1.0 INTRODUCTION

1.1 District Background

In 1977, the Monterey Peninsula Water Management District (District) was created by the California State Legislature. A major finding of the Legislature was that water problems in the area required integrated management. The Legislature concluded that there was a need for conserving and augmenting ground and surface water supplies, for control and conservation of storm and waste water, and for the promotion of reuse and reclamation of water. In addition, it was mandated that the District would promote endeavors to conserve and foster scenic values, environmental quality, native vegetation, fish and wildlife.

The District and its contractors have produced numerous studies of water supply alternatives and their effects on stream flow and steelhead (Kelly, D.W. & D.H. Dettman, 1981, 1982, 1983). In 1989, the District hired a full-time fisheries biologist to help manage water resources to maintain and improve conditions for steelhead (*Oncorhynchus mykiss*). Subsequently, two additional full-time fisheries positions were created, and seasonal aids were hired to assist with fisheries-related tasks. Among other responsibilities, fishery personnel regularly monitor surface water quality parameters that affect steelhead (i.e., dissolved oxygen, carbon dioxide and temperature) at stations along the Carmel River. Other staff and contractors monitor the effects of water production on the status of riparian and wetland vegetation along the river. However, other than an investigation of the feeding requirements of steelhead on the Carmel River (Fields, 1984), there was limited information available about the aquatic invertebrates until the District implemented a Carmel River Bioassessment Program (CRBP) in the year 2000.

1.2 Physical Setting

The Carmel River is approximately 36 miles long, originating in the Santa Lucia Range between 4,500 and 5,000 feet above sea level and discharging into Carmel Bay just south of the City of Carmel-by-the-Sea. The river and its tributaries drain a watershed of approximately 255 square miles (**Figure 1**). According to the United States Forest Service, most of the watershed is located within ecological unit and subsection 261Aj, referred to as the North Coastal Santa Lucia Range, with a small portion of the upper watershed in subsection M262Ae, the interior Santa Lucia Range. Physical and biological characteristics of these subsections are described in detail at (http://www.fs.fed.us/r5/projects/ecoregions/261aj.htm). All of the bioassessment sites on the Carmel River that are discussed in this report are located in subsection 261Aj. The highest elevation site is near the boundary of the two ecological subsections.

California American Water (CAW) has been maintaining rainfall records at San Clemente Reservoir, located at River Mile 18.6 (measured upstream from the mouth of the river at Carmel Bay), since 1922. Based on CAW's records, District staff calculated the mean annual rainfall (measured from October 1 through September 30) to be 21.37 inches, with a maximum of 46.29 inches in 1998 and a minimum of 8.87 inches in 1924. A mean of 69,001 acre-feet of unimpaired flow in the Carmel River at the same site has been calculated from records of the United States Geological Survey and CAW

going back to 1902, with a maximum of 318,987 acre-feet in 1983, and a minimum of 2,855 acre-feet in 1977.

CAW owns and operates two dams on the river, at River Mile 24.8 and 18.6. CAW also operates 16 wells that draw water from the alluvial deposits of the river below River Mile 18. There are also more than 288 private wells that drew approximately 2,300 acre-feet from the Carmel Valley alluvial aquifer in Water Year 2009 (October 1, 2008 through September 30, 2009). The river and alluvial aquifer are the primary source of water for cities on the Monterey Peninsula (Carmel, Del Rey Oaks, Monterey, Pacific Grove, Sand City, Seaside and unincorporated areas within Monterey County such as Pebble Beach and Carmel Valley Village). An Order from the State Water Resources Control Board has directed CAW to reduce production from its Carmel River system sources and rely more heavily on water from the Seaside Coastal Basin since 1995. In Water Year 2009, CAW reported over 10,400 acre-feet of water was produced from its wells in the alluvial aquifer. Carmel Valley itself is relatively developed, in recent years moving toward a more suburban than rural character, especially downstream of River Mile 15.

