Chapter 3

Conditions within the Local Source Water System

3.0 Conditions within the Local Source Water System

Natural water quality varies from place to place, with the seasons, with climate, and with the types of soils and rocks through which water moves. When water from rain or snow moves over the land and through the ground, the water may dissolve minerals in rocks and soil, percolate through organic material such as roots and leaves, and react with algae, bacteria, and other microscopic organisms. Water may also carry plant debris and sand, silt, and clay to rivers and streams making the water appear “muddy” or turbid. When water evaporates from lakes and streams, dissolved minerals are more concentrated in the water that remains. Each of these natural processes changes the water quality and potentially the water use.

The most common dissolved substances in water are minerals or salts that, as a group, are referred to as dissolved solids. Dissolved solids include common constituents such as calcium, sodium, bicarbonate, and chloride; plant nutrients such as nitrogen and phosphorus; and trace elements such as selenium, chromium, and arsenic.

In general, the common constituents are not considered harmful to human health, although some constituents can affect the taste, smell, or clarity of water. Plant nutrients and trace elements in water can be harmful to human health and aquatic life if they exceed standards or guidelines.

Dissolved gases such as oxygen and radon are common in natural waters. Adequate oxygen levels in water are a necessity for fish and other aquatic life. Radon gas can be a threat to human health when it exceeds drinking-water standards.

3.1 Erosion

Erosion is the process of weathering and transporting of solids (sediment, soil, rock and other particles) in the natural environment from their source to deposits elsewhere. A certain amount of erosion is natural and healthy for the ecosystem. Locally, erosion occurs due to transport by down-slope creep under the force of gravity, wind, and primarily water. In general, background erosion removes soil at roughly the same rate that soil is formed.

Given similar vegetation and ecosystems (Table 3.1), areas with high-intensity precipitation, more frequent rainfall, more wind, or more storms are expected to have more erosion. Porosity and permeability of the sediment or rock affects the speed with which the water can percolate into the ground. If the water moves underground, less runoff is generated, reducing the amount of surface erosion.

Table 3.1 - Hydrographic Areas within Local Source Water System Boundaries

SanGIS update 2015

San Diego River System

Watershed	Hydrographic Area	Hydrographic Sub-Area	Acres
El Capitan	Boulder Creek	Cuyamaca	7,660
	Boulder Creek	Inaja	52,194
	Boulder Creek	Spencer	4,758
	El Capitan	Alpine	3,905
	El Capitan	Conejos Creek	51,818
	Total		120,335
Murray	Murray	Murray	2,298
	Total		2,298
San Vicente	San Vicente	Barona	10,201
	San Vicente	Fernbrook	14,077
	San Vicente	Gower	14,853
	San Vicente	Kimball	8,491
	Total		47,622
Sutherland	Santa Ysabel	Sutherland	18,511
	Santa Ysabel	Witch Creek	16,041
	Total		34,552
San Diego River System			
	Grand Total		204,807

Otay-Cottonwood System

Watershed	Hydrographic Area	Hydrographic Sub-Area	Acres
Barrett	Barrett Lake	Barrett Lake	59,131
	Monument	Mount Laguna	5,322
	Monument	Pine	18,804
	Total		83,257
Dulzura	Dulzura	Engineer Springs	7,092
	Total		7,092
Morena	Morena	Morena	14,916
	Cottonwood	Cottonwood	28,560
	Cameron	Cameron	30,067
	Total		73,543
Otay	Dulzura	Jamul	7,795
	Dulzura	Proctor	8,129
	Dulzura	Hollenbeck	31,730
	Dulzura	Lee	2,075

Table 3.1 - Hydrographic Areas within Local Source Water System Boundaries (contd)

SanGIS update 2015

	Dulzura	Savage	10,220
	Dulzura	Lyon	2,076
	Total		62,025
Otay-Cottonwood System			
	Grand Total		225,917

Miramar System

Watershed	Hydrographic Area	Hydrographic Sub-Area	Acres
Miramar	Miramar Reservoir	Miramar Reservoir	640
	Poway	Poway	5
	Total		645

Hodges System

Watershed	Hydrographic Area	Hydrographic Sub-Area	Acres
Hodges	Hodges	Bear	1,716
	Hodges	Del Dios	21,107
	Hodges	Felicita	1,820
	Hodges	Green	5,627
	San Pasqual	Guejito	12,659
	San Pasqual	Hidden	1,193
	San Pasqual	Highland	2,552
	San Pasqual	Las Lomas Muertas	23,954
	San Pasqual	Reed	1,907
	San Pasqual	Vineyard	1,796
	Santa Maria Valley	Ballena	2,494
	Santa Maria Valley	East Santa Teresa	882
	Santa Maria Valley	Lower Hatfield	2,835
	Santa Maria Valley	Ramona	25,850
	Santa Maria Valley	Upper Hatfield	1,019
	Santa Maria Valley	Wash Hollow	2,315
	Santa Maria Valley	West Santa Teresa	1,143
	Santa Ysabel	Boden	10,531
	Santa Ysabel	Pamo	36,878
	Total		158,278

Erosion by Gravity

- Mass wasting is the down-slope movement of rock and sediments, mainly due to the force of gravity. Mass movement is an important part of the erosion process, as it moves material from higher elevations to lower elevations where other eroding agents such as streams can then pick up and move the material. Mass-movement processes are always occurring continuously on all slopes. Some mass-movement processes act very slowly; while others occur very suddenly, often with disastrous results. Any perceptible down-slope movement of rock or sediment is often referred to in general terms as a landslide.

Erosion by Wind

- The rate and magnitude of soil erosion by wind is controlled by the speed and duration of the wind, physical characteristics of the soil, soil moisture levels, and vegetative cover. Very fine particles can be suspended by the wind and then transported great distances. Fine and medium size particles can be lifted and deposited, while coarse particles can be blown along the surface. The continual drifting of an area gradually causes a textural change in the soil. Loss of fine sand, silt, clay and organic particles from sandy soils serves to lower the moisture holding capacity of the soil. During periods of drought, soils with low soil moisture levels release the particles for transport by wind creating a positive feedback system.

Erosion by Water

- Soil erosion by water is the result of rain detaching and transporting vulnerable soil, either directly by means of splash erosion or indirectly by runoff erosion. The rate and magnitude of soil erosion by water is controlled by rainfall intensity and runoff volume. The impact of raindrops on the soil surface can break down soil aggregates and disperse the aggregate material. Splash erosion is the direct detachment and airborne movement of soil particles by raindrop impact. Since soil particles are only moved a small distance, its effects are primarily on-site (at the place where the soil is detached). Although considerable quantities of soil may be moved by splash erosion, it is simply redistributed back over the surface of the soil; although on steep slopes, there will be a modest net down slope movement of detached soil.

- When precipitation rates exceed soil infiltration rates, runoff occurs. Runoff may occur for two reasons: the rain arrives too quickly for it to infiltrate or the soil has already absorbed all the water it can hold. The impact of the raindrop breaks apart the soil aggregate. Particles of clay, silt and sand fill the soil pores and reduce infiltration. Once the rate of falling rain is faster than infiltration, runoff takes place. Surface runoff turbulence often causes more erosion than the initial raindrop impact. In most situations, erosion by concentrated flow is the main cause of erosion by water. It is in such channels that water erosion also operates most effectively to detach and remove soil by its kinetic energy lowering the soils surface. Lowered areas form preferential flow paths for subsequent flow creating a positive feedback system. Eventually, this positive feedback results in well-defined linear concentrations of overland flow. The effects are both on-site and off-site (where the eroded soil ends up). The amount of runoff can be increased if infiltration is reduced due to soil compaction, crusting or freezing.

- The rate of erosion depends on many factors. Climatic factors (Chapter Two) include the amount and intensity of precipitation, storm frequency, wind speed, average temperature, temperature range and seasonality. Geologic factors include the sediment or rock type, porosity and permeability, slope of the land, and position of the rocks (tilted, faulted, folded, or weathered). Biological factors include the type and extent of ground cover from vegetation, and the type and density of organisms inhabiting the area including humans.

3.2 Geology

The San Diego region is underlain by three principle geologic provinces. The majority of the County is in the Peninsular Ranges province bounded by the coastal province to the west and the Salton Trough province to the east. This geomorphic division reflects a basic geologic difference between the three regions, with Mesozoic metavolcanic, metasedimentary, and plutonic rocks predominating in the Peninsular Ranges, and primarily Cenozoic sedimentary rocks predominating to the west and east of the central mountain range. The irregular contact between these geologic regions reflects the ancient topography of this area before it was buried by the thick sequence of Cretaceous and Tertiary sedimentary rocks deposited over the last 75 million years by ancient rivers and in ancient seas.

