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Monitoring Plan for the Napa River Sediment TMDL & Habitat Enhancement Monitoring Program

PREPARED FOR

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Cover photos: Mainstem Napa River (top and bottom left), Sulphur Creek (top right), and Rector Creek (bottom right).

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1 INTRODUCTION

Aquatic habitat conditions throughout the Napa River watershed have been declining since the onset of European settlement in the nineteenth century. Best available historical habitat information indicates that since the 1940s, steelhead trout (*Oncorhynchus mykiss*) runs have decreased from 6,000 – 8,000 to less then a few hundred fish, coho salmon (*Oncorhynchus kisutch)* runs of 2,000 – 4,000 fish have disappeared completely, and Chinook salmon (*Oncorhynchus tshawytscha*) runs have dwindled considerably (USFWS 1968, Leidy et al. 2005, Napolitano et al. 2009). Based on threats to aquatic habitat from erosion throughout the watershed, the California Regional Water Quality Control Board, San Francisco Region (Water Board) listed Napa River as impaired by sediment under Section 303(d) of the Clean Water Act in 1990. As a first step in developing the necessary linkages between aquatic habitat conditions and the impact of fine sediment pollution, the Water Board partnered with the State Coastal Conservancy in funding a Limiting Factors Analysis for several key aquatic species in the Napa River watershed (Stillwater Sciences and W.E. Dietrich 2002). Through a comprehensive survey of ecological and geomorphic conditions throughout the watershed, the study concluded the following factors were contributing to declines in steelhead trout and salmon populations:

1. Excess fine sediment accumulation (and associated low inter-gravel flow rates) within spawning and rearing habitat in the mainstem Napa River and tributaries;
2. Channel incision within spawning and rearing reaches in the mainstem Napa River and tributaries (which in turn contributes to excess production and downstream accumulation of fine sediment and a decrease in aquatic habitat complexity);
3. The presence of passage barriers in the mainstem Napa River and tributary channels that limit or prevent anadromous salmonid access to spawning and rearing habitat as well as downstream migration out of the watershed; and
4. Reduced baseflows and subsequent stressful water temperatures within mainstem and tributary rearing habitat during the spring and summer months.

From this and other information, the Water Board concluded that water quality standards for sediment and for salmonid population and community ecology are not being met. Because of this finding, a sediment total maximum daily load (or sediment TMDL) for the Napa River watershed needed to be developed. A sediment TMDL involves determining acceptable values for impaired water quality parameters related to sediment and developing approaches for tracking progress in reaching those values. Key components of a sediment TMDL include the following:

- Pollutant source analysis.
- Numeric targets (e.g., specification of parameters that can be measured to evaluate attainment of water quality standards).
- Linkage analysis between pollutant sources and numeric targets.
- Pollutant load allocations.
- Implementation Plan (to attain and maintain water quality standards).
- Monitoring Plan (to evaluate progress in achieving pollutant allocations and numeric targets).

The Water Board used the Limiting Factors Analysis and additional focused geomorphic and fisheries surveys as the basis for completing the Napa River Sediment TMDL and Habitat Enhancement Plan (Napolitano et al. 2009, also called the Sediment TMDL Plan). The Sediment TMDL Plan outlines an approach for addressing all four primary factors determined to be affecting steelhead trout and salmon populations and thereby establishes a plan to improve overall habitat conditions throughout the watershed. The numeric targets developed for assessing the attainment of water quality standards (i.e., acceptable levels of fine sediment delivery to channels) relate to inter-gravel streambed permeability and bed scour values associated with successful salmonid spawning and likely salmonid survival to emergence. The numeric target values put forth in the Sediment TMDL Plan are as follows:

"The median value for streambed permeability shall be ≥7,000 cm per hour at potential spawning sites for steelhead and salmon in the Napa River watershed. We estimate this target value corresponds to approximately 50 percent or greater survival of eggs and larvae from spawning to emergence…"

and

"*The mean depth of scour shall be ≤15 cm below the level of the overlying streambed substrate at typical pool-tails/riffle heads in all gravel-bedded reaches of mainstem Napa River and in the lower alluvial reaches of its perennial tributaries in reaches where the streambed slope is gentle (0.001 to 0.01). The target applies in response to all peak flows ≤ bankfull discharge*."

In accordance with sediment TMDL protocol, these parameters will be measured throughout the Napa River watershed during a long-term monitoring effort. The overall goal of the monitoring effort is to collect the appropriate data within representative spawning reaches to track permeability and scour over time and to ascertain whether numeric targets are being met with a high level of statistical confidence. In the process of meeting this goal, the monitoring effort will also help determine the degree to which TMDL-related sediment control measures are impacting downstream habitat conditions, which in turn will help improve subsequent sediment control efforts and ideally help decrease the time required to reach the numeric target values

This document serves as the Monitoring Plan for collecting permeability and scour data over a suitable time period that enables assessment of numeric target achievement. Here, we present a statistically robust approach for measuring these parameters at multiple locations during discrete time periods, tracking the change in parameter values over time, and ultimately determining if/when parameter values begin to approach the specified numeric targets. The results of the monitoring effort will be combined with results from other studies being conducted throughout the watershed as part of the sediment TMDL, which, when combined, will ultimately drive the decision to remove the Napa River watershed from the list of sediment-impaired watersheds.

2 PHYSICAL SETTING

The Napa River drains a 1,200 km^2 watershed and flows through the cities of Calistoga, St. Helena, Yountville, Napa, American Canyon, and Vallejo before discharging into San Pablo Bay near the mouth of the Sacramento-San Joaquin estuary (Figure 2-1). The river originates in steep, forested headwaters (elevation 1,200 m) and then enters the depositional Napa Valley, whose floodplain is dominated presently by agriculture and developed areas. Historically, an array of both 'connected' tributaries (i.e., tributaries with a discrete channel mouth that delivered water and sediment to the mainstem Napa River) and 'disconnected' tributaries (i.e., tributaries without a discrete channel mouth that flowed directly onto the mainstem floodplain) flowed into the Napa Valley (Grossinger 2012). Over the past century, widespread channelization for agricultural land establishment has resulted in the direct connection of most tributaries to the Napa River. Currently, delivery of both water and sediment from tributaries to the Napa River is regulated by the network of water supply dams installed over the past century. Most major dams (i.e., dams large enough to impound water and sediment) are located on the tributaries draining the eastern side of the basin, with the majority being built during the 1940s and 1950s. The largest dams are the municipal water supply projects on Bell, Conn, Rector, and Milliken creeks, which collectively regulate approximately 20% of the total Napa River watershed area.

The Napa Valley has a Mediterranean climate characterized by warm, dry summers and mild, wet winters. The majority of annual precipitation occurs as rain that falls between November and April, with the highest rainfall rates occurring on the western side of the valley. Precipitation decreases southward through the Napa Valley, with average annual precipitation varying from 965 mm at Calistoga (WRCC gage 041312) to 626 mm at the Napa State Hospital near the city of Napa (WRCC gage 046074). Average annual air temperatures are also lower in the southern portion of the valley due to coastal fog influence. Total annual precipitation can be highly variable from year to year, varying by several orders of magnitude between the driest years and the wettest years. At the downstream end of the watershed near the city of Napa, daily mean river flow (as recorded at USGS gage 11458000) is below 20 cfs the majority of the time (i.e., flows exceed 20 cfs less than 50% of the time) but varies considerably between the drier summer months (~2 cfs on average during August and September) and the wetter winter months (>600 cfs on average during January and February). The bankfull event (i.e., storm event with a 1.5- to 2-year recurrence interval) at this location has a peak discharge between 6,000 and 9,000 cfs.

