EXECUTIVE SUMMARY

Ecological, Geomorphic, And Land Use History of the Carneros Creek Watershed: A Component of the Watershed Management Plan for the Carneros Creek Watershed, Napa County, California

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Prepared For: Stewardship Support And Watershed Assessment In The Napa River Watershed: A Calfed Project. Calfed Contract No. 4600001703 Napa County Resource Conservation District

During 2002-2003, the San Francisco Estuary Institute, with the assistance of the Napa County Resource Conservation District, carried out a study of the historical ecology of the Carneros Creek Watershed. The resulting technical report is one of seven produced to inform the development of a watershed management plan through a participatory process that includes the community, natural resource agencies, and scientists.

To assess historical land use and associated changes within the watershed, we used a multifaceted approach to collect and synthesize a diverse range of information. This process included collecting numerous historical documents from the 19th and early 20th centuries, analyzing historical maps and aerial photography, interviewing local residents, and assessing field conditions with other project team members. Interpretations were analyzed in the context of the findings of the other technical teams through project team meetings.

The Carneros Creek watershed has been shaped by a unique and intensive history during the past 200 years and before. Descriptions in the earliest European accounts of the watershed provide direct evidence of indigenous management of the watershed through the use of fire. Following Spanish conquest, Carneros Creek was characterized by a land use history that diverges from other parts of the region, with relatively early, high intensity grazing during the Mexican Rancho era and persistent ranching activity through the 20th century. Several inherent geographic and physical characteristics of the watershed have helped reduce population growth and the maintenance of ecological resources. These include relatively limited groundwater resources; a naturally narrow, single-thread channel; and Carneros' particular geographic position away from the major fertile valleys of the North Bay, and bordered by the vast Napa-Sonoma marshlands.

Direct major alterations to the stream channel, such as straightening and the removal of side channels, have been relatively limited. As a result, the channel network plan form has not been as dramatically altered as in most other local streams. The Carneros Creek watershed has maintained a relatively high level of ecological resources through historical times and displays significant potential for restoration and enhancement of stream, valley, and hillside habitats.

This Historical Ecology report presents a number of specific implications for future management of the watershed; these are listed below. The report also provides a detailed summary of land use history and historical information resources, which are intended to provide a basis for answering subsequent questions about the watershed history.

1. Carneros Creek was noted as a good spot for steelhead fishing in the 19th century, but was also probably never an exceptional steelhead stream because it is naturally "flashy" and seasonally dry. However, the massive modifications experienced by most rivers and streams in the region have probably increased

Carneros' value relative to other Bay Area and Napa Valley streams. While most migration routes through the Bay require difficult passage through agricultural or urban areas with associated contaminants and flood control channels, or past the Delta water supply pumps (Leidy pers. comm.), anadromous fish approaching Carneros Creek from the Bay have a direct route from the Napa River marshlands to the creek mouth. Once in the creek, fish encounter relatively few major road or railroad crossings and no major dams. As a result, Carneros Creek may have particular long-term importance as a viable steelhead stream.

2. Historical evidence indicates that Carneros Creek did not have a substantially broader riparian corridor prior to European land use. Also, unlike many other local streams (e.g. Soda Creek (Pearce et al. 2002), Carneros has not experienced the loss of low-gradient meanders or overflow channels. As a result, the current system is not compromised by the loss of major channel/riparian components. Restoration should focus on watershed processes responsible for the maintenance and improvement of existing channel and riparian canopy.

3. Carneros naturally maintained a well-defined, relatively incised channel across the valley floor into tidal waters. This historical characteristic is in contrast to other small streams for which connecting ditches or flood control channels had to be constructed, often resulting in persistent sediment deposition problems requiring regular dredging (SFEI 2001).

4. While the stream appears to have been relatively incised according to mid-19th century mapping, additional incision may have taken place and could be assessed by field comparison to historical data, dating of exposed tree roots, and other field indicators.

5. There is evidence that pool habitat in the lower reaches, which is currently of poor quality, was substantially better in the past. Summer stream flow, while naturally limited and intermittent during historical times, does appear to have decreased in recent decades. Groundwater levels in the lower watershed have been reported to be quite susceptible to diminishment by pumping, which would likely reduce stream base flow and pool persistence.

6. Riparian habitat in the lower watershed has been extremely dynamic. This indicates that the tree canopy can respond rapidly in response to favorable conditions. However, there is also strong indication of potential loss of riparian trees in the near future, which could have significant detrimental effects to creek shading and aesthetic value [see *Channel Geomorphology* and *Fish Habitat Assessment* reports.

7. Grazing pressure in the watershed was severe by the mid-19th century, such that impacts to sediment dynamics are likely by the time of the 1862 floods, which could have mobilized large amounts of sediment. While no specific effects could be identified at this time, a high level of grazing activity was documented, which may have present-day effects. Intensive ranching on the Alexander property prior to 1993 is also probably still having downstream effects. Assessment of current in-stream sediment problems should attempt to distinguish between sources caused (and potentially solved) by current activities and those triggered by management in previous eras.

8. Substantial parts of the watershed have been subject to over a century of agriculture and associated plowing, vegetation removal, and other practices which could also be responsible for sediment production. Obvious downstream effects were not found in this study, but as in the case of grazing, may nevertheless be present and should be considered as analysis and management of the watershed continues.

