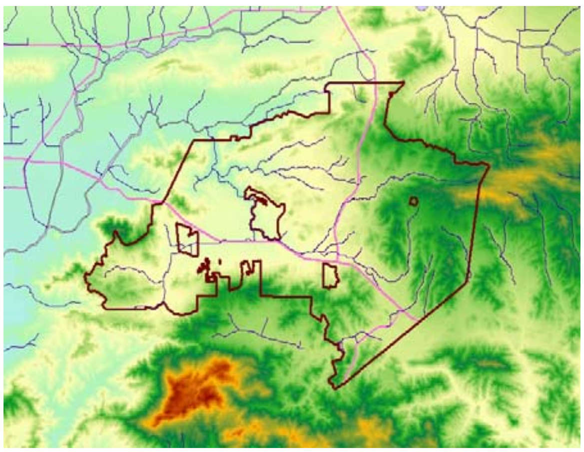
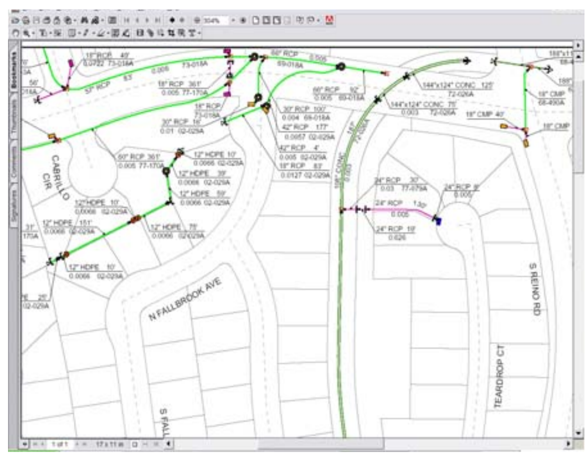
City of Thousand Oaks
Storm Drain System Master Plan
CI 4223

HYDROLOGY & DEFICIENCY STUDY



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OCTOBER 2006 Volume 1 of 4

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1. ACKNOWLEDGMENTS

This study has been completed by *Kasraie Consulting* for the *City of Thousand Oaks* Public Works Department in support of the City's Storm Drain System Master Plan.

It represents a combined effort of key individuals at the *City of Thousand Oaks*, the *Ventura County Watershed Protection District*, and *Nobel Systems, Inc*. whose contributions are hereby gratefully acknowledged.

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2. EXECUTIVE SUMMARY

All of the watersheds and subwatersheds that drain into and through the City of Thousand Oaks, consisting of approximately 60 square miles, have been studied in support of the City's Storm Drain System Master Plan effort (CI 4223).

The new 2006 hydrology and deficiency study benefits from the 2005 detailed color aerial imagery, the 2001 city-wide Light Detection and Ranging (LiDAR) technology topographic mapping, the latest General Plan land use map, and the detailed storm drain system atlas. As a result, it is considered to be the most up-to-date and technologically advanced hydrology study of its kind in the tri-county area.

The existing drainage facility locations and information were collected (by others) from as-built construction plans, and put into the City's Geographic Information System (GIS). This information consisted of storm drain system main lines, laterals, catch basins and inlets, open channels, box conduits, culverts, detention basins, etc. which are privately and or publicly owned and maintained by the City, Ventura County Watershed Protection District (VCWPD), Caltrans, and other entities. In addition to the GIS data layers of storm drainage information, some 300 individual storm drain atlas maps were prepared. The storm drain atlas maps show all the drainage facilities within the City's geographic boundaries overlaid on the parcel boundaries, topographic contours, road rights-of-way and other information.

The hydrologic analysis performed for this study is based on VCWPD's current Modified Rational Method hydrology procedures which were also adopted by the City of Thousand Oaks in the mid-seventies. The City's 1974 and 1992 comprehensive drainage master plans were also prepared using the same methods and procedures.

The hydrology and storm drain deficiency portions of the City's 1992 Master Plan of Drainage study have been updated as part of the current effort. The hydrology consists of the 24-hour 10-year and 100-year hydrology for the entire drainage areas of the City. The results of the 100-year hydrology have been compared with the 1992 drainage master plan hydrology, as well as VCWPD's 2004 Calleguas Creek Watershed hydrology Future Condition draft model results at some eighty key locations throughout the City. (Tables 1 and 2)

The comparison analysis shows that the new 2006 hydrology model peak flow rates and unit runoff values are in a reasonably good agreement with the 1992 model results. With the exception of some explainable differences, the new results are within (plus or minus) 10 percent of the City's 1992 master plan hydrology. However, the comparison with VCWPD's 2004 study did not yield a favorable agreement. Much of the difference can be attributed to routing differences within the South Branch Arroyo Conejo watershed. The 2004 study attempted to control erosive velocities by using a conveyance type of 6 (trapezoidal channel with maximum peak velocity) in the VCRAT model. The velocity restriction flattens out the coded slope of the reach to achieve the decrease in velocity, which in turn offsets the timing and thus decreases the cumulative flow. Further evaluation and discussion with the County staff will be required to reconcile the differences.

The hydraulic capacity of the City's drainage facilities (30" in diameter or larger) was estimated, and they were checked against the new 10-year peak flows. This analysis identified approximately 8% of the storm drain segments within the City may potentially be hydraulically deficient. Corrugated metal pipe storm drains that were built before 1970 and or have an invert slope of 0.01 or flatter were identified as potential structural deficiencies as well as reinforced concrete pipes built on or before 1966. Approximately 8% of these City's drainage facilities (30" in diameter or larger) may be structurally deficient. Additionally, 55 locations where the City's maintenance crew identified storm drainage-related problems were visited, and the problem spots were identified and documented.

The scope of work for the current hydrology and deficiency study was limited to creating city-wide 10-year and 100-year hydrology models, and to identify storm drains that will potentially need to be upgraded and or replaced in order to meet the City's storm drainage design requirements and improve public safety.

As the basis for the city-wide storm drainage Capital Improvement Plan, the hydraulically or structurally deficient storm drain facilities will need to be examined in more detail, and the solutions will be prioritized on the basis of benefits they provide and the associated cost of each project. This will be a future project.

3. INTRODUCTION

The purpose of the 2006 Hydrology & Deficiency Study is to create up-to-date 10-year and 100-year hydrology models for the drainage areas of the City of Thousand Oaks, and to identify storm drain facilities that do not meet the City's drainage design requirements and standards.

As stipulated in the project Scope of Work (see attached Exhibit "A" at end of report), the current study has updated the hydrology portions of the City's 1992 Master Plan of Drainage by utilizing the latest General Plan Land Use map and land cover, the 2001 Light Detection & Ranging (LiDAR) technology topographic mapping prepared by Towill, Inc., the 2005 3-inch resolution aerial imagery, and the City's Geographic Information System (GIS) parcel boundaries, street center lines, and other data layers.

The existing drainage facility locations and information were collected by Nobel Systems, Inc. of San Bernardino, California under a separate contract. The information was collected from as-built construction plans, and put into the City's GIS. This information consisted of storm drain system main lines, laterals, catch basins and inlets, open channels, box conduits, culverts, detention basins, etc. which are privately and or publicly owned and maintained by the City, VCWPD, Caltrans, and or other entities. In addition to the GIS data layers of storm drainage information, over 300 11"x17" individual storm drain atlas maps were prepared. The storm drain atlas maps show all the drainage facilities within the City's geographic boundaries overlaid on the parcel boundaries, topographic contours, road rights-of-way and other information. The storm drain plan drawing numbers are also shown as well as the size, type, length, and the slope of each facility.

The new storm drain atlas GIS data layers were used extensively for the new hydrology and deficiency study. This information was used to delineate the hydrology boundaries, and to calculate times of concentration and stream routing parameters.

Numerous detention basins have been built in Thousand Oaks over the years in order to mitigate the increases in runoff due to development. The majority of them have been built within the South Branch Arroyo Conejo watershed, which drains most of Newbury Park.

The hydraulic capacity of the City's drainage facilities (30" in diameter or larger) was estimated and evaluated against the new 10-year peak flows. This analysis identified storm drain segments within the City that may potentially be hydraulically deficient. Corrugated metal pipe storm drains that were built before 1970 and or have an invert slope of 0.01 or flatter were identified as potential structural deficiencies. Additionally, 55 locations where the City's maintenance crew identified storm drainage-related problems were visited, and the problem spots were identified, reviewed and documented.

4. DELIVERABLES

The current effort has resulted in the following deliverable products in separate bound reports or computer applications. All the project-related computer files are contained on a Compact Disc (CD) at the end of Volume 1.

VOLUME 1 - HYDROLOGY & DEFICIENCY STUDY

This report contains the results of the hydrology and deficiency analyses, comparison of the new study results with the City's 1992 Master Plan of Drainage study, along with the VCWPD 2004 Calleguas Creek Watershed study. A CD is attached at the end of this document which contains all the project-related computer files in their respective subdirectories.

VOLUME 2 - MODIFIED RATIONAL METHOD HYDROLOGY MODELS

This volume contains the input and output files of the Modified Rational Method software, VCRAT version 2.2 developed by VCWPD.

