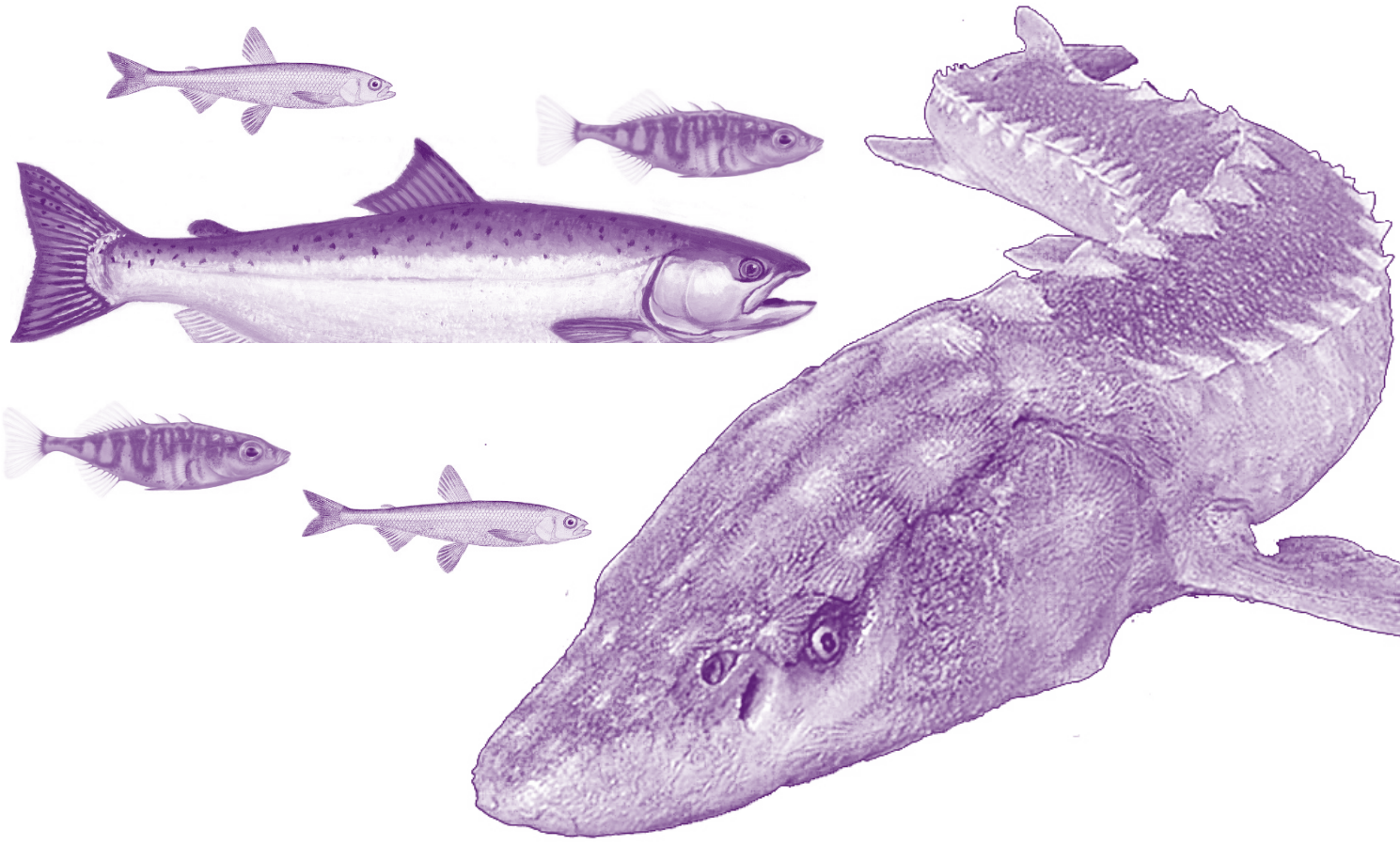
Product-Chemical Profile for Laundry Detergents Containing Nonylphenol Ethoxylates

February 2022



SAFER CONSUMER PRODUCTS

Department of Toxic Substances Control

CalEPA California Environmental Protection Agency

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ABOUT THIS DOCUMENT

The Department of Toxic Substances Control (DTSC) identifies product-chemical combinations for consideration as Priority Products in accordance with the process identified in Article 3 of the Safer Consumer Products (SCP) regulations.[1] DTSC finds nonylphenol ethoxylates (NPEs) in laundry detergent meets these regulatory criteria[2] for listing a Priority Product:

(1) There must be potential public and/or aquatic, avian, or terrestrial animal or plant organism exposure to the Candidate Chemical(s) in the product; and

(2) There must be the potential for one or more exposures to contribute to or cause significant or widespread adverse impacts.

The SCP regulations allow DTSC to use a narrative standard to show how these criteria are met. This Product-Chemical Profile (Profile) provides that narrative, demonstrating that the regulatory criteria have been met and serving as the basis for Priority Product rulemaking. The Profile does not provide a comprehensive assessment of all available adverse impact and exposure literature on NPEs or laundry detergents. DTSC will finalize this Profile after considering public comments and may then start the rulemaking process. If this Priority Product regulation is adopted, the responsible entities must follow the reporting requirements pursuant to the SCP regulations.[3]

Readers should consider the following:

- This Profile is not a regulatory document and does not impose any regulatory requirements.
- The Profile summarizes information compiled by DTSC as of February 2018 and includes consideration of stakeholder feedback[4] provided during the comment period that closed on June 25, 2018. DTSC also considered feedback on the scientific basis of this document from three External Scientific Peer Reviewers on the scientific basis of this document in preparation for rulemaking. Their feedback was provided to DTSC on January 17, 2019, and was considered for this final Profile.
- By proposing to list this product-chemical combination as a Priority Product containing a Chemical of Concern, DTSC is not asserting that the product cannot be used safely. The proposal indicates only that there is a potential for exposure of people or the environment to the Chemical of Concern in the Priority Product, that such exposure has the potential to cause

[1] *CAL. CODE REGS. tit. 22, Division 4.5, Chapter 55, Article 3*
[2] *CAL. CODE REGS. tit. 22, § 69503.2(a)*
[3] *CAL. CODE REGS. tit. 22, § 69503.7 and Article 5 (Alternatives Analysis)*
[4] *https://calsafer.dtsc.ca.gov/cms/commentpackage/?rid=12740*

or contribute to significant or widespread adverse impacts, and that safer alternatives should be explored.

SUMMARY OF THE RATIONALE FOR PRODUCT-CHEMICAL SELECTION

DTSC is investigating laundry detergents containing nonylphenol ethoxylates (NPEs) as a potential Priority Product due to their potential for impacts to aquatic organisms. NPEs are a class of surfactants (compounds in detergents that increase cleaning efficiency) used for their cleaning properties in a variety of consumer products. NPEs are well-known aquatic toxicants that can be environmentally persistent and have been observed through monitoring of environmental media and aquatic species. NPEs are Candidate Chemicals because they appear on two of the 23 authoritative lists that compose the Candidate Chemicals List based on several hazard traits: the European Union's list of Substances of Very High Concern (SVHC) and the Oslo-Paris Convention for the Protection of the Marine Environment for the North-East Atlantic (OSPAR) list of Chemicals for Priority Action. This product falls within the Cleaning Products category of the 2016-2018 Priority Product Work Plan and meets the policy priority to consider chemicals that may adversely impact aquatic resources.

NPEs and their degradation products can impact the growth, reproduction, and development of fish and aquatic invertebrates at low concentrations. Cumulative exposure to NPEs and their degradation products can affect aquatic wildlife populations. While other authoritative organizations have identified human hazards traits, DTSC's focus on aquatic impacts should not be construed as lack of concern for adverse impacts to humans.

Despite international concern for NPEs in the aquatic environment, several consumer products continue to be formulated with NPEs, as they are low-cost, highly effective surfactants. These products include laundry detergents marketed to on-premises launderers like hotels and hospitals, which can discharge significant amounts of NPEs to wastewater treatment plants. An estimated 2 billion pounds of laundry are washed per year by on-premises launderers in California, and concentrations of NPEs in these laundry detergents can range from 5 to 50 percent. Once NPEs are in wastewater treatment plants, they break down into degradation products such as nonylphenol (NP), which are even more persistent and toxic than NPEs. Both NPEs and their degradation products are continuously released to the aquatic environment through wastewater discharge (effluent), so that organisms living in wastewater-impacted environments are chronically exposed.

NP, the most frequently analyzed of the nonylphenolic compounds, has been detected in California surface waters, sediments, and wastewater-related media, including influent, effluent, sludge, and biosolids. These detections can exceed aquatic guidelines, standards, or criteria established by various governments to protect aquatic organisms from adverse impacts. Detections in coastal organisms

across multiple levels of the food chain illustrate that NP can transfer from the aquatic environment to these organisms. Since California's surface water environments provide habitat for hundreds of fish species (including several endangered or threatened species) and hundreds of freshwater invertebrate species, many important populations may be impacted by exposure to NP. In a recent comment letter to DTSC, the San Diego County Water Authority requested consideration of NP in consumer products due to its presence in wastewater that is further treated for beneficial reuse, which can include nonpotable applications, such as irrigation, and potable reuse.

These high environmental concentrations and widespread detections in organisms demonstrate the potential for NPEs and their degradation products to contribute to significant or widespread adverse impacts to aquatic organisms. Several chemical alternatives to NPEs in cleaning products are available that do not persist after wastewater treatment.

1. PRODUCT-CHEMICAL DEFINITIONS AND SCOPE

This section introduces the Candidate Chemical(s) and the product that constitute the proposed product-chemical combination.

1.1. Scope of Candidate Chemical

1.1.1. Background on the class of nonylphenol ethoxylates

Nonylphenol ethoxylates, as further described in Section 1.1.2, are a class of chemicals within the larger class of alkylphenol ethoxylates that are used as non-ionic surfactants in many products. Surfactants lower the surface tension of water against a surface, such as soiled laundry, to facilitate wetting the surface and spreading of the cleaning solution (U.S. EPA 2012b; Ying 2006). Surfactants can also remove soils and prevent them from settling back onto the cleaned surface (ACI 2018). NPEs are surfactants because they have a polar ethoxylate side chain and long (nine carbon) non-polar side chain that can congregate with other NPE molecules to form micelles.

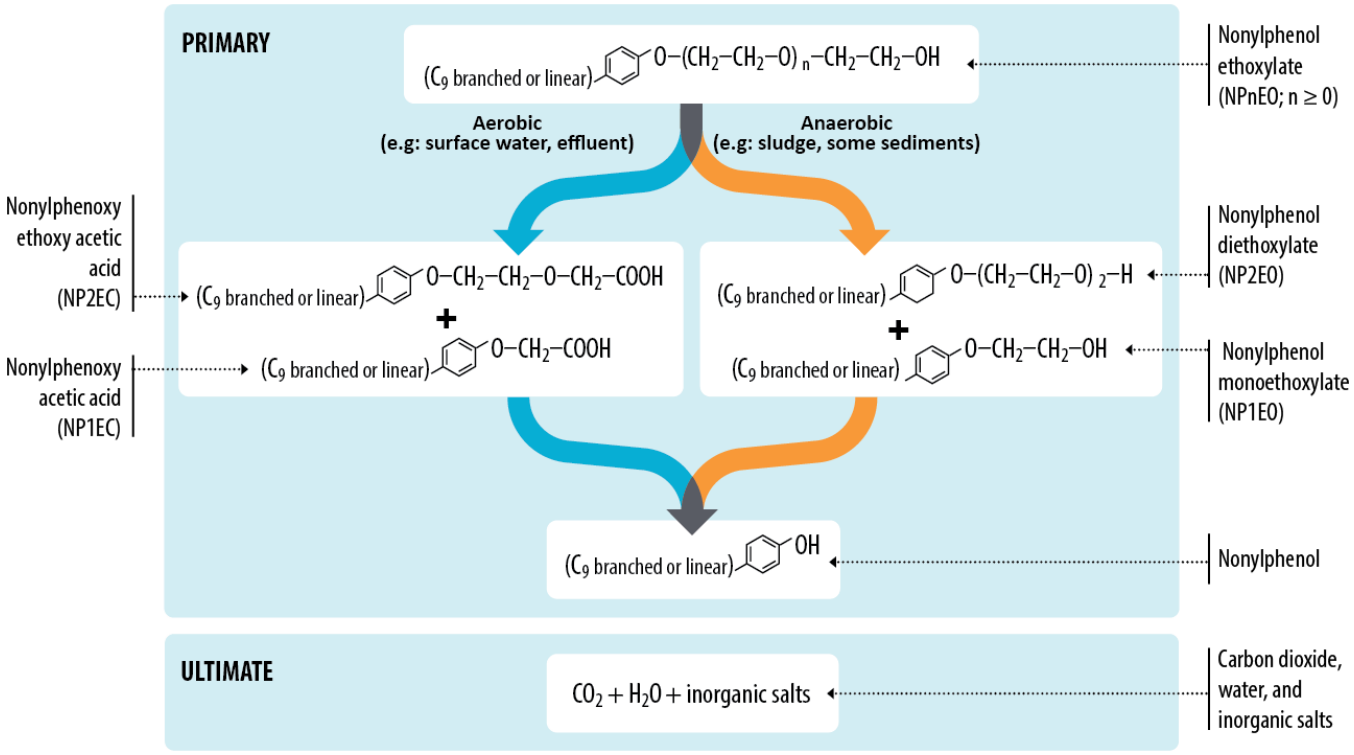
NPEs vary in their ethoxylate chain length, which can reach as much as 70 ethoxylate units long (NP70EO; (Dow 2017b)), depending on the physical properties needed as a surfactant in the product. Cleaning products tend to use NPEs with ethoxylate chain lengths between 4 and 15, while detergents use NPEs with ethoxylate chain lengths between 8 and 15, with NP9EO being the most commonly manufactured NPE (U.S. EPA 2012b). NPEs are typically sold containing a dominant chain length (e.g., 9 ethoxylates (NP9EO)), but contain a mixture of isomers (e.g., 1-, 2-, 4-NP9EO or linear and branched) and other ethoxylate chain lengths. Additionally, NPEs and their resulting degradation products (NPEDs) are generally present as a combination of isomers that vary based on how the chemicals were produced.

The Safer Consumer Products (SCP) regulations[5] include a chemical's degradation products in the definition of "chemical." DTSC included degradation products in this definition "to capture the different forms a chemical may take … in order to deal with where and when public health and environmental harm may be occurring" (DTSC 2013), and because degradation products may be of greater concern than parent chemicals. This consideration is relevant as NPEs are a class of chemicals that can break down to a number of degradation products in wastewater treatment plants (WWTPs) or the environment (see Figure 1). NPEDs include shorter chained NPEs (typically 3 ethoxylate units or less), nonylphenol ethoxycarboxylates (NPECs), and nonylphenol (NP). NPEs and NPECs can all break down to NP, which is persistent under certain environmental conditions and is the most toxic of the NPEDs (see Section 2). The proposal to list the class of NPEs is based on the potential for the members of the class to be directly and indirectly released into the environment and their adverse impacts, including hazard traits. However, the following degradation products are emphasized in this Profile due to availability of information about adverse impacts and exposure: NP1-2EOs, NP1-2EC, and NP.

In this document, NPEs will refer to the product ingredients, typically longer than 3 ethoxylate units, unless otherwise specified. When discussing specific alkylphenolic compounds, the number of ethoxylate units will be specified. For example, NP1EO describes a nonylphenol ethoxylate with one ethoxylate unit. When used collectively, NP1EO and NP2EO will be referred to as NP1-2EOs, and we will follow the same convention for the corresponding NPEC homologues. The term "nonylphenolic compounds" is used to describe NPEs and NPEDs, and other related chemicals that may or may not have hazard traits. Unless otherwise indicated, NPEs and NPEDs will refer to any combination of isomers, since they often occur as mixtures.

[5] *Cal. Code Regs. tit. 22, Division 4.5, Chapter 55*

Figure 1. A schematic of the general biodegradation pathway of long-chain NPEs to NP. Adapted from Environment Canada (2002).



1.1.2. Candidate Chemical Identity

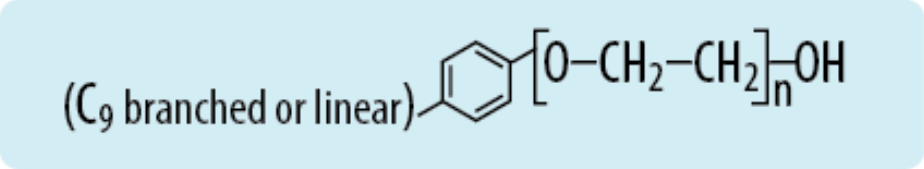
NPEs are characterized by an ethoxylated phenolic ring with a 9-carbon side chain bound at the ortho-, meta-, or para-position (i.e., 2-, 3-, 4-), with the para-position being most prevalent (Lu and Gan 2014). The ethoxylate side chain can vary in length from one to over 70 ethoxylate groups (Dow 2017b).

NPEs appear on two of the authoritative lists that make up the Candidate Chemicals list. The proposed product-chemical combination includes those NPEs that fall under either definition for NPEs as provided on those lists:

- "4-nonylphenol, branched and linear, ethoxylated: substances with a linear and/or branched alkyl chain with a carbon number of 9 covalently bound in position 4 to phenol, ethoxylated covering Unknown of Variable Composition, Complex Reaction Products and Biological Materials and well-defined substances, polymers and homologues, which include any of the individual isomers and/or combinations thereof (ECHA 2013)," or
- "Nonylphenol ethoxylates described with the formula C_9H_{19}-$C_6H_4OH(CH_2CH_2O)_n$, where n = 2 - 50, normally between 6 and 12" (OSPAR Commission 2009).

Figure 2 provides a generic structural formula for chemicals that meet the scope of this proposal. Note that the alkyl side chain (C_9 branched or linear) can vary in position on the phenolic ring.

Figure 2. An example of a generic structure of nonylphenol ethoxylates (NPEs)



A non-exhaustive list of substance identifiers is provided in Appendix B to identify some chemicals that meet these chemical definitions. This inventory does not constitute a comprehensive record of all relevant numerical identifiers available.

1.2. Scope of Product

The scope of laundry detergents covered by this proposal includes any product intended to clean or remove soil or unwanted deposits from laundered clothes and textile products, such as sheets and tablecloths. This includes but is not limited to laundry detergents of any form, including granules, liquids, powders, tabs, crystals, or pods, that are used in washing machines, for hand washing, or as part of a laundry system. Detergents intended for use as a pre-soak or pre-spotter or with fabric or color protection properties are also included. These products may be categorized as Global Product Classification (GPC) laundry detergents identified by the following codes (GS1 2017):

- Segment 47000000 – Cleaning/Hygiene Products
    - Family 47100000 – Cleaning Products
        - Class 47101700 – Laundry
            - Brick 10000424 – Laundry Detergents

1.3. Chemical and Product Use and Trends

NPEs are a family of nonionic surfactants that have been in use for several decades. The major uses of NPEs as surfactants are in industrial and institutional cleaning, emulsion polymerization, textile and leather auxiliary products, agriculture, paints, metal industries, pulp and paper, oilfield chemicals, and electrical and optical equipment (Markets and Markets 2016). The consumption of NPEs in North America has declined by 50 percent between 2005 and 2015 (APERC 2017), in part due to regulation, proposed regulatory action, and voluntary initiatives (The Home Depot 2018; Zero Discharge of Hazardous Chemicals Programme 2014).[6] Levels of NPEs in the environment may be declining (Maruya et al. 2015) as a result of such substitutions or removals, although wastewater effluent (discharge) monitoring data from Los Angeles County indicates that concentrations of NPEDs have not changed considerably over the last decade (LACSD 2012; LACSD 2014a; LACSD 2015).

A recent market report (Markets and Markets 2016) provides information regarding the relative uses of NPEs by sector and region. Globally, industrial and institutional cleaners were the dominant use of NPEs (39 percent by weight) in 2015, which includes laundry detergents and other cleaning products for commercial and industrial facilities. Other uses include the production of paints (13 percent), agrochemicals, such as pesticides, growth promoters, and defoliants (6 percent), leather and textiles (20 percent), oilfield chemicals (11 percent), and “other” (11 percent). The demand for NPEs is driven by the growth in industrial and institutional cleaning, paints, and agrochemical sectors. The overall growth of the industrial and institutional cleaning chemicals market is dependent on new construction of commercial buildings, such as healthcare facilities and hotels. While other products may also have

[6] *Sections 3.1.1 and 5.1.1 - 5.1.3*

routes of exposure to the aquatic environment,[7] laundry detergents containing NPEs can contribute significant amounts of NPEDs to wastewater-impacted environments.[8]

2. POTENTIAL ADVERSE IMPACTS

This section summarizes findings related to the potential adverse impacts of the Candidate Chemical as described in the SCP regulations. The emphasis of the adverse impact factors is to characterize the Candidate Chemical's toxicity and physical properties, and its mobility in the environment. The findings for this Candidate Chemical relate to the potential for one or more exposures described in Section 3 to contribute to or cause significant or widespread adverse impacts. Further clarification of each adverse impact factor is included below.

2.1. Physicochemical Properties

Reference: CAL. CODE REGS. tit. 22, § 69503.3(a)(1)(D).

Physicochemical properties can be helpful in predicting a chemical's behavior during manufacture and use. A chemical's behavior in humans, wildlife, ecosystems, and the environment may also be useful in evaluating its potential adverse public health and environmental impacts.

A narrative summary of key physicochemical properties is provided here to highlight the key findings that influence the environmental fate of NPEs and NPEDs. There are various challenges associated with determining experimental values of the physicochemical properties of this class of chemicals. Therefore, DTSC has evaluated ranges and trends, rather than specific values. NPEs are commercially found as mixtures of homologues (e.g., NP1EO and NP2EO) and isomers, which have physicochemical properties that reflect the mixture and not a specific chemical in the class, as has been demonstrated for NP (Lu and Gan 2014). Also, reported physicochemical properties of NPEs and NP can vary due to testing conditions and overall challenges in evaluating some physicochemical properties for surfactants, as described below.

The environmental partitioning of NPEs and NPEDs in the aquatic environment is largely influenced by the following physicochemical properties, water solubility, octanol-water partition coefficient (K_{ow}), and organic carbon-water partition coefficient (K_{oc}), where K represents the partition coefficient. These properties also dictate bioaccumulation potential. As NPEs degrade to less ethoxylated compounds, they become more hydrophobic as demonstrated by their higher K_{ow} and K_{oc} values, and lower water

[7] *Sections 3.1.3 and 5.2.4*
[8] *Section 3.1.2*

solubility. As a result, NP1-2EO and NP are preferentially found in sediments and bound to particulate matter, while other NPEs and NPECs are more likely to partition to water over sediments.[9]

Determinations of the K_{ow} for longer-chain NPEs using traditional methodologies are difficult, as these compounds tend to form micelles (OECD 1981, as cited in Ahel and Giger (1993)) and are produced as technical mixtures (ECHA 2014a). Additionally, experimental determinations of the K_{oc} and K_{ow} for NP specifically are complicated due to its ability to adhere to the lab materials (Dow 2017a; ECHA 2014a). Lab determinations of K_{ow} and K_{oc} have also been called into question, in part because experiments often use concentrations that are higher than those found in the environment (Ferguson et al. 2001). Nonetheless, physicochemical calculations of K_{ow} and K_{oc} suggest that these values will increase with a decrease in the ethoxylate side chain length (Ahel and Giger 1993; ECHA 2013). Predicted, experimental, and field-determined values of log K_{ow} and K_{oc} for NP and NP1-3EO vary (log K_{ow} 3.3-5.8, (ECHA 2014a); log K_{oc} 3.41-5.46, (ECHA 2013; ECHA 2014a; Ferguson et al. 2001)); such calculations consistently indicate that these compounds are lipophilic and will preferentially concentrate in the organic matter of sediments and particulates (Ying et al. 2002).

The water solubility of NPEs decreases as the ethoxylate side chain decreases (Ahel and Giger 1993; ECHA 2014a), indicating that short-chain NPEs and NP are more likely to be bound to sediments and particulates and therefore are not very mobile in aqueous environments. NP and NP1-5EOs have documented water solubility ranging from 3.02 to 9.48 mg/L (Ahel and Giger 1993). NP1-2ECs are more water soluble than NPEs (ECHA 2014a; Field and Reed 1996), which contributes to the high concentrations of NPECs observed in surface waters (Ahel et al. 1994b).

2.2. Fate and Transport

2.2.1. Environmental fate

Reference: CAL. CODE REGS. tit. 22, § 69503.3(a)(1)(E).

Environmental fate describes a chemical's mobility in environmental media, transformation (physical, chemical, or biological), or accumulation in the environment or biota. A chemical's environmental fate in air, water, soil, and living organisms relates to its exposure potential hazard traits, as defined in California Code of Regulations, Title 22, Chapter 54.

NPEs released into the aquatic environment will break down, mainly through biodegradation, into shorter-chained NPEs, NPECs (primarily NP1-2EC), and NP (ECHA 2013; Klečka et al. 2007), as summarized in Figure 1. The rate of degradation of these NPEDs varies with environmental conditions (e.g., oxygen level, temperature) and chain length. Additionally, isomer-specific differences in NP biodegradation rates have also been observed, and could lead to an overestimation of biodegradability

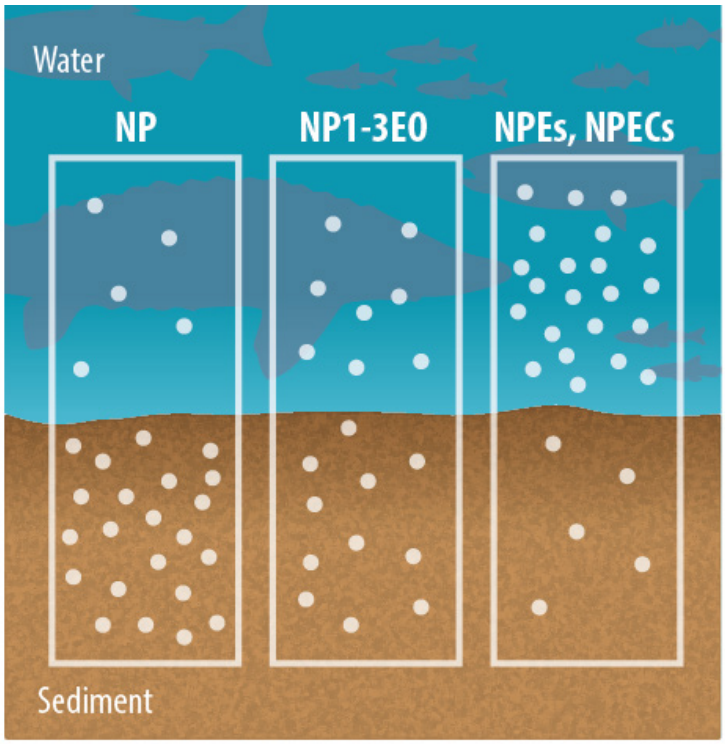
[9] *Section 2.2.3*

if only one isomer is used to represent NP (Lu and Gan 2014). Shorter-chained NPEs (e.g., NP1-3EO) and NP degrade more slowly than longer-chain NPEs and tend to accumulate in sediments (CCME 2002; Ying et al. 2002), while longer-chain NPEs and NPECs are found more readily in the water column (CCME 2002).

As summarized in Figure 3, NPEs and NPEDs partition differently across sediments and water according to their physicochemical properties as described in Section 2.1 (Klečka et al. 2007; U.S. EPA 2005). NP1-3EOs and NP preferentially partition to the organic matter found in sediments, particulates, and sludges (CCME 2002; Ying et al. 2002), while the more water soluble, higher ethoxylated NPEs and NPECs are found more readily in water and effluent (CCME 2002).

While NP is not considered to be mobile in the aquatic environment (Soares et al. 2008), sediments that accumulate NP and NP1-2EOs may become resuspended and serve as a continued source of these compounds to the water column (Ahel et al. 1994b). NPEs and NPEDs may also be transported through the atmosphere bound to particles (Lyons et al. 2014).

Figure 3. Relative environmental partitioning of NPEs and NPEDs



2.2.2. Other harmful chemicals generated from the Candidate Chemical

Reference: CAL. CODE REGS. tit. 22, § 69503.3(a)(1)(G).

A Candidate Chemical may degrade, form reaction products, or metabolize into other chemicals that have one or more hazard traits. These metabolites, degradation products, and reaction products (which may or may not be Candidate Chemicals) may cause different adverse impacts from those of the parent chemical. In some cases, a Candidate Chemical's degradation or reaction products or metabolites may have the same hazard trait, and may be more potent or more environmentally persistent, or both, than the parent chemical. In such cases, adverse impacts may be more severe, or may continue long after the Candidate Chemical's release to the environment.

DTSC is concerned about NPEs because they degrade to more toxic nonylphenolic compounds. The degradation of NPEs occurs in wastewater treatment plants (WWTPs) as well as when released to the environment (ECHA 2014a), and generates a number of different degradation products, some of which have hazard traits that can lead to cumulative impacts.[10] Overall, degradation of NPEs is fastest in oxic (oxygen-containing) environments such as surface waters and slowest in anoxic (low-oxygen) environments such as sediments (ECHA 2014a), and the resulting NPEDs are less biodegradable than the parent compounds (Soares et al. 2008).

The breakdown of NPEs is primarily attributed to biodegradation (ECHA 2013; Klečka et al. 2007). This occurs via shortening of the ethoxylate side chain to short-chain NPEs (typically NP1-2EOs), and oxidation to NPECs in WWTPs and in the aquatic environment (Ahel et al. 1994b; Di Corcia et al. 1998; Lara-Martin et al. 2014). The formation of NP1-2EOs is favored under anaerobic conditions typically found in sediments and anaerobically digested sludge, while the formation of NP1-2EC is favored under aerobic conditions such as those found in wastewater effluent and surface water (Environment Canada 2002).

