

FINAL REPORT

STEELHEAD CREEK DRINKING WATER QUALITY STUDY AND WATERSHED ASSESSMENT

Grant Agreement No: 03-241-555-2

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February 2008

1. Executive Summary

a. Funding: The project was funded by the STATE WATER RESOURCES CONTROL BOARD with funds from SFY 2002 Costa-Machado Water Act of 2000 CALFED Drinking Water Quality Program. Extensive additional resources were provided by Municipal Water Quality Investigations, Office of Environmental Health Hazard Assessment, and Dry Creek Conservancy.

b. Project Description: This project assesses the impact of Steelhead Creek on Sacramento River water quality, and relates the impact of Dry Creek Watershed, a major tributary of Steelhead Creek experiencing rapid growth, on Steelhead Creek flows and water quality. Major tasks of the project are as follows:

- To monitor water quality and measure stream flows at upstream and downstream locations to characterize the watershed. This task was carried out by Dry Creek Conservancy (DCC) and DWR Municipal Water Quality Investigations (MWQI). MWQI and DCC collected numerous seasonal grab samples for laboratory analysis over the course of the grant period, with an emphasis on “first flush” and other major rain events. Autosampler stations were installed by the separate teams to collect flow-integrated composites for estimating loads of selected contaminants. In addition, DCC maintained continuous in-stream sensors on each major tributary, and MWQI maintained a sensor on Steelhead Creek. Each team followed similar field procedures and quality control practices.
- To map land use types and estimate impervious surface (IS) associated with the areas of each type as a first step toward developing a model to describe how future changes in land use could relate to changes in water quality in Dry Creek, Steelhead Creek, and the Sacramento River. The contract was revised August 29, 2006 to include tasks to develop impervious surface (IS) coefficients that can be used to estimate the IS of land uses in the Dry Creek Watershed, and to develop a method of developing coefficients for any watershed in California. This task was carried out by MWQI and CalEPA Office of Environmental Health Hazard Assessment (OEHHA).
- To identify erosion problems in the Dry Creek Watershed due to factors such as unauthorized vehicle traffic, construction runoff, and increased runoff due to urbanization, and to communicate that information to local agencies. This task was done by DCC.

The activities associated with these three tasks are reported in three separate reports from MWQI, OEHHA, and DCC that support each other and are related by overall project goals.

c. Municipal Water Quality Investigations report summary: The objectives of the MWQI portion of this study were to:

- Characterize water quality conditions in Steelhead Creek during dry weather and storm events.
- Relate water quality conditions in Steelhead Creek to activities in the upper watershed.
- Calculate the loads of key drinking water constituents from the Steelhead Creek watershed.

- Relate the Steelhead Creek loads to the urban runoff loads from the greater Sacramento metropolitan area and the loads from wastewater discharged from the Sacramento area.
- Identify data gaps.

The study was subdivided into several different study areas. A summary of results and conclusions are presented below and in the MWQI report.

MWQI Summary of Findings

Hydrology

Understanding the hydrologic conditions in the watershed is critical to understanding the patterns in water quality constituents and to calculating the loads of drinking water constituents discharged to the Sacramento River from Steelhead Creek.

Precipitation in the Steelhead Creek watershed was monitored at a number of locations. Precipitation during the 2001-2006 study period ranged from 80 to 106 percent of normal in the Sacramento River basin.. A precipitation index was developed to estimate average precipitation conditions throughout the watershed.

A variety of hydrologic conditions were present during the study. According to the DWR water year classification system, water years 2001 and 2002 were dry, water year 2004 was below normal, water years 2003 and 2005 were above normal, and water year 2006 was wet. Flow measurements were calculated from a stage/flow curve developed during this study. Flows varied from a low of 10 cubic feet per second (cfs) to a high of over 4,200 cfs (February 2004). The highest flows occurred during the wet season, generally between November and April. The lowest flows occurred during the May to October period, although there were frequent periods in the dry season when short duration storm events with significant precipitation resulted in high, winter-like flows.

Flow Contributions to Steelhead Creek

There are four sub-watersheds that drain to the Municipal Water Quality Investigations (MWQI) Program monitoring station on Steelhead Creek. Flow data are available for Dry Creek and Arcade Creek, but not for Robla and Magpie creeks or the upper Steelhead Creek sub-watershed. Limited information is available on the drainage pumped into Steelhead Creek from the area west of the watershed.

Dry Creek receives urban runoff, open space drainage, high quality water from the Placer County Water Agency (PCWA) canals, and wastewater effluent from the Roseville Dry Creek Wastewater Treatment Plant (WWTP). There is a strong seasonal flow pattern with high flows exceeding 1,000 cfs during the wet season and low flows generally in the range of 10 to 20 cfs during the dry season. The Dry Creek WWTP flows varied from 6.6 to 41 cfs during the time that effluent flow data were available. During the dry season, the effluent flows can exceed the flow in the creek upstream of the WWTP. Dry Creek is the largest tributary to Steelhead Creek and contributes a substantial amount of the flow in Steelhead Creek.

Arcade Creek receives urban runoff from a highly urbanized watershed. There is a seasonal flow pattern with high flows in the wet season exceeding 100 cfs and low flows in the dry season often dropping below 1 cfs. Although flows in Arcade Creek are lower than in Dry Creek, it is a significant source of water to Steelhead Creek during storm events.

