Appendix A:
Continuous Hydrologic Simulation and Water Balance Analyses

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A-1 INTRODUCTION

Proposed development in Rancho Mission Viejo (RMV) can potentially cause changes in the hydrologic characteristics of the sub-basins. This appendix presents a detailed description of hydrologic analyses performed to quantify potential changes in the hydrologic regime from urban development, and to evaluate the effectiveness of Best Management Practices (BMPs) to mitigate potential impacts.

This appendix is divided into three sections:

1. Problem Statement and General Assessment Approach
2. Detailed Model Description and Parameterization Procedures
3. Model Description for Individual Watersheds

A-1.1 Problem Statement

Changes to the hydrologic regime from urban development are referred to as hydromodification. Hydromodification includes two elements:

1. Changes in the low flow hydrology, including base flows and durations of elevated flows following storm events. These changes result from changes in the runoff pattern to existing infiltration area, irrigation of landscape areas and golf course watering, pavement and car washing, as well as the increase in runoff durations from storm events.

The impact of these flows is primarily on the wetting of riparian areas and can result in a type change in vegetation. Other impacts can include water quality if such low flows are higher in nutrients or other materials that can be leached from soils.

2. Changes in runoff characteristics from small and moderate size storm events, including peak values and duration of in-stream flows where the resulting impacts include changes in sediment transport, stream erosion and/or sedimentation, and ultimately habitat. Hydromodification effects on stream stability are most significant for a range of flows from the lowest flow that initiates bedload sediment transport to the bankfull flow. The return period of such “geomorphically significant flows” varies but is generally considered some fraction (say 1/3 to 1/2) of the bankfull flow up to the bankfull flow. The return period of the bankfull flow will vary depending on the stream but is generally considered to be around the 1.5 to 2 year event, but could be as high as a 10-year event. Hydromodification is a cumulative effect in that the more frequent geomorphically significant flows over time contribute far more energy for sediment transport compared to the less frequent large events, even though the larger events clearly transport more sediment on an event basis.

The goals for hydromodification control are to insure that project-induced changes to the hydrologic regime do not adversely affect the duration of those flows that are primarily responsible for hydromodification.

A-1.2 Hydrologic Characteristics and the Relation to Development Plans

A detailed description of hydrologic characteristics in the study area is presented in the Baseline Geomorphic and Hydrologic Conditions report (RMV, February 2002). These descriptions are summarized below in the context of hydrologic abstractions shown Figure A-1. Planning principles of the proposed development are based to a large extent on the recognition and understanding of hydrologic responses of different terrains at the watershed and sub-basin scale (RMV, July 2002). Included below are summaries of pertinent planning principles associated with the hydrologic abstractions, and a description of how the principles are addressed in the hydrologic analysis.

- **Precipitation**. In the absence of development, precipitation is the main source of water to the watershed. Urban development and associated importation of domestic water supplies will increase water inputs to the basins. Precipitation occurs primarily as rain from general winter storms during the wet season from October through March. Little rainfall occurs during the dry season from April through September. The average annual rainfall in the study area is about 15 inches.

  Cyclical periods of above average and below average rainfall are common. The baseline conditions report (RMV, February 2002) states that a protracted dry cycle from 1945 to 1977 lowered groundwater levels and reduced the extent of riparian corridors in the study area. Hamilton (2000) found the magnitude of hydrologic effects from long-term dry and wet cycles were similar or greater to the anticipated effects of proposed development in Muddy Canyon (western Orange County). A planning tenant is the consideration of longer-term wet/dry cycles and how such cycles influence hydrologic conditions (Planning Principle 5, RMV, July 2002). Therefore, hydrologic conditions during dry and wet periods were considered in this assessment. In addition, the hydrologic analyses take into account effects from importation of water for landscape irrigation.

- **Storm Runoff.** The amount of surface runoff from precipitation depends on the rainfall intensity, surface coverage, slope, the soil properties, and the antecedent soil moisture. Impervious areas associated with urban development can dramatically increase surface runoff if hydrologic responses are not considered and/or hydrologic source controls are inadequate.

  Applicable planning principles are: recognize the hydrologic responses of different terrains; and emulate, to the extent feasible, existing runoff patterns by locating proposed developed in areas characterized by high runoff rates/ low infiltration (Planning Principle 1 & 2, RMV, July 2002). A major portion of the hydrologic assessment was devoted to the comparison of pre- and post-development runoff patterns and the evaluation of proposed hydrologic source control measures.

- **Infiltration**. The vast majority of the precipitation will infiltrate into the subsurface. The amount and rate of infiltration depends on the soil type, vegetation coverage, slope, and soil moisture. Infiltration diminishes over the duration of storm events and in relation to the time from preceding storms. Urban development can potentially cause hydromodification by altering runoff patterns to existing infiltration areas.

Applicable planning principles are protect and mimic existing infiltration patterns to the maximum extent feasible by limiting new impervious development in major side canyons and swales; provide setbacks from the main stem channel to retain high infiltration capacity of the valley floor; where feasible, route drainage from development areas detention/infiltration in sandy terrains; and where possible, restore native grasslands to reduce erosion and increase stormwater infiltration (Planning Principle 1, 2, & 7, RMV, July 2002). The hydrologic assessment was based on modeling of rainfall/runoff/infiltration processes over a long-term continuous rainfall record. This permits a direct accounting of infiltration volumes and the potential impacts of development on infiltration, as well as, the assessment of infiltration BMPs for mitigating potential impacts.

- **Groundwater Discharge and Base Flows.** Groundwater discharge supports dry season streamflow and wet season base flow between storms. The duration and aerial extent of groundwater flows varies among the RMV sub-basins, influenced by the geologic and hydrologic characteristics of the sub-basins. Sandy sub-basins (Chiquita and Gobernadora) support perennial or near perennial flows. Other sub-basins only sustain ephemeral streamflow following the rainy season because the geologic conditions do not enable the movement of substantial volumes of water to the creek.

  Applicable planning principles are: address potential effects of future land use changes on dry season streamflow; protect existing groundwater recharge areas supporting slope wetlands and riparian zones; and maximize groundwater recharge of alluvial aquifers to the extent consistent with aquifer capacity and habitat management goals (Planning Principle 3 & 8, RMV, July 2002). The modeling approach used to assess hydrologic conditions includes groundwater routines to model groundwater storage and discharge. This allows the continuous simulation of dry and wet weather streamflow and permits a quantitative evaluation of development impacts on groundwater discharge and dry weather streamflow, as well as assessment of infiltration BMPs.

- **Evapotranspiration.** Evapotranspiration (ET) is the sum of the amount of water transpired by vegetation and the amount of water evaporated from the soil or intercepted by vegetation. Much of the precipitation in the study is lost to ET consumption (Young and Blaney, 1942). ET rates strongly depend on local conditions and are influenced by a number of factors including: vegetation type, coverage and distribution, temperature, humidity, wind speed, soil type, soil moisture, and precipitation. Changes in land-use (e.g. conversion of rangeland or agricultural land to urban development, restoration of grazing areas) can potentially alter ET patterns through changes in the type and distribution of vegetation coverage, as well as the water availability to native and landscape vegetation.

  Applicable planning principles are: address potential effects of future land use changes on hydrology, and where feasible restore native upland and riparian habitat to reduce erosion and reduce pollutant loadings (Planning Principle 1, 3 & 9, RMV, July 2002). ET losses are quantified and differentiated by vegetation groups as part of this hydrologic assessment.

A-1.3 Hydromodification Assessment Approach

Hydromodification effects were quantified with the USEPA Storm Water Management Model (SWMM). SWMM is a public domain model that is widely used for modeling hydrologic and hydraulic processes affecting runoff from urban and natural drainages. The model can simulate all aspects of the urban hydrologic and quality cycles, including rainfall, surface and subsurface runoff, flow routing through the drainage network, storage and treatment.

Two main measures were used to gauge hydromodification in this hydrologic assessment:

1. A Monthly Water Balance
2. Flow Duration Curves

Water Balance. A water balance is a direct accounting of the hydrologic abstractions discussed above. Comparison of the water balance for pre- and post-development conditions provides an indication of potential development impacts on the hydrologic regime.

The SWMM model is well suited for quantifying water balances because it is capable of simulating all aspects of the hydrologic cycle. The water balance was calculated on a monthly basis because hydrologic processes are seasonal. In addition, water balances were determined for dry and wet periods to evaluate natural variation in the hydrologic regime in comparison with potential impacts from development.

Flow Duration Curves. A flow duration curve relates streamflow and the total duration of time in which the flow rate is exceeded. The flow duration curves are a measure of the range of geomorphically significant flows that could potentially impact beneficial uses. Matching of the pre- and post- development flow duration curves was used as a criterion for sizing of hydrologic sources control BMPs.

A-2 SWMM INPUT REQUIREMENTS AND GENERAL PARAMETERIZATION APPROACH

A-2.1 Data Requirements and Data Sources

Data requirements for continuous hydrologic simulation using SWMM are extensive. Data requirements include:

- Catchment characteristics and geometry – area, slope, imperviousness, roughness, width (a shape factor), depression and interception storage, overland flow roughness coefficients
- Infiltration parameters – soil distribution, soil conductivity, suction pressure, moisture deficit
- Subsurface characteristics – average conductivity, depth, moisture retention properties, relative hydraulic conductivity properties
- Channel characteristics – length, slope, shape, roughness
- Precipitation records – hourly precipitation data for the period of continuous simulation; irrigation estimates (volume and timing) for post-development conditions
- Evapotranspiration (ET) properties – vegetation type and distribution, average monthly evapotranspiration rates for representative vegetation types
- Measured discharge hydrographs or point estimates for model calibration
- Land-use information for existing conditions and for proposed development
- BMP identification and sizing estimates

Sources of data used to construct the SWMM input included the following:

- Topographic maps (2 and 5 foot contour intervals) were obtained from Edaw Inc in digital AutoCAD format.
- Existing vegetative and land-use coverage (WES data) was provided by PWA Consultants in digital Geographical Information System (GIS) format.
- Proposed land-use coverage (B4 and B9 Plans) was obtained from Edaw Inc in digital GIS format. These are planning level concept plans that do not include detailed development types. Edaw Inc also provided GIS maps delineating proposed areas for coastal sage restoration.
- Detailed development concepts and grading plans in the Chiquita Canyon watershed were provided by Edaw Inc. The development plans were provided in PDF format, which was then traced into GIS format. The grading plan was provided in AutoCAD format.
- Soils data were obtained from the US Dept of Agriculture Soil Survey of Orange County and Western Part of Riverside County, California (1978). In addition, GIS files of the

perched hardpans areas mapped by Morton (1974) were obtained from Balance Hydrologics. Detailed descriptions of local geomorphic conditions are found in the Base Conditions Report (RMV, February 2003) and in Technical Appendix A (PWA, May 2002) and Appendix C (Balance, September 2001).

- Precipitation data were obtained from the National Climatic Data Center.
- Evaporation data and information was obtained from a variety of sources discussed in Section A-2.6.
- Data used to calibrate the SWMM models include: flow monitoring data collected by Wildermuth Environmental (July, 2003); base flow measurements collected by Balance Hydrologics (September 2001); and peak flow estimates determined from high water marks (Balance, 2003b)

The following describes the procedures and general approach used to compile and parameterize data inputs for SWMM.

A-2.2 Subcatchment Delineation and Disaggregation

To account for variability in spatial properties the study watersheds were subdivided into subcatchments that are idealized in SWMM as having spatially lumped properties. The number of required subcatchments depends on the amount of hydrologic/hydraulic detail that must be modeled. A high-degree of basin disaggregation is generally not necessary for continuous simulations because reasonable agreement is possible between hydrographs produced by coarse and fine catchment discretization (James, 2000). Therefore, it was desirable to disaggregate the study watershed by as few subcatchments as possible, consistent with the needs for hydraulic detail within the catchment.

A conceptualization of the watershed desegregation is shown in Figure A-2. The criteria used to disaggregate the study area watersheds are described below:

- Stream networks. The total watershed was divided into a reasonable number subcatchments based on the stream network based on topography. Each subcatchment typically includes the drainage area from one or a few major side canyons of the main stem channel. Smaller subcatchments were delineated in the development areas or in areas with anticipated changes (e.g. coastal scrub restoration areas); slightly larger subcatchments were typically delineated in areas with no anticipated changes.
- Topography. As shown in Figure A-2, each subcatchment was subdivided into a valley subcatchment and a ridge subcatchment based on topography. The valley subcatchments typically have milder average slopes, permeable alluvial deposits, and more riparian habitat. Each of these factors affects the volume of the surface runoff, infiltration, ET, and groundwater recharge as computed by SWMM.

Routing between the ridge and valley subcatchments in SWMM is depicted in Figure A-2. Surface runoff from the ridge subcatchment was routed to the valley subcatchment, and surface runoff from the valley subcatchment was routed to the stream channel. Both ridge and valley subcatchments were modeled with a groundwater compartment. The groundwater compartment receives recharge from water that infiltrates and percolates through the unsaturated zone. Discharge from the groundwater compartment is the source of dry weather base flows, and is routed to the stream channel in the valley subcatchment. SWMM tracks on a continuous basis, the height of the groundwater table, soil moisture in the unsaturated zone, ET losses from the subsurface, and groundwater discharge to the valley stream.

- Development areas were modeled in two ways:
    a. The development areas were disaggregated into separate catchments to facilitate the assessment of development impacts and the sizing and effectiveness of BMPs. Six development watershed types were defined: residential, estate, transportation, commercial, parks, golf course. Runoff from the development subcatchments were routed in accordance to their location within ridge or valley areas, and/or in accordance to the type of BMP treatment applied to the development. This approach was used to model the Chiquita Watershed and in all watershed where specific BMPs are explicitly modeled with SWMM (e.g. detention basins, infiltration basins).
    b. In some watersheds BMPs were not modeled with SWMM but are addressed through separate quantitative or qualitative analyses. In these watersheds, the development areas were not disaggregated but were retained within the valley/ridge subcatchments. Impacts of the development area are captured in SWMM through the appropriate representation of the imperviousness area and vegetative coverage.

A-2.3 Subcatchment Properties

A-2.3.1 Geometry

Subcatchments are idealized in SWMM as rectangular in shape (see Figure A-2) with dimensions defined by area, length, and width (area = length times width). GIS tools were used to determine the subcatchment areas. The subcatchment lengths were estimated as the maximum overland flow length based on topographic information. The basin width was calculated from the area and length (width = area divided by length).

A-2.3.2 Slope

The GIS contour maps were used to construct Digital Elevation Models (DEM) of the study watersheds. A DEM is a collection of spatially averaged elevations at discrete nodes throughout the watershed. The average slope of the modeled subcatchments was calculated from the DEM using available GIS tools.

A-2.3.3 Stream Network

Channel networks in the study watersheds were modeled as a main stem channel fed by tributary channels in the valley subcatchments (see Figure A-2). The channel network is input into the SWMM as a sequence of channel segments, each with separate dimensions, geometry, and slope. The channel segments were modeled as trapezoidal in shape with varying width and surface roughness. The length and slope of the channel segments was determined from the DEM of the study watersheds.

A-2.4 Rainfall

The hydrologic assessment is based on modeling rainfall-runoff processes over a long-term and continuous period. Hydromodification studies with SWMM require, at a minimum, the use of hourly rainfall records to quantify storm intensities. Daily precipitation data do not accurately represent storm intensity because storm durations are typically less than 24 hours. Periods of greatest rainfall intensity are generally short in duration, often less than one hour.

A-2.4.1 Available Rainfall Records and Gauge Selection

The location of hourly gauging stations in Orange County is shown in Figure A-3 on the County isohyetal map for comparative purposes. Daily rainfall gauges at El Toro and Tustin are also shown, as these gauges have long-term records and are often used in local hydrological studies. Station information of the hourly gauges is summarized in Table A-1 for gauges shown in Figure A-3, as well as additional gauges in neighboring counties.

The most suitable hourly gaging stations on the basis of general proximity to the study area and quantity and quality of data are the Santiago Dam and Trabuco gauges north of the project area, and the Laguna Beach gauge to the west (see Table A-1). Orographic influences were also considered in the gauge selection through the inspection of elevation profiles along two transects shown in Figure A-3. The transect between the Laguna and Santiago Dam gauges shows the Santiago Dam gauge is located behind a ridge that could reduce the orographic influence on precipitation. Similar effects are less evident between the Laguna and Trabuco gauges.

The hourly precipitation data from the Trabuco gauge is the most representative of the study area because it is the closest of the available hourly gauges, it has second least amount of missing records, and it best represents orographic conditions in the study area. Precipitation data from the Trabuco gauge were used in the SWMM modeling

Table A-1:Data Summary of Selected Hourly Rain Gauges

Rain Gauge	Elevation (ft)	Approximate Distance to Study Area (miles)	Available Period of Record	Approximate Number of Missing Days Between 1948-2001
Oceanside PP	30	30	’53 – ‘01	
Laguna Beach No. 2	210	10	’49 – ‘01	1628
Brea Dam	255	28	’49 – ’81, ’83 – ‘01	
Fullerton Dam	340	27	’49 – ’81, ’83 – ‘01	
Fallbrook	660	25	’49 – ‘93	
San Juan Guard Station	730	6	’49 – ’71, ’79 – ‘01	6110
Santiago Dam	855	16	'48-’80, '83-'01	2170
Trabuco Canyon	970	5	’49 – ‘01	1760
Silverado Ranger Station	1095	12	’49 – ’81, ’83 – ‘01	3048
Elsinore	1285	18	’67 - ’01	
Santiago Peak	5638	10	’72 – ‘01	

A-2.4.2 Construction of Continuous Rainfall Records

The hourly rainfall records from the Trabuco, Santiago Dam, and Laguna Beach Stations each contain missing and deleted records (Table A-1**)**. Many of the data gaps are continuous over months, and in some cases years, such that large blocks of missing records occur at some stations. These missing records can potentially lead to inaccurate representation of streamflow hydrographs and water balance results. A procedure to construct a continuous rainfall record was developed.

Monthly and annual rainfall totals at the Trabuco, Santiago Dam, and Laguna Beach stations were found to correlate reasonably well among all three stations (Figure A-5). The monthly data were screened such that only months with no (or minor amounts of) missing records at both stations are included in the correlation. The annual data were screened to exclude records with a substantial amount of missing records. To check that the monthly accumulations are representative of storm events, the storm events at the Trabuco and Santiago stations were paired and plotted (Figure A-5a). A correlation equation for the storm events was found to be similar to that for the monthly and annual accumulations, suggesting that correlation equations developed with the monthly data can be reasonably applied to the hourly data.

