The Boeing Company
Santa Susana Field Laboratory
5800 Woolsey Canyon Road
Canoga Park, CA 91304-1148

Via E-mail

March 31, 2016
In reply, refer to SHEA - 115436

Ms. Cassandra Owens
Regional Water Quality Control Board
Los Angeles Region
320 West 4th Street, Suite 200
Los Angeles, California 90013

Dear Ms. Owens:

Subject: Revised Human Health Risk Assessment Work Plan for Surface Water Runoff, Santa Susana Field Laboratory, Ventura County, CA (Order Pursuant to California Water Code Section 13383; CA0001309, CI No. 6027)

On September 17, 2015, The Boeing Company submitted a Human Health Risk Assessment (HHRA) Work Plan for Surface Water Runoff Exiting the Santa Susana Field Laboratory via the Southern Outfalls (letter SHEA-115326). This was in response to a letter issued by the Los Angeles Regional Water Quality Control Board (Board) on June 24, 2015 requiring Boeing to perform a HHRA at these southern outfall locations under the requirements of the Section 13383 of the California Water Code.

Subsequent to this submission of the draft HHRA Work Plan for review, on January 28, 2016 Boeing received comments from the Board requesting revisions to the work plan. The attached work plan was written to meet the intent of these requested revisions by your agency and address the comments submitted by the California Office of Environmental Health Hazard Assessment (OEHHA) along with ensuring that the results presented in the HHRA will be reflective of current conditions.

If you have any questions or require any further assistance, please contact Paul Costa at (818) 466-8778.

**CERTIFICATION**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted.

Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Executed on the 31st of March 2016 at The Boeing Company, Santa Susana Site.

Sincerely,

Dave Dassler, Manager
Environment, Health & Safety
Southwest Remediation
The Boeing Company

# REVISED
# Human Health
# Risk Assessment Work Plan

## Surface Water Outfalls
## Santa Susana Field Laboratory
## Ventura County, CA

*Prepared for:*

The Boeing Company

*Prepared by:*

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March 2016

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# 1. INTRODUCTION

The Boeing Company is submitting this Human Health Risk Assessment (HHRA) Work Plan (Work Plan) prepared by Geosyntec Consultants, Inc. (Geosyntec) for the Santa Susana Field Laboratory (SSFL or Site) located in Ventura County, California. The Work Plan was reviewed by the Surface Water Expert Panel (Expert Panel) and Boeing's consultant that is conducting a portion of the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) work at the Site. This Work Plan is being prepared to describe the approach that will be used to prepare a Human Health Risk Assessment (HHRA) of surface water runoff exiting the SSFL via Outfalls 001, 002, 008, 009, 011, 018, 019, and 020, as described in the California Water Code Section 13383 Order (Order) from the Los Angeles Regional Water Quality Control Board (Los Angeles RWQCB) dated July 24, 2015. The Order was proposed by the RWQCB in response to health concerns expressed by members of the public regarding exposure to NPDES discharges in the drainages near the SSFL. The HHRA will provide a quantitative assessment of potential risks and hazards associated with contact with discharges from the SSFL regulated by National Pollutant Discharge Elimination System (NPDES) Permit No. CA0001309. In accordance with the Order, the analysis will use conceptual exposure scenarios that are representative of realistic exposures that may occur immediately downstream of the SSFL property boundary.

This Work Plan provides the technical approach that will be used to conduct the HHRA, including the risk assessment guidance and the rationale and assumptions that will be used. As required by the Order, this work plan identifies the data that will be used, including the locations where the data were or will be collected, and the time period during which the discharge data were or will be collected. This work plan also provides the preliminary conceptual site model identifying potential exposure media, receptor populations and exposure pathways that are considered relevant.

## 1.1 Site Background Information

The SSFL occupies approximately 2,850 acres and is located at the top of Woolsey Canyon Road in the Simi Hills, Ventura County, California. The Facility is jointly owned by Boeing and the federal government. The National Aeronautics and Space Administration (NASA) administers the portion of the property owned by the federal government. The site is divided into four administrative areas (Areas I, II, III, and IV) and undeveloped land areas to both the north and south. The site layout is shown in **Figure 1**.

Industrial operations at the SSFL have ceased; current activities at the site include environmental monitoring and sampling, and remediation planning. The SSFL became active in 1948. Site activities have included research, development, and testing of rocket engines, water jet pumps, lasers, liquid metal heat exchanger components, nuclear energy, and related technologies. The principal activity has been large rocket engine testing by Boeing and NASA in Administrative Areas I, II, and III, and energy technology research for DOE in Area IV. Laboratory research, rocket engine assembly, and rocket engine testing were ongoing activities at the site, along with site use supporting these activities (maintenance, site engineering, environment, health and safety, and security). Petroleum fuel hydrocarbons and chlorinated solvents have been used at the SSFL in the largest volumes. The periodic burning of off-spec fuels in ponds may have produced polychlorinated dibenzodioxins and dibenzofurans (collectively referred to "dioxins"). Solid propellants, including perchlorate compounds, were used at the SSFL for research and testing operations. Various metals may have been used in machining operations, or stored or disposed of as construction debris.

Administrative Areas I and III are operated by Boeing, which owns the majority of Area I and all of Area III. A portion of Area I (40 acres) and all of Area II are owned by the federal government and were formerly administered by NASA and operated by Boeing. The land within Area IV is owned by Boeing and was formerly operated by Boeing for DOE. DOE owns specific facilities located on approximately 90 acres of Area IV.

The SSFL has the potential to discharge stormwater runoff impacted by constituents from the facility. Approximately 60% of the discharge exits the property via two southerly discharge points (Outfalls 001 and 002) to Bell Creek, a tributary to the Los Angeles River. Upstream outfalls that contribute to the discharge at Outfalls 001 and 002 include Outfalls 011 and 018. Outfalls 019 and 020 discharge treated groundwater downstream of Outfalls 001 and 002, respectively.

The stormwater from the northern boundary of the site is discharged via Outfalls 003 through 007 and 010 or it is transferred to Silvernale Pond for treatment prior to discharge at Outfall 018. Because of the size and terrain of the watershed and the amount of stormwater runoff routinely generated, Outfall 009 always discharges to Arroyo Simi. The stormwater runoff from Happy Valley (Outfall 008) flows via Dayton Canyon Creek to Chatsworth Creek. Chatsworth Creek flows south to Bell Creek southwest of the intersection of Shoup Avenue and Sherman Way. Bell Creek subsequently flows southeast to the Los Angeles River. In its surface water beneficial use designation tables, the Los Angeles Water Quality Control Plan (Basin Plan) does not explicitly identify the tributary drainages that cross the SSFL boundaries, however downstream creeks (Bell Creek, Dayton Canyon Creek and Arroyo Simi) are included, and these are designated as having intermittent recreational uses (water contact and non-contact water recreation) (Los Angeles RWQCB, 1994).

