Green Valley & Dutch Bill
Watershed Update

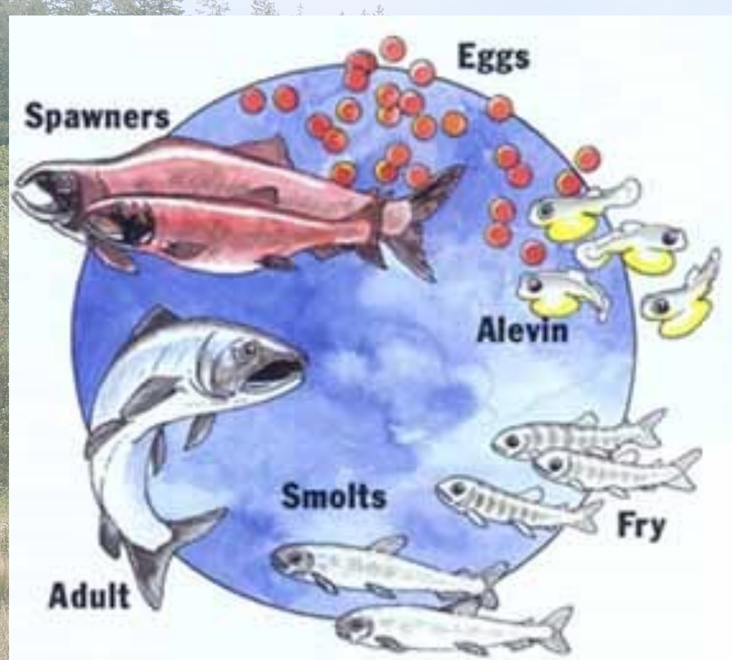
Integrated Groundwater and Surface Water Study for Watershed Restoration Planning

Background

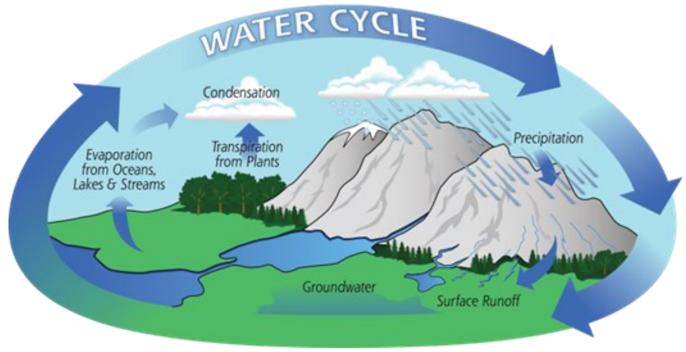
The Dutch Bill and Green Valley/Atascadero Creek watersheds provide some of the best remaining habitat for endangered coho salmon in the greater Russian River watershed. Low stream flows during the summer months are an important factor affecting the survival and recovery of the species. Salmon require sufficient water in the creeks for migrating in from the ocean to their breeding habitat, spawning, developing eggs, rearing young, and migrating back out of the streams to the ocean. Juvenile coho salmon live in creeks for over a year before migrating to the ocean, so they must survive through the summer during periods of low stream flow (Figure 1). In light of recent drought conditions, ongoing climate change, and an increasing demand for water, developing strategies to protect and increase stream flows while having enough water to meet human needs is critically important for sustaining coho in these watersheds.

A four-year scientific study has been completed by the Gold Ridge Resource Conservation District and O'Connor Environmental to gain a better understanding of how stream flows vary across the watersheds and over time, how various natural and man-made factors influence these flows, and what actions can be taken to improve flows and habitat conditions for coho. The study provides a wealth of information and tools for understanding watershed conditions and assisting local stakeholders in sustainably managing water resources and restoring coho populations.

Figure 1:
The Coho Life Cycle
Adults enter the streams during high winter flows and travel throughout the watershed. In our streams, adults mate, spawn, and die. Eggs develop into young who spend a little over one year in freshwater streams. Juvenile smolts migrate down in spring to spend two years in the ocean. In the winter of their third year, they return.

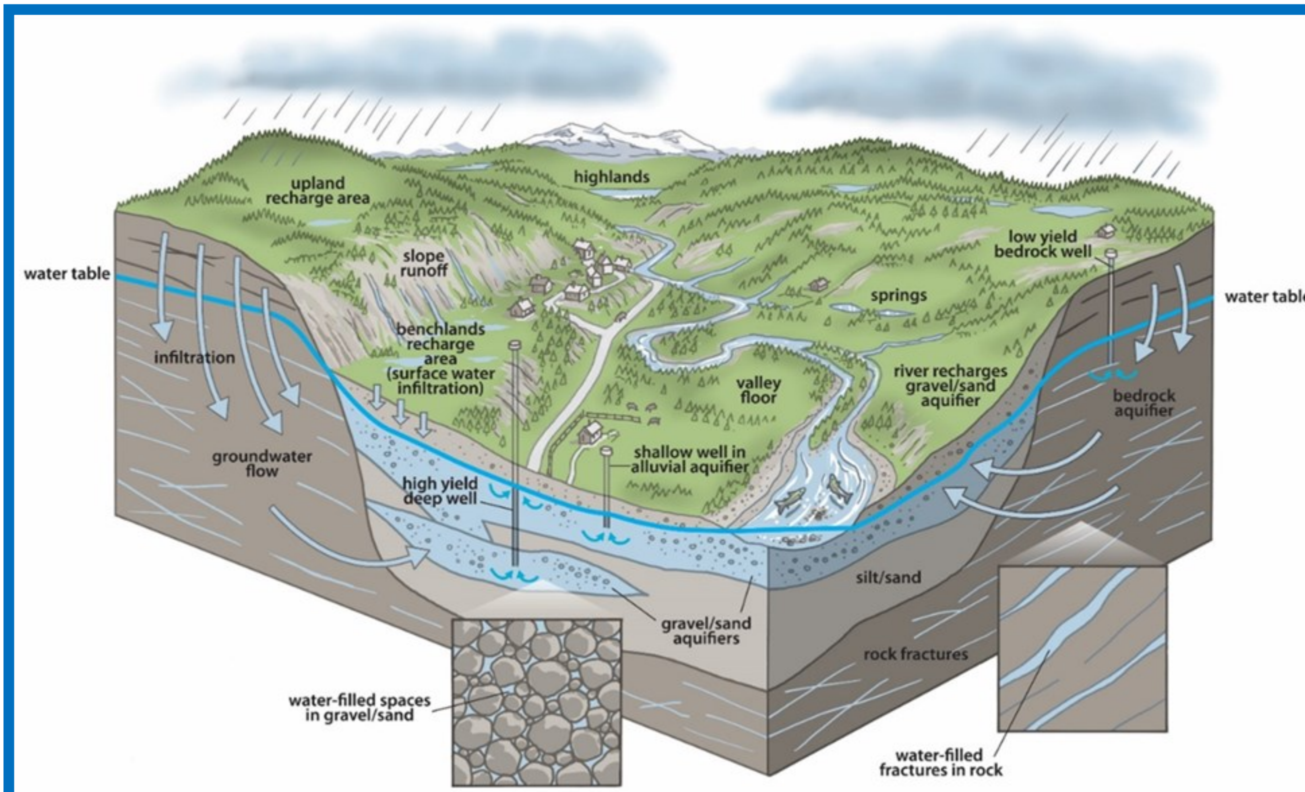


Approach



A major component of the project was the development of a detailed watershed hydrologic model. The model takes into account many of the physical attributes of the watershed, including information about the topography, climate, vegetation, soils, and geology, as well as man-made influences such as urban drainage systems, ponds, water diversions and groundwater wells. The model uses mathematical equations to simulate the movement of water through the various phases of the water cycle including rainfall, water use by plants, soil water, groundwater, and stream flow (Figures 2 and 3). The model has been calibrated to real-world measurements of stream flow and groundwater elevations at various locations throughout the watersheds and it provides estimates of how the various components of the water cycle vary in time and space. We used the model to simulate how drought and streamflow augmentation from existing reservoirs would impact the quantity and timing of stream flow in the study watersheds. The model is well suited for further investigation of the effects of wells, stream diversions, flow augmentation, management of groundwater recharge, land use change, and climate change on stream flow.