The linear regression equations for the monthly accumulations were used to transpose hourly precipitation data between the three stations. A priority was assigned as to which stations would be used if corresponding data were available at more than one station. The following relations were used to estimate missing data at Trabuco gauge:

1. Use data from Santiago if available: $V_{Trabuco} = 1.25\ V_{Santiago}$
2. If data at Santiago are not available use data from Laguna: $V_{Trabuco} = 1.46\ V_{Laguna}$

The relations above were applied only during periods of missing records and when records at the other stations showed measurable rainfall during the period of missing records. In many instances the period of missing records corresponded to an absence of measurable rainfall at the other stations, sometimes for quite extensive periods during the dry season. For this situation it was assumed that there was no measurable rainfall during the period of missing record. If during the period of missing data, rainfall was recorded at the alternate stations, then only data recorded during the missing period was transposed. All data recorded at the Trabuco gauge were retained in constructing the continuous record. In a few instances, missing records occurred simultaneously at all three stations. In this case the missing records were retained in the dataset. The duration of the retained missing records is minor compared to the total duration of the rainfall records.

Summary statistics of the original (unaltered) and extended precipitation data are compared in Table A-2. The extended records have few missing records, which is reflected by greater average annual rainfall and more storms per year. There are relatively minor differences in the average storm features (volume, duration, and intensity). This confirms that the additional (transposed) rainfall records do not appreciably change the storm characteristics of the stations.

Table A-2: Comparison of Summary Statistics for Original and Constructed Rainfall Records at the Trabuco Gauge for WY 1949-2001

	Average Annual Rainfall (in)	Total Missing Records (days)	Average Number of Storms per Year	Total Number of Storms:	Average Storm Volume (in):	Average Storm Duration (hrs):	Average Storm Intensity (in/hr)
Original Record	16.8	1762	18.1	958	0.86	11.6	0.086
Constructed Record	18.7	10	20.5	1084	0.85	11.6	0.087

A-2.4.3 Determination of Dry and Wet Cycles

Figure A-6 shows a plot of cumulative residuals (i.e. difference from the mean annual rainfall volume) for rainfall records at five gauges. The residual plots highlight dry periods, as indicated by decreasing cumulative residuals, and wet period, as indicated by increasing trends. Note that the plot for the El Toro gauge is shifted upward because available data from this gauge begins in 1965. For comparison among stations, the trend in the cumulative residuals is more informative than the magnitude of the residual. Trends in plots of cumulative residual for the Trabuco gauge are similar to trends in cumulative residual plots for rainfall data from the El Toro and Tustin gauges (unaltered). This indicates that the extended rainfall data at the Trabuco gauge captures general dry and wet period trends as reflected in the historical data from El Toro and Tustin gauges.

The cumulative residual diagrams indicate a dry period from WY 1949-1978 and a general wet period from WY 1979-2000. The Baseline Conditions Report (RMV, February 2002) notes that the extended dry period began earlier in 1944, however the plots in Figure A-6 are based on available hourly data beginning in late 1948. The wet-period trend between WY 1978-2001 is intersected by a short period of rainfall deficits between 1984-1990. The following wet and dry periods are used for comparisons in this study:

- Dry periods: WY 1949-1977 and WY 1984-1990 (36 years total)
- Wet periods: WY 1978-1983 and WY 1991-2001 (17 years total)

A-2.4.4 Adjustment for Orographic Effects

The extended precipitation data at the Trabuco gauge were adjusted for orographic influence. A regression procedure was used to relate rainfall and elevation at the Trabuco, El Toro, and Laguna Beach gauges. Based on regression equations, the following expression was used to determine an elevation correction factor for precipitation data at the Trabuco gauge:

$$\frac{P_x}{P_{trabuco}} = 1 + \frac{0.0083\left(El_x - El_{trabuco}\right)}{18.68}$$

where P_x is the average annual rainfall at a variable elevation denoted by El_x. This expression was used to construct continuous hourly precipitation data sets for a total of five representative elevations in the study area by multiplying the hourly rainfall at the Trabuco gauge by the correction factor obtained from the equation above. The selected elevations are between the elevations of the Laguna and Trabuco gauges; there was no extrapolation beyond this range. Table A-3 lists the representative elevations, correction factors, and average annual rainfall of the constructed datasets.

Table A-3: Estimated Average Annual Rainfall by Elevation.

Dataset	Elevation (ft)	Correction Factor	Average Annual Rainfall of Hourly Dataset (WY 49-01)
1 (Trabuco Gauge)	970	1	18.7
2	835	0.94	17.5
3	700	0.88	16.7
4	500	0.79	14.9
5	300	0.70	13.1

SWMM accounts for orographic effects on rainfall by assigning representative rainfall data (hyetographs) to each subcatchment area. For SWMM analysis of the study area sub-basins, each of the modeled subcatchment was assigned the closest of the five rainfall datasets corresponding to the average subcatchment elevation. The average elevation of the subcatchment was obtained from the DEM of the subcatchment.

A-2.5 Soil Properties and Infiltration Parameters

A-2.5.1 Soil Properties

Soils information was obtained from the US Dept of Agriculture Soil Survey of Orange County and Western Part of Riverside County, California (1978). Digitized versions of the soils maps in GIS format were obtained from the USDA. The soils survey provides information about the distribution and physical properties of specific soil types. To simplify parameterization of the soils, the soil types were grouped into texture classes as identified in soil survey report. GIS based maps of soil textual class were developed.

Summit areas in portions Chiquita Canyon and Gobernadora Canyon have surficial deposits of expansive clays (hardpans). The perched hardpan clays expand as they become saturated, restricting infiltration and increasing surface runoff. The hardpan areas have been mapped by Morton (1974) and were recently field checked by personnel from Balance Hydrologics (Balance, 2003a). GIS maps of the perched hardpans were obtained from Balance Hydrologics.

The hardpan areas mapped by Morton generally correspond to Bosanko clays mapped in the USDA soil survey, however, there is some discrepancy in soil types between the two maps. The hardpan areas mapped by Morton were verified in field checks (Balance, 2003a), therefore, these areas were modeled as clay soils. All other areas were modeled with soils mapped in the USDA soil survey report.

The soil properties of each texture class were determined from a variety of literature information and are presented in Table A-4. The texture class value for saturated hydraulic conductivity is presented as a range to permit adjustment of this parameter during model calibration.

Infiltration-related input parameters are entered into SWMM on a subcatchment basis, i.e., infiltration is modeled in SWMM as occurring uniformly over the pervious region of each subcatchment. Thus the infiltration parameters are representative of average soil conditions over the entire subcatchment area. Average soil properties for each subcatchment were quantified with an aerial weighted average (i.e. percentage of area) of the texture properties listed in Table A-4.

Under post-developed conditions, grading in development areas would result in some blending and mixing of surficial soils and possibly deeper soil layers. The extent to which such mixing would occur is unknown, and therefore it is not possible to accurately estimate the distribution of soil properties under post-grading conditions. For modeling purposes, the USDA soil maps were used to determine the surficial soil distribution for both pre- and post- development conditions.

Table A-4: Soil Properties of Soil Texture Classes

Texture Class	Saturated Hydraulic Conductivity Range (in/hr) (2)	Hydraulic Conductivity Starting Value (in/hr)	Porosity(3)	Wilting Point(3)	Field Capacity(3)	Green-Ampt Entry Pressure (in) (2)
Clay	0.001 - 0.04	0.004	0.5	0.21	0.33	24
Loam	0.12 - 0.8	0.4	0.48	0.1	0.26	8
Clay loam	0.02 - 0.16	0.08	0.5	0.15	0.32	12
Silty clay loam	0.01 - 0.08	0.04	0.43	0.13	0.3	6
Sandy loam	0.4 - 3.9	2	0.41	0.05	0.17	3
Gravelly loam(1)	0.4 - 3.9	2	0.41	0.05	0.17	3
Loamy sand	2 - 7.9	5	0.4	0.04	0.14	1.5

(1) Used values for sandy loam.

(2) Determined from Rawls and Brakensiek (1989).

A-2.5.2 Imperviousness

Impervious areas greatly influence the amount of runoff and infiltration from storm events. For development areas the percentage of impervious area was determined on the basis of land-use type. Recommended values from the Orange County Hydrology Manual (OCHM) (1986) were used where appropriate. Table A-5 lists the imperviousness fractions assigned to land-use type in the modeled areas. An average imperviousness for each subcatchment was calculated as an area-weighted average.

Table A-5: Percent Impervious Coverage Values Used the SWMM Models

Land Use	Percent Impervious Coverage
Natural or Agriculture[1]	0
Public Park[1]	15
Nursery	15
Golf Course	10-15
Golf Resort	65
School[1]	40
Single Family Residential[2]	40
Multi-Family Residential – Condominiums[1]	65
Multi-Family Residential – Apartments[1]	80
Commercial, Downtown Business or Industrial[1]	90
Existing Development	50
Quarry	30-90

1) OCHM recommended value

2) OCHM recommended value for 3-4 dwellings/acre

A-2.6 Evapotranspiration

Available ET data was compiled and is summarized in Table A-6. The ET data were grouped into vegetation classes based on PWA Codes defined in Table 2-6 of the Baseline Hydrologic Conditions (PWA, May 2001). Some of the PWA classifications were further consolidated into broad vegetation groups because distribution and coverage of individual plant species is unknown and ET data for specific types of vegetation are limited. The ET data in Table A-6 are also differentiated by potential and actual ET rates. Potential ET is the amount of ET consumption that could occur if water availability is unrestricted. Actual ET is the measured ET rate for the specific measurement conditions.

ET is modeled by SWMM using potential ET rates specified on a monthly basis. The reference ET rates (ET_o) used in this study were obtained from the California Irrigation Management Information System (CIMIS) website (CIMIS, 2003) and represent average year ET rates for grass as the reference crop. The reference ET rates are defined by region. The study area is located in reference ET zone 4 (south coast inland plains) (See Table A-6). For comparison, average monthly ET_o rates at the CIMIS Climate Station in Irvine are included in Table A-6. To estimate evapotranspiration rates for a specific plant types (ET_c), the reference ET (ET_o) is multiplied by the crop coefficient (K_c):

$$ET_c = ET_o * K_c \qquad (1)$$

K_c is dependent on the plant and the season. K_c values have been determined for a wide variety of plant types (CIMIS, 2003). A similar approach is used by SWMM to calculate ET for different vegetation cover. The monthly ET_o rates are multiplied by a constant ET_o scaling factor (K_s) that is defined on the subcatchment basis. K_s is analogous to K_c in eq 1, except that it is not allowed to be seasonally dependent and therefore is applied equally to all months. An area weighted scaling factor was determined for each subcatchment based on the percentage of each vegetation type in the subcatchment.

The ET_o scaling factors used in the SWMM model were estimated from literature information in Table A-6 and are grouped for vegetation classes based on PWA Codes. Table A-7 presents the vegetation group scaling factors used to determine area weighted scaling factors for each subcatchment. For comparison, Table A-7 also shows the associated annual ET for each vegetation group.

Table A-6: Compilation of Monthly ET Rates for Various Vegetation Type

PWA Code	Vegetation Cover / Conditions	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Total	ET	k_c	Source	Assumption/ Additional Information
	CIMIS Reference ET	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	**46.62**	Potential		CIMIS	Reference ET for grass, Zone 4 (south coast inland plains)
		2.24	2.45	3.67	4.73	5.17	5.91	6.35	6.17	4.62	3.57	2.71	2.30	**49.88**	Potential		CIMIS	Reference ET for grass, CIMIS Station 75 (Irvine), All data 1988-2001
		2.56	2.84	4.05	4.25	5.09	5.75	6.54	5.49	4.45	2.93	2.69	2.45	**49.09**	Potential		CIMIS	Reference ET for grass, CIMIS Station 75 (Irvine), Dry Period 1988-1990
		2.15	2.34	3.57	4.87	5.19	5.95	6.30	6.35	4.66	3.75	2.71	2.26	**50.09**	Potential		CIMIS	Reference ET for grass, CIMIS Station 75 (Irvine), Wet Period 1991-2001
	Average Rainfall	4.24	3.92	3.25	1.32	0.43	0.15	0.04	0.13	0.39	0.37	1.91	2.52	**18.68**			Rainfall data	Average Rainfall at the Trabuco Station (WY 1949-2001)
10201-10306	Natural Habitat													**19.60**	Actual		Bulletin 50 / Rainfall	Native Brush in Clay loam. Annual ET distributed monthly based on monthly rainfall
														16.50-19.10	Actual		Bulletin 50 / Rainfall	Native Brush in Gravelly Sand. Annual ET distributed monthly based on monthly rainfall
														18.82-27.00	Potential		Bulletin 50 / Rainfall	Native Brush in Gravelly Sand. Precipitation was supplemented with precipitation.
														12.66-16.35	Actual		Bulletin 50 / Rainfall	Native Brush in Rocky sandy loam. Annual ET distributed monthly based on monthly rainfall
		1.37	1.65	1.22	0.82	0.24	0.12	0.01	0.12	0.22	0.21	1.16	1.25	**7.16**	Actual		Hamilton, 2000	ET in Muddy Canyon (used CIMIS)
		0.62	0.84	1.55	1.50	2.17	0.75	1.09	0.78	0.45	0.62	0.30	0.62	**11.28**	Actual		USGS, 2001	ET from desert-shrub (sagebrush, rabbitbrush) in NV not using groundwater
		0.62	0.84	1.86	1.20	2.17	3.00	2.79	1.86	0.90	0.16	0.30	0.31	**16.01**	Potential		USGS, 2001	ET from saltgrass, rabbitbrush, wildrye, greasewood in NV using groundwater
		0.00	0.03	0.19	0.76	1.93	3.10	3.23	2.08	0.78	0.19	0.03	0.00	**12.33**	Potential	0-0.55	Steinwand, 2001	ET of Three Shrubs (applied k_c values to CIMIS)
					2.22	2.53	3.0	1.39	1.26	1.10					Potential		Wight et al, 1986	Measured sagebrush/grassland with lysimeter in SW Idaho
		0.26	0.31	0.47	0.62	0.72	0.78	0.81	0.77	0.62	0.47	0.33	0.26	**6.41**	Potential	0.138	CIMIS	Assumed sage scrub and chaparral are in equal acreage (VL and L mix)
10401	Grassland	0.37	0.45	0.68	0.90	1.05	1.14	1.18	1.12	0.90	0.68	0.48	0.37	**9.32**	Potential	0.2	CIMIS	Assumes elymus and needlegrass
														10.0	Potential		Bulletin 50	Native grass and weeds in gravelly loam (San Bernardino, 1928-29)
														13.5-15.5	Potential		Bulletin 50	Native grass and weeds in stony sand (Cucomonga, 1927-30)
														12.58	Potential		Bulletin 50	Native grass and weeds in fine sandy loam (Anaheim, 1927-28)
														12.7-14.1	Potential		Bulletin 50	Native grass and weeds in sand (Ontario, 1927-28)
														13.3-13.9	Potential		Bulletin 50	Native grass and weeds in loam (Cucomonga & Wineville, 1927-28)
														9.84	Actual		Wever et al, 2002	ET for grasslands in Canada
10501 & 10502	Woodland and Riparian Habitat & Riparian Willow	0.93	1.12	1.71	2.25	2.64	2.85	2.95	2.79	2.25	1.71	1.20	0.93	**23.31**	Potential	0.5	CIMIS	assumes 1/3 Riparian Habitat (willow, cottonwood) and 2/3 Woodland (sycamore, oak, alder)
		1.21	1.46	2.22	2.93	3.43	3.71	3.83	3.63	2.93	2.22	1.56	1.21	**30.30**	Potential	0.65	CIMIS	Assumed willow and cottonwood
														36.51	Potential		Scott, et al., 2000	ET of willows/cottonwood/mesquite in AZ (max temp 76.64 ^{o}F)
			2.00	3.92	5.72	4.76	4.48	7.34	7.80	6.63	5.36	3.54	2.12	**53.67**	Potential		Bulletin 50	ET of red willows measured in Santa Ana (11 months: July 1930-June 1931)
														47.09	Potential		Scott, et al., 2000	ET of willows growing next to a river in AZ (max temp 76.64 ^{o}F)
10503	Forest (Woodland)	0.65	0.78	1.19	1.58	1.84	2.00	2.06	1.95	1.58	1.19	0.84	0.65	**16.32**	Potential	0.35	CIMIS	Assumed oak, alder, sycamore, needlegrass, and elymus grass
														24.45	Potential		Scott, et al., 2000	ET of mesquite growing next to a river in AZ (max temp 76.64 ^{o}F)
														75.4	Potential		Lewis et al, 2000	ET for oak growing in sierra Nevada near Sacramento
														14.49	Actual		Lewis et al, 2000	ET for oak growing in sierra Nevada near Sacramento
10601	Meadow and Marsh	0.62	0.84	2.79	4.20	5.27	7.95	10.08	7.75	4.95	2.33	1.20	0.62	**48.59**	Potential		USGS, 2001	ET from bulrush marsh in Nevada
														63.3	Potential		Bulletin 50	Estimated consumptive use by round and triangular stem tules and cattails in Santa Ana (adjusted for large area)
20101	General Agriculture	0.47	2.15	3.58	3.85	2.09	0.00	0.00	0.00	0.00	0.00	0.79	0.71	**13.65**	Potential	0.2 - 1.05	CIMIS	Assumes barley. Growing season November 1 to May 30
20401	General Orchards	1.28	1.55	2.35	3.11	3.64	3.93	4.06	3.85	3.11	2.35	1.66	1.28	**32.17**	Potential	0.69	CIMIS	Assumes Citrus (Lemons)
30201-30203	Residential													**27.0**	Potential	0.58	Santa Margarita Water District	Landscape vegetation Assumed 25% shrubs, 75% turf, using landscape coefficients of 0.5 for shrubs, and 0.81 for turf.
30501	General Parks (Golf	1.02	1.21	2.59	3.24	4.16	3.88	4.18	3.96	2.79	1.84	1.39	1.02	**31.29**	Potential	0.54-	CIMIS	Assumes Bermuda Grass or Paspalum

PWA Code	**Vegetation Cover / Conditions**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total**	**ET**	**k_c**	**Source**	**Assumption/ Additional Information**
	Courses)															0.71		
														28.2-34.4	Actual		Bulletin 50	Bermuda Grass grown in San Bernardino
														37.0	Potential	0.81	Santa Margarita Water District	Landscape coefficient for turf

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Table A-7: Vegetation Group Et_o Scaling Factor and Annual ET

PWA Code Vegetation Cover	Vegetation Group	Scale factor (K_s)		Annual ET	
		Estimated Range	Representative Value	Estimated Range	Representative Value
10201-10306	Scrub & Chaparral	0.3-0.5	0.4	14.0-23.3	18.6
10401	Grassland	0.2-0.3	.25	9.3-14.0	11.6
10501 & 10502	Woodland & Riparian	0.9-1.2	1.1	42.0-55.9	51.3
10503	Forest (Woodland)	0.3-0.4	0.35	14.0-18.6	16.3
10601	Meadow and Marsh	0.9-1.2	1.0	42.0-55.9	46.6
20101, 20201, 20202	Agriculture	0.3-0.7	0.6	14.0-32.6	28.0
20401	Orchard		0.69		32.2
30201-30203	Residential		0.58		
30501	Park / Golf Course	0.6-0.81	0.73	30.37.8	34.0

A-2.7 Irrigation

Water usage for landscape irrigation in development areas was quantified with information from the Santa Margarita Water District Landscape Irrigation Water Usage Analysis (2003a). In this study water usage for landscape irrigation was metered for a total of 867 domestic and non-domestic users. The landscape area receiving irrigation was verified for a fraction of the accounts. Results summarized in Table A-8 show that the top 25 users with verified landscape areas used on average about 64-inches/unit area of water for landscape irrigation in 2001. This value drops substantially to about 41-inches/unit area for the top 100 users with verified landscape areas, indicating considerable over-watering by the top 25 users. The average annual water usage for landscape irrigation in 2001 by all monitored domestic and non-domestic users (867 accounts), including accounts with non-verified areas and under-usage was about 50-inches/unit area.

