APPENDIX B

MEMORANDUM, EROSION SEDIMENT AND POLLUTANT YIELD ESTIMATES FOR OUTFALL 008 WATERSHED AND ISRA PEAS (GEOSYNTEC, 2009)

Geosyntec consultants

Memorandum

Date: April 24, 2009

To: Alex Fischl, MWH & Jeremy Hilliard, CH2M HILL

Cc: Lori Blair, The Boeing Company

From: Brandon Steets & Jejal Bathi, Geosyntec Consultants

Subject: Estimates of Erosion Sediment and Pollutant Yield for Outfall 008 & 009 Watershed ISRA PEAs

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Introduction:

Stormwater runoff from The Boeing Company's (Boeing) Santa Susana Field Laboratory (SSFL) is currently regulated by the Los Angeles Regional Water Quality Control Board (Regional Board) through the December 2007 National Pollutant Discharge Elimination System (NPDES) Permit No. R4-2007-055, as well as the December 2007 Cease and Desist Order (CDO) No. R4-2007-056 for Outfalls 008 and 009 specifically. In December 2008, the Regional Board issued a California Water Code Section 13304 Cleanup and Abatement Order (CAO), which requires soil cleanup in the CDO watersheds 008 and 009 to address sources of stormwater constituents of concern (COCs). The CAO, referred to hereafter as the Interim Source Removal Action (ISRA) order, also requires Boeing to submit two work plans -- the first being due February 15, 2009 and the second due May 1, 2009 -- describing plans to develop and select the appropriate treatment technologies to be used during source removal, including identification and delineation of the lateral and vertical extents of contamination in the soil. **This memorandum is intended to provide Boeing and MWH with estimates of sediment and pollutant yield from Preliminary ISRA Evaluation Areas (ISRA PEAs) in the Outfall 008 and 009 watersheds to support the development of the May 1 ISRA Work Plan.**

The Outfall 008 and 009 watersheds comprise approximately 600 acres combined and include several RCRA Facility Investigation (RFI) areas. Historic stormwater discharge monitoring at each outfall has demonstrated elevated constituent concentrations relative to 2007 NPDES Permit benchmark values, indicating a potential to exceed these thresholds when final permit limits become effective and enforceable. For instance, for trace metals, copper, mercury, and lead at Outfall 008 and cadmium, copper, mercury, and lead at Outfall 009 have been measured in some historic samples at concentrations above the 2007 NPDES Permit benchmarks. For organics, dioxins (as TCDD toxic equivalents or TEQ) have been measured at both Outfalls 008 and 009 in some historic samples at concentrations above the NPDES Permit benchmarks. Several of the above listed pollutants are specifically identified in the ISRA Order as COCs for Outfalls 008 and 009.

The stated objective of the ISRA order is to improve surface water quality within the Outfall 008 and 009 watersheds by identifying, evaluating, and remediating areas of contaminated soil in order to eliminate the COCs that exceed NPDES permit benchmarks. A Preliminary ISRA Work Plan was prepared by MWH and CH2MHILL (CH2M) in February 2009 on behalf of Boeing and the National Aeronautics and Space Administration (NASA). This preliminary ISRA Work Plan presented the approach used to identify and control the release of COCs to surface water within the Outfall 008 and Outfall 009 watersheds. As a part of development of proposed ISRA Areas within the Outfall 008 and 009 watersheds, ISRA PEAs were identified based on an evaluation of soil monitoring data for COCs and are presented in the Preliminary ISRA Work Plan (MWH, 2009).

The Outfall 008 watershed has seven identified ISRA PEAs (per e-mail communication with MWH). The identified PEAs are labeled as PEA-CYN-1, PEA-DRG-1, PEA-HVS-1, PEA-HVS-2A, PEA-HVS-2B, PEA-HVS-2C and PEA-HVS-3, and are shown in Figure 1. The Outfall 009 watershed has two identified PEAs (per e-mail communication with CH2M), and are labeled as PEA-ELV-1C and PEA-ELV-1D, as shown in Figure 2. Based on recent communication with CH2M (on April 21th 2009), delineation sampling has not been completed for PEA-ELV-1C and thus, there is currently a “proposed” and “potential” boundary to the site. For this analysis, estimated results are presented for both the proposed and potential boundaries of PEA-ELV-1C.

This technical memorandum presents the estimate of potential annual erosion sediment (and associated pollutants) yield[1], based on the Revised Universal Soil Loss Equation (RUSLE), from the Outfall 008 and Outfall 009 watershed ISRA PEAs, and from the entire Outfall 008 and Outfall 009 watersheds for comparison. This information may be used to support ISRA work plan development and cleanup planning by providing quantitative estimates of sediment erosion and associated pollutant yields from each of the proposed PEAs. All the modeled estimates shown in the memorandum are based on the approach, assumptions and limitations described in this memorandum, and hence are subject to a reasonable degree of uncertainty.

Sediment Yield Model Selection:

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[1] For the purpose of this report, the term “yield” is used to describe sediment and pollutant mass fluxes associated with erosion (as calculated by RUSLE methodology), while the term “load” is used to describe suspended sediment and pollutant mass fluxes associated with stormwater runoff discharges.

The amount of erosion from a particular land surface can be determined from complex interrelations of several factors. These factors include the erosive forces of rainfall and runoff, and the soil resistance to detachment and transport. Erosion Risk Management Tool (ERMPiT), Water Erosion Prediction Project (WEPP), and RUSLE are commonly-used mathematical models for predicting sediment yields. As described in the ERMiT model user's manual (USDA, 2007), ERMiT predicts the sediment yield for individual rain events unlike most erosion prediction models, which typically have "average annual erosion" as output. ERMiT is a web-based application that predicts erosion in probabilistic terms on burned and recovering forest, range, and chaparral lands, with and without the application of mitigation treatments. ERMiT combines weather variability with spatial and temporal variability of soil properties to model the range of post-fire erosion rates that are likely to occur. WEPP is also used to estimate soil loss per rain event. The greatest limitation of the WEPP model is the complex array of variables that must be estimated and entered by the user; this often requires a significant level of effort to gather the ground data in order to use this model effectively (Jones, 2001). RUSLE on the other hand, developed originally for agricultural catchments, is a simple static approach with a long history of usage for estimating average annual erosion sediment yields. Data for factors in the RUSLE model are well established for different regions of the United States. Unlike ERMiT and WEPP, RUSLE predicts sediment yields only on an annual basis, rather than for individual rain events. As discussed, each of these models has their own advantages and disadvantages. As with any model, validating the predictions with site-specific information will ultimately improve the accuracy of the analysis.

In this report, potential erosion sediment yield is estimated based on the RUSLE predictions. The main reason for choosing RUSLE over other models is because it was previously used to predict sediment yields from watersheds 008 and 009 at the site, and hence all parameters required for modeling this and other ISRA PEAs are readily available. Details on prior RUSLE modeling for the Outfall 008 and 009 watersheds can be found in the "Boeing SSFL Stormwater ENTS for Watersheds 008 and 009, Hydrology Report" prepared by Geosyntec Consultants (2008)[2]. Some of the sediment yield results presented in this report have since been revised.

RUSLE Methodology and Key Assumptions:

RUSLE is a revision to the Universal Soil Loss Equation (USLE), an empirical method for quantifying erosion potential originally developed by the United States Department of

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[2] The sediment yield results presented in this memo differ from those presented in the ENTS Hydrology Report due to two reasons: (1) this analysis, which looked at smaller sediment-generating areas, required more finely-resolved spatial data to estimate LS factor values, therefore Ventura County's 10 ft LIDAR dataset was used instead of the 10m USGS DEM; and (2) this analysis, which required greater accuracy to allow for comparison between smaller study areas, required removal of exposed bedrock, paved and rooftop areas to more accurately estimate erosion rates by setting the K factor value to zero at these locations.

Agriculture (USDA) from more than 10,000 plot-years of basic runoff and soil-loss data contributed from 49 locations in the United States (Renard., et al. 1997). Although originally developed for application to areas of agricultural land uses, the USLE is now believed to be applicable wherever numerical values of its factors are available. The RUSLE includes analyses of data not available when the USLE was developed including the basic principles of soil loss due to raindrop impact, overland flow, and rill-erosion processes (Toy, 1998). For instance, earthquakes and wildfire are not directly accounted for in RUSLE, though these factors impact soil erosion processes within the seismically active chaparral environment of the Santa Susana Mountains (USGS, 1996; Sampson, 1944). The actual annual tonnage of soil erosion immediately after a wildfire or earthquake resulting in a landslide would be greater than the RUSLE estimates used in this analysis. Also, RUSLE calculations technically reflect the mass of potentially eroded materials only and do not account for deposition (e.g., atmospheric) within the catchment. Finally, RUSLE calculations, and the input datasets on which they're based, do not account for exposed bedrock, developed, and other impervious areas which likely contribute little to no erosion sediment by comparison, nor do they account for unstable drainage channels (banks and bottoms) which may contribute additional downstream sediment through hydromodification and natural erosion processes. However, to account for this former effect, exposed bedrock and developed areas were delineated as a part of this analysis and subtracted from the areas contributing to erosion sediment yield.