As the Peninsular Ranges province experienced uplifting and tilting, a series of large faults, such as the Elsinore and San Jacinto, developed along the edge of the province. The City of San Diego lies in the coastal plain province which extends from the western edge of the Peninsular Ranges and runs roughly parallel to the coastline. The province is composed of dissected, mesa-like terraces that graduate inland into rolling hills. The terrain is underlain by sedimentary rocks composed mainly of sandstone, shale, and conglomerate beds, reflecting the erosion of the Peninsular Ranges to the east.

Basement Complex

- The basement complex consists of two principal rock units: (1) the Upper Jurassic Santiago Peak Volcanics, a succession of deformed and metamor- phosed volcanic, volcaniclastic, and sedimentary rocks; and (2) mid-Cretaceous plutonic rocks of the Southern California Batholith, which intrude the Santiago Peak Volcanics.

  - *The Santiago Peak Volcanics*
    The Santiago Peak Volcanics are hard and extremely resistant to erosion and form topographic highs. Most of the volcanic rocks are dark greenish gray when fresh but weather grayish red to dark reddish brown. The soil developed on the Santiago Peak Volcanics is the color of the weathered rock and supports the growth of dense chaparral.
  - *Southern California Batholith*:
    Plutonic rocks of the Southern California Batholith in the area are quartz diorite and gabbro. The quartz diorite is typically coarse grained, light gray and

contains large phenocrysts of plagioclase and potassium feldspar. Hornblende and biotite are present in small amounts. The gabbro varies considerably in texture and composition but is mostly medium to coarse grained and medium to dark gray. The chief minerals are calcic feldspar and pyroxene, and the accessory minerals include trace amounts of quartz and biotite. Throughout most of the area, the granitic rocks are deeply weathered.

Rocks known to occur in San Diego County:

- Acmite, Albite, Allanite, Amblygonite, Andalusite, Apatite, Arsenopyrite, Azurite, Basalt, Bavenite, Bertrandite, Beryl, Biotite, Bismite, Bismuth, Bismuthinite, Bornite, Calcite (optical), Cassiterite, Celestite, Cerussite, Chalcocite, Chalcopyrite, Chrysotile, Clintonite, Cookeite, Corundum, Epidote, Erythite, Ferrimolybdite, Ferrisicklerite, Ferroaxinite, Fersmite, Fluorapatite, Francolite, Gabbro, Gahnite, Galena, Garnet, Glauconite, Gneiss, Gold, Granite, Graphite, Gypsum, Helvite, Heterosite, Heulandite, Hydromagnesite, Laumontite, Lawsonite, Leadhillite, Lepidolite, Limonite, Lithiophylite, Magnetite, Malachite, Manganite, Marcasite, Microcline, Molybdenite, Morenosite, Morinite, Muscovite, Nickel, Orthoclase, Pentlandite, Petalite, Plagioclase feldspar, Pollucite, Purpurite, Pyrite, Pyrophyllite, Pyrrhotite, Quartz, Rhodonite, Rutile, Rynersonite, Samarskite, Scheelite, Schist, Sicklerite, Silver, Sphalerite, Spinel, Spodumene, Stellerite, Stokesite, Tellurium, Tenorite, Thorogummite, Todorokite, Topaz, Tourmaline, Tremolite, Tridymite, Triphylite, Uranmicrolite, Uranophane, Violarite, Wollastonite, Zircon

Geology within the Local Source Water System

San Diego River System

- *Dominant:* Pre-Cenozoic granitic and metamorphic rock, Cretaceous granitic rock of the Southern California Batholith
- *Lesser emplacements:* Jurassic metavolcanic and metasedimentary rocks of the Santiago Peak Volcanics, Mesozoic basic intrusive rocks, Pre-Cretaceous metamorphic and metasedimentary rocks, Eocene marine sedimentary and metasedimentary rocks, Pleistocene marine and metasedimentary rocks and marine terrace deposits, Quaternary lake deposits, Alluvium

Otay-Cottonwood System

- *Dominant:* Jurassic metavocanic and metasedimentary rocks of the Santiago Peak Volcanics, Cretaceous granitic rock of the Southern California Batholith
- *Lesser emplacements:* Pre-Cenozoic granitic and metamorphic rock, Mesozoic basic intrusive rock, Pleistocene marine and marine terrace deposits, Plio-Pleistocene non-marine sedimentary and metasedimenntary rocks, Quaternary non-marine terrace deposits, Alluvium

Miramar System

- *Dominant:* Eocene marine and non-marine sedimentary rocks
- *Lesser emplacements:* Jurassic metavocanic and metasedimentary rocks of the Santiago Peak Volcanics

Hodges System

- *Dominant:* Cretaceous granitic rock of the Southern California Batholith
- *Lesser emplacements:* Jurassic metavolcanic and metasedimentary rock of the Santiago Peak Volcanics,
- Mesozoic basic intrusive rock, Alluvium

Soils and Slope

- Soil erodibility is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil. Loose soils can be eroded by water or wind forces, whereas soils with high clay content are generally susceptible only to water erosion. Sediment with a high sand or silt content erodes more easily than areas with highly fractured or weathered rock. Sand, sandy loam and loam textured soils tend to be less erodible than silt, very fine sand, and certain clay textured soils (**Appendix 1, see page A1-1**).
- Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Past erosion also has an effect on a soil's erodibility. Many exposed subsurface soils on eroded sites tend to be more erodible than the original soils due to their poorer structure and lower organic matter.
- As the slope gradient of a field increases, the amount of soil lost from erosion increases. Erosion by water increases as the slope length increases due to the greater accumulation of runoff volume and velocity. Overland flow in disturbed areas is likely to flow downhill more quickly and in greater quantities (i.e. possess more flow power as a result of its kinetic energy), and so may be able to begin transporting and even detaching soil particles. USGS estimates that 70% of soil slips originate in slopes between 20° and 36° (**Table 3.2**).These soil slips have the potential to increase sedimentation in streams and reservoirs.

Table 3.2 - Slopes within Local Source Water System Boundaries

SanGIS Update 2015

	San Diego River System		**Otay-Cottonwood System**		**Miramar System**		**Hodges System**	
Slope	Acres	% Area	Acres	% Area	Acres	% Area	Acres	% Area
0 < 15%	42,792	21.03	53,699	23.90	294	45.51	55,078	35.03
16% < 25%	53,758	26.41	57,642	25.66	203	31.42	40,775	25.93
26% < 50%	84,190	41.37	89,102	39.66	149	23.07	50,926	32.39
51% <	22,785	11.20	24,196	10.77	0	0	10,470	6.66

- Slope failure is a perceptible movement of soil and rock material downhill to a lower position. Landslides are the most common naturally occurring type of slope failure in San Diego. The causes of classic landslides start with the preexisting condition inherent within the rock body itself that can lead to failure. Landslides in the San Diego region generally occur in sedimentary rocks such as sandstone, siltstone, mudstone, and claystone. The actuators of landslides can be both natural events such as earthquakes, rainfall and erosion and human activities such as grading and filling.
- Earthquakes and their aftershocks can intensify or activate an unstable slope. Loosely and weakly consolidated soils, steepened slopes which are due to either human activities or natural causes, and saturated earth materials create a fragile situation easily affected by an earthquake.
- A debris flow or mudslide is a form of shallow landslide comprised of: soils, rock, plants, and water and can be very destructive during periods of heavy rainfall. The City of San Diego is susceptible to mudslides due to abundant natural, hilly terrain.
- A slope can be made potentially unstable by human activities involving:
  1. Removing material from the bottom of the slope, thus, increasing the angle of the slope.
  2. Raising the height of the slope above the previous level.
  3. Saturating the slope with water from septic tank, gutter runoff, or diverted drainage from another part of the slope.
  4. Adding fill to the top of the slope, creating additional weight.
  5. Earth-moving activities reactivating an old slide.

Geological Hazards and Contaminants

Fault Zones

Several earthquake fault zones and numerous faults exist in the City of San Diego and in Southern California. The proximity of the City of San Diego to large earthquake faults increases the potential of earthquake damage to structures and potentially endangers the safety of the City's inhabitants. Damage to structures caused by a major earthquake will depend on the distance to the epicenter, the magnitude of the event, the underlying soil, and the quality of construction.