Table A-8: Average Annual Water Usage for Landscape Irrigation

	Verified Areas for All Uses	Total Area (acres)	Annual Water Usage (in/area)	Annual Water Usage (acre-ft)	Budgeted Water Usage (acre-ft)	Potential Savings (%)
Top 25 users with verified areas:						
Domestic (16 accounts)	Yes	25.96	63.84	138.08	77.98	44 %
Non-domestic (9 accounts)		19.20	64.38	103.42	57.67	44 %
Total (25 accounts)		45.17	64.2	241.5	135.65	44 %
Top 100 users with verified areas:						
Domestic (57 accounts)	Yes	68.75	42.72	244.71	206.48	27 %
Non-domestic (43 accounts)		64.86	38.64	208.79	194.81	25 %
Total (100 accounts)		133.61	40.62	453.50	453.5	26 %
All users excluding accounts with under usage						
Domestic (408 accounts)	No	322.95	67.92	1828	1064	42 %
Non-domestic (166 accounts)		289.85	62.28	1503	955	36 %
Total (574 accounts)		612.8	65.28	3331	2020	39 %
All users						
Domestic (566 accounts)	No	552.26	53.76	2474	1820	26 %
Non-domestic (301 accounts)		621.75	47.28	2448	2049	16 %
Total (867 accounts)		1174.01	50.28	4922	3869	19 %

Source: Santa Margarita Water District (2003)

The Santa Margarita Water District Study includes an analysis of the potential water saving if efficient irrigation practices are adopted. Such practices include the use drought tolerant plants and irrigation controllers that use real-time weather data to adjust irrigation schedules. The water budget for landscape irrigation shown in Table A-8 indicates that potential savings from efficient irrigation practices ranges from about 20-40 %. The water budgets calculated in the Santa Margarita Water District Study are based on the following assumptions and calculations:

1. The water required by landscape irrigation was determined by calculating the ET_{lv} requirements of landscape vegetation using equation 1.

   $$ETlv = ETo * Kc \tag{1}$$

   A value of 45.71 inches was used for the ET_o. The crop coefficient (K_c) for landscape vegetation was 0.5775, which is based on the assumption that 25% of the landscape consists of turf (K_c=0.81) and 75% is shrubs (K_c=0.5).

2. A portion of the annual precipitation contributes to irrigation of the landscape vegetation, but not all of the rainfall will contribute to landscape irrigation because only a portion will penetrate the soil surface and will be usable to the plants. This fraction is known as the effective rainfall. The Santa Margarita Water District found that of the 12.85 inches of precipitation in 2001, 24% (3.04 inches) was effective in reducing the irrigation requirements of landscape vegetation.
3. The irrigation water usage per unit area (WU) is calculated as the ET requirements less the effective rainfall (ER), divided by the irrigation efficiency factor (Eff):

$$WU_{lv} = (ET_{lv} - ER) / Eff \quad (2)$$

> The irrigation efficiency factor accounts for losses such as evaporation and runoff from over watering and non-uniform watering. Irrigation efficiency can range from 30 to 90% depending on the type of irrigation system (e.g. spray head, drip,), the application rate and distribution. An irrigation efficiency of 65% was used in the Santa Margarita Water District Analysis (2003).

The Santa Margarita Water District also conducted an analysis of monthly water usage of the top 25 users of all accounts to highlight potential water savings. Table A-9 shows the monthly irrigation budget analysis, as well as the monthly water usage and potential savings of the top 25 water users (without verified areas).

Table A-9: Average Monthly Water Usage for Landscape Irrigation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Monthly Irrigation Budget for 2001*													
Monthly ETo (inches)	2.35	1.95	3.12	4.03	4.81	5.8	6.12	5.95	4.59	3.11	1.94	1.94	45.71
Crop Coefficient for Turf	0.61	0.65	0.85	1	1	0.95	0.9	0.85	0.8	0.72	0.69	0.6	
Crop Coefficient for Scrubs	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
Composite Crop Coefficient (25% turf, 75% scrubs)	0.5275	0.5375	0.5875	0.6250	0.6250	0.6125	0.6000	0.5875	0.5750	0.5550	0.5475	0.5250	
Monthly ET of landscape vegetation (inches) (ETo x Crop Coefficient)	1.24	1.05	1.83	2.52	3.01	3.55	3.67	3.50	2.64	1.73	1.06	1.02	26.81
Monthly rainfall - 2001 (inches)	3.39	5.48	0.3	1.01	0.21	0.02	0	0	0	0	1.02	1.42	12.85
Effective Rainfall (24% x rainfall)	0.81	1.32	0.07	0.24	0.05	0.00	0.00	0.00	0.00	0.00	0.24	0.34	3.08
Assumed irrigation efficiency	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	
Monthly irrigation requirement (inches)	0.66		2.71	3.50	4.55	5.46	5.65	5.38	4.06	2.66	1.26	1.04	36.92
Monthly Water Usage by Top 25 Accounts*													
Water Usage (inches/unit area)	2.43	1.06	4.22	5.87	10.30	12.94	14.37	11.94	10.80	7.15	3.43	3.20	87.71
Budgeted Water Usage (from above)	0.66		2.71	3.50	4.55	5.46	5.65	5.38	4.06	2.66	1.26	1.04	36.92
Potential Savings (inches/unit area)	1.77	1.06	1.51	2.37	5.76	7.48	8.72	6.57	6.74	4.49	2.17	2.16	50.80
Potential Saving (%)	73%	100%	36%	40%	56%	58%	61%	55%	62%	63%	63%	67%	58%
Monthly Water Usage Used in SWMM Model													
Average monthly rainfall (1949-2001)	3.38	3.13	2.60	1.06	0.35	0.13	0.03	0.10	0.31	0.29	1.53	2.02	14.93
Average Effective Rainfall (24%)	0.81	0.75	0.62	0.25	0.08	0.03	0.01	0.02	0.08	0.07	0.37	0.48	3.58
Crop Coefficient for Golf Courses, Parks and Schools (100% turf)	0.61	0.65	0.85	1	1	0.95	0.9	0.85	0.8	0.72	0.69	0.6	
Crop Coefficient for Landscape Areas in Residential & Commercial Development (50% turf, 50% scrubs)	0.555	0.575	0.675	0.750	0.750	0.725	0.700	0.675	0.650	0.610	0.595	0.550	
Irrigation Efficiency for Golf Courses, Parks and Schools	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	
Irrigation Efficiency for Residential & Commercial Areas	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	
Monthly Irrigation Requirement for Residential & Commercial Development Areas (inches/unit area)	0.76	0.57	2.28	4.26	5.42	6.42	6.58	6.14	4.47	2.81	1.21	0.90	41.8
Monthly Irrigation Requirement for Golf Courses, Parks, and Schools (inches/unit area)	0.85	0.71	2.78	5.17	6.47	7.51	7.54	6.89	4.93	2.97	1.33	0.93	48.0

* From the Santa Margarita Water District Landscape Irrigation Water Usage Analysis (2003a)

The impacts of landscape irrigation on the water balance and hydromodification was assessed through the continuous simulation of the 53-year rainfall record using SWMM. For modeling purposes, it was assumed that all irrigation water is imported into the subcatchments. The rate of irrigation was calculated on a monthly basis using the monthly irrigation volumes shown in Table A-9. Following the approach used in the Santa Margarita Water District Plan of Works (2003b), an annual irrigation depth of about 42 inches was used for residential and commercial development areas, and an annual irrigation depth of about 48 inches was used for golf courses, parks, and schools. The monthly apportionment of these annual depths (Table A-9) is based on the Santa Margarita Water District irrigation budget described above. However, in order to approximately match the annual depths used in the Plan of Works Report, the irrigation efficiency for turf was increased to 0.73 and a 50/50 mix of turf and scrubs was assumed for residential and commercial development areas (see Table A-9).

The areas receiving irrigation are based on information obtained from the Santa Margarita Water District Plan of Works (2003b) and were defined in the model as a percentage of the pervious region of each land-use in the development areas (see Table A-10). For modeling purposes a daily irrigation period of four hours was assumed. Irrigation was not modeling during periods of rainfall.

Table A-10: Irrigated Fraction of Development Areas and Annual Irrigation Depths

Land Use	Percent Impervious	Percent Pervious	Percent Pervious Area Irrigated	Percent Total Area Irrigated*	Annual Irrigation Depth (inches)*
Golf Course	10	90	55.56	50	48.0
Parks	15	85	58.82	50	48.0
School	40	60	83.33	50	48.0
Transportation	100	0	0	0	
Single Family Residential	40	60	41.67	25	41.8
Multi-Family Residential	65	35	100	35	41.8
Estate	20	80	25	20	41.8
Water Treatment Plant	60	40	0	0	
Commercial	72.5	27.5	100	27.5	41.8

- From the Santa Margarita Water District Plan of Works (2003b)

A-2.8 Model Calibration

The SWMM hydrologic simulation model was calibrated to three types of available streamflow measurements:

1. **Dry-Weather Base Flows.** Balance Hydrologics measured dry-weather base flows at various drainages throughout RMV (Balance, 2001). Flows measured between November 1999 and May 2000 were used for model calibration.
2. **Indirect Wet-weather Peak Discharge Estimates.** Balance Hydrologics estimated wet-weather peak discharges from measured high-water marks collected on various drainages throughout RMV (Balance, 2003b). The indirect peak discharge estimates from storms between February 1998 and February 2000 were used for model calibration.

3. **Continuous Stream Flow Hydrographs**. Wildermuth Environmental (2003) conducted continuous flow monitoring at two locations in RMV during the 2003 rainy season. Flow measurements collected on Gobernadora Creek downstream of Coto de Caza were used to calibrate the hydrologic model of this area.

Model calibration entailed systematically varying selected SWMM input parameters and comparing the measured discharge values to the corresponding value in continuous output hydrograph generated by SWMM. The selected calibration parameters were the groundwater storage volume, subsurface conductivity, overland flow roughness, and surface depression storage. These parameters are not easily quantified and subject to uncertainty. Parameters that were readily quantified from GIS mapping (e.g. slope, elevation, soil and vegetation distribution) were not varied.

The most sensitive calibration parameters were found to be those that affected the groundwater storage volume (thickness, field capacity, porosity) the rate of downward percolation, and lateral movement to the stream channel (conductivity, lateral flow length). These parameters affected predictions of both base flows and peak discharges.

A-3 HYDROLOGIC SIMULATION PARAMETERS AND SWMM CALIBRATION RESULTS OF THE MODELED SUB-BASINS

The SWMM model was used for continuous hydrologic simulation of the study area watersheds. SWMM models were developed separately for areas delineated on the basis of major watershed drainage boundaries. The RMV planning areas (Figure A-7) sometimes span major drainage basins, in which case portions of the planning area were divided between different SWMM model boundaries. Table A-11 lists the modeled watersheds and the planning areas included in the SWMM model. The subsequent sections describe the SWMM model inputs and calibration results of the modeled watersheds.

Table A-11: Modeled Watershed Areas

Name of Modeled Area	Major Drainage Channel	Planning Areas Included in Model
Cañada Chiquita Model	Chiquita Creek	PA-2
Cañada Gobernadora Model	Gobernadora Creek	PA-2, PA-3
Central San Juan Model	San Juan Creek, Trampas Creek	PA-3, PA-4, PA-5
Cristianitos Model	Cristianitos Creek	PA-6, PA-7
Gabino/Blind Canyon Model	Gabino and Blind Canyon Creeks	PA-7, PA-8
Talega Development Area Model	Talega and Blind Canyon Creeks	PA-8A and PA-8B

A-3.1 SWMM Model of the Cañada Chiquita Sub-Basin

A-3.1.1 Cañada Chiquita Model - Subcatchment Delineation

The Chiquita Canyon SWMM Model is defined by the catchment area that is directly tributary to Chiquita Creek, and development area immediately south of Chiquita Canyon that is directly tributary to San Juan Creek (see Figure A-8). The majority of PA-2 is in this watershed area. Development plans for PA-2 are the most detailed of any currently available, including detailed plans for grading, development types, and distribution.

The 4000-acre Chiquita Canyon watershed was divided into 18 subcatchments as shown in Figure A-8. Catchment 1-17 are tributary to Chiquita Creek and catchment 18 drains to San Juan Creek. Different subcatchment areas and shapes were delineated for pre- and post-development areas because grading plans alter the topographic boundaries between drainage subcatchments.

The 18 subcatchments were disaggregated into valley and ridge subcatchments, as well as, subcatchments based on land-use designation. Table A-12 and Table A-13 lists the parameters of the modeled subcatchments for the pre- and post-development scenarios, respectively.

Table A-12: Cañada Chiquita Model – Pre-Development Subcatchment Parameters

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
1-Valley	Open Space	24.5	0.079	0.0	1.4	0.72
1-Ridge	Open Space	156.6	0.303	0.0	1.8	0.40
2-Valley	Open Space	61.8	0.086	0.0	1.6	0.61
2-Ridge	Open Space	157.8	0.29	0.0	2.0	0.40
3-Valley	Open Space	66.7	0.147	0.0	1.5	0.67
3-Ridge	Open Space	170.3	0.294	0.0	1.9	0.49
4-Valley	Open Space	33.1	0.089	0.0	2.2	0.74
4-Ridge	Open Space	231.5	0.299	0.0	0.7	0.45
5-Valley	Open Space	21.8	0.056	0.0	1.0	0.71
5-Valley	School	20.9	0.055	40.0	0.9	0.35
5-Ridge	Open Space	138.4	0.282	0.0	0.6	0.47
6-Valley	Open Space	26.3	0.101	7.4	1.0	0.56
6-Valley	School	16.8	0.101	40.0	0.2	0.35
6-Ridge	Open Space	113.6	0.271	0.0	0.6	0.47
6-Ridge	Transportation	2.9	0.271	100.0	0.7	0.00
7-Valley	Open Space	57.1	0.097	0.0	1.1	0.65
7-Ridge	Open Space	410.1	0.241	0.0	1.3	0.50
8-Valley	Open Space	162.5	0.09	0.0	1.7	0.61
8-Valley	Transportation	2.0	0.09	100.0	2.2	0.00
8-Ridge	Open Space	552.9	0.232	0.0	2.2	0.49
8-Ridge	Transportation	2.1	0.232	100.0	2.2	0.00
9-Valley	Open Space	116.2	0.102	0.0	1.7	0.61
9-Valley	School	21.7	0.232	40.0	1.1	0.35
9-Valley	Transportation	1.2	0.1	100.0	2.2	0.00
9-Ridge	Open Space	201.0	0.246	0.0	2.2	0.49
9-Ridge	Transportation	1.0	0.246	100.0	2.1	0.00
10-Valley	Open Space	13.7	0.095	0.0	2.2	0.60
10-Ridge	Open Space	153.5	0.245	0.0	2.2	0.44
11-Valley	Open Space	40.3	0.071	0.0	2.2	0.62
11-Ridge	Open Space	79.3	0.244	0.0	2.2	0.49
12-Valley	Open Space	30.7	0.119	0.0	1.8	0.59
12-Ridge	Open Space	187.4	0.235	0.0	1.7	0.50
13-Valley	Open Space	35.9	0.077	0.0	0.9	0.57
13-Ridge	Open Space	91.8	0.249	0.0	0.1	0.55
14-Valley	Open Space	24.2	0.114	0.0	0.5	0.55
14-Ridge	Open Space	146.2	0.255	0.0	0.1	0.55
15-Valley	Open Space	23.6	0.101	0.0	2.0	0.55
15-Valley	POWTP	24.9	0.101	72.5	0.5	0.16
15-Ridge	Open Space	100.4	0.249	1.5	0.4	0.48
15-Ridge	Parks	55.8	0.249	15.0	0.4	0.62
16-Valley	Open Space	15.8	0.115	5.1	1.6	0.57
16-Ridge	Open Space	136.2	0.265	16.4	1.1	0.46
17-Valley	Open Space	17.2	0.122	0.0	2.3	0.59
17-Ridge	Open Space	68.8	0.275	0.5	1.3	0.63
18-Valley	Open Space	62.2	0.018	0.0	2.3	0.76
18-Ridge	Open Space	123.5	0.215	0.0	2.0	0.58

