0.00	ug/kg
Preclip maximum	1.00E+09	ug/kg
Postclip minimum	0.110	ug/kg
Postclip maximum	10000000.00	ug/kg
LT multiplier	0.10	#
Detection limit	1.10	ug/kg
Variogram Type (Optimized)	Exponential	N/A
Range	1100.00	meters
Sill	1.30	N/A
Nugget	0.000	N/A

Table 19. Detailed mass and volume-averaged concentration for 2013 PV Shelf p,p'-DDNU.

Anisotropy	Mass (0 cm - 8 cm) kg	Mass (below 8 cm) kg	Total Mass kg	Avg. Conc. (0 cm - 8 cm) ug/kg	Avg. Conc. (below 8 cm) ug/kg	Avg. Conc. Total Vol. ug/kg
500	63	368	431	24	26	26
1000	78	618	696	31	45	43
2000	99	888	986	39	66	62
5000	133	1150	1284	54	87	82
Average	93	756	849	37	56	53

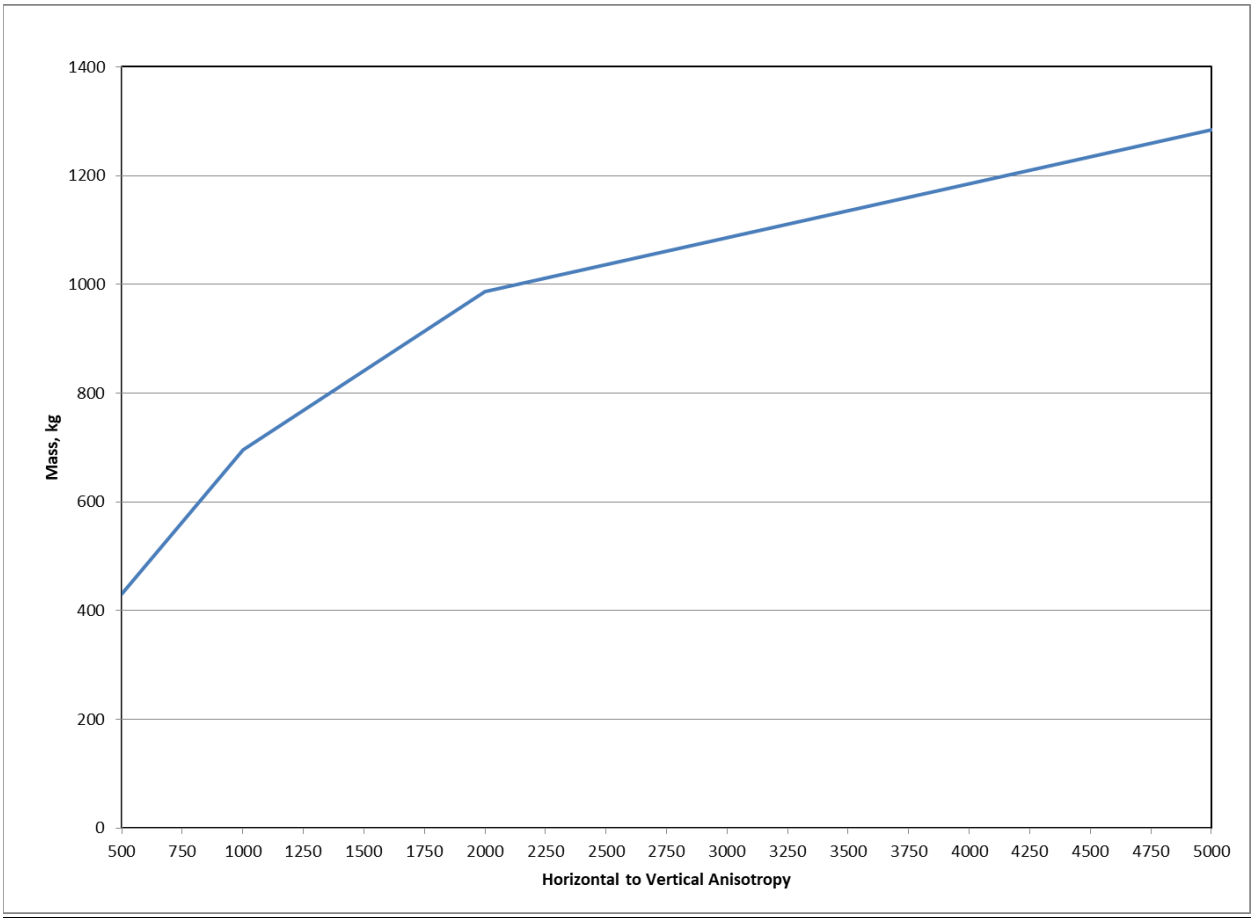

Figure 14. 2013 PV Shelf total p,p'-DDNU mass vs. H:V anisotropy.

Total DDT

Table 20. Geostatistical parameters for 2013 PV Shelf Total DDT analysis.