Drainage from areas on the west side of Steelhead Creek is pumped into Steelhead Creek at two main pumping stations; the Reclamation District 1000 (RD1000) Plant 8 pump station and the City of Sacramento Sump 102. Monthly drainage volumes pumped into Steelhead Creek from the RD1000 Plant 8 pump station and Sump 102 were available from July 2001 through June 2004. The pumped drainage varies from less than 1 percent of the flow in Steelhead Creek in the summer months up to 52 percent during sudden rain events after extended dry periods. The average flow contribution was 17 percent during 2001 to 2004. The RD1000 discharge contributes the most flow to Steelhead Creek.

Water Quality

This report focused on the key constituents of concern to drinking water suppliers. These are organic carbon and related measurements (total trihalomethane formation potential, ultraviolet light absorbance), bromide, TDS and EC, nutrients, and pathogen indicator organisms.

Seasonal Variability

The Steelhead Creek data indicate there is a strong seasonal pattern for all constituents except indicator bacteria. Organic carbon concentrations are lowest during the dry season and highest during the wet season. The other constituents had the opposite seasonal pattern with the highest concentrations during the dry season and lowest concentrations during the wet season.

The lowest total organic carbon (TOC) concentrations occur between June and September and the highest TOC concentrations occur between November and January. For a quick relative indicator of field TTHMFP, UVA₂₅₄ provided the simplest and best screening method

The lowest bromide and total dissolved solids (TDS) concentrations occur in December and January and the highest concentrations occur between July and September. The lowest total nitrogen (total N) and total phosphorus (total P) concentrations occur between December and March. The highest concentrations occur in the early summer and late fall months. Most of the total P detected was orthophosphate, indicating that there is little particulate phosphorus in Steelhead Creek.

High levels (> 1,000 most probable number [MPN] or colony forming unit [CFU]/100 ml) of total coliforms, fecal coliforms, and *Escherichia coli* (*E. coli*) are found year round in Steelhead Creek. Drinking water guidelines and recreational use criteria are exceeded in every month. The highest levels of all indicator bacteria are found during and immediately after storm events.

Concentration/Flow Relationships

The various water quality constituents respond differently to increasing flows during storm events.

TOC concentrations initially increase as flows increase and then drop down to 8 to 10 mg/L when flows exceed 1,000 cfs. This pattern suggests that there is a reservoir of TOC in the watershed that is washed into Steelhead Creek during storm events.

Bromide concentrations generally decrease with increasing flow, with concentrations ranging from 0.01 to 0.03 mg/L at flows exceeding 1,000 cfs. Between 200 and 1,000 cfs there is greater variability in the bromide concentrations (0.01 to 0.2 mg/L). These data suggest that there may be a source of bromide in the watershed that is washed into the creek during some storm events but generally storm runoff dilutes the bromide that is present in the creek during dry weather.

TDS concentrations range from 165 to 338 mg/L at baseflows. Once flows reach about 400 cfs, TDS concentrations start to decrease. At flows in excess of 1,000 cfs, TDS concentrations are generally less than 150 mg/L. This indicates that storm flows dilute the TDS that is present in the creek during dry weather.

Nitrate plus nitrite concentrations are highest and most variable at baseflows, ranging from 0.17 to 5.7 mg/L. The concentrations decrease with increasing flow with concentrations ranging from 0.48 to 1.19 mg/L at flows exceeding 1,000 cfs. Orthophosphate shows the same pattern as nitrate plus nitrite. Concentrations range from 0.09 to 1.3 mg/L at baseflows and decrease to 0.01 to 0.3 mg/L at flows exceeding 1,000 cfs. The immediate decrease in nutrient concentrations as flow increases suggests that storm runoff dilutes the nutrient concentrations present in the creek during dry weather.

Although the bacterial data were not examined in relationship to flows in the creeks, the data indicate that bacterial indicator organisms are highest immediately following rain events.

Annual Variability

Although at Steelhead Creek there were a variety of conditions ranging from dry to wet during the 2001-2006 study period, there was no significant difference between water years for TOC, dissolved organic carbon (DOC), bromide, total Kjeldahl nitrogen, ammonia, total P, and orthophosphate. Although there were statistical differences in TDS and nitrate plus nitrite concentrations between several study years, there was no apparent explanation for the differences.

Comparison to Upper Watershed

The TOC concentrations in Dry Creek and its tributaries are higher than the concentrations in Steelhead Creek. The median concentrations in the upper watershed ranged from 7.1 to 10.4 mg/L with Cirby Creek having the highest concentrations and the greatest variability. The Steelhead Creek median concentration during this time period was 6.7 mg/L. The data indicated that the WWTP does not adversely affect TOC concentrations in Dry Creek.

DCC did not monitor bromide in the Dry Creek watershed so it is unclear if the source of bromide in Steelhead Creek is Dry Creek, one of the other tributaries, or the pump-ins from RD1000 and the City of Sacramento.