Table A-13: Cañada Chiquita Model – Post-Development Subcatchment Parameters

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	**Land Use**					
1-Valley	Open Space	24.5	0.079	0.0	1.4	0.63
1-Ridge	Open Space	156.6	0.303	0.0	1.8	0.40
2-Valley	Open Space	51.7	0.086	0.0	1.6	0.58
2-Valley	Golf Course	10.0	0.080	15.0	1.5	0.62
2-Ridge	Open Space	157.8	0.290	0.0	2.0	0.40
3-Valley	Open Space	51.2	0.147	0.0	1.4	0.55
3-Valley	Golf Course	16.9	0.109	15.0	1.6	0.62
3-Ridge	Open Space	168.8	0.294	0.0	1.9	0.49
4-Valley	Open Space	23.7	0.089	0.0	2.4	0.65
4-Valley	Golf Course	25.7	0.067	15.0	1.8	0.62
4-Ridge	Open Space	215.3	0.299	0.0	0.7	0.44
5-Valley	Open Space	15.6	0.056	0.0	0.8	0.70
5-Valley	Golf Course	8.5	0.055	15.0	1.5	0.62
5-Valley	School	20.9	0.055	40.0	0.9	0.35
5-Ridge	Open Space	136.1	0.282	0.0	0.6	0.46
6-Valley	Open Space	26.3	0.101	7.4	1.0	0.56
6-Valley	School	16.8	0.101	40.0	0.2	0.35
6-Ridge	Open Space	113.6	0.271	0.0	0.6	0.47
6-Ridge	Transportation	2.9	0.271	100.0	0.7	0.00
7-Valley	Open Space	57.1	0.097	0.0	1.1	0.65
7-Ridge	Open Space	410.1	0.241	0.0	1.3	0.50
8-Valley	Open Space	162.5	0.090	0.0	1.7	0.61
8-Valley	Transportation	2.0	0.090	100.0	2.2	0.00
8-Ridge	Open Space	552.9	0.232	0.0	2.2	0.49
8-Ridge	Transportation	2.1	0.232	100.0	2.2	0.00
9-Valley	Open Space	74.0	0.102	0.0	1.8	0.63
9-Valley	MF Residential	33.1	0.051	65.0	1.7	0.20
9-Valley	Parks	3.2	0.040	15.0	1.9	0.62
9-Valley	School	21.7	0.102	40.0	1.1	0.35
9-Valley	Transportation	11.7	0.100	100.0	1.5	0.00
9-Valley	Golf Course	2.3	0.060	15.0	2.2	0.62
9-Ridge	Open Space	185.1	0.246	0.0	2.2	0.49
9-Ridge	Transportation	9.0	0.246	100.0	2.2	0.00
10-Valley	Open Space	10.6	0.095	0.0	2.2	0.61
10-Valley	Golf Course	2.8	0.063	15.0	2.2	0.62
10-Ridge	Open Space	139.1	0.245	0.0	2.2	0.43
10-Ridge	Estate	11.1	0.089	20.0	2.2	0.46
10-Ridge	Transportation	4.2	0.143	100.0	2.2	0.00
11-Valley	Open Space	26.9	0.071	0.0	2.2	0.63
11-Valley	Golf Course	14.0	0.040	15.0	2.2	0.62
11-Ridge	Open Space	44.0	0.244	0.0	2.2	0.50
11-Ridge	Estate	20.1	0.077	20.0	2.2	0.46
11-Ridge	Transportation	3.1	0.064	100.0	2.2	0.00
12-Valley	Open Space	10.9	0.119	0.0	2.1	0.59
12-Valley	Golf Course	22.5	0.061	15.0	1.4	0.62
12-Ridge	Open Space	174.3	0.235	0.0	1.7	0.48
12-Ridge	Estate	23.8	0.095	20.0	1.0	0.46
12-Ridge	Transportation	11.7	0.063	100.0	1.4	0.00
13-Valley	Open Space	23.3	0.077	0.0	1.2	0.56
13-Valley	Golf Course	17.5	0.064	15.0	0.2	0.62
13-Ridge	Open Space	58.9	0.249	0.0	0.1	0.54
13-Ridge	Estate	28.9	0.087	20.0	0.05	0.46

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	**Land Use**					
14-Valley	Open Space	11.7	0.114	0.0	0.8	0.49
14-Valley	Golf Course	14.0	0.066	15.0	0.2	0.62
14-Ridge	Open Space	100.6	0.255	0.0	0.2	0.54
14-Ridge	Estate	29.7	0.097	20.0	0.1	0.46
15-Valley	Open Space	24.1	0.101	0.0	2.0	0.55
15-Valley	POWTP	23.6	0.101	60.0	0.5	0.23
15-Ridge	Open Space	100.3	0.249	1.3	0.4	0.48
15-Ridge	Parks	55.8	0.249	15.0	0.4	0.62
16-Valley	Open Space	11.9	0.115	6.8	1.7	0.57
16-Ridge	Open Space	36.1	0.265	16.6	1.2	0.47
16-Ridge	Residential	90.2	0.043	40.0	1.3	0.35
16-Ridge	Parks	2.9	0.09	52.5	0.3	0.35
16-Ridge	School	3.3	0.038	40.0	1.3	0.35
17-Valley	Open Space	17.3	0.122	0.0	2.3	0.59
17-Ridge	Open Space	31.7	0.275	1.0	1.5	0.72
17-Ridge	School	7.7	0.036	40.0	0.2	0.35
17-Ridge	Residential	26.7	0.045	40.0	1.0	0.35
17-Ridge	Parks	12.7	0.032	15.0	0.3	0.62
18-Valley	Open Space	59.5	0.018	0.0	1.1	0.75
18-Valley	Transportation	2.7	0.215	100.0	0.8	0.00
18-Ridge	Open Space	59.5	0.215	0.0	2.1	0.59
18-Ridge	Residential	44.5	0.215	40.0	2.2	0.35
18-Ridge	Transportation	15.4	0.215	100.0	2.2	0.00
18-Ridge	Commercial	3.4	0.215	60.0	2.2	0.23
18-Ridge	Parks	1.1	0.37	15.0	3.0	0.62

A-3.1.2 Cañada Chiquita Model - Land-Use

Pre- and post-development land-use in Cañada Chiquita is shown in Figure A-7 and tabulated in Table A-14. The modeled pre-development conditions are based on the PWA land-use maps. For pre-development conditions, the lower half of the Canyon is predominantly used for agriculture and the upper half is open space grassland and native vegetation. Existing development includes the publicly owned treatment plant, the Arroyo Trabuco High School, and roads.

The modeled development conditions were based on the B4 development alternative, the B4 principle roads plan, and the habitat restoration plan. These proposed development and habitat restoration plans were superimposed on the PWA land-use maps for existing conditions. The modeled post-development conditions are the amalgamation of these existing and proposed land-uses.

The proposed development includes single and multi-family residential housing, estates, and a golf course. The main arterial road in PA-2 is a six-lane highway with an assumed impervious width of 120 feet. Detailed information about the specific development types and distribution was incorporated into the model. Additionally, there are significant areas in the Chiquita Canyon that are proposed for restoration with native vegetation under post-development conditions. This information was also incorporated into the SWMM model in terms of the effect on ET.

Table A-14: Cañada Chiquita Model – Pre- and Post- Development Land Use

PWA Code	Land-Cover	Pre-Development Scenario (acres)	Post-Development Scenario (acres)
20101, 20201, 20202, 20401	Agriculture & Orchard	1913	1442
10201-10306	Scrub & Chaparral	1718	1701
10401	Grassland	200	187
10501-10502, 10601	Woodland, Riparian, Forest, Meadow & Marsh	196	182
30202	Single Family Residential		117
30203	Multi-Family Residential		33
30202	Estate		90
30101	School	59	70
30401	Transportation	11	40
30101	Development - (treatment plant)	24	24
30501	Park	56	73
30501	Golf Course		134
	Undefined	23	74

A-3.1.3 Cañada Chiquita Model - Soils

The distribution of soil texture is shown in Figure A-9. Sandy soils are predominant in the upper half of the canyon with some clay loam soils on the ridges in the western side of the canyon. Clay loam and clay soils comprise a large portion of the lower half of the canyon, especially of the eastern side of the canyon. Hardpan clays mapped by Morton (1974) are also concentrated in these areas. Comparison of soil texture map (Figure A-9) and the land use coverage map (Figure A-8) shows that much of the proposed residential and estates development is in clayey terrain.

A-3.1.4 Cañada Chiquita Model - Calibration

The Chiquita Canyon Model was calibrated to dry-weather low flow measurements (Balance, 2001) and peak discharge estimates based on observations of high water marks (Balance, 2003b). Calibration results are presented in Table A-15 below.

Table A-15: Cañada Chiquita Model – Calibration Data and Calibration Results

Flow Condition / Location	Date	Time	Measured or Estimated Discharge (cfs)	Predicted Discharge from SWMM (cfs)
Low Flow				
Narrows	5/4/2000	11:22	0.29	0.28
Lower Chiquita	11/17/1999	17:00	0.2	0.20
	5/4/2000	10:30	0.33	0.32
Peak Discharge				
Narrows	2/23/1998	--	428	398
	2/21/2000	--	23	24
Lower Chiquita	2/23/1998	--	1900	1624
	2/21/2000	--	103	121

A-3.2 SWMM Model of the Cañada Gobernadora Sub-Basin

A-3.2.1 Cañada Gobernadora Model - Subcatchment Delineation

The Cañada Gobernadora SWMM Model is defined by the catchment area that is directly tributary to Gobernadora Creek. The approximately 7100-acre Gobernadora model includes large areas of existing upstream development outside of the RMV Boundary. Upper Gobernadora Canyon upstream of the RMV boundary is approximately 3900 acres, with a high proportion of development (Coto de Caza). The 1000-acre Wagonwheel Canyon is a major tributary joining Gobernadora Creek near the upstream RMV boundary. Wagonwheel Canyon also has significant areas of existing development. The RMV project area that is directly tributary to Gobernadora Creek is approximately 2200 acres. The proposed development areas are within PA-3 and PA 2 (Figure A-7).

The 7100-acre Gobernadora Canyon watershed was divided into 12 subcatchments as shown in Figure A-10. The off-site areas in Upper Gobernadora (Coto de Caza) and in Wagonwheel Canyon were each modeled as single large subcatchments. The parameters of the Coto de Caza subcatchment were determined through calibration with available runoff data. Due to lack of runoff data from Wagonwheel, the fitted runoff parameters for Coto de Caza were used to model runoff from Wagonwheel Canyon. Also, model results for the post-development scenario do not include effects of the proposed modulation basin below the confluence of Wagonwheel and Gobernadora Creeks.

A total of 10 subcatchments were defined in the RMV project area. These subcatchments were disaggregated into valley and ridge subcatchments on the basis of topography. Different subcatchment areas and shapes were delineated for pre- and post-development areas because grading plans alter the topographic boundaries between drainage subcatchments. For post-development conditions, the subcatchments were further disaggregated on the basis of land-use. Table A-16 and Table A-17 lists the parameters of the modeled subcatchments for the pre- and post-development scenarios, respectively.

Table A-16: Cañada Gobernadora – Pre-Development Subcatchment Parameters

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
1-Valley	Open Space	5.6	0.160	0.0	1.8	0.40
1-Ridge	Open Space	302.0	0.290	0.0	1.0	0.53
2-Valley	Open Space	69.2	0.140	0.0	1.5	0.32
2-Ridge	Open Space	56.9	0.340	0.0	2.1	0.42
3-Valley	Open Space	131.3	0.060	0.3	1.3	0.14
3-Ridge	Open Space	227.7	0.310	24.2	1.5	0.39
4-Valley	Open Space	4.5	0.060	19.5	1.8	0.04
4-Ridge	Open Space	184.0	0.340	45.5	1.0	0.26
5-Valley	Open Space	49.6	0.080	0.9	1.7	0.43
5-Ridge	Open Space	285.4	0.310	9.7	1.7	0.49
6-Valley	Open Space	44.3	0.050	0.0	2.3	0.16
6-Ridge	Open Space	27.6	0.370	0.0	1.9	0.45
7-Valley	Open Space	57.9	0.030	0.0	1.0	0.20
7-Ridge	Open Space	89.9	0.240	0.0	0.9	0.57
8-Valley	Open Space	39.1	0.100	0.0	1.4	0.48
8-Ridge	Open Space	296.7	0.280	0.0	0.5	0.53
9-Valley	Open Space	17.8	0.100	0.0	1.0	0.46
9-Ridge	Open Space	136.7	0.330	26.1	1.2	0.39
10-Valley	Open Space	78.7	0.092	0.0	2.1	0.58
10-Ridge	Open Space	34.8	0.330	0.0	2.1	0.57
11- Wagonwheel	High K	965.8	0.17	21.4	1.96	0.29
11- Wagonwheel	Low K	67.8	0.17	2	0.03	0.29
11- Wagonwheel	Impervious	1.5	0.17	100	0.0	0.29
12- Coto de Caza	High K	3595.2	0.17	27	1.5	0.29
12- Coto de Caza	Low K	215.5	0.17	2	0.05	0.29
12- Coto de Caza	Impervious	63.1	0.17	100	0.0	0.29

Table A-17: Cañada Gobernadora – Post-Development Subcatchment Parameters

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
1-Valley	Open Space	4.8	0.16	0.0	1.7	0.42
1-Valley	SF Residential	0.8	0.16	40.0	2.1	0.35
1-Ridge	Open Space	32.6	0.29	0.0	0.8	0.50
1-Ridge	SF Residential	259.7	0.29	40.0	1.0	0.35
1-Ridge	Transportation	8.9	0.29	100.0	1.1	0.00
2-Valley	Open Space	68.9	0.14	0.1	1.5	0.32
2-Ridge	Open Space	56.5	0.34	0.0	2.1	0.42
2-Ridge	SF Residential	0.3	0.34	40.0	2.2	0.35
3-Valley	Open Space	84.4	0.06	0.0	1.0	0.13
3-Valley	SF Residential	43.2	0.06	40.0	2.0	0.35
3-Valley	Transportation	3.5	0.06	100.0	1.8	0.00
3-Ridge	Open Space	0.8	0.31	0.0	2.2	0.24
3-Ridge	SF Residential	211.8	0.31	40.0	1.5	0.35
3-Ridge	Transportation	15.5	0.31	100.0	2.0	0.00
4-Valley	Open Space	3.7	0.06	23.7	1.7	0.04

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
4-Valley	SF Residential	0.8	0.06	40.0	2.2	0.35
4-Ridge	Open Space	16.0	0.34	42.8	1.3	0.24
4-Ridge	SF Residential	163.8	0.34	40.0	1.0	0.35
4-Ridge	Transportation	4.2	0.34	100.0	1.2	0.00
5-Valley	Open Space	33.6	0.08	1.4	1.5	0.47
5-Valley	SF Residential	15.0	0.08	40.0	2.2	0.35
5-Valley	Transportation	1.4	0.08	100.0	2.1	0.00
5-Ridge	Open Space	94.5	0.31	9.2	1.9	0.53
5-Ridge	Estate	35.2	0.31	20.0	1.8	0.46
5-Ridge	SF Residential	148.1	0.31	40.0	1.6	0.35
5-Ridge	Transportation	7.6	0.31	100.0	1.4	0.00
6-Valley	Open Space	44.3	0.05	0.0	2.3	0.16
6-Ridge	Open Space	26.1	0.37	0.2	1.8	0.43
6-Ridge	Transportation	1.6	0.37	100.0	2.2	0.00
7-Valley	Open Space	51.6	0.03	0.0	1.0	0.18
7-Valley	Estate	3.2	0.03	20.0	2.1	0.46
7-Valley	Transportation	3.7	0.03	100.0	0.5	0.00
7-Ridge	Open Space	35.9	0.24	0.0	1.0	0.56
7-Ridge	Estate	53.2	0.24	20.0	0.8	0.46
7-Ridge	Transportation	0.7	0.24	100.0	2.3	0.00
8-Valley	Open Space	34.4	0.1	0.0	1.5	0.37
8-Valley	SF Residential	3.1	0.1	46.7	1.5	0.25
8-Valley	Transportation	2.5	0.1	100.0	0.6	0.00
8-Ridge	Open Space	174.1	0.28	0.0	0.6	0.49
8-Ridge	SF Residential	37.9	0.28	40.0	0.3	0.35
8-Ridge	Transportation	10.8	0.28	100.0	0.3	0.00
8-Ridge	Golf-Residential	32.9	0.28	20.0	0.1	0.46
9-Valley	Open Space	11.8	0.1	0.0	1.2	0.38
9-Valley	Estate	6.0	0.1	20.0	0.5	0.46
9-Ridge	Open Space	100.1	0.33	35.2	1.1	0.32
9-Ridge	Estate	36.5	0.33	20.0	1.3	0.46
10-Valley	Open Space	73.2	0.092	0.0	2.2	0.58
10-Valley	Estate	5.2	0.092	20.0	0.8	0.46
10-Ridge	Open Space	34.8	0.33	0.0	2.1	0.57
11- Wagonwheel	High K	965.8	0.17	21.4	1.96	0.29
11- Wagonwheel	Low K	67.8	0.17	2	0.03	0.29
11- Wagonwheel	Impervious	1.5	0.17	100	0.0	0.29
12- Coto de Caza	High K	3595.2	0.17	27	1.5	0.29
12- Coto de Caza	Low K	215.5	0.17	2	0.05	0.29
12- Coto de Caza	Impervious	63.1	0.17	100	0.0	0.29

A-3.2.2 Cañada Gobernadora Model - Land-Use

Pre- and post-development land-use in Cañada Gobernadora is shown in Figure A-10 and is tabulated in Table A-18. The modeled pre-development conditions are based on the PWA land-use maps. The existing land-use in the Gobernadora model is dominated by existing development areas in Upper Gobernadora (Coto de Caza) and Wagonwheel Canyon. The existing land-use in the RMV project area includes a mixture of agriculture and open space areas.

Table A-18: Cañada Gobernadora – Pre- and Post- Development Land Use in the RMV Project Area (excludes Wagonwheel and Coto de Caza)

PWA Code	Land-Cover	Pre-Development Scenario	Post-Development Scenario
20101, 20201, 20202, 20401	Agriculture & Orchard	621	233
20501	Nurseries	30	
10201-10306	Scrub & Chaparral	726	324
10401	Grassland	121	82
10501-10502, 10601	Woodland, Riparian, Forest, Meadow & Marsh	183	88
10701	Rock Outcrops	199	52
90101	General Disturbed Areas	258	203
30202	Single Family Residential		884
30203	Multi-Family Residential		
30202	Estate & Golf Residential		173
30401	Transportation		61
30501	Park	1	
	Undefined		24

The modeled development conditions were based on the B4 development alternative, the B4 principle roads plan, and the habitat restoration plan. These proposed development and habitat restoration plans were superimposed on the PWA land-use maps for existing conditions. The modeled post-development conditions are the amalgamation of these existing and proposed land-uses.

The proposed development includes single-family residential housing, and estates. The main arterial road in PA-2 and PA-3 (through catchments 3-8) was modeled as six-lane highway with an assumed impervious width of 120 feet. The smaller arterial roads (catchments 1/8 and 4/5) were modeled with an impervious width of 56 feet. Proposed habitat restoration areas were incorporated into the SWMM model in terms of the effect on ET.

A-3.2.3 Cañada Gobernadora Model - Subcatchment Soils

The distribution of surficial soils in the Cañada Gobernadora model is shown in Figure A-11. Sandy loams are predominant throughout the canyon. In the lower half of the canyon, however, there are large areas of hardpan clays, clayey soils, and rock outcrops. Comparison of the land use coverage map (Figure A-10) and the soil texture map (Figure A-11) shows that much of the proposed residential and estates development is in terrains with hardpan clays, clayey soils, and rock outcrop.

A-3.2.4 Cañada Gobernadora Model - Calibration

The Gobernadora Canyon Model was calibrated to measured and estimated storm flow and dry-weather base flows.

The parameters of the upper Gobernadora catchment (Coto de Caza) were determined through calibration with continuous flow measurements collected at the bottom end of the Coto de Caza development (Wildermuth Environmental, 2003). The fitted model was able to replicate, quite well, the measured wet and dry weather runoff. Figure A-12 is a sample of the measured and modeled hydrographs for one of the monitored storm in February 2003.

