11/18/09 Board Workshop
Russian River Frost Protection
Deadline: 11/10/09 by 12 noon

COAST ACTION GROUP P.O. BOX 215 POINT ARENA, CA 95468

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NOV - 6 2009
SWRCB EXECUTIVE

November 6, 2009

Clerk of the Board
State Water Resources Control Board
Division of Water Quality
P.O. Box 100
Sacramento, CA 95812-0100

Comment: Comments for Workshop to consider recommendations for actions regarding water diversions for the purpose of Frost Protection

Coast Action Group offers comment to the SWRCB on the need for short and long term regulatory action regarding the issue of diversion of water for frost protection use. Also discussed the current status of actions taken, or needed to be taken by diverters to protect the beneficial uses of water.

Information in the file indicates that diversion, licensed and unlicensed, for use in frost protection can, and does, have sufficient adverse effects on stream flow to cause harm or death to salmonids. The failure of the SWRCB to regulate such diversion activity has added to (and complicates) the problem of maintaining sufficient flows to support salmonids in all life stages.

After months, and years, of dealing with stream flow related activities no effective voluntary solution has been found. Under both, State and Federal Code, the SWRCB must take regulatory action.

Regulatory Action should start with the premise that all water diversion for the purpose of frost protection is not legal - unless the following occurs:

* The diverter must unequivocally demonstrate that diversion will cause no harm.

* No harm can be demonstrated by demonstration of item #1 and any (or all) of the following conditions:

1- The landowner possesses water rights license for such diversion
2- The landowner has offstream storage sufficient to carry out activity with sufficient backup (or guarantee) to eliminate the immediate need to refill storage.
3 -The landowner is participating in a planned program of diversion rotation or scheduling that is demonstrated to assure maintenance of stream flow.
4 - The landowner can demonstrate that well use is not diversion from surface flows or under flow in a defined channel

Burden of proof is to be on the landowner.

The SWRCB should consider the above noted regulatory constraints within the framework of short term emergency regulations until the Board has time to address and integrate a more comprehensible long term program considering diversion for frost protection and stream flow maintenance.

The current consideration of regulation of diversions for frost protection is needed. It must be recognized that the frost protection issue is a subset of the greater issue of maintaining instream flows. Long term policy can not deal with the frost protection issue without integrating it into the long awaited flow maintenance policy.

The final (long term policy) for flow maintenance and frost protection must consider:

* The relationship of frost protection diversion issues with flow maintenance policy

* Analysis of Cumulative Watershed Effects (cumulative diversion) related to planned diversion policy - with limitations of loopholes that would subvert regulation

* Impoundment facilities that block migration and access to habitat must be removed

* By-pass flow numbers must be sufficient to support salmonids in all life stages

* Monitoring and reporting programs must be sufficient to assure success of regulations

To date, none of the above has occurred. Thus, the SWRCB is remiss in its duty to protect the beneficial use of the cold water fishery. Additionally, very little activity by the land owners has taken place to make any real difference in addressing the problem being discussed.

Sincerely,

Alan Levine for Coast Action Group

Attached:

Review of the last two Frost Protection Task Force meetings - indicating small progress with huge outstanding problems. Review of the discussion will shed some light on the problems.

Hydrologic Impacts of Small Scale Instream Diversion for Frost & Heat Protecion - Deitch et al

Surface Water Balance to Evaluate Hydrologic Impacts in Small Stream Diversion - Deitch et al

Comments on Draft Policy for Maintaining Instream Flows - Higgins

FROST PROTECTION WORKSHOP - NOTES 8/18/09

Frost Protection Meeting 9/17 - Notes - below the 8/18

NMFS PRESENTATION

Standards for success - Task Force - Success of Efforts to date.

October 10th - SWRCB Frost Protection - deadline for addressing - will be done at SWRCB meeting.

NMFS will have recs by 10/10

Grapes asks for the 10/10 deadline to be put back due to grape harvest.

Conservation Actions

NMFS looking for Desired Actions and Planning

Planning to include Water Budgets (Vicky Whitney asks for Water Budgets as part of the regulatory and assessment regime).

Land Use - Limits on New Diversion (no new diversions).

Effectiveness - Monitoring - available stream flow (goes back to the Water Budgeting).

Will the process be transparent? (NMFS says it must be)

NMFS supplied power point - copies are available

Vicky Whitney (SWRCB) Presentation

Noted very large demand (instantaneous demand for frost protection - diminished stream flow)

How can a program be actualized to will protect beneficial uses?

Is it possible to put voluntary agreement in place that will meet needs and protect flows?

Court appointed Water Master - can a voluntary agreement meet those needs and controls?

It comes down to accounting? Priorities? When? How much?

The State needs sufficiently detailed use reports (this is not currently happening - nor is there any current plan to make it happen - use is a big secret).

What are the mainstem flows and effects of diversion for frost protection (in relation to above parameters).

Mainstem Flow interrelationships must be determined. Vicky says we just do not know these relationships - demand, use , frost protection effect on flow (mitigated and unmitigated). **This does not include effects of use for frost protection on tributaries (this issue is big and not considered)**

Considerations must be based on Water Budget and Priorities.

Vicky indicated that she would look into changing the dates in October - with no promises.

Sean White - Upper Russian River Working Group Presentation - Task Force Update

Says significant effort:

Initially - low by-pass flows in mainstem - then high demand for frost protection. The problem is high instantaneous demand (they need it when they need it and pump when necessary). Leading do exacerbated low flows.

Flow was 160 cfs, instantaneous demand was 80 cfs (this probably did not include all users - especially those in tribs - he considers only what he knows about - big customers).

Says we do not need additional protections - Water Master.

Says we do need tools - draft protocols - and gauging - short term.

Long term - we need off stream storage and use of recycled water for use in frost protection.

Says working on the flow problem with controlled releases from dam addresses part of issue (NMFS disagrees).

Controlled releases are part of the short term strategy.

Other problem - low lake storage and competing uses.

Additional Gauge in Ukiah Valley will limit lag in measurements.

Need meter upgrades - many have been done - to measure instantaneous demand - daily and monthly diversion - thus you have electronic monitoring (this only gets the big users and leaves out trib diversion and all illegal, non-permitted diversion. Billing only shows use by large customers.

Vicky - Are new water hookups metered?

Noted: No web-site on billing or use - public left out of the loop.

Sean noted the need for better near term Frost forecasting - would help planning - discretionary release surges if needed (this does not deal with trib diversion and other illegal use). NMFS notes that these release surges do not match use withdrawals - it is almost impossible to plan or measure this).
Sean pushed the idea of new off stream ponds will meet demand. Ponds sized for frost event.

Ponds in:

Beckstoffer - 36 cfs - 128 acre feet
La Ribera - 50 acre feet
Fetzer - 50 acre feet

Ponds to take care of 677 acres for Frost are now off line for year 2010.

Does not deal with the question "what are the total acres" or what percentage of the total acres the diversion for frost protection can be serviced by the ponds - and/or - use by illegal diversions, how soon are the ponds refilled, what is the effect of diversion demand for refilling for the next event and/or irrigation use.

Notes that all customers have water rights, permits for storage and stream modification for diversion.

Use of recycled water - Ukiah has 4,000 acre feet of treated waste water to dispose of - which can be stored (?) And used for frost protection.

Fred Euphrat raised the question of how can you irrigate for frost protection with the use of treated waste water with saturated soil conditions - does this not violate Porter-Cologne? (and the Basin Plan). Sean - says the Low Threat Discharge Basin Plan amendment deals with this. Ponds could be used to store treated waste water. Ponds only part of the solution. Lots of small applications, diversions equals large volume (again failure to consider illegal or tributary diversion)

Checking with the EO - This does not automatically fit in the Basin Plan guidelines. They need a special permit for such discharge (with BMPs) and the permit is not automatic. Discharging onto saturated soils where the treated effluent would drain to the river is not permissible.

NMFS and Tributaries

General Permit - Term 91, Term 13 - not liked

Projects have been started without diversion permits from the State Water Board

Stream Flow Monitoring - sub group

80 cfs from the Russian River is huge

Smaller streams, tribs would show larger effects - small streams hammered

Viticulture self governance - questioned. This has been an issue for years and not addressed Nor has there been monitoring. Lots of critical habitat in Sonoma County in areas where viticulture is the primary land use. No monitoring or water budgets - or - availability analysis.

NMFS says the small streams are more vulnerable to dewatering.

Not much coming forward from the growers.

Marc Kelly Presentation

BMPs - where are they?? Big question. Marc is promising something by 10/10

Believes in landowners Board of Governance. This is effectuated by small subgroup discussion Leaves environmental side out of the discussion.

Said - TU is helping with a Water Budget. I do not think they have the data or gauges to do any of this.

Doc passed out said BMPs and Monitoring will be here soon - help by DFG. DFG says no way - we have not been part and party to this.

Mat - says flow requirements are part of a Water Budget. This information is not available.

Bill Hearn says - BMPs developed for reduced water use for frost protection my be helpful - but may not be good enough to avoid take.

No analysis of flows - vs - demand from vines in acres - use demand (all uses) and Water Budget.

Marc - it needs to be determined where to the best places to put gauges in. And then - who will pay for them.

There is the question will the data be available to the public.

Matt - Mainstem Russian River property owners - 4 gauges.

Frost Protection Meeting 9/17 - Notes

Joe Dillon/NMFS - NMFS Fish Friendly Farming Position

Fish Friendly Farming was set up as a voluntary program that was to develop standards to address agricultural effects to water courses - pollutant introduction control - heat, sediment. Actually no true set of BMPs have ever been developed for the area (or approved by NMFS).

The subject of water use was never addressed by Fish Friendly Farming. Now we are moving towards the water use arena.

The word "Certify" means to meet certain standards. No standards have been set or met. "No Take" coverage has not been offered or implied under the Fish Friendly Farming label.

A wanky old Certification letter was issued (several years ago). This letter will be rescinded. If you are in a Fish Friendly Farming program you should not consider that you are covered for Take of listed species.

If you want to amend your water rights and water use practices to avoid TAKE, you can do that for coverage under an HCP.

Laurel M.- We are looking at Frost Protection BMPs

Update on Frost Forecast - Upper Russian River

New information delivered on the development of frost forecasting for specific areas and related water management.

Better Temp maps - human modeling - represents distinct geographical forecasting - connected forecast bias dealt with - use of nudger with modification from firm data points.

This information can be linked with control of discretionary releases from Lake Mendocino for use in frost control

Note: Lining up these releases is difficult and if there are multiple days of use and/or immediate refilling of ponds - there are problems. (see notes on previous meeting)

Mendocino County Frost Response - Sean White

This is a rehash of the information White delivered the previous month - cleaned up a little and put in a paper report form.

Water Management for Frost control

Stewardship Alliance - need to protect a 235 million dollar crop - by use of discretionary releases - for mainstem effects only - does not deal with or consider tributary effects.

Note; There still is no talk of a Water Budget.

Laurel M - AWEP funding - Wine Water Conservation Program (should be BMPs for Water use and conservation - not out yet) - fund construction of ponds for storage

Vicky Whitney (SWRCB) - Missing Water Rights for those ponds

Laurel - Need Water Right to Qualify for funds - Need appropriative water right - can not have applied for water rights. One project approved for **Felta Creek (Fish Stranding area).**

URSA - Upper Russian River Stewardship Alliance. Coporations. large partnerships, and wealthy farmes do not qualify. Assess improvements (such as piping).

BMPs (workshops) still in progress.

River incision effects ground water storage - hydrology model leads to Water Budget - diversion timing - and - surface flows.

Vicky W - No one is using $50,000 worth of flow meters offered.

Sonoma County Report

Conditions different than the north (they say but not supported by evidence) - where tributary effects may be more pronounced in Sonoma County.

Say that near stream wells on the mainstem do not cause instream flow changes (where is the evidence for this? What effects does use in the tribs have? No modeling and no water budget).

Real issue in Sonoma County in tributary use - need to identify silviculture use in the tribs - Franz Creek, Mark West Creek, Macaamas Creek.

Identify who is using and potential conflicts.

Assess if wind machine or well use is most effective or necessary - conditions vary - by year and event.

Opatz - Options - Farm Bureau proposal - or - Russian River Property Owners - BMPs - But nothing on the table after over two years of meetings. When will this happen? When, and if, will monitoring occur - with transparency in the process. BO is pushing the process - and - to be managed by governance. Fetta Creek is being dealt with.

I do not see any of this happening.

RIVER RESEARCH AND APPLICATIONS
River. Res. Applic. **23**: 1–17 (2007)

HYDROLOGIC IMPACTS OF SMALL-SCALE INSTREAM DIVERSIONS FOR FROST AND HEAT PROTECTION IN THE CALIFORNIA WINE COUNTRY

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ABSTRACT

Though many river studies have documented the impacts of large water projects on stream hydrology, few have described the effects of dispersed, small-scale water projects on streamflow or aquatic ecosystems. We used streamflow and air temperature data collected in the northern California wine country to characterize the influence of small instream diversions on streamflow. On cold spring mornings when air temperatures approached 0°C, flow in streams draining catchments with upstream vineyards receded abruptly, by as much as 95% over hours, corresponding to times when water is used to protect grape buds from freezing; flow rose to near previous levels following periods of water need. Streams with no upstream vineyards showed no such changes in flow. Flow was also depressed in reaches below vineyards on hot summer days, when grape growers commonly use water for heat protection. Our results demonstrate that the changes in flow caused by dispersed small instream diversions may be brief in duration, requiring continuous short-interval monitoring to adequately describe how such diversions affect the flow regime. Depending on the timing and abundance of such diversions in a drainage network, the changes in streamflow they cause may be an important limiting factor to valued biotic resources throughout the region. Copyright © 2007 John Wiley & Sons, Ltd.

KEY WORDS: small diversions; natural flow regime; intermittent streamflow; human water abstraction; temperature thresholds

Received 23 January 2007; Accepted 16 November 2007

INTRODUCTION

The methods through which humans acquire water supply can fundamentally alter stream ecosystems. Aquatic scientists across many disciplines have demonstrated that centralized water projects operating on or near major rivers, including dams and large instream and groundwater diversions, can change the flow regime (describing the magnitudes, durations, timing, rate of change and other characteristics of runoff patterns, Poff *et al*., 1997) of that river system (Kondolf *et al*., 1987; Wilcock *et al*., 1995; Cowell and Stroudt, 2002[Q3]; Grams and Schmidt, 2002; Glennon, 2002[Q4]; Nislow *et al*., 2002; Magilligan and Nislow, 2005; Page *et al*., 2005; Claessens *et al*., 2006). Along with these changes in flow regime, large centralized projects also alter the dynamics of sediment (Ligon *et al*., 1995; Sear, 1995; Brandt, 2000[Q5]; Grams and Schmidt, 2002) and reduce hydrologic connectivity (Ward and Stanford, 1995; Pringle, 2003), both upon which aquatic organisms depend (Poff and Ward, 1989; Bunn and Arthington, 2002; Lytle and Poff, 2004). Through a number of mechanisms, changes in the natural flow regime as a result of flow manipulation below large water projects can cause a shift in the composition and function of instream communities (Power *et al*., 1996; Pringle *et al*., 2000; Marchetti and Moyle, 2001; Osmundson *et al*., 2002; Downes *et al*., 2003; Cowley, 2006) as well as those in adjacent riparian zones (Johnson, 2002; Nilssen and Svedmark, 2002; Elderd, 2003; Lytle and Merritt, 2004).

Because of these ecological consequences, and for a number of social, political and economic ones as well, water resource managers are searching for less hydrologically manipulative ways to meet future water needs (Scudder, 2005; Potter, 2006). As an alternative, water users may meet water needs individually through small-scale water projects (e.g. Mathooko, 2001; Levite *et al*., 2003; Dole and Niemi, 2004), including direct instream diversions and surface reservoir storage in small headwater tributaries. The decentralized nature of small-scale projects is believed

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to mitigate pressures on stream ecosystems (Potter, 2006) because they serve only one or a few users, small projects retain smaller volumes and employ lower pumping rates than large centralized projects designed to meet the needs of many water users. Additionally, the distribution of small projects spatially and temporally lessens the hydrologic impairment at any one location or at any time within a drainage network.

Though such small-scale water projects may not be individually capable of influencing streamflow like large dams, the cumulative effect of several projects may have potential to impair ecologically relevant flow regime characteristics in other ways (Pringle, 2000; Stillwater Sciences and Dietrich, 2002; Spina *et al.*, 2006). Such concerns may be especially pertinent in regions where decentralized water projects are the primary means to meet human water needs, such as in the wine country of northern California (including Napa, Sonoma and Mendocino Counties), where virtually all agricultural water needs are met individually and locally. Despite that wine grapes require lower volumes of water per area than most other crops grown in California, virtually no precipitation occurs during the summer growing season, so irrigation is regarded as often necessary for successful wine grape production (Smith *et al.*, 2004). In addition to irrigation, vineyard operators spray water aerially to protect crops from frost in spring and from heat in summer, which can threaten grape survival and sugar quality, respectively. Records describing water rights indicate that grape growers throughout the California wine country depend upon surface water abstraction to meet these water needs (SWRCB, 1997; Deitch, 2006).

The pressures that surface water abstractions place on streamflow in the California wine country depend on how water is acquired to meet various needs, and different needs may be met through different mechanisms. Vineyard irrigation, for example, requires low volumes of water periodically through the dry summer. Irrigation needs may be met through diverting low volumes of water from streams briefly and periodically through the growing season, or through pumping groundwater where such sources are available. In addition to requiring lower volumes of water, crops are not irrigated constantly through the growing season, so the effects of water abstraction for irrigation on streamflow may be temporally dispersed. Other uses, such as springtime frost protection and summer heat protection, require high volumes of water over a short duration. Groundwater pumping may not yield sufficient water volumes (especially from low-yield aquifers common in the region) so surface water in the form of streamflow may be especially attractive for meeting such water needs. Because frost and heat protection are linked to particular climatic conditions, growers who employ such practices likely all require water at the same time. Depending on the magnitude of individual diversions relative to streamflow and the number that occur in a drainage network, small-scale instream diversions may have potential to cause changes in flow regime having consequences to stream biota that depend on particular flow characteristics.

Though literature has recently begun to explore the ecological impacts of small instream diversions on aquatic ecosystem communities (e.g. McIntosh *et al.*, 2002; McKay and King, 2006; Wllis *et al.*, 2006), few studies have described how surface water abstraction practices under a decentralized management regime affect flow regime. Characterizing how water management affects flow regime is an important step for understanding how human development may affect aquatic ecosystems (Richter *et al.*, 1996); it provides the foundation for understanding how detected changes in biotic community composition may occur, and can be used for directing changes in management practices to mitigate those ecological consequences. Here we present data describing streamflow in two tributaries to the Russian River in Sonoma County, California, to illustrate how small-scale diversions alter the natural flow regime when certain water need thresholds are reached (indicating need for frost or heat protection) and distinguish these alterations from those commonly described from large water projects, both relative to the natural flow regime and to the spatial extent of the drainage network.

METHODS

Site description

We monitored streamflow in water years 2004 and 2005 at seven locations within the Maacama Creek and Franz Creek drainages in eastern Sonoma County, California. Maacama Creek is one of the five principal tributaries to the Russian River (3800 km^2) and Franz Creek is the tributary to Maacama just upstream of its confluence with the Russian River (Figure 1), at the southern end of the Alexander Valley grape-growing region. At their confluence, the Maacama and Franz Creek catchments drain 118 km^2 and 62 km^2, respectively. The flow regime of both streams

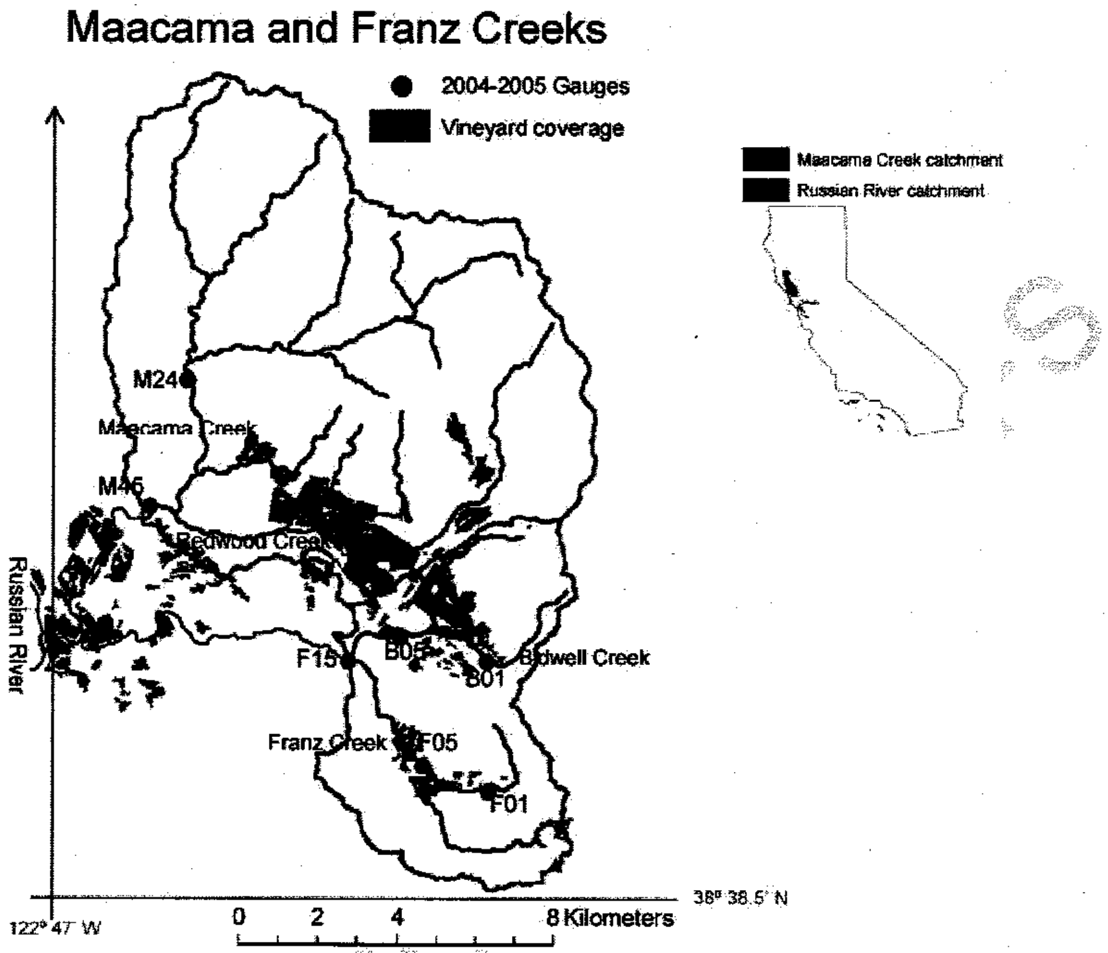

Figure 1. Maacama and Franz Creek channel networks, with gauges 45-Maacama (M45), 24-Maacama (M24), 15-Franz (F15), 05-Franz (F05), 05-Bidwell (B05), 01-Franz (F01) and 01-Bidwell (B01); and vineyards present in 2004

reflects the Mediterranean climate of coastal California; virtually all precipitation occurs as rainfall during the wet half of the year, so streamflow recedes gradually through spring and approaches intermittence by the end of summer (Conacher and Conacher, 1998[Q6]; Gasith and Resh, 1999). Q6

To monitor flow at each of the seven locations, we attached Global Water WL15 pressure transducers encased in high-pressure flexible PVC hose to solid substrate and operated each instrument as a streamflow gauge according to standard USGS methods (Rantz, 1982). We measured flow using Price Mini and AA current meters biweekly to monthly to develop rating curves; instruments recorded stage at 10-min intervals from November 2003 to September 2005. Gauge locations in the Maacama and Franz drainage networks varied with upstream catchment area and vineyard coverage (Table I). Franz Creek was gauged in a nested design (Figure 1). Gauges 01-Bidwell and 01-Franz each measured flow from 2.6 km^2 headwater catchments (1 mi^2; number designations corresponded to catchment area normalized by smallest basin size) with less than 1% of each catchment developed in vineyards; 05-Franz and 05-Bidwell gauges each measured flow from 14 km^2 (5 mi^2) catchments with 5% and 14% of the catchment in vineyards, respectively. The most downstream 15-Franz gauge measured flow immediately below the Bidwell-Franz Creek confluence, with 10% of its 40 km^2 catchment in vineyards. Maacama Creek gauges were installed upstream of the Maacama-Franz confluence. The more downstream 45-Maacama gauge recorded flow from a 112 km^2 catchment with 6.0% of its area in vineyards; and the upstream 24-Maacama gauge recorded flow from a 61 km^2 catchment with no upstream vineyard development. Almost all of the vineyards above 45-Maacama are in the Redwood Creek subcatchment, which is the other major tributary above the 45-Maacama gauge (Figure 1). We also identified the vineyard area in each basin on land parcels abutting streams (termed 'riparian parcels'), indicating the potential for wine grape growers on those parcels to use streamflow as a water source.

DOI: 10.1002/rra

Table I. Characteristics of streamflow gauges and upstream catchments in the Franz Creek and Maacama Creek drainage networks

Gauge (map ID)	Period of record	Catchment area, km^2	Upstream vineyard, ha (% of catchment)	Upstream vineyard on 'riparian' parcels, ha
15-Franz (F15)	2004, 2005	40.4	407 (10%)	276
05-Franz (F05)	2004, 2005	13.7	69 (5.0%)	64
05-Bidwell (B05)	2004, 2005	13.6	193 (14%)	158
01-Franz (F01)	2004, 2005	2.6	0.7 (0.3%)	0
01-Bidwell (B01)	2004, 2005	2.6	2.4 (0.9%)	0
45-Maacama (M45)	2005	112.0	674 (6.0%)	582
24-Maacama (M24)	2005	60.7	0	0

Detecting changes in flow: frost protection

In the Franz Creek drainage, we identified frost protection impacts as sudden changes in streamflow on days when temperatures dropped to near 0°C recorded at a nearby California Irrigation Management Information System weather station at Santa Rosa (weather data were available through the internet at www.cimis.ca.gov). We measured the maximum change in flow as the difference between flow at the beginning of each irregular recession and the minimum flow recorded during the recession period, and the duration as the time from when flow first receded irregularly to the time when flow rose back to near previous levels. We also calculated the total abstraction volume for each irregular flow recession, which we define as the total volume of water extracted from the stream at each gauge over each period of depressed flow, as the difference between the discharge that would occur under an estimated natural flow recession and the actual discharge that occurred over the period of irregular flow recession. In addition, we created a statistic to express flow alteration in a flow regime context. Because flow in Franz Creek recedes naturally through spring and summer, and flow rose to near previous levels following need for frost protection, the minimum flow caused by diversion for frost protection will occur again later in the context of natural flow recession. We measured the number of days before the diversion-induced minimum flow occurred again in the natural recession, a variable we term as the dry-season acceleration.

We used different methods to assess impacts of frost protection in the Maacama Creek basin because we had no gauges on Redwood Creek, where vineyard development is concentrated; we thus could not simply measure flow changes as we did in Franz Creek. Instead, we used a mass-balance approach to determine how the relationship between the two Maacama gauges (24-Maacama representing the undeveloped half of the basin and 45-Maacama representing the entire basin) changed when water would likely be diverted for frost protection. We estimated flow in the ungauged Redwood Creek basin as the difference between the flow at 24-Maacama and flow at 45-Maacama below the confluence of the two forks (Figure 2), and identified the occurrence of frost protection impacts as irregular deviations in the relationship between the flow at 24-Maacama and 45-Maacama that occurred on days when air temperatures were near or below freezing.

Detecting changes in flow: heat protection

We used similar approaches to identify effects of diversions for heat protection on summer base flow as changes in streamflow that occurred on hot days in summers 2004 and 2005. We obtained maximum air temperature data from California Irrigation Management Information System weather station records measured at Santa Rosa and Bennett Valley, California. We used mean daily flows rather than hourly because daily averages dampened the within-day fluctuations from local and catchment-scale evapotranspiration. In the Franz drainage, we focused on changes in flow at 05-Franz and 15-Franz gauges (05-Bidwell became intermittent in early summer, so it was not included in this analysis); for both, we plotted mean daily flow and daily maximum air temperature together to identify whether flow receded similarly at two sites with upstream vineyard development. Unlike our frost protection analyses, we did not attempt to quantify changes in flow magnitude attributed to heat protection: streamflow was very low during summer, increasing the difficulty to distinguish between impacts of instream

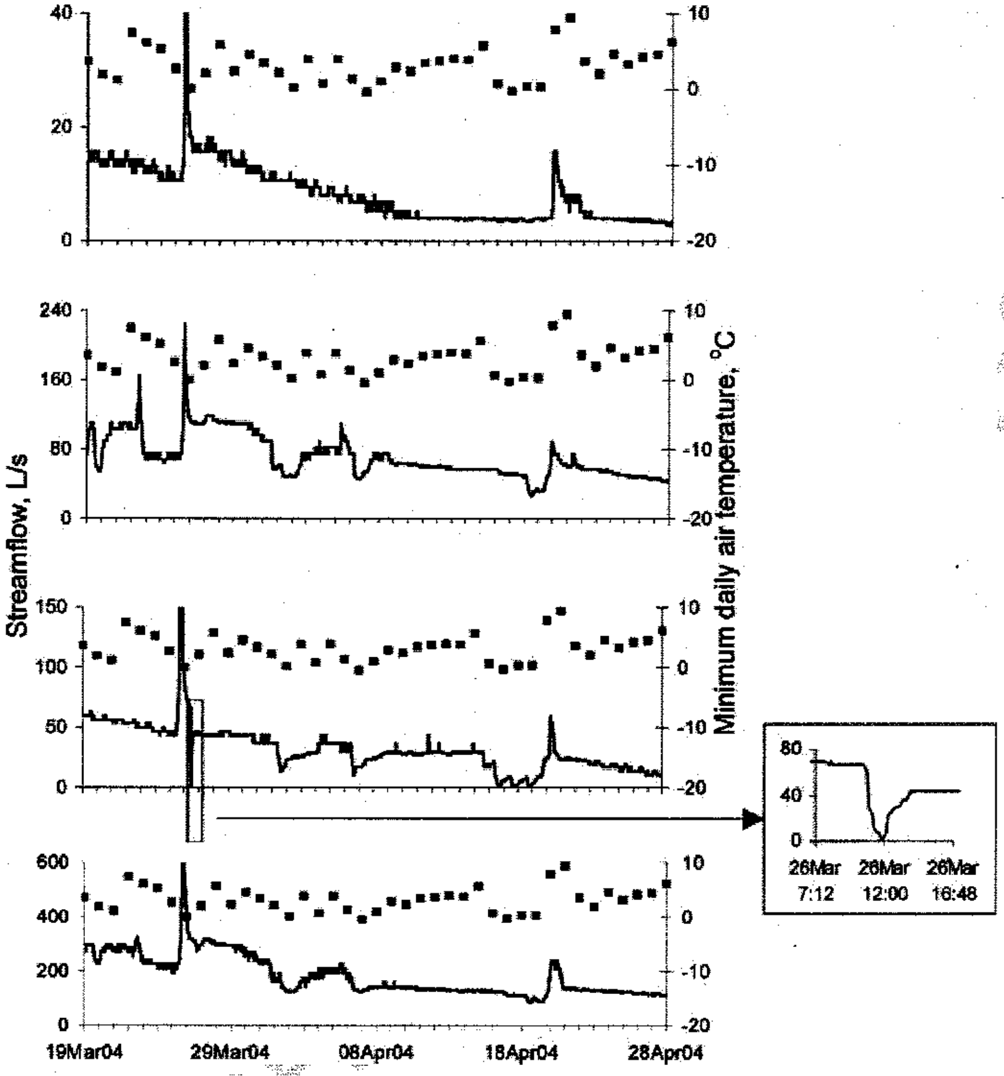

Figure 2. Streamflow hydrographs in the Franz Creek basin in water year 2004, from top to bottom: 01-Franz, 05-Bidwell, 05-Franz and 15-Franz; and minimum daily air temperature recorded in Santa Rosa (southeastern Sonoma County)

diversions and evapotranspiration. For Maacama sites, we plotted mean daily flow at 24-Maacama and 45-Maacama along with daily maximum air temperature to identify whether streamflow receded on days with particularly high temperatures only at the site with upstream vineyard development. In this case, 24-Maacama served as a baseline; with no vineyards in the catchment, flow changes at 24-Maacama could be attributed to natural processes associated with evapotranspiration. Flow changes occurring at 45-Maacama but not at 24-Maacama on very hot days could be attributed to water demand for heat protection.