RUSLE estimates long-term annual average soil loss (A, tons/acre/year) from raindrop splash and runoff from specific field slopes based on five parameters:

$$A = R * K * LS * C * P$$

Where: R = Rainfall-Runoff Erosivity Factor, K = Soil Erodibility Factor, LS = Slope Length-Steepness Factor, C = Cover Management Factor, and P = Support Practice Factor.

R factor: It quantifies the effect of raindrop impact and also reflects the amount and rate of runoff likely to be associated with precipitation events. The R-factor is calculated as total storm energy (E) times the maximum 30-minute intensity (I30), or EI, and is expressed as the rainfall erosion index.

K factor: It is the rate of soil loss per rainfall erosion index unit as measured on a standard plot. It represents the average long-term response of a specific soil and its profile to the combined effects of rainfall, runoff, and infiltration. It is expressed as the change in the soil loss per unit of applied external force or energy.

LS factor: It represents a ratio of soil loss under given conditions to that at a site with the standard slope steepness of 9% and slope length of 72.6 feet. The steeper and longer the slope, the higher is the risk for erosion.

C factor: The C-factor is used to reflect the effect of management practices on erosion rates. The RUSLE program user can easily compare the relative impacts of management options by making changes in the C-factor to reflect grazing impact or burning.

P factor: The P-factor is the ratio of soil loss with a specific support practice to the corresponding loss with upslope and downslope tillage.

GIS-Based Approach and RUSLE Calculation Results:

A GIS raster-based approach was used to do the RUSLE calculations for the PEAs. Rasters of 10 foot by 10 foot pixel size were created for the topographic (LS) and soil erodibility (K) parameters in the RUSLE equation. R, C and P factors were assumed to be constant. The two spatially-variable parameter rasters and three constants were then multiplied together (per the RUSLE equation) using the Raster Calculator function of Spatial Analyst. The result is a raster containing values representative of the average annual soil loss in tons/acre/year for each 100 square foot pixel. This raster was then weighted for pixel size, yielding a raster with each pixel value representing tons of sediment per year. Values were summed for each PEA area as well as the entire Outfall 008 watershed. A bulk density conversion factor of 2000 tons/AF was used to convert between volumetric and weight-based results.

Parameter values for each input raster were estimated based on published values and/or methods. Table 1 summarizes the parameter estimates for the identified PEAs as well as for the entire Outfall 008 and 009 watersheds. Note that multiplying the five factors in Table 1 will not result in the listed Sediment Yield values due to the fact that the calculation must also incorporate spatial heterogeneity within the catchments. It is acknowledged that a significant percentage of the watershed area is associated with impervious areas (such as exposed bedrock, existing building structures and paved parking areas) and these areas are assumed to not contribute to erosion sediment yield. To account for this, such areas were assigned a K factor value of zero in the GIS input grid so that the RUSLE sediment yield result for these areas is also zero. Figures 3 and 4 show the spatially-varying RUSLE parameters for the Outfall 008 and 009 watersheds, respectively. Table 2 presents the estimated sediment yield for the identified PEAs and the percentage of erosion sediments that these PEAs are contributing to the annual sediment yields from corresponding entire Outfall 008 and 009 watersheds. Figures 5 and 6 show the estimated sediment yield rates for entire Outfall 008 and 009 watersheds. As shown on these figures, the estimated sediment yield rates have high spatial variability within the watersheds, which is caused by high spatial variability of RUSLE parameters, especially LS factor values. Also, to demonstrate the impacts of input parameter variability on the RUSLE calculations, a sensitivity analysis for the Outfall 008 watershed is provided in Table3.

In the Outfall 008 watershed, all PEAs are estimated to have comparable annual erosion sediment yield rates other than PEA-CYN-1 which has very low sediment yield due to low K (due to exposed bedrock) and LS (due to flat slope) factor values. For each modeled PEA in the Outfall 008 watershed, the percentage of total watershed annual sediment yield is very low, or <1 %. **Combined, about 1% (14 tons/year) of the annual sediment yield from the entire Outfall 008 watershed is estimated to be contributed by the PEAs.**

Similar to the Outfall 008 watershed, all PEAs in the Outfall 009 watershed contributed comparable sediment yields, with the percentage of total watershed annual sediment yield for each PEA again being very low, or <<1 %. Even when combined, both PEAs in the Outfall 009 watershed are estimated to contribute <<1% of the annual sediment yield from the entire watershed. All PEAs in both watersheds have lower average sediment yield rates (i.e., tons/acre/year) than the average yield rate from the entire watershed; this is due to the PEAs being located in flatter areas with lower erodability (occasionally due to presence of exposed bedrock).

Table 1. Summary of RUSLE Parameter Values

ISRA PEA	Mean K Factor[1]	Mean LS Factor[2]	R Factor[3]	C Factor[4]	P Factor[5]
Outfall 008 Watershed					
PEA-CYN-1	0.08	0.11	50	0.1	1
PEA-DRG-1	0.55	4.0	50	0.1	1
PEA-HVS-1	0.55	3.7	50	0.1	1
PEA-HVS-2A	0.55	4.6	50	0.1	1
PEA-HVS-2B	0.40	4.6	50	0.1	1
PEA-HVS-2C	0.55	5.0	50	0.1	1
PEA-HVS-3	0.51	5.0	50	0.1	1
Entire Outfall 008 Watershed	**0.48**	**7.2**	**50**	**0.1**	**1**
Outfall 009 Watershed					
PEA-ELV-1C (Proposed)	0.15	1.3	50	0.1	1
PEA-ELV-1C (Potential)	0.19	2.0	50	0.1	1
PEA-ELV-1D	0.28	6.7	50	0.1	1
Entire Outfall 009 Watershed	**0.38**	**5.5**	**50**	**0.1**	**1**

[1] Source: U.S. Department of Agriculture, Natural Resources Conservation Service, SSURGO Database, 2008

[2] Source: Ouyang D. and J. Bartholic, 2001

[3] Source: USEPA, 2001.

[4] Source: http://cobweb.ecn.purdue.edu/~sedspec/sedspec/doc/usleapp.doc

[5] Parameter not applicable to this site

Table 2. RUSLE Estimated Sediment Yields

ISRA PEA	Area (acres)	Average Annual Sediment Yield (AF/year)	Average Annual Sediment Yield (tons/year)[1]	Average Sediment Yield Rate (tons/acre/year)	Percentage of Watershed Annual Sediment Yield
Outfall 008 Watershed					
PEA-CYN-1	0.032	0.000001	0.0012	0.036	0.0001%
PEA-DRG-1	0.039	0.00020	0.405	11	0.039%
PEA-HVS-1	0.081	0.00039	0.80	9.9	0.077%
PEA-HVS-2A	0.65	0.0039	8.04	12	0.77%
PEA-HVS-2B	0.21	0.00086	1.8	8.4	0.17%
PEA-HVS-2C	0.12	0.0008	1.6	14	0.16%
PEA-HVS-3	0.15	0.0009	1.8	12	0.18%
Entire Outfall 008 Watershed	**62**	**0.51**	**1000**	**17**	**---**
Outfall 009 Watershed					
PEA-ELV-1C (Proposed)	0.055	0.00003	0.0704	1.3	0.0012%
PEA-ELV-1C (Potential)	0.13	0.00015	0.307	2.5	0.0053%
PEA-ELV-1D	0.091	0.00043	0.88	9.6	0.015%
Entire Outfall 009 watershed	**536**	**2.9**	**5800**	**11**	**---**

[1] Sediment yield (tons/year) = Average annual sediment yield (AF/year) x Sediment bulk density (2000 tons/AF)

Sensitivity Analysis of RUSLE Sediment Yields:

As RUSLE estimates are based on the direct linear relationship between different parameters (R, K, LS, C and P) and sediments yields, varying these parameters values will affect the predicted sediment yields. As an example, Table 3 shows the reasonable range of R, K and LS factors for the Outfall 008 watershed and corresponding RUSLE sediment yield estimates; C and P factor are assumed to be constant across the watershed. With respect to the LS factor, the “low” and “high” LS values that are shown in the Table 3 are calculated based on 10 m USGS DEM and 10 ft LIDAR raster data, respectively, for the watershed, to demonstrate the effects of various input raster datasets on calculated sediment yield rates for the watershed. The results shown in Table 3 demonstrate that a reasonable range for average sediment yield rates for the 008 watershed is 7.3 to 24 tons/acre/year.