Catchments in the lower Gobernadora drainage were calibrated to low flow measurements (Balance, 2001) and peak discharge estimates based on observations of high water marks (Balance, 2003b). Calibration results are presented in Table A-19 below.

Table A-19: Cañada Gobernadora Model – Calibration Data and Calibration Results

Flow Condition / Location	Date	Time	Measured or Estimated Discharge (cfs)	Predicted Discharge from SWMM (cfs)
Low Flow				
Gobernadora Crk below Coto de Caza	11/18/1999	9:40	0.2-0.3	1.0
	5/3/2000	17:00	0.5	0.55
Lower Gobernadora Creek	11/16/1999	16:00	1.8	1.45
	5/4/2000	9:00	0.25	1.63
Peak Flow				
Gobernadora Crk @ Lower Gauge	12/7/1997 or 2/23/1998	--	2214	2278
	2/21/2000	--	258	315
Gobernadora Creek above Sulfur	12/7/1997 or 2/23/1998	--	1457	1450
	2/21/2000	--	532	234

A-3.3 SWMM Model of the Central San Juan Sub-Basin

A-3.3.1 Central San Juan Model - Subcatchment Delineation

The Central San Juan SWMM Model is defined by the catchments that drain to San Juan Creek, and catchments that are tributary to Trampas Creek, XX-Creek, and smaller tributaries of San Juan Creek in Planning Areas 3, 4, and 5.

The existing quarry area in the Trampas Sub-Basin was modeled in two ways under the pre-development scenario: 1) as open space under assumed pre-quarry conditions, and 2) under existing quarry conditions with the area divided into two regions – one with catchments that drain to Trampas Creek, and a second region in which catchments drain to a terminal reservoir. Water stored water is used re-circulated in conjunction with quarry operations.

Figure A-13 shows the catchments used to model pre- and post-development conditions in the Central San Juan Sub-Basin. The Sub-Basin was divided into 26 catchments under pre-development conditions, and 38 catchments under proposed post-development conditions. All catchments were disaggregated into valley and ridge subcatchments on the basis of topography, and on the basis of land-use. Table A-20 and Table A-21 lists the subcatchment properties for pre- and post-development conditions, respectively.

Table A-20: Central San Juan Sub-Basin Model – Pre-Development Subcatchment Parameters

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
13-Valley	Open Space	50.7	0.164	6.8	1.25	0.408
13-Ridge	Open Space	59.1	0.419	48.4	1.12	0.451
13-Ridge	Transportation	2.5	0.419	100.0	1.93	0.000
14-Valley	Open Space	30.4	0.078	2.6	1.81	0.659
14-Ridge	Open Space	59.0	0.367	29.7	1.19	0.377
14-Ridge	Transportation	2.6	0.367	100.0	1.28	0.000
15-Valley	Open Space	46.3	0.050	0.0	2.70	0.607
15-Ridge	Open Space	15.1	0.150	0.0	2.35	0.323
15-Ridge	Nursery	6.0	0.150	15.0	2.20	0.621
16-Valley	Open Space	25.8	0.071	0.0	2.90	0.900
16-Valley	Existing Dev	3.1	0.071	50.0	3.00	0.290
16-Ridge	Open Space	228.7	0.187	34.7	1.32	0.295
16-Ridge	Existing Dev	21.2	0.187	50.0	2.13	0.290
16-Valley	Park	4.9	0.071	15.0	3.00	0.621
16-Ridge	Nursery	96.5	0.187	15.0	2.17	0.621
17-Valley	Open Space	23.5	0.221	7.6	1.06	0.302
17-Ridge	Open Space	115.7	0.378	14.5	1.70	0.390
17-Ridge	Transportation	1.8	0.378	100.0	2.20	0.000
18-Ridge	Open Space	198.2	0.346	8.9	1.95	0.409
19-Valley	Open Space	23.4	0.103	0.0	2.20	0.678
19-Ridge	Open Space	25.1	0.387	0.0	2.20	0.451
19-Ridge	Transportation	4.1	0.387	100.0	2.20	0.000
20-Valley	Open Space	27.1	0.082	0.0	2.69	0.732
20-Valley	Existing Dev	4.3	0.082	48.0	3.00	0.302
20-Valley	Park	13.7	0.820	15.0	2.99	0.621
21-Valley	Open Space	41.8	0.051	0.0	2.73	0.481
21-Valley	Existing Dev	7.0	0.051	50.0	2.64	0.290
21-Ridge	Open Space	9.7	0.091	0.0	2.33	0.425
21-Ridge	Existing Dev	0.3	0.091	50.0	2.20	0.290
21-Valley	Park	3.9	0.051	15.0	2.40	0.621
21-Ridge	Nursery	25.3	0.091	15.0	2.20	0.621
22-Valley	Open Space	9.1	0.108	0.0	1.46	0.390
22-Valley	Transportation	0.5	0.108	100.0	1.90	0.000
22-Ridge	Open Space	118.6	0.302	0.0	1.96	0.489
22-Ridge	Transportation	0.8	0.302	100.0	2.20	0.000
23-Pre Quarry	Open Space	370.9	0.269	12.6	1.72	0.470
25-Pre Quarry	Open Space	559.3	0.320	1.9	1.69	0.430
23-Ridge	Open Space	319.2	0.269	15.6	1.67	0.518
23-Ridge	Existing Dev	19.4	0.269	50.0	1.54	0.290
24-Valley	Open Space	55.1	0.087	0.0	1.92	0.562
24-Valley	Transportation	3.5	0.087	100.0	0.80	0.000
24-Ridge	Open Space	257.7	0.320	0.1	1.93	0.494
24-Ridge	Transportation	4.0	0.320	100.0	2.07	0.000
25-Ridge	Open Space	199.6	0.320	0.0	1.94	0.454

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	**Land Use**					
26-Valley	Open Space	71.2	0.057	0.1	2.62	0.594
26-Valley	Existing Dev	10.7	0.057	49.0	2.91	0.296
26-Ridge	Open Space	214.7	0.221	12.6	1.95	0.299
26-Ridge	Existing Dev	0.6	0.221	47.4	2.45	0.305
26-Ridge	Nursery	24.3	0.221	15.0	2.20	0.621
27-Ridge	Open Space	244.5	0.031	39.4	1.21	0.250
28-Valley	Open Space	28.3	0.084	3.1	2.20	0.39
28-Valley	Existing Dev	21.9	0.084	50.0	2.51	0.29
28-Ridge	Open Space	126.7	0.190	0.3	2.19	0.31
28-Ridge	Existing Dev	1.2	0.190	50.0	2.31	0.29
29-Valley	Open Space	22.7	0.092	1.1	2.20	0.43
29-Valley	Existing Dev	3.2	0.092	50.0	2.35	0.29
30-Valley	Open Space	13.6	0.140	0.7	2.29	0.68
30-Valley	Transportation	0.7	0.140	100.0	2.20	0.00
30-Ridge	Open Space	5.0	0.259	0.0	2.20	0.39
30-Ridge	Transportation	0.5	0.259	100.0	2.20	0.00
31-Valley	Open Space	8.9	0.088	0.0	2.81	0.33
31-Valley	Transportation	1.2	0.088	100.0	2.69	0.00
31-Ridge	Open Space	265.4	0.418	17.7	1.32	0.31
31-Ridge	Transportation	0.9	0.418	100.0	2.37	0.00
32-Valley	Open Space	63.1	0.067	0.5	2.39	0.51
32-Valley	Transportation	4.0	0.067	86.5	2.52	0.08
32-Ridge	Open Space	155.5	0.566	25.0	1.62	0.29
32-Ridge	Transportation	0.9	0.566	100.0	2.22	0.00
33-Valley	Open Space	61.9	0.070	0.7	2.21	0.40
33-Valley	Existing Dev	4.5	0.070	69.5	2.27	0.18
33-Ridge	Open Space	33.5	0.096	0.0	2.20	0.50
34-Valley	Open Space	20.1	0.071	5.5	2.19	0.33
34-Valley	Transportation	1.9	0.071	100.0	2.46	0.00
34-Valley	Parks	8.3	0.071	15.0	2.60	0.62
34-Ridge	Open Space	108.9	0.513	46.5	1.18	0.26
35-Ridge	Open Space	248.4	0.565	56.0	0.97	0.20
36-Valley	Open Space	30.0	0.069	0.0	2.31	0.85
36-Valley	Transportation	3.6	0.069	100.0	2.20	0.00
36-Ridge	Open Space	89.6	0.244	0.2	2.20	0.38
37-Valley	Open Space	14.3	0.046	0.0	2.50	0.89
37-Ridge	Open Space	140.4	0.416	0.0	1.79	0.44
38-Valley	Open Space	53.2	0.066	0.0	2.46	0.82
38-Valley	Existing Dev	4.8	0.066	50.0	2.32	0.29
38-Valley	Transportation	3.7	0.066	100.0	2.46	0.00
36-Valley	Parks	35.7	0.069	15.0	2.54	0.62
38-Ridge	Nursery	15.0	0.066	15.0	2.59	0.62
38-Ridge	Open Space	75.5	0.316	12.9	1.92	0.41
23-Quarry	Quarry	38.2	0.269	14.8	2.19	0.01
25a-Quarry	Open Space	300.4	0.320	3.6	1.42	0.38
25a-Quarry	Quarry	26.3	0.320	15.0	2.12	0.00
23-Quarry	Water	4.0	0.269	100.0	0.00	1.00

Table A-21: Central San Juan Sub-Basin Model – Post-Development Subcatchment Parameters

Sub-catchment		Area	Average Slope	Percent	Hydraulic Conductivity	ET Scale
Name	**Land Use**	**(acres)**	**(ft/ft)**	**Impervious**	**(in/hr)**	**Coefficient**
13-Valley	Open Space	34.3	0.164	3.0	1.20	0.50
13-Valley	Residential	4.3	0.160	40.0	1.81	0.29
13-Ridge	Open Space	51.2	0.419	48.0	1.12	0.50
13-Ridge	Residential	7.6	0.419	40.0	1.14	0.29
13-Ridge	Transportation	2.9	0.419	100.0	1.93	0.00
14-Valley	Open Space	29.6	0.078	0.0	1.86	0.68
14-Ridge	Open Space	43.8	0.367	20.6	1.27	0.47
14-Ridge	Residential	12.2	0.367	40.0	0.76	0.29
14-Ridge	Transportation	2.6	0.367	100.0	1.28	0.00
15-Valley	Open Space	46.3	0.050	0.0	2.70	0.61
15-Ridge	Open Space	9.1	0.150	0.0	2.37	0.35
15-Ridge	Residential	1.3	0.150	40.0	2.30	0.29
16-Valley	Open Space	12.0	0.071	0.8	2.76	0.86
16-Valley	Residential	20.4	0.071	40.0	3.00	0.29
16-Valley	Transportation	1.4	0.071	100.0	2.97	0.00
16-Ridge	Open Space	2.9	0.187	0.0	2.79	0.37
16-Ridge	Residential	3.6	0.187	40.0	2.96	0.29
16-Ridge	Transportation	3.4	0.187	100.0	2.33	0.00
17-Valley	Open Space	7.3	0.221	0.0	2.21	0.54
17-Ridge	Open Space	28.0	0.378	3.4	2.12	0.49
17-Ridge	Residential	38.6	0.378	40.0	1.68	0.29
17-Ridge	Transportation	3.7	0.378	100.0	2.20	0.00
18a-Ridge	Open Space	8.1	0.346	0.0	2.20	0.45
18a-Ridge	Residential	3.5	0.346	40.0	2.20	0.29
18a-Ridge	Transportation	1.6	0.346	100.0	2.20	0.00
18b-Ridge	Open Space	6.1	0.346	0.0	2.20	0.36
18b-Ridge	Residential	0.7	0.346	40.0	2.20	0.29
19-Valley	Open Space	22.1	0.103	0.0	2.20	0.68
19-Valley	Transportation	1.3	0.103	100.0	2.20	0.00
19-Ridge	Open Space	24.6	0.387	0.0	2.20	0.45
19-Ridge	Transportation	4.5	0.387	100.0	2.20	0.00
20-Valley	Open Space	20.2	0.082	0.4	2.42	0.77
20-Valley	Residential	23.9	0.082	40.0	3.00	0.29
20-Valley	Transportation	1.0	0.082	100.0	2.26	0.00
21-Valley	Open Space	11.2	0.051	3.0	2.20	0.37
21-Valley	Residential	37.6	0.051	40.0	2.87	0.29
22-Valley	Open Space	9.1	0.108	0.0	1.46	0.39
22-Ridge	Open Space	56.2	0.302	0.0	1.97	0.67
22-Ridge	Residential	12.5	0.302	40.0	2.08	0.29
22-Ridge	Transportation	0.8	0.302	100.0	2.09	0.00
23-Ridge	Open Space	24.0	0.441	89.3	0.17	0.03
23-Ridge	Residential	19.2	0.441	40.0	1.77	0.29
24-Valley	Open Space	55.1	0.087	0.0	1.92	0.56
24-Valley	Transportation	3.5	0.087	100.0	0.80	0.00
24-Ridge	Open Space	257.7	0.320	0.1	1.93	0.49
24-Ridge	Transportation	4.0	0.320	100.0	2.07	0.00
25a-Ridge	Open Space	30.9	0.350	24.5	0.36	0.20
25a-Ridge	Residential	54.6	0.350	40.0	0.75	0.29
25b-Ridge	Open Space	97.4	0.384	0.0	2.07	0.42
25b-Ridge	Residential	3.3	0.384	40.0	2.14	0.29
25b-Ridge	Transportation	2.1	0.384	100.0	2.20	0.00

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
26-Valley	Open Space	16.1	0.057	0.2	2.20	0.54
26-Valley	Residential	46.0	0.057	40.0	2.78	0.29
27-Ridge	Open Space	75.7	0.031	42.9	1.20	0.23
27-Ridge	Residential	6.6	0.031	40.0	1.47	0.29
28-Valley	Open Space	3.9	0.068	0.6	2.20	0.54
28-Valley	Residential	5.0	0.068	40.0	2.20	0.29
29-Valley	Open Space	22.5	0.096	0.2	2.20	0.51
29-Valley	Residential	0.6	0.096	40.0	2.20	0.29
30-Valley	Open Space	13.6	0.140	0.0	2.28	0.73
30-Valley	Transportation	1.2	0.140	100.0	2.30	0.00
30-Ridge	Open Space	5.0	0.259	0.0	2.20	0.39
31-Valley	Open Space	8.9	0.088	0.0	2.81	0.33
31-Valley	Transportation	1.2	0.088	100.0	2.69	0.00
31-Ridge	Open Space	260.4	0.418	18.1	1.30	0.32
31-Ridge	Transportation	0.9	0.418	100.0	2.37	0.00
32-Valley	Open Space	19.3	0.067	0.0	2.21	0.56
32-Valley	Estates	42.9	0.067	20.0	2.50	0.46
32-Valley	Transportation	4.5	0.067	100.0	2.30	0.00
32-Ridge	Open Space	144.8	0.566	26.9	1.57	0.29
32-Ridge	Estates	10.7	0.566	20.0	2.23	0.46
32-Ridge	Transportation	0.9	0.070	100.0	2.22	0.00
33-Valley	Open Space	29.1	0.070	0.4	2.20	0.61
33-Valley	Residential	7.3	0.070	40.0	2.20	0.29
33-Valley	Estates	1.7	0.070	20.0	2.25	0.46
33-Valley	Transportation	1.0	0.070	100.0	2.20	0.00
33-Ridge	Residential	2.5	0.096	40.0	2.20	0.29
34-Valley	Open Space	0.7	0.071	0.0	2.20	0.24
34-Valley	Estates	27.6	0.071	20.0	2.30	0.46
34-Valley	Transportation	0.6	0.071	100.0	2.36	0.00
34-Ridge	Open Space	55.7	0.513	53.2	1.03	0.20
34-Ridge	Estates	53.1	0.513	20.0	1.33	0.46
35-Ridge	Open Space	248.4	0.565	56.0	0.97	0.20
36-Valley	Open Space	22.9	0.069	0.1	2.20	0.85
36-Valley	Estates	42.3	0.069	20.0	2.55	0.46
36-Valley	Transportation	3.5	0.069	100.0	2.45	0.00
36-Ridge	Open Space	24.5	0.244	0.0	2.20	0.53
36-Ridge	Residential	14.2	0.244	40.0	2.20	0.29
36-Ridge	Estates	1.2	0.244	20.0	2.20	0.46
36-Ridge	Transportation	1.1	0.244	100.0	2.20	0.00
37-Valley	Open Space	14.3	0.046	0.0	2.50	0.89
37-Ridge	Open Space	60.3	0.416	0.0	1.74	0.45
37-Ridge	Residential	11.4	0.416	40.0	1.89	0.29
38-Valley	Open Space	44.7	0.066	4.3	2.35	0.75
38-Valley	Estates	27.2	0.066	20.0	2.68	0.46
38-Valley	Transportation	5.7	0.066	100.0	2.59	0.00
38-Ridge	Open Space	67.7	0.316	14.4	1.88	0.41
38-Ridge	Estates	7.1	0.316	20.0	2.20	0.46
38-Ridge	Transportation	0.8	0.316	100.0	2.20	0.00
PA3-1	Residential	22.7	0.090	40.0	2.23	0.29
PA3-1	Transportation	2.3	0.090	100.0	2.33	0.00
PA3-2	Residential	8.7	0.078	40.0	2.76	0.29
PA3-2	Residential	175.5	0.078	40.0	2.23	0.29
PA3-2	Transportation	4.8	0.078	100.0	2.06	0.00

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
PA3-3	Residential	66.8	0.126	40.0	2.44	0.29
PA3-3	Residential	69.4	0.126	40.0	2.26	0.29
PA3-3	Transportation	3.6	0.126	100.0	2.24	0.00
PA3-4	Residential	19.7	0.075	40.0	2.20	0.29
PA3-4	Residential	65.1	0.075	40.0	2.20	0.29
PA3-4	Transportation	0.2	0.075	100.0	2.20	0.00
PA3-5	Residential	345.9	0.098	40.0	1.67	0.29
PA3-5	Transportation	4.6	0.098	100.0	1.72	0.00
PA3-6	Residential	140.2	0.052	40.0	1.61	0.29
PA3-6	Transportation	3.0	0.052	100.0	1.20	0.00
PA3-7	Residential	134.7	0.064	40.0	1.09	0.29
PA3-7	Transportation	3.1	0.064	100.0	1.82	0.00
PA3-8	Transportation	1.9	0.072	100.0	2.16	0.00
PA3-8	Residential	108.1	0.072	40.0	1.36	0.29
PA5-1	Open Space	3.5	0.156	0.0	2.20	0.33
PA5-1	Residential	85.9	0.156	40.0	2.08	0.29
PA5-1	Transportation	2.9	0.156	100.0	2.20	0.00
PA5-2	Residential	43.0	0.209	40.0	0.56	0.29
PA5-2	Open Space	24.5	0.209	10.0	0.33	0.39
PA5-2	Residential	196.6	0.209	40.0	1.42	0.29
PA5-2	Transportation	1.6	0.209	100.0	2.20	0.00
PA5-3	Residential	195.9	0.080	40.0	1.92	0.29
PA5-3	Transportation	6.5	0.080	100.0	2.03	0.00
PA5-4	Open Space	49.7	0.175	0.7	1.25	0.40
PA5-4	Residential	487.8	0.175	40.0	1.80	0.29
PA5-4	Transportation	6.7	0.175	100.0	1.30	0.00

A-3.3.2 Central San Juan Sub-Basin Model - Land-Use

Pre- and post-development land-use in Central San Juan Sub-Basin is shown in Figure A-14 and is tabulated in Table A-22. The modeled pre-development conditions are based on the PWA land-use maps. The existing land-use in the Gobernadora model is dominated by existing development areas in Upper Gobernadora (Coto de Caza) and Wagonwheel Canyon. The existing land-use in the RMV project area includes a mixture of agriculture and open space areas.

