APPENDIX A
MVS MODEL REPORT

FINAL MVS MODEL REPORT FOR THE FALL 2009 SEDIMENT SAMPLING PROGRAM

PALOS VERDES SHELF (OU 5 OF THE MONTROSE CHEMICAL CORPORATION SUPERFUND SITE)
LOS ANGELES COUNTY, CALIFORNIA

EPA Contract No. EP-S9-08-03
Task Order 0029

Prepared for:

United States Environmental Protection Agency Region IX
75 Hawthorne Street
San Francisco, California 94105

Prepared by:

ITSI Gilbane Company
2730 Shadelands Drive
Walnut Creek, California 94598

and

CDM Smith
100 Pringle Avenue, Suite 300
Walnut Creek, California 94596

August 2013

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ATTACHMENTS

ACRONYMS AND ABBREVIATIONS

C Tech	C Tech Development Corporation
cm	centimeters
COC	chemical of concern
EA	effluent-affected
EPA	United States Environmental Protection Agency
g/cm^3	grams per cubic centimeter
Geo-EAS	Geostatistical Environmental Assessment Software
Kg	kilogram(s)
LACSD	Sanitation Districts of Los Angeles County
M	meter(s)
m^3	cubic meters
µg/kg	micrograms per kilogram
MIV	mass inventory volume
MVS	Mining Visualization System
OC	organic carbon
PCBs	polychlorinated biphenyls
Pph	parts per hundred
PV Shelf	Palos Verdes Shelf
RD	remedial design
RL	reporting limit
SSRC	Superfund Sediment Resource Center
SWAC	surface (area) weighted average concentration
TOC	total organic carbon
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
2D	two-dimensional
3D	three-dimensional

1.0 INTRODUCTION

A three-dimensional (3D) geostatistical model was developed for sediment at Palos Verdes Shelf (PV Shelf) using analytical and geotechnical data sets generated from tests of sediment samples derived from cores collected in October 2009. The geostatistical software package chosen as the basis for the model was the Mining Visualization System (MVS) Version 9.52, by C Tech Development Corporation (C Tech), Bellingham, Washington.

The 3D model as developed is capable of estimating volumes of contaminated sediment and mass of contaminants, based on both depth and area. The model also provides an assessment of how well-characterized the site is with currently available data, and also can serve as a decision-support tool for remedial analyses.

During the upcoming remedial design (RD) of the interim remedy at PV Shelf, the model will assist the remedial process by evaluating the effects of remedial options, e.g., variations in the dimensions of isolation cap footprints (if an isolation cap is needed), and the costs associated with implementing the various options. MVS software will allow the calculation of surface (area) weighted average concentrations (SWAC) of chemicals of concern (COCs). For PV Shelf, the SWAC methodology and MVS model will allow for statistical evaluations of remedial alternatives, e.g., cap dimensions, to help assess whether the alternative reduces exposures to COCs appropriately.

This report outlines the steps taken to develop the model including how the data sets were developed, and presents the model inputs and results. This report ideally will serve as a guide for analysis of the results of future sampling events at PV Shelf, e.g., at the Five Year Review.

2.0 METHODS

This section provides descriptions of the methods used in developing the MVS model.

2.1 MODELING SOFTWARE

As previously mentioned, C Tech's MVS Version 9.52 was the software package used to develop the geostatistical model for sediment at PV Shelf. MVS is able to use United States Environmental Protection Agency (EPA) Geo-EAS (Geostatistical Environmental Assessment Software), and provides a 3D addition to the two-dimensional (2D) Geo-EAS.

Kriging was chosen as the method of interpolation, because it provides both an ability to interpolate sparse measured data in three dimensions and a statistical measurement of the adequacy of the interpolation in the form of confidence. The end result is an understandable, repeatable, and geostatistically defensible product.

MVS uses a system to: (1) analyze the input data; (2) construct a multi-dimensional variogram (which is a best fit to the data set being analyzed); and (3) perform kriging in the domain to be considered in the visualization. The user is given the option to specify values for the parameters that control the variogram-kriging procedure, and the subsequent display and analysis of the data.

For modeling the PV Shelf, fundamental design objectives used in developing the MVS variogram and kriging algorithms included: (1) producing kriged distributions that honored the measured distributions as closely as possible; and (2) providing the user with a valid mechanism for comparing the modeled and measured domains and a method for documenting the calibrated variogram. An examination of the variogram for individual model parameters was completed to arrive at the best fit.

2.2 DATA SELECTION AND EVALUATION

2.2.1 Stratigraphic Data

The bottom depth of each sediment core was used to define the thickness of the modeled area for the stratigraphic model. Shortcomings in the core collection method used in October 2009, i.e., gravity coring, include: (1) potential material loss at the top of the effluent-affected (EA) bed;

(2) possible exceedances of the vertical limit of the EA bed (core penetration into the native sediment); and (3) the possibility of the coring device not reaching the bottom of the EA bed, due to refusal. However, these shortcomings are balanced due to the fact that all cores were collected using the same methodology. The core collection approach was consistent with methods developed by the Sanitation Districts of Los Angeles County (LACSD, 2006) and likely will be used in future monitoring efforts. Section 4.3 of the main report discusses EA bed depth relative to core length.

Vertical relief of the sea floor within the baseline modeled area exceeds 110 meters (m); the estimated bed thickness based on core length is with less than 1 m. 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.

2.2.2 Analytical Data (Chemical and Physical)

The geostatistical modeling effort centered on a subset of the sediment data generated from geotechnical and chemical testing of sediment samples derived from the October 2009 coring event and subsequent core slicing events. Modeled parameters included bulk density; total organic carbon (TOC); and the following chemical groupings: Total DDTs, consisting of six forms of DDT where toxicity data have been established (*o,p*'-DDD, *p,p*'-DDD, *o,p*'-DDE, *p,p*'-DDE, *o,p*'-DDT, , and *p,p*'-DDT); Total DDT Compounds (the six DDTs plus *p,p*'-DDMU and *p,p*'-DDNU); and Total Polychlorinated Biphenyls (PCBs). In addition, each of the eight forms of DDT was individually modeled.

The DDT and PCB analytical data were provided by the testing laboratory without carbon normalization relative to organic carbon (OC). Analytical data were normalized to OC for each sample using the specific TOC value reported for that sample, following accepted methodology for sediment (Michelsen, 1992). Calculations were performed in Microsoft Excel on a sample-by-sample basis. The following equation was used:

$$\mu g/kg\ OC = \mu g/kg\ dry\ weight/(kg\ TOC/kg\ dry\ weight)$$

where:

µg/kg OC	=	micrograms of the chemical per kilogram of OC
µg/kg dry weight	=	micrograms of the chemical per kilogram of dry weight sample
kg TOC/kg dry weight	=	percent TOC in dry weight sample (expressed as a decimal; for example 44 percent TOC = 0.44)

For calculating chemical mass, the laboratory-reported bulk density was converted to dry density using the following equation:

$$dry\ density = bulk\ density/(1+W)$$

where:

W = fractional water content = moisture content/(1-moisture content)

Calculations were performed in Microsoft Excel on a sample-by-sample basis. The intervals noted above that did not have a reported bulk density test result were not included in the input file for calculating dry density or included in the model in the density interpolation step. The model interpreted the data set in these areas using the same algorithm used to calculate density between core locations. As a result of this methodology, no analytical results were rejected from inclusion in the model.

Previous investigators at PV Shelf converted the density and concentration information for each core sample interval into a value expressed as an "inventory" using units of mass per area (Eganhouse, 2008). A similar process was used in this analysis, but the conversions were done by the model at every grid node after density and concentration were interpolated, rather than just at the individual core location. This approach allowed the model to consider spatial trends for density and concentration separately, rather than assuming that the ratio of one to the other at a given sample interval would remain uniform in interpolated areas between core locations. This approach permitted the calculation of the total mass of each analyte or analyte grouping within the entire monitored area.

Analytical data were reported in micrograms per kilogram (µg/kg), and the model input files maintained that unit ratio. TOC data were reported in parts per hundred (pph) and were used as such in the normalization process. Bulk density data were reported in grams per cubic centimeter (g/cm^3) and its conversion to dry density maintained the same unit ratio.

Results for analytical and geotechnical samples (for both primary and replicate cores) were loaded into the geostatistical input files. Where sample intervals overlapped, the values were averaged within the MVS software. Where a result from the analytical laboratory was reported as less than the reporting limit (RL), the result was input into the MVS data files using the same format; however, in the summations for chemical groupings, i.e., Total DDT Compounds, Total DDTs, and Total PCBs, the model assumed a value of ½ of the RL, in conformance with EPA guidance (EPA, 1991). Where no single analyte was detected in a sample, the model used a value of 5 µg/kg.

2.3 MODEL SETUP

Parameters that formed the model input are described below.

2.3.1 Model Domain

The model domain chosen was initially based on an area that extended roughly 10 percent beyond the chosen sediment sampling locations. This was then bounded on the shoreline side at the 30-m isobath and clipped on the continental-shelf side at the 150-m isobath. The vertical extent of the model was the interpolated surface of the bottom of the retrieved cores.

2.3.2 Grid Cell Resolution

A rectilinear grid with a resolution of 371 (X) x 142 (Y) x 44 (Z) was chosen for the model. This yielded approximately 2.3 million grid cells in the model. The resultant cell model size using this resolution is 50 m by 50 m by 0.02 m.

This model grid was referenced to Universal Transverse Mercator (UTM) Zone 11. The Y axis was rotated to align with a 327.6 degree azimuth, equal to a 57.6-degree clockwise rotation of the X axis. This approach allowed for the model grid to align with the predominant direction of ocean currents (and thus with the mode of deposition along PV Shelf) which also fits best with the current data set. This orientation is consistent with previous work by Murray (1994) and Drake (1994), who used a rotation of approximately 60 degrees in the same coordinate system. Table A.1 presents dimensional features of the full monitored area.

2.4 INTERPOLATION OF STRATIGRAPHIC DATA

Kriging was chosen as the geostatistical interpolation mechanism for the stratigraphic data because it allowed the grid to be established in the selected uniform spacing and allowed interpolation of the spatially sparse data set. Stratigraphic data were kriged in two dimensions only. This was done for both the top and the bottom of the sediment bed as sampled, creating two surfaces. Combining the two surfaces created a volume for which all analytic and geotechnical data were interpolated. This 3D volume also was used for all COC mass calculations.

2.4.1 Variograms for Stratigraphic Data

The variogram summaries the relationship between the variance of the difference between measurements and the distance of the corresponding points from each other. The final calibrated variograms used in this model are available upon request. The documentation includes major axis rotation, range, and sill. The range is the distance between locations beyond which observations appear independent, i.e., the variance no longer increases. The sill describes the region where the variogram itself flattens indicating that variance no longer increases. Table A.2 summarizes parameters used in in the model to interpolate the stratigraphic data, including values for range and sill.

2.4.2 Kriging Approach for Stratigraphic Data

The semi-variogram fitting parameters used in the MVS expert system for this model are available upon request. The fitting parameters include: pair search range, semi-variogram symmetry, XY minimum range, reach/points, Z minimum range, and horizontal/vertical anisotropy. Numbers of search pairs are listed in Table A.2.

2.5 INTERPOLATION OF ANALYTICAL DATA (CHEMICAL AND PHYSICAL)

Kriging was used as the geostatistical interpolation mechanism of both chemical and physical data due to its capabilities to grid in the selected uniform spacing and to interpolate the spatially sparse data set.

2.5.1 Variograms for Analytical Data

The variograms selected for this effort are available upon request. Available documentation includes major axis rotation, range, and sill.

2.5.2 Kriging Approach for Analytical Data

Table A.2 lists parameters used in in the model to interpolate the analytical data, including values for range and sill. The semi-variogram fitting parameters used in the MVS expert system are available for comparison in subsequent sampling events. These include the pair search range, semi-variogram symmetry, XY minimum range, reach/points, Z minimum range, and horizontal/vertical anisotropy.

3.0 MODEL OUTPUT

Model output is discussed in this section. Model results of average concentrations and mass of COCs are presented in the main report in Section 4.4.3 and Tables 7 and 8.

3.1 SUBSETTING AND VISUALIZATION

Calculations and visualization of the model utilized the entire data set at all times.

Visualizations of the MVS model output are presented as follows:

- Figures 4 and 6 in the main report depict cross sections along the C (60-m) isobaths for interpretive concentration contours of the groupings of Total DDTs and Total PCBs, respectively.
- Figures A-1 through A-3 depict oblique views of the EA bed showing the groupings of Total DDT Compounds, Total DDTs, and Total PCBs, respectively.

3.2 METHODOLOGY FOR ESTIMATING AVERAGE CONCENTRATIONS AND MASS OF COCS

The volumetrics module within the MVS software was used to calculate average concentrations and mass of COCs. The module functions as follows:

- A subset (plume) within the input grid is computed using the iso level specified in the volumetrics module.
- Each cell having any nodes within the subset is analyzed.
- The portion of the cell above the target iso level value is computed.
- The volumes of all cells are integrated.
- Centers of mass and eigenvectors are computed.

To derive average COC concentrations for the PV Shelf model, the modeled concentrations at all nodes were summed and then divided by the total number of nodes. The calculated volumes of the portions of the cells above the iso level were integrated, along with the calculated mass inventory volume (MIV), to estimate the masses of individual DDT analytes, Total DDTs, Total DDT Compounds, and Total PCBs. The equation for deriving MIV in kilograms per cubic meter (kg/m^3) is given below.

*MIV = Pow(10An0)*Bn0*0.000001*

where:

Pow(10__)	=	Power function to the base 10 (see note)
An(0)	=	kriged analyte concentration in logarithmic units
Bn(0)	=	kriged dry density in g/cm^3 (non-logarithmic units)
0.000001	=	unit conversion factor of concentration (µg/kg) x density (g/cm^3) = (kg/m^3)
Note:		By default, MVS takes the log(10) of each analytical result and stores this value. Therefore, to use the nodal-estimated value for mass calculations, it is necessary to calculate the inverse log of the model-estimated value, or Pow(10,An0) to derive the non-log value.

3.3 CONFIDENCE AND UNCERTAINTY

Uncertainty exists in the data set used based on sampling protocol, analytical methods, and sampling density and locations. The use of kriging allowed us to calculate the model variability and, specifically, the confidence in the model. Specifically, MVS was utilized by first computing the standard deviation for each estimated point. The standard deviation was then used to compute the confidence. The standard deviation is proportional to the square root of the sill in the variogram, because the standard deviation is computed as the square root of the variance (the second data component in the Geo-EAS KT3D module), and the variance is directly proportional to the sill.

For calculating confidence using the PV Shelf model, we set model parameters to solve the question, "What is the confidence that a predicted concentration will fall within a specified factor of the actual concentration?" Confidence was calculated using a confidence bound factor of 2 for this exercise. In this way, the calculated confidence represents the confidence that a predicted concentration falls within a factor of 2 of the actual concentration, i.e., an actual value of 10 µg/kg may be represented in the model as somewhere from 5 to 20 µg/kg.

The actual calculation to determine confidence requires the standard deviation of the estimate at each node (as described above) and the confidence bound value. This approach provides a "statistical goodness" of the modeled result for current and future comparison. The model was used to derive confidence parameters for three analyte groupings, i.e., Total DDTs, Total DDT Compounds, and Total PCBs.

3.3.1 Confidence Results: Total DDTs

For Total DDTs, the confidence was seen to vary from a low of 51.4 percent to a high of 100 percent. The confidence is lowest at the in-shore edge between northern LACSD Transects 1 and 2, near Point Vicente. This low confidence occurs at both the very top of the sediment bed and the bottom of the sampled bed depth. The confidence values of 100 percent occur only at actual sampling locations. The mean of the confidence for Total DDTs is 75.1 percent, with a median value of 74 percent.

Overall, these values indicate that the site is reasonably well characterized, with predicted values likely falling within a factor of 2 of actual values 75 percent of the time. The outfall area has a minimum confidence of 56.8 percent, a maximum of 100 percent, a mean of 82.5 percent, and a median of 83.2 percent. This indicates that the outfall area is well characterized for Total DDTs relative to the entire sediment bed.

3.3.2 Confidence Results: Total DDT Compounds

For Total DDT Compounds, the confidence was seen to vary from a low of 52 percent to a high of 100 percent. Again, the confidence was lowest at the in-shore edge between LACSD Transects 1 and 2, near Point Vicente. This low confidence occurs at both the very top of the sediment bed and the bottom of the sampled bed depth. The confidence values of 100 percent occur only at actual sampling locations. The mean of the confidence for Total DDT Compounds is 75.7 percent, with a median value of 75 percent. Overall, these values indicate that the site is reasonably well characterized, with predicted values likely falling within a factor of 2 of actual values 76 percent of the time. The outfall area has a minimum confidence of 57 percent, a maximum of 100 percent, a mean of 83 percent, and a median of 84 percent. These values indicate that the outfall area is well characterized for Total DDT Compounds relative to the entire sediment bed.