9. General extent and stand density of chaparral and woodlands appears to have increased in the upper watershed, likely due to reduced fire frequency. This change in vegetation may pose a threat for larger fires in the future. Besides the obvious cultural impacts, significant fire, particularly in late summer before substantial rains, could cause large delivery of sediment to the stream.

10. Native management activity in all likelihood had a significant influence upon the composition, distribution, abundance, and productivity of most habitats in the watershed for a very long period of time. Some aspects of native management practices may be useful tools for the future. For example, despite extensive changes remnants of native grassland still exist in the watershed (Graves pers. comm.), constituting a valuable local resource. Restoration and expansion of these native grasslands, potentially with the use of fire, could provide benefits to soil structure, stream flow, and local ecology that could be explored through further research. Trial projects to test management approaches and ecological results could be initiated and would have significance to grasslands management research in the greater region.

Executive Summary

Channel Geomorphology Assessment: A Component of the Watershed Management Plan for the Carneros Creek Watershed, Napa County, California

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Prepared For: Stewardship Support And Watershed Assessment In The Napa River Watershed: A Calfed Project. Calfed Contract No. 4600001703 Napa County Resource Conservation District

In 2001 a group of concerned stakeholders formed the Carneros Creek Stewardship. The stewardship's mission is to preserve and maintain the natural, economic and human resources in watershed, provide education, initiate watershed assessment and restoration, and create a sustainable stewardship group. The group constructed a set of management questions, and helped to instigate this multi-disciplinary science project to help answer these questions. This report is one of seven technical reports written to inform the development of a watershed management plan through a participatory process that includes the community, agencies and scientists. It was made possible through funding from a project entitled "Stewardship Support and Watershed Assessment in the Napa River Watershed". The Napa RCD led CALFED project also provides the same kind of support for the Stewardship of Sulphur Creek in the head of the Valley and confluent to Napa River in the town of St. Helena.

During the summer and fall of 2002, empirical observational data was collected to assess the geomorphological condition of Carneros Creek. This technical report describes the methods, results and conclusions derived from that assessment. This report will be integrated with the other six technical reports by the project partners in close consultation with the Carneros Creek Stewardship to create a management plan for the local community and the Carneros Creek watershed.

Carneros Creek is a western tributary to the Napa River, entering the river approximately 8 km (5 mi) south of the town of Napa. The lower and middle watershed consists primarily of vineyards and suburban residential areas. The upper watershed is primarily grazing, with some open space, vineyards, and residential areas. Carneros Creek historically and currently supports salmonid spawning and rearing, while also providing habitat for other aquatic species. Data collected in this channel geomorphic assessment include surface and subsurface grain size measurements, channel cross-section geometry, channel slope, bank and riparian vegetation characteristics, bank condition, large woody debris (LWD) in the bankfull channel, debris jams, number, type and volume of bars and sediment deposits, number, type and residual depth of pools, indicators and volume of bank erosion, and type and condition of bank revetment.

Surveyed cross-sections illustrate the wide variety of channel morphologies observed throughout the watershed, including the lower entrenched reaches, the middle bedrock-dominated reaches, and the upper shallow and boulder-dominated reaches. Surface and subsurface sediment size analyses suggest that the lower reaches of Carneros Creek are storing moderate amounts of fine sediment (< 2 mm), while the middle and upper reaches are storing low amounts. The majority of Carneros Creek has a nearly continuous riparian corridor. LWD is important in pool formation, with almost 50% of all pools measured either formed by or associated with a LWD piece. In addition, Carneros Creek contains a wide range of residual pool depths, ranging from 0.2 m (0.7 ft) to 1.5 m (4.9 ft). Sediment deposits and bars were measured in all reaches of the creek, with deposit type and volume generally correlated to bankfull channel cross-sectional area. Approximately 90% of the total volume of measured sediment deposits are stored in 50% of the total number of deposits. Most (92%) sediment deposits have been active within the past five years, illustrating the mobility of sediment stored in Carneros Creek. Despite the surface storage of moderate amounts of fine sediment in the lower reaches, the subsurface sediment samples in these same reaches reveal that sediment size distributions are within documented ranges for successful steelhead spawning. It appears that suitable gravel patches and hydraulic locations for spawning are reasonably abundant, especially in the middle reaches. Channel bank erosion is the largest contributor of sediment to the channel, especially in the middle reaches. However, reaches with large amounts of measured bank erosion also have large volumes of sediment storage. The lowest reaches, especially adjacent to residences have the largest length of bank revetments and modifications to the channel morphology.

The habitat in Carneros Creek is currently able to maintain a steelhead population. Salmonid success is primarily limited by the lack of perennial flow in all reaches. The middle reaches contain perennial discharge, fed by a groundwater spring. However, the channel is completely dry upstream of this spring, and is partially dry in the lower reaches where only isolated pools persist. The best salmonid spawning and rearing habitat is provided in the middle reaches because these reaches provide the best combinations of perennial discharge, spawning gravels, pool spacing, pool depth and cover, riparian shading and channel complexity.

The riparian corridor in the lower reaches is typically only a single mature tree in width. Because the channel is entrenched and these trees are being undercut, the riparian canopy is in jeopardy of being significantly modified in the future. The loss of the riparian vegetation would increase the number of scour elements in the channel, but would also decrease bank stability and increase the amount of sunlight to the water. Throughout Carneros Creek, LWD is important in the channel form and function. LWD pieces provide pool-forming agents, provide cover, and help to regulate the transport of sediment and nutrients. Although the middle reaches have the highest amount of measured bank erosion, these reaches also have high amounts of local sediment storage. Besides providing steelhead spawning and rearing habitat, Carneros Creek also supplies other resources to watershed residents including flood conveyance, habitat for wildlife and other aquatic species, and an aesthetically pleasing setting to live, work and play.