The Napa River basin is a northwest-trending structural and topographic depression that has largely evolved since the early Pleistocene (about 2 million years ago) as a result of ‘downwarping’ associated with regional folding and faulting (Hearn et al. 1988). The basin is located at the southern end of the northern California Coast Range province and is within the San Andreas Fault zone. The local deformation zone is bounded by two major northwest striking faults: the Green Valley Fault (approximately 11 km to the northeast of the basin boundary) and the Healdsburg-Rodgers Fault in the west (approximately 24 km to the southwest of the basin boundary). The Napa Valley floor is primarily Quaternary alluvium deposited over the last million years (Johnson 1977, Kunkel and Upson 1960) and the uplands are composed of Jurassic to Pliocene age volcanic and sedimentary units (Jennings 1977 and Wentworth 1997, Figure 2-2). Moderately erodible marine and non-marine sedimentary deposits underlie approximately 25% of the watershed, primarily in the northeastern and southwestern portions of the basin. The northwestern and southeaster portions of the basin are dominated by Sonoma volcanics (hard Tertiary lava flow deposits covering approximately 23% of the watershed area) and Sonoma volcanic tuff and ash flow (moderately erodible Tertiary rocks covering approximately 11% of the watershed area). Bedrock in the eastern and western portions of the basin also includes Franciscan mélange and sheared serpentinite (highly erodible Jurassic to Tertiary marine sedimentary and ultramafic rocks that cover approximately 6% the watershed). The variability in bedrock erodibility is a primary driver of localized areas of higher and lower sediment production and delivery to the channel network throughout the basin (Napolitano et al. 2009).

Since European settlement began in the early nineteenth century, land use throughout the Napa River watershed has changed considerably. By the 1850s, the primary land uses in the Napa River watershed were agricultural activities, including timber production, grazing, and field crops. Vineyards were first developed in the 1860s, and up until about 1960 the valley floor was used primarily for a combination of orchards, field crops, and vineyards, with localized urban development in the cities of Napa, Yountville, St. Helena, and Calistoga. The area under grape production within the watershed rapidly increased from approximately 40 km^2 in 1970 to approximately 130 km^2 in 1996 (of which 75% is located on the valley floor and adjacent alluvial fans) (Napa County RCD 1997). The desire to protect the agricultural lands within the Napa Valley resulted in the construction of a system of flood control berms from the 1960s through the 1990s. Currently, all agricultural cover types combined compose nearly 20% of the total land use, including orchards and vineyards (13%), pasture/hay (6%), and row crops and small grains (each <0.1%) (Figure 2-3). In addition, residential and industrial/commercial/transportation land uses combined cover approximately 10% of the watershed, rangelands (i.e., grasslands and other herbaceous vegetation) cover approximately 25% of the watershed, and forested areas (evergreen, deciduous, and mixed) cover 35% of the watershed.

3 MONITORING APPROACH

3.1 Overall approach

The overall approach entails monitoring gravel permeability and scour depth within several representative reaches throughout the Napa River watershed containing suitable steelhead and Chinook spawning habitat. Permeability will be measured at a number of potential spawning locations within tributary reaches (i.e., steelhead spawning habitat) and mainstem reaches (i.e., Chinook and steelhead spawning habitat), while scour data will be collected at a subset of potential spawning locations only in the mainstem reaches (i.e., reaches with the highest potential for bed scour). Monitoring will occur for storm events with peak flows near or within the bankfull discharge range (called monitoring efforts) and will involve instrument installation and pre-high flow measurements during the fall and subsequent post-high flow measurements directly following the first storm event of appropriate magnitude. Following each individual monitoring effort, the collected data will be compiled and used to assess the degree to which the Napa River watershed is in compliance with the permeability and scour numeric targets defined in the sediment TMDL study. Per the recommendations in the sediment TMDL study, monitoring efforts will occur once every 2 – 5 years for approximately 10 – 20 years; however, the ultimate monitoring frequency and duration will be driven by several factors including stream flow dynamics (i.e., the presence of appropriate flows during selected monitoring years) and the time necessary for attaining defined numeric targets.

3.2 Adaptive Management

Monitoring will occur in two phases: an initial pilot monitoring effort and the long-term monitoring effort. The purpose of the pilot effort is to test the sampling design outlined in this Monitoring Plan and adjust the design if necessary using an adaptive management approach. The pilot monitoring effort will entail permeability and scour data collection at a subset of tributary and mainstem monitoring reaches during the 2012/2013 winter high flow period. Following data collection, statistical analyses and lessons learned (e.g., sampling effectiveness and limitations) will be used, as needed, to update the sampling design described herein. The updated Monitoring Plan will then be used as the guiding document for data collection efforts during the subsequent long-term monitoring effort, which will likely begin in the year after completion of the pilot monitoring effort.

Throughout the course of the long-term monitoring, updates to the Monitoring Plan may be necessary to relocate monitoring reaches or sample sites (due to issues regarding accessibility or major geomorphic change due to extreme flood events) and/or modify monitoring approaches (based on a review of the statistical robustness of the data being collected over the long term). Following each individual monitoring effort, any recommendations for Monitoring Plan modification will be compiled and submitted to the Water Board and other project Stakeholders for review. Based on the outcome of this review, the Monitoring Plan will be modified as needed to ensure the appropriate data is being collected for meeting monitoring goals.

3.3 Monitoring reach selection

3.3.1 Number of reaches

Selection of the long-term tributary and mainstem monitoring reaches involved first determining the minimum number of monitoring reaches needed to provide a statistically robust dataset that could be used to determine representative spawning gravel permeability for the entire watershed. The assessment involved conducting a power analysis (or test of statistical confidence) on the permeability data collected as part of the sediment TMDL study (Napolitano et al. 2009) under the assumption that this dataset provides an adequate representation of the range in permeability values throughout all spawning reaches. This dataset includes multiple permeability measurements within 11 discrete tributary and mainstem reaches, from which representative reach values (reach-median values, per the approach used in Napolitano et al. 2009) were determined. These values were then compiled into a watershed value (mean of the reach values) and used to assess how the degree of statistical confidence in the representative watershed value (determined by the standard error of the dataset) varied as a function of the number of monitoring reaches.

The relationship between the representative watershed permeability standard error and the number of monitoring reaches is shown in Figure 4-1. Based on this analysis and a cursory assessment of likely monitoring time and budgetary constraints for individual monitoring events, it was determined that 20 monitoring reaches ensures an acceptable level of statistical confidence (standard error of ~0.2). As scour will be measured at only a subset of monitoring reaches and permeability will be measured at all monitoring reaches, the total number of monitoring reaches necessary for this study is assumed to be 20. During the pilot monitoring project, collected permeability and scour data will be used to reassess the minimum number of mainstem monitoring reaches required for ensuring statistical confidence in the results. Following the pilot monitoring project, the number of required monitoring reaches for the study will be updated as necessary.

3.3.2 Location of reaches

The locations of 20 long-term monitoring reaches capable of capturing a representative range of reach-average permeability and scour values within both tributary and mainstem spawning habitat were determined using several selection criteria. In choosing locations, it was necessary to consider criteria related to habitat suitability (e.g., appropriate physical conditions) as well as logistical constraints (e.g., site access). The primary criteria used in selecting the 20 monitoring reaches to be used for this study, in order of consideration within the selection process, included the following:

1. Spawning habitat extent and quality;
2. Pre-existing permeability and scour data; and
3. Variation in dominant factors controlling permeability and scour.

The extent of possible Chinook and steelhead spawning habitat was defined as the upstream limit of anadromy throughout the watershed (Figure 4-2), which is determined primarily by the presence of both natural (e.g., bedrock steps) and man-made (e.g., dams and bridges) migration barriers (based on data provided by the Napa County RCD). The extent of potential high quality spawning habitat was then determined as a function of local channel slope, which was determined from a high resolution topographic dataset (1-m LiDAR data flown in 2003, Figure 4-2). Using the assumption that bed substrate size and flow hydraulics prohibit successful steelhead spawning in reaches steeper than those classified as ‘step pool’ (reaches with slopes > ~5%, as described in Montgomery and Buffington 1997), a threshold local channel slope of 5% was used to define those areas where spawning was most likely to occur (i.e., potential high quality habitat).

Permeability and scour measurements from previous studies within the extent of potential high quality spawning habitat were then used as a starting point in selecting the set of potential long-term monitoring reach locations. Re-occupation of existing permeability and scour monitoring locations has two primary benefits: 1) it ensures good reach accessibility (under the assumption that if a reach has been monitored in the past, it can be monitored again with relative ease); and 2) it can enable comparison of past and current reach spawning habitat conditions (depending on similarity in data collection approaches). The existing datasets used to compile the initial set of possible locations included permeability data from 2002 (Stillwater Sciences and W.E. Dietrich 2002), 2003 (Napolitano et al. 2009), 2004 (Stillwater Sciences 2004), and 2007 (Napa County RCD 2009)), and mainstem scour data collected in 2004 in the mainstem Napa River (Napa County RCD and SEC, 2005). Consideration of the 2003 permeability dataset was of particular importance as it contains the data used to develop the sediment TMDL permeability targets and can therefore be used as baseline data for tracking change at those monitoring reaches over the past decade. All told, the existing permeability data included dozens of measurements distributed among 20 major tributary subwatersheds and in the mainstem Napa River from the Zinfandel Road bridge downstream to the Oakville Road bridge (the Rutherford Reach, which is the only area that contains existing scour data).