The hydrology models include the following hydrologic parameters:

- Drainage area unique identification numbers (subarea numbers)
- Drainage area for the local subarea and the total regional drainage area
- Hydrologic soil numbers, percent impervious factors
- Times of concentration, Rainfall zones
- Stream routing length, slope, type, dimensions, etc.
- Calculated peak flow and hydrographs for 10-year and 100-year storms
- Detention basins stage-storage-discharge tables
- 'Hydrograph Fattening' direct runoff and areal reduction factors at basins

Both 10-year and 100-year input and output files are contained for the following major watershed areas and the drainage areas in between:

- Arroyo Conejo
- Arroyo Santa Rosa tributary
- Conejo Mountain Creek
- Hill Canyon
- Lake Eleanor
- Lake Sherwood
- Lang Creek
- Lindero Creek
- North Fork Arroyo Conejo
- Olsen and Waverly Channels
- Potrero Creek
- Russell Creek
- Tierra Rejada Creek
- Schoolhouse Canyon
- South Branch Arroyo Conejo
- Westlake Lake

VOLUME 3 - DETENTION BASIN MANUAL

Several detention basins have been constructed in Thousand Oaks over the years in order to mitigate the increase in runoff as a result of new development. Twelve detention basins, including County owned facilities, have been modeled and included in the final hydrology models. The stage-storage-discharge information has been collected from the construction record drawings, or the latest topographic contours and the storm drain system atlas. The tables along with the associated areal reduction factors and 'fattening' direct runoff values can be found in 'Volume 2 - Modified Rational Method' document at designated detention basin identifiers.

The following detention basins have been included in the final hydrology models:

- Conejo Mountain Creek Flow-through Basin #5 (most upstream)
- Conejo Mountain Creek Flow-through Basin #4
- Conejo Mountain Creek Flow-through Basin #3
- Conejo Mountain Creek Flow-through Basin #2
- Conejo Mountain Creek Bypass Basin #1 (most downstream)
- Lake Eleanor Dam
- Lang Creek Dam
- Los Vientos Detention Basin along Borchard Road
- Maple Leaf Detention Basin
- South Branch Arroyo Conejo Inundation Area above Hwy 101
- South Branch Arroyo Conejo – South Potrero Detention Basin
- South Branch Arroyo Conejo Bypass Detention Basin along Reino Road

Several other smaller detention basins were evaluated, but they were not included in the final hydrology models. That is primarily because they do not seem to provide a meaningful peak flow reduction for 10-year storms and larger. The Bridge Gate and Lang Ranch development basins fall in this category.

Volume 3 also contains an overview map showing the location of all the detention basins and whether or not they were modeled in the final hydrology models.

Also in Volume 3, there are two tables that present the results of the detail hydrology study at each detention basin location for the 10-year and the 100-year storm frequencies, assuming the full Q10 and Q100 will flow through the basins. These tables include the hydrology identification numbers, type of detention basin, drainage areas, peak inflow, peak outflow, maximum stage in the basin, and whether or not the basin would spill over the spillway and for how long.

The detention basin Volume 4 includes recent photographs of all the basins, along with the best available construction record drawings, and other useful and relevant information, charts, etc. The water surface elevations have been adjusted to the North American Vertical Datum (NAVD) 1988 in feet in order to be consistent with the LiDAR topography.

VOLUME 4 - MAINTENANCE PROBLEM AREAS

During two field visits with City maintenance crew, 55 locations were identified as being a ‘maintenance problem area’. During the visits, the city staff explained the perceived problem at each location and shared some history of what had happened during the years past. Please see table below – Table 1.

Several photographs were taken at these sites, and the problems or issues were documented in a separate volume named: “Volume 4 - Maintenance Problem Areas”. This document also includes an aerial photograph of the said problem site with the topographic contours, drainage areas, and other relevant information, along with an overview map of the entire City depicting where the problem sites are with the corresponding identification numbers.

These problem areas have not been evaluated in detail, and no solution has been sought to mitigate the situation under the current contract scope.

Because many of these problem sites may pose a public health and safety hazard to the general public or city staff, the already identified drainage problems need to be evaluated, prioritized and mitigated in the near future.

Table 1

ID	Location	ID	Location
49	1840 Colgate Dr. – Debris/Drain Blockage	10	E. Kelly Rd. and Lynn Rd. – Sheet Flow/Structural Def.
15	Acacia Rd. and Lynn Rd. – Siltation/Debris	24	Kevin St. and Burleson Av. – Water Quality
42	Auto Mall Dr. and Cord Av.–Trash Blockage/H2O Quality	9	Lawrence Dr., Teller Rd. and Hillcrest Dr. – Ponding/Structural Def.
27	E. Avenida De Las Flores – Structural Deficiency/Siltation	38	Los Feliz Dr. and Beyer Ln. - Ponding
28	E. Avenida De Las Flores – Structural Deficiency	4	Lynn Rd and La Cam Rd. – Structural Deficiency
26	E. Calle Zocalo and Olsen Rd. – Sheet Flow/Erosion/Hydraulic Deficiency	16	Lynn Rd. and Haigh Rd. – Hydraulic Def./Ponding
44	Cunningham Rd. at Hwy. 101 – Debris/Siltation	17	Lynn Rd. and Heavenly Valley Rd. – Siltation/Ponding
30	El Monte Dr. and El Cerrito Dr. – Structural Damage	7	Lynn Rd. and Maple Leaf Av. – Structural Deficiency
54	El Monte Dr. and El Dorado Dr. – Structural Deficiency	11	Lynn Rd. and Ventu Park Rd. – Structural Deficiency
37	Erbes Rd. – Structural Damage	13	Maple Rd. and Lynn. Rd. – Structural Deficiency
35	Erbes Rd. and Falmouth Av. – Debris/Structural Def.	25	Marvella Ct. and Santa Rosa Rd. – Structural Deficiency
36	Erbes Rd. and Hillcrest Dr. – Structural Def./Sheet Flow	29	Marview Dr. (Pvt) - Erosion
45	Fairview Rd. and Los Robles Rd. – Sedimentation/Structural Def.	8	Michael Dr. and Borchard Rd. – Debris
40	Fairview Rd. and Willow Ln. – Ponding/Hydraulic Def.	23	Moody Ct. and Long Ct. – Hydraulic/Structural Deficency
41	Foothill Dr. and Hampshire Rd. – Structual Deficiency	12	Newbury Rd. and Ventu Park Rd. – Structural Deficiency
21	Fox Hills Dr. and Los Padres Dr. – Structural Def./Trash	43	Oakview Dr. and Chiquita Ln. – Ponding/Structural Deficency
22	Fox Ridge Dr. and Quails Terr. – Structural Deficiency	20	Pinecrest Dr. and Oak Creek Dr. – Structural Deficiency
19	Green Meadow Av. – Structural Deficiency	6	Regal Av. – Structural Deficiency
14	Haigh Rd. and Mountain Oak Pl. – Siltation/Ponding	48	Reino Rd. and Old Conejo Rd.- Peppertree Basin – Debris clogging
18	Haigh Rd. and Ramona Dr. – Accidents/Falling into Channel	1	Reino Rd. at SBAC Detention Basin – Structural Def./Damage
33	Hauser Cir. – Structural Deficiency	31	Rosario Dr. and Encino Vista Dr. – Hydraulic/Structural Deficiency
34	Hauser Cir. and Erbes Rd. – Hydraulic/Structural Def.	47	Siddlee St. and Young Av. – Sheet Flow/Ponding
52	Hendrix Av. and Marimar St. – Sheet Flow/Sedimentation	46	S. Skyline Dr. Btw. Los Robles Rd./Crescent Way – Blocked Chan.
55	W. Hillcrest Dr. - Erosion	50	Thousand Oaks Blvd. and Erbes Rd. – Surface Flow/Ponding
39	E. Hillcrest Dr. and Avenida de Royale – Structural Def.	32	E. Thousand Oaks Blvd. and Maegan Pl. – Erosion/Sedimentation
53	Hillcrest Dr. and Teller Rd. – Structural Damage	51	Tuolomne Av. – Hydraulic Deficiency
3	W. Kelly Rd. and Borchard Rd. – Structural Deficiency	2	Wendy Dr. and Lynn Rd. – Ponding/Sheet Flow
5	W. Kelly Rd. and Borchard Rd. – Deficient Basin		

1992 MASTER PLAN OF DRAINAGE HYDROLOGY MODELS

In order to make the results of the 1992 study more accessible for comparison purposes and further evaluation, the 1992 Modified Rational Method hydrology models were completely reconstructed. The model input files could not be found after an extensive search in the City and VCWPD files. The developer of the models, Hawks & Associates could not find the input information either.

The computer output paper printouts, which were readily available in the 1992 report were scanned, and converted to standard computer text files using the Optical Character Recognition (OCR) technology software. These files were then checked and corrected line by line so that the new output results would be identical to the 1992 output results. Several imported hydrographs had been used in the 1992 hydrology models. These were from Dos Vientos development runoff in Conejo Mountain Creek, South Potrero Detention Basin outflow, Lake Sherwood dam outflow, and Lake Eleanor outflow.