With the exception of Cirby Creek, the EC levels in the upper watershed were lower than the EC levels in Steelhead Creek. The median concentrations in the upper watershed ranged from 157 $\mu\text{S}/\text{cm}$ to 309 $\mu\text{S}/\text{cm}$. The data indicated that in the upper watershed, the Dry Creek WWTP may influence EC levels. Similarly, the data indicate that other sources in the watershed such as Robla and Magpie creeks or the water pumped in from RD1000 or the City of Sacramento contribute to the EC levels in Steelhead Creek.

The Dry Creek WWTP has a substantial impact on the nutrient concentrations in Dry Creek. The nitrate plus nitrite concentrations in the tributaries to Dry Creek and in Dry Creek at R1 had relatively low nitrate plus nitrite and orthophosphate concentrations. The median concentration of nitrate plus nitrite increased from 0.48 mg/L at R1 to 1.35 mg/L at Hayer Park (below the WWTP). The median orthophosphate concentrations increased from 0.05 mg/L at R1 to 0.24 mg/L at Hayer Park. The Steelhead Creek nitrate plus nitrite concentrations (median of 0.95 mg/L) are lower than the Dry Creek at Hayer Park concentrations, potentially due to lower concentrations in Arcade Creek. The orthophosphate concentrations in Steelhead Creek (median of 0.23 mg/L) are similar to Dry Creek at Hayer Park, even though lower concentration water enters Steelhead Creek from Arcade Creek.

Total coliform levels are high at all of the upstream sites and in Steelhead Creek during periods immediately following rain events and during dry periods. The Steelhead Creek data are more variable than the upstream tributary data. The *E. coli* levels in Steelhead Creek are higher and more variable than the upstream data immediately after rain events and during the dry season, indicating that other tributaries and drainage contribute to the levels in Steelhead Creek.

Comparison to Sacramento River

TOC, bromide, EC, total N, and total P concentrations in Steelhead Creek are significantly higher and more variable than concentrations in the Sacramento River at the West Sacramento Water Treatment Plant (WTP) intake. Indicator bacteria data were not available for the West Sacramento WTP intake so Steelhead Creek data were compared to data from the Sacramento WTP intake on the Sacramento River downstream of Steelhead Creek and the American River. These data indicate that Steelhead Creek bacteria levels are higher than those found at the Sacramento WTP intake.

Loads

An extensive analysis of TOC loads in Steelhead Creek was conducted for this study. Daily TOC loads were calculated with several different methods and compared with loads from the SRWTP and with loads in the Sacramento River. Monthly loads were calculated for TDS, nitrate plus nitrite, and orthophosphate.

The TOC loads from Steelhead Creek show the same pattern as the loads in the Sacramento River at Hood; the greatest loads occur from December to March and the lowest loads occur

during the summer months. The daily load from Steelhead Creek represented as little as 3 percent of the load in the Sacramento River during the dry season and up to 93 percent of the river load during the wet season. Additional urban runoff enters the Sacramento River between the confluence with Steelhead Creek and Hood so the total urban contribution at Hood is higher. The estimated daily TOC load from the SRWTP was up to 40 to 60 percent of the load in the river during the fall months when Sacramento River flows are typically lowest. Although the load from Steelhead Creek and the SRWTP do not represent the total urban load to the river, these data indicate that urban runoff and wastewater discharges have a substantial impact on the Sacramento River at Hood and may have been underestimated in previous synoptic estimations of urban loading.

Bromide, TDS, nitrate plus nitrite, and orthophosphate loads from Steelhead Creek are highest during the December to March period and lowest during the summer months. Based on monthly load estimates, Steelhead Creek contributes between 0.2 and 8.4 percent of the bromide load in the river, 0.08 to 3.5 percent of the TDS load, 0.6 to 19 percent of the nitrate plus nitrite load, and 0.6 to 14 percent of the orthophosphate load. The load of each of these constituents contributed by the SRWTP was not calculated for this study.

Land Use

Several literature sources have stated that impairment can occur with as little as 10 to 12 percent impervious cover (IC) and is likely at 25 percent and above. The Steelhead Creek watershed already has a substantial level of IC at about 24 percent overall. However, IC is spread out throughout the watershed, with the highest areas of IC concentrated in much of the southern and central portions. At 24 percent total watershed IC in 2002, it is highly likely that urbanization has resulted in water quality impairment. This observation is corroborated by data from this study and from monitoring programs on Arcade Creek. A positive observation of these findings is that projected growth, and thus change in IC, occurs mostly around existing urban areas; outlying upper watershed areas appear to remain largely unchanged or in rural/very low-density residential land uses.

There are several regulatory agencies and watershed groups currently involved in identifying sources of water quality problems and implementing potential solutions. If the projected increase in IC of 6 percent at buildout ends up being fairly close to reality, it is possible that these programs can slow or reduce the level of water quality impairment potentially associated with increased development.

There was not enough data within the project timeframe to evaluate potential correlation between land use changes and water quality. This would require at least another full year of adequate data layers and monitoring using probabilistic statistical techniques. However, this analysis has value as baseline data to be compared with additional data five to seven years from now, along with water quality data from watershed tributaries that can be used to correlate with land use changes.

MWQI Conclusions

The Steelhead Creek watershed is more complex and larger than the 181 square mile natural drainage area.