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Fish Habitat Assessment: A Component of the Watershed Management Plan for the Carneros Creek Watershed, Napa County, California

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Prepared For: Stewardship Support And Watershed Assessment In The Napa River Watershed: A Calfed Project. Calfed Contract No. 4600001703 Napa County Resource Conservation District

A fish habitat assessment of Carneros Creek was performed to examine current conditions within the stream that impact aquatic organisms and fish, specifically steelhead (anadromous rainbow trout, *Oncorhynchus mykiss*). The objective of this study was to identify key elements affecting fish habitat and make recommendations to improve and restore the health of the stream. The assessment included habitat-typing surveys, water temperature monitoring, reviewing and summarizing existing data, and GIS analysis. Other habitat conditions were also examined including migration barriers, and suitability of spawning habitat. The fish habitat component is intended to integrate with other technical tasks on geomorphology, water quality, hydrology, sediment delivery, and historical ecology.

Fish habitat conditions were inventoried using CDFG habitat-typing protocols focusing on life history requirements of steelhead. This study found that perennial fish habitat is limited to the middle reaches of Carneros Creek, which begin near Old Sonoma Bridge and extend upstream approximately 4.2 miles until the channel goes dry. The portion of Carneros Creek between the Napa River and Old Sonoma Bridge functions as a migration corridor for steelhead, but does not provide adequate summer rearing habitat due primarily to the absence of stream flow. Some deep isolated pools in this lower portion may support small numbers of fish, but overall they do not contribute a significant amount of favorable habitat. The upper reaches of Carneros Creek were completely dry during the survey, which is the typical pattern during summer months according to local landowners. The upper dry reach does not provide rearing habitat, but spawning may occur in suitable sites during winter when flow is present. Young fry could then migrate downstream to suitable rearing pools in the middle reaches. Adult spawning surveys and redd counts in the upper reach would offer a more distinct upstream limit to steelhead.

Tributaries to Carneros Creek were not surveyed due to absence of water. Several spot visits confirmed the overall lack of summer rearing habitat within tributaries. Two intermittent streams are tributary to the middle reaches of Carneros Creek, and they may provide suitable spawning habitat that functions similarly to the upper dry reach of the main stem. After emerging, young fish would be forced to migrate quickly downstream into perennial main stem pools to survive the summer.

In general, pool habitat is lacking good quality cover such as large woody debris (LWD) for juvenile steelhead rearing throughout Carneros Creek. Pool cover is especially lacking in Reaches 1 and 2, where many young-of-year were observed in open water without hiding refugia from predators such as birds. Reach 3 had abundant pools with suitable cover elements including root masses and aquatic vegetation. These pools had the highest number of observed fish including several age classes of steelhead.

Fish were observed throughout the survey including juvenile steelhead, threespine stickleback, California roach, and sculpin. Several large trout were seen in reach 3, which were likely resident fish. The lower reaches had predominantly roach and stickleback in isolated pools. Only one age class of steelhead (young of year) were observed in reach 1. This suggests that few juvenile steelhead successfully overwintered due to lack of high-flow refugia, seasonal drying, or predation in this reach.

Summer water temperatures in pools appear to be suitable for steelhead rearing in reach 2 and 3. Water temperatures measured in reach 1 reached levels above the physiological "comfortable" range for steelhead; however the pools in this lower reach do not appear to provide suitable rearing habitat due to a combination of no flow and poor water quality. The duration of slightly elevated water temperatures in lower Carneros Creek was not extensive, and these conditions probably do not have chronic impacts on growth rates or fitness. In reach 2, water temperature monitoring showed a very favorable and narrow range of daily temperatures within a representative bedrock pool. Peak values in the middle reach were well below steelhead stress levels.

The best available habitat for steelhead spawning and rearing is presently in reach 3 and parts of reach 2, which span about 2 miles. Deep pools with good cover and spawning gravels are more frequent in these two reaches than lower in the stream. Steelhead habitat in reach 2 and 3 currently makes the most significant contribution to the population, and appears to be where the majority of fish are located. It is not clear whether the habitat conditions in these reaches reflect historic conditions for most of Carneros Creek. Efforts to expand the extent of this high-quality habitat could have a great benefit to the population within Carneros Creek.

Several potential migration barriers were identified along Carneros Creek including the extensive dry lower reach. It is important to maintain the extreme lower extent of the stream as a migration corridor for adults and smolts; however, in a given year, the dry lower part of Carneros probably presents a complete barrier to outward migration during late spring and early summer. Improvements to the lower part of the stream that create more favorable habitat conditions within the creek would increase the odds of a stranded steelhead smolt surviving the dry season in the lower reach. Other potential partial migration barriers include two concrete summer dams in reach 2 and 3, and a bedrock cascade with a small concrete dam in reach 2. These dams do not prevent fish passage, and likely do not present a major obstacle under most high and moderate flows. However, they have the potential to limit outmigrating smolts during low flows and possibly adults that are moving upstream at the tail end of a high-flow event. Modifying these structures to allow for complete fish passage would not be difficult.