Figure 2 (above): Diagram showing the major components of the water cycle.
Figure 3 (below): Diagram shows many of the hydrologic processes and elements evaluated in the study.



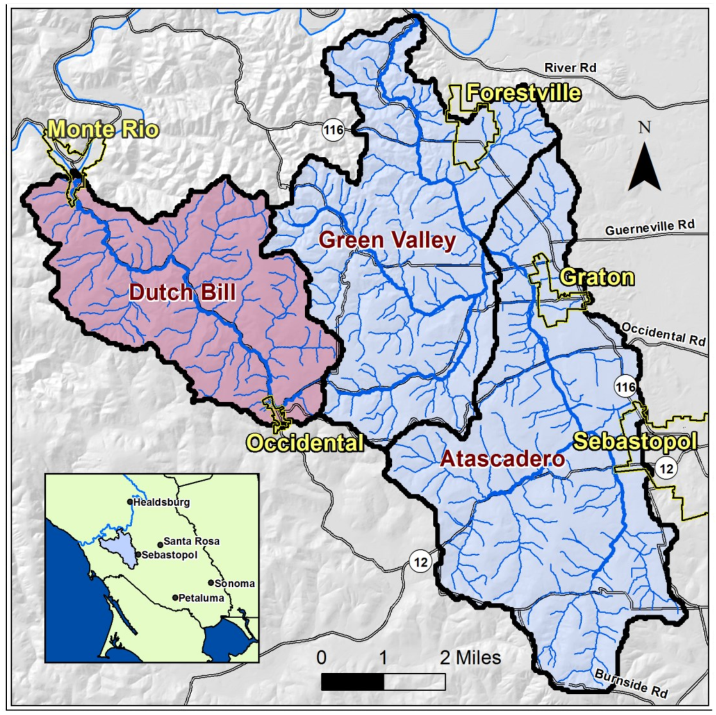
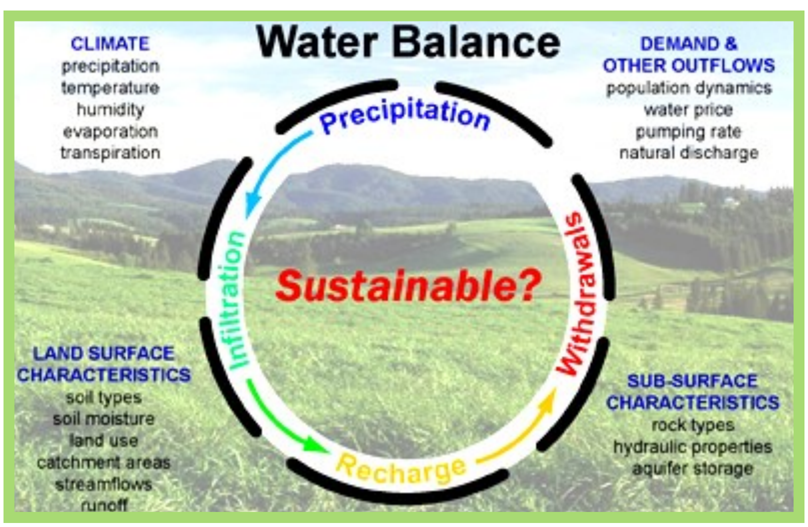


Figure 4: The study area includes both Dutch Bill Creek Watershed (pink) and Green Valley Atascadero Creek Watershed (blue).

Overview of the Watersheds

The Dutch Bill Creek and Green Valley/ Atascadero Creek Watersheds cover a 50-square-mile (32,000 acre) area of western Sonoma County, including portions of the communities of Sebastopol, Graton, Forestville, Occidental, Camp Meeker, and Monte Rio. The watershed map shows town and city limits, the main streams and tributaries, and five sub-watershed areas. Dutch Bill Creek is a distinct and separate watershed from Green Valley Creek, which includes four major sub-watersheds: Lower and Upper Green Valley Creek and Lower and Upper Atascadero Creek.

Mean annual rainfall varies from about 40 inches per year on the east side of the Green Valley Atascadero Creek Watershed to 60 inches per year on the west side of the Dutch Bill Creek Watershed. Land cover in the two watersheds consists primarily of forests, vineyards, grasslands, orchards and rural residential parcels. Soils range in texture from sandy and gravely loams to clays and clay loams. There are two major geologic units in the study area (Figure 8). The Wilson Grove Formation is sandstone which underlies most of Atascadero Creek watershed and southeastern portions of Green Valley Creek watershed. The second major geologic unit is the Franciscan Complex underlying the Dutch Bill Creek Watershed (DBC) and the northwestern portions of the Green Valley Creek Watershed (GVAC).



Water Balance

A water balance (or water budget) is a method used by hydrologists to analyze how water entering a watershed as rainfall is distributed between watershed outputs (e.g. stream flow and use by plants), human use, and storage in groundwater. With the hydrologic model we developed annual water balances for the GVAC and DBC watersheds which **show that most of the water entering these areas as rainfall either runs off as stream flow or is returned to the atmosphere by evaporation from the soil and transpiration by plants (evapotranspiration).** The relative amounts of stream flow and evapotranspiration vary from year to year, depending on annual rainfall. For example, under drought conditions such as occurred in 2014 with rainfall of about 30 to 35 inches, stream flow made up a smaller proportion of the water leaving the study area than did evapotranspiration, while in average years with rainfall of 50 to 53 inches such as 2010, the reverse is true.

