

Mission Creek and Garnet Hill
Water Management Plan

**Technical Memorandum:
Conceptual Groundwater
Model of the Mission Creek
and Garnet Hill Subbasins,
Riverside County,
California - DRAFT**

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SECTION

1.0 Introduction

As part of a settlement agreement between Mission Springs Water District (MSWD), Coachella Valley Water District (CVWD), and the Desert Water Agency (DWA), the agencies agreed to prepare a Water Management Plan for the Mission Creek and Garnet Hill subbasins. Groundwater modeling is required to evaluate various alternatives that will be developed as part of the Water Management Plan for the Mission Creek and Garnet Hill subbasins. The objective of the modeling effort is to support management decisions on a regional basis. The modeling effort is intended to identify general trends in the groundwater system and potential effects from various water management alternatives that will be developed as part of the Water Management Planning process. The initial phase of the modeling effort is development of a groundwater conceptual model. The conceptual model will provide a physical description of the Mission Creek and Garnet Hill subbasins and the factors that influence groundwater flow in the subbasins.

1.1 Purpose

The purpose of the conceptual model is to provide a foundation for the development of the numerical model that would be used to evaluate various alternatives as part of the Water Management Plan for the Mission Creek and Garnet Hill subbasins. The conceptual model will consist of a set of elements that are used to describe the aquifer system components including:

- Boundary conditions
- Recharge estimates
- Discharge estimates
- Aquifer homogeneity/heterogeneity
- Flow regime
- Water Balance

To the extent possible, the development of the conceptual model will be based on existing data. In instances where available data is deficient, assumptions will be developed along with the basis of the assumptions. The conceptual model will be the basis for the numerical model.

1.2 Managing Agencies

As previously stated, CVWD, DWA and MSWD are cooperatively developing a Water Management Plan for the Mission Creek and Garnet Hill subbasins. The location of the districts in relation to the subbasins is depicted in Figure 1. A brief description of the water districts is provided below.

1.2.1 Coachella Valley Water District

CVWD was formed in January 1918 under the County Water District Act provisions of the California Water Code. The Coachella Valley Stormwater District was formed in 1915. The two districts merged in 1937. CVWD now encompasses approximately 637,000 acres, mostly within Riverside County, but also extending into northern Imperial and northeastern San Diego counties (Figure 1).

1.2.2 Desert Water Agency

The Desert Water Agency (DWA) was established in the late 1950s by voters in the Palm Springs area. The DWA is a wholesale distributor of State Water Project water. To resolve the absence of direct service

to the Palm Springs area from the State Water Project distribution system, the DWA trades its State Water Project water allotment with the Metropolitan Water District of Southern California for its Colorado River allotment, which is delivered to recharge basins in Upper Whitewater River and Mission Creek sub-basins.

1.2.3 Mission Springs Water District

The Mission Springs Water District (MSWD) was established in 1953 and was formerly known as Desert Hot Springs County Water District. The District's service area comprises 135 square miles including the City of Desert Hot Springs, 10 smaller communities in Riverside County, and communities in the City of Palm Springs. The District's water source is 100 percent groundwater, drawn from nine active production wells, providing water service to approximately 23,000 people as well as sewer service to approximately 8,000 people in Desert Hot Springs, Desert Crest Country Club and Dillon Mobile Home Park.

SECTION

2.0 Physiography and Climate

2.1 Physiography

Coachella Valley occupies the northwestern part of a great structural trough, the Salton Trough, that extends from the Gulf of California in Mexico northwesterly to the Cabazon area (Figure 2). The Colorado River discharges into this trough and has formed a deltaic barrier between the gulf and the spoon-shaped depression to the north. The depression, which is the main portion of the Colorado Desert of southeastern California, contains Imperial Valley, the Salton Sea, and Coachella Valley.

The Salton Trough lies primarily in Riverside County but also extends into northern San Diego County and northeastern Imperial County. The Colorado River enters this trough, and its delta has formed a barrier between the Gulf of California and the Coachella Valley. The Coachella Valley is ringed with mountains on three sides. On the west and north sides are the Santa Rosa, San Jacinto, and San Bernardino Mountains, which rise more than 10,000 feet above mean sea level (ft MSL). To the northeast and east are the Little San Bernardino Mountains, which attain elevations of 5,500 ft MSL.

The Coachella Valley is divided geographically and hydrologically into the five groundwater subbasins that are shown on Figure 3. In addition, the Whitewater River subbasin is divided into 4 subareas. Along with the Mission Creek and Garnet Hill subbasins (see Section 4.0) the other area of interest is the Palm Springs subarea of the Whitewater River subbasin (see Section 4.0), which is also depicted in Figure 3.

2.2 Climate and Precipitation

The climate of the Coachella Valley can be characterized as that of a typical, arid, rain shadow desert. The valley experiences long, hot, dry summers and relatively short, mild winters. There are several weather stations in the area, including the Palm Springs station, which has the longest period of record. Monthly mean, maximum, and minimum temperature data based on the 83-year record for the Palm Springs weather station are presented in Table 1. The average annual temperature for Palm Springs is 72.9° Fahrenheit (F). Extreme daily temperatures range from 19°F recorded on January 22, 1937, to 123°F recorded on July 10, 1979, and on August 1, 1993 (WRCC, 2010).

Although precipitation in the mountains to the west and north of the valley can reach 40 inches per year (USGS, 1992), average annual precipitation on the valley floor is much lower. The mountains form an effective barrier against coastal storms, and as a result, precipitation on the valley floor is low. Infiltration of direct precipitation does not contribute significantly to the water supply on the valley floor (CPVS, 2007).

Table 1
Monthly Average Temperature Data (°F) for Palm Springs, California

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr.
Max	69.6	73.7	79.3	86.6	94.5	103.0	108.2	106.8	101.7	91.4	78.7	69.8	88.6
Mean	55.9	59.6	64.1	70.3	77.5	85.1	91.7	90.5	84.9	75.4	63.9	56.0	72.9
Min	42.3	45.5	48.8	54.1	60.4	67.0	75.2	74.1	68.0	59.3	49.2	42.3	57.2

Notes:
 These data represent the period of record (1/1/1927-12/31/2008) (WRCC, 2010). Values are in degrees Fahrenheit.

The Palm Springs weather station, located near the intersection of the U.S. Interstate 10 Freeway and Indian Avenue (near Garnet Hill), has an 81-year record of precipitation. Based on this record, the average annual precipitation is 5.41 inches. The nearest weather station for evapotranspiration data is at Cathedral City Station No. 118 located east of the Palm Springs Municipal Airport. In the Coachella Valley, evapotranspiration is approximately 10 times greater than precipitation. Average monthly precipitation for the Palm Springs station and evapotranspiration are shown in Table 2.

Table 2
Monthly Average Precipitation and Evapotranspiration in Coachella Valley

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Yr.
Precip	1.09	1.01	0.59	0.18	0.06	0.05	0.20	0.28	0.30	0.2	0.43	0.94	5.41
ETo	1.59	2.20	3.66	5.08	6.83	7.80	8.67	7.81	5.67	4.03	2.13	1.59	57.06

Sources: Western Regional Climate Center, 2010 and CIMIS, 2010 (Cathedral City station 118)
 Values are in inches.
 ETo = average evapotranspiration

SECTION

3.0 Geology

3.1 Regional & Local Geology

The geology of the area has been studied in detail and explained in previous reports (Bechtel Corporation, 1967; California Department of Water Resources, 1964; Bader and Dutcher, 1963; Proctor, 1968; Vaughn, 1922). For this study the California Division of Mines and Geology Santa Ana and San Bernardino 1:250,000 scale geologic maps were used to identify surficial geology on a regional level for the Coachella Valley Groundwater Basin and are included in Figures 4 and 5.

The consolidated undifferentiated granitic intrusive and metamorphic rocks, of Precambrian and Tertiary age, form the basement complex of Coachella Valley. These consolidated rocks contain little or no water and generally form a no-flow boundary. The semiconsolidated deposits (referred to in Section 4.0 as semi-waterbearing rocks), of Pliocene and Pleistocene age, underlie the Indio Hills and Garnet Hill, generally have low permeability, and yield only small quantities of water to wells. Characteristically, these units exhibit extremely poor bedding and consist mainly of sandstone and conglomerate. Also, many of the units have been warped or faulted, thus further limiting their effectiveness as aquifers. Figures 6 and 7 present geologic cross-sections of portions of the Mission Creek and Garnet Hill subbasins.

The unconsolidated deposits, of late Pleistocene and Holocene age, constitute the valley fill and are the main water-bearing units. In the deeper parts of the valley, these deposits are in excess of 3,000 feet thick (Biehler, 1964), generally have moderate to high permeability, and yield large quantities of water to wells. Figure 8 presents a stratigraphic column of the major surficial geologic units that are discussed in detail below.

3.1.1 Quaternary Alluvium

The Recent age deposits of alluvium are primarily coarse alluvial debris within the present channels of the various rivers and creeks (e.g. Whitewater River, Mission Creek) and its main tributaries is identified as active channel deposits. Downstream, the particle size decreases and the channels become less distinct. The most permeable deposits are found in these channels and infiltration is highest in these areas (DWR, 1964). Coarse, poorly sorted sands and gravels of the many desert washes make up the alluvial fan and stream-wash deposits. As individual piedmont fans coalesce laterally and form relatively uniform alluvial slopes, stream channels become indistinct. Particle size decreases toward the distal portions of the fans where they merge with the alluvial plain.

3.1.2 Older Alluvium (Terrace Deposits)

Exposed portions of these deposits occur on the periphery of the Coachella Valley basin in San Geronio Pass and the Indio and Mecca Hills. The deposits have a maximum thickness at the Indio and Mecca Hills and thin out toward the northwest, the thickness ranging from 0 to 400 feet. The shallow water-bearing zones in the Mission Creek area are probably correlative with the older alluvial fan and terrace deposits (DWR, 1964).

3.1.3 Cabezon Fanglomerate

Stratigraphically correlative with the Ocotillo Conglomerate (see below), the Cabezon Fanglomerate was deposited along the base of the San Bernardino Mountains and underlies at depth the Mission Creek area. It is essentially a coarse and heterogeneous, poorly consolidated fanglomerate that unconformably overlies the Painted Hill Formation. The formation is the primary source of groundwater in the Mission Creek area. The maximum thickness is approximately 1,500 feet to 2,000 feet, however, it is believed (Tyley, 1974) that only the upper 1,000 feet is the effective portion of the main aquifer of the Mission Creek and Garnet Hill subbasins.

The deformed gravels of the Whitewater River, which consist of tilted beds of sandstone and gravels, are considered a basal portion of the Cabezon Fanglomerate, as defined by Allen, 1957 (DWR, 1964)

3.1.4 Ocotillo Conglomerate

The Ocotillo conglomerate consists of poorly consolidated sandstones and conglomerates with thin grey-green and red-brown silts and clays as lens-like interbeds. Exposures in the Mecca and Indio Hills indicate the Ocotillo Conglomerate overlies the Palm Spring Formation unconformably, and that it also underlies upper Pleistocene and Recent fanglomerates unconformably. In addition to the several exposures in the Mecca and Indio Hills, the formation underlies, at depth, the Central Plain and the Dillon Road Piedmont Slope areas. (DWR, 1964)

A characteristic "break," or increase in the resistivity of the electric logs of water wells, at depths ranging from 300 to 400 feet below the surface, was identified as signifying the top of the Ocotillo Conglomerate, underlying the Whitewater River subbasin. Well log data also indicate that the first 100 to 200 feet of material below the top of the conglomerate, underlying the lower portion of the Whitewater River subbasin (southeast of Point Happy), consist predominately of lake-deposited materials. Below this zone, however, the materials are characteristic of the Ocotillo Conglomerate (DWR, 1964).

This unit is at least 2,400 feet thick, and is the principal water-bearing unit in the Whitewater River subbasin.

3.1.5 Semi-Waterbearing Units

A series of semi-consolidated Plio-Pleistocene formations which are present in the Mission Creek and Garnet Hill subbasins consist generally of materials of low permeability and water-yielding capabilities. Although water is present in the interstices of these rocks, it is limited in supply and is not extracted or replenished readily (DWR, 1964). Characteristically, these formations have been highly contorted and faulted, which further limits their effectiveness as groundwater storage reservoirs.

Included in this group are continental Plio-Pleistocene formations which are stratigraphically correlative and similar in lithologic characteristics. They include the Painted Hill, Imperial and Coachella Conglomerate formations and are discussed below.

3.1.5.1 *Painted Hill Formation*

Along the east base of the San Bernardino Mountains, the Painted Hill Formation conformably overlies the Imperial Formation. It consists of up to 3,400 feet of continental light brown to grey conglomerate and sandstone. The semi-consolidated nature and poor sorting of the materials indicate low permeability (DWR, 1964). DWR (1964) reported that during its 1964 study, no water wells were found completed in the formation.

3.1.5.2 *Imperial Formation*

Exposures of the Imperial Formation occur throughout Coachella Valley and represent the last extensive marine environment in the valley. The formation includes interbedded tan to yellow fossiliferous sandstone, siltstone, and shale. Exposures in Coachella Valley appear tight and nonwater-bearing, and the formation probably underlies the greater part of the valley at depth (DWR, 1964).

3.1.5.3 *Coachella Fanglomerate*

The Coachella Fanglomerate is a well-indurated, massive conglomerate exposed on the east flank of the San Bernardino Mountains along the upper Whitewater River. Interlayered within the formation are flows of olivine basalt. DWR considered this formation to contain little or no water however for discussion purposes it has been grouped with the semi-waterbearing units

Figure 9 presents the location of the semi-waterbearing units in the Indio Hills area, which forms the eastern boundary of the Garnet Hill Subbasin.

3.1.6 *Pre-Tertiary Crystalline Bedrock*

Basement rocks of the San Bernardino, Little San Bernardino, and Orocopia Mountains are a complex assemblage of gneisses and schists, Precambrian in age, intruded by younger granitic rocks associated with the Southern California batholith of Cretaceous age. This igneous-metamorphic complex includes the San Geronimo igneous-metamorphic complex, the Chuckwalla complex, and the Orocopia schist. Metamorphic rocks exposed in the San Jacinto and Santa Rosa Mountains are considered younger than either the gneissic complexes or the Orocopia schist of the mountains to the north and east of the valley. Originally sedimentary rocks of probable Paleozoic age, they underwent extensive metamorphism and were ultimately intruded by granodiorite and tonalite intrusives of the Southern California batholith. The core of the San Jacinto Mountains also consists of these intrusives (DWR, 1964).