Analyte	2013 Total DDT	Unit
Xmin	365,797	meters
Xmax	380,559	meters
X length	14,762	meters
X resolution	148	#
X cell width	100	meters
Ymin	3,725,397	meters
Ymax	3,736,948	meters
Y length	11,551	meters
Y resolution	116	#
Y cell length	100	meters
Zmin	-0.838	meters
Zmax	0	meters
Z length	0.838	meters
Z resolution	84	#
Z cell length	0.01	meters
Adaptive gridding	Yes	N/A
Proportional gridding	Yes	N/A
Anisotropy ratio to 1	500, 1000, 2000, 5000	Horizontal to vertical
Minimum sample interval	0.02	meters
Maximum sample interval	0.04	meters
Analyte minimum	0.00	ug/kg
Analyte maximum	312200.00	ug/kg
Max-gap	0.01	meters
Preclip minimum	0.00	ug/kg
Preclip maximum	1.00E+09	ug/kg
Postclip minimum	0.100	ug/kg
Postclip maximum	10000000.00	ug/kg
LT multiplier	0.10	#
Detection limit	1.00	ug/kg
Variogram Type (Optimized)	Exponential	N/A
Range	1000.00	meters
Sill	0.65	N/A
Nugget	0.000	N/A

Table 21. Detailed mass and volume-averaged concentration for 2013 PV Shelf Total DDT.

Anisotropy	Mass (0 cm - 8 cm) kg	Mass (below 8 cm) kg	Total Mass kg	Avg. Conc. (0 cm - 8 cm) ug/kg	Avg. Conc. (below 8 cm) ug/kg	Avg. Conc. Total Vol. ug/kg
500	3252	18498	21750	1301	1386	1373
1000	3596	29476	33072	1430	2313	2174
2000	3961	39604	43565	1562	3187	2932
5000	4596	47716	52312	1810	3889	3563
Average	3851	33823	37674	1526	2694	2511

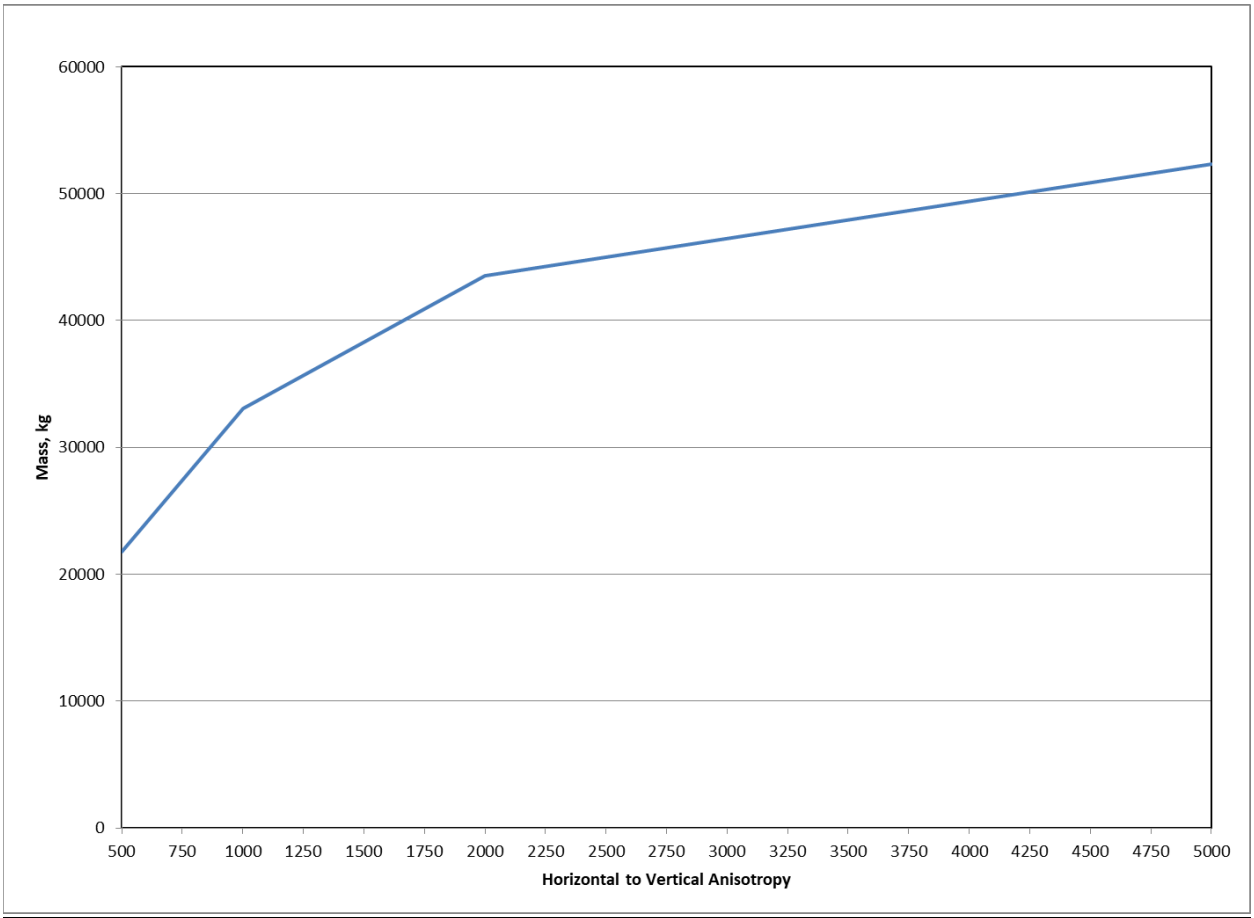

Figure 15. 2013 PV Shelf total Total DDT mass vs. H:V anisotropy.

