LAGUNITAS CREEK SALMONID HABITAT 2011

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Cover photo by Benjamin Schleifer

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EXECUTIVE SUMMARY

During the fall of 2011, Marin Municipal Water District staff conducted a habitat typing survey of Lagunitas Creek and two of its tributaries, San Geronimo Creek and Devil's Gulch. These surveys quantified aquatic habitat for coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*). This report analyzes the data collected during that survey and compares them with data collected during habitat typing surveys between 1992 and 2006.

Many factors could be responsible for the changes in habitat observed between 2006 and 2011, but a driving factor is likely the rebound in habitat conditions following the major flood in December, 2005. Some of the logs that were recruited to upper Lagunitas Creek during that storm appear to have migrated downstream, and as they did so, pools became less frequent in the upstream reaches and more frequent downstream. Bank vegetation increased and some of this vegetation provided additional cover over pools. Banks and slopes that were destabilized by the "New Year's Flood" of 2005-06 may have increased the sediment supply while moderate flows in the intervening years limited sediment transport. As a result, the distribution of substrates became increasingly bimodal, with cobbles and fines increasing and gravel-dominated habitats decreasing. As fine sediments increased, spawning areas became more embedded.

The longer-term trends since 1997 vary between reaches and for different habitat parameters. On the positive side, wood loading has increased or remained stable in all reaches. Pool cover has increased in Devil's Gulch. Bank vegetation appears to be increasing, but this parameter is highly subjective and the trend is difficult to interpret. Likewise, our observed increases in canopy cover were rendered unreliable due to methodological errors. On the downside, pool frequency has declined in upper San Geronimo Creek and Devil's Gulch. Cover in pools has declined in most of Lagunitas and lower San Geronimo Creeks. Pool depths, substrate conditions, and embeddedness don't show strong positive or negative trends. Overall, an increase in wood in the wetted channel has been the only measurably positive habitat trend in the study area. Decreases in pool frequency and total pool cover are worrisome negative trends in salmonid habitat over the last 14 years.

1.0 INTRODUCTION

Lagunitas Creek originates on the north slope of Mount Tamalpais and flows through a series of four water supply reservoirs, the downstream-most being Kent Lake. From there the creek flows northwestward for 12 miles where it discharges into Tomales Bay (Figure 1). The Lagunitas Creek watershed supports both coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Oncorhynchus mykiss*), as well as California freshwater shrimp (*Syncaris pacifica*). San Geronimo Creek, Devil's Gulch, Nicasio Creek, and Olema Creek are the major tributaries to Lagunitas Creek. Devil's Gulch, which flows through National Park and State Park land before entering Lagunitas Creek, is the smallest of these tributaries but it has perennial surface flows in addition to good habitat characteristics that make it an important salmonid stream. The San Geronimo Creek watershed, in contrast to Devil's Gulch, is a mixture of private and public lands, and is the most developed part of the Lagunitas Creek watershed.

Much of the land within the Lagunitas Creek watershed is publicly owned by the Marin Municipal Water District (MMWD), California Department of Parks and Recreation (DPR), and the National Park Service (NPS). The San Geronimo Creek watershed is a mix of private land and county-owned lands of the Marin County Open Space District. Many agencies, organizations and individuals are working to improve the habitat for salmonids and other species in the watershed.

As part of its efforts to improve salmonid habitat, MMWD began habitat typing surveys of Lagunitas Creek in 1992. In 1995 the State Water Resource Control Board (SWRCB) mandated MMWD to monitor populations of salmonids and freshwater shrimp in Lagunitas Creek, as part of SWRCB Order WR95-17. In response to the Order, MMWD developed the *Aquatic Resources Monitoring Workplan for the Lagunitas Creek Drainage* (Trihey 1996), which was recently updated as part of the *Lagunitas Creek Stewardship Plan* (MMWD 2011). Both the workplan and the Stewardship Plan stipulate that habitat typing is to be conducted at least every five years, or more frequently if unusually high flow events alter the riparian zone and stream channel (Trihey 1996, MMWD 1997). Habitat typing enables MMWD to:

- Assess salmonid habitat composition and quality,
- Extrapolate fish densities at survey sites to similar habitats throughout the watershed, and
- Evaluate the success of habitat enhancement efforts.