Table A-22: Central San Juan Sub-Basin Model – Pre- and Post- Development Land Use

PWA Code	Land-Cover	Pre-Development Scenario – (Pre Quarry)	Pre-Development Scenario – (With Quarry)	Post-Development Scenario
20101, 20201, 20202, 20401	Agriculture & Orchard	129	129	17
20501	Nurseries	167	167	
10201-10306	Scrub & Chaparral	1873	1799	985
10401	Grassland	929	881	250
10501-10502, 10601	Woodland, Riparian, Forest, Meadow & Marsh	737	692	405
10701	Rock Outcrops	648	635	360
30101	General Development	82	101	2497
30202	Estate			214
30401	Transportation	38	38	95
30501	Park	68	68	4
	Undefined	127	252	71
	Water		37	

The modeled development conditions were based on the B4 development alternative, the B4 principle roads plan, and the habitat restoration plan. These proposed development and habitat restoration plans were superimposed on the PWA land-use maps for existing conditions. The modeled post-development conditions are the amalgamation of these existing and proposed land-uses.

The proposed development includes single-family residential housing, and estates. The main arterial road in PA-2 and PA-3 (through catchments 3-8) was modeled as six-lane highway with an assumed impervious width of 120 feet. The smaller arterial roads (catchments 1/8 and 4/5) were modeled with an impervious width of 56 feet. Proposed habitat restoration areas were incorporated into the SWMM model in terms of the effect on ET.

A-3.3.3 Central San Juan Sub-Basin Model - Subcatchment Soils

The distribution of surficial soils in the Central San Juan Sub-Basin model is shown in Figure A-14. Sandy loams occur in much of the Sub-Basin. There are large areas of hardpan clays, clayey soils, and rock outcrops in northern and eastern portions of the Sub-Basin, coinciding with much of the proposed development area in PA-3 (Figure A-13).

A-3.3.4 Central San Juan Sub-Basin Model – Calibration

Low flow measurements (Balance, 2001) and peak discharge estimates based on observations of high water marks (Balance, 2003b) are available only for the tributary to San Juan Creek, east of Color Spot. The Central San Juan Sub-Basin Model was not calibrated. Rather, it was assumed that the calibrated parameters from the Gobernadora Sub-Basin Model were applicable for the in the Central San Juan Sub-Basin.

A-3.4 Cristianitos Sub-Basin – SWMM Simulation Parameters

A-3.4.1 Cristianitos Sub-Basin Model - Subcatchment Delineation

The Cristianitos Sub-Basin SWMM Model is defined by the catchment area that is directly tributary to Cristianitos Creek, upstream of the confluence with Gabino Creek. Development areas in the Cristianitos Sub-Basin include PA-6, and a large portion of PA-7. However, due to habitat sensitivity of Cristianitos Creek, a majority of the runoff from the proposed development areas in PA-7 would be directed to the Gabino Sub-Basin. As a result the total watershed area would be reduced from 2370 in the pre-development setting to 2190 acres under proposed post-development conditions.

The entire Cristianitos Sub-Basin was modeled for pre-development conditions to facilitate model calibration with measured and estimated flows. The Cristianitos Sub-Basin was divided into 25 catchments under pre-development conditions (Figure A-15).

For post-development conditions, the subcatchments in development areas were delineated on the basis of grading plans and drainage objectives. A total of 31 catchments were defined for post-development conditions (Figure A-15).

Both pre- and post-development subcatchments were disaggregated into valley and ridge subcatchments, as well as, subcatchments based on land-use designation. Table A-23 and Table A-24 lists the parameters of the modeled subcatchments for the pre- and post-development scenarios, respectively.

Table A-23: Cristianitos Model – Pre-Development Subcatchment Parameters

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
39-Valley	Open Space	38.7	0.136	0.0	1.7	0.320
39-Valley	Transportation	1.6	0.136	100.0	1.7	0.000
39-Ridge	Open Space	2.8	0.208	0.0	1.2	0.284
40-Valley	Open Space	9.3	0.145	0.0	1.5	0.520
40-Ridge	Open Space	8.7	0.290	0.0	1.7	0.295
41-Valley	Open Space	31.7	0.157	0.0	1.3	0.778
41-Ridge	Open Space	170.3	0.402	0.0	1.8	0.489
42-Valley	Open Space	71.3	0.154	0.0	1.8	0.682
42-Ridge	Open Space	303.6	0.298	0.0	1.8	0.499
43-Valley	Open Space	17.7	0.162	0.0	0.9	0.355
43-Valley	Transportation	0.6	0.162	100.0	0.9	0.000
43-Ridge	Open Space	21.8	0.307	0.0	1.4	0.339
43-Ridge	Quarry	15.4	0.307	30.0	1.4	0.020
44-Valley	Open Space	5.3	0.140	0.0	1.0	0.282
44-Valley	Quarry	0.3	0.140	30.0	1.0	0.020
44-Ridge	Open Space	16.8	0.227	0.0	1.5	0.205
44-Ridge	Quarry	15.6	0.227	30.0	1.5	0.020
45-Valley	Open Space	13.4	0.169	0.0	1.7	0.339
46-Valley	Open Space	7.3	0.172	0.0	0.8	0.453
46-Valley	Transportation	1.1	0.172	100.0	0.8	0.000

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
46-Ridge	Open Space	15.4	0.421	0.0	1.7	0.466
47-Valley	Open Space	13.4	0.131	0.0	1.6	0.268
47-Valley	Quarry	1.1	0.131	30.0	1.6	0.020
47-Ridge	Open Space	23.6	0.235	0.0	1.7	0.251
47-Ridge	Quarry	11.3	0.235	30.0	1.7	0.020
48-Valley	Open Space	14.0	0.135	0.0	0.9	0.323
48-Valley	Quarry	0.9	0.135	30.0	0.9	0.020
48-Valley	Transportation	1.2	0.135	100.0	0.9	0.000
48-Ridge	Open Space	10.1	0.236	0.0	0.2	0.291
48-Ridge	Quarry	6.3	0.236	30.0	0.2	0.020
49-Valley	Open Space	6.8	0.158	0.0	0.9	0.359
49-Valley	Transportation	0.6	0.158	100.0	0.9	0.000
49-Ridge	Open Space	22.7	0.388	0.0	1.8	0.460
50-Valley	Open Space	29.3	0.157	0.0	1.6	0.816
50-Valley	Transportation	0.1	0.157	100.0	1.6	0.000
50-Ridge	Open Space	223.0	0.296	0.0	1.6	0.552
51-Valley	Open Space	41.6	0.138	0.0	0.4	0.296
51-Valley	Transportation	1.8	0.138	100.0	0.4	0.000
51-Valley	Quarry	2.1	0.138	30.0	0.4	0.020
51-Ridge	Open Space	84.6	0.286	0.0	0.0	0.280
52-Valley	Open Space	19.9	0.149	0.0	1.4	0.459
52-Valley	Transportation	1.0	0.149	100.0	1.4	0.000
52-Ridge	Open Space	8.8	0.312	0.0	1.6	0.342
53-Valley	Open Space	22.8	0.179	0.0	1.7	0.560
53-Ridge	Open Space	72.4	0.305	0.0	1.7	0.440
54-Valley	Open Space	17.2	0.158	0.0	1.4	0.292
54-Valley	Transportation	0.2	0.158	100.0	1.4	0.000
54-Ridge	Open Space	131.3	0.362	0.0	0.1	0.328
55-Valley	Open Space	48.9	0.108	0.0	1.4	0.283
55-Ridge	Open Space	44.6	0.292	0.0	0.8	0.300
56-Valley	Open Space	35.7	0.188	0.0	1.6	0.355
56-Valley	Transportation	0.3	0.188	100.0	1.6	0.000
56-Valley	Existing Dev	10.1	0.188	50.0	1.6	0.290
56-Ridge	Open Space	0.0	0.071	0.0	1.8	0.311
57-Valley	Open Space	71.9	0.141	0.0	1.3	0.297
57-Ridge	Open Space	61.0	0.260	0.0	0.4	0.300
58-Valley	Open Space	6.9	0.134	0.0	0.9	0.406
58-Ridge	Open Space	240.2	0.383	0.0	0.1	0.469
59-Valley	Open Space	15.3	0.129	0.0	1.2	0.285
59-Ridge	Open Space	39.7	0.340	0.0	1.8	0.448
60-Valley	Open Space	31.3	0.167	0.0	1.5	0.335
60-Valley	Transportation	2.0	0.167	100.0	1.5	0.000
60-Valley	Existing Dev	26.2	0.167	50.0	1.5	0.290
60-Ridge	Open Space	15.4	0.255	0.0	1.8	0.480
61-Valley	Open Space	19.2	0.137	0.0	1.5	0.390
61-Valley	Transportation	0.6	0.137	100.0	1.5	0.000
61-Valley	Existing Dev	0.5	0.137	50.0	1.5	0.290
61-Ridge	Open Space	48.6	0.246	0.0	1.8	0.359
62-Valley	Open Space	6.5	0.120	0.0	1.8	0.324
62-Ridge	Open Space	41.0	0.271	0.0	1.8	0.462
63-Valley	Open Space	45.1	0.156	0.0	1.6	0.278
63-Valley	Transportation	1.4	0.156	100.0	1.6	0.000
63-Ridge	Open Space	21.4	0.300	0.0	1.7	0.384

Table A-24: Cristianitos Model – Post-Development Subcatchment Parameters

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
39-Valley	Open Space	38.59	0.136	7.7	1.66	0.323
39-Ridge	Open Space	1.04	0.208	0.3	1.80	0.251
40-Valley	Open Space	9.32	0.145	4.5	1.49	0.520
40-Ridge	Open Space	8.73	0.290	0.0	1.69	0.295
41-Valley	Open Space	31.71	0.157	0.0	1.26	0.778
41-Ridge	Open Space	170.32	0.402	0.0	1.76	0.489
42-Valley	Open Space	71.26	0.154	0.0	1.75	0.682
42-Ridge	Open Space	303.6	0.298	0.0	1.78	0.500
43-Valley	Open Space	9.15	0.162	10.4	0.75	0.389
44-Valley	Open Space	2.92	0.140	4.7	1.05	0.311
44-Ridge	Open Space	2.20	0.227	0.0	1.12	0.311
45-Valley	Open Space	11.12	0.169	1.9	1.70	0.357
46-Valley	Open Space	8.33	0.172	10.6	0.78	0.453
46-Ridge	Open Space	15.37	0.421	0.0	1.69	0.466
47-Valley	Open Space	5.54	0.131	0.0	1.79	0.303
48-Valley	Open Space	9.11	0.135	2.5	0.97	0.361
48-Ridge	Open Space	2.72	0.236	0.0	0.59	0.349
49-Valley	Open Space	7.44	0.158	12.0	0.92	0.359
49-Ridge	Open Space	22.72	0.388	0.0	1.79	0.460
50-Valley	Open Space	29.41	0.157	0.1	1.64	0.816
50-Ridge	Open Space	223.0	0.296	0.0	1.59	0.553
51-Valley	Open Space	12.58	0.138	7.4	0.38	0.383
52-Valley	Open Space	18.00	0.149	6.2	1.34	0.489
52-Ridge	Open Space	8.77	0.312	0.0	1.59	0.342
53-Valley	Open Space	22.83	0.179	0.0	1.72	0.560
53-Ridge	Open Space	72.42	0.305	0.0	1.69	0.440
54-Valley	Open Space	13.65	0.169	6.3	1.62	0.338
54-Valley	Residential	4.16	0.169	40.0	1.37	0.348
54-Ridge	Residential	4.20	0.169	40.0	0.32	0.348
55-Valley	Open Space	5.97	0.107	0.0	1.80	0.254
55-Valley	Residential	15.24	0.107	40.0	1.40	0.348
55-Valley	Transportation	1.15	0.107	100.0	1.80	0.000
55-Valley	Golf Course	5.75	0.107	10.0	1.80	0.657
55-Ridge	Residential	4.14	0.107	40.0	1.41	0.348
57-Valley	Open Space	16.50	0.141	0.0	0.24	0.250
57-Ridge	Open Space	51.27	0.260	0.0	0.10	0.292
58-Valley	Open Space	4.11	0.134	0.0	0.51	0.347
58-Valley	Residential	1.93	0.134	40.0	1.65	0.348
58-Ridge	Open Space	223.45	0.383	0.0	0.07	0.480
58-Ridge	Residential	8.37	0.383	40.0	0.004	0.348
59-Valley	Open Space	29.51	0.129	1.2	0.97	0.363
59-Ridge	Open Space	39.66	0.340	0.0	1.78	0.448
61-Valley	Open Space	11.24	0.137	0.0	1.26	0.315
61-Ridge	Open Space	41.66	0.246	0.0	1.80	0.461
63-Valley	Open Space	22.23	0.156	0.0	1.37	0.283
63-Ridge	Open Space	20.30	0.300	0.0	1.67	0.389
63-Valley	Transportation	1.12	0.300	100.0	1.80	0.000
PA6-1	Golf Course	38.62	0.162	10.0	1.57	0.657
PA6-1	Transportation	1.86	0.162	100.0	0.92	0.000
PA6-2	Open Space	8.16	0.103	0.0	1.80	0.376
PA6-2	Golf Course	57.57	0.103	10.0	1.75	0.657
PA6-2	Transportation	7.03	0.103	100.0	1.72	0.000

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
PA6-2	Residential	23.76	0.103	40.0	1.78	0.348
PA6-3	Open Space	2.67	0.352	0.0	1.79	0.334
PA6-3	Transportation	3.53	0.352	100.0	1.66	0.000
PA6-3	Residential	22.41	0.352	40.0	1.74	0.348
PA6-4	Open Space	17.31	0.229	0.0	1.77	0.408
PA6-4	Golf Course	95.65	0.229	10.0	1.72	0.657
PA6-4	Residential	2.62	0.229	40.0	1.80	0.348
PA7-9	Open Space	4.20	0.136	0.0	1.29	0.256
PA7-9	Residential	46.57	0.136	40.0	1.12	0.348
PA7-9	Transportation	4.75	0.136	100.0	1.04	0.000
PA7-10	Open Space	2.47	0.129	0.0	0.56	0.250
PA7-10	Residential	64.24	0.129	40.0	1.07	0.348
PA7-10	Transportation	4.15	0.129	100.0	1.29	0.000
PA7-11	Open Space	1.27	0.149	0.0	1.80	0.263
PA7-11	Residential	67.74	0.149	40.0	0.33	0.348
PA7-11	Transportation	8.83	0.149	100.0	0.12	0.000
PA7-14	Residential	28.26	0.185	40.0	0.85	0.348
PA7-14	Transportation	2.14	0.185	100.0	1.22	0.000
PA7-16	Residential	31.34	0.355	40.0	0.44	0.348

A-3.4.2 Cristianitos Sub-Basin Model - Land-Use

Pre- and post-development land-use in Cristianitos Sub-Basin is shown in Figure A-15 and is tabulated in Table A-25. The modeled pre-development conditions are based on the PWA land-use maps. There is little existing development in the pre-development conditions. Clay pit quarries are present in the southeastern potion of the watershed.

Table A-25: Cristianitos Sub-Basin Model – Pre- and Post- Development Land Use

PWA Code	Land-Cover	Pre-Development Scenario	Post-Development Scenario
10201-10306	Scrub & Chaparral	960	805
10401	Grassland	980	483
10501-10502, 10601	Woodland, Riparian, Forest, Meadow & Marsh	328	304
90101	General Disturbed Areas (roads, residential, quarry)	93	49
30202	Single Family Residential		326
30401	Transportation		49
30501	Golf Course		198

The modeled development conditions were based on the B4 development alternative, the B4 principle roads plan, and the habitat restoration plan. These proposed development and habitat restoration plans were superimposed on the PWA land-use maps for existing conditions. The modeled post-development conditions are the amalgamation of these existing and proposed land-uses.

The proposed development includes single-family residential housing in PA-6 and PA-7, and a golf course in PA-7. The main arterial road in the B4 principle roads plan crosses through PA-6 and the upper section of PA-7. The road was modeled as six-lane highway with an assumed impervious width of 120 feet. Proposed habitat restoration areas in Upper Cristianitos were incorporated into the SWMM model in terms of the effect on ET.

A-3.4.3 Cristianitos Sub-Basin Model - Subcatchment Soils

The distribution of surficial soils in the Cristianitos Sub-Basin is shown in Figure A-16. Surficial deposits of sandy loams are dominant throughout the watershed, however, many areas are underlain by clayey deposits at shallow depths. Surficial deposits of clayey soils are dominant in the northern and eastern portions of the watershed. Comparison of the land use coverage map (Figure A-15) and the soil texture map (Figure A-16) shows that much of the proposed residential in PA-7 is located in areas with clayey soils.

A-3.4.4 Cristianitos Sub-Basin Model – Calibration

The Cristianitos Sub-Basin Model for pre-development conditions was to low flow measurements (Balance, 2001) and peak discharge estimates based on observations of high water marks (Balance, 2003b). Calibration results are presented in Table A-26 below.

Table A-26: Cristianitos Sub-Basin Model - Calibration Data and Calibration Results

Flow Condition / Location	Date	Time	Measured or Estimated Discharge (cfs)	Predicted Discharge using SWMM (cfs)
Low Flow				
Upper Cristianitos Canyon	11/17/1999	7:00	Dry	0.003
Cristianitos Crk upstream of Gabino	11/17/1999	8:00	Dry	0.001
Peak Discharge				
Cristianitos Crk upstream of Gabino	12/7/1997 or 2/23/1998	--	296	76 on 12/7/1997 345 on 2/23/98

A-3.5 <u>Gabino Sub-Basin Model</u>

A-3.5.1 Gabino Sub-Basin Model - Subcatchment Delineation

The Gabino Sub-Basin SWMM Model is defined by the catchment area that is directly tributary to Gabino Creek, excluding La Paz Canyon and Blind Canyon. Development areas in the Gabino Sub-Basin include PA-9, a portion of PA-7, and a small section of PA-8C.