Riparian canopy density is generally high throughout Carneros Creek. Throughout the survey, much of the immediate stream canopy is provided by mature oaks and bays with large exposed root masses along the bank. The stream has a relatively narrow riparian tree zone, and the loss of these trees may have a deleterious effect on water temperature and water quality. Improving the long term viability of the riparian canopy by stabilizing stream banks and planting second-growth trees would allow for natural succession without compromising the aquatic habitat.

Successful steelhead spawning appears to occur primarily in reach 2 and 3 where good spawning gravel is abundant. Analysis of spawning gravels in reach 1 and the areas downstream show levels of fine sediment that are not favorable to salmonids. Values for several sites indicate amounts of fine sediment that are near levels that begin to significantly impact spawning success. The amounts of fine sediment in these reaches are not as important directly to steelhead spawning however since this part of the stream does not provide suitable year-round habitat.

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Sediment Source Assessement: A Component of the Watershed Management Plan for the Carneros Creek Watershed, Napa County, California

By Pacific Watershed Associates

Prepared For: Stewardship Support And Watershed Assessment In The Napa River Watershed: A Calfed Project. Calfed Contract No. 4600001703 Napa County Resource Conservation District

In March 2002, Pacific Watershed Associates was contracted to conduct a sediment source assessment as a part of the watershed management plan for the Carneros Creek watershed. The assessment consisted of 3 work elements to identify past and potential sediment sources that may be affecting water quality and fish habitat. The first phase of the assessment included a historic air photo analysis of the 1942, 1985 and 2002 air photo periods. The historic air photo analysis was conducted to record road construction, land use, landslide and stream channel disturbance histories for the Carneros Creek watershed.

The second phase of the project involved a systematic field inventory of road systems in the watershed to identify road-related sites that pose a risk of sediment delivery to streams. Sites of potential sediment delivery identified in the road inventory were characterized and quantified, and prioritized treatment prescriptions were suggested to reduce or eliminate future erosion and sediment delivery. The second phase of the assessment also included a stream channel erosion assessment of selected tributaries to identify sites of past and future erosion and sediment delivery and the need for erosion control and erosion prevention treatment.

Finally, Phase 2 of the assessment also included a field review and reconnaissance sampling of non road-related sediment sources associated with a variety of other land uses including viticulture, reservoir development and maintenance, grazing and rural residential development. Land use practices were evaluated in the field for their contribution to erosion and sediment delivery to streams.

The third phase of the sediment source assessment involved the development of a prioritized erosion control and erosion prevention treatment plan to cost effectively control current and potential road-related erosion and sediment delivery. It also included a cursory evaluation of the magnitude of past sources of erosion and sediment delivery in the watershed, as well as an evaluation of current non road-related land use practices that may still be contributing erosion and sediment delivery to streams.

Phase 1- As of the 2002 air photo period, approximately 43 miles of road had been constructed in the Carneros Creek watershed. Of the 43 miles of road, 23 miles (52%) were constructed as of the 1942 air photo period, 14 miles (33%) were constructed as of the 1985 air photo period and 6 miles (14%) were constructed as of the 2002 air photo period. The majority of roads in the watershed were constructed along the mainstem of Carneros Creek and along the eastern hillslopes of the watershed. Very few roads were constructed on the steep western slopes of the watershed.

As of the 1942 air photo period, land use in the Carneros Creek watershed was dominated by grazing and agricultural activities such as orchards and other activities excluding vineyards. Between the 1942 and 2002 air photo periods, grazing activity and non viticulture activities decreased in the watershed. By the time of the 2002 air photo period, vineyard development had increased dramatically through the conversion of grazing and “other” agricultural areas. Rural residential development in the watershed increased slowly over the entire air photo period.

One hundred one (101) landslides were identified in the historic air photo analysis. Landslide types included debris landslides and debris flows. The majority of the landslides occurred on the eastern side of the Carneros Creek watershed and appeared to be controlled by the local geology rather than by management-related activities. Approximately 11,500 yds^3 of sediment was estimated to have been delivered to Carneros Creek and its tributaries as of the 2002 air photos. The majority of landslides occurred in grassland settings within steep headwall swale areas and on streamside slopes.

Phase 2-Roads- Approximately 24 miles of road were field inventoried to identify road-related sites of current and future sediment delivery to streams. Two basic types of erosion were identified in the road assessment including episodic erosion and persistent or chronic road surface erosion. Episodic erosion occurs in response to large and infrequent storms and includes stream crossing washouts and road-related landslides and gullying. Persistent road surface erosion is caused by excessive road and ditch lengths that are "hydrologically connected" to streams. Road surface erosion is generated from the mechanical breakdown of the road surface from vehicle use, cutbank erosion and failures, and ditch erosion.

A total of 147 sites of future episodic erosion and sediment delivery were identified from the 24 miles of inventoried road. Of the 147 sites, 128 were recommended for erosion control and erosion prevention treatment including 90 stream crossings, 7 potential landslides, 16 ditch relief culverts and 15 "other" sites. Approximately 11.4 miles of road were identified as "hydrologically" connected to streams along roads inventoried in the Carneros Creek watershed. Of the 11.4 miles of connected road, 10.3 miles were recommended for erosion control and erosion prevention treatment. If left untreated, it is estimated that up to 11,030 yds^3 of fine sediment could be delivered to streams. Other treatments include upgrading stream crossing culverts to handle the 100 year design storm flow, excavating potential road-related landslides that could deliver sediment to streams, and disconnecting the road surface and ditch from streams and stream crossing culverts.