Total DDT Compounds

Table 22. Geostatistical parameters for 2013 PV Shelf Total DDT Compounds analysis.

Analyte	2013 Total DDT Compounds	Unit
Xmin	365,797	meters
Xmax	380,559	meters
X length	14,762	meters
X resolution	148	#
X cell width	100	meters
Ymin	3,725,397	meters
Ymax	3,736,948	meters
Y length	11,551	meters
Y resolution	116	#
Y cell length	100	meters
Zmin	-0.838	meters
Zmax	0	meters
Z length	0.838	meters
Z resolution	84	#
Z cell length	0.01	meters
Adaptive gridding	Yes	N/A
Proportional gridding	Yes	N/A
Anisotropy ratio to 1	500, 1000, 2000, 5000	Horizontal to vertical
Minimum sample interval	0.02	meters
Maximum sample interval	0.04	meters
Analyte minimum	0.00	ug/kg
Analyte maximum	349740.00	ug/kg
Max-gap	0.01	meters
Preclip minimum	0.00	ug/kg
Preclip maximum	1.00E+09	ug/kg
Postclip minimum	0.100	ug/kg
Postclip maximum	10000000.00	ug/kg
LT multiplier	0.10	#
Detection limit	1.00	ug/kg
Variogram Type (Optimized)	Exponential	N/A
Range	1000.00	meters
Sill	0.63	N/A
Nugget	0.000	N/A

Table 23. Detailed mass and volume-averaged concentration for 2013 PV Shelf Total DDT Compounds.

Anisotropy	Mass (0 cm - 8 cm) kg	Mass (below 8 cm) kg	Total Mass kg	Avg. Conc. (0 cm - 8 cm) ug/kg	Avg. Conc. (below 8 cm) ug/kg	Avg. Conc. Total Vol. ug/kg
500	4306	25674	29980	1713	1899	1869
1000	4867	40362	45229	1932	3122	2936
2000	5484	54324	59808	2169	4305	3970
5000	6506	66044	72550	2585	5297	4872
Average	5291	46601	51892	2100	3656	3412