- *San Andreas Fault Zone:*
  The San Andreas Fault Zone is approximately 100 miles east of the City of San Diego and outside the City and San Diego County limits. It extends a total of 650 miles from Baja California to the Northern California coast. In the vicinity of the San Diego region, the San Andreas Fault follows the east side of Coachella and Imperial valleys. The nearest inhabited sections of the San Diego region are 30 miles away. The San Andreas Fault Zone longer distances from the City would indicate lesser potential for damaging impacts.\
- *San Jacinto Fault Zone:*
  The San Jacinto Fault is the largest of the active faults (faults that have moved in the last 11,000 years) in the San Diego region. The fault extends 125 miles from the Imperial Valley to San Bernardino. The northern portion of the fault is

Halocene (fault displacement within the past 11,700 years) while the southern portion has experienced displacement with the last 200 years. The maximum probable earthquake expected to occur along the San Jacinto fault would be a magnitude of 7.5 to 7.8 on the Richter scale. Although faults within the San Jacinto Fault Zone have greater historic and instrumental activity, their longer distances from the City would indicate lesser potential for damaging impacts.

- *Elsinore Fault Zone:*
  The Elsinore Fault is approximately 135 miles long, located approximately 40 miles north and east of Downtown San Diego. The Elsinore fault is a combination of Halocene and Late Quaternary (fault displacement within the past 700,000 years), and can register earthquakes in the range of magnitude 6.9 to 7.0 on the Richter scale. An event on the Elsinore fault would potentially cause considerable damage in Northeast San Diego, but only limited damage in Urban San Diego.
- *Rose Canyon Fault Zone:*
  The Rose Canyon Fault Zone is located offshore approximately two to six miles and parallels the San Diego north county coastline before coming ashore. This portion of the fault is a combination of Halocene and Quaternary (fault displacement within the past 1.6 million years). The fault trends through coastal San Diego before travelling off shore through San Diego Bay and parallel to the south county coastline. This portion is a combination of Halocene and Late Quaternary. The Rose Canyon Fault Zone is capable of generating an earthquake of magnitude 6.2 to 7.0 on the Richter scale; potential damage resulting from the event would be especially severe in Urban San Diego.
- *The La Nacion Fault Zone:*
  The La Nacion Fault Zone is located about five miles east of the Rose Canyon and runs parallel through central and southern San Diego County. This is a Quaternary fault experiencing displacement within the last 1.6 million years. The La Nacion Fault Zone is capable of generating an earthquake of magnitude 6.2 to 6.6 on the Richter scale; potential damage resulting from the event would be especially severe in Urban San Diego.
- *Offshore Fault Zones:*
  The major offshore fault zones are the San Clemente (Halocene, Late Quaternary, and Quaternary), San Diego Trough (Halocene), and Coronado Bank (Halocene, Quaternary). The San Clemente fault zone, located 40 miles west of San Diego, is the largest offshore fault zone. It is estimated that the maximum plausible quake along this fault would be between magnitude 6.7 and 7.7. This fault is about the same distance from downtown San Diego as the Elsinore fault, and their maximum credible events appear to be of the same order. However, since its historic recorded activity has been less, the San Clemente fault does not appear to pose as significant a hazard to the San Diego area. The San Diego Trough located 25 miles west of San Diego, and the Coronado Bank located 12 miles west are capable of seismic events of magnitude 6.0 to 7.7. There is a high potential for damage in the San Diego area resulting from the event.

Accelerated Erosion

- Accelerated erosion is the loss of soil at a much faster rate than it is formed and can result in ecosystem damage. Damage caused by excessive erosion can include: loss of soil, damage to drainage networks, reduction of surface water quality, and receiving water degradation. Impacts can be both on-site and off-site.

  The main on-site impact of accelerated erosion is the reduction of soil quality. Soil quality is diminished due to the loss of the nutrient-rich upper layers of soil and reduced water-holding capacity. Erosion's removal of the nutrient-rich upper horizons of the soil results in a reduction of soil suitability for vegetation. In addition, eroded soils become preferentially depleted of their finer fraction over time, this breakdown of aggregates and the removal of smaller particles or entire layers of soil or organic matter can weaken the structure and even change the texture. Textural changes can affect the water-holding capacity of the soil, making it more susceptible to extreme conditions such a drought. The implications of soil erosion extend beyond the removal and textural changes of the soil. Seeds and plants can be disturbed or completely removed from the eroded site.

  In addition to on-site effects, soil that is detached by accelerated water or wind erosion may be transported considerable distances causing off-site effects. Eroded soil deposited down slope can inhibit or delay the emergence of seeds, bury small seedlings, and necessitate replanting in the affected areas. Sediment which reaches streams or watercourses can clog drainage ditches and stream channels resulting in flooding and local property damage, reduced downstream water quality, buried fish spawning grounds, and reservoir siltation.

Asbestos

Asbestos is a term used for a group of naturally occurring magnesium silicate minerals that display heat and chemical resistance, high tensile strength, and flexibility. Serpentine (chrysotile) and amphibole (tremolite) asbestos occur naturally in San Diego County, most commonly in association with ultramafic rocks (over 90 percent of whose content consists of ferromagnesian minerals) and along associated faults. Because asbestos fibers are resistant to heat and most chemicals, they have been mined for use in more than 3,000 products including cement pipe used in distributing water to communities. The major sources of asbestos in drinking water are decay of asbestos cement water mains and erosion of natural deposits.

- *Anthropogenic Source:*
  Building materials, manufacturing, mining
- *Health Effects:*
  Asbestos is carcinogenic to humans. Inhalation of asbestos may result in the development of lung cancer or mesothelioma, ingestion increases the risk of developing benign intestinal polyps.

Mercury

Mercury occurs naturally in the earth's crust. It is released into the environment from volcanic activity, weathering of rocks and as a result of human activity. Mercury occurs in various forms and compounds in the environment some of which are not bioavailable, although, when mercury enters an aquatic environment either by erosion, atmospheric deposition, or as the result of human activity, it may encounter conditions that cause its conversion to methyl mercury. Methyl mercury is readily taken up by aquatic organisms and tends to concentrate as it moves up the food chain. This process is referred to as bio magnification and can result in high mercury concentrations in predatory fish, fish eating birds, and mammals. The principal route of human exposure is through consumption of contaminated fish.

- *Anthropogenic source:*
  Sources related to human activities include: coal combustion, waste incineration, industrial activities, and mining activities. California environmental mercury issues relate to historical mining operations in two ways. The first is mercury mining activity that occurred between 1846 and 1981, during which time about 100 million kilograms of mercury were produced within the state. The second is historic gold mining activities that took place between 1848 and the first part of the 20th century, which depended upon using mercury during the gold recovery process. Significant quantities of mercury were lost to the environment during both of these activities.
- *Health Effects:*
  Mercury is a human neurotoxin. Ingestion of mercury may result in neurological and behavioral disorders with developing fetuses and small children at greatest risk.

Radon

Radon gas is a naturally-occurring radioactive gas that is invisible, odorless, tasteless, and soluble in water. It forms from the radioactive decay of small amounts of uranium and thorium naturally present in rocks (Gneiss) and soils. Certain rock types, such as black shales and certain igneous rocks, can have thorium and uranium in amounts higher than is typical for the earth's crust. Increased amounts of radon will be generated in the subsurface at these locations. Because radon is a gas, it can easily move through soil. Radon-222 is the isotope of most concern to public health because it has a much longer half-life (3.8 days) than other radon isotopes (radon-219 at 4 seconds and radon 220 at 55.3 seconds). The longer half-life allows radon-222 to migrate farther through the soil. The average concentration of radon in American homes is about 1.3 picocuries per liter and the average concentration in outdoor air is about 0.4 picocuries per liter. The geologic radon potential for San Diego County is low (<2pCi/L). Higher levels of radon tend to be found in ground water sources than in surface water sources.

- *Anthropogenic source:*
  Mining, coal combustion
- *Health Effects:*
  Radon is carcinogenic to humans. Inhalation of elevated levels of radon gas increases the risk of developing lung cancer. To date, epidemiological studies have not found an association between consumption of drinking-water containing radon and an increased risk of stomach cancer.