NP1-2EO and NP1-2EC can be further degraded to NP, although these NPEDs are less biodegradable than the parent compounds.[11] Breakdown of NP1-2EO and NP1-2EC to NP occurs most frequently under anoxic conditions (ECHA 2013). Once NP is formed, ultimate breakdown to carbon dioxide and water under anaerobic conditions is unlikely (Ahel et al. 1994a; Soares et al. 2008), and contributes to the persistence of NP under anoxic conditions. Other, less likely, degradation pathways have been observed including degradation of NP1-2EO and NP1-2EC to NP in oxic environments (ECHA 2013; Soares et al. 2008; Writer et al. 2012) and degradation of NP in anaerobic (Chang et al. 2005; Chang et al. 2004) and aerobic environments (Soares et al. 2008).

Temperature affects biodegradation rates (Chang et al. 2004; Soares et al. 2008; Staples et al. 1999; Yuan et al. 2004), and thus environmental concentrations of NPEDs (Ahel et al. 1994a; Loyo-Rosales et

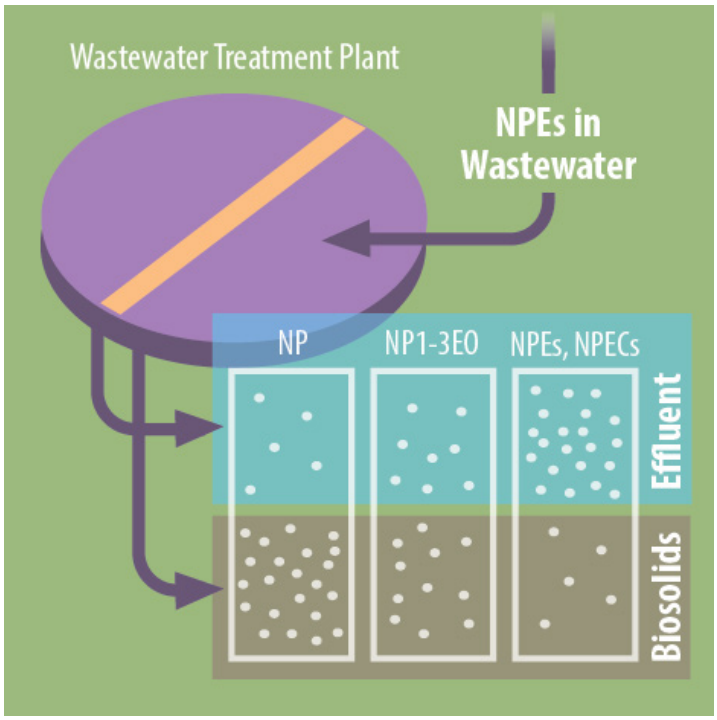
[10] *Sections 2.3 and 2.4.1*
[11] *Section 2.2.3*

al. 2007a; Lozano et al. 2012). Additionally, some studies have found that NP degrades more slowly in saltwater than in freshwater environments (U.S. EPA 2005).

Wastewater treatment plants are only partially effective in removing NPEs, and incomplete removal can lead to high concentrations of NPEDs in wastewater effluent, sludge, and biosolids (Ahel et al. 1994a; Environment Canada 2002), as is shown in Section 3.3.1 and Figure 4. Studies have shown that, while higher ethoxylated NPEs are effectively degraded in WWTPs (93-99 percent removed, (Naylor 1996; Ying 2006)), the removal rate drops to between 26-79 percent when all NPEDs are accounted for (Ahel et al. 1994a; Loyo-Rosales et al. 2007a). As much as 60 percent of the total mass of NPEs entering WWTPs is expected to be released to the environment through effluent or sludge (Ahel et al. 1994a; Loyo-Rosales et al. 2007a).

NPECs are the dominant NPED in effluent (Ahel et al. 1994a; Barber et al. 2015; Lara-Martin et al. 2014; Loyo-Rosales et al. 2007a; Loyo-Rosales et al. 2010), constituting as much as 50 percent of NPEDs, with NP1-2EOs and NP constituting 20 percent and 5 percent, respectively (Ahel et al. 1994a). NP that enters the WWTP in influent or is formed within the plant is primarily diverted from the aqueous waste stream through adsorption to sludge (Ahel et al. 1994a), where additional NP formation can occur during anaerobic treatment of the sludge before disposal (Giger et al. 1984).

Figure 4. Relative distribution of nonylphenolic compounds in outputs from the WWTP process



2.2.3. Behavior of the Candidate Chemical or its degradation products in the environment

Reference: Cal. Code Regs. tit. 22, § 69503.3(b)(4)(H).

The Candidate Chemical and/or its degradation products can migrate into or distribute across different environmental media. These chemicals may persist or bioaccumulate in these environmental media or in biological tissues.

Figure 3 illustrates the potential for NPEDs to migrate between environmental media. NPEDs can be found in high concentrations in particulates, sediment, and sludge as a result of this strong affinity for organic matter and their persistence in anoxic conditions.[12] Longer-chained NPEs and NPECs have relatively high water solubility and low K_{ow} and K_{oc} values, which indicate a greater tendency for these compounds to dissolve in water (ECHA 2014a; Field and Reed 1996; Ying et al. 2002). This is particularly true for NPECs, which have been found at high concentrations in surface water and effluent.[13] However, adsorption of NPEs, particularly NP6-7EO, to particulates and sediment can occur as a result of hydrogen-binding between the ethoxylate side chain and the sediment (Environment Canada 2002). The ability for NPEs and NPEDs to persist and bioaccumulate is summarized in Section 2.3.2.

2.3. Hazard Traits and Environmental or Toxicological Endpoints

Reference: CAL. CODE REGS. tit. 22, § 69503.3(a)(1)(A).

The hazard traits and environmental or toxicological endpoints summarized in this section are defined in the SCP regulations sections 69501.1(a)(36) and (33), respectively, both of which refer to the Office of Environmental Health Hazard Assessment's (OEHHA) Green Chemistry Hazard Trait regulations (California Code of Regulations, Title 22, Chapter 54).[14] These include exposure potential, toxicological, and environmental hazard traits.

2.3.1. Environmental hazard traits

NP and NPEs can impair growth, development, reproduction, and survival in fish, aquatic invertebrates, and algae (ECHA 2014a; Environment Canada and Health Canada 2001; OEHHA 2009; U.S. EPA 2005). Using the U.S. Environmental Protection Agency's (U.S. EPA) standard evaluation procedure for acute toxicity testing for freshwater fish and invertebrates, NP is highly to very highly toxic, and long-chain NPEs (e.g., NP9-10EOs) are moderately to slightly toxic (Staples et al. 1998). NPEs' toxicity increases as the ethoxylate unit chain length decreases (Environment Canada and Health Canada 2001; Servos

[12] *Section 3.3.1, Appendices E-3 and E-5*
[13] *Section 3.3.1, Appendices E-1 and E-2*
[14] *http://oehha.ca.gov/multimedia/green/pdf/GC_Regtext011912.pdf*

1999; U.S. EPA 2010b). Nonylphenolic compounds induce toxicity through various pathways, including narcosis (non-specific mode of action) and endocrine-mediated pathways (Environment Canada 2002).

NPEs and NPEDs exhibit endocrine-mediated activity mainly through estrogenic modes of action (specifically estrogen agonist activity), although inhibition of the androgen receptor-mediated pathways has also been exhibited *in vitro* (ECHA 2012). Although NP and NPEs are weakly estrogenic when studied *in vitro* and *in vivo*, with NP reported as 1,000 to 100,000 times weaker in estrogenic potential than endogenous 17β-estradiol, the concentrations of steroid hormones are detected at low levels compared to NPEDs in surface waters and sediment (Elliott et al. 2017; Lawrence Livermore National Laboratory and State Water Board 2006; Servos 1999; Staples et al. 1998). As such, NPEDs can contribute substantially to estrogenic effects in the environment (Elliott et al. 2017). T. Traditional environmental endpoints associated with growth, reproduction, development, and survival impairment are reported here (and in Appendix C), some of which are known to be estrogen sensitive (ECHA 2012). NP is recognized as an endocrine disruptor (ECHA 2012; ECHA 2013; WHO 2017) since it is endocrine active and causes adverse health effects in fish (see below). NP1-2EOs also have the potential to be endocrine disruptors since they exhibit similar endocrine activity to NP (ECHA 2013).

Acute toxicity studies in fish, invertebrates, and algae have reported LC50 (median lethal concentration) and EC50 (median effect concentration) values much higher for NPEs than NP (Servos 1999). For example, 96-hour LC50s were mostly between 100 and 300 µg/L for freshwater fish exposed to NP (Servos 1999) and as high as 6,600 µg/L for fathead minnows exposed to NP9EO (Staples et al. 1998). Additionally, LC50s were 92.4, 328, and 716 µg/L for zooplankton exposed to NP, NP1EO, and NP2EO, respectively (Teneyck and Markee 2007). NPECs are much more water soluble and much less toxic than corresponding NPEs. NP1-2EC has acute toxicities similar to NP9EOs (Environment Canada and Health Canada 2001; Servos 1999). See Section 2.4.1 for discussion of the relative toxicity of NPEDs.

A summary of hazard traits and endpoints from chronic and subchronic exposure to environmentally relevant concentrations of NP (<20 µg/L) is reported here and in Appendix C. NP is emphasized here because it is the most toxic NPED. Wildlife reproductive impairments,[15] which include endocrine toxicity,[16] are documented in fish. ECHA (2012) has identified 4-NP as a substance of very high concern as it is an endocrine disruptor in all fish species tested. Aquatic organisms are reported as more sensitive to the estrogenic effects of endocrine-disrupting compounds such as NP than mammals, including humans (EC 2018; WHO 2017). NP-induced reproductive impairments in fish studies (Japanese medaka, rainbow trout, and Chinese rare minnows) include endpoints such as an occurrence of intersex organs (i.e., testis-ova) in males, induction of vitellogenin (egg yolk protein) in males, increases in zona radiata protein (an estrogen-dependent biomarker for eggshell formation), and

[15] *CAL. CODE REGS. tit. 22, § 69404.8*
[16] *CAL. CODE REGS. tit. 22, § 69403.3*

occurrence of mixed secondary sex characteristics (Ackermann et al. 2002; Balch and Metcalfe 2006; Jobling et al. 1996; Seki et al. 2003; Yokota et al. 2001; Zha et al. 2008). Reproductive impairments have been documented in invertebrates as well. For example, exposure of barnacle larvae to NP resulted in decreased larval settlement (Billinghurst et al. 1998).

Wildlife growth impairment[17] from NP exposure is documented in a variety of aquatic organisms. Rainbow trout and Japanese medaka exposed to NP during early life-stage studies have reduced growth and body weight (ECHA 2014a; Seki et al. 2003; U.S. EPA 2005). Invertebrates exposed to NP in water and sediment exhibited reduced body length in mysids (Ward and Boeri 1991b, as cited in Environment Canada 2002 and U.S. EPA 2005), inhibited growth in copepod larvae (Lesueur et al. 2013), and decreased growth in mysids (England and Bussard 1993, as cited in Environment Canada 2002). NP exposures also caused developmental impairments in aquatic organisms, including decreased hatch rates in rainbow trout (Schwaiger et al. 2002), decreased numbers of molts in mysids (Hirano et al. 2009), and increased larval malformations in sea urchins (Arslan and Parlak 2007; Arslan et al. 2007).

Other hazard traits exhibited by aquatic organisms include survival impairment[18] and immunotoxicity.[19] Survival impairment endpoints include increased mortality in fathead minnows and decreased survival in mysids (Ward and Boeri 1991a as cited in both ECHA 2014a and U.S. EPA 2005); (Ward and Boeri 1991b as cited in both Environment Canada 2002 and U.S. EPA 2005). Immunotoxicity has been demonstrated in Pacific oysters exposed to low concentrations of NP, where innate immune responses to bacterial challenge are altered as evidenced by repressed total hemocyte counts and increased lysozyme activity (Hart et al. 2016).

2.3.2. Exposure potential hazard traits

2.3.2.1. Environmental persistence (Cal. Code Regs. tit. 22, § 69405.3)

Reviews by authoritative organizations, including the U.S EPA, Environment Canada, and ECHA, indicate that some NPEDs can exhibit environmental persistence, particularly in anoxic conditions (ECHA 2014a; Environment Canada 2002; U.S. EPA 2010b; U.S. EPA 2014b). In addition, various lab studies have found that some calculated half-lives of NP and NPEs in oxic and anoxic sediments exceed the definition of persistence (half-life greater than 2 months in sediments) for the purposes of the SCP regulations. These studies and their findings are summarized in Table 1, below. Information on the biodegradation of NPs and NPEs can be found in Section 2.2.2.

[17] *CAL. CODE REGS. tit. 22, § 69404.7*
[18] *CAL. CODE REGS. tit. 22, § 69404.9*
[19] *CAL. CODE REGS. tit. 22, § 69403.8*

Table 1. Sediment biodegradation studies indicating persistence of NP and NPEs

Reference	Half-life (days)		°C	Study description and notes
	Oxic	Anoxic		
NP				
Bradley et al. (2008)		>154	23	Microcosm experiment where no mineralization of linear NP was observed.
Chang et al. (2004) and Yuan et al. (2004)	40.8	99	20	Lab study; highly contaminated river sediment was spiked with NP.
	13.6-99	46.2-69.3	30	
De Weert et al. (2011)		>703	30	Lab study; polluted river sediment. Half-life excludes results from nitrate-reducing conditions for linear NP. No degradation of branched NP was observed under any conditions.
Ekelund et al. (1993)	>56	>56	11	Lab study; marine sediments. Approximately 45% of radiolabeled NP was recovered in 56 days.
Ferguson and Brownawell (2003)	178	231	25	Lab study; sewage-impacted estuarine sediment was spiked with branched NPEOs
Shang et al. (1999)		21,900	n/a	Field study; coastal marine sediments; half-life estimated from sediment cores.
Ying and Kookana (2003)		>70	20	Lab study; little to no degradation of linear NP observed during experiment.
NPEs				
Chang et al. (2004) and Yuan et al. (2004)	57.8	115.5	20	NP1EO; lab study with NPE-spiked highly contaminated river sediment.
	69.3-115.5	49.5-77	30	
Ferguson and Brownawell (2003)	45-204	169-301	25	NP1-9EO; lab study with NPE-spiked sewage-impacted estuarine sediment.
Shang et al. (1999)		21,900	n/a	NP1-19EO; Field study; coastal marine sediments. Half-life estimated from sediment cores.

n/a: Field study, experiment temperature not applicable

NP and NPEs persist under anoxic conditions and can accumulate in sediments. Waterbodies with high nutrient inputs and biological activity, such as estuaries, may be more prone to anoxic sediment, and are therefore more likely to accumulate contaminants such as NP that degrade more slowly under anoxic conditions (Diehl et al. 2012). Elevated nutrient inputs are of concern within California (State Water Board 2013b), as they can lead to excessive growth of algae and other plants. Available oxygen

in an ecosystem can be depleted once the plants die and are degraded (National Research Council et al. 2000).

There are few studies about the persistence of NPECs, and there is insufficient information to determine if they meet the regulatory criteria for environmental persistence. A field study suggests that NPECs may be more resistant to degradation than other NPEDs (Ahel et al. 1994b), however lab studies indicate that NPECs should be biodegradable under aerobic conditions (Di Corcia et al. 1998; Staples et al. 1999).

2.3.2.2. Bioaccumulation (Cal. Code Regs. tit. 22, § 69405.2)

NP can bioaccumulate in aquatic organisms, although this can depend on environmental conditions and species. Reports by authoritative organizations do not discuss the potential for bioaccumulation among NPEs or other NPEDs, and DTSC does not have enough information to determine if NPEs and NPEDs are bioaccumulative. However, the findings below show that NP arising from NPE and NPED degradation[20] has the potential to bioaccumulate.

A summary of the criteria for the bioaccumulation hazard trait for the purposes of the SCP regulation and related data are provided below:

- An authoritative organization has identified a substance to be bioaccumulative:
    - ECHA (2014a), OSPAR Commission (2009), and U.S. EPA (2005) indicate NP is moderately bioaccumulative;
- A compound with a bioaccumulation (BAF) or bioconcentration factor (BCF) greater than 1,000:
    - NP's BCF was specified as 1,280 L/$kg_{wet\ weight\ (ww)}$ (European Chemicals Bureau 2002), using a log K_{OW}-based BCF relationship developed for freshwater fathead minnow;
    - NP's wet-weight-based BCFs for saltwater organisms ranged from 90 L/kg_{ww} to 4,120 L/kg_{ww}, or 53 L/kg_{lipid} to 2,168 L/kg_{lipid} for lipid-normalized BCFs (Ekelund et al. 1990);
    - NP's BCFs ranged up to 10,000 in freshwater algae but were less than 500 in freshwater and saltwater fish tissues (Ahel et al. 1993);
    - NP's BAFs greater than 1,000 (relative to seawater) occurred in whole ghost shrimp, goby liver, sanddab and sculpin liver, oyster, otter liver, porpoise liver, and sea lion liver, but were less than 1,000 for benthic (sediment-dwelling) invertebrates, whole goby, seabird liver, and mussels (Diehl et al. 2012).
- A compound with a log $K_{OW} \geq 4$:
    - NP has a reported log K_{OW} ranging from 3.80 to 4.77 (Roy F. Weston Inc. 1990 as cited in U.S. EPA 2005);
- Studies which show bioaccumulation in human, domesticated animal, wildlife, or plant tissues:

[20] *Section 2.2.2*

- The presence of NP and NP1-2EOs in some biological tissues[21] indicates bioaccumulation can occur (i.e., the rate of uptake equals or exceeds the rate of elimination from the organism) for aquatic organisms, including those collected from California coastal environments.

2.3.3. Human hazard traits

DTSC is basing this proposal on the potential for NPEs from laundry detergents to contribute to significant or widespread adverse impacts to aquatic organisms. DTSC's emphasis on aquatic organisms aligns with other reports on NPEs by authoritative organizations (ECHA 2013; ECHA 2014a; Environment Canada and Health Canada 2001; OSPAR Commission 2009; U.S. EPA 2010b). While we are not basing this proposal on human health impacts, DTSC has nevertheless conducted a limited review of reports by authoritative organizations to identify the potential adverse impacts of NP and NPEs to humans.

Hazard traits identified for NP and NPEs include dermatotoxicity, ocular toxicity, nephrotoxicity, reproductive toxicity, developmental toxicity, and endocrine toxicity based on dermal and oral exposures (Environment Canada and Health Canada 2001; European Chemicals Bureau 2002; Minnesota Department of Health 2015; OEHHA 2009; U.S. EPA 2006; USDA 2003). DTSC received a public comment regarding the carcinogenicity of NP (BCPP 2018). However, human hazard traits are not the basis for the listing, and these hazard traits have not been thoroughly evaluated. This Profile is not intended to be a complete evaluation of adverse impacts or exposures, but demonstrates how DTSC has met the regulatory requirement for considering significant or widespread adverse impacts to exposed organisms. Human hazard traits and exposure may be relevant factors for the purposes of an Alternatives Analysis, depending on the nature of the alternatives selected.

2.4. Related Chemicals and Their Adverse Impacts

2.4.1. Cumulative effects with other chemicals

Reference: CAL. CODE REGS. tit. 22, § 69503.3(a)(1)(C).

Cumulative effects occur from cumulative exposures to the Candidate Chemical and other chemicals with similar hazard traits or endpoints.

[21] *Section 3.3.1*

2.4.1.1. NPEs, octylphenol ethoxylates, and their degradation products

Canada's water quality guidelines and Minnesota's draft water quality standards[22] developed different approaches to account for mixtures of NPEDs in the aquatic environment and their cumulative impacts. DTSC does not apply one approach over another to compare to environmental concentrations as the basis for this listing. Canada uses a toxic equivalency (TEQ) approach to assess NPEDs' combined effects, with their potency expressed relative to NP because it is the most toxic NPED (Environment Canada 2002). Narcosis is the mode of toxicity for NP and for at least the shorter chain length NPEs and NPECs at typical environmental concentrations, and for conventional toxicity endpoints (Environment Canada 2002). The relative potency of each compound can be estimated by applying a Toxic Equivalency Factor (TEF; see Table 2 below) to each compound's respective environmental concentration to determine an NP-equivalent concentration. The total NP-equivalent concentration of a nonylphenolic mixture is the sum of the NP concentration and the NP-equivalents (see Equation 1 below).

Equation 1:

$$\text{Total Concentration of NP and NP equivalents"}=\sum(\text{"Cx} \times \text{TEF"})$$

Where,

C_x = concentration of each nonylphenolic compound
TEF = Toxic Equivalency Factor for each nonylphenolic compound

The TEFs for some compounds (e.g., NP3-8EO) are a conservative estimate due to the paucity of toxicity tests conducted with these substances. As such, the total NP-equivalent concentration may overestimate the toxicity of a mixture (Environment Canada 2002). The Canadian assessment also recognizes the potential for octylphenol ethoxylates (OPEs, or OPnEOs where n = number of ethoxylates) and their degradation products, including octylphenol (OP), to have additive effects due to structural and behavioral similarities to nonylphenolic compounds. OPEs and OP are also Candidate Chemicals that are on the same authoritative lists as NPEs and NP (DTSC 2018), and found in California environments (Bradley et al. 2017; Sengupta et al. 2014), wastewater (Bradley et al. 2017; Sengupta et al. 2014), and biota (Maruya et al. 2014). OP is the most toxic in its class and as toxic as NP. Researchers and ECHA have used this concept of cumulative impacts to provide a more comprehensive evaluation of potential exposures of aquatic organisms to mixtures of

[22] *Section 2.5.1*

alkylphenolethoxylatesalkylphenol ethoxylates including NPEs and NPEDs (Bistodeau et al. 2006; Dodder et al. 2014).

Table 2. Summary of relative toxicity of nonylphenolic and related compounds. Adapted from Environment Canada (2002).

Chemical		Toxic equivalency factor relative to NP
NP series	OP series	
NP	OP	1
NP1EO		0.5
NP2EO		0.5
NPnEO (3 ≤ n ≤ 8)*	OPnEO (1 ≤ n ≤ 8)*	0.5
NPnEO (n ≥ 9)	OPnEO (n ≥ 9)*	0.005
NP1EC	OP1EC	0.005
NP2EC	OP2EC	0.005

* Conservative estimation.

Minnesota uses a different approach to approximate the total adverse impacts from NPED exposures as provided in its draft water quality standards (MPCA 2010). Minnesota considers NP1-2EOs to be as toxic as NP for the purposes of water quality standard development. As a result, NP-equivalent concentrations are calculated by simply adding the concentrations of NP and NP1-2EOs. Minnesota expects short-chain NPEs to be the most common NPE in surface waters and, as such, a continuous source of NP under anaerobic conditions found in many aquatic sediments. These standards are intended to ensure additional protection of aquatic organisms from exposure to a broader suite of NPEs by preventing the release of the most toxic nonylphenolic compounds into the environment.

2.4.1.2. Pesticides

NPEs are ingredients in a variety of consumer products,[23] including pesticides, due to their ability to enhance bioavailability of the active ingredient. Some studies have evaluated the potential for greater than additive ("synergistic") effects of pesticides and other ingredients in the formulations, including alkylphenol and alkylphenol ethoxylates, which include NPEs, due in part to concern for estrogenic effects and the potential nexus to certain declining fish species in the San Francisco Bay-San Joaquin Delta (Schlenk et al. 2012). There is increasing evidence that NPEs contribute to adverse impacts from pesticides (Cox and Surgan 2006; Kroon et al. 2015), including greater than additive effects to aquatic organisms (Schlenk et al. 2012; Xie et al. 2005). Vitellogenin production increased in fish exposed to mixtures of alkylphenol ethoxylate-containing surfactants and pesticides at environmentally relevant or higher concentrations (Schlenk et al. 2012; Xie et al. 2005). In contrast, this enhanced effect was not

[23] *Section 3.1.3*

demonstrated in the *in vitro* experiment (trout liver-cell cultures exposed to comparable conditions (Schlenk et al. 2012). This study's greater than additive *in vivo* results but negative *in vitro* results suggest there are additional, alternative, or altered uptake and physiological pathways that result in increased vitellogenin but don't necessarily rely on binding to estrogen receptors. Additional studies of how these co-exposures contribute to adverse impacts would better represent exposure scenarios for fish in the natural environment, compared to single chemical exposures. This is particularly relevant in regions that have fish species affected by Pelagic Organism Decline (POD), a phenomenon where certain fish species have experienced severe population declines from unknown causes (Baxter et al. 2010). The potential co-exposure of these POD species and their exposure to these chemical mixtures in the environment is further described in Section 5.1.4.

2.4.2. Structurally or mechanistically similar chemicals

Reference: CAL. CODE REGS. tit. 22, § 69503.3(a)(3).

Some chemicals may lack sufficient data to establish presence or absence of harm. In such cases, DTSC may also consider data from other chemicals closely related structurally to the Candidate Chemical to identify potential public health and environmental impacts.

This factor is not the basis for the proposed listing.

2.5. Populations That May Be Harmed by the Candidate Chemical

2.5.1. Human populations or organisms that have the potential for adverse impacts from exposure to the Candidate Chemical

Reference: CAL. CODE REGS. tit. 22, § 69503.3(a)(1)(F).

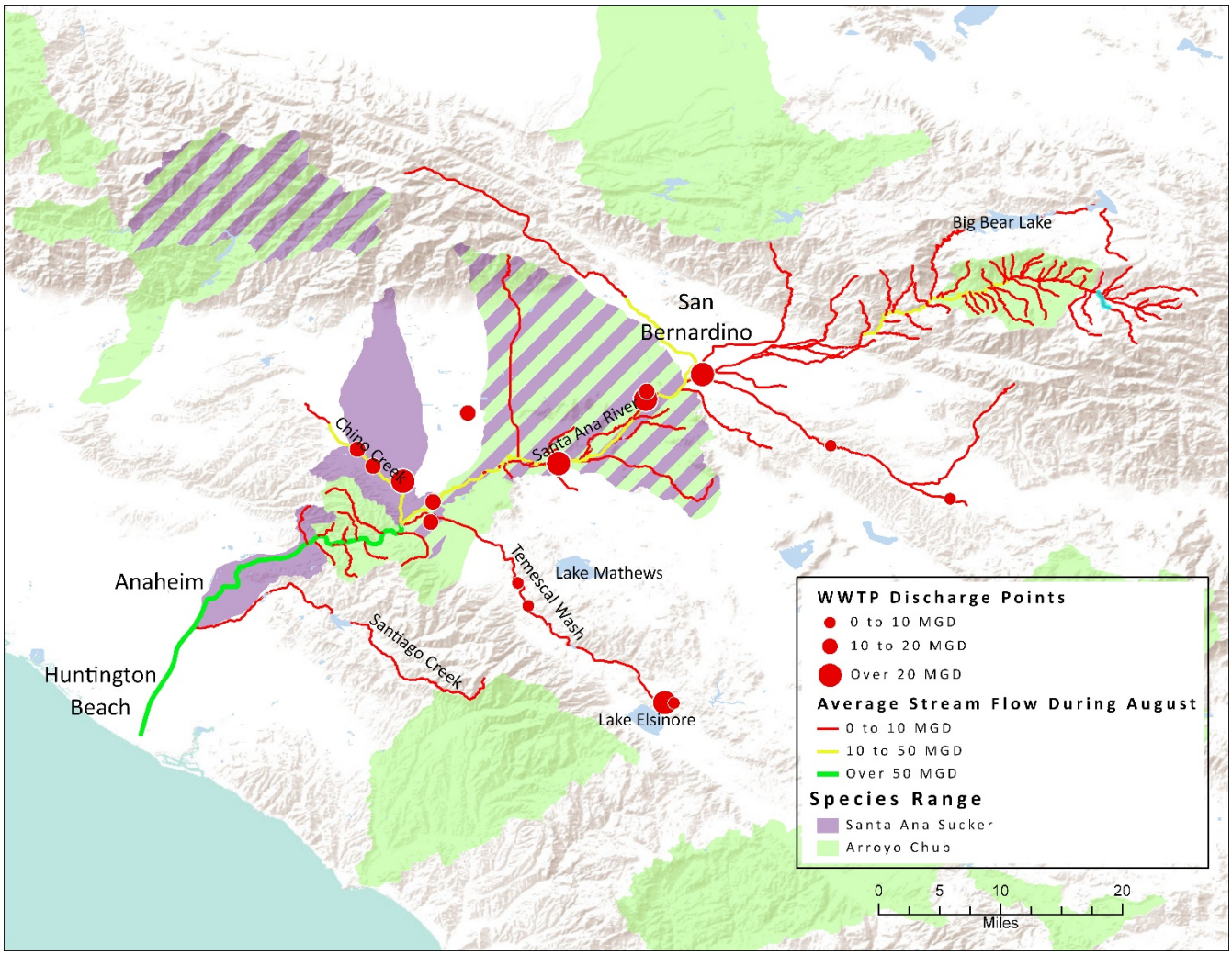
This section identifies specific populations of humans and environmental organisms that may be harmed if exposed to the Candidate Chemical, based on the hazard traits identified in section 2.3 and the type of exposures (e.g., single, intermittent, or chronic).