Habitat typing was previously qconducted in the Lagunitas Creek watershed in 1992, 1995, 1997, 1998 (completed in 1999), 2003, and 2006. The 2011 survey was conducted as scheduled since no channel-forming flows occurred in the previous five years.

2.0 METHODS

2.1 Habitat Typing

The Lagunitas Creek survey began in Point Reyes Station and ended at Peters Dam, approximately 12 miles upstream (Figure 1). The habitat survey for Devil's Gulch began at its confluence with Lagunitas Creek and continued upstream for approximately two miles. San Geronimo Creek was surveyed from its confluence with Lagunitas Creek at Shafter Bridge, upstream

approximately five miles to the Dickson Weir in Woodacre, a grade control structure that is impassable to coho salmon.

Habitat typing protocols and methodology followed guidelines from the California Salmonid Stream Habitat Restoration Manual (Flossi et al. 2010). A "Level II" survey, which classifies habitats as either "pool," "riffle," or "flatwater," was performed with two modifications. Throughout the survey, "flatwater" habitats were distinguished as either "run" or "glide"; and "riffle" habitats were identified as either "riffle" or "cascade." Habitat unit classifications used in this survey were, therefore, identified as either "pool," "run," "riffle," "glide" or "cascade." Units encountered that did not definitively fall into one of these classifications were classified as "other" and measurements were taken where possible.

The habitat survey was conducted between late August and early October, prior to any significant rainfall or scheduled increase in stream flows. Flows in the mainstem of Lagunitas Creek are regulated and are typically between eight and ten cubic feet per second (cfs) at this time of year, in each year since the 1995 State Water Board Order. This consistency allows for comparisons between surveys conducted since 1995, without having any variations in flow conditions.

Surveys were conducted by walking upstream to a designated landmark. Parameters collected for each habitat are presented in Table 1. Habitats shorter than the stream width (typically short riffles) were lumped with the upstream unit and not identified as separate habitat units. Measurements were taken using a measuring tape and measuring rod. Data collection and rating criteria followed guidelines set forth by the California Salmonid Stream Habitat Restoration Manual (Flossi et al. 2002), using the "ten percent methodology." This protocol requires that data be collected on all parameters for all pools and for 10% of other habitats. Habitat dimensions and a count of large woody pieces were collected for every habitat unit. Substrates, bank vegetation, bank composition and in-stream shelter were quantified for one in ten randomly selected habitats. Habitats were randomly selected by using the last digit of the most recent GPS coordinate reading. GPS coordinates as well as air and water temperatures (in degrees centigrade) were recorded at the start of every tenth habitat or new datasheet.

2.2 Analysis of Parameters

Habitat typing data collected in 2011 were compared to data collected in 1992, 1995, 1997 and 1998 (data from Lagunitas Creek below Nicasio Creek were collected in 1999), 2003 and 2006. For all years, data from side channel habitats were not analyzed. Habitat composition was determined by totaling the lengths of each habitat type (pool, riffle, run, etc.) and dividing by the total length of stream. Most other habitat comparisons are based on habitat surface area, but habitat composition is calculated by length in order to compare with past surveys when only habitat lengths were collected. Mean pool depths were calculated by totaling the pool volumes (mean length x mean width x mean depth) and dividing by the total pool surface area. Average maximum pool depths were determined by averaging the maximum depths of individual pools. Mean creek widths were calculated by dividing the total surface area of all habitats in a reach by the length of that reach.

Surveys since 2003 recorded fish cover in the field as the percentage of the habitat covered, plus an estimate of the contribution of each cover type (woody debris, terrestrial vegetation, etc.). In

earlier years, shelter ratings were assigned to each cover type, which corresponded to a general level of contribution (16-25%, for example). To compare years, earlier shelter ratings were converted to a percentage using the midpoint of the contribution range while ensuring that the total of all cover types equaled 100%. An area was then calculated for each cover type for each habitat, and the total area of all cover types was always equal to the area of cover estimated in the field.