The entire Gabino Sub-Basin was modeled for pre-development conditions to facilitate model calibration with measured and estimated flows above the confluence with La Paz Canyon. The Gabino Sub-Basin was divided into 37 catchments under pre-development conditions (Figure A-17).

A water balance evaluation for post-development conditions was conducted for development areas in PA-7 and PA-8, however, the analysis for PA-9 was handled qualitatively. Thus, only catchments that drain to Lower Gabino Canyon were modeled in the post-development scenario. These catchments are the numbers catchments 68-80 and development catchments in PA-7 and PA-8 (see Figure A-17). The development areas were delineated on the basis of grading plans and drainage objectives. A total of 24 catchments were defined for post-development conditions.

Both pre- and post-development subcatchments were disaggregated into valley and ridge subcatchments, as well as, subcatchments based on land-use designation. Table A-27 and Table A-28 lists the parameters of the modeled subcatchments for the pre- and post-development scenarios, respectively.

Table A-27: Gabino Sub-Basin Model – Pre-Development Subcatchment Parameters

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
68-Valley	Open Space	83.8	0.091	4.3	2.68	0.63
68-Ridge	Open Space	74.5	0.240	3.0	1.80	0.29
69-Valley	Open Space	15.8	0.132	31.9	2.09	0.20
69-Ridge	Open Space	256.7	0.243	5.1	0.75	0.27
69-Ridge	Existing Dev	11.2	0.125	50.0	0.04	0.29
70-Valley	Open Space	33.3	0.101	4.2	2.84	0.73
70-Ridge	Open Space	66.3	0.306	2.3	0.33	0.35
70-Ridge	Existing Dev	0.1	0.798	50.0	0.03	0.29
71-Valley	Open Space	2.9	0.059	0.0	4.72	1.03
71-Ridge	Open Space	58.6	0.423	0.0	0.04	0.44
72-Valley	Open Space	27.3	0.121	0.0	2.24	0.94
72-Valley	Existing Dev	3.6	0.097	50.0	1.89	0.29
72-Ridge	Open Space	51.6	0.353	0.0	0.40	0.42
72-Ridge	Existing Dev	6.3	0.270	50.0	1.59	0.29
73-Valley	Open Space	0.3	0.084	0.0	3.88	1.10
73-Ridge	Open Space	55.2	0.421	0.2	0.13	0.36
73-Ridge	Existing Dev	0.7	0.250	50.0	0.11	0.29
74-Valley	Open Space	21.8	0.092	0.0	1.94	0.68
74-Ridge	Open Space	114.3	0.382	1.6	1.03	0.47
74-Ridge	Existing Dev	2.0	0.151	50.0	0.01	0.29
75-Valley	Open Space	0.0	0.401	0.0	2.92	0.40
75-Ridge	Open Space	39.2	0.427	0.0	1.48	0.57
76-Ridge	Open Space	113.9	0.344	0.4	1.29	0.37
76-Ridge	Existing Dev	7.1	0.225	50.0	0.40	0.29
77-Ridge	Open Space	316.4	0.402	0.0	1.61	0.42
78-Valley	Open Space	30.1	0.094	0.0	1.38	0.66
78-Ridge	Open Space	62.1	0.350	0.0	1.63	0.50
79-Valley	Open Space	4.2	0.165	0.0	2.05	1.08
79-Ridge	Open Space	57.9	0.419	0.0	1.79	0.45
80-Valley	Open Space	20.8	0.129	0.0	2.48	0.65
80-Ridge	Open Space	27.6	0.485	0.0	1.49	0.52
81-Valley	Open Space	3.9	0.191	0.0	3.13	0.74
81-Ridge	Open Space	360.0	0.418	0.0	1.81	0.41
82-Valley	Open Space	25.4	0.162	0.0	2.86	0.86
82-Ridge	Open Space	39.9	0.478	0.0	1.36	0.46
83-Valley	Open Space	30.0	0.142	0.0	3.49	0.89

Sub-catchment		**Area (acres)**	**Average Slope (ft/ft)**	**Percent Impervious**	**Hydraulic Conductivity (in/hr)**	**ET Scale Coefficient**
Name	**Land Use**					
83-Ridge	Open Space	363.1	0.402	0.0	1.60	0.46
84-Valley	Open Space	35.6	0.154	0.0	2.93	0.90
84-Ridge	Open Space	89.9	0.418	0.0	1.75	0.42
85-Valley	Open Space	2.3	0.153	0.0	2.14	0.93
85-Ridge	Open Space	198.6	0.325	0.0	1.66	0.42
86-Valley	Open Space	16.9	0.153	0.0	3.23	0.88
86-Ridge	Open Space	20.5	0.440	0.0	1.65	0.40
87-Valley	Open Space	0.4	0.346	0.0	4.26	0.65
87-Ridge	Open Space	236.8	0.331	0.0	1.78	0.41
88-Valley	Open Space	53.3	0.194	0.0	1.38	0.57
88-Ridge	Open Space	76.4	0.406	0.0	0.89	0.40
89-Valley	Open Space	6.9	0.215	0.0	0.32	0.35
89-Ridge	Open Space	54.4	0.396	0.0	0.12	0.43
90-Valley	Open Space	5.3	0.126	0.0	2.41	0.54
90-Ridge	Open Space	48.9	0.373	0.0	1.63	0.45
91-Valley	Open Space	7.7	0.148	0.0	0.63	0.29
91-Ridge	Open Space	128.6	0.288	0.0	0.73	0.37
92-Valley	Open Space	4.3	0.137	0.0	2.85	0.48
92-Ridge	Open Space	61.2	0.313	0.0	0.11	0.31
93-Valley	Open Space	23.5	0.167	0.0	1.74	0.46
93-Ridge	Open Space	7.3	0.258	0.0	0.28	0.30
94-Valley	Open Space	2.2	0.120	0.0	3.51	0.33
94-Ridge	Open Space	132.3	0.225	0.0	0.90	0.32
94-Ridge	Existing Dev	0.1	0.225	50.0	0.08	0.29
95-Valley	Open Space	30.0	0.109	0.0	3.15	0.55
95-Ridge	Open Space	41.8	0.239	0.0	0.95	0.33
96-Valley	Open Space	6.9	0.172	0.0	3.40	0.64
96-Ridge	Open Space	38.5	0.223	0.0	0.72	0.40
97-Valley	Open Space	7.3	0.111	0.0	2.45	0.34
97-Ridge	Open Space	122.6	0.267	0.0	0.73	0.30
98-Valley	Open Space	1.9	0.332	0.0	1.97	0.40
98-Ridge	Open Space	74.4	0.276	0.0	0.81	0.40
99-Valley	Open Space	8.9	0.308	0.0	2.36	0.65
99-Ridge	Open Space	16.3	0.389	0.0	1.45	0.36
100-Valley	Open Space	4.6	0.316	0.0	2.89	0.87
100-Ridge	Open Space	106.8	0.307	0.0	0.98	0.35
101-Valley	Open Space	15.6	0.133	0.0	3.53	0.45
101-Ridge	Open Space	37.4	0.188	0.0	1.82	0.38
102-Valley	Open Space	27.1	0.149	0.0	1.28	0.36
102-Ridge	Open Space	123.7	0.267	0.0	0.82	0.37
103-Ridge	Open Space	127.4	0.376	0.0	1.96	0.40
104-Ridge	Open Space	213.5	0.356	0.4	1.90	0.40

Table A-28: Gabino Sub-Basin Model – Post-Development Subcatchment Parameters

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
68-Ridge	Open Space	31.4	0.240	2.6	1.81	0.32
68-Valley	Open Space	75.9	0.091	3.7	2.73	0.67
68-Valley	Transportation	2.4	0.091	100.0	3.06	0.00
69-Ridge	Open Space	11.1	0.243	30.4	2.29	0.27
69-Valley	Open Space	6.7	0.132	24.5	2.91	0.50
70-Ridge	Open Space	20.5	0.306	1.3	0.56	0.51
70-Valley	Open Space	30.9	0.101	4.4	2.97	0.77
71-Ridge	Open Space	34.7	0.423	0.0	0.06	0.53
71-Valley	Open Space	2.9	0.059	0.0	4.72	1.03
72-Ridge	Open Space	47.2	0.353	0.0	0.56	0.42
72-Ridge	Estate	8.8	0.353	20.0	0.59	0.46
72-Valley	Open Space	30.9	0.121	0.0	2.20	0.86
73-Ridge	Open Space	44.2	0.421	0.3	0.14	0.38
73-Ridge	Estate	16.3	0.421	20.0	0.16	0.46
74-Ridge	Open Space	102.5	0.382	1.4	1.05	0.49
74-Ridge	Existing Dev	0.4	0.151	50.0	0.03	0.29
74-Ridge	Estate	12.1	0.382	20.0	0.81	0.46
74-Valley	Open Space	21.8	0.092	0.0	1.94	0.68
75-Ridge	Open Space	37.6	0.427	0.0	1.47	0.58
75-Ridge	Estate	1.6	0.427	20.0	1.80	0.46
76-Ridge	Open Space	74.0	0.344	0.7	1.64	0.41
76-Ridge	Existing Dev	2.8	0.225	50.0	0.29	0.29
76-Ridge	Estate	47.7	0.344	20.0	0.64	0.46
77-Ridge	Open Space	288.0	0.402	0.0	1.65	0.43
77-Ridge	Estate	24.9	0.402	20.0	1.28	0.46
78-Ridge	Open Space	62.1	0.350	0.0	1.63	0.50
78-Valley	Open Space	30.1	0.094	0.0	1.38	0.66
79-Ridge	Open Space	57.9	0.419	0.0	1.79	0.45
79-Valley	Open Space	4.2	0.165	0.0	2.05	1.08
80-Ridge	Open Space	27.6	0.485	0.0	1.49	0.52
80-Valley	Open Space	20.8	0.129	0.0	2.48	0.65
PA7-1	Open Space	6.9	0.314	22.4	3.00	0.21
PA7-1	Residential	1.8	0.314	40.0	3.08	0.35
PA7-1	Transportation	3.6	0.314	100.0	3.01	0.00
PA7-2	Open Space	6.0	0.132	0.9	22.80	0.27
PA7-2	Estate	3.6	0.132	20.0	23.99	0.46
PA7-2	Residential	85.7	0.132	40.0	9.51	0.35
PA7-3	Residential	65.1	0.075	40.0	5.87	0.35
PA7-3	Transportation	1.2	0.075	100.0	11.96	0.00
PA7-4	Open Space	5.0	0.139	0.0	20.96	0.26
PA7-4	Estate	1.0	0.139	20.0	24.00	0.46
PA7-4	Residential	29.0	0.139	40.0	21.06	0.35
PA7-5	Residential	53.3	0.125	40.0	18.48	0.35
PA7-6	Open Space	15.1	0.088	10.8	20.82	0.27
PA7-6	Estate	7.6	0.088	20.0	16.81	0.46
PA7-6	Residential	50.6	0.088	40.0	22.98	0.35
PA7-7	Open Space	9.1	0.148	1.3	20.16	0.27
PA7-7	Estate	3.2	0.148	20.0	14.60	0.46
PA7-7	Residential	9.2	0.148	40.0	18.43	0.35
PA7-12	Residential	27.7	0.133	40.0	15.66	0.35
PA7-12	Transportation	0.2	0.133	100.0	23.93	0.00
PA7-13	Open Space	1.9	0.167	0.0	24.00	0.25

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	**Land Use**					
PA7-13	Residential	36.7	0.167	40.0	18.56	0.35
PA7-15	Open Space	12.0	0.185	0.0	23.45	0.27
PA7-15	Estate	1.3	0.185	20.0	24.00	0.46
PA7-15	Residential	66.9	0.185	40.0	16.84	0.35
PA6-12	Golf Course	20.3	0.128	10.0	0.33	0.66
PA6-14	Open Space	6.0	0.317	0.0	0.01	0.36
PA6-14	Golf Course	29.7	0.317	10.0	0.01	0.66

A-3.5.2 Gabino Sub-Basin Model - Land-Use

Pre- and post-development land-use in Gabino Sub-Basin is shown in Figure A-18 and is tabulated in Table A-29 for the Lower Gabino catchments. Note that the area of the Lower Gabino Watershed increases from pre- to post-development because runoff from some development areas in the Cristianitos Watershed are routed to Gabino Creek.

Table A-29: Gabino Sub-Basin Model – Pre- and Post- Development Land Use

PWA Code	Land-Cover	Pre-Development Scenario (Catchments 68-80)	Post-Development Scenario (Catchments 68-80; PA7-1-7, 13, 15; PA-6 12,14)
10201-10306	Scrub & Chaparral	707	586
10401	Grassland	525	277
10501-10502, 10601	Woodland, Riparian, Forest, Meadow & Marsh	229	224
90101	General Disturbed Areas (roads, existing dev, quarry)	105	42
30202	Single Family Residential		426
30202	Estate		128
30401	Transportation		7
30501	Golf Course		50

The modeled pre-development conditions are based on the PWA land-use maps. The vast of majority of the Lower Gabino Watershed is undeveloped open space, with some small pockets of existing development.

The modeled development conditions were based on the B4 development alternative, the B4 principle roads plan, and the habitat restoration plan. These proposed development and habitat restoration plans were superimposed on the PWA land-use maps for existing conditions. The modeled post-development conditions are the amalgamation of these existing and proposed land-uses.

The proposed development includes single-family residential and estate housing in PA-7, and a portion of the proposed golf course in PA-8C. The main arterial road in the B4 principle roads plan is aligned north to south near the western boundary of the watershed. The road was modeled as six-lane highway with an assumed impervious width of 120 feet.

A-3.5.3 Gabino Sub-Basin Model - Subcatchment Soils

The distribution of surficial soils in the Gabino Sub-Basin is shown in Figure A-18. Surficial deposits of sandy loams are dominant throughout the watershed, however, there are large area of clayey soils in the upper and lower portions of the watershed. Comparison of the land use coverage map (Figure A-17) and the soil texture map (Figure A-18) shows that much of the proposed residential in the Gabino Sub-basin is located in areas with clayey soils.

A-3.5.4 Gabino Sub-Basin Model – Calibration

The Gabino Sub-Basin Model for pre-development conditions was to low flow measurements (Balance, 2001) and peak discharge estimates based on observations of high water marks (Balance, 2003b). Calibration results are presented in Table A-26 below.

Table A-30: Gabino Sub-Basin Model - Calibration Data and Calibration Results

Flow Condition / Location	Date	Time	Measured or Estimated Discharge (cfs)	Predicted Discharge using SWMM (cfs)
Low Flow				
Gabino Creek above La Paz	11/17/1999	11:00	Dry	0.0
	5/4/2000	15:30	Dry	0.01
Peak Discharge				
Gabino Creek above La Paz	12/7/1997 or 2/23/1998	--	786	795 on 2/23/98
	2/21/2000	--	20	29

A-3.6 Blind Canyon and Talega Canyons Model

A-3.6.1 Blind Canyon and Talega Model - Subcatchment Delineation

Proposed development in PA-8 is primarily situated within Blind Canyon, with some development proposed along the ridge between Blind and Talega Canyons. Blind Canyon is a 700-acre watershed that is tributary to Gabino Creek. Talega Canyon is a large watershed with the majority of the drainage outside of the RMV boundary. Only a small portion of the proposed development in PA-8 drains towards Talega Canyon, and under post-development conditions, most of the runoff from the development area would be directed to Gabino. For these reasons, the Blind Canyon and Talega Model encompasses all areas tributary to Blind Canyon Creek and only proposed development areas in Talega Canyon.

For the pre-development scenario, 4 catchments are defined in Blind Canyon, and 6 catchments are defined in Talega Canyon (Figure A-19). For post-development conditions, 7 catchments are defined in PA-8A and 8B, 3 catchments are defined in PA8-C, and 3 catchments are defined in open space areas in Blind Canyon (see Figure A-19). All catchments would drain to Gabino Creek, with the exception that some runoff from development areas in Talega Canyon would be routed to Talega Creek to maintain pre-development hydrology.

Both pre- and post-development subcatchments were disaggregated into valley and ridge subcatchments, as well as, subcatchments based on land-use designation. Table A-31 and Table A-32 lists the parameters of the modeled subcatchments for the pre- and post-development scenarios, respectively.