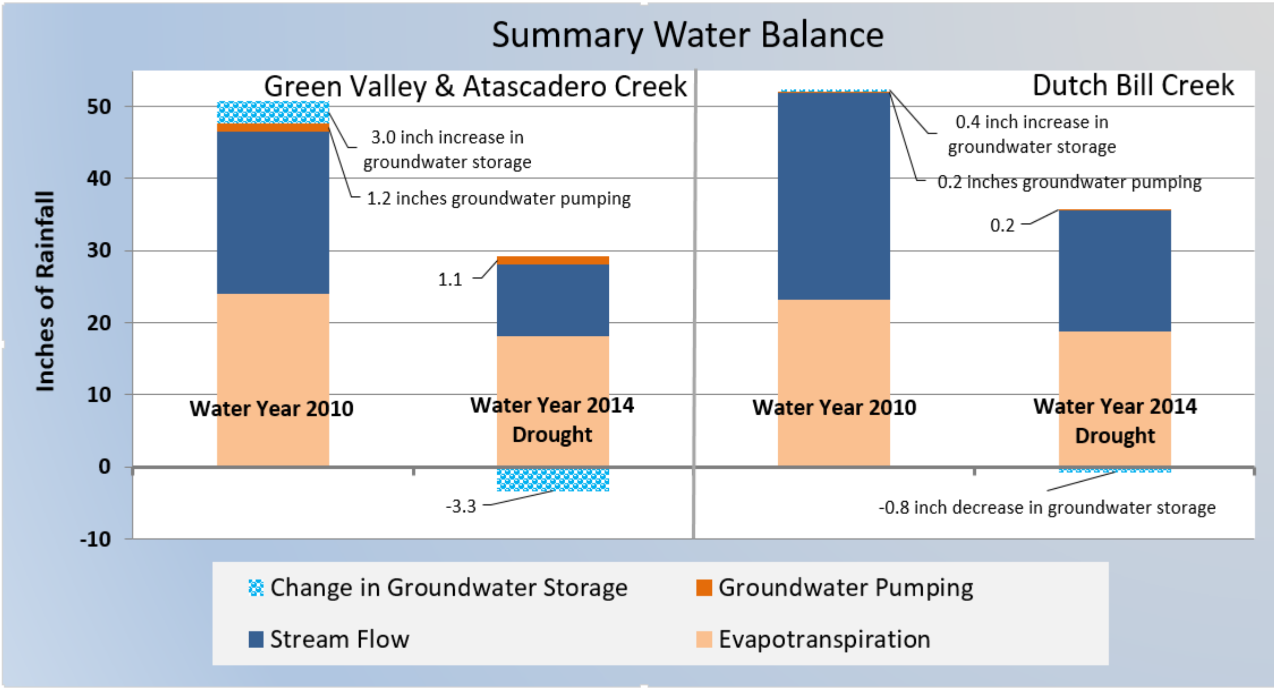


Figure 5: Annual water balances for the GVAC and DBC watersheds.

Annual groundwater pumping from wells represents a small fraction of the annual water balance (Figure 5). Groundwater use in GVAC is equivalent to 1.2 inches of rainfall across the watershed; in DBC, groundwater use is equivalent to 0.2 inches of rainfall. The low rate of use of groundwater in DBD reflects the limited availability of groundwater in the Franciscan bedrock. During years of average rainfall such as 2010 there is a net increase in the amount of stored groundwater (3.0 inches in GVAC and 0.4 inches in DBC) while in drought years such as 2014, there is a net decrease in groundwater storage (-3.3 inches in GVAC and -0.8 inches in DBC). A decline in water table elevation is associated with the decline in groundwater storage, and this creates potential negative impacts on summer stream flow and coho habitat. Although groundwater use is a small component of the annual water budget, it is possible that pumping groundwater from wells could affect water table elevation that in turn affects stream flow, particularly during the summer and in drought years.

Increases and decreases in groundwater storage tend to balance out over many years unless the amount of groundwater use consistently exceeds groundwater recharge, creating overdraft conditions. Model simulations of groundwater cover the five-year period beginning in October 2009 and ending in September 2014. The first two years were aver-

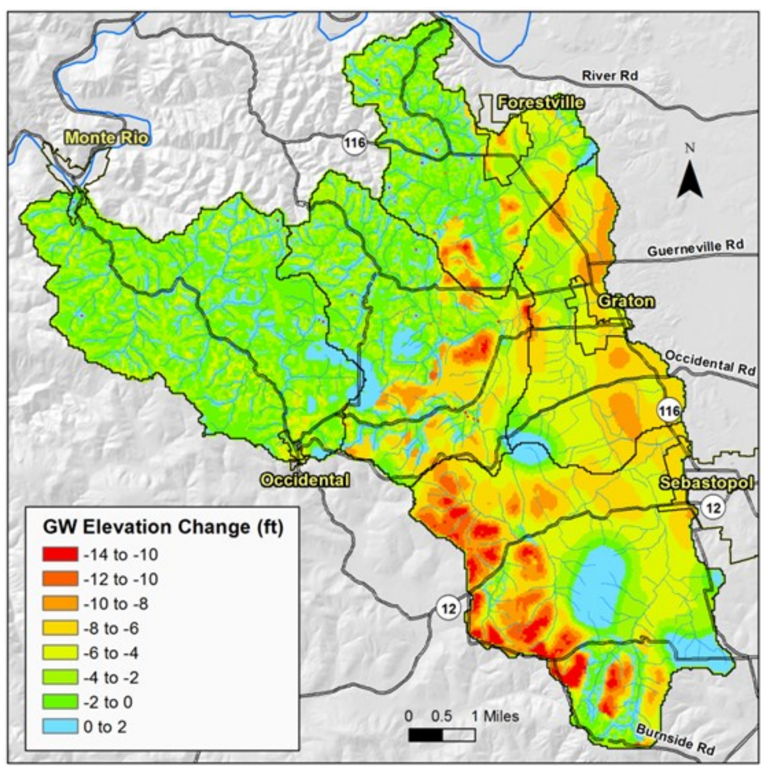


Figure 6: Simulated change in depth to groundwater between 2009 and 2014.

age or wet years and were followed by three consecutive dry years, part of the historic statewide drought that continued through 2015.

The model simulations indicate accumulated reductions in groundwater storage during the drought, but they also indicate that normal rainfall conditions would be expected to replenish groundwater storage. The reductions in groundwater storage manifested as small decreases in groundwater elevations in most areas and modest decreases of up to 14-ft in other areas such as upper Atascadero Creek (Figure 6). **In other words, the drought created short-term groundwater overdraft, but the model simulations suggest that long-term groundwater overdraft under current climate and water use conditions is NOT occurring.**

Water Use

Water use rates used in the model were estimated from available data. Water use in this study is divided into three categories: vineyard irrigation, vineyard frost protection, and domestic (Table 1 & Figure 7). Domestic use includes both indoor household use and outdoor irrigation of gardens and landscaping. Water use for other agricultural purposes simulated in the model are very small; it is assumed that orchards are not irrigated. Legal or illegal cannabis grown in the region was unknown so not taken into account. Use of surface water diverted from streams for agriculture and water imported by public water suppliers was accounted for first, and the remaining demand for water was assumed to be satisfied by pumping groundwater from wells.

The majority of the water use in both watersheds comes from groundwater sources. Surface water diverted from streams under terms of existing water rights represents a relatively small amount of annual water use compared to groundwater pumped from wells in the GVAC watershed (Table 1). In Atascadero Creek about 85 acre-feet per year is diverted from streams, representing 5% of the total water use in the watershed. In Green Valley Creek watershed about 130 acre-feet per year is diverted from streams, representing about 15% of the total water use in the watershed. In Dutch Bill Creek, 115 acre-feet per year is diverted from streams, representing about 41% of the total water use. Stream diversions locations and rates were obtained in 2013 from the State water rights public database. The model development preceded the State emergency conservation and information order issued in 2015.

Agricultural Use

The annual vineyard irrigation rate was estimated to be 0.3 acre-feet per acre per year of vineyard (equivalent to 3.6 inches of applied water) based on the average use reported for stream diversions for vineyard irrigation allowed by water rights permits. All vineyards are assumed to be irrigated using this average rate which is consistent with the extent of dry-farmed vineyards and low irrigation rates in coastal Sonoma County (the average irrigation rate in Sonoma County is about 0.5 acre-feet per acre of vineyard, equivalent to 6 inches of applied water). Water for irrigation of vineyards with no surface water rights was assumed to be supplied by private wells. **Mean annual water**

use for frost protection was estimated based on available climate data and frost protection system information obtained from County permit data specific to each vineyard.