Table 3. Reasonable Range of Sediment Yields for the Outfall 008 Watershed

Parameter Range Value for Outfall 008 Watershed	R	K	LS	C	P	Sediment Yield Rate (tons/acre/yr)
Low	40	0.32	5.7	0.10	1.0	7.3
High	60	0.55	7.2			24

Pollutant Mass Associated with RUSLE Sediment Yield:

Table 4 presents the average annual pollutant yield associated with erosion sediment for the ISRA constituents of concern identified for the Outfall 008 watershed (copper, lead and dioxin) and identified for the Outfall 009 watershed (copper, lead, cadmium, mercury and dioxin) based on the soil background concentrations and RUSLE sediment yield estimates. The pollutant background concentrations (shown in Table 4) used in calculating the average annual pollutants yields were provided by MWH and were approved by the Department of Toxic Substances Control (DTSC) (MWH, 2005). These are the soil background concentrations used previously to develop the PEAs as part of the Preliminary ISRA Work Plan (MWH, 2009). Since average soil pollutants concentrations for the watershed could not be accurately determined, pollutant background concentrations and half of the background concentrations are used as a conservative measure for predicting the pollutant yields that accompany eroded sediment from the watershed.

The maximum concentration observed for the ISRA constituents of concern (COCs) in the Outfall 008 watershed PEAs (provided by MWH) and in the Outfall 009 watershed PEAs (provided by CH2M) are presented in Table 5. Maximum concentrations at each PEA are used to allow for a conservatively high estimate of PEA sediment pollutant yields as a percent of total watershed yields. Only those ISRA pollutants that were found to be present at each PEA at concentrations above background were included as COCs for these yield analyses. Pollutant yields associated with eroded sediment from individual PEAs are calculated using the RUSLE sediment yield for each PEA multiplied by soil pollutant maximum concentrations for each PEA. Table 5 also shows the calculated percentage of sediment pollutant yield that the individual PEAs are contributing to the total sediment pollutant yield from the respective entire watersheds.

For the Outfall 008 watershed, other than lead from PEA-HVS-2A, copper from PEA-HVS-2B, and dioxin from PEA-HVS-3 areas, all other PEAs, for all listed pollutant listed in Table 4, are estimated to contribute only small portions (<1 %) of the pollutants' total yield from the entire Outfall 008 watershed. Higher pollutant concentration in the soil samples from the PEA areas are causing higher percentage contributions of lead from PEA-HVS-2A, copper from PEA-HVS-2B, and dioxin from PEA-HVS-3.

For the Outfall 009 watershed, PEA-ELV-1C is estimated to contribute a considerable percentage of dioxin to the total yield from the entire watershed (1.2% - 10%), while PEA-ELV-1D, for all listed pollutants in Table 4, is estimated to contribute only small portions (<1 %) of the pollutants' total yield from the entire Outfall 009 watershed. Comparatively higher dioxin concentration in the soil samples from the PEA-ELV-1C are causing higher percentage contribution of dioxin from this area than the dioxin contribution from PEA-ELV-1D. It should be noted again however that these percentages are considered conservative because they assume background concentrations for the watershed and maximum concentrations for the PEAs.

Table 4. Estimated Annual Pollutant Yields Associated with Eroded Sediment

Pollutant (ISRA COCs)	**Soil Background Concentration (mg/kg)**	**Annual Sediment Pollutant Yield (kg/year)**	
		Based on Soil Background Concentration	**Based on 1/2 Soil Background Concentration**
Outfall 008 Watershed			
Copper	29	27	14
Lead	34	32	16
Dioxin	8.7E-07	8.2E-07	4.1E-07
Outfall 009 Watershed			
Copper	29	153	77
Lead	34	179	90
Cadmium	1	5.3	2.6
Mercury	0.09	0.47	0.24
Dioxin	8.7E-07	4.6E-06	2.3E-06

[1] Soil background values from MWH, 2005.

Table 5. Estimated Annual Pollutant Yields Associated with Eroded Sediment from PEAs

ISRA Area and ISRA COC	Soil Concentration[1] (mg/kg)	Average Annual Sediment Yield (tons/year)	Sediment Pollutant Load (kg/year)	% of Watershed Annual Sediment Pollutant Yield	
				Based on Soil Background Concentration	Based on 1/2 Soil Background Concentration
Outfall 008 Watershed					
PEA-CYN-1					
Lead	88	0.0012	0.0001	0.00029%	0.00057%
PEA-DRG-1					
Dioxin	3.3E-06	0.41	1.2E-09	0.15%	0.30%
PEA-HVS-1					
Lead	41	0.80	0.030	0.093%	0.19%
Dioxin	4.3E-06	0.80	3.1E-09	0.38%	0.76%
PEA-HVS-2A					
Lead	71	8.0	0.52	1.6%	3.2%
PEA-HVS-2B					
Copper	414	1.8	0.66	2.40%	4.8%
Lead	40	1.8	0.064	0.20%	0.40%
PEA-HVS-2C					
Lead	35	1.6	0.052	0.16%	0.32%
PEA-HVS-3					
Dioxin	9.8E-05	1.8	1.6E-07	19.74%	39.4%
Outfall 009 Watershed					
PEA-ELV-1C (Proposed)					
Dioxin	8.4E-04	0.071	5.4E-08	1.2%	2.4%
PEA-ELV-1C (Potential)					
Dioxin	8.4E-04	0.31	2.4E-07	5.1%	10%
PEA-ELV-1D					
Copper	64	0.88	0.051	0.033%	0.067%
Lead	120	0.88	0.096	0.053%	0.11%
Cadmium	7.3	0.88	0.0059	0.11%	0.22%
Mercury	0.3	0.88	2.4E-04	0.05%	0.10%
Dioxin	1.0E-05	0.88	8.3E-09	0.18%	0.36%

[1] Maximum soil pollutant concentrations for each PEA were provided by MWH.

Pollutant Loads Associated with Suspended Sediment in Stormwater Discharges at the Outfall:

Between August 2004 and March 2008, Boeing collected and analyzed storm runoff water samples (which were collected as manual grab samples) from Outfalls 008 and 009 for various NPDES COCs. Table 6 summarizes Outfalls 008 and 009 stormwater discharge monitoring data for the ISRA COCs.

Table 6. Outfalls 008 and 009 Discharge Water Quality Data Summary

Pollutant (ISRA COC)	Number of Samples	Range of Concentration	Average Concentration
Outfall 008			
Total Copper	19 (1 ND[1])	0 - 15 µg/L	6.5 µg/L
Dissolved Copper	3	1.6 - 2.9 µg/L	2.1 µg/L
Dioxin[2]	19 (14 ND[1])	0 - 3.19E-07 µg/L	2.1E-08 µg/L
Total Lead	19	0.17 - 120 µg/L	12 µg/L
Dissolved Lead	3 (2 ND[1])	0 - 0.92 µg/L	0.31 µg/L
TSS	11 (1 ND)	0 - 1300 mg/L	260 mg/L
Outfall 009			
Total Copper	31	1.6 - 39 µg/L	6.6µg/L
Dissolved Copper	9	2 - 6 µg/L	3.1 µg/L
Total Lead	31 (4 ND[1])	0 - 260 µg/L	13µg/L
Dissolved Lead	9(1 ND[1])	0 - 0.87 µg/L	0.34 µg/L
Total Cadmium	31 (11 ND[1])	0 - 9.2 µg/L	0.40 µg/L
Dissolved Cadmium	9 (8 ND[1])	0 - 0.11 µg/L	0.012 µg/L
Total Mercury	31 (21 ND[1])	0 - 0.21 µg/L	0.043 µg/L
Dissolved Mercury	9 (9 ND[1])	0 - 0 µg/L	0 µg/L
Dioxin[2]	31 (11 ND[1])	0 - 9.10E-04	3.06E-05 µg/L
TSS	22 (14 ND[1])	0 - 4000 mg/L	230 mg/L

[1] ND = Non detect; ND is replaced by 0 here for average calculations (for dissolved pollutant concentration, this is to allow for a conservatively high estimate of average particulate pollutant concentration, which is the difference between total and dissolved measurements).

[2] Here and elsewhere in the report, when dioxin concentrations are presented the results shown are for TCDD Toxicity Equivalent (TEQ) assuming Detected but Not Quantified (DNQ) congener results are equal to zero.