A study of the Mission Creek subbasin was conducted in 2005 by GSi to develop a better understanding of basic geology and hydrogeology of the Mission Creek area. As part of the study, GSi conducted a geophysical survey of the Mission Creek subbasin and surrounding area. For depth to bedrock calculations, GSi used a density contrast of 0.40 grams/cm³, which correlated with previous studies (Biehler, 1964). GSi (2005) indicated that no wells to bedrock were available for calibration. Figure 10 presents the estimated depth to bedrock in the Mission Creek and Garnet Hill subbasins. For the Mission Creek subbasin, the deepest point to bedrock appears to be in the southeastern portion of the subbasin at approximately 4,600 feet below ground surface (bgs). Within the Garnet Hill subbasin, the deepest portion is also in the southeast portion and reaches an estimated depth of 4,000 feet bgs.

3.2 **Regional Tectonic Setting**

Geologic structures within the area of investigation have a marked influence on the occurrence and movement of groundwater. Principal structural features of Coachella Valley are faults of the northwest-trending San Andreas Fault system (Banning and Garnet Hill faults), and associated drag and compressional folds.

Faults of the San Andreas Fault system act as partial barriers to groundwater movement, affecting both water quality conditions and the depth at which groundwater occurs. Thermal waters in Coachella Valley are related to faulting. Folding of sedimentary formations in the hills and along the mountains has exposed Tertiary formations which generally limit groundwater movement. Pleistocene formations structurally uplifted above the water table have been dewatered, reducing the area of effective groundwater storage and yield.

The Indio Hills, located along the southern boundary of the Mission Creek subbasin and the eastern edge of the Garnet Hill subbasin are the largest unit of hills within the Coachella Valley. They are bordered on the southwest by the Banning Fault (see Figure 4). Sedimentary formations in the Indio Hills have been compressed between the Banning and Mission Creek faults and are folded along axes trending generally northwest-southeast. Highly contorted Plio-Pleistocene formations are exposed along breached anticline axes in the northwestern portion of the hills. Folding and tilting of late Pleistocene beds have resulted in the dewatering of potentially water-bearing materials in the Indio Hills (DWR, 1964).

3.3 Local Faulting

Large subparallel and branching faults present in Coachella Valley are part of the San Andreas Fault zone. They have developed from a general north-south regional stress that began in late Tertiary time and continues today. Although movement within the San Andreas Fault Zone is predominantly right lateral (the southwest block moving northwest relative to the northeast block), vertical displacement has also depressed the southwest block. Faults of the San Andreas system, which are partial barriers to groundwater movement within Coachella Valley, include the San Andreas, Mission Creek, Banning, Garnet Hill, Indio Hills and Mecca Hills faults. In addition, buried faults probably account for the localized quality differences and high temperature of the groundwater in some areas. Several related faults are present in the highland and hill areas.

From Point Arena north of San Francisco, the San Andreas Fault extends to the southeast about 450 miles where it splits into several major branches northwest of the study area. The branch fault given the parent name terminates in the San Bernardino Mountains northeast of Banning. Continuing southeast, in Coachella Valley, it is questionable whether any one of the remaining branches deserves the parent name. However, the prominent fault that extends from the junction of the Banning and Mission Creek faults in the central Indio Hills southeast along the base of the Indio and Mecca Hills is generally identified as the San Andreas Fault. The fault trace is nearly straight, indicating that dominant horizontal displacement has occurred here along an essentially vertical plane. The break consists of a crushed and sheared zone encrusted with gypsum. Exposures in the Mecca Hills indicate a crushed zone up to 350 feet wide. Palm tree oases along the southwest flank of the Indio Hills and abrupt changes in vegetation southeast of the Indio Hills, are indicative of the effectiveness of this zone as a barrier to groundwater movement (DWR, 1964).

There are three major faults that control groundwater movement in the Mission Creek and Garnet Hill subbasins. They include the Mission Creek Fault, the Banning Fault and the Garnet Hill Fault (Figure 4), and are discussed below.

3.3.1 Mission Creek Fault

The Mission Creek Fault extends northwest from the junction with the Banning and San Andreas faults, crossing the Indio Hills. Continuing northwest the fault trace passes from the valley area into the Little San Bernardino Mountains at the mouth of Little Morongo Canyon. Between the junction with the Banning Fault and Little Morongo Canyon the fault is a fracture zone made up of a principal northwesterly break and several splinter breaks that fray off toward the Little San Bernardino Mountains on the northeast. Miracle Hill consists of Recent alluvium that has been uplifted between the main trace of the Mission Creek Fault along the southwest flank and a splinter fault on the northeast flank of the hill (DWR, 1964).

The fault trace curves gently to the west beyond Little Morongo Canyon. Branches of the San Geronio and Whitewater Rivers follow the large east-west crushed zone of the fault trace in the San Bernardino Mountains. The dominant direction of movement on the Mission Creek Fault has probably been lateral,

although evidence of some vertical displacement is seen at Miracle Hill and in the Indio Hills. The Indio Hills indicate upward movement of the southwest block relative to the northeast block; however, the younger Miracle Hill is apparently a reversal of this relative vertical movement and a similar topographic pattern could have resulted from lateral displacement alone. The fault, which has apparently existed since late Miocene time, is active in the study area; the Desert Hot Springs earthquake in 1948 centered on this fault. The Mission Creek Fault is an effective groundwater barrier where it crosses the alluvial basin between the Little San Bernardino Mountains and the Indio Hills. Water levels measured in the spring of 1961 show differences on either side of the fault ranging from 260 to 130 feet between Little Morongo Canyon and the Indio Hills. In addition, fault springs and cienegas at Miracle Hill and along the traces of the several branch faults in the Indio Hills are evidence of an impediment to the movement of groundwater. Groundwater temperatures ranging up to 200°F have been measured in the vicinity of Miracle Hill along the northeast side of the Mission Creek Fault (DWR, 1964).

3.3.2 Banning Fault

From the west end of San Gorgonio Pass to the Whitewater River, the Banning Fault is an east-west trending reverse fault that dips steeply to the north. Crystalline basement rocks on the north side are in contact with Quaternary sedimentary formations. A crushed zone up to several thousand feet wide is present in the pass area. East of Whitewater River the Banning Fault curves to the southeast and its trace through valley fill extends into the Indio Hills. Southeast of Thousand Palms Canyon it merges with the Mission Creek Fault. Movement along the portion of the fault east of the Whitewater River Canyon appears to be a transition from the vertical displacement in the pass area to the dominant right lateral movement of the San Andreas Fault.

Movement on the Banning Fault dates from pre-Pliocene time and has been recurrent during Recent time. The Banning Fault is an effective barrier to groundwater movement where it offsets Pleistocene and Recent formations within Coachella Valley and San Gorgonio Pass. A difference of 200 feet in the groundwater levels on either side of the fault between Whitewater River and the Indio Hills is indicated from water level measurements made during the spring of 1961. Shallow water levels, springs and cienegas in Whitewater River Canyon and Seven Palms Valley, on the northeast side of the fault trace, result from the barrier effects to groundwater movement.

The fault trace through these areas is sharply defined by the southern limit of dense vegetation sustained by the shallow groundwater. The barrier effect is also indicated by differences in quality of groundwater on either side of the fault (see Section 4.0).

3.3.3 Garnet Hill Fault

The Garnet Hill Fault is located approximately 1 to 1-1/2 miles south of and generally parallel to the Banning Fault between Flat Top Mountain and Whitewater Hills. The surface expression of the fault is two en echelon faults along the south flank of the hills west of Whitewater River Canyon. Elsewhere, the structure is buried by Recent alluvium. Southeast of Flat Top Mountain the fault is undetermined. The fault is probably a branch of the Banning Fault. Apparent vertical displacement on the fault is suggested by the topographic highs of Garnet Hill, Edom Hill and Flat Top Mountain aligned on the northeast block. Exposures of Imperial Formation on Garnet Hill suggest a stratigraphic displacement of several thousand feet (DWR, 1964).

It is believed that the fault has not displaced Recent alluvium but is effective as a groundwater barrier below depths of 100 feet, based on water level measurements at the fault. Measurements made in the spring of 1961, west of Garnet Hill, indicated that water levels on the northeast side of the fault were at least 100 feet below the surface. On the southwest side of the fault, however, water levels were found to be 130 to 180 feet lower than those of the northeast side of the fault (DWR, 1964).

3.4 Structural Deformation

As previously stated, structural deformation of sedimentary formations beneath the floor of the valley is apparently limited to tilting and compression caused by downwarping of the trough and the loading of younger alluvial deposits on older sediments.

Along the northeast flank of Coachella Valley disrupted and highly contorted Tertiary and early Pleistocene beds are present in the hills associated with the San Andreas rift zone. Folding and disruption of the beds are a result of drag and compression associated with fault displacement. Tertiary formations are most intensely folded and have suffered repeated deformation. Early Pleistocene sediments are steeply tilted adjacent to faults. Late Pleistocene beds have been gently folded within the San Andreas rift zone. Sedimentary formations in the Indio Hills have been compressed between the Banning and Mission Creek faults and are folded along axes trending generally northwest-southeast. Highly contorted Plio-Pleistocene formations are exposed along breached anticline axes in the northwestern portion of the hills. Sediments in the southeastern portion of the hills are exposed along the western limb of an anticline whose axis is parallel to and immediately adjacent to the Indio Hills fault. Folding and tilting of late Pleistocene beds have resulted in the dewatering of potentially water-bearing materials in the Indio Hills.

Whitewater Hill and Edom Hill are domical anticlines resulting from movement on the Banning Fault in Recent time. Devers Hill and Seven Palms Valley Ridge are probably topographic expressions of drag or compressional folds along the Banning Fault. The significance of these folds to the occurrence of groundwater is the disruption or diversion of flow of groundwater due to the placement of impermeable materials in the path of groundwater movement.

SECTION

4.0 Hydrogeology

The CVGB extends from the northwest near Whitewater, California to the southeast at the Salton Sea. The CVGB has been divided by the CVWD and others (Tyley, 1974; Reichard & Meadows, 1992) into Upper and Lower Coachella Valley Groundwater Basins (Upper Valley Basin and Lower Valley Basin) (MWH, 2002 and 2005). Geographically, the Upper Valley Basin is northwest of a line extending from Washington Street and Point Happy near Indian Wells and La Quinta, California, to the Indio Hills near Jefferson Street north of Bermuda Dunes. The Lower Valley Basin is southeast of this line. Figure 11 presents the various subbasins within the CVGB.

4.1 Groundwater Basins

The hydrogeology of the CVGB and its subbasins have been described in numerous publications by the U.S. Geological Survey (USGS) (e.g., Tyley, 1974; Reichard and Meadows, 1992), Department of Water Resources (DWR) (1964), in consultants' studies for the water districts in the area (Slade, 2000; GSi/water, 2006; MWH, 2002 and 2005; Psomas, 2004 and 2006), and by other parties.

Groundwater in the CVGB occurs in the alluvium, terrace deposits, and older sedimentary units that fill the valley. The CVGB is bounded on the east by the non-water bearing crystalline rocks of the San Bernardino and Little San Bernardino Mountains and on the west by the crystalline rocks of the Santa Rosa and San Jacinto Mountains. The northern boundary is formed by the San Gorgonio Pass. The Mecca Hills and the Salton Sea form the southern boundary. The faults that cross the valley form partial barriers to groundwater flow and interrupt the overall flow of groundwater in the valley, which occurs from northwest to southeast. Based on the faults in the area and their effect on groundwater flow, the USGS, the DWR, and the California Regional Water Quality Control Board (RWQCB) have divided the CVGB into five groundwater subbasins. The subbasins are shown on Figure 11 and are as follows:

1. Whitewater River [referred to as Indio in Bulletin 118] Subbasin (7-21.01 - RWQCB designation)
2. Mission Creek Subbasin (7-21.02)
3. Desert Hot Springs Subbasin (7-21.03)
4. San Gregornio Pass (7-21.04)
5. Garnet Hill Subbasin [included in Indio as a subarea in Bulletin 118]

These subbasins are typically long and relatively narrow, and extend from northwest to southeast between the mountains and the various branches of the San Andreas Fault zone. Of the five subbasins, the Garnet Hill is the smallest and least developed. The Whitewater River subbasin is by far the largest, and is the most developed of the subbasins in the CVGB. The Upper Valley Basin includes the Mission Creek and Garnet Hill subbasins as well as the San Gregornio Pass subbasin and upper portions of the Desert Hot Springs and Whitewater River subbasins. The Lower Valley Basin only includes the lower portions of the Desert Hot Springs and Whitewater River subbasins.

4.1.1 Whitewater River Subbasin (7-21.01)

The Whitewater River subbasin, known also as the Indio subbasin, comprises the major portion of the floor of the Coachella Valley and encompasses approximately 400 square miles. Beginning approximately one mile west of the junction of State Highway 111 and Interstate 10, the Whitewater River subbasin extends southeast approximately 70 miles to the Salton Sea. The subbasin is bordered on the southwest by the Santa Rosa and San Jacinto Mountains, and is separated from Garnet Hill, Mission Creek and Desert Hot Springs subbasins to the north and east by the Garnet Hill and San Andreas faults. Originally, the Garnet Hill subbasin was considered a subarea of the Whitewater River subbasin (DWR, 1964). However, the USGS (Tyley, 1974) considered the Garnet Hill to be a separate subbasin and it is discussed as such in this report.

The limit of the Whitewater River subbasin along the base of the San Jacinto Mountains and the northeast portion of the Santa Rosa Mountains coincides with the Coachella Valley groundwater basin boundary. The Whitewater River subbasin in this vicinity includes only the recent terraces and alluvial fans. The Garnet Hill Fault, which extends southeastward from the north side of San Geronio Pass to the Indio Hills, is a relatively effective barrier to groundwater movement in the Garnet Hill subbasin. The San Andreas Fault, extending southeastward from the junction of the Mission Creek and Banning faults in the Indio Hills and continuing out of the basin on the east flank of the Salton Sea, is also an effective barrier to groundwater movement.

The Whitewater River subbasin is divided into four subareas: Palm Springs, Thermal, Thousand Palms, and Oasis subareas. The Palm Springs subarea is the forebay or main area of recharge to the subbasin (see Figure 3), and the Thermal subarea comprises the pressure or confined area within the basin. The other two subareas are peripheral areas having unconfined groundwater conditions. The historical fluctuations of water levels within the Whitewater River subbasin indicate a steady decline in the levels throughout the subbasin prior to 1949.