The SSFL site has been regulated under a NPDES permit as required by the Clean Water Act since 1976. A wide range of constituents have been monitored. Parameters vary by outfall but generally include: dioxins, acute and chronic toxicity, metals, radionuclides, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), chloride, cyanide, fluoride, nutrients, oil and grease, perchlorate, pH, sulfate, Total Suspended Solids (TSS), and Total Dissolved Solids (TDS).

In the Outfall 008 and 009 watersheds, Interim Source Removal Action (ISRA) and Best Management Practices (BMP) programs were implemented since 2010 with oversight and participation of the Los Angeles RWQCB to improve compliance with NPDES Permit limits through the dual approach of remediation of surface soils that are above defined thresholds for NPDES constituents of concern, and through distributed control and/or treatment of stormwater runoff from prioritized subareas, respectively.

At Outfalls 011 and 018, active treatment systems have been in place since 2011 for advanced treatment of stormwater. Outfalls 001 and 002 are downstream of outfalls 011 and 018, respectively, and also receive runoff from the undeveloped buffer areas of the Site. Outfalls 019 and 020 (under construction) receive treated groundwater.

## 1.2 Risk Assessment Approach

The HHRA is a predictive tool used to estimate the nature and probability of adverse health effects in humans resulting from exposure to constituents in environmental media. Currently, surface water discharges from the SSFL are regulated under the NDPES Permit and surface water samples are collected at each outfall as a part of the permit. Potential chronic health risks will be estimated for Constituents of Potential Concern (COPCs), including both chemicals and radionuclides that have been identified in surface water as a part of the NPDES Permit monitoring.

The overall methodology that will be used in the HHRA is generally consistent with current United States Environmental Protection Agency (USEPA) and California Environmental Protection Agency (Cal-EPA) guidance and agency approved risk assessment approaches for the SSFL as documented in the Final Standardized Risk Assessment Methodology (SRAM) Work Plan Revision 2 Addendum (SRAM Rev. 2 Addendum) (MWH, 2014).

The HHRA will include the major components of risk assessment:

- Data Evaluation and Selection of COPCs;
- Exposure Assessment;
- Toxicity Assessment;
- Risk Characterization; and
- Uncertainty Analysis.

Based on current and planned future uses of the drainage areas immediately adjacent to the SSFL and the designated use of the surface water, the HHRA will address potential exposures to surface water by future recreators (recreational users entering the drainage areas while hiking). The direct contact pathways of incidental ingestion and dermal contact and the inhalation pathway will be considered based on sampling results and likely routes of exposure. Edible aquatic plants and fish are not present in the drainages near the outfalls and therefore the consumption of plants or aquatic organisms pathway is not complete near the outfalls. There is the potential that stormwater constituents may have migrated downstream beyond the outfall area to areas where aquatic plants or fish are present. The completeness of this pathway will be evaluated in the HHRA

Conservatism has been incorporated into the HHRA, such as the use of an upper-bound estimate of the average concentrations, evaluation of younger children as well as older children and adults, consideration of the incidental ingestion, dermal contact and inhalation exposure pathways, incidental ingestion rate and assuming that a recreator will be entering the drainages for over a long time-frame. In addition, the use of current concentration data is conservative in that over the long-term exposure duration (i.e., as site-wide remediation occurs), water quality should improve relative to existing conditions.

This HHRA Work Plan addresses potential human exposures to surface water runoff that is leaving the SSFL through the outfalls identified above. Potential recreator exposures to sediment in the drainages, including areas near the outfalls, are being addressed as part of Site closure activities in accordance with three regulatory orders under oversight of the Cal-EPA Department of Toxic Substances Control (DTSC), as discussed in more detail below.

Boeing is completing Site closure activities in Administrative Area I, Area III, and in the Southern Undeveloped Land in accordance with the 2007 Consent Order for Corrective Action, which requires that environmental media be remediated to acceptable risk-based levels developed following methods outlined in the DTSC-approved Standardized Risk Assessment Methodology Revision 2 Addendum (SRAM Rev. 2 Addendum; MWH, 2014). Boeing is completing human health and ecological risk assessments to address contamination in environmental media in Boeing areas at the SSFL, or in adjacent areas where contamination from Boeing areas has migrated onsite or offsite. Boeing is conducting risk assessments for 21 RFI sites and the Southern Undeveloped Land, and reporting those results in RFI Data Summary and Findings Reports (DSFRs) for DTSC review and approval. Risk assessments are performed for all environmental media present at the site, typically including soil (which encompasses ephemeral sediment in drainages), soil vapor, and groundwater. Permanent surface water sediment is only present at one RFI site. Based on risk assessment and other groundwater modeling results, the DSFRs identify areas for remediation planning in the Corrective Measure Study (CMS). To aid in DTSC's review, Boeing RFI site DSFRs are grouped by location and submitted together in 'Subarea DSFR Reports' to DTSC.

To date, Boeing has submitted seven RFI site risk assessments as part of two draft Subarea DSFRs. The other RFI site risk assessments are either in progress, or are planned to be completed by the summer of 2016. Once DTSC comments are received on the draft DSFRs, the RFI reports, including areas identified for the CMS, will be finalized for remediation planning.

DOE and NASA are completing Site closure activities for soil (including ephemeral sediment) in accordance with Administrative Orders on Consent for Remedial Action (AOCs). The DOE AOC includes Administrative Area IV and the Northern Buffer Zone, and the NASA AOC includes Administrative Area II and a 40-acre parcel of Administrative Area I, where the Liquid Oxygen Plant was formerly located. The AOCs require soil cleanup to Lookup Table values based on background or reporting limits established by DTSC for the SSFL. DOE and NASA are completing DSFRs for their portions of the SSFL. To date, NASA has published the DSFR for Area II and the Area I LOX Plant. DOE is in progress preparing the DSFR for Area IV and the Northern Buffer Zone.

Soil remediation activities are planned to commence in 2017 for the SSFL, including sediment in the drainages, as required by the AOCs and 2007 Consent Order.

# 2. DATA EVALUATION AND SELECTION OF CONSTITUENTS OF POTENTIAL CONCERN (COPCS)

An initial step in the HHRA process is an evaluation of available data to develop a data set for use in the HHRA and identify media-specific COPCs. Appropriate site data must be available to support the characterization of COPC levels and media relevant to transport processes and exposure pathways. This section discusses the data evaluation steps that will be considered in the HHRA, as well as the methodology that will be used to identify the COPCs for the Site.

## 2.1 Data Evaluation

A variety of constituents have been detected in surface water samples collected as a part of the NPDES Permit monitoring. Each sample collected has been analyzed for a number of different constituents consistent with NPDES Permit requirements. In addition, multiple years of sampling have been conducted both before and after various BMPs, interim remediation (including the ISRA program), and demolition projects were completed. Surface water data collected from the outfalls will be evaluated in consideration of these factors to identify the data set for use in the HHRA and to verify the data are of acceptable quality for use in risk assessment.