Domestic Use

A significant portion of the domestic water used in the study area is obtained from outside the watershed and provided to residents by public water supply agencies serving Sebastopol, Forestville, Monte Rio, and portions of Camp Meeker and Occidental. Based on 2010 census data, 4,465 residents of the study area obtain water from such public supplies. The remaining 10,651 residents obtain domestic water from groundwater wells. Domestic water use from private wells was estimated based on census data and City of Sebastopol water use data for 2010 through 2013. **Mean annual per capita use was estimated at 129 gallons per person per day, of which 46% (59 gallons per person per day) is indoor use.**

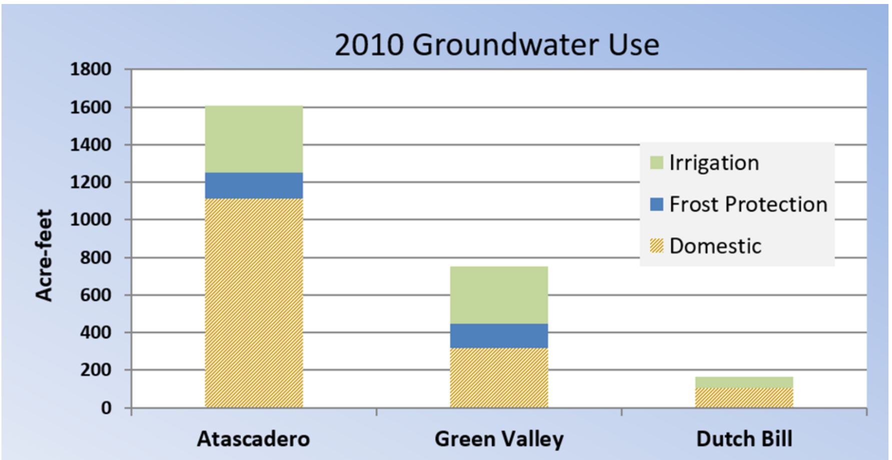


Figure 7: Breakdown of total annual groundwater use by type of use, units are acre-feet per year.

				2010 Groundwater Use (acre-feet)			Surface Water Diversions Reported to SWRCB (acre-feet)
Watershed	Drainage Area (acres)	Population Served by Wells	Vineyard Acres Served by Wells	Irrigation	Frost	Domestic	
Atascadero	12,961	7,660	1,187	359	138	1,112	85
Green Valley	11,361	2,261	1,013	306	131	328	130
Dutch Bill	7,654	730	201	61	0	106	115
Total	31,976	10,651	2,401	726	289	1,546	330

Table 1: Breakdown of annual surface water and groundwater use by sub-watershed.

Groundwater

Most groundwater is pumped from the Wilson Grove Formation, which underlies Atascadero Creek and the southeastern portion of the Green Valley Creek watershed (Figure 8). The thickness of the Wilson Grove Formation increases from west to east from less than 50-ft thick east of Occidental to more than 600-ft thick in the Sebastopol area. Groundwater is also pumped from fractures within rocks of the Franciscan Complex, which underlies all of DBC and the northwestern portion of Green Valley Creek. This source of groundwater is relatively limited compared to groundwater in the Wilson Grove Formation sandstone. The Wilson Grove Formation is a significant source of groundwater; municipal wells operated by the City of Sebastopol drilled in the Laguna de Santa Rosa watershed pump groundwater from the Wilson Grove Formation. Alluvium (sediments deposited by streams) is also present along the major streams in the study area, and many groundwater wells are located to pump water from it. In general the alluvium contains large amounts of

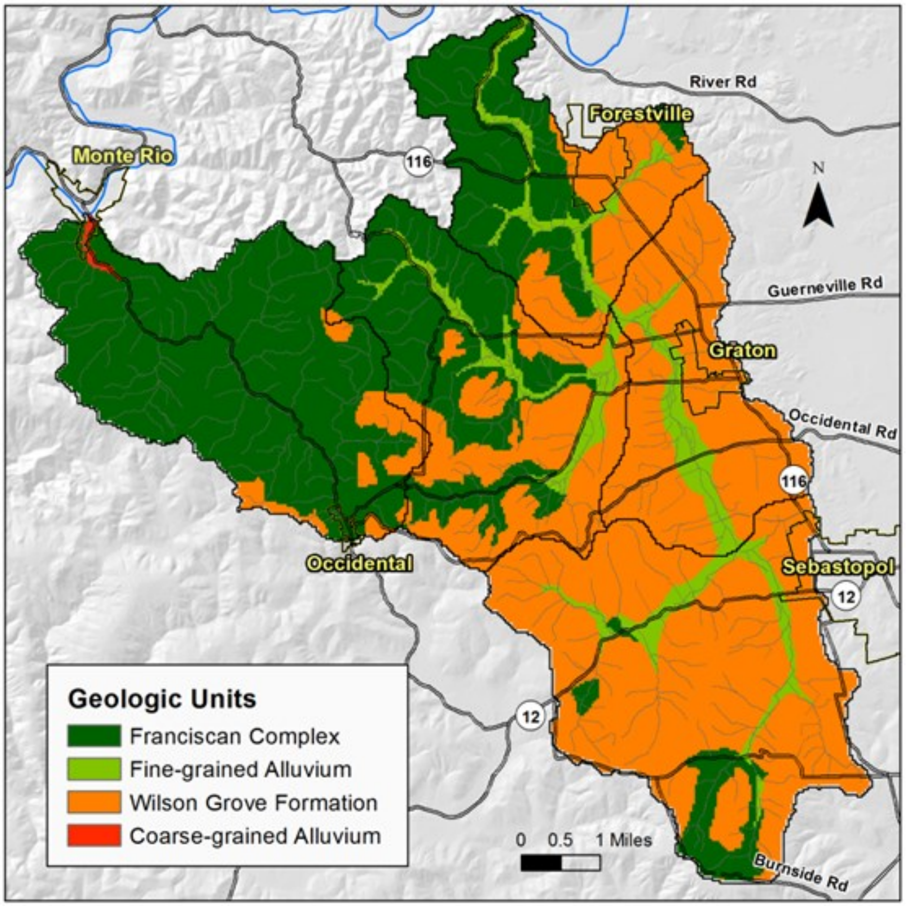


Figure 8: Major geologic units.

silt and clay, is relatively thin, and is not a major source of groundwater. In some areas, however, such as lower Purrington and Atascadero Creeks, the alluvium reaches thickness of more than 100-ft. The alluvium in lower Dutch Bill Creek is much coarser containing large amounts of sand and gravel.