Once NPEs and NPEDs are discharged into receiving waters via wastewater effluent, they are in contact with aquatic organisms. Fish and aquatic invertebrate organisms are the most sensitive species to the hazards of NPEs and NPEDs, such as wildlife reproductive impairment.[24] California's diverse and unique assemblage of aquatic species includes 136 freshwater fish species, hundreds of coastal fish species, and hundreds of freshwater invertebrate species (Howard et al. 2013; Miller and Lea 1972). Freshwater invertebrate species alone make up 60 percent of all species in California's freshwater environment (Howard et al. 2013).

[24] *Section 2.3*

Impacts from pollution can adversely impact fish and aquatic invertebrates, which are essential to maintaining California's unique biodiversity and healthy populations. For example, the Santa Ana River and its tributaries represent the largest watershed in Southern California. Wastewater effluent represents a significant contribution to the natural river flow in summer months. This watershed provides habitat for endangered fish species such as the Santa Ana sucker and Arroyo chub (Figure 5; (Santos et al. 2014; Walters et al. 1985)). Additional examples of effluent-dominated ecosystems in California and examples of species in those habitats are provided in Appendix D, along with some background information about the references used to generate the maps.

Figure 5. Co-occurrence of select threatened and endangered fish species and WWTPs in effluent-dominated Santa Ana Watershed



Several authoritative organizations have developed environmental quality guidelines, standards, or criteria (collectively referred to herein as "aquatic guidelines, standards, or criteria," or "aquatic GSC") to protect aquatic organisms from exposure to NPEs and NPEDs. These are summarized in Table 3,

below. While none of the aquatic GSC apply for regulatory purposes in the United States, recent water and sediment samples collected in California and elsewhere in the U.S. have met or exceeded these aquatic GSC, demonstrating the potential for adverse impacts in this country and this state.

The aquatic GSC show a range of concentrations used to indicate adverse impacts to aquatic organisms and are not directly comparable to one another. Each is developed for its own distinct regulatory objective. The aquatic GSCs are based on different methodologies and statistical extrapolation approaches, and include data from different types of toxicity studies (Wang et al. 2017). Some of these authoritative organizations calculated both chronic and acute aquatic GSC. However, only the chronic values are provided in Table 3 because exposure to NPEs and NPEDs from WWTPs is likely to occur continuously, over a long period of time.[25] Some of the aquatic GSC included in Table 3 are not finalized (i.e., are draft or interim thresholds); they are included in the table to illustrate the extent of analyses conducted by authoritative organizations. DTSC evaluated the ranges of the GSCs against ranges for environmental detections[26] as part of the basis for concluding that NPEs and NPEDs have the potential to contribute to significant or widespread adverse impacts. Although the GSCs differ, collectively they provide an overall qualitative indication of potential adverse impacts from NPEs. DTSC did not perform a statistical evaluation of the extent of environmental concentrations exceeding aquatic GSC as this is not needed to support this listing.

Table 3. Summary of aquatic GSC to protect aquatic life from chronic exposure to NPEs and/or NPEDs

Name of GSC	Level of organism protection	Chemicals	GSC for water		GSC for sediment (dry weight)	
			Freshwater	Marine	Freshwater	Marine
Canada: Environmental Quality Guidelines	Negligible risk to biota, their functions, or any interactions that are integral to sustaining the health of ecosystems and the designated resource uses they support	∑NP, NPEs, NPECs	1.0 µg/L	0.7 µg/L*	1.4 mg/kg*	1.0 mg/kg*
Europe: Environmental Quality Standards	Protection against long-term exposure to pollutants in the aquatic environment	NP	0.3 µg/L		0.180 mg/kg*	

[25] *Section 3.3.3*
[26] *Section 3.3.1*

U.S. EPA Ambient Water Quality Criteria	Chronic exposure should not unacceptably affect freshwater aquatic organisms	NP	6.6 µg/L	1.7 µg/L		
U.S. (Minnesota) Ambient Water Quality Standard	Chronic exposure should not unacceptably affect freshwater aquatic organisms	∑NP, NP1EO, NP2EO	2.4 µg/L (salmonids) ,* 7.4 µg/L (other species)*			

*Aquatic guideline, standard, or criteria is not finalized.

2.5.1.1. Canada: Environmental Quality Guidelines for the Protection of Aquatic Life

Environmental Quality Guidelines (EQGs) are developed by the Canadian Council of Ministers of the Environment and represent concentrations in air, water, sediment, soil, and wildlife tissue that should result in "negligible risk to biota, their functions, or any interactions that are integral to sustaining the health of ecosystems and the designated resource uses they support" (Environment Canada 2002). While the EQGs are developed at the national level, the legislative authority to implement the EQGs is limited to each provincial or territorial jurisdiction.

The water quality guideline (Environment Canada 2002) is determined by identifying the most sensitive, nonlethal-effect concentration in freshwater and marine species, and applying a safety factor to account for factors such as variation in toxicity between laboratory and field exposures (Environment Canada 2002). The EQGs for NPEs recommend using the toxic equivalency approach[27] to account for co-exposure to NPEs, octylphenol ethoxylates, and their respective degradation products. A provisional interim sediment quality guideline for nonylphenol and its ethoxylates in freshwater and marine sediments was developed using an equilibrium partitioning approach.

2.5.1.2. European Commission: Environmental Quality Standards

The European Commission publishes Environmental Quality Standards (EQS) to limit the concentrations of certain chemical substances in surface waters of the European Union (EU) that pose a significant risk to the environment or to human health (European Union 2008). For member states to have "good surface water chemical status," they must ensure that concentrations of pollutants do not exceed the EQS (European Commision 2011). An assessment of several environmental compartments (water, sediment, and/or biota) is needed when a substance poses a risk through direct toxicity in the water column, to predators through the food chain, or to benthic biota. An EQS for sediments may be

[27] *Section 2.4.1*

developed for substances that tend to accumulate in or partition into sediment to ensure that the sediment concentrations do not increase significantly. Water column EQSs are developed to protect pelagic (free-swimming) organisms against short-term (acute) and long-term (chronic) exposures to pollutants. A maximum acceptable concentration-Environmental Quality Standard (MAC-EQS) is based on acute toxicity, and/or an annual average concentration-Environmental Quality Standard (AA-EQS) is based on chronic toxicity data. The MAC-EQS for NP is 2 µg/L European Commision (2011), and the AA-EQS and sediment EQS are provided in Table 3. The overall EQS is enforceable in the EU, and is selected based on the lowest environmental quality standard calculated for the different objectives of protection. For NP, the overall EQS is the AA-EQS.

2.5.1.3. U.S. EPA ambient water quality criteria

U.S. EPA created ambient water quality criteria (AWQC) for NP as a non-regulatory, scientific assessment of health and ecological effects (U.S. EPA 2005). States may use the AWQC as a guideline in the development of their own enforceable water quality standards. California has not adopted such standards for NPEs or NPEDs. The national methodology (Stephen et al. 1985) indicates that the criteria for chronic exposure in surface water should not unacceptably affect aquatic organisms, and states can consider locally important and sensitive species when setting their own criteria. In addition, the federal criteria are not a threshold of adverse effect, and U.S. EPA acknowledges that "some adverse effect, possibly even a small reduction in survival, growth, or reproduction of commercially or recreationally important species, will probably occur at, and possibly even below the threshold." The criteria also define the frequency with which exceedances would be allowed. For example, the chronic criterion represents a four-day average concentration not to be exceeded more than once every three years if the criteria were to become adopted. U.S. EPA also calculated acute values for freshwater and saltwater (28 and 7 µg/L, respectively), in addition to the chronic values.

2.5.1.4. U.S. (Minnesota) AWQS

The Minnesota Pollution Control Agency drafted proposed standards for the combined exposure to NP and NP1-2EOs (MPCA 2010). Using the national methodology, draft standards were developed using a broader set of aquatic species (amphibians) and including locally important species (rainbow trout) for a cold-water standard.

2.5.1.5. Other aquatic guidelines, standards, or criteria

There are publications relating to concern for impacts to aquatic organisms that provide predicted no-effect concentrations (PNECs). Wang et al. (2017) estimated chronic PNECs of 0.721 µg/L and 4.28 µg/L for NP using species sensitivity-weighted distribution (SSWD) and species sensitivity distribution (SSD), respectively. The SSWD method uses both traditional (i.e., growth, reproduction, and survival) and non-traditional (e.g., molecular and genetic biomarkers) endpoints, and considers intraspecies

variation and proportions of data between taxonomic groups. Staples et al. (2004) used an SSD analysis and chronic aquatic toxicity data to estimate a chronic value of 5.7 µg/L at the lower bound tenth percentile for NP.

These publications provide additional approaches for evaluating impacts to aquatic organisms, and provide additional information on concentrations that may contribute to adverse impacts. The PNECs identified in these reports are within the ranges identified by authoritative organizations, and they illustrate that there is no scientific consensus for a definitive numerical threshold for adverse impacts to aquatic organisms. However, the various aquatic GSC, including the published PNECs, are generally within an order of magnitude of each other, with the EU's threshold on the lower end and U.S. EPA's threshold on the higher end. For simplicity in comparing environmental concentrations to these aquatic GSC, the publications by Wang et al. (2017) and Staples et al. (2004) were not included in those assessments, as their values are consistent with the values for the aquatic GSC identified by the authoritative organizations.

2.5.2. Sensitive subpopulations, species, or environments that have the potential for adverse impacts from exposure to the Candidate Chemical

Reference: CAL. CODE REGS. tit. 22, §§ 69503.3(a)(1)(F) and 69503.3(a)(2).

Sensitive subpopulations, environmentally sensitive habitats, endangered and threatened species, and impaired environments have special consideration as they may be more vulnerable than the general population.

Exposure to NPEs and NPEDs has the potential to cause adverse impacts on aquatic species, such as reproductive impairment.[28] As a result, DTSC is concerned that some threatened and endangered fish and aquatic invertebrate species within California may be exposed to NPEs and NPEDs. California has 34 threatened and/or endangered fish species, 62 fish species of special concern, and 11 threatened or endangered aquatic invertebrate species (CDFW 2017a; CDFW 2017b). Considerable effort is underway to protect these ecologically, economically, and socially important species in California. As further described below, some of these species live exclusively in freshwater environments, which may be wastewater-impacted and have less diluted effluent than other environments with outfalls that discharge to the ocean. Other species live in wastewater-impacted freshwater or estuarine environments during their early life stage and for reproduction, which is a particularly sensitive life stage for fish.[29] The co-occurrence of select endangered or threatened fish species with WWTP locations are provided below to illustrate the potential for these species to be exposed to NPEs and

[28] *Section 2.3.1*
[29] *Section 2.3.1*

NPEDs from wastewater effluent (see Appendix D for references and their related background information).

2.5.2.1. Select Northern California species (Figure 6 and Figure 7)

Salmon

Several species of California salmon have experienced serious population level declines, and 45 percent of salmonid species are expected to be extinct in the next 50 years (California Trout 2017). In addition to other pressures (e.g., land development), salmonids may experience adverse impacts from wastewater discharge because they spend much of their early development as incubating eggs in freshwater environments that can be near wastewater treatment plant outfalls. For example, coho salmon, which are endangered in parts of California, spend up to several years of their early life stages in estuarine and/or inland freshwater environments before they migrate to the ocean (Regents of the University of California 2017a). Two populations, the Central California Coast coho and Sacramento River winter-run chinook, are included in the top eight species identified as most at-risk of extinction (NOAA Fisheries 2016b).

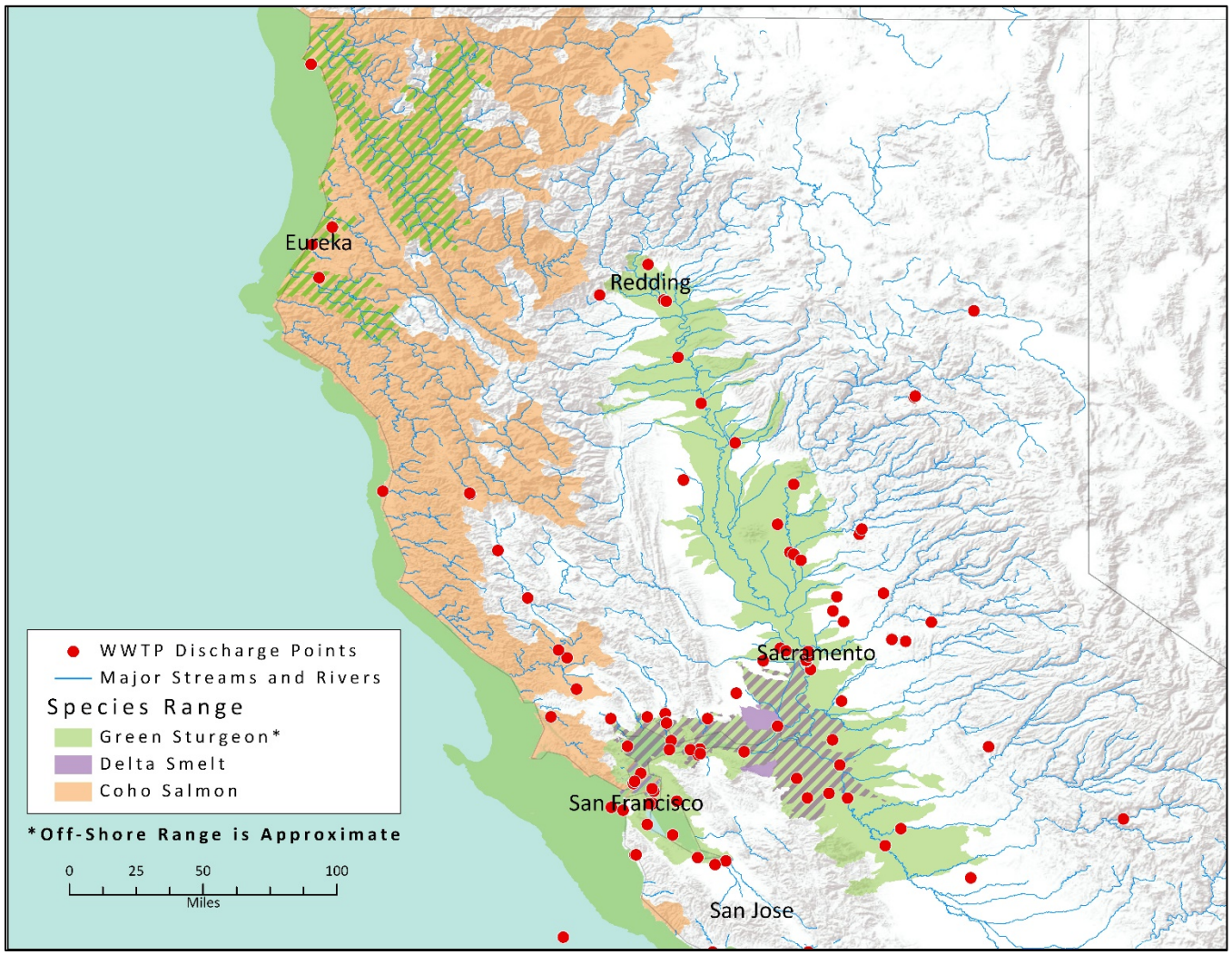
Green sturgeon

Green sturgeon may be impacted by NPEs and NPEDs, as these are long-living species (up to 70 years) that can spend their early life history in freshwater or estuarine environments that can be effluent-impacted, and they feed on benthic organisms living on the river bottom (CalFish 2017). Their extendable mouth is used as a vacuum to capture prey, such as small invertebrates, and they are likely to incidentally ingest contaminated sediments along with some of these prey items (British Columbia Ministry of Environment 2018). This federally threatened species hatches in freshwater and spends several years in the Sacramento-San Joaquin Delta before moving to the ocean (CalFish 2017). They spend approximately 15 years in the ocean before returning to spawn in freshwater, a cycle they repeat every three to five years during their long lifespan (CalFish 2017).

Delta Smelt

The endangered Delta smelt is one species included in the Pelagic Organism Decline (POD), the phenomenon where four pelagic fish populations in the upper San Francisco Estuary (the Delta and Suisun Bay) rapidly declined to record low levels in the early 2000s. Other POD fishes include the endangered longfin smelt, as well as threadfin shad and juvenile striped bass. Significant efforts have been underway to identify the multiple factors, including contaminants, which contributed to their rapid declines. Delta smelt typically live less than two years, and migrate from lower salinity zones to the Delta to spawn (Baxter et al. 2010).

Figure 6. Co-occurrence of WWTP discharge points and select Northern California endangered or threatened aquatic species



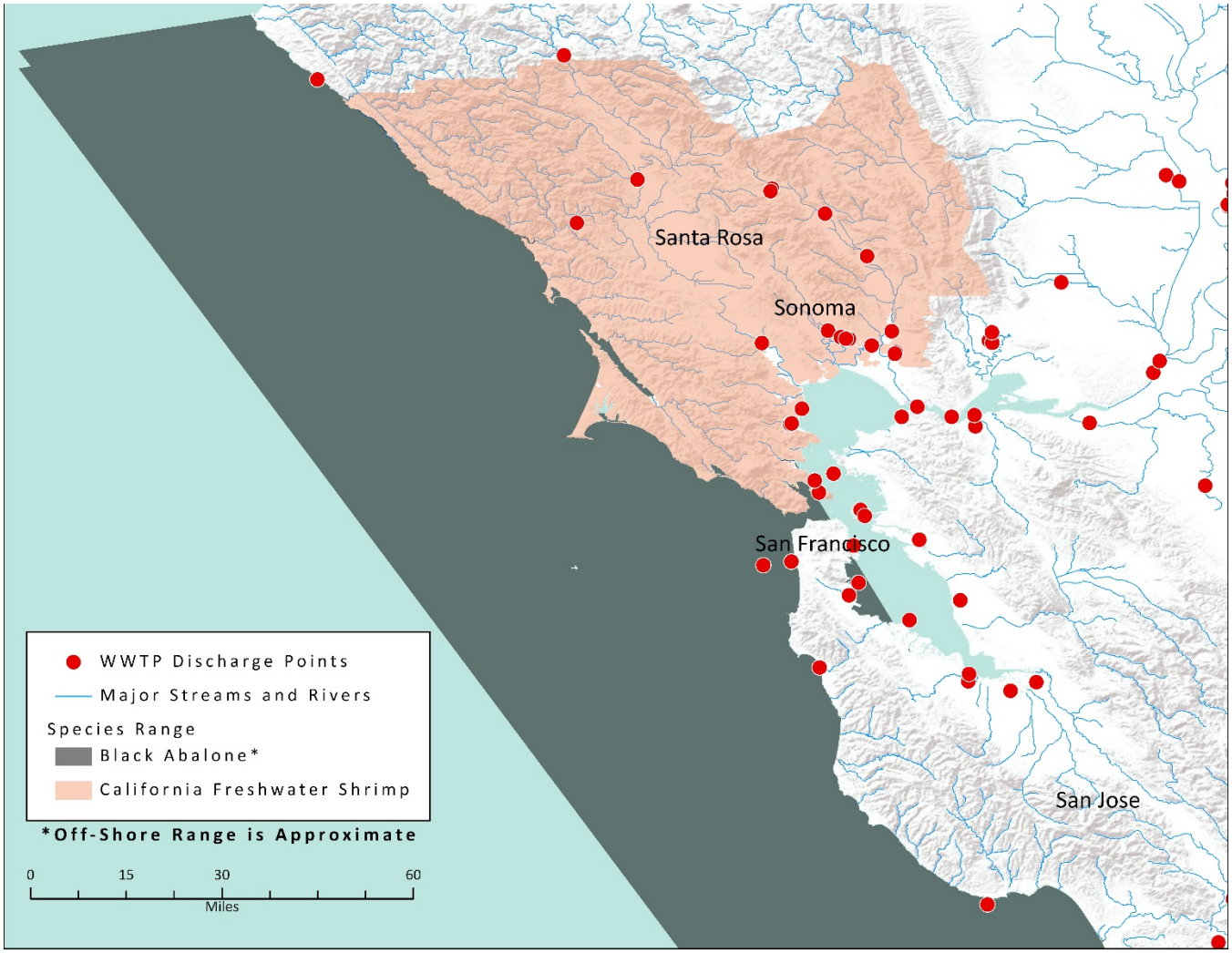
Aquatic Invertebrates

The California freshwater shrimp lives exclusively in freshwater streams in Marin, Sonoma, and Napa counties (see Figure 7). They may live more than three years, and they feed on fine organic material and other items that can be scavenged (U.S. EPA 2010a). They are likely prey for native fish, such as trout and salmon (National Park Service 2007).

Two endangered aquatic mollusk species, black abalone and white abalone, can co-occur with offshore WWTP discharge locations (see Figures 7 and 8) and can have long lifespans of 20-40 years(NOAA Fisheries 2016a; NOAA Fisheries 2016c). The black abalone are found in intertidal and subtidal environments along most of the California coast, although populations are locally extinct in most locations in southern California (NOAA Fisheries 2016c). The white abalone, a deeper water species, are among the top eight marine species that are at most at risk for extinction (NOAA Fisheries 2016b),

with an estimated population of approximately 1,600-2,500 individuals (NOAA Fisheries 2016c). NOAA Fisheries decided against designating critical habitat for this species, as it could increase the threat of poaching (NOAA Fisheries 2018b). Abalone are a food source for sea stars, crustaceans, and sea otters (NOAA Fisheries 2016c).

Figure 7. . Co-occurrence of WWTP discharge points and select endangered or threatened aquatic invertebrates in Northern California



2.5.2.2. Select Southern California species

Unarmored threespine stickleback

These endangered fish have a very limited distribution and dwindling populations, and their recovery efforts became a top priority for the California Department of Fish and Wildlife (CDFW) during an extreme drought condition (CDFW 2015). The unarmored threespine stickleback are only found in

three drainages in Southern California (Figure 8), and generally live one year and feed mostly on benthic invertebrates or algae (Aquarium of the Pacific 2017; Regents of the University of California 2017b).

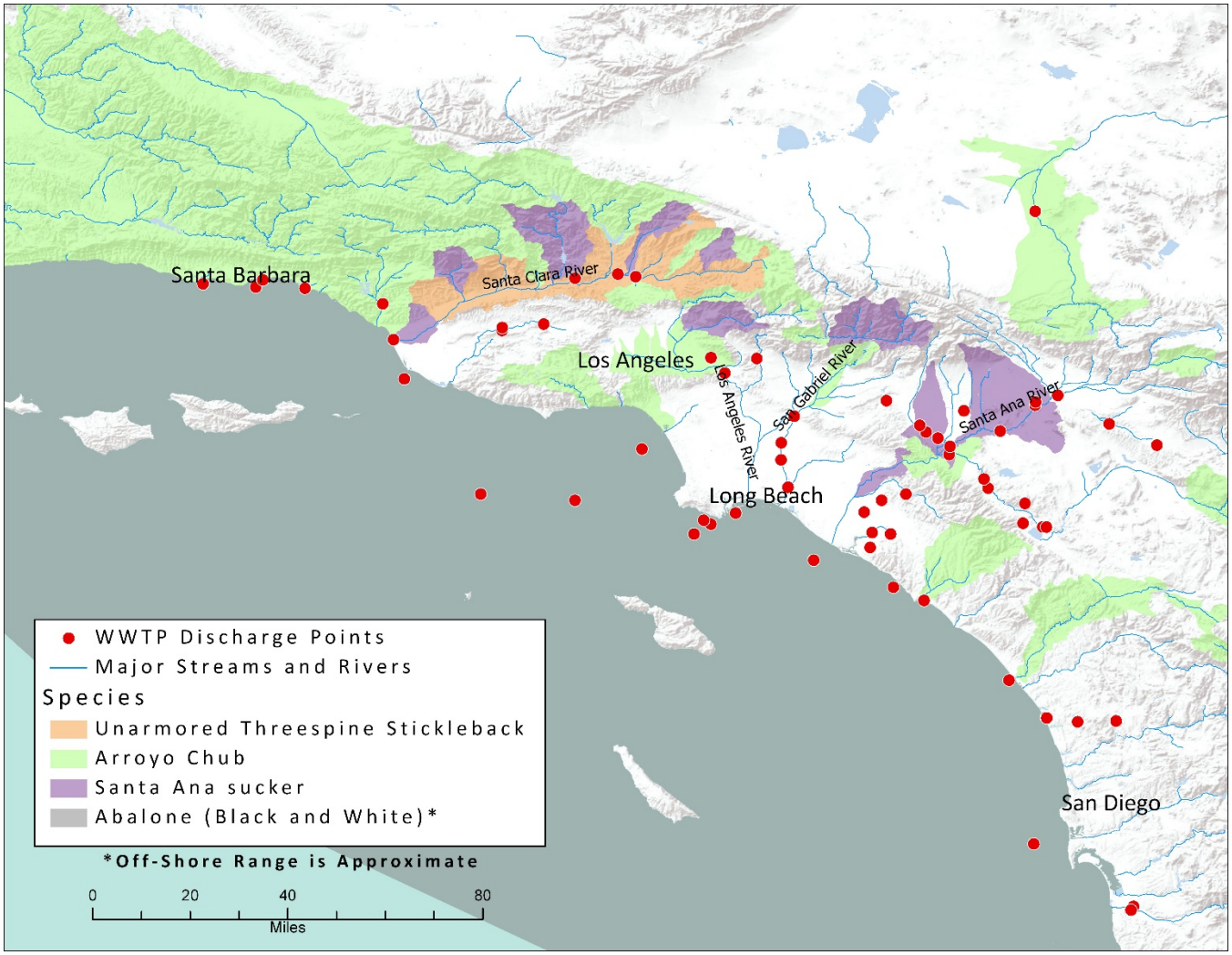
Santa Ana sucker

The Santa Ana sucker is one of only a few native freshwater species of fish currently living in Southern California. This species' range has been reduced in the three watersheds where it occurs (Figure 8), and there is no opportunity for natural movement between watersheds. These threatened fishes are called suckers because of the downward-pointing mouth, which allows them to suck up algae, small invertebrates, and other organic matter with their fleshy, extendable lips. The lifespan of these fish generally ranges from three to five years (U.S. FWS 2017).

Arroyo chub

A California Fish Species of Special Concern, the arroyo chub is a relatively small fish found in slow-moving rivers and streams with mud or sandy bottoms. Natively found in the Los Angeles, San Gabriel, San Luis Rey, Santa Ana, and Santa Margarita rivers and in Malibu and San Juan creeks, the species is now only abundant in a few places within its native range and is vulnerable to extinction in these areas within the next 100 years. The arroyo chub prefers to eat algae, including their roots. The lifespan of these fish is one to four years (Moyle et al. 2015).

Figure 8. Co-occurrence of WWTP discharge points and select Southern California endangered aquatic species



3. FACTORS RELATED TO POTENTIAL EXPOSURE TO THE CANDIDATE CHEMICAL IN THE PRIORITY PRODUCT

This section summarizes significant findings related to the exposure factors that that are relevant to this product-chemical combination because they may contribute to or cause significant or widespread adverse impacts. Further clarification of each exposure factor is included below.

3.1. Presence and Use Patterns of the Product

3.1.1. Market presence of the product

Reference: CAL. CODE REGS. tit. 22, §§ 69503.3(b)(1)(A) and (B).

Product market presence information may be used as a surrogate to assess potential exposures to the Candidate Chemical in the product. This information may include statewide sales by volume, the number of units sold or amount of sales generated, or information on the targeted customer base.

Due to voluntary phase-outs in the household and industrial laundry markets, the prevailing use of laundry detergents containing NPEs appears to be by on-premises laundries (OPLs) such as hotels, hospitals, and nursing facilities (Riesenberger and Koeller 2005). In a 2017 online search of laundry detergents intended for use in large-scale laundry operations such as OPLs, detergents containing NPEs were still available from over 25 percent of the manufacturers as determined by safety data sheets (ABC 2015; HD Chem 2015; Noble Chemical Inc. 2013; Simoniz USA Inc. 2015; Sunburst Chemicals 2017; US Chemical 2014; Zep 2018). Some of these products were marketed as "100 percent biodegradable and environmentally safe."

The use of NPEs in household laundry detergents is thought to have been completely phased out (U.S. EPA 2010b). Proctor and Gamble, the leading household liquid laundry detergent vendor in the U.S. (Statista 2017), stopped using them around 2005 (Proctor & Gamble 2005) and Walmart and Target added them to their priority list of chemicals for their suppliers to remove from products in 2015 and 2016, respectively (Target 2018; Wahba 2016).

The use of laundry detergents containing NPEs by industrial laundries has also declined. In 2010, the Textile Retail Services Association (TRSA), representing approximately 98 percent of industrial laundry facilities in the United States, entered into a voluntary agreement with U.S. EPA to phase out the use of NPEs in detergents by 2014 (TRSA 2010). While significant progress has been made towards implementing this agreement, U.S. EPA estimates it only covers approximately 50 percent of NPE laundry detergent use, and the complete phase-out has not been confirmed (U.S. EPA 2017).

3.1.2. Intended use of the product

Reference: CAL. CODE REGS. tit. 22, §§ 69503.3(b)(1)(C) and 69503.3(b)(4)(D)1.

Potential exposures can also be inferred by assessing how a product is typically used, the typical useful life (i.e., replacement frequency) of durable products, the typical rate of consumption of consumable products, the frequency of use, and the typical quantity consumed per use. The SCP regulations give special consideration to household and recreational use.

Laundry detergents containing NPEs continue to be marketed to and used by OPLs. The amount of laundry washed by OPLs in California can be significant, with an estimated 2 billion pounds of laundry generated by the majority of OPLs, represented by hotels, hospitals, and nursing homes (See Table 4).