The outfalls collect water from several different types of discharges. Outfalls 001 and 002 collect runoff from the Southern Undeveloped Land areas of the SSFL as well as discharges from Outfalls 011 and 018 which may be made up of effluent from surface water treatment systems. Outfalls 008 and 009 collect water from watersheds that use distributed natural treatment systems. Outfalls 019 and 020 (yet to be constructed) collect water from groundwater treatment system discharges. The HHRA will evaluate the surface water samples collected from each of these outfalls.

- An important consideration in evaluating the data for the HHRA is the change in site conditions that has occurred over time, including stormwater BMPs, interim remediation and ISRA, and demolition. These changes have resulted in significant changes on the site due to the removal of contaminants, structural improvements in stormwater management, and reduction in impervious surfaces. Therefore, to evaluate current and future conditions, water quality data during and following these activities will be evaluated in the HHRA. An additional consideration is the desire to have sufficient samples to evaluate potential exposures to the primary constituents detected in surface water leaving the Site while not including data that are clearly not representative of current conditions. To accommodate these data needs, the sampling period from February 16, 2009 to present[1] will be included. This sampling period provides at least five (5) sampling events for each outfall, and at least five (5) sampling results for most constituents of potential concern. For outfall-constituent combinations where sample counts are limited, alternative summary statistics may be used to address this source of uncertainty; this is discussed further in section 3.2.

The data evaluation will be consistent with guidance provided by USEPA in *Risk Assessment Guidance for Superfund* (1989) and *Guidance for Data Usability in Risk Assessments* (1992). The evaluation will include:

- Evaluating the quality of data with respect to sample quantification and detection limits;
- Examining laboratory qualifiers assigned to monitoring data and evaluating potential quality assurance/quality control issues; and
- Evaluating split/duplicate samples.

The analytical data will also be reviewed with respect to any potential qualifiers that may impact the HHRA significantly. Data qualifications will be discussed in the uncertainty analysis section of the HHRA.

For metals data, both dissolved and total concentrations have been detected in some instances. Both sets of data will be evaluated in the HHRA. For dioxin data, toxicity equivalents (TEQs) will be calculated consistent with the SRAM, which uses the most current (2005) World Health Organization (WHO) Toxicity Equivalency Factors (TEFs) (Van Berg, et. al. 2005).

Field duplicates are collected to evaluate the quality of sample collection as well as sample analysis. Field duplicate samples are usually two samples collected simultaneously from the same sampling location and are used as measures of either the homogeneity of the medium sampled in a particular location or the precision in the sampling and sample handling (in transport and/or in the laboratory) (USEPA, 1989). Unless otherwise specified in the analytical method, duplicate samples have generally been analyzed at a frequency of 5 percent.

For cases where a field duplicate or split sample result is present for the same chemical in a sample, a single representative concentration for the sample will be selected as follows:

[1] At the time of this report, the latest sample result available is January 6, 2016.

1) If there is a detection in both samples, the higher concentration will be selected;
2) If there is a detection in one sample but not the other, the detected concentration will be selected; and
3) If both samples are nondetects, the lowest method detection limit will be selected and appropriate techniques for handling nondetect data will be applied in calculating statistics later in the data evaluation.

## 2.2 Selection of Constituents of Potential Concern

USEPA risk assessment guidance (1989) presents a methodology for identifying which detected constituents should be included in a quantitative HHRA. These are defined by USEPA (1989) as constituents potentially related to the site whose data are of sufficient quality for use in a quantitative HHRA.

As discussed above, the existing data will be evaluated in terms of quality and usability in an HHRA. Because of the large number of samples that have been historically collected, the list of constituents that have been analyzed for and detected is considered representative of existing surface water quality. All data determined to be of sufficient quality (i.e., not rejected during data validation) will be carried forward into the COPC selection process. A constituent will be selected as a COPC if it has been detected at least once in the samples collected from the outfall discharges for the date ranges presented above. Additional COPC selection criteria include whether the constituent is considered an essential nutrient (e.g., iron, manganese) or is not commonly evaluated in human health risk assessments due to low toxicity (e.g., chloride). Table 1 presents the constituents that have been detected at least once at any outfall and the number of times each constituent has been analyzed in water samples at each outfall over the time periods presented above.

# 3. EXPOSURE ASSESSMENT

The objectives of an exposure assessment are to identify populations that may potentially be exposed to constituents in environmental media, the exposure pathways, and the route of potential intake. In addition, for pathways considered complete (See below for the five elements required for a complete exposure pathway), the constituent concentrations to which the individuals are potentially exposed (exposure point concentrations, EPCs) and the frequency, magnitude, and duration of potential exposures (exposure parameters) need to be estimated.

To determine whether the levels of constituents present in surface water would pose a risk to human populations, it is necessary to identify the receptor groups that may potentially be exposed to these constituents, and determine the pathways by which the exposures may occur.

Once the potentially exposed populations are identified, the potentially complete exposure pathways by which individuals may contact constituents must be determined. The following five elements comprise a complete exposure pathway:

- A source of chemical;
- A mechanism of constituents release to the environment;
- An environmental transport medium (e.g., soil vapor or air);
- A point of potential human contact with the medium (e.g., surface water); and
- A means of entry (i.e., intake route) into the body (e.g., ingestion).

There must be a complete exposure pathway from the source of constituents in the environment (i.e., from surface water or air) to human receptors in order for exposure and intake to occur. If all exposure pathways are incomplete (i.e. there is no mechanism for contact with the constituent to occur) for human receptors, no constituent intake occurs and hence, no human health effects are associated with site-related COPCs.

These source-pathway-receptor relationships provide the basis for the quantitative exposure assessment. Potentially complete source-pathway-receptor relationships which will be included in the HHRA are discussed in the Conceptual Site Model (CSM) section below.

The end product of the exposure assessment is a measure of chemical or radionuclide intake that integrates the exposure parameters for the receptors of concern (e.g., contact rates, exposure frequency, and duration) with the EPCs for the media of concern.

## 3.1 Conceptual Site Model

The CSM, presented in **Figure 2**, represents the current understanding of the sources of COPCs, the means by which they may be released and transported within and among media, and the exposure pathways and routes by which they may contact human receptors. The major components of the CSM are discussed below.

### 3.1.1 Constituents Characteristics and Potential Exposure Routes

Potential exposure to constituents detected in surface water discharges to the outfalls is partly dependent on the type of COPCs that are present and the respective exposure media. Potential exposure routes to be considered include both direct and indirect contact with surface water. If volatile chemicals are detected, indirect exposures (outdoor inhalation) from vapors migrating from surface water to outdoor air may occur. If constituents such as metals or dioxins are detected, the direct contact routes of exposure, such as incidental ingestion or dermal contact, are the most relevant.

### 3.1.2 Identification of Potential Receptors and Exposure Pathways

The proposed current and planned future land use for the areas immediately downstream of the outfalls is open space and recreational. In addition, the Basin Plan identifies intermittent recreational beneficial use designations for the creeks downstream of the Site, although the smaller tributary drainages near the SSFL boundary are not explicitly identified in the Basin Plan (Los Angeles RWQCB, 1994).