Since 2003 substrates were recorded as either dominant or sub-dominant, as opposed to estimating the contribution of each substrate type, as was done in 1997 and 1998-99. Comparing these datasets meant only comparing the areas dominated by each substrate. Sub-dominant substrates were not analyzed due to the uncertainty of their contribution in each habitat. Habitats were grouped by their most-abundant substrates and their surface areas were totaled. These totals were compared with the total surface area of each reach and with data from other years. Substrate data were collected for every pool and for 10% of other habitat types (as part of the 10% methodology), which overrepresented pool substrates in the dataset. To analyze these data, the area of pool substrates was multiplied by 10% before totaling the areas of dominant substrates. Sand was identified separately from silt/clay in 2003, but was lumped in all other surveys. Large cobble was identified separately from small cobble since 2003, but lumped in earlier surveys.

Bank vegetation data were collected similarly in all years, with the exception that since 2003 data from the right and left banks were recorded separately. The dominant vegetation type was recorded along with the percentage of the banks vegetated, between the water and 20 feet upslope. “Vegetated” banks included not just ground covered by plants, but areas stabilized by roots, which often required a subjective assessment of root extent. The proportions of banks covered by each vegetation type were calculated by multiplying habitat lengths by two (two banks), and then by the percentage of the banks vegetated by each type. When multiple vegetation types were recorded for a single habitat they were assumed to be equally abundant. Total lengths of vegetated bank were divided by reach lengths to produce the proportion of the reach vegetated by each vegetation type.

3.0 RESULTS

3.1 Habitat Composition and Dimensions

The overall habitat composition for Lagunitas Creek in 2011 was 44% pool, 23% run, 21% glide, and 12% riffle (Figure 2). The frequency of pools in 2011 was similar to that observed in previous years in all reaches of Lagunitas Creek, except for upstream of Shafter Bridge. Pools were least frequent between Devil’s Gulch and Shafter Bridge and most frequent between Nicasio Creek and Tocaloma. Mean pool depths were the greatest yet observed downstream of Devil’s Gulch but farther upstream pool depths were close to average (Figure 3). Pools were shorter than previously documented upstream of Tocaloma, and were less than half the length observed in 1997 (Figure 4).

Glide habitats were more abundant in Lagunitas Creek than had been previously documented. Upstream of Tocaloma, glides accounted for 26% of the creek, which is the most identified in

those reaches. The abundance of all other habitat types fell within the ranges documented in previous surveys.

In San Geronimo Creek, habitat proportions were similar to those documented in 2003 and 2006. Fewer pools were seen in the upper half of the creek than have ever been documented, while pools were more abundant than average downstream. Pool depths and lengths in both reaches were similar to those documented in previous surveys.

In Devil's Gulch, riffle habitats were less common than previously documented while glide habitats made a significant contribution for the first time. Cascades made up 6% of the creek, which was the most documented in any creek for any survey. The number of pools, their depths and their lengths were similar to what was documented in 2003 and 2006.

The wetted channel of Lagunitas Creek between Devil's Gulch and Shafter Bridge became wider in 2011 than previously measured, and was nearly as wide as the channel downstream of Nicasio Creek (Figure 5). The narrowest reach of Lagunitas Creek was between Nicasio Creek and Tocaloma, where the creek becomes increasingly incised as it approaches the confluence with Nicasio Creek. San Geronimo Creek and Devil's Gulch were found to be wider, on average, than previously documented. Devil's Gulch has been steadily widening since 1999, expanding from eight feet to 11 feet wide.

3.2 Fish Cover

Pool cover was more abundant throughout Lagunitas Creek than in 2006 (Figure 6). The reasons for the increase differed between reaches, with terrestrial vegetation cover increasing most between Nicasio Creek and Tocaloma and between Devil's Gulch and Shafter Bridge. Root mass and large woody debris were largely responsible for the increased cover between Tocaloma and Devil's Gulch and upstream of Shafter Bridge, respectively.