3.3.3 Confidence Results: Total PCBs

For Total PCBs, the confidence was seen to vary from a low of 57.9 percent to a high of 100 percent. Much like the Total DDTs model, the confidence is lowest at the in-shore edge between Transect 1 and Transect 2, near Point Vicente. This low confidence occurs at both the very top and bottom of the sampled bed depth. An additional area of low confidence is exhibited south of the outfall area, deep in the sampled bed. The confidence values of 100 percent occur only at actual sampling locations. The mean of the confidence for Total DDTs is 81 percent, with a median value of 81 percent. Overall, these values indicate that the site is reasonably well characterized, with predicted values likely falling within a factor of 2 of actual values 81 percent of the time. The outfall area has a minimum confidence of 64 percent, a maximum of 100 percent, a mean of 88 percent, and a median of 89 percent. This indicates that the outfall area is well characterized for Total PCBs relative to the entire sediment bed. Overall, the Total PCBs are better characterized than the Total DDTs.

Confidence values for Total DDT Compounds, Total DDTs, and Total PCBs are presented in Table A.3 for the full model and Table A.4 for the outfall area, respectively.

4.0 MODEL OUTPUT FILES

Model output files (.4d extension) that run on the 4D Interactive Model Player software (C Tech) are available upon request. The files allow the user to examine the model output as a 3D document. The files document the various components of the model, e.g., geologic framework, bathymetry, and analytic data, and provide a visual analysis of the semi-variogram through a 3D cloud plot. These files are licensed to be opened via a special viewer, also available upon request, and can provide full 3D zoom, translation, and rotation capability.

The following is the list of the model files, with general content:

- Bathymetry_with_LandSurface.4d – an overview of the site referenced to elevation
- Geological_Framework1.4d – an overview of the geological framework, referenced to elevation
- All_Analytes_Plotted_24_Frames.4d – plots of sample concentrations for all modeled analytes presented one per frame
- TotalDDT_top 8cm.4d – Total DDTs in the top 8 cm of sediment
- Total_DDT_Semivariogram_3D_CloudPlot.4d – a cloud plot of the semi-variogram for the Total DDT calibration
- TotalDDT_3DPlumes_8Frames_v3.4d – Total DDT distribution at eight specific concentration levels (denoted on each frame)
- Total DDT_ExplodedbyDepth_wAerial1.4d – Total DDT distribution presented as separated sediment intervals

5.0 MODEL CONFIRMATION

EPA, through the Superfund Sediment Resource Center (SSRC), conducted an independent modeling effort using MVS software to verify and confirm the model output as described herein. Conclusions of the SSRC effort were that the original model was valid and that the difference in mass of COCs for the fall 2009 data set compared to previous data sets was likely due to reductions in COC concentrations in test results, and not due to factors related to the model. Copies of the SSRC technical memoranda are provided in Attachment 1 to this appendix.

6.0 REFERENCES

Drake, D.E., C.R. Sherwood, and P.L. Wiberg, 1994. Predictive Modeling of the Natural Recovery of the Contaminated Effluent-Affected Sediment, Palos Verdes Margin, Southern California. Expert Report for U.S. vs. Montrose.

Eganhouse, R.P. and J. Pontolillo, 2008. DDE in Sediments of the Palos Verdes Shelf, California: In Situ Transformation Rates and Geochemical Fate, Environmental Science and Technology, 2008, 42 (17).

Gardner, J.V., Dartnell, P., L.A. Mayer, and J.E. Hughes Clark, 1999. Shaded-relief bathymetric and backscatter maps of Santa Monica margin, California. USGS Geologic Investigation Series I-2648 (2 sheets).

Michelsen, Teresa C., 1992. Organic Carbon Normalization of Sediment Data, Technical Information Memorandum, Washington Department of Ecology, Sediment Management Unit. December.

Murray, C.J. 1994. Geostatistical Mapping of the Distribution of Effluent-Affected Sediment Deposits and Associated Contaminant Inventories, Palos Verdes Margin, Southern California as Appendix M to The Distribution and Character of Contaminated Effluent-Affected Sediment, Palos Verdes Margin, Southern California. Expert Report, U.S. Geological Survey. October.

Sanitation Districts of Los Angeles County (LACSD), 2006. Palos Verdes Ocean Monitoring Annual Report 2005. 30 June.

United States Environmental Protection Agency (EPA), 1991. Interim Final Guidance on Handling Chemical Concentration Data Near the Detection Limit in Risk Assessments. 04 November, 1991.

APPENDIX A TABLES

Table A.1 - Dimensional Features of the Geostatistical Model
Fall 2009 Sediment Sampling Program
Palos Verdes Shelf (OU 5 of the Montrose Chemical Corp. Superfund Site)
Los Angeles County, California

Parameter	***Value***
Full model	
Modeled area (sq km)	29.8
Modeled volume (million cu m)	14.5
Number of cells	2,318,008
Number of nodes	2,393,820
Easting minimum (m)	365,798
Easting maximum (m)	380,694
Easting extent (m)	14,896
Northing minimum (m)	3,725,454
Northing maximum (m)	3,737,180
Northing extent (m)	11,726
Centroid coordinates (northing, easting, depth	3,731,317; 373,246; -0.44

Abbreviations
cu m - Cubic meters
m - Meters
sq km - Square kilometers

Table A.2 - Parameters for Data Interpolation
Fall 2009 Sediment Sampling Program
Palos Verdes Shelf (OU 5 of the Montrose Chemical Corp. Superfund Site)
Los Angeles County, California

Model	***Range***	***Sill***	***Number of search pairs***
Stratigraphic data kriging (2D)			
Modeled area	5,210	34,573	124,000
Analytical (chemical) data kriging (3D)			
Total DDTs	9,994	0.87	124,768
o,p'-DDE	9,994	0.36	124,768
o,p'-DDT	9,994	0.60	124,768
p,p'-DDD	9,994	0.11	124,768
p,p'-DDE	9,994	0.69	124,768
p,p'-DDT	9,994	0.78	124,768
p,p'-DDMU	9,994	0.55	124,768
p,p'-DDNU	9,994	0.68	124,768
Total PCBs	9,994	0.65	124,768
Analytical (physical) data kriging (3D)			
Modeled area	9,994	0.05	124,768
Bathymetry			
Modeled area	4,870	0.43	1,711

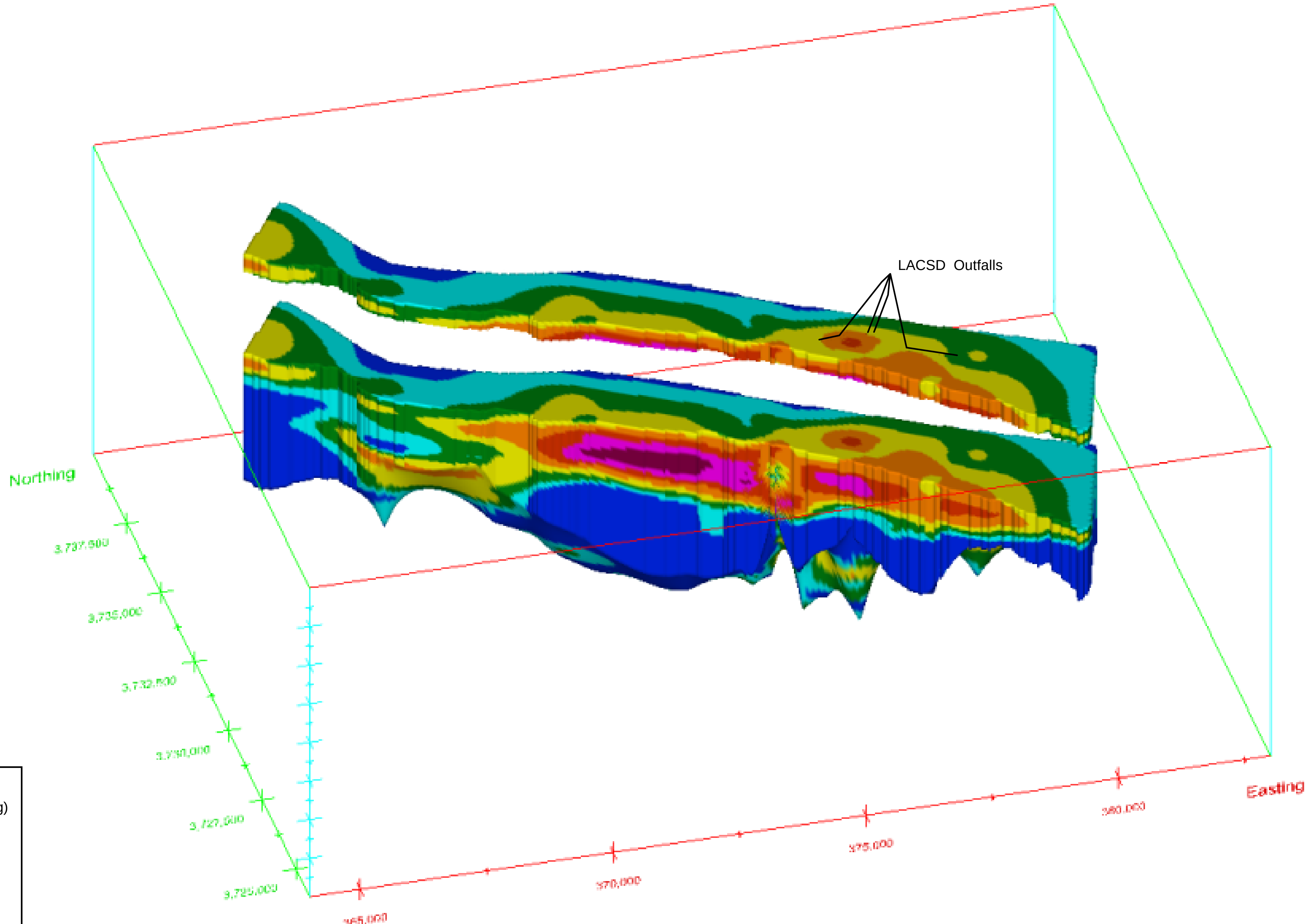
Table A.3 - Confidence Values of the Geostatistical Model - Full Model
Fall 2009 Sediment Sampling Program
Palos Verdes Shelf (OU 5 of the Montrose Chemical Corp. Superfund Site)
Los Angeles County, California

Parameter	***Value* (percent)**
Total DDT Compounds	
Mean	75.7
Median	75.3
Data minimum	52.0
Data maximum	100.0
Total DDTs	
Mean	75.7
Median	75.3
Data minimum	52.0
Data maximum	100.0
Total PCBs	
Mean	81.2
Median	81.3
Data minimum	57.9
Data maximum	100.0

Table A.4 - Confidence Values of the Geostatistical Model - Outfall Area
Fall 2009 Sediment Sampling Program
Palos Verdes Shelf (OU 5 of the Montrose Chemical Corp. Superfund Site)
Los Angeles County, California

Parameter	***Value* (percent)**
Total DDT Compounds	
Mean	83.1
Median	83.8
Data minimum	57.4
Data maximum	100.0
Total DDTs	
Mean	82.5
Median	83.2
Data minimum	56.8
Data maximum	100.0
Total PCBs	
Mean	87.9
Median	88.9
Data minimum	63.5
Data maximum	100.0

APPENDIX A FIGURES



Legend

Total DDT Compounds (ug/kg)

- <230
- 230 - 500
- 500 - 1,000
- 1,000 - 2,000
- 2,000 - 5,000
- 5,000 - 10,000
- 10,000 - 20,000
- >20,000

Notes

1. Top 8 cm of sediment is shown separated from the remainder of the monitored area sediment.
2. Concentrations are not normalized for organic carbon.

Abbreviations

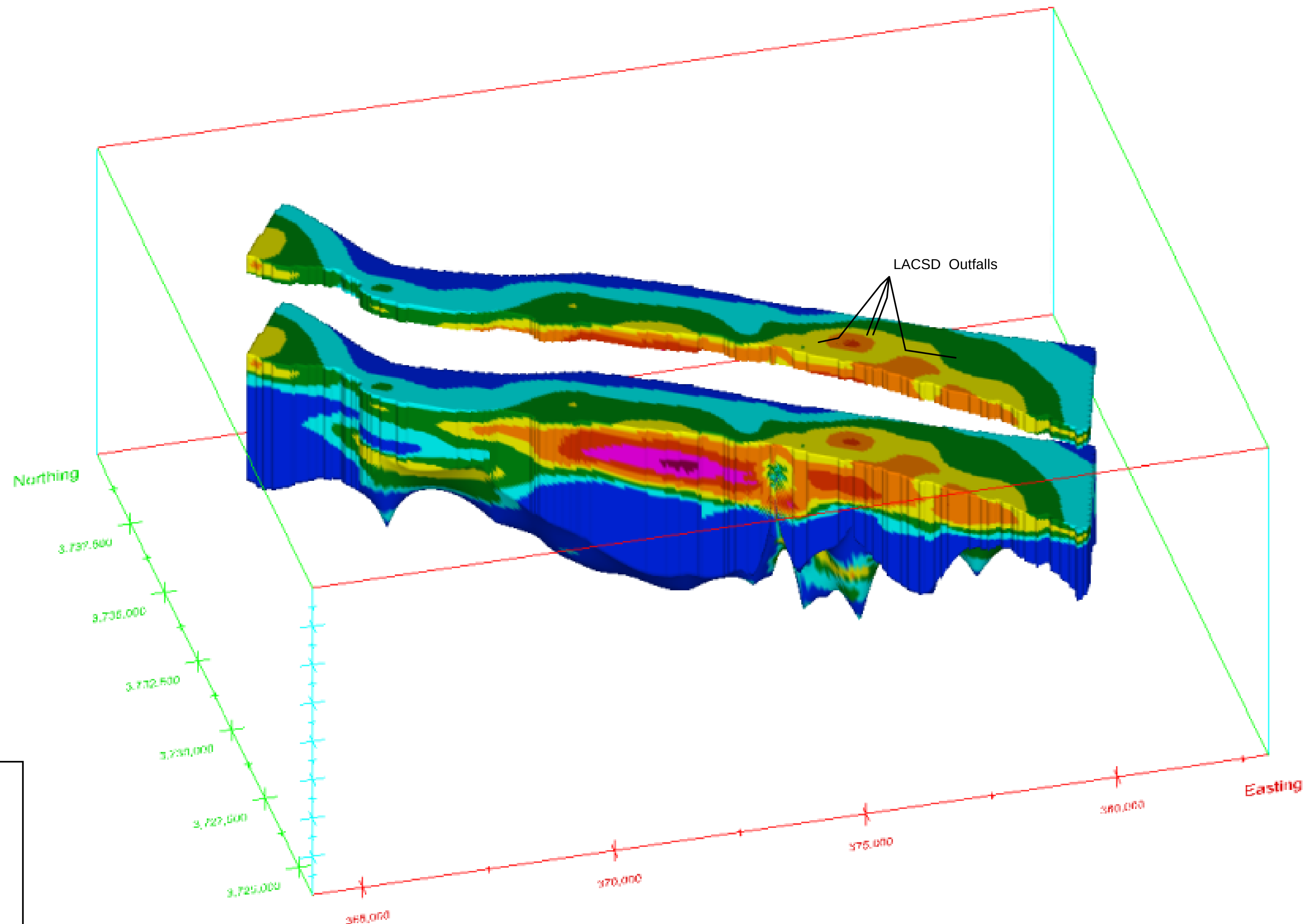
cm	Centimeters
LACSD	Sanitation Districts of Los Angeles County
ug/kg	Micrograms per kilogram

Figure A.1
Interpretive Concentrations of
Total DDT Compounds (Oblique View)

Fall 2009 Sediment Sampling Program
Palos Verdes Shelf
Los Angeles County, California

EPA United States Environmental Protection Agency

Z:\0030 TO 29 PV Shelf Pre-Design Investigation\6.0 Graphics\DDT compounds oblique.ai



Legend

Total DDTs (ug/kg)

- <230
- 230 - 500
- 500 - 1,000
- 1,000 - 2,000
- 2,000 - 5,000
- 5,000 - 10,000
- 10,000 - 20,000
- >20,000

Notes

1. Top 8 cm of sediment is shown separated from the remainder of the monitored area sediment.
2. Concentrations are not normalized for organic carbon.