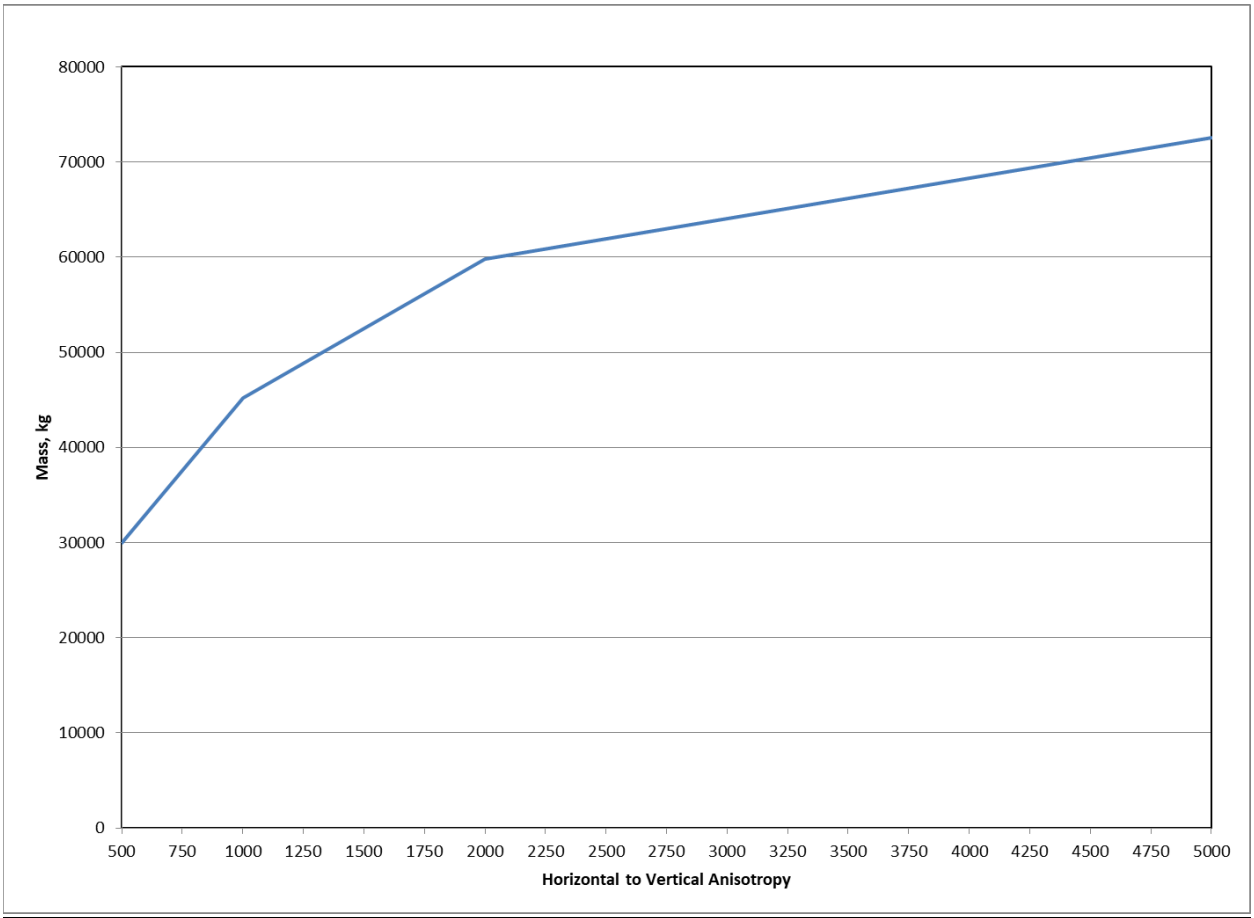

Figure 16. 2013 PV Shelf total Total DDT Compounds mass vs. H:V anisotropy.

Total PCB

Table 24. Geostatistical parameters for 2013 PV Shelf Total PCB analysis.

Analyte	2013 Total PCB	Unit
Xmin	365,797	meters
Xmax	380,559	meters
X length	14,762	meters
X resolution	148	#
X cell width	100	meters
Ymin	3,725,397	meters
Ymax	3,736,948	meters
Y length	11,551	meters
Y resolution	116	#
Y cell length	100	meters
Zmin	-0.838	meters
Zmax	0	meters
Z length	0.838	meters
Z resolution	84	#
Z cell length	0.01	meters
Adaptive gridding	Yes	N/A
Proportional gridding	Yes	N/A
Anisotropy ratio to 1	500, 1000, 2000, 5000	Horizontal to vertical
Minimum sample interval	0.02	meters
Maximum sample interval	0.04	meters
Analyte minimum	0.00	ug/kg
Analyte maximum	34764.00	ug/kg
Max-gap	0.01	meters
Preclip minimum	0.00	ug/kg
Preclip maximum	1.00E+09	ug/kg
Postclip minimum	0.100	ug/kg
Postclip maximum	10000000.00	ug/kg
LT multiplier	0.10	#
Detection limit	1.00	ug/kg
Variogram Type (Optimized)	Exponential	N/A
Range	1000.00	meters
Sill	1.45	N/A
Nugget	0.000	N/A

Table 25. Detailed mass and volume-averaged concentration for 2013 PV Shelf Total PCB.

Anisotropy	Mass (0 cm - 8 cm) kg	Mass (below 8 cm) kg	Total Mass kg	Avg. Conc. (0 cm - 8 cm) ug/kg	Avg. Conc. (below 8 cm) ug/kg	Avg. Conc. Total Vol. ug/kg
500	350	1896	2247	139	140	140
1000	406	3135	3541	161	242	229
2000	485	4288	4773	192	337	314
5000	622	5273	5896	248	415	389
Average	466	3648	4114	185	283	268