There are several sources of water from outside the natural drainage area that discharge to Dry Creek and Steelhead Creek. The quantity and quality of these additional sources are not well characterized. Water from the Placer County Water Agency (PCWA) canal system is discharged to several tributaries of Dry Creek. No information is available on the quantity of water discharged from the canal system. According to DCC (2007), canal water generally improves the quality of the tributaries to Dry Creek but no data are presented in the DCC report on the canal discharges. RD1000 and the City of Sacramento pump water into Steelhead Creek from the area west of the natural drainage. Data were available on the monthly quantities of water pumped for several years. These data indicate that the Westside drainage can represent up to 52 percent of the monthly volume of water in Steelhead Creek. The extent of these drainage areas is unknown and land use in these areas was not analyzed as part of this study.

The concentrations of key drinking water constituents in Steelhead Creek are substantially higher than the concentrations in the Sacramento River.

This study provided data collected over five years and under a variety of hydrologic conditions that showed that Steelhead Creek contains significantly higher concentrations of organic carbon, bromide, TDS, and nutrients than the Sacramento River at the West Sacramento WTP intake. Although not statistically analyzed, the bacteria levels in Steelhead Creek are higher than the levels found in the Sacramento River at the Sacramento WTP intake (the only location on the Sacramento River for which bacterial data were available). These data provide key information on the impacts of urbanization on water quality.

Steelhead Creek provides a substantial load of key drinking water constituents to the Sacramento River.

The loads of TOC, bromide, TDS, and nutrients in Steelhead Creek are highest between December and March and lowest during the summer months. The daily load from Steelhead Creek represented as little as 3 percent of the load in the Sacramento River during the dry season and up to 93 percent of the river load during the wet season. Based on monthly load estimates, Steelhead Creek contributes between 0.1 and 8.2 percent of the TOC load in the river, 0.2 and 8.4 percent of the bromide load, 0.08 to 3.5 percent of the TDS load, 0.6 to 19 percent of the nitrate plus nitrite load, and 0.6 to 14 percent of the orthophosphate load. Additional urban runoff from the Sacramento metropolitan area is pumped into the American and Sacramento rivers so the impact of urban runoff on loads in the Sacramento River is underestimated by simply examining the loads from Steelhead Creek.

The SRWTP provides a substantial load of TOC to the Sacramento River.

Based on the limited data available for this study, the estimated daily TOC load from the SRWTP was up to 40 to 60 percent of the load in the river during the fall months when Sacramento River flows are typically lowest and less than 5 percent of the load during storm events.

Water quality in Dry Creek and Steelhead Creek is influenced by the Dry Creek WWTP, particularly during dry periods.

Dry Creek, the largest tributary to Steelhead Creek, receives treated effluent from the City of Roseville’s Dry Creek WWTP. During the dry season, flow from the WWTP can exceed the background flows in Dry Creek. The concentrations of TDS, nitrate plus nitrite, and orthophosphate are higher downstream of the WWTP than upstream of the plant. The TOC concentrations are lower downstream of the plant and the *E. coli* levels are lower in the dry season. During storm events, urban runoff dilutes the TDS and nutrient concentrations in Dry Creek, resulting in lower concentrations during the wet season than the dry season.

MWQI Recommendations

Routine monitoring of Steelhead Creek should continue

As the watershed continues to urbanize, monthly monitoring of key drinking water constituents should continue to obtain a longer period of record. Trend analyses should be conducted each year to determine if the effects of urbanization of the watershed can be differentiated from effects due to various hydrologic conditions.

Arcade Creek should be added to any routine monitoring program of Steelhead Creek.

Arcade Creek drains a watershed that is almost 100 percent urbanized and provides a good benchmark against which to evaluate Steelhead Creek as the watershed continues to urbanize. Because the Dry Creek WWTP has such a large influence on Steelhead Creek, particularly during the dry season, monitoring of Arcade Creek will provide a better characterization of the effects of urban runoff on water quality.

Additional data is needed that would assist in understanding the various factors affecting Steelhead Creek water quality.

This study identified a number of data gaps that could potentially be filled:

- PCWA Canal Water –PCWA should be contacted to determine if there are records of the quantity of water from the canal system that is discharged to the tributaries of Dry Creek. Any available data on the quality of the canal water should be obtained.
- Dry Creek WWTP –City of Roseville should be contacted to obtain data on effluent flows and quality.
- Arcade Creek –All data from the USGS and Sacramento Stormwater Program data should be examined.
- RD1000 Pump-ins –RD1000 should be contacted to obtain information on the quantity of water pumped into Steelhead Creek and any data on the quality of the discharge. If no water quality data are available, occasional samples should be collected from these pump-ins, particularly during the times of the year when the greatest quantity of water is pumped into Steelhead Creek. Information should be requested on the drainage area served by RD1000. The City and/or County of Sacramento should be contacted to determine if there is land use information for the drainage area.

- City of Sacramento Pump-ins –The City of Sacramento should be contacted to obtain information on the quantity and quality of water pumped into Steelhead Creek from Sump 102, the drainage area, and land use information for the drainage area.
- West Sacramento WTP Intake –Bacteria data collected by the City of West Sacramento at the WTP intake should be obtained. The data used in this study were from the City of Sacramento’s WTP intake, which is located downstream of Steelhead Creek and the American River.
- Urban Runoff from Remainder of Sacramento Urban Area –The City of Sacramento should be contacted to obtain information on the quantity and quality of urban drainage
- SRWTP –The Sacramento Regional County Sanitation District should be contacted to obtain recent data on effluent flows and quality.