Even though every effort was made to duplicate the 1992 hydrology models verbatim, the results in some of the main channels or streams are not identical to the 1992 printed results. This is because the input hydrographs for the above four locations that were found, were not exactly the same as the ones used by Hawks & Associates in 1992.

The results of the individual subareas and reaches that did not have an imported hydrograph table were nearly identical to the printed 1992 hydrology results.

In addition to reconstructing the 1992 hydrology models, the drainage subareas, hydrology links and nodes where also digitized and vectorized into GIS data layers. All the hydrology results were also attached, as attributes, to the GIS shapefiles. This information is readily available through the new ArcGIS application. Please see the following section.

ELECTRONIC DATA

Two kinds of electronic data files have been prepared and delivered to the City.

- Report documents: These will be delivered on CD-ROM, and are intended for use on the City's computer network, along with the associated tables, charts, and maps in Microsoft Word, Excel, text, image format, etc. Some files have also been converted to PDFs for distribution. Please see the attached CD in the back of Volume 1.

- ArcGIS Data Layers: Several GIS data layers have been created and delivered as part of this effort. An ArcView ArcGIS application has been set up for use on City personal computers running ArcGIS 9.1 or later that provides user-friendly access to all the hydrology or storm drain-related data layers.

  The GIS application includes the latest delineated subareas and hydrologic links, land use assumptions, hydrologic soils map, percent impervious factors, times of concentration, 100-year rainfall isohyetals and rain zones, calculated peak 10-year and 100-year flows, unit runoff values, and many other watershed parameters.

  The results of the 1992 Master Plan of Drainage hydrology are also readily available, such as subarea boundaries, hydrologic links and nodes for the 10-year and 100-year storms.

  In addition to the above information, a special data layer has been prepared that shows the results of an analysis comparing the 2006 hydrology peak flows with the above 1992 study peak runoff values at over 80 locations throughout the City. The purpose of this comparison is to determine whether or not the peak flows, drainage area sizes, and unit runoff values are in good agreement or not and to allow the user a quick and simple way of determining peak flow changes between the 1992 and 2006 studies.

  Similarly, a separate analysis has been completed which compares the 2006 hydrology with the VCWPD Calleguas 2004 study.

  The above comparative analyses are further discussed in the following sections.

- Intranet MapGuide System: The City's internal GIS system is also capable of displaying the above hydrology and facility GIS data layers and information. Even though the Intranet software functionality is somewhat different from the ArcGIS application and the system is not used as an analysis tool, the Intranet system is more readily available to everyone with access to the system, and it provides an exceptional platform to disseminate the hydrologic and drainage facility information. This application is developed and maintained by the City IT staff.

5. HYDROLOGY

The 2006 hydrology models, similar to the 1974 and 1992 Master Plans of Drainage studies, are based on the VCWPD Modified Rational Method (VCRAT) version 2.2 procedures. The complete 10-year and 100-year hydrology input and output are included in VOLUME 2 - MODIFIED RATIONAL METHOD HYDROLOGY MODELS.

A complete hydrology model includes several watershed parameters, such as drainage area size, rainfall and intensity, land use and land cover, hydrology soil numbers, watershed and stream conveyance parameters, time of concentration, and other drainage facility information such as detention basins.

Hydrology Plates 1 through 8 depict the latest hydrology subarea delineation, stream network used in the hydrology models, along with the subarea identification numbers corresponding to the above Modified Rational Method hydrology models, drainage area size, the 10-year and 100-year unit runoff values per City's request.

The following paragraphs explain the basis for all the important watershed parameters used in the modeling effort:

5.1 RAINFALL

The current VCWPD Hydrology Manual contains the 50-year rainfall isohyetals, along with the designated rainfall zones. Please see the 'Rainfall Map'. Approximately three quarters of the City falls within the K-zone, and the remaining area is mostly in L-zone and a small area tributary to Arroyo Santa Rosa tributary falls within the J or J'-prime zone.

The L-zone has the highest total 24-hour rainfall and the highest intensity. Coupled with the highest runoff producing hydrologic soil type 1, areas of the Westlake Lake watershed and the upper portions of South Branch Arroyo Conejo watershed produce the highest amounts of runoff on average than other parts of the City.

VCWPD has not published 100-year 24-hour isohyetals. The 100-year rainfall contours shown on the above Rainfall Map are based on the published 50-year isohyetals multiplied by the VCWPD storm frequency adjustment factor of 1.11.

Generally speaking, the L-zone produces more runoff than K-zone, and the K-zone areas produce more runoff than J or J-prime zones.

5.2 LAND USE

The City's latest General Plan Land Use map was used as the basis for the ultimate future condition land use and land cover assumptions for hydrologic modeling purposes. The following table presents the land use map designations, descriptions of those designations, total area (sq. miles) of each designation, and the assumed effective percent impervious values used for the runoff factor. The subarea weighted average values of effective imperviousness were calculated through a GIS overlay analysis. Some of the subareas are partly outside the City of Thousand Oaks boundary with the runoff draining into the City. Therefore, a decision was made to apply the adjacent land use from within the city and verify it against the latest aerial photography.

Table 2

LAND USE ASSUMPTION	LAND USE CODE	EFFECTIVE PERCENT IMPERVIOUS	TOTAL AREA (SQUARE MILES)	PERCENT OF TOTAL
Residential-High Density	1	47	0.92	1.7
Residential-Medium Density	2	42	3.40	6.1
Residential-Low Density	3	25	13.68	24.7
Residential-Very Low Density	4	23	5.38	9.7
Residential-Reserve	5	23	1.07	1.9
Commercial/Residential	6	47	0.05	0.1
Commercial	7	60	2.71	4.9
Industrial	8	80	1.88	3.4
Institutional (CLU)	9	42	0.85	1.5
School-Elementary	10	42	0.36	0.7
School-Intermediate	11	42	0.13	0.2
School-High School	12	47	0.24	0.4
Parks & Open Space-Existing	13	5	20.13	36.4
Parks & Open Space-Proposed	14	5	1.75	3.2
Residential-Developable Land	15	23	0.36	0.7
Undevelopable Land	16	5	1.84	3.3
Lake & Other Water Bodies	17	100	0.07	0.1
Special Study Area	18	Variable	0.03	0.1
Flood Control R/W	19	80	0.44	0.8

TOTAL AREA: 55 SQ MI

5.3 EFFECTIVE IMPERVIOUSNESS

The percent impervious used for the land use designations are modified from previous accepted values listed in the 1975 Ventura County Hydrology Manual (Manual). With thirty years of experience using the Manual, and with the valuable aerial photo coverage, properties designated as low density or large parcels were discovered to have added much more pavement than anticipated by planners. For example, North Ranch area contains very large parcels with large homes that are surrounded by tennis courts, circular driveways, swimming pools, and walkways which increase the assumed 15 percent effective imperviousness to 25 percent or more. As land and property values have increased, lot size for single family homes have decreased. New tracts within Dos Vientos are a good example of large homes on relatively smaller lots compared to houses built in the 1980’s. Working parents or young couples without children do not have time or funds to manage big yards with extensive grass. The current trend is to have pots on pavement and small green lawns cared for by a Home Owners Association. Often the latter maintain common ground for the use of all owners on land set aside for neighborhood play areas or parks.

5.4 HYDROLOGIC SOIL TYPES

The complex soil designations contained in the 1970 Soil Conservation Service Report are divided into seven hydrologic soils. They are a family of curves which are similar to the soils adopted for Los Angeles Public Works. The densest, hardest and least impervious soil is Soil 1. The loss rate used to produce this curve that relates “C” value to rainfall intensity is 0.25 inches per hour. Most of the hilltops are Soil 1. Soil 2 is more porous with a loss rate of 0.40 inches per hour but it too has a low percolation rate since most of it is degenerated bedrock mixed with fine silt. Soil 3 is the most common soil in the agricultural areas. It is a rich loam that produces abundant lemons, avocados and strawberries. The loss rate is 0.5 inch per hour; however with much urbanization occurring in the valleys the “C” value is often modified for impervious cover. Soil 4 is alluvial and usually is a mixture of loam and some gravel or sand. It occurs at the foot of eroding mountains and in old streambeds. Soil 4 loss rate is 0.75 inch per hour. Soil 5 occurs in well-drained areas and consists of mostly gravel and rocks. It quite often originates from water-borne soil that stays on the bottom of flow-paths while the lighter silt particles wash out. The final two soils, 6 and 7 comprise an even smaller percentage of the County area and have very high porosity and percolation rates. The following table presents the area of each hydrologic soil group and the percentage of total area within the City of Thousand Oaks. Total area is approximately 55 square miles.

Table 3

SOIL NUMBER	TOTAL AREA (SQUARE MILES)	PERCENT OF TOTAL
1	33.42	60.9
2	15.02	27.4
3	4.04	7.4
4	1.64	3.0
5	0.40	0.7
6	0.32	0.6
7	0.00	0.0

5.5 STREAM ROUTING

Within the Modified Rational Method Hydrology Model, specific channel sections including natural mountain channel, natural valley channel, standard street section, circular pipe and rectangular or trapezoidal channels may be specified as water conveyances. The pipe diameter or channel side slopes, bottom width, and depth may be specified in addition to the composite lining roughness values for each reach.