Groundwater stored in our watersheds is replenished by percolation of rainfall through soils and by infiltration through creek beds. The study identified areas where soils with abundant sand and gravel (typically in uplands) are capable of high rates of infiltration of rainfall, as well as clay-rich soils (typically in low-lying floodplains) where infiltration rates are low. During average rainfall years, the mean groundwater recharge rate is about 10 inches per year in the GVAC watershed and about half that in the DBC watershed (Figure 9). Under drought conditions, average recharge is about 2 inches per year. Infiltration of stream flow through stream beds in normal rainfall years is about 6.4 inches per year in GVAC and only about 1 inch in DBC. In drought years, stream bed infiltration declines to 4.8 inches in GVAC, but

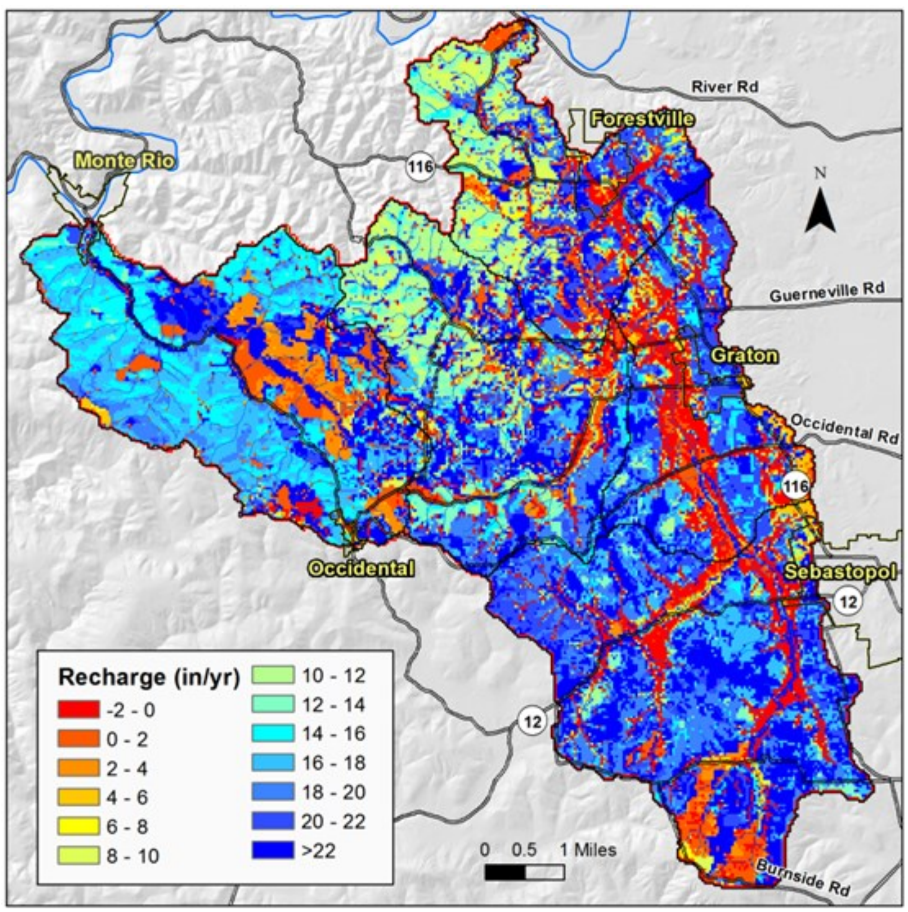


Figure 9: Simulated annual groundwater recharge rate in units of inches per year. Blue areas have high potential recharge rates because of sandy-gravelly soils. Red and orange areas have low potential recharge rates because of clay-rich soils. Recharge rates are also influenced by variations in rainfall, land cover, and geology.

increases somewhat in DBC. It is desirable to maintain recharge processes by constructing percolation ponds or otherwise managing rainfall, runoff, soils and vegetation in areas where soils and bedrock are favorable for percolation. **The model provides an objective starting point for identifying locations where management of groundwater recharge is most important. The model can also be used to develop land management strategies that would maintain and enhance recharge processes.**

Surface Water/Groundwater Exchange

Water flows from groundwater to streams in much of the watershed, maintaining year-round flow in some areas (gaining streams). However in other areas water flows from streams to groundwater (losing streams), sometimes to the point that surface flows disappear, along with fish habitat.

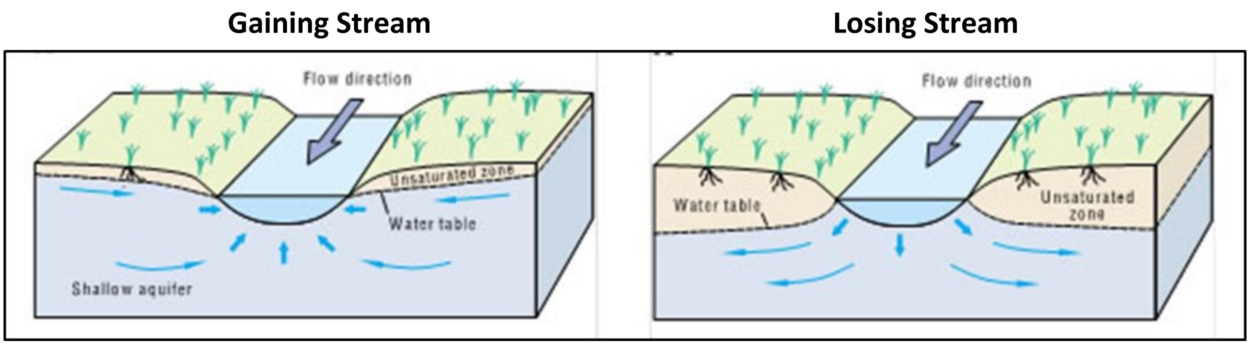


Figure 10: Diagram showing how surface water and groundwater interact in gaining and losing streams.

The location of gaining and losing reaches varies through the watershed as shown in the map of annual net exchange between surface water and groundwater (Figure 11). The exchange can also change seasonally such that the same stream location may be gaining during one season and losing in another. Stream flow conditions during summer at any given location are determined by inflows from upstream and the height of the water table adjacent to the stream.

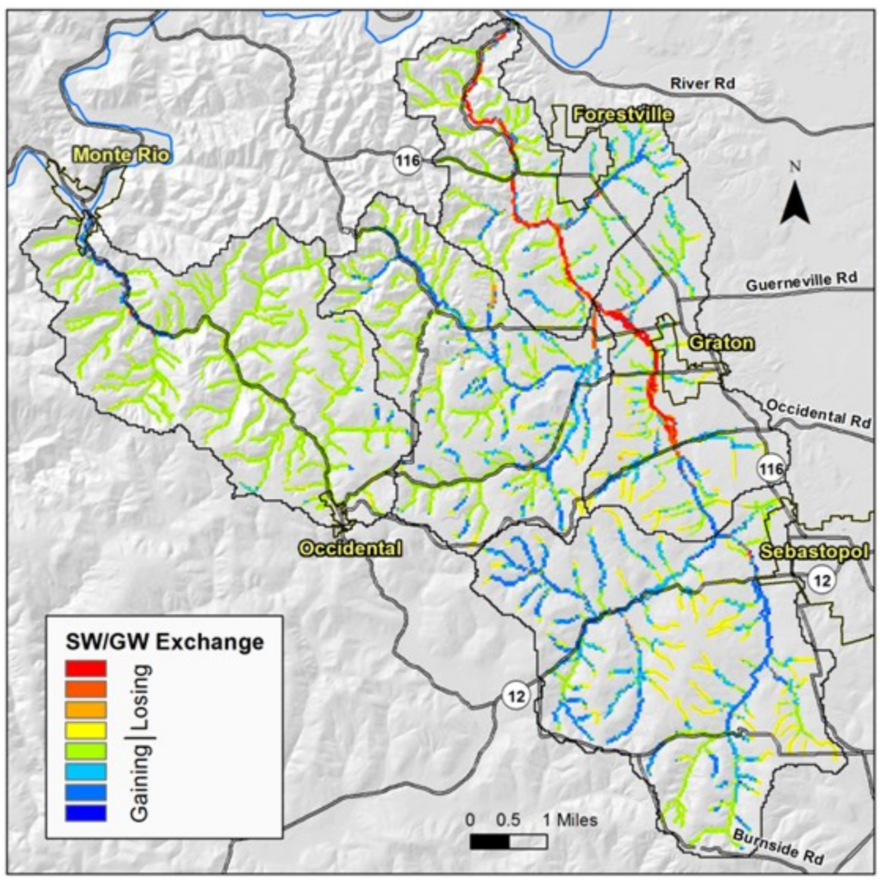


Figure 11: Annual exchange between surface water (SW) and groundwater (GW).