Table 4. Table 4. Estimated quantity of laundry generated annually by California on-premises launderers

Facility type	Units	Millions of units per year	Generation rate (lbs per unit)[4]	Percentage washed in OPLs[5]	Laundry generated (millions of lbs) per year
Hotels and motels	Occupied room nights	132.8[1]	13.25	100%	1,760
Hospitals	Inpatient days	16.8[2]	15	10%	25
Nursing facilities	Resident days	36.8[3]	7.1	100%	261
Total					**2,046**

[1] AHLA (2017)

[2] KFF (2015a),U.S. Census Bureau (2017): calculated by 428 Inpatient Days per 1,000 people × 39.3 million people in CA

[3] KFF (2015b): calculated by 100,808 nursing home residents × 365 days per year

[4] B&C Technologies (2014):

- Hotels and motels = Average of estimated pounds generated per unit per day for all hotel/motel types
- Nursing facilities = Estimate of 50 pounds per bed per week divided by seven days per week

[5] Riesenberger and Koeller (2005)

The usage rate of laundry detergent is highly dependent on the amount of soil required to be removed. Laundry processed by OPLs typically is more heavily soiled than household laundry in both the variety and concentration of substances required to be removed (Alliance for Water Efficiency 2016), and is often required to meet high standards for sanitation and appearance (Riesenberger and Koeller 2005). Thus OPLs are likely to use relatively high amounts of detergent to clean an equivalent amount of laundry.

DTSC believes there is the potential for the use of laundry detergents to release a significant amount of NPEs to California wastewater treatment plants, approximating over 2 million pounds per year. This estimate is based on the OPL laundry generation rate from Table 4, and an estimated discharge rate of 0.1 pounds of NPEs released per 100 pounds of OPL laundry washed. This discharge rate is based on an estimated average of 8 fluid ounces of 20 percent NPE-containing liquid laundry detergent used per 100 pounds of laundry. DTSC's 2017 online search, described in Section 3.1.1 found that recommended usage rates can range from 3 to 16 fluid ounces of detergent per 100 pounds of laundry and NPE concentrations can range from 5 to 50 percent. Since the purpose of NPEs is to remain in the wash

water, it is assumed that all of the NPEs in laundry detergents is released to wastewater treatment plants (U.S. EPA 2007a).

3.1.3. Household and workplace presence of the product and other products containing the Candidate Chemical, and aggregate effects

Reference: CAL. CODE REGS. tit. 22, §§ 69503.3(a)(1)(B) and 69503.3(b)(3).

The potential for exposure to the Candidate Chemical in the product relates to how common the product is in households and workplaces. The household and workplace presence of other products that contain the same Candidate Chemical may increase the potential for aggregate effects.

While laundry detergents are of principal concern for this listing, NPEs are found in a wide variety of consumer products with similar pathways to the aquatic environment via wastewater effluent or runoff, and can contribute to aggregate effects. Table 5 summarizes some of the products that may contribute to NPEs in the aquatic environment. The types of products included as "cleaners" include certain cleaning products that are banned in California[30] but available for sale in other states.

[30] *Section 8.1*

Table 5. Summary of exposure information relating to products containing NPEs

Product type	NPE concentration in product	Exposure information	Reference
Automobiles or related products	Unknown	Estimated to release 28 µg/vehicle x km into stormwater	Bjorklund (2010)
Cleaners (including laundry detergents)	10-100%*	A percentage of these products will be released down the drain during cleaning (product use)*	U.S. EPA (2010b)
Clothing	> 500 mg/kg (from color pigments) 10-500 mg/kg (intentional use of NPEs) <10 mg/kg (contamination)	NPEs may be released from manufacturing (exposure mostly outside of California) and use phase (e.g., washing new garments in California) Possibly very high volume of product sales in California*	ECHA (2014a)
Concrete	Unknown	Estimated to release 80 mg/m^2 x year into stormwater	Bjorklund (2010)
De-icers	∑NPEOs 641,000 µg/L (NP10EO > 90,000 µg/L, NP1EO and NP15EO <1,500 µg/L)	May contribute to surface water in limited California environments*	U.S. EPA (2010b) Corsi et al. (2003)
Firefighting gels/foams	Unknown	May contribute to surface water loading via runoff and stormwater*	U.S. EPA (2010b)
Pesticides (inert ingredients)	1-10%*	6% of NPEs usage is attributed to agrochemicals. May contribute to surface water loading via runoff and stormwater*	Markets and Markets (2016); U.S. EPA (2010b)
Paints	Unknown	13% of NPEs usage is attributed to paint manufacturing. A percentage of these products will be released down the drain during cleaning and disposal*	Markets and Markets (2016)

Product type	NPE concentration in product	Exposure information	Reference
Toilet paper	Average: 0.367 mg/kg NP (virgin wood pulp) Average: 1.72 mg/kg NP (recycled paper)	Ubiquitous product from household waste may be a sizable proportion of NP contamination, including in California*	Diehl et al. (2012)

* Information contributed by DTSC.

3.2. Potentially Exposed Populations and Product-Use Scenarios

3.2.1. Targeted customer base

Reference: CAL. CODE REGS. tit. 22, § 69503.3(b)(1).

This section may include information on who typically buys or uses the product, and where the product is marketed or sold.

See Section 3.1.1.

3.2.2. Use scenarios that may contribute to adverse impacts

Reference: CAL. CODE REGS. tit. 22, § 69503.3(b)(4)(D).

The SCP regulations consider a variety of uses that may contribute to the exposure to the product-chemical combination. These include household and recreational use, use by sensitive subpopulations, and use by workers, customers, clients, and members of the general public in homes, schools, workplaces, or other locations.

While human exposure to NPEs from laundry detergents and their resulting adverse impacts are not the focus of this document, some sensitive subpopulations (e.g., workers in on-premises laundry operations) have a higher potential for exposure compared to the general population. The greatest potential for occupational exposure to NPEs in laundries occurs when transferring chemicals into washers. However, as of May 2006, less than 6 percent of workers had direct contact with wash chemicals during unloading (U.S. EPA 2007a). These workers may have been exposed to either powdered or liquid detergents. The potential exposure to liquid detergents is reduced because they are almost exclusively loaded using automatic liquid injection systems (U.S. EPA 2007a; U.S. EPA 2007b). Powdered detergents increase the potential for inhalation exposure to dust containing NPEs (U.S. EPA 2007b). During both automatic and manual transfer operations, inhalation of vapors was not expected because NPEs are non-volatile (U.S. EPA 2007a). For both types of detergents, dermal exposure is possible but insignificant, due to negligible dermal absorption of NPE (U.S. EPA 2007b). More information on the extent of OPLs' use of automatic liquid injection systems would increase

DTSC's understanding of OPL workers' exposure potential. Residential laundry detergent is not expected to contain NPEs[31] and so that exposure pathway is not addressed here. The potential exposure to NPEs from laundry detergents is primarily to aquatic organisms, as this product is washed down the drain upon its use. More information on this exposure pathway is found in Section 3.3.2.

3.3. Exposures to the Candidate Chemical Throughout the Product Life Cycle

3.3.1. Indicators of potential exposures to the Candidate Chemical from the product

Reference: CAL. CODE REGS. tit. 22, § 69503.3(b)(2).

The SCP regulations consider various data that indicate potential for exposure to the Candidate Chemical or its degradation products, including: (i) the Candidate Chemical's presence in and release from the product; (ii) monitoring data indicating the Candidate Chemical's presence in the indoor and outdoor environment, biota, humans (e.g., biomonitoring studies), human food, drinking water, and other media; and (iii) evidence of persistence, bioaccumulation, lactational and transplacental transfer.

NPEs and their degradation products (NPEDs) have been detected in environmental media for decades throughout California, the United States (see below), and other countries (David et al. 2009; ECHA 2014a). The following types of data were considered to assess current and relevant exposure to NPEs and NPEDs:

- Environmental detections of surface water, sediment, and aquatic biota collected from U.S. sources between 2006 and 2017;
- Wastewater-related samples (i.e., effluent, influent, biosolids, and septic tank liquids and solids) collected from U.S. sources between 2000 and 2017; and
- Samples of other environmental media (e.g., dust, groundwater) collected from U.S. sources between 2000 and 2017 that are published in peer-reviewed literature and have contributed to DTSC's understanding of exposure pathways. A summary of these findings is included in Section 3.3.2.

3.3.1.1. General conclusions

NPEs and NPEDs have been detected in a wide variety of environmental compartments including sediment, surface water, effluent, sludge and biosolids, groundwater, dust, and human and animal specimens (Calafat et al. 2005; Lawrence Livermore National Laboratory and State Water Board 2006; Mitro et al. 2016; Rudel et al. 2003), and as summarized in Appendix E). Concentrations of NPEs and NPEDs in these environments can range from non-detects to concentrations that exceed aquatic GSC.

[31] *Section 3.1.1*

Environmental monitoring data is often limited to only NP, which does not represent the cumulative effects from exposure to the full range of constituents in the class of NPEs.[32]

NPEDs continue to be detected in wastewater effluent and the environment (Appendix E) despite reported declines in the use of NPEs in consumer products (APERC 2017) and decreases in environmental concentrations (Maruya et al. 2015). Monitoring data from Los Angeles County indicates that concentrations of NP, NP1EO, and NP2EO in effluent have remained relatively unchanged in the last decade (LACSD 2012; LACSD 2014a; LACSD 2015), although a recent collection event suggests a decline in NP1-2EOs (LACSD 2015). Available data indicate that there are instances in California and the United States where environmental concentrations of NPEs and NPEDs are above chronic aquatic GSC (Appendix E).

Monitoring of biota in California (Appendix E-6) indicates that NPEDs are bioavailable and can be detected at various trophic levels. These studies indicate that NPEDs are often detected in almost all samples analyzed (Dodder et al. 2014; Klosterhaus et al. 2013a; Lozano et al. 2012; Maruya et al. 2015; Maruya et al. 2012; Washington Department of Ecology 2017). Sludge and biosolids (Appendix E-3) are also of concern due to their high concentrations of NP and leaching potential after land application, and thus they may serve as a secondary pathway of NP to the aquatic environment.[33]

DTSC is concerned that the exposure to NPEs and NPEDs in California may be underestimated. Most monitoring studies assessed for this Profile only analyzed NP, yet research indicates that NP is not the dominant NPED in surface water, effluent, or sediment. For example, NP may comprise as little as 5 percent of the total NPEDs in a surface water. Additionally, analytical challenges (e.g., high reporting limits) may obscure concentrations that may be of concern, and a lack of current monitoring, particularly in effluent-dominated environments, complicates our understanding of exposure to NPEs and NPEDs in aquatic environments.[34]

3.3.1.2. Aquatic compartments and wastewater

Studies of chemicals of emerging concern (CECs, i.e., unregulated or under-monitored chemicals that may adversely impact the environment) indicate that NPEDs can be some of the most ubiquitous chemicals detected in sediment (Maruya et al. 2012; Meador et al. 2016) and wastewater effluent (Meador et al. 2016), and they have been detected at some of the highest concentrations of all CECs analyzed in sediment (Maruya et al. 2012), sludge (Kinney et al. 2006), and wastewater effluent (LACSD 2012; LACSD 2014a; LACSD 2015). Concentrations of NPEDs in sediments and surface waters can exceed aquatic GSC (Appendices E-4 – E-5; (Barber et al. 2015; Diehl et al. 2012; Elliott et al. 2017;

[32] *Section 5.2.2*
[33] *Section 3.3.2*
[34] *Section 5.2*

Lozano et al. 2012; Maruya et al. 2016; Maruya et al. 2015; Maruya et al. 2012; SCCWRP 2017; State Water Board 2008; State Water Board 2011). Surface water data from Region 7 of the California State Water Resources Control Board (2013a), Bradley et al. (2017)and Elliott et al. (2017), and Elliott et al. (2017) also exceed aquatic GSC, although values are below the reporting limit and are therefore considered to be estimated. Samples collected from the Tijuana River near San Diego exceeded aquatic GSC; however, these were most likely influenced by activity in Mexico (State Water Board 2011). Detections of NP in the San Gabriel River near the San Jose Creek WWTP outfall (LACSD 2012; Sengupta et al. 2014) were in line with concentrations in the treatment plant's effluent (LACSD 2012; LACSD 2014a; LACSD 2015).

Concentrations of NPEs and NPEDs in wastewater effluent, biosolids, surface water, and sediment can vary by an order of magnitude or more.[35] This is particularly apparent in effluent, where reported concentrations range from 0.03 to 120 µg/L. In other studies NP is found in only a few of the analyzed samples, but at concentrations at or above an aquatic GSC (State Water Board 2008; State Water Board 2011). For example, NP had the highest concentrations of any constituent analyzed in Los Angeles Harbor sediments (as high as 0.493 mg/kg, Maruya et al. (2016)), but was not detected in the nearby, effluent-dominated Santa Clara River (see Section 5.3.2 for additional discussion).

As noted in Section 2.2.2, temperature can have an effect on the biodegradation rate of NPEs. The implications of these effects can be seen in an environmental monitoring study by Loyo-Rosales et al. (2007a), where influent and effluent samples from three WWTPs were compared across regions and season. While influent samples had consistent NPE and NPED concentrations across treatment plants and season, total effluent concentrations of NPEs and NP1-2EC were seven and five times higher, respectively, in the winter than summer. These variations were attributed to the effects of temperature on the microbial degradation of NPEs (Loyo-Rosales et al. 2007a). Similar results were observed in surface waters collected in the fall and spring (Lozano et al. 2012). These results suggest that environmental conditions during sampling can influence concentrations of NPEs and NPEDs, and that samples collected in warmer conditions may have lower concentrations than samples collected in colder months.

3.3.1.3. Aquatic biota

Detections of NPEs and NPEDs in the majority of California biota analyzed (Appendix E-6) indicate that these chemicals are bioavailable in aquatic ecosystems. Surveys of CECs in aquatic biota indicate that NPEDs are some of the most frequently detected compounds compared to other CECs analyzed (Klosterhaus et al. 2013a; Maruya et al. 2014; Meador et al. 2016), and at some of the highest concentrations (Klosterhaus et al. 2013a; Maruya et al. 2014; Meador et al. 2016). For example, a 2009-10 survey of contaminants in mussels throughout California found that NP, NP1EO, and NP2EO

[35] *Appendices E-2 – E-5*

were detected in 100 percent, 100 percent, and 88 percent, respectively, of stations that passed quality assurance protocols, and NP was detected at the highest concentration of all 166 CECs analyzed (Dodder et al. 2014).

Concentrations of NP were highest in sea otter livers (3.68 mg/kg wet weight), oysters (11.2 mg/kg dry weight), and water column organisms (982 mg/kg lipid weight; all reported in Diehl et al. (2012)). While the different units of measurement cannot be compared to each other, the data indicate the presence of NP in a range of aquatic biota.

In some studies, aquatic biota had higher concentrations of NP than NP1EO (Klosterhaus et al. 2013a; Maruya et al. 2014), but this was not always the case (Lozano et al. 2012; Maruya et al. 2015; Meador et al. 2016). This may indicate a difference in accumulation potential for the lower ethoxylated NPEs as compared to NP (Maruya et al. 2015), but further study is needed to better understand the differences in bioavailability and metabolism of these compounds.

3.3.2. Potential exposure to the Candidate Chemical during the product's life cycle

Reference: CAL. CODE REGS. tit. 22, § 69503.3(b)(4)(A).

Potential exposures to the Candidate Chemical or its degradation products may occur during various product life cycle stages, including manufacturing, use, storage, transportation, waste, and end-of-life management practices. Information on existing regulatory restrictions, product warnings, or other product use precautions designed to reduce potential exposures during the product's life cycle may also be discussed here.

3.3.2.1. Manufacturing, storage, transportation

Although there are manufacturers of laundry detergents containing NPEs within California (State Water Board 2018e), worker exposure from these life cycle segment is not the basis for the listing. Any discharges to the aquatic environment as a result of these manufacturing processes are captured in the section below.

3.3.2.2. Use, waste, end-of-life

A conceptual model of exposure pathways during product use and the end-of-life phase of laundry detergents containing NPEs (once the product is used and released into wastewater) is provided in Figure 9. The potential exposure to NPEs and NPEDs during the use of laundry detergents is most likely

for workers in on-premises laundries.[36] While human health hazards have been identified by other authoritative organizations,[37] human exposure to NPEs is not the focus of this proposal.

Discharge of NPEs to WWTPs during the waste and end-of-life phase of these laundry detergents is the predominant route of exposure for fish and aquatic invertebrates. NPEs used in laundry detergents remain in the wash water and are released to WWTPs. WWTPs in California discharge significant volumes of wastewater directly into the aquatic environment, potentially exposing aquatic organisms to NPEs and NPEDs. Secondary wastewater-related sources of NPEs and NPEDs in the aquatic environment include WWTP effluent discharged to land, irrigation with recycled water, wastewater treated by septic tanks, and runoff from the land application of biosolids (additionally treated sludge). Discharges from these sources are authorized and regulated in California through permits called Waste Discharge Requirements (WDRs), but the permits do not regulate or NPEs or NPEDs.[38]

NPEs and NPEDs have been found in wastewater effluent and in a variety of California environmental media.[39] Cleaning products, including laundry detergents, can contribute to high concentrations of NPEs in wastewater as demonstrated by samples collected from facilities that use large amounts of these products (Nagarnaik et al. 2010). NPEDs may also be introduced to wastewater effluent due to increasing California efforts to develop beneficial uses of treated wastewater. Enhanced treatment of recycled water can generate brine containing CECs, including NPEDs, which is then added to wastewater effluent for discharge (SCCWRP 2012a).

Significant volumes of wastewater can be discharged into ecologically important habitat, and can potentially expose threatened or endangered fish species to NPEs and NPEDs.[40] Furthermore, these discharges can be necessary for wetland habitat restoration (City of Ventura et al. 2010; LACSD 2014b; RWQCB San Francisco 1995). Given the high nutrient loads of wastewater effluent, some of these environments may have significant amounts of anoxic sediments where NP forms and persists.[41] These sediments may serve as a source of NP exposure for species living in these environments. WWTP effluent can also be discharged directly to land for disposal (Diehl et al. 2012; U.S. EPA 2012a) or can be further treated into recycled water for use in irrigation (State Water Board 2013b). Wastewater treated by septic tanks may also represent a source of NPEDs to the aquatic environment, as NP concentrations as high as 48.8 µg/L have been found in California septic systems (Diehl et al. 2012).

WWTP biosolids applied to land as a soil amendment (fertilizer) may also contribute NPEDs to surface water by leaching NPEDs into stormwater and runoff. Studies have documented that considerable

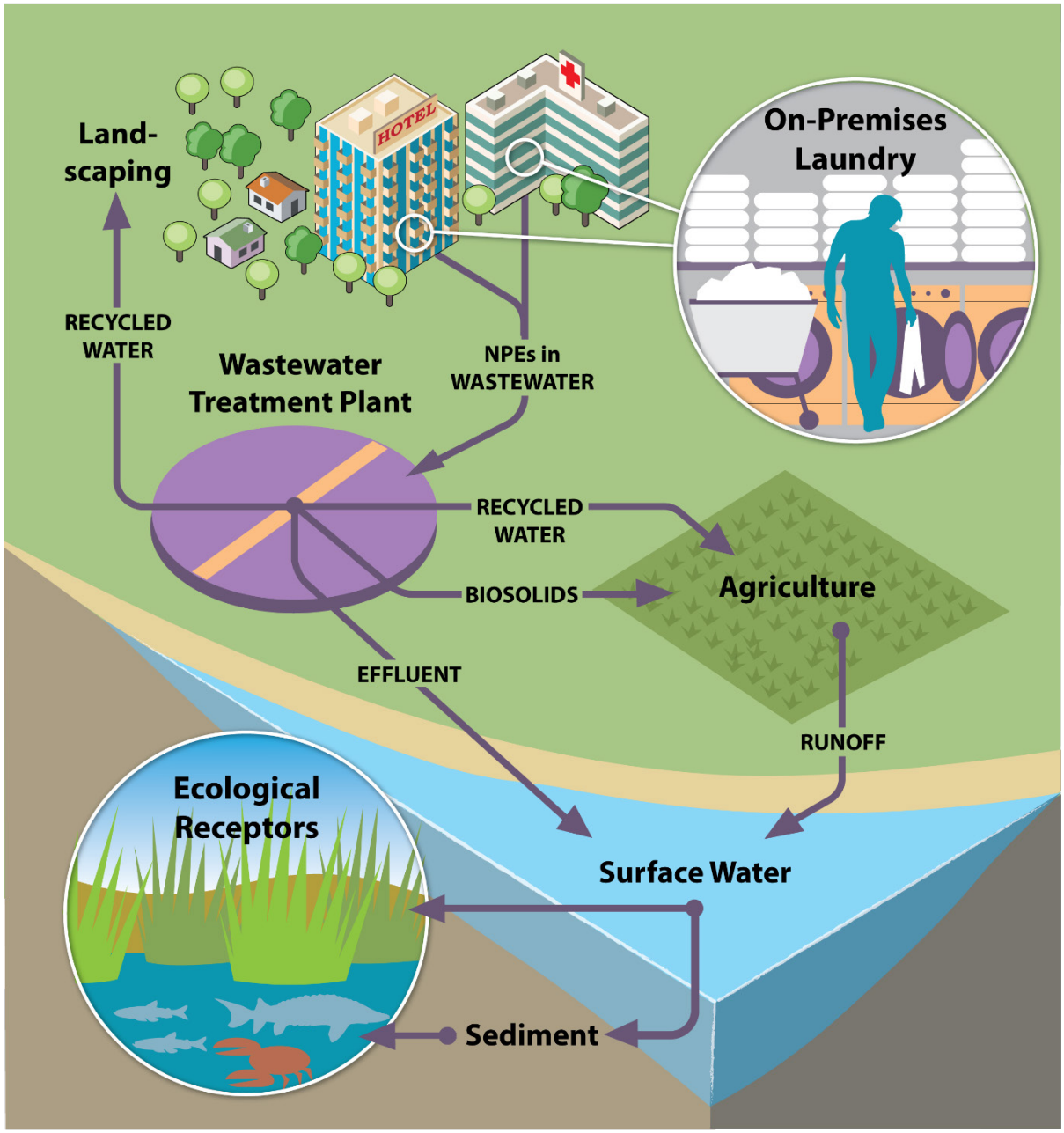
[36] *Section 3.2.2*
[37] *Section 2.3.3*
[38] *Section 8.3*
[39] *Section 3.3.1*
[40] *Section 2.5.2*
[41] *Section 2.3.2*

concentrations of NPEDs can leach out from land-applied biosolids into runoff (mean concentrations: 172, 12.4, and <1.5 µg/L; (La Guardia et al. 2001) and can continue to leach from biosolids for up to 35 days after application (Gray et al. 2017). Other studies have found relatively low concentrations of NPEDs in runoff (average: 0.028 µg NP/L; (Giudice and Young 2011)) and limited mobility of NPEDs in biosolid-amended soil (Brown et al. 2009). While wastewater discharge is the significant exposure pathway to the aquatic environment, potential leaching from biosolids is of particular concern in California because more than 50 percent of biosolids generated in the state are applied to land (CalRecycle 2015). Also, NPEDs have been detected in California biosolids samples (see Appendix E-3) at concentrations exceeding the limits set for land application limits by Denmark (10 mg/kg dry weight; (Danish Environmental Protection Agency 2006)) and Sweden (50 mg/kg dry weight; (Milieu Ltd et al. 2010)).

The waste and end-of-life phase of products containing NPEs also can indirectly expose the general population to "negligible amounts" of NPEDs via air, drinking water, and soil (Environment Canada and Health Canada 2001; European Chemicals Bureau 2002; U.S. EPA 2010b). According to WHO (2017), risks to human health from endocrine-disrupting compounds such as NP in drinking water are "unlikely." NPEDs have been detected in California recycled water and well water (Lawrence Livermore National Laboratory and State Water Board 2006; SCCWRP 2010). Fish consumption is also a potential exposure pathway for the general population. However, estimated daily intakes of NP from consuming contaminated fish, including by substantial fish consumers (e.g., fishermen), are well below tolerable daily intakes proposed by the Danish Institute of Safety and Toxicology (Ferrara et al. 2008; Nielsen et al. 2000). Environmental quality standards for the protection of aquatic life for NP are considered to be protective of human health since aquatic organisms are more sensitive to the estrogenic effects of NP than humans are (EC 2018; WHO 2017).[42]

[42] *Section 2.3.1*

Figure 9. Potential exposure pathways for NPEs from laundry detergents. This figure does not include all possible exposure sources and pathways for NPEs from consumer products to the environment.



3.3.3. Frequency, extent, level, and duration of potential exposure for each use and end-of-life scenario

Reference: CAL. CODE REGS. tit. 22, § 69503.3(b)(4)(E).

Frequency of product use (how often), and the extent (the number of routes of exposure), level (concentration of the Candidate Chemical), and duration (length of time) of use, are all considered when assessing the potential for exposure to the Candidate Chemical or its degradation products.

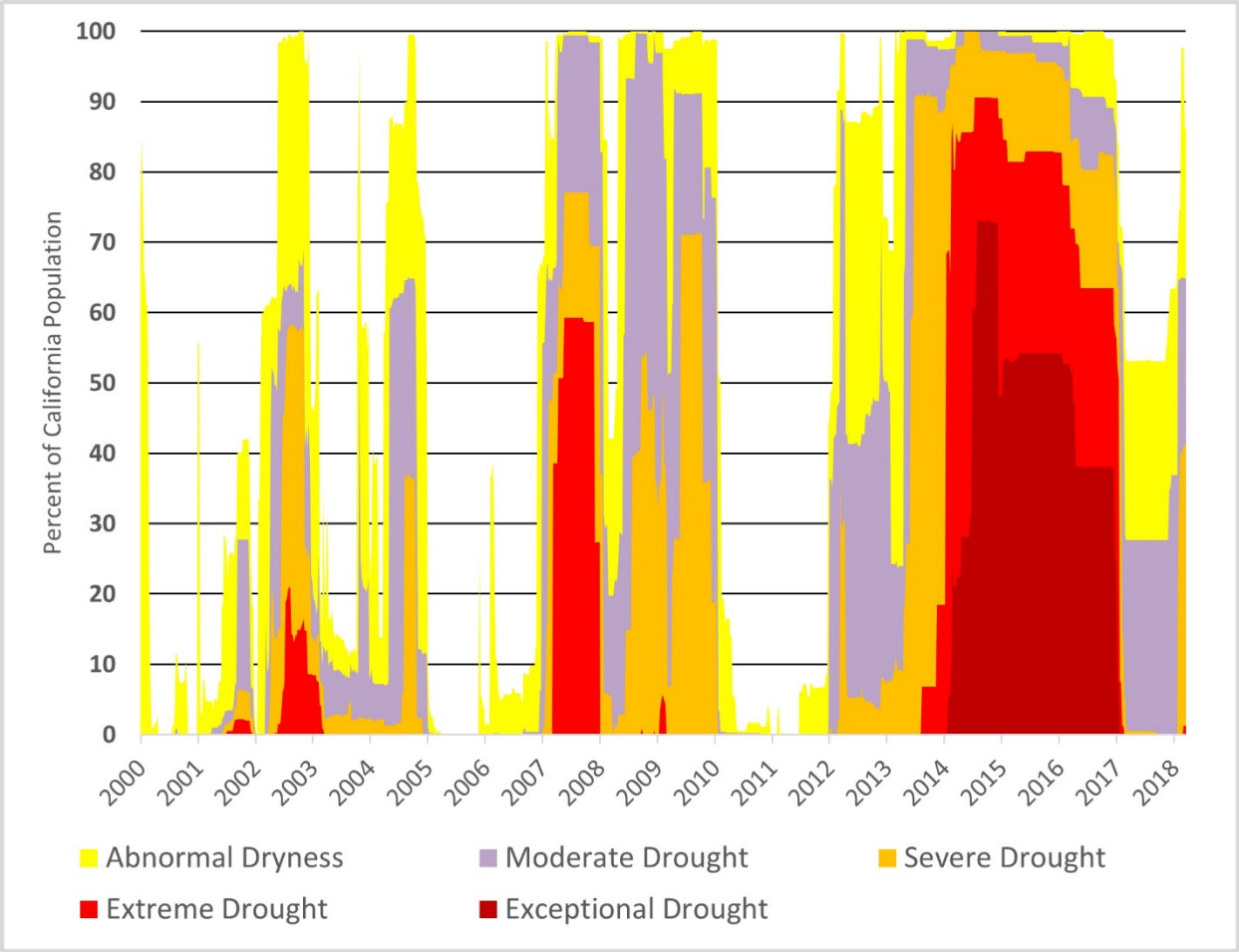
Aquatic organisms may experience chronic exposure to NPEs and NPEDs from municipal wastewater effluent due to frequent use of NPE-containing laundry detergents.[43] WWTPs discharge effluent into surface water continuously or at various intervals, exposing aquatic organisms to wastewater over long periods of time. The breadth and hydrological influences of discharges by WWTPs are highly variable, as California has hundreds of treatment plants (Appendix D-1) that are permitted to discharge to surface waters. These surface water systems range from natural flow-dominated waterways with limited effluent contributions to effluent-dominated waterways with little natural inflow, all of which can vary spatially and temporally (Ackerman et al. 2003; Crauder et al. 2016). Regardless of the dynamics, wastewater discharges provide near-constant long-term inputs of NPEs into aquatic systems and present a chronic contribution to exposures of aquatic organisms.

In addition to inputs from WWTPs, environmental concentrations of CECs can also increase as a result of drought conditions (Benotti et al. 2010). Drought-related reductions in rainfall, groundwater, snowfall, and snowmelt can contribute to decreased surface water volume (USGS 2017), resulting in less dilution of WWTP effluent upon discharge. Additionally, residential water conservation efforts (via CA Executive Order B-37-16) have decreased per capita water use (State Water Board 2017a). While water conservation efforts are beneficial overall, they can result in decreases in wastewater effluent, as well as increased concentrations of pollutants in WWTP influent and effluent if the volume of water decreases but the source of pollution remains unchanged.