Abbreviations

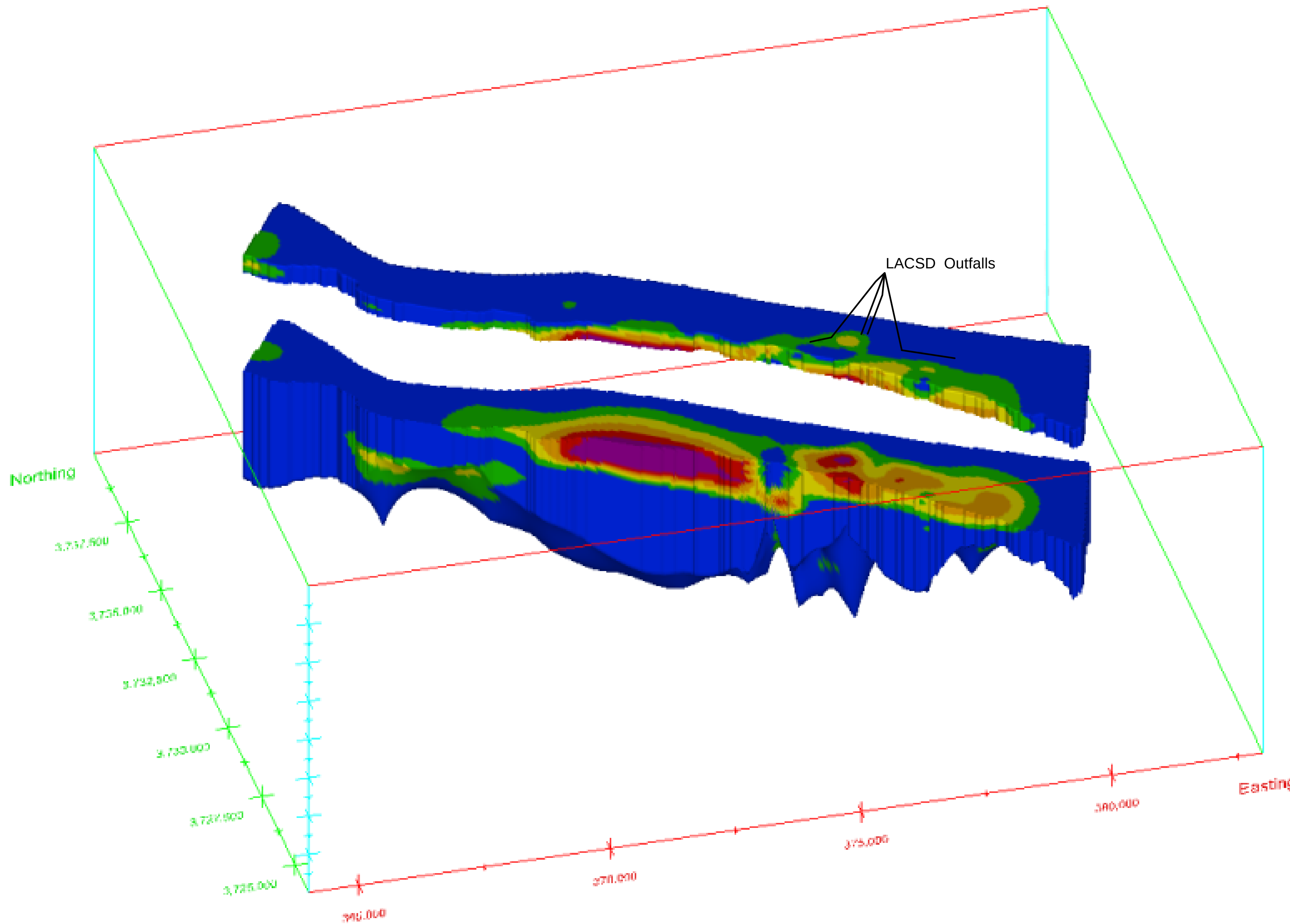
cm	Centimeters
LACSD	Sanitation Districts of Los Angeles County
ug/kg	Micrograms per kilogram

Figure A.2
Interpretive Concentrations of Total DDTs (Oblique View)

Fall 2009 Sediment Sampling Program
Palos Verdes Shelf
Los Angeles County, California

EPA United States Environmental Protection Agency

Z:\0030 TO 29 PV Shelf Pre-Design Investigation\6.0 Graphics\DDTs oblique.ai



Legend

Total PCBs (ug/kg)

- 5 - 70
- 70 - 150
- 150 - 300
- 300 - 600
- 600 - 1,000
- >1,000

Notes

1. Top 8 cm of sediment is shown separated from the remainder of the monitored area sediment.
2. Concentrations are not normalized for organic carbon.

Abbreviations

cm	Centimeters
LACSD	Sanitation Districts of Los Angeles County
ug/kg	Micrograms per kilogram

Figure A.3
Interpretive Concentrations of Total PCBs (Oblique View)

Fall 2009 Sediment Sampling Program
Palos Verdes Shelf
Los Angeles County, California

EPA United States Environmental Protection Agency

Z:\0030 TO 29 PV Shelf Pre-Design Investigation\6.0 Graphics\PCBs oblique.ai

ATTACHMENT 1 TO APPENDIX A:
SSRC TECHNICAL MEMORANDA

Technical Memorandum - Draft

Review of CDM MVS Palos Verdes Shelf Contaminant Mass Modeling

Questions addressed in Sundance review of MVS Palos Verdes (PV) Shelf contaminant mass calculations by CDM:

1. Is the MVS-based approach used by CDM for PV contaminant mass calculations reproducible?

2. Are CDM MVS-based contaminant mass estimates reasonable for the PV datasets analyzed?

3. If Question #2 is true – why are CDM's contaminant mass calculations significantly lower than previous mass calculations?

***Question #1**: Is the MVS-based approach used by CDM for PV contaminant mass calculations reproducible?*

Question #1 approach – Review CDM MVS model modules and architecture; run (if possible) CDM MVS model with provided CDM derived data files.

Tables shown in Attachment A show all files that were initially provided to Sundance for the review of CDM's Palos Verdes contaminant mass calculations via CTech Development Corporation's MVS software. Subsequent to this information turnover, the file "totalpcbcompounds.efb" was separately provided. The MVS application file "masscalc8.v" highlighted in yellow in the tables was the base model used by CDM for mass calculations. "masscalc8.v" includes several MVS calculations and visualizations in addition to the mass calculation. While Sundance was able to load "masscalc8.v" in MVS and evaluate the architecture of the model along with the functionality of each MVS module in the application we could only partially "run" the application. It appears that "masscalc8.v" was used to test a number of different model scenarios and was not setup specifically for reproduction of CDM's mass calculations. For example, the horizontal to vertical anisotropy was set at 20,000:1 although the CDM reported mass was based on an anisotropy ratio of 2,000:1. In other instances modules were not linked thus disabling the calculation end results. Nevertheless, our review of the "masscalc8.v" architecture indicates that the overall modeling approach to contaminant mass calculations is appropriate for the data sets analyzed.

Answer to Question 1: No, Sundance could not reproduce CDM mass calculations with the files submitted.

***Question #2*: Are CDM MVS-based contaminant mass estimates reasonable for the PV datasets analyzed?**

Question #2 approach – Construct MVS-based models for PV contaminant mass (p,p'-DDE and total PCBs) from original 2009 data and compare to CDM calculations.

Step 1: Calculate in MVS the sediment bed thickness and compare to CDM's calculation to affirm a representative comparison of mass estimates based on sediment bed thickness

CDM EA Sediment Bed Thickness, m, is shown in Attachment B, Figure 1.

Area = 30 km^2, Volume = $1.5X10^7$ m^3

Sundance EA Sediment Bed Thickness, m, is shown in Attachment B, Figures 2-4**.**

Area = 29.8 km^2, Volume = $1.5X10^7$ m^3

The Effluent Affected (EA) sediment bed thickness models by CDM and Sundance are virtually identical thus enabling the comparison of Sundance contaminant mass estimates to CDM contaminant mass estimates based on sediment bed thickness. The Sundance approach to MVS mass modeling employed adaptive gridding so that each sample location is represented by a grid node. This approach ensures that at each sample location the kriged estimate matches the sample value. To calculate contaminant mass that is comparable to CDM mass estimates Sundance first created a sediment bed thickness model Figures 2-4. The Sundance EA sediment bed thickness model is nearly identical to the CDM sediment bed thickness model (Figure 1 compared to Figure 2) which is important in ensuring that the mass calculations are based on the same volume of sediment.

Step 2: Delineate the similarities and differences in MVS parameters for Sundance and MVS visualizations.

The MVS parameters for the Sundance and CDM MVS visualizations are shown in Attachment B, Figure 5**.** The model parameters for each are shown for comparison purposes. The Sundance model is a lower spatial resolution than the CDM model to increase the computational speed and reduce the time required to run the Sundance model. Nevertheless, it is shown in the comparison of sediment bed thickness models that the Sundance MVS model is accurate and suitable for comparison to the CDM model.

Step 3: Delineate the MVS approach for calculating mass and describe the three methodologies that can be utilized under this approach.

Contaminant mass calculations are performed in the MVS "volumetrics" module with the following formula.

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

Concentration results from MVS Krig_3D (i.e., plume model); density is typically a constant in MVS; volume is based on the selected concentration is o level (equal to zero for entirety of contaminant mass; and 10^{-3} is for units conversion.

There are three (3) methods, or approaches, in MVS to mass calculations.

Method 1: Variable concentration and constant density.

Method 2: Variable concentration and variable density data multiplied together and the product kriged.

Method 3: Variable concentration and variable density independently kriged and both fields multiplied via MVS "data_math" before "Volumetrics" calculation.

Mass calculation accuracy increases from Method 1 to Method 3 but so does computational effort.

Step 4: Determine MVS-based contaminant mass estimates sensitivity to max-gap and anisotropy with Sundance MVS model.

CDM MVS-based mass calculations in current report (Table 10 of that report) are shown in Attachment B, Figure 6, and their results for p,p'-DDE mass estimate are 9,700 kg and total PCBs mass estimate is 1,000 kg.

Sundance MVS-Based Mass Calculations with testing of sensitivity of mass to max-gap and anisotropy are shown in Attachment B, Figures 7. Determination of the sensitivity of MVS mass calculations to internal MVS parameters was necessary to confirm that the resulting contaminant mass estimates were not biased by these parameters, or, to account for the bias. Figure 7 shows eight MVS model runs wherein the anisotropy and max-gap were varied. Note that the resulting mass estimates for p,p'-DDE are very sensitive to the value of horizontal to vertical anisotropy chosen but virtually insensitive to max-gap. Therefore, for all additional Sundance mass calculations max-gap was held at 0.01 meter but anisotropy was varied to show its effect on the resulting mass calculations. For all sensitivity runs in Figure 7 dry density was held constant at the mean calculated by CDM.

<u>Step 5: Calculate mass estimates for p.p'-DDE and total PCBs using the methods described above and compare results to CDM mass estimates.</u>

Figure 8 shows the results of Sundance MVS-based mass estimates for p.p'-DDE. The top portion of the figure shows the results when using Method 1 (described above) for mass calculation. Three different mean dry density constant values where used in this analysis. The "green" results are for the mean dry density calculated from the raw data. The "blue" dry density is the mean dry density from the Sundance kriged dry density field. The "yellow" dry density is the mean from CDM's kriged dry density field. The same type of Method 1 mass calculation was also performed (middle portion of Figure 8) using the three median dry density estimates (i.e., raw data, Sundance kriged, and CDM kriged). Method 1 was used to benchmark the mass calculations as this is the "standard" MVS approach to mass calculation. Also, the results in Figure 8 show the effect of varying dry density on the resultant mass calculations. The mean and median dry densities computed by CDM produce significantly lower mass estimates. Finally, the bottom part of Figure 8 shows the results of the Method 3 p,p'-DDE mass calculations.

CDM p,p'-DDE MVS-based mass calculation (Table 10) = 9,700 kg which is in good agreement with the Sundance p,p'-DDE mass estimate of 13,795 kg for equivalent anisotropy ratio of 2,000:1. Thus, the dry density used by CDM for their reported p,p'-DDE mass of 9,700 kg was not the same field provided in the turnover file "drydensity.efb" or their estimate would be lower than 9,700 kg.

Figure 9 shows the results of the Sundance MVS-based mass estimates for total PCBs. For this analysis Method 2 and Method 3 (described above) where used. Method 3 corresponds most closely to the approach taken by CDM. Method 2 was used for comparison to validate the overall approach and provide confidence in the calculations.

CDM total PCBs MVS-based mass calculation (Table 10) = 1,000 kg which is nearly identical to the Sundance total PCBs mass estimate of 996 kg for equivalent anisotropy ratio of 2,000:1.

Answer to Question #2: Yes, based on Sundance MVS calculations of p,p'-DDE and Total PCBs mass derived from the raw 2009 data, the MVS-based mass estimates derived by CDM appear to be reasonable for the datasets analyzed.

<u>Question #3</u>: If Question #2 is true – why are CDM's contaminant mass calculations significantly lower than previous mass calculations?

Lee, et al. (2002) state "Because virtually all of the area mapped has surface concentrations of p,p'-DDE greater than 1 ppm, the total area lying within the 1 ppm isopleth is likely much greater than the 43.1 km^2 given in the table."

Figure 10, Attachment B, from Lee, et al. (2002) shows that all concentrations in the study area are above 1 ppm (1,000 µg/kg). Murray et al. (2002) document excellent spatial correlations between total DDT and p,p'-DDE, and between total PCBs and p,p'-DDE (correlation coefficients of 0.97 and 0.99, respectively). This is the justification for focusing the Sundance review of p,p'-DDE and total PCBs.

Figure 11, Attachment B, shows the spatial distribution of the 2009 p,p'-DDE sediment sample concentrations. The majority of samples in 2009 had p,p'-DDE concentrations well below the minimum 1,000 µg/kg concentration shown in Lee, et al. (2002). Thus, the total mass of p,p'-DDE in 2009 is substantially less than what would be calculated based on the concentration distribution shown in Figure 10 from Lee, et al. (2002).

Sundance computed the MVS-based p,p'-DDE mass estimates assuming minimum 2009 concentration was 1,000 µg/kg (1 ppm). In other words, for every 2009 p,p'-DDE sample concentration that was below 1,000 µg/kg it was raised to 1,000 µg/kg. This analysis represents the minimum 2009 p,p'-DDE mass that could be assumed if the Lee, et al. (2002) 1 ppm minimum concentration applied to the 2009 sample data (which Figure 6 shows is not the case).

Results of the Sundance MVS calculations are shown in Figure 12, Attachment B**.** Results demonstrate that the mass calculations for p,p'-DDE for 2009 would be significantly higher had the 2009 sample concentrations been on the order of magnitude of those shown in Figure 10 and used for the mass calculations presented by Lee, et al. (2002).