The final step in selecting the long-term monitoring reaches involved assessing reach-specific factors that control permeability and scour and identifying the 20 reaches that best represent the range of conditions within salmonid spawning habitat throughout the watershed. The primary factors assessed included the following:

- <u>Sediment production</u> – Considered fine sediment and total average annual sediment production for tributary locations and total average annual sediment production for mainstem locations. The sediment TMDL and subsequent studies have shown that underlying geologic terrain is the dominant control on sediment production throughout the watershed (Napolitano et al. 2009, SFEI 2012). Land use is also an important factor driving fine sediment production and delivery, especially the presence of agricultural and/or developed land in the contributing watershed.
- <u>Total sediment production/stream power index</u> – Considered for tributary and mainstem sites. Provides an indication of the ability of a channel reach to transport the sediment delivered from upstream and has been shown to be a primary control on reach-average permeability (Napolitano et al. 2009). The index is for long-term average conditions (i.e., average annual total sediment production and bankfull stream power). Lower index values are indicative of reaches that are very efficient at transporting delivered sediment and have modest fine sediment accumulation while high values are indicative of more depositional reaches that have can have a considerable amount of fine sediment within the bed sediment matrix.
- <u>Degree of channel confinement by levees</u> – Considered for mainstem sites only. Confinement provides a dominant control on local bed shear stress and associated sediment transport and bed scour dynamics, which in turn affects not only spawning habitat conditions, but overall aquatic habitat complexity as well.

Average annual fine sediment production and total sediment production were calculated at potential tributary reaches by assigning a sediment production value to each geologic terrain in the contributing watershed and developing a weighted-average value (geologic terrain total sediment production values were derived from Napolitano et al. 2009 and relative fine sediment production values were derived from SFEI 2012). Average annual total sediment production values for the potential mainstem reaches were taken directly from values reported by Napolitano et al. (2009) for the Napa River between Calistoga and Napa. Stream power was calculated at each potential site as a product of local reach slope (used as a proxy for bankfull water slope and determined from the 2003 LiDAR dataset) and contributing drainage area (used as a proxy for bankfull discharge, considering only the regulated watershed area downstream of the four major dams). The degree of channel confinement by levees for the potential mainstem reaches was determined from analysis of recent aerial photographs combined with the 2003 LiDAR dataset. For the sake of simplicity, reaches where levees are immediately adjacent to the channel bank were considered 'confined' while all other reaches were considered 'unconfined.'

The 20 selected monitoring reach locations (12 tributary and 8 mainstem) are shown in Figure 4-3 and the reach characteristics and other pertinent information is given in Tables 3-1 to 3-3. Overall, the tributary monitoring reaches are located in 10 different subwatersheds and include four Sediment TMDL Plan monitoring reaches. The areal representation of geologic terrains within the contributing watersheds for all tributary monitoring reaches combined (as percent of total drainage area) is similar to that of the entire Napa River watershed, indicating that these monitoring sites likely capture a representative range of sediment production conditions. The estimates for total sediment production at the tributary reaches range from ~100 to ~2,000 $\mathrm{tkm}^{-2}\mathrm{yr}^{-1}$, with a range of fine sediment contribution based on upstream geologic terrain. The total sediment production/stream power index values range from approximately 800 to over 11,000, which is similar in magnitude to the range of values from the sediment TMDL study (see Napolitano et al. 2009) and suggests an appropriate range in associated reach permeability values. The amount of agricultural land within the contributing watersheds is also quite variable, indicating there is no bias in reach selection with respect to land use (i.e., the reaches are distributed among geologic terrains and land use types), which in turn translates to a set of reaches that represent the varying degree of both geologic terrain and land use controls on fine and total sediment production.

Table 3-1. Relative coverage of geologic terrains upstream of tributary monitoring reaches.

Geologic Terrain	% of total area upstream of tributary monitoring sites	% of total area in all tributary subwatersheds
Sedimentary rocks	41%	38%
Franciscan mélange and sheared serpentinite	11%	10%
Sonoma volcanics	35%	34%
Sonoma volcanic tuff and ash flow	13%	17%

Table 3-2. Summary of tributary monitoring site characteristics.

Monitoring reach	Tributary	Sediment TMDL monitoring reach[a]	Channel slope[b]	Drainage area (km^2)[b]	Stream power[d]	Estimated total sediment supply (tkm^{-2}yr^{-1})	Sediment supply/Stream power index	Relative subwatershed fine sediment production[f]	Agricultural land coverage within contributing watershed	Previous permeability data collection efforts
T-1	Carneros Cr	Lower Carneros	0.006	20.0	0.12	666[e]	5,658	Medium	24%	2002 2003
T-2	Redwood Cr		0.019	12.0	0.22	333	1,495	Medium	11%	2002
T-3	Redwood Cr		0.012	26.0	0.32	408	1,261	Medium	13%	2002
T-4	Dry Cr		0.008	47.7	0.38	525	1,376	Medium	4%	2002
T-5	Sulphur Cr	Sulphur 4	0.021	10.1	0.21	1,938[e]	9,254	Medium	12%	2002 2003
T-6	York Cr		0.018	9.3	0.17	730	4,394	Medium-High	17%	2003 2004
T-7	York Cr	Upper York	0.044	5.9	0.26	570[e]	2,204	Medium-High	14%	2003 2004
T-8	Ritchey Cr	Upper Ritchie	0.036	5.7	0.21	931[e]	4,470	High	0.3%	2002 2003
T-9	Cyrus Cr		0.019	2.6	0.05	558	11,030	Medium-High	0.8%	2002
T-10	Selby Cr		0.010	12.8	0.13	108	817	Low-Medium	0.9%	2002
T-11	Soda Cr		0.024	11.3	0.27	238	884	Low-Medium	0.01%	2002
T-12	Milliken Cr		0.003	20.5[c]	0.07	99[e]	1,457	Medium	11%	2007

[a] From Napolitano et al. 2009, Table 8
[b] From 2003 1-m LiDAR dataset
[c] Includes just the regulated drainage area downstream of Milliken Reservoir
[d] Product of channel slope and drainage area
[e] Values taken from Napolitano et al. 2009, Table 8
[f] Derived from information provided in SFEI 2012, Appendix IV Table 2

Table 3-3. Summary of mainstem monitoring site characteristics.

Monitoring reach	Mainstem reach	Sediment TMDL monitoring reach[a]	Channel slope[b]	Drainage area (km^2)[b,c]	Stream power[b,d]	Estimated total sediment supply ($tkm^{-2}yr^{-1}$)[e]	Sediment supply/Stream power index	Reach type	Previous permeability and scour data collection efforts
M-1	R1 (Calistoga)		0.0030	79.8	0.24	700	2,942	Confined	None
M-2			0.0029	119.6	0.35	700	1,986	Unconfined	None
M-3	R2 (St. Helena)		0.0014	143.8	0.20	700	3,481	Confined	None
M-4			0.0023	189.9	0.44	700	1,589	Unconfined	None
M-5	R3 (Rutherford)	Rutherford (lower)	0.0021	232.0	0.49	584	1,200	Unconfined	2004
M-6		Rutherford (lower)	0.0020	239.2	0.48	584	1,208	Confined	None
M-7	R4 (Oakville-Oak Knoll)		0.0015	257.4	0.38	450	1,192	Unconfined	None
M-8			0.0015	297.4	0.46	450	987	Confined	None

[a] From Napolitano et al. 2009, Table 8
[b] From 2003 1-m LiDAR dataset
[c] Includes just the regulated drainage area downstream of the four major reservoirs (Bell Canyon, Rector, and Milliken reservoirs and Lake Hennessey)
[d] Product of channel slope and drainage area
[e] Values taken from Napolitano et al. 2009, Section 3.6

The selected mainstem monitoring reaches are distributed among four larger mainstem river reaches that were defined, in large part, by variations in reach-average stream power and sediment delivery from adjacent tributaries (Figure 4-3). From upstream to downstream, the mainstem river reaches included the Calistoga reach (R1, upstream of the Bell Canyon confluence), the St. Helena reach (R2, between the Bell Canyon confluence and the Zinfandel Lane bridge, the pre-established Rutherford reach (R3, between the Zinfandel Lane and the Oakville Road bridges), and the pre-established Oakville–Oak Knoll reach (R4, between the Oakville Road and Oak Knoll Road bridges). The upper mainstem reaches are characterized by relatively lower stream power and relatively higher sediment production values while the lower reaches have relatively higher stream power and relatively lower sediment production values (see Table 4-3). Each mainstem reach contains both a ‘confined’ and an ‘unconfined’ monitoring reach, with total sediment production/stream power index values within the range of values for the tributary monitoring reaches (~1,000 to ~3,500) and provide a good representation of the range of values previously measured within mainstem Napa River spawning reaches.