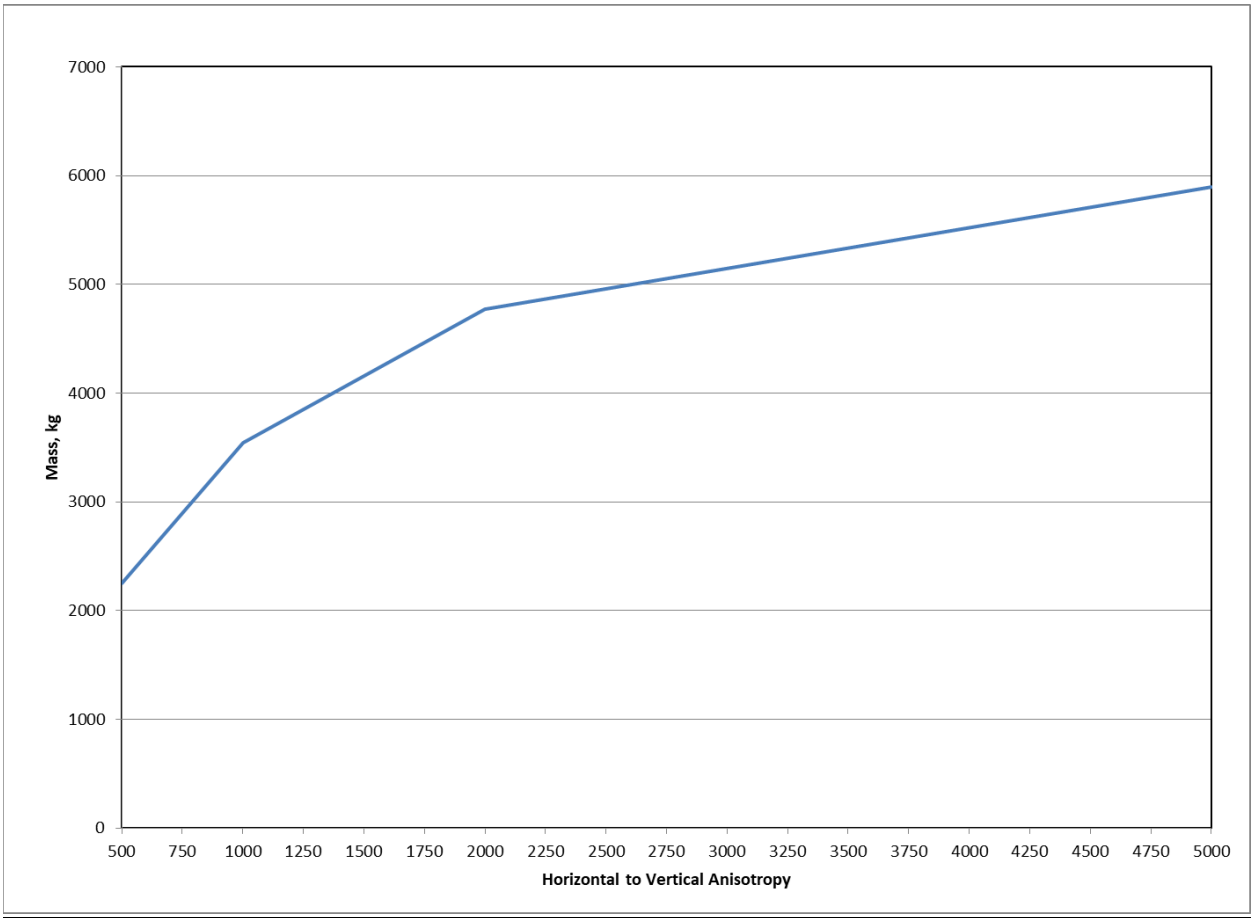

Figure 17. 2013 PV Shelf total Total PCB mass vs. H:V anisotropy.

4.3 Uncertainty Analysis

Spatially varying uncertainty is associated with every concentration estimate throughout the 3D PV Shelf EA sediment domain except at each sample point because kriging is an exact interpolator and reproduces the input data at each data point location. Away from each data point the uncertainty is primarily a function of the spatial correlation of the data, the distance each estimation point is from known values, and the predicted concentration. Unlike confidence, within EVS uncertainty also includes consideration of the magnitude of the predicted concentration. According to C Tech "uncertainty is high where concentrations are predicted to be relatively high, but the confidence in that prediction is low." Uncertainty is a better measure of the overall "quality" of the interpolation than confidence alone. Uncertainty is a dimensionless parameter that theoretically ranges from zero at known data points to values that can exceed 100. The higher the uncertainty the less well-characterized is the surrounding area.

Uncertainty calculations were made for the 2013 PV Shelf p,p'-DDE sediment data as being generally representative of uncertainty for the remaining chemicals and chemical groupings because all chemical and chemical groupings have the identical spatial distribution of data points. Further, concentrations for all chemicals and chemical groupings are, in general, high in the same locations throughout the PV Shelf EA sediment domain. The 2013 p,p'-DDE estimation uncertainty is presented as horizontal slices moving

downward through the sediment bed. Three slices are shown for depths in the sediment bed of 4 cm, 8 cm, and 12 cm, respectively. Figure 18 through Figure 20 present these uncertainty slices.