4.1.2 Mission Creek Subbasin (7-21.02)

The Mission Creek Fault and the Banning Fault create the northeastern and southwestern boundaries of the Mission Creek subbasin, respectively. Differential movement along these faults has created more or less effective barriers to groundwater flow by deforming the alluvial sediments along the fault plane to create a poorly permeable zone. The Mission Creek subbasin is bounded on the west and southeast by barriers of uplifted poorly permeable consolidated bedrock of the San Bernardino Mountains and the Indio Hills, respectively.

The Pre-Tertiary Crystalline rocks that underlie and constitute the northwestern and southeastern borders of the subbasin are a complex assemblage of gneisses and schists, Precambrian in age, and have been intruded by younger granitic rocks associated with the Southern California batholith of Cretaceous age (DWR, 1964). DWR classified these rocks as “non-water-bearing.” However, DWR (1964) also acknowledges that in the surrounding mountains, the crystalline rocks may be the only source of water and that groundwater wells extract water from along faults and fractures within the system. With the amount of faulting in the area due to the San Andreas Fault complex, it is possible that this igneous-metamorphic complex is highly fractured and may transmit groundwater more readily than previously assumed.

The Indio Hills is not included as part of either the Mission Creek or Garnet Hill subbasins. The reasoning was that this area is underlain by semi-waterbearing rocks (see Section 3.1.5), or by potential water-bearing formations that are at elevations above the water levels of the groundwater basin (DWR,

1964). Figure 9 presents the areas within the Indio Hills along the southeastern boundary of the Mission Creek subbasin where the semi-waterbearing rocks are located.

4.1.3 Desert Hot Springs Subbasin (7-21.03)

The Desert Hot Springs subbasin is bounded to the north by the Little San Bernardino Mountains and to the southeast by the Mission Creek and San Andreas faults. The San Andreas Fault separates the Desert Hot Springs subbasin from the Whitewater River subbasin and serves as an effective barrier to groundwater flow. The subbasin has been divided into three subareas: Miracle Hill, Sky Valley and Fargo Canyon. The Desert Hot Springs subbasin is not extensively developed except in the area of Desert Hot Springs. Relatively poor groundwater quality has limited the use of this subbasin for groundwater supply. The Miracle Hill subarea is characterized by hot mineralized groundwater, which supplies a number of spas in the area.

4.1.4 San Gregorio Pass Subbasin

The portion of the CVGB that lies entirely within San Gorgonio Pass is described as the San Gorgonio Pass subbasin. The limits of the subbasin coincide with the basin boundaries except at the east end of San Gorgonio Pass, and north of the community of Banning. The Banning Bench area borders the subbasin north of Banning. The eastern boundary separates the San Gorgonio Pass subbasin from the Whitewater River subbasin.

4.1.5 Garnet Hill Subbasin

The area between the Garnet Hill Fault and the Banning Fault, named the Garnet Hill subarea (within the Whitewater River subbasin) by DWR (1964), was considered a distinct subbasin by the USGS (Tyley, 1974) because of the effectiveness of the Banning and Garnet Hill faults as barriers to groundwater movement. This is illustrated by a difference of 170 feet in groundwater level elevation in a horizontal distance of 3,200 feet across the Garnet Hill Fault, as measured in the Spring of 1961. The fault is not reported to extend to the surface and is probably effective as a barrier to groundwater movement only below a depth of about 100 feet.

Although some recharge to this subbasin may come from Mission Creek and other streams that pass through during periods of high flood flows, the chemical character of the groundwater plus its direction of movement indicate that the main source of recharge to the subbasin comes from the Whitewater River through the permeable deposits which underlie Whitewater Hill. Based on groundwater level measurements, this area is thought to be partially influenced by artificial recharge activities at the Whitewater Spreading Facilities at Windy Point.

4.2 Water Bearing Units

Most of the sediments of the Upper Valley Basin consist of coarse sand and gravel with minor occurrences of clay. Sediments in the northern portion near Whitewater tend to be coarser than in the southern portion near Indio. Due to the large portion of coarser sediments in the northern portion of this subbasin, water that is applied at the ground surface (e.g., at the Whitewater Spreading Facility) will percolate directly through the sand into the underlying groundwater aquifer (MWH, 2002).

The water-bearing units in both the Mission Creek and the Garnet Hill subbasins consist of the Cabezon fanglomerate (Mission Creek and Garnet Hill subbasins), Ocotillo conglomerate (Whitewater River subbasin), alluvium, and terrace deposits. These materials are estimated to have a total thickness of approximately 2,000 feet (Reichard and Meadows, 1992); however, most studies completed for the region assume the thickness of the active flow system in these deposits to be approximately 1,000 feet (DWR, 2004; Tyley, 1974; Geotechnical Consultants, 1979). The aquifer system is considered to be unconfined

with no vertical boundaries between the various geologic formations. Studies of the area by the USGS and others indicate that the water-bearing sediments in each of the subbasins within the Upper Valley Basin form single, thick unconfined aquifers. Extensive low permeability clay or silt layers that would form aquitards or separating layers between aquifers, or that would act as confining layers, have not been reported. These deposits are underlain by semi-waterbearing units that are not deemed to yield significant quantities of water to wells.

4.3 Groundwater Occurrence and Movement

Groundwater in the Upper Valley Basin generally flows to the southeast. In some cases, the faults form partial to substantial barriers to groundwater flow, with water levels varying between subbasins by several hundred feet or more, along most of the length of the faults. In some areas, however, there is underflow between subbasins, as groundwater flows over, through, or around the faults that otherwise form barriers to groundwater flow. The majority of flow between subbasins appears to occur in the eastern portions of the various subbasins. There is some groundwater flow from the Desert Hot Springs subbasin into the Mission Creek subbasin, which in turn has some outflow into the Garnet Hill subbasin. The Garnet Hill subbasin has some outflow to the Whitewater River subbasin (MWH, 2005).

Depth to groundwater varies throughout the Basin. Within the Upper Valley Basin, the depth to the water table ranges from more than 500 feet bgs near Whitewater Hill near the west end to less than 100 feet bgs near the east end. Shallower depths to groundwater can be found near Mission Creek and Whitewater River.

The following discussion presents the current understanding of the various occurrences and movement of groundwater between the various subbasins.

4.3.1 Groundwater Flow

Groundwater in the Upper Valley Basin is recharged by runoff and underflow from the surrounding mountains, and percolation of surface water flows at the mouths of the larger canyons in the area. Groundwater generally flows toward the southeast, in a direction similar to the slope of the valley floor. Between 1936 and 1973, water levels in the upper Coachella Valley declined more than 100 feet in the Palm Springs area and more than 70 feet in the Palm Desert area (MWH, 2005). In 1936, there was relatively little groundwater pumping in the valley, and groundwater flowed under generally natural conditions. By 1973, water levels declined due to development in the valley. Figure 12 presents the 1936 groundwater elevation contour map developed by Tyley (1974). As can be observed, groundwater level elevations in the Desert Hot Springs subbasin are approximately 300-400 feet higher on the eastern side of the Mission Creek Fault as opposed to groundwater level elevations in the Mission Creek subbasin. Tyley (1974) indicated a south to south-southwesterly flow. Mission Creek subbasin indicates a southeasterly flow until about mid-basin where the contour lines curve indicating a southerly flow on the eastern side of the subbasin.

The Garnet Hill subbasin has groundwater level elevations approximately 100 to 200 feet lower than the Mission Creek subbasin along the Banning Fault, indicating groundwater flow is partially restricted by the Banning Fault. Groundwater flow in the Garnet Hill subbasin flows to the east-southeast until the southeastern end of the subbasin where groundwater flow direction turns south and presumably discharges into the upper portion of the Whitewater subbasin.

The Upper Whitewater subbasin has groundwater level elevations approximately 150-200 feet lower than what is observed in the Garnet Hill subbasin, indicating groundwater flow is partially restricted by the

Garnet Hill Fault. Groundwater flow in the Upper Whitewater subbasin area is flowing in an east to southeast direction towards the Salton Sea.

Figure 13 presents the groundwater level elevation contours for 1951 as interpreted by Tyley (1974). By this time, groundwater development had proceeded with the majority of extraction occurring in the Whitewater River subbasin. One well in the Garnet Hill subbasin was extracting over 2,000 afy. This well was located in alluvial gravels of the Whitewater River just north of the Garnet Hill Fault. The contours are similar to what was observed in 1936.

Figure 14 presents the groundwater level elevation contours for 2003 as interpreted by Krieger and Stewart (2007). By this time groundwater development had proceeded and groundwater depressions had formed in the Mission Creek subbasin around areas with major production wells. The Garnet Hill subbasin has observed a decline in water levels in the upper part of the subbasin and the Upper Whitewater River subbasin has observed an almost 100 feet increase in elevation from the 1951 map which is presumably related to the recharge facility located in the same area.

Figure 15 presents the groundwater level elevation contours for measurements collected in 2009. Similar to 2003, groundwater development has created depressions in the Mission Creek subbasin in the central portion of the subbasin. The Garnet Hill subbasin exhibited similar groundwater elevation contours as those observed in 2003. However a lack of data in the western portion of the subbasin prohibited development of groundwater contours in this area.

Figure 16 presents long-term hydrographs for selected wells in the Mission Creek, Garnet Hill and Upper Whitewater River subbasins. The hydrographs indicate that for the Mission Creek subbasin, groundwater elevation has been declining since the 1960s generally about 2 feet per year. For the Garnet Hill subbasin, a gradual decline in groundwater elevations were observed until the mid 1980s where groundwater elevations started to rise slightly above 1960s levels. This increase may be related to the artificial recharge that commenced in 1973 in the adjacent Upper Whitewater River subbasin (see Section 4.5).

4.3.2 Groundwater Barriers

Other than the crystalline bedrock and the semi-waterbearing rocks in the Indio Hills, the principal barriers to groundwater flow are the major faults identified in the Upper Coachella Valley Groundwater basin. These faults include the Mission Creek, Banning, and Garnet Hill faults and their influence on groundwater flow on the Mission Creek and Garnet Hill subbasins is discussed below.

4.3.2.1 *Mission Creek Fault*

As previously discussed, the Mission Creek Fault is an effective groundwater barrier where it crosses the alluvial basin between the Little San Bernardino Mountains and the Indio Hills. Various investigators have estimated the flux between the Desert Hot Springs subbasin and the Mission Creek subbasin. Tyley (1974) indicated that flow was probably occurring but indicated that it was insignificant. Mayer (2008) indicated that the flux estimated after calibration of a numerical model was 1,790 afy ($0.07 \text{ m}^3/\text{s}$).

4.3.2.2 *Banning Fault*

The Banning Fault forms the barrier between the Mission Creek and Garnet Hill subbasins, although, as indicated above, there is some flow from the Mission Creek subbasin to the Garnet Hill subbasin (MWH, 2005). Tyley (1974) estimated the flux across the Banning Fault to be approximately 2,000 afy. Mayer (2008) estimated the flux to be approximately 4,600 afy ($0.18 \text{ m}^3/\text{s}$).

4.3.3 Garnet Hill Fault

South of the Banning Fault, groundwater in the Garnet Hill subbasin flows generally to the southeast (Tyley, 1974; DWR, 2004). The Garnet Hill Fault forms a substantial barrier to groundwater flow, forcing groundwater to flow more easterly, rather than flowing across the fault. Tyley (1974) has suggested that since the Garnet Hill Fault does not displace Recent alluvial deposits (estimated between 0-100 feet bgs) that the restriction to groundwater flow is from the top of the Cabezon Conglomerate to the base of the aquifer and that above 100 feet bgs, there is no restriction. Tyley (1974) did not specify an amount of discharge across the fault but suggested that approximately 2,000 afy was attributed to miscellaneous recharge to the Whitewater River subbasin. In addition, Swain (1978) estimated the hydraulic conductivity of the fault barrier at between 0.02 to 2 ft/day with the lower values generally occurring along the northwestern extent of the fault and the higher values occurring along the southeastern end of the fault but did not provide an annual discharge for the Garnet Hill Fault. Assuming a similar amount of outflow across the Garnet Hill Fault as was suggested for the Banning Fault, a value of 2,000 afy was applied for budgeting purposes for the Garnet Hill Fault.

4.4 Aquifer Characteristics

Table 3 summarizes the aquifer characteristics for the various subbasins in the Upper Coachella Valley. Tyley (1974) estimated transmissivity of various areas in the Mission Creek and Garnet Hill subbasins using specific capacity data from various well tests. The Mission Creek subbasin exhibits the largest variation in transmissivities ranging from 2,000 to 200,000 gpd/ft. The Garnet Hill subbasin had a lower and narrower range for transmissivity varying from 10,000 to 50,000 gpd/ft. Figure 17 presents the estimated distribution of transmissivity in the various subbasins.

Tyley (1974) also estimated the storage coefficient distribution in the various subbasins in the Upper Coachella Valley and is depicted in Figure 18. The Mission Creek subbasin ranged from 0.08 in the upper portion to 0.18 near the middle portion of the subbasin. Garnet Hill had a narrow range for storage coefficient and varied from 0.15 to 0.18. The storage coefficient values for both the Mission Creek and Garnet Hill subbasins are consistent with an unconfined aquifer.

4.5 Groundwater Inflow/Outflow

A groundwater subbasin water balance is a useful tool for understanding the inflow and outflow of water from a subbasin, and for evaluating the effects of water use in the area. For a groundwater subbasin, the inflows include recharge to the groundwater from percolation of precipitation on the subbasin, percolation of surface water entering the subbasin as creeks, subsurface inflow of groundwater, return flow of groundwater pumped from the subbasin, and imported water that is percolated into the groundwater subbasin. Outflow of groundwater occurs as groundwater rises to the surface and flows out of the subbasin as surface water, underflow of groundwater out of the subbasin, and consumptive use. Consumptive use includes that portion of groundwater that is pumped from groundwater wells that does not infiltrate back into the groundwater as return flow, and evapotranspiration of groundwater by phreatophytes. When the outflows exceed the inflows, groundwater is removed from storage in the subbasin, and water levels in the subbasin decline.

The CVWD, DWA, and MSWD are actively participating in the implementation of management actions to reduce the overdraft and return the Coachella Valley Groundwater Basin to a state of long-term balance. These measures include a groundwater replenishment program using State Water Project (SWP) water exchanged for Colorado River Aqueduct (CRA) water. The CRA water is percolated at the Whitewater Spreading Facility and the Mission Creek Recharge Basin (see Figure 21).