3.4 Sample site selection

Similar to the determination of the number of monitoring reaches necessary for providing a statistically robust dataset, the Sediment TMDL Plan permeability data were used to determine the minimum number of sample sites per monitoring reach needed to detect change over time with a relatively high level of confidence. For each Sediment TMDL Plan monitoring reach, permeability data were converted to estimates of percent egg survival using the following empirical equation based on data for coho (from Tagart 1976) and Chinook (from McCuddin 1977):

Percent egg survival = 0.1488 x ln(permeability) – 0.8253

A power analysis was then performed on the percent survival estimates to determine how the amount of detectible change in reach-average percent egg survival (as percentage points) varies as a function of the number of sample sites within the reach.

The relationship between the detectible change in the percent egg survival estimate for a reach (at the 90% and 95% confidence levels) and the number of permeability sample sites is shown in Figure 4-4. In general, the intra-reach variability necessitates a relatively high number of monitoring locations to detect a relatively modest amount of change. Under the assumption that the Sediment TMDL Plan dataset provides an adequate representation of the range of permeability values in spawning reaches throughout the watershed, the power analysis suggests that detecting even a modest 10 percent change in egg survival estimates (e.g., an increase from 40% to 50%) at the 95% confidence level would require 40 to 45 sample sites per monitoring reach for this study (or, ~4 times the number of sample locations per reach than in the sample dataset). Monitoring this many sites within each monitoring reach would be both time- and cost-prohibitive. Therefore, it was necessary to examine the trade-off between a realistic number of sample sites per reach and an acceptable level of detectible change.

Based on the power analysis results and the assessment of a feasible number of sample sites per monitoring reach, 20 sample sites was determined to be appropriate for ensuring a reasonable degree of confidence in detecting change over time (i.e., a maximum 15 percentage point change in reach-average percent egg survival with 95% confidence) while operating within likely budgetary and logistical constraints. As there is no adequate Napa River watershed scour dataset available for determining the adequate number of sample locations per monitoring reach, we will assess the scour variability during the pilot project using 10 scour measurements per reach (located adjacent to permeability sample locations). Following the pilot project, the number of permeability and/or scour sample sites may be revised based on the newly collected permeability and scour datasets and an ‘on-the-ground’ understanding of the number of sites that can be sampled given time/budget considerations and site constraints.

4 MONITORING METHODOLOGY

4.1 Monitoring reach establishment

Monitoring reaches will be established during an initial field visit at or as near as feasible to the locations identified during the reach selection process (as described in Section 3.3.2). The initial field visit will take place at the beginning of the first monitoring effort during low-flow conditions. Each monitoring reach will be located within a channel area that is homogenous with respect to geomorphic characteristics and processes (i.e., consistent channel type with no considerable local flow and/or sediment inputs or losses) and is considered likely spawning habitat (i.e., suitable hydraulic conditions with D_{50} [median sediment size] >2 mm and < 50 mm in tributary reaches and < 70 mm in mainstem reaches, per Kondolf and Wolman [1993]). To ensure adequate channel length necessary for assessing average permeability and scour characteristics, each reach will be approximately 30 bankfull widths in length and will begin and end at major breaks in channel slope or at changes in channel geomorphic units. For monitoring reaches with pool-riffle morphology, the reach will be of sufficient length to capture a minimum of three pool-riffle sequences. Following reach establishment, a hand-held global positioning system (GPS) unit will be used to record the reach location (e.g., upstream end, middle, and downstream end coordinates) and each reach will be photo-documented in detail.

The 20 permeability sample site locations within each tributary and mainstem monitoring reach will also be established during the initial field visit. Sample sites will be distributed throughout each monitoring reach in areas considered to have relatively high spawning potential (i.e., appropriate particle size and flow rate), yet are outside areas of local forced flow acceleration or deceleration (i.e., areas that either scour or accumulate fine sediment regardless of changes in sediment supply). In reaches with pool-riffle morphology, sites will be located in pool tail outs and at the upstream end of riffles (i.e., areas with the likely highest quality habitat). In steeper, coarser plane-bed and step-pool reaches, sites will be more dispersed among localized patches of suitable habitat. A hand-held GPS unit will be used to record the coordinates of each selected sample site.

Within the mainstem monitoring reaches, a subset of 10 sample sites will be selected for monitoring both redd permeability and scour. These sample sites will be distributed throughout the reaches and, to the extent possible, will represent the range of spawning habitat characteristics present. For mainstem reaches with similar habitat characteristics throughout, the 10 sites selected for scour monitoring will be evenly distributed among the full 20 sample sites (i.e., similar number at the upstream end, middle, and downstream end of the reach).

4.2 Monitoring procedures

4.2.1 Artificial redd construction

Permeability and scour will be monitored within artificial redds constructed at the beginning of each individual monitoring effort (i.e., during fall low-flow conditions). Artificial redd construction will involve raking bed sediment out of a simulated redd 'pot' and onto a simulated redd 'mound' downstream at each sample site location. The sediment will be raked vigorously to mimic the action of spawning salmonids, thereby leading to the suspension and partial downstream transport of the finer sediment present (<2 mm). The raking depth will be approximately 20 cm below the adjacent bed surface, which represents an anticipated bed sediment disturbance depth (and subsequent egg pocket depth) suitable for both Chinook and steelhead (see DeVries 1997 for more detail). The raked sediment will then be deposited into a mound whose crest height will be approximately 10 cm (or approximately half the pot depth). The total area of disturbed bed sediment will be approximately 2 m^2 for mainstem monitoring reach redds while tributary monitoring reach redds will be scaled to spawning patch size and have a maximum area of approximately 2 m^2. Following redd construction, a hand-held GPS unit will be used to record redd coordinates and each redd will be photographed from upstream, downstream, and from each bank.

4.2.2 Redd permeability monitoring

Permeability at all artificial redds will be assessed at the end of each individual monitoring effort (i.e., during low-flow conditions following any storm-induced sediment deposition) using a modified Mark IV standpipe and vacuum pump (Terhune 1958, Barnard and McBain 1994). The standpipe (perforated steel pipe with a 2.5 cm inner diameter and a 3.2 cm outer diameter) will be driven into the middle of each artificial redd mound to a depth that ensures the standpipe perforations are within a suitable egg pocket depth range (i.e., 10 – 20 cm below the adjacent bed surface). To reduce the potential for water 'slippage' down the pipe, the standpipe will be held, but not forced in any direction, during the driving process and a rubber gasket will be placed on the bed surface around the standpipe. A vacuum pump (Model 107CDC20, powered by a 12-volt rechargeable battery) will then be used to siphon water out of the standpipe at a constant hydraulic head (2.5 cm lower than the adjacent river water) until a set volume of water is siphoned. Siphoning will be repeated five times at each standpipe drive location and the time required to reach the set water volume during each replicate will be recorded. Ambient water temperature will also be recorded at each artificial redd.

Following data collection, the raw siphoned volume per time measurements (or recharge rates) will be converted into permeability measurements (units of length per time) using an empirically derived rating table and a water viscosity correction factor determined from water temperature measurements (per Barnard and McBain 1994). The median permeability value for the five replicate measurements at each artificial redd will then be calculated and used as the representative redd permeability value.