Arsenic

Arsenic occurs naturally in earth's crust (Arsenopyrite) and is widely distributed throughout the environment in the air, water and land. It can be released into the environment through natural activities such as volcanic action, erosion of rocks, forest fires, or through human actions related to agricultural and industrial activities. When deposits of Arsenopyrite become exposed to the atmosphere, usually due to mining, the mineral will slowly oxidize, converting the arsenic into oxides that are more soluble in water. Higher levels of arsenic tend to be found in ground water sources than in surface water sources. Compared to the rest of the United States, western states have more systems with arsenic levels greater than USEPA's standard of 10 parts per billion (ppb).

- *Anthropogenic source:*
  Approximately 90 percent of industrial arsenic in the U.S. is currently used as a wood preservative; it is also used in paints, dyes, metals, drugs, soaps, and semi-conductors. Arsenic can be released into the environment by the use of certain fertilizers, and through industrial practices involving animal feeding operations, copper smelting, mining, and coal burning.
- *Health Effects:*
  Arsenic is carcinogenic to humans. Ingestion of water with elevated levels of arsenic increases the risk of skin cancer.

3.3 Biology

Vegetation

Vegetation anchors the soil, protects the soil from splash erosion, slows down the movement of surface runoff, allows excess surface water to infiltrate, and provides a wind break effect. The lack of windbreaks (*e.g.*, trees, shrubs, and residue) allows the wind to put soil particles into motion for greater distances thus increasing the abrasion and soil erosion. The effectiveness of vegetative covers depends on the type, extent and quantity of cover; vegetation and residue combinations that completely cover the soil, and which intercept all falling raindrops at and close to the surface are the most effective (*e.g*. forests, shrubs, and permanent grasses). Partially incorporated residues and residual roots are also important as these provide channels that allow surface water to move into the soil. Typically, only the most severe rainfall and large hailstorm events will lead to overland flow in a forest.

In addition to providing soil stability, vegetation cover provides other ecological services pertinent to water quality. Wetlands and other riparian plant communities act as natural filters removing suspended sediments and contaminants. Sediments are trapped by densely growing wetland plants, and many contaminants are absorbed or chemically altered by the vegetation (**Table 3.3**).

Table 3.3 - Vegetation Categories within Local Source Water System Boundaries SanGIS updates 2010, 2015					
San Diego River System		**2015**		**2010**	
Watershed	Vegetation Category	**Acres**	**% Area**	**Acres**	**% Area**
El Capitan	Scrub and Chaparral	70,721	59	70,721	59
	Disturbed or Developed Areas	4,956	4	6,381	5
	Grasslands, Vernal Pools, Meadows, and Other Herb Communities	7,133	6	7,133	6
	Bog and Marsh	109	0	109	0
	Riparian and Bottomland Habitat	4,918	4	3,529	3
	Forest	16,346	14	16,346	14
	Woodland	16,026	13	15,990	13
	Total	120,209	100	120,209	100
Murray	Scrub and Chaparral	366	16	366	16
	Disturbed or Developed Areas	1,738	76	1,902	83
	Grasslands, Vernal Pools, Meadows, and Other Herb Communities	23	1	23	1
	Bog and Marsh	2	0	2	0
	Riparian and Bottomland Habitat	168	7	4	0
	Total	2,297	100	2,297	100
San Vicente	Scrub and Chaparral	35,420	75	35,530	75
	Disturbed or Developed Areas	5,995	13	6,941	15
	Grasslands, Vernal Pools, Meadows, and Other Herb Communities	1,218	3	1,219	3
	Bog and Marsh	12	0	12	0
	Riparian and Bottomland Habitat	1,888	4	865	2
	Woodland	2,958	6	2,929	6
	Total	47,491	100	47,496	100
Sutherland	Scrub and Chaparral	10,082	29	10,082	29
	Disturbed or Developed Areas	1,083	3	1,243	4
	Grasslands, Vernal Pools, Meadows, and Other Herb Communities	6,619	19	6,619	19
	Bog and Marsh	449	1	449	1
	Riparian and Bottomland Habitat	881	3	729	2
	Forest	3,679	11	3,679	11
	Woodland	11,760	34	11,752	34
	Total	34,553	100	34,553	100
San Diego River System	Scrub and Chaparral	116,589	57	116,699	57

Table 3.3 - Vegetation Categories within Local Source Water System Boundaries (contd)

SanGIS updates 2010, 2015

Grand Totals	Disturbed or Developed Areas	13,772	7	16,467	8
	Grasslands, Vernal Pools, Meadows, and Other Herb Communities	14,993	7	14,994	7
	Bog and Marsh	572	0	572	0
	Riparian and Bottomland Habitat	7,855	4	5,127	3
	Forest	20,025	10	20,025	10
	Woodland	30,744	15	30,671	15
	Grand Total	204,550	100	204,555	100
Otay-Cottonwood System		**2015**		**2010**	
Watershed	Vegetation Category	**Acres**	**% Area**	**Acres**	**% Area**
Barrett	Scrub and Chaparral	65,577	79	65,534	79
	Disturbed or Developed Areas	1,964	2	2,857	3
	Grasslands, Vernal Pools, Meadows, and Other Herb Communities	1,855	2	1,824	2
	Bog and Marsh	1	0	1	0
	Riparian and Bottomland Habitat	1,859	2	1,032	1
	Forest	8,227	10	8,247	10
	Woodland	3,760	5	3,750	5
	Total	83,243	100	83,245	100
Dulzura	Scrub and Chaparral	6,415	91	6,415	91
	Disturbed or Developed Areas	279	4	280	4
	Grasslands, Vernal Pools, Meadows, and Other Herb Communities	15	0	15	0
	Riparian and Bottomland Habitat	53	1	52	1
	Woodland	325	5	325	5
	Total	7,087	100	7,087	100
Morena	Scrub and Chaparral	57,709	78	57,709	78
	Disturbed or Developed Areas	1,426	2	1,854	3
	Grasslands, Vernal Pools, Meadows, and Other Herb Communities	3,884	5	3,884	5
	Riparian and Bottomland Habitat	1,841	3	1,413	2
	Forest	4,070	6	4,070	6
	Woodland	4,617	6	4,617	6
	Total	73,547	100	73,547	100
Otay	Scrub and Chaparral	44,759	72	44,852	72
	Disturbed or Developed Areas	6,475	10	7,389	12
	Grasslands, Vernal Pools, Meadows, and Other Herb Communities	3,408	6	3,340	5

Table 3.3 - Vegetation Categories within Local Source Water System Boundaries (contd) SanGIS updates 2010, 2015					
	Bog and Marsh	302	0	302	0
	Riparian and Bottomland Habitat	1,693	3	796	1
	Forest	3,179	5	3,179	5
	Woodland	2,112	3	2,070	3
	Total	61,928	100	61,928	100
Otay-Cottonwood System	Scrub and Chaparral	174,460	77	174,510	77
Grand Totals	Disturbed or Developed Areas	10,144	4	12,380	5
	Grasslands, Vernal Pools, Meadows, and Other Herb Communities	9,162	4	9,063	4
	Bog and Marsh	303	0	303	0
	Riparian and Bottomland Habitat	5,446	2	3,293	1
	Forest	15,476	7	15,496	7
	Woodland	10,814	5	10,762	5
	Grand Total	225,805	100	225,807	100
Miramar System		**2015**		**2010**	
Watershed	Vegetation Category	**Acres**	**% Area**	**Acres**	**% Area**
Miramar	Scrub and Chaparral	232	36	232	36
	Disturbed or Developed Areas	258	40	405	63
	Grasslands, Vernal Pools, Meadows, and Other Herb Communities	10	2	10	2
	Riparian and Bottomland Habitat	147	23	0	0
	Grand Total	647	100	647	100
Hodges System		**2015**		**2010**	
Watershed	Vegetation Category	**Acres**	**% Area**	**Acres**	**% Area**
Hodges	Scrub and Chaparral	71,982	46	72,003	46
	Disturbed or Developed Areas	44,204	28	45,539	29
	Grasslands, Vernal Pools, Meadows, and Other Herb Communities	14,774	9	14,773	9
	Bog and Marsh	259	0	259	0
	Riparian and Bottomland Habitat	5,213	3	4,041	3
	Forest	120	0	120	0
	Woodland	21,476	14	21,298	13
	Grand Total	158,028	100	158,033	100

The description of the different plant communities found in the watershed (Sawer and Keeler-Wolf classification, 1995) and their respective response to fire is from the 2003 Southern California Fires Burned Area Emergency Stabilization and Rehabilitation Plan prepared by: Interagency Burned Area Emergency Response Team in November, 2003. For an in depth list of vegetation potentially found within the local source water system see **Appendix 2 (see page, A2-1)**.