Table 3
Upper Coachella Valley Groundwater Basin Characteristics

	Garnet Hill Subbasin^a	Mission Creek Subbasin^b	Upper Whitewater Subbasin^c	Upper Desert Hot Springs Subbasin^d
Subbasin Area	16 square miles	76 square miles	250 square miles	50 square miles (approximate)
Transmissivity ^e	10,000 to 50,000 gpd/ft	2,000 to 200,000 gpd/ft	50,000 to 360,000 gpd/ft	2,000 to 30,000 gpd/ft
Hydraulic Conductivity ^f	10 to 50 gpd/ft ²	2 to 200 gpd/ft ²	50 to 360 gpd/ft ²	7 to 100 gpd/ft ²
Storage Coefficient ^e	0.15 to 0.18	0.08 to 0.18	0.06 to 0.15	0.08
Groundwater Storage Capacity	1.0 million acre- feet	2.6 million acre- feet	4.6 million acre- feet	2.5 million acre- feet
Groundwater in Storage	1 million acre- feet	1.4 million acre- feet	2.3 million acre- feet	0.8 million acre- feet

Sources: DWR (2004), RWQCB (2004), Tyley (1974), MWH, 2005, URS, 2007.

Notes:

- a. Storage capacity for the Garnet Hill subbasin is from MWH, 2005. For purposes of this illustration and since this subbasin has never been considered to be in overdraft, the amount of groundwater in storage is assumed to be the same as the storage capacity.
- b. Per DWR (2004), total theoretical storage capacity of the Mission Creek subbasin is approximately 2.6 million acre-feet and is based on 1,000 feet of saturated thickness. The estimated amount of groundwater in storage in 2000 was estimated to be approximately 1.4 million acre-feet (DWR, 2004).
- c. Storage capacity for the Upper Whitewater River subbasin is from MWH, 2005 (includes Palm Springs subarea) and is based on 1,000 feet of saturated thickness. Amount of groundwater in storage is from CVWD 2010 Engineer's Report..
- d. Per DWR (2004), the total area of the Desert Hot Springs subbasin is 158 square miles. For purposes of this summary, it is assumed that approximately 50 square miles of the subbasin (based on information from Tyley, 1974) is within the upper Coachella Valley. Tyley (1974) estimated the amount of storage in the upper Desert Hot Springs subbasin to be 779,000 acre-feet based on a saturated depth of 300 feet and a storage coefficient of 0.08. In comparison, DWR (2004) estimated the total theoretical storage capacity of the entire Desert Hot Springs subbasin to be approximately 4.1 million acre-feet.
- e. Transmissivity and storage coefficient values are from Tyley, 1974
- f. Hydraulic conductivity is based on Transmissivity values and 1,000 feet of saturated thickness for Upper Whitewater River, Garnet Hill and Mission Creek subbasins and 300 feet for Desert Hot Springs subbasin.

gpd/ft = gallons per day per foot

Source: Derived from CPV, 2007.

Since 1973, more than 2.1 million acre-feet of CRA was delivered to the Upper Whitewater River recharge facility and 59,000 acre-feet of CRA water has been delivered to the Mission Creek Recharge Basin. Table 5 presents a summary by year of the amount of water recharged to various recharge facilities in the Upper Whitewater River and Mission Creek subbasins.

Historically, because the amount of groundwater pumped from the Basin (i.e., primarily from the Whitewater River and Mission Creek subbasins) exceeded the amount replenished, these subbasins were in overdraft condition for a significant portion of the last century (MWH, 2005). In 2004, the estimated amounts of overdraft in the Upper Whitewater River subbasin and the Mission Creek subbasin were approximately 82,000 afy and 2,300 afy, respectively (MWH, 2005).

4.5.1 Groundwater Inflow

4.5.1.1 Mission Creek Subbasin

4.5.1.1.1 Precipitation

As previously mentioned, the potential for recharge from deep percolation of direct precipitation is considered negligible. The principal form of recharge would come from mountain front runoff derived from precipitation (including snowmelt). DWR (1964) estimated that for the Mission Creek subbasin, approximately 6,000 afy was attributed to recharge from precipitation principally from streamflow runoff and mountain front infiltration. Studies published by USGS report approximately 7 to 8 percent of the total precipitation falling on bedrock mountains in other arid basins goes to mountain front recharge (USGS 2007). CVWD (2010) reported an estimate of 5,000 afy that included both natural recharge and flow across subbasin boundaries for 2009.

Psomas conducted an evaluation of the Mission Creek subbasin and the sources of natural groundwater recharge associated with mountain front recharge from precipitation. The catchment areas were identified for each of the drainages that drain into the Mission Creek area. Figure 19 shows the various catchment areas and associated name. Isohyetal contours of mean annual precipitation (see Figure 20) for the various catchment areas were overlain to assess the total average volume of water that is available for recharge. Two methods were used, Hely & Peck (1964) and a percentage of total precipitation volume. Hely & Peck suggested using runoff curve classification which would equate to a runoff curve number and an overall percentage of the overall precipitation ending up in mountain front recharge. Applying the factors results in a total estimated recharge of 11,706 afy, which is equivalent to nearly 17 percent of the total volume of rainfall. As previously indicated, the USGS indicated approximately 7-8 percent for arid regions. With the presumption that less than 10 percent would actually reach the groundwater system calculations were conducted using 5, 7, and 10 percent of the total volume of precipitation. This equates to approximately 3,500 (5 percent), 4,900 (7 percent) and 7,000 afy (10 percent) based on a percentage of total volume of precipitation..

Table 4 presents the estimate of recharge from mountain front precipitation. Total recharge from mountain front precipitation under average conditions was estimated at 4,900 afy.

4.5.1.1.2 Underflow and Recharge from Streams

The Mission Creek subbasin receives inflow primarily from the Mission Creek drainage however water quality data suggest some underflow is occurring across the Mission Creek Fault from the Desert Hot Springs subbasin. Mayer estimated that the underflow across the Mission Creek Fault was on the average of 1,700 afy.

TABLE 4
ESTIMATE OF MOUNTAIN FRONT RECHARGE FROM PRECIPITATION IN SELECTED DRAINAGES FOR THE MISSION CREEK SUBBASIN

CATCHMENT NAME (a)	AREA (acres)	AVERAGE PRECIPITATION (inches)	TOTAL VOLUME OF RAINWATER FROM MEAN ANNUAL PRECIPITATION (acre-feet)	HELY & PECK METHOD FOR ESTIMATING MOUNTAIN FRONT RECHARGE (b)				MOUNTAIN FRONT RECHARGE BASED ON PERCENTAGE OF POTENTIAL RUNOFF (AFY)		
				Runoff Curve Classification (c)	Runoff Curve Number (c)	Runoff (% of Precipitation) (d)	Total Annual Volume of Infiltration (af)	Based on 5% (e)	Based on 7% (e)	Based on 10% (e)
Mission Creek	593	35	1,730	Mountains	90	20%	345.92	86	121	173
Mission Creek	2,008	27.5	4,602	Mountains	90	20%	920.33	230	322	460
Mission Creek	10,648	22.5	19,965	Mountains	90	20%	3993.00	998	1,398	1,997
Mission Creek	5,233	18	7,850	Mountains	90	20%	1569.90	392	549	785
Mission Creek	2,531	14	2,953	Mountains	90	20%	590.57	148	207	295
Mission Creek	2,446	11	2,242	Hills	80	8%	179.37	112	157	224
Dry Morongo	1,892	14	2,207	Mountains	90	20%	441.47	110	155	221
Dry Morongo	2,853	11	2,615	Hills	80	8%	209.22	131	183	262
Dry Morongo	1,105	9	829	Hills	80	8%	66.30	41	58	83
Dry Morongo	355	8	237	Hills	80	8%	18.93	12	17	24
Big Morongo	222	22.5	416	Mountains	90	20%	83.25	21	29	42
Big Morongo	6,654	18	9,981	Mountains	90	20%	1996.20	499	699	998
Big Morongo	4,108	14	4,793	Mountains	90	20%	958.53	240	335	479
Big Morongo	2,853	11	2,615	Alluvium, steep slope	70	3%	78.46	131	183	262
Big Morongo	2,671	9	2,003	Alluvium, steep slope	70	3%	60.10	100	140	200
Big Morongo	1,190	8	793	Alluvium, steep slope	70	3%	23.80	40	56	79
Painted Hills	1,269	11	1,163	Hills	80	8%	93.06	58	81	116
Painted Hills	2,440	9	1,830	Alluvium, steep slope	70	3%	54.90	92	128	183
Painted Hills	1,695	8	1,130	Alluvium, flat slope	68	2%	22.60	57	79	113
TOTAL	52,766	---	69,954	---	---	---	11,706	3,498	4,897	6,995

Notes:

a - See Figures 19 & 20 for Catchment areas and average annual precipitation.

b - From Hely & Peck, 1964.

c - See Hely & Peck, 1964, Figure 10.

d - See Hely & Peck, 1964, Figure 9.

e - Based on a percent of Total Volume of Rainwater from Mean Annual Precipitation (column 4).

GSI (2005) speculated that a portion of the recharge to the Mission Creek subbasin also came from active stream channels located in the various catchment areas. It is known that the upper reaches of Whitewater River and Mission Creek drainages contain extremely coarse alluvial material and that underflow is likely occurring. However, it is believed that the stream underflow would be part of the mountain front recharge and consequently it is not included as a separate component of recharge.

4.5.1.1.3 Artificial Recharge

Since 2002, water from the CRA has been artificially recharged to the ground-water system through recharge facilities at the upper end of the Mission Creek subbasin (see Figure 21). The water is released to the recharge facilities that consist of approximately 100 acres of percolation ponds. The total volume of water diverted to the percolation ponds from 2003 to 2009 is about 59,900 acre-ft. Table 5 presents the total volume of water diverted to each of the artificial recharge areas.

4.5.1.1.4 Irrigation Return Flow and Infiltration from Septic Systems

An estimate of the infiltration of septic systems along with the irrigation return flow was calculated for the Mission Creek subbasin (MWH, 2010) for the period 1978-2008. Total return flows ranged from 983 afy in 1978 to over 4,400 afy in 2008. Table 6 presents a summary of the estimated return flows for both MSWD and CVWD supplied water in the Mission Creek subbasin.

CVWD (2010) estimated the 2009 Calendar Year that return flow (nonconsumptive return of applied water) at 5,305 afy, which is 35 percent of the estimated groundwater production of 15,156 afy. In addition, it should be noted that URS indicated that up to 11 percent of the production from the MSWD system was unaccounted-for-water that may include leaks, evaporation, mis-metering of water usage and/or production. While not included in the overall numbers, an additional 2-5 percent (of total production) in system losses due to leakage may need to be factored into the overall return flows.

4.5.1.2 Garnet Hill Subbasin

4.5.1.2.1 Precipitation

As previously mentioned, the potential for recharge from deep percolation of direct precipitation is considered negligible. The principal form of recharge would come from mountain front runoff derived from precipitation (including snowmelt). The Garnet Hill subbasin lies within two catchment areas: the lower portion of the Mission Creek catchment area and the Whitewater River catchment area. Previous studies have indicated that the majority of runoff generated in the Mission Creek catchment area infiltrates into the Mission Creek subbasin with very little surface runoff making it to surface drainages south of the Banning Fault. Consequently, for estimation purposes, it was assumed that the only mountain front recharge reaching the Garnet Hill subbasin was associated with the Whitewater River catchment.

Two methods were used, Hely & Peck (1964) and a percentage of total precipitation volume. Hely & Peck suggested using runoff curve classification which would equate to a runoff curve number and an overall percentage of the overall precipitation ending up in mountain front recharge. Applying the factors results in a total estimated recharge of 12,775 afy, which is equivalent to nearly 16 percent of the total volume of rainfall. As previously indicated, the USGS indicated approximately 7-8 percent for arid regions. With the presumption that less than 10 percent would actually reach the groundwater system calculations were conducted using 5, 7, and 10 percent of the total volume of precipitation. This equates to approximately 4,000 (5 percent), 5,600 (7 percent) and 8,000 afy (10 percent) based on a percentage of total volume of precipitation and is presented in Table 7. Total recharge from mountain front precipitation originating in the Whitewater River watershed (under average conditions) was estimated at 5,600 afy.

TABLE 5
ESTIMATED DELIVERIES TO ARTIFICIAL
RECHARGE FACILITIES IN UPPER WHITEWATER
RIVER AND MISSION CREEK SUB-BASINS

Year	Deliveries to Recharge Facilities (in acre-feet)	
	Whitewater River Recharge Facility	Mission Creek Recharge Facility
1973	7,475	---
1974	15,396	---
1975	20,126	---
1976	13,206	---
1977	0	---
1978	0	---
1979	25,192	---
1980	26,341	---
1981	35,251	---
1982	27,020	---
1983	53,732	---
1984	83,708	---
1985	251,994	---
1986	298,201	---
1987	104,372	---
1988	1,097	---
1989	12,479	---
1990	31,721	---
1991	14	---
1992	40,870	---
1993	60,183	---
1994	32,325	---
1995	61,318	---
1996	138,266	---
1997	113,677	---
1998	132,455	---
1999	90,601	---
2000	72,450	---
2001	707	---
2002	33,435	4,733
2003	861	100
2004	13,244	5,564
2005	165,554	24,723
2006	98,959	19,901
2007	16,009	1,011
2008	8,008	503
2009	49,032	3,336
TOTAL	2,135,279	59,871

Source: MWH, 2010.

TABLE 6
SUMMARY OF ESTIMATED RETURN FLOWS FOR THE
MISSION CREEK SUB-BASIN

Year	MSWD Supplied Water				CVWD Supplied Water			Total of All Return Flows (afy)
	Septic Return Flow (afy)	Wastewater Infiltration Ponds (afy)	Outdoor Irrigation Return Flow (afy)	Other Return Flows (afy)	Septic Return Flow (afy)	Outdoor Irrigation Return Flow (afy)	Other Return Flows (afy)	
1978	157	50	108	580	57	32	0	983
1979	208	68	149	580	67	37	0	1,109
1980	232	81	169	580	74	41	0	1,177
1981	225	96	171	580	95	53	0	1,220
1982	205	107	164	580	87	49	0	1,192
1983	237	143	206	580	97	54	0	1,316
1984	321	149	254	580	128	71	0	1,503
1985	333	137	257	580	144	80	0	1,531
1986	424	125	301	580	145	81	0	1,654
1987	504	150	373	658	150	83	0	1,918
1988	587	165	438	568	83	46	370	2,257
1989	695	195	520	568	104	58	370	2,509
1990	670	250	548	568	97	54	370	2,558
1991	608	262	524	568	83	46	370	2,461
1992	684	274	567	940	76	42	370	2,953
1993	697	310	609	535	98	55	370	2,674
1994	856	289	697	535	121	67	370	2,935
1995	877	273	692	535	121	67	370	2,934
1996	958	272	738	535	119	66	370	3,059
1997	919	288	729	535	70	39	370	2,949
1998	934	310	758	535	114	63	370	3,084
1999	973	327	796	535	130	73	370	3,203
2000	974	362	824	535	159	89	370	3,313
2001	960	371	823	535	192	107	370	3,358
2002	996	383	854	535	222	124	370	3,483
2003	997	445	903	538	231	129	451	3,694
2004	1,247	468	1,061	670	229	127	487	4,287
2005	1,549	500	1,261	575	203	113	686	4,887
2006	1,366	551	1,201	542	246	137	703	4,746
2007	1,285	539	1,161	636	248	138	658	4,665
2008	1,192	520	1,094	644	223	124	675	4,472
TOTAL	22,867	8,461	18,950	18,035	4,211	2,347	9,213	84,085

Source: MWH, 2010.