Cover also increased in San Geronimo Creek, particularly in the upstream half (Figure 7). On average, 24% of pools in upper San Geronimo Creek were covered, which was the largest amount of cover ever recorded in this stream. Terrestrial vegetation was responsible for most of the increase in cover.

In Devil's Gulch, pool cover averaged 28%, nearly doubling from 2006. Nearly all cover types increased, and the largest increases were seen in terrestrial vegetation, woody debris, and undercut bank. In fact, these cover types were more abundant than during any previous survey.

Fewer large logs were found in Lagunitas Creek pools, both in the wetted and bankfull channels, compared to 2006. Logs were less abundant in upstream reaches but more abundant between Nicasio Creek and Tocaloma. Logs were more abundant overall, however, than in either 1998 or 2003. Large woody debris covered 3.5% of pools in 2011, on average, which was less than in 2006 but more than in 1998 or 2003. Despite the reduction in logs between 2006 and 2011, the percentage of pools with at least one large log increased in most reaches of Lagunitas Creek.

In San Geronimo Creek, the number of logs in the wetted channel was essentially unchanged from 2006 and 1998. The low log count in 2003 is unreliable. Cover provided by large woody debris was also very similar between 2011, 2006 and 1998.

In Devil's Gulch, slightly fewer large logs were seen in the wetted channel but more were seen in the bankful channel. Large woody debris provided more cover, however, than was seen in previous surveys.

3.3 Bank Vegetation

Bank vegetation along Lagunitas Creek increased in extent throughout Lagunitas Creek, and returned to levels similar to what was documented in 1998-99 (Figure 8). However, the proportions of vegetation types differed substantially from previous surveys in most survey reaches. Evergreen tree cover (e.g., redwood and bay) was far more abundant upstream of Tocaloma than has been documented previously, while herbaceous vegetation and shrubs were rarely dominant. Farther downstream, deciduous trees (willow, alder and ash) were dominant over roughly 80% of the banks.

Along San Geronimo Creek, bank vegetation increased from 2003 and 2006, due to substantial increases in evergreen and deciduous trees (Figure 9). Approximately 70% of the banks were vegetated in lower San Geronimo Creek and 80% in the upper half. In Devil's Gulch, evergreen trees were observed to be the dominant vegetation over nearly half the banks, and total vegetation cover rose sharply to 80%.

Canopy cover in Lagunitas Creek was observed to be between 85% and 94% upstream of Nicasio Creek, and evergreen trees comprised the greatest proportion of the canopy yet observed. Methodological problems associated with measuring canopy cover will be addressed in the Discussion.

3.4 Substrates

The largest change to the streambed of Lagunitas Creek between 2006 and 2011 was the decrease in gravel-dominated habitats (Figure 10). In the primary coho spawning reaches, upstream of Tocaloma, gravel-dominated habitats were less abundant than previously recorded and only half as abundant as in 2006. This decrease was accompanied by an increase in cobble and boulder-dominated habitats. Habitats dominated by fine substrates were less common between Tocaloma and Devil's Gulch but more prevalent elsewhere. For the first time, a significant proportion of habitats were dominated by fine sediment upstream of Shafter Bridge.

Substrate conditions changed very little in the lower half of San Geronimo Creek since 2006, but in the upper half gravel-dominated habitats declined dramatically. Only a single pool was described as having gravel as the dominant substrate, while one third of the streambed was characterized as cobble-dominated. Fine sediment was dominant in 65% of the streambed; more than in 2006 but similar to what was observed in 1998 (Figure 11).

Devil's Gulch substrate conditions changed the most of any reach in the study area. Fine sediments went from a minor component of the streambed to the dominant substrate in over half of

the creek. Gravel declined by a similar margin. The substrate size distribution is bimodal, with 80% of the streambed being dominated by either fines, cobbles or boulders.