Oak Woodlands

- *Vegetation Types:*
  Oak woodlands typically occur in the foothills and transition into mixed conifer/oak woodlands at higher elevations. Each community type can vary from open savannas in broad valleys and rolling hills, to dense woodlands in canyons and along streams. Oak woodlands are dominated by live oak tree species that include Black Oak, Coast Live Oak, Engelmann Oak, and Canyon Live Oak.
- *Response to Fire:*
  Oak woodlands have evolved with fire. Dense woodlands typically experience infrequent stand destroying fires. Oak trees that experience some canopy fire often survive unless the ground fire temperature is extreme enough to kill the root system. The complex of species associated with dense oak woodlands will either re-sprout or germinate from seed. Frequent or hot fires can affect the seed bank and the root system of Oak Woodland species, resulting in degraded habitat that is susceptible to habitat conversion.

Eucalyptus Woodland

- *Vegetation Types:*
  Eucalyptus Woodland is a non-native closed canopy community. This community is typically a monotypic stand of Eucalyptus trees with a thick mulch of Eucalyptus tree leaves.
- *Response to Fire:*
  Eucalyptus stands can be fire retardant to low intensity fires. Low intensity fires will consume the leaf litter and can be carried into the canopy where leaves are singed or tops are burned. High intensity fires are typically stand destroying.

Forests

- *Vegetation Types:*
  Coniferous forests occur in the lower to upper montane zone in the Peninsula Ranges. The lower montane forests typically include the Southern Interior

Cypress Forest, which is intermixed with oak woodlands and chaparral. Upper montane forests include Coulter Pine Forest, Jeffery Pine Forest, and mixed Sierran Forest. They range from pure stands of a single species, to mixed conifer forests intermixed with oak woodlands and chaparral.

- *Response to Fire:*
  Montane forests are typically surrounded by chaparral or adjacent to forests subject to fire, and are therefore susceptible to fire. When fires occur more frequently than twenty-five years, Coulter pine habitat may convert to chaparral. Jeffery Pine Forests and Mixed Coniferous Forests historically experience periodic low-to-moderate intensity fires in the understory. Fuel buildup due to fire suppression can increase the risk of stand replacing crown fires.

Chaparral

- *Vegetation Types:*
  Chaparral occurs throughout the coastal lowlands, foothills, and montane region. This community typically forms a dense, almost impenetrable shrub community with no herbaceous layer. Chaparral is a highly variable plant community that includes Chamise Chaparral, Coastal Sage-Chaparral Scrub, Mixed Chaparral, Montane Chaparral, Semi-desert Chaparral, and Scrub Oak Chaparral.
- *Response to Fire:*
  Chaparral is a fire adapted community, that stump sprouts or germinates from seed after a low-to-moderate intensity burn. Large fires often result in homogenous stands of chaparral. Frequent fires or hot fires can burn the root systems and surface seed banks, resulting in a loss of diversity and can lead to low-density vegetative communities. For a few years after a fire, annual forbes germinate and establish on site, until the woody shrubs mature.

Coastal Sage Scrub

- *Vegetation Types:*
  Locally, Coastal Sage Scrub consists of low, woody soft-shrubs and is classified as Diegan Coastal Sage Scrub (DCSS). DCSS is dominated by California sagebrush and/or flat-topped buckwheat and often intergrades with Chaparral communities.
- *Response to Fire:*
  DCSS species are fire adapted and quickly regenerate from seed after a fire. However, frequent fires in an area can reduce the seed bank for native shrub species and increase the presence of non-native grasses and forbs resulting in degraded habitat. Once this habitat conversion occurs, DCSS species typically do not re-colonize the area due to competition from dense populations of invasive grasses that increase the fire frequency.

Big Sagebrush Scrub

- *Vegetation Types:*
  Locally, big sagebrush is dominated by flat-topped buckwheat, broom snakeweed, deer weed, saw-toothed golden brush, and a variety of DCSS species.
- *Response to Fire:*
  The fire ecology of Big Sagebrush Scrub in eastern San Diego County is not well documented. Many of the species in this community occur in DCSS and are fire adapted. Frequent fires in the vegetative community will result in habitat conversion to non-native grasslands.

Grasslands

- *Vegetation Types:*
  Perennial Grasslands vary among Valley Needle grass and Valley Sacaton grasslands. Valley Needle Grassland is dominated by the tussock forming purple needle grass with a variety of native forbs including colar lupin, rancher's fireweed, and adobe popcorn-flower; and the native bunchgrasses, foothill needle grass, and coast range melic. The species composition can vary as it transitions into the foothills and montane zone. Valley Sacaton Grassland is dominated by sacton or salt grass. This community typically occurs in the areas with a high seasonal water table and is often associated with Alkali Seeps and Alkali Meadows. Non-native grasslands are dominated by Red brome, Ripgut brome, and Softchess brome. Non-native grasslands often intergrade with open oak woodlands and disturbed DCSS communities.
- *Response to Fire:*
  Grassland communities in San Diego County have evolved with, and are typically maintained by fire. Fire in non-native grasslands results in a continued dominance by invasive grasses, and prevents reestablishment by native shrub species.

Meadows

- *Vegetation Types:*
  Montane Meadows occur in the montane zone and are dense growths of sedges and perennial herbs that experience wet cold winters. Montane Meadows are typically interspersed with montane forests. Wildflower Field is an amorphous community of herbaceous plant species where dominance varies from site to site and year to year, depending on climatic factors. Wildflower Field is typically associated with grasslands and oak woodlands in the valleys and foothills.
- *Response to Fire:*
  Wet meadows typically do not burn since the moisture content in the plants and soils retards fire advance. During drought times and in dry meadows fire will quickly burn through these communities. Fall fires typically have little impact on local meadows since most plants are dry and have dispersed their seed.

Riparian

- *Vegetation Types:*
  Riparian communities vary depending on the aquatic system they are associated with and can have seral stages of community succession. Mulefat Scrub and Southern Willow Scrub are typically early seral stages for Southern Cottonwood-Willow Riparian Forest, which develops into Southern Coast Live Oak Riparian Forest. In steep drainages, Mulefat Scrub and Southern Willow Scrub may be early stages for Southern Sycamore-Alder Riparian Forest or White Alder Riparian Forest.
- *Response to Fire:*
  Riparian communities often resist fire since they are not as susceptible to drought. During drought, riparian species become more vulnerable to fire. Stand destroying fires can assimilate flooding events in that they set communities back to early seral stages. Stump sprouting species can reestablish in the early successional communities. Most mature trees that experience high intensity fires will die.

Wetlands

- *Vegetation Types:*
  Wetland communities are highly variable. Riparian and Wet Meadows are communities that can establish in areas with sufficient hydrology to be considered wetlands. In addition, emergent wetlands occur along seeps and as emergent wetlands in shallow water. These wetlands include Alkali Seep, Freshwater Seep, and Freshwater Marsh.

- *Response to fire:*
  Historically, fire impacts to wetlands in San Diego County are not documented. Wetlands typically do not experience fire. Many wetland species are rhizomous and will likely survive fires. Woody species in scrub and forested wetlands may recover from fire by epicormic sprouting from stems or basal sprouting from roots.

Wildlife

A diverse assemblage of wildlife species including; reptiles, birds, and mammals are commonly found within the boundaries of the local source water system. Many species are common to both upland and lowland areas occurring form sea level to the mountains where suitable habitat is available. Few of the terrestrial mammals of southern California are dependent on wetland habitats; however, some are more common along streams than in upland areas. Many birds are adapted to life on open water, and in or adjacent to wetland habitats. These include numerous species of waterfowl and wading birds. Most amphibians are also associated with temporary or permanent sources of water. The fishes associated with southern California streams and reservoirs are primarily warm-water fishes. For an in depth list of wildlife potentially found within the local source water system see **Appendix 3 (see page A3-1)**.