Treatments in the watershed were prioritized based on their immediacy and included consideration of factors such as the potential volume of sediment to be delivered to streams, the likelihood of future erosion, the urgency of treating the site and the ease and cost of the accessing the site for treatment. Costs to implement treatments along the 24 miles of inventoried in the Carneros Creek watershed is estimated at approximately $493,000. The cost estimate includes the costs to upgrade approximately 6 miles of county maintained roads.

Stream channels- Approximately 3.7 miles of tributary channel was inventoried to identify past, current and future sediment sources that could deliver sediment to the stream system. A total of 47 sites with >20 yds^3 of past and/or future erosion and sediment delivery were identified in the assessment. From the 47 sites, approximately 2,306 yds^3 of sediment have been delivered to streams in the past and nearly 965 yds^3 is estimated to be delivered in the future. Of the 47 sites, 45% of the sites were classified as bank erosion and 41% were classified as debris landslides. Approximately 49% had no apparent management cause, 27% were associated with grazing activities, 13% were associated with reservoirs and 2% of the sites were associated with the road system. Ninety-four (94) small sites (<20 yds^3) were also identified in the assessment. Approximately 1,170 yds^3 of sediment is estimated to have been delivered to streams from these small features.

Other sediment sources- Reservoirs, grazing activities, viticulture and rural residential activities were evaluated as part of the non road-related sediment source sampling. Fifty-seven reservoirs were identified in the Carneros Creek watershed constituting approximately 2% of the total watershed area. Of the 57 reservoirs, 19 were classified as on-stream reservoirs and these collect runoff from approximately 32% of the watershed area. The majority of observed erosion from reservoirs resulted from a few reservoir outlets where flow discharged onto unprotected slopes causing large hillslope gullies.

In general, reservoirs act as large effective sediment retention traps allowing the majority of fine and coarse sediment transported from upstream areas to settle out before flow is released into a natural stream. Although reservoirs can be used as sediment traps, sediment infilling can occur and result in lowered capacity and an increase in the likelihood of failure and overtopping. Reservoirs should be monitored regularly it they are used as sediment traps.

Grazing activities were observed in the northeastern portion of the Carneros Creek watershed. The majority of erosion from grazing activity resulted from the trampling of steep stream banks in the upper portions of the watershed. No exclusionary fencing was noted to keep cattle away from unstable stream banks which resulted in stream bank failures and surface erosion.

Five vineyard plots were inspected in the watershed to assess impacts of vineyard related erosion and sediment delivery. Vineyard plots ranged in size from 1.6 acres to 28.2 acres. The majority of erosion from vineyards consisted of sheet, rill and gully erosion along bare sections of vineyard rows and along long sections of undrained vineyard avenues. Rilling and gullying on vineyard slopes was more prominent on steeper slopes (>10%). Once cover crops were established along vineyard rows, rilling and gullying were significantly reduced in the observed vineyards. Another source of erosion from vineyards resulted from slope drainage pipes that discharge flow onto stream banks above the stream channel causing local stream bank collapse and/or gullying.

Past sediment sources- The largest sources of erosion and sediment delivery in the Carneros Creek watershed over the past 50 years resulted from road-related chronic surface erosion and gullying (29%), mainstem bank erosion (26%), and vineyard surface erosion (20%). The estimate of past erosion and sediment delivery from roads is a minimum because it does not include past erosion from stream crossing washouts and small road-related landslides that have been repaired and are no longer visible. The estimate of past erosion and sediment delivery from vineyard surface erosion may be high since 35% of the active vineyards drain to reservoirs that may act as large sediment traps.

Of the past sediment sources assessed in the Carneros Creek watershed, management-related erosion and sediment delivery can be reduced through a variety of land management treatments. Road-related erosion and sediment delivery can be addressed by disconnecting road the road system from streams by applying adequate road drainage, upgrading stream crossings to the 100-year design storm flow and excavating landslides that could deliver to streams. Road-related erosion and sediment delivery is the most easily identified and the most cost effectively treated sediment source in the watershed.

Vineyard surface erosion can be reduced through the more extensive application of cover crops along vineyard rows and avenues before the winter period. In vineyards which currently drain to streams, local improvements can be made so that slope drainage discharges into sediment retention traps or is downspouted directly to streams. Vineyard avenues should be disconnected from the stream system through the installation of road surface drainage structures such as ditch relief culverts, rolling dips and/or water bars.

Surface erosion associated with grazing activities can be reduced through the rotation of cattle to prevent over grazing. Exclusionary fencing can be useful to keep cattle away from sensitive hillslope areas and erodible or potentially unstable stream channel banks.

In contrast to management-related erosion and sediment delivery, bank erosion along the mainstem and tributary stream channels can be difficult to control. Engineered structures can be constructed to control bank erosion but they can be costly and potentially ineffective. The key to reducing sediment production and delivery in the Carneros Creek watershed should not be to control natural erosion and sediment delivery, but to reduce the amount of management-related erosion and sediment delivery to the stream system through the application of relatively straightforward and cost-effective erosion prevention measures and land management actions.