Answer to Question #3:

- *2009 p,p'-DDE sediment sample concentrations are significantly lower than those used by Lee, et al. (2002) in their p,p'-DDE mass calculations.*
- *The areal footprint for the 2009 contaminant mass calculations is 30 km^2 vs. 43 km^2 for Lee, et al. (2002).*
- *Therefore, it seems reasonable that 2009 contaminant mass estimates are lower than those calculated by Lee, et al. (2002).*

ATTACHMENT A: FILES RECEIVED FROM CDM FOR REVIEW

TreeSize Free Report, 10/24/2011 6:33 PM

V 2.5

C:\Work\Sundance Environmental\Palos Verdes\Information\ on [OS]

Drive: C:\ Size: 905,695.8 MB Used: 242,674.5 MB Free: 663,021.3 MB 4096 Bytes per Cluster (NTFS)

This Folder: Size: 208.8 MB Allocated: 209.0 MB Percent of Drive: 0 % Files: 103 Folders: 7

Name ▲	Size	Allocated	Files	Folders	% of Parent	Last Change	Last Access
Palos Verdes -Sundance	113.3 MB	113.4 MB	45	5	54.3 %	10/20/2011	10/20/2011
Tables -Attach F	0.3 MB	0.3 MB	4	0	0.1 %	10/13/2011	10/24/2011
[Files]	95.2 MB	95.3 MB	54	0	45.6 %	10/18/2011	10/24/2011
App F narrative v2.doc	0.2 MB	0.2 MB	1	0	0.2 %	10/16/2011	10/5/2011
Attach F w tables.pdf	0.3 MB	0.3 MB	1	0	0.3 %	10/13/2011	10/24/2011
Attach G - BA grain size Level 3.xls	0.5 MB	0.5 MB	1	0	0.6 %	10/16/2011	10/12/2011
Attach H - OA Grain Size Level 3.xls	0.5 MB	0.5 MB	1	0	0.5 %	10/16/2011	10/12/2011
Attach I - BA BD MC SG Level III.xls	0.3 MB	0.3 MB	1	0	0.3 %	10/16/2011	10/12/2011
Attach J - OA BD, MC, SG Level III.xls	0.3 MB	0.3 MB	1	0	0.3 %	10/16/2011	10/12/2011
Attach K - BA DDTs.xls	0.6 MB	0.6 MB	1	0	0.7 %	10/16/2011	10/12/2011
Attach L - BA PCBs.xls	0.8 MB	0.8 MB	1	0	0.8 %	10/16/2011	10/12/2011
Attach M - OA DDTs.xls	0.5 MB	0.5 MB	1	0	0.5 %	10/16/2011	10/12/2011
Attach N - OA PCBs.xls	1.0 MB	1.0 MB	1	0	1.1 %	10/16/2011	10/12/2011
Attach O - Vert Profiles - BA.xlsx	0.4 MB	0.4 MB	1	0	0.4 %	3/1/2011	10/24/2011
Attach P - Vert Profiles - OA.xlsx	0.4 MB	0.4 MB	1	0	0.4 %	10/18/2011	10/18/2011
Attachment F w tables.pdf	0.3 MB	0.3 MB	1	0	0.3 %	10/16/2011	10/16/2011
Attachment O - Vert Profiles - BA.xlsx	0.4 MB	0.4 MB	1	0	0.4 %	10/18/2011	10/18/2011
DDT distribution on PVShelf.ppt	0.4 MB	0.4 MB	1	0	0.4 %	9/9/2011	9/9/2011
DRAFT DATA REPORT FOR THE FALL 20...	1.2 MB	1.2 MB	1	0	1.3 %	10/12/2011	10/24/2011
Draft text - fall 2009 sed rpt w tables.pdf	1.2 MB	1.2 MB	1	0	1.3 %	10/16/2011	10/16/2011
Ferre_etal_2010_CSR.pdf	2.9 MB	2.9 MB	1	0	3.1 %	10/16/2011	10/16/2011
Fig 1 - Location maps.pdf	2.9 MB	2.9 MB	1	0	3.1 %	10/18/2011	10/18/2011
Fig 2 - Baseline cores.pdf	0.8 MB	0.8 MB	1	0	0.8 %	10/18/2011	10/18/2011
Fig 3 Outfall cores.pdf	0.5 MB	0.5 MB	1	0	0.5 %	10/18/2011	10/18/2011
Figure 4.pdf	0.8 MB	0.8 MB	1	0	0.8 %	10/18/2011	10/18/2011
Figure 5.pdf	0.8 MB	0.8 MB	1	0	0.8 %	10/18/2011	10/18/2011
Figure 6.pdf	1.3 MB	1.3 MB	1	0	1.3 %	10/18/2011	10/18/2011
Figure 7.pdf	1.5 MB	1.5 MB	1	0	1.6 %	10/18/2011	10/18/2011
Figure 8.pdf	0.5 MB	0.5 MB	1	0	0.5 %	10/18/2011	10/18/2011
Figure 9.pdf	0.7 MB	0.7 MB	1	0	0.7 %	10/18/2011	10/18/2011
Figure 10.pdf	4.9 MB	4.9 MB	1	0	5.1 %	10/18/2011	10/18/2011
Figure 11.pdf	1.5 MB	1.5 MB	1	0	1.6 %	10/18/2011	10/18/2011
Figure 12.pdf	0.4 MB	0.4 MB	1	0	0.5 %	10/18/2011	10/18/2011
final-feas-study-may09.pdf	9.3 MB	9.3 MB	1	0	9.8 %	10/4/2011	10/4/2011
Forecasting WQ.pdf	4.1 MB	4.1 MB	1	0	4.3 %	10/16/2011	10/16/2011
Forecasting WQ-Forecasting Water Quality...	4.1 MB	4.1 MB	1	0	4.3 %	10/12/2011	10/24/2011
modification-date.pdf	22.0 MB	22.0 MB	1	0	23.1 %	10/16/2011	10/16/2011
ppDDE3C5C6CRep123 - LACSD core sedi...	0.2 MB	0.2 MB	1	0	0.3 %	10/11/2011	10/24/2011
ppDDE3C5C6CRep123.pdf	0.2 MB	0.2 MB	1	0	0.3 %	10/16/2011	10/16/2011
PV Shelf request.docx	0.0 MB	0.0 MB	1	0	0.0 %	9/9/2011	9/9/2011
PVshelf_evolution_figs_2006_03_13.pdf	1.0 MB	1.0 MB	1	0	1.0 %	9/9/2011	9/9/2011
PVShelf_Sed figures 7-12 June 2011.pdf	8.6 MB	8.6 MB	1	0	9.1 %	9/9/2011	9/9/2011
pvs-remediation-inv.pdf	10.9 MB	10.9 MB	1	0	11.4 %	10/4/2011	10/4/2011
R2M.pdf	4.8 MB	4.8 MB	1	0	5.1 %	10/17/2011	9/25/2011
Table 5 - Core lengths and number of sam...	0.1 MB	0.1 MB	1	0	0.1 %	2/21/2011	10/24/2011
Table 6 - Chemistry tests.doc	0.2 MB	0.2 MB	1	0	0.2 %	2/5/2011	10/24/2011
Table 8 Average and max COC values.xlsx	0.1 MB	0.1 MB	1	0	0.1 %	2/17/2011	10/24/2011
Table 9 - Average COCs - model output C...	0.1 MB	0.1 MB	1	0	0.1 %	3/22/2011	10/24/2011
Table 10 - Mass Estimates of COCs round ...	0.1 MB	0.1 MB	1	0	0.1 %	3/21/2011	10/24/2011
Task Order 17 initial SOW.pdf	0.0 MB	0.0 MB	1	0	0.0 %	10/2/2011	10/2/2011
Tbl 3 - Baseline locations.doc	0.1 MB	0.1 MB	1	0	0.1 %	2/21/2011	10/24/2011
Tbl 4 - Outfall locations.doc	0.1 MB	0.1 MB	1	0	0.1 %	2/21/2011	10/24/2011
Tbl 7 - Average grain sizes for select locati...	0.2 MB	0.2 MB	1	0	0.2 %	2/17/2011	10/24/2011
Tbl F1 - Model dimensions.xlsx	0.1 MB	0.1 MB	1	0	0.1 %	10/13/2011	10/24/2011

Name ▲	Size	Allocated	Files	Folders	% of Parent	Last Change	Last Access
Tbl F2 - Interpolation parameters.xlsx	0.1 MB	0.1 MB	1	0	0.1 %	10/13/2011	10/24/2011
Tbl F3 - Confidence values - full model.xlsx	0.1 MB	0.1 MB	1	0	0.1 %	3/22/2011	10/24/2011
Tbl F4 - Confidence values - OA.xlsx	0.1 MB	0.1 MB	1	0	0.1 %	10/13/2011	10/24/2011

TreeSize Free Report, 10/24/2011 6:34 PM

V 2.5

C:\Work\Sundance Environmental\Palos Verdes\Model Application Files\ on [OS]

Drive: C:\ Size: 905,695.8 MB Used: 242,682.4 MB Free: 663,013.3 MB 4096 Bytes per Cluster (NTFS)

This Folder: Size: 0.3 MB Allocated: 0.3 MB Percent of Drive: 0 % Files: 4 Folders: 0

Name ▲	Size	Allocated	Files	Folders	% of Parent	Last Change	Last Access
masscalc8.v	0.1 MB	0.1 MB	1	0	25.9 %	2/4/2011	2/4/2011
perspectivefigure8_krigtotalddtsoc.v	0.1 MB	0.1 MB	1	0	36.3 %	6/14/2011	6/14/2011
strat9_ddt9_mappedtoC.v	0.1 MB	0.1 MB	1	0	21.0 %	11/29/2010	11/29/2010
strat9_pDDE_2.v	0.1 MB	0.1 MB	1	0	16.8 %	10/20/2010	10/20/2010

TreeSize Free Report, 10/24/2011 6:36 PM

V 2.5

C:\Work\Sundance Environmental\Palos Verdes\Model Input Files\ on [OS]

Drive: C:\ Size: 905,695.8 MB Used: 242,682.4 MB Free: 663,013.3 MB 4096 Bytes per Cluster (NTFS)

This Folder: Size: 35.0 MB Allocated: 35.1 MB Percent of Drive: 0 % Files: 58 Folders: 2

Name ▲	Size	Allocated	Files	Folders	% of Parent	Last Change	Last Access
Imagery	22.2 MB	22.2 MB	5	0	63.6 %	10/8/2010	10/8/2010
large1.aux	0.2 MB	0.2 MB	1	0	1.0 %	10/8/2010	10/8/2010
large1.jpg	2.1 MB	2.1 MB	1	0	9.6 %	10/8/2010	10/8/2010
large1.jpg.aux.xml	0.0 MB	0.0 MB	1	0	0.0 %	10/8/2010	10/8/2010
large1.jpgw	0.0 MB	0.0 MB	1	0	0.0 %	10/8/2010	10/8/2010
large1.rrd	19.9 MB	19.9 MB	1	0	89.5 %	10/8/2010	10/8/2010
Shapefiles	0.2 MB	0.3 MB	39	0	0.5 %	9/25/2011	9/25/2011
Outfall_Area_Domain.dbf	0.0 MB	0.0 MB	1	0	0.0 %	1/28/2011	1/28/2011
Outfall_Area_Domain.sbn	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
Outfall_Area_Domain.sbx	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
Outfall_Area_Domain.shp	0.0 MB	0.0 MB	1	0	8.7 %	2/4/2011	2/4/2011
Outfall_Area_Domain.shp.xml	0.0 MB	0.0 MB	1	0	3.9 %	1/28/2011	1/28/2011
Outfall_Area_Domain.shx	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
Sediment_Bed_Domain.dbf	0.0 MB	0.0 MB	1	0	0.0 %	10/12/2010	10/12/2010
Sediment_Bed_Domain.sbn	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
Sediment_Bed_Domain.sbx	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
Sediment_Bed_Domain.shp	0.1 MB	0.1 MB	1	0	29.3 %	2/4/2011	2/4/2011
Sediment_Bed_Domain.shp.xml	0.0 MB	0.0 MB	1	0	0.5 %	10/12/2010	10/12/2010
Sediment_Bed_Domain_reprojected.dbf	0.0 MB	0.0 MB	1	0	0.1 %	9/25/2011	9/25/2011
Sediment_Bed_Domain_reprojected.prj	0.0 MB	0.0 MB	1	0	0.2 %	9/25/2011	9/25/2011
Sediment_Bed_Domain_reprojected.shp	0.1 MB	0.1 MB	1	0	29.3 %	9/25/2011	9/25/2011
Sediment_Bed_Domain_reprojected.shx	0.0 MB	0.0 MB	1	0	0.1 %	9/25/2011	9/25/2011
Shoreline.dbf	0.0 MB	0.0 MB	1	0	0.1 %	10/8/2010	10/8/2010
Shoreline.prj	0.0 MB	0.0 MB	1	0	0.2 %	10/8/2010	10/8/2010
Shoreline.sbn	0.0 MB	0.0 MB	1	0	0.1 %	10/8/2010	10/8/2010
Shoreline.sbx	0.0 MB	0.0 MB	1	0	0.1 %	10/8/2010	10/8/2010
Shoreline.shp	0.0 MB	0.0 MB	1	0	13.9 %	10/12/2010	10/12/2010
Shoreline.shp.xml	0.0 MB	0.0 MB	1	0	5.7 %	10/8/2010	10/8/2010
Shoreline.shx	0.0 MB	0.0 MB	1	0	0.1 %	10/12/2010	10/12/2010
transect_60_single.dbf	0.0 MB	0.0 MB	1	0	0.2 %	2/4/2011	2/4/2011
transect_60_single.prj	0.0 MB	0.0 MB	1	0	0.2 %	2/4/2011	2/4/2011
transect_60_single.sbn	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
transect_60_single.sbx	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
transect_60_single.shp	0.0 MB	0.0 MB	1	0	0.5 %	2/4/2011	2/4/2011
transect_60_single.shp.xml	0.0 MB	0.0 MB	1	0	5.5 %	2/4/2011	2/4/2011
transect_60_single.shx	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
transect7.dbf	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
transect7.sbn	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
transect7.sbx	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
transect7.shp	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
transect7.shx	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
transect9.dbf	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
transect9.sbn	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
transect9.sbx	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
transect9.shp	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
transect9.shx	0.0 MB	0.0 MB	1	0	0.1 %	2/4/2011	2/4/2011
[Files]	12.6 MB	12.6 MB	14	0	35.9 %	2/18/2011	2/18/2011
density_sediment_data_Depth.gwc	0.0 MB	0.0 MB	1	0	0.3 %	11/17/2010	11/17/2010
EA_Sediment_bath_Depth1.geo	0.0 MB	0.0 MB	1	0	0.0 %	10/13/2010	10/13/2010
geo_including_water3.geo	3.5 MB	3.5 MB	1	0	28.2 %	10/8/2010	10/8/2010
gmf_with_ocean_and_land.gmf	4.6 MB	4.6 MB	1	0	36.9 %	10/7/2010	10/7/2010
gmf_withoutoceanandland2.gmf	4.0 MB	4.0 MB	1	0	31.8 %	9/24/2010	9/24/2010
Reduced_sediment_data_BulkDensity_112...	0.0 MB	0.0 MB	1	0	0.3 %	11/24/2010	11/24/2010
reduced_sediment_data_Depth_TotalDDT...	0.0 MB	0.0 MB	1	0	0.3 %	11/24/2010	11/24/2010

Name ▲	Size	Allocated	Files	Folders	% of Parent	Last Change	Last Access
reduced_sediment_data_Depth_TotalDDTc...	0.0 MB	0.0 MB	1	0	0.4 %	11/24/2010	11/24/2010
Reduced_sediment_data_TotalDDTCompu...	0.0 MB	0.0 MB	1	0	0.3 %	11/24/2010	11/24/2010
Reduced_sediment_data_TotalDDTs_1124...	0.0 MB	0.0 MB	1	0	0.3 %	11/24/2010	11/24/2010
Reduced_sediment_ppDDD_OC_only_De...	0.0 MB	0.0 MB	1	0	0.4 %	10/19/2010	10/19/2010
Reduced_sediment_ppDDE_OC_only_De...	0.0 MB	0.0 MB	1	0	0.4 %	10/19/2010	10/19/2010
Reduced_sediment_TotalPCBs_and_OC_...	0.0 MB	0.0 MB	1	0	0.4 %	1/26/2011	1/26/2011
Sediment_Levels2.geo	0.0 MB	0.0 MB	1	0	0.0 %	2/18/2011	2/18/2011

TreeSize Free Report, 10/24/2011 6:38 PM

V 2.5

C:\Work\Sundance Environmental\Palos Verdes\Model Output Files\ on [OS]

Drive: C:\ Size: 905,695.8 MB Used: 242,682.5 MB Free: 663,013.2 MB 4096 Bytes per Cluster (NTFS)

This Folder: Size: 280.4 MB Allocated: 280.4 MB Percent of Drive: 0 % Files: 25 Folders: 3