The channel length and slope plus the above channel section data provide the information necessary for the system to route the hydrographs in a drain from one confluence to the next downstream confluence. Using GIS, these attributes can be quickly and accurately applied for each reach.

For the 2006 hydrology models, the representative slopes of each reach were calculated using the latest 10-meter Digital Elevation Model (DEM) downloaded from the USGS website. The average slope for each cell within the DEM was calculated and an overlay analysis with the digitized reaches was performed. From this, a representative slope for each reach was achieved.

5.6 TIME OF CONCENTRATION

5.6.1 GENERAL

Of all the parameters in the Modified Rational Hydrology Modeling, the most important one is Time of Concentration. With recommended subarea size from 40 to 80 acres, times of concentration usually fall between 5 minutes to 30 minutes with the latter being a rare occurrence of very flat ground of a porous quality. The conditions that effect the time include the size of the subarea, the soil type and percent impervious, the slope and conveyance type of the different reaches, the roughness of the reaches, the total length of travel for the slowest drop of rain to the outlet, and most important of all, the intensity of the rainfall. The Intensity-Duration curves for 10-year to 100-year storms are a family of curves but the Thousand Oaks area contains considerable area that is in the higher intensity rain-zone called L Zone. The other dominant zone in Thousand Oaks is K Zone. The procedure for computing time of concentration is spelled out in two examples in the Manual. In that same Manual the sensitivity of the time can be understood more easily by looking at Plates C-1 through C-4. The difference for the 100-year intensity between a five minute time of concentration and a seven minute concentration in the L Zone rainfall is 23 percent. For the K Zone the change is not so dramatic but still significant at 20 percent. In flatter areas such as the area between Wendy Drive and Borchard Road, times of concentration are much longer.

The times of concentration, Tc values were calculated for 50-60 subareas for both the 10-year and the 100-year storm frequencies, and the all the rest of the Tc values were estimated, using professional judgement with the 1992 hydrology model information as a guide.

5.6.2 DETERMINATION OF AREA

From the known point of concentration and with the best topography available, the ridge line perpendicular to the contours is drawn or digitized until the uppermost ridge where rain falling on that point flows away from the subarea. Often the person at this point will return to the lowest point and proceed up the ridge on the opposite side until the previous high point is intersected. With today's GIS programs, the acreage is easily determined. If the subarea is in excess of 80 acres, it is wise to see where another division point could be. If the subarea is much less than 40 acres, try to move down-stream if possible. There are times when circumstances do not warrant following the rules but very small subareas produce times of concentration so short as to not be a true representation of that watershed and the impact of the runoff and facility cost estimates are inflated.

5.6.3 SOIL TYPE AND PERCENT IMPERVIOUS

Often a subarea is more than one soil type. Since the C values in the formula for Modified Rational belong to a family of curves, it is possible to calculate the weighted soil type and use the curve closest to the dominant type. For example, if half the subarea is soil type 1 and the other half is soil type 3, then values for soil type 2 would be correct to use. A land use table was presented above (Table 2 on pg. 12) that shows the land use designation and the assumed effective percent impervious factors to use for various land uses. For a given subarea, the calculated weighted-average effective percent impervious value is used in the Modified Rational analysis.

5.6.4 INITIAL ESTIMATION FOR TIME

In order to proceed, the engineer or hydrologist must estimate the time that will be required for this subarea to concentrate at the outlet. As a rough "rule of thumb", a 10-year storm can have times as short as 9 minutes and as long as 17 minutes. The steeper the slope, the smoother the conveyance, and more impervious a subarea is, the shorter the time. If an area has a flatter slope, minimum development and rough ground like an orchard or field crop, the time will be much longer.

Using engineering judgment, begin with a medium trial value of 12 minutes. Using the D Plates in the Manual for the storm frequency applied (Zone K, 10-year in this example) find the column for 12 minutes. Scanning down the column determine the maximum intensity ("I") for 12-minutes (2.29 inches per hour). Earlier the engineer or hydrologist determined the correct soil type and percent imperviousness to use for this subarea. Refer to the F Plates in the Manual that correspond to the dominate soil type. The F Plates only indicate "C" values for zero, 23, and 50% imperviousness. Usually the "C" value is an interpolation between the lines at the max intensity value previously determined. The initial flow rate can now be calculated by multiplying the area (in acres) times the intensity in Inches per hour times the C value. The flow value ("Q") is in cubic feet per second (cfs). Q = A x I x C is the Algebraic expression for the relationship of the hydrologic variables to flow.

5.6.5 SUBAREA SUBDIVIDING

In an urban setting with natural off-site area, the most logical break point for a Tract is where the upstream flow reaches the Tract boundary. Upstream of that point the natural watershed may have more than one tributary canyon. Begin at a point where the junction occurs and follow the ridge between them up to the boundary ridge. Start again at the junction to divide the smaller tributary for the lower boundary. Do the same for the main line so two sub-subareas are now delineated. Perhaps the reach below the junction is the only one needed to reach the Tract. Thousand Oaks currently has a fine storm drain facility Atlas for every constructed drain through mid-2005. If this example includes an existing Tract, the area served by the collector pipe becomes an additional sub-subarea. Now our example has four parts where each part has area that is a percent of the total area. Since the flow is in direct proportion to the area, prorate the flow into cfs for each subarea. Now you are ready to calculate the time in minutes.

5.6.6 NATURAL WATERSHEDS INITIAL AREA

In the Modified Rational Hydrology Method, the Initial area of overland flow in a natural watershed, where no flow path has been eroded, is the most important decision the engineer or hydrologist has to make. Many other methods have set limits on the length of overland flow or derived an equation to plug in values. Ventura County still requires that the point of scour from the ridge to a point where the slope through a short reach at the outlet for the initial area is the end of sheet flow. Examining hundreds of prior studies, there are some guidelines to decrease the number of reiterations. From the most hydraulically remote point, start with a 10-acre subarea that is part of your whole subarea. Check the slope through the lowest elevation to the next contour. Using Plate F 2 (Velocity- Discharge-Slope Relationships, Natural Mountain Channels) find your small area discharge (using the cfs per acre from your first assumption of 12 minutes) on the abscissa and proceed up until you intersect the slope through the reach. It frequently happens that the slope is over ten percent in which case the slope needs to be modified by the Slope Correction Curve, plate G-1 in the Manual. Scour can occur at lower velocities in streambeds, but in the mountains and hills of Ventura County the hard soil needs six to eight feet per second to scour. Once the point is established, the distance from the most remote point is measured in feet. The *minimum* overland velocity for different frequency storms and effective slopes up to 25-percent is shown on Plate F-1 in the Manual. The velocities can be higher if the ground is bare of vegetation, shallow bedrock, or recently burned. Often this time to reach concentrated river outlet flow is 65-80-percent of the time of concentration for the whole subarea.

In a typical subarea, only one or maybe two reaches will bring the flow to the Tract for which the drain is being designed. The time for each reach is calculated by measuring the distance from the uppermost point (where scour began) to a point that seems like a wise choice to stop. Examples would be just prior to a large lateral junction to the main channel, an obvious change in slope, or a point where man-made channelization is going to occur. The difference between the upper and lower elevations for that reach divided by the distance gives the slope. Again entering into the Plate F-2 and using the flow determined previously for the scour point determination but using the new slope for the next reach, find the upstream velocity. (It will not necessarily be the same as the velocity through the scour velocity check since the slope is different). Divide the reach length by the velocity and convert the time to minutes which is added to the initial time. Use this same technique until the bottom of the subarea is reached. If the sum of the times does not equal the estimate of 12-minutes there will be two possibilities for the next iteration. If your calculated time is longer than the 12 minutes estimated, use the time that you calculated for travel time. There will be a less value for both the intensity and the C value. If the resulting flow differs by ten percent or less from your initial iteration, that is a good value and the task is complete. However, if the time is shorter, the impact is two fold. Shorter time means higher intensity and also a higher C value. When you calculate the new flow rate with your second iteration, the result may be more than 10 percent different. If that happens, the process must be repeated until a result is found within 10 percent.

5.6.7 URBAN AREAS INITIAL TIME

Usually this situation is much easier to calculate than the natural areas. By inspection the engineer or hydrologist decides where to begin. Most of the time this point will be at the hydraulically most remote part of the area. Modern lots are graded to drain to the street since garden walls often mark the perimeter of a Tract and block drainage. Carefully measure the distance to the street from the most remote point of the back yard. The Manual recommends using the minimum value on the F-1 curve unless long and steep grades require applying the slope.

5.6.8 STREET FLOW TIME

The H curves in the Manual, which represent four different street designs and their Velocity-Discharge-Slope Relationships, contain a lot of information that is useful. The user is often confused by the fact that only a half street section is shown as an insert on the Log-Log curve. The Discharge is for a full street and not a half street. Other information includes the depth of flow including top of curb, the property line and building line. Depending on the standard used in the past in the City of Thousand Oaks, it may be necessary to provide curb inlets and a drain pipe once the flow reaches top of curb in a 10-year storm. That point will constitute the end of the street flow reach. Additional time in the pipe to the subarea outlet will be calculated and is typically very short.