Land Ownership and Population

Land ownership (**Table 3.4**) and population (**Table 3.5**) are indicators of current and future potential levels of human disturbance within an area. These effects accumulate from a variety of outdoor human activities arising from too many people using a finite land resource and are generally in the form of development and the overuse of open spaces. Land areas with small population densities are usually rural areas with natural landscapes that trap rainwater and allow it to filter slowly into the ground. In contrast, large population densities are associated with urbanized areas. Development can result in vegetation modification and increased impervious surface area with a resulting modification to runoff amounts, velocities, and patterns. Urbanization also increases the variety and amount of pollutants carried into streams, rivers, and lakes. The overuse of open spaces by increased recreational use causes erosion from vegetation removal, foot traffic, and off road vehicle activity.

Table 3.4 - Land Ownership within Local Source Water System Boundaries
SanGIS; retrieved 2010 & 2015

San Diego River System

Watershed	Ownership Category	2015 Acres	2015 % Watershed	2010 Acres	2010 % Watershed
El Capitan	Public Agencies	81,628	68	81,570	68
	Private	38,710	32	38,768	32
	City of San Diego	3,987	3	3,995	3
Murray	Public Agencies	939	41	940	41
	Private	1,359	59	1,358	59
	City of San Diego	592	26	592	26
San Vicente	Public Agencies	25,470	53	21,010	44
	Private	22,154	47	26,614	56
	City of San Diego	3,851	8	3,850	8
Sutherland	Public Agencies	17,840	52	17,704	51
	Private	16,713	48	16,849	49
	City of San Diego	1,984	6	1,984	6
San Diego River System	Public Agencies	125,877	61	121,224	59
Grand Total	Private	78,936	39	83,589	41
	City of San Diego	10,414	5	10,421	5

Table 3.4 – Land Ownership within Local Source Water System Boundaries (contd)

SanGIS retrieved, 2010 & 2015

Otay-Cottonwood System

		2015		2010	
Watershed	Ownership Category	Acres	% Watershed	Acres	% Watershed
Barrett	Public Agencies	73,585	88	73,207	88
	Private	9,673	12	10,051	12
	City of San Diego	3,905	5	3,947	5
Dulzura	Public Agencies	3,522	50	3,527	50
	Private	3,570	50	3,565	50
	City of San Diego	875	12	875	12
Morena	Public Agencies	62,064	84	62,061	84
	Private	11,478	16	11,481	16
	City of San Diego	3,204	4	3,204	4
Otay	Public Agencies	30,274	49	29,615	48
	Private	31,747	51	32,406	52
	City of San Diego	3,181	5	3,199	5
Otay-Cottonwood System Grand Total	Public Agencies	169,445	75	168,410	75
	Private	56,468	25	57,503	25
	City of San Diego	11,165	5	11,225	5

Miramar System

		2015		2010	
Watershed	Ownership Category	Acres	% Watershed	Acres	% Watershed
Miramar	Public Agencies	459	71	459	71
	Private	186	29	186	29
	City of San Diego	459	71	459	71

Hodges System

		2015		2010	
Watershed	Ownership Category	Acres	% Watershed	Acres	% Watershed
Hodges	Public Agencies	56,980	36	52,907	33
	Private	101,301	64	105,374	67
	City of San Diego	21,093	13	21,082	13

Table 3.5 - Population within Local Source Water System Boundaries

SanGIS, retrieved 2010; U.S. Census Bureau, retrieved 2015

San Diego River System

Watershed		2015 (Estimated) Total Population	2015 (Estimated) % Population	2015 (Estimated) Density	2010 Total Population	2010 % Population	2010 Density	Acres	% Area
El Capitan	County of San Diego	5,938	32	<1	5,634	32	<1	107,578	89
	Alpine	11,585	62	1	10,991	62	1	10,293	9
	Harbison Canyon	164	1	23	156	1	22	7	0
	Julian	601	3	<1	570	3	<1	2,009	2
	San Diego Country Estates	390	2	1	370	2	1	444	0
	Total	18,678	100	<1	17,721	100	<1	120,331	100
Murray	El Cajon	759	3	9	720	3	9	82	4
	La Mesa	4,126	18	43	3,915	18	41	96	4
	San Diego	18,335	79	9	17,396	79	8	2,114	92
	Total	23,221	100	10	22,031	100	10	2,292	100
San Vicente	County of San Diego	4,509	31	<1	4,278	31	<1	35,983	75
	Poway	0	0	0	0	0	0	587	1
	Ramona	455	3	1	432	3	<1	885	2
	San Diego Country Estates	9,762	66	1	9,262	66	1	10,267	22
	Total	14,726	100	<1	13,972	100	<1	47,722	100
Sutherland	County of San Diego	857	100	<1	813	100	<1	34,548	100
	Total	857	100	<1	813	100	<1	34,548	100

Table 3.5 - Population within Local Source Water System Boundaries (contd)

SanGIS, retrieved 2010; U.S. Census Bureau, retrieved 2015

San Diego River System Grand Totals	County of San Diego	11,304	20	<1	10,725	20	<1	178,109	87
	Alpine	11,585	20	1	10,991	20	1	10,293	5
	El Cajon	759	1	9	720	1	9	82	0
	Harbison Canyon	164	0	23	156	0	22	7	0
	Julian	601	1	<1	570	1	<1	2,009	1
	La Mesa	4,126	7	43	3,915	7	41	96	0
	Poway	0	0	0	0	0	0	587	0
	Ramona	455	1	1	432	1	<1	885	0
	San Diego	18,335	32	9	17,396	32	8	2,114	1
	San Diego Country Estates	10,152	18	1	9,632	18	1	10,711	5
	Total	57,482	100	<1	54,537	100	<1	204,893	100
Otay-Cottonwood System									
		2015 (Estimated)			2010				
Watershed		Total Population	% Population	Density	Total Population	% Population	Density	Acres	% Area
Barrett	County of San Diego	3,464	69	<1	3,287	69	<1	78,591	94
	Pine Valley	1,582	31	<1	1,501	31	<1	4,659	6
	Total	5,047	100	<1	4,788	100	<1	83,250	100
Dulzura	County of San Diego	1,359	100	<1	1,289	100	<1	7,026	100
	Total	1,359	100	<1	1,289	100	<1	7,026	100
Morena	County of San Diego	1,351	70	<1	1,282	70	<1	73,536	100
	Pine Valley	571	30	44	542	30	42	13	0

	Total	1,922	100	<1	1,824	100	<1	73,549	100
Otay	County of San Diego	3,539	54	<1	3,358	54	<1	54,113	87
	Chula Vista	180	3	<1	171	3	<1	1,837	3
	Jamul	2,874	44	<1	2,727	44	<1	6,025	10
	Total	6,594	100	<1	6,256	100	<1	61,975	100
Otay-Cottonwood System	County of San Diego	9,714	65	<1	9,216	65	<1	213,266	94
Grand Totals	Chula Vista	180	1	<1	171	1	<1	1,837	1
	Jamul	2,874	19	<1	2,727	19	<1	6,025	3
	Pine Valley	2,153	14	<1	2,043	14	<1	4,672	2
	Total	14,921	100	<1	14,157	100	<1	225,800	100

Hodges System

Watershed		2015 (Estimated)			2010				
		Total Population	% Population	Density	Total Population	% Population	Density	Acres	% Area
Hodges	County of San Diego	22,312	19	<1	21,169	19	<1	119,041	75
	Escondido	23,211	20	4	22,022	20	4	5,632	4
	Poway	12,836	11	1	12,178	11	1	9,011	6
	Ramona	16,538	14	2	15,691	14	2	8,719	6
	San Diego	37,701	33	2	35,769	33	2	15,845	10
	San Diego Country Estates	2,258	2	87	2,142	2	82	26	0
	Total	114,855	100	1	108,971	100	1	158,274	100

Table 3.5 - Population within Local Source Water System Boundaries (contd)

SanGIS, retrieved 2010; U.S. Census Bureau, retrieved 2015

Miramar System

Watershed		2015 (Estimated) Total Population	2015 (Estimated) % Population	2015 (Estimated) Density	2010 Total Population	2010 % Population	2010 Density	Acres	% Area
Miramar	San Diego	6,405	100	10	6,077	100	9	645	100
	Total	6,405	100	10	6,077	100	9	645	100

Aquatic Invasive Species

In California, the spread of invasive species has threatened the biodiversity of native plant and wildlife and the quality and quantity of water supplies. The term “invasive species” refers to non-native (i.e., exotic) pests and diseases that are likely to cause agricultural, environmental, economic harm, or be harmful to food safety and human health. They also raise maintenance costs for roads, public lands, and waterways.