Name ▲	Size	Allocated	Files	Folders	% of Parent	Last Change	Last Access
4D Files	95.7 MB	95.7 MB	11	0	34.1 %	6/14/2011	6/14/2011
All_Analytes_Plotted_24_Frames.4d	19.2 MB	19.2 MB	1	0	20.1 %	10/12/2010	10/12/2010
Bathymetry_with_LandSurface.4d	3.1 MB	3.1 MB	1	0	3.2 %	10/7/2010	10/7/2010
EA_SedimentBedThickness_withTOC.4d	10.5 MB	10.6 MB	1	0	11.0 %	10/8/2010	10/8/2010
Geological_Framework1.4d	5.2 MB	5.2 MB	1	0	5.4 %	9/28/2010	9/28/2010
Total_DDT_Semivariogram_3D_CloudPlot....	0.0 MB	0.0 MB	1	0	0.0 %	10/15/2010	10/15/2010
totalddt_compounds_exploded_at_carmen...	10.3 MB	10.3 MB	1	0	10.7 %	6/13/2011	6/13/2011
totalddt_exploded_at_carmens_isolevels2_...	10.3 MB	10.3 MB	1	0	10.7 %	5/13/2011	5/13/2011
totalddts_oc_exploded bydepth.4d	10.2 MB	10.2 MB	1	0	10.7 %	6/14/2011	6/14/2011
totalDDTS_slicedat60mbathymetry.4d	8.4 MB	8.4 MB	1	0	8.8 %	6/13/2011	6/13/2011
totalPCBS_ExplodedbyDepthwAerial.4d	10.1 MB	10.1 MB	1	0	10.6 %	6/13/2011	6/13/2011
totalpcbs_slicedat60mbathymetry.4d	8.4 MB	8.4 MB	1	0	8.7 %	6/14/2011	6/14/2011
4D Viewer	8.3 MB	8.3 MB	1	0	3.0 %	9/16/2011	9/16/2011
4D_Viewer_Install.exe	8.3 MB	8.3 MB	1	0	100.0 %	9/16/2011	9/16/2011
Field Files (EnterVol)	176.4 MB	176.4 MB	13	0	62.9 %	10/5/2011	10/5/2011
drydensity.efb	18.1 MB	18.1 MB	1	0	10.2 %	1/31/2011	1/31/2011
reduced_compound_list_formass_calc.efb	32.0 MB	32.0 MB	1	0	18.1 %	2/2/2011	2/2/2011
total_ddtcompounds_regulargeologybound...	19.7 MB	19.7 MB	1	0	11.2 %	2/21/2011	2/21/2011
total_ddtcompounds_regulargeologybound...	20.4 MB	20.4 MB	1	0	11.6 %	10/5/2011	10/5/2011
total_ddts_regular_geology_adaptivekriged...	19.9 MB	19.9 MB	1	0	11.3 %	5/13/2011	5/13/2011
total_ddts_regulargeologyboundfactor2-Plu...	19.5 MB	19.5 MB	1	0	11.1 %	5/13/2011	5/13/2011
total_ddts_within_fake_geologiclayers2.efb	19.1 MB	19.1 MB	1	0	10.8 %	2/18/2011	2/18/2011
total_pcbs_regulargeologyboundfactor2.efb	19.7 MB	19.7 MB	1	0	11.2 %	2/21/2011	2/21/2011
totalpcbcompounds_oc-Plume-Plume6.efb	0.0 MB	0.0 MB	1	0	0.0 %	5/18/2011	5/18/2011
totalpcbcompounds-FenceCut.efb	1.5 MB	1.5 MB	1	0	0.9 %	5/13/2011	5/13/2011
totalpcbcompounds-FenceCut-Explode.efb	1.5 MB	1.5 MB	1	0	0.9 %	5/13/2011	5/13/2011
totalpcbcompounds-Plume2.efb	5.0 MB	5.0 MB	1	0	2.8 %	5/18/2011	5/18/2011
totalpcbcompounds-Plume2-Plume12.efb	0.1 MB	0.1 MB	1	0	0.0 %	5/18/2011	5/18/2011

ATTACHMENT B: FIGURES

Attachment B. Figures for Review of CDM Palos Verdes Shelf MVS Contaminant Mass Modeling

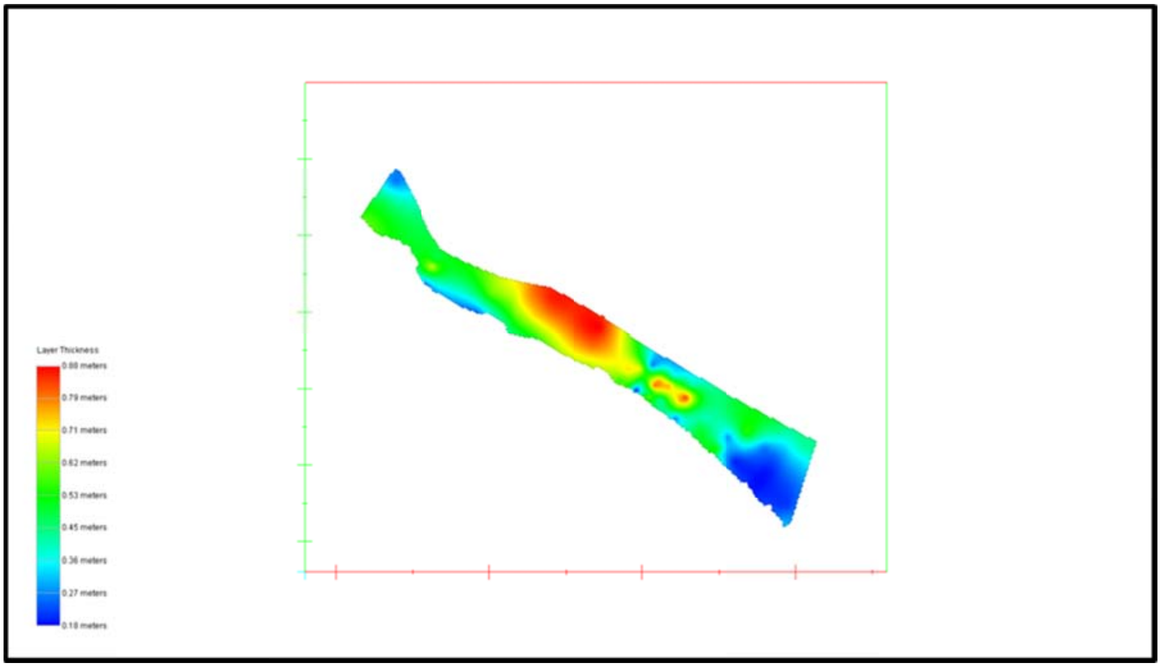


Figure 1. CDM EA sediment bed thickness, m.

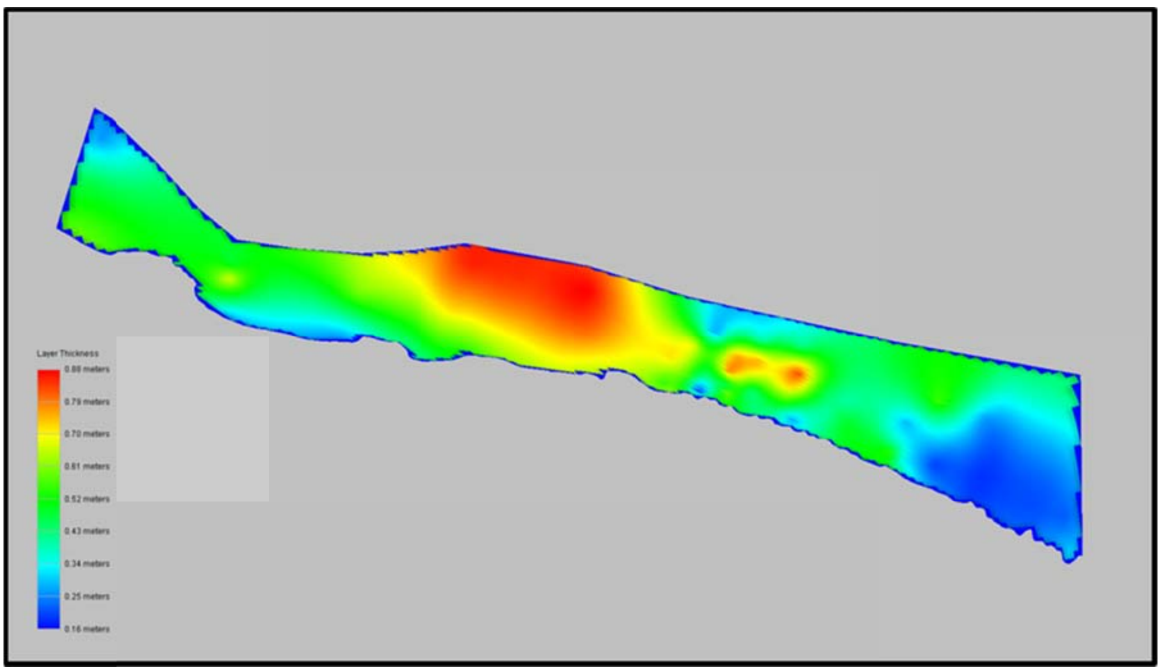


Figure 2. Sundance EA sediment bed thickness, m.

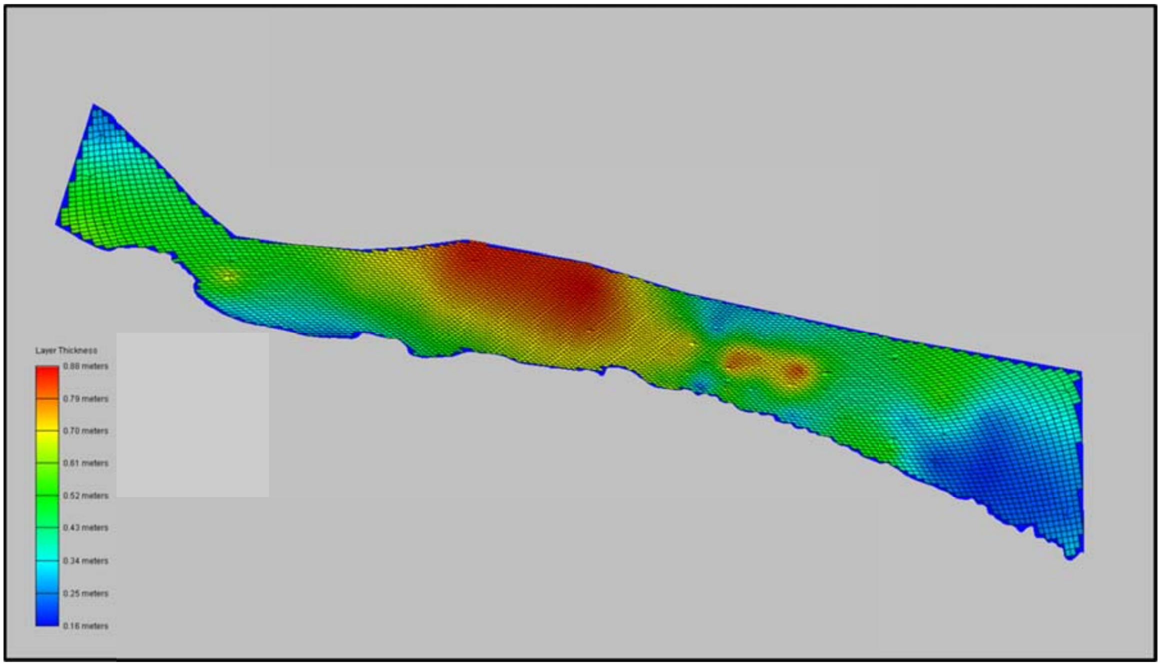


Figure 3. **Sundance EA sediment bed thickness showing MVS adaptive grid.**

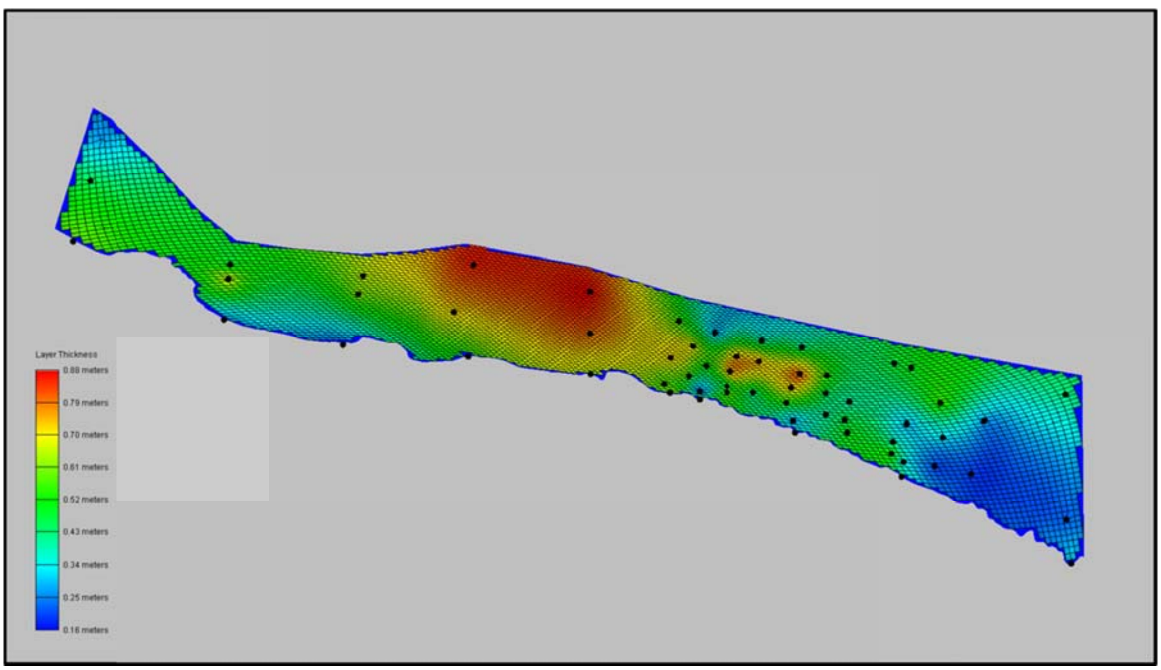


Figure 4. **Sundance EA sediment bed thickness showing MVS adaptive grid and location of BA/OA sediment samples on adaptive grid.**

MVS Parameters	Sundance	CDM
Xres	**144**	**371**
Yres	**114**	**142**
Zres	**35**	**44**
Gridding	**Adaptive**	**Finite Difference**
Variography	**MVS Expert System**	**Preset**
Replicates	**Not Included**	**Averaged**
Max-gap	**0.01 m**	**1.00 m**

Figure 5. MVS Parameters for Sundance and CDM Models

Table 10 - Mass of COCs Based on Model Output
Fall 2009 Sediment Sampling Program
Palos Verdes Shelf (OU 5 of the Montrose Chemical Corp. Superfund Site)
Los Angeles County, California

	o,p'-DDD	*o,p'-DDE*	*o,p'-DDT*	*p,p'-DDD*	*p,p'-DDE*	*p,p'-DDT*	*Total DDTs*	*p,p'-DDMU*	*p,p'-DDNU*	*Total DDT Compounds*	*Total PCBs*
Baseline											
Total bed	290	1,900	120	1,300	9,700	530	14,000	5,200	940	20,000	1,000
0-8 cm interval	36	210	16	190	1,200	63	1,700	410	71	2,200	110
Outfall area											
Total bed	150	930	33	920	5,000	310	7,300	1,200	330	8,800	460
0-8 cm interval	19	110	5.8	140	600	37	910	210	33	1,200	58

Abbreviations
cm - Centimeter

Notes
1. All values are in kilograms and were rounded to two significant figures.
2. For results reported as non-detected, a value of 5 ug/kg was used.
3. The baseline modeled area was 30 km^2. The outfall modeled area was 11 km^2.
4. The volume of the baseline modeled grid was 15 million m^3.
5. The volume of the 0-8 cm interval as modeled was 2.3 million m^3.

Figure 6. CDM MVS-Based Mass Calculations in Current Report (Table 10):

Run	X res	Y res	Z res	Adaptive gridding	Proportional gridding	Anisotropy	Max-gap	Preclip min	Preclip max	Postclip min	Postclip max	LT Multiplier	DL	Analyte	Analyte Density	Dry Density	Mass, mt
1	144	114	35	Yes	Yes	1000:1	0.005	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	0.7843	8.1
2	144	114	35	Yes	Yes	1000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	0.7843	8.1
3	144	114	35	Yes	Yes	1000:1	0.020	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	0.7843	8.1
4	144	114	35	Yes	Yes	2000:1	0.005	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	0.7843	10.8
5	144	114	35	Yes	Yes	2000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	0.7843	10.8
6	144	114	35	Yes	Yes	2000:1	0.020	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	0.7843	10.7
7	144	114	35	Yes	Yes	2000:1	1.000	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	0.7843	10.7
8	144	114	35	Yes	Yes	10000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	0.7843	14.7

Figure 7. Sundance MVS-based Mass Calculations for Sensitivity Analysis.

Method 1: Variable concentration and constant density.

Mean Dry Density (g/cm^3)		
Data	1.1131	
Sundance	1.1355	Kriged
CDM	0.7843	Kriged

Run	X res	Y res	Z res	Adaptive gridding	Proportional gridding	Anisotropy	Max-gap	Preclip min	Preclip max	Postclip min	Postclip max	LT Multiplier	DL	Analyte	Analyte Density	Dry Density	Mass, kg	Mean Mass , kg
9	144	114	35	Yes	Yes	500:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1131	8,005	
10	144	114	35	Yes	Yes	1000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1131	11,492	
11	144	114	35	Yes	Yes	2000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1131	15,265	11,587
12	144	114	35	Yes	Yes	500:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1355	8,166	
13	144	114	35	Yes	Yes	1000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1355	11,723	
14	144	114	35	Yes	Yes	2000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1355	15,572	11,820
15	144	114	35	Yes	Yes	500:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	0.7843	5,641	
16	144	114	35	Yes	Yes	1000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	0.7843	8,097	
17	144	114	35	Yes	Yes	2000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	0.7843	10,756	8,165

Median Dry Density (g/cm^3)		
Data	1.1543	
Sundance	1.1618	Kriged
CDM	0.8258	Kriged

Run	X res	Y res	Z res	Adaptive gridding	Proportional gridding	Anisotropy	Max-gap	Preclip min	Preclip max	Postclip min	Postclip max	LT Multiplier	DL	Analyte	Analyte Density	Dry Density	Mass, kg	Mean Mass , kg
18	144	114	35	Yes	Yes	500:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1543	8,302	
19	144	114	35	Yes	Yes	1000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1543	11,917	
20	144	114	35	Yes	Yes	2000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1543	15,830	12,016
21	144	114	35	Yes	Yes	500:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1618	8,356	
22	144	114	35	Yes	Yes	1000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1618	11,994	
23	144	114	35	Yes	Yes	2000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1618	15,932	12,094
24	144	114	35	Yes	Yes	500:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	0.8258	5,939	
25	144	114	35	Yes	Yes	1000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	0.8258	8,525	
26	144	114	35	Yes	Yes	2000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	0.8258	11,325	8,596

Method 3: Variable concentration and variable density independently kriged and both fields multiplied via MVS “data_math” before “Volumetrics” calculation.