TABLE 7
ESTIMATE OF MOUNTAIN FRONT RECHARGE FROM PRECIPITATION IN SELECTED DRAINAGES FOR THE GARNET HILL
SUBBASIN

CATCHMENT NAME (a)	AREA (acres)	AVERAGE PRECIPITATION (inches)	TOTAL VOLUME OF RAINWATER FROM MEAN ANNUAL PRECIPITATION (acre-feet)	HELY & PECK METHOD FOR ESTIMATING MOUNTAIN FRONT RECHARGE (b)				MOUNTAIN FRONT RECHARGE BASED ON PERCENTAGE OF POTENTIAL RUNOFF (AFY)		
				Runoff Curve Classification (c)	Runoff Curve Number (c)	Runoff (% of Precipitation) (d)	Total Annual Volume of Infiltration (af)	Based on 5% (e)	Based on 7% (e)	Based on 10% (e)
Whitewater River	4,516	45	16,935	Mountains	90	20%	3387.00	847	1,185	1,694
Whitewater River	9,033	35	26,346	Mountains	90	20%	5269.25	1,317	1,844	2,635
Whitewater River	4,299	27.5	9,852	Mountains	90	20%	1970.38	493	690	985
Whitewater River	5,690	22.5	10,669	Hills	80	8%	853.50	533	747	1,067
Whitewater River	4,451	18	6,677	Hills	80	8%	534.12	334	467	668
Whitewater River	5,170	14	6,032	Hills	80	8%	482.53	302	422	603
Whitewater River	2,491	11	2,283	Hills	80	8%	182.67	114	160	228
Whitewater River	1,587	9	1,190	Hills	80	8%	95.22	60	83	119
TOTAL	37,237	---	79,984	---	---	---	12,775	3,999	5,599	7,998

Notes:

a - See Figures 19 & 20 for Catchment areas and average annual precipitation.

b - From Hely & Peck, 1964.

c - See Hely & Peck, 1964, Figure 10.

d - See Hely & Peck, 1964, Figure 9.

e - Based on a percent of Total Volume of Rainwater from Mean Annual Precipitation (column 4).

The majority of this recharge only recharges a portion of the western portion of the Garnet Hill subbasin and the majority is estimated to recharge the upper Whitewater River subbasin. For an initial estimate, it was assumed that 20 percent of the total mountain front recharge (1,120 afy) originating in the Whitewater River watershed recharged the Garnet Hill subbasin.

4.5.1.2.2 Underflow

The Garnet Hill subbasin receives inflow either from the Mission Creek subbasin (across the Banning Fault) or from underflow from the Whitewater River. Tyley (1974) suggested that ground-water contours indicate that some groundwater does move across the Banning Fault from the Mission Creek subbasin. This inflow is also shown by heavy phreatophyte growth east of Indian Avenue. Groundwater also moves into this subbasin through the semiconsolidated deposits of Whitewater Hill, but the quantity is probably small. Tyley (1974) estimated that the subsurface inflow was estimated at 2,000 afy.

4.5.1.2.3 Artificial Recharge

No artificial recharge facilities are located in the Garnet Hill subbasin.

4.5.1.2.4 Irrigation Return Flow and Infiltration from Septic Systems

An estimate of the infiltration of septic systems along with the irrigation return flow was calculated for the Garnet Hill subbasin for the period 1936-2008. Total return flows ranged from 0 afy in 1978 to over 250 afy in 2008. Table 8 presents a summary of the estimated return flows for the Garnet Hill subbasin.

4.5.2 Groundwater Outflow

4.5.2.1 *Mission Creek Subbasin*

4.5.2.1.1 Pumpage

The main groundwater outflow in the Mission Creek subbasin is from pumping of production wells. Records of production data were compiled for various wells from the period 1947 through 2009 and are presented in Table 9. Figure 22 presents the location of the various production wells. Tyley estimated for the period between the years 1936 to 1967 that the Mission Creek subbasin had net pumpage of 4,370 af. When compared to records for a slightly shorter period (1947-67), CVWD had reported net pumpage of over 28,000 af. The reason for this discrepancy is unclear but Tyley (1974) lacked production records from specific wells in the subbasin. With respect to later years, CVWD reported in the 2010 Engineers report (CVWD, 2010) generally higher numbers than what was reported from specific pumpers pumping greater than 25 afy. For example, commencing in 2001, the CVWD Engineers Report (CVWD, 2010) had total net annual pumpage from 2,000 to 4,000 afy greater than what was reported by individual pumpers (>25 afy). For purposes of the conceptual model development, the higher values are used to represent historical conditions.

TABLE 8
SUMMARY OF ESTIMATED RETURN
FLOWS FOR THE
GARNET HILL SUBBASIN

Year	MSWD Supplied Water		Total of All Return Flows (afy)
	Septic Return Flow (afy)	Outdoor Irrigation Return Flow (afy)	
1936	0	0	0
1937	0	0	0
1938	0	0	0
1939	0	0	0
1940	0	0	0
1941	0	0	0
1942	0	0	0
1943	0	0	0
1944	0	0	0
1945	0	0	0
1946	0	0	0
1947	0	0	0
1948	0	0	0
1949	6	3	9
1950	0	0	0
1951	88	52	140
1952	0	0	0
1953	0	0	0
1954	1	0	1
1955	0	0	0
1956	0	0	0
1957	0	0	0
1958	4	2	6
1959	0	0	0
1960	0	0	0
1961	0	0	0
1962	0	0	0
1963	0	0	0
1964	0	0	0
1965	0	0	0
1966	0	0	0
1967	81	47	128
1968	0	0	0
1969	1	1	2
1970	5	3	8
1971	1	0	1
1972	32	19	51
1973	4	2	6
1974	7	4	10

TABLE 8
SUMMARY OF ESTIMATED RETURN
FLOWS FOR THE
GARNET HILL SUBBASIN

Year	MSWD Supplied Water		Total of All Return Flows (afy)
	Septic Return Flow (afy)	Outdoor Irrigation Return Flow (afy)	
1975	7	4	12
1976	15	9	24
1977	14	8	23
1978	3	8	11
1979	14	35	49
1980	16	40	56
1981	19	40	59
1982	18	33	50
1983	23	35	58
1984	23	43	65
1985	20	40	61
1986	17	44	61
1987	36	81	118
1988	38	84	122
1989	60	131	192
1990	77	135	212
1991	80	126	206
1992	78	132	210
1993	69	106	175
1994	59	105	164
1995	53	100	152
1996	54	109	164
1997	57	107	165
1998	61	108	169
1999	63	110	174
2000	70	115	185
2001	72	115	187
2002	77	123	200
2003	89	130	219
2004	93	151	245
2005	104	183	287
2006	114	174	288
2007	107	156	264
2008	104	147	251
TOTAL	2,035	3,201	5,236

Source: MWH, 2010.

TABLE 9
ESTIMATED PUMPAGE FROM VARIOUS PRODUCTION WELLS IN THE MISSION CREEK AND GARNET HILL SUB-BASINS

[illegible]

TABLE 9
ESTIMATED PUMPAGE FROM VARIOUS PRODUCTION WELLS IN THE MISSION CREEK AND GARNET HILL SUB-BASINS

SUBBASIN	WELL NUMBER	WELL NAME	PRODUCTION BY YEAR (acre-feet)																											TOTAL			
			1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006		2007	2008	2009
Garnet Hill	3S/3E-02B		0	0	0	25	0	0	0	25	0	10	0	0	0	0																10,999	
	3S/3E-02C		578	578	575	555	0	0	570	555	538	441	0	0	0	0																20,996	
	3S/3E-02P1		0	0	0	0	0	0	0	0	0	0	0	0	0	0																727	
	3S/3E-02P2		0	0	0	0	0	0	0	0	0	0	0	0	0	0																2,140	
	3S/3E-11K1		0	0	0	0	0	0	0	0	0	0	0	0	0	0																20,038	
	3S/4E-07M1		19	24	27	0	46	43	32	31	30	37	39	38	41	0																	631
	3S/4E-14J1	33																											516	330		846	
	3S/4E-17K2	MSWD 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0																582	
	TOTALS		597	602	602	580	46	43	602	611	568	488	39	38	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	516	330	0	56,959
Tyley (1974)																																80	
	Preliminary Estimate	597	602	602	580	46	43	602	611	568	488	39	38	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	516	330	0	56,959
Mission Creek	2S/4E-17K1		0	0	0	0	0	0	0	0	0	0	0	0	0	0																12	
	2S/4E-18D1		0	0	0	0	0	0	0	0	0	0	0	0	0	0																4,242	
	2S/4E-18D2		0	0	0	0	0	0	0	0	0	0	0	0	0	0																654	
	2S/4E-18D3		0	0	0	0	0	0	0	0	0	0	0	0	0	0																3,711	
	2S/4E-23N1	MSWD 23	293	317	236	245	301	277	836	890	1,027	1,042	380	532	383	0																8,738	
	2S/4E-23N2	MSWD 30														328	447	499	445	487	405	374	409	396	416	468	761	766	777	752	90	7,819	
	2S/4E-25P	CVCWD NO 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0																619	
	2S/4E-26C1		0	0	0	0	0	0	0	0	0	0	0	402	670	0																1,072	
	2S/4E-26D1	MSWD 28										375	551	402	670	827	872	871	975	1,045	1,233	1,302	1,210	1,260	1,368	1,324	1,507	1,548	1,705	1,345	1,326	21,717	
	2S/4E-35B1	MSWD 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0																975	
	2S/4E-35J	CVCWD NO 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0																764	
	2S/4E-36D1	MSWD 22	1,119	1,219	1,090	877	1,006	1,184	792	649	679	1,233	1,038	1,473	2,145	1,421	874	933	358	403	1,304	981	1,633	1,684	1,715	1,776	1,963	2,323	2,078	1,314	929	45,773	
	2S/4E-36D2	MSWD 24	1,297	1,047	1,035	1,566	0	1,494	1,399	1,550	1,777	1,456	2,258	1,752	1,664	1,838	1,366	1,030	1,891	1,967	1,190	1,392	719	986	611	876	1,315	1,126	927	1,563	2,433	42,817	
	2S/4E-36K1	MSWD 29														274	1,411	1,432	1,397	1,260	1,125	1,338	1,575	1,256	1,664	1,824	1,950	1,983	2,134	1,796	1,429	23,848	
	2S/5E-31H1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0																3,119	
	2S/5E-31P2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0															2,036	
	2S/5E-31Q7	CVCWD NO 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0															879	
	3S/4E-11B2	MSWD 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0															62	
	3S/4E-11L1	MSWD 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0															1,530	
	3S/4E-11L2	MSWD 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0															1,632	
	3S/4E-11L3	MSWD 27	0	104	265	289	947	1,039	1,252	1,394	1,352	1,566	1,564	1,442	1,325	1,645	1,320	312	484	397	430	458	379	449	498	484	501	656	450	494	518	22,014	
	3S/4E-11L4	MSWD 31															498	1,810	1,734	1,609	1,652	1,744	1,929	1,811	1,829	1,815	2,041	1,672	1,220	1,410	1,362	24,137	
	3S/4E-11M1	MSWD 21	354	207	24	0	0	0	0	0	0	0	0	0	0	0	0															2,625	
	3S/4E-11P1		0	0	0	0	87	0	0	0	0	0	0	0	0	0	0															2,862	
	3S/4E-12B1	3406	277	0	0	0	0	0	0	0	0	0	0	0	0	0	0															4,388	
	3S/4E-12B2	3408	277	0	292	230	516	814	661	665	1,748	2,210	2,145	1,215	846	493	910	1,358	142	109	695	739	737	69	735	792	701	520	810	790	732	280	22,476
	3S/4E-12C1	3405	277	0	1,010	1,212	1,399	1,334	1,498	0	555	396	368	1,077	1,310	910	1,796	980	539	95	349	610	321	120	436	470	731	477	324	195	311	62	21,794
	3S/4E-12F1	3410														0	0	0	793	403	766	728	1,251	926	1,510	1,176	1,138	1,112	1,073	1,054	1,774	1,027	14,731

4.5.2.1.2 Underflow

As previously indicated, underflow from the Desert Hot Springs subbasin across the Mission Creek Fault has been estimated at 1,790 afy.

4.5.2.1.3 Evapotranspiration from Phreatophytes

Mayer and May (1998) estimated the total area populated by phreatophytes to be 1,123 acres. Mesquite is the dominant phreatophyte found along the Mission Creek and Banning faults. The amount of water extracted from the aquifer by the phreatophytes was estimated using the approach of Lines and Bilhorn (1996) who have estimated transpiration losses from phreatophytes in the Mojave Desert. Lines and Bilhorn (1996) estimated that the annual water consumption by mesquite was 1.3 af/acre/yr. This method used in the Mojave Desert seems to correlate well to the Mission Creek basin area. Using these values an approximation of 1,460 afy is estimated as loss from the Mission Creek subbasin due to evapotranspiration.

4.5.2.2 *Garnet Hill Subbasin*

4.5.2.2.1 Pumpage

Production in the Garnet Hill subbasin has been extremely limited until recently. The majority of production was associated with wells in the Whitewater River drainage in the upper end of the Garnet Hill subbasin. Records of production data were compiled for various wells from the period 1947 through 2009 and are presented in Table 9. Production varied from a high of 4,165 afy in 1949 to less than 100 afy in the 1980s and 1990s. Figure 22 presents the location of the various production wells in the Garnet Hill subbasin. For budgeting purposes, 500 afy was used for an average year.

4.5.2.2.2 Underflow

As previously indicated, underflow from the Mission Creek subbasin across the Banning Fault has been estimated at 2,000 afy.