In many portions of the GVAC watershed, groundwater that can be exchanged with stream flow may be in alluvial deposits that are separated from the underlying Wilson Grove Formation by thick layers of clay. In these and other hydrogeologic circumstances, groundwater pumping from wells near streams might have little or no effect on stream flow conditions. On the other hand, pumping groundwater from shallow wells near streams could potentially have significant effects on stream flow.

Seasonal Stream Flow Conditions

To learn more about where and when water is available, particularly in creeks where coho salmon could live, the study utilized the hydrologic model to examine groundwater and surface water conditions across the watersheds and through time. The water balance for GVAC watershed described previously on an annual basis can be viewed monthly for the period October 2009 through September 2014 (Figure 13); this graph emphasizes the Mediterranean climate cycle of wet winters and dry summers with low stream flow. The amount of water flowing in streams varies widely from winter to summer with the highest flows occurring during rain storms and declining at various rates through the spring and summer depending largely on the exchange between groundwater and surface water. Portions of the graph showing negative recharge are indicative of groundwater discharge to wetland areas primarily located along portions of Atascadero Creek.

As shown in Figure 12, small but significant flows are maintained year-round where upstream inflows from groundwater are substantial and the stream bed sediment and underlying rock do not permit high rates of loses to groundwater, such as lower Purrington Creek, lower Green Valley Creek, portions of West Fork Atascadero Creek and the middle reaches of Dutch Bill Creek. In streams where upstream groundwater transfers to surface water are relatively low and where the stream bed sediment is comprised of thicker layers of sand and gravel, surface flows tend to disappear in the summer (for example, lower Dutch Bill Creek near Monte Rio and portions of Atascadero and Green Valley Creeks between Graton and Forestville).

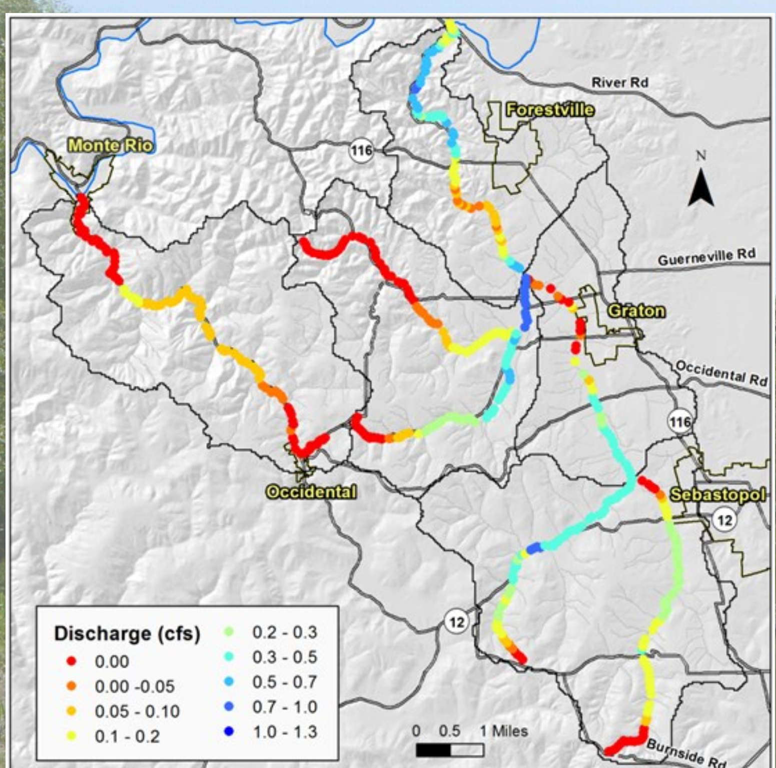


Figure 12: Minimum stream flow or discharge in units of cubic feet per second (cfs) during an average water year (2010).

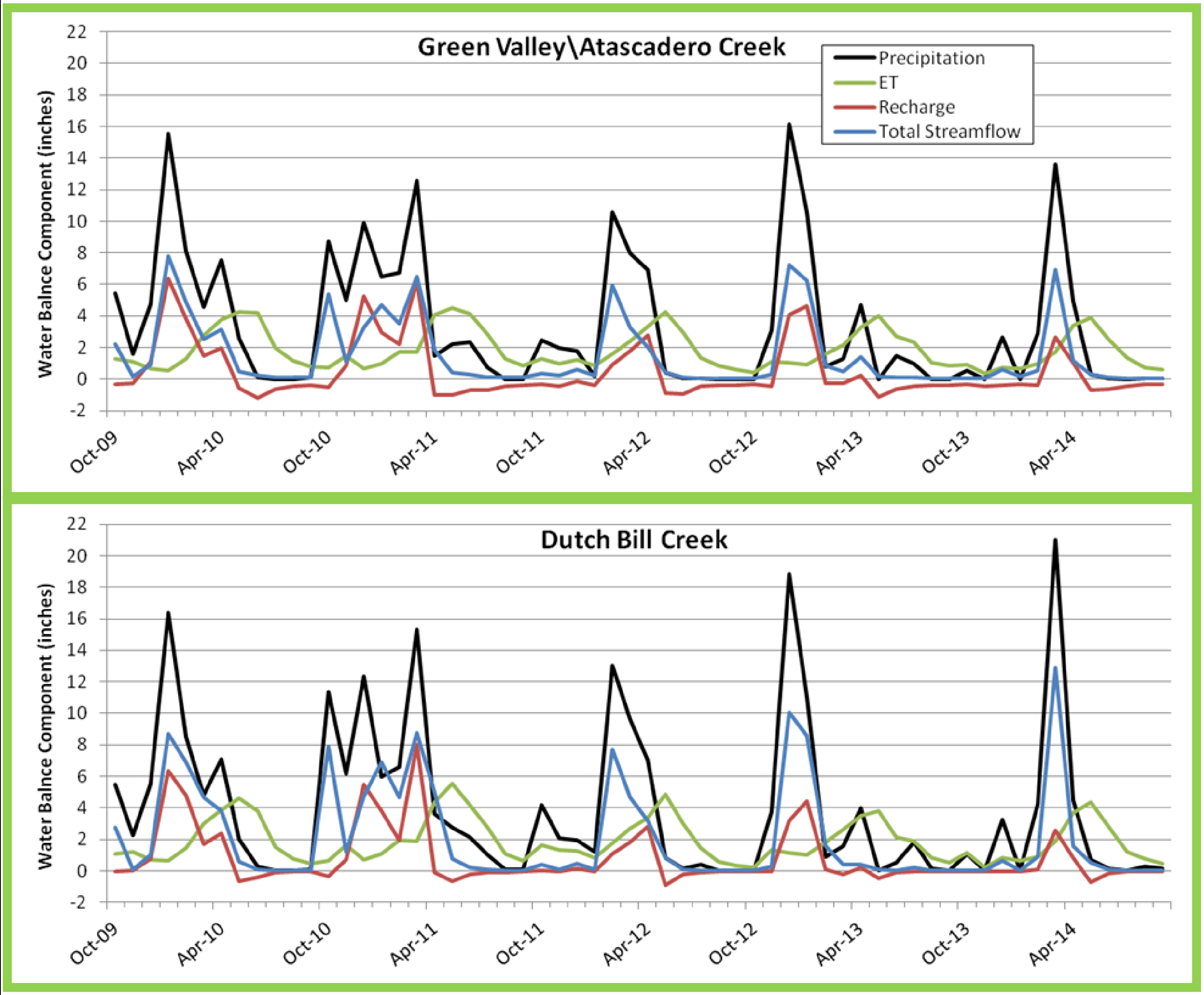


Figure 13: Monthly water balances showing the seasonal and annual variations in rainfall, recharge, evapotranspiration (ET), and stream flow in the GVAC and DBC watersheds.