Pool tail embeddedness increased in most survey reaches since 2006 but fell within the range of past estimates in all reaches except for Devil's Gulch (Figure 12). Embeddedness in Devil's Gulch was estimated at 41%, which was higher than previously estimated and higher than in any other reach other than upper San Geronimo Creek. In 2006 Devil's Gulch embeddeness was the lowest of any reach. Since 1997 these estimates have been highly variable in the tributaries and between Nicasio Creek and Tocaloma, but relatively stable elsewhere in Lagunitas Creek.

4.0 DISCUSSION

Salmonid habitat in Lagunitas Creek and its surveyed tributaries showed both improvement and degradation between 2006 and 2011. Pools were generally more frequent, had more cover, and were by and large as deep or deeper than in 2006. Bank vegetation also appeared to increase in all reaches. On the other hand, pool area decreased overall, gravel became less abundant in the streambed, and both coarser material and fines were more frequently dominant. Related to the increase in fine sediments, pool tail embeddedness increased in most reaches, particularly in the tributaries.

Glide habitat in Lagunitas Creek was more abundant than ever recorded, contributing 23% of the creek length upstream of Nicasio Creek. In 2006 glides comprised 16% the creek, and in 2003 less than 2% of the creek. While most of the glides identified in 2011 clearly met the definition of glide habitat, it appears that some glides would likely have been classified as shallow pools in previous years. Between 2003 and 2011, the maximum depth of glides upstream of Nicasio Creek increased from an average of 1.6 feet to 2.2 feet. At the same time, the ratio of the glides' maximum depths to their mean depths (i.e., the heterogeneity of their depths) increased from 1.5 to 1.8. Deeper, more heterogeneous habitats (more like pools) appear to have been called glides in 2011 than in 2003. To improve consistency between surveys, a more stringent definition of glide habitat will be implemented prior to the next habitat survey.

Glide habitats were also more abundant in San Geronimo Creek and Devil's Gulch than previously observed. In both streams the increase in glide habitat was associated with a decrease in run habitat. The proportion of pool habitat increased slightly in both creeks. In San Geronimo Creek, the small increase in glide habitat may have been related to lower flows in 2011. Flows in San Geronimo Creek were 0.34-0.52 cfs during the habitat survey, while flows were slightly higher (0.52-0.56 cfs) in 2006. In Devil's Gulch, the large increase in fine substrates may have resulted in more uniform channel morphology and a large increase in glides.

Pool frequency (e.g. pools/mile) has been positively correlated with salmonid habitat quality (NMFS 1996), as has the ratio of pool to riffle habitat (Nichelson et al 1992). Pools were more frequent between Nicasio Creek and Devil's Gulch than has been previously observed and were also longer. In fact, between Nicasio Creek and Tocaloma the high frequency of pools met the standard for a "properly functioning" stream for the first time (Figure 13).There were fewer pools upstream of Devil's Gulch than have been documented since 1999, but the large increase in pools between Nicasio Creek and Tocaloma raised the total number of pools found in Lagunitas Creek to the highest yet observed. In lower San Geronimo Creek, pools became shorter and

more frequent. Changes in pool frequency appear to be related to wood loading, so that an increase in logs tended to coincide with an increase in pools (Figure 14). Changes in wood loading explain nearly half of the observed changes in pool frequency.

The number of large logs observed throughout the watershed decreased between 2006 and 2011, both in the wetted and bankfull channels. In both Lagunitas Creek and San Geronimo Creek logs decreased upstream and increased downstream, suggesting a downstream movement of logs without adequate recruitment of additional logs in the upstream reaches (Figure 15). The proportion of pools containing at least one log remained relatively stable or increased in all reaches. This supports the hypothesis that pool frequencies are related to wood loading, with pool frequencies declining in reaches with reduced wood loading, and the proportion of pools with at least one log remaining relatively stable.