The duration, rate of spread and extent of invasion determine the feasible response. Nevertheless, pest control measures are not without controversy, whether they be mechanical removal, depopulation, application of chemical pesticides, introduction of predatory or disease causing “biocontrol” organisms, genetic engineering for pest resistance, or regulatory imposition of quarantines and the requirement of pest-free certification and permits for export, import or local transport. However, a policy of preemptive surveillance and exclusion rather than reactive adaptation would likely minimize the long-run costs associated with invasive species.

California’s waterways are vulnerable to the introduction of invasive species from multiple sources and damage to the water transfer system could impact irrigation and urban water supplies. Aquatic Invasive Species (AIS) includes both aquatic plant and aquatic animal species. Invasive aquatic plants are introduced plants that have adapted to living in, on, or next to water, and that can grow either submerged or partially submerged in water. Invasive aquatic animals require a watery habitat, but do not necessarily have to live entirely in water.

Aquatic invasive species found in the CSD reservoirs:

- D*reissena bugensis*
  Quagga mussel, *Dreissena bugensis*, is a freshwater mussel whose ability to rapidly colonize hard surfaces causes serious economic problems. These major biofouling organisms can clog water intake structures, such as pipes and screens, therefore reducing pumping capabilities for power and water treatment plants, causing increased costs to industries, companies, and communities. Recreation-based industries and activities have also been impacted; docks, break walls, buoys, boats, and beaches have all been heavily colonized. Many of the potential impacts of *Dreissena* are unclear due to the limited time scale of North American colonization. In response to the detection of Quagga mussels in Lake Mead and the Colorado Aqueduct, the CSD Public Utilities Department initiated a *Dreissena* veliger (planktonic life stage) monitoring program and updated its settled adult monitoring program. This Response and Control Plan was prepared to satisfy the CSD's obligation under Fish and Game Code 2301 and 2302.
- *Corbicula fluminea:*
  Asian clam, *Corbicula fluminea,* is a freshwater clam that has caused millions of dollars in damage to intake pipes used by power, water, and other industries. In addition, the introduction of C. fluminea has caused many populations of native clams to decline due to competition for food and space. C. fluminea requires well-oxygenated waters and prefers fine, clean sand, clay, and coarse sand substrates. Introduction and spread of this species is caused when it is attached to boats or carried in ballast water, used as bait, sold through the aquarium trade, and carried with water currents.
- *Pomacea canaliculata;*
  Channeled apple snail, *Pomacea canaliculata,* is a freshwater snail with a voracious appetite for water plants including lotus, water chestnut, taro and rice. Introduced widely from its native South America by the aquarium trade and as a source of human food, it is a major crop pest in south-east Asia (primarily in rice) and Hawaii (taro) and poses a serious threat to many wetlands around the world through potential habitat modification and competition with native species.
- *Myriophyllum spicatum:*
  Eurasian water-milfoil, *Myriophyllum spicatum,* is a submerged aquatic plant that can rapidly colonize a pond, lake or area of slow-moving water. It creates dense mats of vegetation that shades out other native aquatic plants, diminishes habitat and food resource value for fish and birds, and decreases oxygen levels in the water when the plant decays.

Biological Hazards and Contaminants

Ecosystem Degradation

Ecosystems perform services pertinent to water quality, flood protection, water storage, and decomposition of organic wastes. The health and biodiversity of ecosystems depends on the maintenance of high-quality habitat. Habitat provides essential food, cover, migratory corridors, and breeding/nursery areas for a broad array of organisms. Ecosystems can be damaged through change or degradation in structure, function, composition, or a loss of habitat. Degradation can encourage the establishment of invasive species; alter the natural flow regimes of tributaries, increase runoff of sediments, nutrients, pathogens, and toxins causing significant effects to the water quality and distribution of living organisms in the receiving waters.

- *Anthropogenic source:*
  Ecosystem degradation is usually caused by overuse of a resource due to overpopulation, pollution, or over-exploitation related to development, agriculture, industry, and recreation.

Habitat Loss

Habitat destruction involves outright loss of areas used by wild species due to removal of vegetation and erosion. Plants and other sessile organisms in these areas are usually directly destroyed. Mobile animals (especially birds and mammals) retreat into undisturbed areas of habitat.

Habitat fragmentation invariably involves some amount of habitat destruction. Fragmentation occurs when native species are squeezed onto small patches of undisturbed land surrounded by disturbed areas. Habitat fragments are rarely representative samples of the initial landscape. The remaining habitat fragments are smaller than the original habitat; therefore, this can lead to crowding effects and increased competition. Species that can move between fragments may use more than one fragment. Species which cannot move between fragments must survive utilizing resources available in the single fragment.

- *Anthropogenic source:*
  Habitat loss is generally due to the conversion of open land to commercial development and agriculture.

Nutrients

Nutrients such as nitrogen and phosphorus are necessary for growth of plants and animals and support a healthy aquatic ecosystem. In excess, however, eutrophication or nutrient enrichment of the water body can occur resulting in an abundance of phytoplankton, cyanobacteria, and other aquatic plants. When the increased mass of organic matter subsequently dies and decomposes it can release toxins (cyanotoxins) and deplete the dissolved oxygen content of the water. The condition where dissolved oxygen is less than 2 parts per million is referred to as *hypoxia*. Many species are likely to die below that dissolved oxygen level as the dissolved oxygen level of healthy waters is 5 or 6 parts per million. Under reduced oxygen conditions, foul odors are generated, fish populations are adversely affected, and the aesthetic quality and recreational value of the water is reduced.

- *Anthropogenic sources:*
  Nutrient sources include sewage discharges, urban and agricultural stormwater runoff, erosion, pet and livestock wastes, atmospheric deposition originating from power plants or vehicles, and groundwater discharges.
- *Health Effects:*
  Acute exposure to nitrates and nitrites through ingestion increases the risk of developing methemoglobinemia. Chronic exposure through ingestion may potentially increase the risk of developing certain cancers and birth defects.

Pathogens

Pathogens are disease-causing organisms that are typically found in animal waste. Humans, pets, livestock, and wildlife species may act as potential sources of contaminants by spreading waterborne pathogenic bacteria, viruses, and protozoa such as *Giardia* cysts and *Cryptosporidium* oocysts. Numerous species of waterfowl and wading birds may be considered a source of pathogenic bacteria contamination as they can introduce fecal matter directly into the surface waters.

- *Anthropogenic source:*
  Pathogen sources include sewage discharges, urban and agricultural stormwater runoff, erosion, pet and livestock wastes.
- *Health effects:*
  Pathogens may cause diseases that range in severity from mild gastroenteritis and viral infections to potentially life-threatening ailments such as giardaiasis, cryptosporidiosis, cholera, dysentery, infectious hepatitis, and severe gastroenteritis.

Toxins

Toxins can damage an aquatic ecosystem by contaminating the water and food chain. Toxic substances and compounds including metals, cyanotoxins, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides can alter aquatic habitat, harm animal health, reduce reproductive potential, render many fish unsuitable for human consumption due to bioaccumulation, and make recreational areas unsafe and unpleasant.

- *Anthropogenic sources:*
  Sources of toxins include sewage discharges, urban and agricultural stormwater runoff, industrial discharges, and atmospheric deposition originating from power plants or vehicles.
- *Health effects:*
  Toxins can be carcinogenic to humans, cause acute and chronic illnesses along with organ damage.

Harmful Algae Blooms (HABs)

Cyanobacteria, also known as blue-green algae, naturally occur in fresh waters. Under certain environmental conditions, cyanobacteria can rapidly increase in number producing a cyanobacterial bloom. Excessive nutrient loads and concentrations are a major contributing factor to the increased occurrence of cyanobacterial bloom formation in water bodies.

A number of cyanobacteria species are capable of producing toxins, called cyanotoxins, which can pose health risks to humans and animals. Blooms producing toxins are often referred to as HABs. The prevalence and duration of HABs in freshwater is expanding in the United States. The water quality, human health and socioeconomic impacts of HABs can be significant.

- *Anthropogenic sources:*
  Nutrient sources include sewage discharges, urban and agricultural stormwater runoff, erosion, pet and livestock wastes, atmospheric deposition originating from power plants or vehicles, and groundwater discharges.
- *Health Effects:*
  Cyanotoxins can impact the liver, kidney and nervous system functions

Introduced Species

Intentional or accidental introduction of invasive species may often result in unexpected ecological and economic impacts to the environment. Through predation and competition, introduced species have contributed to the eradication of some native populations and drastically reduced others; fundamentally altering the food web. Overpopulation of some introduced herbivorous species has resulted in vegetation loss, altered water tables, modified nutrient cycles or soil fertility, increased erosion, and introduced pathogens.