The severity of impacts from drought is a function of duration and intensity. Since 1895, California has had six prolonged dry periods lasting two years or longer, three of which have occurred since 2000 (USGS 2017). The most recent drought, lasting from 2012 through 2016, is considered one of the most severe in California's recorded history, considering duration (USGS 2017) and intensity (National Drought Mitigation Center et al. 2018) and Figure 10). The 2017 water year extends through September 2018, so the end of the current drought remains undetermined. Below-normal precipitation over Southern California during the end of 2017 led to a prediction that the drought is likely to persist (NOAA 2018).

[43] *Section 3.1.2*

Figure 10. Percentage of California population experiencing various intensities of drought (2000-2018)



Source: National Drought Mitigation Center et al. (2018)

3.4. Potential Cases of Exposure to the Candidate Chemical in the Product from Various Life Cycle Segments – Special Situations

The exposure considerations in SCP regulations section 69503.3(b)(4)(B) and (D) would be used to discuss potential exposures to a Candidate Chemical used in products that 1) may be made in, stored in, or transported through California but are not used in the state, or 2) are exempted from the statutory definition of a consumer product. Laundry detergents containing NPEs do not meet either of these criteria, so this section does not apply.

3.5. Factors That May Mitigate or Exacerbate Exposure to the Candidate Chemical

The exposure considerations in SCP regulations section 69503.3(b)(4)(F) and (G) would be used to discuss containment of the NPEs in laundry detergent that reduce releases during the useful life and at

end of life, which does not apply to this product. This section would also describe engineering and administrative controls that reduce exposure concerns. DTSCs understanding of these controls is described in Section 3.2.2.

4. ADVERSE WASTE AND END-OF-LIFE EFFECTS

Reference: CAL. CODE REGS. tit. 22, §§ 69503.2(b)(1)(B) and 69501.1 (a)(8).

This section summarizes findings related to the waste materials and byproducts generated during the life cycle of the product, and their associated adverse effects. The subsections, below, are elements in the definition of Adverse Waste and End-of-Life, as described in the SCP regulations. These considerations can form part of the basis for proposing the product-chemical combination.

While the adverse effects of exposure to NPEs at the end of the product's life are the primary basis for the proposed listing, as described throughout this Profile, there are additional considerations related to impacts on wastewater treatment plans that contribute to the basis for this listing. These considerations are also supported by concern from California agencies over wastewater treatment costs, increased opportunities for beneficial reuse of wastewater and biosolids, decreased need for other methods of waste disposal, and reduced presence of NPEs (CentralSan 2017; RWQCB San Francisco 2018). The San Diego County Water Authority has also voiced concern about the potential impacts on humans and the environment due to the presence of NPEs in effluent that is further treated for beneficial reuse (SDCWA 2017), which can include nonpotable applications (irrigation, landscaping, and groundwater recharge) and, increasingly, potable uses (State Water Board 2013b). Sludge and biosolids are used for a variety of purposes, including land application for agriculture and to cover solid waste at landfills (CalRecycle 2015). NPEs are currently unregulated in wastewater effluent, sludge, and biosolids in California, but WWTPs are concerned about the presence of CECs, including NPEs and NPEDs, in their discharges, as their presence could limit options for beneficial reuse (CentralSan 2017).

4.1. The Volume or Mass of Waste or Byproducts Generated

Chemicals in products can increase the volume or mass of waste materials or byproducts generated during the life cycle of a product. For example, biosolids are normally produced in great volumes daily as a byproduct of wastewater treatment. When biosolids contain concentrations of hazardous substances above predetermined limits and meet the definition of hazardous waste, they cannot be disposed at sanitary landfills.

California's Integrated Waste Management Act and subsequent legislation (Assembly Bill (AB) 939, Statutes of 1989; AB 341, Statutes of 2011) require significant reductions in solid waste generation and landfilling, emphasizing diversion programs such as land application of biosolids (CalRecycle 2016). In

2013, California generated 723,000 dry metric tons of biosolids, of which only 13 percent were landfilled (CalRecycle 2015).

While there are currently no regulatory limits on the concentrations of NPEDs in sludge or biosolids in the U.S., California WWTPs are continuously exploring or implementing costly wastewater and sludge treatment methods to reduce the concentrations of contaminants and nutrients in their waste streams (CentralSan 2017). These advanced treatment options also serve to enable beneficial reuse of waste products. NPEDs, and NP in particular, have been detected at high concentrations in sludges and biosolids.[44] Additionally, recent studies indicate that biosolids can serve as a secondary source of NP in the aquatic environment,[45] which may further encourage WWTPs to remove CECs such as NPEs and NPEDs from biosolids. California's Central Contra Costa Sanitary District has asked DTSC to help address the presence of NPEs in wastewater (CentralSan 2017).

4.2. Special Handling of Waste or Byproducts Needed to Mitigate Adverse Impacts

The SCP regulations consider whether additional requirements are necessary to mitigate workers' exposures and prevent releases to the environment, such as the proper handling, storage, transportation, and disposal of the product as waste or hazardous waste.

DTSC is not basing its proposal on this factor.

4.3. Effects on Solid Waste and Wastewater Disposal, Treatment, and Recycling

Chemicals discharged from discarded products can adversely affect the operation of solid waste and wastewater handling and treatment facilities, and may lead to human and environmental chemical exposures. Additionally, improper recycling of certain products may hinder the treatment and recycling of other products, or reduce the value of recycled materials. Further, use of contaminated recycled materials could pose a risk to public health. Removal or treatment of Candidate Chemicals from waste or recycling streams could result in financial impacts on wastewater, treatment, or recycling facilities.

Disposal of WWTP waste products like effluent and biosolids can result in the release of CECs to the aquatic environment.[46] While enhanced treatments remove some CECs such as NPEs and NPEDs from the waste stream, they are often expensive to install and can result in high energy demand and high operation and maintenance costs (CentralSan 2017).

[44] *Appendix E-3*
[45] *Section 3.3.2*
[46] *Section 3.2.2*

The San Diego County Water Authority (SDCWA) has requested that DTSC consider NP and consumer product sources of the chemical to the wastewater stream (SDCWA 2017). In a comment submitted to DTSC, SDCWA indicated that NP has been detected in feed water at San Diego advanced water purification facilities. The SDCWA produces recycled water for beneficial reuse, which currently constitutes 5 percent of the total water supply for the region and is anticipated to increase (SDCWA 2017). Additionally, the region is in the process of implementing potable reuse projects that will produce treated wastewater for human consumption, which is expected to constitute 16 percent of the region's drinking water supply by 2035 (SDCWA 2017). The use of recycled wastewater is an important part of San Diego's water management strategy, given current and projected drought conditions and Southern California's limited water sources. The State Water Board has also urged all local and regional water agencies within California to use recycled water to help move the state toward a sustainable water future (State Water Board 2013b). The presence of NP in feed streams and brine generated from advanced treatment is of concern, as these represent a concentrated source of NP that may be discharged directly to wastewater effluent outfalls. In listing NPEs in laundry detergents as a Priority Product, DTSC is considering the burden placed on local agencies to remove CECs like NP from waste streams intended for beneficial reuse. The State Water Board indicates that this listing would be less costly and time-intensive than permit requirements to control NPEs in waste streams (State Water Board 2018d).

4.4. Discharges or Disposal to Storm Drains or Sewers That Adversely Affect Operation of Wastewater or Stormwater Treatment Facilities

The SCP regulations consider that wastewater treatment facilities are not designed to capture synthetic chemicals used in consumer products. Candidate Chemicals may be detrimental to the microbial activity necessary to digest biodegradable materials. The Candidate Chemical or its degradation products may also be released to the environment from wastewater treatment plants or via storm drains.

DTSC is not basing its proposal on this factor.

4.5. Releases of the Candidate Chemical into the Environment During Product End-of-Life

Candidate Chemicals can be released to the environment from various activities at the end of a product's useful life, including solid waste handling, treatment, or disposal. These discharges may enter the environment via storm drains, sewers, or landfill leachate. Many municipal waste landfills are unlined, and their leachate (i.e., water that drains through a land mass or solid) and air emissions may be hazardous. Even lined landfills will eventually fail and leak leachate into groundwater and surface water.

The down-the-drain nature of laundry detergents and resulting disposal of NPEs to wastewater systems is discussed in Section 3.3.2.

5. ADDITIONAL CONSIDERATIONS

This section summarizes other relevant information not captured under the adverse impact and exposure factors named in section 69503.3 of the Safer Consumer Products regulations.

5.1. Other Relevant Factors Not Identified by the Regulation

5.1.1. Potential for Priority Product selection to make effective use of public funds

Listing laundry detergents with NPEs as a Priority Product may decrease environmental concentrations of NPEs and NPEDs, which may reduce the need for future public funds to be spent on regulating or monitoring NPEs. Several publicly funded organizations have identified NPEs and NP as a risk to the aquatic environment; these organizations may collect new data that could inform future regulatory or policy decisions by DTSC and other organizations. Some of these efforts have a nexus to regulatory requirements but do not affect how the chemical is used in detergents manufactured or imported into California. For example, environmental monitoring is costly, and may be unnecessary once California environmental concentrations remain low over time. A summary of these monitoring and regulatory efforts is listed below:

- A State Water Resources Control Board (State Water Board) Science Advisory Panel for CECs in California's Aquatic Ecosystems (CEC Ecosystems Panel) recommended prioritizing statewide monitoring of NP in marine sediments (SCCWRP 2012b). This panel was convened to "provide unbiased science-based recommendations for monitoring of chemicals of emerging concern in oceanic, brackish and fresh waters across the State that receive discharge of treated municipal wastewater effluent and stormwater." The CEC Ecosystems Panel reviewed 82 CECs and prioritized 15, including NP, based on environmental concentrations and their calculated monitoring trigger level, or an aquatic toxicity benchmark with an uncertainty factor applied. The CEC Ecosystems Panel recommended prioritizing CECs that have a high trigger level in comparison to environmental monitoring data. While the trigger level is used to prioritize environments that may be adversely impacted by NP, it is considered to be a very conservative screening tool and not an aquatic toxicity threshold (SCCWRP 2010), and therefore was not included in Section 2.5.1.
- The Regional Monitoring Program for Water Quality in San Francisco Bay's (RMP) CEC strategy prioritized NP and NPEs as chemicals of "moderate concern" (SFEI 2017) in the San Francisco Bay (bay). The moderate concern risk tier includes contaminants that are frequently found at concentrations equal to or slightly higher than an effect threshold, and the RMP recommends aggressive pollution prevention strategies to keep these CECs from becoming a more significant

problem in the bay. The RMP does not list any CECs in the "high concern" tier, which would include contaminants that occur frequently in the bay at levels that indicate a high probability of a moderate or high-level effect on aquatic life, wildlife, or people. Legacy chemicals of comparable concern would include methylmercury. The RMP provides data to federal, state, and regional agencies to support assessments and improvements to the aquatic health of the bay. The RMP published recommendations regarding relative risks of CECs in the bay and is developing a monitoring strategy for each chemical of moderate concern.

- U.S. EPA's Action Plan for NP and NPEs (U.S. EPA 2010b) proposes several strategies for U.S. EPA to undertake in order to manage risk and address concerns about potential ecological effects from the manufacturing, processing and distribution in commerce, and use of NP and NPEs. Possible strategies include:
    - Proposing a Significant New Use Rule (SNUR) (U.S. EPA 2014a) for NP and NPEs, which would require industry to notify U.S. EPA of any new use of the chemical. Notification allows the agency to review the proposed new use and, if necessary, limit potential adverse exposure or effects. Existing uses listed in the proposed SNUR include laundry detergents. U.S. EPA has proposed a SNUR for 13 Chemical Abstracts Service Registry Numbers (CASRNs) for specific NPs and NPEs due to their persistence, low to moderate bioaccumulation, and high toxicity to aquatic organisms. To date, no further action on the proposed SNUR has been announced.
    - Listing NP and NPEs for U.S. EPA'S Toxic Releases Inventory (TRI) program. The regulations for these chemicals took effect in 2014 (79 FR 58686) and 2018 (83 FR 27291), respectively. The aim of this program is to track the management of certain toxic chemicals that may pose a threat to human health and the environment. Facilities in specific industrial sectors (e.g., manufacturing, mining, electric power generation) that manufacture, process, or use NP-related compounds in quantities above threshold levels are required to report how much of the identified chemicals are released to the environment and/or managed through recycling, energy recovery, and treatment. U.S. EPA listed NPEs because they break down to short-chain NPEs and NP, which are toxic and can adversely affect aquatic organisms.
- U.S. EPA's Design for the Environment program evaluated alternatives to NPEs to help industries choose safer chemicals (U.S. EPA 2012b). Design for the Environment, now called Safer Choice, and other parts of EPA have spent years gathering information and conducting research on safer alternatives to surfactants. To prepare the NPE surfactant alternatives assessment report, the program worked with stakeholders to identify alternative chemicals and develop Criteria for Safer Surfactants. (See Section 7 of this Profile for a summary of their findings.)

5.1.2. Concurrence with experts in chemicals of emerging concern or aquatic pollutants

- See bullet on the CEC Ecosystems Panel science advisory panel above.
- See bullet on the RMP above.
- The EU Water Framework Directive listed NP as a "priority hazardous substance" (Decision No. 2455/2001/EC) due to its aquatic toxicity, human toxicity through aquatic exposure routes, distribution in the environment in time and space, the amount produced and used, and the way these chemicals are used. The directive aims to achieve good water status in identified waterbodies in the EU, in part by developing a list of chemicals that pose a significant risk to or via the aquatic environment. As a result of this list, the European Commission has a policy to reduce discharges and emissions of NP (Directive 2003/53/EC), which includes using the Registration Evaluation Authorization and Restriction of Chemicals (REACH) restriction process. Restrictions for NPEs are now in place in the EU for some cleaning products containing NPEs,[47] and for certain textiles, because the textile manufacturing process uses NPEs as a detergent or an emulsifying agent (REACH 2016).
- The Minnesota Pollution Control Agency drafted a water quality standard to protect salmonids from chronic exposure to NPEs.[48] This effort was part of the development of the agency's 2013 triennial standards review of water quality standards to protect water resources (MPCA 2010).
- The Chemicals of Emerging Concern program at Minnesota's Department of Health has prioritized NP to address public health concerns relating to exposure via drinking water. Minnesota prioritized evaluation of the chemical based on endocrine disruption in fish, potential impacts to human kidneys and reproduction, and frequency of detection in a WWTP study (Minnesota Department of Health 2015).
- The OSPAR Commission identified NP and NPEs as Priority Chemicals due to their persistent, bioaccumulative, and toxic (PBT) properties (OSPAR Commission 2009). This Commission administers the work under the Convention for the Protection of the Marine Environment of the North-East Atlantic, by which 15 governments in Europe agreed to protect the marine environment of the Northeast Atlantic. OSPAR's objective is to prevent pollution of the OSPAR maritime area by reducing emissions and discharges of hazardous substances (OSPAR Commission 2010).

[47] *Section 5.1.3*
[48] *Section 2.5.1*

5.1.3. Harmonization with other regulatory programs to reduce NPEs in cleaning products

- The California Air Resources Board adopted regulations that ban alkylphenol ethoxylates (APEs), including NPEs, from specific household cleaning products not including laundry detergent (CAL. CODE REGS. tit 17, §§ 94507-94517). These include various nonaerosol products (general-purpose cleaners, general-purpose degreasers, glass cleaners, heavy-duty hand cleaners or soaps), and oven or grill cleaners. While the regulation focuses on volatile organic compounds, which are harmful for air quality, APEs were included due to concerns about their impact on the aquatic environment (State Water Board 2011). The State Water Board supported this regulation because environmental concentrations of additive exposure to NPEs and NPEDs are high enough to cause concern for aquatic toxicity (State Water Board 2011).
- In accordance with Directive 2003/53/EC, the European Commission adopted a restriction for NPEs (≥0.1 percent) in various products, including domestic, industrial, and institutional cleaning products (REACH 2009).
- South Korea's K-REACH (The Act on the Registration and Evaluation of Chemicals) program has recently adopted restrictions similar to the European Commission's to restrict the use of NPEs (≥0.1 percent) in various products, including domestic, industrial, and institutional cleaning products (Chemical Watch Global Risk & Regulations News 2016).

5.1.4. Cumulative effects from exposures to chemical mixtures

Fish and aquatic invertebrates are exposed to complex mixtures of chemical contaminants, including pharmaceuticals, pesticides, and other chemicals found in consumer products which may influence the adverse impacts experienced by these organisms. The cumulative (combined) effects of exposure to APEs including NPEs, NPEDs, octylphenol ethoxylates (OPEs), and octylphenol (OP) can exacerbate adverse impacts because they have the same hazard traits and because these chemicals co-occur in environmental samples. Two approaches have been used to quantify the cumulative adverse impacts of these alkylphenolic mixtures based on estimated potency,[49] referred to here as effective NP concentration. In summary, Canada's approach sums the concentrations of NP and the NP-equivalents for many alkylphenolic compounds, and Minnesota's approach sums the concentrations of NP and NP1-2EO. Regardless of the approach, the effective NP concentration in samples monitored for the larger array of APEs is greater than when measured NP concentrations alone are considered. This is demonstrated in the examples below, using the Canadian approach. These examples also illustrate that effective NP concentrations can exceed the Canadian environmental quality guidelines:

- Sediment (ocean; Appendix E-5; (Maruya et al. 2015))

[49] *Section 2.4.1*

    - 1.8-fold increase from NP to effective NP (0.547 to 1.01 mg/kg)
- Water (Appendix E-4)
    - Freshwater (Lozano et al. 2012):
        - 3.6-fold increase from NP to effective NP (0.55 to 2.00 µg/L)
        - 6.2-fold increase from NP to effective NP (1.01 to 6.24 µg/L)
    - Marine (Lara-Martin 2017; Lara-Martin et al. 2014)
        - 4.2-fold increase from NP to effective NP (0.29 to 1.22 µg/L)[50]

Additionally, the high effective NP concentration compared to measured NP concentrations is particularly apparent in a recent survey of NP, NP1-2EOs, OP, and OP1-2EOs in California wastewater. This is unsurprising, given that NP is not expected to be the dominant degradant in wastewater.[51] For example, the effective NP concentration of these chemicals (1.08 µg/L) was over five times greater than the measured NP concentration in one example collection event (0.21 µg/L)[52] (LACSD 2012) using the Toxic Equivalency Factor (TEF) approach. Using Minnesota's approach, the effective concentration is 1.56 µg/L. Although DTSC is not comparing these values to aquatic GSC, the effluent data provide insight about the potential adverse impacts from co-exposure to chemicals that have cumulative adverse impacts, because the data are relatively current and include many of these chemicals of interest.

These studies illustrate that the actual exposure of aquatic organisms to NPEs and NPEDs may be underestimated when only NP is measured. In its risk assessment on NPEs from laundering textiles, ECHA (2014a) used predicted concentrations to estimate co-exposures to NPEDs in freshwater and marine water, and provided relative proportions of NP, NP1-2EOs, NP3-8EOs, and NP1-2ECs. The predicted concentrations were used in combination with the toxic equivalency factors to generate risk quotients for the NPEDs. While NP alone generated a risk quotient of 0.28, the combination of these NPEDs generated a total risk quotient of 1.2 (ECHA 2014a).

While NP1-2EO and NP1-2EC may not be as toxic as NP, they have been measured at higher concentrations than NP (Ahel et al. 1994a; Ahel et al. 1994b; Bradley et al. 2017; Ferguson et al. 2001; Klečka et al. 2010; Lozano et al. 2012; Meador et al. 2016) and can result in higher effective NP concentrations compared to NP itself. That means these compounds contribute to the potential for adverse impacts on aquatic organisms. In contrast to older California surface water samples that

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[50] Based on the following concentrations (µg/L) in the same sample: ∑NP1-8EO: 1.86; ∑NP9-15EO: 0.093; ∑NP1-2EC: 1.81

[51] Section 2.2.2

[52] Based on the following concentrations (µg/L) in the same sample: OP: 0.0406, NP1EO: 0.586, NP2EO: 0.772, OP1EO: 0.165, OP2EO: 0.143 µg/L

emphasized NP as an analyte, the RMP is beginning to specifically analyze for higher ethoxylated NPEs due to these concerns about underestimated exposure to NPEs and NPEDs (SFEI 2017).

Another example of greater than additive effects can occur when aquatic organisms are exposed to mixtures of pyrethroid pesticides and NPEs (Schlenk et al. 2012), which increases vitellogenin production *in vivo*.[53] These types of effects could potentially play a role in Pelagic Organism Decline.[54] While the underlying causes of these abrupt population declines have yet to be well-characterized, experts have identified contaminant exposure, including to endocrine-disrupting compounds, as a stressor that warrants further investigation (Baxter et al. 2010). Notably, there is a significant correlation between pyrethroid use and the decline of POD fish populations (Fong et al. 2016). The co-exposure dosing studies and this correlation suggest that complex mixtures in the environment (including NPEs, NPEDs, and pesticides) can impact fish species, possibly in additive or greater ways.

5.2. Key Data Gaps

The information in Sections 2-4 of this Profile amply supports the proposal to list NPEs in laundry detergents as a Priority Product. Nonetheless, DTSC believes that information to fill the following data gaps would further strengthen this proposal.

5.2.1. Limited monitoring of California wastewater-related media

Wastewater treatment plants are the most important source of NPEs and NPEDs in the aquatic environment, and California has hundreds of WWTPs that are permitted to discharge to surface water.[55] However, there are limited data for the full range of NPEs in California wastewater and biosolids, and there are relatively few monitoring studies for NPEs and NPEDs in effluent-dominated environments, which are expected to have high concentrations of down-the-drain chemicals, such as NPEs and NPEDs.

As a result of these data limitations, DTSC considered a wider range of sampling years in the environmental monitoring review of wastewater-related media.[56] For example, only three biosolid and six wastewater effluent studies were found to contain California data, and the majority of the recent California data are focused in the Los Angeles region (LACSD 2012; LACSD 2014a; LACSD 2015; RWQCB Los Angeles 2017). Some of the data reported to the Los Angeles Regional Water Quality Control Board are preliminary findings that have yet to be verified (RWQCB Los Angeles 2017). The data in Appendices E-2 and E-3 illustrate that wastewater and biosolids contribute to NP in the aquatic

[53] *Section 2.4.1*
[54] *Section 2.5.2*
[55] *Section 3.3.2*
[56] *Section 3.3.1*

environment, but most of the data are older and may no longer represent current contributions from consumer products.

Current California data are also limited in wastewater-impacted environments, such as near WWTP outfalls (Maruya et al. 2015), in effluent-dominated environments (Diehl et al. 2012; Maruya et al. 2016), and other environments (SFEI 2017b), which are can all be prone to higher concentrations of NPEs and NPEDs. In fact, the RMP, in conjunction with San Francisco Estuary Institute (SFEI), one of Northern California's leading aquatic and ecosystem science organizations, has recently recognized the margins of San Francisco Bay (mudflats and shallow areas of the bay) as another type of environment to have higher concentrations of contaminants (SFEI 2017), but these environments have not been sampled for nonylphenolic compounds. Evaluating these types of environments for CECs may become increasingly important as California is impacted by long-term drought.[57]

While some studies have analyzed NP in wastewater-dominated environments in Southern California, there are too few data to identify trends (see Section 5.3). In monitoring data for San Francisco Bay, almost all of the water and sediment samples were collected over five kilometers away from WWTP outfalls and found low concentrations of NP (Klosterhaus et al. 2013a; Maruya et al. 2015). Nonetheless, some wastewater and biosolid samples show high concentrations of NPEDs, which suggest continuing inputs of NPEs and NPEDs to the environment. As a result, California's wastewater-impacted environments have the potential for significant or widespread adverse impacts.

5.2.2. Limitations of analytical approaches and methods may underestimate exposure

As discussed above in Section 1.1, NPEs and NPEDs are a group of chemicals that vary by ethoxylate chain length, the position of the alkyl side chain on the phenolic ring, the degree of branching of both the alkyl side chain and the ethoxylate chain, and the degree of carboxylation (ECHA 2013; Environment Canada and Health Canada 2001; U.S. EPA 2010b). Despite these variations and the possibility of cumulative impacts from exposure to this suite of compounds,[58] most analytical studies focus only on the most toxic of these degradants, NP or more specifically, 4-NP.[59] Reporting limits at or above environmentally relevant concentrations and governmental aquatic GSC also limit DTSC's ability to characterize exposure to NPEs and NPEDs for all the studies that were considered.

Data from environmental studies indicate that restricting analyses to just NP may result in an underestimation of the total concentration of NPEs and NPEDs. DTSC calculates that total concentrations could be underestimated by 47 to 86 percent in wastewater-impacted sediments (Ferguson et al. 2001), by more than 95 percent in wastewater secondary effluent (Ahel et al. 1994a),

[57] *Section 3.3.3*
[58] *Section 2.4.1*
[59] *Appendix E-1*

and by more than 97 percent in surface waters (Ahel et al. 1994a; Ahel et al. 1994b; Lin et al. 2006). In sediments, the remaining fraction of nonylphenolic compounds is often made up of NP1-3EOs (Ferguson et al. 2001). In effluent and surface water, NPECs have been found to be the dominant nonylphenolic compound in several studies, comprising over 40 percent of the total NPEs and NPEDs in effluent (Ahel et al. 1994b) and 85 percent or higher in surface waters (Ahel et al. 1994b; Gross et al. 2004; Lin et al. 2006; Loyo-Rosales et al. 2007b). In surface water, concentrations of NP2-8EO have been shown to exceed NP or NP1EO concentrations (Klečka et al. 2010). A comment letter from SFEI indicates the Institute has recent unpublished data supporting the concern that NP monitoring may underestimate total exposure to NPEs and NPEDs (SFEI 2018).

Analytical methodologies may also contribute to underestimates of NPEs and NPEDs in the environment. Some studies reported in Appendix E used analytical methods with detection limits or reporting limits that are not low enough to meet some of the aquatic GSC (Bradley et al. 2017; Elliott et al. 2017; Klečka et al. 2010; State Water Board 2008; U.S. EPA 2009; Washington Department of Ecology 2017). This can be, in part, a result of contamination of the sample during collection or analysis (Klosterhaus et al. 2013b; SCCWRP 2017). Concentrations below the reporting limit but above the detection limit are of reported as estimates, and therefore their use to evaluate the potential for adverse impacts is limited. These analytical limitations combined with a tendency to only monitor NP result in the potential for an underestimation of aquatic organism exposures to NPEs and NPEDs.

Available studies frequently lack information needed for a complete understanding of environmental exposures to nonylphenolic compounds. NP and lower ethoxylated NPEs are not routinely analyzed separately on suspended solids in the water column, despite the known affinity of these chemicals for the organic matter found in sediments and suspended solids,[60] and studies indicate that NPED concentrations in suspended solids can exceed sediment aquatic GSC (Ferguson et al. 2001; Lara-Martin et al. 2014). These studies suggest the possibility of exposure of filter feeders to high concentrations of NPEDs through ingestion of particulates (see Section 5.2.3).

5.2.3. Limited understanding of hazard traits and exposure potential for filter- and detritus-feeding organisms

While the potential impacts of aqueous exposure of NPEs and NPEDs are relatively well-characterized for pelagic fish and aquatic invertebrates, the impacts of exposures via ingestion by filter- and detritus-feeding organisms are not. Furthermore, NP and lower ethoxylated NPEs are not routinely analyzed separately on suspended solids in the water column, despite these chemicals' known affinity for organic matter.[61] NPED concentrations measured in suspended solids (Ferguson et al. 2001; Lara-Martin et al. 2014) can exceed sediment aquatic GSC. Organisms that ingest suspended particles,

[60] *Section 2.2.3*
[61] *Section 2.2.3*

sediment, and detritus can have an additional direct route of exposure to these chemicals. This includes organisms that are vital to benthic (sediment-dwelling) and shoreline communities, such as filter-feeding bivalves (e.g., mussels, clams, and oysters) and worms. Other organisms exposed to organic-rich media include filter-feeding crustaceans (e.g., barnacles and shrimp) and detritus-feeding fish (e.g., catfish, suckers). Also, pore water (water found between particles in sediment) can be a source of exposure for benthic organisms (Naylor et al., 1992), yet the toxicity studies for these organisms and routes of exposures are rarely considered[62] or in development of the aquatic GSC created by authoritative organizations.[63]

5.2.4. Limited understanding of sources for NPEs

NPEs may be present in a number of products in addition to laundry detergents, with direct and indirect routes of exposure through the aquatic environment.[64] The presence of NPEs in these products may contribute to the environmental burden of these compounds. However, our understanding of which products contain NPEs, and of the potential for these products to contribute to environmental exposures to NPEs, is limited. NPEs and NPEDs can be among the most prevalent compounds found in dust in residences (Ferguson et al. 2017; Rudel et al. 2003), and house dust has been suggested as an additional source of contaminants to the waste stream (Schreder and La Guardia 2014), yet information on product-specific contributions to house dust is not available. Additional sources, including runoff and pesticide use, can also contribute to aquatic loadings of NPEs and NPEDs (Maruya et al. 2015). The role of cumulative exposure from multiple products is relevant when assessing the potential for adverse impacts and prioritizing product-chemical combinations. A better understanding of the use of NPEs in consumer products and their relevant direct and indirect exposure pathways to the aquatic environment would help DTSC to prioritize other products containing NPEs.