RESULTS: EFFECTS OF MANAGEMENT PRACTICES ON STREAMFLOW

Frost protection, Franz Creek

No abrupt changes in flow occurred in reaches without upstream vineyard development (e.g. 01-Franz; Figure 2), but streamflow in reaches draining vineyards abruptly receded on spring days when air temperature dropped to near freezing. On 19 March 2004, when minimum daily air temperature fell below 2°C, flow at 05-Bidwell receded by nearly 50% over 12 h, while flow returned to previous levels over the following 18 h (Figure 2; Table II). Flow at this

Table II. Changes in streamflow and abstraction volumes on freezing or near-freezing mornings in the Franz Creek drainage network, spring 2004 and 2005

Event date	Site	Change in flow, L/s		Magnitude of change	Percent change	Duration, hours	Total volume, m^3
		Initial	Minimum				
19–20 March 2004	05-Bidwell	110	55	55	50	30	3300
	05-Franz	(No change)		0	0	—	0
	15-Franz	300	225	75	25	24	2400
22–25 March 2004	05-Bidwell	110	70	40	36	72	9100
	05-Franz	(No change)		0	0	—	0
	15-Franz	300	210	90	30	70	14 000
26 March 2004	05-Bidwell	(No change)		0	0	—	0
	05-Franz	65	2	63	97	8	300
	15-Franz	310	270	40	13	6	1200
31 March–04 April 2004	05-Bidwell	90	50	40	44	72	7900
	05-Franz	45	15	30	67	90	2900
	15-Franz	240	125	115	48	80	14 000
06–07 April 2004	05-Bidwell	75	45	30	40	36	2400
	05-Franz	40	15	25	63	54	1600
	15-Franz	175	125	50	29	30	2400
14–20 April 2004	05-Bidwell	55	25	30	55	84	3800
	05-Franz	30	1	29	97	110	7700
	15-Franz	125	85	40	32	72	4600
24 March 2005	05-Bidwell	650	570	80	12	10	1200
	05-Franz	840	670	170	20	12	1100
	15-Franz	1750	1580	170	10	4	1700
25 March 2005	05-Bidwell	545	465	80	15	12	1200
	05-Franz	600	70	530	88	12	8800
	15-Franz	1580	1360	220	14	10	5100
30 March 2005	Bidwell	420	320	100	24	14	1900
	05-Franz	510	280	230	45	10	5300
	15-Franz	1280	1160	120	9	10	2400
31 March 2005	05-Bidwell	(No change)		0	0	—	0
	05-Franz	410	165	245	60	6	3000
	15-Franz	1220	1035	185	15	7	1900
12 March 2005	05-Bidwell	270	150	120	44	97	20 000*
	05-Franz	205	45	160	78	14	3100
	15-Franz	470	400	70	15	14	1600
13 April 2005	05-Bidwell	—		—	—	—	*
	05-Franz	165	35	130	78	16	5100
	15-Franz	420	340	80	19	16	5500
14–16 April 2005	05-Bidwell	—	—	—	—	—	*
	05-Franz	160	35	125	78	30	6700
	15-Franz	395	320	75	19	36	14 000

*Hydrograph depression at 05-Bidwell on 12 April 2005 was sustained until 16 April 2005.

site changed similarly when temperature approached freezing from 22 March 2004 through 19 April 2004, receding irregularly when minimum daily air temperature approached zero and rose in the days following; the artificially depressed flows lasted from 1.5 to 3.5 days (Table II), corresponding with the number of consecutive days with minimum daily air temperatures near 0°C. Surface water abstraction volumes over these periods ranged from 2400 to 9100 m^3, corresponding to in between 1000 and 3000 m^3 per morning of depressed flows (i.e. for each instance when water would have been used for frost protection).

Other gauges showed similar patterns of irregular changes in flow on mornings when minimum daily air temperature was near freezing. Data at 05-Franz first indicated irregular flow recession on 26 March 2004 (minimum temperature 0°C), when flow fell from 65 L/s (0.065 m^3/s) to near zero in 2 h; flow rose again to previous levels during the following 3 h (Figure 2). Flow recessions over the following weeks more closely resembled the

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changes in nearby Bidwell Creek in terms of magnitude and duration (Table II), with the exception of alteration from 14 April 2004 to 19 April 2004 (during which minimum daily air temperature ranged from 0°C to 1°C on four consecutive mornings), when flow receded from 30 L/s to 0 L/s and then remained depressed for 3 days before rising back gradually to 30 L/s. Over the three intervals when frost protection impacts were detected, total abstraction volume at 05-Franz ranged from 300 m^3 to 7700 m^3 (corresponding to between 300 m^3 and 1900 m^3 per morning of depressed flow).

Changes in streamflow at the 15-Franz gauge mirrored the changes upstream. Flow at 15-Franz decreased by 75 L/s and 90 L/s on 19 March 2004 and 22 March 2004, respectively, exceeding the magnitude of flow change recorded at 05-Bidwell (i.e. when flow was not affected at 05-Franz; Table II). Flow at 15-Franz fell by as much as the sum of 05-Franz and 05-Bidwell on 06 April 2004, and by more than the sum of 05-Bidwell and 05-Franz from 01 April 2004 to 03 April 2004 (Figure 2; Table II), suggesting that additional water was drawn from the Franz Creek drainage downstream of the 05-Bidwell and 05-Franz gauges on the latter period. Flow at 15-Franz receded from 16 April 2004 to 19 April 2004, less than the sum of the recession detected at 05-Bidwell and 05-Franz. Abstraction volumes detected at 15-Franz also varied from event to event, ranging from 1200 m^3 to 14 000 m^3 (corresponding to between 1200 m^3 and 4800 m^3 per morning of depressed flow). These total abstractions measured at 15-Franz were also frequently less than the sum of abstraction detected at the two upstream gauges.

Similar irregular recessions occurred through the Franz drainage network in spring 2005. Streamflow was higher throughout the drainage as a result of late-spring rainfall, but changes in streamflow on days with low temperatures occurred over similar duration at 05-Franz, 05-Bidwell and 15-Franz (Figure 3, Table II). The most dramatic change was detected at 05-Franz, where flow on 24 March 2005 fell from 600 L/s to 70 L/s over a few hours, and rose to previous levels by the end of the day (Figure 3). At all sites, changes in flow on cold mornings were greater in magnitude and duration than the previous year, but because of higher spring flows in 2005, the relative magnitude of flow recession was less. Abstraction volumes over each instance of frost protection need were also greater than the previous year, but their impacts on overall discharge were also tempered by higher discharge in spring 2005.

Frost protection, Maacama Creek

Data in the Maacama drainage indicates that flows in Redwood Creek changed abruptly as a result of extractions for frost protection as well. Streamflow at 45-Maacama was 1.8–2 times the flow at 24-Maacama through the winter until late March when this discharge relationship changed systematically during the two periods. Following rainfall on 26 March 2005, streamflow in 45-Maacama receded to approximately equal flow at 24-Maacama; minimum air temperature on 26 March 2005 was 0°C (Figure 4). A high-flow event following rainfall on 27 March 2005 raised flow at 45-Maacama again to approximately two times that at 24-Maacama; but flow receded in the days following to again equal to 24-Maacama from 30 March 2005 to 03 April 2005 and from 04 April 2005 to 08 April 2005. Each instance corresponded to minimum air temperatures near 0°C. According to the mass-balance relationship described above, when flow at 24-Maacama equalled flow at 45-Maacama, flow from Redwood Creek was zero. Streamflow at 45-Maacama rose again to approximately two times the flow at 24-Maacama following the occurrence of minimum daily air temperatures near 0°C.

Heat protection, Franz Creek

Streamflow at 05-Franz and 15-Franz changed systematically in summer 2004 and 2005 in patterns suggesting that water was diverted from streams for heat protection on very warm days. Flow at 15-Franz receded to intermittence during the third week of July 2004, corresponding to a period when daily maximum air temperatures exceeded 32°C (Figure 5). Flow then rose when maximum temperatures were lower in late July, but receded again when maximum temperatures exceeded 32°C in early August. Flow rose briefly in mid-August but fell when maximum temperatures again exceeded 32°C; 15-Franz remained intermittent until late September. During sustained intermittence from late August to late September, stage continued to fall when maximum daily air temperatures were high and rise when temperatures were cooler (Figure 6). Streamflow at 05-Franz showed some but not all of the patterns illustrated at 15-Franz; flow receded abnormally with high air temperatures in early and mid-August, and rose again afterward (Figure 6). In summer 2005, streamflow at 15-Franz and 05-Franz did not change as frequently with high temperatures. Flow at 05-Franz receded gradually throughout summer 2005, falling

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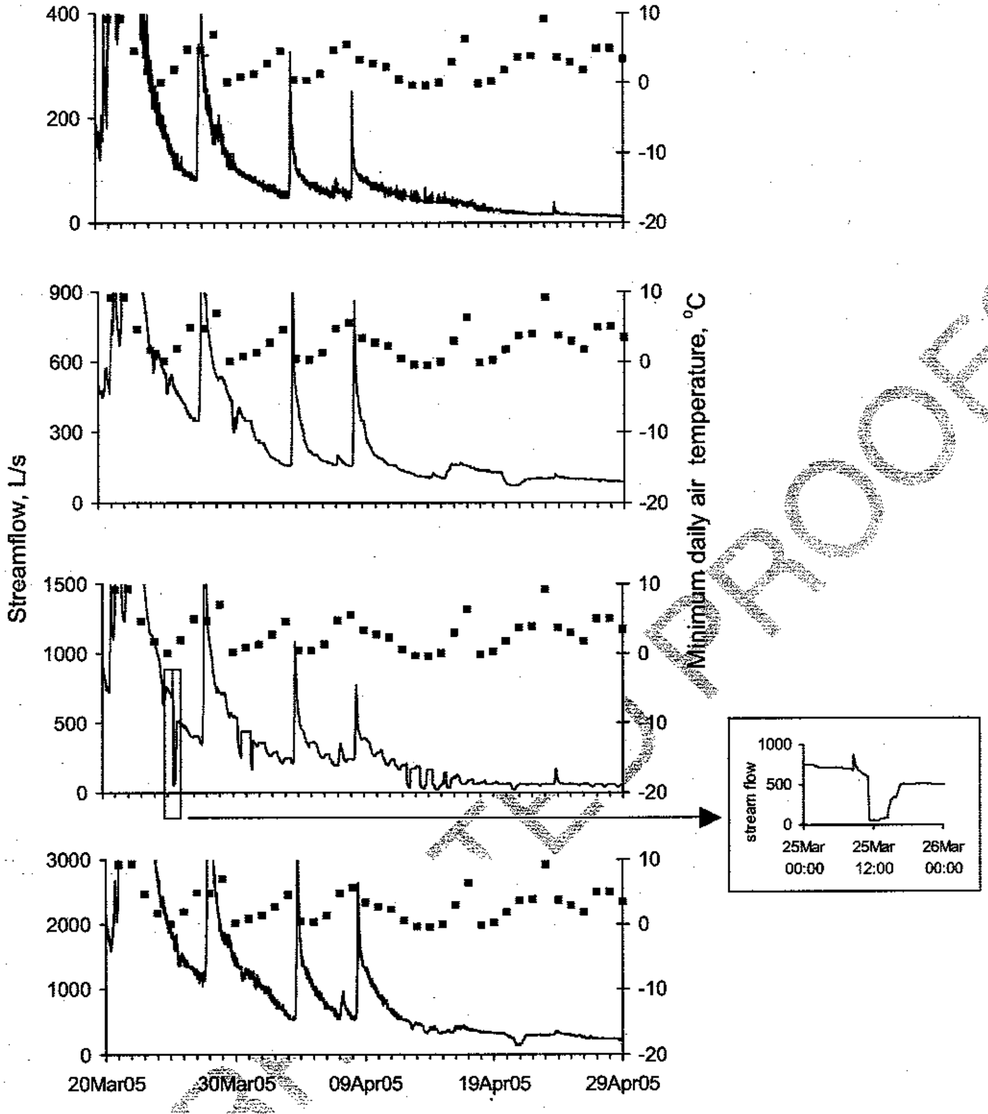

Figure 3. Streamflow hydrographs in the Franz Creek basin in water year 2005, from top to bottom: 01-Franz, 05-Bidwell, 05-Franz and 15-Franz, and minimum daily air temperature recorded in Santa Rosa (southeastern Sonoma County)

only once during a period with temperatures above 32°C in mid-July (Figure 5); flow at 15-Franz also fell during the same period. At both sites, flow rose when maximum air temperatures were lower in the days that followed, and receded gradually through the remainder of the summer.

Heat protection, Maacama Creek

Changes in streamflow at 45-Maacama also suggested that water was diverted for heat protection on very warm days. Streamflow receded more quickly on days when maximum temperature exceeded 32°C and then rose when maximum daily air temperatures were lower in June and early July 2004, and again in August and September 2004 (Figure 7). The same sustained period of maximum daily air temperatures above 32°C that caused flow to cease at 15-Franz caused flow to cease at 45-Maacama as well. At 24-Maacama, where no vineyards exist upstream, flow receded regularly until early August, then rose slightly and remained steady throughout the remainder of summer 2004 (including the period of sustained high temperature in early September). Similar to fluctuations at 15-Franz, flow at 45-Maacama changed abnormally in mid-July 2005 during a period of high maximum daily temperature,

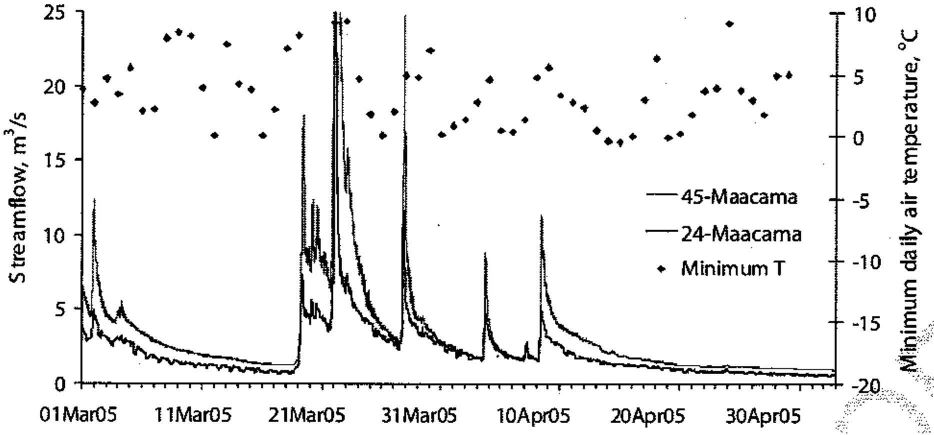

Figure 4. Streamflow at 45-Maacama and 24-Maacama, and minimum daily air temperatures (recorded at Santa Rosa, CA), spring 2005

and then rose in the days following (Figure 7). Flow at 24-Maacama, with no upstream vineyards, receded regularly through summer 2005.

Dry-season acceleration

The irregular changes in flow in spring 2004 can be used to illustrate how water demand for frost protection in the Franz Creek drainage network causes flow recession to accelerate. Diversions caused flow at 05-Bidwell fall to

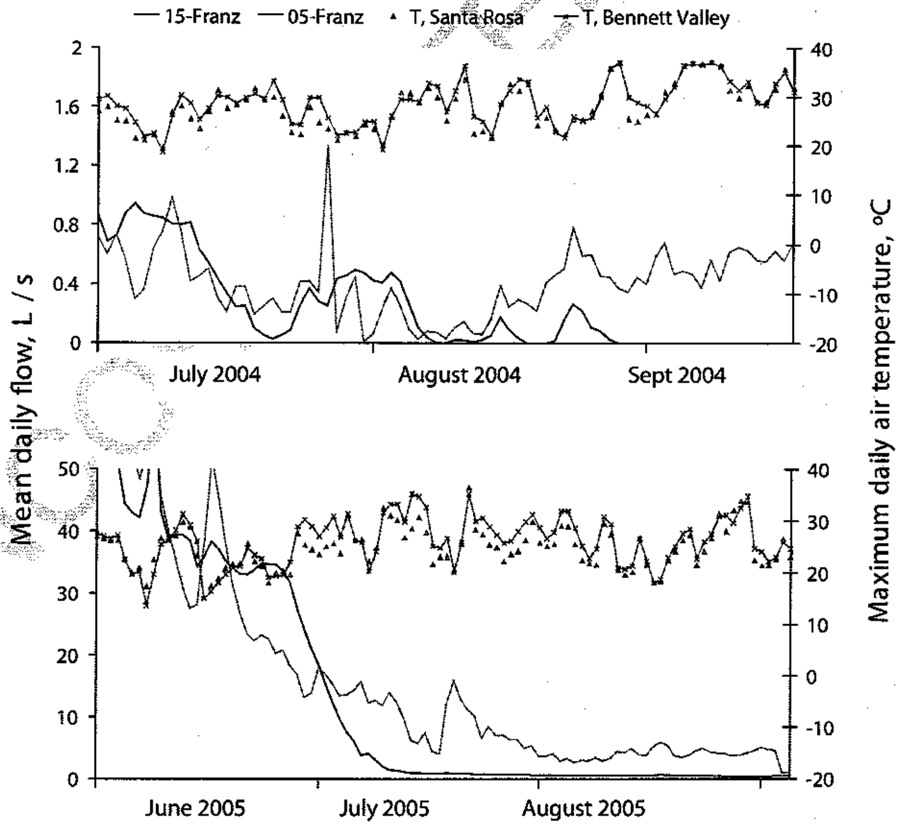

Figure 5. Maximum daily air temperatures at Santa Rosa and Bennett Valley (eastern Sonoma County) and streamflow in Franz Creek, summer 2004 and 2005

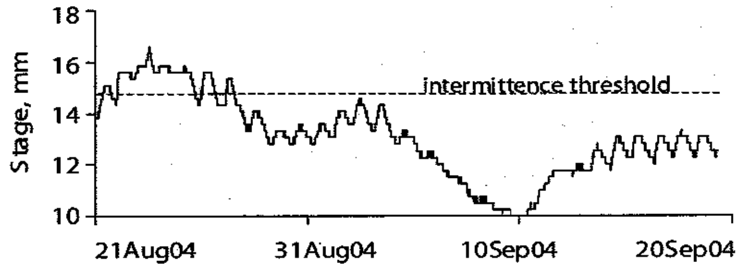

Figure 6. Surface water stage recorded at 15-Franz after surface flow ceased, summer 2004; irregular flow recession occurred within the context of natural diurnal fluctuations in flow

60 L/s on 19 March 2004; flow then rose to the previous level in the days that followed, when minimum daily air temperatures were above freezing. Following a more natural flow regime, flow at 05-Bidwell receded gradually and remained above 60 L/s until 12 April 2004 (Figure 3). This difference in time between the 60 L/s flow magnitude caused by diversion and its occurrence under natural flow recession is 24 days; thus diversions for frost protection at 05-Bidwell on 19 March 2004 accelerated the summer drought by 24 days. Similarly, diversions caused flow at 05-Franz to fall to 16 L/s on 01 April 2004; when minimum daily air temperatures were again above zero, flow returned to its previous level. Under a natural recession, flow did not reach 16 L/s until 24 April 2004; again, the summer drought was accelerated by 24 days. Flow at 05-Franz became nearly intermittent on 16 April 2004, and then rose when diversions ceased; flows did not recede to near intermittency naturally until July. In this case, frost protection accelerated the dry season by over 2 months. Similarly, diversions for frost protection accelerated the dry season in the Maacama Creek drainage. Equal flow at 24-Maacama and 45-Maacama indicated that flow from Redwood Creek ceased over two 4-day periods in April 2005; summer flow hydrographs show that flow from Redwood Creek continued for the remainder of summer 2005 (Figure 7).

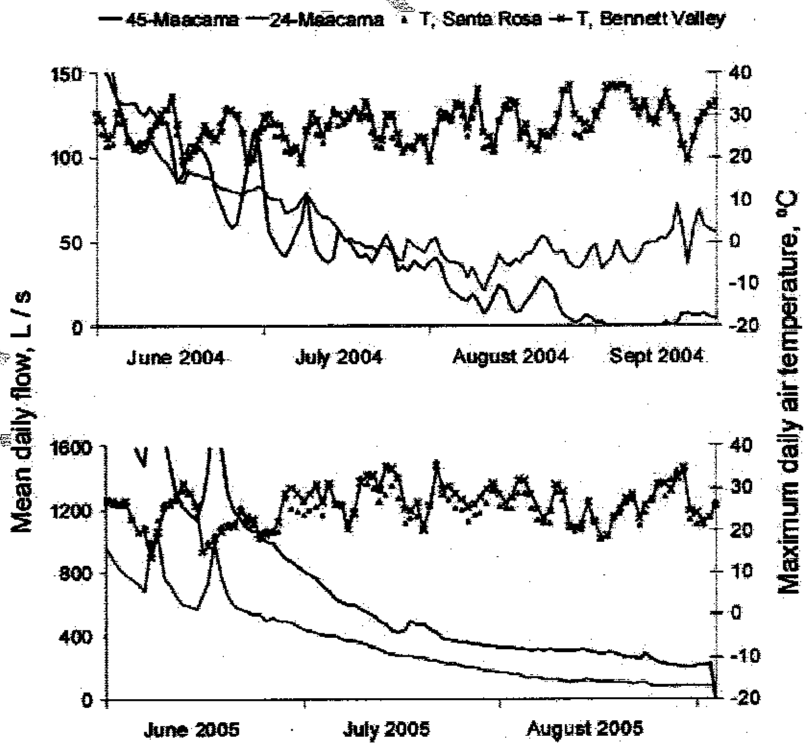

Figure 7. Maximum daily air temperatures at Santa Rosa and Bennett Valley (eastern Sonoma County) and streamflow in Maacama Creek, summer 2004 and 2005

DISCUSSION

Natural catchment processes are insufficient to explain the irregular changes in streamflow in Franz and Maacama Creeks documented above that occurred when particular temperature thresholds were crossed. In spring, sudden decreases occurred only on days when temperatures were near freezing, when water was needed for frost protection; changes were only detected at gauges with vineyard development upstream. The causes of flow alteration on hot summer days are less straightforward, as it is conceivable that there could be some characteristics of soil, topography and/or vegetation in the catchments of 05-Franz, 15-Franz and 45-Maacama that caused ET to abruptly increase when air temperature exceeded 32°C. Evapotranspiration is one factor that may reduce streamflow, especially in semi-arid environments (Mwakalila *et al.*, 2002; Lundquist and Cayan, 2002); it seems less plausible, however, that such processes would only be activated beyond particular temperature thresholds. The relatively abrupt declines in discharge that we attribute to diversions for heat protection occurred when air temperatures exceeded 32°C, and only in catchments with vineyard development. The declines were followed by increased discharge in subsequent days.

Though results above indicate that irregular flow recession occurred repeatedly at particular temperature thresholds at sites with vineyard development upstream, the changes in streamflow magnitude and total volumes of abstraction were not always consistent from one occurrence of water need to the next. The magnitude of flow alteration at the Franz Creek gauges, for example, varied throughout water years 2004 and 2005; in only a few cases the maximum magnitude of change at a site will ever be the same (Table II). The total volume of abstraction also frequently varied at the same site from one instance to the next (Table II). Such variations may partly reflect irregularities that are characteristic of water management in the wine country. Wine grape growers tend only to apply water for frost protection as needed. Aerial spraying only occurs when temperatures reach certain thresholds, and the durations of these temperature thresholds may vary from one instance of need to the next. The total volume of water abstraction for a given need reflects the amount of time over which water was diverted. Additionally, geographic analyses of land parcel data in Sonoma County indicate that at least six different land owners with property abutting the streams above the 05-Franz and 05-Bidwell gauges have vineyards planted on their property (Figure 8). Because water in this region is managed on the individual level, each grape grower may have a different temperature threshold at which water is initially applied to crops, and each grower who diverts from the stream to meet water needs may do so with a different pumping rate than a neighbour upstream or downstream. These management variations, along with temperature variability across space, can contribute to the differences in abstraction volume and magnitude of flow alteration each time air temperatures approached freezing. Similar variations likely occurred during the summer heat protection season as well.

The data presented in this study document another important discrepancy related to the impacts of decentralized water management in the region. In a few instances when water was needed for frost protection, the maximum magnitude of diversion and total abstraction volume at the downstream 15-Franz gauge is greater than or equal to the sum of diversion magnitudes and total volumes extracted at the upstream 05-Franz and 05-Bidwell gauges. Such results could be expected: impacts of diversion in headwaters, both as a maximum rate and total abstraction, could propagate downstream in a cumulative fashion (additional vineyards between the upstream and downstream gauges could account for greater diversion rates and total abstractions at the downstream gauge than the two upstream gauges combined). However, for the majority of instances when water is diverted from the Franz Creek drainage for frost protection, the maximum change in flow rate and total estimated abstraction was greater at one of the upstream sites than at the downstream 15-Franz site. Our detection of greater change in flow and greater overall abstraction detected upstream than downstream may seem counterintuitive to basic principles of stream hydrology. Streamflow at any point is a product of an upstream drainage network, so an abstraction that occurs in headwaters should appear in lower reaches as well. One possible explanation for this detected phenomenon may be the means by which we calculated maximum diversion rates and abstraction volumes. For each apparent frost protection occurrence, we selected an arbitrary point where diversion began based on irregular hydrograph changes, and selected the end point as the maximum flow following the rise in discharge after apparent water need had ended; we may have incorrectly identified when management actions began and ended.

The greater detected abstraction at upper than lower reaches of Franz Creek may also be attributed to the complexities of hydrological processes that influence streamflow. During base flow periods, streamflow may be

DOI: 10.1002/rra

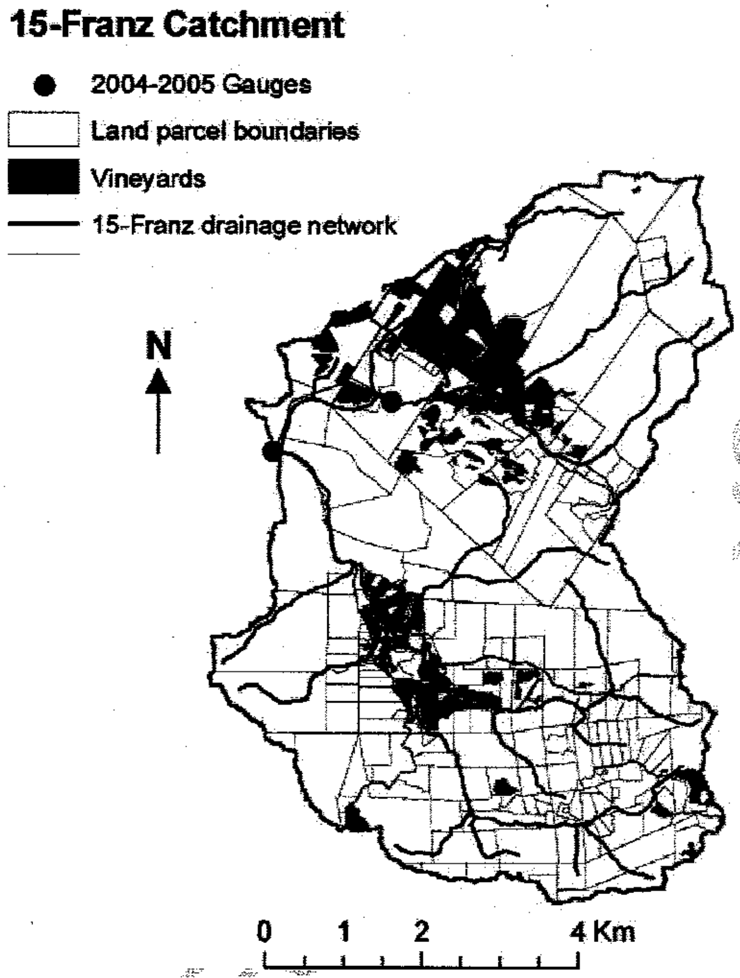

Figure 8. Land parcel data and vineyard coverage in the 15-Franz drainage basin, Sonoma County, California

derived from headwater drainages and adjacent shallow aquifers alike; the water level in the stream is often interpreted as the surface exposure of the shallow groundwater table (Dunne and Leopold, 1978; Ward and Trimble, 2004). If a volume of water diverted at an upstream reach causes a sudden depression of the surface water level, shallow groundwater could supplement streamflow in an effort to make the surface water and shallow groundwater levels equal once again. As a result, the impact of abstraction would appear less downstream. If this process were occurring in Franz Creek between headwater and downstream gauges, it appears that the rate at which groundwater can supplement streamflow is less than the rate at which water is diverted from the stream because there is some abstraction detected at the 15-Franz gauge. Though the abstraction may not fully manifest itself at 15-Franz through surface flow, the gap in water caused by upstream abstractions may instead accelerate the recession of shallow groundwater table between gauges. It would be inappropriate to attribute this mitigated flow impact to 'return flow', (the process whereby water applied to a crop percolates through soil and returns to the stream); return flow would return to the stream above the 05-Franz gauge where water was removed, and thus would not appear in the 05-Franz hydrograph. These unexpected differences in abstraction at upper and lower reaches highlight an important point regarding assessments of cumulative effects at the catchment scale. Local hydrologic impacts may manifest themselves differently at a different location in the drainage network. Impacts of changes to streamflow in the upstream catchment may not be accurately depicted by abstractions or changes in flow detected downstream.

Despite the differences in abstraction volumes at the same site and among different sites along the same drainage, the abstractions from Franz and Bidwell Creek correspond to reasonable estimates of water need if a fraction of the vineyard operators in each basin divert from the stream for a particular instance of frost protection in each basin. Regional vineyard extension specialists indicate that frost protection requires approximately 1000 m^3 of water per hectare of vineyard in a given year to be used over six events (Smith *et al.*, 2004), corresponding to 166 m^3 per hectare for each frost protection event. Given the total vineyard area on riparian properties in the 05-Franz catchment, the total water need for 1 day of frost protection above the 05-Franz gauge is 10 600 m^3 per event. Even the highest calculated abstraction for a single day (8800 m^3) is less than the total water need among all potential upstream diverters. Water need versus abstraction above 05-Bidwell and 15-Franz compare similarly. Volumes of abstraction for each day indicate that only a fraction of water needed for frost protection for each event is met through direct instream diversion.

Small- versus large-scale water management projects

As small-scale water projects are increasingly developed to meet individual water needs, the potential local-scale and cumulative catchment-scale impacts of such projects on flow must be better understood (Potter, 2006). It may be most useful to frame these impacts through a comparison of our results described above to the hydrologic effects of larger projects. Magilligan and Nislow (2005) reported the greatest changes to the natural regime among 21 river systems with large-scale dams as reduced high-flow magnitudes, a point that was reiterated consistently in case studies (Ligon *et al.*, 1995; Richter *et al.*, 1996; Batalla^{Q7} *et al.*, 2002; Grams and Schmidt, 2002; Marston *et al.*, 2005; Page *et al.*, 2005). In addition, large water projects commonly alter the rate of change of peak flows. Magilligan and Nislow (2005) describe more gradual rises in the rising limb of flood hydrographs in dammed river systems, and Wilcock *et al.* (1995) describe longer persistence of elevated flows than would occur naturally; Page *et al.* (2005) describe both higher and lower peak flow durations in a series of nested large dams.

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These changes in peak flow characteristics reflect the capacity for large projects to regulate discharge for purposes such as flood protection and storage for uses during other periods, a characteristic that is absent among small-scale diversions in this study. Small diversions from Franz and Maacama Creeks did not reduce peak flow magnitude, timing or duration in winter or spring; peaks at 15-Franz in March and April, for example, occur at the same time and with the same duration as at upstream sites without diversions (Figure 3); and peaks at 45-Maacama occur with similar timing, duration and relative magnitude as at 24-Maacama (Figure 5). Although the small diversions did not reduce peak flows, they affected spring and summer base flows. In most cases, the magnitudes of spring and summer flows caused by diversion are not lower than what would typically occur at some point during the dry season, but diversions alter the rate of flow recession and cause low flows to occur earlier in the year. In contrast, large dams frequently augment base flow during the growing season by releasing more water to provide for conjunctive uses (e.g. Batalla *et al.*, 2002; Grams and Schmidt, 2002; Magilligan and Nislow, 2005; Marston *et al.*, 2005). Effects of small-scale water projects more closely resemble alterations caused by large-scale groundwater pumping. Kondolf *et al.* (1987) and Zariello and Reis (2000) both describe groundwater pumping as causing long-term reductions to streamflow during base flow periods by lowering groundwater tables. Unlike large-scale groundwater pumping, however, impacts caused by small-scale projects are not sustained; flows fall and then rise again even in summer, suggesting that a depleted groundwater table is not the cause of changes in spring and summer flows in Franz and Maacama Creeks.