This HHRA evaluates surface water data collected at the outfalls and therefore addresses potential exposures in the drainage areas at the location of the surface water discharge. The drainage areas in the vicinity of the outfalls and immediately adjacent to the SSFL boundary are typically steep and difficult to access for very young children, however an older child and adult could access the areas of the drainage. Based on the steep configuration of the upper drainage areas adjacent to the SSFL, water is not expected to be pooled at depths to allow for swimming. Therefore the HHRA will evaluate potential exposures to children and adults that are assumed to be wading when water is present.

Potential direct exposures to surface water (incidental ingestion and dermal contact) and inhalation in outdoor air will be considered in the HHRA based on the sampling results and likely routes of exposure. Edible aquatic plants and fish are not present in the drainages near the outfalls and therefore the consumption of aquatic plants or fish pathway is not complete. As mentioned in Section 1, potential recreator exposures to sediment in the drainages, including areas near the outfalls, are being addressed as part of site closure activities in accordance with three regulatory orders under oversight by the Cal-EPA DTSC.

Edible aquatic plants and fish are not present in the drainages near the outfalls and therefore the consumption of plants or aquatic organisms pathway is not complete near the outfalls. There is the potential that stormwater constituents may have migrated downstream beyond the outfall areas to areas where aquatic plants or fish are present. The completeness of this pathway will be evaluated in the HHRA and if determined to be complete will be included in the risk assessment.

### 3.1.3 Exposure Assumptions

An important consideration for the HHRA is the frequency of surface water flow from the outfalls and the likelihood of exposure to water in the drainages adjacent to the SSFL. Exposure to surface water can only occur when water is flowing at the outfalls. For Outfalls 019 and 020, surface water comes from groundwater treatment system discharges and therefore flow (and potential exposure) may occur for a majority of the year. For the remaining outfalls, flow is intermittent and dependent on rainfall and onsite surface water pond operation. Recent flow monitoring data from the outfalls, combined with output data from calibrated hydrologic models where available (e.g., Outfalls 008 and 009), will be used to estimate annual discharge frequency, and may be adjusted where necessary to reflect an average rainfall year. This information will be used to estimate the days per year (exposure frequency) that exposure to surface water may occur for each outfall.

Incidental ingestion of water is possible when walking or wading in streams. There is limited information on incidental ingestion rates of water during low contact recreational uses of water bodies. A recent study suggests that mean and upper confidence estimates of water ingestion during limited-contact recreational activities on surface waters are about 3-4 mL and 10-15 mL, respectively (Dorevitch et al. 2011). By contrast, a study conducted in swimming pools with swimmers actively swimming at least 45 minutes resulted in estimates of the average amount of water swallowed by non-adults and adults as 37 ml and 16 ml, respectively (Dufour 2006). The USEPA refers to a value of 50 ml/hour for both children and adult swimmers (USEPA 2015b). Given the more limited potential for incidental ingestion through hiking and wading, the upper-bound estimate of 15 ml per event estimated from recreational activities will be used as the incidental ingestion rate for this HHRA.

For dermal contact, exposure is assumed to occur through contact of the lower legs and feet while walking through the water. In addition, contact is assumed to occur to the forearms and hands assuming that the recreator may pick something up from the drainage. Surface areas for each of these parts of the body will be taken from the USEPA Exposure Factors Handbook (EFH; EPA, 2011) for children and adults.

To be conservative, exposures are assumed to be possible for relatively young children from two years of age. Age ranges that will be evaluated are consistent with USEPA 2015b and include children from 2 to 16 years old and adults (assumed to be over 16 years of age). Additional exposure parameters such as exposure duration and body weight will also be taken from the EFH and USEPA 2015b.

### 3.2 Exposure Point Concentrations

Exposure point concentrations (EPCs) are the concentrations of constituents in environmental media to which receptors may be exposed through defined exposure pathways considered complete in the CSM. Depending on the nature of the exposure, the number of samples, and constituent distribution, the maximum detected COPC concentrations can be used as EPCs. However, long-term exposure to a single sample point is highly unlikely (i.e., a recreator is unlikely to be exposed only to the maximum concentration for each exposure event). A more realistic estimate of the EPC would be the average concentration over the assumed exposure duration. A conservative estimate of the average can be calculated by using the 95 percent upper confidence limit of the average concentration (95UCL) for each COPC if sufficient data are available (Cal-EPA, 1996; USEPA, 2002). The 95UCL concentration for each constituent detected at each outfall over the data periods discussed in Section 2 will be calculated and used as the EPC. The latest version of the USEPA ProUCL software (Version 5.1.00) will be used to calculate the 95UCL (USEPA, 2014). For constituents where a 95UCL cannot be calculated (e.g., due to a limited number of detected results), the maximum observed concentration will be used in the HHRA.

# 4. TOXICITY ASSESSMENT

The toxicity assessment characterizes the relationship between the magnitude of exposure to a COPC and the nature and magnitude of adverse health effects that may result from such exposure. Consistent with regulatory risk assessment policy, adverse health effects resulting from potential chemical exposures are classified into two broad categories: cancer effects and noncancer effects. The basis for the selection of toxicity values in each of these categories is described in more detail below. For radionuclides exposure, toxicity criteria will be taken from the Preliminary Remediation Goals for Radionuclides (http://epa-prgs.ornl.gov/radionuclides/prg_guide.html). Additional COPC-specific parameters needed for the HHRA such as dermal permeability constants will also be obtained from USEPA documentation (USEPA 2015b and 2015c).

The two key toxicity criteria used in HHRAs for exposures to chemicals are: 1) cancer slope factors (CSFs) or Unit Risk Factors (URFs) for estimating long term, chronic cancer risks from exposure to carcinogens; and 2) oral reference doses (RfDs) or Reference Concentrations (RFCs) for estimating long term hazard from exposure to noncarcinogens. For the HHRA, toxicity criteria will be selected following the general hierarchy approved by Cal-EPA for use at the SSFL listed below (SRAM Rev. 2 Addendum, MWH 2014) and will be consistent with the values presented in the SRAM Rev. 2 Addendum:

1. California Environmental Protection Agency Office of Environmental Health Hazard Assessment Toxicity Criteria Database (OEHHA, 2015).
2. Integrated Risk Information System (IRIS; USEPA, 2015a).
3. Provisional Peer Reviewed Toxicity Values (PPRTV), as cited in the June 2015 version of the USEPA RSL Tables (USEPA, 2015b).
4. Provisional Peer Reviewed Toxicity Values (PPRTV) Appendix, as cited in the June 2015 version of the USEPA RSL Tables (USEPA, 2015b).
5. Agency for Toxic Substances and Disease Registry (ATSDR) Minimum Risk Levels (MRLs), as cited in the June 2015 version of the USEPA RSL Tables (USEPA, 2015b).
6. Health Effects Assessment Summary Table (HEAST; USEPA 1997).
7. National Center for Environmental Assessment (NCEA), as cited in the USEPA Region 9 PRG tables (USEPA, 2004).
8. New Jersey Department of Environmental Protection (NJDEP), as cited in the June 2015 version of the USEPA RSL Tables (USEPA, 2015b).

