RAYMOND BASIN
SALT AND NUTRIENT MANAGEMENT PLAN

FINAL DRAFT

RAYMOND BASIN MANAGEMENT BOARD

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EXECUTIVE SUMMARY

The State Water Resources Control Board approved Resolution No. 2009-0011 to adopt the Recycled Water Policy in February 2009. Included in that resolution is a requirement for a Salt and Nutrient Management Plan (SNMP) to be prepared for all groundwater basins. The Raymond Basin Management Board is the lead agency for the preparation of the Raymond Basin SNMP. The primary stakeholders include the Metropolitan Water District of Southern California, the Los Angeles County Sanitation Districts, and the Los Angeles County Department of Public Works.

The SNMP reviewed the geology, hydrology and hydrogeology of the Raymond Basin, along with the institutional and management structure for the Raymond Basin. TDS, Nitrate, Sulfate, and Chloride were identified as the primary constituents of concern. Sources of loading (precipitation, subsurface inflow, infiltration of applied water, storm runoff and untreated imported water replenishment) and unloading (groundwater pumping and subsurface outflow) were included in a spreadsheet computer model, along with average water quality data for TDS, Nitrate, Sulfate, and Chloride, on an annual basis. The Raymond Basin Management Board developed this spreadsheet model as a tool to calculate the impacts of loading and unloading from numerous water supply components.

The SNMP determined the assimilative capacity of the primary constituents of concern and evaluated hypothetical groundwater replenishment projects in order to determine the loadings and impacts resulting from the projects. The loading and unloading calculations were performed for each of the three subareas (Monk Hill, Pasadena, and Santa Anita) of the Raymond Basin. The assimilative capacity was also determined for each subarea. The Recycled Water Policy sets an interim goal that no single project is to use more than 10 percent of the available assimilative capacity, or combination of projects to use more than 20 percent of the available assimilative capacity. Consequently, as part of this SNMP, the antidegradation analysis calculated the collective amount of water from potential future projects that could be replenished in the Basin

without exceeding the very conservative value of 10 percent of the available assimilative capacity.

Using the assimilative capacity assessment tool and conservatively assuming a water quality similar to recycled water, the maximum annual recharge of new water allowed before exceeding 10 percent of the assimilative capacity was determined for each subarea in the Basin. Table III.18 indicates that approximately 225 acre-ft per year of new water with a particular quality would use 10 percent of the available assimilative capacity for TDS and the Monk Hill Subarea. Table III.19 indicates that approximately 405 acre-ft per year of new water with a particular quality would use 10 percent of the available assimilative capacity for sulfate in the Pasadena subarea. Table III.20 indicates that approximately 245 acre-ft per year of new water with a particular quality would use 10 percent of the available assimilative capacity for sulfate in the Santa Anita subarea.

The Raymond Basin has been managed for many decades by the Raymond Basin Management Board, in conjunction with other stakeholders, in order to control salt and nutrient loading to preserve the high quality groundwater supplies. The SNMP acknowledges the historical practice of replenishing the Raymond Basin with stormwater runoff which has high quality water, particularly regarding TDS. Existing programs include support of stormwater runoff replenishment conducted by LACDPW and a water quality monitoring program conducted by area water purveyors.

The Raymond Basin has experienced unprecedented drought conditions since calendar year 2006. As a result, the groundwater elevation in the three subareas has decreased. Since 1943, when the Raymond Basin was adjudicated, to present, the RBMB has actively managed water quality through existing implementation measures. Nonetheless, the SNMP acknowledges increasing water quality trends in the Monk Hill and Pasadena subareas. The SNMP identifies a variety of existing and potential implementation measures including continued basin management practices; pursuit of potential new replenishment sites; water quality monitoring; and coordination between agencies which will help manage salts and nutrients in the Raymond

Basin.

The implementation of the SNMP will satisfy the requirements of the Recycled Water Policy by providing a framework for the long-term management of salts and nutrients in the Raymond Basin, while encouraging and allowing for increased use of recycled water areas.

CHAPTER I

INTRODUCTION

In February 2009, the State Water Resources Control Board of the State of California (State Water Board) approved the Resolution No. 2009-0011 adopting the Recycled Water Policy (Policy), as shown in Appendix A, to encourage the use of recycled water from municipal wastewater sources as a safe alternative source of water supply while complying with Resolution No. 68-16 to *"achieve the highest water quality consistent with maximum benefit to the people of the State."* The goal of this Policy is to increase the use of recycled water over 2002 levels by at least one million acre-feet per year (af/yr) by 2020 and at least two million af/yr by 2030. Recognizing that some groundwater basins in the state contain salt and nutrients that exceed or threaten to exceed water quality objectives established in the Water Quality Control Plans (Basin Plans), and that not all Basin Plans include adequate implementation procedures for achieving or ensuring compliance with the water quality objectives for salt and nutrients, the State Water Board determined that the appropriate way to address salt and nutrient issues is through the development of regional or sub-regional salt and nutrient management plans (SNMPs) rather than through imposing requirements solely on individual recycled water projects. The SNMP development process should include compliance with the California Environmental Quality Act (CEQA) and participation by Regional Water Boards' staff, and the Plans should be submitted to the appropriate Regional Water Board within five years from the effective date of the Policy, i.e. May 14, 2014. The Raymond Basin Management Board (RBMB) has received an extension to submit the Raymond Basin SNMP by May, 2015. The Policy requires Regional Water Boards to review the plans and consider each for adoption as basin plan amendments within one year of submittal.

In accordance with the Policy, a science advisory panel (Panel) was convened to provide guidance on future actions related to monitoring constituents of emerging concerns (CECs) in recycled water. The Panel, in its June 25, 2010 report entitled *"Monitoring Strategies for Chemicals of Emerging Concern in Recycled Water – Recommendations of a Scientific Advisory*

Panel" (Appendix A), provided recommendations for monitoring specific CECs in recycled water used for groundwater recharge reuse. The State Water Board incorporated the Panel's recommendations into a proposed revision of the Policy dated September 14, 2012 (Revised Policy).

Section 6.b(1)(a) of the Recycled Water Policy (see Appendix A) states in part "…the local water and wastewater entities, together with local salt/nutrient contributing stakeholders, will fund locally driven and controlled, collaborative processes open to all stakeholders that will prepare salt and nutrient management plans…" In compliance with the Policy, the Regional Water Boards act as an overseer and facilitator of the SNMP development process. In the Los Angeles Region, Board staff has attended stakeholder meetings for various groundwater basin/subbasin groups to provide support and information. In the Raymond Groundwater Basin (Basin), the RBMB is the lead agency for the development of the SNMP for the Basin (Raymond Basin SNMP) in conjunction with Raymond Basin Producers. In the Raymond Basin, the sources of salt/nutrient loading is recharge of stormwater runoff and imported water. The "local salt/nutrient contributing stakeholders" have been identified as the County of Los Angeles Department of Public Works (LACDPW) which is responsible for stormwater recharge; and Metropolitan Water District of Southern California (MWD) which collectively are responsible for the delivery of imported water in the Raymond Basin. RBMB staff has coordinated closely with the Regional Water Board/Los Angeles Region (LARWQCB) staff on the development progress and the contents of the Raymond Basin SNMP. Following the annual stakeholder workshop in November 2011, LARWQCB staff authorized RBMB to proceed with the development of the Raymond Basin SNMP.

RBMB has held numerous meetings with the "local salt/nutrient contributing stakeholders" including meetings held on October 7, 2010; March 7, 2013; December 11, 2014; and May 21, 2015. The primary source of salt and nutrient unloading is through groundwater extraction by Basin groundwater producers. RBMB staff regularly informed the Basin producers during the Pumping and Storage Committee meetings.

In the letter dated October 4, 2012 RBMB described its assimilative capacity approach to LARWQCB staff. Subsequently, in a letter dated December 21, 2012, LARWQCB staff provided a response approving the proposed assimilative capacity approach. Furthermore, RBMB staff participated in LARWQCB SNMP workshops held on November 15, 2010; November 15, 2011; November 15, 2012; November 14, 2013; and December 4, 2014.

The development of the Raymond Basin SNMP considers document entitled *"Regional Water Board Assistance in Guiding Salt and Nutrient Management Plan Development in the Los Angeles Region"* (Guidance). The final Guidance was dated June 28, 2012, and is included as Appendix B. The purpose of the Guidance is to provide information and guidance to assist on certain aspects of the SNMP development identified by stakeholder groups to ensure the final product is compliant with the specific requirements of the Policy, and state and federal water quality laws, but the *"stakeholders have the flexibility to apply any scientifically defensible methodology to make these determinations,"* i.e. estimates of basin/subbasin assimilative capacities and mass loadings. As a result, RBMB staff reorganized the Raymond Basin SNMP contents and developed an approach for determining the Raymond Basin salt/nutrient loading and assimilative capacities.

The RBMB has developed a spreadsheet computer model that assigns annual volume and concentration to the various components of loading and unloading. The annual quantity (volume) for each component has been taken from the draft report entitled "Raymond Basin Conjunctive Use Management Plan for the Foothill Communities Water Supply Reliability Study - 50 percent Model Update and Recalibration" (Water Supply Reliability Study – 50 percent Update). Components of loading include subsurface inflow, precipitation, percolation of applied water (irrigation), runoff from mountains, percolation of stormwater run-off in spreading grounds, and injection of treated imported water. Components of unloading include subsurface outflow and groundwater production.

Calculations of loading and unloading are performed on an annual basis Water quality data for Total Dissolved Solids (TDS), Nitrate, Chloride, and Sulfate have been researched and

concentrations have been applied. In some cases, water quality data was not readily available. Loading and unloading calculations have been performed for the 18-year period of fiscal year 1994-95 through fiscal year 2011-12.

This SNMP was prepared to fulfill the Policy specific requirements. Chapter II describes the Policy's mandate for the use of recycled water. Chapter III describes the Raymond Basin SNMP including its goal and objectives; characterization of the Basin; sources of salt and nutrients including their fate and transport; methodology for determining salt/nutrient loadings and assimilative capacities; estimates for salt/nutrient loadings and assimilative capacities; and implementation measures for recycled water, stormwater recharge, and others. Chapter IV provides an antidegradation analysis. Chapter V describes the basinwide salt/nutrient monitoring plan including a description of the monitoring network, monitoring schedule and frequency, and responsible stakeholders. Recommendations for future activities are provided in Chapter VI.

CHAPTER II

MANDATE FOR THE USE OF RECYCLED WATER

II.1. BACKGROUND

On February 9, 2009, the State Water Board adopted Resolution 2009-0011 which created the "Recycled Water Policy". The Recycled Water Policy recognized that "…collapse of the Bay-Delta ecosystem, climate change, and continuing population growth have combined with a severe drought on the Colorado River, and failing levees in the Delta, to create a new reality that challenges California's ability to provide the clean water need for a healthy environment, a healthy population and a healthy economy, both now and in the future." The Recycled Water Policy encourages appropriate water recycling, water conservation and use of stormwater to increase water supplies within California. The mandates contained within the Recycled Water Policy are briefly addressed below.

II.2. SUMMARY OF MANDATES

Section 4 of the Recycled Water Policy provides the "Mandate for the Use of Recycled Water" and is summarized below.

"*a. The State Water Board and Regional Water Boards will exercise the authority granted to them by the Legislature to the fullest extent possible to encourage the use of recycled water, consistent with state and federal water quality laws.*

(1) The State Water Board hereby establishes a mandate to increase the use of recycled water in California by 200,000 afy [acre-feet per year] by 2020 and by an additional 300,000 afy by 2030. These mandates shall be achieved through cooperation and collaboration of the State Water Board, the Regional Water Boards, the environmental community, water purveyors and the operators of publicly owned

treatment works. The State Water Board will evaluate progress toward these mandates biennially and review and revise as necessary the implementation provisions of this Policy in 2012 and 2016.

(2) Agencies producing recycled water that is available for reuse and not being put to beneficial use shall make that recycled water available to water purveyors for reuse on reasonable terms and conditions. Such terms and conditions may include payment by the water purveyor of a fair and reasonable share of the cost of the recycled water supply and facilities.

(3) The State Water Board hereby declares that, pursuant to Water Code sections 13550 et seq., it is a waste and unreasonable use of water for water agencies not to use recycled water when recycled water of adequate quality is available and is not being put to beneficial use, subject to the conditions established in sections 13550 et seq. The State Water Board shall exercise its authority pursuant to Water Code section 275 to the fullest extent possible to enforce the mandates of this subparagraph.

b. These mandates are contingent on the availability of sufficient capital funding for the construction of recycled water projects from private, local, state, and federal sources and assume that the Regional Water Boards will effectively implement regulatory streamlining in accordance with this Policy.

c. The water industry and the environmental community have agreed jointly to advocate for $1 billion in state and federal funds over the next five years to fund projects needed to meet the goals and mandates for the use of recycled water established in this Policy.

d. The State Water Board requests the California Department of Public Health (CDPH), the California Public Utilities Commission (CPUC), and the California Department of Water Resources (CDWR) to use their respective authorities to the fullest extent practicable to assist the State Water Board and the Regional Water Boards in increasing the use of recycled water in California." [1]

As a result of these mandates and coordination with LARWQCB staff, RBMB has taken the role of lead agency to develop the SNMP for the Raymond Basin. The SNMP, and the spreadsheets models which have been developed, will be used as a tool to evaluate the impacts of future projects on the existing water quality of the groundwater basin.

CHAPTER III

SALT AND NUTRIENT MANAGEMENT PLAN

III.1. GOAL AND OBJECTIVES

The primary goal of the Raymond Basin SNMP is to assist the RBMB and participating/potential stakeholders to comply with the Policy regarding the use of the recycled water from municipal wastewater treatment facilities as a safe source of water supply, while maintaining the water quality objectives for salt and nutrients in the Basin Plan established by the LARWQCB.

The primary objective of the Raymond Basin SNMP is to comply with the specific requirements described in the Policy. They include (1) characterization of the Basin, (2) identification of sources of salt, nutrients, and their fate and transport, (3) estimation of salt, nutrients loadings and assimilative capacities, (4) identification of water recycling and stormwater recharge/use goals and objectives, (5) verification of compliance with Resolution No. 68-16 through antidegradation analyses, and (6) monitoring plan to verify compliance with the Basin water quality objectives. The focus of the Raymond Basin SNMP is on Total Dissolved Solids (TDS), nitrate, chloride and sulfate.

III.2. BASIN PLAN WATER QUALITY OBJECTIVES

The Raymond Basin is one of 24 groundwater basins located within the Los Angeles Region under jurisdiction of the LARWQCB, extending from Rincon Point (on the coast of western Ventura County) to the eastern Los Angeles County line, as shown on Plate III.1. The LARWQCB adopts and implements the Basin Plan that serves as a basis for its regulatory program. The current Basin Plan, as amended through 1994 [2], combines and replaces the earlier plans: the *Water Quality Control Plan: Santa Clara River Basin* [3] *and* the *Water Quality Control Plan: Los Angeles River Basin* [4].

The Basin Plan establishes water quality standards for the surface and ground waters of the Los Angeles Region based upon designated beneficial uses of water and numerical water quality objectives that must be maintained or attained to protect those uses. Beneficial uses for regional groundwater basins generally include:

- Municipal and Domestic Supply (MUN) for community, military, or individual water supply systems including, but not limited to, drinking water supply;
- Industrial Service Supply (IND) for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, geothermal energy production, hydraulic conveyance, gravel washing, fire protection, and oil well repressurization;
- Industrial Process Supply (PROC) for industrial activities that depend primarily on water quality;
- Agricultural Supply (AGR) for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, and support of vegetation for grazing stock; and
- Aquaculture Supply (AQUA) for aquaculture or mariculture operations including, but not limited to, propagation, cultivation, maintenance, and harvesting of aquatic plants and animals for human consumption or bait purposes.

The Basin designated beneficial uses (Table 2-2 of the Basin Plan [2]) include MUN, IND,] PROC, and AGR. The Basin groundwater is subject to the following objectives (Referenced tables in italics are included in the Basin Plan.):

Bacteria, Coliform

In ground waters designated as MUN, the concentration of coliform organisms over any seven-day period shall be less than 1.1/100 milliliters.

Chemical Constituents and Radioactivity

Ground waters designated as MUN shall not contain concentrations of chemical constituents and radionuclides in excess of the limits specified in the following provisions of Title 22 of the California Code of Regulations which are incorporated by reference into this plan: Table 64431-A of Section 64431 (Inorganic Chemicals), Table 64431-B of Section 64431 (Fluoride), Table 64444-A of Section 64444 (Organic Chemicals), and Table 4 of Section 64443 (Radioactivity). This incorporation by reference is prospective including future changes to the incorporated provisions as the changes take effect. (See Tables 3-5, 3-6, 3-7, and 3-9.)

Ground waters shall not contain concentrations of chemical constituents in amounts that adversely affect any designated beneficial uses.

Mineral Quality

Numerical mineral quality objectives for individual groundwater basins are contained in Table 3-10.

Nitrogen (Nitrate, Nitrite)

Ground waters shall not exceed 10 mg/L nitrogen as nitrate-nitrogen plus nitrite-nitrogen (NO_3-N + NO_2-N), 45 mg/L as nitrate (NO_3), 10 mg/L as nitrate-nitrogen (NO_3-N), or 1 mg/L as nitrite-nitrogen (NO_2-N).