In addition to different hydrograph impacts, small-scale water projects also have different spatial implications relative to centralized projects. Small projects in Franz and Maacama Creek, and throughout the northern California wine country, are distributed through the drainage network, and thus have potential to alter base flow dynamics wherever they operate. Franz Creek data indicate that diversions appear to have greatest influence locally and upstream in the drainage network; diversions above the 05-Franz gauge caused large local-scale changes in flow, and comprised a greater fraction of discharge than at 15-Franz (partly because flows were less in headwater reaches than further downstream). Several diversions in a catchment can depress flow throughout the drainage network, rather than at one location. Franz Creek data also illustrate the importance of measuring impacts locally over extrapolating to predict upstream impacts based on downstream measurements; local upstream changes in flow were frequently of greater magnitude than downstream gauge indicated.

Ecological consequences of small-scale water management

Because small water diversions have different hydrologic impacts than larger projects, they likely have different ecological effects as well. Small diversions are unlikely to significantly alter the magnitude and timing of high

DOI: 10.1002/rra

flows, which are critical to maintaining channel form and gravel bed texture and composition (Kondolf and Wilcock, 1996; Power *et al.*, 1996), and thus are unlikely to cause changes to riparian and aquatic ecology commonly attributed to large storage projects. Preserving the timing of peak flows also maintains the biological signals and energy transport that high-flows provide (Ward and Stanford, 1995; Puckridge *et al.*, 1998). In addition to altering peak flows, large water projects frequently augment summer base flows, which can benefit exotic (often predatory) fish populations (Marchetti and Moyle, 2001); small instream diversions have no capacity to increase base flows, and instead cause base flows to drop abruptly to unseasonably low levels earlier in the year. These changes in base flows may alter macroinvertebrate and fish community composition (McIntosh *et al.*, 2002; McKay and King, 2006; Wllis *et al.*, 2006). The hydrologic effects of small instream diversions more closely resemble those of large-scale groundwater pumping, but groundwater pumping also has different ecological consequences than small instream diversions. By lowering shallow aquifers, groundwater overdraft frequently causes loss of riparian vegetation that can no longer reach shallow aquifers (Shafroth *et al.*, 2000; Naumburg *et al.*, 2005). The rise of streamflow in Maacama and Franz Creeks immediately following periods of water demand, and the persistence of flow at most sites through summer, suggests that adjacent groundwater tables are not impaired by surface diversions to the extent that riparian vegetation would likely be unaffected under this management regime.

The potential ecological consequences of small instream diversions in the California wine country may be best described in the context of dry-season acceleration. Diversions in 2004 caused streamflow to resemble natural discharge 4 weeks later. Dry-season acceleration by up to 4 weeks in Franz Creek means that the depressed flows in late April more closely resembled those that occurred in late May; as a result, processes dependent on April flow conditions may not persist under depressed April flows. Even in Mediterranean-climate ecosystems where biota are adapted to a prolonged dry season each year, drought is considered a major ecosystem stressor (Gasith and Resh, 1999); instream processes dependent on a more gradual flow recession may be truncated if low-flow conditions occur prematurely. In Mediterranean climate streams in coastal California, longer or more intense drought can lead to different aquatic community organization, either resulting in lower overall numbers of certain organisms (e.g. Fawcett *et al.*, 2003) or community composition more closely resembling lentic communities rather than lotic ones (Beche *et al.*, 2006).

Though it is impossible to know for certain how small-scale water projects affect stream biota without a thorough analysis of how accelerated drought conditions affect instream resources, the changes that small instream diversions cause in the flow regime may be sufficient to change conditions that valued biota such as *anadromous salmonids* depend upon for persistence in a given stream. *Anadromous salmonids*, those fishes including steelhead trout (*Oncorhynchus mykiss)* and *coho salmon* (*Oncorhynchus kisutch*) that live as juveniles in freshwater streams and adults in the ocean, use tributaries such as Franz and Maacama Creeks for reproductive spawning and nursery habitat (SWRCB, 1997; Marcus and Associates, 2004). Their migration from the ocean to freshwater streams to complete their life cycle begins at the onset of the rainy season in late fall and early winter, and may occur throughout winter months. After redd construction and egg fertilization, water must pass over redds so that eggs remain oxygenated for between 40 and 60 days before fry emerge (Moyle, 2002). Changes in streamflow as a result of instream diversion can cause portions of riffles to be exposed (Spina *et al.*, 2006); if flow conditions in March or April are manipulated to resemble those in late April or May, riffle exposure could cause egg mortality among redds laid as early as late January. Irregular flow recession in late spring may also adversely affect recently hatched juvenile salmonids by causing a loss of steady food supply via downstream drift, and by reducing long-term macroinvertebrate food supply (depending on the mobility of macroinvertebrates to regions that remain wetted), which provide important energy resources through summer (Suttle *et al.*, 2004). In the Russian River catchment, hundreds of small diversions have the potential to impair spring and summer flows throughout the drainage network (Deitch, 2006). Because of their potential impacts on low flows and ubiquity throughout the northern California wine country, small instream diversions may threaten the survival of salmonids throughout the region.

CONCLUSIONS

Small instream diversions operating under a decentralized management regime may not impair the high flows as documented for large water projects, but instead deplete streamflow over short durations when water is needed for specific uses. Flow in subcatchments of Maacama and Franz Creeks with vineyards dropped abruptly as air temperatures approached 0°C and 32°C due to multiple, simultaneous small diversions, for frost and heat protection, respectively. The changes in flow at our gauges indicated that impacts of small projects tended to occur over brief periods and during base flow, a significant departure from the impacts of large water projects; the dispersed nature of these diversions means these flow regime alterations may occur throughout the catchment where such practices are prevalent.

Small-scale water projects may, as Potter (2006) implies, play an important role in alleviating the pressures of human water needs on aquatic ecosystems, but small projects as currently operated in Franz and Maacama Creeks do not achieve this objective. Instream diversions such as those in the Franz and Maacama catchments withdraw water when needed; this tends to occur during periods when streamflow is naturally low. Stable summer base flow is increasingly scrutinized as an essential factor for the persistence of *anadromous salmonids* in the region (RWQCB, 2005); if small instream diversions have similar effects throughout the northern California wine country, the changes that small water projects cause to the natural flow regime may play a principal role in limiting valued ecological resources such as *anadromous salmonids* throughout the region.

Just as the data presented here illustrate the impacts that these diversions may cause, they also may play a role in directing how future management can alleviate such pressures. Water needs for wine grapes are low relative to most crops, so if water needs could be satisfied through other methods of abstraction, then ecologically sustainable water management in California may still be achieved. Efforts to meet human needs while protecting instream values may be best addressed, not by altering how water may be diverted, but rather by changing when such diversions may occur. In this context, the natural flow regime of Mediterranean-climate rivers in coastal California can serve as a guide; the abundance of discharge that occurs during the wet winters may provide ample resources to meet all needs.

ACKNOWLEDGEMENTS

This research was funded through National Science Foundation Biocomplexity Award 0119992, United States Environmental Protection Agency STAR Cumulative Effects Award R829803 and United States Environmental Protection Agency STAR Ecological Thresholds Award 83243901; and through the Beatrix Farrand Fund in the Department of Landscape Architecture and Environmental Planning at the University of California, Berkeley. The authors are especially grateful to Vincent Resh, David Newburn, Colin Brooks, Kathleen Lohse and Alison Whipple for additional support and helpful feedback through the planning and research process.

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DOI: 10.1002/rra

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Accepted: Aquatic Conservation: Marine and Freshwater Ecosystems

Surface water balance to evaluate the hydrological impacts of small instream diversions and application to the Russian River basin, California, USA

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Abstract

1. Small streams are increasingly under pressures to meet water needs associated with expanding human development, but their hydrologic and ecological effects are not commonly described in scientific literature.

2. To evaluate the potential effects that surface water abstraction can have on flow regime, scientists and resource managers require tools that compare abstraction to streamflow at ecologically relevant time scales.

3. We adapted the classic water balance model to evaluate how small instream diversions can affect catchment streamflow; our adapted model maintains the basic mass balance concept, but limits the parameters and considers surface water data at an appropriate time scale.

4. We applied this surface water balance to evaluate how recognized diversions can affect streamflow in twenty Russian River tributaries in north-central California.

5. The model indicates that existing diversions have little capacity to influence peak or base flows during the rainy winter season, but may reduce streamflow during spring by 20% in one-third of all the study streams; and have potential to accelerate summer intermittence in 80% of the streams included in this study.

Introduction

The methods through which humans meet water needs frequently alter aquatic ecosystems. Manipulations caused by large centralized water projects have been well-documented: large dams and diversions can change the magnitude, frequency, duration, timing, and rates of change of peak flows and base flows (Cowell and Stroudt, 2002, Nislow *et al.*, 2002; Magilligan and Nislow, 2005; Page *et al.*, 2005; Marston et al., 2005; Singer, 2007), which may in turn change the sediment regime, disturbance regime, and biogeochemical processes upon which instream and riparian biota are dependent (Poff *et al.*, 1997; Whiting 2002; Bunn and Arthington 2002; Lytle & Poff 2004; Doyle et al. 2005). Ecohydrologists and stream ecologists frequently focus aquatic ecosystem management and restoration efforts on mitigating the impacts of large-scale water projects on major rivers (Baron *et al.*, 2002; Tharme, 2003; Fitzhugh and Richter, 2004; Arthington *et al.*, 2006; Richter and Thomas, 2007), whereby the natural flow regime serves as a reference for ameliorating those impacts (Postel and Richter, 2003; Suen and Eheart, 2006; Wohl *et al.*, 2005). Where data are available to illustrate pre- or post-dam streamflow conditions, managers use tools (e.g., Indicators of Hydrologic Alteration or IHA, Richter *et al.*, 1996; Dundee Hydrologic Regime Assessment Method or DHRAM, Black *et al.*, 2005) can explore how these projects affect discharge and direct management operations to more closely match a natural flow regime.

As an alternative to large-scale projects, water users are increasingly turning to smaller-scale projects, including small surface reservoirs and low-volume diversions, to meet water needs (SWRCB, 1997; Mathooko, 2001; Liebe *et al.*, 2005; *Economist,* 2007). Small-scale water projects are attractive from an ecosystem management perspective because they entail less abstraction and tend to be distributed in the catchment, thus spreading their impacts throughout the drainage network (Potter, 2006). However, the uncertainty regarding the impacts of small water projects on streamflow both locally and cumulatively and their growing numbers in many regions across the globe have caused concern among managers and scientists over their potential effects on stream hydrology and aquatic ecosystems (Pringle, 2000; Malmqvist and Rundle, 2002; Spina *et al.*, 2006). Recent literature has attributed changes in aquatic macroinvertebrate and fish communities to the operation of small diversions and reservoirs in the upstream drainage network (Rader and Belish, 1999; McIntosh *et al.*, 2002; McKay and King, 2006; Willis *et al.*, 2006). Despite these concerns, however, no clear frameworks have been presented in literature to evaluate or predict the effects of small projects on streamflow.

Tools designed to make ecologically meaningful evaluations of small-scale water projects on streamflow must consider potential interactions of two factors, flow regime and management regime (describing the means through which users acquire water from the ecosystem), over ecologically relevant timescales. Whereas streamflow gauges operating below large-scale water projects provide the resources necessary to evaluate the impairments they cause, fewer resources exist to characterize the changes to stream of small projects on streamflow. In the research that follows, we present a tool for ecologists and water resource managers based on the classic water balance (Thornthwaite and Mather, 1959; Dunne and Leopold, 1978) that can be used to predict the impacts of small decentralized water diversions on catchment discharge. We then demonstrate this tool to evaluate the impacts of small instream diversions on streamflow in the major tributaries to the 3800 km^2 Russian River catchment in the northern California wine country, and extrapolate to predict the potential effects that these projects may have on anadromous salmonids that use these tributaries for a large part of their life cycle.

Study area and methods

Water users have used small-scale water projects to meet water needs in the Russian River basin in northern coastal California for over 100 years (SWRCB, 1997; Deitch, 2006). The regional climate is Mediterranean: virtually all of the annual precipitation occurs as rainfall between November and April, so water users cannot rely on precipitation for agricultural or domestic uses for several months each year. Instead, users frequently divert water directly from streams as needed. The climate also places pressures on aquatic ecosystems: streamflow recedes gradually through spring and summer to approach (and frequently reach) intermittence in the dry season, forcing aquatic ecosystems to persist through the annual drought each summer until precipitation returns the following winter. Impacts of diversion for human water needs may thus be greatest on stream hydrology and aquatic ecosystems during the spring and summer growing season: naturally low flows may be further depressed by diversions for agricultural uses such as frost protection, heat protection, and irrigation.

State and federal agencies have grown concerned about the increasing number of small-scale water projects in far upland watersheds, hillslopes, and hilltops of the Russian River catchment because of the potential impacts to environmental flows necessary for native anadromous salmonids (namely, federally protected coho salmon *Oncorhynchus kisutch* and steelhead trout *Oncorhynchus mykiss*) (SWRCB, 1997). The life cycle of these fishes is well-adjusted to regional streamflow patterns, but alterations to streamflow at particularly sensitive times may disrupt important ecological processes. Adult salmonids migrate into freshwater streams throughout the rainy winter, so winter flows must be high enough to allow salmonid passage and spawning, and keep redds submerged through incubation (which may last as long as 60 days). Juveniles must remain in streams through summer until the rainy season begins again in late fall; many juvenile salmonids remain in freshwater streams for more than one year before migrating back to the ocean (Moyle, 2002). Base flows during spring must keep redds submerged over adequate duration to complete incubation and supply energy to juvenile salmonids via downstream drift; and water levels in summer must be sufficient to maintain adequate habitat and energy supply as streams approach intermittence through summer. Streamflow alterations during this dry season may be a primary consideration to the conservation of salmonid populations in this region: the persistence of appropriate low-flow conditions is frequently a limiting factor for the survival of organisms adapted to seasonal environments (Gasith and Resh, 1999; Marchetti and Moyle, 2001; Lake, 2003).

Model description and rationale

Hydrologists and resource managers frequently use the water balance as a foundation for exploring the effects of human water demand on river discharge (Dunne and Leopold, 1978; Ward and Trimble, 2004). The water balance uses a mass balance design (where output from a system equals input minus the change in storage, or $O = I \pm \Delta S$) to quantify water in various forms within a catchment. Input occurs via precipitation; output may occur as runoff, evaporation, plant transpiration, and/or groundwater flow (depending on its purpose or data availability); and change in storage may include plant water uptake and change in deep or shallow groundwater storage (also variable with data availability and purpose). Water balances can be expressed mathematically as

$$0 = P - Q - ET \pm \Delta G \pm \Delta \theta - U \tag{1}$$

where P is precipitation, Q is stream discharge, ET is evapotranspiration (a combination of plant transpiration and surface evaporation), ΔG is change in groundwater storage, $\Delta \theta$ is change in soil water storage, and U is plant uptake (Ward and Trimble, 2004).

The water balance has found many applications in contemporary applied hydrology. In ecology, it is used most commonly to project the changes in discharge under a managed change in catchment vegetation (often termed "water yield," reviewed by Bosch and Hewlett, 1982; Stednick, 1996; and Brown *et al.*, 2005), where changes in discharge are attributed to altered catchment evaporation and transpiration. Water balances have also been used along with new modeling techniques to predict how land management decisions that alter catchment processes affect discharge (*e.g.*, de Roo *et al*, 2001; Fohrer *et al.*, 2001; Wegehenkel, 2003; Vaze *et al.*, 2004; Ott and Uhlenbrook, 2004). Other recent applications include informing water budgeting and water management on a regional or national scale (*e.g.*, Hatton *et al.*, 1993; Yin and Nicholson, 1998; Habets *et al.*, 1999; Shankar *et al.*, 2004) and projecting impacts of climate change on stream discharge (*e.g.*, Strzepek and Yates, 1997; Middelkoop *et al.*, 2001; Walter *et al.*, 2004).

The classic water balance as commonly applied is not useful for exploring impacts of human water use relative to flow regime because the time scale over which it typically operates is not congruent with streamflow. Water balances employ data at annual or monthly scales, partly because of the scales over which certain trends may be illustrated, and partly because of level of detail over which certain components may be available. Though data at monthly and annual scales are useful for illustrating broad-scale changes in discharge over time for many common management objectives, such time scales are insufficient for characterizing streamflow, which ultimately dictates the timing and duration of ecological processes. Streamflow fluctuates naturally over finer scales such as daily or sub-daily (Poff, 1996; Deitch, 2006); aquatic organisms are exposed to water constantly; and human-caused changes to streamflow may be short-term, as brief as hours (Deitch *et al., submitted*).

To evaluate the potential impacts of small water projects on catchment discharge at ecologically meaningful time scales, we have modified the classic water balance by retaining the mass-balance concept and considering only the interactions between streamflow already in the drainage network and the diversions from that drainage. We define input (*I*) as the sum of surface water contributed to the stream from the upstream drainage network, described by streamflow measured at a defined point in the watershed. Change in storage (ΔS) is defined by diversions from the drainage network upstream of that point. Output (*O*) is defined as the flow from the drainage network that leaves the catchment, reflecting that which is not removed by upstream diversions. Conceptually, our surface water balance can be described as:

$$\text{O (catchment discharge)} = \text{I (sum of upstream flow)} - \Delta\text{S (sum of upstream diversions)} \quad (2)$$

Each component of the water balance describes flow over a per-second time interval, thus expressing the impacts of instream diversions on streamflow at appropriate time scales.

Application

We first used publicly available data to define input and change in storage for seven historically gauged Russian River tributaries in rural Sonoma and Mendocino County, California (A through G, Figure 1): the upper Russian River, Feliz Creek, Pena Creek, Maacama Creek, Franz Creek, Santa Rosa Creek, and Austin Creek (Table 1). Streamflow data provided the temporal resolution necessary for our intended purpose (i.e., volume per second); all streams were unimpaired by large dams or hydroelectric projects at the time of collection and depicted streamflow under low development, thus representing a more natural flow regime than current discharge measurements would express. For six streams gauged in the 1960s, we chose streamflow measured in water year 1966 as input data: 1966 was the year with median annual discharge among four of the six gauges and with median annual precipitation at a central location in the Russian River basin (Healdsburg, California) from 1950 to 2000. The underlying assumption in choosing median-discharge year 1966 as the input is that the 1966 flows depict normal-year streamflow characteristics, so the water balances we depict here illustrate potential changes in flow through an annual cycle in a typical year. For Pena Creek, which operated in the 1980s, we chose streamflow from median annual discharge year 1981 for input.

Change in storage (i.e., maximum allowable water removal) in each study drainage was determined from surface water rights applications, which include the proposed rate of diversion (in volume per second), period of year for diversion (e.g., 1 May to 30 September), and drainage in which the diversion operates. We gathered water rights data for each study stream and summed the approved pumping rates over the period of permitted diversion to calculate a daily maximum rate of diversion for all users in each drainage (unapproved appropriative requests were not included). For the two streams where only the headwaters were gauged (upper Santa Rosa and Upper Russian), only those diversions upstream of the gauge were included. For the other five stream gauges, which were all located near confluences with the Russian River, we used all catchment diversions and adjusted daily streamflow as a ratio of total- to gauged-catchment areas to estimate total catchment flow (e.g., daily streamflow from Maacama Creek was multiplied by [total catchment area / gauged catchment area], or [118 km^2 / 112 km^2] to estimate total catchment mean daily flow).

We depicted surface water balances by plotting input and change in storage for each stream on the same graph. Streamflow hydrographs illustrated input (I) as described above. To graphically depict instantaneous water demand (ΔS), we plotted the daily maximum rate of diversion on each day as derived from water rights records, which we call a *demand hydrograph.* The demand hydrograph expresses the maximum impact that diversions can have on total catchment discharge at any time. Projected output (*O*) can be for each day can be calculated or conceptualized as the difference between I and ΔS.

Water balance expansion to ungauged catchments

For our second analysis, we created surface water balances for all other Russian River tributaries fourth-order and greater to more thoroughly explore the potential impacts of diversions on streamflow in the Russian River drainage network (1 through 13, Figure 1). We used records of all registered diversions in each drainage to calculate the daily maximum rate of diversion (ΔS) from each; the two largest streams, Dry Creek and Mark West Creek, were broken up into sub-catchments (Dry into Mill Creek and Pena Creeks; and Mark West into upper Mark West, Windsor, and Santa Rosa Creeks) and each was evaluated separately. We estimated input (I) by converting flow from each gauged stream in Part 1 to flow-per-area (L / s / km^2); we then ranked each day's flow values to create a high, median, and low-flow estimate for a Russian River tributary in a typical year. These flow estimates represent three stream-type scenarios, capturing the variability in catchment properties and precipitation in the Russian River basin that could be expected in a typical year. Because our initial low-flow estimate did not depict the natural flow regime (illustrating no peak flow events, atypical even among dry-type streams in a normal year), we instead used median-year flow data from Pena Creek, which had lowest per-area annual discharge and dried the earliest among gauged streams, to depict dry-type conditions. We depicted water balances for ungauged streams through similar methods as the seven gauged streams above: demand hydrographs were plotted along with the wet-type, median-type, and dry-type streamflow estimates to illustrate how diversions could impair normal-year streamflow.

Results

Historically gauged streams

Surface water balances were best illustrated graphically on a logarithmic scale because magnitudes of diversion and dry-season flow were orders of magnitude less than flow during winter. All gauged streams show similar flow regime characteristics of high-flow and base flow timing through winter and steady flow recession through spring and summer (Figure 2). Demand from each stream, however, varies considerably from one stream to the next: Maacama Creek and Franz Creek are subject to many surface water diversions, while few diversions have been approved on the upper Russian River and upper Santa Rosa Creek (Table 1). Pena Creek has no formal requests for surface water from its catchment, indicating that its flow is unaffected by approved small-scale water projects.

For those streams with upstream surface water demand, seasonal demand hydrograph trends are similar: demand is lowest in winter, rises during spring and early summer, and recedes in late summer and fall. Peak flows during winter exceed basin demand by over two orders of magnitude in all cases. Also, winter base flows are consistently an order of magnitude greater than winter demand in most drainages (Figure 2; the exceptions being the upper Russian River and Maacama Creek gauges, though only for brief durations in December). In spring, this trend begins to shift. Demand in early April (marking the beginning of the growing season) equals 13% and 26% of normal-year flow in Franz and Maacama Creeks, respectively; by mid-May, demand equals 33% of flow in Franz Creek, 20% of flow in Feliz Creek, and 87% of flow in Maacama Creek (Table 2). By mid-July, surface water demand exceeds flow from the Upper Russian River, Feliz Creek, Franz Creek, and Maacama Creek catchments. Demand is greatest in the Maacama Creek catchment: demand exceeds flow in early June, threatening flow persistence that lasts through September in a normal year. The potential impact of registered diversions is low in Santa Rosa and Austin Creek, comprising less than 10% of flow until late September.

Ungauged streams

Each of the three estimated input conditions for ungauged stream water balances illustrate high peak flows in winter and receding base flows through spring and summer; but they differ in peak flow magnitudes (8000 L / s / km^2 in the wet-type and 2400 L / s / km^2 in the dry-type streams) and base flow magnitudes. They also differ with respect to the point at which they become intermittent in summer: the wet-type streamflow approaches intermittency but retains low flow through summer months, while the normal-type stream becomes intermittent in early August and the dry-type stream in early June (Figure 3).

Similar to gauged streams, the potential impact of demand on streamflow in ungauged streams varies with season. Winter demand among all ungauged streams comprises less than 2% of peak flows throughout winter, even relative to flow in the dry-type stream (Figure 3). In most cases, winter base flow is also unimpaired, though demand from two of the 13 ungauged streams exceeds the dry-type winter base flow in early winter and equals more than 10% of median-type base flow later in winter (Table 3).

The potential impact of demand is more variable among ungauged streams during spring. In early April, demand comprises more than 10% of the dry-type streamflow in seven of the 13 streams, and 10% of the wet-type streamflow among five of those (Table 3). As flow recedes through spring, the potential impact of demand becomes greater. By mid-May, demand equals more than 10% of dry-type spring base flow from 12 of the 13 ungauged catchments, and exceeds dry-type flows in five of those 13. The potential impact of demand in summer is not as variable as on spring and winter discharge. By 15 July, demand exceeds dry-type flow in all of the 13 ungauged streams; and exceeds even the wet-type flow in seven of these (Table 3). Also, similar to the gauged streams, the time during summer when demand exceeds discharge varies among catchments. Demand exceeds median-type discharge in two streams as early as May, while demand exceeds median-type discharge in most streams by the end of June (median-type discharge would typically persist until early August).

Discussion

Potential effects to flow and ecological consequences

The surface water balances for the 20 major Russian River tributaries described above provide important insights for understanding how regional surface water management practices may affect aquatic resources through the year. Because of the interest in conserving and restoring anadromous salmonids in the region, it may be most useful to compare the impacts of small diversions to environmental flows necessary for salmonid persistence. Flushing flows, which prevent vegetation encroachment and maintain channel form and gravel size distribution for salmonid spawning (Wilcock *et al.,* 1996; Kondolf and Wilcock, 1996), are likely unimpaired by small instream diversions in this region because peak flows are much higher than cumulative demand in all streams studied. Additionally, instantaneous demand comprises less than 10% of base flow over most of the winter in all streams, suggesting that processes dependent upon winter base flows such as spawning and upstream passage are unimpaired by approved instream diversions in these streams for most of the winter.

Instream diversions from Russian River tributaries have greater potential to impair ecological processes through spring and summer because the steady flow recession corresponds with increasing demand during the agricultural growing season. Surface water balances predict that flow may be impaired during spring in almost all of the Russian River tributaries studied here; diversions that depress spring base flow may leave parts of riffles desiccated, which may reduce egg viability and downstream energy drift for juvenile salmonids (Spina *et al.,* 2006). Though most of the gauged streams become intermittent by August under natural conditions (Figure 2), surface water balances suggest that this intermittence may occur as early as June in more than half of the streams studied here. Given their historical distribution throughout central coastal California (Leidy *et al.,* 2005), salmonids native to this region can likely withstand some intermittence; but an accelerated intermittence by as much as 6 weeks could reduce downstream energy drift, essential for juvenile salmonid survivorship in this region (Suttle *et al.,* 2004). Additionally, prolonged isolation of pools may disrupt natural biochemical regimes (e.g., dissolved oxygen, nitrogen), potentially threatening juvenile survivorship (Carter, 2005); and observations and empirical evidence suggest that late summer diversions may continue to deplete pools even where surface flow has ceased (Fawcett *et al.*, 2002; Deitch, *2006*). The imbalance between streamflow and demand in nearly all study streams suggests that summer water demand may be a primary limitation to the persistence of anadromous salmonids throughout this region.

Model assumptions and strengths

Like any model, the surface water balance described here makes assumptions that may cause inaccurate depictions of interactions among components of interest (here, streamflow and water demand). Most notably, the cumulative catchment demand (reflected here by the demand hydrograph) may not always depict the actual effect of diversions on catchment discharge. The demand hydrograph expresses the pumping rate of all users in a catchment, but all users likely do not operate their diversions continuously or simultaneously through most of the year. Grape growers may need water only for part of the day and for a few days a week, so the sum of all registered diversions over-predicts the impacts to streamflow for most of the spring and summer. At times, however, conditions may occur when all users in a catchment need water simultaneously for the same purpose. For example, on spring mornings when temperatures are below freezing, water is sprayed aerially to prevent recently emerged grape buds from freezing; and on particularly hot summer days, water is sprayed aerially to prevent changes in crop quality associated with high temperatures. Empirical data collected in Maacama and Franz Creeks indicate that streamflow recedes quickly when water is needed for frost or heat protection at magnitudes approximately equal to the demand hydrographs presented here (Deitch, *2006*).

The physical simplification of watershed processes may also constrain the ability of the surface water balance to depict actual diversion impacts. Our model neglects many of the components commonly incorporated into water balances such as catchment evapotranspiration and loss to subsurface aquifers, both of which are important components of the hydrologic cycle. These components may alter the impact of a diversion on catchment discharge from that depicted in our demand hydrograph, but most catchment processes (e.g., evapotranspiration and loss to groundwater) would already be incorporated into discharge. Input already considers these factors. Perhaps more importantly, the surface water balance evaluates discharge and diversion impacts at a catchment scale, and thus does not address the distribution of diversions in the drainage network. It instead projects catchment output based on inputs from upstream and total change in storage throughout the drainage network. Demand may have a larger effect locally near a point of diversion, or a lesser effect on catchment output depending on the distribution of diversions in the drainage network if streamflow can be supplemented by shallow aquifers.

Despite these drawbacks, the surface water balance incorporates some important strengths. The most important feature of our model is the use of data at a temporal scale sufficient for characterizing flow regime: here, input is depicted as mean daily flow, and change in storage is defined by the basinwide demand for surface water each day through the year. Both express changes in volume over per-second time intervals. Similar conceptual comparisons of discharge and appropriation are used in California to determine whether a stream is categorized as "fully appropriated," but the evaluations are performed at an annual scale as volumes per year (SWRCB, 2004); the surface water balance provides a framework to evaluate whether streams are fully appropriated at a daily scale, which is more important for evaluating impacts relative to ecological processes.

Additionally, simple adaptations to the input parameters can allow managers to create surface water balances under a variety of conditions. We used streamflow data from a median-type year as an input, but flow data from a typically dry-type year could illustrate how demand would impair streamflow under a low-flow scenario. Such analyses may be useful to evaluate impacts of instream diversions when systems are under hydrological stresses typically imposed by a regional climate. Our analyses have also demonstrated that the surface water balance can be created quickly to compare interactions between streamflow and management regimes for many streams, and can provide a framework for rapid visual interpretation of these streams as well.

Conclusions

Because of its ease to create and interpret, the surface water balance tool described here can have many applications in regional water management and restoration prioritization. River restoration tends to emphasize physical channel rehabilitation (Palmer *et al.*, 2005; Wohl *et al.*, 2005), but such actions can be beneficial to biota only if streamflow is sufficient to support the necessary ecological processes (Richter *et al.*, 1998; Arthington *et al.*, 2006; Stromberg *et al.*, 2007). Management and restoration practitioners can use the surface water balance to evaluate the extent to which water management practices may limit streamflow necessary for important ecological processes. Though managers and restoration ecologists frequently emphasize physical channel rehabilitation (Kondolf *et al.*, 2006), the data presented here indicate that water availability in summer months may also play an important role in limiting salmonid persistence throughout the Russian River basin. For many of these tributaries to serve as viable over-summering habitat for juvenile salmonids, changes in water management strategies may be necessary so that small diversions do not impair spring and summer flow regime characteristics.

Just as the surface water balances above illustrate potential problems with small-scale water management, they also can point to possible solutions. In the streams studied here, sufficient flows do not exist to meet human demands during spring and summer, but winter discharge may be sufficient to meet human needs later in the year. The surface water balance illustrates how winter flows in a normal year may be removed from the stream in a way that will not impede the natural flow regime, and thus ameliorate pressures on aquatic organisms that depend on spring and summer flows. Once goals for water management are established, small-scale water projects may operate in strategic ways to maintain the needs of both humans and aquatic biota; but such management will likely require careful planning and may require additional expenses. Without acknowledging the effects of small-scale instream diversions over fine temporal scales, ecologically sustainable water management cannot be achieved.

Acknowledgements

This research was funded through National Science Foundation Biocomplexity Award 0119992, United States Environmental Protection Agency STAR Cumulative Effects Award R829803, and United States Environmental Protection Agency STAR Ecological Thresholds Award 83243901; and through the Beatrix Farrand Fund in the Department of Landscape Architecture and Environmental Planning at the University of California, Berkeley. The authors are especially grateful to Vincent Resh, David Newburn, Colin Brooks, Kathleen Lohse, and Alison Whipple for additional support and helpful feedback through the planning and research process.

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Table 1. Gauged Russian River tributaries used in the surface water balance application: streamflow gauge and watershed properties.

Stream	USGS gauge number	Total area, km^2 (letter, Fig. 1)	Period of record (water years)	Number of diversions	Intermittence date, Figure 2
Pena	11465150	58.8 (F)	1979-1990	0	06 June
Santa Rosa	11465800	32.4 (D)	1960-1970	1	29 September
Austin	11467200	181 (E)	1960-1966	16	(perennial)
Upper Russian	11460940	36.5 (A)	1964-1968	1	13 July
Franz	11463940	62.1 (C)	1964-1968	10	23 July
Feliz	11462700	109 (G)	1959-1966	5	17 July
Maacama	11463900	118 (B)	1961-1980	32	(perennial)

Table 2. Comparison of catchment streamflow and upstream catchment demand among gauged study streams at various times through the water year, representing different seasonal flows: winter base flow (26 January), early spring base flow (01 April), late spring base flow (15 May), and mid-summer base flow (15 July).