5.7 AREAL REDUCTION

A very important factor in completing a large-scale VCRAT model is to account for the decreased rainfall intensity over a large area. While the VCRAT model assumes uniform rainfall intensity across the entire watershed, this is not necessarily the case in reality. Observations of recording rain gage charts and corresponding stream gage records show a pattern of shifted high intensity rainfall with time to reflect the passage of bands of rain across or up the valley of a watershed for most severe winter storms. VCWPD continues to apply a watershed-specific ‘areal reduction’ factor to reduce peak runoff values computed in their Modified Rational Method hydrology studies. The areal reduction factor is a percentage that come from a curvilinear relationship between drainage area size and percent reduction of flow. The smaller the drainage area size, the higher the areal reduction factor and the lower the peak flow reduction will be. Similarly, the larger the drainage area size, the lower the areal reduction factor, and the higher the peak flow reduction will be.

Because VCWPD jurisdictional channels generally drain large watersheds and drainage basins, the use of areal reduction factors is justified. However, the City drainage facilities generally drain smaller subwatersheds and drainage areas (under 1000 acres), and consequently the use of areal reduction factors for most City-owned drains are probably not justified. The exception to this guideline may be in places where the City owns a culvert on a jurisdictional channel or other special cases.

Currently, the common practice at VCWPD is to apply areal reduction factors to drainage facilities whose tributary drainage area size is over 500 acres.

5.8 COMPARISON OF RESULTS

The current project has updated the City's 1992 Master Plan of Drainage hydrology report, and therefore it is important to compare the results of the current hydrology with the previous study and consider any wide variations or discrepancies. Additionally, the current study results have been compared with the results of the VCWPD Calleguas Creek Watershed 'Future Condition' draft report which was shared with the Cities in the watershed in May 2004.

The following table compares the drainage area sizes for each of the three hydrology models within the Arroyo Conejo watershed, which is the watershed that all three models have in common. The Hydrology Manual guideline is to limit the drainage area size between 40 to 80 acres, but under a few specific conditions this study has deviated from this guideline, because of the size of the drainage area, point of runoff concentration, etc. Occasionally deviation from the above guideline is inevitable.

The major difference between the current 2006 model with the two previous hydrology models is that the latest LiDAR topography, aerial imagery and the actual storm drain atlas have been utilized for the new study, therefore, it is deemed to be the most up-to-date and accurate or precise model.

Table 4

NAME OF MODEL	1992 THOUSAND OAKS MPD	2004 VCWPD 'FUTURE' CALLEGUAS	2006 THOUSAND OAKS SDSMP UPDATE
Total # of Subareas	492	689	528
Drainage Area (acres)	28906	29168	29141
Average Subarea Size (acres)	55	42	55
Minimum Subarea Size (acres)	13	1	18
Maximum Subarea Size (acres)	114	114	104

However, the most equitable and fair comparison between hydrology models is to compare the unit runoff values (cfs-per-acre) on a subarea level after all the watershed parameters are taken into account and the final calculations are completed.

Because, the subarea unit runoff values comparison does not compare runoff values in streams or channels, a second comparison is required to compare the overall peak runoff differences at selected concentration points such as bridges, culverts, confluences, junction structures, and other key points.

Three major comparative analyses have been performed:

- The overall 100-year unit runoff values (cfs/acre) for all the subareas in the above three hydrology models have been calculated. The calculated unit runoff values for each subarea has been colorized and plotted, so that it will be easier to compare the results between the three models. Three color maps are included in the report called “Q100 CFS/ACRE UNIT RUNOFF” one for each model.

- Over 80 comparison points have been selected along the storm drain system or the stream network throughout the City. The calculated peak 100-year runoff values at the above 80 locations have been tabulated from both the 1992 hydrology and the current 2006 model. The following Table 1 presents the location identification number, location description and the drainage areas, Q100 values, and the ratio of the 2006 results over the 1992 hydrology results.

  An additional column presents the ratio of the unit runoff values. The purpose behind this information is to provide a balanced comparison of the two models at the selected comparison points, regardless of the differences in the drainage area sizes, land use, conveyance and other assumptions.

- At the above 80 comparison points, the calculated peak 100-year runoff values have been tabulated from both the 2004 VCWPD Calleguas Creek Watershed Future Condition (draft) hydrology and the current 2006 model. The following Table 2 presents the location identification number, location description and the drainage areas, Q100 values, and the ratio of the 2006 results over the 2004 hydrology results.

  An additional column presents the ratio of the unit runoff values. The purpose behind this information is to provide a balanced comparison of the two models at the selected comparison points, regardless of the differences in the drainage area sizes, land use, conveyance and other assumptions.

  Because the Calleguas Creek watershed does not include the drainage areas tributary to Westlake Lake and other areas that drain into Los Angeles County, the values in the table for drainage areas tributary to Los Angeles are empty.

- As stated in the Executive Summary, the comparison analysis shows that the new 2006 hydrology model peak flow rates and unit runoff values are in a reasonably good agreement with the 1992 model results. With the exception of some explainable differences, the new results are within (plus or minus) 10 percent of the City’s 1992 master plan hydrology. However, the comparison with VCWPD’s 2004 study did not yield a favorable agreement. Much of the difference can be attributed to routing differences within the South Branch Arroyo Conejo watershed. The 2004 study attempted to control erosive velocities by using a conveyance type of 6 (trapezoidal channel with maximum peak velocity) in the VCRAT model. The velocity restriction flattens out the coded slope of the reach to achieve the decrease in velocity, which in turn offsets the timing and thus decreases the cumulative flow. Further evaluation and discussion with the County staff will be required to reconcile the differences.

- The hydraulic capacity of the City’s drainage facilities (30” in diameter or larger) was estimated, and they were checked against the new 10-year peak flows. This analysis identified approximately 8% of the storm drain segments within the City may potentially be hydraulically deficient. Corrugated metal pipe storm drains that were built before 1970 and or have an invert slope of 0.01 or flatter were identified as potential structural deficiencies as well as reinforced concrete pipes built on or before 1966. Approximately 8% of these City's drainage facilities (30" in diameter or larger) may be structurally deficient.

6. EXISTING DRAINAGE FACILITY DEFICIENCIES

As the basis for the City's future Capital Improvement Plan, hydraulic and structural deficiencies in the storm drain system need to be identified. Because the new storm drain system atlas and the hydrology are developed in GIS, we are afforded an opportunity to integrate the two databases and data layers together and identify potential deficiencies in the City's existing storm drain system.

6.1 HYDRAULIC DEFICIENCIES

Potential hydraulic deficiencies have been identified by estimating a 'full flow' condition capacity for all the City storm drains that are 30" in diameter or larger, and checking those values against the calculated 10-year peak flows. The storm drain capacity is estimated by using the Manning's formula to calculate the discharge assuming the drain is flowing full. The Manning's formula takes into account the storm drain size and dimensions, flow area, wetted perimeter, slope, and the roughness factor. The peak Q10 has been estimated along the length of each storm drain through GIS manipulation, or manually. It is assumed the inlets and catch basins feeding flow to each storm drain intercept at least a full Q10. The potential hydraulic deficiencies are identified by performing a GIS 'query' to see if the estimated capacity of each storm drain segment is within 10 percent of the projected Q10 for that segment. The results of the special hydraulic deficiency analysis is in the form of a GIS data layer, and they are also plotted in red on the 'Existing Deficient Facilities' Plates 1 through 8.

6.2 STRUCTURAL DEFICIENCIES

Additional structural deficiencies have been identified by isolating the CMP storm drains which were built before 1970 with a 0.01 or flatter slope as well as reinforced concrete pipes built on or before 1966.

According to the City's 1999 CMP Remediation Study CI-1274 prepared by Hawks & Associates, 'the majority of the CMPs are in average to good condition which is significant considering that most of the drains are 30 years old. All drains however, with only a few exceptions, show some corrosion within the bottom third of the pipe. The corrosion is more severe in arch pipes and pipes that have relatively flat slopes where ponding of water can occur.'

The results of the special structural deficiency analysis is also in the form of a GIS data layer, and they are also plotted with double black lines on the 'Existing Deficient Facilities' Plates 1 through 8.

6.3 MAINTENANCE PROBLEM AREAS

The City's maintenance crew was very helpful during our field visits. Over forty problem spots were visited in December 2005 and January 2006. The 'Maintenance Problem Areas' have been documented as Volume 4, which includes a description of the perceived problem, photographs of the site, GIS location map containing aerial imagery, topography and some other relevant information. Because these maintenance problem areas have not been studied and evaluated, it is difficult to know if they are really a problem, or the symptom of a problem. The location of the maintenance problem spots are shown on the above 'Existing Deficient Facilities' Plates 1 through 8 as a star with a unique identification number.