5.3. Conflicting Studies

5.3.1. Scope of environments of concern for NP according to a State Water Board science panel

The State Water Board CEC Ecosystems Panel reviewed 82 CECs, including NP and NP1-2EOs, in marine, coastal embayment, and freshwater environments, and recommended prioritizing statewide monitoring of NP in ocean sediments and ocean wastewater outfalls (SCCWRP 2012b). The panel did not prioritize statewide monitoring for NP1-2EO, nor did it prioritize statewide monitoring of NP in

[62] *Section 2.3.1*
[63] *Section 2.5.1*
[64] *Section 3.1.3*

freshwater environments. These differences relate to the scope of the panel's charge, and the availability of information at the time.

The scope of the panel's recommendations is narrower than that presented in this Profile, as SCP's regulations consider more factors relating to adverse impacts and exposure. Additional adverse impact factors reflected in this Profile include the cumulative effects of NPEs and NPEDs; additional exposure considerations include detections of NP in organisms and high concentrations in wastewater effluent.[65] The State Water Board panel's findings were also based on a more limited set of references (published between 2003 and 2011) than those provided in this Profile. Additional studies providing environmental monitoring data have been released since the panel's 2012 evaluation. These more recent reports include environmental data that support DTSC's concern for wastewater-impacted freshwater and coastal embayment environments:

- Bradley et al. (2017): includes various freshwater samples from California and elsewhere in the U.S. (all detections were below the reporting limit but above the detection limit)
- California Environmental Data Exchange Network (CEDEN) data (State Water Board 2008; State Water Board 2011; State Water Board 2013a): includes some California freshwater detections that exceed Canada's water quality guidelines and the EU's Environmental Quality Standards
- Diehl et al. (2012): includes California freshwater and coastal embayment water detections that approach or exceed Canada's water quality guidelines and the EU's Environmental Quality Standards
- Maruya et al. (2015): includes California coastal embayment sediment detections that exceed Canada's interim sediment quality guidelines and the EU's Environmental Quality Standards
- Maruya et al. (2016): includes California coastal embayment sediment detections that exceed the EU's Environmental Quality Standards

5.3.2. Conflicting detections of NPEDs in effluent-dominated environments

NP was undetected, or detected at very low concentrations, in two monitoring publications in wastewater-dominated environments in Southern California (Maruya et al. 2016; Sengupta et al. 2014). In one instance, Sengupta et al. (2014) did not detect NP in most of their sampling of the Los Angeles and San Gabriel rivers. However, it was detected in effluent sampling reported by LACSD (2012) and in a more recent follow up study of the Los Angeles and San Gabriel Rivers (SCCWRP 2017). Additionally, detections of OP in the Sengupta study suggests the presence of NP given the greater use of NP in consumer products and industrial processes (ECHA 2014a).

In the other instance, water samples from the Santa Clara River showed NP was undetected in the sediment or water (Maruya et al. 2016), despite other accounts of NP in effluent directly discharged to

[65] *Section 2.4.1, Appendix E-6 and Appendix E-2*

the river (0.03 to 1 µg/L; (RWQCB Los Angeles 2017)). The lack of NP detections in the Santa Clara River may be in part a result of the relatively high reporting limits due to background NP contamination (Maruya et al. 2016) or the lower total organic carbon (TOC) content of the sediment samples (0.2-2.6 percent TOC). Sediments with higher percentage TOC, such as those found at the mouth of the Los Angeles River (7.4 percent TOC), are more likely to concentrate CECs like NP (Maruya et al. 2016) because of the tendency for NP to adsorb to organic matter (see Section 2.1). Sediment samples collected near the mouth of the Los Angeles River (max 0.493 mg NP/kg; (Maruya et al. 2016)) were also lower than DTSC expected given the very high reported concentrations of NP in effluent (0.1-27 for µg/L; (RWQCB Los Angeles 2017)) for the multiple WWTPs that discharge to the effluent-dominated river (Ackerman et al. 2003) and to Los Angeles Harbor. Additional monitoring of these environments, including analysis of the other NPEDs, can help DTSC understand the actual exposure scenario that aquatic organisms are likely to experience.

6. DISCUSSION OF POTENTIAL FOR SIGNIFICANT OR WIDESPREAD ADVERSE IMPACTS

This section integrates the information provided in the profile to demonstrate how the key prioritization principles, as identified in the SCP regulations, are met.

6.1. Potential Public and/or Aquatic, Avian, or Terrestrial Animal or Plant Organism Exposure to the Candidate Chemical in the Product

NPEs continue to be used in laundry detergents, especially those used by on-premises laundries. The volumes of NPE-containing laundry detergents discharged to wastewater treatment plants may be significant given the number of on-premises facilities, the amounts of laundry generated and detergent used, and the concentration of NPEs in detergents. Once used, laundry detergents and the NPEs they contain are discharged down the drain and enter wastewater treatment plants. An estimated 2.05 billion pounds of laundry are washed per year by on-premises launderers in California, and concentrations of NPEs in these laundry detergents can range from 5 to 50 percent. [66]

Within WWTPs, NPEs are efficiently degraded (93-99 percent removal),[67] but the degradation products are even more potentially harmful than NPEs. Given the number and broad distribution of treatment plant outfalls across California,[68] organisms living in aquatic environments throughout California may potentially be exposed to NPEs and NPEDs. Substantial concentrations of NPEDs have been measured

[66] *Sections 3.1.1-3.1.2*
[67] *Section 2.2.2*
[68] *Appendix D-1*

in wastewater effluent and biosolids.[69] Concentrations of NPEs in WWTP effluent measured over time by the Los Angeles Regional Water Quality Control Board illustrate the potential magnitude of NP discharges to wastewater-impacted environments (up to 120 µg/L (RWQCB Los Angeles 2017), and suggest that concentrations of NP in wastewater effluent have remained relatively unchanged over the last decade.[70]

NPEs and NPEDs have been detected in surface waters and sediments in California.[71] NPEs and NPEDs are some of the most ubiquitous CECs detected in several sediment (Maruya et al. 2012; Meador et al. 2016) and wastewater effluent studies (LACSD 2012; LACSD 2014a; Meador et al. 2016). NPEs and NPEDs have also been detected at some of the highest concentrations of all chemicals analyzed in sediments, wastewater effluent, and sludge (Kinney et al. 2006; LACSD 2012; LACSD 2014a; Maruya et al. 2012). NPEs and NPECs have been found at high concentrations in surface water and can represent an ongoing source of NP as they are further degraded to NP in the environment.[72]

Available monitoring data may underrepresent total concentrations of nonylphenolic compounds in these samples, as most of the studies only measured NP and several had high detection or reporting limits.[73] Studies indicate that only analyzing for NP may underestimate the total concentration of nonylphenolic compounds by as much as 40-70 percent in sediments and 92 percent in surface waters. In fact, NP is not the dominant nonylphenolic compound in wastewater effluent.[74] Another potential limitation of the available monitoring data is the underrepresentation of environments that may be highly impacted by effluent.[75] This is increasingly important as California experiences long-term droughts, when surface water volumes available to dilute effluent discharges may be lower than in non-drought conditions.

NP and NP1-2EO have been detected in a variety of aquatic organisms, many from California environments.[76] Notably, NP represented the most frequently and highly detected compound out of the 116 CECs analyzed in a California-wide mussel survey (Dodder et al. 2014; Maruya et al. 2014). NP was also detected in a wide variety of estuarine animal species (four invertebrate, three fish, one bird, and three mammal species) collected from four California bays (Diehl et al. 2012).

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[69] *Section 3.3.1, Appendices E-1 and E-5*
[70] *Section 3.3.1*
[71] *Section 3.3.1, Appendices E-2 and E-3*
[72] *Section 2.2.1*
[73] *Section 5.2.2*
[74] *Section 2.2.2*
[75] *Section 5.2.1*
[76] *Section 3.3.1 and Appendix E-6*

6.2. Potential for One or More Exposures to Contribute to Significant or Widespread Adverse Impacts

The exposures to NPEs and NPEDs identified in Section 6.1 have the potential to contribute to significant or widespread adverse impacts because these chemicals: (i) can persist in the environment; (ii) are harmful to fish and aquatic invertebrates; (iii) are present in the environment at concentrations that exceed or have the potential to exceed aquatic GSC; and (iv) can have cumulative and/or synergistic impacts with other chemicals.

Numerous studies indicate that NP and some NPEs persist in anoxic environmental conditions. Some studies even indicate that these compounds can persist in oxic sediments. Persistence of NP and some NPEs in the environment increases the exposure potential of aquatic biota, particularly sediment-dwelling organisms, to these compounds.[77]

NPEs and NPEDs are internationally recognized as hazardous to fish and aquatic invertebrates. They can adversely impact their growth, reproduction, development, and survival.[78] Some reproductive and endocrine toxicity endpoints in fish include increased ovary weight, intersex organs (i.e., testis-ova) in males, and mixed secondary sex characteristics. Given the breadth of fish and aquatic invertebrate species in California and the potential exposures,[79] many aquatic populations may be adversely impacted by NPEs and NPEDs. For example, endangered or threatened fish species can co-occur with WWTP outfalls,[80] and can be exposed to high concentrations of NPEs and NPEDs when they are near discharges or in wastewater-dominated environments. Also, filter- and detritus-feeding organisms have multiple routes of exposure to the more potent nonylphenolic compounds, NP and NP1-2EOs, because these chemicals can accumulate in organic-rich sediments.[81]

Because of concerns about the potential adverse impacts to chronically exposed aquatic organisms, several authoritative organizations have created aquatic GSC for NP, NPEs, and NPEDs in water and sediment.[82] While the purposes for and assumptions behind these aquatic GSC vary, the fact that NPEDs have been measured at levels that approach or exceed them demonstrates the potential for adverse impacts to aquatic organisms. These exceedances were demonstrated in environmental monitoring data in the United States, including in California, for surface water (Barber et al. 2015; Diehl et al. 2012; Lara-Martin et al. 2014; Lozano et al. 2012; SCCWRP 2017; State Water Board 2008; State

[77] *Section 2.3.2 and 5.2.3*
[78] *Section 2.3.1*
[79] *Section 2.5.1 and Section 6.1*
[80] *Section 2.5.2*
[81] *Section 5.2.3 and Section 2.2.2*
[82] *Section 2.5.1*

Water Board 2011) and sediment (Diehl et al. 2012; Elliott et al. 2017; Lara-Martin et al. 2014; Maruya et al. 2016; Maruya et al. 2015; Maruya et al. 2012; SCCWRP 2017).

Due to study design limitations summarized in Section 6.1, these examples of aquatic GSC exceedances may underrepresent the number and breadth of exceedances of GSC. For example, NP concentrations in a sediment sample reported in Maruya et al. (2012) exceeded the European Environmental Quality Standard (0.420 mg/kg NP, dw). However, DTSC could not evaluate the cumulative effects of exposure to the suite of NPEDs as required for comparison to the Canadian Interim Sediment Quality Guideline because other NPEDs were not analyzed in the study. This is also the case for surface water samples, where NPECs, not NP, have been found to be the dominant nonylphenolic compound. Since NP1-2EOs are among the most potent of the nonylphenolic compounds, additional data for these analytes would have increased DTSC's understanding to the effective NP concentration[83]. Nonetheless, there are sufficient data to demonstrate that detections of NPEs and NPEDs in the environment can result in exceedances of GSC and demonstrate the potential for significant or widespread impacts to aquatic organisms.

In addition to the cumulative effects of exposure to the various NPEDs, some fish species may experience wildlife reproductive impairment when these chemicals co-occur with pesticides and OPEs.[84] These additive or synergistic effects for NPEs and pesticides could play a role for some sensitive species in California, such as the Delta smelt, that can co-occur with WWTPs.[85]

These considerations, along with the further supporting efforts by other experts and regulators, [86] support the proposal to list NPEs in laundry detergents as a Priority Product. Additional contributing factors to this proposal include concurrence among CEC experts about the hazards associated with NPEs and alignment of this action with other phase-outs of NPEs in cleaning and consumer products.[87] Chemical alternatives to NPEs appear readily available, as many laundry detergent manufacturers have removed NPEs from their products. DTSC has not evaluated the potential adverse impacts of these chemical alternatives relative to those of NPEs, but manufacturers of laundry detergents may be well-positioned to consider if NPEs are indeed necessary in their products, and if NPE alternatives are safer for human health and the environment.[88]

7. ALTERNATIVES

[83] *Section 2.4.1*
[84] *Section 5.1.4*
[85] *Appendix D*
[86] *Sections 5.1.1-5.1.3*
[87] *Section 5.1*
[88] *Section 7*

Reference: CAL. CODE REGS. tit. 22, § 69503.2(b)(3).

This section summarizes information available to DTSC regarding alternatives that may or may not be safer than the Candidate Chemical. DTSC does not need to ensure that these alternatives are safer and may summarize their associated hazards to illustrate readily available information. The sections below may include information such as how readily available an alternative is, product functions addressed by the alternative, and implications for manufacturers using the alternative (e.g., use limitations, product reformulation, different equipment needs).

Readily available reports have identified possible chemical replacements for NPEs as surfactants in cleaning products (U.S. EPA 2012b) and textile manufacturing (ECHA 2014a). A summary of the scope of these reports and information about their findings are provided in Section 7.1. The hazard information from U.S. EPA (2012b), along with some information about availability of these alternatives in laundry detergents, are summarized in Section 7.2. DTSC has not assessed whether the possible alternatives are safer and has not assessed relevant factors,[89] such as potential adverse impacts to humans and potential exposure of humans or the environment. However, these summaries illustrate that there are alternative surfactants for NPEs for which some environmental hazard trait information is available. These chemicals should be considered as part of any Alternatives Analysis process that may be conducted as a result of any future regulation of this product-chemical combination.

7.1. Summary of Existing Alternatives Assessments

7.1.1. U.S. EPA alternatives assessment for NPEs

The U.S. EPA Design for the Environment (DfE)/Safer Choice program released its "Alternatives Assessment for Nonylphenol Ethoxylates" in 2012 to support the recommendations in the U.S. EPA Action Plan (U.S. EPA 2010b). Each chemical identified in this report was evaluated against U.S. EPA's Criteria for Safer Surfactants for the following hazard characteristics (U.S. EPA 2012b): 1) rate of aerobic biodegradation; 2) hazard profiles of degradation products; 3) the acute and chronic aquatic toxicity of the parent compound; and 4) the aquatic toxicity of the degradation products. The report then applied environmental toxicity and fate elements taken from the DfE's Alternatives Assessment Criteria for Hazard Evaluation to develop screening-level hazard profiles for NPEs and nine possible alternatives, one from each chemical class that DfE has identified in detergents and cleaning products. Chemicals rating "High" or "Very High" for aquatic toxicity were determined acceptable for use in a DfE-labeled product only if they rated "Very Low" for persistence. Chemicals rating "Moderate" or "Low" for aquatic toxicity were deemed acceptable only if they rated "Low" or "Very Low" for persistence. Of the nine alternative chemicals evaluated, eight of them passed the DfE Criteria for Safer

[89] *As defined in Cal. Code Regs. tit. 22, §69505*

Surfactants and were deemed “Safer” than NPE. OPEs did not pass the DfE Criteria for Safer Surfactants due to high aquatic toxicity, high persistence, and the formation of persistent biodegradation products more toxic than the parent compound.

7.1.2. ECHA’s Risk Assessment Committee for restricting NPEs in certain textiles

In 2014 the European Chemicals Agency (ECHA) released its background document (ECHA 2014a) supporting the proposed restriction of NPEs in textile articles that can be washed in water. The report found that NPEs used in the manufacturing process, mainly as a detergent or emulsifier, can be found in textiles and then unintentionally discharged to the environment through laundering of clothing as the finished product.

The report identifies nonionic surfactants as the most probable group of surfactant chemicals to replace NPEs as a detergent in textile manufacturing, with alcohol ethoxylates and glucose-based detergents as the most commercially common nonionic surfactants. Both of these chemical groups have surfactant qualities and physical properties similar to NPE, which is also nonionic. A review of the hazard traits associated with human and ecological risks for each of these chemical classes, but not for the individual chemicals within the class, was provided. Despite the chemicals’ structural similarity, the report found no indication that manufacturers are replacing NPEs with OPEs as surfactants in textile detergents.

7.2. Summary of Identified Chemical Alternatives

The aquatic impact hazard traits for the alternatives as identified by U.S. EPA (2012c) are summarized in Table 6, along with information regarding their current use in laundry detergents. Additional detail is provided in Sections 7.2.1 through 7.2.8. The following information is not an endorsement of any of the identified alternatives.

Table 6. Summary of aquatic hazard traits and uses for NPEs and their chemical alternatives

Chemical class	Chemical name	CASRN	Type of surfactant	Use in laundry detergents[1]	Environmental fate[2]		Aquatic toxicity[2]	
					Persistence	Degradate of concern	Acute	Chronic
Nonylphenol ethoxylates	Nonylphenol ethoxylate (NP9EO)	127087-87-0	Nonionic	Rare	Moderate	Yes	High	Moderate
Octylphenol ethoxylates	Octylphenol ethoxylate (OP10EO)	9036-19-5	Nonionic	Not used	High	Yes	High	Very high
Linear akylbenzene sulfonates	Benzenesulfonic acid, C10-10-alkyl derivatives, sodium salts	68411-30-3	Anionic	Common	Very low	No	High	High
Alkyl polyglucosides	D-glucopyranose, oligomeric, decyloctyl glycosides	68515-73-1	Nonionic	Rare	Very low	No	Moderate	Moderate
Alkyl sulfate esters	Sodium lauryl sulfate	151-21-3	Anionic	Rare	Very low	No	High	High
Alcohol ethoxylates	C9-11 alcohols, ethoxylated (6EO)	68439-46-3	Nonionic	Rare	Very low	No	High	High
Alcohol ethoxylates	C12-15 alcohols, ethoxylated (9EO)	68131-39-5	Nonionic	Common	Very low	No	Very High	High
Sorbitan esters	Sorbitan monostearate	1138-41-6	Nonionic	Not used	Low	No	High	High
Ethoxylated/ propoxylated alcohols	Oxirane, methyl-, polymer with oxirane, mono(2-ethylhexyl ether)	64366-70-7	Nonionic	Not used	Low	No	Moderate	Moderate

Chemical class	Chemical name	CASRN	Type of surfactant	Use in laundry detergents[1]	Environmental fate[2]		Aquatic toxicity[2]	
					Persistence	Degradate of concern	Acute	Chronic
Alkyl ether sulfates	Poly(oxy-1,2-ethanediyl), alpha-sulfo-omega-dodexcyloxy-,sodium salt	9004-82-4	Anionic	Common	Low	No	High	High

[1] Prevalence of use is based on number of laundry detergents containing chemical listed on the U.S. Department of Health and Human Services Household Product Database (U.S. Department of Health and Human Services et al. 2017). “Common” means chemical is listed as an ingredient in over 25 laundry detergents. “Rare” means chemical is listed as an ingredient in one to five laundry detergents. “Not used” means there was no laundry detergent found containing the chemical.

[2] U.S. EPA (2012b)

7.2.1. Octylphenol ethoxylates

As discussed in Section 2.4.1, octylphenol ethoxylates (OPEs) and their degradation products have structural and behavioral similarities to NPEs and NPEDs. DfE determined that OPEs did not meet U.S. EPA's Criteria for Safer Surfactants. Based on experiments on fish and algae, the acute toxicity of OPEs is considered high. Chronic toxicity is also considered high, based on acute toxicity data and expert opinion. OPEs have high environmental persistence, and when they do degrade, they form persistent biodegradation products that are more toxic to aquatic organisms than the parent compound (U.S. EPA 2012b).

7.2.2. Benzenesulfonic acid, C10-10-alkyl derivatives, sodium salts

Benzenesulfonic acid, C10-10-alkyl derivatives, sodium salts (Chemical Abstracts Service Registry Number CASRN 68411-30-3), is part of a class of chemicals called linear alkylbenzene sulfonates (LASs). LASs are anionic surfactants widely used in various applications, including laundry detergents (IHS Markit 2015). DfE determined that benzenesulfonic acid, C10-10-alkyl derivatives, sodium salts did meet the Criteria for Safer Surfactants. LASs have very low environmental persistence and do not generate any persistent degradates. The acute and chronic aquatic toxicity are both high based on experimental data in fish, daphnia, and algae (U.S. EPA 2012b).

7.2.3. D-glucopyranose, oligomeric, decyloctyl glycosides

D-glucopyranose, oligomeric, decyloctyl glycosides (CASRN 68515-73-1), also known as alkyl polyglucosides (APGs), are a class of nonionic surfactants used in household, industrial, and institutional detergent formulations where high amounts of stable foam is required, or where highly alkaline concentrations are necessary (Dow 2011). DfE determined that the D-glucopyranose, oligomeric, decyloctyl glycosides did meet the surfactant criteria (U.S. EPA 2012b). Experimental data indicate that the environmental persistence of this material is very low. There are no persistent degradates formed. The acute toxicity for D-glucopyroanose is moderate based on experiments in fish and algae. Chronic toxicity is also moderate based on experimental data in algae. An analog of the chemical was evaluated for chronic toxicity to fish, daphnia, and algae and also found to be moderate (U.S. EPA 2012).

7.2.4. Sodium lauryl sulfate

Sodium lauryl sulfate (CASRN 151-21-3) is an anionic surfactant derived from coconut and/or palm kernel oil (NIH 2018). This chemical passed the DfE Criteria for Safer Surfactants (US EPA 2012) based on a classification of "High" for acute toxicity and "Very Low" for persistence, with no persistent degradates formed. Acute aquatic toxicity is high based on experimental data in fish,

daphnia, and algae. Chronic aquatic toxicity is high based on experimental data on fish, invertebrates, and green algae.

7.2.5. Alcohol ethoxylates

Alcohol ethoxylates (AEs) are a class of nonionic surfactants composed of a hydrophobic fatty alcohol chain combined with a varying number of ethoxylate units via an ether linkage. AEs are some of the most commonly used nonionic surfactants worldwide and are already in wide use in the United States (381,000 metric tons in 2008, Blagoev and Gubler, 2009, as cited in (Sanderson et al. 2013). There are hundreds of possible AEs with different physical and chemical properties depending on the lengths of the alcohol and ethoxylate chains. The 2014 ECHA report concluded that AEs were the most investigated and suitable alternative to NPEs in textile manufacturing processes, with no expected concerns to human health or the aquatic environment. U.S. EPA DfE evaluated two groups of AEs: those with alcohols in the C9-C11 range and an average of 6 ethoxylate units and those in the C12-15 range with an average of 9 ethoxylates.

C9-11 alcohols, ethoxylated (6EO) (CASRN 68439-46-3): This group of AEs passed the DfE Criteria for Safer Surfactants (U.S. EPA 2012c) based on a classification of "High" for acute toxicity and "Very Low" for persistence, with no persistent degradates formed. The acute aquatic toxicity is high based on studies in fish, invertebrates, and algae. Chronic toxicity is also high based on measurements in juvenile fish and in algae. DfE determined that the C9-C11 ethoxylated alcohols did meet the surfactant criteria (U.S. EPA 2012b).

C12-15 alcohols, ethoxylated (9EO) (CASRN 68131-39-5): This group of AEs passed the DfE Criteria for Safer Surfactants (US EPA 2012c) based on a classification of "Very High" for acute toxicity and "Very Low" for persistence, with no persistent degradates formed. The acute aquatic toxicity rating is based on studies in fish, daphnia, and green algae, with the chronic toxicity based on measurements in fish and daphnia (U.S. EPA 2012b).

7.2.6. Sorbitan monostearate

Sorbitan monostearate (CASRN 1138-41-6) is a nonionic surfactant most commonly used in food and healthcare products as an emulsifier to keep water and oils mixed (NIH 2018). This chemical passed the DfE Criteria for Safer Surfactants with a classification of "High" for acute toxicity and "Low" for persistence, with no persistent degradates formed. The acute aquatic toxicity rating is based on experimental data in fish, daphnia, and green algae, with the chronic toxicity based on a reproduction study in daphnia (U.S. EPA 2012b).

7.2.7. Oxirane, methyl-, polymer with oxirane, mono(2-ethylhexyl ether)

Oxirane, methyl-, polymer with oxirane, mono(2-ethylhexyl ether) (CASRN 64366-70-7) is part of a class of chemicals similar to AEs with the exception that one or more propoxylate groups is used in

place of a corresponding number of ethoxylated groups. This chemical passed the DfE Criteria for Safer Surfactants with moderate aquatic toxicity and low environmental persistence, with no persistent degradates formed. The acute aquatic toxicity rating is based on experimental data in daphnia and algae, with the chronic toxicity based on acute data and expert opinion (U.S. EPA 2012b).

7.2.8. Poly(oxy-1,2-ethanediyl), alpha-sulfo-omega-dodexcyloxy-, sodium salt

Poly(oxy-1,2-ethanediyl), alpha-sulfo-omega-dodexcyloxy-, sodium (CASRN 9004-82-4) is part of a class of chemicals made in a similar process to sodium lauryl sulfate but with an added ethoxylation step. This chemical passed the DfE Criteria for Safer Surfactants based on a classification of "High" for acute toxicity and "Low" for persistence, with no formation of biodegradation products of concern. The acute and chronic aquatic toxicity rating is based on experimental data in fish, daphnia, and algae (U.S. EPA 2012b).

8. OTHER REGULATORY PROGRAMS

Reference: CAL. CODE REGS. tit. 22, § 69503.2(b)(2).

DTSC has identified the following state and federal regulatory programs related to the product and/or the Candidate Chemical in the product to protect public health and the environment. DTSC has assessed these programs to ensure that they do not overlap or conflict with this proposal to list laundry detergents containing NPEs as a Priority Product, nor with any subsequent regulation that may result for such listing.

8.1. California Air Resources Board's Consumer Products Regulation

The California Air Resources Board adopted regulations to restrict the use of volatile organic compounds (VOCs) in a variety of consumer products (Cal. Code Regs. tit. 17, §§ 94507-94517). As a part of these regulations, alkylphenol ethoxylates, which include NPEs, were also restricted from sale in California in a variety of cleaning products, including certain general-purpose cleaners, general-purpose degreasers, glass cleaners, oven or grill cleaners, and heavy-duty hand soap. Any potential regulation from the Safer Consumer Products Program would not duplicate the Air Resources Board's regulation because commercial laundry detergents are not included in its list of restricted consumer products.

8.2. U.S. EPA-Proposed Significant New Use Rule

U.S. EPA proposed a Significant New Use Rule (SNUR) for 13 CASRNs for specific NPs and NPEs in 2014 (U.S. EPA 2014a). If the proposed SNUR were to be adopted, manufacturers and importers would have to report any new uses of the chemicals. The NPEs identified in the proposed rule are limited and only represent a few of the NPEs that are included in the scope of this proposal. The proposal provided a list of existing uses in products, such as laundry detergents, cleaners, and de-icers. Public comments were submitted, which provided additional current uses that may inform the scope of the SNUR. Since the public comment period closed in 2015, U.S. EPA has not released any updated information on the status of the proposed SNUR.

8.3. California State Water Board Waste Discharge Requirements

Discharges with the potential to affect California's surface, coastal, or ground waters are regulated by permits called Wastewater Discharge Requirements (WDRs) issued by the State Water Resources Control Board and nine regional water quality control boards (State Water Board 2018b). California's WDR program incorporates requirements of the National Pollutant Discharge Elimination System (NPDES), a federal permit program (State Water Board 2018b), as well as state-specific requirements for discharges not subject to the Federal Water Pollution Control Act (e.g. discharges to land, use of recycled water)(State Water Board 2016). When granting a permit for facilities like WWTPs, the State Water Board and regional water quality control boards consult the lists of priority toxic pollutants established for California (Code of Federal Regulations. tit. 40, § 131.38) and established pollutant total maximum daily loads (State Water Board 2017b). However, NPEs and NPEDs are not included in either of these lists. The State Water Board and regional water quality control boards also establish Water Quality Control Plans and Policies to address chemicals of concern, but none of these plans or policies include NPEs or NPEDs (State Water Board 2018c).