Stream	Surface water balance, 26 Jan		Surface water balance, 01 April		Surface water balance, 15 May		Surface water balance, 15 July	
	Flow, L/s	Demand, L/s	Flow, L/s	Demand, L/s	Flow, L/s	Demand, L/s	Flow, L/s	Demand, L/s
Pena	2400	0	1100	0	82	0	0	0
Santa Rosa	260	0.37	190	0.37	6	0.37	6	0.37
Austin	2700	11	2200	11	820	11	100	11
Upper Russian	270	4.0	280	4.0	71	4.0	0	4.0
Franz	400	19	250	31.6	120	40	4	21
Feliz	500	12	690	13.3	140	27	4	27
Maacama	1200	120	790	205	340	290	80	270

Table 3. Ungauged Russian River study tributaries used in the surface water balance application: catchment properties, and catchment demand as a percent of streamflow under the *high* flow regime and *low* flow regime estimates, at periods of winter base flow (26 January), early spring base flow (01 April), late spring base flow (15 May), and mid-summer base flow (15 July; **low flow regime flow estimate is 0 L/s).

Stream	Area, km^2 (Num., fig. 2)	Number diversions	Demand as % of flow, 26 Jan		Demand as % of flow, 01 April		Demand as % of flow, 15 May		Demand as % of flow, 15 July	
			High est.	Low est.	High est.	Low est.	High est.	Low est.	High est.	Low est.
Dooley	40.6 (2)	9	11	64	46	92	200	560	660	**
Ackerman	51.6 (11)	4	12	68	34	69	140	400	710	**
York	30.0 (12)	4	0.0	0.0	28	57	120	350	530	**
McClure	44.8 (1)	6	0.0	0.0	26	53	110	320	500	**
Pieta	98.2 (3)	3	0.0	0.0	14	29	29	83	190	**
Mark West	134 (6)	20	0.0	0.1	6.6	13	35	100	200	**
Windsor	69.4 (5)	4	0.0	0.0	8.9	18	19	54	120	**
Robinson	67.3 (10)	8	0.0	0.0	1.3	2.7	19	54	82	**
Forsythe	125 (13)	18	0.1	0.4	3.4	6.9	17	48	18	**
Green Valley	98.6 (8)	9	0.1	0.3	0.8	1.6	7.5	21	50	**
Mill	60.0 (9)	19	0.1	0.4	0.9	1.9	5.6	16	44	**
Santa Rosa	203 (7)	8	0.0	0.0	0.5	1.0	4.2	12	25	**
Brooks	21.0 (4)	1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	**

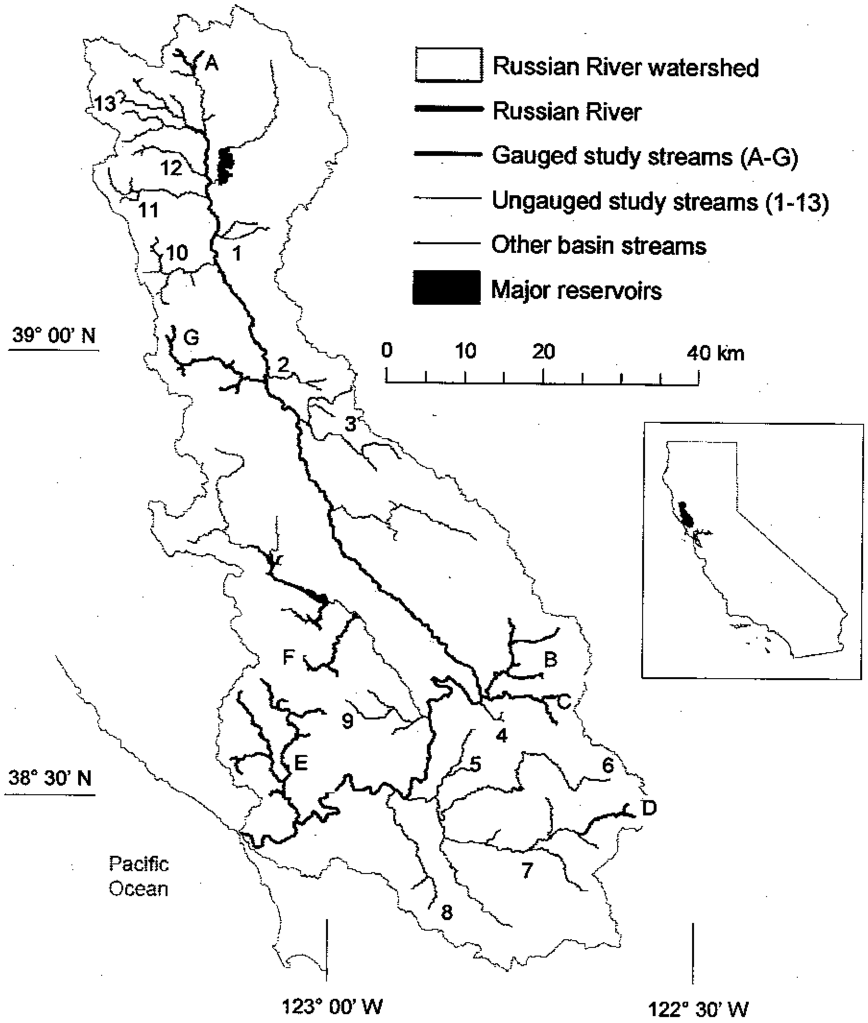

Figure 1. Study streams, tributaries to the Russian River, gauged (A through F) and ungauged (1 through 13). Identifiers correspond to letters and numbers in Tables 1 and 3.

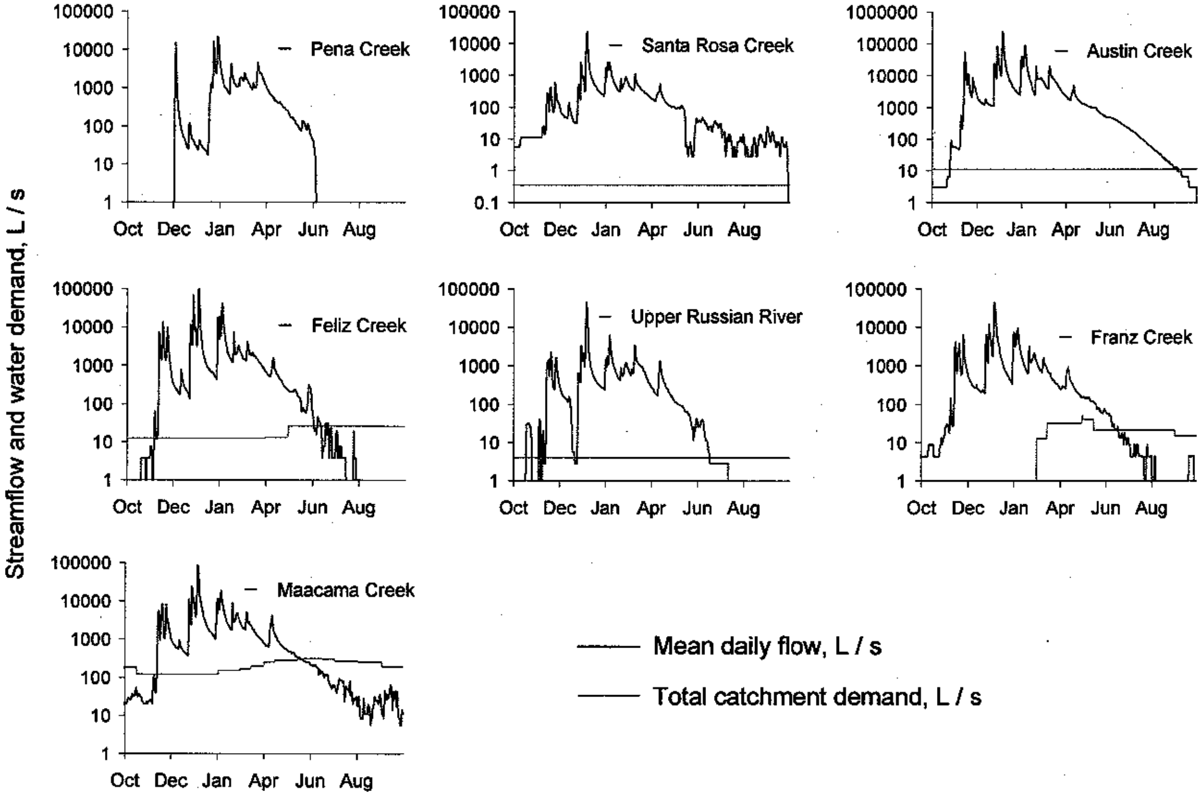

Figure 2. Log-scale plots of surface water balances through a typical water year (based on historical streamflow data) for seven gauged Russian River tributaries, Mendocino and Sonoma Counties, California, USA.

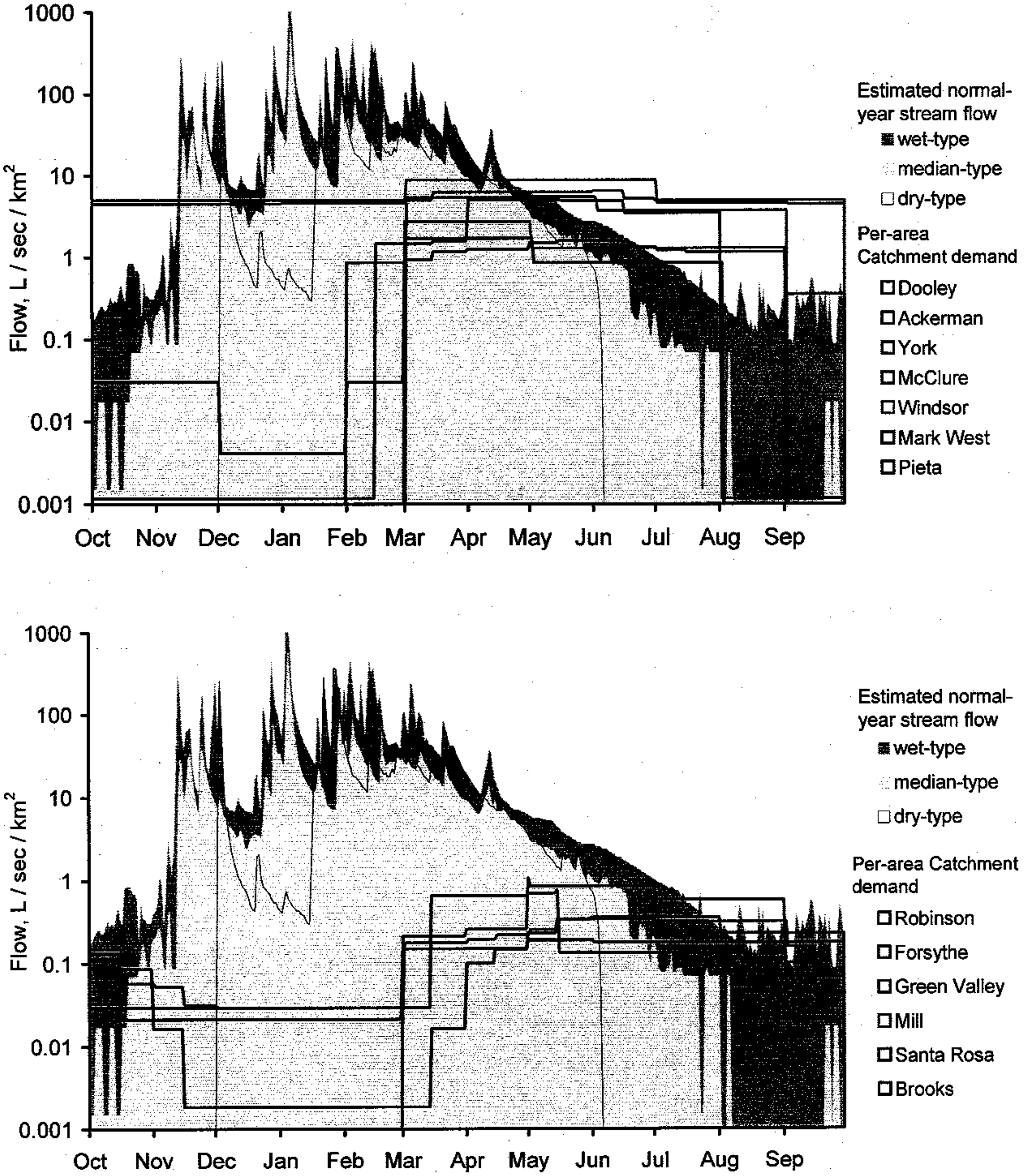

Figure 3. Surface water balances through a water year for the thirteen ungauged Russian River tributaries used in this study: estimates of normal-year flow under a wet-type, middle-type, and dry-type flow regime, and surface water demand from each catchment, both as L/sec/km^2 (plotted on a logarithmic scale). Streams were split between two graphs for visual purposes, grouped as higher and lower demand based on demand during spring and summer (Brooks Creek demand is less than 0.001 L/sec/km^2 throughout the year).

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March 11, 2008

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Re: Comments on *Draft Policy for Maintaining Instream Flows in Northern California Coastal Streams*

Dear Ms. Niiya,

I have reviewed the *Draft Policy for Maintaining Instream Flows in Northern California Coastal Streams* on behalf of the Redwood Chapter of the Sierra Club and provide comments on their behalf below. In addition to commenting specifically on the proposed *Policy*, I provide information on the status of Pacific salmon species in northern California, climatic cycles that affect salmon abundance, and on the interplay of cumulative watershed effects caused by land use management and those caused by diversion. I also provide case studies of several northern California watersheds where water diversion is limiting Pacific salmon, including ones outside the area defined by the *Policy*.

I have read the *Draft Policy* and read peer review comments from Dr. Lawrence Band (2008), Dr. Margaret Lang (2008), Dr. Robert Gearheart (2008), Dr. Charles Burt (2008), and Dr. Thomas McMahon (2008). In addition I read McBain and Trush and Trout Unlimited (MTTU, 2000) and the California Department of Fish and Game and National Marine Fisheries Service (2002) guidelines for central California coastal streams and reviewed Appendices to the *Policy* (Stetson Engineering, 2007a; 2007b; R2 Consulting, 2007a; 2007b; 2007c). Although I find the *Draft Policy for Maintaining Instream Flows in Northern California Coastal Streams* to have substantial technical merit, much more action is needed on regulation of water use to prevent the further decline of Pacific salmon stocks and the likelihood of stock extinctions.

Qualifications

With regard to my qualifications, I have been a consulting fisheries biologist with an office in Arcata, California since 1989 and my specialty is salmon and steelhead restoration. I authored fisheries elements for several large northern California fisheries and watershed restoration plans (Kier Associates, 1991; Pacific Watershed Associates, 1994; Mendocino Resource Conservation District, 1992) and co-authored the northwestern California status review of Pacific salmon species on behalf of the American Fisheries Society (Higgins et al., 1992). Although I am not a hydrologist, I have considerable expertise in the area of water use and its effect on Pacific salmon.

Since 1994 I have been the project manager for a regional fisheries, water quality and watershed information database system, known as the Klamath Resource Information System or KRIS (www.krisweb.com). This custom program was originally devised to track restoration success in the Klamath and Trinity River basins, but has been applied to another dozen watersheds in northwestern California, including a number that fall within the targeted area of the *Policy*.

The California Department of Forestry (CDF) funded KRIS projects in the Mattole, Ten Mile, Noyo, Big and Gualala rivers as part of the North Coast Watershed Assessment Planning effort. The Sonoma County Water Agency (SCWA) also funded regional KRIS projects (IFR, 2003), including ones for the Garcia, Russian and Navarro rivers and tributaries of the Pacific Ocean and San Francisco Bay in Marin and Sonoma Counties. I am submitting a DVD including all KRIS projects for the geographic area covered by the *Policy*.

Since January 2004, I have been working under contract with the Klamath Basin Tribal Water Quality Work Group, a consortium of environmental departments of Lower Klamath River Basin Indian Tribes, to improve enforcement of the Clean Water Act. Through work on review of Total Maximum Daily Load (TMDL) reports, I have become further acquainted with factors limiting Pacific salmon, including those related to flow depletion.

I also have extensive field experience as a field biologist in the South Fork Trinity, Klamath, Eel, Navarro, Mattole and Garcia rivers as well as smaller coastal streams from Humboldt Bay to San Diego County.

Overview

The *Draft Policy for Maintaining Instream Flows in Northern California Coastal Streams* (*Policy*) (SWRCB, In Review) was created in response to California Assembly Bill 2121, which requires the State Water Resources Control Board (SWRCB) Water Rights Division (WRD) to adopt principles and guidelines for maintaining instream flows in coastal streams from the Mattole River to San Francisco and in coastal streams entering northern San Pablo Bay (Figure 1). Much of the *Policy* is derived from a California Department of Fish and Game (CDFG) and National Marine Fisheries Service (NMFS) and central California coast water supply paper (CDFG and NMFS, 2002). The *Policy* proposes to:

1) Restrict new appropriative rights for diversion of surface water to October 1 to March 15,
2) Establish minimum bypass flows,
3) Set cumulative diversion limits, and
4) Discontinue permitting dams on Class I and II streams.

The *Policy* also calls for universal screening of new diversions, construction of fish passage facilities, non-native species control and riparian restoration. Appropriate monitoring parameters are identified in the Policy and the adaptive management strategy is theoretically sound (Band, 2008; McMahon, 2008).

Unfortunately, the Policy will only be narrowly applied to new appropriative water right applications in a restricted geographic area and does not deal with other aspects of long recognized water supply problems. Shortcomings of the approach include:

- No action will be taken to assess summer and fall flows, when the most critical flow shortages for juvenile salmonid rearing are known to occur,
- The *Policy* does not recognize changes in stream channels and watershed hydrology due to land use nor the implications for salmonid suitability or surface water supply,
- The *Policy* only applies to new diversions seeking appropriative water rights, but would have no control over additional riparian water rights that could be exercised at any time,

Figure 1. This map shows the North Coast area defined by the Policy in which the statutes defined therein will be applied and its program implemented. It does not cover the Klamath or Eel River basins that have greater need of water rights reform and greater potential for salmon and steelhead recovery.

- There is no in-depth consideration of ground water extraction despite known linkage to diminished surface flow and carrying for Pacific salmon species regionally,
- The SWRCB WRD refuses to enforce water law and to provide a disincentive for unpermitted water use, creating an epidemic problem of illegal diversions, and
- The *Policy* recommends recognizing Watershed Groups that are comprised of diverters and envisions transfer of many SWRCB WRD responsibilities to local extraction interests.

Although AB 2121 has forced publication of this *Policy*, there seems to be a great deal of reluctance on behalf of the SWRCB WRD to fully engage in this effort as indicated by the tone of the report, a lack of willingness to set limits on diversion and to enforce SWRCB codes 1650, 1052 and 1055. Also the geographic area of the *Policy* does not cover some northern California watersheds with greater need for water rights reform for Pacific salmon species protection, such as the Scott, Shasta and Eel Rivers. Consequently, the *Policy* is not likely to recover coho salmon, Chinook salmon and steelhead in northern California.

Policy Framework

The SWRCB WRD has been working on this *Policy* for more than a decade (R2 Consultants, 2007a) and there is a great deal of merit in the theoretical basis for its minimum base flow and maximum cumulative diversion calculation. Dr. Lawrence Band (2008) summed limitations and benefits of the *Policy*:

> "The documents provided for review contain a set of references to the limited time and budget available for data collection and analysis, and present very limited field sampling at one specific time, with flow records drawn from different periods of time. Given these limitations, the approach adopted in the proposed policy, to provide more conservative restrictions on in-stream water use at the regional level, is a sound strategy."

There are, however, some instances where the *Policy* strays from a sound scientific basis and potential major data gaps that may confound the application of the system. The five elements of the *Policy* framework are listed below with observations of peer reviewers and my own comments.

1. *"Water diversions shall be seasonally limited to periods in which instream flows are naturally high to prevent adverse effects to fish and fish habitat."*

In fact, the only limitation on water diversions would be on new water rights applicants and no study or action is envisioned for extraction from April through October, when flows are severely limiting for juvenile salmonid rearing. Dr. Thomas McMahon (2008) cautions that the entire exercise will be confounded due to this deficiency:

> "Implementation of a diversion season along with the proposed minimum base flow (MBF) and maximum cumulative diversion (MCD) standards to maintain the fall-winter hydrograph could offer a false sense of protection to the listed species if flow levels during other seasons are insufficient to support the completion of rest of the freshwater life cycle."

The Policy gives little or no scientific defense of its choice of October 1 versus December 15 as the start up of the winter water diversion:

> "Although the DFG-NMFS Draft Guidelines recommended a season of diversion from December 15 through March 31, an earlier diversion season start date is still protective of fishery resources when minimum instream flows and natural flow variability are maintained. This policy limits new water diversions in the policy area to a diversion season beginning on October 1 and ending on March 31 of the succeeding year."

Band (2008) points out that "The recommended limits of October 1 to March 31 is a compromise between the two other options (all year diversions and December 15-March 31), but places the beginning of the diversion season at the beginning of flow increases and Chinook migration in most years." Dr. Margaret Lang concurred and recommended the later start date: "The December 15 start date is much more likely to prevent water diversion during the extreme low flows present before the onset of consistent rainfall." She points out that numerous years there is little runoff on the first major storms of the season, as soil pores and the groundwater matrix soak up most early rainfall.

2. *"Water shall be diverted only when stream flows are higher than the minimum instream flows needed for fish spawning and passage."*

Peer reviewers (Lang, 2008; McMahon, 2008) suggest that impacts on rearing salmonids need equal consideration with those on migrating and spawning adults. Steelhead juveniles typically spend two years in freshwater (Barnhart, 1989) and coho salmon spend a full year feeding before migrating to the ocean (Groot and Margolis, 1991). Dr. Lang (2008) notes that factors such as "food availability, food delivery from upstream, and hiding cover, that are also important and not well characterized" by modeling exercises. She points to work by Harvey et al. (2006) showing differences in growth rates of juvenile salmonids between diverted and undiverted stream reaches.

Again there is no mention of limiting diversion from April through October, no limit proposed for riparian diversions that do not require off-stream storage, nor restrictions on ground water extraction to actually maintain and restore flows for salmon and steelhead, even if the *Policy* were enacted (Band, 2008; Gearheart, 2008).

3. *The maximum rate at which water is diverted in a watershed shall not adversely affect the natural flow variability needed for maintaining adequate channel structure and habitat for fish.*

This policy requires calculation of minimum base flow (MBF) and maximum cumulative diversion (MCD), but lack of recent or historic flow data and problems with application of models confound accurate estimates (Lang, 2008). Even if the MBF and MCD were accurately calculated, they do not properly account for interactions between diversions. Synergy between diversions in multiple tributaries will cause unintended consequences on flows, fish passage and alteration of substrate quality in downstream reaches that need to be more fully considered (Band, 2008; Gearheart, 2008).

4. Construction or permitting of new on-stream dams shall be restricted. When allowed, on-stream dams shall be constructed and permitted in a manner that does not adversely affect fish and their habitat.

Although future permit activities may restrict the construction of new dams, there are over 1500 illegal dams already constructed within the geographic area covered by the *Policy* (Stetson Engineers, 2007a) (Figure 3) for which permits are being considered. Avoiding cumulative effects from thousands of impoundments, many of which are on Class I streams that contain salmonids, will not be possible without widespread enforcement action to remove a significant number of these illegal dams.

Several peer reviewers express reservations about damming and diversion of small headwater tributaries (Band, 2008; McMahon, 2008). Band (2008) notes a high risk of cumulative effects despite mitigations proposed for such projects in the *Policy*. According to McMahon (2008) “dams on ephemeral streams have the potential to greatly dampen the early fall/winter freshets important for access to the upper reaches of small spawning tributaries by their capture of the entire flow within the stream until the reservoir is filled, potentially resulting in significant dewatering downstream.”

5. The cumulative effects of water diversions on instream flows needed for the protection of fish and their habitat shall be considered and minimized.

The *Policy* does not properly deal with cumulative effects of diversions (Gearheart, 2008; Band, 2008) nor those associated with long term changes to streams and watershed hydrology due to land use that effect surface and ground water availability (see Cumulative Effects). Gearheart expressed the following concern:

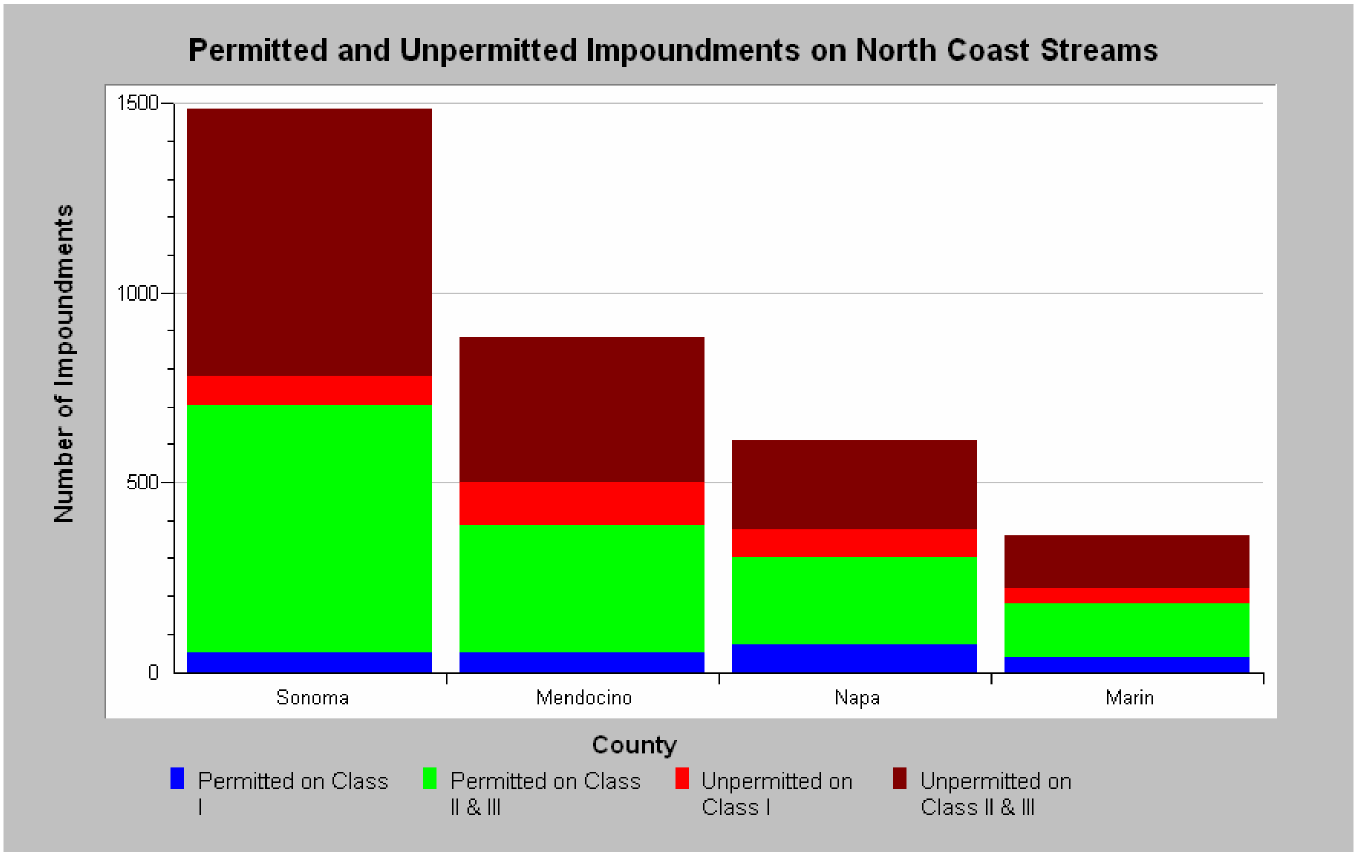


Figure 2. This chart shows the number of permitted and unpermitted impoundments within the geographic area covered by the *Policy*, with illegal diversion impoundments outnumbering legal ones. Data from Stetson Engineers (2007a).

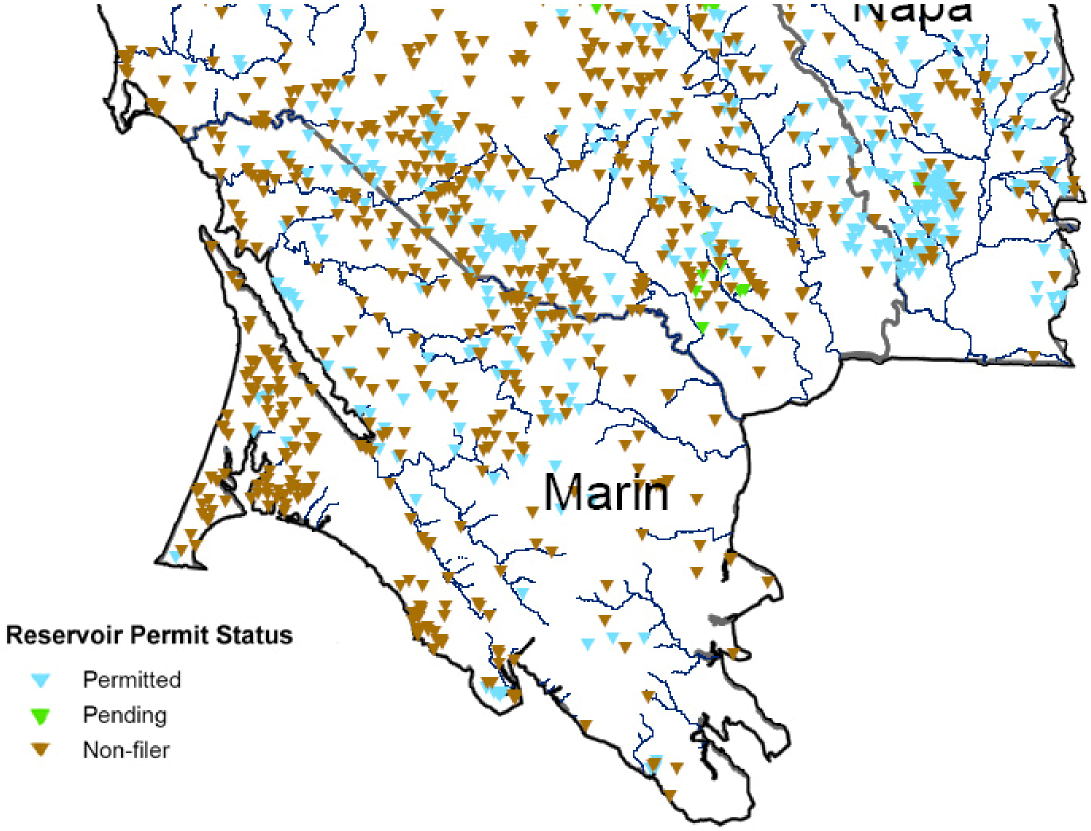


Figure 3. This map shows Marin County and southern Sonoma and Napa County diversion impoundments that are permitted, have permits pending or are unpermitted (Non-filer) as an example of the challenge that an appropriative right water applicant faces in inventorying quantities diverted.

> “It appears to me as one evaluates the cumulative effect of scalping 5% of the peak as the storm hydrograph precedes down stream the reduction in the total flow reduces and the delay time (1/2 day recession -flow restricted) increases.”

Band (2008) suggests that flow depletion below stream convergence points will magnify fluctuations. This in turn will cause depositions of fine sediment and other undesirable channel changes that could affect spawning salmon and steelhead downstream (see Cumulative Effects).

Minimum Base Flow (MBF) and Maximum Cumulative Diversion (MCD): The Policy hinges on relatively accurate estimate of MBF and MCD. Although the scientific basis for calculation of these statistics is theoretically sound, accurate calculation is confounded by lack of historic records and problems with model simulations.

The *Policy* defines the MBF as “the minimum instantaneous flow rate of water that must be moving past the point of diversion (POD) before water may be diverted” and recommends 60% of the mean annual unimpaired flow (0.60 Q_m) as needed for flows and fish passage in watersheds greater than 290 square miles either at the point of diversion, or at the upper limit of anadromy. Lang (2007) states that 68% (0.68 Q_m) is actually needed for protection of fisheries resources and also points out that there may be substantial error in calculation of mean annual unimpaired flow because there is very sparse gauge data, often with periods of record of less than 10 years. Lang (2008) cautions additionally that model generated mean flow estimates may have significant error:

> "Scaling by watershed area and mean annual precipitation works reasonably well for peak and major storm flows dominated by the rainfall generated runoff (assuming the storm influences at nearby gauged sites are consistently similar to the watershed of interest) but at lower flows, more subtle factors such as watershed geology, slopes, ground cover, soil thickness, etc. influence the stream flow. The mean annual flow is as much a function of storm flows as low flows that do not generally correlate as well to drainage area."