Taste and Odor

Ground waters shall not contain taste and odor or odor-producing substances in concentrations that cause nuisance or that adversely affect beneficial uses.

The numerical water quality objectives for the Basin groundwater, which are based on the June 21, 2012 update of Title 22 of the California Code of Regulations (CCRs) [5], are summarized in Table III.1. Neither the Basin Plan nor Title 22 of the CCRs has established the numerical water quality objectives for taste and odor.

The LARWQCB also implements State and federal antidegradation policies to maintain high quality of both surface and ground waters in California (Resolution No. 68-16 and 40 CFR 131.12 [6]). Under the State Nondegradation Objective, whenever the existing quality of water is better than that needed to protect all existing and probable future beneficial uses, the existing high quality shall be maintained until or unless it has been demonstrated to the State that any change in water quality will be consistent with the maximum benefit of the people of the State, and will not unreasonably affect present and probable future beneficial uses of such water. Therefore, unless conditions are met, background water quality concentrations (the concentrations of substances in natural waters which are unaffected by waste management practices or contamination incidents) are appropriate water quality goals to be maintained. If it is determined that some degradation is in the best interest of the people of California, some increase in pollutant level may be appropriate. However, in no case may such increases cause adverse impacts to existing or probable future beneficial uses of waters of the State.

III.3. RAYMOND GROUNDWATER BASIN

The Raymond Basin geology and hydrogeology was characterized in Bulletin No. 45, “South Costal Basin Investigation”, prepared by the California Department of Public Works, Division of Water Resources in 1934 [7]. Subsequently the State of California released the “Report of Referee” in 1943 which expanded on the geology and hydrogeology of the area, and provided an emphasis on groundwater production, groundwater replenishment, and safe yield, and served as the basis for the Raymond Basin adjudication. CDWR published Bulletin 104-6 which provided information regarding the future effective management of the groundwater supplies in coordination with surface water supplies and facilities. The Raymond Basin SNMP contains information on geology and hydrology of the Raymond Basin which is referenced from these

reports. Furthermore, since the publication of these reports, additional information on hydrogeology, water quality, and groundwater management has become available to provide a better understanding of the characteristics and responses of groundwater in the Raymond Basin.

III.3.1. Geography

The Raymond Basin underlies the northwesterly portion of the San Gabriel Valley and is located in Los Angeles County about 10 miles northeasterly of downtown Los Angeles (Plate III.1). Raymond Basin is a wedge in the northwestern portion of the San Gabriel Valley and is bounded on the north by the San Gabriel Mountains, on the west by the San Rafael Hills, and is separated from the Main San Gabriel Basin on the southeast by the Raymond Fault. The Raymond Basin is divided into an eastern unit, the Santa Anita Subarea, a central unit, the Pasadena Subarea, and a western unit, the Monk Hill Subarea (Plate III.2). The surface area of Raymond Basin is about 40.9 square miles. Within the Raymond Basin, the Monk Hill Subarea underlies the City of La Canada - Flintridge and the northwesterly portion of the City of Pasadena. The larger Pasadena Subarea underlies most of the City of Pasadena and the unincorporated area of Altadena. The Santa Anita Subarea underlies the Cities of Arcadia and Sierra Madre.

The principal streams in the Raymond Basin are the Arroyo Seco, which drains the Monk Hill Subarea to the Los Angeles River, the Eaton Wash which drains the Pasadena Subarea and flows to the Rio Hondo, a distributary of the San Gabriel River, and the Santa Anita Wash which drains the Santa Anita Subarea and flows to the Rio Hondo, as shown on Plate III.2.

III.3.2. Geology

The geology of the Raymond Basin is described in detail in the “Report of Referee” prepared in 1943 [8] by the State of California, Division of Water Resources, and the geology is summarized below.

The Raymond Basin is roughly triangular in shape. Its northerly boundary, about twelve miles in

length, is formed by a portion of the southern front of the San Gabriel Mountains. The western boundary of the Raymond Basin is about eight miles long and is composed chiefly of the same Basement Complex rocks which form the mountains, and which are continuous at depth, together with a small area of marine Tertiary sediment at the southern end. Raymond Fault, the southern boundary of the triangle, crosses the San Gabriel Valley floor for a distance of about nine miles, connecting a granitic spur from the San Gabriel Mountains at the eastern end of the Raymond Basin with Tertiary sediments outcropping in its southwestern corner. The Raymond Fault separates the Raymond Basin from the Main San Gabriel Basin in the vicinity of the southeasterly boundary. The fault zone is not impervious and groundwater can flow across this boundary into the Main Basin. The source of natural groundwater supply to the Raymond Basin is direct rainfall, percolation from surface runoff from the northern and western sides, underflow from the Verdugo Basin, and possibly some underground percolation of water from the mountain mass to the alluvium. The general geology of the Basin is shown on Plate III.3.

III.3.2.1 Nonwater-Bearing Formations

The nonwater-bearing formations include the Basement Complex rocks and Tertiary sediments of the Topanga, Modelo and Puente formations (Plate III.3). The nonwater-bearing formations do not absorb, transmit or yield water readily. The Basement Complex is comprised of old pre-Cretaceous series of crystalline rocks that comprise the basal formation of the region. These are chiefly igneous plutonic rocks of granitic type, together with their metamorphic phases, such as schists, gneisses, and also various intrusive dikes. The Basement Complex comprises the majority of San Gabriel Range to the north and the San Rafael Hills to the west. The Basement Complex protrudes above the alluvium at Monk Hill and near the head of Eaton Wash demonstrating that it is continuous beneath the area. The Topanga formation is of Tertiary age. In Raymond Basin, it is represented by fairly well bedded shales, sandstones, and conglomerates that are well consolidated and practically impervious. The exposed Topanga beds are limited to the southwesterly corner of the area along a fault block where the formation is exposed for a mile in the channel of Arroyo Seco just northerly of the Raymond Fault and for about one and one-quarter miles easterly from the Arroyo Seco to Raymond Hill.

III.3.2.2 Water-Bearing Formations

The CDWR Bulletin No. 45 [7] characterized the water-bearing formations of the Raymond Basin as alluvial fill having characteristics of the coarse deposits found in the small basins near the mountain margins. The deposits are coarsest at the base of the mountains where they contain boulders several feet in diameter, but even in the southerly part of the basin, cobbles, stones, and boulders are not uncommon. There are practically no true sand beds in the northerly part of Raymond Basin. The average sand content in the basin sediments as determined from well logs is only 2.8 percent. The deposits are characterized throughout by an abundance of weathered material. Decomposed yellowish gravels, clayey yellow and red gravels, and red or brown residual soil clays are the typical deposits (Plate III.3).

The older alluvium found within the area is practically continuous along the entire southerly flank of San Gabriel Range with little change in composition or structure. Within the Raymond Basin, it constitutes practically all of the water-bearing series and is not only dominant at the surface but appears to continue with depth to bedrock, although at depth, it may be in contact with some of the late Tertiary sediments. No attempt to differentiate these sediments has been attempted because of the similarity of material recorded in well logs. The older alluvial fill consists of a small portion of sand and almost equal proportions of gravel and clay. Older alluvial fill is of great thickness and its deposition has occurred through a long period. Weathering, disintegration, and cementation have been continuous and the results have varied with local conditions and there is considerable spatial variation in the water yielding characteristics of this formation.

Recent alluvium occupies channels, washes, and flood plains of Arroyo Seco, Eaton Creek, and Big and Little Santa Anita Creeks, and to a lesser extent, exists as veneers scattered along the slope of the valley resulting from flood discharges of ephemeral streams (Plate III.3). For the most part, the recent alluvium is believed to be shallow, but in the upper portions of Little Santa Anita Wash, the indications are that the recent alluvium may extend to a depth of about 150 feet. These sediments are similar to those found in the older alluvium but contain a much smaller

proportion of clay and are unconsolidated.

III.3.2.3 Geological Features and Faults

According to the Report of Referee [8], the geologic structure of Raymond Basin is complicated. The rough surface topography of the Basement Complex outside the area indicates that the bedrock floor beneath the alluvium undulates, although the present mountain block undoubtedly exhibits a more rugged topography due to its recent rejuvenation with accompanying accentuation of erosive forces, then the old erosion surface was buried and protected by alluvial deposits of the area. However, within the area, except at the boundaries, and the granitic protrusions at Monk Hill and near the north end of Eaton Wash, there is no surface expression of undulations of bedrock which might indicate possible impediments to groundwater movement.

The San Gabriel Fault cuts through the central portion of San Gabriel Mountains and has an east-west trend. It is one of the main faults in the mountain block but is so distant that its effect upon the Raymond Basin area is only indirect.

The Sierra Madre Fault system is a broad zone of faulting with an east-west trend roughly parallel to the southern edge of the San Gabriel Mountains, swinging to the northwest in the vicinity of Sierra Madre. The main trace of this zone leaves the southern edge of the foothills at a point west of the mouth of Eaton Wash, penetrating the mountain block in a north-westerly direction for some distance before it again swings to the west. The bedrock contours as a result of the geophysical survey indicate a uniform northerly slope of the buried bedrock surface from San Rafael Hills.

The Raymond fault forms the boundary between the Raymond Basin and the Main San Gabriel Basin from the City of South Pasadena on the west to the City of Monrovia on the east. It is likely a thin, impervious gouge formed in alluvium because it creates a several hundred foot difference in water level elevation in approximately 2,700 feet between Del Mar Well of California American Water Company (CAWC) and Well No. 3 of San Gabriel County Water

District (Plate III.4). In addition to the difference in water level elevation, the barrier effect of the Raymond fault is indicated by the presence of artesian conditions during periods of high water levels, and by the creation of ponds and swampy areas north of the fault line. As shown on semi-annual groundwater contour maps generated by the RBMB (Plate III.5), the Raymond fault appears to impede groundwater movement southward from the Raymond Basin into the Main San Gabriel Basin.

III.3.3. Hydrology

III.3.3.1 Precipitation

The Raymond Basin is located within a region of both semiarid and Mediterranean climate, with warm, dry summers and mild winters with intermittent rain. The majority of the annual rainfall occurs between December and March. Precipitation in the Raymond Basin area has been monitored by a network of precipitation stations operated by Los Angeles County, Department of Public Works (LACDPW). For the purposes of the Raymond Basin SNMP, stations with the longest continuous records (1924-25 to 2011-12 fiscal years) were selected (Plates III.6). The annual precipitation at the selected stations was obtained from LACDPW (Appendix C). Station Nos. 63, 175, 235, and 338, all of which are outside Raymond Basin, were used to calculate the mean annual precipitation for the mountain watershed, as shown on Plate III.7a. Station Nos. 167, 176, 591, and 610 were used to calculate the mean annual precipitation of the valley floor as shown on Plate III.7b. Annual precipitation within the Raymond Basin is more variable in the mountain watershed than in the valley floor. The mountain watershed (28.40 inches) averages about 7 inches more annual precipitation than the valley floor (21.33 inches).

<u>Monk Hill Subarea</u>

Recharge of the Monk Hill Subarea from precipitation occurs on the mountain watershed and on the valley floor. Precipitation in the mountain watershed has ranged from 760 acre-feet to 9,280 acre-feet during the period of 1994-95 through 2011-12, as shown in Appendix G. The long-

term average annual recharge has been 3,500 acre-feet, as shown on Plate III.8a.

Recharge of the Monk Hill subarea from precipitation on the valley flow has ranged from 17 acre-feet to 3,220 acre-feet during the period 1994-95 through 2011-12, as shown in Appendix G. The long-term average annual recharge has been 790 acre-feet, as shown on Plate III.8a.

Pasadena Subarea

Recharge of the Pasadena Subarea from precipitation occurs on the mountain watershed and on the valley floor. Precipitation in the mountain watershed has ranged from 180 acre-feet to 2,250 acre-feet during the period of 1994-95 through 2011-12, as shown in Appendix H. The long-term average annual recharge has been 850 acre-feet, as shown on Plate III.8b.

Recharge of the Pasadena subarea from precipitation on the valley flow has ranged from 40 acre-feet to 8,620 acre-feet during the period 1994-95 through 2011-12, as shown in Appendix H. The long-term average annual recharge has been 2,120 acre-feet, as shown on Plate III.8b.

Santa Anita Subarea

Recharge of the Santa Anita subarea from precipitation occurs on the mountain watershed and on the valley floor. Precipitation in the mountain watershed has ranged from 410 acre-feet to 5,040 acre-feet during the period of 1994-95 through 2011-12, as shown in Appendix I. The long-term average annual recharge has been 1,900 acre-feet, as shown on Plate III.8c.

Recharge of the Santa Anita subarea from precipitation on the valley flow has ranged from 10 acre-feet to 1,480 acre-feet during the period 1994-95 through 2011-12, as shown in Appendix I. The long-term average annual recharge has been 370 acre-feet, as shown on Plate III.8c.

III.3.3.2 Surface Water System

The entire Raymond Basin area lies within the watershed of the Los Angeles River (CDWR Bulletin 104-6 [9]), and surface runoff from the San Gabriel Mountains enters the area through numerous streams, principally the Arroyo Seco, Eaton Wash, and Santa Anita Wash. About one-third of the surface runoff is conveyed by the Arroyo Seco, the largest of the streams, which flows across the Monk Hill Subarea and the Pasadena Subarea, and joins the Los Angeles River by cutting through the San Rafael Hills. Outflow from the western portion of the Monk Hill Subarea reaches the Los Angeles River through the Verdugo Wash. The balance of the surface runoff primarily flows in Eaton Wash and the Santa Anita Wash to the Rio Hondo and ultimately drains to the Los Angeles River.

Artificial recharge of stormwater runoff occurs in off-stream spreading grounds (Plate III.6). The Raymond Basin does not receive untreated imported water for groundwater replenishment; however, treated imported water has been injected into the Monk Hill Subarea for many years (Appendix D.

Monk Hill Subarea

Artificial recharge of the Monk Hill subarea historically has occurred as a result of infiltration of stormwater runoff and, to a lesser degree, injection of treated imported water. Artificial recharge has ranged from 450 acre-feet to 9,700 acre-feet during the period of 1994-95 through 2011-12, as shown in Appendix G. Injection of treated imported water has range from zero acre-feet to 1,480 acre-feet during the period of 1994-95 through 2011-12, as shown in Appendix G. The average combined annual recharge from artificial recharge and injection has been 3,400 acre-feet, as shown on Plate III.8a.

Pasadena Subarea

Artificial recharge of the Pasadena subarea historically has occurred as a result of infiltration of

stormwater runoff and to a lesser degree, injection of treated imported water. Artificial recharge has ranged from 820 acre-feet to 8,740 acre-feet during the period of 1994-95 through 2011-12, as shown in Appendix H. Injection of treated imported water has ranged from zero acre-feet to 16 acre-feet during the period of 1994-95 through 2011-12, as shown in Appendix H. The average combined annual recharge from artificial recharge and injection has been 3,000 acre-feet, as shown on Plate III.8b.

Santa Anita Subarea

Artificial recharge of the Santa Anita subarea historically has occurred as a result of infiltration of stormwater runoff. Artificial recharge has ranged from 520 acre-feet to 4,540 acre-feet during the period of 1994-95 through 2011-12, as shown in Appendix I. The average annual recharge has been 2,000 acre-feet, as shown on Plate III.8c.

III.3.4. Hydrogeology

The Raymond Basin is a structural basin filled with permeable alluvial deposits, which is underlain and surrounded by relatively impermeable rock. It forms an aquifer, i.e. *"a geologic unit that can store and transmit water at rates fast enough to supply reasonable amounts to wells"* [13]. The Basin aquifer is stratified in some areas by confining or semi-confining layers consisting of impermeable or less-permeable materials such as clay or silt. In these areas, the Basin aquifer is an aquifer system that may include an unconfined or water-table aquifer overlying individual confined or artesian aquifers separated by semi-confining or confining layers. Groundwater in the confined aquifers is normally under pressure; therefore, water will rise in a well drilled to these aquifers to a level above their overlying confining layer, which is called the potentiometric surface [13]. In general, the Basin aquifer is classified as an unconfined to semi-confined aquifer system because the semi-confining or confining layers are not continuous across the Basin. The base of the water bearing zones is considered bedrock with elevations ranging from approximately 500 feet below sea level to 2,000 feet above mean sea level. Depth to bedrock ranges from 450 to 750 feet below ground surface (bgs) in the Monk Hill

and Santa Anita subareas to more than 1,200 feet bgs in the Pasadena subarea. The total storage capacity of the Raymond Basin is estimated to be approximately 1.37 million AF [7]. The amount of water in storage in 2003 was approximately 800,000 AF, with an unused storage space of about 570,000 [12].