ACRONYMS AND ABBREVIATIONS

Acronyms

AB	Assembly Bill
AA-EQS	annual average concentration – Environmental Quality Standards
AE	alcohol ethoxylate
AWQC	ambient water quality criteria
BAF	bioaccumulation
BCF	bioconcentration factor
Cal. Code Regs. tit.	California Code of Regulations title
CalRecycle	California Department of Resources Recycling and Recovery
CalSAFER	California Safer Products Information Management System
CDFW	California Department of Fish and Wildlife
CASRN	Chemical Abstracts Service Registry Number
CEC	chemical of emerging concern
CEC Ecosystems Panel	State Water Board's Science Advisory Panel for CECs in California's Aquatic Ecosystems
CEDEN	California Environmental Data Exchange Network
DfE	Design for the Environment
DTSC	Department of Toxic Substances Control
ECHA	European Chemicals Agency
EQG	Environmental Quality Guideline
EQS	Environmental Quality Standard
EU	European Union
IUPAC	International Union of Pure and Applied Chemistry

K_{oc}	organic carbon-water partition coefficient
K_{ow}	octanol-water partition coefficient
MAC-EQS	maximum acceptable concentration – Environmental Quality Standards
MGD	million gallons per day
NOAA	National Oceanographic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NP	nonylphenol
NPE	nonylphenol ethoxylate
NPEC	nonylphenol ethoxycarboxylate
NPED	nonylphenol ethoxylates degradation product
NPnEO	nonylphenol ethoxylate, where n represents the number of ethoxylate units
OEHHA	Office of Environmental Health Hazard Assessment
OP	octylphenol
OPE	octylphenol ethoxylate
OPnEO	octylphenol ethoxylates, where n represents the number of ethoxylate units
OPL	on-premises laundry
OSPAR	Oslo-Paris Convention for the Protection of the Marine Environment for the North-East Atlantic
PNEC	predicted no-effect concentration
POD	Pelagic Organism Decline
REACH	Registration Evaluation Authorization and Restriction of Chemicals
RMP	Regional Monitoring Program for Water Quality in San Francisco Bay

SCP	Safer Consumer Products
SDCWA	San Diego County Water Authority
SFEI	San Francisco Estuary Institute
SNUR	Significant New Use Rule
SSD	species sensitivity distribution
SSWD	species sensitivity-weighted distribution
State Water Board	State Water Resources Control Board
SVHC	Substances of Very High Concern
TRSA	Textile Retail Services Association
TEF	Toxic Equivalency Factor
TEQ	toxic equivalency
TOC	total organic carbon
TRI	Toxic Releases Inventory
U.S. EPA	United States Environmental Protection Agency
WWTP	wastewater treatment plant

Units of Measure

L/kg	liter per kilogram
µg/vehicle x km	microgram per vehicle times kilometer
µg/L	microgram per liter
mg/kg	milligram per kilogram
mg/L	milligram per liter
lbs.	pounds

Symbols

§	Section
∑	(sigma) summation

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APPENDIX A. REPORT PREPARATION

Prepared and Contributed by:

Daphne Molin, M.S., Safer Consumer Products, Senior Environmental Scientist (Specialist)

Anne Cooper Doherty, Ph.D., Safer Consumer Products, Senior Environmental Scientist (Specialist)

Lynn Nakayama Wong, Ph.D., Human and Ecological Risk Office, Staff Toxicologist (Specialist)

Edward A. Fendick, Ph.D., Human and Ecological Risk Office, Staff Toxicologist (Specialist)

Michael Ernst, P.E., Safer Consumer Products, Hazardous Substances Engineer

Valerie Hanley, Ph.D., Human and Ecological Risk Office, Staff Toxicologist (Specialist)

Patrick Kerzick, Ph.D., D.A.B.T., Human and Ecological Risk Office, Staff Toxicologist (Specialist)

Andrew King, MPP, Safer Consumer Products, Research Program Specialist II

Reviewed by:

Andre Algazi, Manager for Chemical-Product Evaluation Team

Karl Palmer, Branch Chief for Safer Consumer Products Program

Meredith Williams, Ph.D., Deputy Director for Safer Products and Workplaces Program

APPENDIX B. NON-EXHAUSTIVE LIST OF IDENTIFIERS FOR NPES

Examples of NPEs were obtained from OSPAR Commission (2009) and/or ECHA (2014b), which are the authoritative lists included in the SCP regulations that allow NPEs to be identified as Candidate Chemicals. Corresponding Chemical Abstract Services (CAS) Registry Numbers or European Community (EC) numbers, and their corresponding names, including International Union of Pure and Applied Chemistry (IUPAC) names were provided in these lists or in ECHA (2018).

CASRN	EC number	Chemical name
9016-45-9	500-024-6	**IUPAC Name**: 2-(2-nonylphenoxy)ethanol
25154-52-3	246-672-0	**IUPAC Name**: 2-nonylphenol
104-35-8		**IUPAC Name**: 2-(4-nonylphenoxy)ethanol
7311-27-5	230-770-5	**EC name:** 2-[2-[2-[2-(4-nonylphenoxy)ethoxy]ethoxy]ethoxy]ethanol **CAS name:** Ethanol, 2-[2-[2-[2-(4-nonylphenoxy)ethoxy]ethoxy]ethoxy]- **IUPAC name**: 2-(2-(2-(2-(4-Nonylphenoxy)ethoxy)ethoxy)ethoxy)ethanol
14409-72-4	604-395-6	**CAS name:** 3,6,9,12,15,18,21,24-Octaoxahexacosan-1-ol, 26-(4-nonylphenoxy)- **IUPAC name:** 26-(4-Nonylphenoxy)-3,6,9,12,15,18,21,24-octaoxahexacosan -1-ol
20427-84-3	243-816-4	**EC name:** 2-[2-(4-nonylphenoxy)ethoxy]ethanol **CAS name:** Ethanol, 2-[2-(4-nonylphenoxy)ethoxy]- **IUPAC name:** 2-(2-(4-onylphenoxy)ethoxy)ethanol
26027-38-3	500-045-0	**CAS name:** Poly(oxy-1,2-ethanediyl), α-(4-nonylphenyl)-ω-hydroxy- **IUPAC name:** Poly(oxy-1,2-ethanediyl), α-(4-nonylphenyl)-ω-hydroxy-
27942-27-4	248-743-1	**EC name**: 20-(4-nonylphenoxy)-3,6,9,12,15,18-hexaoxaicosan-1-ol **CAS name:** 3,6,9,12,15,18-Hexaoxaeicosan-1-ol, 20-(4-nonylphenoxy)- **IUPAC name:** 20-(4-Nonylphenoxy)-3,6,9,12,15,18-hexaoxaicosan-1-ol
34166-38-6		**CAS name:** 3,6,9,12,15-Pentaoxaheptadecan-1-ol, 17-(4-nonylphenoxy)- **IUPAC name:** 17-(4-Nonylphenoxy)-3,6,9,12,15-pentaoxaheptadecan-1-ol
37205-87-1		**IUPAC name:** 1-ethoxy-4-(7-methyloctyl)benzene
127087-87-0	500-315-8	**IUPAC name:** 2-[2-[2-[2-[2-[2-(4-nonylphenoxy)ethoxy]ethoxy]ethoxy]ethoxy]ethoxy]ethanol
156609-10-8		**CAS name:** 4-t-Nonylphenol-diethoxylate

APPENDIX C. SUMMARY OF HAZARD TRAITS ASSOCIATED WITH NP

Taxa	Endpoint	Study conditions	Reference
Immunotoxicity §69403.8			
Invertebrate - Pacific oyster (*Crassostrea gigas*) (saltwater)	Repressed total hemocyte counts and increased lysozyme activity	Oysters exposed to 2 and 100 µg 4-NP/L for 7 days. Challenge conditions: Injected with $1x10^6$ CFU/mL bacteria (*Vibrio campbellii*)	Hart et al. (2016)
Wildlife Development Impairment §69404.6			
Vertebrate - fish - rainbow trout (*Oncorhynchus mykiss*) (freshwater)	Decreased hatch rate	Intermittent exposure (10 days/month from July to October prior to spawning) to 10 µg technical NP/L (98% NP isomers)	Schwaiger et al. (2002)
Invertebrate - mysid (*Americamysis bahia*)	Decreased number of molts	Mysids (<24 hours) exposed to 10 µg 4-NP/L for 14 days	Hirano et al. (2009)
Invertebrate - midge (*Chironomus tentans*) (freshwater)	Decreased growth	Larvae exposed to 34.2 mg NP/kg dry weight in spiked sediment for 14 days	England and Bussard (1993), as cited in Environment Canada (2002)
Echinoderm - Sea urchin (*Arbacia lixula*) (saltwater)	Increased larval malformations	Sperm and eggs exposed to 0.94 µg NP/L under static conditions for 3 days	Arslan and Parlak (2007)
Echinoderm - Sea urchin (*Paracentrotus lividus*) (saltwater)	Increased larval malformations	Sperm and eggs exposed to 0.94 µg NP/L under static conditions for 3 days	Arslan et al. (2007)
Echinoderm - Sea urchin (*Paracentrotus lividus*) (saltwater)	Arrest of differentiation at the gastrula stage P2	Sperm and eggs exposed to 18.7 µg NP/L under static conditions for 3 days	Arslan et al. (2007)
Wildlife Growth Impairment §69404.7			
Vertebrate - fish - rainbow trout (*Oncorhynchus*	Reduced body length and body weight	Fertilized eggs and embryos exposed to 10.3 µg 4-NP/L under	Brooke (1993), as cited in ECHA

Taxa	Endpoint	Study conditions	Reference
mykiss) (freshwater)		flow-through conditions for 91 days	(2014a) and U.S. EPA (2005)
Vertebrate - fish - Japanese medaka (*Oryzias latipes*) (freshwater)	Reduced body weight	Fertilized eggs and embryos exposed to 23.5 µg 4-NP/L under flow-through conditions for 60 days	Seki et al. (2003)
Invertebrate - mysid (*Mysidopsis bahia*) (saltwater)	Reduced body length	<24-hour mysids exposed to 6.7 µg 4-NP/L under flow-through conditions for 28 days	Ward and Boeri (1991b), as cited in Environment Canada (2002) and U.S. EPA (2005)
Invertebrate - mysid (*Americamysis bahia*)	Reduced average body length	Mysids (<24 hours) exposed to 1 µg 4-NP/L for 14 days	Hirano et al. (2009)
Invertebrate - calanoid copepod (*Eurytemora affinis*) (estuarine)	Inhibited growth	Larvae (nauplii) exposed to 8,453 ng NP/g dry weight sediment for 6 days	Lesueur et al. (2013)
Wildlife Reproductive Impairment §69404.8			
Vertebrate - Fish			
Japanese medaka (*Oryzias latipes*) (freshwater)	Occurrence of testis-ova in males 60 days post hatch (F1 generation)	Fertilized eggs and embryos exposed to 17.7 µg 4-NP/L under flow-through conditions for 104 days	Yokota et al. (2001)
Japanese medaka (*Oryzias latipes*) (freshwater)	Occurrence of testis-ova in males and induction of hepatic vitellogenin protein	Fertilized eggs and embryos exposed to 11.6 µg 4-NP/L under flow-through conditions for 60 days	Seki et al. (2003)
Japanese medaka (*Oryzias latipes*) (freshwater)	Occurrence of mixed secondary sex characteristics	Fertilized eggs and embryos exposed to 8.7 µg 4-NP/L under semi-static conditions (renewal every 48 hours) for 100 days	Balch and Metcalfe (2006)
Japanese medaka (*Oryzias latipes*) (freshwater)	Vitellogenin induction in adult males	Sexually mature medaka pair wise exposed to 5.4 µg 4-NP/L under semi-static conditions (renewal every 24 hours) for 21 days	Ishibashi et al. (2006), as cited in ECHA (2012) and OEHHA (2009)

Taxa	Endpoint	Study conditions	Reference
rainbow trout (*Oncorhynchus mykiss*) (freshwater)	Increased zona radiate protein (biomarker for eggshell formation)	Fertilized eggs (embryonic larval juvenile) exposed to 10 µg 4-NP/L under flow-through conditions for 1 year	Ackermann et al. (2002)
rainbow trout (*Oncorhynchus mykiss*) (freshwater)	Elevated hepatic vitellogenin in males	Fertilized eggs (embryonic larval juvenile) exposed to 1.05 µg 4-NP/L under flow-through conditions for 1 year	Ackermann et al. (2002)
rainbow trout (*Oncorhynchus mykiss*) (freshwater)	Increased plasma vitellogenin	Two-year-old males exposed to 20.3 µg NP/L under flow-through conditions for 3 weeks	Jobling et al. (1996)
rainbow trout (*Oncorhynchus mykiss*) (freshwater)	Increased plasma vitellogenin	Adult 2-year-old females exposed to 8.3 µg 4-NP/ L under flow-through conditions for 18 weeks during early ovarian development (March - July)	Harris et al. (2001), as cited in ECHA (2012)
Chinese rare minnows – (G*obiocypris rarus*) (freshwater)	Occurrence of testis-ova	Adults (9 months) exposed to 18 µg 4-NP/L (technical grade) under flow-through conditions for 21 days	Zha et al. (2008)
Chinese rare minnows - (G*obiocypris rarus*) (freshwater)	Increased plasma vitellogenin in males	Adults (9 months) exposed to 5 µg 4-NP/L (technical grade) under flow-through conditions for 21 days	Zha et al. (2008)
Invertebrates			
Crustacean-Barnacle (*Balanus amphitrite)* (saltwater)	Decreased larval settlement	Cyprid-stage larvae (i.e., just prior to the sessile adult) exposed to nominal concentrations of 0.1, 1.0, and 10 µg NP/L under static conditions for 24 up to 48 hours	Billinghurst et al. (1998)
Wildlife Survival Impairment §69404.9			
Vertebrate - fathead minnow (*Pimephales promelas*) (freshwater)	Increased mortality	Embryos (<24 hours) exposed to 14 µg 4-NP branched/L under flow-through conditions for 33 days	Ward and Boeri (1991a), as cited in ECHA (2014a) and U.S. EPA (2005)

Taxa	Endpoint	Study conditions	Reference
Invertebrate - saltwater mysid (*Mysidopsis bahi*a)	Decreased survival	Mysids (<24 hours) exposed to 9.1 µg NP /L under flow-through conditions for 28 days	Ward and Boeri (1991b), as cited in Environment Canada (2002) and U.S. EPA (2005)
Vertebrate - fish - Japanese medaka (*Oryzias latipes*) (freshwater)	Decreased post-swim up mortality (60 days post hatch)	Fertilized eggs and embryos exposed to 17.7 µg NP/L under flow-through conditions for 104 days	Yokota et al. (2001)

APPENDIX D. CO-OCCURRENCE OF SELECT ENDANGERED OR THREATENED AQUATIC SPECIES AND EFFLUENT-DOMINATED ENVIRONMENTS IN CALIFORNIA

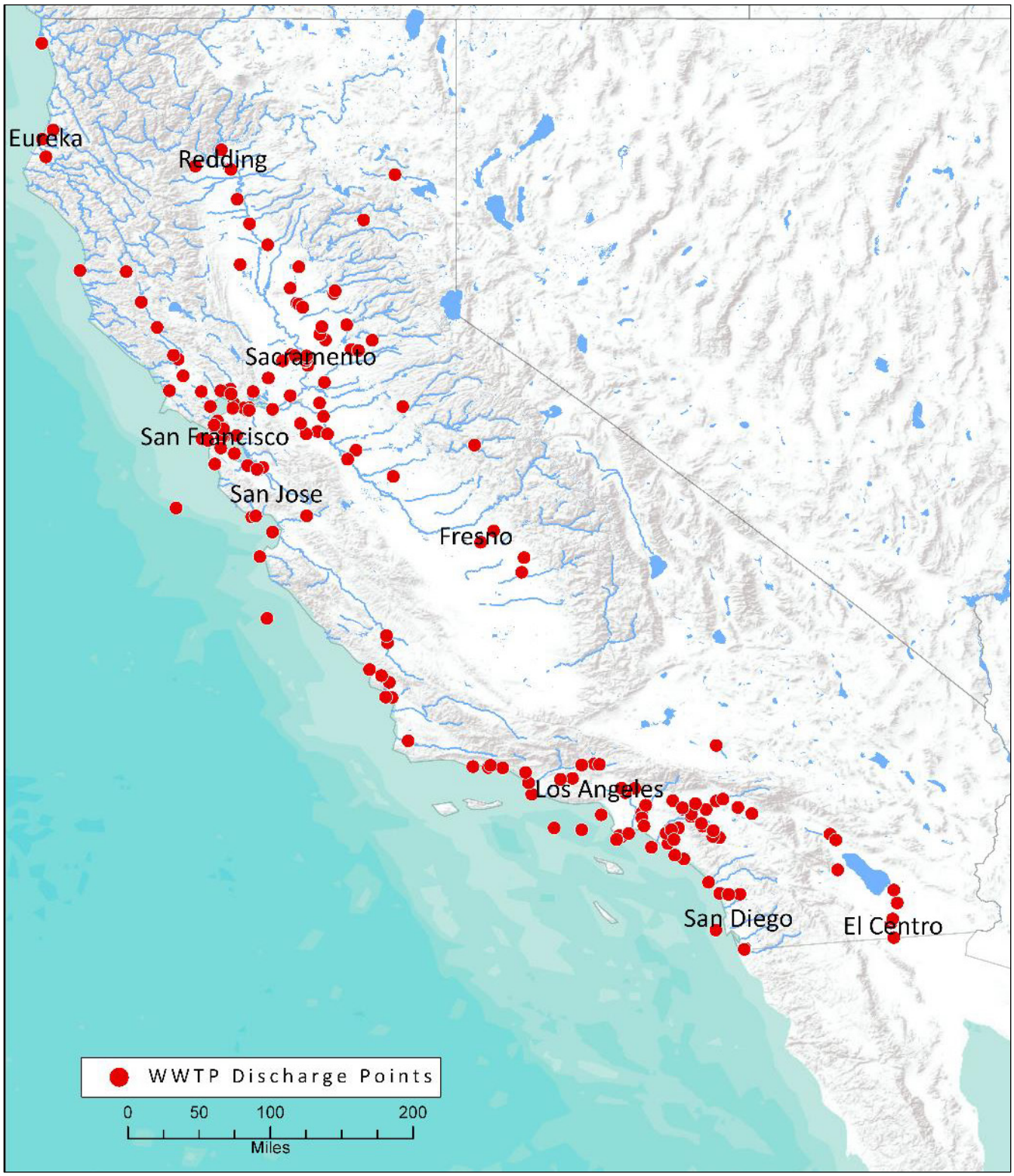
In many locations throughout California, flows of historically ephemeral streams are now dominated by wastewater treatment plant effluent. These streams, and the waterbodies they flow to, represent likely scenarios for potential adverse impacts on the aquatic environment. For this document, DTSC considers environments to be "effluent-dominated" when permitted flow from WWTP discharge points is more than 50 percent of the estimated stream flow.

In order to determine the discharge points and flows for WWTPs in California, DTSC created a geospatial dataset based on information from the U.S. EPA and the California Integrated Water Quality System (State Water Board 2018a; U.S. EPA 2012c). The discharge points depicted represent the general location of municipal wastewater discharges to oceans, lakes, rivers, and streams from WWTPs permitted to discharge more than one million gallons per day (MGD). Permitted, rather than actual, flows were used as they are not subject to year-to-year variability and represent the maximum amount the WWTP is allowed to discharge.

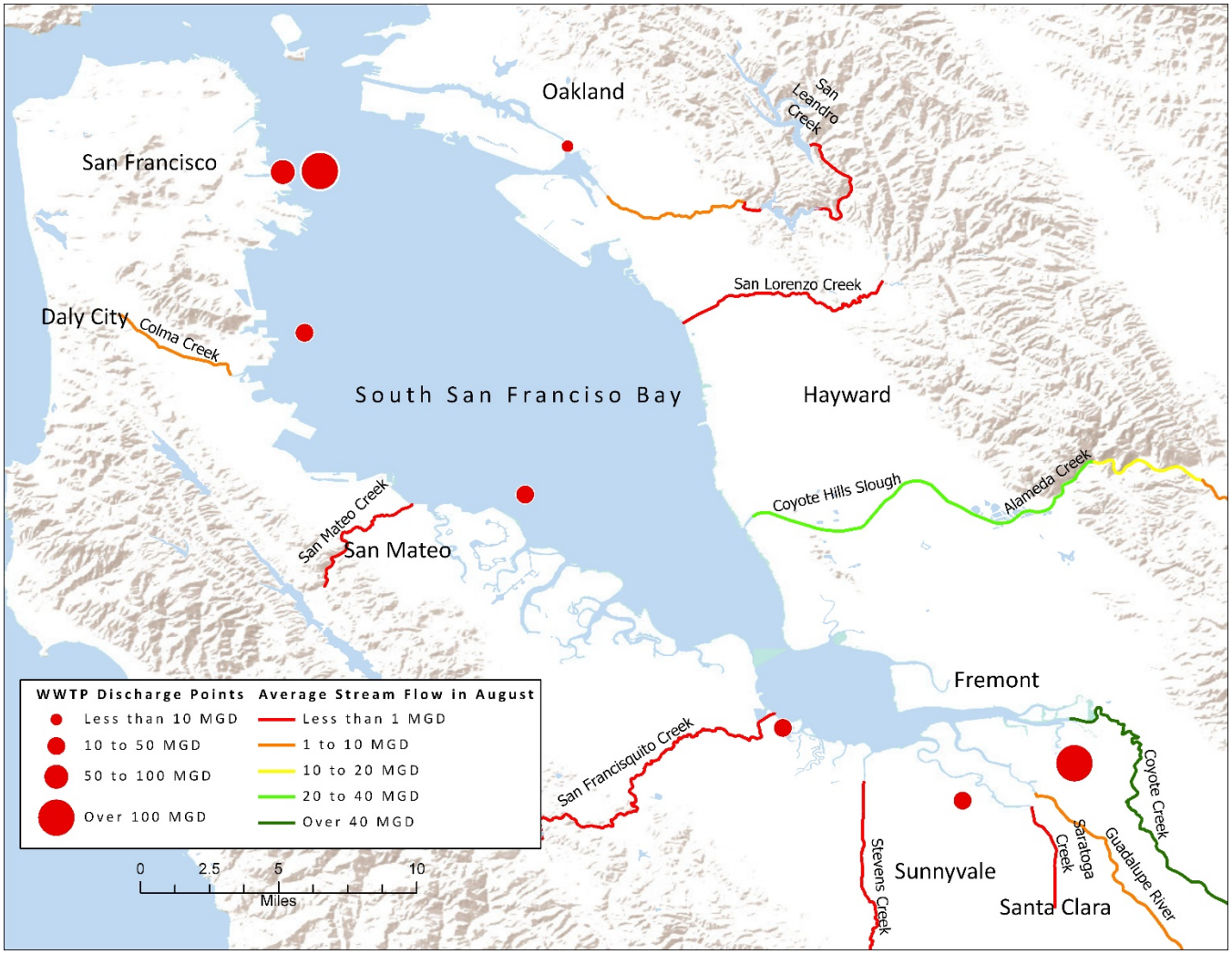
Stream flow estimates were obtained for the National Hydrograph Dataset Plus (NHDPlus) Version 2.1 National Seamless Geodatabase (U.S. EPA and USGS 2012). This dataset uses historical runoff, temperature, precipitation, and stream gauge measurements to compute estimates for the mean annual and twelve mean monthly flows for every stream in the continental United States. Flows selected for the analysis represent estimate of mean flow during the month of August.

The figures in this appendix also depict distributions or critical habitats of select threatened or endangered aquatic species potentially impacted in each environment. Distributions of fish species are from the PISCES Fish Data and Management Software developed by the University of California, Davis, Center for Watershed Science (Santos et al. 2014). Critical habitats from fish species and distributions for invertebrate species are from the National Oceanographic and Atmospheric Administration (NOAA Fisheries 2018a; NOAA Fisheries 2018c).

D-1. Wastewater Treatment Plant Discharge Points to California's Aquatic Environment

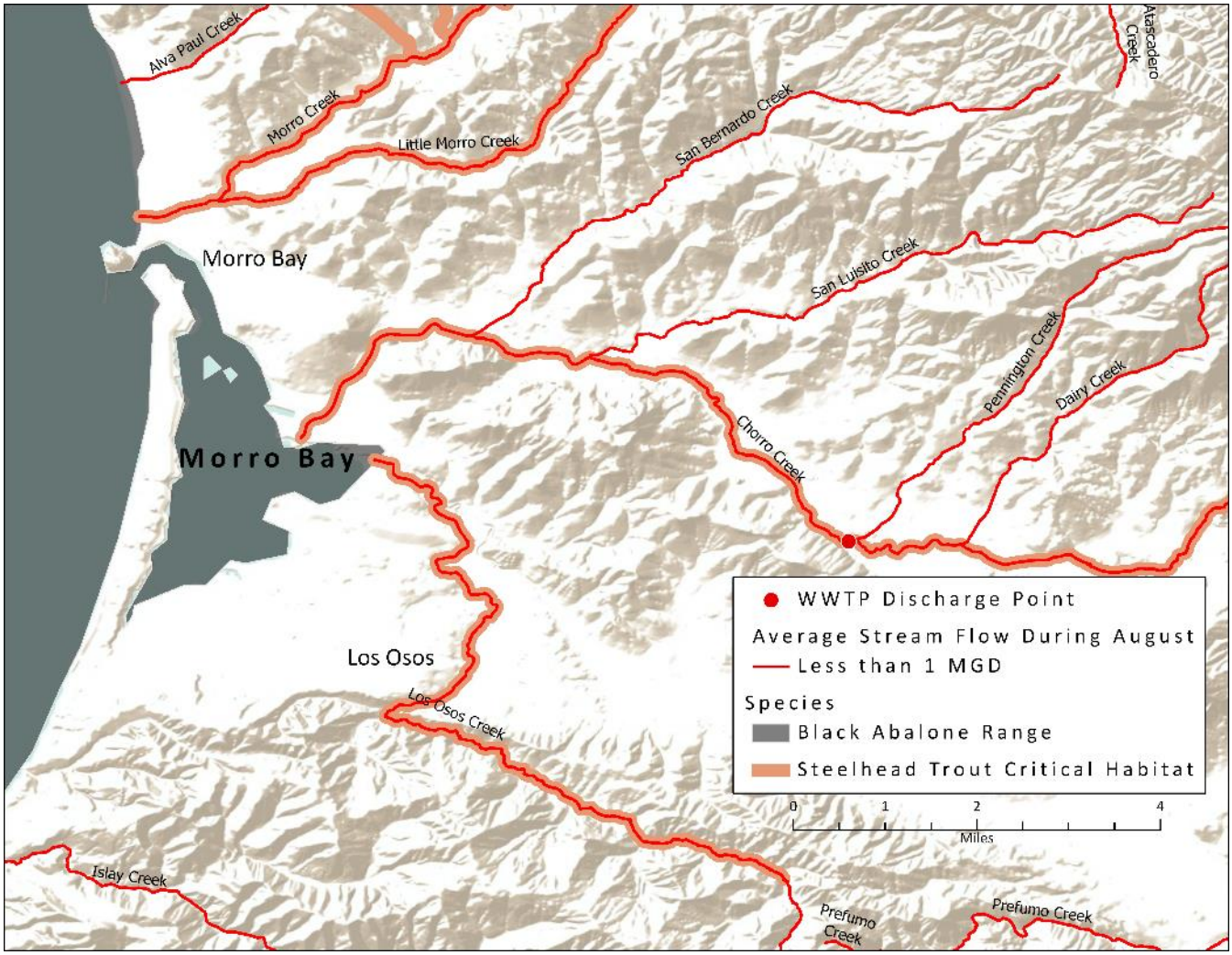


D-2. Effluent-Dominated Environment in South San Francisco Bay



San Francisco Bay is the largest bay on the California coast. The Bay supports over 130 species of fish, including several threatened and endangered species (BCDC 2015; U.S. FWS 2013), and has been designated by NOAA and the Pacific Fishery Management Council as Habitat of Particular Concern for groundfish (e.g. rockfish) and salmon species (e.g. chinook, coho;(NOAA Fisheries 2018c)). The Bay is composed of two distinct parts. The northern reach, between to the Sacramento-San Joaquin River system and the Golden Gate Bridge, has significant year-round freshwater input and is partially to well-mixed. In contrast, the South Bay, between Coyote Creek and the Golden Gate Bridge, has poor circulation for most of the year (Walters et al. 1985). Stream flows into the South Bay can drop to under 100 MGD in summer months (U.S. EPA and USGS 2012). The South Bay receives flow from nine WWTP discharge points, with permitted dry-weather flows totally over 480 MGD (State Water Board 2018a; U.S. EPA and USGS 2012) and residence times of several months for pollutants entering the Bay during summer periods (Walters et al. 1985).