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Water Balance Study: A Component of the Watershed Management Plan for the Carneros Creek Watershed, Napa County, California

By Bob Zlomke, P.E., Napa County Resource Conservation District

Prepared For: Stewardship Support And Watershed Assessment In The Napa River Watershed: A Calfed Project. Calfed Contract No. 4600001703 Napa County Resource Conservation District

This is one of a series of technical reports prepared under a grant from the CALFED watershed program. It is intended to provide technical support for a watershed management plan for the Carneros Creek watershed, responding to stakeholder interest in water quantity issues.

A Thornthwaite-type water balance model was developed for the watershed, using estimates of monthly precipitation and potential evapotranspiration (PET) to estimate actual evapotranspiration (AET) and runoff, based on the estimated soil storage capacity for the watershed.

Data used include long-term monthly average rainfall at Napa State Hospital (NSH) and estimated monthly average values of PET provided by the California Irrigation Management Information System (CIMIS). NSH rain data are amplified by 15%, so that the rainfall in an average year is consistent with mapped information for Napa County. PET values are multiplied by a landscape coefficient that is a weighted average of estimated values for wooded grasslands, rural residential land, and vineyards. AET is estimated on the basis of PET by use of the original Thornthwaite method.

The model distinguishes between quick runoff, which runs off immediately without infiltration, and slow runoff, which contributes to soil moisture recharge before it enters the runoff stream. Quick runoff is estimated in the model by the use of a parameter which defines the fraction of monthly precipitation which runs off immediately; it is defined only for the period from December through March. Slow runoff is estimated each month on the basis of a second parameter, which defines the fraction of available water (water beyond that required to satisfy soil moisture needs) which runs off. There is no separate accounting of groundwater storage; rather, recharge of groundwater is included in total runoff.

The model was calibrated using flow information at Old Sonoma Road Bridge collected from December 2001 through June 2002. The model showed a tendency to overpredict total runoff, which may reflect the inclusion of groundwater recharge in runoff. The sensitivity of the model to variations in landscape coefficient and soil moisture capacity was explored.

The basic water balance for an average year was calculated (Figure 5), displaying typical characteristics of California streams, with a rainy season peaking in January and a dry season at its driest in July and August. Modeled streamflow begins to rise in December; it roughly follows the rise and fall of rainfall from then until midsummer, when the stream slows to a trickle. The model shows essentially no streamflow from September through November. Actual ET follows potential ET quite closely from October through April but then is reduced from the potential, as the ground begins to dry out; when rainfall begins to pick up again in September, actual ET begins to recover immediately as well.

Of the 710 mm of rainfall in an average year, a total of 371 mm runoff is estimated by the model, for an overall runoff coefficient of 0.52.

The model was used to simulate the water balance in years that were significantly wetter or drier than average. Two recent water years were selected, 1996-97 and 1986-87, with a rainfall total approximately one standard deviation above and one standard deviation below the mean, respectively. In both these extreme years, the model gives a convincing quantitative picture of the shifting water balance resulting from this particular distribution of rainfall over the water year.

Runoff estimated by the model for an average year compares favorably with an estimate prepared by the State Division of Water Rights for Carneros Creek and with a recent application of the Thornthwaite method in the Tomales Bay Watershed. However, comparison of these modeled values with regional work would suggest that both models are overpredicting runoff. The explanation may lie in the fact that both the Tomales study and the present work follow the original Thornthwaite method in not distinguishing groundwater recharge from surface runoff.

The model can be greatly improved as more local rainfall data and more years of measured flow become available. These data will make possible much more exact calibration of the model, so that the following potential additions to the model may be considered:

- Groundwater recharge and extraction
- Timing of withdrawals from the stream and their return to the atmosphere as ET
- Variation of vegetative cover, soil moisture capacity and precipitation through the watershed

These additions will require the development of data representing the variability of the relevant processes over the watershed and over the water year.

Water Quality Study: A Component of the Watershed Management Plan for the Carneros Creek Watershed, Napa County, California

By Jonathan Koehler, Napa County Resource Conservation District

Prepared For: Stewardship Support And Watershed Assessment In The Napa River Watershed: A Calfed Project. Calfed Contract No. 4600001703 Napa County Resource Conservation District

1.0 Introduction

Water quality is a key factor affecting fish and other aquatic organisms within a stream ecosystem. This is especially true of salmonids including steelhead (anadromous rainbow trout, *Oncorhynchus mykiss*), which have narrow tolerances for a variety of water quality parameters. In reaches of Carneros Creek that experience drastic seasonal recessions of surface flow during summer and fall, water quality plays a critical role in the quality of summer rearing habitat for juvenile steelhead. As stream flows diminish in late spring and early summer, steelhead and other resident fish are forced into isolated pools for the duration of the summer. During this time, water quality can quickly degrade without the flushing effects of continuous surface flow. Subsurface flow through the substrate is a vital source of new fresh water, but in the absence of agitation it contributes little or no dissolved oxygen.

Benthic macroinvertebrates are good indicators of water quality and overall stream function over time. Samples taken from several locations along the stream will reflect environmental conditions within the aquatic ecosystem. Certain organisms are highly intolerant to a variety of pollutants including sediment, nutrients, and temperature. Taxonomic analysis of such samples yields information on the benthic community which relates to water quality in the stream. Essentially the quality of the water can be determined based on what organisms are present within a given reach of stream.