Habitat Improvement Opportunities

During late summer, the survival of coho salmon is threatened because the extent of habitat defined in terms of quantity of stream flow and surface connectivity of stream flow dramatically declines throughout the watersheds. This occurs in average years and is much worse in drought years. Where stream flows diminish to the point of having no surface flow, coho cannot survive. Where surface flows diminish significantly but deeper areas of the stream (i.e. pools) remain filled with water, coho may survive but habitat is marginal at best. Field studies of coho by University of California Cooperative Extension fish biologists have found that habitat suitability declines when surface flows connecting pools disappear due to low stream flows. When pools are disconnected for more than a few days, coho are at a high risk of mortality.

In an average year, flows are sufficient to maintain connectivity between pools and provide suitable (though not optimal) habitat in about 16.2 stream miles in the study area (Figure 14). During drought, the total habitat area decreases to about 12.8 stream miles. Stream flow simulations corroborated by field observations and flow data indicate that certain stream reaches tend to have persistent flows that maintain higher quality habitat (for example, the middle reaches of Dutch Bill and Purrington Creeks), while other stream reaches tend to have more frequent and extensive interruptions of surface flows and pool habitat or complete loss of surface flow (for example, upper Green Valley Creek).

Coho habitat in the study area was systematically evaluated and classified based on the persistence and depth of stream flow during late summer determined by flow simulations. These classifications of flow conditions provide the basis for prioritization of recommended locations and objectives of coho habitat restoration activities (Figure 14).

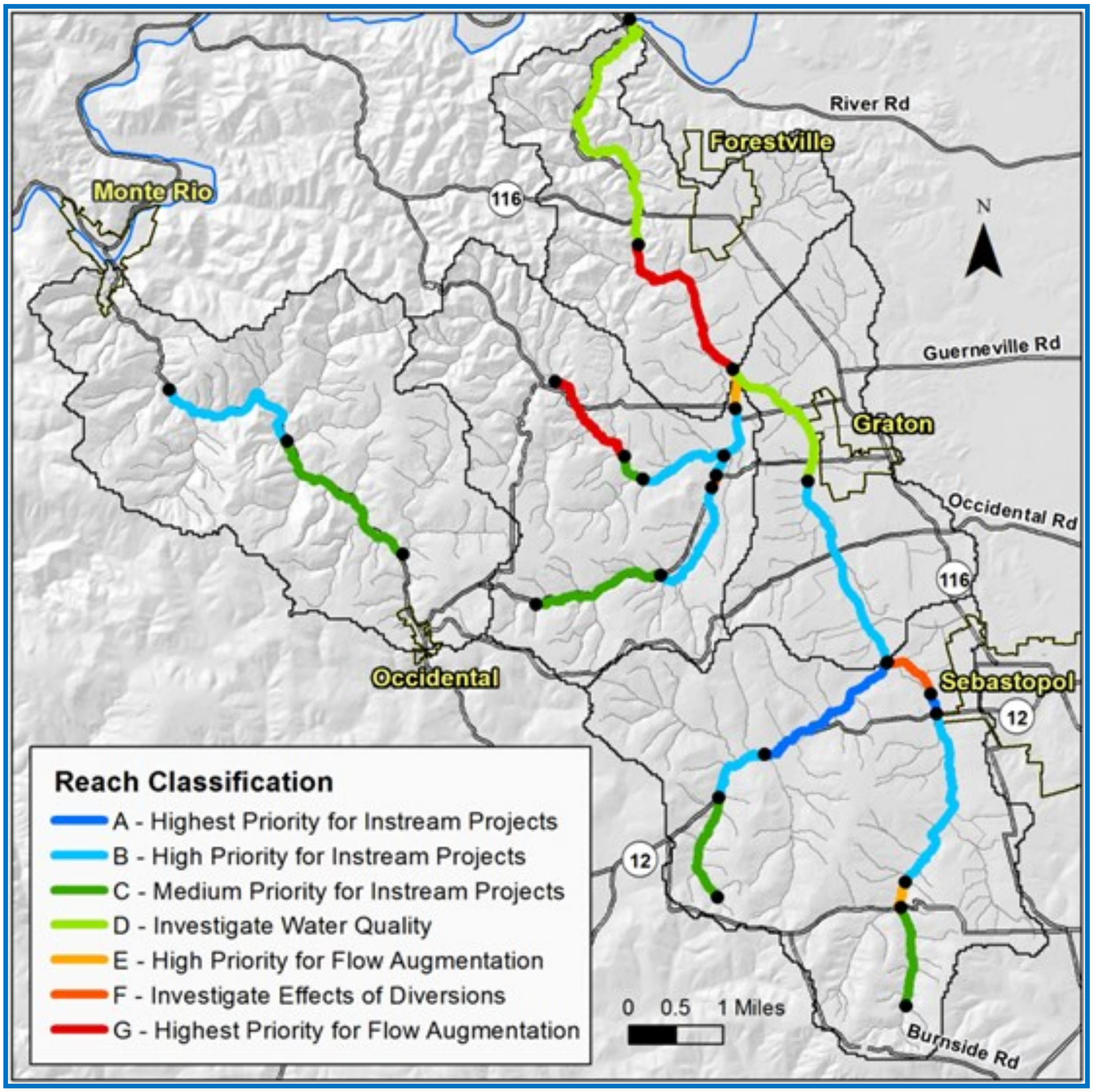


Figure 14: Coho habitat classification based on simulated flow conditions and associated restoration recommendations.

Highest quality habitat (Reaches A & B): Stream flow persists even during drought conditions providing suitable flows for coho summer rearing habitat.

Marginal quality habitat (Reaches C, D, E, & G): Late summer stream flow is very low and pools may become disconnected from surface flow. These reaches are critically sensitive to the effects of drought, and inconsistent flow may severely curtail coho summer rearing habitat.

Habitat potentially impacted by diversions (Reach F): These reaches have the potential to be high quality habitat, but utilization of water rights under existing licenses has the potential to significantly diminish stream flow and coho habitat.