For any monitoring study, each of the above entities should be contacted and asked to provide this data on a routine basis to the sampling agency.

An intensive study of Steelhead Creek, its tributaries, and the west-side drainage should be conducted in three to five years.

The objective of this study would be to evaluate long-term trends and more fully understand the impacts of various sources on Steelhead Creek and Sacramento River water quality. This study should include monitoring at the mouths of Dry, Arcade, Robla, and Magpie creeks, in addition to monitoring in Steelhead Creek. The discharges from RD1000 and the City of Sacramento should also be monitored. The analysis of data for this study should include the long-term data collected by MWQI on Steelhead Creek and the Sacramento River and the data obtained from the other sources, listed above.

Land use data determined by OEHHA should be provided to future Steelhead Creek studies.

In order for the water quality data to be placed into context with continuing urbanization, the GIS tools developed by OEHAA to estimate IC must be applied to the whole watershed so that in the future, land use can be analyzed for each of the sub-watersheds of the Steelhead Creek watershed and trends identified as urbanization in the watershed continues.

d. Dry Creek Conservancy report summary: The principal water quality objectives for this project were to:

- Identify seasonal stressors suspected of degrading the Dry Creek Watershed
- Assess the contribution of drinking water contaminants in the Dry Creek Watershed to Steelhead Creek.
- Characterize seasonal stream flow patterns.

Water Quality Monitoring and Assessment

Sampling Procedures

The project was guided by the standards and procedures described in the *Quality Assurance Project Plan for the Steelhead Creek Drinking Water Quality Study and Watershed Assessment*.

QAPP procedures were carefully followed and results show nearly all data to be within prescribed limits.

Sampling type and locations were:

- Grab samples at five stations on the lower sections of Dry Creek and each of its four major tributaries.
- Grab samples at four seasonal sites on small drainages.
- An autosampler placed below the confluence of the major tributaries.
- Five instream sensors on each major tributary.

During the wet season DCC water quality monitoring was scheduled twice a month, with efforts made to capture storm events, and during the dry season for once a month. Parameters sampled included:

- Stage and temperature at three instream sensors
- Stage, temperature, conductivity, D.O., NTU, Turbidity and pH at two instream sensors
- CAM -17 Metals, TDS, TSS, TS, Organic Carbon, COD, MBAS, Nutrients, Pesticides, Alkalinity, Bacteria and O&G) at grab sample locations.

Appendices to the report show graphic representations of data for each category.

DCC Conclusions and Recommendations

The pattern of data in the Dry Creek Watershed appears to be largely determined by the presence of ditch water from PCWA operations in upper Dry Creek tributaries, by effluent from the Waste Water Treatment Plant (WWTP), and by flashy stormwater flows.

Addition of clean, cold ditch water from PCWA operations improves water quality in tributaries receiving the flows and in Dry Creek itself during the dry season:

- Temperature is lower than might be expected during the dry season.
- Dissolved oxygen (DO) is higher as this parameter inversely follows temperature.
- Specific conductance, dissolved solids and related parameters are lower than might be expected for creeks in this area because of canal water additions.

Recommendation - minimum flows should be maintained, especially during mid-October canal maintenance to avoid stranding spawning salmon in DCW.

Effluent from Waste Water Treatment Plants (WWTP) reduces water quality in DCW:

- During the dry season, most conventional parameters and nutrients (except ammonia) on Dry Creek are higher downstream of the Roseville WWTP.
- Nutrients are high enough in concentrations to trigger increased algae growth causing eutrophic conditions leading to wide diurnal swings in both DO and pH.

Recommendations –

- Roseville WWTP staff should routinely test its effluents for nitrates.
- Placer WWTP #3 should be upgraded or phased out to avoid release of elevated nitrates.

Stormwater runoff, intensified by stream alteration and rapid urbanization, reduces water quality in Dry Creek and its tributaries:

- YSI logger data shows that NTU turbidity increases predictably during storm events with 90 percentile samples between 20 and 30 NTU.
- Specific conductance rapidly decreases with fresh rainwater and then gradually increases as storm water recedes.
- Nutrients and a good number of conventional water quality parameters increase in concentration during the wet season for most sites above the Roseville WWTP.
- Storm events increased heavy metal concentrations, especially copper and lead, to levels occasionally exceeding ambient water quality levels for aquatic toxicity. Metal contamination may be from sources such as copper used in canals to control algae, arsenic from legacy agricultural pesticides contained in sediment, and lead from contaminated soils along roadways.
- Stream bed incision was apparent at both YSI installation sites with loggers needing to be lowered to remain in the water.

Recommendation – Subwatersheds should be evaluated and prioritized for installation of mitigation retrofits. LID measures should be installed in new developments.

Additional DCC conclusions and recommendations

For large residential construction projects in upland areas near Secret Ravine Creek and Miners Ravine Creek, existing BMP's and/or their implementation appear inadequate to protect water quality.

Recommendation – BMP's should be evaluated for effectiveness and modified to provide better protection of waterways.