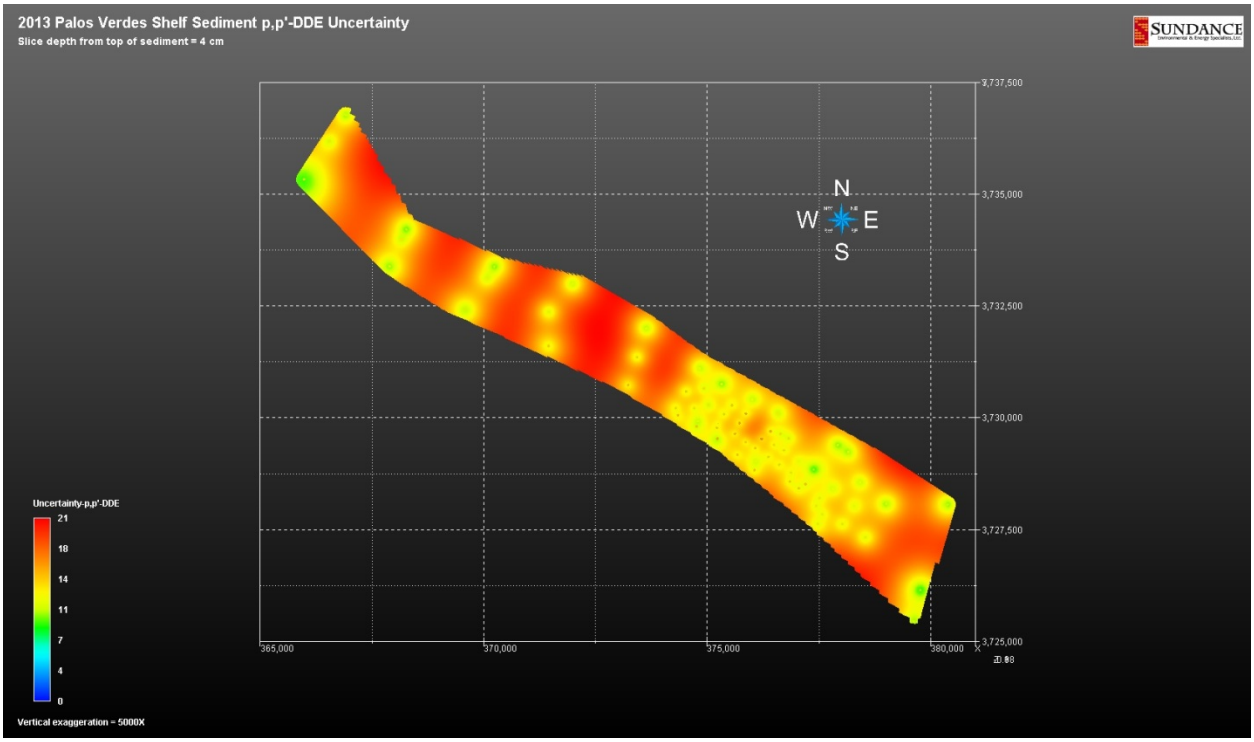

Figure 18. Horizontal 2013 p,p'-DDE uncertainty slice at 4 cm depth into the sediment bed.

The uncertainty in 2013 p,p'-DDE concentration estimates ranges from 0 (at sample locations of known concentration) to a maximum of 21. Considering the three slices shown there is little discernable difference in vertical uncertainty from 4 cm depth to 12 cm depth. The major variability in uncertainty is horizontally across the EA sediment domain. The influence of sample locations (that is, sediment core locations) is clearly evident. The lowest uncertainty (cooler colors) is associated with the spatially densest sampling. Fortunately, this is also the area of highest concentrations and greatest contribution to overall mass. Away from this densely sampled area the uncertainty is higher owing mostly to more sparsely located data. The areas of higher uncertainty contribute less to the total mass than the areas of denser sampling. Consequently, the locations with greater uncertainty in concentration estimates have a relatively low and therefore less consequential contribution to the total mass estimate.