4.2.3 Redd scour monitoring

4.2.3.1 Scour monitors

Maximum redd scour depth for individual storm events at the selected mainstem artificial redds will be assessed using either scour chains (per Lisle and Eads 1991) or sliding bead monitors (per Nawa and Frissell 1993). At the beginning of the first monitoring effort (i.e., during fall low-flow conditions), one scour monitor will be installed near the center of the mound at each selected artificial redd within the mainstem monitoring reaches. Each scour monitor type has inherent advantages and disadvantages and it is not yet clear which type will work best under the high flow conditions within the mainstem Napa River. For example, scour chains are sturdy yet easily buried and unrecoverable while sliding bead monitors are easily visible but not nearly as sturdy during high flow and sediment transport rates as scour chains. To determine which scour monitor type will be best suited for use in the long-term monitoring, both types will be employed in each mainstem monitoring reach during the pilot monitoring period (i.e., 5 scour chains and 5 sliding bead monitors per monitoring reach). Following compilation of the pilot monitoring scour data, the preferred scour monitoring approach will be selected and the project Monitoring Plan will be updated to reflect this selection.

Scour chains

Scour chains will be approximately 100 cm long with heavy gage steel links and a pointed steel driving tip at one end that will also anchor the chain into the bed sediment. Installation will involve inserting each scour chain into a hollow steel rod and driving the rod and exposed steel tip into the artificial redds to a depth of at least 50 cm (or the maximum anticipated scour depth). Following the initial installation and at the beginning of all subsequent monitoring efforts when chains are re-set, the length of exposed chain above the constructed artificial redd mound surface will be measured and the exposed chain will be laid flat and oriented downstream.

At the end of each individual monitoring effort (i.e., during low-flow conditions following any storm-induced scour), the length of chain lying horizontally either on the bed surface or buried under deposited sediment will be measured for comparison with the initial measurement and determination of maximum instantaneous scour. When necessary, a metal detector will be used to relocate buried chains. Scour chains will be replaced as needed.

Sliding bead monitors

Sliding bead monitors will be approximately 250 cm long steel cable with a pointed steel driving tip at the bottom end, a small flotation device at the top end, and 1-2 cm diameter plastic balls covering 50 cm of cable above the driving point. Similar to scour chain installation, sliding bead monitor installation will involve inserting each monitor into a hollow steel rod and driving the rod and exposed steel tip into the artificial redds until all of the balls are below the redd surface (at least 50 cm, considered to be the maximum anticipated scour depth). Following the initial installation and at the beginning of all subsequent monitoring efforts when the monitors are reset, the length of exposed cable above the constructed artificial redd mound surface will be laid flat and oriented downstream.

At the end of each individual monitoring effort (i.e., during low-flow conditions following any storm-induced scour), the number of plastic balls exposed and floating on the steel cable will be counted as an indication of maximum scour depth. The sliding bead monitors will record maximum scour depth after the first monitoring effort during any given high-flow season only when the scour depth is greater than that of the first storm (i.e., only if additional balls are exposed). Sliding bead monitors need to be removed at the end of each monitored high-flow season and replaced at the beginning of the next monitoring effort.

4.2.3.2 Cross-sections

Net redd scour or deposition (i.e., total change in redd mound elevation) for individual storm events at the selected mainstem artificial redds will be assessed using repeat cross-section surveys. During the initial field visit, cross-section endpins (capped rebar) will be installed on both banks adjacent to the selected artificial redds (at least 1 m away from the bank edge) and their coordinates will be recorded using a hand-held GPS unit. At each monitoring reach, the relative elevation and position of endpins will be surveyed using an auto level and stadia rod. Following the initial endpin survey and at the beginning of all subsequent monitoring efforts, channel cross-sections across the artificial redd mounds will be surveyed using an auto-level and stadia rod. During each survey, a measuring tape will be strung between the cross-section endpins and elevations will be taken within the active channel at intervals appropriate for capturing relevant topographic breaks (approximately 0.3 – 1 m spacing) (per Harrelson et al. 1994). Surveys will begin and end at the cross-section endpins and will capture the presumed bankfull elevation, edges of water, and the channel bed adjacent to and across the width of the artificial redd. Observations regarding channel condition and bed/bank substrate size will also be recorded.

At the end of each individual monitoring effort (i.e., during low-flow conditions following any storm-induced scour), channel cross-sections will be re-surveyed to assess local changes in bed elevation and the associated net change in bed elevation at individual artificial redds (either scour or deposition). In addition, the location of the maximum water surface reached along each cross-section during the winter high flow period (as identified from bank disturbance indicators) will be surveyed for use in assessing peak flow water surface slope and depth.

4.2.4 Bed texture assessment

At the beginning and end of each individual monitoring effort, bed texture data will also be collected throughout each monitoring reach to help characterize reach geomorphic and habitat conditions, and for use in understanding changes to permeability and scour values over time. At the beginning of each individual monitoring effort, a facies map (or map depicting areas of similar particle size distribution) of each monitoring reach will be constructed based on observed differences in bed texture combined with pebble counts (per Buffington and Montgomery 1999). Pebble counts will entail measuring the length of the intermediate axis (or b-axis) of 100 particles (Wolman 1954) in and around redd locations. The pebble count data will be used to construct particle size distributions and determine facies' representative bed particle sizes (the particle size for which 16% of the distribution is finer [D_{16}], D_{50} [the median particle size], and D_{84}) and the substrate type based on the particle sizes present (e.g., gravely cobble [GC] or sandy gravel [SG]). If there is noticeable change at the end of an individual monitoring effort, an updated facies map will be constructed based on additional pebble counts.

5 DATA COMPILATION & REPORTING

Following each individual monitoring effort, collected data will be compiled into a data package of electronic and hardcopy files for addition to the larger sediment TMDL project database and a summary report will be prepared. The summary report will provide the following:

- Presentation of data collected at each reach during the individual monitoring event, including redd permeability data (range, median, mean, and standard deviation values), maximum instantaneous redd scour data (range, median, mean, and standard deviation values), net redd scour data (as net percent change in channel areas from cross-section surveys), reach-average shear stress for the peak discharge (as derived from peak flow slope and depth estimates), and particle size distributions and bed texture at the beginning and end or the monitoring effort;
- Examination of the relationships between observed permeability and scour dynamics and reach geomorphic and hydraulic characteristics (e.g., peak flow shear stress, bed fining/coarsening over the course of a winter high flow period, known changes in sediment delivery since the previous monitoring effort); and
- Comparison of data with data from previous monitoring efforts and an assessment of the magnitude of change in both permeability and scour over time at each monitoring reach.

The compiled permeability and scour information will be used to determine representative watershed values for each individual monitoring effort. These values will then be compared to the sediment TMDL target values as a primary mechanism for assessing the relative change in watershed-wide spawning habitat quality over time.

6 SCHEDULE

The schedule for individual monitoring efforts, from data collection to reporting, is described below in Table 6-1. Monitoring efforts begin in the fall with reach preparation and instrument installation and conclude the following fall with the submittal of the data package and summary report. Ideally, post-high flow data collection will occur directly after flow events with peak discharges near or within the bankfull range. However, this may not be possible in many years due to elevated flows during the entire winter high flow period prohibiting reach access. During those years when elevated flows persist, data collection will occur as soon as flow conditions allow for safe access to all mainstem and tributary sites (as indicated by Napa River discharge measurements at USGS gage 11458000 and direct observations during field reconnaissance).

Table 6-1. Proposed schedule for individual monitoring efforts.

Monitoring Tasks	**Month**												
	S	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**
Pre-high flow monitoring	🟦	🟦	🟦										
Monitoring coordination	■												
Monitoring reach preparation and data collection • *Redd construction* • *Scour monitor preparation or installation* • *Cross-section surveys* • *Facies mapping*		■	■										
Post-high flow monitoring			🟦	🟦	🟦	🟦	🟦	🟦	🟦				
Monitoring coordination			▨	▨	▨	▨	▨	▨	▨				
Data collection • *Permeability measurements* • *Scour monitor measurements* • *Repeat cross-section surveys* • *Repeat facies mapping*			▨	▨	▨	▨	▨	▨	▨				
Synthesis and reporting							🟦	🟦	🟦	🟦	🟦	🟦	🟦
Data compilation and analysis							■	■	■	■			
Prepare Draft Summary Report										■	■	■ ✓	

Monitoring Tasks	**Month**												
	S	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**
Prepare Final Summary Report and Data Package											▒	▒	✓

Note: Blue and grey shading indicates the time periods when tasks will be conducted, cross-hatching indicates the full time period when tasks can occur (depending on flow conditions), and checks indicate months when deliverables will be submitted.