The maximum cumulative diversion (MCD) is defined in the policy as "the largest value that the sum of the rates of diversion of all diversions upstream of a specific location in the watershed can be in order to maintain adequate peak stream flows. The maximum cumulative diversion criterion is equal to five percent of the 1.5-year instantaneous peak flow."

Lang (2008) recommended against the use of MCD in the Policy:

> "The analysis by R2 Resources (2007) and Stetson Engineers, Inc (2007) clearly shows that maximum cumulative diversion limits set as volumes failed to meet the stated criteria of providing for channel maintenance flows. Stating the criteria as a volume would not meet objectives of the policy."

Lang (2008) is joined by most other peer reviewers (Band, 2008; Gearheart, 2008; McMahon, 2008) in calling for additional data collection to better establish flow regime targets.

Water Availability Analysis: Before the SWRCB WRD can issue a permit for an appropriative water right, it must demonstrate that there is "unappropriated water available to supply the applicant" (CA Water Code § 1375) and that sufficient water for remains for "recreation and the preservation and enhancement of fish and wildlife resources" (CA Water Code § 1243). A multi-party regional assessment is laid out as part of the *Policy* plan, but it also envisions a great deal of information being contributed by permit applicants and permit holders (see Watershed Groups).

The *Policy* section entitled Data Submissions (4.1.1.1) repeatedly refers to public domain spreadsheets and programs. The issue is not whether data analysis and models are done using public or private software, but whether the raw data are made available and the computer codes for models are made available so that results can be fully audited. Any revision of the *Policy* should have clear language that specifies full raw data availability and model transparency.

Water Supply Reports and Instream Flow Analysis Required of Applicants: The *Policy* provides the following description of study requirements facing new applicants:

> "This policy requires a water right applicant to conduct a water availability analysis that includes (1) a Water Supply Report that quantifies the amount of water remaining instream after senior rights are accounted for, and (2) an Instream Flow Analysis that evaluates the effects of the proposed project, in combination with existing diversions, on instream flows needed for fishery resources protection."

The water supply report is *not* required to describe flow conditions in the stream or determine surplus availability for April through November. Applicants are asked, however, to hire consultants to make a case that there is surplus water available in winter. This will not only be expensive, the consultants may actually be unable to determine the amount of cumulative diversion without an extensive survey because of unregistered riparian rights, pre-1914 water rights and those that have been established illegally (Figure 3). They will also be forced to use models and simulated data that produce considerable error (Lang, 2008) as discussed above.

Effectiveness Monitoring: Most peer reviewers stress that extensive field data need to be collected on an on-going basis to support adaptive management, or the implementation of the *Policy* will be seriously flawed (Lang, 2008; Band, 2008, Gearheart, 2008; McMahon, 2008). The tone of the *Policy* on this topic, however, is very disappointing and shows little commitment on behalf of the WRD with every passage in this section using *may* not will: "The State Water Board *may* develop and implement a policy effectiveness monitoring program."

Enforcement: The SWRCB WRD has clear authority to regulate water extraction and to penalize those who appropriate water without a permit:

> "Pursuant to Water Code section 1052, an unauthorized diversion or use of water is a trespass against the State subject to a maximum civil liability of $500 per each day of unauthorized diversion or use of water. Water Code section 1055, subdivision (a), provides that the Executive Director of the State Water Board may issue an Administrative Civil Liability (ACL) complaint."

The problem is the WRD's near absolute refusal to enforce the law. Stetson Engineering (2007a) lists 1771 unpermitted diversions in the North Coast region as defined by this project (Figure 2). They note the potential need to remove 1569 structures, but also note that 519 unpermitted structures now have pending permit applications. The pattern of non-enforcement is clear in a number of basins (Figure 3) and I have documented similar problems in northern California case studies below both inside and outside the *Policy* area (i.e. Napa, Navarro, Russian, Gualala, Scott, and Shasta).

Instead of active enforcement, the WRD relies on mechanisms like self-enforcement, whereby permit holders self-report violations, and on complaints from citizens. I know several individuals who have filed hundreds of complaints over several decades with the WRD and have had few resolved as a result (Bob Baiocchi; Stan Griffin, personal communication).

The reluctance to enforce the law is evident in the following passage from the Policy:

> "Every violation deserves an appropriate enforcement response. Because resources may be limited, however, the State Water Board will balance the need to complete its non-enforcement tasks with the need to address violations. It must also balance the importance or impact of each potential enforcement action with the cost of that action. Informal enforcement actions, described below, have been the most frequently used enforcement response. *Such informal actions will continue to be part of this policy for low priority violations*."

Some of the criteria for prioritization include any violations:

- On Class I or Class II streams,
- That threatens or causes a take of endangered species,
- That constitute waste, unreasonable use, or unreasonable method of use,
- That illegally takes water in a fully appropriated stream system, or
- That injures a prior right holder.

Despite pages of text on enforcement, there is no specific plan mentioned for decommissioning dams that are high priority. Almost all dams in the region effect at-risk salmonids and 308 illegal impoundments are on Class I streams (Figure 2) (Stetson Engineering, 2007 a).

Informal Enforcement: “The purpose of an informal enforcement action is to quickly bring a violation to the water diverter’s attention and to give the diverter an opportunity to voluntarily correct the violation and return to compliance as soon as possible.” While quickly and voluntarily correcting violations is desirable, as one reads further into the *Policy*, deficiencies become apparent. Informal enforcement may only mean that WRD staff calls or emails the violator and then creates a file as a record of contact.

Penalties: The lack of willingness to enforce extends into the realm of use of fines as a disincentive:

> “The ability to pay administrative civil liability is limited by diverter’s revenues and assets. In some cases, it is in the public interest for the diverter to continue in business and bring operations into compliance. If there is strong evidence that administrative civil liability would result in widespread hardship to the *service population* or undue hardship to the diverter, it may be reduced on the grounds of ability to pay.”

I have added emphasis to the term “service population” above because it shows the inherent bias of the WRD for diverters (their clients) as opposed to protection of public trust. They also express a willingness to skip the enforcement phase, if the diverters just agree to pay for cooperative management:

> “Accordingly, flexibility should be provided to groups of diverters who endeavor to work together to allow for cost sharing, real-time operation of water diversions, and implementation of mitigation measures.”

<u>Watershed Groups</u>: The *Policy* proposes to use watershed groups to fund studies, assess flow availability, and mitigate all problems related to diversions. A watershed group is defined as follows:

> “A watershed group is a group of diverters in a watershed who enter into a formal agreement to effectively manage the water resources of a watershed by maximizing the beneficial use of water while protecting the environment and public trust resources.”

Any watershed group formed by special interests that does not include public participation is unacceptable. Consultants working for water diverters would protect vested interests and the quality of science would not likely be as unbiased or equal to that collected by government scientists who have public trust responsibility.

The *Policy* defines further the role these watershed groups would play:

> “The watershed group shall provide the technical information necessary for the State Water Board to determine water availability, satisfy the requirements of CEQA (if applicable), evaluate the potential impacts of water appropriation on public trust resources, make decisions on whether and how to approve pending water right applications for diverters in the watershed group, and make decisions on whether to approve the watershed group’s proposed watershed management plan.”

In other words, they want to turn their job and that of other State agencies over to local diverters. There are numerous streams in northwestern California that are already so over-subscribed they are dry in summer and fall. Many of the diversions may be unpermitted or constructed illegally and have permit applications pending. This strategy is not going to do anything for public trust and fish and it is likely illegal.

Cumulative Watershed Effects

The California Environmental Policy Act (CEQA) requires that cumulative effects be considered and defines them as "indirect or secondary effects that are reasonably foreseeable and caused by a project, but occur at a different time or place." The *Policy* is subject to CEQA yet fails to meet its requirements in considering cumulative watershed effects. Discussions of this topic are parsed below into 1) discussion of cumulative effects from networks of diversion on downstream reaches, and 2) on how all the watersheds under consideration are cumulatively effected by land use. The emphasis in the latter discussion is on changes in stream channel form and watershed hydrology that effect surface water availability.

Water Use Related Cumulative Effects: Band (2008) described numerous cumulative watershed effects likely from the interaction of diversions, even if all were operating in accordance with MBF. "The cumulative impacts of water diversions from all areas of the drainage network requires consideration of the network as an entity, and not just the sum of all individual reaches." While each diversion might only capture less than 5% of the 1.5 recurrence interval flow at one location, Band (2008) calculated the interaction between diversions in the stream system could increase to 28% downstream. He sees the necessity of increasing model parameters "to analyze the impacts of sequential dependencies of reach conditions as they will not be randomly distributed."

If interactions of multiple diversions are not factored into consideration, Band (2008) predicts "perturbations to the downstream hydraulic geometry, as well as bed sediment grain size, and seasonal variations in bed composition." Of specific concern to Band (2008) is fine sediment delivery from early storms in streams where flow is depleted: "the first few increased flows of the year may flush fine grained sediment, perhaps without mobilizing coarser grain sizes, which may accumulate in reaches where discharge is drawn down." These reaches might be ones used for spawning.

Band (2008) and Gearheart (2008) expressed concern about cumulative effects potential associated with dams on ephemeral streams (Class III). These headwater swales may constitute 50% of a watershed's area and "the vast majority of coarse grained material delivered to larger streams with salmonid habitat are generated from small, headwater catchments" (Band, 2008). Figure 2 above shows permitted and unpermitted impoundments and there are 1357 permitted impoundments in the Policy's area of interest and another 1771 unpermitted ones (Stetson Engineering, 2007a). Therefore, there is significant likelihood of advanced cumulative effects from interactions of releases from diversions.

Stetson Engineering (2007a) estimates that the capacity of illegal impoundments in the North Coast watershed region, as defined by the Policy, is 48,515 acre feet and that 3,234 surface acres of reservoirs now submerge former stream reaches or headwaters. These impoundments in turn are ideal habitat for bull frogs, which decimate native amphibian populations. They are often stocked with warmwater game fish that escape into water bodies below and may predate upon salmonids or displace them through competition (Higgins et al., 1992).

Ground water is not considered in the *Policy*, yet over-extraction is known to contribute to diminished water quality and greatly reduced fish habitat in many streams within the region (see Case Studies). Peer reviewers (Band, 2008; Gearheart, 2008; McMahon, 2008) point out that no real water budget can be calculated without knowing the influence of ground water withdrawals. The Department of Water Resources, a separate State agency, has oversight over ground water withdrawal, but all well logs are treated as proprietary and restriction of ground water use is uncommon.

Potential additional water withdrawal under riparian water rights is another flow-related cumulative effect. Riparian rights are those where water is extracted for use on lands that directly boarder the stream and any owner of a parcel immediately adjacent to a water course has the right to take water for domestic and agricultural use at any time unless specific deed restrictions are stated in the title to the land. Riparian rights do not require a permit from the WRD. Although the WRD requests that riparian water users file a statement of diversion and use, there is no penalty for not complying and few are filed.

Band (2008) mentions tailwater as a major issue needing consideration by the WRD as a potential effect. Agricultural waste water may have elevated temperature and nutrients and its impact is recognized as substantial on the Shasta River (NCRWQCB, 2006a)

<u>Upland Cumulative Effects and Surface Water Supply</u>: Cumulative effects in northern California watersheds related to logging and associated road networks are well studied (Ligon et al., 1999; Dunne et al., 2001; Collison et al., 2003). Although much of the geographic area defined by the *Policy* is now in agricultural production, virtually all the watersheds have been logged at least historically. All of those logged after WW II have extensive road networks that alter watershed hydrology (Jones and Grant, 1996). High road densities act to extend stream networks and intercept ground water flows (Jones and Grant, 1996), resulting in increased peak flows and decreased base flows (Montgomery and Buffington, 1993).

Most of the streams within the *Policy* area are listed for sediment impairment on the SWRCB 303d list and targeted for remediation under the Clean Water Act TMDL program. A huge amount of sediment recognized as polluting north coast rivers is moving downstream in waves. The level of aggradation can be up to 25 feet (i.e. South Fork Trinity) (PWA, 1994) and high sediment yield has caused dozens of regional streams, such as those of the Lower Klamath (Voight and Gale, 1998), to lose surface flow even when there is no diversion (Figure 4).

The *Policy* needs to consider the question of water supply in a stream environment that is profoundly changed by cumulative effects. The increased flood peaks and excess sediment transport in north coast rivers has caused a loss of pool habitat, an increased width to depth ratio, reduced large wood, and overall diminishment of salmon and steelhead habitat. Because the streams have become wider and shallower, they are more subject to warming (Poole and Berman, 2000). (The *Policy* skips the discussion of cumulative effects due to April-October flow depletion on stream temperatures by concerning itself only with the October-March time period.) The North Coast Regional Water Quality Control Board (2006a) found that flow depletion in the Shasta River was contributing to temperature pollution and NRC (2003) found the same relationship on the Scott River (see Case Studies).

Anderson Creek in the Navarro River basin might serve as an example. When an early water right was granted for 2 cubic feet per second (cfs), pools were likely frequent and 6-10 feet deep, and the effect of the withdrawal was likely minimal. The stream has experienced substantial cumulative effects and pools are now infrequent and maximum pool depth is now often 4 feet or less; *the effects on fish of the permitted quantity of water may now be significant*. Add to the equation decreased baseflows due to high road densities, recent logging and development and one can understand why streams are running dry and fish are going without water. All of these are factors that the *Policy* needs to consider in order to meet CEQA requirements and to determine water availability that truly reflects the needs of fish.

Figure 4. Lower Terwer Creek running underground in late fall 1990. High sediment yield related to watershed disturbance has caused a large accretion of sediment. The stream runs underground in late summer and fall yet there is no diversion upstream. Photo from KRIS Klamath-Trinity Version 3.0.

Case Studies

There are a number of watersheds in northwestern California that have flow levels that limit salmonid production and case studies are provided below for areas both inside and outside the geographic area covered by the *Policy*. Many of my reports are provided on the DVD that is being filed with these comments so that WRD can get more detailed information from them.

Napa River: I am intimately familiar with the Napa River watershed from having commented (Higgins, 2006a) on the *Napa River Sediment TMDL* (SFBWQCB, 2006) and on several proposed vineyard conversions (Higgins, 2006b; 2007). The diminishment of flow from historic levels is most clearly seen through examining what would have been coho habitat. USFWS (1968) estimated the historic coho population in the Napa River at 2000-4000 fish. Coho salmon inhabit reaches with a gradient of less than <2% and suitable water temperature, with juveniles spending one year in freshwater. Figure 5 illustrates where coho are likely to have ranged in the middle Napa River watershed. The majority of low gradient mainstem and tributary reaches were found to be dry (Figure 6) or stagnant in 2001 by Stillwater and Dietrich (2002). Figure 7 is taken from Stetson Engineers (2007a) and shows the number of diversions in Carneros Creek, where 43% of flow is diverted.

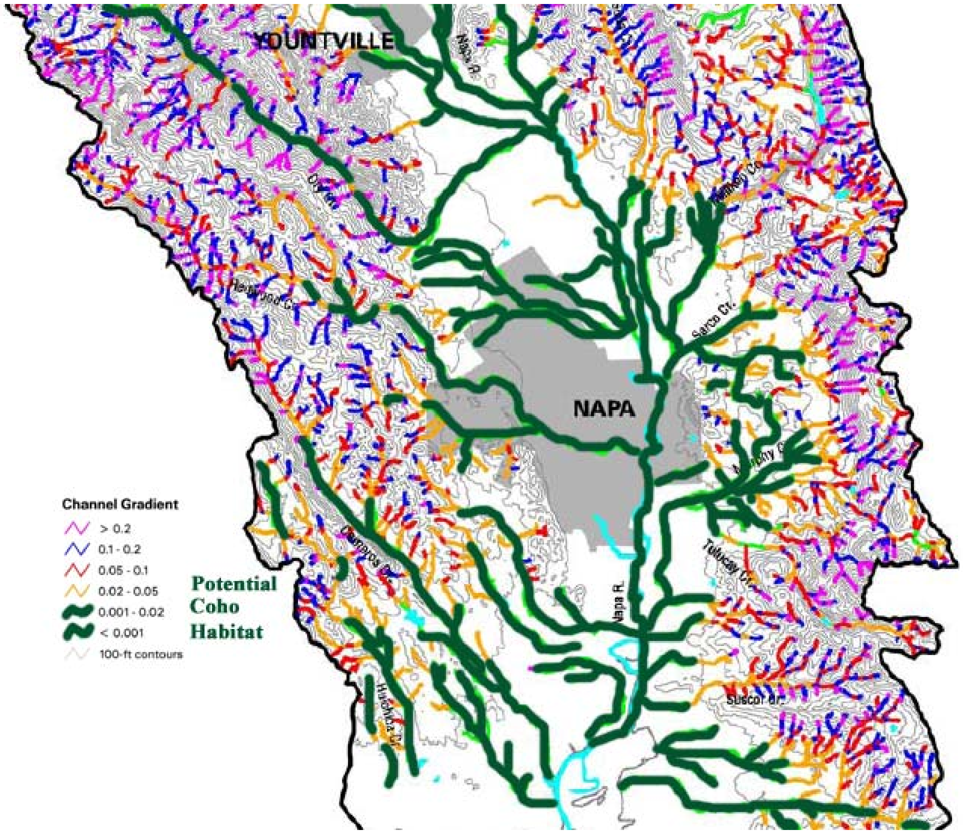


Figure 5. Gradient Map 6 from Stillwater and Dietrich (2002) with an overlay of dark green on all reaches with gradient less than 2% (0.02) to show likely range of coho salmon prior to human disturbance.

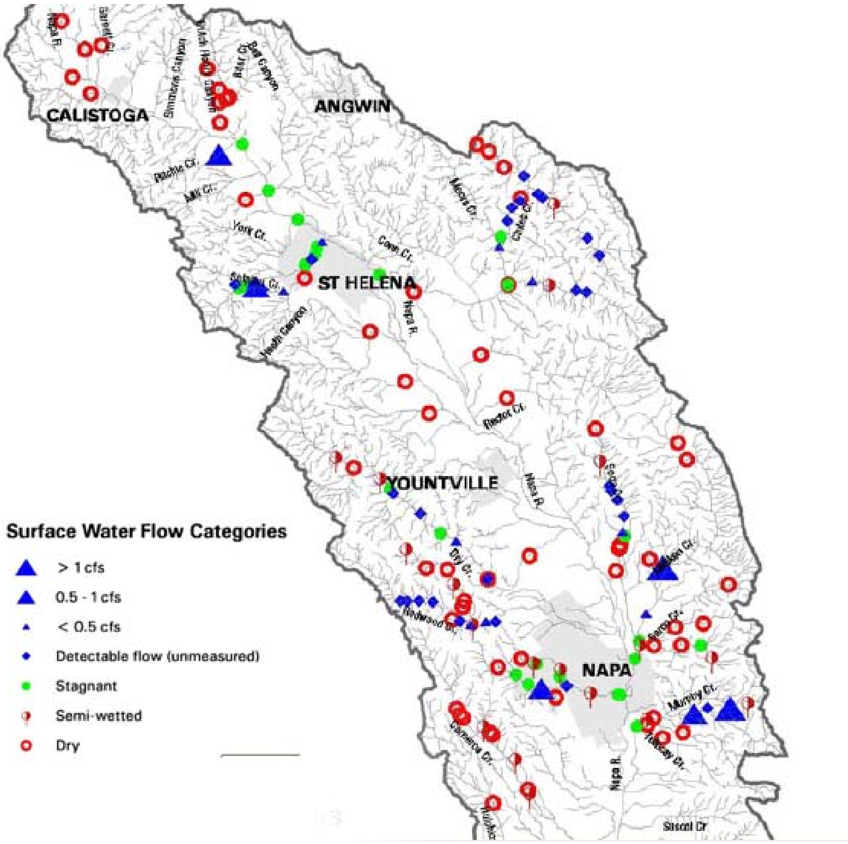


Figure 6. This map image is taken from Stillwater and Dietrich (2002) where it appears as Map 13 and is shown here to illustrate that reaches likely formerly inhabited by coho now lack surface flow.

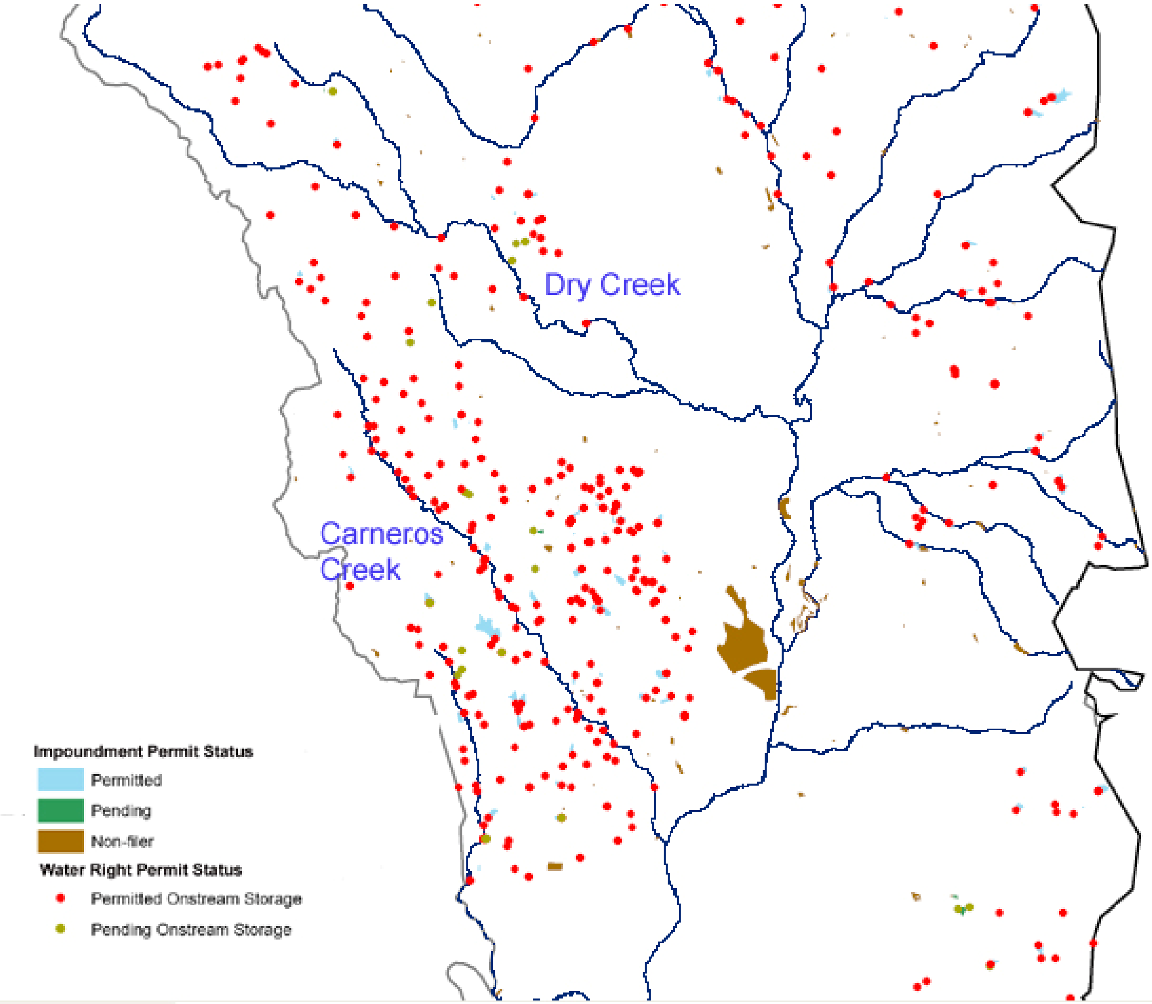


Figure 7. This map shows the lower Napa River basin with Huachuca, Carneros and Dry creeks at left and the locations of impoundments, both permitted and unpermitted. Stetson Engineers (2007a).

While Napa River coho are extinct, steelhead are still present, although there is a homogeneous disturbance in the watershed because of urbanization, timber harvest, vineyard development, dams for municipal water supply and changes in the stream channel. Steelhead are blocked from 30% of the Eastside of the watershed by large municipal water supply dams, the mainstem Napa River is now either dry or unsuitable for steelhead rearing, and Westside tributaries sustain steelhead in isolated pools. Stillwater and Dietrich (2002) noted that steelhead juveniles stranded in isolated pools lost weight during summer due to lack of insect drift delivered by flows. Given the precipitous decline in steelhead habitat, I concluded that their population is likely dropping significantly. Chinook salmon still return to the Napa River, but their population is small and also at risk of loss.

My *Napa River TMDL* comments (Higgins, 2006a) conclude that sediment and flow problems cannot be remedied without limiting watershed disturbance, and that temperature and fish problems cannot be remedied without additional flows:

> “The State Water Resources Control Board Water Rights Division has the authority to install stream gages where ever necessary to insure protection of public trust, water quality and water rights. The TMDL should make explicit reference to reaches effected by low flows and called on the SWRCB WRD to take appropriate monitoring and enforcement actions.”

Navarro River: I am familiar with the Navarro River having worked in the basin as a CDFG seasonal aid in 1972, commented on proposed timber harvests in Rancheria Creek and Indian Creek in 1993-1994, and more recently helped complete the KRIS Navarro project (IFR, 2003). The WRD is intimately familiar with the Navarro River as documented in previous comments on regional flow policy by Friends of the Navarro River Watershed (Hall, 2006) and the Sierra Club (2006).

In 1994 the Sierra Club Legal Defense Fund (Volcker, 1994) filed a water rights complaint with the SWRCB WRD for failing to adequately address instream flow needs under the Public Trust Doctrine in the Navarro River basin. In the complaint, Volker (1994) stated that:

> "Illegal and unreasonable water diversions from the Navarro River and its tributaries, primarily for agricultural purposes, have significantly impaired instream fish and wildlife beneficial uses, to the point where the river was literally pumped dry during August and September of 1992. Such illegal and unreasonable diversions threaten again this fall to eliminate the natural flow of the river and its tributaries necessary to sustain constitutionally and statutorily protected instream fish and wildlife beneficial uses."

Volcker's (1994) assertion that the Navarro loses surface flow was correct at the time and the condition is still chronic in summer (Figure 8). In processing the complaint, the WRD (SWRCB, 1998) found 121 illegal impoundments (Figure 9), none of which were removed and many of which have now applied for permits. The SWRCB (1998) declined to take public trust protection action:

> "The SWRCB could initiate a public trust action in the watershed. However, the cause of the anadromous fish decline may be principally due to factors other than flow, and there is not adequate information available regarding the flow needs of the fishery in the summer. Consequently, the Division recommends that a public trust action should not be initiated at this time. If the complainants, DFG, or some other entity develops adequate information regarding the summer flow needs of the anadromous fishery, this recommendation can be reevaluated."

Illegal diversions of two types for Mendocino County watersheds are shown in Figure 10, which is taken from Stetson Engineers (2007a). The Navarro River appears at left with a combination of regulatory dams, diversions that do not impound water, and illegal impoundments.

Russian River: I am familiar with the Russian River due to work on a KRIS Russian database (IFR, 2003a) and from having provided comments on the Bohemian Grove NTMP (Higgins, 2007b).

As one of the centers of the booming wine industry, the Russian River is one of the most heavily diverted streams in northwestern California as indicated by the prevalence of unpermitted diversions (Figure 10). Major tributaries lose surface flow during summer and early fall (Figure 11) and significant numbers of large pumps have been installed to tap ground water, some immediately adjacent to the river (Figure 12). The Sierra Club (2006) documented problems with over-diversion and widespread illegal water use in Maacama Creek causing severe damage to public trust.

Coho salmon are increasingly rare in the Russian River, but still known to occur in some tributary sub-basins. Figure 13 shows the existing appropriative rights and those proposed for all tributaries known to have harbored coho salmon in the past. Coho were present in Green Valley Creek all three years of CDFG surveys from 2000-2002, but present in Dutch Bill Creek only one year in that period. While there is only one permit on Green Valley Creek, there were 17 applications as of 2001 and Dutch Bill had 7 water rights permitted, but an additional 10 in the application process. Figure 14 shows identified illegal water withdrawal specifically on these streams (Stetson Engineers, 2007a). Legal and illegal diversions pose significant risk to the last streams where coho still persist in the Russian River.

Figure 8. The lower mainstem Navarro River near Flume Gulch is shown at left during low flow conditions on September 21, 2001. The USGS flow gauge indicated that the average flow on this day was 1.1 cubic feet per second. The algae on the margins of the stream indicates stagnation and no fish were present at the time of observation. Photo from KRIS Navarro by Pat Higgins.

Kimsey (1952) sampled this exact location in August 12, 1962 and found steelhead trout of two age classes (young-of-year, 1+) and a flow of 15 cfs during what was an average water year.

U.C. Davis (Johnson et al., 2002) found only seven suckers in many miles of Navarro stream surveys indicating that even this hardy species is disappearing.

Figure 9. This aerial photo of agricultural development in the Navarro River basin shows ten ponds of different types typical of water storage in the Navarro River basin. Vineyard development and aggradation has almost completely eliminated salmonid summer rearing habitat. Photo from KRIS Navarro.

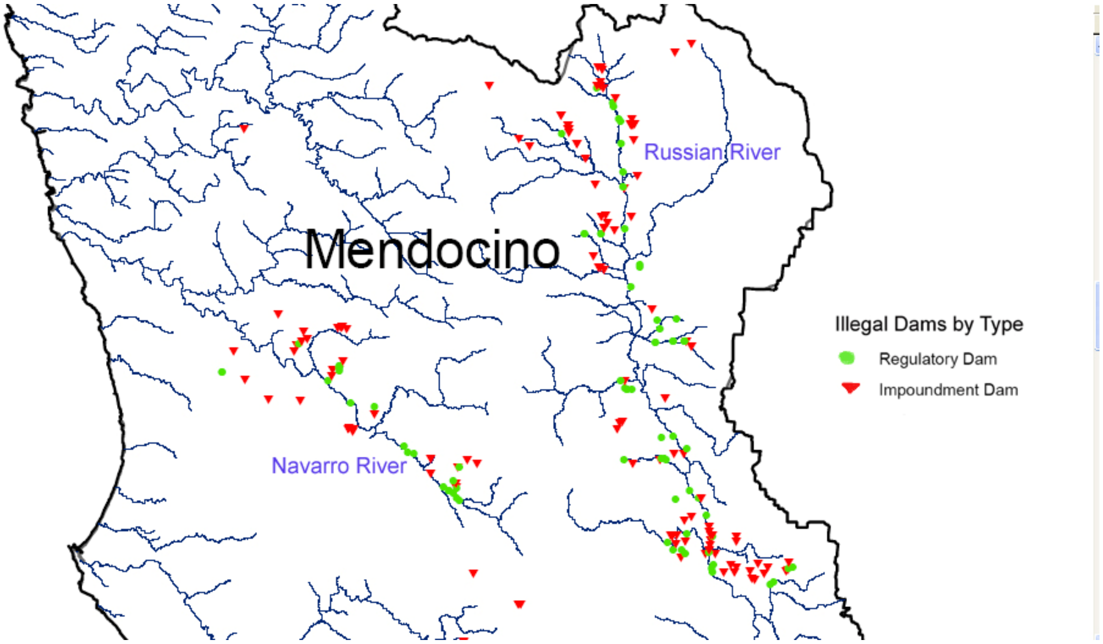


Figure 10. This map shows the locations of unpermitted diversion dams of two types in central Mendocino County with the Navarro at left and upper Russian River at right. Regulatory dams are diversions with no impoundments. From Stetson Engineering (2007a).

Figure 11. This photo was taken looking downstream at the dry bed of the West Fork Russian River off the Eastside Road Bridge. The riparian vegetation lining both banks and extending back on the terrace on the right is a result of a bioengineering project by Evan Engber. Photo by Patrick Higgins from KRIS Russian. July 13, 2003.

Figure 12. This photo shows a large ground water pump in the riparian zone of the Russian River looking west off East Side Road north of Hopland. KRIS Russian. Photo by Patrick Higgins. July 15, 2003.