2.0 Methods

Water quality was measured in Carneros Creek to establish a limited baseline for current conditions within the stream. The objective of this study was to establish monitoring sites along the stream and to collect water quality data using field tests that can be conducted by volunteers. These tests include dissolved oxygen (D.O.), electrical conductivity (E.C.), pH, water temperature, and air temperature. Additional information on physical habitat is also collected including water color, odor, weather, stream bed appearance, water depth, flow, and habitat change.

All water quality tests were done using the Napa County RCD stream monitoring protocol. One site was selected in the lower reach (CAR-1) near Old Sonoma Road bridge where surface water was present in late summer. Another site was established in the middle reach (CAR-2) to get a satisfactory geographic range along the stream. It was obvious at the onset of the site selection process that suitable monitoring sites would be limited by the presence of water. Surface flow was present in mid June at CAR-2, but there was no surface flow in the lower site, CAR-1. Further, sites were selected based on their potential to support fish which eliminated the far upper and far lower (below Old Sonoma road) sections of the stream. Samples were collected on an approximately monthly basis at both sites.

Dissolved oxygen, electrical conductivity (*specific conductance*), and water temperature were measured using a YSI-85 meter, which was calibrated prior to sampling. A hand held pH meter was used, which was also calibrated prior to sampling. Flow was estimated and categorized as brisk, moderate, low, or stagnant. Water depth at time of sampling was visually estimated.

3.0 Water Quality Monitoring Summarized Results

PARAMETER	CARNEROS SITE 1 (CAR-1)	CARNEROS SITE 2 (CAR-2)
Sample Dates	8/1/02, 8/15/02, 9/12/02, 10/4/02, 12/6/02	8/1/02, 8/15/02, 9/12/02, 10/4/02, 12/6/02
Water Temperature (°C)		
Range	8.2 - 18.4	7.9 -16.3
Maximum	18.4 (8/15/02)	16.3 (8/1/02)
Minimum	8.2 (12/6/02)	7.9 (12/16/02)
Air Temperature (°C)		
Range	12.5 - 21	11.5 - 23
Maximum	21 (8/15/02)	23 (8/15/02)
Minimum	12.5 (12/6/02)	11.5 (12/6/02)
Dissolved Oxygen (mg/L)		
Range	1.2 - 4.2	2.1 - 8.8
Maximum	4.2 (10/4/02)	8.8 (12/6/02)
Minimum	1.2 (12/6/02)	2.1 (9/12/02)
Dissolved Oxygen (% Sat.)		
Range	10.2 - 39.1	19.9 -74.1
Maximum	39.1 (10/4/02)	74.1 (12/6/02)
Minimum	10.2 (12/6/02)	19.9 (9/12/02)
pH (units)		
range	6.3 - 7.8	7.0 - 8.0
Maximum	7.8 (10/4/02)	8.0 (9/12/02)
Minimum	6.3 (12/6/02)	7.0 (12/6/02)
Electrical Conductivity (µS/cm)		
range	923 - 1349	608 - 829
Maximum	1349 (9/12/02)	829 (10/4/02)
Minimum	923 (8/1/02)	608 (12/6/02)
Flow category	No flow during sampling period. Isolated pools	Low flow during first two samples ended in Sept. then returned in Dec.

TABLE 1. Water Quality Summary Table

Results from water quality monitoring provide limited baseline information on conditions within the stream environment during the late summer and fall. This is the period when cold water fish, including juvenile steelhead, in arid California streams experience the most stress from declining water quantity and quality. Water quality generally improves during winter as storms introduce fresh water. However a different set of water quality stressors can have an impact on both juvenile and adult fish. These are chiefly turbidity, extreme low temperatures, and the effects of urban and agricultural runoff. It is therefore important to conduct year-round water chemistry monitoring that is supplemented with macroinvertebrate samples throughout the stream.

Steelhead have a narrow tolerance range for DO and require generally well-saturated water to thrive. Temperature affects how much DO water can hold (Mitchell et al., 1995). As temperature rises, the amount of dissolved oxygen decreases and vice versa. When water holds all the dissolved oxygen it can hold at a given temperature, it is 100% saturated. Steelhead and other salmonids require high levels of DO saturation in order to thrive. Streams with DO levels above 90% saturation are considered best for maintaining healthy steelhead. There is a great deal of variation from one population to another in terms of how well the fish are adapted to tolerate reduced DO levels. Rainbow trout living in reservoirs for example often encounter water less than 90% saturation. Favorable levels of DO are 6 mg/L or greater. General guidelines suggest that stream dwelling rainbow trout (and steelhead) can tolerate DO levels as low as 4 mg/L before a metabolic compromise is initiated (Moyle, 2002).

Carneros Creek had low measured DO levels at both sites during the late summer and early fall. Rainbow trout were observed at sampling site CAR-02 throughout the study, suggesting that the fish were either able to tolerate low DO or had located a stratified area of the pool with higher levels than measured. These fish may have been able to tolerate lower DO levels due to the relatively cold water temperatures at this site, which would reduce metabolic rates during the warmest months. The DO levels at the lower CAR-01 site were too low to support even well-adapted juvenile steelhead during the summer rearing period.

The ranges of pH and electrical conductivity were within general guidelines for suitable rearing habitat. There was very little variation in pH at both sites. Electrical conductivity at site 2 increased as summer progressed into fall, then fell with the return of surface flow.