For the Engineered Natural Treatment System (ENTS) project, Geosyntec Consultants, on behalf of Boeing, conducted long term continuous runoff modeling at Outfall 008 and at Outfall 009 using US EPA's SWMM (Geosyntec, 2008). The modeling was conducted based on 58 years of hourly rainfall data to predict the runoff flow rates and volumes at the outfall over the long-term period. In Table 7, the estimate of annual average runoff volume from SWMM output is combined with the average total suspended solids (TSS) concentration from Table 6 to estimate the average annual TSS load in runoff from the Outfall 008 and Outfall 009 watersheds. As discussed above, Geosyntec previously conducted RUSLE calculations for the entire Outfall 008 and Outfall 009 watersheds for predicting the erosion sediment yields. Comparing the estimated annual TSS load at the outfalls with the estimated annual erosion sediment yield from the corresponding outfall watersheds, **<1% of eroded sediment in each watershed (while acknowledging the significant uncertainty of this estimate) appears to be leaving the watershed as TSS in storm runoff discharges.** The remaining potentially eroded sediment is likely being caught in depressions throughout the catchments or in the drainages, or being transported as bed load material in the drainages (which isn't captured in the TSS measurement).

Table 7. TSS Load in Stormwater Discharges at Outfalls 008 and 009

Outfall	Average Annual Runoff Volume (AF/year)	Average TSS Concentration in the Runoff (mg/L)	Average Annual TSS Load in the Runoff (tons/year)	RUSLE estimated Average Annual Sediment Load (tons/year)	% of Watershed Annual Sediment Load
008	15	257	5.2	1000	0.50%
009	128	230	40	5800	0.69%

For copper lead, cadmium and mercury, average particulate pollutant concentrations (which aren't measured for stormwater runoff samples) in the runoff at the outfalls were calculated by subtracting average dissolved concentrations from the average total concentrations. The resulting number was divided by average TSS concentration to get the average mass of particulate pollutant per mass of suspended sediment, or the particulate pollutant concentration on suspended soils as shown in Table 8. This number was then multiplied by average annual runoff TSS load from Table 7 to estimate annual particulate pollutant load in runoff at the outfalls.

For the Outfall 008 watershed, when compared with pollutant yields associated with RUSLE erosion sediment for the entire watershed (from Table 4), **only a small portion (0.29% – 1.3%) of the estimated annual copper and lead yields associated with erosion sediment from the entire watershed are leaving the watershed in the suspended form (attached to TSS) in the runoff at Outfall 008. For the Outfall 009 watershed, also, a small portion (0.36%-2.9%) of the estimated annual copper, lead, cadmium and mercury yields associated with erosion sediment from the entire watershed are leaving the watershed in the suspended form**

(attached to TSS) in the runoff at Outfall 009. These results indicate that a major portion of the estimated pollutant loads is either (a) being carried by stormwater discharges as bed load sediment or as dissolved fraction (through desorption/exchange processes), (b) being captured in the catchments or drainages and not discharged in storm runoff at the outfall, or (c) erosion pollutant yield estimates are too high.

These pollutant percentages are consistent with the estimated percentage of eroded sediment that is leaving the watershed as TSS in stormwater discharge at the respective outfalls. In stormwater discharges in general, these metals tend to be sediment-associated rather than in the dissolved phase; this understanding is confirmed by monitoring data presented in Table 7 which shows low dissolved concentrations relative to total concentrations. This would imply that if bed load too is not significant (i.e., less than say, 5 times suspended sediment load), and if the RUSLE sediment yield estimates are correct and the soil pollutant concentrations that were used are representative of average conditions, then (b) would be the most likely explanation for the low mass of eroded sediment (and associated pollutants) being measured in stormwater discharges at the outfalls. Another possible explanation might be that recent dry years reflected in the storm runoff monitoring dataset has biased these sediment and pollutant loads low.

For the purpose of estimating the TSS-associated dioxin load, it is assumed that 100% of dioxin measured in stormwater discharge samples at the outfalls is associated with TSS. This assumption is acceptable based on the physical-chemical properties of dioxin, such as its low solubility and high organic-carbon partition coefficient (K_{oc}). It should also be noted that the dioxin stormwater monitoring data at the outfalls include a large number of non-detected values, which are replaced by zero for calculations purposes here (to allow for a slightly conservatively low estimate of runoff associated pollutant loads) (Table 6). **For the Outfall 008 watershed, even less than with copper and lead, a very small percentage (0.10%) of the estimated annual dioxin yield associated with erosion sediment from the entire watershed is leaving the watershed in the suspended form (attached to TSS) in the runoff at Outfall 008. For the Outfall 009 watershed however, a very high percentage (210%) of the estimated annual dioxin yield associated with erosion sediment from the entire watershed is leaving the watershed in the suspended form (attached to TSS) in the runoff at Outfall 009.** The relatively high dioxin concentrations in runoff samples at Outfall 009 are the cause of this higher percentage of dioxin associated with erosion sediment yield from entire watershed leaving the watershed with TSS in runoff. While interpreting the dioxin results at the outfalls, it is very important to recall that larger number of non-detects are replaced by zero for the purpose of calculating average concentrations and that may introduce errors in the estimations. The observed average concentration of TSS-associated dioxin at Outfall 009 is about 150 times higher than the soil background concentrations for dioxin in the watershed (1.3E-04 mg/kg of TSS in the runoff versus 8.7E-07 mg/kg of soil based on the reported background concentration). Furthermore, the observed TSS-associated dioxin concentration in runoff at Outfall 009 is about

1500 fold higher than it is Outfall 008 (1.3E-04 mg/kg at Outfall 009 versus 8.38E-08 mg/kg at outfall 008).

Table 8. Particulate Pollutant Loads in Runoff at Outfalls 008 and 009

Pollutant (ISRA COC)	Particulate Pollutant Concentration on TSS[1] (mg pollutant / kg TSS)	Average Annual Particulate Pollutant Load in the Runoff[2] (kg/year)	% of Watershed Annual Pollutant Yield	
			Based on Soil Background Concentration	Based on 1/2 Soil Background Concentration
Outfall 008 Watershed				
Copper	17	0.08	0.29%	0.58%
Lead	45	0.21	0.66%	1.3%
Dioxin	8.4E-08	3.9E-10	0.05%	0.10%
Outfall 009 Watershed				
Copper	15	0.56	0.36%	0.73%
Lead	56	2.06	1.2%	2.3%
Cadmium	1.7	0.061	1.2%	2.3%
Mercury	0.19	0.0068	1.4%	2.9%
Dioxin	1.3E-04	4.8E-06	105%	210%

[1] Average pollutant concentration on TSS = (Average total pollutant concentration - Average dissolved pollutant concentration) / (Runoff average TSS concentration)

[2] Average annual particulate pollutant load in the Runoff = (particulate pollutant concentration on TSS) x (Average annual TSS load in the runoff)

References:

Geosyntec, 2008. Boeing SSFL Stormwater ENTS for Watersheds 008 and 009, Hydrology Report. Prepared by Geosyntec Consultants for The Boeing Company. December 2008.

Jones, C., 2001. RUSLE applications on Arizona Rangelands. Rangeland Management, Agriculture Resource Economics, The University of Arizona. Available at http://ag.arizona.edu/AREC/pubs/rmg/1%20rangelandmanagement/11%20rusle01.pdf.

MWH, 2005. Standardized Risk Assessment Methodology (SRAM) Work Plan, Revision 2. Santa Susana Field Laboratory, Ventura County. September.

MWH, 2009. Priliminary Interim Source Removal Action (ISRA) Work Plan, Santa Susana Field Laboratory, Ventura County, California. Prepared by MWH for The Boeing Company and The National Aeronautics and Space Administration. February 2009.