In the stream reaches that saw large increases in pool cover (Nicasio to Tocaloma, upper San Geronimo Creek, and Devil's Gulch), terrestrial vegetation played the largest role in the increase. In each of these reaches, terrestrial vegetation provided more cover than had previously been observed. Bank vegetation may have been recovering from the large flood in 2006, when many mature trees were toppled. We've observed that these trees were often replaced by new, bushier growth that extended over the water. Winter stream flows between 2006 and 2011 were not high enough to prune this new growth back.

Rank growth could help explain the large increases in bank vegetation observed in 2011, although most of that increase was in evergreen vegetation (redwood and bay), which would not be expected to expand as quickly as herbaceous vegetation, shrubs or even alders. A more likely explanation may be the inherent bias associated with estimating the proportion of a bank stabilized by vegetation. The purpose of estimating bank vegetation is to assess bank stability, so tree roots are generally included in the vegetation estimate. Estimating vegetation cover on a redwood-dominated bank, for example, is difficult because while little vegetation may be growing between trees trunks, the bank may be highly stable. Thus, surveyor bias is introduced when estimating how much of an otherwise bare bank is being stabilized by tree roots. In 2011 surveyors may have overestimated the extent of tree roots within otherwise bare banks.

Canopy cover in 2011 was greater than previously recorded in every stream reach. Not only were the mean estimates of canopy cover unusually high, but in many reaches the distribution of estimates were heavily skewed towards total canopy cover. As an example, in 2011 more than half of Lagunitas Creek habitats were observed to have at least 85% canopy cover. In 2006 only 3% of habitats had that much cover. This discrepancy appears to be largely a result of surveyor error. The most significant source of error was likely the locations at which canopy cover was measured. According to the California Salmonid Stream Habitat Restoration Manual (Flossi et al., 2010), canopy cover should be measured at the center of the stream habitat, and this is how canopy was measured in 2003 and 2006. In 2011, surveyors recorded canopy cover at the upstream end of each habitat. The upstream ends of most habitats, particularly pools, are narrower than at the centers, so have denser canopies. Canopy cover estimates for 2011 are included in Figure 16 to provide a comprehensive summary, but these data are unreliable.

The large increase in fine sediments between 2006 and 2011 may have been a delayed effect of the 2006 flood. Uphill areas and banks destabilized in 2006 may have contributed a higher load

of fines in the intervening years. Winter stream flows were most likely inadequate to flush these sediments out of the creek. The decrease in gravels in most reaches, coupled with an increase in cobbles and boulders, is more difficult to explain. Stream flows since 2006 were inadequate to deliver cobbles and boulders, so these substrates were likely uncovered, but it's unclear how these larger substrates were uncovered given the low winter flows. This question warrants further investigation by a geomorphologist, and should be placed into the context of longer-term sediment dynamics in the Lagunitas Creek watershed.

Long-term habitat trends vary greatly between streams and for individual parameters. Since 1997 Lagunitas Creek has maintained a relatively stable number of pools while pool frequency appears to be declining in San Geronimo Creek and Devil's Gulch. Pool depths show no significant trends in any of the streams. The number of logs has increased or at least not declined in all streams. Cover in pools, which includes woody debris, has declined in Lagunitas and San Geronimo Creeks, but has increased in Devil's Gulch. Bank vegetation has been highly variable, with some indication of an overall increase throughout the study area. However, as described above, this apparent trend may be the result of surveyor bias. Substrate conditions and embeddedness have been highly variable and don't show strong trends. Overall, an increase in wood in the wetted channel has been the only measurably positive habitat trend in the study area, and that improvement may be offset by decreases in pool frequency and total pool cover.

5.0 CONCLUSIONS

The overall story of habitat changes between the previous habitat survey in 2006 and 2011 could be told as a recovery following a significant flood. A large volume of wood was recruited into the creek in 2005-06, and some of these logs may have have migrated downstream in the intervening years. As logs decreased between Devil's Gulch and Peters Dam, so did pools, while both logs and pools increased downstream. Bank vegetation recovered from the scouring that occurred in 2005-06, and some of this vegetation provided increased fish cover over pools. Slopes and banks destabilized by the flood increased the sediment supply in the intervening years, while moderate winter flows limited sediment transport.