7. REFERENCES

1. 1974 – Master Plan of Drainage by Koebig & Koebig. Ventura, California.
2. 1987 – Lake Sherwood Hydrology Study for the Haaland Group, Inc. by Hawks & Associates, Ventura, California.
3. 1992 – Master Plan of Drainage by Hawks & Associates, Ventura, California.
4. 1999 – CMP Remediation Study CI 1274 by Hawks & Associates, Ventura, California.
5. 2003 – Calleguas Creek Watershed Feasibility Study – Hydrology Appendix by US Army Corps of Engineers Los Angeles District, Los Angeles, California.
6. 2003 – Calleguas Creek Watershed Hydrology Study (Year 2000 Present Condition) by Ventura County Watershed Protection District, Ventura, California.
7. 2004 – Calleguas Creek Watershed Hydrology Study (Future Condition-Draft Report) by Ventura County Watershed Protection District, Ventura, California.
8. 2006 – Storm Drain Atlas by Nobel Systems, Inc. San Bernardino, California.
9. 2006 – Storm Drain System Master Plan – Hydrology & Deficiency Study by Kasraie Consulting, Ventura, California.

			2006 SDSMP	1992 MPD	1992 MPD		2006 SDSMP		RATIO-AREA	RATIO-Q100	RATIO-UNIT RUNOFF
WATERSHED	**2006 SDSMP ID**	**LOCATION**	**NODE ID**	**NODE ID**	**TOTAL AREA (ACRES)**	**TOTAL Q100 (CFS)**	**TOTAL AREA (ACRES)**	**TOTAL Q100 (CFS)**	**2006/1992**	**2006/1992**	**2006/1992**
ARROYO CONEJO	138	SKELETON CANYON AT KANAN ROAD	138C	129C	175	495	179	514	1.02	1.04	1.02
	151	SKELETON CANYON AT CRESTHAVEN DRIVE	151B	142B	1184	3048	1138	2907	0.96	0.95	0.99
	160	ARROYO CONEJO (SKELETON CANYON) AT HILLCREST DRIVE	160B	152B	1628	3862	1565	3350	0.96	0.87	0.90
	174	LOS ROBLES DRAIN	174C	N/A			263	813			
	203	ARROYO CONEJO PRIOR TO JCT. WITH ERBES ROAD DRAIN	203B	197B	2925	6613	2936	6612	1.00	1.00	1.00
	207	ERBES ROAD DRAIN PRIOR TO JCT. WITH ARROYO CONEJO	207C	207C	258	733	243	606	0.94	0.83	0.88
	209	ARROYO CONEJO AFTER JCT. WITH ERBES ROAD DRAIN	209BC	208BC	3239	7254	3179	7142	0.98	0.98	1.00
	262	ARROYO CONEJO PRIOR TO JCT. WITH LANG CREEK	262B	274B	5145	10928	5082	11347	0.99	1.04	1.05
	263	ARROYO CONEJO AFTER JCT. WITH LANG CREEK	263AB	276AB	9105	15020	9042	15651	0.99	1.04	1.05
	324	PARK DRAIN, EXCLUDING THE OAKS MALL DRAIN	324C	345B	642	1420	743	1946	1.16	1.37	1.18
	361	ARROYO CONEJO PRIOR TO JCT. WITH SBAC	361AB	378AB	12257	19506	12358	22318	1.01	1.14	1.13
	670	ARROYO CONEJO AFTER JCT. WITH SBAC	670AB	579AB	20954	31626	20956	31280	1.00	0.99	0.99
	709	ARROYO CONEJO PRIOR TO JCT. WITH NORTH FORK ARROYO CONEJO	709A	612A	22324	32311	22328	32945	1.00	1.02	1.02
	879	ARROYO CONEJO AFTER JCT. WITH NORTH FORK ARROYO CONEJO	879AB	N/A			27595	44825			
	922	CONEJO CREEK PRIOR TO JCT. WITH ARROYO SANTA ROSA AT CITY LINE	922A	799A	28906	42927	29061	47167	1.01	1.10	1.09
	923	CONEJO CREEK PRIOR TO JCT. WITH ARROYO SANTA ROSA	923A	800A	28906	42927	29141	47181	1.01	1.10	1.09
CONEJO MOUNTAIN CREEK	474	CMC INLFLOW TO MOST U/S BASIN	474C	N/A			212	697			
	532	CMC BYPASS BASIN INFLOW	532CD	N/A			1545	3242			
	534	CMC BYPASS BASIN OUTFLOW	534CE	449C	1584	1933	1545	966	0.98	0.50	0.51
HILL CANYON	913	HILL CANYON	913C	646B	1078	2905	1169	3007	1.08	1.04	0.95
LANG CREEK	36	LANG CREEK ABOVE WESTLAKE BLVD AND LANG RANCH DEV	36AB	36AB	1302	3054	1279	2984	0.98	0.98	0.99
	57	LANG CREEK TRIBUTARY FROM LANG RANCH- WESTLAKE BL	57B	56B	167	545	187	616	1.12	1.13	1.01
	70	LANG CREEK DAM INFLOW	70A	61AB	2144	3617	2238	4024	1.04	1.11	1.07
	71	LANG CREEK DAM OUTFLOW	71A	61AB	2144	3617	2238	829	1.04	0.23	0.22
	89	LANG CREEK TRIBUTARY FROM LANG RANCH	89B	76B	328	969	361	1028	1.10	1.06	0.96
	92	LANG CREEK ABOVE ERBES ROAD DAM PEAK REDUCTION	92A	79A	2820	3753	2838	2149	1.01	0.57	0.57
	109	LANG CREEK DAM PEAK REDUCTION	109AB	91A	3327	3867	3324	3130	1.00	0.81	0.81
	118	LANG CREEK TRIBUTARY	118BC	100BC	298	801	316	844	1.06	1.05	0.99
	124	LANG CREEK PRIOR TO JCT. WITH ARROYO CONEJO	124A	107A	3960	4116	3960	4321	1.00	1.05	1.05
LOS ANGELES COUNTY	1544	LINDERO CREEK AT LINDERO CANYON ROAD	1544AB	1544AB	1228	2690	1231	2466	1.00	0.92	0.91
	1559	LINDERO CREEK AT COUNTY LINE	1559AB	1559AB	1965	4553	1967	4883	1.00	1.07	1.07
	1582	RUSSELL CREEK AT CITY LINE	1582C	1582C	409	1083	446	1145	1.09	1.06	0.97
	1712	WESTLAKE LAKE OUTFLOW INTO LOS ANGELES COUNTY	1712A	1706A	14713	16338	14604	17198	0.99	1.05	1.06
NORTH FORK ARROYO CONEJO	739	NORTH FORK ARROYO CONEJO TRIBUTARY	739B	663B	375	917	384	1035	1.02	1.13	1.10
	750	NORTH FORK ARROYO CONEJO PRIOR TO JCT. WITH CASTANO CHANNEL	750B	673B	724	1588	749	1758	1.03	1.11	1.07
	765	CASTANO CHANNEL PRIOR TO JCT. WITH NORTH FORK ARROYO CONEJO	765C	690C	496	1371	488	1372	0.98	1.00	1.02
	766	NORTH FORK ARROYO CONEJO AFTER JCT. WITH CASTANO CHANNEL	766BC	691BC	1220	2929	1237	3119	1.01	1.06	1.05
	780	NORTH FORK ARROYO CONEJO BELOW LYNN ROAD	780B	703BC	1613	3655	1672	3990	1.04	1.09	1.05
	782	NORTH FORK ARROYO CONEJO PRIOR TO JCT. WITH WAVERLY CHANNEL	782B	705B	1738	3849	1798	4232	1.03	1.10	1.06
	789	WAVERLY CHANNEL BELOW MOORPARK ROAD	789C	712C	211	632	210	640	1.00	1.01	1.02
	798	WAVERLY CHANNEL AT LYNN ROAD	798C	721C	627	1732	634	1879	1.01	1.08	1.07
	811	WAVERLY CHANNEL PRIOR TO JCT. WITH NORTH FORK ARROYO CONEJO	811C	733C	1029	2728	1039	2998	1.01	1.10	1.09
	812	NORTH FORK ARROYO CONEJO AFTER JCT. WITH WAVERLY CHANNEL	812BC	734BC	2767	6485	2837	7083	1.03	1.09	1.07
	818	NORTH FORK ARROYO CONEJO PRIOR TO JCT. WITH OLSEN CHANNEL	818B	739B	3052	6916	3122	7613	1.02	1.10	1.08
	829	OLSEN CHANNEL AT MOORPARK ROAD	829C	750C	251	826	253	842	1.01	1.02	1.01
	864	OLSEN CHANNEL TRIBUTARY TO NORTH FORK ARROYO CONEJO	864C	779C	1562	3803	1610	3880	1.03	1.02	0.99
	865	NORTH FORK ARROYO CONEJO AFTER JCT. WITH OLSEN CHANNEL	865BC	780BC	4614	10688	4732	11451	1.03	1.07	1.04
	875	NORTH FORK ARROYO CONEJO ABOVE HILL CANYON TR PLANT	875B	789B	4992	11002	5111	11816	1.02	1.07	1.05
	878	NORTH FORK ARROYO CONEJO PRIOR TO JCT. WITH ARROYO CONEJO	878B	792B	5148	10968	5267	11880	1.02	1.08	1.06