1.3 Implementation of the District's Bioassessment Program

In 1997, the United States Environmental Protection Agency (EPA) developed a Rapid Bioassessment Protocol that used benthic macroinvertebrates (BMI) as indicators of stream health. In 1999, the California Department of Fish and Game (CDFG) approved the California Stream Bioassessment Procedure (CSBP) based on the EPA protocol (Harrington 1999). CDFG has recommended the use of bioassessment techniques for determining the condition of streams. Further, monitoring of BMI using the CSBP has been required by the State Water Resources Control Board - Division of Water Quality, and Regional Water Quality Boards for NPDES (National Pollutant Discharge Elimination System) discharge permits, enforcement cases, storm water discharge, and for Agricultural and Timber Harvest Waivers.

District staff recognized that monitoring of BMI could supplement and complement their ongoing surface water quality sampling. Reasons cited to implement a BMI monitoring program (Peckarsky 1997) include:

- BMI are relatively easy to collect and identify
- BMI have cosmopolitan distribution (are present in a wide variety of habitats).
- BMI have a diversity of species that are responsive to conditions ranging from healthy to degraded
- BMI are abundant enough that reasonable sampling does not deplete the overall population
- Many BMI have well-documented natural histories and tolerances to environmental conditions
- Many BMI have limited mobility, so they do not move in and out of habitats seasonally, or in response to degradation
- Some BMI are relatively long-lived, so chronic degradation can be detected.

Conventional water quality programs focus on chemical contamination, but degradation often stems from other factors, such as sedimentation. In some cases, BMI provide a more effective analytical tool. District staff also recognized that they had primarily been managing the watershed for a single

species (i.e., steelhead), but individual species do not thrive outside of a sustaining biological context. In June 2004 a three-year bioassessment report was prepared with the following objectives:

- Document biological integrity of the Carmel River using BMI assemblages at selected stream locations;
- Consolidate existing BMI data and associated information for the Carmel River;
- Establish a baseline data set using a standardized procedure from which future biological assessments may be compared;
- Contribute data to a Monterey region-wide data set intended to characterize watershed health and development of an Index of Biological Integrity.

This bioassessment report includes 10 years of bioassessment data from years 2000 to 2009 and supplements the previous 2004 bioassessment report with several new components:

1. a reference site was established in 2004 upstream of Los Padres Reservoir, which provided needed perspective for evaluating biotic integrity across monitoring sites,
2. an index of biotic integrity (IBI) was published by Ode et al. in 2005, which was applied to all BMI data collected for each sampling event for the CRBP. The IBI provided an empirical assessment of CRBP sites and produces a single biotic variable that facilitates the assessment of monitoring site quality through time and space,
3. an ordination technique was applied to the 10-year data set to gain further insight into taxonomic composition potentially influenced by sample type, season (spring and fall), and environmental variables, and
4. an estimate of BMI biovolume was added in 2005 to supplement BMI abundance estimates.

1.4 Historical Information

A literature review of historical information regarding BMI assemblages in the Carmel River and nearby drainages was conducted, and the results are summarized below.

Spatial Distribution of Invertebrates in Carmel Lagoon, Carmel, California

Thomas Evan De Lay prepared a paper as part of a Bachelor of Science Degree through the CSU, Monterey Bay that described substrate complex preferences for a variety of invertebrates in the Carmel Lagoon. Several of the invertebrates are known to be important food resources for the federally threatened Central-California Coast Steelhead (*Oncorhynchus mykiss*). De Lay found that *Neomysis* (mysid shrimp) was more abundant among sandy substrates with grass; *Eogammarus* (amphipod or scud) was more abundant among fine sand with mud, coarse particulate organic matter (CPOM) with mud and sand substrate with grass. *Corophium* (amphipod or scud) was more abundant among CPOM with mud and sandy substrate with grass. De Lay emphasized that identifying spatial patterns of epibenthic invertebrates among the different substrate types will allow for more efficient management to commence and therefore provide optimal habitat conditions for the food sources of steelhead.

The Life History Demographics of *Corophium spinicorne* in the Carmel River Lagoon

Jessica Watson prepared a paper as part of a Bachelor of Science Degree through the CSU, Monterey Bay that described life history demographics of the amphipod *Corophium spinicorne* in the Carmel Lagoon in 2007. The importance of this species as a food resource for the federally threatened

Central-California Coast Steelhead (*Oncorhynchus mykiss*) was previously established. Significant changes in length or abundance of *C. spincorne* were not evident during the four month duration of the study. There was evidence of a synchronous reproductive cycle perhaps associated with the lunar cycle and that there was higher *C. spinicorne* abundance in sandy substrates when compared to other substrate types. *C. spinicorne* abundance did not appear to be related to variation in basic water quality constituents. Watson suggested that subtle changes in bottom habitat may have the strongest effect on *C. spinicorne* populations, which confounded the focus of the life history emphasis of the study. A follow-up study described above supports Watson's observation that sandy bottomed substrate is preferred habitat for *C. spinicorne*.