III.3.4.1 Aquifer Characteristics

Performance of an aquifer depends on two characteristics or parameters: transmissivity (T) and storage coefficient or coefficient storage or storativity (S). The transmissivity of an aquifer is defined as *"the amount of water that can be transmitted horizontally by the full saturated thickness of the aquifer under a hydraulic gradient [or slope] of 1"* [13]. It is the product of the hydraulic conductivity or permeability (K) and the saturated thickness of the aquifer (b), T = bK. Common units are gallons per day per square foot (gpd/ft^2) or feet per day (ft/d) for K and gallons per day per foot (gpd/ft) or square feet per day (ft^2/d) for T. The storage coefficient or storativity of an aquifer is defined as *"the volume of water that a permeable unit will absorb or expel from storage per unit surface area per unit change in head"* [13]. It is a dimensionless quantity and representative of the aquifer condition. It is usually less than 0.005 for confined aquifers and ranges from 0.02 to 0.30 for unconfined aquifers.

III.3.5. Groundwater Storage Capacity and Groundwater in Storage

The CDWR defines groundwater storage capacity of an individual basin as the product of the total volume of that basin (from ground surface to the base) and its average specific yield. The storage capacity is constant and is dependent on the geometry and hydrogeologic characteristics of the aquifer(s) [15]. As a result, the storage capacity defined by the CDWR is the amount of groundwater that can be drained by gravity from the completely saturated basin, i.e. the amount of groundwater that can be extracted from the basin. The CDWR groundwater storage capacity does not include the amount of groundwater that is retained in small pore spaces due to surface retention. The CDWR further defines groundwater in storage as the amount of groundwater that can be drained (or extracted) from a basin between the water table and its base.

According to CDWR Bulletin 104-6 [9], the total storage capacity of the Raymond Basin was calculated at 1,450,000 acre-feet applying specific yield values ranging from 3 to 35 percent to all aquifer material from 20 feet below the surface to the base of sediments. This value is consistent with an area of 26,200 acres, an average thickness of about 550 feet, and an average specific yield of about 10 percent. CDWR estimated the available stored water to be 1,000,000 acre-feet in 1970 [9], leaving about 450,000 acre-feet of storage space available. In the Baseline Ground Water Assessment of the Raymond Basin – Final Report, prepared by Geoscience [12], the Raymond Basin storage capacity was estimated at 1,370,000 acre-feet with an estimated stored water of 800,000 acre-feet, leaving about 570,000 acre-feet of storage space available. For the basin characterization for this salt and nutrient management plan, it was assumed that the water-bearing zones were uniform across the basin. Therefore, the volume of groundwater in storage for each subarea was determined as a percentage of the surface area, using 800,000 AF as the base water volume (Table III.2).

III.3.5.1 Groundwater Level and Movement

Raymond Basin historical groundwater levels are presented in Plates III.9a, III.9b, and III.9c. Groundwater levels in the Raymond Basin range from about 350 feet above Mean Sea Level (MSL) in Santa Anita subarea (Plate III.9c) to more than 1,050 feet above MSL in the Monk Hill Subarea (Plates III.9a). Groundwater generally flows southeast from the Monk Hill Subarea in the northwest to the Raymond fault in the southeast (Plates III.10a and III.10b).

<u>Monk Hill Subarea</u>

Groundwater levels in the Monk Hill subarea (Plate III.9a) have fluctuated, but remained relatively stable since 2000. In general, groundwater flows from the Monk Hill subarea into the Pasadena subarea, as shown on Plates III.10a and III.10b. The quantity of subsurface flow is discussed in Section III.3.5.2.

Pasadena Subarea

The Pasadena Subarea has experienced a significant decrease in the groundwater levels as shown on Plate III.9.b. As a result of the decreasing groundwater levels, RBMB adopted Resolution 42-0109 which put in place a self-imposed pumping reduction to allow more groundwater to remain in the Basin. During fiscal year 2008-09 to fiscal year 2012-13 the "1955 Decreed Rights" were reduced by 6 percent per year from each of the five years for a total of 30 percent.

In general, groundwater flows from the Pasadena subarea into the Santa Anita subarea, as shown on Plates III.10a and III.10b. As previously mentioned, there is very little no flow across the Raymond Fault into the Main Basin.

Santa Anita Subarea

Groundwater levels have been decreasing in the Santa Anita subarea, as noted on Plate III.9c. Groundwater from the southeasterly portion of the Santa Anita subarea historically flowed into the Main Basin as shown on Plates III.10.a and III.10.b. The quantity of subsurface flow is discussed in Section III.3.5.2.

III.3.5.2 Subsurface Flow

CDWR Bulletin 104-2 address subsurface inflow from the Raymond Basin into the Main Basin and states in part "…*Underflow into San Gabriel Valley across the Raymond fault varied from 2,000 to 12,000 acre-feet per year during the base period [from 1943-44 to 1959-60]. This subsurface flow did not occur at the same rate along the length of the fault, but varied from west to east. The lowest rates occurred near the western edge of the basin where the Raymond fault constitutes a nearly impervious barrier to groundwater movement, and the highest rates occurred near Santa Anita where the barrier effect is negligible. Estimates of underflow across the Raymond fault were based on values of groundwater gradients between water levels north of the fault"* [12].

The draft Raymond Basin Conjunctive Use Management Plan for the Foothill Communities Water Supply Reliability Study – 50 percent Model Update and Recalibration" [12], developed annual water budgets for each subarea based on the January 1981 to April 2012 study period. These values have been used in the Raymond Basin SNMP and included in Appendix G (Monk Hill Subarea), Appendix H (Pasadena Subarea), and Appendix I (Santa Anita Subarea), as described below.

Monk Hill Subarea

Subsurface inflow from the Verdugo Basin into the Monk Hill subarea has ranged from 890 acre-feet to 3,990 acre-feet over the period of 1994-95 to 2011-12 as shown in Appendix G. The long-term (31-year) average annual subsurface inflow has been 2,270 acre-feet, as shown on Plate III.8a. Subsurface outflow from the Monk Hill subarea into the Pasadena subarea has ranged from 5,750 acre-feet to 7,270 acre-feet over the period 1994-95 through 2011-12, as shown in Appendix G. The mean subsurface outflow to the Pasadena subarea was 6,700 acre-feet as shown on Plate III.8a.

Pasadena Subarea

Subsurface outflow from the Monk Hill subarea into the Pasadena subarea has ranged from 5,750 acre-feet to 7,270 acre-feet over the period of 1994-95 to 2011-12, as shown in Appendix H. The long-term average annual subsurface inflow has been 6,300 acre-feet, as shown on Plate III.8b. Subsurface outflow from the Pasadena subarea goes into the Santa Anita subarea and the Main San Gabriel Basin. The total outflow has ranged from 3,940 acre-feet to 5,910 acre-feet over the period 1994-95 to 2011-12, as shown in Appendix H. The mean subsurface outflow to the Santa Anita subarea was 900 acre-feet, and the mean subsurface outflow to the Main San Gabriel Basin was 3,950, as shown on Plate III.8b.

Santa Anita Subarea

Subsurface inflow for the Pasadena Subarea into the Santa Anita Subarea has ranged from 110 acre-feet to 1,840 acre-feet over the period 1994-95 to 2011-12, as shown in Appendix I. The long-term average annual subsurface inflow has been 950 acre-feet, as shown on Plate III.8c. Subsurface outflow from the Santa Anita subarea into the Main San Gabriel Basin has ranged from 350 acre-feet to 1,110 acre-feet, as shown in Appendix I. The mean subsurface outflow to the Main San Gabriel Basin was 860 acre-feet as shown on Plate III.8c.

III.3.6. Water Demands

Raymond Basin water supply is from groundwater extracted from the Raymond Basin, treated surface water diversion of runoff from the San Gabriel Mountains, and treated imported from the Weymouth Treatment Planted operated by MWD. A portion of the Raymond Basin groundwater production is also exported by producers for use in the Main San Gabriel Basin (Appendix E).

The following provides a summary of production in these subareas:

Monk Hill Subarea

Water production in the Monk Hill Subarea includes groundwater pumping, purchases of treated imported water and a minor amount of treated water from local surface water diversions. Groundwater production has ranged from 3,870 acre-feet to 12,970 acre-feet during the period 1994-95 to 2011-12 and has averaged 6,990 acre-feet, as shown on Plate III.8a. Treated imported water which comes from MWD's Weymouth Treatment Plant, is used in the Monk Hill subarea to augment local groundwater production. Treated imported water purchases have ranged from approximately 5,300 acre-feet to 25,200 acre-feet during the period 1994-95 to 2011-12 (Appendix F).

Pasadena Subarea

Water production in the Pasadena Subarea includes groundwater pumping, purchases of treated imported water and a minor amount of treated water from local surface water diversions. Groundwater production has ranged from 10,930 acre-feet to 21,120 acre-feet during the period 1994-95 to 2011-12 and has averaged 17,750 acre-feet, as shown on Plate III.8b. Treated imported water which comes from MWD's Weymouth Treatment Plant, is used in the Pasadena subarea to augment local groundwater production. Treated imported water purchases have ranged from approximately 1,200 acre-feet to 28,800 acre-feet during the period 1994-95 to 2011-12 (Appendix F).

Santa Anita Subarea

Water production in the Santa Anita Subarea includes groundwater pumping, purchases of treated imported water and a minor amount of treated water from local surface water diversions. Groundwater production has ranged from 5,320 acre-feet to 8,510 acre-feet during the period 1994-95 to 2011-12 and has averaged 6,330 acre-feet, as shown on Plate III.8c. Treated imported water which comes from MWD's Weymouth Treatment Plant, is used in the Santa Anita subarea to augment local groundwater production. Treated imported water purchases have ranged from approximately 0 acre-feet to 800 acre-feet during the period 1994-95 to 2011-12 (Appendix F).

III.3.7 Groundwater Quality

DDW Title 22 sampling requires all wells used for potable water supplies to be sampled at least once every three years for TDS, chloride and sulfate, and at least annually for Nitrate. In addition, all wells are sampled for General Mineral, General Physical, Inorganics, Radioactivity, VOCs, plus various emerging contaminants on a regular and continuous basis. All data is provided to DDW electronically.

Since fiscal year 1985-1986, RBMB has organized the collection of water quality data from

producers within the Raymond Basin. The groundwater quality monitoring program has resulted in a large volume of water quality records that are currently stored in the databases managed by RBMB and CDPH.

Groundwater quality is described for each subarea of the Raymond Basin and addresses Nitrate, Chloride, Sulfate, and Total Dissolved Solids (TDS) for each subarea. Nitrate, Chloride, Sulfate, and TDS are typically sampled as part of DDW "General Mineral" compliance sampling, which typically occurs once every three years. Consequently, in the 18-year review period, there are about six sets of data for each well available for review, which are summarized on Table III.3. For all water quality data in a subarea from 1986-87 to 2011-12, mean annual constituent concentration was calculated as the arithmetic average concentration of all available water quality data at the production wells within subarea. Due to the 3-year sampling cycle, each annual data point was calculated as the mean of the previous six years (inclusive) data available in the production wells in the subarea.

There is considerable annual variation in water quality for each constituent. The water quality concentrations vary with many factors, including the volume of groundwater in storage. The water quality concentrations tend to be inversely related to groundwater in storage, increasing as groundwater levels decrease, and vice versa. Water quality data were presented as means for subareas. When data for an individual constituent was limited in a subarea due to the 3-year sampling cycling and few wells sampled, 6-yr or 9-yr means were determined and used in the loading/unloading models.

Monk Hill Subarea

Generally, the water quality in the Monk Hill subarea has degraded since 1984-1985, with almost 200 percent increase in Sulfate and 40 percent increase in TDS concentrations, as discussed below. The sources of the salts likely come from the use of imported water to supplement groundwater production to meet demands. The sources are discussed in greater detail in Section III.4.1.1.

Nitrate, NO_3

The mean nitrate concentrations from 1986-87 to 2011-12 in the production wells (excluding those of the Valley Water Company (VWC)) in the Monk Hill subarea varied from 14 mg/L to 35 mg/L, with an overall average of 27 mg/L, as determined from Appendix J and shown in Table III.4a. During the same period, the production wells of VWC varied from 17 mg/L to 60 mg/L, with an overall average of 42 mg/L, as determined from data in Appendix J. The water quality varies by purveyor, with the Lincoln Avenue Water Company (LAWC) and Rubio Canyon Land and Water Association (RCLWA) having lower nitrate concentrations than the Las Flores Water Company (LFWC) and La Canada Irrigation District (LCID), as shown in Plate III.11.

From 1986-87 to 2011-12, three patterns can be seen in the annual average nitrate concentration of the Monk Hill subarea (excluding VWC), i.e. the average concentration of groundwater extracted from the Monk Hill subarea. In the first period, until 1993-94, the nitrate concentration decreased about 15 percent, as shown in Plate III.12a. In the next period, from 1993-1994 through 2001-02, the nitrate concentration increased about 40 percent. Several years of data are missing, but following the trend from 2002-03 until 2011-12, the nitrate concentration decreased about 10 percent. For the entire observation period, the net change was an increase of about 6 percent. During the same period, the increase was more than 20 percent in VWC wells (determined from Appendix J). The average nitrate concentration for the most recent 5-year period is 27 mg/L, as shown in Table III.4a. Though the Monk Hill subarea mean groundwater nitrate concentration is well below the Basin Plan Water Quality Objective, the mean nitrate concentration in the LFWC and LCID wells is approaching 45 mg/L, and in the VWC wells exceeds 45 mg/L, as shown in Plate III.12a.

Chloride, Cl

The mean chloride concentrations from 1986-87 to 2011-12 in the production wells (excluding those of the VWC) in the Monk Hill subarea varied from 18 mg/L to 64 mg/L, with an overall

average of 35 mg/L, as determined from Appendix K, and shown on Table III.4b. During the same period, the production wells of VWC varied from 78 mg/L to 116 mg/L, with an overall average of 97 mg/L, as determined from data in Appendix K. The water quality varies by purveyor, and is similar to the pattern observed with nitrates, with the LAWC and RCLWA having lower chloride concentrations than the LCID, as shown in Plate III.13a.

From 1986-87 to 2011-12, the annual average chloride concentration of the Monk Hill subarea (excluding VWC), i.e. the average concentration of groundwater extracted from the Monk Hill subarea, increased about 50 percent, as shown in Plate III.13a. The average chloride concentration for the most recent 5-year period is 45 mg/L, as shown in Table III.4b. Though the Monk Hill subarea mean groundwater chloride concentration is well below the Basin Plan Water Quality Objective, the mean chloride concentration in the LCID wells has been increasing rapidly, and in the VWC wells often exceeds 100 mg/L, as shown in Plate III.13b.

Sulfate, SO_4

The mean sulfate concentrations from 1986-87 to 2011-12 in the production wells (excluding those of the VCW) in the Monk Hill subarea varied from 23 mg/L to 78 mg/L, with an overall average of 50 mg/L, as determined from Appendix K, and shown on Table III.4c. During the same period, the production wells of VWC varied from 14 mg/L to 178 mg/L, with an overall average of 152 mg/L, as determined from data in Appendix K. The water quality varies by purveyor, with the LAWC and RCLWA having lower sulfate concentrations than the LFWC and LCID, as shown in Plate III.14a.

From 1986-87 to 2011-12, the annual average sulfate concentration of the Monk Hill subarea (excluding VWC), i.e. the average concentration of groundwater extracted from the Monk Hill subarea, more than doubled, as shown in Plate III.14a. The average sulfate concentration for the most recent 5-year period is 61 mg/L, as shown in Table III.4c. Though the Monk Hill subarea mean groundwater sulfate concentration is well below the Basin Plan Water Quality Objective, the mean sulfate concentration in the LFWC and LCID wells is essentially at 100 mg/L, and in

the VWC wells exceeds 150 mg/L, or 150 percent of the objective as shown in Plate III.14b.

Total Dissolved Solids, TDS

The mean TDS concentrations from 1986-87 to 2011-12 in the production wells (excluding those of the VWC) in the Monk Hill subarea varied from 231 mg/L to 426 mg/L, with an overall average of 342 mg/L, as determined from Appendix K, and shown on Table III.4d. During the same period, the production wells of VWC varied from 521 mg/L to 820 mg/L, with an overall average of 670 mg/L, as determined from data in Appendix K. The water quality varies by purveyor, with the LAWC and RCLWA having lower TDS concentrations than the LFWC and LCID, as shown in Plate III.15a.

From 1986-87 to 2011-12, the annual average TDS concentration of the Monk Hill subarea, i.e. the average concentration of groundwater extracted from the Monk Hill subarea, increased about 40 percent, as shown in Plate III.15a. The average TDS concentration for the most recent 5-year period is 405 mg/L, as shown in Table III.4d. Though the Monk Hill subarea mean groundwater TDS concentration is still below the Basin Plan Water Quality Objective, the mean TDS concentration in the LFWC and LCID wells already exceeds 450 mg/L, and in the VWC wells is about 175 percent of the objective, as shown in Plate III.15b.