4.5.2.2.3 Phreatophytes

The depth to groundwater in the Garnet Hill subbasin at the present time is too great to have established any significant phreatophyte population. Consequently, no discharge associated with phreatophytes has been assumed.

4.5.3 Groundwater Budget

4.5.3.1 *Mission Creek Subbasin*

The Hydrologic Budget for the Mission Creek subbasin is summarized in Table 10. The Mission Creek subbasin has an estimated annual average inflow of 10,633 afy and an estimated annual average outflow of 18,660 afy. The total average annual groundwater budget for the Mission Creek subbasin was estimated at approximately -8,027 afy.

4.5.3.2 *Garnet Hill Subbasin*

The Hydrologic Budget for the Garnet Hill subbasin is summarized in Table 8. The Garnet Hill subbasin has an estimated annual average inflow of 3,370 afy and an estimated annual average outflow of 2,500 afy. The total average annual groundwater budget for the Garnet Hill subbasin was estimated at approximately 870 afy.

TABLE 10
HYDROLOGIC BUDGET FOR THE MISSION CREEK AND GARNET HILL SUB-BASINS

Recharge and Discharge	MISSION CREEK SUB-BASIN (acre-feet/year)	GARNET HILL SUB-BASIN (acre-feet/year)	Basis for Estimate
RECHARGE (INFLOW)			
UNDERFLOW FROM			
Desert Hot Springs Sub-basin	1,790	---	Tyley, 1974
Mission Creek Sub-basin	---	2,000	Tyley, 1974
PERCOLATION from			
Water System Leakage			
Septic and Irrigation Return Flows	2,930	250	MWH, 2010.
Horton and Desert Crest Infiltration Ponds	1,013	0	MWH, 2010.
Mountain Front Recharge and Stream Underflow	4,900	1,120	Calculations from existing data
Artificial Recharge Facilities	0	0	Varies from year to year.
TOTAL INFLOW	10,633	3,370	
DISCHARGE (OUTFLOW)			
UNDERFLOW TO GARNET HILL SUB-BASIN	2,000	---	Tyley, 1974
UNDERFLOW TO UPPER WHITEWATER RIVER SUB-BASIN	---	2,000	Tyley, 1974
PUMPAGE	15,200	500	Calculations from existing data
EVAPOTRANSPIRATION	1,460	0	Tyley, 1974
TOTAL OUTFLOW	18,660	2,500	---
INFLOW-OUTFLOW	-8,027	870	

4.6 Change in Basin Storage

4.6.1 Mission Creek Subbasin

CVWD reported in the *Engineer's Report on Water Supply and Replenishment Assessment for the Mission Creek Subbasin* (2010) that the total estimated cumulative overdraft of the Mission Creek subbasin between the years 1978-2009 was -118,061 acre-feet. Tyley (1974) estimated that the change in water level elevation for the Mission Creek subbasin between 1936-1967 was only -5 feet, which was attributed to little pumping in the subbasin and that the pumping that was occurring was for the City of Desert Hot Springs [the City of Desert Hot Springs at the time took the majority of its water from Desert Hot Springs subbasin (Tyley, 1974)]. Tyley (1974) went on to indicate that for the same period the estimated total decrease in storage from the Mission Creek subbasin was approximately 1,000 acre-feet.

To more fully understand the relationship between groundwater inflow and outflow in the Mission Creek subbasin, the change in the quantity of groundwater in storage was computed using two methods. One method uses the average change in water levels over a selected period by the area of that change and then multiplying the result by the storativity of that area. The second method involves using the hydrologic balance to estimate the change in storage.

Groundwater level contours for 1936 (see Figure 12) were compared to groundwater level contours for 2003 (see Figure 14) and contours were developed for the total change in water level that occurred during the period. The Year 2003 was selected because it was primarily before the majority of artificial recharge that occurred in the upper reaches of the Mission Creek subbasin. Figure 23 presents estimated water level change in the Mission Creek subbasin between the years 1936-2003. The volumes of each of the contour intervals were calculated and a storativity value of 0.15 was applied to each volume to represent the quantity of water that would have been released from storage in each of the area-volumes. Table 11 presents the estimated volumes for each contour interval. The data suggests that the change in storage during the period between 1936 and 2003 is approximately 158,000 acre-feet.

The second method to estimate the change in storage was to use the inflows and outflows developed during the previous periods and carry it through the same period and to calculate what the overall change was. The problem with this method is that the inflows and outflows for some parameters are based on an average year condition (mountain front recharge, flow across the Mission Creek and Garnet Hill faults, phreatophyte loss) which would have changed somewhat based on climatic conditions (i.e. in low precipitation years less recharge and more phreatophyte loss would likely have occurred). However, since the period examined is relatively long (67 years), it could be argued that the climatic variations would be accounted for using average values for mountain front recharge, flow across the Mission Creek and Garnet Hill faults, and phreatophyte loss for the entire period. Appendix A Table A-1 presents an estimate of the total change in storage using the inflows and outflows developed in the previous discussion. The analysis suggests that between the years 1936-2008 there would be a net increase in the overall budget for the Mission Creek subbasin. However, as previously indicated the actual measured change in storage is -100,000 to -150,000 acre-feet. Assuming that the inflow from the Desert Hot Springs Subbasin were reduced by 50 percent and the net outflow to the Garnet Hill subbasin were increased by 75 percent and maintaining all other inflows/outflows unchanged would yield a net basin balance of -120,000 acre-feet from 1936 to 2008. As can be observed, subtle changes can have major impacts when carried over long periods. It is expected that these numbers will be refined during calibration of the numerical model and the values will be updated in this technical memorandum.

TABLE 11
ESTIMATED CHANGE IN GROUNDWATER IN STORAGE 1936-2003

SEGMENT* CONTOUR INTERVAL (feet)	AREA (acres)	ESTIMATED AVERAGE WATER LEVEL CHANGE FOR THE SEGMENT (feet)	STORATIVITY (unitless)	ESTIMATED CHANGE IN STORAGE FOR THE SEGMENT (acre-feet)
0-20	510	10	0.15	765
20-40 (SE)	1,490	30	0.15	6,705
20-40 (NW)	1,030	30	0.15	4,635
40-60 (SE)	5,282	50	0.15	39,615
40-60 (NW)	1,028	50	0.15	7,710
60-80	5,016	70	0.15	52,668
80-100	3,357	90	0.15	45,320
100	1,108	10	0.15	1,662
TOTAL	18,821	---	---	159,080

* - See Figure 23

4.6.2 Garnet Hill Subbasin

Tyley estimated that for the period 1936-1967, groundwater level elevations had decreased from between -10 feet in the western portion of the subbasin to as much as -30 feet in the southeastern portion of the basin. Tyley (1974) went on to indicate that for the same period the estimated total decrease in storage from the Garnet Hill subbasin was approximately 5,000 acre-feet.

4.7 Groundwater Quality

The quality of groundwater in the CVGB has been studied by the USGS, other agencies, and local water districts. Table 12 summarizes water quality data for groundwater in the CVGB, with focus on the Upper Valley portion of the groundwater basin. In general, groundwater quality in the Upper Valley Groundwater Basin (with the exception of the Desert Hot Springs subbasin) is good and meets current drinking water standards. Based on water quality data collected by CVWD between 1996 and 2004, the only parameters that have exceeded either primary or secondary drinking water standards within the Upper Valley Groundwater Basin include total dissolved solids (TDS), nitrate, and perchlorate (MWH, 2005).

Concentrations of TDS are generally below 500 mg/L (the recommended secondary drinking water standard is 500 mg/L) in the Upper Valley Groundwater Basin except in the limited areas adjacent to the Whitewater Spreading Facility and in the Palm Desert area (MWH, 2005). Based on data for 1996 to 1999, wells in the vicinity of the Whitewater Spreading Facility had TDS concentrations of 378 and 505 mg/L (MWH, 2005), just barely above the secondary drinking water standard. A cluster of wells in the Palm Desert area have had TDS concentrations ranging from 500 to 1,000 mg/L.

Within the Upper Valley Groundwater Basin, elevated levels of nitrate have been detected in shallow groundwater wells in the vicinity of the Whitewater River from Cathedral Hill to La Quinta. However, municipal wells generally do not have elevated levels of nitrates due to the depth of the well perforations (several hundred feet below the ground surface). DWA, however, has several municipal wells in the Palm Springs area with nitrate levels up to 70 mg/L (MWH, 2005); the use of these wells is currently restricted. In general, nitrate levels in groundwater are due to fertilizers or discharges from individual domestic septic tank/leachfield systems.

Throughout the Basin, very low levels of perchlorate (less than one mg/L) have been detected in groundwater sources (MWH, 2005). Perchlorate at these low levels may occur naturally in groundwater (MWH, 2005). Water quality monitoring of the CRA water (which is used for percolation into the Basin) by Metropolitan Water District since 1997 indicates that percolate levels in this water have ranged from non-detect to 9 micrograms per liter ($\mu\text{g/L}$) and have been generally declining. In 2005, perchlorate levels in CRA water were in the range of about 2 to 4 $\mu\text{g/L}$ (MWH, 2005).

Table 12
Water Quality in the Upper Coachella Valley

Component	Units	Regulatory Level California MCL ^a	Coachella Valley Groundwater ^b	CVWD Cove Communities Groundwater ^c	CVWD Indio Hills & Desert Hot Springs Groundwater ^d	MSWD Desert Hot Springs Area Groundwater ^d	MSWD West Palm Springs Village Groundwater ^d	DWA Groundwater ^f	DWA Surface Water ^f	Colorado River Water ^g	Whitewater River at Whitewater, CA ^h
Aluminum	ug/L	1,000	ND to 300	—	—	—	—	—	ND to 210	29	
Ammonia-N	mg/L	—	—	—	—	—	—	—	—	ND	ND to 0.05
Antimony	ug/L	6	ND to 3	—	—	—	—	—	—	ND	
Arsenic	ug/L	50	0.3 to 100	ND to 5.0	ND	—	—	—	—	2.7	ND to 2
Barium	ug/L	1,000	ND to 100	—	—	—	—	ND to 220	—	97	ND
Beryllium	ug/L	4	ND to 0.5	—	—	—	—	—	—	ND	
Bicarbonate Alkalinity	mg/L	—	ND to 50	—	—	—	—	120 to 220	55 to 140	160	137 to 240
Cadmium	ug/L	5	ND to 0.68	—	—	—	—	—	—	0.062	ND
Calcium	mg/L	—	0.3 to 2,310	—	—	—	—	29 to 110	11 to 34	76	31 to 63
Carbonate Alkalinity	mg/L	—	ND to 280	—	—	—	—	—	—	0.3	ND to 19
Chloride	mg/L	(500)	0.6 to 9,600	6.6 to 47	13 to 21	13 to 28	8 to 16	9.3 to 68	5.90 to 6.70	83	2 to 26
Chromium	ug/L	50	0.7 to 22	ND to 19	13 to 18	ND to 17	ND	—	—	0.42	—
Copper	ug/L	1,000	ND to 50	ND to 0.08	ND	—	—	—	—	ND	ND
Fluoride	mg/L	2	0.01 to 8.6	0.2 to 1.0	0.5 to 0.8	0.46 to 0.81	0.37 to 1.2	0.11 to 0.7	ND to 0.12	0.31	—
Hardness, as CaCO ₃	mg/L	—	0.8 to 6,430	22 to 310	120 to 200	100 to 260	160 to 200	80 to 340	30 to 92	308	110 to 230
Iron	ug/L	(300)	ND to 280	ND to 110	ND	—	—	ND to 240	ND to 330	ND	3 to 2400
Lead	ug/L	15	ND to 15	—	—	—	—	—	—	ND	ND
Magnesium	mg/L	—	ND to 213	—	—	—	—	0 to 21	1.1 to 3.5	29	6 to 17
Manganese	ug/L	(50)	ND to 50	—	—	—	—	—	—	0.12	ND to 4.3
Mercury	ug/L	2	ND to 1	—	—	—	—	—	—	ND	—
Nickel	ug/L	100	ND to 5	—	—	—	—	—	—	1.9	—
Nitrate as N	mg/L	45	ND to 145	ND to 32	ND to 6.2	ND to 5.9	3.4 to 26	2.6 to 22	ND to 2.4	0.2	ND to 0.9
Nitrite as N	mg/L	1	—	—	—	—	—	—	—	ND	—
Orthophosphate as P	mg/L	—	—	—	—	—	—	—	—	—	ND to 0.04
Perchlorate	ug/L	—	—	—	—	—	—	—	ND to 6.6	5 to 9	—
pH	SU	(6.5 to 8.5)	—	7.2 to 8.3	7.7 to 8.0	—	—	7.3 to 7.8	7.4	8.3	7.9 to 8.6
Potassium	mg/L	—	0.3 to 56	—	—	—	—	2.3 to 6	1.5 to 5.3	4.1	3 to 6
Selenium	ug/L	10	ND to 11	—	—	—	—	—	—	ND	—
Silica	mg/L	—	—	—	—	—	—	—	—	—	9.8 to 17
Silver	ug/L	(100)	ND to 5	—	—	—	—	—	—	ND	ND
Sodium	mg/L	—	17 to 3,900	6.1 to 56	58 to 81	49 to 75	18 to 26	19 to 63	5.7 to 14	95	8 to 36
Specific Conductance	umhos/cm	(1,600)	—	230 to 730	580 to 750	ND to 780	380 to 420	260 to 870	84 to 230	1,012	—
Sulfate	mg/L	(500)	0.3 to 1,980	13 to 160	150 to 210	70 to 220	17 to 20	22 to 220	8.2 to 14	258	17 to 95
Thallium	ug/L	2	ND to 0.8	—	—	—	—	—	—	ND	—
Total Alkalinity as CaCO ₃	mg/L	—	—	—	—	—	—	100 to 180	45 to 110	132	—
Total Dissolved Solids	mg/L	(1,000)	111 to 19,500	140 to 480	370 to 480	240 to 530	230 to 320	170 to 580	68 to 140	637	—
Total Organic Carbon	mg/L	—	—	—	—	—	—	—	—	3	—
Uranium	pCi/L	20	-	ND to 12	ND to 11	2 to 24	2 to 5.5	ND to 21.48	ND to 6.75	4	—
Vanadium	ug/L	—	—	ND to 39	5.8 to 24	—	—	ND to 19	—	—	—
Zinc	ug/L	(5,000)	ND to 50	—	—	—	—	—	—	ND	ND

Notes

- a. California Maximum Contaminant Level as of September 12, 2003. Values in parenthesis are secondary standards.
- b. Coachella Valley groundwater quality for wells throughout the valley for the period 1996 to 2004 (MWH, 2005) Note that higher values typically are found in Lower Coachella Valley wells.
- c. Includes wells in Rancho Mirage, Thousand Palms, Palm Desert, Indian Wells, La Quinta, and portions of Bermuda Dunes, Cathedral City and Riverside County in 2005 (CVWD, 2006).
- d. CVWD wells in Indio Hill, Sky Valley, and areas around Desert Hot Springs (CVWD, 2006).
- e. MSWD water quality for Desert Hot Springs area and West Palm Springs Village/Palm Springs Crest in 2005 (MSWD, 2006).
- f. Water quality for DWA groundwater and surface water in 2004 (DWA, 2005).
- g. Colorado River water is used by CVWD, MSWD, and DWA to recharge groundwater Values represent average results for Colorado River at Lake Havasu (Parker Dam) for 1990 TO 1999.
- h. Surface water quality for the Whitewater River at Whitewater, CA, USGS gaging station 10256000 Period of record is from November 1966 through March 2005 (USGS, 2007).