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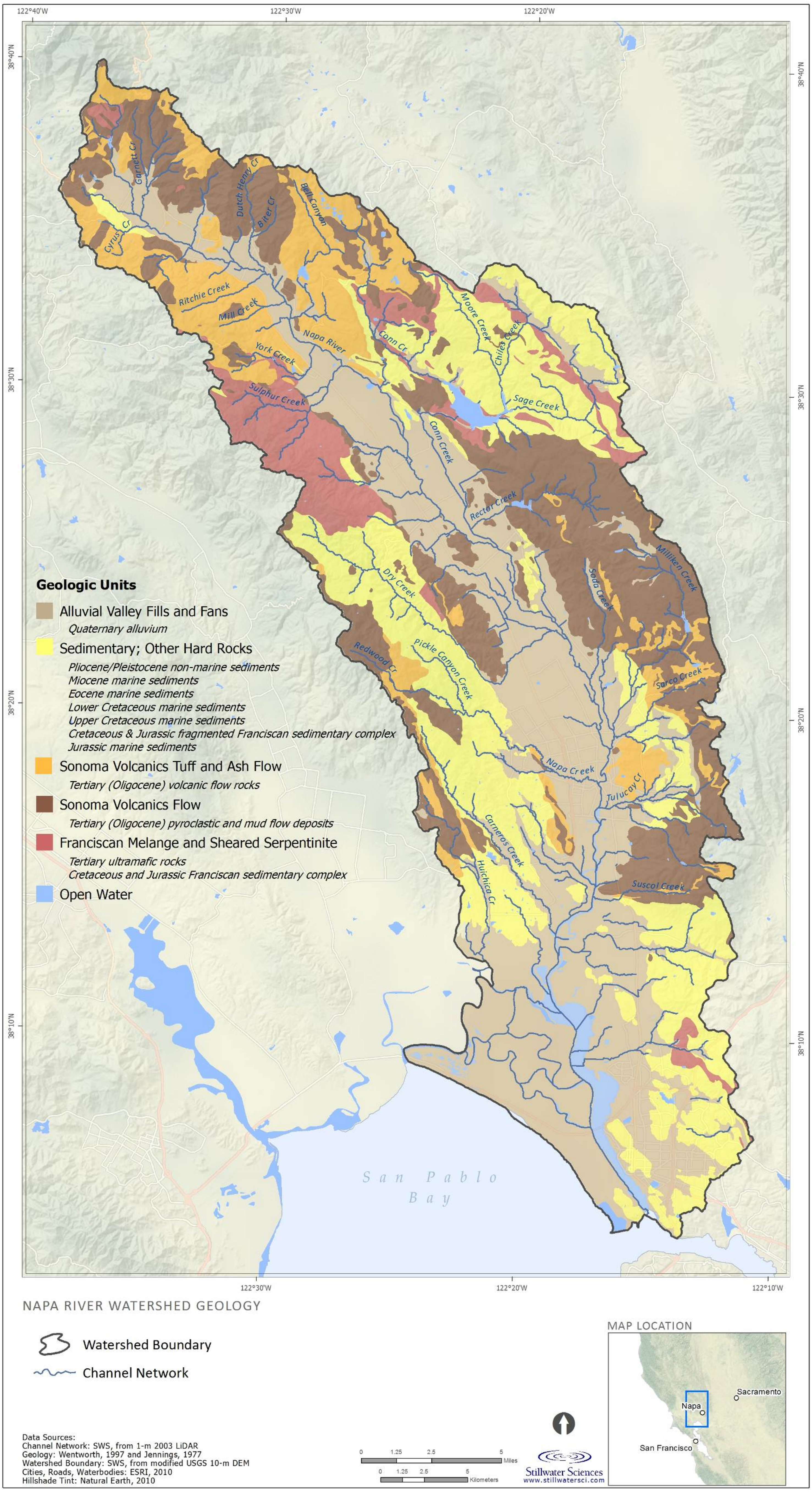
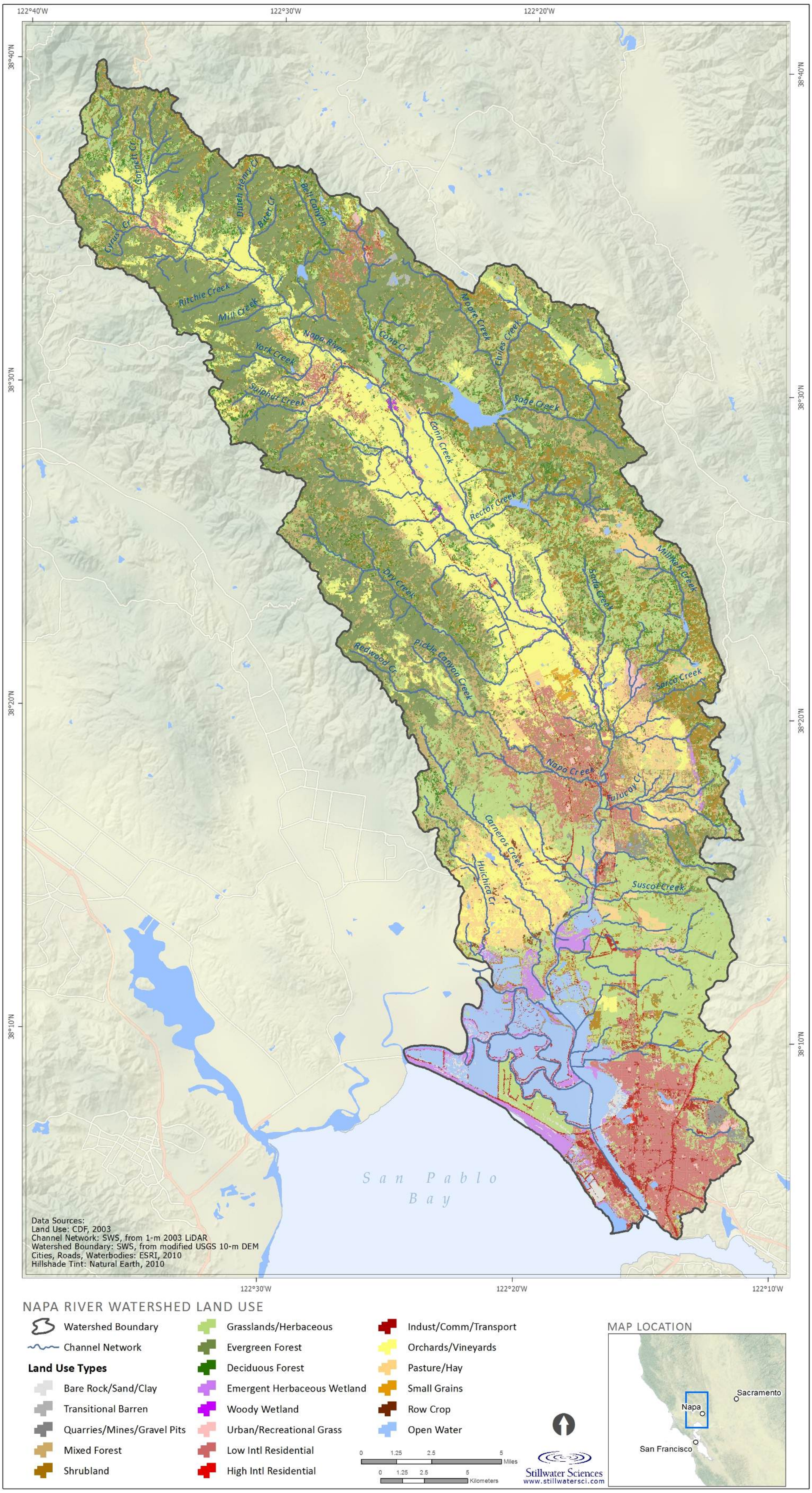
Figures

Figure 2-1. Napa River watershed.



Data Sources:
Channel Network: SWS, from 1-m 2003 LiDAR
Geology: Wentworth, 1997 and Jennings, 1977
Watershed Boundary: SWS, from modified USGS 10-m DEM
Cities, Roads, Waterbodies: ESRI, 2010
Hillshade Tint: Natural Earth, 2010

Figure 2-2. Napa River watershed geology.