As noted above, the water quality data for VWC is measurably higher than other producers in the Monk Hill Subarea. VWC has insufficient 1955 Decreed Rights to produce groundwater to meet its demands. Consequently, VWC has implemented a conjunctive use program to take advantage of the availability of treated imported water. VWC historically has maintained an injection program whereby treated imported water from the MWD Weymouth Treatment Plant has been injected into the groundwater basin during the winter time, stored and then re-pumped during the summer. This program is reviewed by RBMB pursuant to the terms of the "Criteria for Delivery of Supplemental Water" (see Section V.3). In addition, DDW requires VWC to conduct monthly water quality sampling during the summer period when the injected treated imported water is pumped out of the Monk Hill Subarea. Much of the "groundwater" quality included in the Monk

Hill Subarea water quality data set is likely indicative of the treated imported water quality which had been injected several months earlier. Consequently, it is questionable whether the Monk Hill Subarea is being "degraded". Nonetheless, MWD's goal is to blend sources of imported water to maintain TDS at or below 500 mg/l is discussed in Section III.6.1.

Pasadena Subarea

Nitrate, NO_3

The mean nitrate concentrations from 1986-87 to 2011-12 in the production wells in the Pasadena subarea varied from 13 mg/L to 37 mg/L, with an overall average of 30 mg/L, as shown in Table III.4a. In the same period, the annual average nitrate concentration of the Pasadena subarea, i.e. the average concentration of groundwater extracted from the Pasadena subarea, increased about 25 percent, as shown in Plate III.16a. The average nitrate concentration for the most recent 5-year period is 36 mg/L, as shown in Table III.4a. Though the Pasadena subarea mean groundwater nitrate concentration is still below the Basin Plan Water Quality Objective, the concentration in many of the test wells exceeds 45 mg/L, as shown in Plate III.16a.

Chloride, Cl

The mean chloride concentrations from 1986-87 to 2011-12 in the production wells in the Pasadena subarea varied from 18 mg/L to 57 mg/L, with an overall average of 34 mg/L, as shown in Table III.4b. In the same period, the annual average chloride concentration of the Pasadena subarea, i.e. the average concentration of groundwater extracted from the Pasadena subarea, increased about 15 percent, as shown in Plate III.16b. The average chloride concentration for the most recent 5-year period is 41 mg/L, as shown in Table III.4b. The Pasadena subarea mean groundwater chloride concentration is well below the Basin Plan Water Quality Objective, and none of the test has approached 100 mg/L, as shown in Plate III.16b.

Sulfate, SO_4

The mean sulfate concentrations from 1986-87 to 2011-12 in the production wells in the Pasadena subarea varied from 43 mg/L to 80 mg/L, with an overall average of 64 mg/L, as shown in Table III.4c. In the same period, the annual average sulfate concentration of the Pasadena subarea, i.e. the average concentration of groundwater extracted from the Pasadena subarea, increased about 60 percent, as shown in Plate III.16c. The average sulfate concentration for the most recent 5-year period is 77 mg/L, as shown in Table III.4c. Though the Pasadena subarea mean groundwater sulfate concentration is still below the Basin Plan Water Quality Objective, the concentration in many of the test wells exceeds 100 mg/L, as shown in Plate III.16c.

Total Dissolved Solids, TDS

The mean TDS concentrations from 1986-87 to 2011-12 in the production wells in the Pasadena subarea varied from 302 mg/L to 400 mg/L, with an overall average of 350 mg/L, as shown in Table III.4d. In the same period, the annual average TDS concentration of the Pasadena subarea, i.e. the average concentration of groundwater extracted from the Pasadena subarea, increased about 15 percent, as shown in Plate III.16d. The average TDS concentration for the most recent 5-year period is 361 mg/L, as shown in Table III.4d. Though the Pasadena subarea mean groundwater TDS concentration is still below the Basin Plan Water Quality Objective, the concentration in many of the test wells exceeds 450 mg/L, as shown in Plate III.16d. A distinct pattern is observable among the tested wells: 19 wells never had TDS concentrations exceeding 500 mg/L, while the other 12 wells had some observations exceeding 500 mg/L. The mean concentration in these 12 wells is about 50 percent more than in the other 19 wells. Further, the TDS increase in the observation period was about 20 percent compared to 15 percent in the wells with better water quality.

Santa Anita Subarea

Nitrate, NO_3

The mean nitrate concentrations from 1986-87 to 2011-12 in the production wells in the Santa Anita subarea varied from 14 mg/L to 37 mg/L, with an overall average of 22 mg/L, as shown in Table III.4a. In the same period, the annual average nitrate concentration of the Santa Anita subarea, i.e. the average concentration of groundwater extracted from the Santa Anita subarea, decreased about 50 percent, as shown in Plate III.17a. The average nitrate concentration for the most recent 5-year period is 16 mg/L, as shown in Table III.4a. The Santa Anita subarea mean groundwater nitrate concentration is well below the Basin Plan Water Quality Objective of 45 mg/L, as shown in Plate III.17a.

Chloride, Cl

The mean chloride concentrations from 1986-87 to 2011-12 in the production wells in the Santa Anita subarea varied from 8 mg/L to 25 mg/L, with an overall average of 16 mg/L, as shown in Table III.4b. In the same period, the annual average chloride concentration of the Santa Anita subarea, i.e. the average concentration of groundwater extracted from the Santa Anita subarea, decreased slightly, as shown in Plate III.17b. The average chloride concentration for the most recent 5-year period is 15 mg/L, as shown in Table III.4b. The Santa Anita subarea mean groundwater chloride concentration is well below the Basin Plan Water Quality Objective of 100 mg/L, as shown in Plate III.17b.

Sulfate, SO_4

The mean sulfate concentrations from 1986-87 to 2011-12 in the production wells in the Santa Anita subarea varied from 29 mg/L to 45 mg/L, with an overall average of 37 mg/L, as shown in Table III.4c. In the same period, the annual average sulfate concentration of the Santa Anita subarea, i.e. the average concentration of groundwater extracted from the Santa Anita subarea,

decreased slightly, as shown in Plate III.17c. The average sulfate concentration for the most recent 5-year period is 34 mg/L, as shown in Table III.4c. The Santa Anita subarea mean groundwater sulfate concentration is well below the Basin Plan Water Quality Objective of 100 mg/L, as shown in Plate III.17c.

Total Dissolved Solids, TDS

The mean TDS concentrations from 1986-87 to 2011-12 in the production wells in the Santa Anita subarea varied from 230 mg/L to 305 mg/L, with an overall average of 273 mg/L, as shown in Table III.4d. In the same period, the annual average TDS concentration of the Santa Anita subarea, i.e. the average concentration of groundwater extracted from the Santa Anita subarea, has remained constant, as shown in Plate III.17d. The average TDS concentration for the most recent 5-year period is 268 mg/L, as shown in Table III.4d. The Santa Anita subarea mean groundwater TDS concentration is well below the Basin Plan Water Quality Objective of 450 mg/L, as shown in Plate III.17d.

III.4. SALT and NUTRIENTS SOURCES

III.4.1. Source Identification

III.4.1.1. Salt

Salts in the environment and hydrologic systems have natural and anthropogenic sources. Salts are soluble compounds of anions (negatively-charged particles) and cations (positively-charged particles) that are attracted to each other electrically, as the opposing poles of a magnet attract. Chemically, salts are composed of an acid and a base, though these acid-base mixtures vary greatly in strength of bonding, solubility, and activity in the solution. The solubility of salts in natural systems varies considerably, e.g. the solubility of salts based on the anion is, in decreasing order, nitrates, chlorides, sulfates, bicarbonate, and carbonate. The mobility of salts corresponds to their solubility.

Water moving through soil and the vadose zone always has dissolved salts in it. The concentration of these salts depends upon the concentration in the water and in the mineral solids through which the water travels. Everything in nature seeks an equilibrium. If the concentration of salts is greater in the mineral solids than in the water, salts will dissolve and increase the salt concentration in the water. If the concentration in the water is greater than in the surrounding solids, salts will precipitate from the water into the solid phase, decreasing the concentration of salts in the water.

Natural Sources

The Raymond Basin is situated on alluvial fans, terraces, and flood plains comprised of alluvium (river-deposited sediments) weathered from rocks and minerals from several sources: sedimentary, granitic, andesitic, volcanic, and mixed rocks. The associated watersheds in the mountains flow across weathering sediments of andesite, breccia, schist, and metamorphosed volcanic, basic igneous, granitic and metamorphic rocks. These weathering minerals are a primary source of salts in the Raymond Basin, though the solubility may vary, and the dominant salts found vary from one part of the watershed or basin to another, depending upon the specific mineralogy present.

Soils and geologic materials in the vadose (unsaturated zone above an aquifer) contain minerals of varying solubility that may dissolve in water. The most common salts in the Raymond Basin's soils include chlorides, sulfates, and carbonates of calcium, magnesium, potassium, and sodium. The weathered sedimentary materials have the greatest natural salinity of the rocks found in the Raymond Basin and associated watersheds.

Once dissolved, salts move with the water. If water flowing through soil and the vadose zone enters a river or stream, the salts enter surface water. If water percolates to the groundwater, the salts leach with it and enter the aquifer. If water is insufficient to leach the salts to the groundwater, the salts will accumulate at characteristic depths in the soil or vadose zone, as

determined by their solubility. The solubility and mobility of salts in the soil and vadose zone from least to greatest is carbonates, sulfates, and chlorides. Due to its mobility, chloride is often used as an environmental tracer.

If atmospheric demand for water through evaporation and transpiration exceed precipitation and irrigation (or water spreading), salts will tend to accumulate at the surface. This process is accelerated in the case of shallow water tables that allow salts to wick upward with water through capillary action.

Atmospheric deposition is a minor source of salts, including nitrates, sulfates, chlorides, and fossil fuel combustion products.

Anthropogenic Sources

Many human activities may contribute salts to the environment. These include household sources such as detergents, water softeners, swimming pool treatment chemicals, runoff from washing cars, use of treated municipal drinking water or gray-water reuse in residential irrigation systems, and on-site wastewater treatment facilities, as well as centralized wastewater treatment facilities, and many industrial processes. Return-flow from water used for surface or subsurface irrigation of agricultural crops, golf courses, parks, sports fields and lawns contribute salt, especially when water is added in excess of the amount required to meet the combined evaporation and transpiration needs of a crop. This may be intentional in an effort to manage the salinity in the root zone to meet crop requirements, or unintentional due to inefficient or unmanaged irrigation systems. Salts from some sources may enter storm drains or surface water systems with no treatment. Others are directly applied to, or disposed in, the soil-vadose zone as a treatment media. These non-point sources salt sources are the most difficult to monitor. The most obvious salt contributors are the point-sources originating from industrial or municipal centralized waste treatment facilities.

The Raymond Basin water quality objective for salts is influenced by the maximum contaminant

level (MCL) of TDS, a measure of the salts that dissolve in a water system. Because TDS is a measure of all dissolved solids, including nitrates, chlorides, sulfates, and their companion cations, the TDS increases with the concentration of these constituents. The TDS Basin Plan objective for each of the three subareas of the Raymond Basin is 450 mg/L, as shown on Table III.1.

Monk Hill Subarea

The Raymond Basin Judgment identifies the "1955 Decreed Rights" of each of the Pumpers from the Monk Hill Subarea. Any water demand in excess of the 1955 Decreed Rights historically has been met through the purchase of treated imported water from MWD's Weymouth Treatment Plant. Section III.3.6 notes that treated imported water purchases have ranged from about 5,300 acre-feet about 25,200 acre-feet. Since SWP Water became available in the early 1970's, MWD typically has attempted to maintain the TDS concentrations at a below 500 mg/l in the treated water from the Weymouth Treatment Plant. Historically this has been accomplished by providing a 50/50 blend of SWP water and Colorado River water. The blend goal of 500 mg/l for TDS is consistent with the Basin Plan Water Quality Objectives for the Monk Hill Subarea, as shown on Plate III.II. For example, MWD's 2007-08 Annual Report notes the blend averaged about 44 percent SWP water and TDS averaged about 490 mg/l. However, the average Sulfate concentration was reported as 166 mg/l, which the average Chloride concentration was reported as 91 mg/l. Both of these concentrations comply with DDW Title 22 regulations of 250 mg/l, but are close to, or exceed, the Basin Plan Water Quality Objectives of 100 mg/l. The annual mean water quality of treated imported water from Weymouth Treatment Plan for chloride, sulfate, and TDS has increased in the most recent five years as shown in Appendix O. These increases in constituent concentrations likely lead to an increase in groundwater concentrations in the Monk Hill Subarea.

In addition, VWC, which produces from the Monk Hill Subarea, historically maintains an injection program whereby treated imported water from MWD's Weymouth Treatment Plant was injected into the Monk Hill Subarea in the winter and extracted during the summer.

Consequently, some of the water quality data from the Monk Hill Subarea may have been influenced by this injection program and the water quality data set may not have been indicative of solely groundwater quality.

The specific causes of the increasing trend for TDS, Sulfate, and Chloride in the Monk Hill Subarea is not clearly understood. However, it is likely influenced by the long-term direct use of treated imported water to meet consumer demand and comply with the groundwater production limitations required by the Raymond Basin Judgment. In addition, the injection program historically may have influenced water quality.

Pasadena Subarea

The Raymond Basin Judgment identifies the "1955 Decreed Rights" of each of the Pumpers from the Pasadena Subarea. Any water demand in excess of the 1955 Decreed Rights historically has been met through the purchase of treated imported water from MWD's Weymouth Treatment Plant. Section III.3.6 notes that treated imported water purchases have ranged from 1,200 acre-feet about 28,800 acre-feet. Since SWP Water became available in the early 1970's, MWD typically has attempted to maintain the TDS concentrations at a below 500 mg/l in the treated water from the Weymouth Treatment Plant. Historically this has been accomplished by providing a 50/50 blend of SWP water and Colorado River water. The blend goal of 500 mg/l for TDS is consistent with the Basin Plan Water Quality Objectives for the Pasadena Subarea, as shown on Plate III.II. For example, MWD's 2007-08 Annual Report notes the blend averaged about 44 percent SWP water and TDS averaged about 490 mg/l. However, the average Sulfate concentration was reported as 166 mg/l, which the average Chloride concentration was reported as 91 mg/l. Both of these concentrations comply with DDW Title 22 regulations of 250 mg/l, but are close to, or exceed, the Basin Plan Water Quality Objectives of 100 mg/l. As discussed in Section 4.1.1.1, the annual mean water quality of treated imported water from Weymouth Treatment Plan for chloride, sulfate, and TDS has increased in the most recent five years as shown in Appendix O. These increases in constituent concentrations likely lead to an increase in groundwater concentrations in the Pasadena Subarea.

The specific causes of the increasing trend for TDS, Sulfate, and Chloride in the Pasadena Subarea is not clearly understood. However, it is likely influenced by the long-term direct use of treated imported water to meet consumer demand and comply with the groundwater production limitations required by the Raymond Basin Judgment.

Santa Anita Subarea

The Raymond Basin Judgment identities the "1955 Decreed Rights" of each of the Pumpers from the Santa Anita Subarea. Any water demand in excess of the 1955 Decreed Rights must be met through the purchase of treated imported water from MWD's Weymouth Treatment Plant. However, Section III.3.6 notes that historically there have been essentially no treated imported water purchases.

III.4.1.2. Nutrients

At least 18 minerals are recognized as essential for plants, and at least 24 for animals, including humans. In surface water systems, the primary nutrients of concern are nitrogen as nitrate (NO_3^-) or nitrite (NO_2^-), and phosphorus as particulates in runoff water, or dissolved in water as orthophosphates (HPO_4^{2-}, $H_2PO_4^-$). Historically, nitrate has been the primary concern for groundwater quality, but recently more recently, it has been realized that phosphorus may become mobile in the soil and vadose zone, and therefore may be found in groundwater and aquifers [26].

The nutrients for which Raymond Basin water quality objectives exist are nitrate (as NO_3^-, 45 mg/L), nitrogen (nitrate + nitrite, 10 mg/L), sulfate (SO_4^{2-}, 100 mg/L), chloride (Cl^-, 100 mg/L), and boron (B, 0.5 mg/L) (Table III.1).

Nutrient additions include atmospheric deposition with precipitation of nitrogen as ammonium and nitrate, sulfur, and chloride. Some of these are by-products of fossil fuel combustion, while

others are the result of natural phenomena, such as lighting converting atmospheric nitrogen into nitrate, or denitrification in wetlands which releases nitrogen into the atmosphere. Wildfires release nutrients into the atmosphere which may return to the surface through precipitation. Other nutrients remain on the surface after fires, and will enter surface waters during precipitation events that generate runoff. Other natural nutrient additions occur through natural biogeochemical nutrient cycles through microbial decomposition of plant and animal residues in the soil. Nutrients are released into the soil as minerals during decomposition of organic structures by soil microbes. Nutrient cycling is accelerated when lawns and turf areas are irrigated during the dry season. Boron, sulfates, and chlorides are constituents of naturally-occurring minerals, and that are released into the environment as the minerals weather.

Anthropogenic sources likely provide the greatest nutrient additions in the Raymond Basin. Municipalities, academic institutions, industrial parks, and homeowners maintain turf and lawns with fertilizer. The primary ingredient in most fertilizers is nitrogen, either as urea, ammonium or nitrate. Once in the soil, though, microbes generally convert other nitrogen forms into nitrate. Commercial fertilizers are soluble salts that dissolve in water. Chloride is a common component in many fertilizers due to its high solubility, especially those containing potassium. Sulfates and chlorides are common ingredients in fertilizers and soil amendments. Fertilizer nutrients may enter surface waters through runoff if high-intensity precipitation events occur soon after spreading. Nitrates and chlorides will leach readily if irrigation and/or precipitation exceed the combined atmospheric demand of water from evaporation and transpiration.