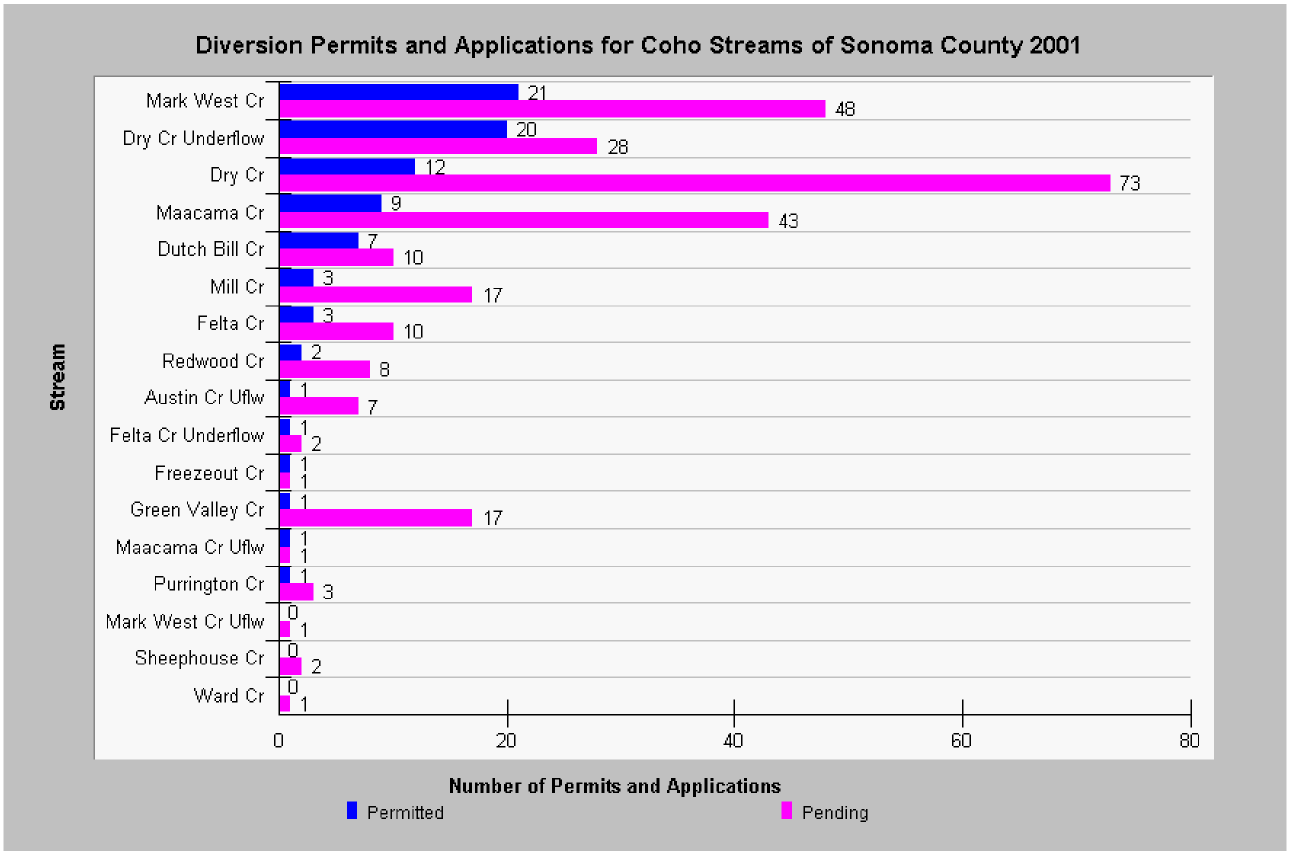


Figure 13. This chart displays the number of approved permits for appropriative water rights and those submitted for approval in Russian River tributaries known to have harbored coho salmon, including Green Valley Creek and Dutch Bill Creek. Data from the SWRCB WRD. March 2001.

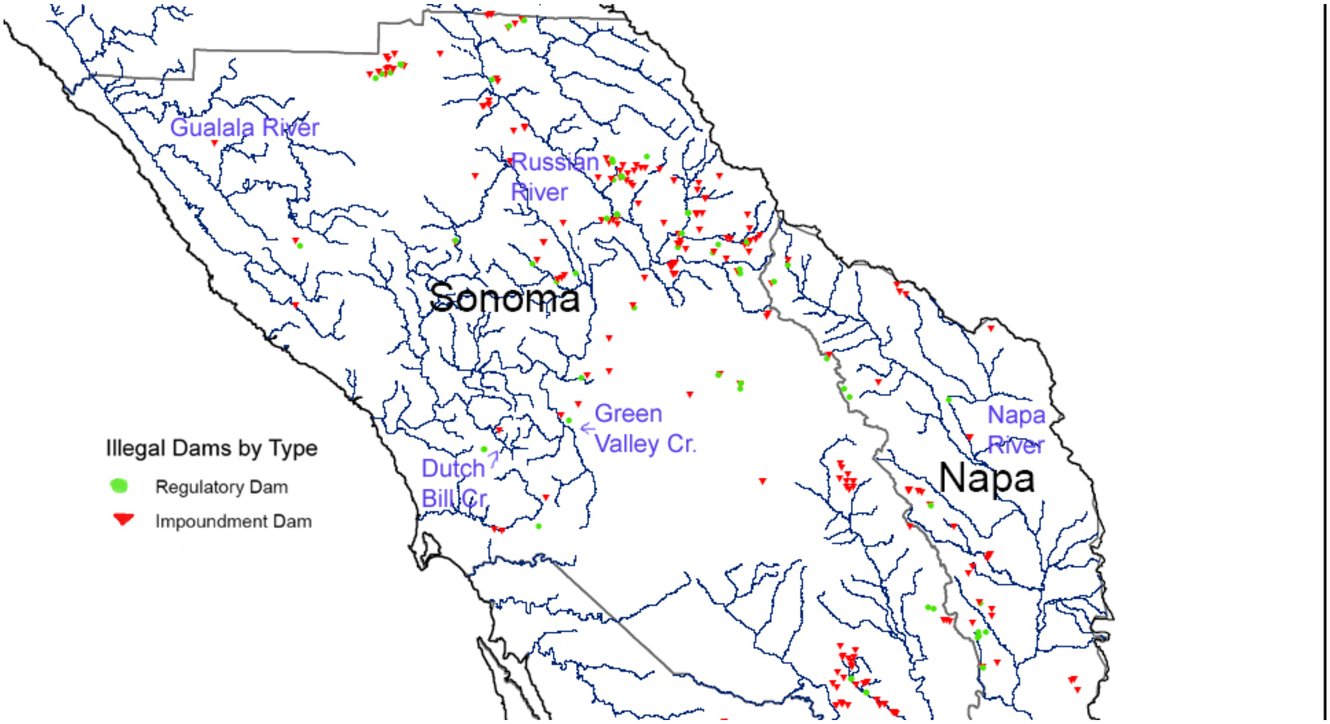


Figure 14. This map shows the locations of unpermitted diversion dams of two types in southern Sonoma and Napa counties, including lower Russian River tributaries Green Valley and Dutch Bill Creeks, which have recently harbored coho. Regulatory dams are diversions with no impoundments. From Stetson Engineering (2007a).

California Department of Fish and Game habitat typing surveys of Green Valley Creek and Dutch Bill Creek show that both streams lose surface flow in some reaches (Figure 15). Pool frequency is also low relative to the CDFG (2004) target of 40% as optimal for salmonids and coho juveniles are known to require pools for freshwater rearing (Reeves et al., 1988). Additional permitted extraction of surface water is likely to both raise water temperatures and decrease depth and cover for juvenile coho salmon. The extent of dry habitats suggests that both streams are fully or possibly over-allocated and that coho habitat is already significantly diminished.

Sonoma Creek: My familiarity with Sonoma Creek is primarily due to my participation in the KRIS East Marin-Sonoma database project. Similar types of evidence are available to those used to demonstrate problems on the Russian River above. Habitat typing data (Figure 16) from upper Sonoma Creek indicates that reaches downstream of the headwaters go dry in summer. The cause of this loss of surface flow might be partially related to aggradation, but is still a sign that surface water availability has been diminished and that fish habitat is currently compromised. Figure 17 shows the dry bed of Carriger Creek, a tributary of Sonoma Creek, with what appears to be a large diversion pipe upstream. While Sonoma Creek itself has some problems with unpermitted diversion (Figure 18), diversion in the Tolay Creek basin indicates major illegal over-appropriation. It is likely that steelhead in Tolay Creek are at a very low level, if they persist at all.

Gualala River: I am familiar with the Gualala River from having worked on the KRIS Gualala database (IFR, 2003), completed a literature search and data assessment (Higgins, 1997), and commented on several proposed vineyard conversions (Higgins, 2003; 2004a, 2004b).

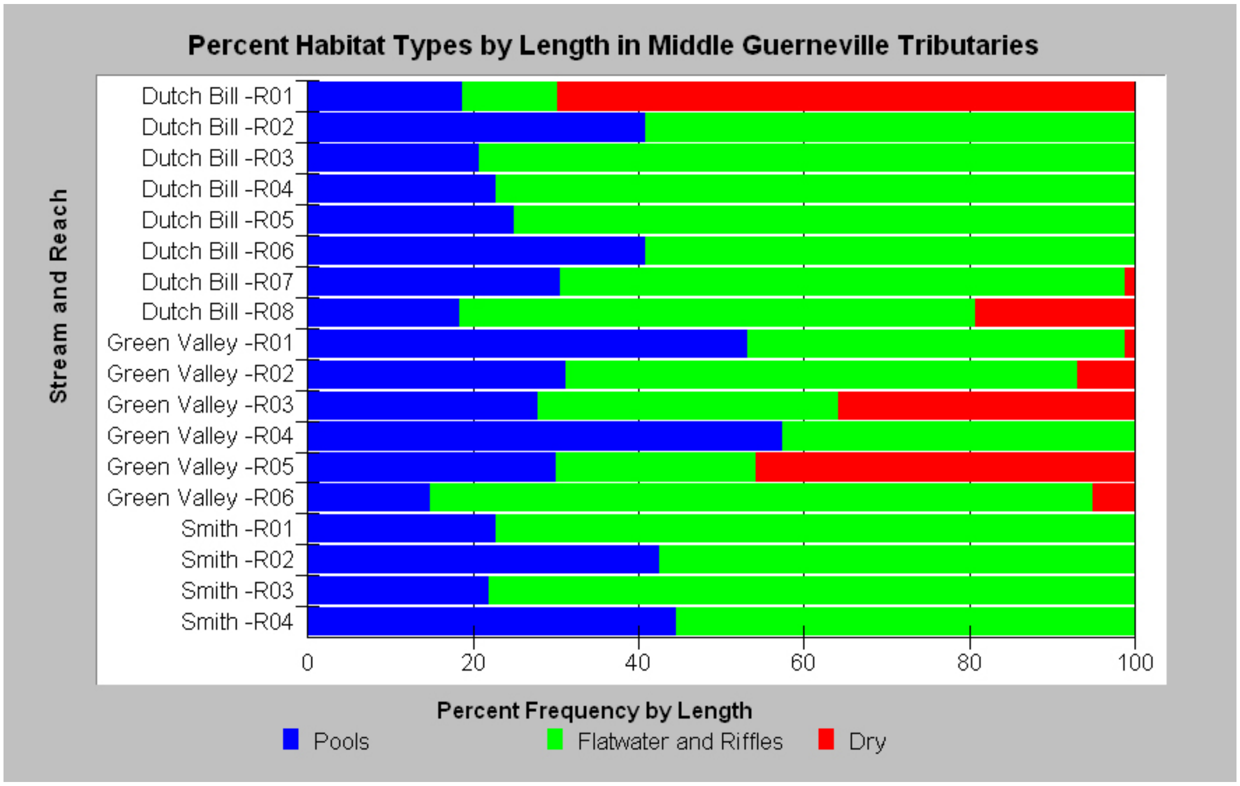


Figure 15. This chart shows CDFG habitat typing data for three lower Russian River tributaries. Notice that Dutch Bill and Green Valley Creek have significant dry reaches. Data from CDFG chart from KRIS Russian.

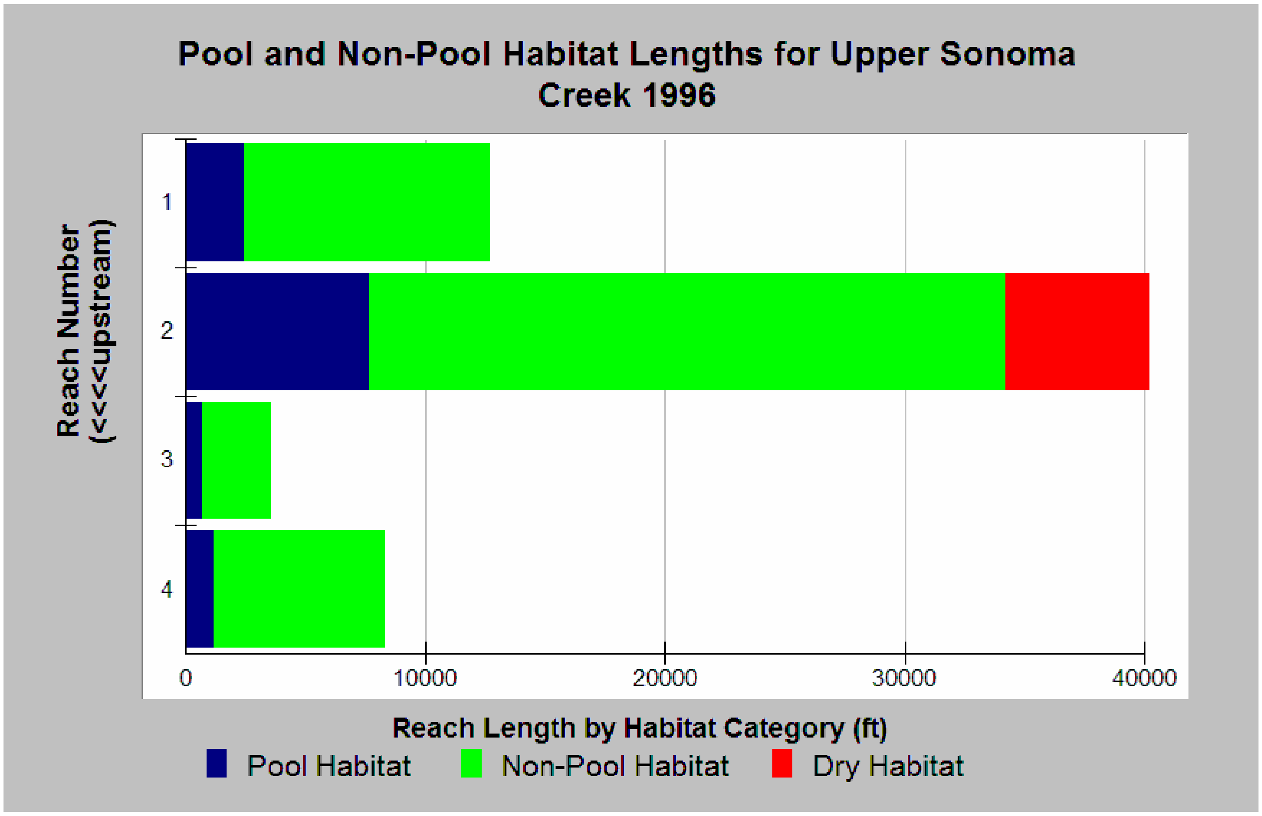


Figure 16. This chart shows Sonoma Creek Ecology Center habitat typing data for upper Sonoma Creek. The pool frequency is lower than optimal for salmonids (CDFG, 2004) and there are significant dry reaches. From KRIS East-Marin Sonoma.

Figure 17. This photo shows Carriger Creek, a tributary of Sonoma Creek, with a dry stream bed and what appears to be a large diversion pipe along cutbank upstream. From KRIS East-Marin Sonoma.

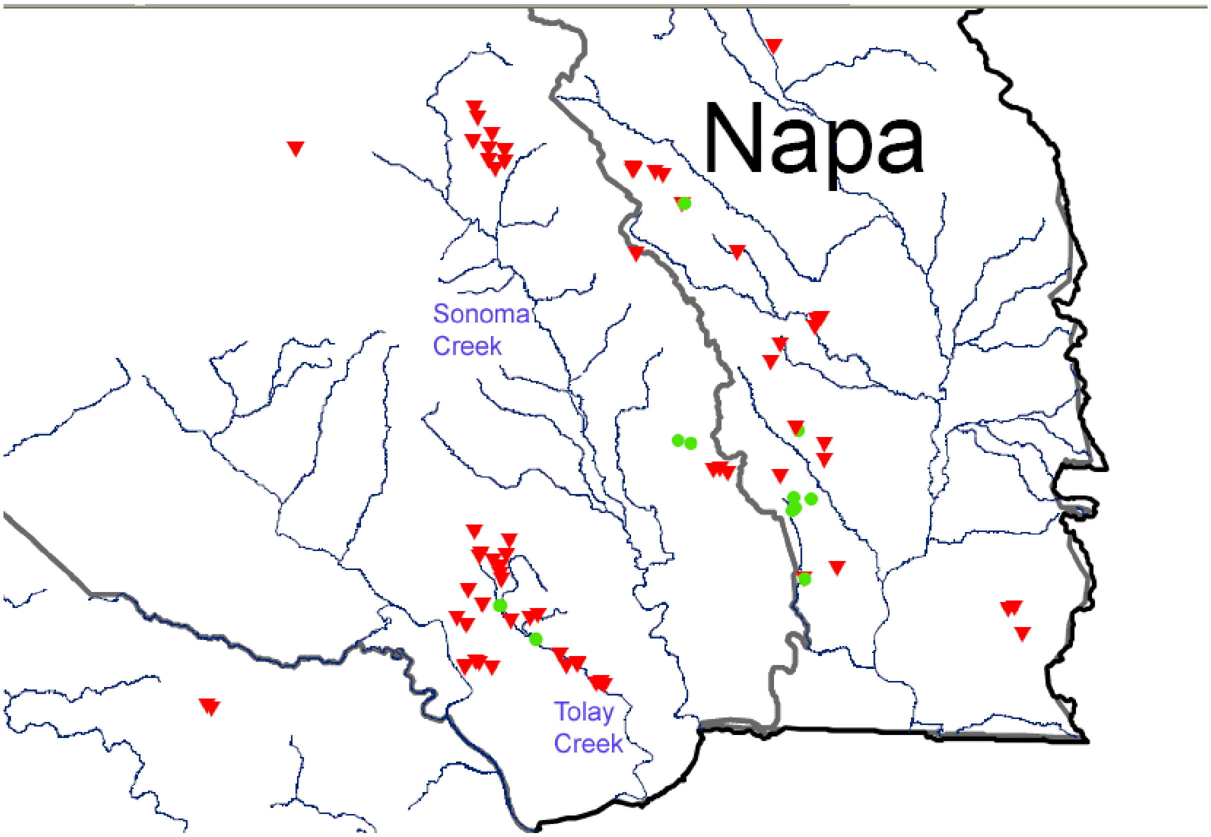


Figure 18. This map shows the locations of unpermitted diversion dams of two types in the Sonoma Creek watershed. Regulatory dams are diversions with no impoundments. While there are about 15 illegal diversions in Sonoma Creek, cumulative effects risk is much greater in Tolay Creek, a much smaller basin, where there are 29 unpermitted diversions. From Stetson Engineering (2007a).

The Gualala River lies within southern Mendocino and northwestern Sonoma counties. It is recognized as impaired with regard to sediment (NCRWQCB, 2004) and has major problems with loss of surface flow and high water temperature (IFR, 2003b). CDFG (2001) characterized coho salmon in the Gualala River as "extirpated or nearly so."

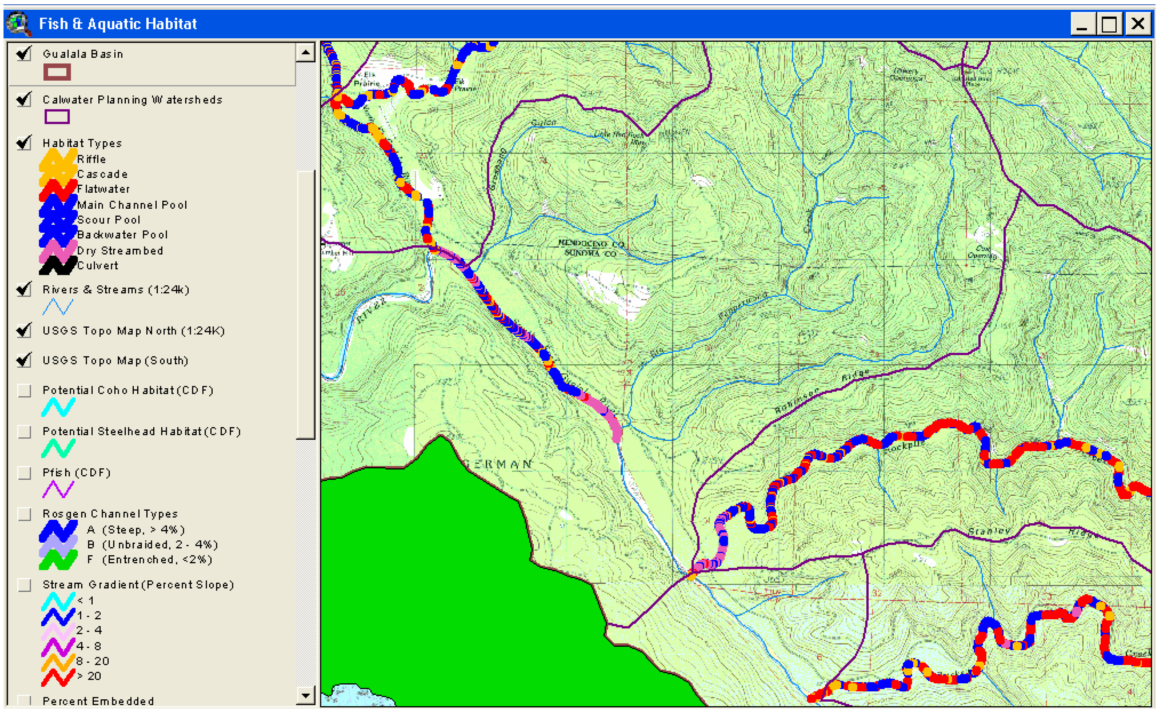
The following passage from KRIS Gualala (IFR, 2003b) characterizes SWRCB WRD prior actions in the North Fork:

> "The California Department of Fish and Game (Hunter, 1996) expressed concern about the diversion of the North Fork Gualala by the North Gualala Water Company, citing reduction in fish habitat if minimum stream flows were not retained. The State Water Resources Control Board (1999) prohibited diversion of surface water when the North Fork dropped below four cubic feet per second (cfs), then in August 2000, ruled that this order applied to two NGWC groundwater wells (SWRCB, 2000). This decision recognizes the importance of North Fork flows to the lower mainstem Gualala as well."

The Gualala River combination of aggradation and increased water use due to vineyard expansion has created an expanding problem with stream reaches in this basin losing surface flow (Figure 19), including the lower mainstem, Wheatfield Fork, South Fork, Buckeye Creek and Rockpile Creek (Higgins, 2003; 2004). Habitat typing surveys by CDFG (2001) as part of the North Coast Watershed Assessment Program found mainstem reaches going dry (Figure 20) in reaches that maintained surface flow during the 1976-77 drought (Boccione and Rowser, 1977). Although rainfall in 1976-77 was only 16.0 inches, total rainfall in 2001 was 24.6 inches, yet flows in 1976-77 were 12.5 cfs and all major tributaries contributed surface flow. This indicates a major decrease in water yield and water supply.

The extensive loss of surface flows in the Gualala River represents a major threat to the continuing survival of steelhead, which are still a major part of the local tourist-based economy.

Figure 19. The Wheatfield Fork, just upstream of its convergence with the South Fork, ran underground in 200. Although the aggradation of the Wheatfield Fork is a factor contributing to lack of surface flows, water diversion for several vineyards also contribute to the problem. Photo by Pat Higgins from KRIS Gualala database.



☑ Gualala Basin
☑ Calwater Planning Watersheds
☑ Habitat Types
  - Riffle
  - Cascade
  - Flatwater
  - Main Channel Pool
  - Scour Pool
  - Backwater Pool
  - Dry Streambed
  - Culvert
☑ Rivers & Streams (1:24k)
☑ USGS Topo Map North (1:24K)
☑ USGS Topo Map (South)
☐ Potential Coho Habitat (CDF)
☐ Potential Steelhead Habitat (CDF)
☐ Pfish (CDF)
☐ Rosgen Channel Types
  - A (Steep, > 4%)
  - B (Unbraided, 2 - 4%)
  - F (Entrenched, <2%)
☐ Stream Gradient (Percent Slope)
  - < 1
  - 1 - 2
  - 2 - 4
  - 4 - 8
  - 8 - 20
  - > 20
☐ Percent Embedded

Figure 20. CDFG habitat typing of the Gualala River in 2001 shows the lower mainstem Gualala River below Big Pepperwood Creek ran underground for an extensive reach. Lower Rockpile Creek also lost surface flows in more than a quarter mile. KRIS Gualala and Higgins (2003).

West Marin Tributaries: Salmon, Americano, Stemple and Walker creeks all have agricultural water extraction that both compromises water quality and limits habitat for steelhead and coho salmon. Figure 21 shows a close up of these West Marin tributaries with all impoundments, 1) permitted, 2) those with applications pending, and 3) illegal diversions with no contact from the operator. The epidemic problem of over diversion and potential for cumulative effects is self-evident.

All these West Marin tributaries have extensive agricultural land use, mostly by dairies. Cattle may deposit fecal material directly into streams or it may enter as a result of overland flow. Grazing takes place up to stream banks leaving no riparian buffer capacity (Figure 22). Lack of canopy also promotes stream warming and flow depletion contributes promotion of both increased water temperatures and nutrient pollution.

Charts from KRIS West-Marin Sonoma (IFR, 2003a) show the degree of water quality impairment due to the cumulative effects of agricultural activity and flow depletion. Salmon Creek is the most northerly of tributaries considered, entering the Pacific Ocean north of Bodega Bay. Figure 23 shows dissolved oxygen (DO) values from several stations sampled by CDFG on Salmon Creek that are indicative of nutrient pollution. Super-saturated DO of greater than 10 mg/l at Highway 1 is linked to very high biological activity of algae blooms that thrive in the stagnant, nutrient-rich waters. Minimum DO levels at the Bodega location approached the recognized lethal limit for salmonids of 3.8 mg/l (WDOE, 2002). While DO is super-saturated during daylight hours due to photosynthesis, DO becomes depressed as algae respire at night or as algae dies off.

Merritt and Smith Consulting (1996) studied Americano Creek for the City of Santa Rosa. Figure 24 shows flow measurements indicating that surface flow near Garicke Road (Station E-6) was not present from April until November 1988 and from May-September 1989. Flow depletion also contributes to major pollution problems similar to those in neighboring creeks. Stemple Creek shows another symptom of nutrient pollution, high pH (Figure 25). A pH value of over 9.5 is directly lethal to rainbow trout and causes ammonium ions to be converted to deadly dissolved ammonia.

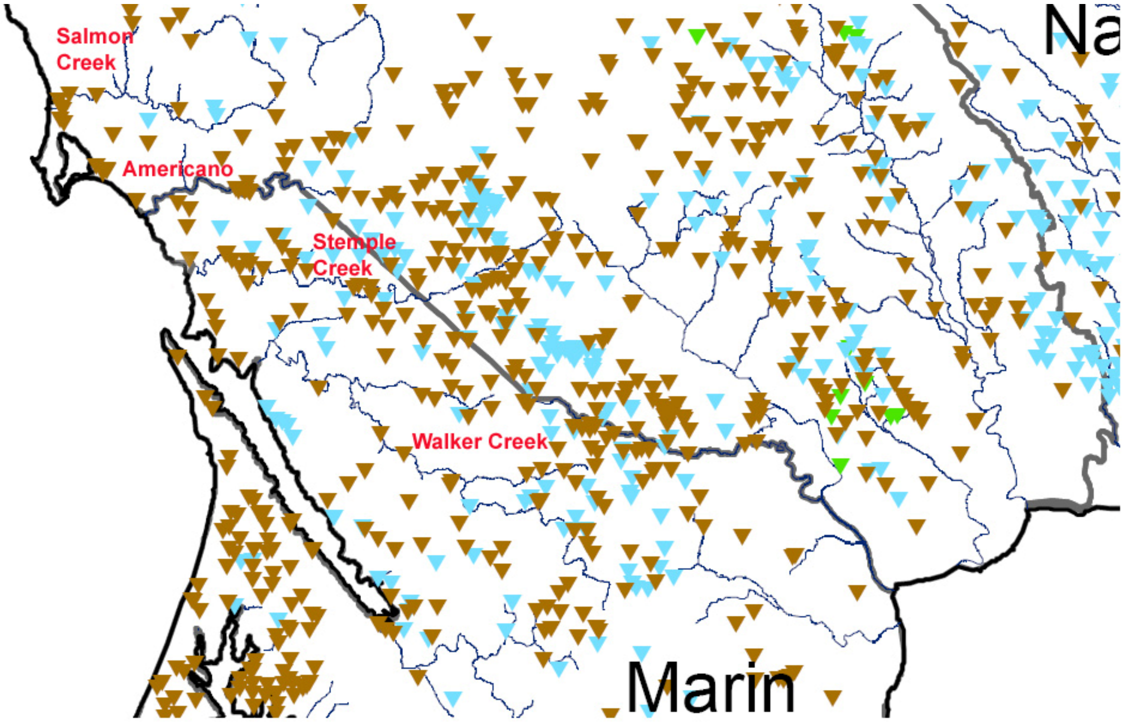


Figure 21. This map shows a zoom of the same type as Figure 2 with a zoom in on West Marin County creek diversion impoundments that are permitted, have permits pending or are unpermitted (Non-filer). There is an obvious huge cumulative effects problem with diversion and water use. From Stetson Engineers (2007a).

Figure 22. The photo at left shows the lower mainstem of Walker Creek with very poor fish habitat as a result of livestock grazing and flow depletion. The shallow, wide stream channel and lack of riparian vegetation makes the stream subject to warming. Photo from KRIS West Marin-Sonoma.

Creel census data from 1949-1974 indicate that hundreds of adult steelhead were harvested in some years and adult coho were present in the catch (Kelley, 1976). Kelley (1976) interviewed long time residents and anglers, who said that the coho salmon run in Walker Creek was much more robust prior to 1950.

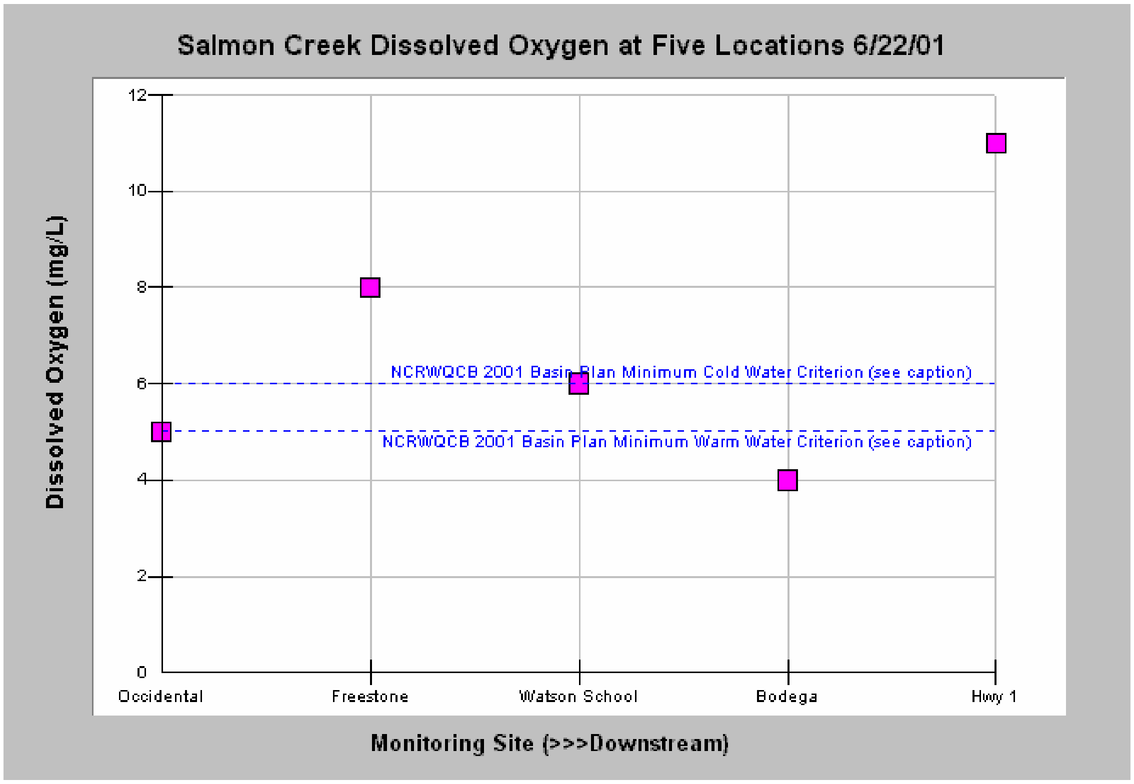


Figure 23. This graph shows dissolved oxygen at five stations (going downstream from left to right) in Salmon Creek. The high dissolved oxygen at Highway 1 is consistent with pH values indicating photosynthetic activity characteristic of nutrient pollution, which also likely contributes to D.O. sags. These data were collected by the North Coast Regional Water Quality Control Board as a part of the Surface Water Ambient Monitoring Program (SWAMP). June 22, 2001. From KRIS West Marin-Sonoma.