Data Sources:
Land Use: CDF, 2003
Channel Network: SWS, from 1-m 2003 LiDAR
Watershed Boundary: SWS, from modified USGS 10-m DEM
Cities, Roads, Waterbodies: ESRI, 2010
Hillshade Tint: Natural Earth, 2010

Figure 2-3. Napa River watershed land use.

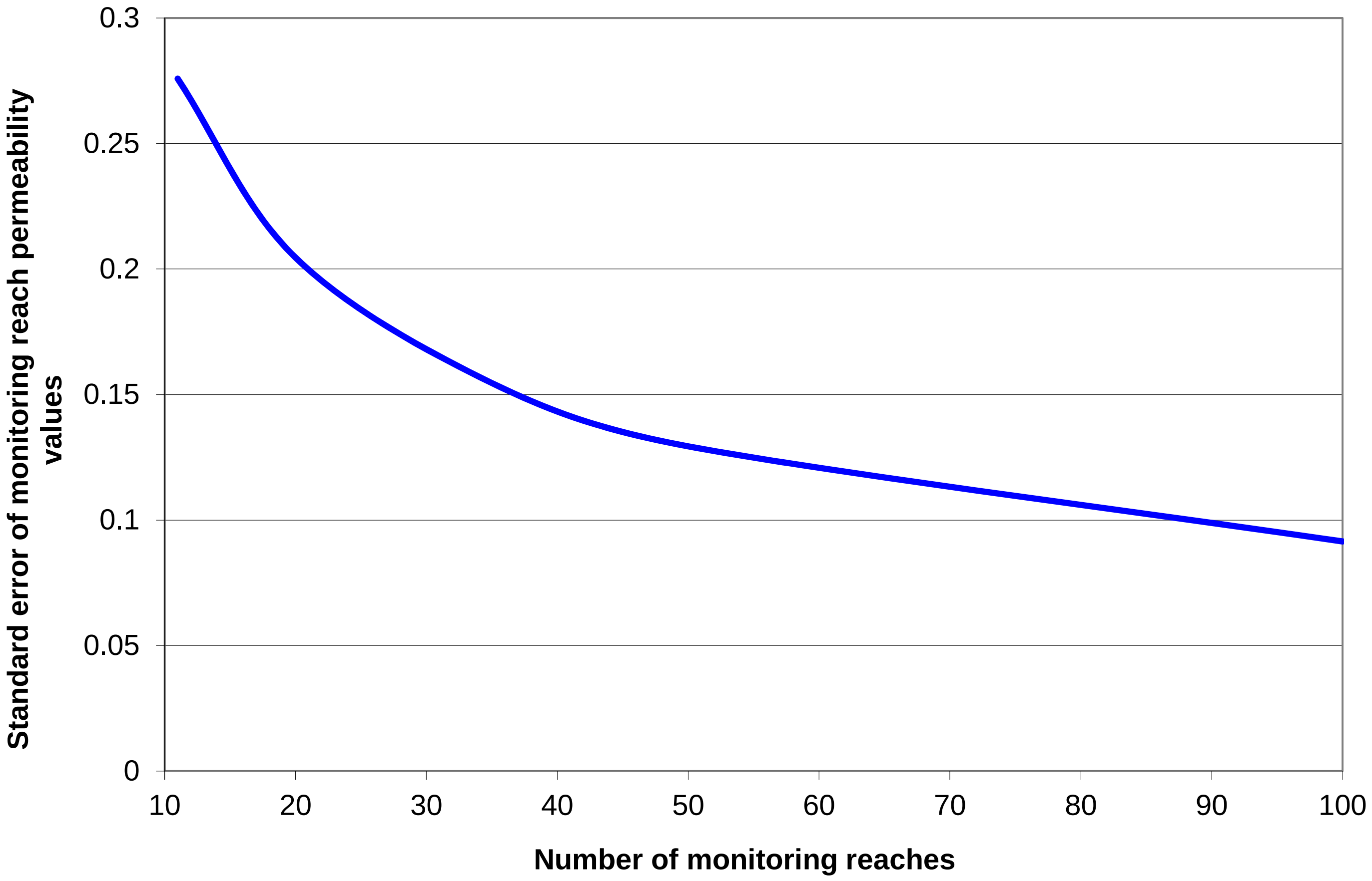
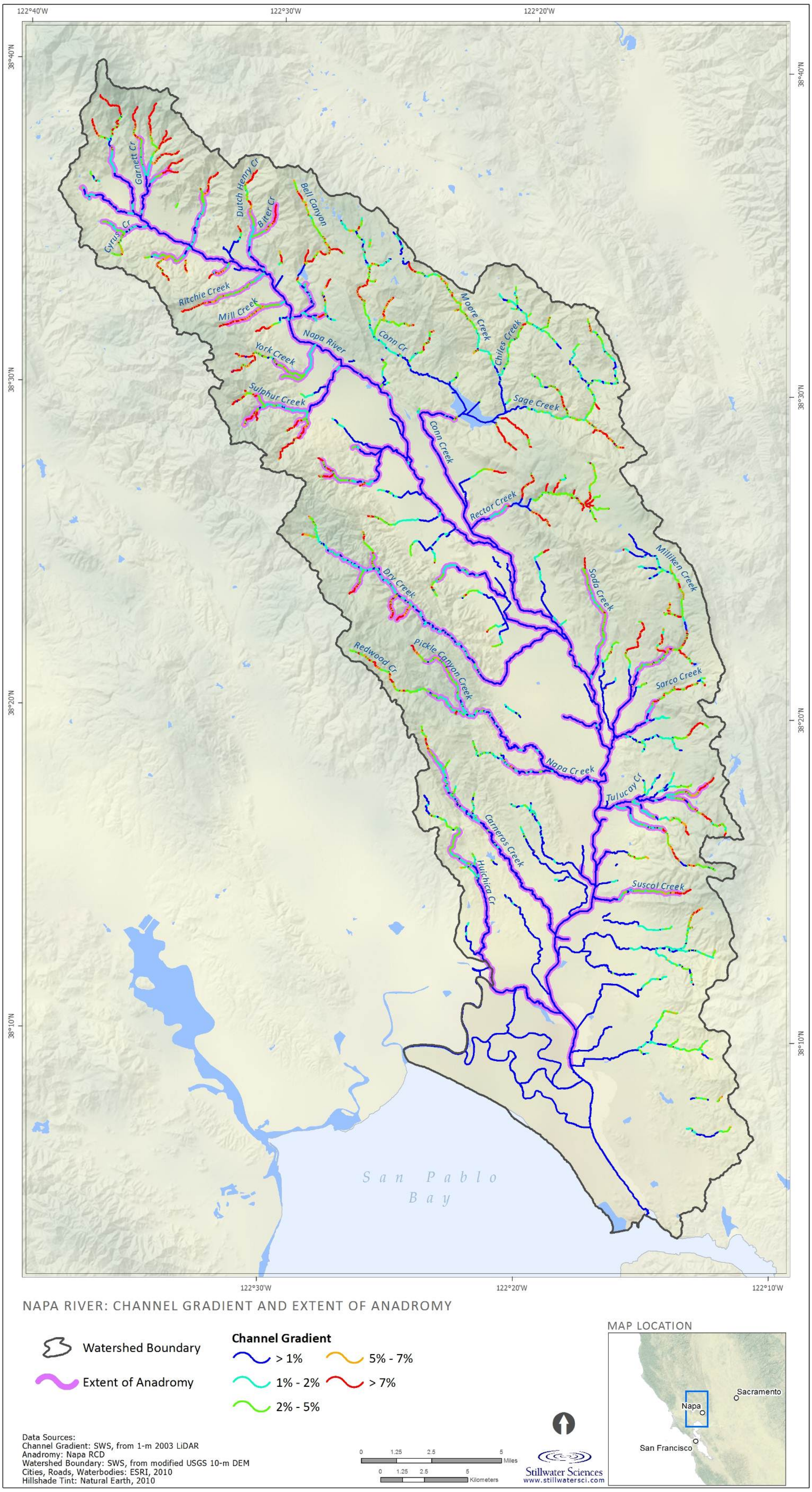


Figure 4-1. Relationship between permeability standard error and number or monitoring reaches (derived from data presented in Napolitano et al. 2009).