- *Anthropogenic sources:*
  Sources of invasive species include commercial land development, agriculture, and recreation.

3.4 Watershed Improvements

Otay Watershed

Proctor Valley ORV Barrier:

In 2010, under partial funding from a TransNet grant, CSD installed a steel pipe barrier along 1.3 miles of Proctor Valley Road to exclude off road vehicles. The pipe barrier was fashioned after a barrier used by the US Forest Service and installed on both sides of the road. In subsequent years additional barriers were installed on CA Department of Fish Wildlife and US Fish and Wildlife properties adjacent to Proctor Valley Road. Today, approximately 3.4 miles of Proctor Valley road has a barrier that protects watershed land from illegal off road vehicles.

Acquisition for Source Water Protection:

The Public Utilities acquired a five acre parcel in Proctor Valley from a private land owner. This parcel will be restored to its natural coastal sage scrub habitat and provide additional source water protection. The restoration will reduce impacts associated with rural living such as septic leaching, livestock disturbance, grading, and soil compaction.

Vernal Pool Restoration:

The Proctor Valley Vernal Pool Project restored and enhanced six acres of vernal pools and sensitive upland watershed habitat in Proctor Valley. The project will benefit the City of San Diego MSCP Cornerstone Land and boost the valley's habitat value.

Stream Restoration:

In 2008, Public Utilities and River Partners submitted an application for Urban Streams Restoration Program (USRP) grant funds under California's Proposition 84. In April 2012, the project was conditionally awarded $909,700. In January 2013 the project was submitted to the state's Environmental Enhancement and Mitigation Program (EEMP), and is in line to receive $300,000. The project was awarded $18,000 by the San Diego Foundation. The project proposes restoration along five small urban streams and in the main drainage to Upper Otay Reservoir, totaling nearly 6,900 linear feet of streambed over 101 acres. Using the grant money, River Partners will remove invasive plants and establish healthy riparian and upland plant communities along and adjacent to the streams, for the purpose of creating high quality habitat. An ancillary benefit will be that the restored drainages will attenuate urban runoff flows and remove pollutants; thus, helping to protect water quality in the City's source water system.

Tactical Air Operations:

In a recent renewal of the Tactical Air lease the overall footprint of the lease was reduced to protect water quality in the reservoir. The reduction in size pulled the footprint back from the reservoir's HWL. Other source water protection components include mandatory full volume containment of fuel tanks and secondary containment of toilet and wastewater tanks.

Other Work in the Otay Catchment:

Another TransNet grant paired the San Diego County Department of Parks & Recreation and River Partners to remove invasive plant infestations of giant reed (*Arundo donax*), tamarisk (*Tamarix parviflora*), and castor bean (*Ricinus communis*) on 55 acres. The team also developed a native plant design and site management plan for the habitat restoration work. The site is located north of SR 94, east of Honey Springs Road, just west of Dulzura.

Hodges Watershed

Institute for Conservation Research (ICR):

ICR is currently restoring around 20 acres between four sites at Hodges Reservoir. The restoration will benefit coastal sage habitat and provide source water protection of sites affected by the 2007 wildfires.

Del Dios Habitat Preservation League:

The Public Utilities Department partnered with the Del Dios Habitat Protection League and Friends of Los Peñasquitos Canyon to remove eucalyptus trees and other invasive and non native plants around Hodges Reservoir since 2010. In August of 2014, the Natural Resources Conservation Service awarded a $250,000 grant to the Friends of los Peñasquitos Canyon Preserve for the purpose of removing large eucalyptus, palm trees, pepper trees, Arundo, and acacia within a 90 acre project area around the reservoir. A significant project benefit will be that the restored drainages around the reservoir will attenuate urban runoff flows and remove pollutants, thus, helping to protect water quality in the City's reservoir.

Weed Management in SPV:

In 2010 the City applied for and was awarded a TransNet grant to develop an Integrated Weed Management Plan for the San Pasqual Valley. Since then we have controlled nearly 2,000 tamarisk, 20 tree tobacco, 24 fan palms, 1 Canary Island palm, 40 castor bean, and 0.5 acre of Lepidium in Santa Maria Creek.

Santa Ysabel Creek Barrier:

Recently, large boulders were placed along Santa Ysabel creek crossing in SPV to exclude ORV activity in the stream bed. The boulders are a temporary solution and will be removed before the winter rains to allow for full stream flow.

Sutherland Reservoir:

In 2012 a concerted effort was made to exclude livestock (cattle and horses) from City land surrounding the reservoir by installing a fence around three-quarters of the site where animal access was identified. As a result, there are no longer cattle and horses on the reservoir buffer, nor in the reservoir.

3.5 Special Studies

Otay Tracer Study

The City of San Diego Public Utilities Department conducted two tracer studies at Otay Reservoir in support of the City's indirect potable reuse reservoir augmentation projects. The results of the tracer studies will be used to validate the performance of a three-dimensional hydrodynamic model of Otay Reservoir. The model, in turn, will be used to assess retention, blending, and dilution of purified water in the reservoir.

The tracer chemical used in these studies was elemental lanthanum, which will be added to the reservoir as an acid salt.

There were two separate tracer studies at Otay Reservoir, one in March 2014 and the second in July 2014. Each study will have a separate release of lanthanum into the reservoir.

The amount of lanthanum added for each study was calibrated to yield a fully-mixed concentration of 1.0 µg/l. That is to say, with the lanthanum uniformly dispersed throughout the entire volume of the reservoir the concentration will be 1.0 µg/l. For the winter tracer study, with a reservoir volume of 35,300 AF [44 x 10^9 L], 44 kg [88 pounds] of elemental lanthanum was added to give a fully-mixed concentration of 1.0 µg/l. For the summer study the reservoir was somewhat drawn down; thus, a smaller amount of tracer was added to achieve the fully-mixed concentration of 1.0 µg /l. For the summer tracer study, with a reservoir volume of 31,000 AF [38 x 10^9 L], 38 kg [76 pounds] of elemental lanthanum will be added.

The lanthanum tracer was added to the surface of the reservoir over a one-hour period. The point of release was at the far north end of the reservoir 3,000 meters [1.9 miles] from the reservoir outlet. In both the winter and summer study, the open outlet [i.e., the outlet delivering water to the Otay Treatment Plant] was deep in the reservoir approximately 30 feet below the surface. After release, the lanthanum dispersed across the span of the reservoir, reaching the furthest points in the reservoir in two to four weeks

Samples were collected from the reservoir at mid-lake stations, and from reservoir inflows and outflows. Samples were analyzed for lanthanum by Inductively-Coupled Plasma Mass Spectrometry [ICPMS], with a detection limit of 0.1 µg/l.

Lanthanum has been assessed by NSF International as a drinking water treatment additive. NSF provides a drinking water action level for lanthanum that is supportive of public health, with a total allowable concentration of 4,000 µg/l [4 mg/l]. This allowable concentration is three orders of magnitude greater than the concentrations that was seen in Otay Reservoir.

Fish as biocontrol agents: An integrated pest management tactic worth considering for quagga mussels?

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The quagga mussel, *Dreissena bugensis*, is a devastating aquatic pest that recently invaded the western United States. Many existing mussel control methods are problematic for infested systems in the west because these systems serve as primary water sources for humans. To address this problem, we investigated the efficacy of using resident fishes as biocontrol agents for managing quagga mussels. We conducted field experiments to test whether planktivorous bluegill sunfish, *Lepomis macrochirus*, reduced mussel infestations on substrates of varying orientations and water depths through predation on larval mussels. We also conducted an experiment to evaluate whether the carnivorous redear sunfish, *Lepomis microlophus*, reduced mussel infestations on substrates of varying orientations with and without established mussel populations through the predation of juvenile and adult mussels.

Bluegills significantly reduced mussel populations on all substrates and at all depths through predation on larvae and small, juvenile mussels. Redear sunfish reduced juvenile and adult mussel populations, but consumption varied among individuals and with substrate orientation. Our results indicate that fishes may represent effective site-specific biocontrol agents for quagga mussels. As such, biological control should be considered when developing an integrated pest management strategy for quagga, and potentially zebra, mussels.