At the present time, Cal-EPA and USEPA have only developed toxicity criteria for the oral and inhalation routes of exposure. In the absence of values specific to the dermal route, the oral toxicity criteria will be used to evaluate dermal exposures to surface water. For those COPCs for which toxicity values are not available, a surrogate chemical approach will be employed in which toxicity values developed for structurally similar compounds will be assigned to the COPCs lacking toxicity criteria to avoid underestimating potential hazards. Surrogate compounds will be selected consistent with the SRAM Rev. 2 Addendum.

The traditional RfD approach to the evaluation of chemicals is not applied to lead because most adverse human health effects data associated with exposure to lead have been correlated with concentrations of lead in blood and not with intake of lead by an individual (Cal-EPA, 1996). Blood lead concentration is an integrated measure of internal dose, reflecting total exposure from Site-related and background sources. Currently, Cal-EPA uses a 1 microgram per deciliter (µg/dL) benchmark for source-specific incremental change in blood lead levels for protection of children and fetuses (Cal-EPA, 2015) as the health criterion for lead. This benchmark is the estimated incremental increase in a child's blood lead level that would reduce their IQ by up to 1 point. The Cal-EPA spreadsheet version Leadspread 7 (Cal-EPA, 2009) will be used to evaluate potential exposures to surface water.

# 5. RISK-BASED CONCENTRATIONS

Risk-based Concentrations (RBCs) will be derived for each COPC in the HHRA. The RBCs incorporate the results of the exposure assessment and toxicity assessment and represent the concentrations of COPCs in the relevant environmental medium (i.e., surface water) that would be considered safe for recreational receptors under conservative (i.e., protective) exposure conditions. Potential cumulative cancer risks and noncancer hazards will then be estimated by summing the ratios of measured COPC concentrations and the appropriate RBCs.

Deriving RBCs for COPCs in surface water requires information regarding the level of human intake of the COPC (exposure assessment), the relationship between intake of the COPC and its toxicity (toxicity assessment), and the assumed target cancer risk or noncancer hazard. The methodology is based principally on guidelines provided by the USEPA in *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A), Interim Final* (USEPA, 1989) and *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part B: Development of Risk-Based Preliminary Remediation Goals)*, (USEPA, 1991a). The RBCs will be calculated using the USEPA Regional Screening Level online calculators for both chemicals and radionuclides (USEPA, 2015) modified to incorporate site-specific exposure assumptions and using the toxicity criteria hierarchy noted above. The equations used to calculate the RBCs for chemicals are presented in the *User's Guide for Regional Screening Levels* (USEPA, 2015) and for radionuclides in the *User's Guide for Preliminary Remediation Goals for Radionuclides* (USEPA, 2015).

Various demarcations of acceptable risk have been established by regulatory agencies. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP; 40 CFR 300) indicates that lifetime incremental cancer risks posed by a site should not exceed a range of one in one million ($1\times10^{-6}$) to one hundred in one million ($1\times10^{-4}$) and noncarcinogenic chemicals should not be present at levels expected to cause adverse health effects (i.e., a hazard index [HI] greater than 1). In addition, other relevant guidance (USEPA, 1991b) states that sites posing a cumulative cancer risk of less than $10^{-4}$ and hazard index less than unity (1) for noncancer endpoints are generally not considered to pose a significant risk warranting remediation. The California Hazardous Substances Account Act (HSAA) incorporates the NCP by reference and, thus, also incorporates the acceptable risk range set forth in the NCP. In California, the Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65) regulates chemical exposures to the general population and is based on an acceptable risk level of $1\times10^{-5}$. Cal-EPA considers the $1\times10^{-6}$ risk level as the generally accepted point of departure for unrestricted land use.

Under most situations, cancer risks in the range of $10^{-6}$ to $10^{-4}$ may be considered to be acceptable with cancer risks less than $10^{-6}$ considered *de minimus.* These risk estimates are in contrast to the background risk of Americans developing cancer. The background risk is one chance in three (0.3 or $3\times10^{-1}$) for an American female, and one chance in two (0.5 or $5\times10^{-1}$) for an American male of eventually developing cancer (American Cancer Society (ACS), 2013).

For the HHRA described herein, a target cancer risk level of $1\times10^{-6}$ based on the Cal-EPA point of departure cancer risk level will be used to derive RBCs for the recreator scenarios. The target hazard quotient (THQ) used for noncarcinogens of 1 will be used.

# 6. RISK CHARACTERIZATION

Risk characterization integrates the results of the toxicity assessment and the exposure assessment to estimate potential cancer risks and adverse noncancer health effects associated with exposure to chemicals detected at the Site. This integration provides quantitative estimates of cancer risk and noncancer hazard that are then compared to acceptable standards.

The process of an HHRA is an iterative process where factual site, receptor, and chemical-specific data are used when available. When specific data are not available, conservative (i.e., health protective) assumptions are utilized. The use of repeated, conservative assumptions can lead to overly conservative estimations of cancer risk or noncancer hazard, but which provides an upper-bound estimate of the actual risk or hazard. Thus, for any site, the estimated cancer risk or noncancer hazard level reflects an upper-bound estimate of the most probable risk or hazard. The most probable cancer risk or noncancer hazard is likely to be much less, perhaps as low as zero, and probably not measurable in the potentially exposed population.

This section presents the specific approach that will be used in comparing the concentrations of individual COPCs detected in the various environmental media to the RBCs, and in estimating the cumulative cancer risk and noncancer hazard associated with potential exposure to all detected chemicals at the Site. This approach can be used to determine if the target risk or hazard ranges are exceeded for a given outfall. The cumulative cancer risk and noncancer hazard posed by the presence of all COPCs detected in surface water runoff at a given outfall location will be estimated in the HHRA using the following equations.

Cumulative cancer risk (at a given outfall location):

$$R_{tot} = \left[ \sum_{i=1}^{n} \left( \frac{C_{SW_i}}{RBC_{SW\text{-}C,i}} \right) \right] \times TR$$

Cumulative noncancer hazard index (at a given sampling location):

$$HI_{tot} = \left[ \sum_{i=1}^{n} \left( \frac{C_{SW_i}}{RBC_{SW\text{-}NC,i}} \right) \right] \times THI$$

Where:

$R_{tot}$ = cumulative cancer risk from all COPCs detected in specific medium at given sampling location (unitless);

| | | |
|---|---|---|
| $C_{SWi}$ | = | concentration of COPC *i* detected in surface water (mg/L or pci/L); |
| $RBC_{SW\text{-}C,i}$ | = | risk-based concentration for COPC *i* in surface water based on cancer effects (mg/L or pci/L ); |
| TR | = | target cancer risk (unitless); |
| $HI_{tot}$ | = | cumulative noncancer hazard index from all COPCs detected in the specific medium at given sampling location (unitless); |
| $RBC_{SW\text{-}NC,i}$ | = | risk-based concentration for COPC *i* in surface water based on noncancer effects (mg/L or pci/L); |
| THI | = | target noncancer hazard index (unitless); and |
| n | = | number of COPCs for the medium evaluated (unitless). |

Using the methodology presented here, the cumulative cancer risk and noncancer hazard posed by the presence of multiple COPCs will be estimated for each outfall and compared to the regulatory risk range of $10^{-6}$ to $10^{-4}$ and a noncancer hazard index of 1 discussed in the previous section.