NAPA RIVER: CHANNEL GRADIENT AND EXTENT OF ANADROMY

Data Sources:
Channel Gradient: SWS, from 1-m 2003 LiDAR
Anadromy: Napa RCD
Watershed Boundary: SWS, from modified USGS 10-m DEM
Cities, Roads, Waterbodies: ESRI, 2010
Hillshade Tint: Natural Earth, 2010

Figure 4-2. Channel gradients and extent of anadromy throughout the Napa River watershed.

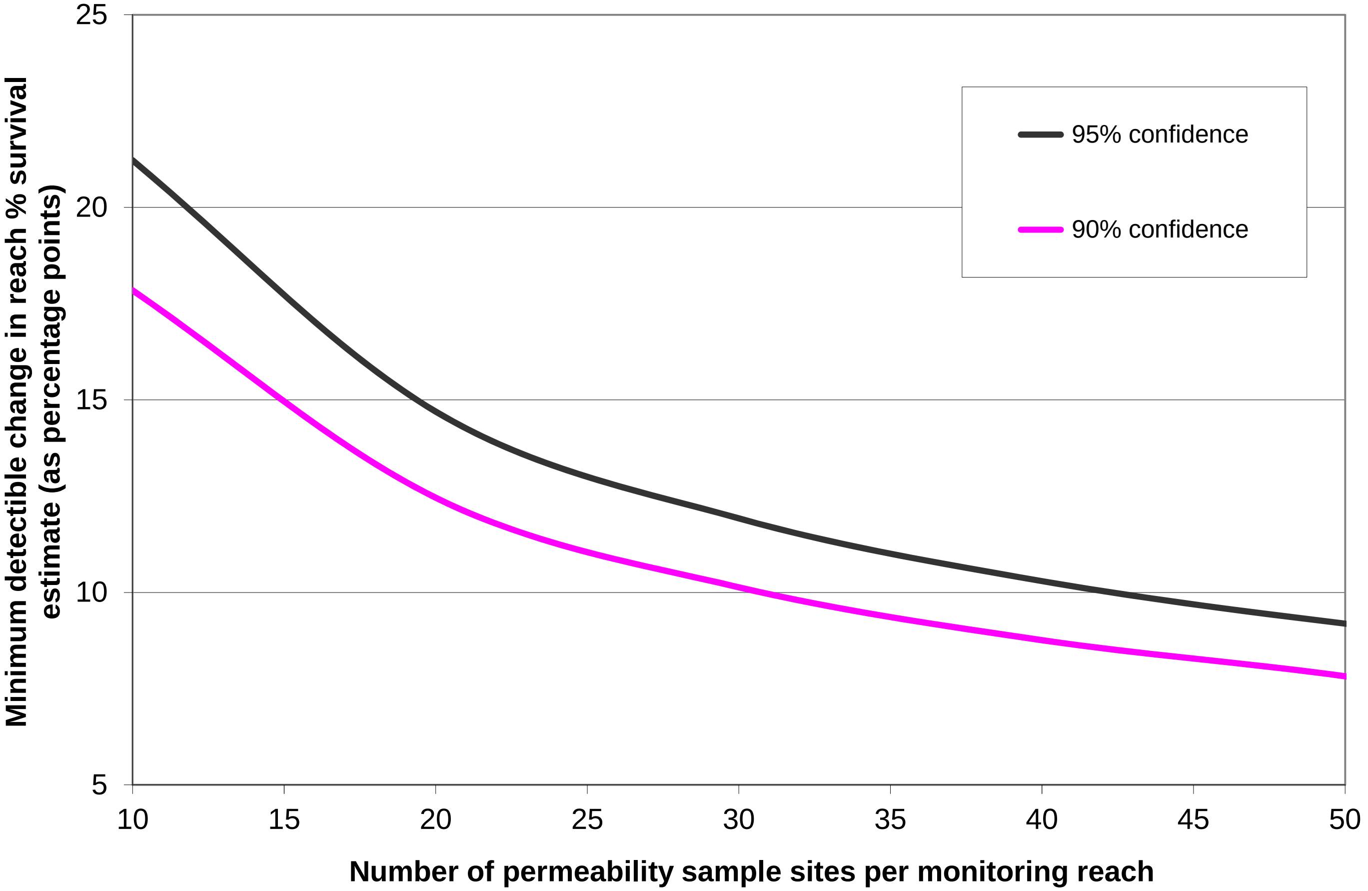


Figure 4-3. Relationship between minimum perceptible change in percent egg survival and number of permeability samples (derived from data presented in Napolitano et al. 2009).

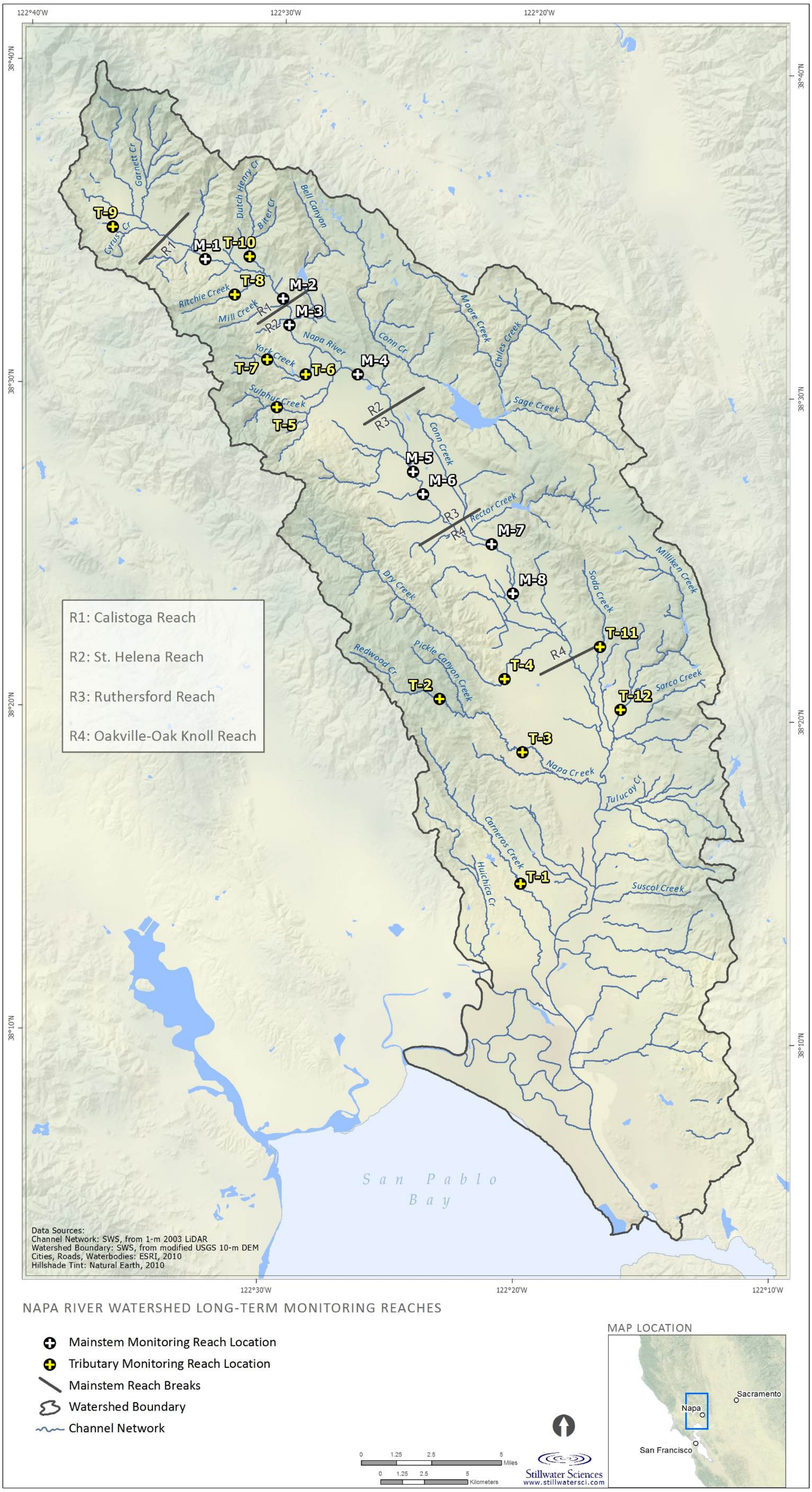


Figure 4-4. Locations of mainstem and tributary monitoring reaches.