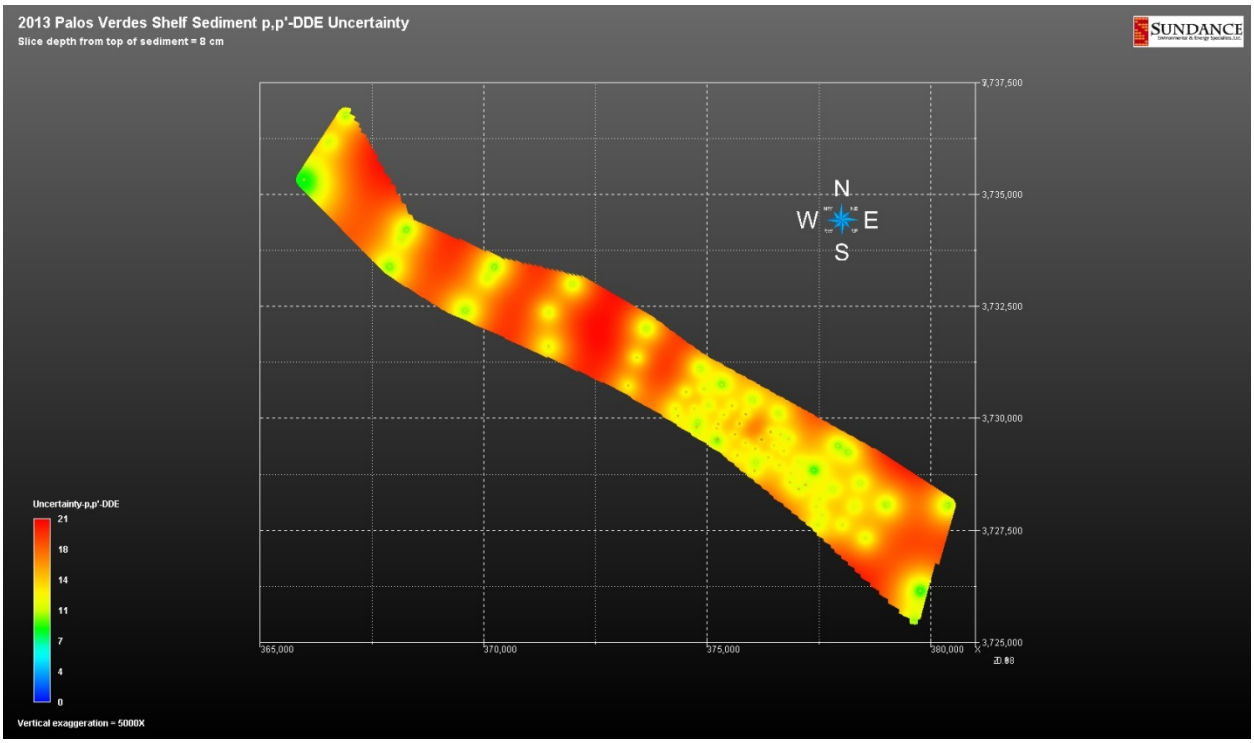

Figure 19. Horizontal 2013 p,p'-DDE uncertainty slice at 8 cm depth into the sediment bed.

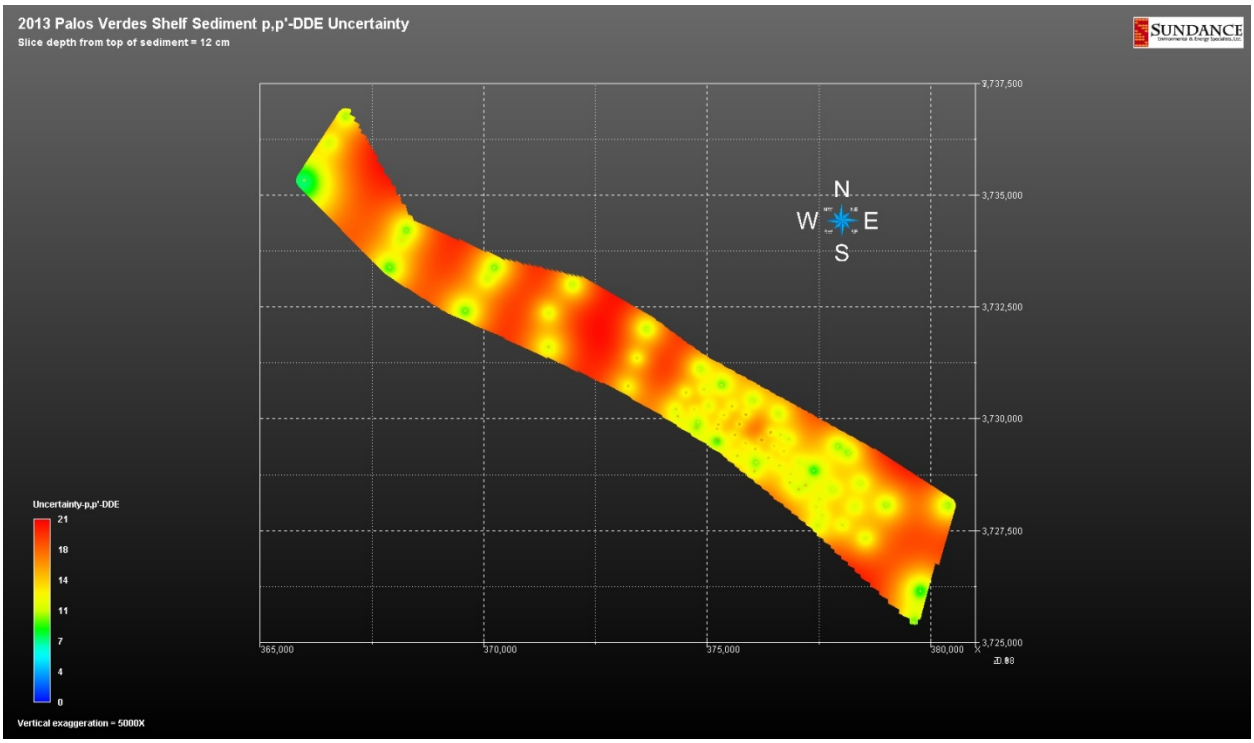

Figure 20. Horizontal 2013 p,p'-DDE uncertainty slice at 12 cm depth into the sediment bed.