On-site wastewater treatment systems return nutrients to the soil throughout the Raymond Basin in areas not associated with a centralized treatment facility. Centralized municipal wastewater treatment systems and some industrial wastewater treatment systems release nutrients into the environment, particularly nitrates, sulfates, and chlorides.

Though agriculture is widely recognized as a contributor of nutrients to surface and groundwater, it is a minor contributor in the Raymond Basin, as agriculture currently occupies only a small portion of the land area.

III.4.2. Fate and Transport

III.4.2.1 Salt

Once salts are in the soil and vadose zone, there are three possible fates: remain where they are, wick upward to the surface with water, leach downward with water. For simplicity in the following discussion, all references to soil apply equally to the vadose zone (unsaturated zone between the soil and groundwater). On a landscape scale, salts remain in the soil, or they move to surface waters, or to aquifers.

Salts will remain at the same relative depth if the balance of water applied plus precipitation approximately equals atmospheric demand through evaporation from soil surfaces and transpiration from plant leaves.

Salts will move downward if the balance of water applied plus precipitation exceeds atmospheric demand through evaporation from soil surfaces and transpiration from plant leaves.

Salts will move upward if the balance of water applied plus precipitation approximately is less than atmospheric demand through evaporation from soil surfaces and transpiration from plant leaves. This situation is enhanced in the case of water tables within 4 to 6 feet of the soil surface, depending upon texture of the soils. Finer-textured soils (silts, loams, and clays) promote upward capillary movement of water in greater quantity, and from greater depths, resulting in greater salt accumulation at the surface than occurs on coarse-textured soils (sands and sandy loams).

Salts move with water, in the same direction, and generally at the same rate. The exception occurs when the soil chemistry alters the form and solubility of the salt. This may occur through several possible chemical reactions, including salts precipitating out of the water as a solid.

Most clay minerals in the soil are negatively charged, and may adsorb some cations (positively-charged ions), e.g., calcium, magnesium, potassium, and sodium to the mineral surfaces. Anions

(negatively-charged ions) move through the soil more readily, though some will be attracted to the cations on soil surfaces. The result is preferential movement of anions, such as chloride sulfates, and nitrates through the soil.

The soils in the basin are typical of semiarid and arid region soils that typically have high concentrations of calcium, often in the form of calcium carbonate (often seen as caliche) and gypsum (calcium sulfate). These salts dissociate weakly in the soil solution, allowing the components to move with water, and to participate in chemical reactions. The most common salt reaction in the soil is precipitation. Some anions, such as chloride, moving through the soil solution may precipitate with cations, such as calcium, to form a salt, such as calcium chloride. Once precipitated, the salt does not move until it dissolves and the individual components enter the soil solution again.

All soils have a limit to the cations and anions they can adsorb. Precipitation of salts in the solid phase is controlled by the concentration of salts in the water, and the availability of minerals in the soil to react with the salts in the water. Salts always precipitate when the amount of water is insufficient to continue leaching them. When sufficient water is available, some salts will be dissolved in the water and leach as the water percolates.

If conditions in the soil become anaerobic, due to saturation and lack of free oxygen, some soil bacteria have the ability to “breathe” minerals such as nitrogen, iron and manganese. When this occurs, iron and manganese become more soluble, and also may participate in precipitation reactions in the soil. Precipitation removes ions from the soil solution. However, anaerobic conditions are associated with greater leaching, since these conditions occur with saturation.

Water moves from areas of high potential energy to areas of low potential energy, on a landscape, or in the soil or vadose zone. This is commonly stated as water flows downhill. Though gravity pulls water downward, there are other forces in soil that can pull water upward. A wet soil generally has higher potential energy than a dry soil, and so water typically moves toward drier soil. This is the reason that water moves upward from a water table through the

capillary fringe. If the soil surface is within the capillary fringe, water will move to the surface. Salts move with water, so if the water goes to the surface, so do the salts. Once at the surface, the water evaporates, and the salts precipitate on the soil surface. This accumulation of salts is common in arid and semiarid regions with shallow water tables, or in areas where irrigation management does not incorporate necessary leaching fractions to leach the salts out of the root zone. When irrigation results in artificially high water tables, a drainage system must be installed to remove the water from the soil profile and root zone. The salts move with the water through the drainage system, typically into surface water, such as rivers.

The salts will move as far downward in the soil as does the water. In semiarid and arid regions, the long-term historic depth of water penetration from natural precipitation is identified by the presence of a zone of increased chloride concentration, often called chloride bulge. This is the reason chloride is used as a tracer; it is the most soluble, and moves the furthest with water. Other salts of lower solubility, such gypsum, precipitate above the chloride bulge, while calcium carbonate precipitates above the gypsum.

If sufficient water is added to the surface (precipitation and/or irrigation and/or water spreading) to move water through the soil to the groundwater table and aquifer, the salts reach the groundwater and aquifer, as well. Once in the aquifer, the salts remain there unless removed from the aquifer through groundwater pumping or outflow from one basin to another, if a hydraulic connection between aquifers exists.

III.4.2.2 Nutrients

Nutrients in the soil have been classified historically as mobile or immobile, referring to their solubility and tendency to move within the soil. Mobile nutrients have long been recognized as those with the potential to leach below the root zone. However, even “immobile” nutrients may be leached from the soil if sufficient water moves through the soil. Though initially high in calcium and other cations, soils in humid regions often have little calcium remaining because centuries of leaching have washed it out of the soil. More recently, ideas about other immobile

nutrients, such as phosphorus, are being revisited as more is learned about the fixation (holding) capacity of soils for a given nutrient. Once the fixation capacity is reached, the nutrient becomes mobile and may leach into groundwater.

Nitrogen is involved in a complex, natural biochemical nutrient cycle, passing through inorganic solid and gas phases, and solid organic compounds through living organisms and decomposition products of dead organisms and waste products. There are no naturally-occurring soil minerals that contain nitrogen. Nitrogen in the soil is most commonly found in organic compounds, and as ammonium, and nitrate. Nitrite is seldom present in large concentrations in soil, except in anaerobic conditions. Naturally-occurring soil organisms readily convert ammonium to nitrite, and nitrite to nitrate, a process called nitrification. Other organisms decompose proteins in organic materials to release ammonium, which then undergoes nitrification. The abundance of these organisms decreases with soil depth, and so does the conversion of nitrogen from one form to another.

Once in the soil, nitrate may be taken up by plants, used by soil organisms, leached, or reduced. The same processes occur when nitrate is added directly to a soil as fertilizer or as a constituent of recycled water. Nitrate reduction occurs under anaerobic conditions when biological oxygen demand is great. Once all the oxygen is consumed by aerobic organisms during the decomposition of organic compounds, decomposition continues by organisms that “breathe” nitrate instead of oxygen. In these circumstances, nitrate is converted to nitrite. However, nitrite may be further converted to gaseous nitric or nitrous oxides, or dinitrogen gas. Depending upon the depth at which this conversion occurs, these gases may be released into the atmosphere, or may remain dissolved in water. Once in these gas forms, they are unusable to plants or animals, and to most soil organisms.

Nitrate and nitrate have the same solubility characteristics as chloride, and so all previous discussion about chloride transport applies equally to nitrate and nitrite.

Sulfur undergoes similar biological reactions in the soil as nitrogen, but also exists in chemical

equilibrium with sulfur-containing soil minerals. Sulfates are soluble, but not quite as mobile as nitrate or chloride. Sulfates may be taken up by plants, used by soil microorganisms, leached, or reduced under anaerobic conditions with high biological oxygen demand. Reduced sulfur compounds are odorous gasses that are released into the atmosphere or remain dissolved in water.

Boron is present in soils as boric acid, which is highly soluble, and prone to leach in sandy soils. In fine-textured soils, boron leaching is less likely until the fixation capacity is reached.

III.5. LOADING ESTIMATES AND ASSIMILATIVE CAPACITY

To comply with Section 9(c)(1) of the Policy, which states "*the available assimilative capacity of a basin/subbasin shall be calculated by comparing the mineral water quality objective [Basin Plan objective] with the average concentration of the basin/sub-basin [background basin water quality conditions], either over the most recent five years of data available or using a data set approved by the Regional Water Board Executive Officer,*" models were developed to estimate the mineral loading/unloading, storage, and available assimilative capacity.

III.5.1. Loading Estimates

For the Raymond Basin SNMP characterization, loading is defined as the amount of a mineral component entering the groundwater already in storage via natural or artificial groundwater replenishment. Loading estimates using groundwater balance components of the 50 percent Model Update and Recalibration (Geoscience, 2013) and existing water quality data for those components (Tables III.4a, III.4b, III.4c and III.4d, and Appendices J, K, L, M, N, and O) have been tabulated. The inputs from the groundwater balance model include: precipitation on from the valley floor and the mountain watershed; direct spreading and injection of local runoff and imported water; return flow from applied surface, ground and imported water from MWD; subsurface flow into and out of each subarea; groundwater extraction and exported water (Appendices G, H, and I). For this characterization, it is assumed that all of the groundwater in

storage in each subarea of the Raymond Basin is subject to mixing.

Because the format and availability of data for return flow (Basin-wide rather than subarea) did not precisely match the water quality data available, a technique was used to calculate the weighted average water quality in returned flow using the relative volume of diverted surface water, groundwater, and imported water that contributed to return flow in each subarea of the Basin. Then the water quality for each water component was multiplied by the relative return flow component to obtain the weighted average water quality for returned flow, as presented in Table III.4.

III.5.1.1 Precision of Estimates

Due to the uncertainty of the estimated quantities of water in each component of the groundwater balance model, all salt/nutrient quantities are rounded to the nearest 1,000 pounds (lbs). It is questionable even this level of precision exists because:

- The groundwater quality varies spatially and with depth, and the groundwater data are inadequate to accurately determine the quantity of each constituent salt present.
- The actual quantity of some components in the groundwater model are estimated, but not precisely measured.
- No data exist for the constituent salts at various depths from the soil surface in the vadose zone to the groundwater level. It is therefore impossible to predict or describe the potential chemical reactions that occur in the constituent salts as they move through the vadose zone to the groundwater table.
- The concentration of the constituent in recharge component when it reaches the aquifer/groundwater is estimated. There are no measurements of water quality parameters in the unsaturated zone immediately above the aquifer water level.
- The residence time of the constituent salts as they move through the vadose zone is not known, and varies spatially across the basin. Water from the spreading grounds moves rather quickly to the groundwater, while the time period for return flow to reach the groundwater level is not known. There is no correlation between the constituent salt

concentrations added to the surface and changes in the groundwater concentration in periods less than 10 to 15 years, depending upon the constituent. Since only about 26 years of water quality data and 18 years of water balance data are available, it is not possible to identify a correlation for residence time of each mineral constituent in the vadose zone.

- Some components of the quantity of subsurface inflow and outflow from the Raymond Basin are estimated. The actual groundwater quality of subsurface inflow and outflow to is estimated.
- The aquifer exhibits some degree of concentration/dilution effects. In years when the aquifer level declines, the concentration of the constituent salts tends to increase (but not always). Conversely, in years when the aquifer levels rise due to increased recharge, the concentration of the constituent salts tends to decrease.
- Water quality for each constituent salt is not available for each groundwater balance component for each year. In this case, data from adjacent years or sampling events were averaged to provide a water quality value for each year. Due to the water sampling frequency, 6-year and 9-year intervals were used to obtain representative water quality data for each year.

The lack of water quality data that contributes to such uncertainties makes it impossible to accurately predict the concentration of groundwater constituent salts on a year-to-year basis. For this reason, the emphasis is on trends, and the models that will be described attempt to match the long-term trends of mineral concentration in the groundwater rather than the observed annual groundwater mineral concentration.

III.5.1.2 Loading/Unloading Estimation Models and Calibration

The quantity of groundwater in storage (ac-ft) and existing water quality data from wells (mg/L, concentrations of nitrate, chloride, sulfate, and TDS) were used to determine the quantity (in pounds) of each component stored in the groundwater. For each year, the quantity of each component of the groundwater balance model (ac-ft/yr) and the concentration of the constituent

salts (mg/L) for that component were used to estimate the amount of the constituent salt that was added to, or removed from, the groundwater in storage. A separate loading/unloading spreadsheet model was prepared for each of the constituent salts and nutrients in each subarea. The full calculation process for each loading/unloading estimate using the volume of each groundwater balance component and the water quality for each constituent salt in that component is documented in Appendices P, Q, R, S, T, U, V, W, X, Y, Z, and AA. The discussion below explains how the loading/unloading estimation models were calibrated.

Long-term trends in the groundwater concentration of each constituent salt were used to calibrate the specific spreadsheet model. The following assumptions were used to calibrate the spreadsheet model for each constituent salt.

- The current groundwater concentration for the constituent salt represents the historical (geologic time frame) equilibrium for the amount of salt that dissolves as water moves through the vadose zone from natural recharge processes (precipitation, percolation from the watershed and surface waters, subsurface inflow and outflow from the Basin). The current groundwater quality also integrates recent changes to the equilibrium as a result of human activities in the past century.
- When the concentration of the constituent salt for components of precipitation, recycled water, return flow, or direct spreading in the groundwater balance model were less than the current groundwater concentration for that constituent, it generally was assumed the concentration of that constituent increased as it moved through the vadose zone so that the concentration matched the groundwater concentration upon recharging the aquifer.
- When the concentration of the constituent salt for components of precipitation, recycled water, return flow, or direct spreading in the groundwater balance model were greater than the current groundwater concentration for that constituent, it generally was assumed the concentration of that constituent decreased as it moved through the vadose zone so that the concentration matched the groundwater concentration upon recharging the aquifer. Exceptions were made for some return flow constituents, as noted below.
- Generally, the concentration of constituent salts in water used for direct spreading generally was assumed not to change as it passed through the vadose zone into the

aquifer (the concentration stayed the same).

- The trend in groundwater quality (1994-95 to 2010-2011) for each constituent salt was determined using all of the groundwater in storage volume to estimate the quantity of loading/unloading (lbs/yr).
- Concentrations or coefficients (multipliers) for each of the groundwater balance components were adjusted to match the long-term trend identified. These values are reported in Tables III.5a (Monk Hill subarea), III.5b (Pasadena subarea), and III.5c (Santa Anita subarea).
    - There are complex interactions of salts with minerals and elements in the vadose zone. There is a lack of data available to describe these interactions. Though some approaches apply a concentration factor only to return flow to calibrate a model, this characterization does not use that approach. Such approaches ignore the interaction of precipitation and other good water quality sources as they move through the vadose zone toward the groundwater. Further those models may use concentration factors that defy physical and chemical equilibria points in nature, at which salts would precipitate out of solution.
    - As the recharge water often had better water quality than the groundwater, with some exceptions, the mean groundwater concentration provided the upper limit of concentration for any mineral component for any recharge or return flow component except direct spreading and injection. Water quality of the recharge water was more often considered when the water quality of the recharge water was poorer than the groundwater.
    - Ratios of the volume of annual recharge from precipitation to the mean recharge were used to adjust coefficients (multipliers). Similarly, ratios of the volume of annual surface spreading to the mean were used to adjust coefficients (multipliers). The logic behind adjusting the coefficients is dilution is more likely when a greater volume of water is moving through the vadose zone to the groundwater. With increasing volume of recharge, the coefficients were adjusted according to three assigned categories:
        - ratio less than 75 percent of the mean;

    - ratio between 75 percent and the mean;
    - ratio greater than the mean.
  - Ratios of the water quality (mineral concentration) of the returned flow to the mean groundwater quality for each constituent were used to adjust coefficients for the weighted return flow factors. With increasing ratio, the coefficients were adjusted according to three assigned categories:
    - ratio less than 1, i.e., concentration in the returned flow component was less than the mean groundwater concentration;
    - ratio between 1 and 1.25;
    - ratio greater than 1.25, i.e., concentration in the returned flow component was 1.25 time greater than the mean groundwater concentration.
  - Each subarea and mineral constituent required different coefficients to calibrate the models, as shown in Tables III.5a, III.5b and III.5c.

Particular challenges were encountered in calibrating the Pasadena model because the groundwater concentration was increasing while the groundwater in storage was decreasing, and the Santa Anita model because both the groundwater concentration and the groundwater in storage were decreasing.

The results of the calibrated models will be discussed in the next section in the context of allowable load and assimilative capacity.

III.5.2 Allowable Load and Assimilative Capacity

For this characterization, the allowable load is defined as the quantity (in pounds) of a constituent salt that may be present in the groundwater in storage without exceeding the Basin Plan water quality objective. This was determined using the total volume of groundwater in storage and the Raymond Basin water quality objectives for the constituent salt, TDS (450 mg/L), nitrate (as NO_3^-, 45 mg/L), chloride (Cl^-, 100 mg/L), and sulfate (SO_4^{2-}, 100 mg/L).

The assimilative capacity is defined as the difference between the quantity of the constituent salt stored in the groundwater, and the allowable load of that constituent. This was determined on an annual basis. As the assimilative capacity changed with time (decreasing for most constituents), the mean assimilative capacity of the last 10 years (2002-03 to 2011-2012) was used as the assimilative capacity for that constituent.