The impact of these changes on coho is difficult to assess. Shorter, more frequent, and well-covered pools are beneficial for coho. However, pool habitat decreased in the primary spawning areas upstream of Devil's Gulch and in upper San Geronimo Creek. Pool depths were generally stable, despite an increase in fine sediments, but these sediments increased embeddedness, which is detrimental to incubating coho eggs.

The picture was also mixed for steelhead, which are more impacted by changes to the streambed than are coho (Sheppard and Johnson, 1985). The increase in cobble-dominated substrates may have provided more cover for steelhead fry, possibly ameliorating the incubation impacts of increased fine sediments. Steelhead rely less on wood and vegetative cover than coho, so are less impacted by changes in those habitat parameters. In summary, the habitat changes observed between 2006 and 2011 would not be expected to cause significant negative impacts to the Lagunitas Creek steelhead population.

6.0 REFERENCES

Balance Hydrologics, Inc. 2002. Interim Analysis of Streambed Monitoring Data: Lagunitas Creek Sediment and Riparian Management Plan, Marin County, California. Report Prepared for Marin Municipal Water District. 32pp plus appendices.

Ettlinger, E., G. Andrew and G. Aull. 2000. Habitat Typing Survey Report for Lagunitas Creek, San Geronimo Creek, and Devil's Gulch, Marin County, California 1992-1999.

Flossi, G., S. Downie, J. Hopelain, M. Bird, R. Coey, and B. Collins. 2010. California Stream Habitat Restoration Manual. Fourth Edition, Volume II. State of California, Resources Agency, California Department of Fish and Game, Inland Fisheries Division.

Garcia and Associates. 2004. Lagunitas Creek Habitat Typing Survey 2003. Prepared for Marin Municipal Water District.

Johnston, N.T. and P.A. Slaney. 1996 Fish Habitat Assessment Procedures. Watershed Restoration Technical Circular No. 8. Ministry of Environment, British Columbia. 67pp.

MMWD. 1997. Lagunitas Creek Sediment and Riparian Management Plan. Prepared for MMWD.

National Marine Fisheries Service. 1996. Coastal Salmon Conservation: Working Guidance for Comprehansive Salmon Restoration Initiatives on the Pacific Coast.

Nickelson, T.E., M.F. Solazzi, S.L. Johnson, and J.D. Rodgers. 1992. Seasonal changes in habitat use by juvenile coho salmon (*Oncorhynchus kisutch*) in in Oregon coastal streams. Canadian Journal of Fisheries and Aquatic Sciences 49:783-789.

Rosgen, D. 1994. Classification of Natural Rivers. Catena (22):169-199.

Sheppard, J.D. and J.H. Johnson. 1985. Probability-of-Use for Depth, Velocity, and Substrate by Subyearling Coho Salmon and Steelhead in Lake Ontario Tributary Streams. North American Journal of Fisheries Management, Vol. 5, pp. 277-282.

Trihey & Associates, Inc. 1996. Aquatic Resources Monitoring Workplan for the Lagunitas Creek Drainage, Marin County, California. Prepared for MMWD.