NTU appears useful for calculating TSS by using regression formulas that are appropriate for particular NTU levels.

Recommendation – Develop a practical way to compute continuous TSS results from continuous NTU logger data, and for citizen monitors to calculate TSS using a handheld turbidity meter.

Rain events trigger the most extreme bacteria concentrations. Cirby Creek and Dry Creek (below its major tributaries) consistently exceed the Central Valley CRWQCB Basin Plan interim single sample criteria for E. coli.

Recommendation - The E. coli O157:H7 variety originating from human waste is of particular concern since it can cause illness after contact with stream water during recreational activities. Genetic studies are needed to determine the sources of E. coli during the dry season.

The data show a limited presence of pesticides in DCW and it is apparent that the compounds screened for and those detected are not drinking water quality problems.

Summary of DCC Upper Watershed Monitoring and Assessment

Erosion in the stream channel and stream corridor has long been considered an important problem in Dry Creek Watershed. Based on observations over the period of this project, suspected causes of erosion include:

- Removal of vegetation and soil disturbance at construction sites
- Landowner practices such as removing stream corridor vegetation or armoring streambanks
- Flood control programs that remove vegetation and dredge channels
- Ecosystem factors such as beaver activity
- Improperly designed drainage systems for facilities such as roads, residential areas, recreational areas, etc.
- Increased stormwater volume and peaks due to increased impervious surface in the watershed.

DCC carries on a program of observing and reporting erosion problems. With funding from this grant, and other sources, DCC was able to document a number of erosion problems and point them out to responsible agencies. Funding from additional sources supported restoration and other projects to reduce erosion.

A report of sites monitored is included in the *item 6* portion of the complete report.

e. Office of Environmental Health Hazard Assessment report summary

Goals of the Project

The goal of this project was to develop a tool by which land use planners, natural resource managers, and others can determine the amount of imperviousness associated with projects, watersheds and subwatersheds. This tool will:

- Permit local planners to analyze the possible effects on aquatic resources of city or specific plans.
- Serve as a resource for stormwater engineers in calculating the amount of runoff.
- Aid natural resource managers in the analysis of potential risks to aquatic ecosystems.
- Support analysis by staff at the Regional Water Quality Control Boards of the amount of imperviousness associated with a new development and the need for mitigation such as the use of low impact development techniques to reduce potential for harmful impacts on beneficial uses.
- Possibly support a system of regulations and credits for reducing impervious cover.

Background

As agricultural and open lands are urbanized, the amount of impervious surface increases. Impervious surfaces are hardened areas, such as houses, driveways, roads, parking lots, and even highly compacted soil. The amount of impervious surface directly affects its hydrology, chemistry, and biotic integrity of a watershed. There is a well-documented relationship between the amount of imperviousness and the condition of aquatic ecosystems. Although the threshold at which effects are noted varies in different regions of the country, it is clear that a standard

pattern of degradation occurs as areas urbanize, in large part due to these hydrological changes. There are strong indications that streams in dry western climates are impacted at lower levels of imperviousness than streams in the eastern and central United States (Coleman et. al., 2005). A greater appreciation for the impacts of imperviousness has led to consideration of planning and regulatory measures, and consequently, a need to better estimate impervious cover.

Project tasks and deliverables

Task 1: A review of methods of estimating impervious cover, prepared by Jeff Sturman of Tetra-Tech, is attached to this report as an Appendix. The “interactive method” for determining impervious area was identified as the most accurate and economical approach.

Task 2: Calculations were made of the impervious cover associated with major land use categories (LUC) for three representative cities: Sacramento, Irvine, and Santa Cruz. These communities were selected to represent geographical diversity as well as different degrees of urbanization. Sacramento was the representative Central Valley city with a moderately-high degree of urbanization; Irvine was selected to represent a Southern California, highly urban community; Santa Cruz was the representative smaller, coastal community.

Task 3: Analysis of all data was done using appropriate statistical methods.

Task 4: The main purpose of this work is to develop a set of impervious surface coefficients (ISC’s) that can be used throughout California to facilitate the protection of aquatic resources. A set of ISC’s for non residential land uses is provided. The regression relationship describing residential land uses is also provided.

ISC’s are values that reflect the average percent of hardscape associated with all the major land use categories in California. By multiplying these coefficients by the area of the relevant land use types and summing the individual values, it is relatively simple to estimate the amount of impervious cover within a watershed, a specific plan, or a city or region. The calculations can be made for both current and future or build-out conditions.

The long term goal of this project, not addressed under this contract, is the development of an impervious surface analysis tool (ISAT). This tool can be built in Excel or as an ArcGIS extension. The ISAT would operationalize the impervious surface coefficients.

Task 5: Approximately 75 articles, primarily from peer-reviewed literature, on the impacts of imperviousness on aquatic ecosystems were surveyed and those most relevant were included in an annotated bibliography attached as an appendix. This bibliography contains all known literature on the topic relevant to California. It will be available online at websites such as OEHHA and UCD Center for Land and Water Use.

2. Monitoring and Management Reports

- Municipal Water Quality Investigations Report
- Office of Environmental Health Hazard Assessment Report
- Dry Creek Conservancy Report

Complete reports are attached.