Central Coast Ambient Water Quality Monitoring Program, Carmel River

The Central Coast Regional Water Quality Control Board (RWQCB) collected and processed benthic samples using the CSBP from two sites on the Carmel River in the spring season from 2001 to 2004 as part of its Central Coast Ambient Water Quality Monitoring Program (CCAMP). In 2005 CCAMP used the Surface Water Ambient Monitoring Program (SWAMP) sampling method but not the targeted riffle component. In 2007 CCAMP used the SWAMP sampling method including the targeted riffle component. Samples were collected from sites located from the Carmel River at the Highway 1 road crossing and at river mile 14.5 at Esquiline Road. BMI data from riffle habitat from the CCAMP Carmel River sites were compared with BMI data compiled for the District's Bioassessment Program, results of which are described in Section 3.4.

Coastal Lagoons Biomonitoring Project

As part of its ambient water quality monitoring program, the RWQCB developed its CCAMP to assess the water quality at the confluence of freshwater streams within the central California coast region. In September 2001, the CDFG's Aquatic Bioassessment Laboratory participated in this effort by conducting a pilot study to evaluate the utility of BMI bioassessment for monitoring water quality in these coastal lagoon environments. The objectives of the pilot study were to determine a chemical contaminant gradient for fourteen coastal lagoons; collect BMI samples using a standardized procedure to determine a biological gradient; assess whether the biological gradient correlated with the contaminant gradient; and provide recommendation for incorporating biological assessment data into the Coastal Confluence Monitoring and Assessment Program.

For each of the fourteen lagoon sites, biological metrics (numerical attributes of BMI assemblages) were integrated into a site score, which provided a relative assessment of site quality as a function of BMI assemblage quality. Also, organic chemical constituents (pesticides and PCBs) extracted from sampled sediments at the fourteen lagoon sites were analyzed. Resultant organic chemical values were integrated into a mean Sediment Quality Guideline Quotient (SQGQ). Results of the biological and chemical integrative indices were plotted to explore possible relationships.

One of the fourteen sites was located at the mouth of the Carmel River. The BMI metric site score for the Carmel River lagoon site was above average when compared to the other sites; five sites ranked higher and eight sites ranked lower than the Carmel River lagoon site. The SQGQ determined for the Carmel River lagoon site was lowest when compared to the SQGQs determined for the other lagoon sediment samples. This indicates that the Carmel River lagoon site had the lowest levels of pesticide and PCB values associated with sediment when compared to the other sites. Because there was not a

strong relationship determined for biological metric scores and SQGQs, the authors of the study suggested that factors associated with local habitat condition may have had a stronger influence on biological metric scores.

Numerically dominant BMI taxa sampled from the Carmel River lagoon included (in order of decreasing numerical dominance): *Corophium* (amphipod or scud), Gnorimosphaeroma (intertidal pill bug), Cyprididae (ostracod or seep shrimp), *Gammarus* (amphipod or scud) and Oligochaeta (segmented worm).

Pajaro River Biological/Physical Habitat Assessment

The Pajaro River watershed drains approximately 1,270 square miles and discharges into Monterey Bay approximately 25 miles north of the outlet of the Carmel River. In 1997, the RWQCB, with assistance from the Association of Monterey Bay Area Governments initiated an ambient water quality monitoring program in the Pajaro River watershed. The objective of the program is to evaluate the chemical, biological and physical habitat in surface waters in seven tributaries and the Pajaro River mainstem. To date, one compiled report was available for review, which provided information on the biological assessment component of the program (CDFG, unpublished). Biological and habitat assessments were conducted by the CDFG's Aquatic Bioassessment Laboratory using the CSBP in April 1998 and results compiled into a report (unpublished).