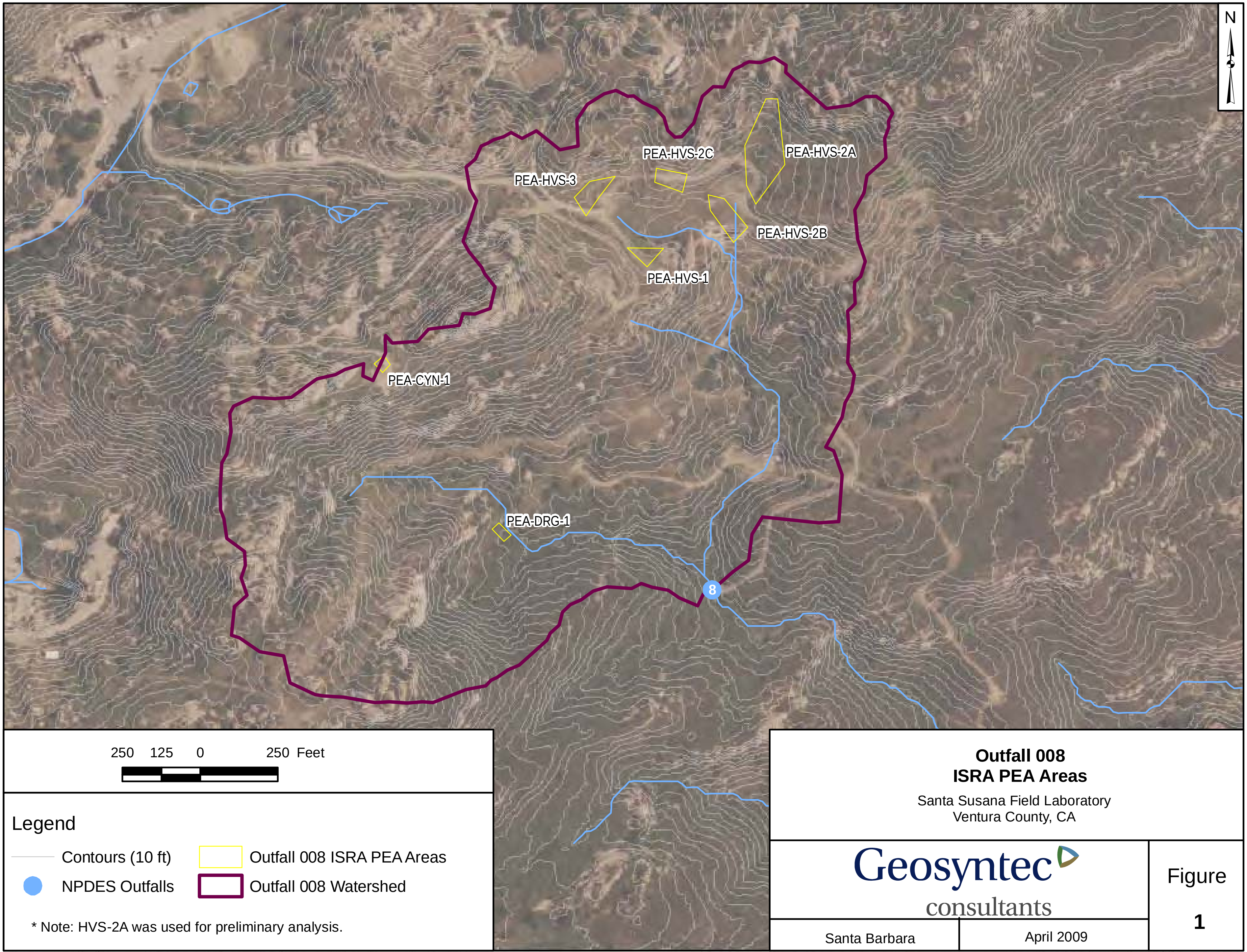
Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder., 1997. *Predicting Soil Erosion by Water*. *A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)*. USDA Agricultural Handbook, #703.

Robichaud, P.R., W.J. Elliot., F.B. Pierson, D.E. Hall, C.A. Moffet, and L.E. Ashmum., 2007. *Erosion Risk Management Tool (ERMiT) User Manual 9Version 2006.01.18)*. United States Geological Survey (USGS), Rocky Mountain Research Station. General Technical Report RMRS-GTR-188.

Sampson, A.W., 1944. *Effect of Chaparral Burning on Soil Erosion and on Soil-Moisture Relations*. Ecology, Vol. 25 No.2, pg 171-191.

Toy, T.J., 1998. *Guidelines for the Use of the Revised Universal Soil Loss Equation (RUSLE) Version 1.06 on Mined Lands, Construction Sites, and Reclaimed Lands*.

United States Geological Survey (USGS), 1996. *USGS Response to an Urban Earthquake: Northridge '94*. http://pubs.usgs.gov/of/1996/ofr-96-0263/valley.htm.



Legend

Contours (10 ft)

● NPDES Outfalls

☐ Outfall 008 ISRA PEA Areas

☐ Outfall 008 Watershed

* Note: HVS-2A was used for preliminary analysis.

Outfall 008
ISRA PEA Areas

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Ventura County, CA

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Figure

1

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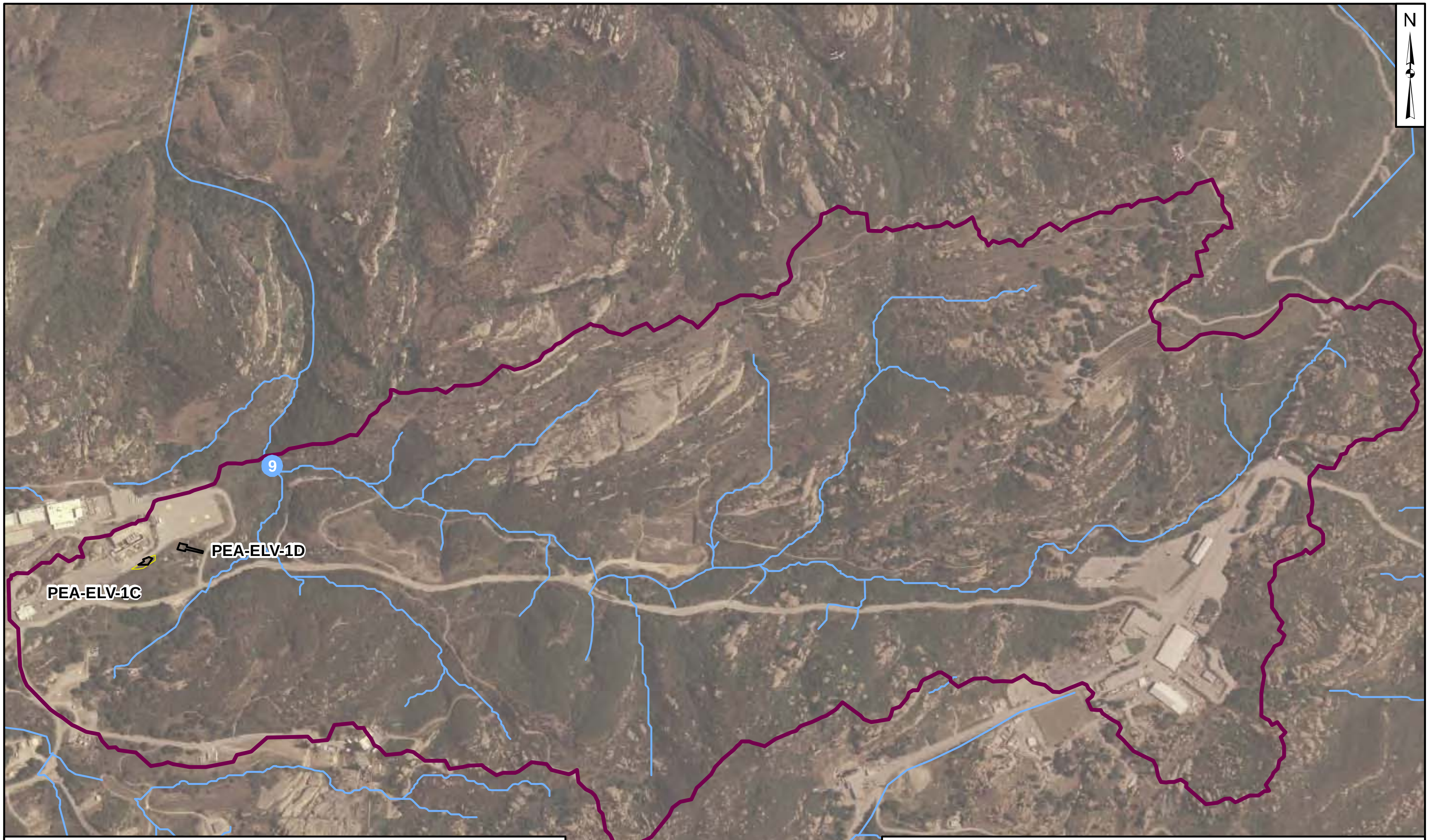

Legend

- ● NPDES Outfalls
- ☐ Excavation Areas
- ☐ Potential Excavation Area
- ☐ Outfall 009 Watershed