Full Spatially Varying Dry Density

Run	X res	Y res	Z res	Adaptive gridding	Proportional gridding	Anisotropy	Max-gap	Preclip min	Preclip max	Postclip min	Postclip max	LT Multiplier	DL	Analyte	Analyte Density	Dry Density	Mass, kg	Mean Mass , kg
27	144	114	35	Yes	Yes	500:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	-------	7,572	
28	144	114	35	Yes	Yes	1000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	-------	10,538	
29	144	114	35	Yes	Yes	2000:1	0.010	0.10	1.00E+09	1.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	-------	13,795	10,635

Figure 8. Sundance MVS-based mass calculations for p,p’-DDE.

Method 2: Variable concentration and variable density data multiplied together and the product kriged.

Run	X res	Y res	Z res	Adaptive gridding	Proportional gridding	Anisotropy	Max-gap	Preclip min	Preclip max	Postclip min	Postclip max	LT Multiplier	DL	Analyte	Analyte Density	Dry Density	Mass, kg	Mean Mass , kg
30	144	114	35	Yes	Yes	500:1	0.010	0.001	1.00E+09	0.50	1.00E+07	1.00	0.50	PCB	1.5930	------	266	
31	144	114	35	Yes	Yes	1000:1	0.010	0.001	1.00E+09	0.50	1.00E+07	1.00	0.50	PCB	1.5930	------	524	
32	144	114	35	Yes	Yes	2000:1	0.010	0.001	1.00E+09	0.50	1.00E+07	1.00	0.50	PCB	1.5930	------	962	584

Method 3: Variable concentration and variable density independently kriged and both fields multiplied via MVS "data_math" before "Volumetrics" calculation.

Run	X res	Y res	Z res	Adaptive gridding	Proportional gridding	Anisotropy	Max-gap	Preclip min	Preclip max	Postclip min	Postclip max	LT Multiplier	DL	Analyte	Analyte Density	Dry Density	Mass, kg	Mean Mass , kg
33	144	114	35	Yes	Yes	500:1	0.010	0.001	1.00E+09	0.50	1.00E+07	1.00	0.50	PCB	1.5930	------	294	
34	144	114	35	Yes	Yes	1000:1	0.010	0.001	1.00E+09	0.50	1.00E+07	1.00	0.50	PCB	1.5930	------	554	
35	144	114	35	Yes	Yes	2000:1	0.010	0.001	1.00E+09	0.50	1.00E+07	1.00	0.50	PCB	1.5930	------	996	615

Figure 9. Sundance MVS-based mass calculations for Total PCBs

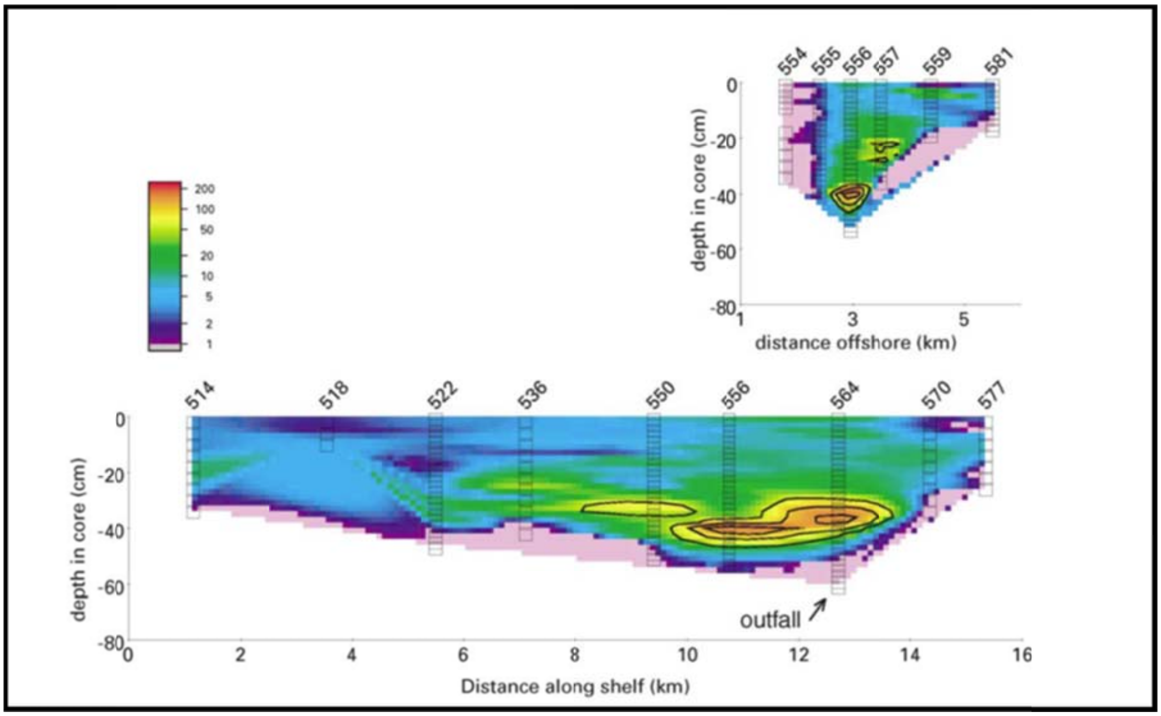


Figure 10. p,p'-DDE concentrations shown in Let, et al. (2002).

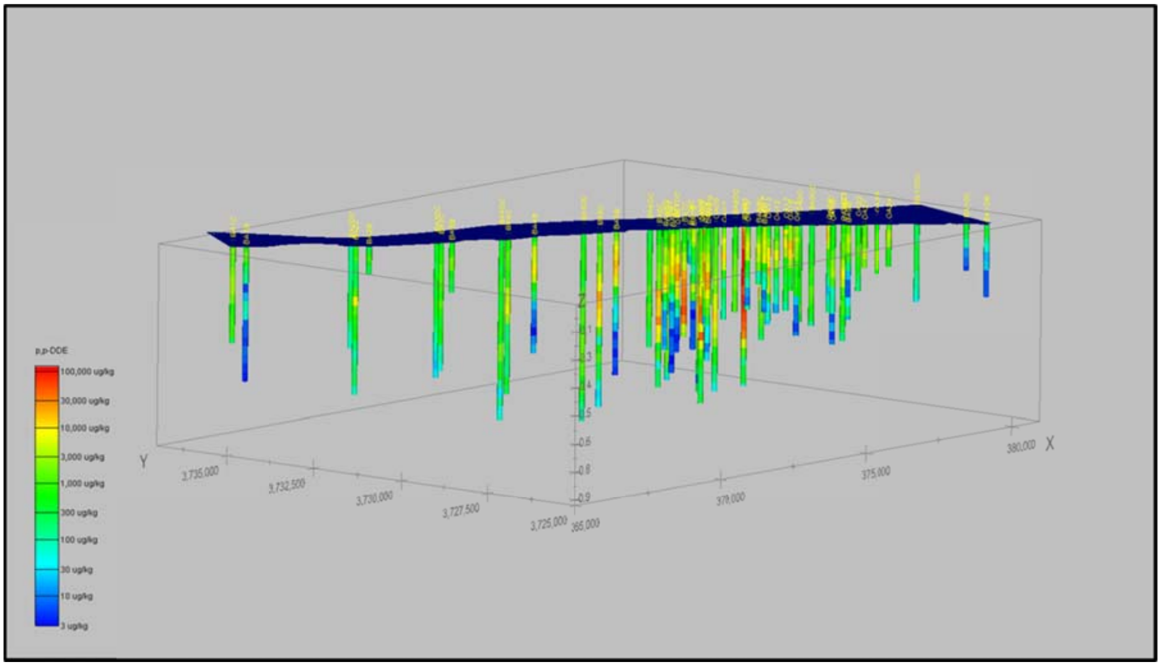


Figure 11. 2009 p,p'-DDE sediment sample concentrations (vertical exaggeration = 5,000:1). Note that 1 ppm (Lee, et al. 2002) corresponds to 1,000 μg/kg. Most concentrations in 2009 are below 1,000 μg/kg (greens to dark blue on legend).

Method 1: Variable concentration and constant density.

Run	X res	Y res	Z res	Adaptive gridding	Proportional gridding	Anisotropy	Max-gap	Preclip min	Preclip max	Postclip min	Postclip max	LT Multiplier	DL	Analyte	Analyte Density	Soil Density	Mass, kg
36	144	114	35	Yes	Yes	500:1	0.010	0.001	1.00E+09	1000.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1131	21,144
37	144	114	35	Yes	Yes	1000:1	0.010	0.001	1.00E+09	1000.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1131	23,911
38	144	114	35	Yes	Yes	2000:1	0.010	0.001	1.00E+09	1000.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1131	26,420
39	144	114	35	Yes	Yes	500:1	0.010	0.001	1.00E+09	1000.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1543	21,927
40	144	114	35	Yes	Yes	1000:1	0.010	0.001	1.00E+09	1000.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1543	24,796
41	144	114	35	Yes	Yes	2000:1	0.010	0.001	1.00E+09	1000.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	1.1543	27,398

Method 3: Variable concentration and variable density independently kriged and both fields multiplied via MVS "data_math" before "Volumetrics" calculation.

Run	X res	Y res	Z res	Adaptive gridding	Proportional gridding	Anisotropy	Max-gap	Preclip min	Preclip max	Postclip min	Postclip max	LT Multiplier	DL	Analyte	Analyte Density	Soil Density	Mass, kg
42	144	114	35	Yes	Yes	500:1	0.010	0.001	1.00E+09	1000.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	-------	20,913
43	144	114	35	Yes	Yes	1000:1	0.010	0.001	1.00E+09	1000.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	-------	23,291
44	144	114	35	Yes	Yes	2000:1	0.010	0.001	1.00E+09	1000.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	-------	25,441
44	144	114	35	Yes	Yes	10,000:1	0.010	0.001	1.00E+09	1000.00	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	-------	28,364

Figure 12. Sundance MVS computation of p,p'-DDE mass estimates assuming minimum 2009 concentration was 1,000 μg/kg (1ppm).

Technical Memorandum – January 12, 2012

Sundance MVS-based Analysis of 1992 Palos Verdes Shelf p,p'-DDE Mass

Objectives:

1. Using 1992 PV Shelf sediment core concentrations for p,p'-DDE perform mass estimates following Sundance's MVS-based approach to analyzing the 2009 PV Shelf core data previously demonstrated.

2. Compare estimated 1992 p,p'-DDE mass based on the 2009 sediment bed domain to the 2009 p,p'-DDE mass estimates.

3. Compare estimated 1992 p,p'-DDE mass based on the 2009 sediment bed domain to the 1992 p,p'-DDE mass estimates based on the convex hull of the 1992 core locations.

Figure 1 shows the point locations of the 1992 PV Shelf p,p'-DDE core samples superimposed on the polygon representing the 2009 effluent affected (EA) sediment bed domain. Figure 2 is the thickness map of the 2009 EA sediment bed calculated as part of the previously presented analysis of the 2009 PV Shelf mass. Table 1 shows the comparison between the 1992 PV Shelf p,p'-DDE core samples and the 2009 PV Shelf p,p'-DDE core samples. There was roughly one-third the number of 2009 concentration estimates available for 1992 PV Shelf p,p'-DDE mass estimates. However, concentrations were higher in the 1992 data set than in the 2009 data set.

Parameters	1992	2009
No. of Samples	288	842
Max core depth (m)	0.60	0.88
Min p,p'-DDE (μg/L)	56	2.98
Max p,p'-DDE (μg/L)	180,000	127,000
Min dry density (g/cm^3)	0.20	0.67
Max dry density (g/cm^3)	1.69	1.60
Mean dry density (g/cm^3)	0.90	1.11
Median dry density (g/cm^3)	0.88	1.15

Table 1. Comparison of 1992 and 2009 p,p'-DDE datasets.

Figure 3 shows the distribution, concentration, and spatial orientation of the 1992 PV Shelf p,p'-DDE core samples. Sundance estimated the 1992 PV Shelf p,p'-DDE mass that would have been in the 2009 sediment bed domain using the identical MVS parameters employed in the 2009 data analysis to ensure compatibility and to provide an "apples to apples" mass estimate comparison between these two data sets. Table 2 shows the Sundance MVS parameters used for the original 2009 and then the 1992 p,p'-DDE mass estimates.

MVS Parameters	1992	2009
Xres	144	144
Yres	114	114
Zres	35	35
Gridding	Adaptive	Adaptive
Variography	MVS Expert System	MVS Expert System
Replicates	None	Not Included
Max-gap	0.01 m	0.01 m

Table 2. MVS parameters for 1992 and 2009 p,p'-DDE datasets, respectively.

As discussed in the Technical Memorandum presenting the 2009 PV Shelf p,p'-DDE mass estimates there are three approaches within MVS for calculating constituent mass based on the following equation as implemented in the MVS "Volumetrics" module.

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

There are three (3) methods, or approaches, in MVS to mass calculations.

Method 1: Variable concentration (i.e., kriged plume) and constant density.

Method 2: Variable concentration and variable density data multiplied together and the product kriged.

Method 3: Variable concentration and variable density independently kriged and both fields multiplied via MVS "data_math" before "Volumetrics" calculation.

Mass calculation accuracy increases from Method 1 to Method 3 but so does computational effort.

Only **Method 3** (the most accurate method) was applied to the analysis of the 1992 PV Shelf p,p'-DDE data.

In a similar fashion to the 2009 PV Shelf MVS-based mass estimates the sensitivity of the mass calculations to the MVS parameters max-gap and horizontal to vertical anisotropy were determined for the 1992 p,p'-DDE data. First, the anisotropy was held constant and max-gap was varied as 0.005 m, 0.01 m, and 0.02 m. Table 3 shows that the PV Shelf p,p'-DDE mass estimates for the 1992 data set are virtually insensitive to the value of max-gap within a reasonable range of values. Consequently, max-gap was set at 0.01 m for all 1992 PV Shelf p,p'-DDE mass calculations.

1992 Full Spatially Varying Dry Density w 2009 Sediment Bed Thickness

X res	Y res	Z res	Adaptive gridding	Proportional gridding	Anisotropy	Max-gap	Preclip min	Preclip max	Postclip min	Postclip max	LT Multiplier	DL	Analyte	Analyte Density	Dry Density	Mass, kg
144	114	35	Yes	Yes	500:1	0.005	0.10	1.00E+09	0.20	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	Variable	38,529
144	114	35	Yes	Yes	500:1	0.010	0.10	1.00E+09	0.20	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	Variable	38,499
144	114	35	Yes	Yes	500:1	0.020	0.10	1.00E+09	0.20	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	Variable	38,457

Table 3. Analysis of impact of max-gap on 1992 p,p'-DDE mass calculations.

On the other hand as is shown in Table 4 below the MVS-based mass estimate for 1992 PV Shelf p,p'-DDE is very sensitive to the value of horizontal to vertical anisotropy selected. Horizontal to vertical anisotropy values of 500:1. 1,000:1, 2,000:1, and 5,000:1 were considered. This range spans an order of magnitude in anisotropy and therefore should provide a reasonable range within which to evaluate the resultant mass of 1992 p,p'-DDE contained in the 2009 EA sediment bed domain.

1992 Full Spatially Varying Dry Density w 2009 Sediment Bed Thickness

X res	Y res	Z res	Adaptive gridding	Proportional gridding	Anisotropy	Max-gap	Preclip min	Preclip max	Postclip min	Postclip max	LT Multiplier	DL	Analyte	Analyte Density	Dry Density	Mass, kg
144	114	35	Yes	Yes	500:1	0.010	0.10	1.00E+09	0.20	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	Variable	38,499
144	114	35	Yes	Yes	1000:1	0.010	0.10	1.00E+09	0.20	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	Variable	40,394
144	114	35	Yes	Yes	2000:1	0.010	0.10	1.00E+09	0.20	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	Variable	43,486
144	114	35	Yes	Yes	5000:1	0.010	0.10	1.00E+09	0.20	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	Variable	53,069

Table 4. Analysis of impact on anisotropy on 1992 p,p'-DDE mass estimates.