# 7. UNCERTAINTIES

The results of a HHRA are estimates only and include some uncertainty. Where possible, conservative (health-protective) assumptions will be used for the inputs into the HHRA, which is consistent with agency guidance. Major sources of uncertainty in an HHRA may include the following:

1) Natural variability (e.g., differences in body weight in a population);
2) Lack of knowledge about basic physical, chemical, and biological properties and processes (e.g., the affinity of a chemical to sorb to particles and its solubility in water);
3) Assumptions in the models used to estimate key inputs (e.g., dose-response models);
4) Measurement error; and
5) Assumptions used to estimate exposure as they relate to actual conditions at the site.

Perhaps the greatest single source of uncertainty in HHRAs is a chemical's dose-response relationship, which typically relies on animal studies as the basis for determining the appropriate toxicity value for effects on humans. Typically adverse effects are assumed to be additive in nature. This assumption may over or underestimate estimate risks if there are antagonistic or synergistic effects among the constituents. Additional uncertainty may also be associated with analytical data, which are subject to both systematic error (bias) and random error (imprecision). Other major sources of uncertainty include computation of average EPCs, particularly for outfall-constituent combinations with limited available data and/or few detected results. For dioxins, differences exist with how the dioxin TEQs are calculated under the NPDES reporting requirements using older TEF values and the values in the 2005 dioxin guidance. These differences will be discussed in the uncertainty section. While the basic approach to the HHRA is to incorporate conservative assumptions in the analysis to be inclusive of these uncertainties, these and other sources of uncertainty and their anticipated effect in estimated potential risks associated with the surface water runoff will be discussed in the HHRA.

# 8. SCHEDULE

The Draft Work Plan was provided to the Los Angeles RWQCB on August 4, 2015. Comment letters from the Office of Environmental Health Hazard Assessment (OEHHA) and the Los Angeles RWQCB were provided on November 25, 2015 and January 28, 2016, respectively. This Revised Work Plan is being provided to the Los Angeles RWQCB on March 31, 2015. When the Work Plan is deemed complete, the Los Angeles RWQCB will provide a 30-day public review and comment period on the completed HHRA Work Plan. Upon Work Plan approval by the Los Angeles RWQCB, the HHRA will be completed and submitted to the Los Angeles RWQCB within 180 days. When the HHRA is deemed complete by the RWQCB, Boeing and the Expert Panel will present the results to the RWQCB at a public meeting.

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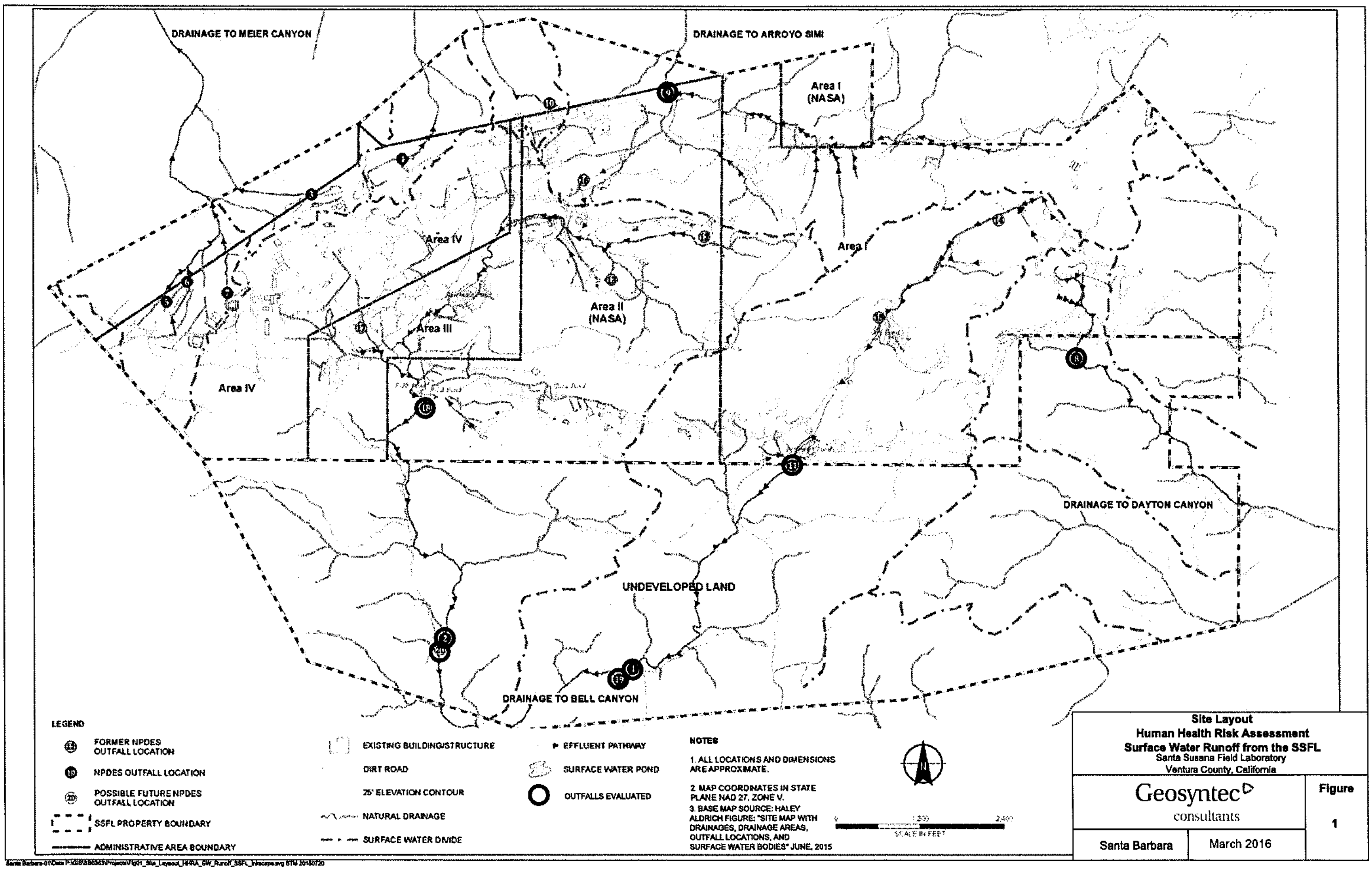
# FIGURES