Outfall 009
ISRA PEA Areas

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Figure

2

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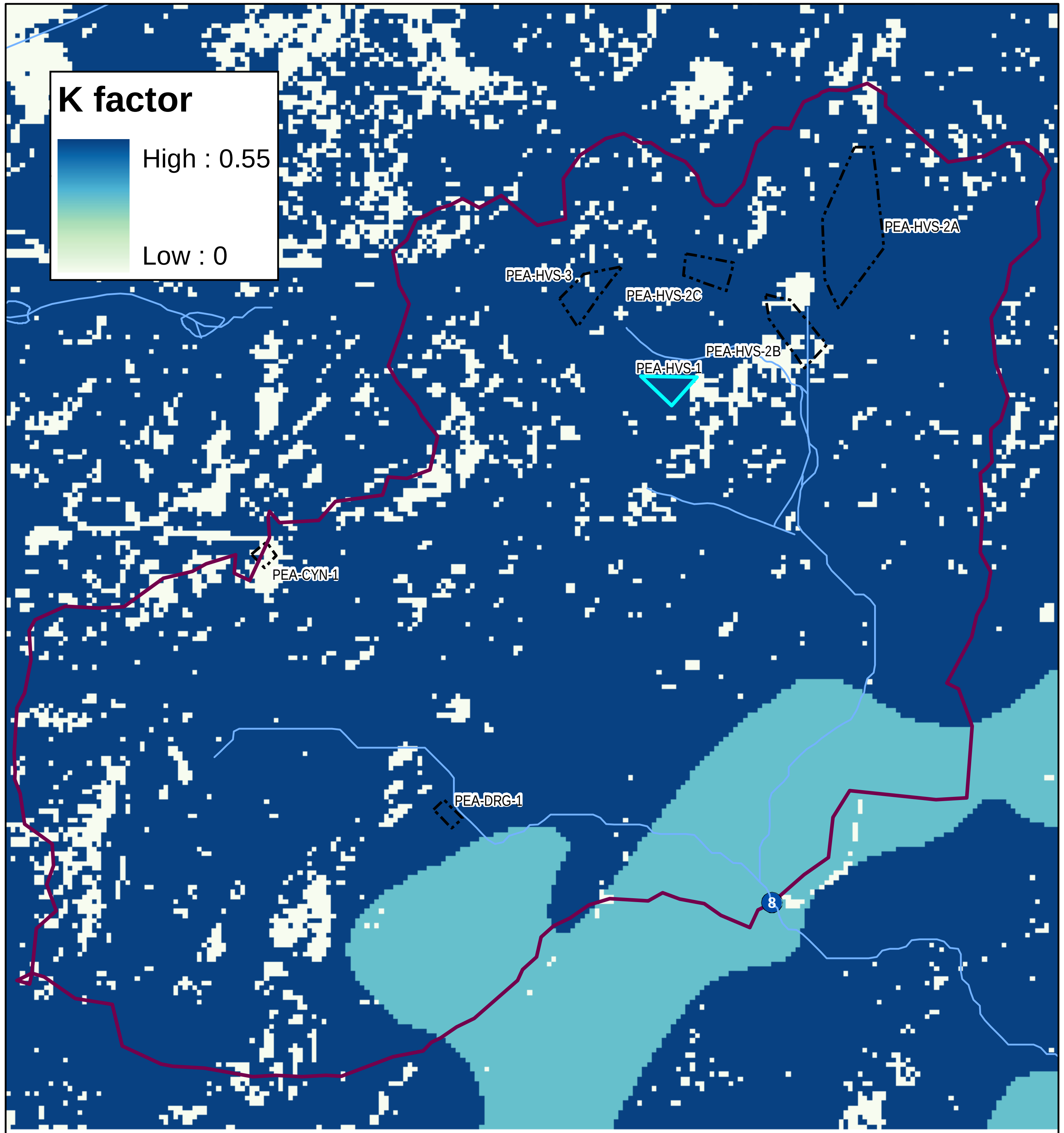
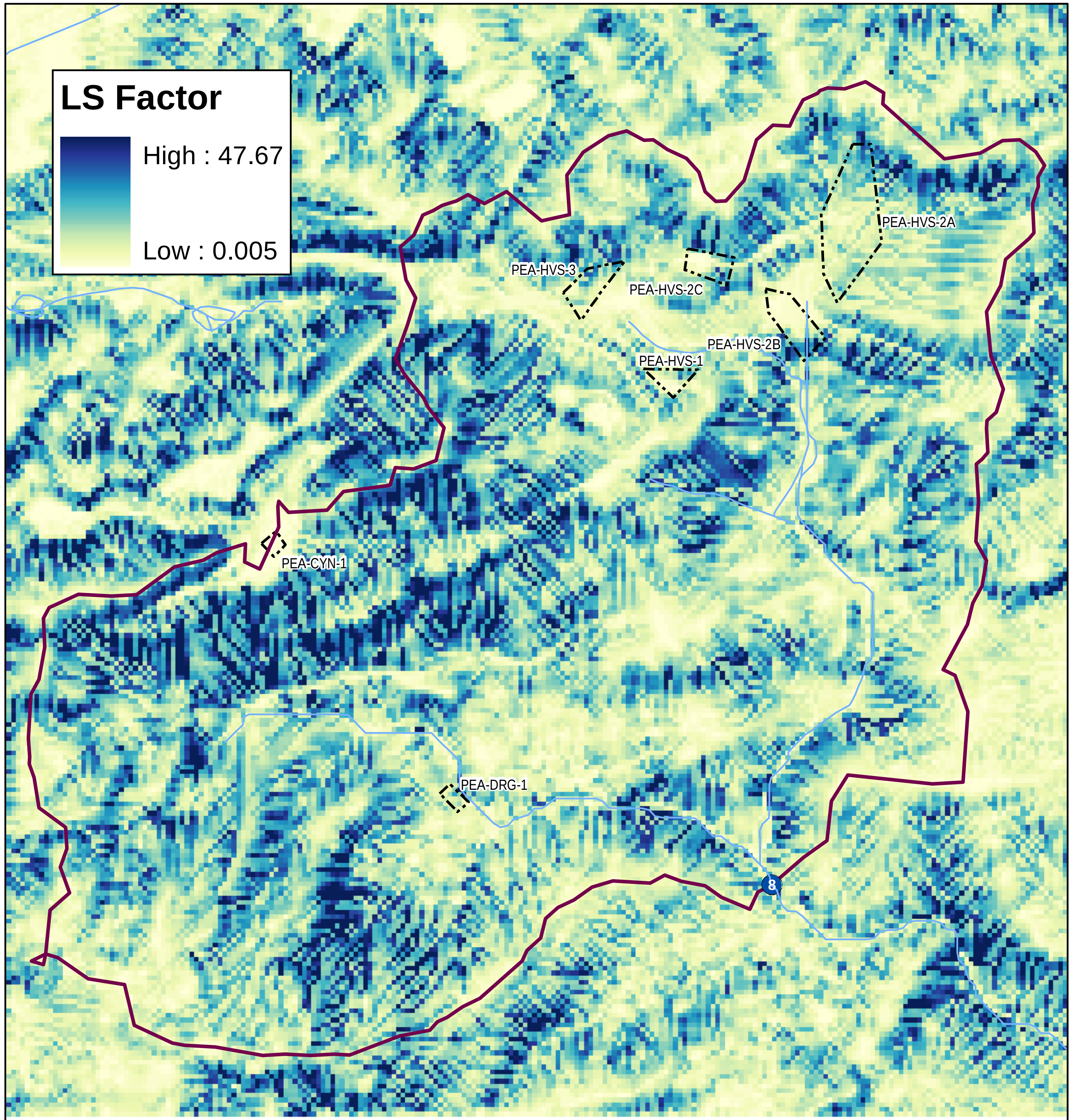


Note: Areas in while reflect exposed bedrock, pavement or buildings which have a K factor value of zero.



200 100 0 200 Feet

Soil data source: SSURGO, Natural Resources Conservation Service,
United States Department of Agriculture
LS data source: Derived from 10 meter LIDAR, County of Ventura

ISRA PEA	Area (acres)	Average Annual Sediment Yield (AF/year)	Bulk Density (tons/AF)	Average Annual Sediment Yield (tons/year)	Estimated Sediment Yield Rate (tons/acre/year)	Mean K Factor	Mean LS Factor	R Factor	C Factor	P Factor
PEA-CYN-1	0.03	0.000001	2000	0.0012	0.036	0.08	0.11	50	0.1	1
PEA-DRG-1	0.04	0.00020	2000	0.41	10	0.55	4.0	50	0.1	1
PEA-HVS-1	0.08	0.00039	2000	0.8	9.9	0.55	3.7	50	0.1	1
PEA-HVS-2A	0.65	0.0039	2000	8.0	12	0.55	4.6	50	0.1	1
PEA-HVS-2B	0.21	0.00086	2000	1.8	8.4	0.40	4.6	50	0.1	1
PEA-HVS-2C	0.12	0.00080	2000	1.6	14	0.55	5.0	50	0.1	1
PEA-HVS-3	0.15	0.00090	2000	1.8	12	0.51	5.0	50	0.1	1
Entire Outfall 008 Watershed	62	0.51	2000	1000	17	0.48	7.2	50	0.1	1

Outfall 008 ISRA Areas
RUSLE Calculation Parameters
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Figure
3