Table 4 shows the final estimated values of 1992 p,p'-DDE mass in the 2009 sediment bed volume for the four different levels of horizontal to vertical anisotropy. The results are graphed in Figure 4 against the estimates of 2009 p,p'-DDE mass in the same volume of sediment (i.e., 2009 EA sediment bed). One can see in Figure 4 that in each anisotropy case there was a threefold to fourfold difference between the 1992 p,p'-DDE mass and the 2009 p,p'-DDE mass estimated for the same volume of sediment.

MVS was also used to estimate the 1992 p,p'-DDE mass that occupies the convex hull of the 1992 data set. The convex hull may be imagined as stretching a rubber band so that it surrounds the entire set of points and then releasing it, allowing it to contract; when it becomes taut, it encloses the convex hull of the points. Figure 5 shows the convex hull of the 1992 p,p'-DDE sediment samples plus a small buffer around the points. Figure 5 also shows the thickness of the 1992 p,p'-DDE sediment samples which creates the volume of the convex hull within which MVS estimates mass. Figure 6 shows a comparison between the 2009 EA sediment bed (purple) and the 1992 data convex hull. Even though the area of the 1992 convex hull is larger than the area of the 2009 EA sediment bed (36.3 km^2 vs. 29.8 km^2) the volume of the 1992 convex hull is less than that of the 2009 EA sediment bed ($1.2X10^7$ m^3 vs. $1.5X10^7$ m^3) due to the shorter sediment cores in the 1992 p,p'-DDE data set.

The following set of MVS parameters was used in kriging the 1992 p,p'-DDE and dry density (Table 5). The Xres and Yres values were selected to maintain the grid cells as nearly square as possible.

MVS Parameters	1992 Convex Hull
Xres	174
Yres	100
Zres	35
Gridding	Adaptive
Variography	MVS Expert System
Replicates	None
Max-gap	0.01 m

Table 5. MVS grid resolution and kriging parameters for 1992 p,p'-DDE convex hull mass estimates.

The MVS mass calculations for 1992 p,p'-DDE in the 1992 data convex hull are shown below (Table 6) for the same range of horizontal to vertical anisotropy previously used. Figure 7 shows the results of the 1992 p,p'-DDE mass estimates for the 1992 convex hull (blue) compared to the results shown above for the 1992 p,p'-DDE mass estimates for the 2009 EA sediment bed. There is less mass associated with the 1992 convex hull due to the difference in the overall volume of sediment (Figure 6) in which the mass is calculated. Even so, there is still greater mass estimated for the 1992 p,p'-DDE convex hull than for the 2009 p,p'-DDE mass estimates.

1992 Full Spatially Varying Dry Density w 1992 Sediment Bed Thickness

X res	Y res	Z res	Adaptive gridding	Proportional gridding	Anisotropy	Max-gap	Preclip min	Preclip max	Postclip min	Postclip max	LT Multiplier	DL	Analyte	Analyte Density	Dry Density	Mass, kg
174	100	35	Yes	Yes	500:1	0.010	0.10	1.00E+09	0.20	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	Variable	26,354
174	100	35	Yes	Yes	1000:1	0.010	0.10	1.00E+09	0.20	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	Variable	28,245
174	100	35	Yes	Yes	2000:1	0.010	0.10	1.00E+09	0.20	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	Variable	31,545
174	100	35	Yes	Yes	5000:1	0.010	0.10	1.00E+09	0.20	1.00E+07	1.00	1.00	p,p'-DDE	1.5060	Variable	37,235

Table 6. 1992 p,p'-DDE mass estimates for 1992 p,p'-DDE convex hull.

Finally, all 1992 and 2009 p,p'-DDE MVS-based mass estimates are plotted in Figure 8.

The Sundance analysis of p,p'-DDE mass provides a visual demonstration of the effect of horizontal to vertical anisotropy on the mass calculations. Figure 3 shows the distribution of 1992 p,p'-DDE data. The highest concentrations (red) are near the bottom of the cores near the center of the distribution. Two examples of the MVS kriged 1992 p,p'-DDE distribution of concentration are show in Figure 9 for the horizontal to vertical anisotropy end members (i.e., 500:1 and 5,000:1). The views are from the bottom of the model looking upward in order to see the effect of the anisotropy on the high concentrations. The top image in Figure 9 is for anisotropy equal to 500:1 and the bottom image in Figure 9 is for anisotropy equal to 5,000:1. Note the greater "smearing" of higher concentrations (red) in the bottom image around the sample points with the higher anisotropy. This leads to greater mass in the resulting mass estimates.

Conclusions:

1. For all MVS-based p,p'-DDE mass calculations p,p'-DDE total mass is greater for 1992 data vs. 2009 data. Core sample concentrations are greater in 1992 than in 2009 even though there are fewer samples.

2. 1992 MVS calculated p,p'-DDE mass is greater for the 2009 sediment bed domain than for the 1992 convex hull. Although 1992 convex hull area is larger the volume is smaller due to more shallow 1992 core depths than 2009 core samples.

3. In all cases the selection of horizontal to vertical anisotropy ratio significantly affects the resultant mass estimate.

Figures:

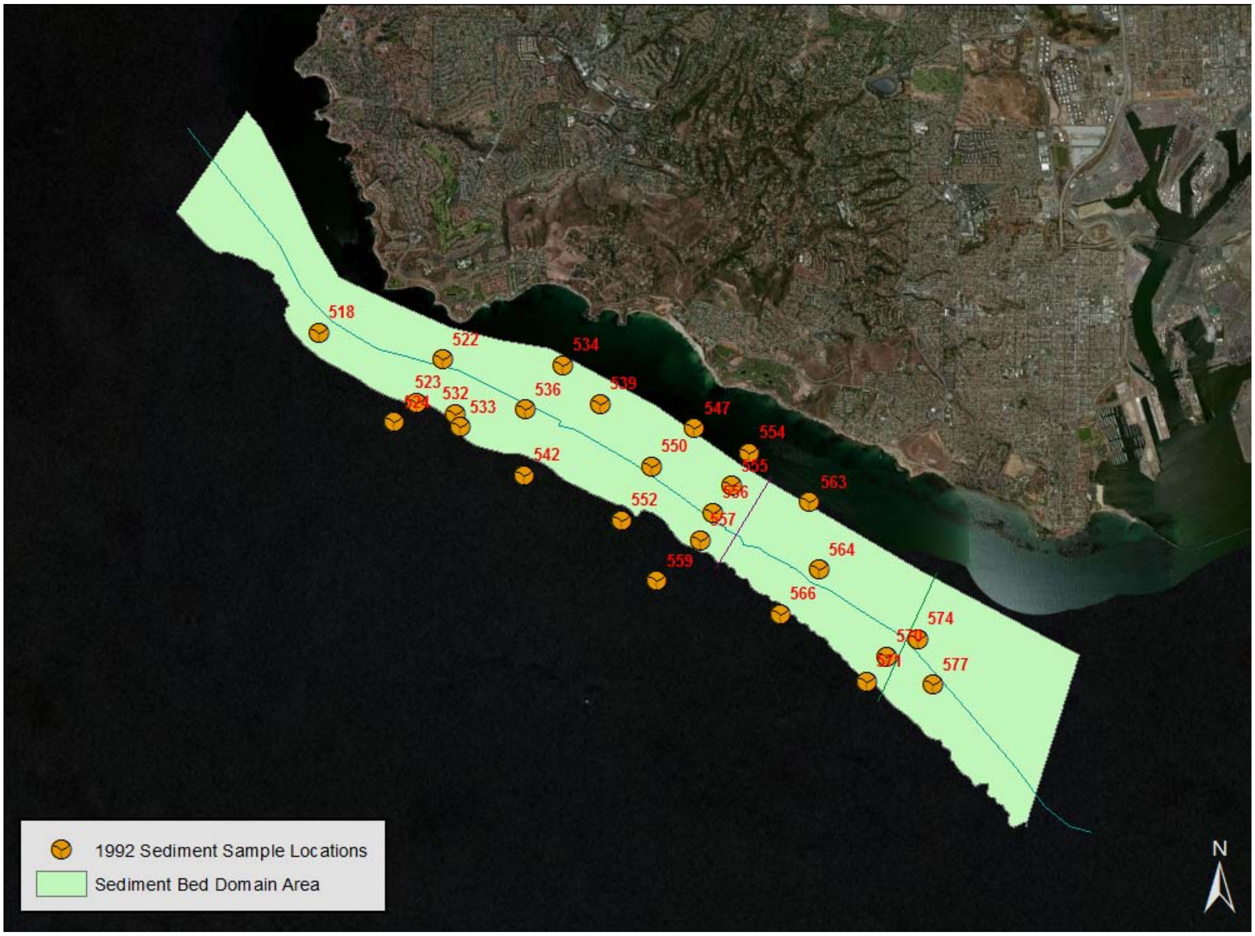


Figure 1. Locations of 1992 PV Shelf core samples and the 2009 sediment bed domain.

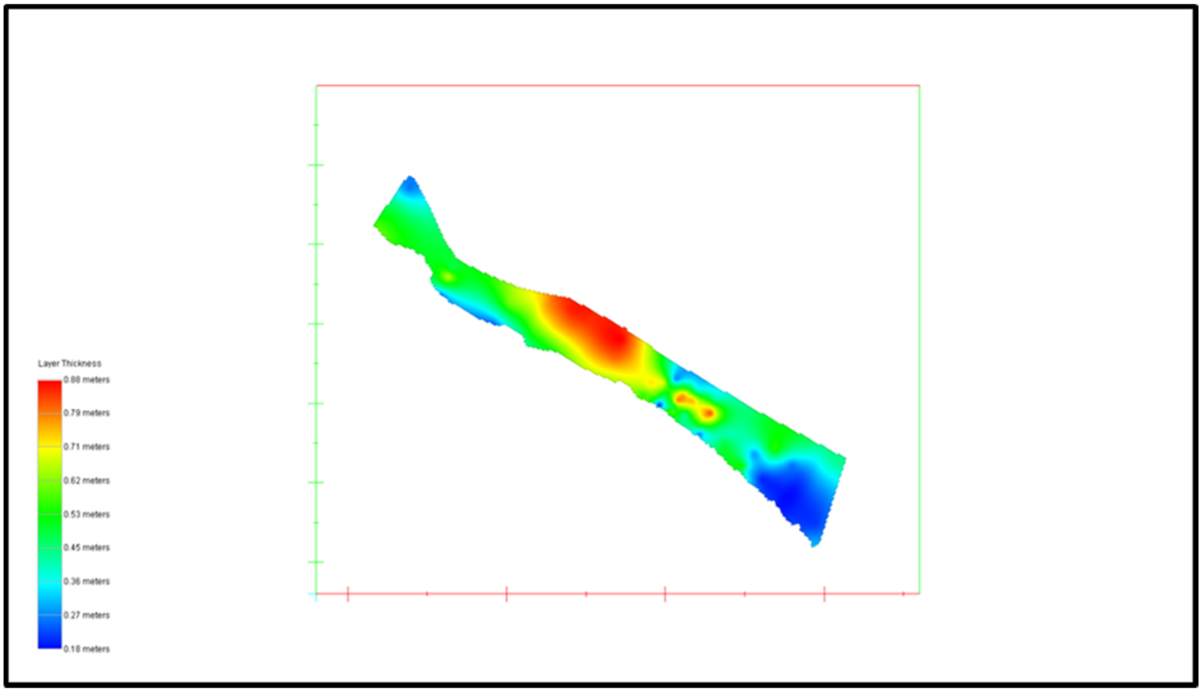


Figure 2. EA sediment bed thickness based on 2009 sediment bed domain.

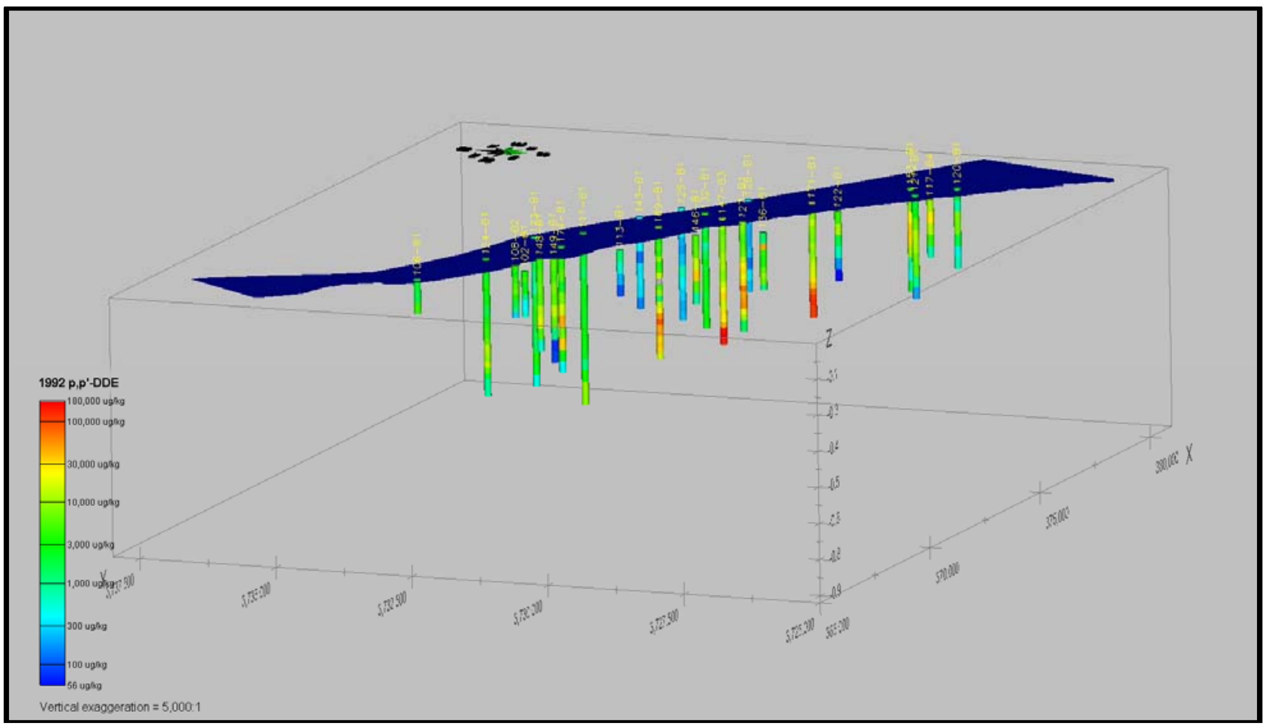


Figure 3. 1992 p,p'-DDE sediment core concentrations.

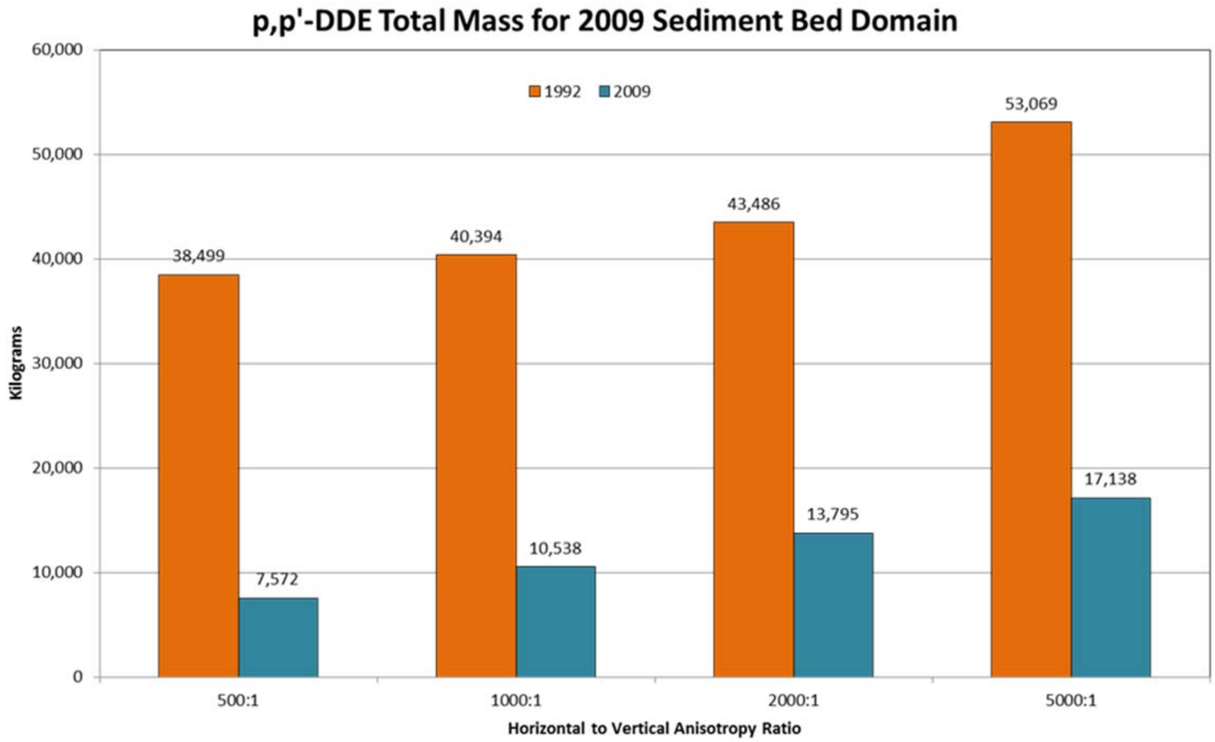


Figure 4. 1994 p,p'-DDE mass compared to 2009 p,p'-DDE mass in 2009 EA sediment bed domain.