3. Project Performance

Original project goals have been exceeded since a method was developed to characterize land use patterns by estimating impervious cover that can be used throughout California. This is a widely applicable tool that was not included in the original scope of work. On the other hand, one desired outcome turned out to be unattainable with resources currently available. The necessary data was not available during the project time frame to discover a baseline relationship of watershed land use patterns to water quality assessment.

Project goals and desired outcomes were identified in the performance and evaluation plan as follows:

Project goals

1. To assess the contribution of drinking water contaminants in the Steelhead Creek Watershed to the Sacramento River.
2. To assess the contribution of drinking water contaminants in the Dry Creek Watershed to Steelhead Creek.
3. To characterize the current land use pattern in the Steelhead Creek Watershed as a baseline to be related to contaminant loading.
4. To support community based watershed management actions that can lead to reduced sedimentation in the Dry Creek Watershed.

Desired Outcomes

1. A quantitative measure of Steelhead Creek contributions of parameters of concern such as organic carbon to the Sacramento River.
2. A quantitative measure of parameters of concern contributed to Steelhead Creek by the Dry Creek Watershed.
3. A baseline relationship of watershed land use patterns to water quality assessment.
4. Local agency action taken to decrease sedimentation due to storm water runoff.

Goals and Outcomes 1 and 2

This project is almost entirely Planning, Research, Monitoring and Assessment. As outlined in the summaries above, the assessments of goals and outcomes numbers one and two were successfully completed, and impacts of Dry Creek on Steelhead Creek, and impacts of Steelhead Creek on the Sacramento River have been identified. It is expected that information from the project will guide management procedures throughout the Steelhead Creek and Dry Creek watersheds.

Goal and Outcome number 3

Goal number three was also successfully completed. DCC was able to coordinate a similar project in progress by Office of Environmental Health Hazard Assessment with the Steelhead Creek project to the benefit of both the DWR and OEHHA project. The DWR task was made compatible with current efforts to estimate impervious cover by standardizing the land use units analyzed to categories compatible with Sacramento Council of Governments (SACOG) categories. This will make it more useful for comparisons of trends in the future since SACOG will continue to collect land use information from its members. It will also enable future

comparisons to other areas that use the standard categories. As reported in the OEHHA section of this report a standardized method for estimating impervious cover (IC) was developed by developing impervious surface coefficients (ISC's) that can be applied throughout California. Calculation of IC using ISC's was not included in the original scope of work.

Desired outcome number three turned out to be unattainable with the resources available. However, now that baseline water quality and hydrologic conditions have been described, and a method for calculating IC has been developed, the stage is set for drawing inferences about the relationship of water quality to IC which is considered a good indicator of urbanization. In addition, the methods developed in this project can be applied throughout California.

Goal and Outcome number 4

DCC monitored a number of erosion sites during the project and observations showed that management of sediment problem areas by some local jurisdictions improved noticeably.

During the period of this grant the approach of local government to construction related erosion problems changed markedly. Early in the grant period staff were often not responsive to DCC reports of problems. Post construction problems especially were considered to be outside the responsibility of public works staff since permits had been given and designs approved and projects had been installed. There was no funding available to go back and fix problems that occurred after the project was built. As phase 2 NPDES permitting progressed DCC began to find that, though there was no explicit acknowledgment of the problems we pointed out, measures were often taken to fix them. Also, monitoring of construction projects by local government staff gradually became more thorough.

As part of Phase 2 education of contractors about BMP's increased, and in the 2005/2006 wet season DCC began to spend more time checking to see that BMP's were in place and properly installed than in making observations of problems and failures during storms. Observations of problem areas from previous seasons often showed great improvement had been made. This change seemed to be largely a result of several large fines that were imposed in local watersheds. It also seems that DCC served the function of bringing attention to problems that before escaped the notice of local staff. The combination of more stringent permitting coupled with a third party observer resulted in positive changes.

4. Lessons Learned

Technical lessons – A number of difficulties were encountered in processing samples at the several laboratories used for the project. Some of them could be resolved and others proved to be ongoing. Generally in a project this size there are many possibilities for different expectations between the lab and client. It may be difficult to find one lab that can provide all the services needed. Handling the large amount of samples can be a logistical problem. Working with the large volume of data can be overwhelming. It's best to give as much consideration to these issues as possible when planning the project. Below are some specific issues that arose during the project. Further details are included with the full report.