Source: Derived from CPV, 2007.

Piper (trilinear) diagrams provide a graphical means of comparing compositional differences in the geochemical makeup of water samples from the various subbasins. In 1954, the USGS collected water samples from each of the subbasins (Desert Hot Springs, Garnet Hill, Mission Creek and Whitewater River) as part of groundwater investigations in the Coachella Valley. The water samples included analysis of major cations and anions. For each groundwater sample, concentrations of major anions (chloride (Cl), sulfate (SO₄), carbonate (CO₃) and bicarbonate (HCO₃) and major cations (calcium [Ca], magnesium [Mg], sodium [Na] and potassium [K]) were determined in milliequivalents per liter (Hem, 1985).

Two equilateral triangles, one for cations and one for anions are used to create the plot. Each vertex on the triangles represents 100 percent of a particular ion or group of ions. The composition of the water with respect to cations is indicated by a point plotted in the cation triangle and the composition of the water with respect to anions is indicated by a point plotted in the anion triangle. The coordinates of each point add to 100 percent. The points are then projected onto the central diamond shaped figure by projecting along lines parallel to the upper edges of the central field. The intersection of these projections represents the composition of the water with respect to the combination of ions shown. This plot reveals useful properties and relationships for large sample groups. Thus, the main purpose of the Piper diagram is to show clustering of data points to indicate samples that have similar geochemical composition.

Figure 24 presents a diagram of samples collected in the Desert Hot Springs subbasin. The diagram indicates the predominance of sodium-potassium cations with sulfate anions resulting in a plot of the samples in the upper diagram (diamond) to the far right. The dominance of sulfate is believed related to the geothermal activity (hot springs) that is predominant in the upper Desert Hot Springs subbasin.

Contrastingly, the upper Whitewater River subbasin water chemistry is dominated by Ca and HCO₃ ions and plots to the far left in the upper diagram in Figure 24. Groundwater samples collected in the Mission Creek subbasin generally had a balance of two cations (Ca & Na+K) and anions (SO₄ & HCO₃) and plotted in the center of the upper diagram in Figure 24. This probably represents the effects of inflow from the Desert Hot Springs subbasin on the Mission Creek subbasin geochemistry. Some samples collected in the southeastern portion of the Mission Creek subbasin appeared to have the largest influence from the Desert Hot Springs subbasin as they started to trend towards the right hand side of the upper diagram in Figure 24.

Groundwater samples collected in the Garnet Hill subbasin appeared to be dominated by HCO₃ and SO₄ anions and Na+K cations and noticeably reduced Ca ions characteristic of the upper Whitewater River subbasin geochemistry as shown in Figure 24.

SECTION

5.0 Summary of Conceptual Model for the Mission Creek and Garnet Hill Subbasins

5.1 Mission Creek Subbasin

The Mission Creek subbasin is bounded on the north by the Mission Creek Fault and on the south by the Banning Fault. An estimated 2,000 afy of groundwater moves laterally across the constrictive Banning Fault to the Garnet Hill subbasin (GHS). To the west, the subbasin is bounded by the San Bernardino Mountains and to the east by the Indio Hills and the Mission Creek Fault. Artesian conditions have historically been present near a narrow strip along the northwest portion of the Seven Palms Ridge (DWR1964), allowing for the development of a unique Willow-Mesquite biological community that includes phreatophytes. Depth to groundwater in other parts of the sub-basin averages 300 feet below ground surface.

The Mission Creek subbasin is filled with Holocene and late Pleistocene unconsolidated sediments eroded from the San Bernardino and Little San Bernardino Mountains. There are three significant water bearing sedimentary deposits recognized in the subbasin: Pleistocene Cabazon Fonglomerate and Pleistocene to Holocene Older alluvium and alluvial deposits. These deposits are generally coarse sand and gravel, poorly sorted alluvial fan and pediment deposits that coalesce with one another.

The Mission Creek subbasin is considered an unconfined aquifer with a saturated thickness of 1,200 feet or more and an estimated total storage capacity on the order of 2.6 million af. The subbasin is naturally recharged by surface and subsurface flow from the Mission Creek and Dry and Big Morongo Washes, Painted Hills, and surrounding mountain drainages. Irrigation return flow and discharges from municipal and individual subsurface wastewater disposal systems also contribute to recharge. Total average inflow to the Mission Creek subbasin is estimated at 10,600 acre-feet.

The primary outflows from the Mission Creek subbasin are through groundwater production for domestic, agricultural and commercial use. While groundwater production has varied over the years, it generally has been increasing from approximately 2,000 afy in 1978 to 17,000 afy in 2008. In addition, outflow occurs across the Banning Fault to the Garnet Hill subbasin and has been estimated at 2,000 afy. Lastly, the consumption of groundwater by phreatophytes in the southern end of the subbasin has been estimated at 1,500 afy. Total outflow from the Mission Creek subbasin has been estimated to be approximately 18,700 afy. Correspondingly, the subbasin water budget (inflow-outflow) is estimated at -8,100 afy which would indicate that the subbasin is in overdraft.

As previously indicated, the Mission Creek subbasin is in a state of overdraft. Water level declines have been apparent since the early 1960s and, in the 1970s, when the United States Geological Survey (USGS) sponsored the development of groundwater analog models to assist the DWA and CVWD in their water management decisions regarding importing water for groundwater recharge (Tyley1971; Tyley1974). Water levels have declined in the portions of the Mission Creek subbasin approximately 100 feet between the years 1936 to 2003. Based on estimates conducted by others as well as this report, cumulative change in storage between 1936 -2003 ranges between -100,000 to -150,000 acre-feet.

5.2 Garnet Hill Subbasin

The GHS is bounded on the north by the Banning Fault and on the south by the Garnet Hill Fault. An estimated 2,000 afy of groundwater moves laterally across the constrictive Garnet Hill Fault to the Upper Whitewater River subbasin. To the west, the subbasin is bounded by the San Bernardino Mountains and to the east by the Indio Hills.

The GHS is considered an unconfined aquifer with a saturated thickness of 1,000 feet or more and an estimated total storage capacity on the order of 1.0 million af. The subbasin is naturally recharged by subsurface flow from the Mission Creek subbasin and runoff from the Whitewater River watershed on the west. Irrigation return flow and discharges from municipal and individual subsurface wastewater disposal systems also contribute to recharge but is considered very small. Total average inflow to the GHS is estimated at 3,000 acre-feet.

The primary outflows from the GHS are across the Garnet Hill Fault to the Upper Whitewater River subbasin and has been estimated at 2,000 afy. In addition, limited groundwater production for domestic, agricultural and commercial use also occurs but has only recently been of any significance. Groundwater production has varied over the years, ranging from a high of over 4,000 afy in the early 50s to less than 50 afy in the mid-1980s. Currently, groundwater production is estimated at between 300-500 afy. Total outflow from the GHS has been estimated to be approximately 2,500 afy. Correspondingly, the subbasin water budget (inflow-outflow) is estimated at 800-900 afy which would indicate that the subbasin has a slightly positive balance.

SECTION

6.0 References

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Appendix A

Change in Groundwater Storage for the Mission Creek and Garnet Hill Subbasins

TABLE A-1
PRELIMINARY ESTIMATE OF GROUNDWATER INFLOW/OUTFLOW IN THE MISSION CREEK SUBBASIN
1936-2009

YEAR	INFLOW (acre-feet)				OUTFLOW (acre-feet)			INFLOW- OUTFLOW (acre-feet)	CUMULATIVE CHANGE IN STORAGE (acre feet)
	Mountain Front Recharge	Underflow from Desert Hot Springs Subbasin	Septic and Return Flows	Artificial Recharge	Underflow to Garnet Hill Subbasin	Pumpage	Evapo- transpiration		
1936	4,900	1,790	200	---	2,000	5	1,460	3,425	3,425
1937	4,900	1,790	219	---	2,000	5	1,460	3,444	6,869
1938	4,900	1,790	237	---	2,000	5	1,460	3,462	10,331
1939	4,900	1,790	256	---	2,000	15	1,460	3,471	13,802
1940	4,900	1,790	275	---	2,000	20	1,460	3,485	17,286
1941	4,900	1,790	293	---	2,000	30	1,460	3,493	20,780
1942	4,900	1,790	312	---	2,000	35	1,460	3,507	24,287
1943	4,900	1,790	331	---	2,000	40	1,460	3,521	27,807
1944	4,900	1,790	349	---	2,000	50	1,460	3,529	31,336
1945	4,900	1,790	368	---	2,000	55	1,460	3,543	34,879
1946	4,900	1,790	386	---	2,000	65	1,460	3,551	38,430
1947	4,900	1,790	405	---	2,000	105	1,460	3,531	41,961
1948	4,900	1,790	424	---	2,000	1,116	1,460	2,538	44,499
1949	4,900	1,790	442	---	2,000	151	1,460	3,521	48,021
1950	4,900	1,790	461	---	2,000	132	1,460	3,559	51,580
1951	4,900	1,790	480	---	2,000	483	1,460	3,227	54,806
1952	4,900	1,790	498	---	2,000	1,378	1,460	2,350	57,157
1953	4,900	1,790	517	---	2,000	446	1,460	3,301	60,458
1954	4,900	1,790	536	---	2,000	429	1,460	3,337	63,795
1955	4,900	1,790	554	---	2,000	196	1,460	3,589	67,384
1956	4,900	1,790	573	---	2,000	1,208	1,460	2,595	69,979
1957	4,900	1,790	592	---	2,000	654	1,460	3,168	73,147
1958	4,900	1,790	610	---	2,000	802	1,460	3,039	76,186
1959	4,900	1,790	629	---	2,000	530	1,460	3,329	79,515
1960	4,900	1,790	647	---	2,000	518	1,460	3,359	82,875
1961	4,900	1,790	666	---	2,000	1,143	1,460	2,753	85,628
1962	4,900	1,790	685	---	2,000	1,080	1,460	2,835	88,462
1963	4,900	1,790	703	---	2,000	1,045	1,460	2,888	91,351
1964	4,900	1,790	722	---	2,000	818	1,460	3,134	94,485
1965	4,900	1,790	741	---	2,000	302	1,460	3,669	98,154
1966	4,900	1,790	759	---	2,000	2,240	1,460	1,749	99,903
1967	4,900	1,790	778	---	2,000	1,430	1,460	2,578	102,482
1968	4,900	1,790	797	---	2,000	1,898	1,460	2,129	104,611
1969	4,900	1,790	815	---	2,000	1,889	1,460	2,156	106,767
1970	4,900	1,790	834	---	2,000	1,178	1,460	2,886	109,653
1971	4,900	1,790	853	---	2,000	1,879	1,460	2,204	111,856
1972	4,900	1,790	871	---	2,000	4,581	1,460	-480	111,377
1973	4,900	1,790	890	---	2,000	2,270	1,460	1,850	113,227
1974	4,900	1,790	909	---	2,000	2,755	1,460	1,384	114,610
1975	4,900	1,790	927	---	2,000	2,155	1,460	2,002	116,612
1976	4,900	1,790	946	---	2,000	2,449	1,460	1,727	118,339
1977	4,900	1,790	964	---	2,000	2,821	1,460	1,373	119,712
1978	4,900	1,790	983	---	2,000	2,704	1,460	1,510	121,222
1979	4,900	1,790	1,109	---	2,000	3,504	1,460	836	122,058
1980	4,900	1,790	1,177	---	2,000	4,103	1,460	304	122,362
1981	4,900	1,790	1,220	---	2,000	3,603	1,460	848	123,209
1982	4,900	1,790	1,192	---	2,000	3,947	1,460	475	123,684
1983	4,900	1,790	1,316	---	2,000	4,432	1,460	115	123,799
1984	4,900	1,790	1,503	---	2,000	4,962	1,460	-229	123,570
1985	4,900	1,790	1,531	---	2,000	5,930	1,460	-1,169	122,401
1986	4,900	1,790	1,654	---	2,000	6,443	1,460	-1,559	120,842

TABLE A-1
PRELIMINARY ESTIMATE OF GROUNDWATER INFLOW/OUTFLOW IN THE MISSION CREEK SUBBASIN
1936-2009

YEAR	INFLOW (acre-feet)				OUTFLOW (acre-feet)			INFLOW- OUTFLOW (acre-feet)	CUMULATIVE CHANGE IN STORAGE (acre feet)
	Mountain Front Recharge	Underflow from Desert Hot Springs Subbasin	Septic and Return Flows	Artificial Recharge	Underflow to Garnet Hill Subbasin	Pumpage	Evapo- transpiration		
1987	4,900	1,790	1,918	---	2,000	5,945	1,460	-798	120,045
1988	4,900	1,790	2,257	---	2,000	7,141	1,460	-1,654	118,391
1989	4,900	1,790	2,509	---	2,000	8,292	1,460	-2,553	115,838
1990	4,900	1,790	2,558	---	2,000	8,307	1,460	-2,520	113,318
1991	4,900	1,790	2,461	---	2,000	8,041	1,460	-2,351	110,968
1992	4,900	1,790	2,953	---	2,000	8,746	1,460	-2,562	108,406
1993	4,900	1,790	2,674	---	2,000	8,861	1,460	-2,956	105,449
1994	4,900	1,790	2,935	---	2,000	9,664	1,460	-3,500	101,950
1995	4,900	1,790	2,934	---	2,000	9,927	1,460	-3,763	98,187
1996	4,900	1,790	3,059	---	2,000	10,341	1,460	-4,052	94,135
1997	4,900	1,790	2,949	---	2,000	9,585	1,460	-3,406	90,728
1998	4,900	1,790	3,084	---	2,000	10,193	1,460	-3,879	86,850
1999	4,900	1,790	3,203	---	2,000	10,784	1,460	-4,350	82,499
2000	4,900	1,790	3,313	---	2,000	11,434	1,460	-4,892	77,608
2001	4,900	1,790	3,358	---	2,000	12,350	1,460	-5,762	71,846
2002	4,900	1,790	3,483	4,733	2,000	13,968	1,460	-2,522	69,324
2003	4,900	1,790	3,694	100	2,000	13,768	1,460	-6,744	62,580
2004	4,900	1,790	4,287	5,564	2,000	16,697	1,460	-3,616	58,964
2005	4,900	1,790	4,887	24,723	2,000	16,315	1,460	16,525	75,489
2006	4,900	1,790	4,746	19,901	2,000	17,751	1,460	10,126	85,614
2007	4,900	1,790	4,665	1,011	2,000	17,007	1,460	-8,101	77,513
2008	4,900	1,790	4,472	503	2,000	16,270	1,460	-8,065	69,449