DRAINAGE TO MEIER CANYON
DRAINAGE TO ARROYO SIMI
Area I
(NASA)
Area IV
Area I
Area II
(NASA)
Area III
Area IV
DRAINAGE TO DAYTON CANYON
UNDEVELOPED LAND
DRAINAGE TO BELL CANYON
LEGEND
FORMER NPDES OUTFALL LOCATION
NPDES OUTFALL LOCATION
POSSIBLE FUTURE NPDES OUTFALL LOCATION
SSFL PROPERTY BOUNDARY
ADMINISTRATIVE AREA BOUNDARY
EXISTING BUILDING/STRUCTURE
DIRT ROAD
25' ELEVATION CONTOUR
NATURAL DRAINAGE
SURFACE WATER DIVIDE
EFFLUENT PATHWAY
SURFACE WATER POND
OUTFALLS EVALUATED
NOTES
1. ALL LOCATIONS AND DIMENSIONS ARE APPROXIMATE.
2. MAP COORDINATES IN STATE PLANE NAD 27, ZONE V.
3. BASE MAP SOURCE: HALEY ALDRICH FIGURE: "SITE MAP WITH DRAINAGES, DRAINAGE AREAS, OUTFALL LOCATIONS, AND SURFACE WATER BODIES" JUNE, 2015
SCALE IN FEET
Site Layout
Human Health Risk Assessment
Surface Water Runoff from the SSFL
Santa Susana Field Laboratory
Ventura County, California
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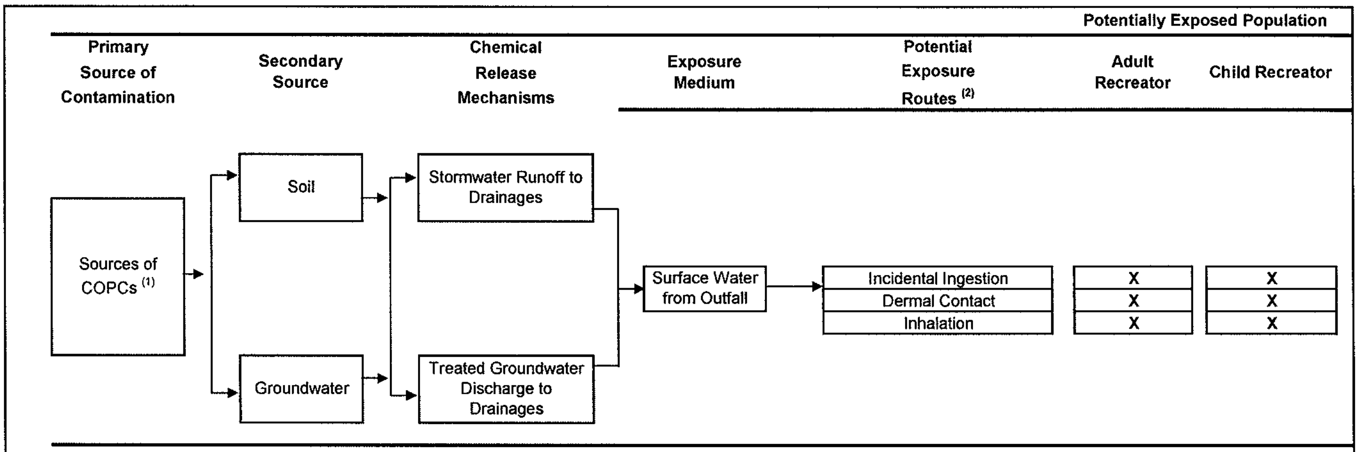
Figure
1
Santa Barbara
March 2016




X — Potentially complete pathway will be considered for inclusion in HHRA based on sample results and exposure potential

☐ — Incomplete Pathway not considered

Notes:

1. Historical facility operations, impacted and unimpacted/natural soils, paved surfaces, atmospheric deposition
2. Potential exposures to sediment in drainages are being addressed under the three regulatory orders under DTSC oversight (See Section 1.2)
   Potential exposure pathway completeness to downstream aquatic plants and fish evaluated in HHRA

COPC - Constituent of Potential Concern

**Conceptual Site Model**
**Human Health Risk Assessment**
**Surface Water Runoff from Outfalls**

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**Figure 2**

March 2016

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# TABLE

**Table 1**
**Number of Samples for Constituents Detected in NPDES Permit Monitoring Surface Water Samples**
**Santa Susana Field Laboratory**

| Detected Constituent | Outfall | | | | | | |
|---|---|---|---|---|---|---|---|
| | 001 | 002 | 008 | 009 | 011 | 018 | 019 |
| **Metals** | | | | | | | |
| Aluminum, Dissolved | 1 | 0 | 5 | 6 | 0 | 0 | 0 |
| Aluminum, Total | 1 | 0 | 5 | 6 | 0 | 0 | 0 |
| Antimony, Dissolved | 4 | 5 | 14 | 41 | 3 | 4 | 3 |
| Antimony, Total | 4 | 5 | 14 | 41 | 3 | 4 | 3 |
| Arsenic, Total | 4 | 9 | 5 | 6 | 3 | 4 | 3 |
| Barium, Dissolved | 4 | 9 | 0 | 0 | 3 | 4 | 3 |
| Barium, Total | 4 | 9 | 0 | 0 | 3 | 4 | 3 |
| Beryllium, Total | 4 | 9 | 5 | 6 | 3 | 4 | 3 |
| Cadmium, Dissolved | 7 | 20 | 14 | 41 | 5 | 12 | 18 |
| Cadmium, Total | 7 | 20 | 14 | 41 | 5 | 12 | 18 |
| Calcium, Dissolved | 3 | 3 | 4 | 5 | 3 | 4 | 7 |
| Calcium, Total | 3 | 3 | 4 | 5 | 3 | 4 | 6 |
| Chromium VI (Hexavalent), Total | 4 | 5 | 4 | 6 | 3 | 4 | 3 |
| Chromium, Dissolved | 3 | 8 | 5 | 6 | 2 | 3 | 3 |
| Chromium, Total | 4 | 9 | 5 | 6 | 3 | 4 | 3 |
| Cobalt, Dissolved | 4 | 5 | 0 | 0 | 3 | 4 | 3 |
| Cobalt, Total | 4 | 5 | 0 | 0 | 3 | 4 | 3 |
| Copper, Dissolved | 7 | 20 | 14 | 41 | 5 | 12 | 18 |
| Copper, Total | 7 | 20 | 14 | 41 | 5 | 12 | 18 |
| Iron, Dissolved | 7 | 20 | 5 | 6 | 5 | 12 | 3 |
| Iron, Total | 7 | 20 | 5 | 6 | 5 | 12 | 3 |
| Lead, Dissolved | 7 | 20 | 14 | 41 | 5 | 12 | 18 |
| Lead, Total | 7 | 20 | 14 | 41 | 5 | 12 | 18 |
| Magnesium, Dissolved | 3 | 3 | 4 | 4 | 3 | 4 | 7 |
| Magnesium, Total | 3 | 3 | 4 | 4 | 3 | 4 | 6 |
| Manganese, Dissolved | 7 | 13 | 0 | 0 | 5 | 8 | 3 |
| Manganese, Total | 7 | 13 | 0 | 0 | 5 | 8 | 3 |
| Mercury, Dissolved | 7 | 20 | 14 | 40 | 5 | 11 | 18 |
| Mercury, Total | 7 | 20 | 14 | 41 | 5 | 12 | 18 |
| Nickel, Dissolved | 4 | 9 | 5 | 7 | 3 | 4 | 3 |
| Nickel, Total | 4 | 9 | 5 | 7 | 3 | 4 | 3 |
| Selenium, Dissolved | 7 | 20 | 14 | 8 | 5 | 12 | 18 |
| Selenium, Total | 7 | 19 | 14 | 8 | 5 | 12 | 18 |
| Silver, Total | 4 | 5 | 5 | 6 | 3 | 4 | 3 |
| Thallium, Dissolved | 4 | 5 | 14 | 41 | 3 | 4 | 3 |
| Thallium, Total | 4 | 5 | 14 | 41 | 3 | 4 | 3 |
| Vanadium, Dissolved | 4 | 5 | 5 | 6 | 3 | 4 | 3 |