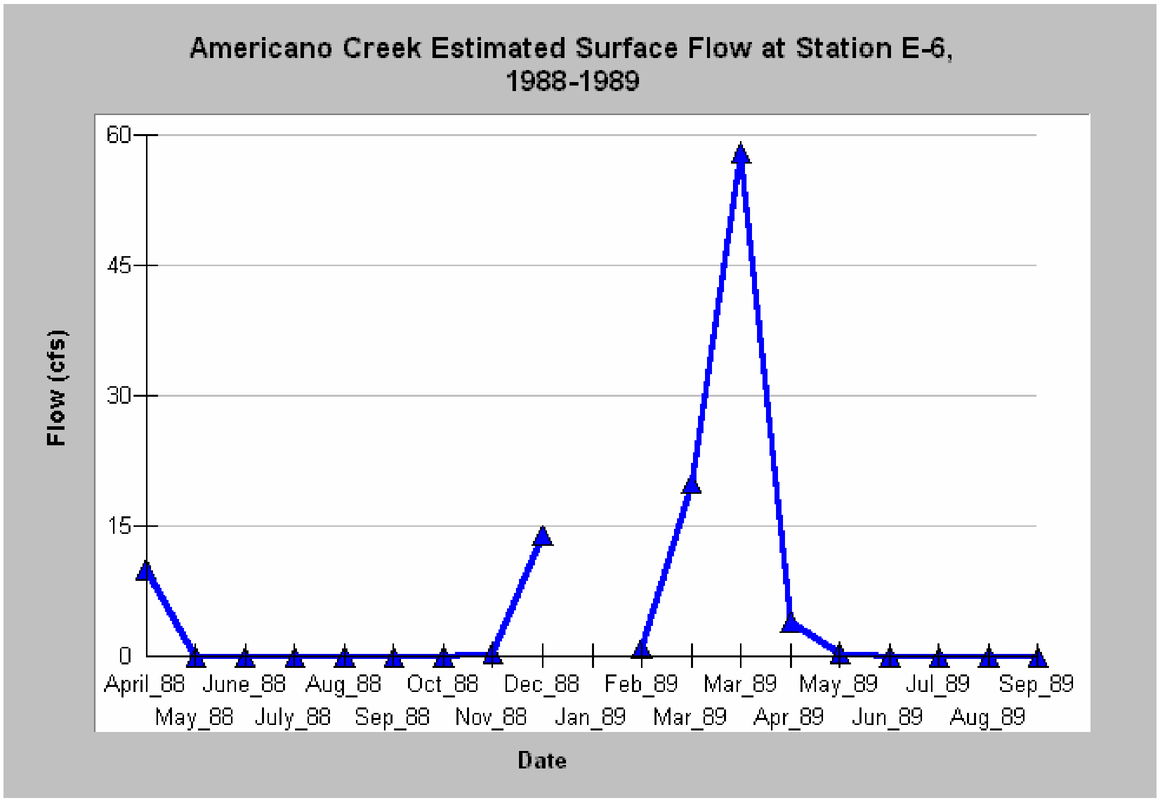


Figure 24. Surface flow was estimated approximately once monthly near Garicke Road (Station E-6) in Americano Creek from 1988-1989. Flow was not present after April in 1988 until November 1988 from May-September 1989. Data from Merritt Smith Consulting for the City of Santa Rosa and U.S. Army Corps of Engineers. KRIS West Marin-Sonoma.

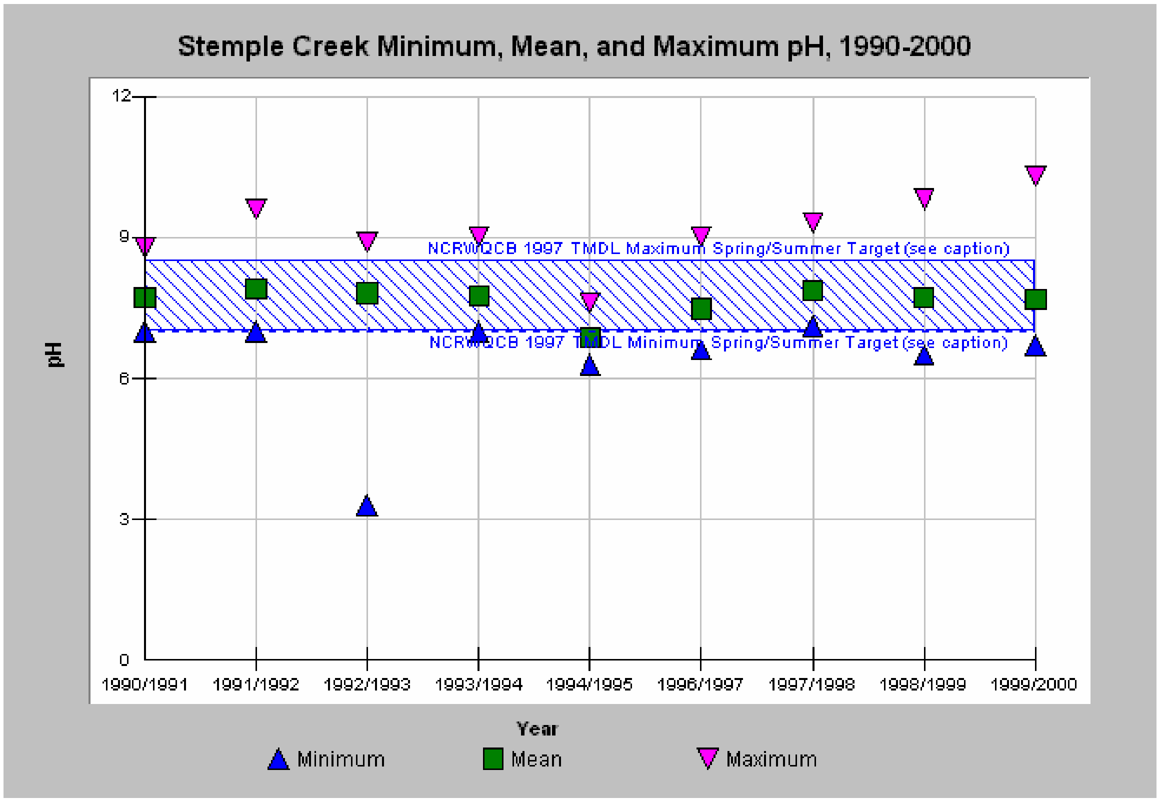


Figure 25. The pH of Stemple Creek exceeded stressful or lethal for salmonids (>9.5) as a result of nutrient enrichment from dairy operations in combination with flow depletion. Data from CDFG and chart from KRIS West Marin-Sonoma.

Walker Creek had coho salmon historically (Figure 26) but flow depletion and nutrient pollution have contributed to their disappearance. Kelly (1976) used electrofishing and netting for the Marin Municipal Water District sponsored studies that found coho, abundant Pacific lamprey juveniles and steelhead juveniles of all age classes in Walker Creek. Flows now annually fall to near 5 cfs or less from July through September (Figure 27). Reduced flow and grazing impacts have resulted in water quality problems similar to previously discussed tributaries related to nutrient pollution.

Scott River: Although the Scott River is not within the *Policy* area, it has very well recognized water quality and fisheries problems related to surface and ground water extraction (NRC, 2003). I am intimately familiar with this basin from helping with restoration planning (Kier Associates, 1991), restoration evaluation (Kier Associates, 1999), building three versions of KRIS databases, and four years of work on Scott River issues for the Klamath Basin Tribal Water Quality Work Group. Several papers on the Scott, Shasta and Klamath TMDLs are posted on their website and WRD can easily access documents on the Internet at www.klamathwaterquality.com.

I draw below from previous comments on the Scott TMDL (Higgins, 2006c) that are on the DVD with regional KRIS projects filed with these comments. The principal findings were as follows:

1. Flows have been decreased by ground water extraction,
2. Flows have declined to far below those required by the Scott River adjudication and often cause stream reaches and tributaries to go dry,
3. Low flow exacerbates water temperature problems, and
4. Flow and temperature problems combine with sediment to severely limit productivity of salmon and steelhead populations.

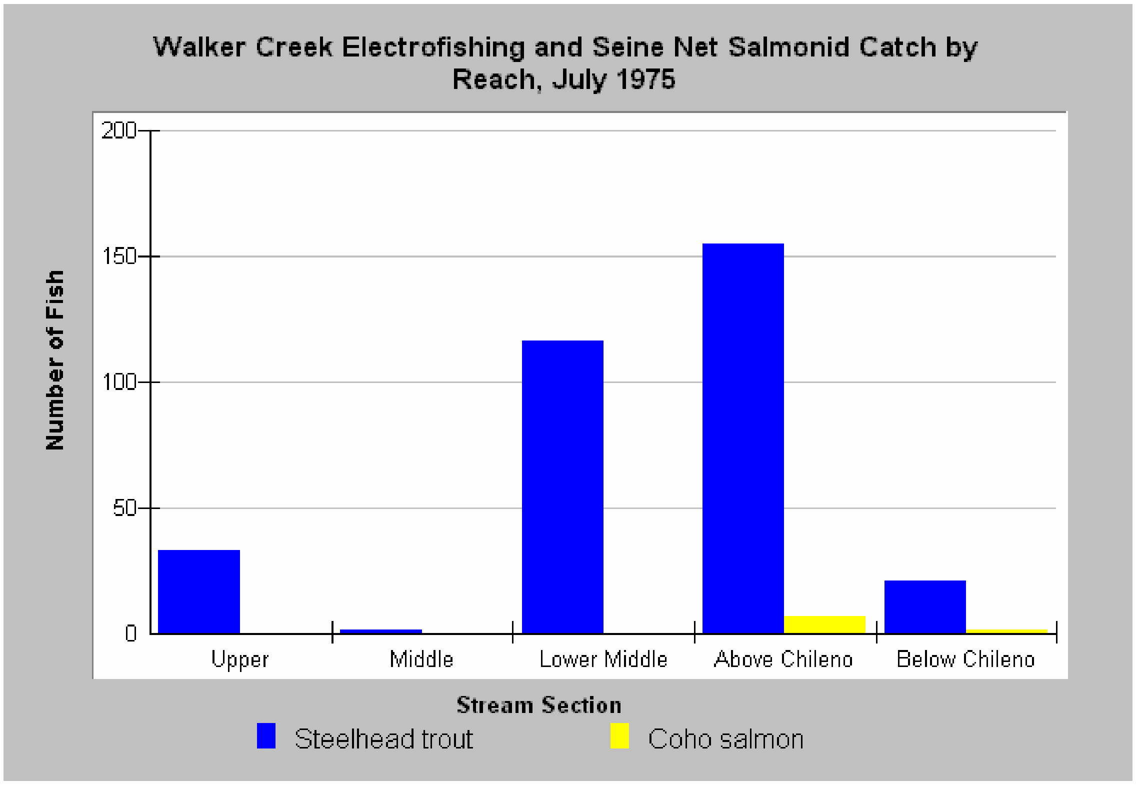


Figure 26. Fish sampling in Walker Creek in 1975 found coho salmon and numerous steelhead. Kelly (1976).

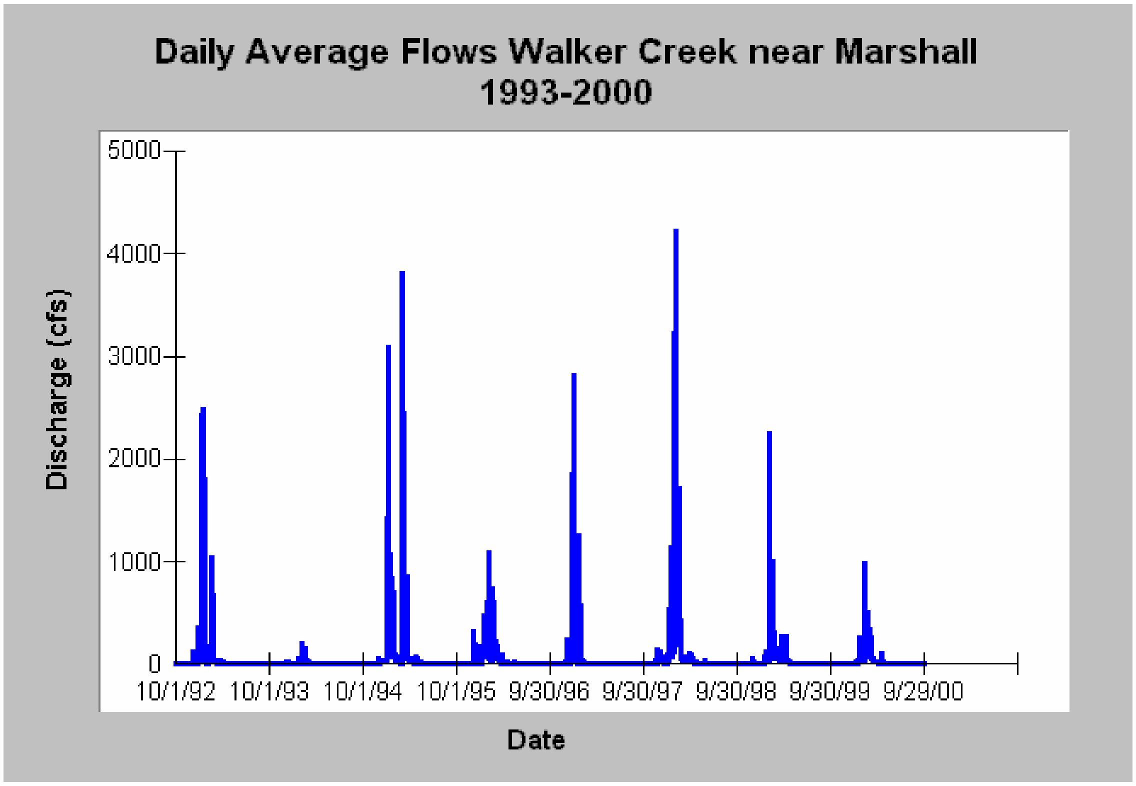


Figure 27. Flows in Walker Creek, tributary of Tomales Bay, dropped to 5 cfs or less on average annually according to USGS flow gauge records. Chart from KRIS West Marin-Sonoma.

The Scott River channel and many of its major tributaries are dried up annually, in violation of CDFG code 5937 (Figure 27 & 28), severely limiting rearing habitat for salmonids. Although the Scott River is adjudicated (SWRCB, 1980), flow levels fall below those required for months of the year (Figure 29). This causes major reductions in habitat quality in the lower Scott River, which formerly served as a summer refugia for juvenile salmonids.

The *Long Range Plan for the Klamath River Basin Conservation Area Fishery Restoration Program* (Kier Assoc., 1991) noted that ground water pumping in the Scott River valley depleted surface flows because of interconnections between surface and ground water. The Scott River has experienced major declines in surface flows coincident with installation of ground water pumps beginning in the 1970's. Pumps continue to be installed through NRCS and EQIP funding (Figure 30) and drops in ground water levels are becoming evident (Figure 31). The chart suggests that while annual maximum levels have remained relatively constant over time, annual minimum levels have declined since 1965, although they fluctuate with precipitation.

The National Research Council (2003) makes a clear case that flow depletion is at the root of temperature problems in the Scott River. As flows drop, transit time for water increases allowing an opportunity for stream warming. A thermal infrared radar (TIR) image of Shackleford Creek (Figure 32) was taken by Watershed Associates (2003) as part of the Scott River TMDL and shows dramatic effects of flow depletion on water temperature. Shackleford Creek is cool enough for juvenile salmonid rearing above points of diversion, then warms rapidly as its flow is depleted. Flow resumes below the major tributary Mill Creek, warms again as flow is reduced by irrigation until surface flows are lost, just upstream of the convergence with the Scott River.

Fall chinook salmon from the Scott River are an important component of the Klamath River run that supports ocean, sport and Native American fishing. Scott River fall chinook returns plummeted in 2004 and 2005 to the lowest level on record for two years in a row (Figure 33). Even after prolonged drought from 1986-1992 Scott River fall chinook returns ranged from 3000-5000 adults annually.

A major potential problem for chinook salmon is that they are stranded in the lowest reaches of the Scott River due to continuing stock water activities and other illegal diversions after October 1 (Figure 32). The fish are forced to spawn in lower reaches of the Scott River (Figure 34) where decomposed granitic sand levels are very high, which threatens egg survival as sand is transported during winter storms.

The SWRCB WRD needs to make the Scott River a priority for enforcement. Fall chinook are collapsing and coho salmon only have one strong year class of three, indicating a high risk of extinction. Immediate action is appropriate given the change in weather and flow patterns expected with a change of the Pacific Decadal Oscillation (PDO) expected sometime from 2015 to 2025 (Collision et al., 2003) and with longer term drought cycles expected with global warming (see Climate Cycles and Change).

<u>Shasta River</u>: My experience on the Shasta River parallels that described for the Scott River and my TMDL comments (Higgins, 2006d) also serve as the source for information below. The Shasta River Adjudication (CDPW, 1932) does not require a minimum flow level similar to the Scott River Adjudication (CSWRCB, 1980) and average daily flows can fall to near 20 cfs (Figure 35), which has major consequences for elevated stream temperatures (NRC, 2003). Lack of coordination of irrigation operations may sometimes cause flows to fall below the listed average and present an even greater challenge for fish survival. Dwinnell Reservoir (Figure 36) blocks the headwaters of the Shasta River and is a major source of pollution itself (NCRWQCB/UCD, 2005). Major tributaries like Parks Creek (Figure 37) and the Little Shasta River lose surface flows for several months a year.

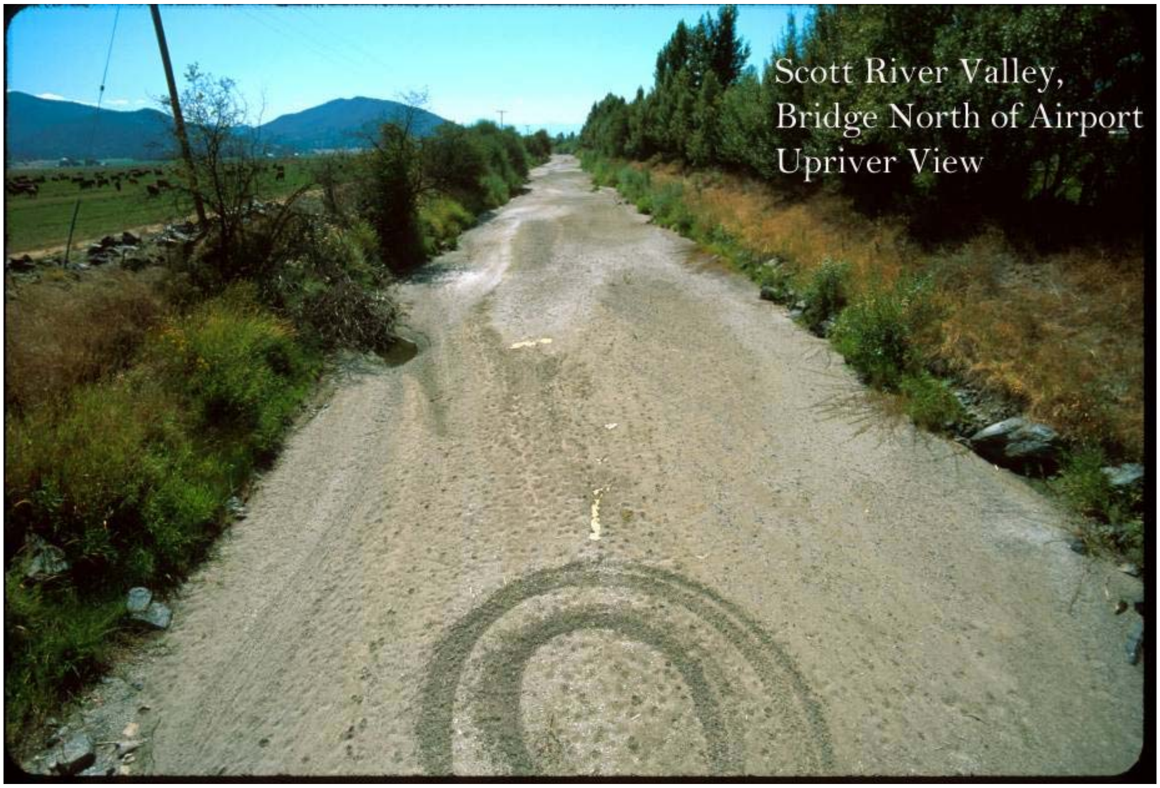


Figure 27. This photo shows the dry bed of the Scott River in a reach near the airport looking upstream. Photo from KRIS Klamath-Trinity V 3.0 taken by Michael Hentz. 2002.

Figure 28. Shackleford Creek is shown here running dry at its convergence with Scott River in August 1997. The creek has coho and chinook salmon and steelhead trout, but diversions dry it up annually during summer and fall. Photo by Pat Higgins from KRIS V 3.0.

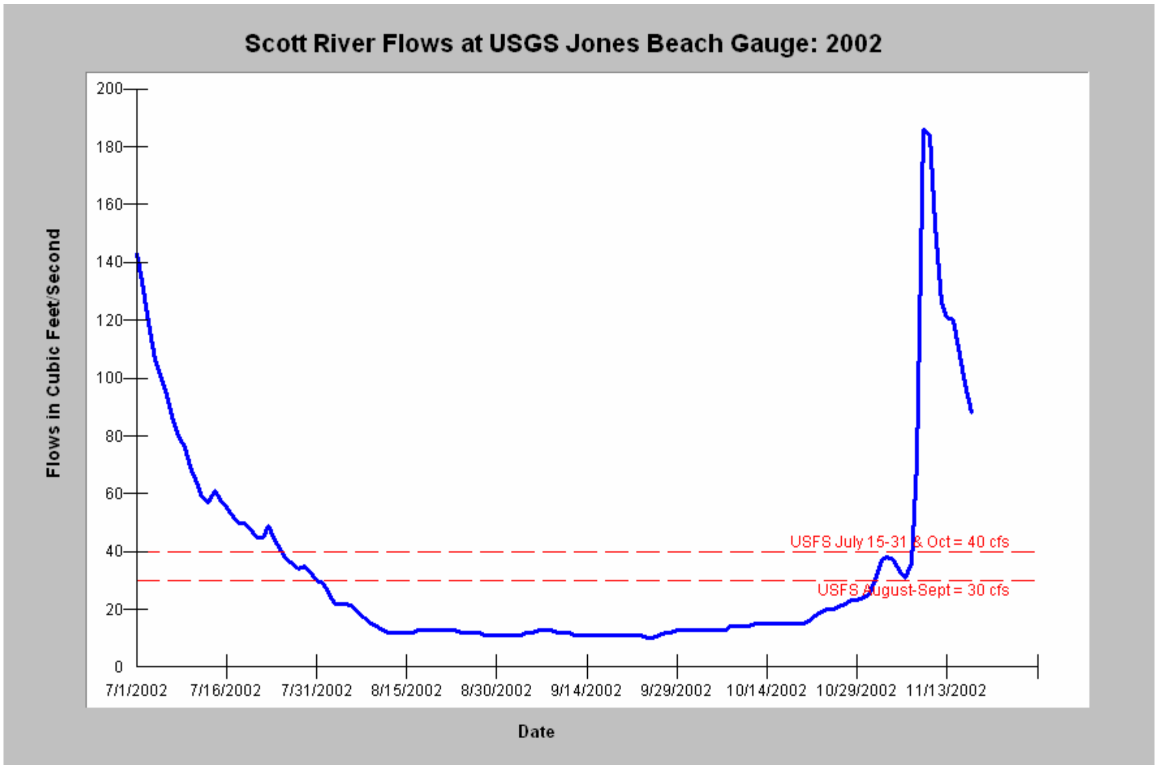


Figure 29. Jones Beach USGS flow gauge data from the irrigation season of 2002 show that flows failed to meet adjudicated levels for the USFS and flows needed for fish migration, spawning and rearing in August, September and October. Reference lines are those from the SWRCB (1980) adjudication.

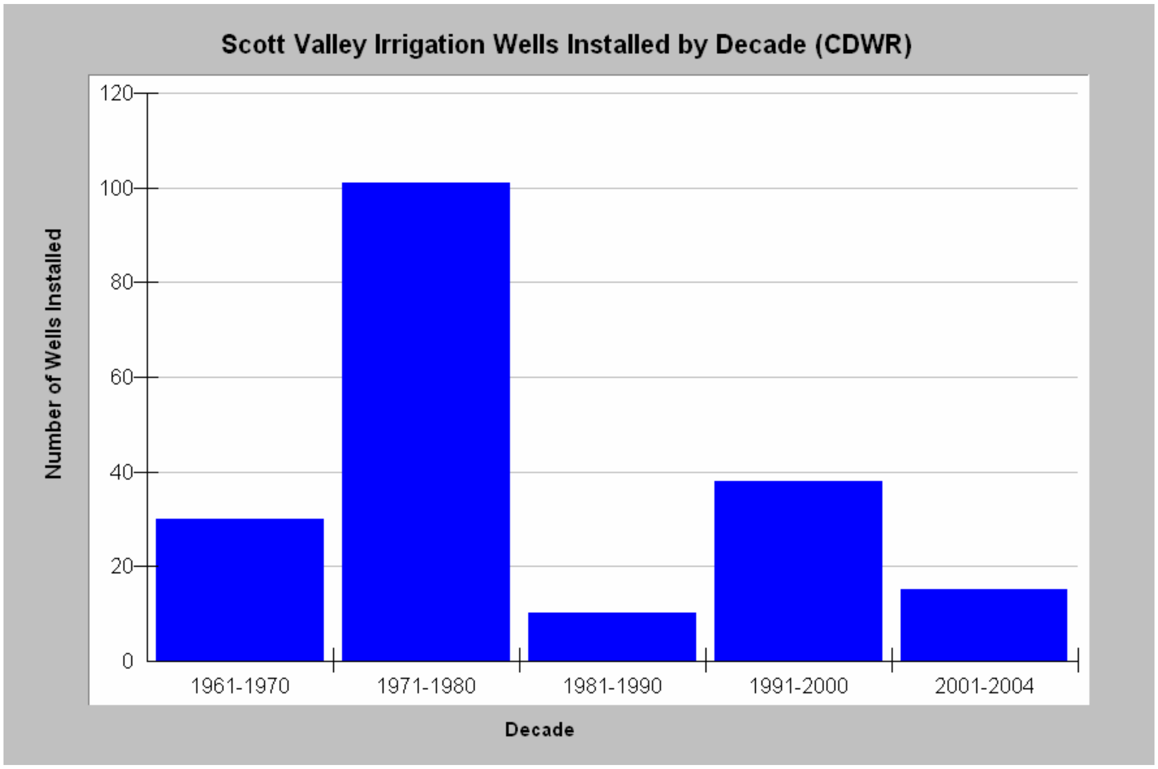


Figure 30. This chart shows the number of irrigation wells recorded by the California Department of Water Resources. Data may be only partial as not all parties installing wells file with DWR.

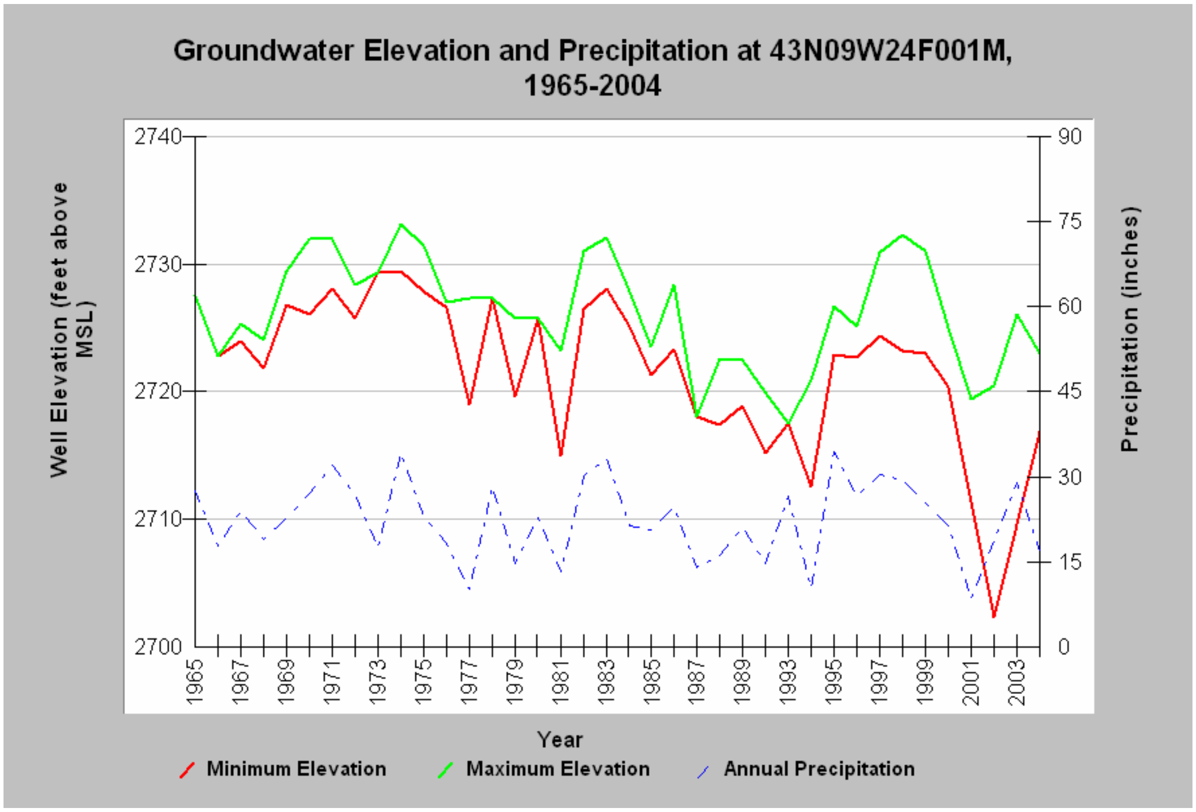


Figure 31. Department of Water Resources well 43N09W24F001M, approximately 5 kilometers south-southeast of Fort Jones, for the years 1965-2004. Minimum elevation declines are likely indicative of ground water depletion.

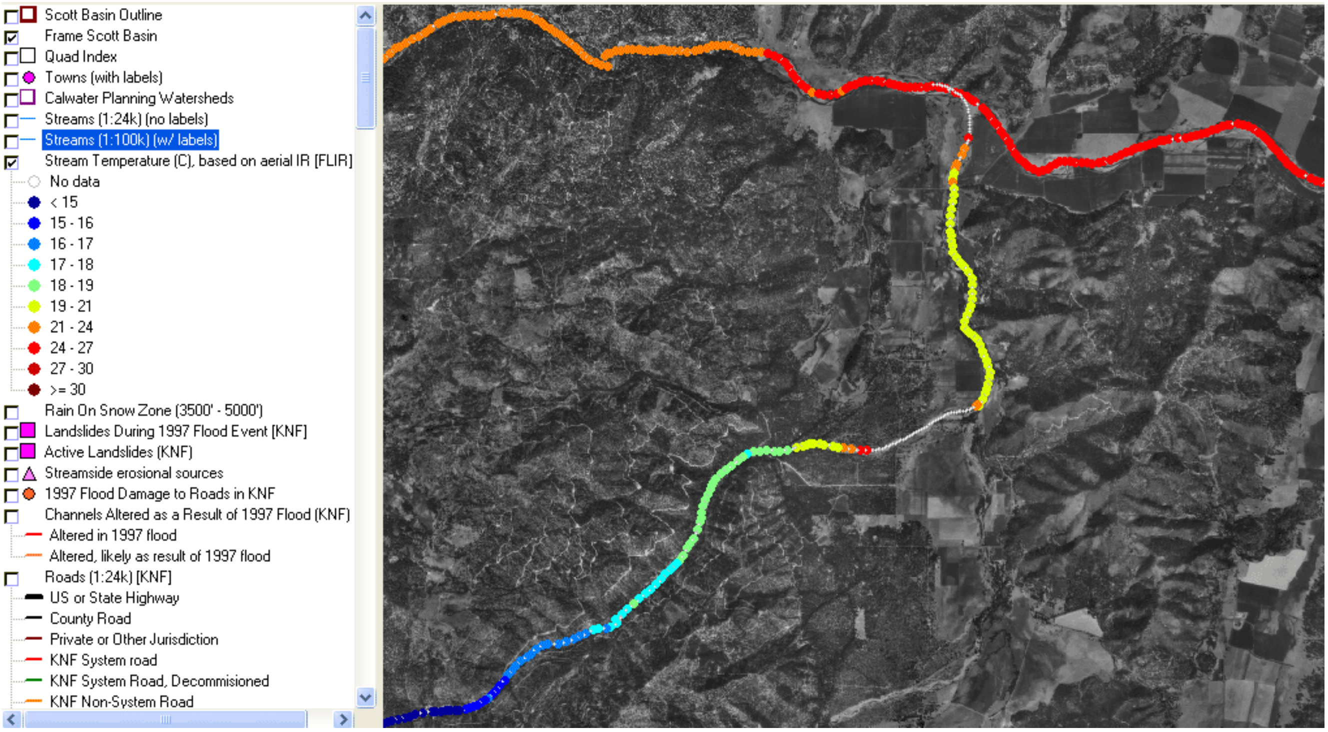


Figure 32. This map shows summary data of Scott River Thermal Infrared Radar (TIR) surveys for Shackleford Creek. Note that water temperature warms in a downstream direction as flow is depleted. Reaches with no temperature coded color are dry. Data from Watershed Sciences (2003).