Table 1. Parameters recorded during habitat typing surveys

	1992	1995	1997	1998	1998	1999	2003	2006	2011
	Lag	SG, DG	Lag	Lag, SG	DG	Lag	Lag, SG, DG	Lag, SG, DG	Lag, SG, DG
Habitat Unit Number	☑	☑	☑	☑	☑	☑	☑	☑	☑
Habitat Unit Type	☑	☑	☑	☑	☑	☑	☑	☑	☑
Side Channel Type	☐	☐	☑	☐	☐	☐	☑	☑	☑
GPS Coordinates	☐	☐	☐	☐	☐	☐	☐	☑	☑
Mean Length	☑	☑	☑	☑	☑	☑	☑	☑	☑
Mean Width	☐	☑	☑	☑	☑	☑	☑	☑	☑
Mean Depth	☐	☐	☑	☑	☐	☑	☑	☑	☑
Max Depth	☐	☑	☑	☑	☑	☑	☑	☑	☑
Depth of Pool Tail Crest	☐	☑	☑	☑	☑	☑	☑	☑	☑
Pool Tail Embeddedness	☐	☐	☑	☑	☐	☑	☑	☑	☑
Pool Tail Substrate	☐	☐	☐	☐	☐	☐	☑	☑	☑
Shelter Ratings									
Lg Wood in Stream (6-20' long)	☐	☐	☐	☐	☐	☐	☑	☑	☑
Lg Wood in Stream (>20' long)	☐	☐	☐	☐	☐	☐	☑	☑	☑
Lg Wood in Bankfull (6-20' long)	☐	☐	☐	☐	☐	☐	☐	☑	☑
Lg Wood in Bankfull (>20' long)	☐	☐	☐	☐	☐	☐	☐	☑	☑
Shelter Value	☐	☐	☑	☑	☐	☑	☑	☑	☑
% Unit Cover	☐	☐	☑	☑	☐	☑	☑	☑	☑
Undercut Bank	☐	☐	☑	☑	☐	☑	☑	☑	☑
Small Woody Debris (d<12")	☐	☐	☑	☑	☐	☑	☑	☑	☑
Large Woody Debris (d>12")	☐	☑	☑	☑	☐	☑	☑	☑	☑
Root Mass	☐	☑	☑	☑	☐	☑	☑	☑	☑
Terrestrial Vegetation	☐	☐	☑	☑	☐	☑	☑	☑	☑
Aquatic Vegetation	☐	☐	☑	☑	☐	☑	☑	☑	☑
Bubble Curtain	☐	☐	☐	☐	☐	☐	☑	☑	☑
Boulders (d>10")	☐	☑	☑	☑	☐	☑	☑	☑	☑
Bedrock Ledges	☐	☐	☑	☑	☐	☑	☑	☑	☑
Substrate									
Silt/Clay/Sand	☐	☐	☑	☑	☐	☑	☐	☑	☑
Silt/Clay	☐	☐	☐	☐	☐	☐	☑	☐	☐
Sand	☐	☐	☐	☐	☐	☐	☑	☐	☐
Gravel	☐	☐	☑	☑	☐	☑	☑	☑	☑
Small Cobble	☐	☐	☑	☑	☐	☑	☑	☑	☑
Large Cobble	☐	☐	☐	☐	☐	☐	☑	☑	☑
Boulder	☐	☐	☑	☑	☐	☑	☑	☑	☑
Bedrock	☐	☐	☑	☑	☐	☑	☑	☑	☑
% Exposed Substrate	☐	☐	☑	☑	☐	☑	☑	☑	☑
Banks									
Bank Composition	☐	☐	☑	☑	☐	☑	☐	☐	☐
Dominant Bank Vegetation	☐	☐	☑	☑	☐	☑	☐	☐	☐
Bank % Vegetated	☐	☐	☐	☑	☐	☑	☐	☐	☐
% Total Canopy	☐	☐	☐	☐	☐	☐	☑	☑	☑
% Deciduous Trees	☐	☐	☐	☐	☐	☐	☑	☑	☑
% Evergreen Trees	☐	☐	☐	☐	☐	☐	☑	☑	☑
Rt Bank Composition	☐	☐	☐	☐	☐	☐	☑	☑	☑
Rt Bank Dominant Veg	☐	☐	☐	☐	☐	☐	☑	☑	☑
% Rt Bank Vegetated	☐	☐	☐	☐	☐	☐	☑	☑	☑
Lf Bank Composition	☐	☐	☐	☐	☐	☐	☑	☑	☑
Lf Bank Dominant Veg.	☐	☐	☐	☐	☐	☐	☑	☑	☑
% Left Bank Vegetated	☐	☐	☐	☐	☐	☐	☑	☑	☑

Lag = Lagunitas Creek, SG = San Geronimo Creek, DG = Devil's Gulch