Results of the biological assessment indicated substantial variability in site quality based on the BMI assemblages. Two tributary sites with high-ranking habitat quality also had the highest quality BMI assemblages as determined by integrating several biological metrics. BMI assemblages at all other sites ranked average or below average when compared to the two high quality tributary sites. One factor, which may have contributed to the dissimilar quality of BMI assemblages was the wide range of substrate composition at the sites; notably the sandy, transitory substrate in the larger river system sites including the Pajaro River and San Benito River.

Invertebrate Fauna of the Carmel River System

As part of an assessment of the Carmel River steelhead resource, a report by Hydrozoology (Fields 1984) was prepared for the District. Fields' report on the Carmel River comprised elements associated with BMI including:

1. benthic sampling (March and May) and diel drift on the lower river,
2. terrestrial drift in open versus canopied stream reaches,
3. benthic sampling on the river reach and tributaries between the San Clemente and Los Padres reservoirs,
4. food habits of trout in San Clemente and Los Padres Reservoirs, and
5. food habits of steelhead for various river reaches including the lagoon.

For element 1 above, black fly and midge larvae were the most numerically dominant BMI groups for both months but the benthic fauna was less diverse with fewer individuals in March than benthic fauna sampled in May. Although the mayfly *Baetis tricaudatus* was common in March, their abundance in May was much greater. In March, average BMI density at the sites was 1,800 BMI per m^2 (range 510 to 3,000); in May, average BMI density was 3,300 (range 620 to 5,500). There were fewer differences in abundance and composition of benthic fauna in March and May samples at sites

where the substrate was relatively stable. Diel drift was highest in areas where substrate consisted of gravel and cobble and was considerably lower in areas dominated by sand substrate. Chironomids, simuliids, baetid mayflies and oligochaetes comprised over 93 percent of drifting organisms.

For element 2 above, contribution of terrestrial organisms to drift as a food resource for steelhead was considerably higher (numerical abundance and biovolume) in canopied river reaches when compared to river reaches with no or little canopy cover.

For element 3 above, Fields reported the BMI assemblages of Pine Creek to be the most diverse and attributed the high diversity to the "unperturbed" condition of the site where samples were collected. Fields also found that while there was ample BMI drift downstream of San Clemente Reservoir, species diversity was low and almost all the food available as drift to steelhead consisted of black fly larvae.

For element 4 above, Fields found that trout inhabiting both San Clemente and Los Padres Reservoirs fed on invertebrates from three sources, in order of decreasing relative importance: riverine, lucustrine and terrestrial. By far, the terrestrial component was the least important food source to trout. Of the lucustrine food source, benthic invertebrates were more important than planktonic invertebrates.

2.0 METHODS

2.1 Monitoring Sites

To optimize time and budget constraints, originally only four sites were established by District staff. In fall of 2000, four monitoring sites on the Carmel River were chosen to conduct the CRBP. An additional site at the Sleepy Hollow Steelhead Rearing Facility's (SHSRF) rearing channel (SHRC) was sampled three times during the monitoring period. In 2004 a site was added upstream of Los Padres Reservoir (CRLP) and a site (CRSW) approximately one river mile upstream of site CRRR was added as an alternative to site CRRR during conditions of inadequate flow for sampling. A summary of all BMI sites monitored by the District is provided in **Table 1** where "B" indicates that benthic samples were collected and "H" indicates that a site scale habitat assessment was performed using the parameters shown in **Appendix A**. Site CRDD was sampled using a point-source design as part of a separate project, which precludes a site scale habitat assessment.

The sites are shown in **Figure 1**, along with the approximate locations of three of the District's streamflow gaging stations. Flow data for those stations, Below Los Padres (BLP), Sleepy Hollow Weir (SHW) and Don Juan Bridge (DJB) are provided in **Appendix I** along with continuous water temperature data monitored at three sites, upstream of Los Padres Reservoir, and downstream of Los Padres and San Clemente reservoirs. The four original invertebrate sampling sites were selected because they corresponded to established juvenile steelhead population survey sites and they were representative of most reaches of the Carmel River. Reaches farther downstream have lower gradients, a higher percentage of sand and fines, and frequently dry up during the dry season in response to pumping and low flows. The CRRW site was added in 2002 to determine if detrimental