It is important to note the only ways in which assimilative capacity may increase are an increase in the groundwater in storage, or a decrease in the groundwater concentration of the mineral constituent. The latter case is indicative of net unloading of the mineral, i.e., more of the mineral constituent is unloaded through groundwater extraction and subsurface outflow than is loaded through the groundwater recharge components. If there is a long-term degradation of water quality, the assimilative capacity of the basin will decrease. It is possible that at some point in the future, the assimilative capacity will not be controlled by the amount of groundwater in storage, but by the annual loading/unloading balances.

The loading/unloading tables for each subarea and mineral constituent have the same format. The load from each component was determined, as shown in the worksheets in Appendices P through AA. These worksheets were condensed into the loading/unloading balance tables which show only the mass of the mineral constituent for each component of the water balance model, as shown in Tables III.6 through III.17. The process followed these steps.

1. The mineral constituent loading is estimated from precipitation, subsurface inflow, returned flow, and artificial recharge (injection and spreading).
2. The unloading is estimated from groundwater extraction and subsurface outflow.
3. The balance is the difference between the quantity of mineral constituent loaded and the quantity unloaded.
4. The quantity of the mineral constituent present in groundwater in storage was estimated as the product of the groundwater volume and the mineral constituent concentration in the groundwater.
5. The allowable loading was determined as the product of the volume of the amount of

groundwater in storage and the basin plan water quality objective.

6. The assimilative capacity was determined as the difference between the quantity of the mineral constituent stored in the groundwater and the allowable loading. Positive values of assimilative capacity indicate the basin has the ability to receive more of the mineral constituent without exceeding the basin plan water quality objective.
7. All data were evaluated on an annual basis. For each component, the median (50 percent value) and overall mean of the observation period, and means for the last 10 years (2002-03 to 2011-02), and last 5 years (2007-08 to 2011-12) are presented. Because the assimilative capacity changes through time, the means of the last ten years are used to present the mineral component balances for each subarea (Plates III.18, III.19, and III.20), and the mean assimilative capacity from the last ten years is later used as the input into the assimilative capacity assessments.

It is important to realize the allowable load and the assimilative capacity are both dependent upon the quantity of groundwater in storage. Long-term changes in the quantity of groundwater in storage will have concomitant effects on the assimilative capacity. For the reporting period, the groundwater in storage in the Monk Hill subarea increased about 1,300 ac-ft/yr, while the groundwater in storage decreased in the Pasadena subarea by about 2,200 ac-ft/yr, and in the Santa Anita subarea by 900 ac-ft/yr.

The allowable loading and assimilative capacity for Nitrate, Chloride, Sulfate, and TDS for each of subarea is discussed in the following section.

Monk Hill Subarea

Comparing the mean of the first and last five years of the observation period, the volume of groundwater in storage increased about 5 percent, resulting in a 5 percent increase in allowable loading for each mineral constituent, as shown in Tables III.6, III.7, III.8, and III.9.

Nitrate, NO_3

The calibrated Monk Hill nitrate loading/unloading model is provided in Table III.6 (condensed from Appendix P). Though the allowable loading increased about 5 percent during the observation period, the nitrate concentration in the groundwater had a net increase of about 6 percent (Plate III.11). Comparing the mean loading and assimilative capacity of the first and last 5-yr periods, the result is about a 10 percent increase in assimilative capacity. The results of the nitrate loading/unloading model for the last 10 years (2002-03 to 2011-12) are presented in Plate III.18a. Over the last 10 years, deep percolation of water from precipitation accounts for the greatest nitrate contribution, contributing about 280,000 pounds per year which is more than additions from return flow, artificial recharge, and inflow from Verdugo Basin. Groundwater extraction removes about 380,000 pounds per year. There is a net addition of about 70,000 lbs nitrate annually. The current nitrate load is about 60 percent of the allowable load, leaving an assimilative capacity for nitrate of about 10 million pounds.

Chloride, Cl

The calibrated Monk Hill chloride loading/unloading model is provided in Table III.7 (condensed from Appendix Q). Though the allowable loading increased about 5 percent during the observation period, the chloride concentration in the groundwater had a net increase of about 50 percent (Plate III.13a). Comparing the mean loading and assimilative capacity of the first and last 5-yr periods, the result is about a 13 percent decrease in assimilative capacity. The results of the chloride loading/unloading model for the last 10 years are presented in Plate III.18b. Over the last 10 years, return flow accounts for the greatest chloride contribution, contributing about 580,000 pounds per year which is more than the additions from precipitation, artificial recharge, and inflow from Verdugo Basin. Groundwater extraction removes about 500,000 pounds per year from the Monk Hill subarea. There is a net addition of about 500,000 lbs chloride annually. The current chloride load is about 45 percent of the allowable load, leaving an assimilative capacity for chloride of about 31 million pounds.

Sulfate, SO_4

The calibrated Monk Hill sulfate loading/unloading model is provided in Table III.8 (condensed from Appendix R). Though the allowable loading increased about 5 percent during the observation period, the sulfate concentration in the groundwater had a net increase of about 200 percent (Plate III.14a). Comparing the mean loading and assimilative capacity of the first and last 5-yr periods, the result is about a 40 percent decrease in assimilative capacity. The results of the sulfate loading/unloading model for the last 10 years are presented in Plate III.18c. Over the last 10 years, return flow accounts for the greatest sulfate contribution, contributing about 980,000 pounds per year which is more than either additions from precipitation, artificial recharge, and inflow from Verdugo Basin. Groundwater extraction removes about 870,000 pounds per year. There is a net addition of about 750,000 lbs of sulfate annually. The current sulfate load is about 70 percent of the allowable load, leaving an assimilative capacity for sulfate of about 17 million lbs pounds.

Total Dissolved Solids, TDS

The calibrated Monk Hill TDS loading/unloading model is provided in Table III.9 (condensed from Appendix S). Though the allowable loading increased about 5 percent during the observation period, the TDS concentration in the groundwater had a net increase of about 40 percent (Plate III.15a). Comparing the mean loading and assimilative capacity of the first and last 5-yr periods, the result is about 50 percent decrease in assimilative capacity. The results of the TDS loading/unloading model for the last 10 years are presented in Plate III.18d. Over the last 10 years, additions from precipitation and return flow account for the greatest TDS contribution at about 4.3 million pounds per year. Groundwater extraction removes about 5.6 million pounds per year. There is a net addition of about 2.3 million lbs TDS annually. The current TDS load is about 90 percent of the allowable load, leaving an assimilative capacity for TD of about 30 million pounds.

Pasadena Subarea

Comparing the mean of the first and last five years of the observation period, the volume of groundwater in storage decreased about 8 percent, resulting in an 8 percent decrease in allowable loading for each mineral constituent, as shown in Tables III.10, III.11, III.12, and III.13.

Nitrate, NO_3

The calibrated Pasadena nitrate loading/unloading model is provided in Table III.10 (condensed from Appendix T). The allowable nitrate loading decreased about 8 percent during the observation period, while the nitrate concentration in the groundwater had a net increase of about 25 percent (Plate III.16a). Comparing the mean loading and assimilative capacity of the first and last 5-yr periods, the result is almost a 30 percent decrease in assimilative capacity. The results of the nitrate loading/unloading model for the last 10 years are presented in Plate III.19a. Over the last 10 years, inflow from the Monk Hill subarea accounts for the greatest nitrate contribution, contributing about 470,000 pounds per year. Groundwater extraction removes about 500,000 pounds per year and is more than the combined outflow to the Main San Gabriel Basin and the Santa Anita subarea. There is a net addition of about 100,000 lbs nitrate annually. The current nitrate load is about 80 percent of the allowable load, leaving an assimilative capacity for Nitrate of about 14 million pounds.

Chloride, Cl

The calibrated Pasadena chloride loading/unloading model is provided in Table III.11 (condensed from Appendix U). The allowable chloride loading decreased about 8 percent during the observation period, while the chloride concentration in the groundwater had a net increase of about 15 percent (Plate III.16b). Comparing the mean loading and assimilative capacity of the first and last 5-yr periods, the result is about a 20 percent decrease in assimilative capacity. The results of the chloride loading/unloading model for the last 10 years are presented in Plate III.19b. Over the last 10 years, return flow accounts for the greatest chloride contribution,

contributing about 760,000 pounds per year and is more than inflow from the Monk Hill subarea, precipitation and artificial recharge. Groundwater extraction removes about 540,000 pounds per year. There is a net addition of about 800,000 lbs chloride annually. The current chloride load is about 45 percent of the allowable load, leaving an assimilative capacity for chloride of about 73 million pounds.

Sulfate, SO_4

The calibrated Pasadena sulfate loading/unloading model is provided in Table III.12 (condensed from Appendix V). The allowable sulfate loading decreased about 8 percent during the observation period, while the sulfate concentration in the groundwater had a net increase of about 60 percent (Plate III.16c). Comparing the mean loading and assimilative capacity of the first and last 5-yr periods, the result is about a 45 percent decrease in assimilative capacity. The results of the sulfate loading/unloading model for the last 10 years are presented in Plate III.19c. Over the last 10 years, return flow accounts for the greatest sulfate contribution, contributing almost 1.5 million pounds per year which is more than inflow from the Monk Hill subarea, precipitation and artificial recharge. Groundwater extraction removes about one million pounds per year which is about the same quantity of sulfate as the outflow to the Main San Gabriel Basin and the Santa Anita subarea. There is a net addition of about 1.3 million lbs sulfate annually. The current sulfate load is almost 75 percent of the allowable load, leaving an assimilative capacity for sulfate of about 39 million pounds.

Total Dissolved Solids, TDS

The calibrated Pasadena TDS loading/unloading model is provided in Table III.13 (condensed from Appendix W). The allowable loading decreased about 8 percent during the observation period, the TDS concentration in the groundwater had a net increase of about 15 percent (Plate III.16d). Comparing the mean loading and assimilative capacity of the first and last 5-yr periods, the result is about 30 percent decrease in assimilative capacity. The results of the TDS loading/unloading model for the last 10 years are presented in Plate III.19d. Over the last 10

years, return flow accounts for about 3.1 million pounds which is more than inflow from the Monk Hill subarea, and artificial recharge. Groundwater extraction removes about 5.2 million pounds, which is more than the combined outflow to the Main San Gabriel Basin and the Santa Anita subarea. There is a net addition of about 2.2 million lbs TDS annually. The current TDS load is about 80 percent of the allowable load, leaving an assimilative capacity of TDS of about 139 million pounds.

Santa Anita Subarea

Comparing the mean of the first and last five years of the observation period, the volume of groundwater in storage decreased about 17 percent, resulting in a 17 percent decrease in allowable loading for each mineral constituent, as shown in Tables III.14, III.15, III.16, and III.17.

Nitrate, NO_3

The calibrated Santa Anita nitrate loading/unloading model is provided in Table III.14 (condensed from Appendix X). While the allowable nitrate loading decreased about 17 percent during the observation period, the nitrate concentration in the groundwater also decreased by about 50 percent (Plate III.17a). Comparing the mean loading and assimilative capacity of the first and last 5-yr periods, the result is about a 10 percent decrease in assimilative capacity. The results of the nitrate loading/unloading model for the last 10 years are presented in Plate III.20a. Over the last 10 years, nitrate loading from precipitation, inflow from the Pasadena subarea, and artificial recharge, are each about 80,000 pounds per year. Groundwater extraction removes almost about 320,000 pounds per year which is more than outflow to the Main San Gabriel Basin. There is a net removal of about 60,000 lbs nitrate annually. The current nitrate load is about 50 percent of the allowable load, leaving an assimilative capacity for nitrate of about 4 million pounds.

Chloride, Cl

The calibrated Santa Anita chloride loading/unloading model is provided in Table III.15 (condensed from Appendix Y). Though the allowable loading decreased about 17 percent during the observation period, the chloride concentration in the groundwater changed little (Plate III.17b). Comparing the mean loading and assimilative capacity of the first and last 5-yr periods, the result is about a 15 percent decrease in assimilative capacity. The results of the chloride loading/unloading model for the last 10 years are presented in Plate III.20b. Over the last 10 years, inflow from the Pasadena subarea accounts for the about 80,000 pounds per year and is more than the chloride additions from precipitation and artificial recharge. Groundwater extraction removes about 270,000 pounds per year which is more than outflow to the Main San Gabriel Basin. There is a net removal of about 70,000 lbs chloride annually. The current chloride load is about 15 percent of the allowable load, leaving an assimilative capacity for chloride of about 16 million pounds.

Sulfate, SO_4

The calibrated Santa Anita sulfate loading/unloading model is provided in Table III.16 (condensed from Appendix Z). Though the allowable loading decreased about 17 percent during the observation period, the sulfate concentration in the groundwater changed little (Plate III.17c). Comparing the mean loading and assimilative capacity of the first and last 5-yr periods, the result is about a 15 percent decrease in assimilative capacity. The results of the sulfate loading/unloading model for the last 10 years are presented in Plate III.20c. Over the last 10 years, the greatest sulfate contribution is from additions from precipitation, contributing about 200,000 pounds per year. Groundwater extraction removes about 540,000 pounds per year which is more than outflow to the Main San Gabriel Basin. There is a net addition of about 30,000 lbs sulfate annually. The current sulfate load is about 30 percent of the allowable load, leaving an assimilative capacity for sulfate of about 13 million pounds.

Total Dissolved Solids, TDS

The calibrated Santa Anita TDS loading/unloading model is provided in Table III.17 (condensed from Appendix AA). Though the allowable loading decreased about 17 percent during the observation period, the TDS concentration in the groundwater had a net increase of about 40 percent (Plate III.17d). Comparing the mean loading and assimilative capacity of the first and last 5-yr periods, the result is about 50 percent decrease in assimilative capacity. The results of the TDS loading/unloading model for the last 10 years are presented in Plate III.20d. Over the last 10 years, precipitation and artificial recharge each contribute about 1.5 million pounds per year. Groundwater extraction removes about 4.8 million pounds per year which is more than outflow to the Main San Gabriel Basin. There is a net removal of about 700,000 lbs TDS annually. The current TDS load is about 60 percent of the allowable load, leaving an assimilative capacity for TDS of about 33 million pounds.

III.5.3 Assimilative Capacity Assessment Tool (ACAT)

For the purpose of this characterization, these assessments of water management assume that new water will be recharged into the aquifer. In order to provide a conservative estimation of the assimilative capacity and loadings resulting from new water replenishment activities, the quality of the new water is assumed to be similar to recycled water quality found in the Basin. The recycled water quality characteristics used for the assessment were taken from the RMC Technical Memorandum (October 25, 2013) to the Pasadena Water and Power Recycled Water Program concerning “Planned Recycled Water Projects”. These values are as follows: 26 mg/L nitrate, 163 mg/L chloride, 210 mg/L sulfate, 720 mg/L TDS. The TDS in the recycled water represents the highest water quality concentration, followed by sulfate (about 30 percent of the TDS concentration), chloride (about 20 percent of the TDS concentration), and nitrate (about 4 percent of the TDS concentration). Depending upon the treatment method, other combinations of water quality are possible that might have different ratios of chloride and sulfate to TDS, and chloride to sulfate.

The ACAT uses the allowable loading and assimilative capacity discussed in the previous section. It considers how much new water in a given year could be used to recharge the aquifer before using 10 percent of the existing assimilative capacity for the most limiting mineral constituent in each subarea, using this process:

1. The volume of groundwater stored in each Basin subarea is used to determine the allowable load and assimilative capacity.
2. The quantity of new water and water quality for each mineral constituent is used to determine the load.
3. Recharge and removal quantities are assumed constant and equal within each subarea and are used to determine the unloading and the remaining loading.
4. The net load is calculated as the difference between the total loading and unloading weights.
5. The net load is divided by the assimilative capacity to determine the percent of the assimilative capacity used for each mineral constituent.
6. The quantity of new water is adjusted in several iterations until one of the mineral constituents reaches 10 percent of the assimilative capacity.
7. That mineral component is the most limiting factor determining the use of new water of the stated quality for recharge in the subarea.
8. It is possible to develop other scenarios using different water quality.

As discussed earlier, the assimilative capacity changes with the water quality and volume of the groundwater in storage. Therefore, the allowable loading and assimilative capacity determinations should be revisited periodically.

Monk Hill Subarea

Using the assigned water quality for new water used for replenishment, the ACAT demonstrates that TDS will be the limiting mineral constituent controlling the use of new water for recharging the aquifer in the Monk Hill subarea, as shown in Table III.18. Assuming 190,400 ac-ft of groundwater in storage and 13,300 ac-ft of groundwater recharge and removal, 10 percent of the

TDS assimilative capacity of the groundwater in the subarea will be utilized after 225 ac-ft of recharge with new water annually. The utilization of the assimilative capacity for nitrate chloride, and sulfate is less than TDS, and therefore, these constituents are not limiting. If water of a different quality is used, TDS will remain the limiting factor until the ratio of TDS to sulfate (TDS concentration divided by sulfate concentration) is less than 3.0, at which time sulfate will become the limiting factor.