4.4 Comparison of 2013 PV Shelf p,p'-DDE Chemical Mass to Earlier Estimates

The mass of p,p'-DDE was estimated for the 1992 and 2009 PV Shelf sediment sampling (Sundance 2012; USEPA 2013) and can be compared to the p,p'-DDE mass estimates from the 2013 PV Shelf sediment cores. Although the EA sediment bed area and thickness varied among the 1992, 2009, 2013 sediment sampling programs there is sufficient similarity between the 2009 EA sediment bed and the 2013 EA sediment bed (Figure 3) for reasonable comparison of p,p'-DDE mass estimates from these two sets of sediment samples. The EA sediment bed for the 1992 PV Shelf sampling program was larger in area than the 2009 and 2013 EA sediment beds but not as thick. However, Sundance (2012) estimated the 1992 p,p'-DDE mass using the convex hull of the larger 1992 EA sediment bed and also using the 2009 EA sediment bed as the 3D domain. p,p'-DDE mass was estimated from the 1992 data and the 2009 data for the same four horizontal to vertical anisotropies applied to the 2013 PV Shelf sediment sample analysis. Figure 21 shows the comparative results for the p,p'-DDE mass estimates from the 1992, 2009, and 2013 PV Shelf sediment sampling programs. Regardless of H:V anisotropy ratio 1992 had the most estimated p,p'-DDE mass whether based on the 1992 EA sediment bed domain or the 2009 sediment bed domain. The 2009 p,p'-DDE mass estimates were the lowest regardless of the H:V anisotropy used in the estimation. The 2013 p,p'-DDE mass estimates are roughly twice those estimated for p,p'-DDE in 2009 but lower than either 1992 p,p'-DDE mass estimates.

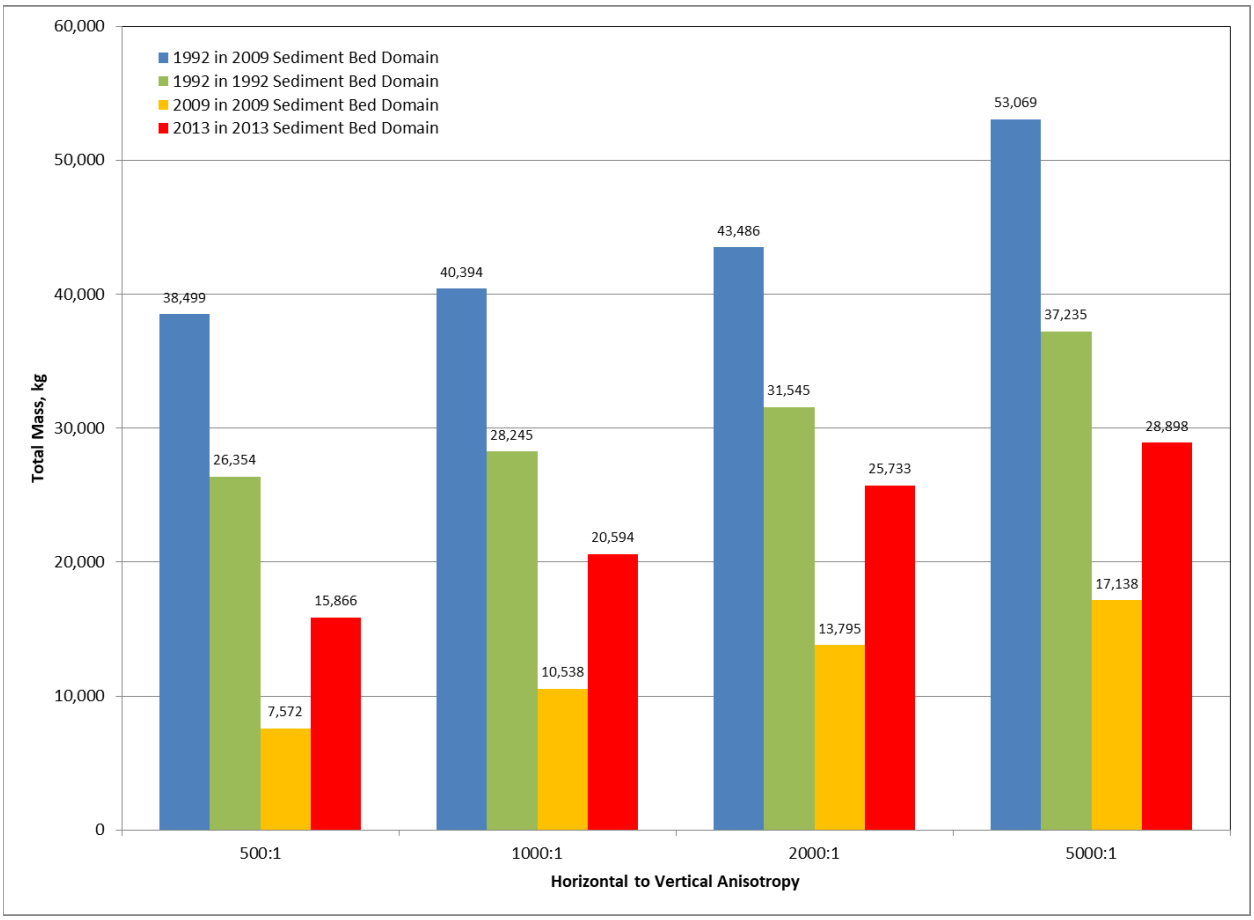

Figure 21. Comparison of 1992, 2009, and 2013 p,p'-DDE mass estimates for PV Shelf sediment.

5.0 REFERENCES

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