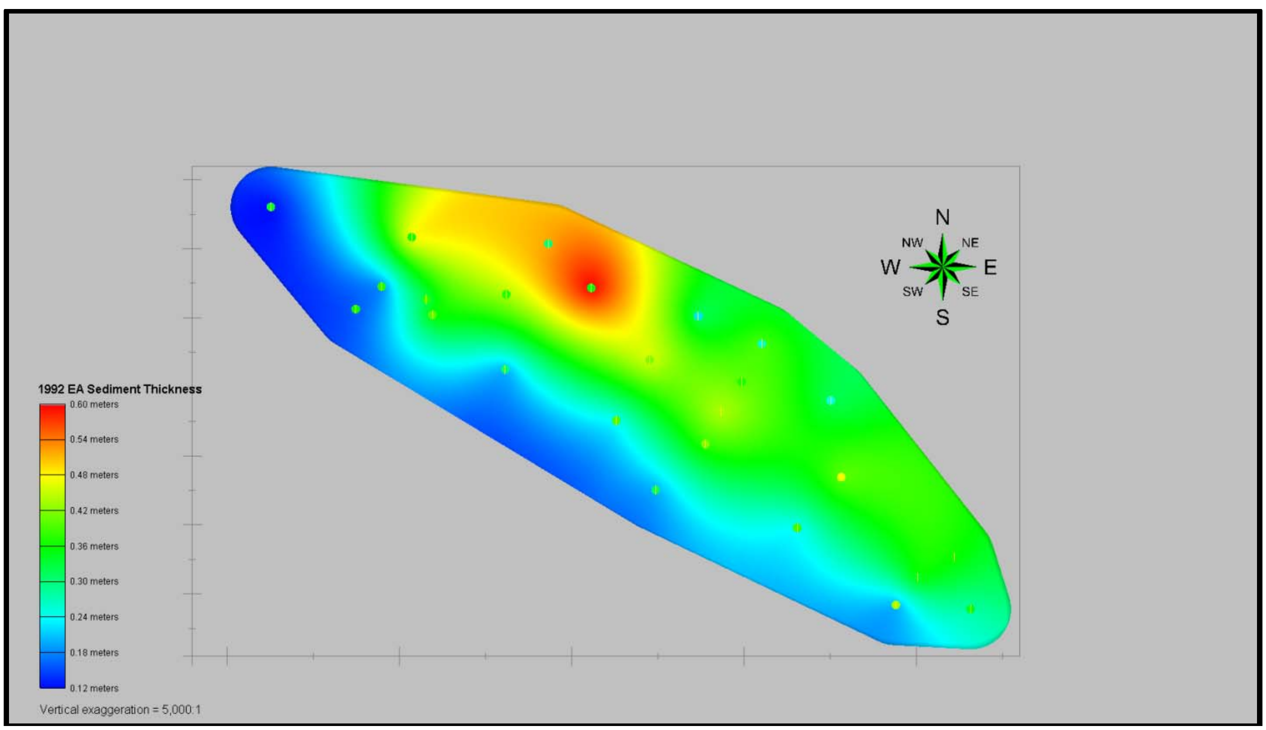


Figure 5. Convex hull of 1992 core samples plus buffer.

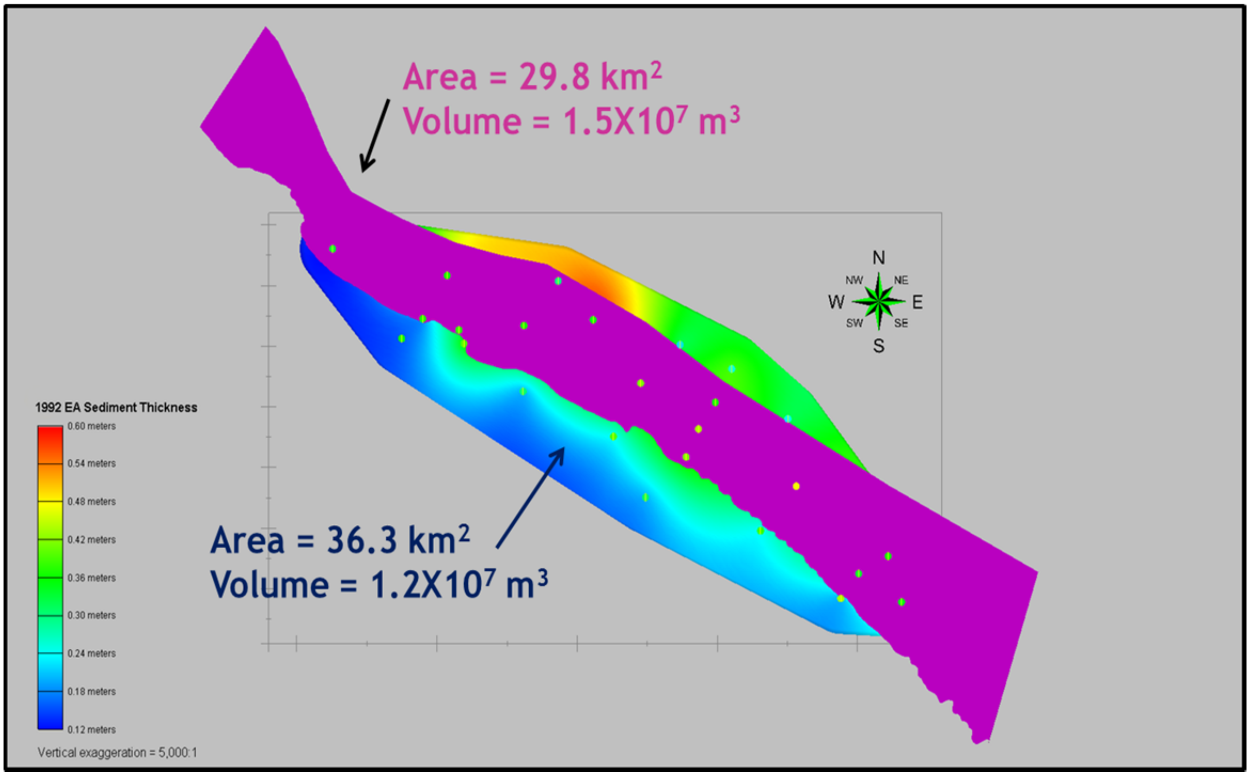


Figure 6. 1992 convex hull vs. 2009 sediment bed domain.

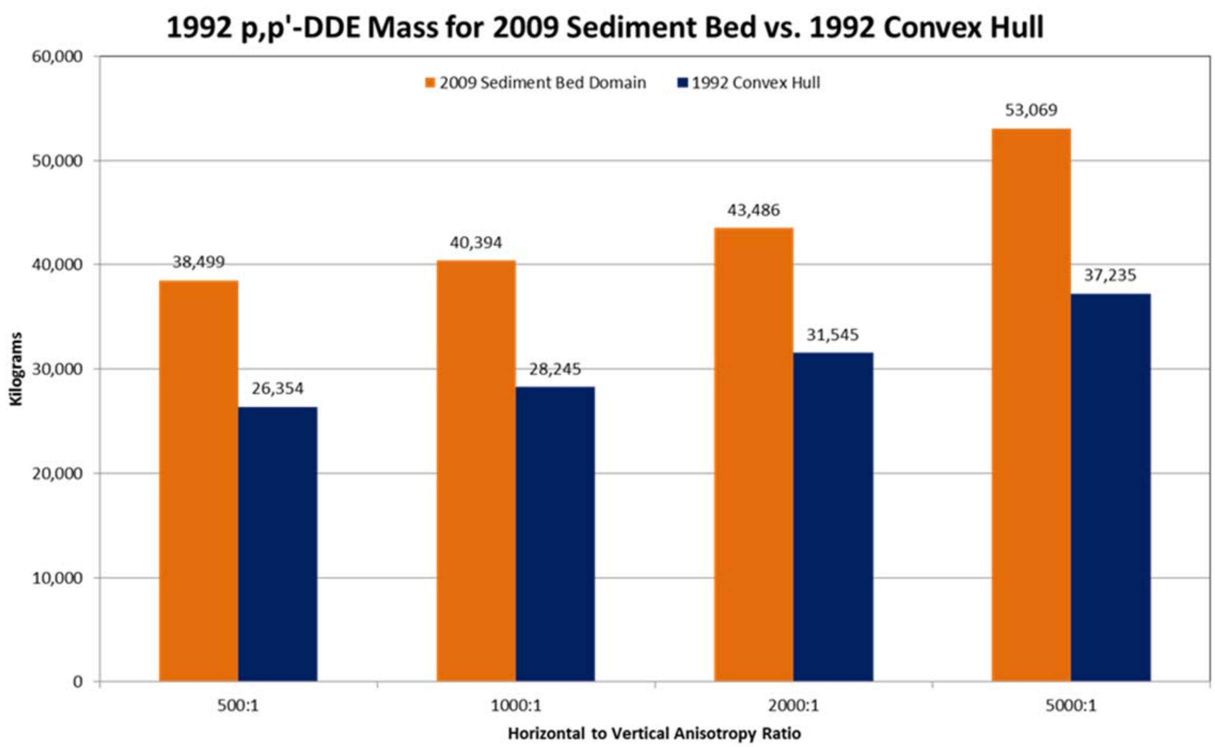


Figure 7. Comparison of 1992 p,p'-DDE mass in 2009 sediment bed vs. 1992 p,p'-DDE in convex hull.

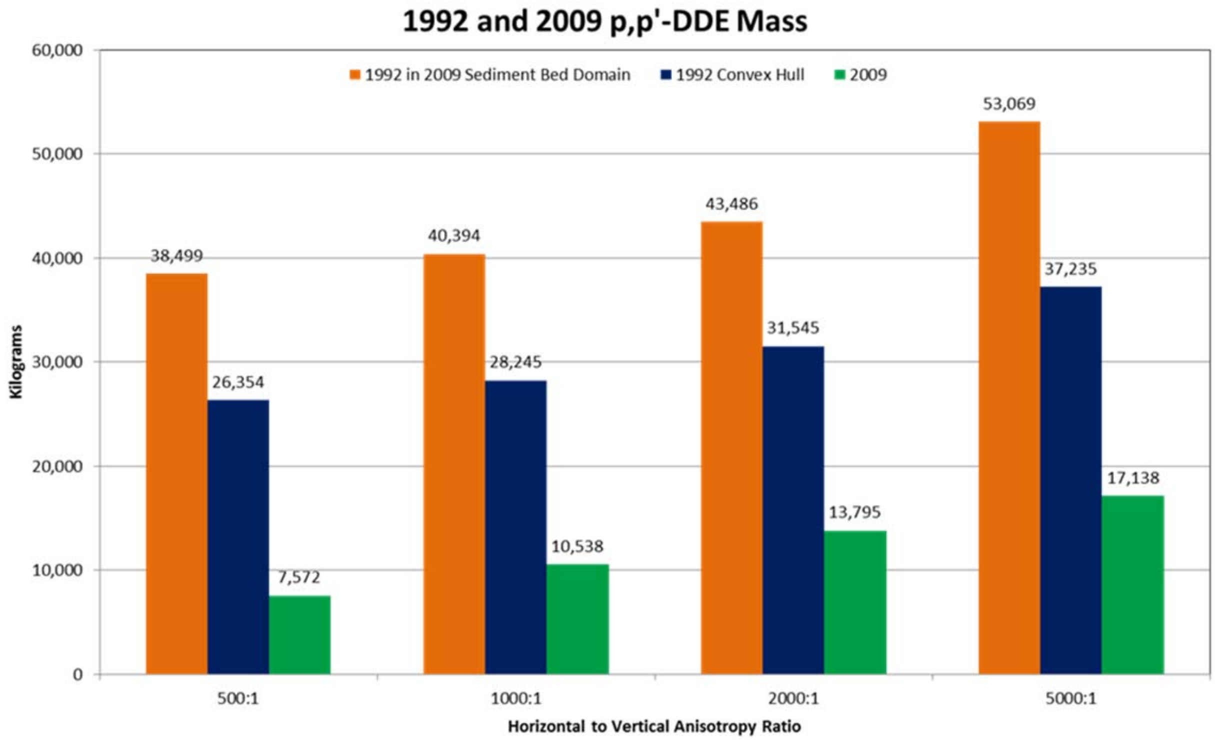


Figure 8. Comparison of 1992 p,p'-DDE MVS mass estimates with 2009 p,p'-DDE MVS mass estimates.

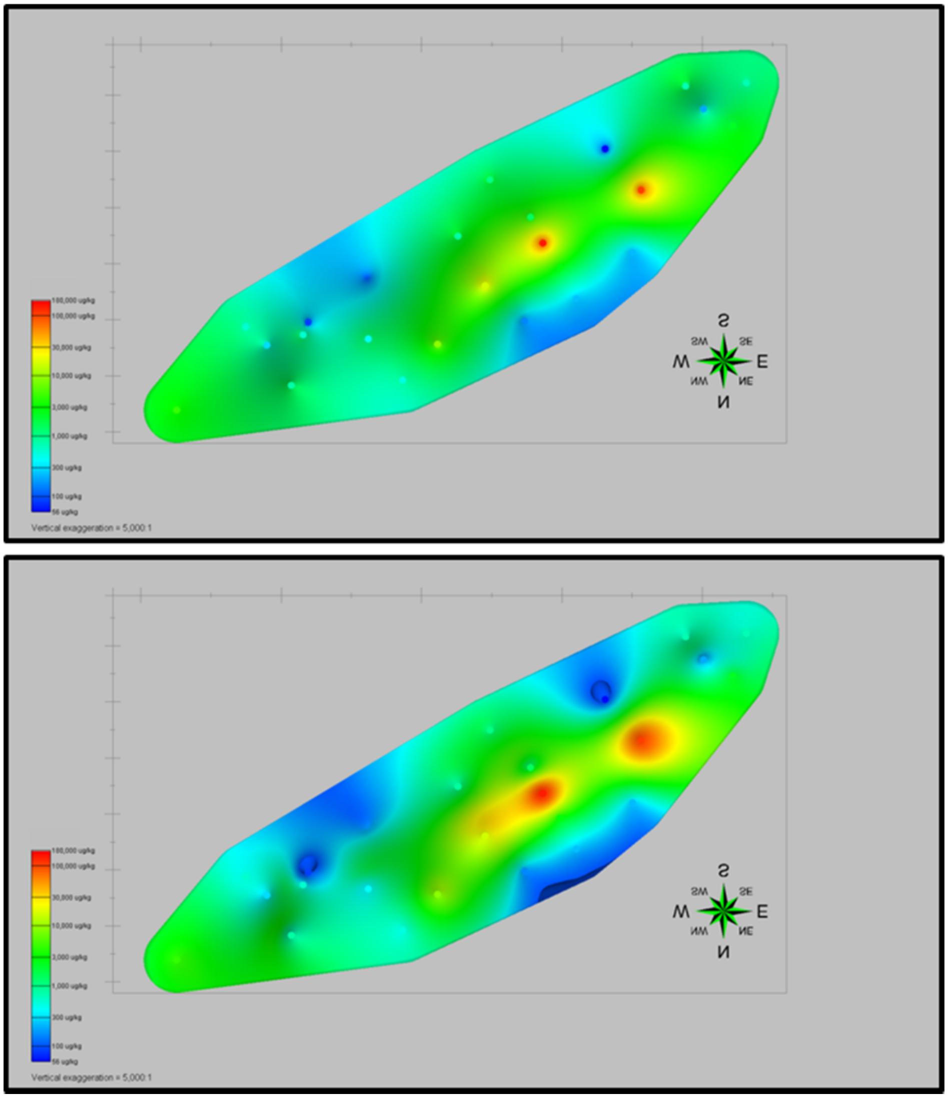


Figure 9. Effect of anisotropy on MVS mass calculations.