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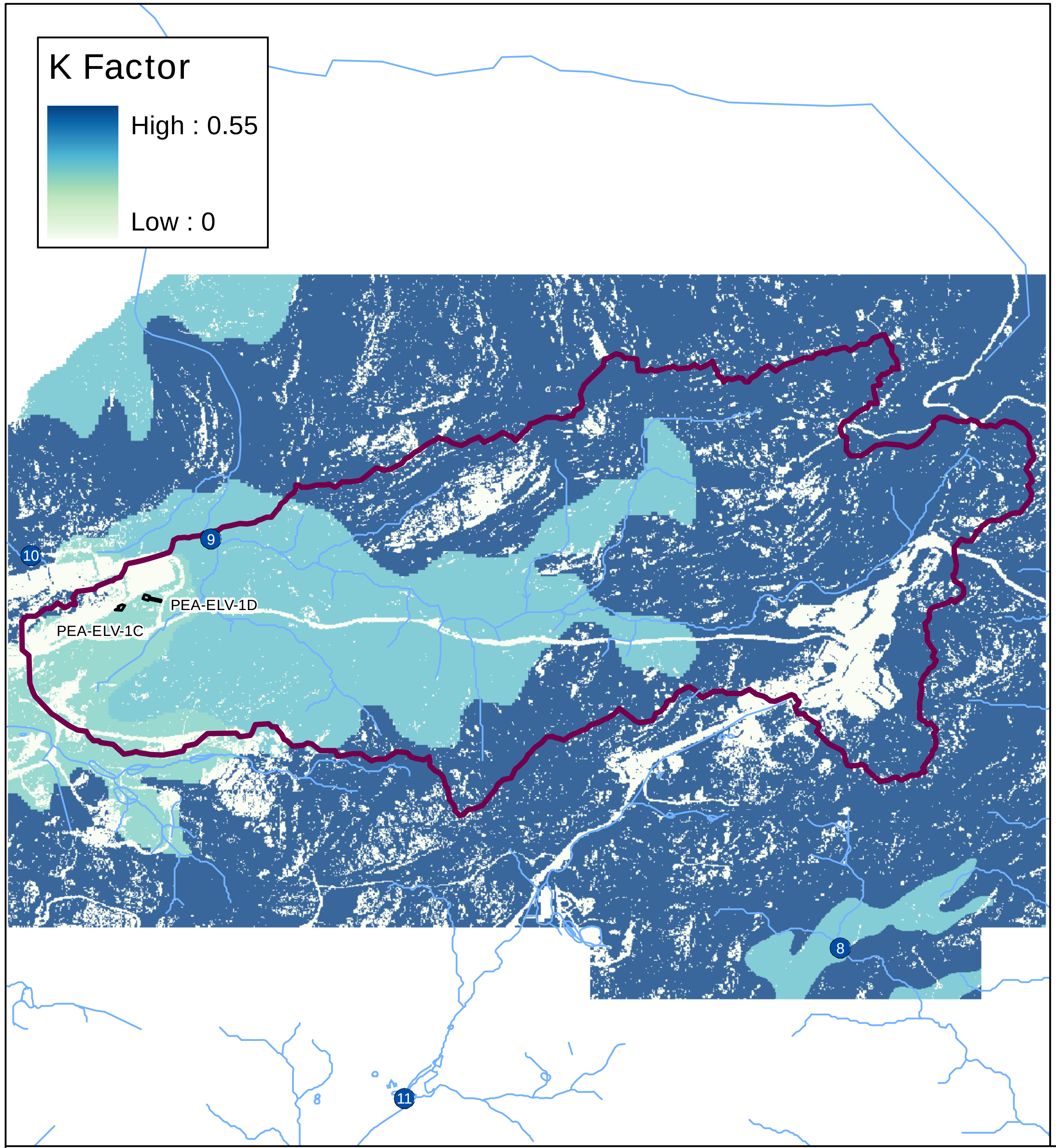

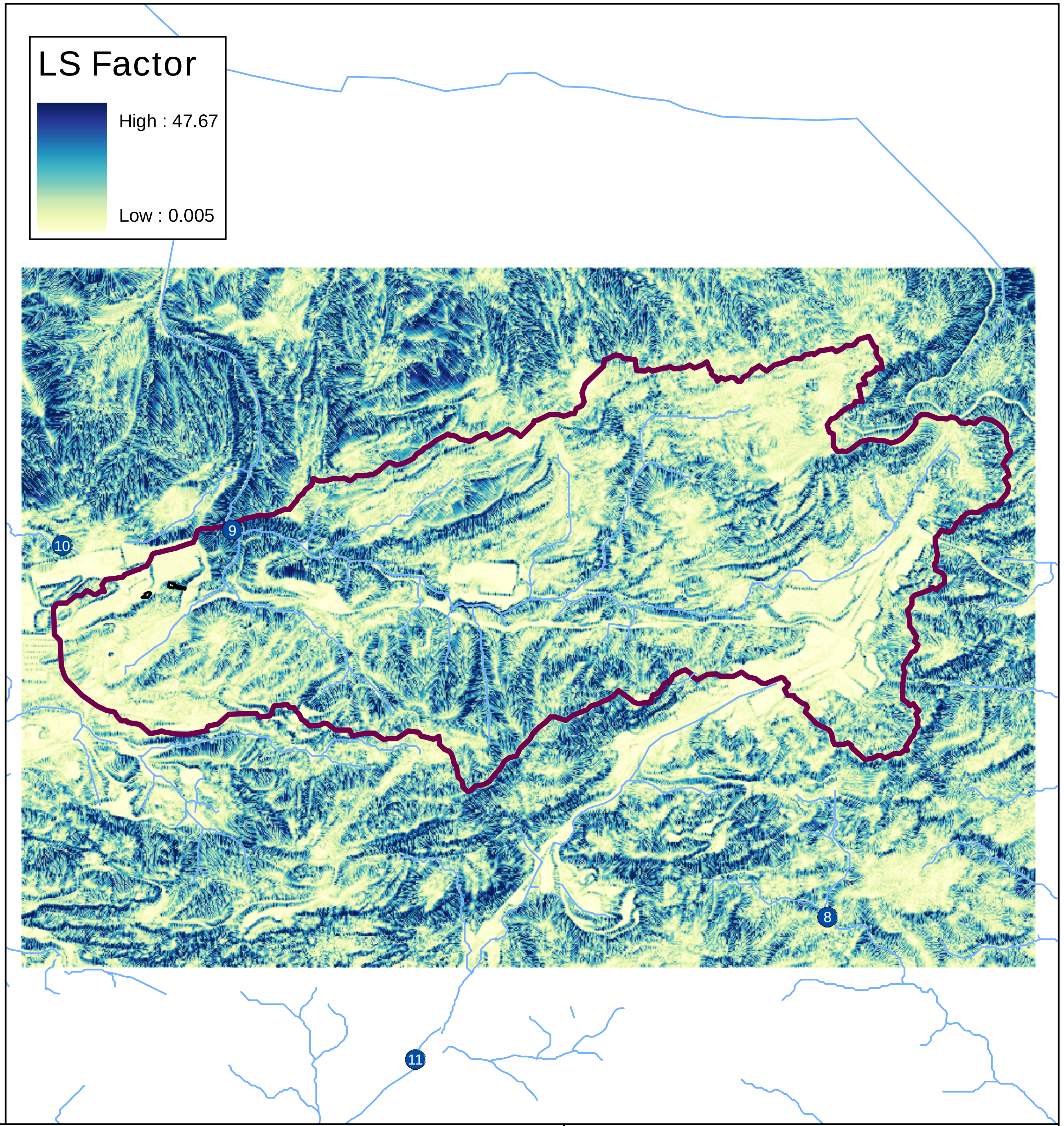

1,000 500 0 1,000 Feet

Soil data source: SSURGO, Natural Resources Conservation Service, United States Department of Agriculture
LS data source: Derived from 10 meter LIDAR, County of Ventura

ISRA PEA	Area (acres)	Average Annual Sediment Yield (AF/year)	Bulk Density (tons/AF)	Average Annual Sediment Yield (tons/year)	Estimated Sediment Yield Rate (tons/acre/year)	Mean K Factor	Mean LS Factor	R Factor	C Factor	P Factor
PEA-ELV-1C (Proposed)	0.06	0.00003	2000	0.070	1.3	0.15	1.3	50	0.1	1
PEA-ELV-1C (Potential)	0.13	0.00015	2000	0.31	2.5	0.19	2.0	50	0.1	1
PEA-ELV-1D	0.09	0.00043	2000	0.88	9.6	0.28	6.7	50	0.1	1
Entire Outfall 009 Watershed	536	2.9	2000	5800	11	0.38	5.5	50	0.1	1