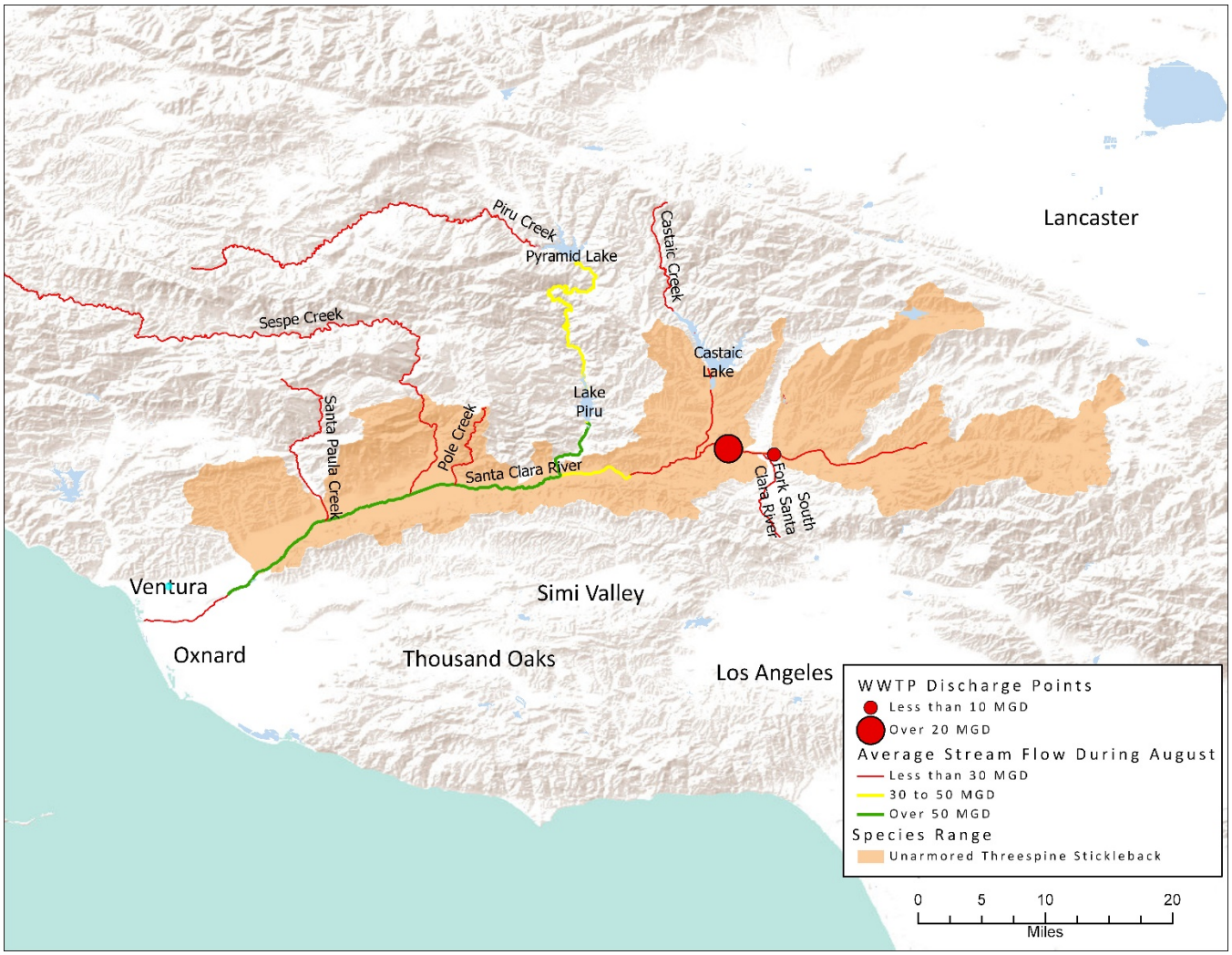
D-3. Co-Occurrence of Effluent-Dominated Environment and Select Aquatic Species in California's Central Coast (Morro Bay species)



The Morro Bay watershed is located on the Central Coast of California in San Luis Obispo County. This watershed is an important biological and economic resource, providing commercial shellfish growing areas and habitat for numerous threatened and endangered species such as steelhead trout and black abalone (NOAA Fisheries 2018a; NOAA Fisheries 2018c). Two creeks, Los Osos and Chorro, drain the watershed into the bay. Most wastewater is discharged offshore, and one wastewater treatment plant, with a dry-weather design flow rate of 1.2 MGD, discharges into Chorro Creek (State Water Board 2018a; U.S. EPA 2012c). During summer months, effluent can represent 100 percent of Chorro Creek flow and the majority of total flow into Morro Bay (U.S. EPA and USGS 2012). Diehl et al. (2012) provided a multifaceted evaluation of NP in this area and found sediment and surface water NP concentrations that can exceed aquatic GSC, detections of NP in various trophic levels of aquatic

organisms, and relatively high concentrations of NP in septic tank liquids and solids. Suspected septic systems failures in this region may have resulted in groundwater seepage (RWQCB Central Coast 2002).

D-4. Co-Occurrence of Effluent-Dominated Environment and Select Aquatic Species in Southern California (Santa Clara River)



The Santa Clara River is the largest natural river (116 miles) in Southern California and supports many endangered and threatened species, including the unarmored threespine stickleback (Santos et al. 2014). Unarmored threespine stickleback have a very limited distribution, with populations found only in three Southern California drainages (CDFW 2015). Extreme drought conditions exacerbated the status of the dwindling populations in the Santa Clara River, and translocating fish from this river became a top priority for the California Department of Fish and Wildlife in an effort to recover the species (CDFW 2015). Two WWTPs, with a total dry-weather design flow of approximately 30 MGD, discharge to the upper watershed (State Water Board 2018a; U.S. EPA 2012c). River flows in this part of the watershed vary considerably throughout the year, but are typically less than 30 MGD for over half of the year (U.S. EPA and USGS 2012).

APPENDIX E. ENVIRONMENTAL MONITORING DATA FOR NPES AND NPEDS

The tables in this appendix include study summaries for reports and publications that meet the study parameters provided in Section 3.3.1. Reported concentrations that exceeded study detection limits and percent detection for these concentrations is reported when provided in the study. DTSC calculated percent detection when sufficient sample detail was available.

The following legend applies to the tables in this appendix:

Blank cells indicate no information was provided in the original study.

n Number of samples collected in study, when available.

ND Analyte was not detected. This abbreviation is only used when the study detected other nonylphenolic compounds.

% Percent detection.

A Average concentration. Standard error is provided in parentheses when provided in the original study.

M Maximum concentration.

E Estimated concentration from a figure. When used with a range, all values within the range are estimated.

BRL Below reporting or quantification limit, and above detection limit. Reporting limit value is included in parentheses when provided in the original study.

* NP concentration exceeds the respective aquatic GSC by the EU, as described in Table 3.

** NP concentration exceeds the respective aquatic GSC by Canada and the EU, as described in Table 3.

*** NP concentration exceeds the respective aquatic GSC by Minnesota, Canada, and the EU, as described in Table 3.

**** NP concentration exceeds the respective aquatic GSC by U.S. EPA, Minnesota, Canada, and the EU, as described in Table 3.

E-1. Detections in Environmental Monitoring Studies

Reference	Sample location	Sample year(s)	Analyte(s)	Media analyzed				
				WW	WS	W	S	B
Barber et al. (2015)	Midwest U.S.	1999 - 2009	4-NP, 4-NP1-4EO, 4-NP1-4EC	X		X		
Bradley et al. (2017)	Various streams in U.S	2012 - 14	4-NP, 4-NP1-2EO			X		
Diehl et al. (2012)	Morro Bay, CA, and other West Coast estuaries	2008 - 10	4-NP	X	X	X	X	X
Elliott et al. (2017)	US Tributaries to Great Lakes	2013-2014	4-NP, 4-NP1-2EO			X	X	
Gray et al. (2017)	Colorado	2008	4-NP		X			
Kinney et al. (2006)	U.S. (various)		4-NP, NP1-2EO		X			
Klečka et al. (2010)	Ohio and Indiana	2003	NP, NP 1-15EO	X		n/a		
Klosterhaus et al. (2013a)	San Francisco Bay, CA	2009 - 10	4-NP, 4-NP1-2EO			X	X	X
La Guardia et al. (2001)	U.S. (various)	1999 - 2000	NP, NP1-2EO		X			
LACSD (2012)	Los Angeles County, CA	2007 - 12	4-NP, NP1-2EO	X		X		
LACSD (2014a)	Los Angeles County, CA	2013	4-NP, NP1-2EO	X				
LACSD (2015)	Los Angeles County, CA	2014	4-NP, NP1-2EO	X				
Lara-Martin et al. (2014) and Lara-Martin (2017)	New York	2009	NP, NP1-15, NP1-2EC	X		X	X	
Lavado et al. (2009)	Central Valley, CA	2006 - 07	NP, NP1-2EO			X		
Lawrence Livermore National Laboratory and State Water Board (2006)	Livermore, CA	2005	4-NP, AP1-2EC	X				

Reference	Sample location	Sample year(s)	Analyte(s)	Media analyzed				
				WW	WS	W	S	B
RWQCB Los Angeles (2017)	Southern CA (various)	2012 - 16	NP	X				
Loyo-Rosales et al. (2007a), Loyo-Rosales (2006), Loyo-Rosales (2018)	Mid-Atlantic and Midwest	2004 - 05	NP, NP1-16EO, NP1-2EC	X	X			
Loyo-Rosales et al. (2007a)	Mid-Atlantic	2004	NP, NP1-16EO, NP1-2EC	X		n/a		
Loyo-Rosales et al. (2010)	Maryland	2001 - 05	NP, NP1-16EO, NP1-2EC	X		n/a		
Lozano et al. (2012)	Chicago, IL	2006 - 07	NP, NP1-18EO	X		X		X
Lubliner et al. (2010)	Puget Sound, WA	2008	4-NP	X				
Meador et al. (2016)	Puget Sound, WA	2014	4-NP, NP1-2EO	X		X		X
Maruya et al. (2012)	Southern California Bight	2006	4-NP				X	X
Maruya et al. (2014) and Dodder et al. (2014)	Coastal California	2009 - 10	4-NP, 4-NP1-2EO					X
Maruya et al. (2015)	California coast	2006 - 09	4-NP, NP1-2EO				X	X
Maruya et al. (2016)	Southern California embayments	2013 - 14	4-NP			ND	X	
MPCA (2017)	Minnesota	2006 - 07, 2012	4-NP, 4-NP1-2EO	X				
Nagarnaik et al. (2010)	Texas	2008	NP, NP3-18EO	X				
Oates et al. (2017)	Texas	2006 - 07	NP	X		X		
Pryor et al. (2002)	New York	2000	NP		X			

Reference	Sample location	Sample year(s)	Analyte(s)	Media analyzed				
				WW	WS	W	S	B
SCCWRP (2017)	Los Angeles River and San Gabriel River watersheds, California	2016	4-NP			X	X	
SCCWRP (2018)	Russian River Watershed	2016	4-NP	X		X	X	
State Water Board (2008)	Creeks and rivers in North Coast region of CA	2005 - 08	NP, NPEs			X		
State Water Board (2011)	Creeks and rivers in San Diego County, CA	2011	4-NP, NP, NPE			X		
State Water Board (2013a)	New River, in Colorado River Basin, CA	2013	4-NP			X		
U.S. EPA (2009)	U.S. (various)	2005 - 06, 2007 - 08	4-NP, NP1-2EO	X				
Washington Department of Ecology (2017)	Washington	2006 - 15	4-NP, NP, 4-NP1-2EO	X	X	X	X	X
Writer et al. (2012)	Minnesota	2008	4-NP, 4-NP1-2EO, 4-NP1-2EC	X				
Venkatesan and Halden (2013)	U.S. (various)	2001	4-NP, 4-NP1-2EO		X			
Xia et al. (2010)	U.S. (various)	2005	4-NP		X			

Legend

Blank cells indicate no information was provided in the original study.

WW: wastewater S: sediment

WS: waste solids B: biota

W: water

n/a: information provided in the report, but does not meet the parameters in Section 3.3.1 so not included in subsequent tables in this Profile.

E-2. Concentrations in Wastewater Effluent (and related media)

Reference and sample description	CA sample	n	NP		NP1EO		NP2EO		Other	
			%	µg/L	%	µg/L	%	µg/L	%	µg/L
Barber et al. (2015) *9 sites*	No	61		0.24[M]-14[M]		0.12[M]-7.7[M]		0.24[M]-19[M]		NP3EO: 0.19[M]-7.5[M]; NP4EO: 0.05[M]-2.4[M]
Barber et al. (2015) *9 sites*	No	54								NP1EC: 54[M]-230[M]; NP2EC: 110[M]-270[M]; NP3EC: 2.5[M]-19[M]; NP4EC: 1.9[M]-11[M]
Diehl et al. (2012) *Septic Systems*	Yes	4		22.1[A] ± 5.8						
		3		48.8[A] ± 6.5						
Klečka et al. (2010)	No	3	100	0.02-1.0	100	0.06-2.4			100	∑NP2-8EO: 0.23-30.8 NP≥9EO: 0.08-1.8 NPEC: ND
Lawrence Livermore National Laboratory, State Water Board (2006)	Yes	2	100	2-4						AP1EC:20; AP2EC:60
LACSD (2012) *Ocean discharger*	Yes	4	100	0.99-3.84	100	2.36-3.28	100	8.00-9.70		
LACSD (2012) *Various inland dischargers*	Yes	197	95	0.03-1.26	100	0.08-1.03	100	0.15-2.94		
LACSD (2014a) *Ocean discharger*	Yes	1	100	0.80	100	6.38	100	7.17		
LACSD (2014) *Various inland dischargers*	Yes	8	88	0.03-0.37	100	0.12-0.68	100	0.08-2.10		

Reference and sample description	CA sample	n	NP		NP1EO		NP2EO		Other	
			%	µg/L	%	µg/L	%	µg/L	%	µg/L
LACSD (2015) *Ocean discharger*	Yes	1	100	1.77	100	3.43	100	3.66		
LACSD (2015) *Various inland dischargers*	Yes	8	100	0.03-0.32	100	0.11-0.56	100	0.11-0.22		
Lara-Martin et al. (2014) and Lara-Martin (2017)	No	1					100	0.071	100	∑NP3-15EO: 0.31; ∑NP1-2EC: 25.2
Los Angeles RWQCB (2017)	Yes	23 WWTPs	83[E]	0.05-120[E]						
Loyo-Rosales et al. (2007a) *Summer*	No	5	100	0.16-0.64	100	0.72-1.66	100	0.31-1.91	100	∑NP3-5EO: 0.14-0.97; NP1EC: 1.48-8.41; NP2EC: 5.82-18.4
Loyo-Rosales et al. (2007a) *Winter*	No	5	100	1.35-5.16	100	4.18-13.1		2.4-11.7	100	∑NP3-5EO: 2.99-8.74; NP1EC: 9.66-57.2; NP2EC: 27-57.4
Loyo-Rosales et al. (2007b)	No	1	100	0.65[E]	100	1.3[E]	100	1.3[E]	100	∑NP+NP1-16EO: 4 NP1EC: 8[E] NP2EC: 15.5[E]
Loyo-Rosales et al. (2010)	No	3		0.5-1.5[E]						∑NP1-3E0: 2.9-16[E]; ∑NP4-16EO: 0.25-5[E]; ∑NP1-2EC: 7.5-92[E]
Lozano et al. (2012) *Fall*	No	6		0.31[A]		0.83[A]		1.44[A]		NP3-18: ND
Lozano et al. (2012) *Spring*	No	6		1.38[A]		6.47[A]		3.12[A]		NP3E: 1.49[A]
Lubliner et al. (2010)	No	5		200[M]						

Reference and sample description	CA sample	n	NP		NP1EO		NP2EO		Other	
			%	µg/L	%	µg/L	%	µg/L	%	µg/L
Meador et al. (2016)	No	2	100	0.51-1.69	100	1.22-1.76	100	1.69-2.61		
Minnesota Pollution Control Agency (2017) *2006-2007 sampling*	No	5	100	0.40-4.60						
Minnesota Pollution Control Agency (2017) *2012 Sampling*	No	1	100	0.26 M	100	0.46 M	100	0.23 M		
Nagarnaik et al. (2010) *Healthcare wastewater*	No	4		ND						∑NP3-18EO: 19-258
Oates et al. (2017) *Healthcare wastewater*	No	6	33	29M						
Oates et al. (2017)	No	3	33	0.18M						
SCCWRP (2018)	Yes	2	100	0.06-0.25						
U.S. EPA (2009)	No	9	11	<0.52 BRL	11	1.1M	0	ND		
Washington Department of Ecology (2016)	No	24	100	0.560-1BRL						
Writer et al. (2012)	No	1	100	0.22A ± 0.030					100	∑NP1-2EO: 0.30 A ± 0.10 NP1-2EC: ND

Legend

Blank cells indicate no information was provided in the original study.

n Number of samples collected in study, when available.

ND Analyte was not detected.

A Average concentration. Standard error is provided in parentheses when provided in the original study. M Maximum concentration.

E Estimated concentration from a figure. When used with a range, all values within the range are estimated.

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E-3. Concentrations in Wastewater Solids

Reference and sample description	CA sample	n	NP		NP1EO		NP2EO		Other	
			%	mg/kg dry weight	%	mg/kg dry weight	%	mg/kg dry weight	%	mg/kg dry weight
Diehl et al. (2012) *Post-polymerization, dewatered biosolids*	Yes	3		0.72[A] ± 0.28						
Diehl et al. (2012) *Septic tank solids (top layer) servicing 186 homes*	Yes	3		50[A] ± 35						
Diehl et al. (2012) *Septic tank solids (top layer) servicing 89 homes*	Yes	3		6,270[A] ± 5,520						
Diehl et al. (2012) *Septic tank sludge (bottom layer) servicing 186 homes*	Yes	3		3,750[A] ± 2,250						
Gray et al. (2017) *Biosolids from anaerobic digestion*	No	1		325						
Kinney et al. (2006) *Activated sludge (secondary) + various treatments*	No	9 WWTPs	100	2.18 - 1,520 (organic carbon normalized)	100	3.96 - 79.4 (organic carbon normalized)	100	0.79 - 89.0 (organic carbon normalized)		
La Guardia et al. (2001) *Biosolids from anaerobic digestion*	Yes	5	100	683 - 887	100	25.7 - 102	40	22.7 - 32.6		

Reference and sample description	CA sample	n	NP		NP1EO		NP2EO		Other	
			%	mg/kg dry weight	%	mg/kg dry weight	%	mg/kg dry weight	%	mg/kg dry weight
La Guardia et al. (2001) *Compost, heat, or lime (alkali) treated biosolids*	No	6	100	5.4 - 820	83	0.7 - 154	50	7.4 - 254		
Loyo-Rosales (2006) *Sludge from secondary treatment*	No	2	100	41.8 - 71.80	100	66.5 - 118.00	100	79.10-128	100	∑NP3-16EO: 33.62-41.55
Loyo-Rosales (2006) *Sludge from tertiary treatment*	No	1	100	39.4	100	51.3	100	15.8	100	∑NP3-16EO: 9.19
Pryor et al. (2002)	No	21	100	1130[A]-1840[A]						
Venkatesan and Halden (2013) *Sewage sludge composites*	No	5	100	405 - 861	100	34.3 - 103	100	32.8 - 153		
Washington Department of Ecology (2016) *Biosolids*	No	4		1.21 - 1.78[BRL]						
Xia et al. (2010) *Biosolids and composted biosolids*	Yes	25	80	4.85-1,380						

Legend

Blank cells indicate no information was provided in the original study.

n Number of samples collected in study, when available.

A Average concentration. Standard error is provided in parentheses when provided in the original study.

BRL Below reporting or quantification limit, and above detection limit. Reporting limit value is included in parentheses when provided in the original study.

E-4. Concentrations in Surface Water

Reference and sample description	CA sample	n	NP		NP1EO		NP2EO		Other	
			%	µg/L	%	µg/L	%	µg/L	%	µg/L
Barber et al. 2015 *Rivers and urban waterways, 6 sites*	No	58		0.05[M]-6.7[M]****		0.14[M]-1.4[M]		0.10[M]-2.7[M]		NP3EO: 0.32[M]-0.85[M]; NP4EO: 0.05[M]-0.23[M]
Barber et al. 2015 *Rivers and urban waterways, 6 sites*	No	51								NP1EC: 8.1[M]-150[M]; NP2EC: 8.1[M]-103[M]; NP3EC: 1.3[M]-2.5[M]; NP4EC: ND
Bradley et al. (2017) *Freshwater, California*	Yes	4	25	0.30 [BRL (1.6); M]	25	0.53 [BRL (1.6); M]	50	0.48 - 1.28 [BRL (1.6)]		
Bradley et al. (2017) *Freshwater, United States*	No	38	26	0.11 - 0.46 [BRL (1.6)] *	29	0.18-0.53 [BRL (1.6)]	39	0.36 - 1.45 [BRL (1.6)]		
Diehl et al. (2012) *Seawater/estuary*	Yes	5		0.9 [M]**						
Diehl et al. (2012) *Upstream of wastewater discharge*	Yes	3		1.8 (±1.3) [A; **]						
Diehl et al. (2012) *Downstream of wastewater discharge*	Yes	3		1.0 (±0.3) [A; **]						
Elliott et al. (2017) *Freshwater tributaries to US Great Lakes*	No	291	13	1.23[BRL(1.6);M **]	15	2.99[M]	25	9.11[M]		
Klosterhaus et al. (2013) *Estuarine*	Yes	5	60	0.073[M]		ND		ND		

Reference and sample description	CA sample	n	NP		NP1EO		NP2EO		Other	
			%	µg/L	%	µg/L	%	µg/L	%	µg/L
LA County San 2012 *River*	Yes	4	100	0.12 - 0.22	100	0.39-0.42	100	0.39-0.57		
Lara-Martin et al. (2014) *Estuarine*	No	15	100	0.13 - 0.46*	100	0.09-0.57				
Lara-Martin et al. (2014) and Personal Communication (2017) *Estuarine*	No	16					100	0.09-0.68	100	∑NP3-15EO: 0.11 - 0.70; ∑NP1-2EC: 0.72-2.19
Lavado et al. (2009) *Inland waterways*	Yes	5	95	0.0003 - 0.19	98	0.0005 - 0.04	100	0.0003 - 0.24		
Lozano et al. (2012) *Urban stream, fall*	No	21		0.55 [A]*		1.16 [A]		1.73 [A]		NP3-18: ND
Lozano et al. (2012) *Urban stream, Spring*	No	21		1.01 [A]**		5.80 [A]		2.92 [A]		NP3EO: 1.74 [A]
Meador et al. (2016) *Estuarine*	No	11		0.04						
Oates et al. (2017) *San Marcos River, TX*	No	6	16	0.22[M]						
SCCWRP (2017) *Los Angeles River watershed*	Yes	6	100	0.08-0.20						
SCCWRP (2017) *San Gabriel River watershed*	Yes	10	100	0.04-0.51*						
SCCWRP (2018) *Russian River*	Yes	8	100	0.03-0.08						
State Water Board (2011) *Freshwater*	Yes	6	33	0.80 [BRL (2)]* 2.12**					17	Undescribed NPE: 2.97

Reference and sample description	CA sample	n	NP		NP1EO		NP2EO		Other	
			%	µg/L	%	µg/L	%	µg/L	%	µg/L
State Water Board (2013a) *New River, CA*	Yes	4	25	1.470 BRL (2)**						Undescribed NPE: ND
State Water Board (2008) *Freshwater, 2005-2006*	Yes	28	14	0.66 BRL (2) - 3.20***					7	Undescribed NPEs: 0.81 BRL (2.00) - 2.32
State Water Board (2008) *Freshwater, 2006-2007*	Yes	20	10	2.61 - 3.74***						Undescribed NPE: ND
State Water Board (2008) *Freshwater, 2007-2008*	Yes	57	5	1.21 BRL (2) - 4.78***					11	Undescribed NPEs: 0.60 BRL (2) - 2.13
Washington Department of Ecology (2016) *Wetland near WWTP*	No	1		0.98 BRL; *						
Washington Department of Ecology (2016) *Rivers, lakes*	No	149		0.03 - 0.37BRL;*						
Washington Department of Ecology (2016) *Salt/Marine*	No	44		0.310 BRL;*-0.360 BRL;*						

Legend

Blank cells indicate no information was provided in the original study.

E Estimated concentration from a figure. When used with a range, all values within the range are estimated.

n Number of samples collected in study, when available.

BRL Below reporting or quantification limit, and above detection limit. Reporting limit value is included in parentheses when provided in the original study.

ND Analyte was not detected.

A Average concentration. Standard error is provided in parentheses when provided in the original study.

M Maximum concentration.

* NP concentration exceeds the respective aquatic GSC by the EU, as described in Table 3.

** NP concentration exceeds the respective aquatic GSC by Canada and the EU, as described in Table 3.

**** NP concentration exceeds the respective aquatic GSC by Minnesota, Canada and the EU, as described in Table 3.

E-5. Concentrations in Sediment

Reference and sample description	CA sample	n	NP		NP1EO		NP2EO		Other	
			%	mg/kg dry weight	%	mg/kg dry weight	%	mg/kg dry weight	%	mg/kg dry weight
Diehl et al. (2012) *Estuary, top 2 cm*	Yes	9		0.53(±0.14)[A,*]						
Diehl et al. (2012) Creek, upstream of *wastewater discharge, top 2 cm*	Yes	3		0.03 (±0.03)[A]						
Diehl et al. (2012) *Creek, downstream of wastewater discharge, top 2cm*	Yes	3		0.22 (± 0.16) [A,*]						
Elliott et al. (2017) *Freshwater tributaries to US Great Lakes*	No	77	23	2.71[M**]	5	0.91[M]	1	0.49[BRL(0.66);M]		
Klosterhaus et al. (2013) *Near shore, estuary*	Yes	5	100	0.02 - 0.09	100	0.004 - 0.04	80	0.01 - 0.019		
Lara-Martin et al. (2014) *Estuarine*	No	13	100	0.12 - 0.70*	100	0.004 - 0.31	85	0.001 - 0.15		∑NP3-15EO: 0.01 - 0.54; ∑NP1-2EC: 0.002-0.34
Maruya et al. (2012) *Ocean, top 2 cm*	Yes	5	100	0.02 - 0.38*						
Maruya et al. (2015) *Coastal, top 5 cm*	Yes	2	100	0.10 - 1.86**	100	0.03 - 0.46	100	0.03 - 0.59		
Maruya et al. (2015) *Ocean, top 4cm*	Yes	1	100	0.55*	100	0.49	100	0.43		

Reference and sample description	CA sample	n	NP		NP1EO		NP2EO		Other	
			%	mg/kg dry weight	%	mg/kg dry weight	%	mg/kg dry weight	%	mg/kg dry weight
Maruya et al. (2016) *River and coastal embayment*	Yes	22	31	0.08 - 0.49*						
Southern California Coastal Water Research Project (2017) *Los Angeles River watershed*	Yes	6	100	0.08-0.8*						
Southern California Coastal Water Research Project (2017) *San Gabriel River watershed*	Yes	8	100	0.02-1.6**						
SCCWRP (2018) *Russian River Watershed*	Yes	8	100	0.01-0.03						
Washington Department of Ecology (2016) *Freshwater*	No	42		0.02 - 1.00[BRL]*						
Washington Department of Ecology (2016) *Estuary/Ocean*	No	792		0.003 - 0.40[BRL]*						

Legend:

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n Number of samples collected in study, when available.

[A] Average concentration. Standard error is provided in parentheses when provided in the original study.

[M] Maximum concentration.

E Estimated concentration from a figure. When used with a range, all values within the range are estimated.

BRL Below reporting or quantification limit, and above detection limit. Reporting limit value is included in parentheses when provided in the original study.

* NP concentration exceeds the respective aquatic GSC by the EU, as described in Table 3.

** NP concentration exceeds the respective aquatic GSC by Canada and the EU, as described in Table 3.

E-6. Concentrations in Aquatic Biota

All units are mg/kg (wet weight), unless specified as "dw" for dry weight; some lipid-based concentrations are also available in Diehl et al. (2012) and Dodder et al. (2014). Standard error presented where available.

Organism	CA sample	NP			Other		
		N	% det.	mg/kg	N	% det.	mg/kg
Plants							
Eelgrass[1]	Yes	1	100	0.033[A]			
Invertebrates							
Benthic species[1]	Yes	3		0.10[A] (±0.03)			
Ghost shrimp[1]	Yes	3		2.38[A] (±1.14)			
Mussels[1]	No	3		0.63[A] (dw)			
Mussels[2]	Yes	14	100	0.016 - 0.290; 0.096 - 3.00 (dw)			NP1EO: 0.001 - 0.05 (n = 32; 100%) NP2EO: 0.02[M] (n = 25; 88%)
Mussels[3]	Yes	4	75	0.06 - 0.15 (dw)	4	75	NP1EO: 0.11 - 0.48 (dw)
Mussels[1]	Yes	3		0.12[A] (±0.035); 0.66[A] (dw)			
Mussels[4]	Yes	5	40	0.09 - 0.10	5		NP1EO: 0.04[M] (40%) NP2EO: 0.19 (20%)
Oyster[1]	No	3		4.10[A] (dw)			
	Yes	3		11.20[A] (dw)			
	Yes	3		0.48[A] (±0.24); 3.37[A] (dw)			
	No	3		2.44[A] (dw)			
	Yes	3		1.71[A] (dw)			
Fish							
Arrow goby[1]	Yes	27		0.24[A] (±0.04)			
	Yes	6		0.18[A]			
	Yes	6		0.22[A]			
	No	4 composites		0.12[A]			

Organism	CA sample	NP			Other		
		N	% det.	mg/kg	N	% det.	mg/kg
Goby liver[1]	Yes	2		2.07[A] (±0.996)			
Hornyhead turbot livers[5]	Yes	10 composites	90	0.03 - 0.29			
Largemouth bass[6]	No	11		0.07[E, A] - 0.20[E, A]			NP1EO: 0.49[E, A] - 3.50[E, A] NP2EO: 0.30[E, A] - 1.30[E, A]
Juvenile salmon[7]	No	6	100	0.03[BRL (0.046)] - 0.08	6	100	NP1EO: 0.001 [BRL (0.046)] - 0.06 NP2EO: 0.001 [BRL (0.046)] - 0.051
Fish, continued							
Sanddab liver[1]	Yes	1	100	2.92			
Sculpin liver[1]	Yes	2	100	1.76[A] (±0.05)			
Sculpin[7]	No	5	100	0.008 - 0.036 BRL (0.046)	5		NP1EO: 0.003 - 0.005[(0.046)] (60%) NP2EO: 0.002-0.017 [(0.046)] (80%)
Bird							
Seabird liver[1]	Yes	3		0.26[A] (±0.1)			
Mammals							
Porpoise liver[1]	Yes	3		0.81[A] (±0.39)			
Sea lion liver[1]	Yes	3		0.75[A] (±0.28)			
Sea otter liver [1]	Yes	3		3.68[A] (±1.61)			
Unknown/Mixtures							
Not indicated [8]	No	44	100	0.009 - 0.06 BRL	44	100	NP1EO: 0.0004 - 0.0041 [BRL] NP2EO: 0.0005 - 0.003 [BRL]
Water column organisms (plankton and detritus) [1]	Yes	3 composites		0.43[A] (±0.23)			

Legend:

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M Maximum concentration.

E Estimated concentration from a figure. When used with a range, all values within the range are estimated.

BRL Below reporting or quantification limit, and above detection limit. Reporting limit value is included in parentheses when provided in the original study.

Footnotes

1 Diehl et al. 2012

2 Maruya et al. 2014; Dodder et al. 2014

3 Maruya et al. 2015

4 Klosterhaus et al. 2013

5 Maruya et al. 2012

6 Lozano et al. 2012

7 Meador et al. 2016

8 Washington Department of Ecology 2016