Pasadena Subarea

Using the assigned water quality for new water used for replenishment, the ACAT demonstrates that sulfate will be the limiting mineral constituent controlling the use of new water for recharging the aquifer in the Pasadena subarea, as shown in Table III.19. Assuming 536,800 ac-ft of groundwater in storage and 19,700 ac-ft of groundwater recharge and removal, 10 percent of the sulfate assimilative capacity of the groundwater in the subarea will be utilized after 405 ac-ft of recharge with new water annually. The utilization of the assimilative capacity for nitrate chloride, and TDS is less than sulfate, and therefore, these constituents are not limiting. If water of a different quality is used, sulfate will remain the limiting factor until the ratio of TDS to sulfate (TDS concentration divided by sulfate concentration) is greater than 4.0, at which time TDS will become the limiting factor.

Santa Anita Subarea

Using the assigned water quality for new water used for replenishment, the ACAT demonstrates that sulfate will be the limiting mineral constituent controlling the use of new water for recharging the aquifer in the Santa Anita subarea, as shown in Table III.20. Assuming 72,800 ac-ft of groundwater in storage and 6,200 ac-ft of groundwater recharge and removal, 10 percent of the sulfate assimilative capacity of the groundwater in the subarea will be utilized after 245 ac-ft of recharge with new water annually. The utilization of the assimilative capacity for nitrate chloride, and TDS is less than sulfate, and therefore, these constituents are not limiting. If water of a different quality is used, sulfate will remain the limiting factor until the ratio of TDS to

sulfate (TDS concentration divided by sulfate concentration) is less than 2.7, at which time sulfate will become the limiting factor.

The ACAT provides a valuable management tool that could be employed in decisions concerning use of new water for aquifer recharge. The ACAT identifies which of the mineral constituents in the water will most limit the volume of new water that can be used for recharge without passing a defined assimilative capacity threshold, e.g., 10 percent as in this example. Furthermore, the ACAT allows the evaluation of the effects of using new water with different water quality characteristics. The ACAT has the ability to identify the ratio of the concentration of the mineral constituents in the water that will be thresholds that will determine which constituent imposes the greatest limitation on the assimilative capacity in the subarea.

III.6. IMPLEMENTATION MEASURES

The Raymond Basin has been managed for many decades to control salt and nutrient loading to preserve the high quality groundwater supplies. Existing programs include support of stormwater runoff replenishment conducted by LACDPW and a water quality monitoring program conducted by area water purveyors. Raymond Basin management is conducted by the RBMB in conjunction with other Stakeholders including LACDPW and MWD. Historically, stakeholders have coordinated with the RBMB to replenish the groundwater supplies with the greatest amount of high quality water as possible which principally has been stormwater runoff. As a result, replenishment of the subareas with high quality (low TDS) water may actually result in an estimated net loading of the Raymond Basin during high storm runoff /replenishment. However, the additional groundwater volume from such replenishment dilutes the groundwater TDS concentration in the long-term.

The Raymond Basin has experienced unprecedented drought conditions since calendar year 2006. As a result, the groundwater elevation in the three subareas has decreased, as shown on Plates III.9a, III.9b, and III.9C. Since 1943, when the Raymond Basin was adjudicated, to present, the RBMB (and its predecessor prior to 1984) has actively managed water quality

through existing implementation measures (described in greater detail below).

Section 6.b (3)(e) of the Recycled Water Policy states in part that a SNMP shall include "…implementation measures to manage salt and nutrient loading on a sustainable basis…" in the Basin.

Implementation measures to reduce salt and nutrient loading may have two types of impacts to a groundwater basin. Those impacts consist of 1) loading as the result of additional water replenished in the groundwater basin and 2) change to the concentration of salts and nutrients that are included in the water that is replenished. The following sections address existing and potential implementation measures that may impact salt and nutrient loading. Those implementation measures are summarized on Table III.21 and are briefly described below.

III.6.1 Groundwater Replenishment

LACDPW maintains a complex system of dams, retention basins, storm channels and off-stream spreading grounds to control stormwater runoff and to maximize replenishment of the stormwater flow. The existing spreading grounds are operated to enable stormwater run-off to be replenished into each of the subareas in an efficient and effective manner. A lesser source of replenishment is injection of treated imported water into the Monk Hill subarea. Local stormwater replenished in these facilities typically has the lowest concentrations of TDS, Nitrate, Sulfate, and Chloride of the various sources contributing to loading. As shown on Appendices P, Q, R, S, T, U, V, W, X, Y, Z, and AA the concentration of the TDS, chloride, nitrate, and sulfate in local stormwater is lower than the quality of the groundwater extracted. Consequently, the quality of the Raymond Basin will be maintained over time assuming replenishment is greater than or equal to extractions. During drought conditions with little stormwater runoff, this may not be the case.

Maintain Spreading Grounds (Existing) – Artificial recharge of stormwater runoff occurs in off-stream spreading grounds located off the Arroyo Seco, Eaton Wash, and Santa Anita Wash.

The stormwater augments naturally occurring groundwater replenishment from precipitation. Replenishment of high quality stormwater contributes to the long-term enhancement of groundwater quality.

Groundwater Replenishment Coordinating Group (Existing) - Representatives from the RBMB, LACDPW, and MWD meet approximately every two months to coordinate the replenishment of local water and the availability of groundwater replenishment facilities. As the highest quality source of water, stormwater run-off is typically given the highest priority for replenishment activities.

Develop New Spreading Facilities (Potential) – The RBMB and LACDPW continually investigate opportunities to expand the network of spreading grounds. Potential new sites include debris basins.

III.6.2 Reduce Stormwater Runoff (Potential)

Cities within the Raymond Basin are co-permittees for the new MS4 permit. As such, cities are directed to take proactive steps, both individually and collectively, to implement stormwater Best Management Practices (BMPs) to reduce or eliminate stormwater runoff from facilities and consequently reduce flow in storm channels. These practices may result in increased stormwater replenishment. As noted in Section III.6.1, stormwater runoff typically contains the highest (best) quality of water used to replenish the Basin. Increased replenishment of high quality will tend to improve Basin water quality over time.

III.6.3 Institutional

Raymond Basin Judgment (Existing) – The Raymond Basin was adjudicated in 1944 and groundwater rights were assigned to producers. The RBMB was created by the Court in 1984 (as an amendment to the original Judgment) to administer the Raymond Basin Judgment. The RBMB maintains records of all groundwater produced from the Raymond Basin, maintains a

database of groundwater quality from all municipal water supply wells, and keeps track of all water entering and leaving the Raymond Basin.

Title 22 Water Quality Monitoring (Existing) - All municipal water suppliers are required to adhere to the provisions of Title 22 regarding water quality monitoring of municipal water supply wells. In general TDS, chloride, and sulfate samples are collected once every three years and nitrate samples are collected annually. Based on water quality results, municipal water suppliers may need to construct groundwater treatment facilities and/or develop water quality blending plans to maintain production from wells. In those situations, DDW may require more frequent water quality monitoring than those noted above. The municipal water supply wells are distributed throughout the Raymond Basin and water quality data from Title 22 water quality sampling will be incorporated into the Basin-wide Salt and Nutrient Monitoring Program described in Chapter V.

SNMP Monitoring Program (Future) - RBMB will implement a proposed monitoring plan as required by the Recycled Water Policy (See Section V.4). As required by the Recycled Water Policy Section 6.b(3)(a)(iii) water quality data will be reported to the LAWRWQCB at least every three years. The sampling frequency for salts and nutrients will be periodically evaluated and adjusted accordingly as necessary.

III.6.4 Regional Salinity Control

The Raymond Basin Judgment limits groundwater production to the 1955 Decreed Rights. Demand in addition to groundwater supplies historically has been met through the purchase of treated imported water from MWD's Weymouth Treatment Plant (along with the groundwater impaction/withdrawal program historically conducted by VWC). Return flow from domestic water usage contributes to loading of salts in the Raymond Basin. (Historically, there has not been an imported water groundwater replenishment program.) Consequently, it is critical the treated imported water quality be managed.

The MWD is responsible for all treated imported water used in the Raymond Basin and that water is from the Weymouth Treatment Plant. MWD has a goal to maintain the TDS concentrations at or below 500 mg/l. This is done through blending SWP water with Colorado River water. The RBMB will continue to coordinate with MWD and those water companies which use treated imported water to maintain records of the water quality, particularly TDS, Chloride, and Sulfate.

CHAPTER IV

ANTIDEGRADATION ANALYSIS

IV.1. REGULATORY BACKGROUND

In 1968, the SWRCB adopted Resolution No. 68-16 (Resolution) as the State's Anti-Degradation Policy:

1. *Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water and will not result in water quality less than that prescribed in the policies.*
2. *Any activity which produces or may produce a waste or increased volume or concentration of waste and which discharges or proposes to discharge to existing high quality waters will be required to meet waste discharge requirements which will result in the best practicable treatment or control of the discharge necessary to assure that (a) o pollution or nuisance will not occur and (b) the highest water quality consistent with maximum benefit to the people of the State will be maintained.* [29]

The Policy acknowledges that groundwater recharge with recycled water benefits the public; however, the SWRCB finds that groundwater recharge with recycled water has the potential to degrade water quality in groundwater basins. Therefore, the Policy requires that an antidegradation analysis be included in each salt and nutrient management plan to demonstrate the projects included within the plan will, collectively, satisfy the requirements of the Resolution. The Policy states in part with regards to the Resolution:

- *The proponent of a groundwater recharge project must demonstrate compliance with*

Resolution No. 68-16. Until such time as a salt/nutrient management plan is in effect, such compliance may be demonstrated as follows:

(1) A project that utilizes less than 10 percent of the available assimilative capacity in a basin/sub-basin (or multiple projects utilizing less than 20 percent of the available assimilative capacity in a basin/sub-basin) need only conduct an antidegradation analysis verifying the use of the assimilative capacity. For those basins/sub-basins where the Regional Water Boards have not determined the baseline assimilative capacity, the baseline assimilative capacity shall be calculated by the initial project proponent, with review and approval by the Regional Water Board, until such time as the salt/nutrient plan is approved by the Regional Water Board and is in effect. For compliance with this subparagraph, the available assimilative capacity shall be calculated by comparing the mineral water quality objective with the average concentration of the basin/sub-basin, either over the most recent five years of data available or using a data set approved by the Regional Water Board Executive Officer. In determining whether the available assimilative capacity will be exceeded by the project or projects, the Regional Water Board shall calculate the impacts of the project or projects over at least a ten year time frame.

(2) In the event a project or multiple projects utilize more than the fraction of the assimilative capacity designated in subparagraph (1), then a Regional Water Board-deemed acceptable antidegradation analysis shall be performed to comply with Resolution No. 68-16. The project proponent shall provide sufficient information for the Regional Water Board to make this determination. An example of an approved method is the method used by the State Water Board in connection with Resolution No. 2004-0060 and the Regional Water Board in connection with Resolution No. R8-2004-0001. An integrated approach (using surface water, groundwater, recycled water, stormwater, pollution prevention, water conservation, etc.) to the implementation of Resolution No. 68-16 is

encouraged.

- *Landscape irrigation with recycled water in accordance with this Policy is to the benefit of the people of the State of California. Nonetheless, the State Water Board finds that the use of water for irrigation may, regardless of its source, collectively affect groundwater quality over time. The State Water Board intends to address these impacts in part through the development of salt/nutrient management plans described in paragraph 6.*

  (1) A project that meets the criteria for a streamlined irrigation permit and is within a basin where a salt/nutrient management plan satisfying the provisions of paragraph 6(b) is in place may be approved without further antidegradation analysis, provided that the project is consistent with that plan.

  (2) A project that meets the criteria for a streamlined irrigation permit and is within a basin where a salt/nutrient management plan satisfying the provisions of paragraph 6(b) is being prepared may be approved by the Regional Water Board by demonstrating through a salt/nutrient mass balance or similar analysis that the project uses less than 10 percent of the available assimilative capacity as estimated by the project proponent in a basin/sub-basin (or multiple projects using less than 20 percent of the available assimilative capacity as estimated by the project proponent in a basin/sub-basin). [Appendix A]

IV.2. PROJECT EVALUATION

An antidegradation analysis was conducted to identify the use of available assimilative capacity, as described in the Policy Section 9(c)(1). For this antidegradation analysis, mass-balance calculations were performed using the Basin annual groundwater in storage estimated by the spreadsheet groundwater balance model for the Monk Hill subarea (Appendix G) the Pasadena subarea (Appendix H) and the Santa Anita Subarea (Appendix I) the annual water quality data

for all water used within the Raymond Basin (Appendices J and K). These mass-balance spreadsheets for nitrate, sulfate, chloride, and TDS are summarized in Tables III.6, III.7, III.8, III.9, III.10, III.11, III.12, III.14, III.15, III.16, and III.17.

Section III.5 of this SNMP identified the quantity of new water that could be introduced annually to the Basin before 10 percent of the available assimilative capacity for TDS would be used. The Nitrate, Chloride, and/or Sulfate concentrations in replenishment water are not sufficient for these compounds to become limiting to assimilative capacity before TDS. The antidegradation analysis consists of separate calculations for Nitrate, Chloride, Sulfate, and TDS showing the percentage utilization of each respective assimilative capacity after 1 year, 5 years, 10 years, 20 years, and when equilibrium is reached, as shown in Tables III.18, III.19, and III.20. The Recycled Water Policy sets an interim goal that no single project is to use more than 10 percent of the available assimilative capacity, or combination of projects to use more than 20 percent of the available assimilative capacity. Consequently, as part of this SNMP, the antidegradation analysis calculated the collective amount of water from potential future projects that could be replenished in the Basin without exceeding the very conservative value of 10 percent of the available assimilative capacity. These calculations are shown on Table III.18, III.19 and III.20 respectively for the Monk Hill, Pasadena, and Santa Anita subareas.

Monk Hill Subarea

The water quality of new water supplies is assumed to be 720 mg/l for TDS, 26 mg/l for nitrate, 163 mg/l for chloride and 210 mg/l for sulfate. Table III.18 shows the summary of the calculations and indicates TDS is the central constituent and will use 10.0 percent of the Monk Hill TDS assimilative capacity through annual replenishment of about 225 ac-ft of new water when equilibrium is reached.

Pasadena Subarea

The water quality of new water supplies is assumed to be 720 mg/l for TDS, 26 mg/l for nitrate,

163 mg/l for chloride and 210 mg/l for sulfate. Table III.19 shows the summary of the calculations and indicates sulfate is the central constituent and will use 10.0 percent of the Pasadena sulfate assimilative capacity through annual replenishment of about 405 ac-ft of new water when equilibrium is reached.

Santa Anita Subarea

The water quality of new water supplies is assumed to be 720 mg/l for TDS, 26 mg/l for nitrate, 163 mg/l for chloride and 210 mg/l for sulfate. Table III.20 shows the summary of the calculations and indicates sulfate is the central constituent and will use 10.0 percent of the Santa Anita sulfate assimilative capacity through annual replenishment of about 245 ac-ft of new water when equilibrium is reached.

The antidegradation analysis is extremely conservative, as it assumes no additional constituent removal beyond historical amounts. Additionally, the analysis only considers direct spreading where 100 percent of the water is assumed to reach the groundwater. A recycled water project utilizing direct use would only result in a fraction of the recharge water reaching the groundwater; therefore, a significantly greater volume of replenishment water could be used before utilizing 10 percent of the assimilative capacity. Recycled water quality in the Raymond Basin could potentially have a higher water quality than the assigned quality used in the antidegradation analysis, if, for example, a higher level a treatment is utilized, which would allow for a greater volume of water to be used for replenishment before exceeding 10 percent of the assimilative capacity.

Pasadena Water and Power has proposed the Pasadena Non-Potable Water Project which involves the installation of a new non-potable water distribution system to deliver recycled water and local stream water for direct use to customers within the Monk Hill and Pasadena subareas. Pasadena Water and Power has estimated that upon full buildout, there will be a recycled water demand of 2,700 ac-ft/yr for direct use irrigation between the Monk Hill and Pasadena subareas. Assuming that 10 percent of irrigated recycled water percolates to the groundwater table,

approximately 270 ac-ft/yr may contribute to loading in the Raymond Basin, which should fall within the Policy's recommendations for a single project to utilize less than 10 percent of the available assimilative capacity.

IV.3. PREDICTIVE TRENDS

As discussed in Section III.3.7, the general water quality trends for chloride, sulfate, and TDS based solely on the period 1985-86 to 2011-12 are increasing in the Monk Hill Subarea and the water quality trends for nitrate, chloride, sulfate, and TDS are all increasing in the Pasadena subarea, excluding the impacts of potential future water projects. Therefore, an evaluation of the compiled historical water data for the period 1994-95 to 2011-12 was conducted to project future groundwater quality assuming no hypothetical scenarios are implemented. First, the linear interpolation of the annual mean extraction well quality was determined for each subarea over the long term time period (WY 1994-95 through WY 2011-12) to determine the historical trend. Next, the linear interpolation was extrapolated from WY 2011-12 to WY 2030-31 to plot the future predictive trends without taking into consideration any additional projects, future implementation measures, or changes in hydrology. Along with the long term trend of the constituent concentration, lines representing 10 percent and 20 percent of the baseline average assimilative capacity were also plotted to compare the constituent concentration trends to the recommended acceptable usage of the available assimilative capacity for a single project (10 percent) and multiple projects (20 percent). The baseline period is from WY 2002-03 to WY 2011-12.