Outfall 009 Excavation Areas
RUSLE Calculation Parameters

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Figure
4

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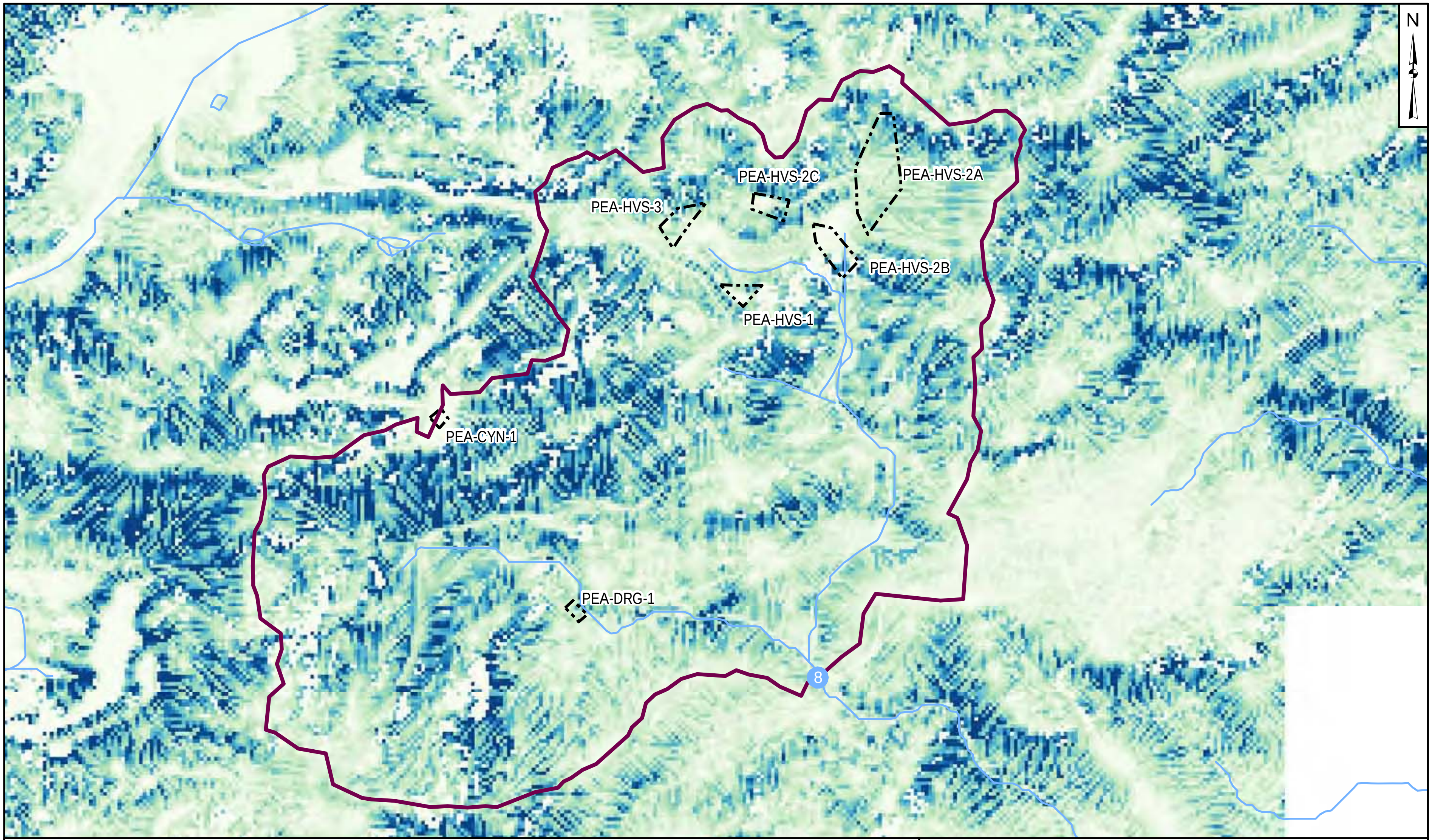

Legend

● NPDES Outfalls

▭ Outfall 008 Watershed

⬚ Outfall 008 ISRA PEA Areas

Estaimted RUSLE Sediment Yield Rate (Tons/Acre/Year)

High : 131.105

Low : 0

250 125 0 250 Feet

Outfall 008
Estimated RUSLE Sediment Yield Rate

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Figure

5

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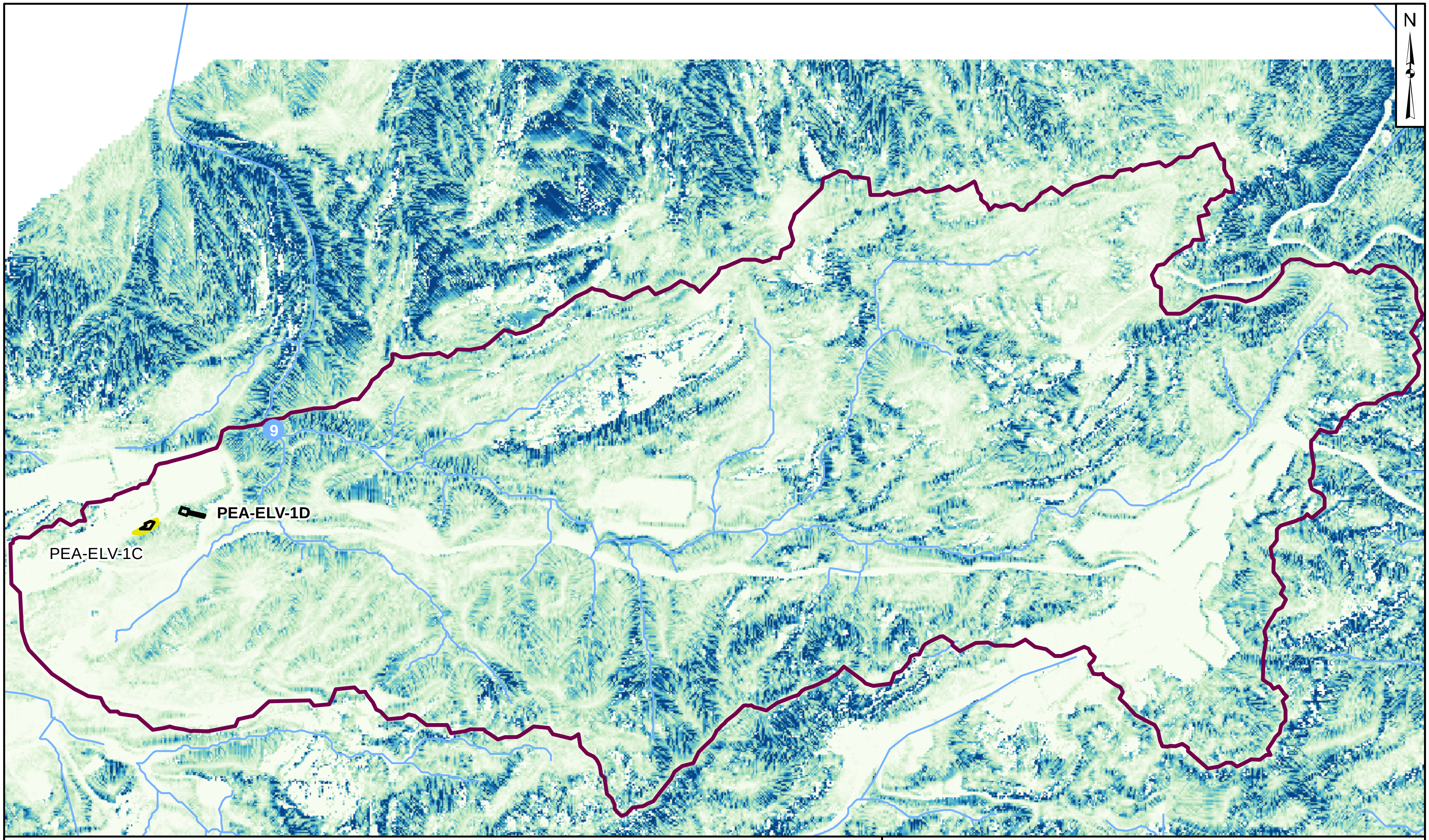

Legend

● NPDES Outfalls

▭ Outfall 009 Watershed

▭ Excavation Areas

▭ Potential Excavation Area

Estiamted RUSLE Sediment Yield Rate (Tons/Acre/Year)

Value

High : 131.105

Low : 0

500 250 0 500 Feet

Outfall 009
Estimated RUSLE Sediment Yield Rate

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Ventura County, CA

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Figure

6

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