TABLE A-2
PRELIMINARY ESTIMATE OF GROUNDWATER INFLOW/OUTFLOW IN THE MISSION CREEK SUBBASIN
1936-2009

YEAR	INFLOW (acre-feet)				OUTFLOW (acre-feet)			INFLOW- OUTFLOW (acre-feet)	CUMULATIVE CHANGE IN STORAGE (acre feet)
	Mountain Front Recharge	Underflow from Desert Hot Springs Subbasin	Septic and Return Flows	Artificial Recharge	Underflow to Garnet Hill Subbasin	Pumpage	Evapo- transpiration		
1936	4,900	700	200	---	3,500	5	1,460	835	835
1937	4,900	700	219	---	3,500	5	1,460	854	1,689
1938	4,900	700	237	---	3,500	5	1,460	872	2,561
1939	4,900	700	256	---	3,500	15	1,460	881	3,442
1940	4,900	700	275	---	3,500	20	1,460	895	4,336
1941	4,900	700	293	---	3,500	30	1,460	903	5,240
1942	4,900	700	312	---	3,500	35	1,460	917	6,157
1943	4,900	700	331	---	3,500	40	1,460	931	7,087
1944	4,900	700	349	---	3,500	50	1,460	939	8,026
1945	4,900	700	368	---	3,500	55	1,460	953	8,979
1946	4,900	700	386	---	3,500	65	1,460	961	9,940
1947	4,900	700	405	---	3,500	105	1,460	941	10,881
1948	4,900	700	424	---	3,500	1,116	1,460	-52	10,829
1949	4,900	700	442	---	3,500	151	1,460	931	11,761
1950	4,900	700	461	---	3,500	132	1,460	969	12,730
1951	4,900	700	480	---	3,500	483	1,460	637	13,366
1952	4,900	700	498	---	3,500	1,378	1,460	-240	13,127
1953	4,900	700	517	---	3,500	446	1,460	711	13,838
1954	4,900	700	536	---	3,500	429	1,460	747	14,585
1955	4,900	700	554	---	3,500	196	1,460	999	15,584
1956	4,900	700	573	---	3,500	1,208	1,460	5	15,589
1957	4,900	700	592	---	3,500	654	1,460	578	16,167
1958	4,900	700	610	---	3,500	802	1,460	449	16,616
1959	4,900	700	629	---	3,500	530	1,460	739	17,355
1960	4,900	700	647	---	3,500	518	1,460	769	18,125
1961	4,900	700	666	---	3,500	1,143	1,460	163	18,288
1962	4,900	700	685	---	3,500	1,080	1,460	245	18,532
1963	4,900	700	703	---	3,500	1,045	1,460	298	18,831
1964	4,900	700	722	---	3,500	818	1,460	544	19,375
1965	4,900	700	741	---	3,500	302	1,460	1,079	20,454
1966	4,900	700	759	---	3,500	2,240	1,460	-841	19,613
1967	4,900	700	778	---	3,500	1,430	1,460	-12	19,602
1968	4,900	700	797	---	3,500	1,898	1,460	-461	19,141
1969	4,900	700	815	---	3,500	1,889	1,460	-434	18,707
1970	4,900	700	834	---	3,500	1,178	1,460	296	19,003
1971	4,900	700	853	---	3,500	1,879	1,460	-386	18,616
1972	4,900	700	871	---	3,500	4,581	1,460	-3,070	15,547
1973	4,900	700	890	---	3,500	2,270	1,460	-740	14,807
1974	4,900	700	909	---	3,500	2,755	1,460	-1,206	13,600
1975	4,900	700	927	---	3,500	2,155	1,460	-588	13,012
1976	4,900	700	946	---	3,500	2,449	1,460	-863	12,149
1977	4,900	700	964	---	3,500	2,821	1,460	-1,217	10,932
1978	4,900	700	983	---	3,500	2,704	1,460	-1,080	9,852
1979	4,900	700	1,109	---	3,500	3,504	1,460	-1,754	8,098
1980	4,900	700	1,177	---	3,500	4,103	1,460	-2,286	5,812
1981	4,900	700	1,220	---	3,500	3,603	1,460	-1,742	4,069
1982	4,900	700	1,192	---	3,500	3,947	1,460	-2,115	1,954
1983	4,900	700	1,316	---	3,500	4,432	1,460	-2,475	-521
1984	4,900	700	1,503	---	3,500	4,962	1,460	-2,819	-3,340
1985	4,900	700	1,531	---	3,500	5,930	1,460	-3,759	-7,099
1986	4,900	700	1,654	---	3,500	6,443	1,460	-4,149	-11,248

TABLE A-2
PRELIMINARY ESTIMATE OF GROUNDWATER INFLOW/OUTFLOW IN THE MISSION CREEK SUBBASIN
1936-2009

YEAR	INFLOW (acre-feet)				OUTFLOW (acre-feet)			INFLOW- OUTFLOW (acre-feet)	CUMULATIVE CHANGE IN STORAGE (acre feet)
	Mountain Front Recharge	Underflow from Desert Hot Springs Subbasin	Septic and Return Flows	Artificial Recharge	Underflow to Garnet Hill Subbasin	Pumpage	Evapo- transpiration		
1987	4,900	700	1,918	---	3,500	5,945	1,460	-3,388	-14,635
1988	4,900	700	2,257	---	3,500	7,141	1,460	-4,244	-18,879
1989	4,900	700	2,509	---	3,500	8,292	1,460	-5,143	-24,022
1990	4,900	700	2,558	---	3,500	8,307	1,460	-5,110	-29,132
1991	4,900	700	2,461	---	3,500	8,041	1,460	-4,941	-34,072
1992	4,900	700	2,953	---	3,500	8,746	1,460	-5,152	-39,224
1993	4,900	700	2,674	---	3,500	8,861	1,460	-5,546	-44,771
1994	4,900	700	2,935	---	3,500	9,664	1,460	-6,090	-50,860
1995	4,900	700	2,934	---	3,500	9,927	1,460	-6,353	-57,213
1996	4,900	700	3,059	---	3,500	10,341	1,460	-6,642	-63,855
1997	4,900	700	2,949	---	3,500	9,585	1,460	-5,996	-69,852
1998	4,900	700	3,084	---	3,500	10,193	1,460	-6,469	-76,320
1999	4,900	700	3,203	---	3,500	10,784	1,460	-6,940	-83,261
2000	4,900	700	3,313	---	3,500	11,434	1,460	-7,482	-90,742
2001	4,900	700	3,358	---	3,500	12,350	1,460	-8,352	-99,094
2002	4,900	700	3,483	4,733	3,500	13,968	1,460	-5,112	-104,206
2003	4,900	700	3,694	100	3,500	13,768	1,460	-9,334	-113,540
2004	4,900	700	4,287	5,564	3,500	16,697	1,460	-6,206	-119,746
2005	4,900	700	4,887	24,723	3,500	16,315	1,460	13,935	-105,811
2006	4,900	700	4,746	19,901	3,500	17,751	1,460	7,536	-98,276
2007	4,900	700	4,665	1,011	3,500	17,007	1,460	-10,691	-108,967
2008	4,900	700	4,472	503	3,500	16,270	1,460	-10,655	-119,621

TABLE A-3
PRELIMINARY ESTIMATE OF GROUNDWATER INFLOW/OUTFLOW IN THE GARNET HILL
SUBBASIN

YEAR	INFLOW (acre-feet)			OUTFLOW (acre-feet)			INFLOW- OUTFLOW (acre-feet)	CUMULATIVE CHANGE IN STORAGE (acre feet)
	Mountain Front Recharge	Underflow from Mission Creek Subbasin	Septic and Return Flows	Underflow to Whitewater River Subbasin	Pumpage	Evapo- transpiration		
1936	1,120	2,000	0	2,000	0	0	1,120	1,120
1937	1,120	2,000	0	2,000	0	0	1,120	2,240
1938	1,120	2,000	0	2,000	0	0	1,120	3,360
1939	1,120	2,000	0	2,000	0	0	1,120	4,480
1940	1,120	2,000	0	2,000	0	0	1,120	5,600
1941	1,120	2,000	0	2,000	0	0	1,120	6,720
1942	1,120	2,000	0	2,000	0	0	1,120	7,840
1943	1,120	2,000	0	2,000	0	0	1,120	8,960
1944	1,120	2,000	0	2,000	0	0	1,120	10,080
1945	1,120	2,000	0	2,000	0	0	1,120	11,200
1946	1,120	2,000	0	2,000	0	0	1,120	12,320
1947	1,120	2,000	0	2,000	2,710	0	-1,590	10,730
1948	1,120	2,000	0	2,000	686	0	434	11,164
1949	1,120	2,000	9	2,000	4,165	0	-3,036	8,128
1950	1,120	2,000	0	2,000	4,094	0	-2,974	5,154
1951	1,120	2,000	140	2,000	3,214	0	-1,954	3,200
1952	1,120	2,000	0	2,000	4,305	0	-3,185	15
1953	1,120	2,000	0	2,000	4,353	0	-3,233	-3,218
1954	1,120	2,000	1	2,000	1,535	0	-414	-3,632
1955	1,120	2,000	0	2,000	3,898	0	-2,778	-6,410
1956	1,120	2,000	0	2,000	1,225	0	-105	-6,515
1957	1,120	2,000	0	2,000	560	0	560	-5,955
1958	1,120	2,000	6	2,000	144	0	982	-4,973
1959	1,120	2,000	0	2,000	399	0	721	-4,252
1960	1,120	2,000	0	2,000	1,372	0	-252	-4,504
1961	1,120	2,000	0	2,000	1,994	0	-874	-5,378
1962	1,120	2,000	0	2,000	2,357	0	-1,237	-6,615
1963	1,120	2,000	0	2,000	1,929	0	-809	-7,424
1964	1,120	2,000	0	2,000	1,601	0	-481	-7,905
1965	1,120	2,000	0	2,000	1,959	0	-839	-8,744
1966	1,120	2,000	0	2,000	848	0	272	-8,472
1967	1,120	2,000	128	2,000	889	0	359	-8,113
1968	1,120	2,000	0	2,000	717	0	403	-7,710
1969	1,120	2,000	2	2,000	163	0	959	-6,751
1970	1,120	2,000	8	2,000	802	0	326	-6,425
1971	1,120	2,000	1	2,000	745	0	376	-6,049
1972	1,120	2,000	51	2,000	966	0	205	-5,845
1973	1,120	2,000	6	2,000	1,091	0	35	-5,809
1974	1,120	2,000	10	2,000	1,061	0	69	-5,740
1975	1,120	2,000	12	2,000	1,000	0	132	-5,608
1976	1,120	2,000	24	2,000	1,476	0	-332	-5,940
1977	1,120	2,000	23	2,000	1,310	0	-167	-6,108
1978	1,120	2,000	11	2,000	55	0	1,076	-5,032
1979	1,120	2,000	49	2,000	27	0	1,142	-3,890
1980	1,120	2,000	56	2,000	597	0	579	-3,310
1981	1,120	2,000	59	2,000	602	0	577	-2,734
1982	1,120	2,000	50	2,000	602	0	568	-2,166

TABLE A-3
PRELIMINARY ESTIMATE OF GROUNDWATER INFLOW/OUTFLOW IN THE GARNET HILL
SUBBASIN

YEAR	INFLOW (acre-feet)			OUTFLOW (acre-feet)			INFLOW- OUTFLOW (acre-feet)	CUMULATIVE CHANGE IN STORAGE (acre feet)
	Mountain Front Recharge	Underflow from Mission Creek Subbasin	Septic and Return Flows	Underflow to Whitewater River Subbasin	Pumpage	Evapo- transpiration		
1983	1,120	2,000	58	2,000	580	0	598	-1,568
1984	1,120	2,000	65	2,000	46	0	1,139	-429
1985	1,120	2,000	61	2,000	43	0	1,137	709
1986	1,120	2,000	61	2,000	602	0	579	1,287
1987	1,120	2,000	118	2,000	611	0	626	1,914
1988	1,120	2,000	122	2,000	568	0	674	2,588
1989	1,120	2,000	192	2,000	488	0	824	3,412
1990	1,120	2,000	212	2,000	39	0	1,293	4,705
1991	1,120	2,000	206	2,000	38	0	1,287	5,992
1992	1,120	2,000	210	2,000	41	0	1,289	7,282
1993	1,120	2,000	175	2,000	0	0	1,295	8,576
1994	1,120	2,000	164	2,000	0	0	1,284	9,860
1995	1,120	2,000	152	2,000	0	0	1,272	11,132
1996	1,120	2,000	164	2,000	0	0	1,284	12,416
1997	1,120	2,000	165	2,000	0	0	1,285	13,701
1998	1,120	2,000	169	2,000	0	0	1,289	14,990
1999	1,120	2,000	174	2,000	0	0	1,294	16,283
2000	1,120	2,000	185	2,000	0	0	1,305	17,588
2001	1,120	2,000	187	2,000	0	0	1,307	18,895
2002	1,120	2,000	200	2,000	0	0	1,320	20,215
2003	1,120	2,000	219	2,000	0	0	1,339	21,554
2004	1,120	2,000	245	2,000	0	0	1,365	22,919
2005	1,120	2,000	287	2,000	0	0	1,407	24,325
2006	1,120	2,000	288	2,000	0	0	1,408	25,734
2007	1,120	2,000	264	2,000	516	0	868	26,602
2008	1,120	2,000	251	2,000	330	0	1,041	27,642