TABLE 5
Comparison Points Table-2006 vs. 1992 Hawks Study

			2006 SDSMP	1992 MPD	1992 MPD		2006 SDSMP		RATIO-AREA	RATIO-Q100	RATIO-UNIT RUNOFF
WATERSHED	2006 SDSMP ID	LOCATION	NODE ID	NODE ID	TOTAL AREA (ACRES)	TOTAL Q100 (CFS)	TOTAL AREA (ACRES)	TOTAL Q100 (CFS)	2006/1992	2006/1992	2006/1992
POTRERO CREEK	1658	LAKE SHERWOOD OUTFLOW	1658B	1661B	10916	13115	10916	13115	1.00	1.00	1.00
	1670	BRIDGEGATE PRIOR TO JCT. WITH POTRERO CREEK (BASIN INFLOW)	1670C	1670C	265	947	265	875	1.00	0.92	0.92
	1671	BRIDGEGATE PRIOR TO JCT. WITH POTRERO CREEK (BASIN OUTFLOW)	1671C	1670C	265	947	265	875	1.00	0.92	0.92
	1685	LAKE ELEANOR CREEK AT COUNTY LINE (SE POTRERO CRK)	1685CD	1687C	500	1527	570	1785	1.14	1.17	1.03
	1691	LAKE ELEANOR CREEK OUTFLOW PRIOR TO JCT. WITH POTRERO CREEK	1691C	1691C	826	1710	877	1483	1.06	0.87	0.82
	1692	POTRERO CREEK AFTER JCT. WITH LAKE ELEANOR CONFLUENCE	1692BC	1692BC	12283	13797	12359	14012	1.01	1.02	1.01
	1700	POTRERO CREEK INFLOW TO WESTLAKE LAKE	1700B	1700B	12631	13917	12732	14175	1.01	1.02	1.01
SCHOOL HOUSE CANYON	1620	SCHOOL HOUSE CANYON ABOVE THOUSAND OAKS BLVD	1620A	1620A	596	1434	632	1648	1.06	1.15	1.08
	1624	SCHOOL HOUSE CANYON ABOVE HWY 101	1624A	1624A	755	1641	745	1747	0.99	1.06	1.08
	1641	SCHOOL HOUSE CANYON INFLOW TO WESTLAKE LAKE	1641AB	1640AB	1418	3610	1400	3099	0.99	0.86	0.87
SOUTH BRANCH ARROYO CONEJO	409	SBAC SOUTH POTRERO DETENTION BASIN INLFOW	409B	N/A			359	1252			
	410	SBAC SOUTH POTRERO DETENTION BASIN OUTFLOW	410B	400C	369	498	359	336	0.97	0.67	0.69
	541	SBAC ABOVE KIMBER	541B	453B	4305	8722	4314	5395	1.00	0.62	0.62
	547	SBAC ABOVE REINO & BORCHARD	547B	456B	4455	8781	4506	5474	1.01	0.62	0.62
	551	SBAC TRIBUTARY BASIN INFLOW	551C	N/A			161	473			
	553	SBAC TRIBUTARY BASIN OUTFLOW	553C	N/A			161	465			
	555	SBAC TRIBUTARY ABOVE REINO & BORCHARD	555C	461D	232	636	245	687	1.06	1.08	1.02
	556	SBAC BELOW REINO & BORCHARD	556BC	463BC	4744	9226	4751	5797	1.00	0.63	0.63
	576	NEWBURY PARK DRAIN NO 2 AT REINO ROAD	576CD	480C	437	1331	544	1585	1.24	1.19	0.96
	580	NEWBURY PARK DRAIN NO 2 AT NB HIGH SCHOOL	580C	484C	575	1502	667	1657	1.16	1.10	0.95
	582	NEWBURY PARK DRAIN NO 2 PRIOR TO JCT. WITH SBAC	582CD	489C	762	1878	719	1760	0.94	0.94	0.99
	587	SBAC ABOVE WENDY DRIVE	587B	492B	5656	11097	5639	7352	1.00	0.66	0.66
	595	NEWBURY PARK DRAIN NO 1 ABOVE JESSICA ST	595C	499C	266	975	259	799	0.97	0.82	0.84
	599	NEWBURY PARK DRAIN NO 1 PRIOR TO JCT. WITH SBAC	599C	505C	428	1390	473	1363	1.11	0.98	0.89
	610	SBAC TRIBUTARY	610C	516C	264	795	312	750	1.18	0.94	0.80
	617	SBAC ABOVE BORCHARD/HWY 101 (BASIN INFLOW)	617B	523BC	6753	12213	6774	9111	1.00	0.75	0.74
	618	SBAC ABOVE BORCHARD/HWY 101 (BASIN OUTFLOW)	618B	523BC	6753	12213	6774	5435	1.00	0.45	0.44
	N/A	RANCHO CONEJO BLVD CULVERT TRIBUTARY TO SBAC	N/A	539C	537	1255	443	1177	0.82	0.94	1.14
	639	MAPLE LEAF DETENTION BASIN INLFLOW	639C	544C	107	388	124	357	1.16	0.92	0.79
	646	KELLY ROAD DRAIN	646C	554C	483	1500	403	836	0.83	0.56	0.67
	662	SBAC PRIOR TO JCT. WITH ARR CONEJO	662B	578B	8697	13717	8598	9190	0.99	0.67	0.68
TIERRA REJADA CREEK	1027	TIERRA REJADA CREEK AT CITY BOUNDARY LINE	1027A	932A	1168	3423	1160	3059	0.99	0.89	0.90
TRIUNFO CANYON ROAD DRAIN	1654	TRIUNFO CANYON ROAD DRAIN INFLOW INTO WESTLAKE LAKE	1654B	1654B	396	1264	418	1383	1.06	1.09	1.04