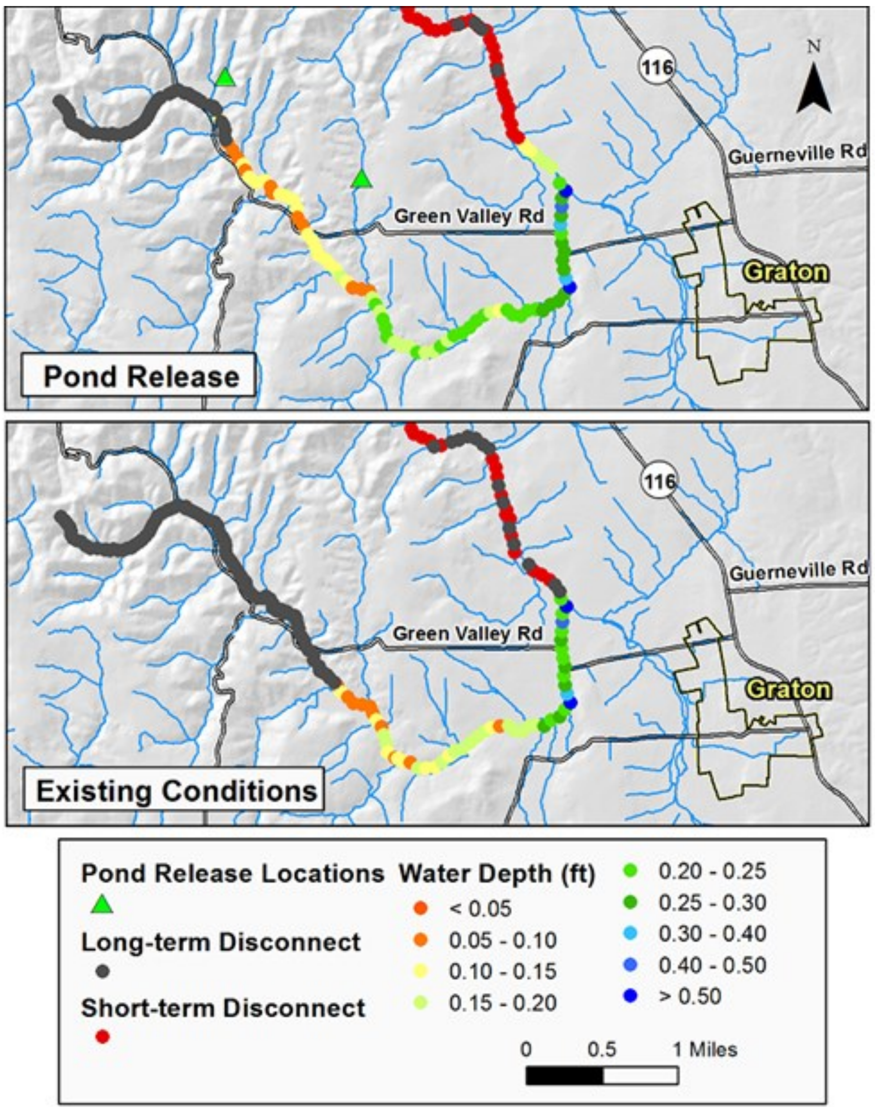


Figure 15: Increases in water depth and extent of suitable habitat resulting from releasing water from ponds in upper Green Valley Creek.

Stream Flow Augmentation

The effectiveness of releasing water back to the creeks from reservoirs was tested using the model. We simulated the release of 0.6 cubic feet per second (cfs) of water (equivalent to about one acre-foot in one day) from two ponds in upper Green Valley Creek. The model indicated that these reservoir releases were very effective at improving streamflow and surface connectivity during drought conditions. These modest flow releases resulted in a two-fold increase in the extent of suitable habitat in upper Green Valley Creek (Figure 15). Based on these findings, efforts to provide water from ponds should be pursued as an effective means to improve flow conditions for coho, particularly during droughts.

Management Recommendations

Highest quality habitat (A and B reaches): Since stream flow in these reaches is not critically limiting coho summer rearing habitat, projects that enhance in-stream habitat are appropriate under existing conditions. Coho habitat can be improved with projects such as restoration of native riparian vegetation, installing large woody debris for fish shelter and improved depth and cover, and constructing off-channel pools or wetlands for juvenile fish habitat.

Marginal quality habitat (C, D, E and G reaches): Increase the amount of water entering these reaches by releasing water from existing or new storage facilities during the summer. Conduct further study of potential effects of wells on stream flow using the model with new well data. Summer release of water that was collected during the winter can significantly improve flow and habitat in these reaches. Projects that could enhance stream flow in these reaches are a high priority. Habitat enhancement projects to improve rearing habitat may have lower priority, but could be appropriate particularly if successful flow enhancement projects are implemented.

Potentially impacted by diversions (F reaches): Operations of diversions should be evaluated with respect to potential impacts on stream flow and habitat. Management strategies for operation of diversions to avoid impacts to habitat should be identified and their adoption should be encouraged. If appropriate, the feasibility of developing alternatives to direct stream diversion (for example, building new water storage facilities) should be investigated.

Investigate coho habitat potential in Atascadero Creek: The study revealed that more than eight miles of upper Atascadero Creek have flow conditions that are suitable for providing coho habitat. Flow in the lowest two miles of Atascadero Creek stagnates, which likely degrades water quality. Additionally, dense wetland vegetation in this reach has encroached on the principal channels and could inhibit fish migration. Whether or not coho presently utilize Atascadero Creek is not known, but favorable flow conditions in the upper watershed suggest that if conditions in lower Atascadero Creek could be improved, it would be possible to significantly increase the extent of coho habitat in the study area.

An A-grade reach enhanced with large woody debris. Large wood installations add complexity to stream habitat over time, providing scour pools and cover for fish.

C-G grade reaches can be enhanced by increasing the amount of water flowing in the stream in the summer. Here, a landowner works with wildlife agencies to fill a pond with winter water that will be released at a slow rate into the stream in the summer.

Conclusions

This study characterized the spatial and temporal variations in stream flow and groundwater conditions throughout the Dutch Bill and Green Valley/Atascadero Creek watersheds. Stream flow conditions were related to habitat requirements for juvenile coho in order to understand the variations in habitat suitability throughout the watersheds. The study identified reaches with suitable flow conditions where projects to enhance in-stream habitat would be most beneficial, reaches where flow conditions are marginal and where efforts to augment stream flows should be focused, and reaches potentially impacted by diversions. The study found that augmenting stream flows by releasing water from ponds has the potential to significantly enhance habitat conditions. Another key finding is that upper Atasacadero Creek has the potential to provide significant habitat for coho but water quality and/or fish passage issues in the lower portions of the creek may be limiting use of the upper watershed.

In addition to characterizing coho habitat and making restoration recommendations, the study provides detailed hydrologic information for informing a wide variety of land and water use management efforts. For example, maps of groundwater recharge potential provide a valuable means of planning locations of projects designed to protect or enhance recharge processes. The study found that the recent drought resulted in modest declines in groundwater elevations and groundwater storage in some areas and significantly reduced groundwater recharge, summer stream flow, and extent of suitable coho habitat. These findings provide an important basis for understanding the resiliency of the watersheds in terms of maintaining stream flow, fish habitat, and water supply reliability.

Ideally this hydrologic study and its model will become a management tool. The “watershed atlas” produced by the simulation model can be used to inform water resources management now and into the future. A wealth of detailed information is available from the existing study that can be organized or evaluated to identify opportunities to promote groundwater recharge and to augment stream flow from existing or new reservoirs. In addition, the model can be used to evaluate impacts of climate change, increased water use, and changes in land use. As more detailed information about wells and diversions becomes available, the model can be improved and applied to evaluate the effects of water use and water conservation on stream flow and habitat conditions.

For more information including a full technical report please visit the Gold Ridge RCD website www.goldridgercd.org or contact Sierra Cantor at sierra@goldridgercd.org