Table A-31: Blind Canyon and Talega Model – Pre-Development Subcatchment Parameters

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
64-Valley	Open Space	93.5	0.161	0.0	1.59	0.58
64-Ridge	Open Space	212.4	0.323	0.0	1.05	0.47
64-Ridge	TRW	30.6	0.403	90.0	1.63	0.06
65-Valley	Open Space	2.7	0.193	0.0	0.30	0.28
65-Ridge	Open Space	120.0	0.329	0.0	0.59	0.38
66-Valley	Open Space	11.6	0.142	0.0	2.93	0.43
66-Ridge	Open Space	197.9	0.339	0.0	1.06	0.43
66-Ridge	Existing Dev	0.5	0.183	50.0	1.79	0.29
67-Valley	Open Space	10.1	0.156	0.0	0.23	0.28
67-Ridge	Open Space	53.8	0.273	0.0	0.03	0.30
PA8-3	Open Space	78.3	0.336	0.0	1.80	0.30
PA8-3	TRW	0.1	0.336	90.0	1.80	0.06
PA8-4	Open Space	103.5	0.605	0.0	1.80	0.35
PA8-4	TRW	9.0	0.605	90.0	1.80	0.06
PA8-5	Open Space	80.3	0.526	0.0	1.25	0.33
PA8-5	TRW	21.0	0.526	90.0	1.53	0.06
PA8-6	Open Space	129.0	0.759	0.0	1.23	0.34
PA8-6	TRW	3.7	0.759	90.0	1.60	0.06
PA8-7	Open Space	31.2	0.827	0.0	1.37	0.37
PA8-8	Open Space	15.1	0.603	0.0	1.00	0.34
PA8-9a	Open Space	0.4	0.209	0.0	0.15	0.32
PA8-9b	Open Space	1.6	0.463	0.0	0.74	0.36

Table A-32: Blind Canyon and Talega Model – Post-Development Subcatchment Parameters

Sub-catchment		Area	Average Slope	Percent	Hydraulic Conductivity	ET Scale
Name	Land Use	(acres)	(ft/ft)	Impervious	(in/hr)	Coefficient
64-Ridge	Open Space	64.5	0.323	0.0	1.21	0.62
64-Ridge	Golf Course	5.0	0.323	10.0	0.38	0.66
64-Ridge	Transportation	2.1	0.323	100.0	1.80	0.00
64-Ridge	Residential	36.4	0.323	40.0	1.42	0.35
64-Valley	Open Space	36.7	0.161	0.0	2.16	0.74
64-Valley	Golf Course	1.5	0.161	10.0	1.33	0.66
64-Valley	Transportation	1.2	0.161	100.0	3.52	0.00
65-Ridge	Open Space	43.6	0.329	0.0	0.07	0.48
65-Ridge	Golf Course	0.8	0.329	10.0	0.01	0.66
65-Ridge	Estate	5.6	0.329	20.0	0.50	0.46
65-Valley	Open Space	1.6	0.193	0.0	0.27	0.28
66-Ridge	Open Space	181.1	0.339	0.0	1.16	0.44
66-Valley	Open Space	9.5	0.142	0.0	3.28	0.42
PA8-3	Open Space	0.8	0.336	0.0	1.80	0.55
PA8-3	Residential	102.6	0.336	40.0	1.80	0.35
PA8-3	Transportation	5.8	0.336	100.0	1.80	0.00
PA8-4	Residential	123.3	0.605	40.0	1.80	0.35
PA8-4	Transportation	5.6	0.605	100.0	1.80	0.00
PA8-5	Residential	137.0	0.526	40.0	1.32	0.35
PA8-6	Open Space	2.0	0.759	0.0	1.27	0.33
PA8-6	Residential	130.6	0.759	40.0	1.23	0.35
PA8-6	Estate	13.0	0.759	20.0	0.14	0.46
PA8-7	Estate	33.5	0.827	20.0	1.36	0.46
PA8-8	Estate	18.7	0.603	20.0	0.80	0.46
PA8-9	Open Space	4.2	0.173	0.0	0.60	0.33
PA8-9	Estate	60.5	0.173	20.0	1.00	0.46
PA8-10	Open Space	4.9	0.095	0.0	1.06	0.26
PA8-10	Residential	72.8	0.095	40.0	0.91	0.35
PA8-10	Golf Course	58.0	0.095	10.0	1.34	0.66
PA8-10	Transportation	1.8	0.095	100.0	1.80	0.00
PA8-11	SFR	4.1	0.111	40.0	0.27	0.35
PA8-11	Golf Course	73.8	0.111	10.0	0.72	0.66
PA8-13	Golf Course	10.8	0.181	10.0	0.13	0.66
PA8-13	Golf Resort	13.8	0.181	65.0	0.23	0.20

A-3.6.2 Blind Canyon and Talega Model - Land-Use

Pre- and post-development land-use in Blind and Talega Canyons is shown in Figure A-19 and is tabulated in Table A-33.

The modeled pre-development conditions are based on the PWA land-use maps. Commercial development (TRW) is present along the ridge between Blind and Talega Canyon. The remaining modeled area is primarily open space.

The modeled development conditions were based on the B4 development alternative, the B4 principle roads plan, and the habitat restoration plan. These proposed development and habitat restoration plans were superimposed on the PWA land-use maps for existing conditions. The modeled post-development conditions are the amalgamation of these existing and proposed land-uses (see Figure A-19).

The proposed development includes single-family residential and estate housing, a golf course and a golf resort. The main arterial road in the B4 principle roads plan is aligned north to south near the western edge of the modeled area. The road was modeled as six-lane highway with an assumed impervious width of 120 feet.

Table A-33: Blind Canyon and Talega Model – Pre- and Post- Development Land Use

PWA Code	Land-Cover	Pre-Development Scenario – Drainage to Blind Canyon (Catchments 64-67)	Pre-Development Scenario – Drainage to Talega Canyon (Catchments PA8 – 3-8, 9a, 9b)	Post-Development Scenario (Catchments 64-66; PA8 – 3-11, 13)
10201-10306	Scrub & Chaparral	261	241	166
10401	Grassland	329	197	109
10501-10502, 10601	Woodland, Riparian, Forest, Meadow & Marsh	113	1	74
	Existing Development – TRW	31	34	
30202	Single Family Residential			606
30202	Estate			132
30401	Transportation			16
30501	Golf Course			150
30203	Golf Resort			14

A-3.6.3 Blind Canyon and Talega Model - Subcatchment Soils

The distribution of surficial soils in Blind Canyon and the Talega development area is shown in Figure A-20. Surficial deposits of sandy loams are dominant throughout the area, however, there are large regions of clayey soils in the middle portions of the Blind Canyon, extending south into Talega Canyon. Similar to other areas in RMV, comparison of the land use coverage map (Figure A-19) and the soil texture map (Figure A-20) shows that major portions of the proposed residential development are located in areas with clayey soils.

A-3.6.4 Blind Canyon and Talega Model – Calibration

Low flow measurements (Balance, 2001) and peak discharge estimates based on observations of high water marks (Balance, 2003b) were not collected or estimated in the Blind and Talega Canyons. Thus, data similar to that used to calibrate the SWMM models for other sub-basins in RMV were not available for the Blind Canyon and Talega Model. Therefore, it was assumed that the calibrated parameters from the Gabino Sub-Basin Model were applicable for the Blind Canyon and Talega Model.

A-3.7 Verdugo Canyon Model

A-3.7.1 Verdugo Canyon - Subcatchment Delineation

Proposed development in PA-4 within the Verdugo Sub-Basin was modeled only for the B9 Alternative. Impacts from the B4 Alternative were qualitatively evaluated and are discussed in Section 5.8.

Modeling of the Verdugo Sub-Basin was limited to the proposed development areas in the lower portion of the Canyon. For the pre-development scenario, 6 catchments are defined in Verdugo Canyon (Figure A-21), while 10 catchments were modeled in for the post-development conditions.

Both pre- and post-development subcatchments were disaggregated into valley and ridge subcatchments, as well as, subcatchments based on land-use designation. Table A-34 and Table A-35 lists the parameters of the modeled subcatchments for the pre- and post-development scenarios, respectively.

Table A-34: Verdugo Sub-Basin Model – Pre-Development Subcatchment Parameters

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
120-Valley	Open Space	34.20	0.98	0.0	2.97	0.61
120-Ridge	Open Space	74.28	0.86	0.0	2.20	0.42
121-Ridge	Open Space	428.16	0.29	9.9	1.91	0.40
122-Ridge	Open Space	218.58	1.01	0.0	1.86	0.43
123-Valley	Open Space	40.09	0.99	0.0	2.32	0.58
123-Ridge	Open Space	231.86	0.41	0.0	2.20	0.40
124-Valley	Open Space	11.41	0.95	0.0	2.99	0.52
124-Ridge	Open Space	146.45	0.29	0.0	1.31	0.50
125-Valley	Open Space	41.58	1.35	0.0	2.96	0.66
125-Ridge	Open Space	287.49	0.72	0.0	1.76	0.44

Table A-35: Verdugo Sub-Basin Model – Post-Development Subcatchment Parameters

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
120-Valley	Open Space	34.2	0.98	0	2.97	0.61
120-Ridge	Open Space	73.1	0.86	0	2.20	0.42
120-Ridge	Residential	0.0	0.86	40	2.20	0.35
120-Ridge	Transportation	0.7	0.86	100	2.20	0.00
121a-Ridge	Open Space	17.9	1.02	0	1.88	0.40
121a-Ridge	Residential	17.5	1.02	40	1.72	0.35
121b-Ridge	Open Space	60.7	0.98	0	2.05	0.34
121b-Ridge	Residential	49.7	0.98	40	2.07	0.35

Sub-catchment		Area (acres)	Average Slope (ft/ft)	Percent Impervious	Hydraulic Conductivity (in/hr)	ET Scale Coefficient
Name	Land Use					
121c-Ridge	Open Space	18.5	0.84	0	2.20	0.55
121c-Ridge	Residential	0.9	0.84	40	2.20	0.35
121c-Ridge	Transportation	1.2	0.84	100	2.20	0.00
122-Ridge	Open Space	70.5	1.15	0	1.98	0.39
122-Ridge	Residential	19.5	1.15	40	1.90	0.35
123-Valley	Open Space	39.8	0.99	0	2.31	0.58
123-Ridge	Open Space	231.9	0.41	0	2.20	0.40
124-Valley	Open Space	11.4	0.95	0	2.99	0.52
124-Ridge	Open Space	146.4	0.29	0	1.31	0.50
125-Valley	Open Space	41.6	1.35	0	2.96	0.66
125-Ridge	Open Space	287.5	0.72	0	1.76	0.44
PA4-4	Open Space	61.9	0.91	15	1.88	0.42
PA4-4	Residential	146.5	0.91	40	1.59	0.35
PA4-4	Transportation	6.5	0.91	100	2.10	0.00
PA4-5	Residential	236.2	0.93	40	1.97	0.35
PA4-5	Transportation	1.9	0.93	100	2.20	0.00

A-3.7.2 Verdugo Sub-Basin Model - Land-Use

Pre- and post-development land-use in Verdugo Sub-Basin Model is shown in Figure A-21 and is tabulated in Table A-36.

Table A-36: Verdugo Sub-Basin Model – Pre- and Post- Development Land Use

PWA Code	Land-Cover	Pre-Development Scenario	Post-Development Scenario
10201-10306	Scrub & Chaparral	1203	878
10401	Grassland	126	99
10501-10502, 10601	Woodland, Riparian, Forest, Meadow & Marsh	142	108
10701	Rock Outcrops	43	8
30202	Single Family Residential		470
30401	Transportation		10

A-3.7.3 Verdugo Sub-Basin Model - Subcatchment Soils

The distribution of surficial soils in Blind Canyon and the Talega development area is shown in Figure A-22. Surficial deposits of sandy loams are dominant throughout the area, however, there are large regions of clayey soils in catchments 122 and 124.

A-3.7.4 Verdugo Sub-Basin Model – Calibration

Available calibration data in the Verdugo Sub-Basin were upstream of the modeled catchments. Therefore, no calibration was conducted for the Verdugo Sub-Basin Model. Model parameters are based on the calibrated model from the Gobernadora Sub-Basin.

A-4 MONTHLY WATER BALANCE

The SWMM hydrologic simulation model was used to develop a monthly water balance for the modeled Sub-Basins. To enable assessment of potential impacts from proposed development, water balances were developed for three scenarios:

1. Pre-development conditions
2. Post-development conditions without BMPs
3. Post-development conditions with BMPs

The water balances of the first two scenarios were developed directly from output of the continuous hydrologic simulations using SWMM. Water balances of the third scenario were determined through subsequent analyses. The proposed BMPs were not modeled with SWMM. Rather, separate analyses were conducted to quantify the hydrologic effects of proposed BMPs, and to incorporate these effects into the water balance. All water balance results are presented in Appendix D.

A-4.1 Water Balance Calculation Procedure

The SWMM hydrologic simulation model was adapted to provide the following monthly output for each modeled subcatchment:

- Accumulated volume of precipitation
- Accumulated volume of irrigation
- Accumulated volume of surface flows from the catchment
- Accumulated volume of ET losses from the surface and subsurface
- Accumulated volume of surface flows from the catchment
- Accumulated volume of groundwater flows from the catchment

For each of the modeled catchments, the SWMM model generates 53-years of accumulated monthly output. The results can then be summed, on a monthly basis, for all catchments in the Sub-Basin, or if desired, for a subset of catchments in the Sub-Basin. The water-balance results for the first two scenarios are then simply the monthly average of the accumulated monthly output over the Sub-Basin. Monthly averages were calculated for complete 53-record, and for the dry and wet periods.

A-4.2 BMP Sizing and Inclusion in the Monthly Water Balance

BMPs were not modeled directly with SWMM, and therefore separate analyses were required to incorporate the hydrologic effects of BMPs into the water balance. The following describes the methods used to size various BMPs and the approach used to incorporate the hydrologic effects from these BMPs into the water balance.

A-4.2.1 Detention Basin – Sizing and Inclusion in Water Balance

Water quality detention basins were sized with the Water Environment Federation (WEF) standard method and criteria for sizing water quality (WQ) facilities for treatment of stormwater. Detention basins for WQ treatment were designed to capture 80 percent of the total runoff volume that achieves 80 percent reduction in pollutant loads, resulting in an overall pollutant load reduction of about 64 percent.

Following the sizing of the WQ basin, a separate analysis was used to incorporate the hydrologic effects of the WQ basin into the water balance. The main hydrologic effects of the WQ Basins are to alter the timing of surface discharges, and to increase ET. Infiltration occurring in the WQ basin was not incorporated into the water balance.

Output hydrographs generated from SWMM were routed through the WQ basins. These output hydrographs represent the predicted runoff (on a continuous basis) generated from the proposed development areas. Results from this routing analysis provides the inflows to the WQ Basin, the treated outflows routed to the stream, the untreated bypass flows routed to the stream, and ET losses, each expressed as accumulated monthly volumes over the 53-year simulation period. These monthly results were then incorporated into the water balance by appropriately modifying the monthly surface runoff and total ET.

A-4.2.2 Flow Duration Basin – Sizing and Inclusion in Water Balance

Hydrologic source control BMPs were sized to match pre- and post- development flow duration curves. With flow duration (FD) matching, 60% to 80% of the total runoff volume is captured and infiltrated, thus achieving 60% to 80% overall load reduction. Flow duration matching was designed to maintain the pre-development runoff volume as well as the distribution of hourly flows. For example, if 1000 hours of 50 cfs flows occur under pre-urban conditions, than about 1000 hours of 50 cfs flows must be maintained to match flow duration. This criterion is applied to the full range of flows under pre-developed conditions from near zero to the 10-peak flow.

The size of the FD/WQ basin was determined through an iterative process of adjusting basin storage and selecting and adjusting orifice sizes in the outlet structure until pre- and post-development flow duration curves were similar within an acceptable range. The basin was initially sized to capture the increase in runoff volume that is generated from the impervious surfaces. This capture volume is not arbitrary, but depends on the development characteristics and the soil types, and the magnitude of change in runoff created by the proposed development.

Once the lower portion of the basin was sized to capture the correct volume of runoff, the upper portion of the basin was established to detain and discharge larger flows through a specific set of orifice holes in such a way to reproduce the flow duration curve. The number, diameter and elevation of these orifice holes are determined by trial and error and by experience. The combination of sizing the lower portion of the FD/WQ basin and the upper portion to detain and discharge high flows has the affect of capturing the correct volume of runoff and matching the pre-urban distribution of hourly flows.

Similar to the WQ Basin, a separate analysis was used to incorporate the hydrologic effects of the FD/WQ basin into the water balance. The main hydrologic effects of the FD/WQ Basins are to reduce and alter the timing of surface discharges, and to increase ET. Infiltration occurring in the FD/WQ basin was not incorporated into the water balance.

Output hydrographs generated from SWMM were routed through the FD/WQ basins. Results from this routing analysis provides the inflows to the WD/WQ Basin, the treated outflows that are routed to the infiltration basin, the bypass flows routed to the stream, and ET losses, each expressed as accumulated monthly volumes over the 53-year simulation period. These monthly results were then incorporated into the water balance by appropriately modifying the monthly surface runoff and total ET.

A-4.2.3 Infiltration Basin – Sizing and Inclusion in Water Balance

The infiltration basins were sized to infiltrate the increase in the volume caused by the proposed development. The volume and surface area required for infiltration was determined through an iterative process using a spreadsheet model. The model requires the user to input the infiltration rate, evaporation rate and surface area of the infiltration basin as well as the time series discharged through the bottom orifice of the FD/WQ basin. An infiltration rate of 1 in/hr was used to approximate infiltration into sandy soils. The evaporation rate was approximated at 4 in/month to represent typical wintertime evaporation rates.

The size of the infiltration basin was determined by first specifying the area of the basin (assuming vertical sidewalls), then routing the times series output of the WQ/FD basin discharges through the infiltration basin. The basin volume is tracked for each time increment and the maximum volume that occurred within the time series is recorded. The required basin depth is then estimated by dividing the maximum volume by the area. The basin surface area is modified iteratively until a maximum basin depth of 2-ft is achieved. A maximum design depth of 2-ft was used to allow for the growth of emergent vegetation for improved water treatment.

Once the infiltration basin was sized, a separate analysis was used to incorporate the hydrologic effects of the infiltration basin into the water balance. The main hydrologic effects of the infiltration basin are to increase infiltration into the subsurface, and to increase ET. The output hydrograph generated from the spreadsheet infiltration model was converted into accumulated monthly infiltration volumes. These monthly volumes were then added to the GW flows in the water balance, and subtracted from the surface runoff.

A-4.2.4 Bioinfiltration Swale – Sizing and Inclusion in Water Balance Sizing

The bioinfiltration swales were sized using the same concepts that were utilized in sizing the infiltration basins. One main difference is that the swales can be sized to discharge runoff to the receiving streams rather than infiltrating the entire flow. As with the infiltration basins, the user defines the infiltration rate, evaporation rate, and surface area. Evaporation rates and infiltration rates were approximated at 0.0055 in/hr and 1.0 in/hr, respectively. The user also defines the swale depth. Swales were assumed to have an overflow depth of 1-ft. Depths in excess of 1-ft would not allow adequate contact between the runoff and vegetation, thus reducing treatment efficiency.

Similar to the WQ Basin, a separate analysis was used to incorporate the hydrologic effects of the swales into the water balance. The main hydrologic effects of the swale are to increase infiltration into the subsurface, and to increase ET. Output from the swale sizing program are accumulated into monthly infiltration volumes, discharge volumes to the stream, and ET volumes. These monthly totals were then appropriately incorporated into the water balance.

A-4.2.5 Storage of Non-Potable Water for Golf Course Irrigation

A potential BMP for development areas adjacent to golf courses is to capture and store urban runoff as a source of non-potable water for golf course irrigation. The potential benefits of this concept include a reduction of runoff volumes typically associated with urban development and a reduction of water importation to meet irrigation demands. The storage facilities would additionally function as a wet pond for treatment of the stormwater, prior to use for irrigation. The main limitation is that runoff and peak irrigation demands are seasonally out of phase (runoff occurs in the wet season and peak irrigation demands are in the dry season). Larger storage volumes can mitigate this limitation, however, there is point at which increased costs of larger storage facilities negate the marginal increases in benefits.

An analysis of 53-years of monthly runoff volumes from development areas and monthly irrigation demands was conducted to determine the average annual volume of runoff that could be stored as a non-potable water supply. The runoff volumes were determined from the SWMM simulations and the monthly irrigation demands are given in Table A-9. Using an assumed storage capacity, a monthly routing procedure was used to determine storage volume, irrigation withdrawals, bypass volumes, and ending storage volume. Monthly averages were then determined over the total 53-year record, as well as, during the dry and wet periods. The analysis was repeated for a range of storage capacities. A plot of storage capacity versus average irrigation usage was then used to select a favorable storage volume, one that balances the maximum irrigation usage and minimum facility size. To insure that the water quality treatment requirements are met, the selected storage volume was compared to the sizing requirements for water quality treatment, as determined by WEF method described above.

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