TABLE 5

Comparison Points Table-2006 vs. 1992 Hawks Study

			2006 SDSMP	2004 CALLEGUAS FUTURE MODEL	2004 CALLEGUAS FUTURE MODEL (VCWPD)		2006 SDSMP		RATIO-AREA	RATIO-Q100	RATIO-UNIT RUNOFF
WATERSHED	2006 SDSMP ID	LOCATION	NODE ID	NODE ID	TOTAL AREA (ACRES)	TOTAL Q100 (CFS)	TOTAL AREA (ACRES)	TOTAL Q100 (CFS)	2006/2004	2006/2004	2006/2004
ARROYO CONEJO	138	SKELETON CANYON AT KANAN ROAD	138C				179	514			
	151	SKELETON CANYON AT CRESTHAVEN DRIVE	151B				1138	2907			
	160	ARROYO CONEJO (SKELETON CANYON) AT HILLCREST DRIVE	160B	2852D	1594	2579	1565	3350	0.98	1.30	1.32
	174	LOS ROBLES DRAIN	174C				263	813			
	203	ARROYO CONEJO PRIOR TO JCT. WITH ERBES ROAD DRAIN	203B	2895DE	2904	5231	2936	6612	1.01	1.26	1.25
	207	ERBES ROAD DRAIN PRIOR TO JCT. WITH ARROYO CONEJO	207C	2907E	255	774	243	606	0.95	0.78	0.82
	209	ARROYO CONEJO AFTER JCT. WITH ERBES ROAD DRAIN	209BC	2908DE	3209	6044	3179	7142	0.99	1.18	1.19
	262	ARROYO CONEJO PRIOR TO JCT. WITH LANG CREEK	262B	2973DE	5044	10056	5082	11347	1.01	1.13	1.12
	263	ARROYO CONEJO AFTER JCT. WITH LANG CREEK	263AB	2976CD	9003	13572	9042	15651	1.00	1.15	1.15
	324	PARK DRAIN, EXCLUDING THE OAKS MALL DRAIN	324C				743	1946			
	361	ARROYO CONEJO PRIOR TO JCT. WITH SBAC	361AB	3079C	12311	16791	12358	22318	1.00	1.33	1.32
	670	ARROYO CONEJO AFTER JCT. WITH SBAC	670AB	3080BC	20948	23727	20956	31280	1.00	1.32	1.32
	709	ARROYO CONEJO PRIOR TO JCT. WITH NORTH FORK ARROYO CONEJO	709A	3113B	32350	23679	22328	32945	0.69	1.39	2.02
	879	ARROYO CONEJO AFTER JCT. WITH NORTH FORK ARROYO CONEJO	879AB				27595	44825			
	922	CONEJO CREEK PRIOR TO JCT. WITH ARROYO SANTA ROSA AT CITY LINE	922A	3293BC	28725	31662	29061	47167	1.01	1.49	1.47
	923	CONEJO CREEK PRIOR TO JCT. WITH ARROYO SANTA ROSA	923A	3300B	29033	31579	29141	47181	1.00	1.49	1.49
CONEJO MOUNTAIN CREEK	474	CMC INLFLOW TO MOST U/S BASIN	474C	2363CE	206	699	212	697	1.03	1.00	0.97
	532	CMC BYPASS BASIN INFLOW	532CD	N/A	1545	N/A	1545	3242	1.00		
	534	CMC BYPASS BASIN OUTFLOW	534CE	2510C	1537	952	1545	966	1.01	1.01	1.01
HILL CANYON	913	HILL CANYON	913C				1169	3007			
LANG CREEK	36	LANG CREEK ABOVE WESTLAKE BLVD AND LANG RANCH DEV	36AB	2736CD	1260	2616	1279	2984	1.02	1.14	1.12
	57	LANG CREEK TRIBUTARY FROM LANG RANCH- WESTLAKE BL	57B				187	616			
	70	LANG CREEK DAM INFLOW	70A	2764CE	2158	3197	2238	4024	1.04	1.26	1.21
	71	LANG CREEK DAM OUTFLOW	71A	2764CE	2158	647	2238	829	1.04	1.28	1.24
	89	LANG CREEK TRIBUTARY FROM LANG RANCH	89B				361	1028			
	92	LANG CREEK ABOVE ERBES ROAD DAM PEAK REDUCTION	92A	2782CD	2875	2155	2838	2149	0.99	1.00	1.01
	109	LANG CREEK DAM PEAK REDUCTION	109AB				3324	3130			
	118	LANG CREEK TRIBUTARY	118BC				316	844			
	124	LANG CREEK PRIOR TO JCT. WITH ARROYO CONEJO	124A	2807C	3892	3599	3960	4321	1.02	1.20	1.18
LOS ANGELES COUNTY	1544	LINDERO CREEK AT LINDERO CANYON ROAD	1544AB				1231	2466			
	1559	LINDERO CREEK AT COUNTY LINE	1559AB				1967	4883			
	1582	RUSSELL CREEK AT CITY LINE	1582C				446	1145			
	1712	WESTLAKE LAKE OUTFLOW INTO LOS ANGELES COUNTY	1712A				14604	17198			
NORTH FORK ARROYO CONEJO	739	NORTH FORK ARROYO CONEJO TRIBUTARY	739B				384	1035			
	750	NORTH FORK ARROYO CONEJO PRIOR TO JCT. WITH CASTANO CHANNEL	750B				749	1758			
	765	CASTANO CHANNEL PRIOR TO JCT. WITH NORTH FORK ARROYO CONEJO	765C	3190D	505	1245	488	1372	0.97	1.10	1.14
	766	NORTH FORK ARROYO CONEJO AFTER JCT. WITH CASTANO CHANNEL	766BC				1237	3119			
	780	NORTH FORK ARROYO CONEJO BELOW LYNN ROAD	780B				1672	3990			
	782	NORTH FORK ARROYO CONEJO PRIOR TO JCT. WITH WAVERLY CHANNEL	782B	3205C	1813	2921	1798	4232	0.99	1.45	1.46
	789	WAVERLY CHANNEL BELOW MOORPARK ROAD	789C				210	640			
	798	WAVERLY CHANNEL AT LYNN ROAD	798C	3221D	644	1427	634	1879	0.98	1.32	1.34
	811	WAVERLY CHANNEL PRIOR TO JCT. WITH NORTH FORK ARROYO CONEJO	811C				1039	2998			
	812	NORTH FORK ARROYO CONEJO AFTER JCT. WITH WAVERLY CHANNEL	812BC	3234CD	2883	5250	2837	7083	0.98	1.35	1.37
	818	NORTH FORK ARROYO CONEJO PRIOR TO JCT. WITH OLSEN CHANNEL	818B				3122	7613			
	829	OLSEN CHANNEL AT MOORPARK ROAD	829C	3250D	251	878	253	842	1.01	0.96	0.95
	864	OLSEN CHANNEL TRIBUTARY TO NORTH FORK ARROYO CONEJO	864C				1610	3880			
	865	NORTH FORK ARROYO CONEJO AFTER JCT. WITH OLSEN CHANNEL	865BC	3280CD	4773	7717	4732	11451	0.99	1.48	1.50
	875	NORTH FORK ARROYO CONEJO ABOVE HILL CANYON TR PLANT	875B				5111	11816			
	878	NORTH FORK ARROYO CONEJO PRIOR TO JCT. WITH ARROYO CONEJO	878B	3292C	5312	7617	5267	11880	0.99	1.56	1.57

TABLE 6
Comparison Points Table-2006 vs. 2004 VCWPD Study

			2006 SDSMP	2004 CALLEGUAS FUTURE MODEL	2004 CALLEGUAS FUTURE MODEL (VCWPD)		2006 SDSMP		RATIO-AREA	RATIO-Q100	RATIO-UNIT RUNOFF
WATERSHED	**2006 SDSMP ID**	**LOCATION**	**NODE ID**	**NODE ID**	**TOTAL AREA (ACRES)**	**TOTAL Q100 (CFS)**	**TOTAL AREA (ACRES)**	**TOTAL Q100 (CFS)**	**2006/2004**	**2006/2004**	**2006/2004**
POTRERO CREEK	1658	LAKE SHERWOOD OUTFLOW	1658B				10916	13115			
	1670	BRIDGEGATE PRIOR TO JCT. WITH POTRERO CREEK (BASIN INFLOW)	1670C				265	875			
	1671	BRIDGEGATE PRIOR TO JCT. WITH POTRERO CREEK (BASIN OUTFLOW)	1671C				265	875			
	1685	LAKE ELEANOR CREEK AT COUNTY LINE (SE POTRERO CRK)	1685CD				570	1785			
	1691	LAKE ELEANOR CREEK OUTFLOW PRIOR TO JCT. WITH POTRERO CREEK	1691C				877	1483			
	1692	POTRERO CREEK AFTER JCT. WITH LAKE ELEANOR CONFLUENCE	1692BC				12359	14012			
	1700	POTRERO CREEK INFLOW TO WESTLAKE LAKE	1700B				12732	14175			
SCHOOL HOUSE CANYON	1620	SCHOOL HOUSE CANYON ABOVE THOUSAND OAKS BLVD	1620A				632	1648			
	1624	SCHOOL HOUSE CANYON ABOVE HWY 101	1624A				745	1747			
	1641	SCHOOL HOUSE CANYON INFLOW TO WESTLAKE LAKE	1641AB				1400	3099			
SOUTH BRANCH ARROYO CONEJO	409	SBAC SOUTH POTRERO DETENTION BASIN INLFOW	409B	2275C	358	1215	359	1252	1.00	1.03	1.03
	410	SBAC SOUTH POTRERO DETENTION BASIN OUTFLOW	410B	2277F	358	325	359	336	1.00	1.03	1.03
	541	SBAC ABOVE KIMBER	541B	2545B	4363	3500	4314	5395	0.99	1.54	1.56
	547	SBAC ABOVE REINO & BORCHARD	547B				4506	5474			
	551	SBAC TRIBUTARY BASIN INFLOW	551C				161	473			
	553	SBAC TRIBUTARY BASIN OUTFLOW	553C				161	465			
	555	SBAC TRIBUTARY ABOVE REINO & BORCHARD	555C				245	687			
	556	SBAC BELOW REINO & BORCHARD	556BC	2559BC	4737	3989	4751	5797	1.00	1.45	1.45
	576	NEWBURY PARK DRAIN NO 2 AT REINO ROAD	576CD				544	1585			
	580	NEWBURY PARK DRAIN NO 2 AT NB HIGH SCHOOL	580C				667	1657			
	582	NEWBURY PARK DRAIN NO 2 PRIOR TO JCT. WITH SBAC	582CD				719	1760			
	587	SBAC ABOVE WENDY DRIVE	587B		5643	6242	5639	7352	1.00	1.18	1.18
	595	NEWBURY PARK DRAIN NO 1 ABOVE JESSICA ST	595C				259	799			
	599	NEWBURY PARK DRAIN NO 1 PRIOR TO JCT. WITH SBAC	599C				473	1363			
	610	SBAC TRIBUTARY	610C				312	750			
	617	SBAC ABOVE BORCHARD/HWY 101 (BASIN INFLOW)	617B	2611BC	6529	6546	6774	9111	1.04	1.39	1.34
	618	SBAC ABOVE BORCHARD/HWY 101 (BASIN OUTFLOW)	618B				6774	5435			
	N/A	RANCHO CONEJO BLVD CULVERT TRIBUTARY TO SBAC	N/A	2646D	483	1212	443	1177	0.92	0.97	1.06
	639	MAPLE LEAF DETENTION BASIN INLFLOW	639C				124	357			
	646	KELLY ROAD DRAIN	646C				403	836			
	662	SBAC PRIOR TO JCT. WITH ARR CONEJO	662B	2690BC	8637	8348	8598	9190	1.00	1.10	1.11
TIERRA REJADA CREEK	1027	TIERRA REJADA CREEK AT CITY BOUNDARY LINE	1027A				1160	3059			
TRIUNFO CANYON ROAD DRAIN	1654	TRIUNFO CANYON ROAD DRAIN INFLOW INTO WESTLAKE LAKE	1654B				418	1383			

TABLE 6
Comparison Points Table-2006 vs. 2004 VCWPD Study