1. Inappropriately diluted nutrient samples which reduced the reporting limit of ortho-phosphate.

2. Inappropriately rounding trace metals to one significant figure (e.g.: 0.006 mg/L versus 0.0062) which truncated the data at concentration levels needed for evaluating water quality.
3. Results provided in Excel spreadsheets that had to be laboriously manipulated to get them into useable formats for statistical analysis and data plotting.
4. Excel copies of individual laboratory reports had to be initially transposed and then assembled to produce a data compilation for pesticides (Appendix 36). With the potential for errors then dealing with large and non-standardized spreadsheets, pesticide results and reporting limits (RL) had to be verified line-by-line against the original pdf copies of analytical results from Sequoia Analytical and Bryte Chemical.
5. In-stream loggers (YSI 6600 EDS Sondes) were successfully modified to add pH which operated over a year before they had to be replaced before slowly failing. The YSI polarographic dissolved oxygen sensors were found to require considerable maintenance during the course of the study, with membrane replacement and recalibration required in the field. Because of the difficulty in performing direct calibrations in the field, secondary checks were performed in-stream using carefully calibrated hand-probes.
6. Stream bed down-cutting required repositioning in-stream loggers to keep their sensors in the water, especially for the larger multi-parameter units. Smaller loggers were added to the two original YSI logger locations.
7. Local stream channel changes due to construction or beaver activity affected the ability to make discharge measurements, sometimes making sites unusable.
8. Large single NTU spikes were caused by floating debris.
9. The YSI proprietary software generated multiple reports when gaps appeared in the data.
10. Expensive software and specialized expertise are necessary to calculate rating curves.
11. A large flood damaged the autosampler causing loss of data.

Lessons about influencing local management

As mentioned in the section above on Project Performance local staff may not be interested in reports of problems after permits have been given, designs approved, and projects installed. Generally funding is not available to go back and fix problems that occur after the project is built. Regulatory requirements such as phase 2 NPDES permitting can create more attention to problems. Fines combined with a third party observer can result in positive changes.

On the other hand, third parties may encounter aggressive retaliation. The DCC citizen team leader resigned when threatened with legal action by a construction company building creek-side homes. To compensate DCC worked with city staff and provided sampling support.

Lessons about the relationship between urbanization and water quality

This is a complex relationship that can be evaluated in different ways. Continued work and contact with other programs will be necessary to discover the most useful indicators to use.

5. Outreach

The results of the project will be presented and discussed at the American Basin Council of Watersheds stakeholder group. The final report will be posted on the Dry Creek Conservancy website. Data from this project will be used in an assessment by OEHHA of watershed stressors; the assessment will be used to guide management procedures. OEHHA has already initiated a

discussion regarding the impact of turbidity on salmon, and a subcommittee was formed with stormwater managers from local jurisdictions. It is expected that the subcommittee will discuss the usefulness of information from project reports in guiding future stormwater management plans required by the regional water quality board.

The results of MWQI monitoring in Steelhead Creek are in the process of being published in a peer reviewed journal and presentations of the results have been made at a number of meetings. These items include:

- Sickman, J.O., M.J. Zanoli and H. Mann. 2007. Effects of Urbanization on Organic Carbon Loads in Rivers. In press: Water Resources Research.
- 4th Biennial CALFED Science Conference, 2006. Steelhead Creek Drinking Water Quality Study and Watershed Assessment, Mike Zanoli, DWR, presenter, October 23-25, 2006.
- Nonpoint Source Conference, November 2005. Urbanization, Water Quality, and Local Watershed Management: An Integrated Approach; Mike Zanoli, DWR presenter, November 5, 2005.
- CALFED Science Conference, October 2004, Michael Zanoli, DWR, presenter.

The techniques for estimating impervious cover will continue to be refined and applied to communities throughout California.

6. Funding

The cost of the project was originally projected at \$1,058,598 of which \$595,131 was to be contributed from grant funds and \$463,467 to be contributed from partner funds. During the course of the project MWQI chose to rely on internal funding for a greater share of the project. That allowed for redistribution of grant funds to cover higher than expected personnel costs and to fund additional contract work by OEHHA on methods to estimate impervious cover. The total amount of grant funding remained the same; additional matching funds of \$265,898 were provided by partners for a total matching of \$729,365 or 55% of the total project cost. The total cost of the project increased about \$265,000 due to higher than expected lab costs, higher than expected personnel costs, and additional costs associated with IC related tasks added for OEHHA. All additional costs were funded by partners, whose total contribution increased from 44% to 55% of the total project cost

The state funding used in this project will provide benefits far beyond its absolute purchasing value. The grant funds made several partnerships possible that resulted in a more comprehensive understanding of the link between source watersheds and a large regional watershed. Increased monetary contributions by project partners resulted in greater leverage of grant funds than anticipated by the original proposal. The larger scope of the revised land use tasks provided products that will have applicability many times in the future throughout the state. The products of the grant will be used by the three partners and others in future activities that will be funded from future budgets thus further extending the impact of funds provided by the grant.

7. Follow-up activities

The Municipal Water Quality Investigations Unit is interested in the impacts of urban loading to drinking water quality in the Sacramento-San Joaquin Delta. Although grant funding is no longer available, MWQI is continuing monthly sampling of Steelhead creek. MWQI has proposed to upper management that a more intensive sampling regime similar, to the one it conducted in this study, be initiated in its 2009/2010 funding cycle.

Information from this project is being used in a comprehensive watershed assessment being done by OEHHA as a demonstration of methods from the California Watershed Assessment Manual. Dry Creek Conservancy is seeking funds to develop collaborative management in the watershed and to continue key elements of the monitoring program. Funding for these DCC activities is currently not available.

8. Items for Review

In addition to this final report items for review have been provided to the grant manager as required including:

- Contracts and permits
- Quality Assurance Project Plan and monitoring plan
- Quarterly progress reports and invoices
- Draft final project report
- Expenditure projections
- Grant summary form
- Natural Resource Project Inventory Project Survey form
- Project Assessment and Evaluation Plan