**Table 1**
**Number of Samples for Constituents Detected in NPDES Permit Monitoring Surface Water Samples**
**Santa Susana Field Laboratory**

| Detected Constituent | Outfall | | | | | | |
|---|---|---|---|---|---|---|---|
| | 001 | 002 | 008 | 009 | 011 | 018 | 019 |
| **Metals** | | | | | | | |
| Vanadium, Total | 4 | 5 | 5 | 6 | 3 | 4 | 3 |
| Zinc, Dissolved | 7 | 20 | 14 | 7 | 5 | 12 | 18 |
| Zinc, Total | 7 | 20 | 14 | 7 | 5 | 12 | 18 |
| **Organics** | | | | | | | |
| 1,2-Dichloroethane | 7 | 20 | 5 | 6 | 5 | 12 | 18 |
| 2,3,7,8-TCDD TEQ_NoDNQ | 7 | 20 | 14 | 41 | 5 | 12 | 18 |
| alpha-BHC | 7 | 20 | 4 | 6 | 5 | 12 | 18 |
| Benzene | 6 | 12 | 5 | 6 | 5 | 10 | 18 |
| Benzoic acid | 3 | 3 | 3 | 3 | 2 | 3 | 1 |
| beta-BHC | 4 | 5 | 4 | 6 | 3 | 4 | 3 |
| bis(2-Ethylhexyl)phthalate | 7 | 20 | 5 | 6 | 5 | 12 | 18 |
| Bromodichloromethane | 4 | 5 | 5 | 6 | 3 | 5 | 3 |
| Butyl benzylphthalate | 4 | 5 | 5 | 6 | 3 | 4 | 3 |
| Chloroform (Trichloromethane) | 6 | 12 | 5 | 6 | 5 | 10 | 18 |
| cis-1,2-Dichloroethene | 4 | 5 | 3 | 4 | 3 | 5 | 14 |
| Dibromochloromethane | 4 | 5 | 5 | 6 | 3 | 5 | 3 |
| Diethyl phthalate | 4 | 5 | 5 | 6 | 3 | 4 | 3 |
| Di-n-butylphthalate | 4 | 5 | 5 | 6 | 3 | 4 | 3 |
| Endrin aldehyde | 4 | 5 | 4 | 6 | 3 | 4 | 3 |
| Isophorone | 4 | 5 | 5 | 6 | 3 | 4 | 3 |
| Methylene chloride | 4 | 5 | 5 | 6 | 3 | 5 | 3 |
| Naphthalene | 4 | 5 | 6 | 9 | 3 | 5 | 3 |
| Pentachlorophenol | 7 | 20 | 5 | 6 | 5 | 12 | 18 |
| Trichloroethene | 7 | 20 | 5 | 6 | 5 | 12 | 18 |
| **Inorganics** | | | | | | | |
| Ammonia | 7 | 20 | 14 | 0 | 5 | 12 | 18 |
| Boron, Dissolved | 4 | 5 | 5 | 6 | 3 | 4 | 3 |
| Boron, Total | 4 | 5 | 5 | 6 | 3 | 4 | 3 |
| Chloride | 7 | 20 | 14 | 42 | 5 | 12 | 18 |
| Cyanide | 7 | 20 | 10 | 33 | 5 | 12 | 18 |
| Fluoride | 4 | 5 | 5 | 6 | 3 | 4 | 3 |
| Nitrate (as N) | 7 | 20 | 14 | 0 | 5 | 12 | 18 |
| Nitrite/Nitrate Nitrogen | 7 | 20 | 14 | 41 | 5 | 12 | 18 |
| Perchlorate | 7 | 20 | 14 | 14 | 5 | 12 | 18 |
| Sulfate | 7 | 20 | 14 | 42 | 5 | 12 | 18 |
| **Radionuclides** | | | | | | | |
| Gross Alpha Analytes, Total | 7 | 20 | 14 | 41 | 5 | 12 | 18 |

**Table 1**
**Number of Samples for Constituents Detected in NPDES Permit Monitoring Surface Water Samples**
**Santa Susana Field Laboratory**

| Detected Constituent | Outfall | | | | | | |
|---|---|---|---|---|---|---|---|
| | 001 | 002 | 008 | 009 | 011 | 018 | 019 |
| **Radionuclides** | | | | | | | |
| Gross Beta Analytes, Total | 7 | 20 | 14 | 41 | 5 | 12 | 18 |
| Potassium-40, Total | 7 | 20 | 14 | 41 | 5 | 12 | 18 |
| Radium-226 & 228, Total | 6 | 19 | 14 | 41 | 4 | 11 | 18 |
| Radium-226, Total | 7 | 20 | 14 | 41 | 5 | 12 | 18 |
| Radium-228, Total | 6 | 19 | 14 | 41 | 4 | 11 | 18 |
| Strontium-90, Total | 7 | 20 | 14 | 41 | 4 | 12 | 18 |
| Total Uranium | 7 | 19 | 14 | 38 | 5 | 11 | 18 |
| Tritium, Total | 7 | 20 | 14 | 41 | 5 | 12 | 18 |

Notes:
(1) Time period includes samples collected from February 16, 2009 through January 6, 2016
(2) Includes NPDES monitoring parameters detected at least once at one or more outfall during the time period specified
(3) Excludes NPDES monitoring parameters not relevant for evaluating human health exposure (e.g. total dissolved solids, pH, aquatic toxicity tests)
NPDES - National Pollutant Discharge Elimination System
HHRA - Human Health Risk Assessment
BHC - benzene hexachloride
TCDD - Tetrachlorodibenzo para dioxin
TEQ - toxic equivalent