VWC operates an injection program in the Monk Hill Subarea using treated imported water from MWD that is injected during the winter months and removed through pumping in the summer months during peak demand. Because of this program, water quality data from VWC wells does not reflect native groundwater quality. Therefore, water quality data from VWC extraction wells was omitted from the data set to remove any influence of the imported water injection program on mean groundwater extraction water quality.

The following is a summary of the groundwater trends by subarea:

Monk Hill Subarea

Nitrate concentration trends are gradually decreasing. Chloride concentrations are increasing, while sulfate and TDS concentrations are increasing more significantly. Monk Hill concentration trends are provided in Plates IV.1a, IV.1b, IV.1c, and IV.1d.

Pasadena Subarea

Nitrate and chloride concentration trends are increasing. Sulfate and TDS concentrations are increasing more significantly. Pasadena concentration trends are provided in Plates IV.2a, IV.2b, IV.2c, and IV.2d.

Santa Anita Subarea

Nitrate, chloride, sulfate, and TDS concentration trends are all decreasing. Santa Anita concentration trends are provided in Plates IV.3a, IV.3b, IV.3c, and IV.3d.

The specific causes of the increasing constituent trends in the Monk Hill and Pasadena Subareas are not clearly understood. However, one of the cause may be the results of long-term direct use of treated imported water to meet consumer demand, which has been necessary to comply with the groundwater production limitations required by the Raymond Basin Judgment. The Raymond Basin Judgment has established groundwater rights for groundwater producers in the basin. Any water demand in excess of the 1955 Decreed Rights historically has been met through the purchase of treated imported water from MWD's Weymouth Treatment Plant.

MWD has attempted to maintain the TDS concentrations in the treated imported water from Weymouth Treatment Plant to below 500 mg/l. However, the TDS concentrations can exceed the

Basin Plan Water Quality Objective of 450 mg/l. The annual mean water quality of treated imported water from Weymouth Treatment Plan for chloride, sulfate, and TDS has increased in the most recent five years. These increases in constituent concentrations likely lead to an increase in groundwater concentrations in the Monk Hill Subarea and Pasadena subareas which rely heavily on imported water to meet water demands. As noted in Section III.3.6, the Santa Anita subarea historically has not required imported water purchases to meet demands. Therefore, the groundwater concentration has not been influenced by treated imported water, as reflected by the constituent trends. In addition, the VWC injection program historically may have influenced water quality in the Monk Hill Subarea.

As discussed in Section III.3.7, there is a considerable of degree of annual variation of water quality for each constituent. Salt concentrations vary with several different factors including the volume of groundwater in storage. TDS concentrations are typically inversely related to volume of groundwater in storage; therefore, the volume of groundwater in storage has the potential to greatly impact constituent concentration trends. The frequency of sampling impacts at certain impaired wells also affects the mean of the constituent concentration data set.

These predictive trends have limitations and are broad generalizations of the available data; however, they indicate potential areas of concern by subarea. Consequently, RBMB will update the data sets and trends annually and provide these trends to RWQCB staff for discussion and evaluation. In response to the increasing TDS concentrations trends in the Monk Hill and Pasadena subareas, RBMB will increase the frequency of monitoring of TDS in production wells to at least once annually to gather more annual data to evaluate future trends. This monitoring may also help confirm the source/cause of increasing concentrations and assist with identifying potential management measures to address them. As discussed in Section III.6, RBMB is managing current implementation measures and has proposed potential implementation measures with the aim of continuing to manage and maintain the water quality in the Raymond Basin.

CHAPTER V

BASIN-WIDE SALT AND NUTRIENT MONITORING PLAN

V.1 BACKGROUND

Section 6.b.(3)(a) of the Recycled Water Policy states in past "Each salt and nutrient management plan shall include the following components:

a) A basin/sub-basin wide monitoring plan that includes an appropriate network of monitoring locations. The scale of the basin/sub-basin monitoring plan is dependent upon the site-specific conditions and shall be adequate to provide a reasonable, cost-effective means of determining whether the concentrations of salt, nutrients, and other constituents of concern as identified in the salt and nutrient plans are consistent with applicable water quality objectives. Salts, nutrients, and the constituents identified in paragraph 6(b)(1)(f) shall be monitored. The frequency of monitoring shall be determined in the salt/nutrient management plan and approved by the Regional Water Board pursuant to paragraph 6(b)(2).

   i. The monitoring plan must be designed to determine water quality in the basin. The plan must focus on basin water quality near water supply wells and areas proximate to large water recycling projects, particularly groundwater recharge projects. Also, monitoring locations shall, where appropriate, target groundwater and surface waters where groundwater has connectivity with adjacent surface waters.

   ii. The preferred approach to monitoring plan development is to collect samples from existing wells if feasible as long as the existing wells are located appropriately to determine water quality throughout the most critical areas of the basin.

   iii. The monitoring plan shall identify those stakeholders responsible for conducting, compiling, and reporting the monitoring data. The data shall be reported to the Regional Water Board at least every three years."

The Raymond Basin is a relatively small groundwater aquifer with a surface area of approximately 40.9 square miles. Raymond Basin contains approximately 800,000 acre-feet of fresh water and supports annual groundwater production of about 31,000 acre-feet. Municipal water supply companies (purveyors) collectively have about 50 active, producing wells. The wells are required to be sampled on a regular basis pursuant to Title 22, Chapter 15 "Domestic Water Quality and Monitoring" (Title 22). As described in the section below, water purveyors have the responsibility to collect water quality samples to satisfy Title 22 requirements.

The RBMB will be the primary stakeholder responsible for "…conducting, complying and reporting the monitoring data…" pursuit to Section 6.b(3)(a) of the Recycled Water Policy. RBMB has implemented a program in conjunction with water purveyors in the Raymond Basin, to collect TDS, Nitrate, Chloride, and sulfate samples from all active potable water supply wells at least once every three years.

TDS, sulfate and chloride samples from wells are collected once every three years to ensure there is a record of "salts" and "nutrient" data so that a long-term trend can be established. As noted in Section III.3.7, the average concentrations for the most recent 5-year period are about 405 mg/l TDS, 27 mg/l Nitrate, 45 mg/L Chloride, and 61 mg/L Sulfate for the Monk Hill subarea, about 361 mg/l TDS, 36 mg/l Nitrate, 41 mg/L Chloride, and 77 mg/L Sulfate for the Pasadena subarea, and about 268 mg/l TDS, 16 mg/l Nitrate, 15 mg/L Chloride, and 34 mg/L Sulfate for the Santa Anita subarea.

The RBMB adopted the "Criteria for Delivery of Supplemental Water" (Criteria) on October 18, 2006 (see Appendix BB). The Criteria sets forth procedures the RBMB follows to ensure the highest quality imported water is replenished in the Raymond Basin. At any time the highest quality of imported water is not available, the Criteria has established steps the RBMB follows to determine the impacts of delivering lesser quality imported water, including a potential option of not delivering untreated imported water until a time when the water quality improves and/or a different source becomes available. This SNMP proposes to use RBMB's existing Title 22 water quality monitoring program for groundwater to satisfy the monitoring plan requirement of the SNMP.

V.2 TITLE 22 WATER QUALITY MONITORING PROGRAM

There are approximately 50 active and standby potable water supply wells in the Raymond Basin. The greatest amount of groundwater production occurs in the Pasadena subarea. Groundwater quality conditions vary throughout the Raymond Basin due to natural and human influences.

Water purveyors in the Raymond Basin conduct well water sampling and provide the water quality data to the RBMB. Water purveyors sample their potable supply wells for the following chemical groups regulated by the California Safe Drinking Water Act (California Health and Safety Code) under the specific drinking water standards contained in the California Code of Regulations: radioactivity, VOCs, Synthetic Organic Chemicals (SOCs are primarily pesticides and herbicides) and inorganics.

Water samples are collected from potable supply wells and then analyzed for a variety of constituents by a State-certified testing laboratory to demonstrate compliance with the requirements of the California Code of Regulations, Title 22, Chapter 15, "Domestic Water Quality and Monitoring" (Title 22). The Title 22 water quality test results summarized in this report have been submitted to the California Department of Public Health (CDPH), as required by the following sections of Title 22:

- Sections 64431-64432, Primary Standards -Inorganic Chemicals;
- Section 64449, Secondary Drinking Water Standards;
- Section 64442, MCL and Monitoring-Gross Alpha Particle Activity, Radium-226, Radium-228 and Uranium;
- Sections 64444 to 64445 Organic Chemicals (SVOCs only); and
- Sections 64530 to 64537 Disinfectant Residuals, Disinfection Byproducts, and Disinfection Byproduct Precursors.

A State-certified laboratory analyzes the samples and submits results to CDPH and Producers

electronically. The Producers then provide the results to the RBMB. Title 22 establishes testing requirements and the format for reporting laboratory results of public water systems' water quality analyses. The regulations require all certified drinking water analytical laboratories to submit water quality data directly to CDPH in digital, electronic form. This submittal is referred to as Electronic Data Transfer (EDT). RBMB coordinates with Producers to obtain general mineral and general physical water quality results.

The Title 22 Producer monitoring program provides much of the source water data used develop the Raymond Basin SNMP and the data are incorporated into a database maintained by the RBMB.

V.2.1 Participating Purveyors

Purveyors who submit Title 22 water quality monitoring data to the RBMB are categorized according to the subarea from which they produce.

<u>Monk Hill Subarea:</u>

1. La Canada Irrigation Company
2. Las Flores Water Company
3. Lincoln Avenue Water Company
4. City of Pasadena
5. Pasadena Cemetery Association
6. Rubio Canon Land & Water Association
7. Valley Water Company

<u>Pasadena Subarea:</u>

1. City of Alhambra
2. City of Arcadia
3. California-American Water Company
4. East Pasadena Water Company

5. H.E. Huntington Library &Art Gallery
6. Kinneloa Irrigation District
7. City of Pasadena
8. San Gabriel County Water District
9. Sunny Slope Water Company

Santa Anita Subarea:

1. City of Arcadia
2. City of Sierra Madre

V.2.2 Title 22 Sampling Schedules

Title 22 source water monitoring frequencies are specified by DDW in "Vulnerability Assessment and Monitoring Frequency Guidelines", issued to Raymond Basin purveyors (by CDPH) every three years. Raymond Basin purveyors develop schedules for source water sample collection according to the monitoring frequencies specified in the "Vulnerability Assessment and Monitoring Frequency Guidelines" and incorporate more frequent monitoring into the schedules when required by Title 22 drinking water regulations.

General Mineral (GM) and General Physical (GP) – Raymond Basin purveyors are responsible for source water compliance monitoring of GM/GP constituents, including TDS, Chloride, Sulfate, and Nitrate.

Producers sample their wells based on requirements and frequencies prescribed in Title 22 and enforced by DDW. Based on the water quality concentration, DDW may require additional sampling. In the event a constituent in a well exceeds an MCL, DDW may require treatment, a blend plan, or that the well ceases production.

Historically, there have been no issues throughout the Basin with chloride and sulfate concentrations in production wells whereby DDW has required increased monitoring beyond

once every three years. Any production well which has a nitrate concentration between 50 percent and 100 percent of the MCL (or pumps to a liquid-phase granular activated carbon treatment facility) must be sampled on a quantity basis. DDW has also approved numerous nitrate treatment facilities and blend plans to mainstream production from wells with nitrate at or above the MCL of 45 mg/l. TDS is required by DDW to be sampled at least once every three years. Similar to nitrate, DDW staff review water quality results and may require additional sampling based on the TDS concentrations. Historically, production wells in the Main Basin have not required blending or treatment for TDS.

Groundwater sources are required to be sampled at least once every three years for GM/GP constituents. Standby groundwater sources are sampled at least once every nine years. In accordance with CDPH regulations, a standby source shall be used only for short-term emergencies of five consecutive days or less, and for less than a total of fifteen days a year.

Inorganics - Groundwater sources are required to be sampled at least every three years for inorganic chemicals, except for nitrate, which is sampled at least annually. Approximately one-third of the groundwater sources are monitored for inorganic chemicals each year on a rotating basis. Standby groundwater sources are monitored at least once every nine years.

CDPH requires quarterly or more frequent nitrate testing of operating wells when 1) a well is being treated or blended to reduce the nitrate level below the MCL, 2) the nitrate concentration in a well exceeds one-half the MCL, or 3) a well supplies water to a Granular Activated Carbon treatment system. Purveyors collect quarterly nitrate samples at wells which meet the criteria above and collect annual nitrate samples for all other productions wells.

Radioactivity - On December 7, 2000, USEPA promulgated the final revised drinking water standards for radionuclides, which became effective on December 8, 2003. The CDPH adopted the federal standards. The radionuclide rule requires all community water systems to monitor gross alpha. Monitoring frequencies have been determined based on the results of the initial round of quarterly samples.

V.3 CRITERIA FOR DELIVERY OF SUPPLEMENTAL WATER

The RBMB adopted the "Criteria for Delivery of Supplemental Water" on October 18, 2006. A copy of the Criteria is included in Appendix BB. The Supplemental Water Criteria provides a background of regulatory and institutional requirements which, must be considered when delivering Supplemental Water, with an emphasis on delivery of the highest quality water at all times.

V.4 PROPOSED MONITORING PLAN

The Recycled Water Policy, Section 6.b(3)(a) requires a water quality monitoring plan to be developed. Specifically section 6.b(3)(a)(ii) states "…the preferred approach to monitoring plan development is to collect samples from existing wells if feasible as long as the existing wells are located approximately to determine water quality throughout the most critical areas of the basin…"

The RBMB is the Court appointed agency which manages both the quality and quantity of water supplies in the Raymond Basin. The RBMB also coordinates the existing Title 22 Water Quality Monitoring Program described in Section V.2 of this SNMP. Consequently, RBMB will serve as the responsible agency to oversee collection of water quality data. Water quality data will be submitted to DDW pursuant to Title 22 requirements. As required by the Recycled Water Policy Section 6.b(3)(a)(iii) water quality data will be reported to the LAWRWQCB at least every three years.

Water quality samples for TDS, Nitrate, Chloride, and Sulfate will be collected at least once every three years at all production wells.

CHAPTER VI

SUMMARY AND RECOMMENDATIONS

VI.1 SUMMARY

The SWRCB approved Resolution No. 2009-0011 to adopt the Recycled Water Policy in February 2009. Included in that resolution is a requirement for a SNMP to be prepared for all groundwater basins. The Raymond Basin Management Board is the lead agency for the preparation of the San Gabriel Basin SNMP. The primary stakeholders include MWD, LACSD, and LACDPW.

The SNMP reviewed the geology, hydrology and hydrogeology of the Raymond Basin, along with the institutional and management structure for the Raymond Basin. TDS, Nitrate, Sulfate, and Chloride were identified as the primary constituents of concern. Sources of loading (precipitation, subsurface inflow, infiltration of applied water, storm runoff and untreated imported water replenishment) and unloading (groundwater pumping and subsurface outflow) were included in a spreadsheet computer model, along with average water quality data for TDS, Nitrate, Sulfate, and Chloride, on an annual basis.

The loading and unloading calculations were performed for each of the three subareas (Monk Hill, Pasadena, and Santa Anita) of the Raymond Basin. The assimilative capacity was also determined for each subarea. Table III.18 indicates that approximately 225 ac-ft of new water with a particular quality would use 10 percent of the available assimilative capacity for TDS and the Monk Hill Subarea once equilibrium is reached. Table III.19 indicates that approximately 405 ac-ft of new water with a particular quality would use 10 percent of the available assimilative capacity for sulfate in the Pasadena subarea once equilibrium is reached. Table III.20 indicates that approximately 245 ac-ft of new water with a particular quality would use 10 percent of the available assimilative capacity for sulfate in the Santa Anita subarea once equilibrium is reached.

The SNMP acknowledges the historical practice of replenishing the Raymond Basin with stormwater runoff which has high quality water, particularly regarding TDS. The SNMP identifies a variety of existing and potential activities including continued basin management practices; pursuit of potential new replenishment sites; water quality monitoring; and coordination between agencies which will help manage salts and nutrients in the Raymond Basin.

VI.2 RECOMMENDATIONS

The RBMB manages the Raymond Basin, in cooperation with other stakeholders, and has successfully managed the salt and nutrient loading. The RBMB recognizes the SNMP is a tool by which salts and nutrients can continue to be managed into the future. The following are recommendations for on-going salt and nutrient management in the Raymond Basin.

On-going Activities

- Regularly update the SNMP spreadsheet data so that impacts of potential future projects on salt and nutrient loading may be evaluated.
- Continue to collect water quality data throughout the Raymond Basin.
- Continue to meet with stakeholders on a regular basis to coordinate Raymond Basin management activities with an emphasis on stormwater runoff replenishment and continued use of SWP water for groundwater replenishment.

Potential Activities

- Develop new/expand existing groundwater replenishment facilities to increase stormwater replenishment capabilities.
- Encourage local planning efforts which result in reduced stormwater runoff.

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