3.1 Benthic Macroinvertebrate Sampling

Benthic Macroinvertebrate (BMI) sampling was conducted in the lower reach of Carneros Creek near Old Sonoma Bridge by EcoTrust Environmental Inc in 2000 and 2001. The data from 2001 is still being analyzed by the laboratory and will be available in April, 2003. Samples were collected using the CDFG Rapid Bioassessment protocol, which collects three replicate BMI samples per site in randomly selected riffles. The protocol is designed to eliminate, or greatly reduce, sampling bias within a sample reach. Sample reaches are defined as a series of five riffles, of which three are randomly selected. Three areas along a transect within the riffle are then agitated to dislodge BMI's within the substrate and wash them into a net. The contents of the net are then emptied into an alcohol-filled jar for analysis by a laboratory.

Table 2 summarizes the data from 2000 using standardized macroinvertebrate classifications and metrics. The data from this sampling effort are being compared to a preliminary IBI (Index of Biological Integrity) for the Russian River basin to roughly determine water quality. The IBI uses 5-6 key biological metrics calculated from a sample to rank the stream reach in terms of water quality. The following metrics were selected and integrated into a single scoring criteria: Taxa Richness, EPT Taxa, Modified EPT Index, Shannon Diversity, Tolerance Value and Percent Dominant Taxa. The EPT indices represent three sensitive taxa of aquatic insects: *Ephemeroptera* (Mayflies), *Plecoptera* (Stoneflies), and *Trichoptera* (Caddisflies). These three groups are excellent indicators of various water quality parameters including temperature, sediment, and nutrient loading. To date, no IBI has been developed in Napa County, but efforts are being made to develop such a scoring system.

To calculate a ranking for any given site, the values for each metric (e.g. Taxa richness, EPT Taxa) is compared to the Visual Distribution Score ranges and given a score of 5, 3, or 1. A score is given for each of the six metrices. These scores are then added together to form a composite score (with a possible total of 30 points) that can be compared with other sites and rated using the scale below. In general, higher composite scores indicate better water quality.

Biological Metric	**Visual Distribution Score**

	5	3	1
Taxa Richness	≥36	35-26	<26
% Dominant Taxa	≤14	15-39	>39
EPT Taxa	≥19	18-12	<12
Modified EPT	≥54	53-17	<17
Shannon Diversity	≥3.0	2.9-2.3	<2.3
Tolerance Value	≤3.0	3.1-4.6	>4.6

Using this preliminary IBI, a sample can be scored using the following scale:

Excellent	Good	Fair	Poor
30-24	23-18	15-11	11-6

The scale has been modified for Napa data, which does not include a modified EPT Index:

Excellent	Good	Fair	Poor
25-21	20-16	15-11	10-5

Using the modified Napa scoring criteria, the sample collected in Carneros Creek was given a score of 7, which indicates poor water quality. In order to draw conclusions based on any water quality data, including BMI samples, a sufficiently large dataset must be analyzed. In light of the very limited data currently available on BMI populations within Carneros Creek, it is prudent to only discuss the immediate implications of this data. Sampling one reach does not characterize the entire stream or even stream reach. The sample reflects conditions within a relatively narrow region of the stream and should be interpreted to reflect this limitation.

The sample contained a high number of *Baetis tricaudatus* mayflies that accounted for 67% of *Ephemeroptera* analyzed. This abundance of Baetids may reflect high levels of fine sediment. As a group mayflies are highly sensitive to pollution, but Baetids thrive in streams with large amounts of fine sediment. Baetids and Simulids accounted for 76% of the total sample, which suggests a generally unhealthy benthic distribution as reflected by this low diversity. Both taxa are relatively tolerant to pollution of various forms. In terms of abundance the sample ranked very highly, however it was dominated by these two tolerant taxa.

The dominant feeding group was collector-gatherer which accounted for 68% of the total. A more even distribution of functional feeding groups is favorable and indicates a stable stream environment. Almost no scrapers or shredders were found in the sample, which suggests a lack of organic material including woody debris.

4.0 Conclusions:

At the CAR-01 site several native minnows (California roach) were observed in early summer, but were not seen in later visits. It is likely that these fish survive the conditions present in the lower reaches, however young steelhead probably can not. Several young-of-year steelhead were observed in pools just upstream from this site in late summer, but it is unclear whether they survived the warmest months when temperatures increased and dissolved oxygen declined.

In the middle reach, water quality was significantly better but still not optimal for steelhead. Low levels of dissolved oxygen were measured during the summer when flows tapered off. Fish were observed in the deeper parts of the sampling pool, where they may have been in a slowed metabolic state to conserve energy. The temperature was consistently low, which may have contributed to the fish’s ability to survive periods of depressed DO.

Very limited data are available for water quality within Carneros Creek. Observations from habitat-typing surveys were consistent with general trends seen in this limited dataset (Fish Habitat). In general the lower reach had lower habitat scores and poor water quality during summer and fall. Middle reaches provided more suitable habitat and had better water quality. To fully assess the water quality in the creek over time, sampling throughout the year combined with BMI results will yield a more detailed picture of the aquatic environment.

Although not optimal, summer water quality appears to be adequate to support young steelhead in the middle reaches of Carneros Creek and despite relatively low levels of DO (Table 1), fish were observed throughout the study. In lower Carneros Creek, water quality may not be sufficient to support juvenile summer rearing steelhead due to DO depletion and elevated temperatures. Peak water temperatures were generally elevated, which combined with the absence of flow created pool conditions with extremely low DO levels.

5.0 References

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