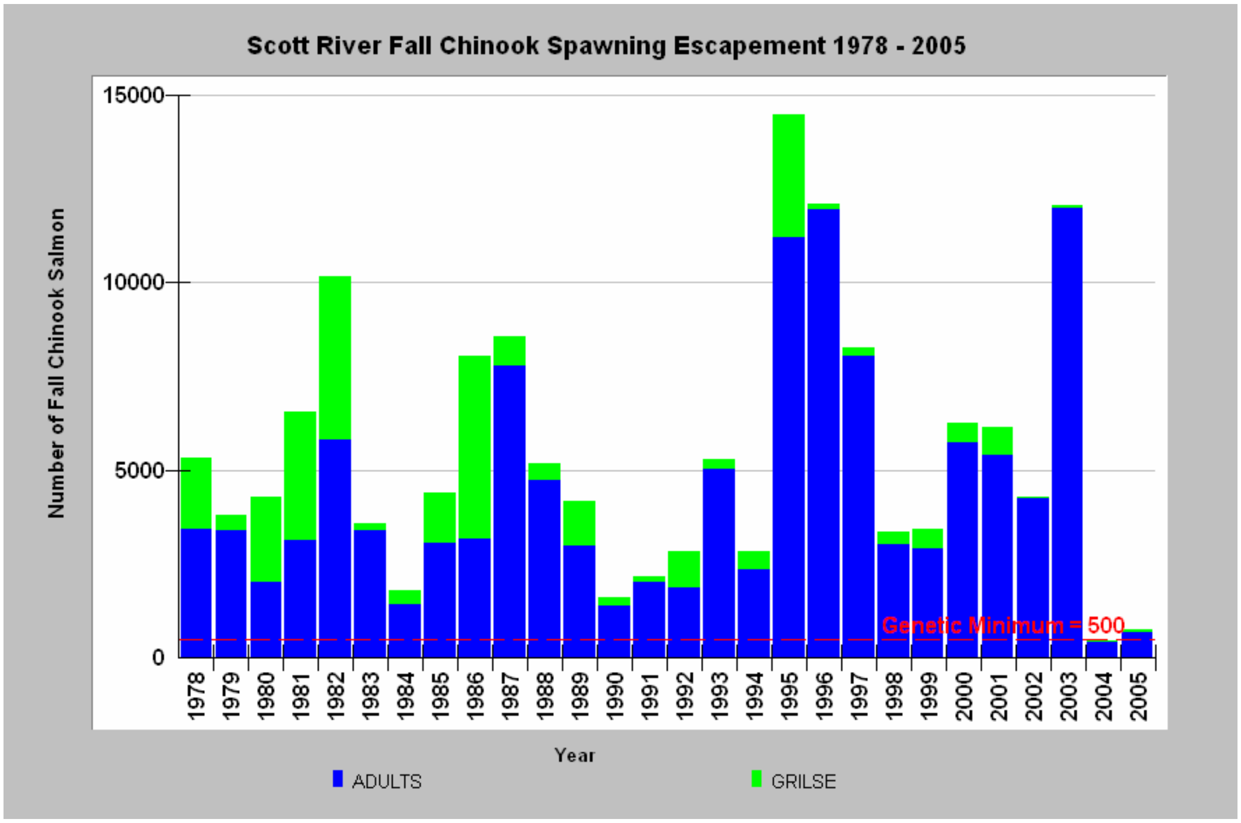


Figure 33. Scott River fall chinook spawning runs from 1978 to 2005 shows both 2004 and 2005 as the lowest years on record. Data from CDFG.

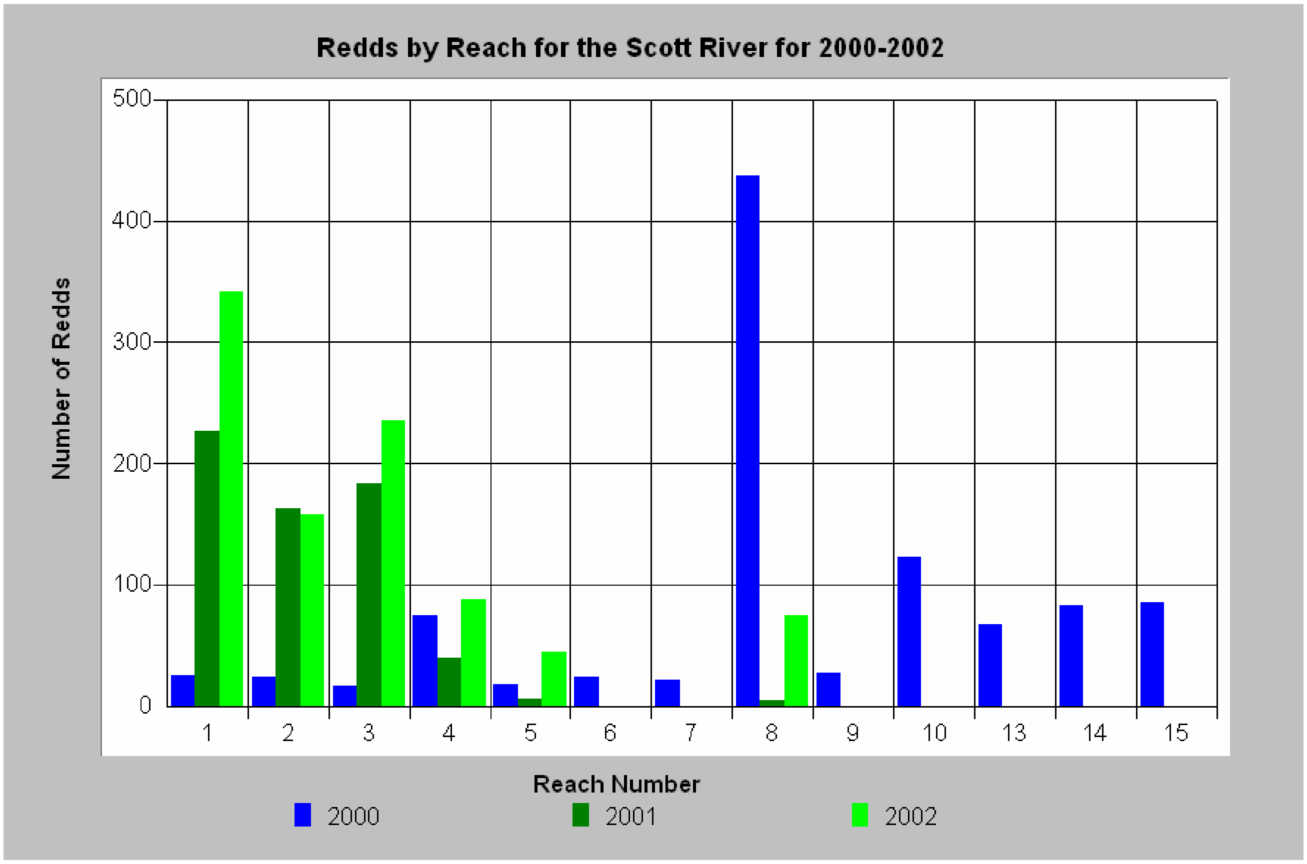


Figure 34. Data from CDFG spawner surveys show that fall chinook salmon spawned mostly in the lowest five reaches of the Scott River in 2001 and 2002, where eggs may be vulnerable due to potential for bed load movement or transport of decomposed granitic sands. Salmon are not able to disperse to upstream reaches where gravel conditions are superior and chances of egg survival greater. From KRIS KT V 3.0.

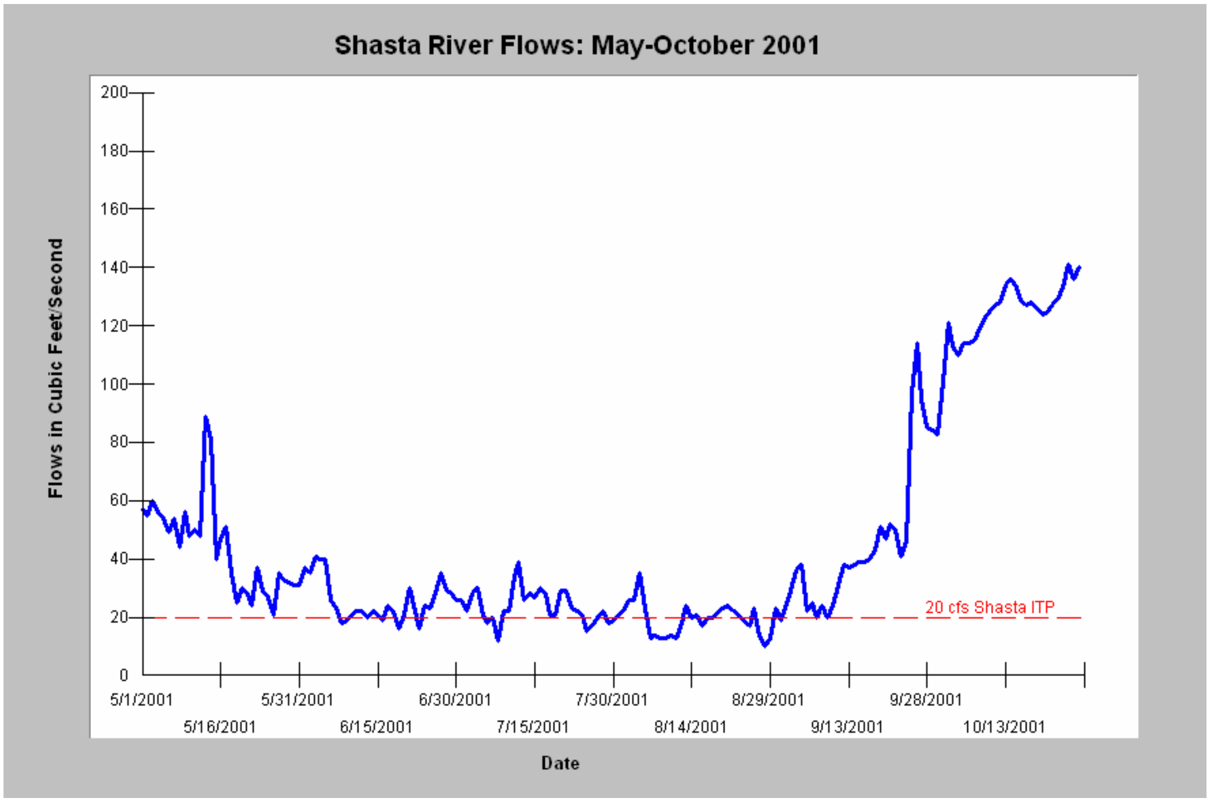


Figure 35. Average daily flow at the USGS Shasta River gauge for May through October 2001 shows a pattern of extremely low flows with many days falling below 20 cubic feet per second.

Figure 36. Dwinnell Reservoir looking southeast off the dam with water levels at less than full pool in 2002. Long retention time and exposure to sunlight trigger algae blooms and nutrient pollution. Water releases from this reservoir are restricted to avoid adding to water pollution downstream. It has blocked downstream flow since 1928 in violation of CDFG 5937. Photo from KRIS V 3.0 by Michael Hentz.

Figure 37. Parks Creek is shown here below the diversion to Dwinnell Reservoir with surface flows almost completely depleted. This not only shuts off cool water that could buffer high Shasta River water temperatures but also blocks spawning gravel recruitment. Photo by Michael Hentz.

Mack (1958) measured flow in Big Springs Creek of 103 cfs, which is very similar to the measurements taken by the California Department of Public Works (1925) for the Shasta River Adjudication (CDPW, 1932). This spring source was at optimal temperatures for salmonid rearing and the California Department of Water Resources (1981) found that it was also the reach of the Shasta River with the highest spawning use. Kier Associates (1999) noted that the spring feeding Big Springs had been depleted due to ground water pumping to less than 20 cfs.

Major increases in diversion of surface and groundwater have changed the temperature regime of the Shasta River. Thermal infrared radar (TIR) imagery captured by Watershed Sciences (2003) illustrates how flow depletion affects Big Springs Creek and Shasta River water temperature (Figure 36). The image shows water temperatures below 20^{o} C only immediately downstream of Big Springs Lake, but warming to 21.7^{o} C (Watershed Sciences, 2003), which is stressful for salmonids (U.S. EPA, 2003). The NCRWQCB (2006b) recommends that flows increases at Big Springs to at least 50 cfs to restore water quality.

The Shasta River and Scott River will also be where new private Watermaster service will be pioneered. The service has been ineffective in protecting instream flows in these basins (Kier Associates, 1991; 1999). The cost of DWR Watermaster service is born by the water users and it has been rising in recent years. Recent legislation now allows the water users to hire private contractors to render the same service. Questions have been raised as to whether a private contractor working for the water users can be expected to elevate public trust interests over those of his clients.

The NRC (2003) asked for consideration of removal of Dwinnell Dam in order to restore fish passage and increase flows. Models of snow fall changes resulting from global warming indicate that only Mt. Shasta's snow pack will increase, which makes the Shasta River one of the best places to maintain salmonids in the Klamath Basin in the face of climate change.

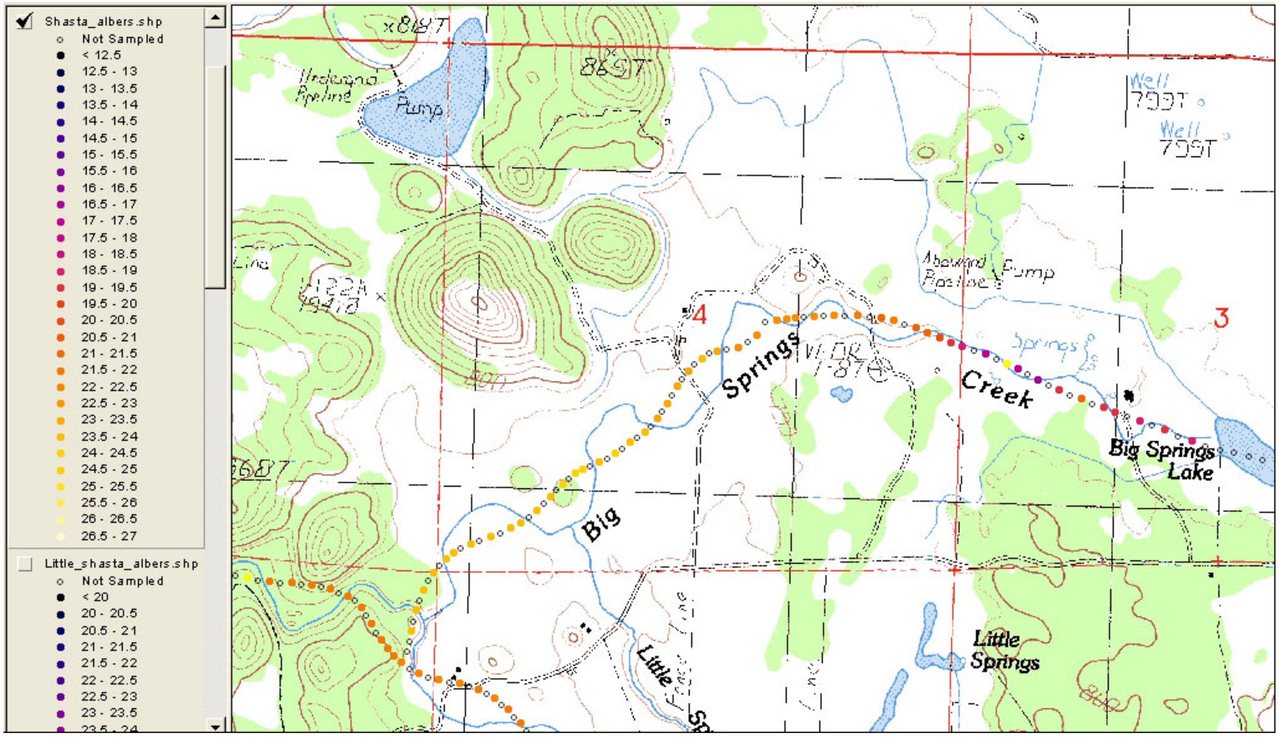


Figure 36. Thermal infrared radar (TIR) map of Big Springs Creek shows that the stream warms rapidly as a result of diversion and now is too warm for optimal salmonid rearing within a distance of less than three miles. Data from Watershed Sciences (2003) provided as GIS by NCRWQCB staff.

Climatic Cycles and Climate Change

The majority of the peer reviewers of the *Policy* (Lang, 2008; Gearheart, 2008; Band, 2008; McMahon; 2008) stated that SWRCB WRD needed to factor climate change into their planning. As mentioned above, NRC (2003) asserts that the Shasta River has the greatest restoration potential in the Klamath Basin in the face of global warming. Oscillations of climatic cycles will likely accentuate drought, which will act in concert with increased water demand from a growing population (Stetson Engineering, 2007b). While study of climate change is still progressing, shorter term cycles of rainfall and ocean productivity are now well recognized (Hare, 1998).

The Pacific Decadal Oscillation (PDO) cycle causes major shifts in ocean productivity from favorable to unfavorable for salmon approximately every 25 years off the coast of California, Oregon and Washington. Good ocean conditions are linked to wetter weather cycles and prevailed from 1900-1925 and 1950-1975 and returned to favorable again in 1995 (Hare et al., 1999). Poor ocean productivity and dry on-land cycles from 1925-1950 and 1976-1995 created very adverse conditions for salmon, particularly coho. The wet climatic cycle from 1950 to 1975 included the 1955 and 1964 floods. As the PDO cycle shifted, the 1976-1977 drought combined with highly aggraded stream beds to create a freshwater habitat bottleneck. Poor upwelling in the ocean also reduced growth and survival. Coho salmon populations on the California coast from Santa Cruz to Mendocino plummeted and many have never recovered (Figure 38).

The PDO influence is also evident in the Shasta River fall Chinook spawning returns (Figure 39). The highest return of 80,000 adults was just after Dwinnell Reservoir was built, despite being in a less productive ocean and climatic cycle (1925-1950). Even with access to less spawning habitat, runs in the 1960's exceeded 30,000 fall Chinook. The lowest ebb of the Shasta came during an extended drought from 1986-1992, when adult returns dropped to as low as 500 fish. Hopefully the WRD and DWR will get more water back in the Shasta River before the PDO switches in 2015-2025.

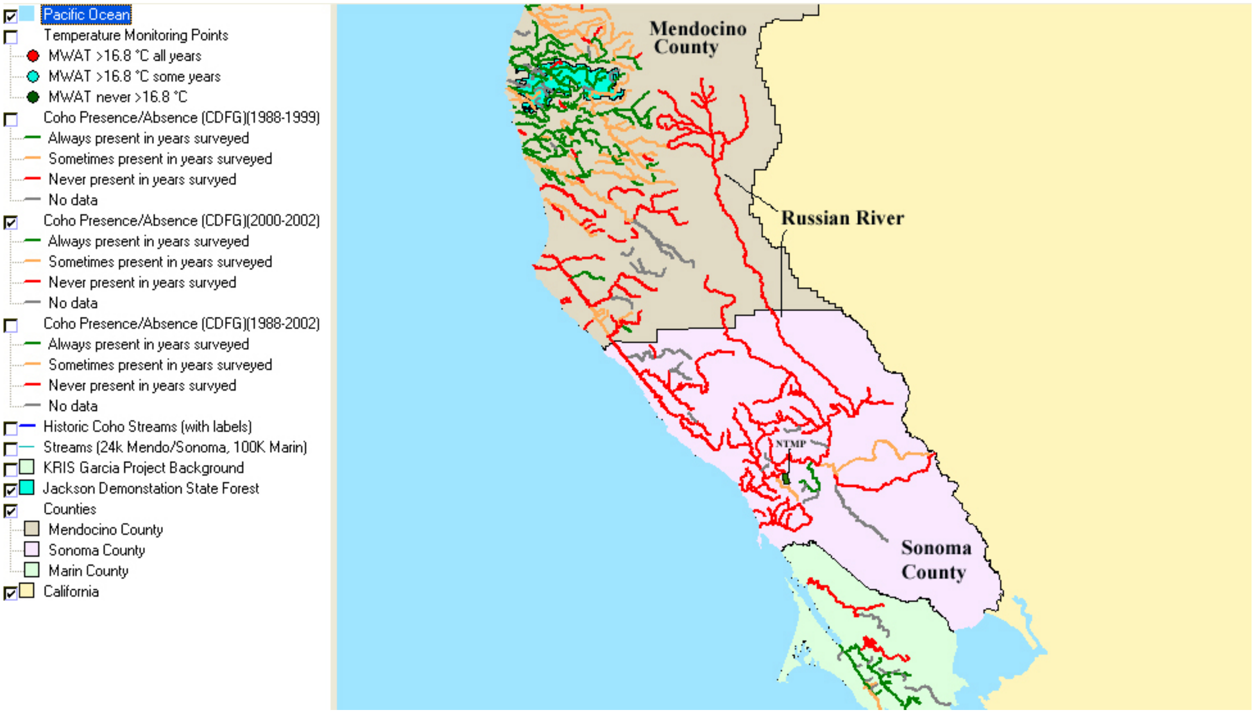


Figure 37. CDFG northern California coho salmon presence and absence maps show streams as green, if coho were always present, yellow if present in at least one year and red if absent in all three years from 2000-2002. Remaining populations are mostly near the coast within the redwood ecosystem and associated with more intact forests patches in coastal Marin County and around Jackson Demonstration State Forest. KRIS Russian.

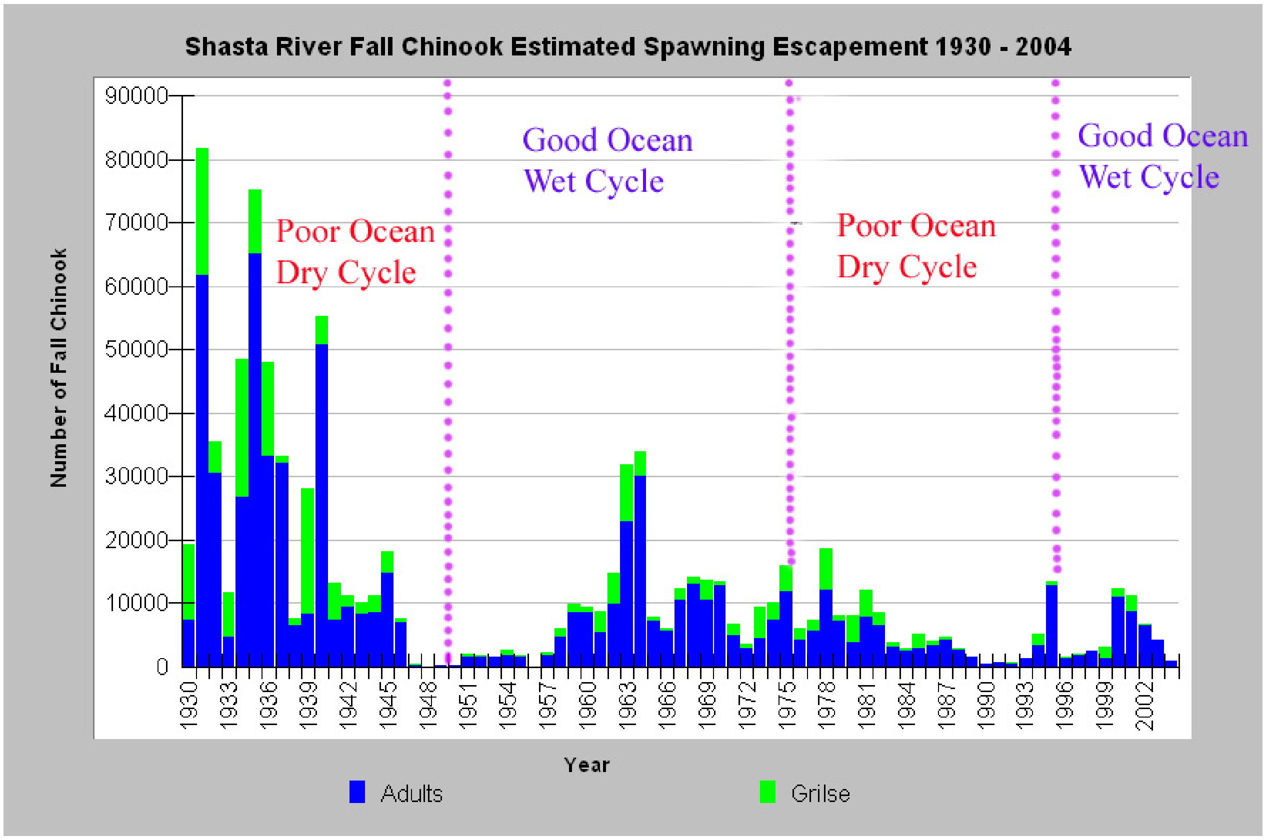


Figure 38. The CDFG Shasta Rack counts show fall Chinook returns from 1930 to 2004 with the PDO cycles overlaid. Returns fluctuate with climate and ocean cycles but the long term trend is down as a result of continuing loss and degradation of freshwater habitat. From Higgins (2006c) and KRIS V 3.0.

Restricted Geographic Scope Misses Basins With Greater Need

The *Policy* implementation is restricted to coastal watershed from the Mattole River south to San Francisco Bay (Figure 1) and does not include either the Klamath or the Eel River basins, which have enormous fisheries potential and arguably greater need for help resolving flow issues.

Timely action to restore flow and improve water quality in the Scott and Shasta Rivers could get the best return on investment for the WRD, if fish production is the index. The Shasta River has recently produced more than 10,000 adult Chinook salmon (Figure 37) and still has a run of coho salmon. Similarly, a restored Scott River could produce 10,000 fall chinook and viable populations of coho and steelhead as well. As NRC (2003) points out, increasing flow in the Shasta River would decrease water temperature. Functional Scott and Shasta River canyons would once again revitalize the rearing capacity of the both rivers for steelhead.

The Klamath River is recognized as being in crisis with regard to water quality and fish disease (Nichols and Foott, 2004) and the potential cumulative benefit of restoring flows and cold water from the Scott and Shasta Rivers should not be overlooked. Currently the Shasta and Scott contribute very little flow in summer to the mainstem Klamath River and what water they do contribute is warm and high in nutrients. McIntosh and Li (1998) used forward looking infra-red radar (FLIR) to examine water temperatures of the Klamath River. Figure 38 shows the FLIR image of the convergence with Shasta River water temperatures exceeding 29^{o} C (84^{o} F) and the Klamath River itself above stressful or lethal limits for salmonids. This influence is the opposite of the historic role the Shasta River played in moderating Klamath River water temperatures and nutrient loads.

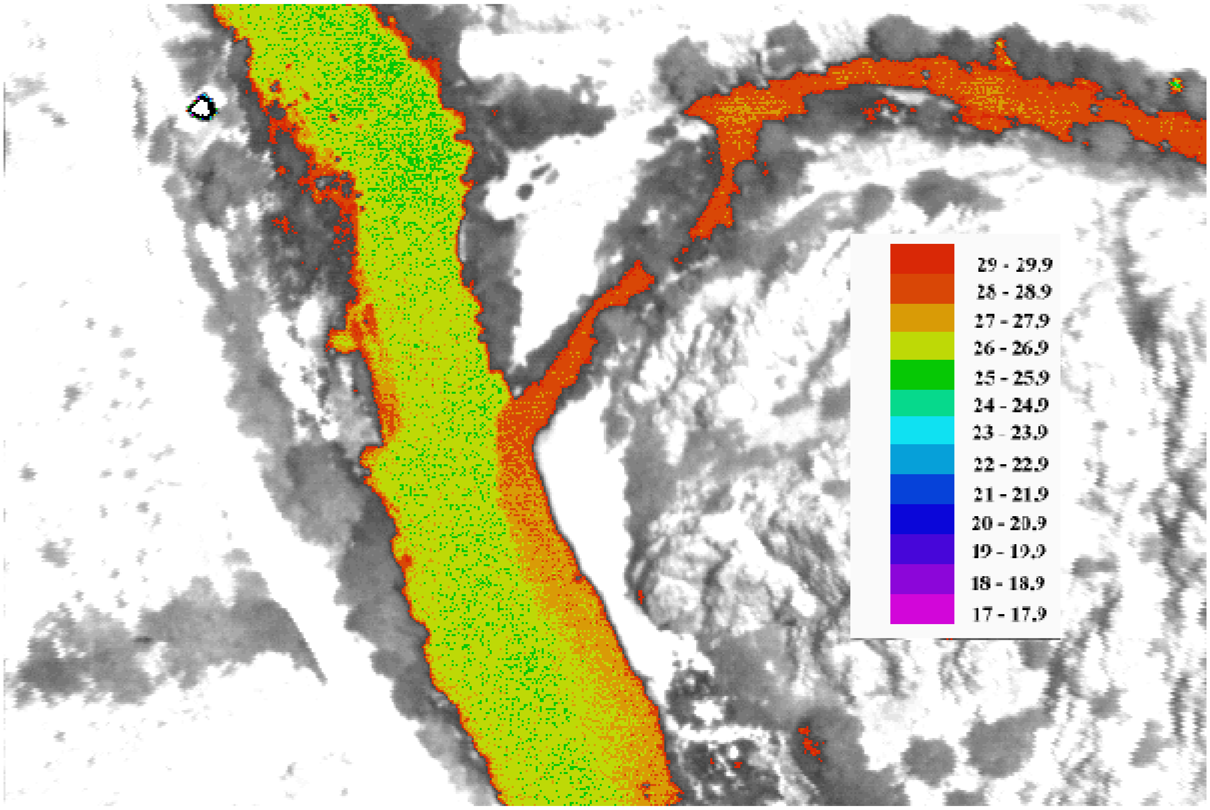


Figure 38. Thermal Forward Looking Infrared Radar Image (FLIR) showing the confluence of the Klamath River (flowing from the top of the image to the bottom of the image) and the Shasta River (flowing right to left in the image). The Shasta River is approximately 29 degrees C and a warm water plume is observed in the Klamath River below. From McIntosh and Li (1998).

The Eel River once had hundreds of thousands of salmon and steelhead, yet even the mainstem has gone dry in recent years just above Fernbridge in late summer. Flow depletion due to Pillsbury Dam reduces mainstem habitat, but the South Fork Eel is now also flow depleted. The latter has become so stagnant in recent years that blue green algae has proliferated that is toxic to dogs and makes recreational use impossible. Because the Eel River watershed remains largely unpopulated and wild land, it has a great deal more chance for recovery than urbanizing watersheds or those with extensive agricultural activity.

Monitoring and Adaptive Management

The *Policy* calculation of protective base flows and water availability rely on fragmentary history flow data and flawed synthetic data (Lang, 2008) and "additional data collection on small stream hydrology and fish usage is needed to verify these relationships." A major problem is that all monitoring envisioned is on winter flows (October-March) when surplus water is theoretically available, not on April-September period that is known to be more flow limited.

There is a need for year around data collection in small and large streams throughout the region, with the priority identification of stream reaches where surface flows are lacking but historically had surface flows and carrying capacity for salmon and steelhead. Band (2008) suggests gages "with real-time capability, likely co-funded with the USGS to take advantage of the National Water Information System (NWIS) real-time discharge system."

McMahon (2008) recommends installation of inexpensive stage height and temperature sensors (www.trutrack.com) that can be purchased inexpensively ($200) and are easy to install. He also recommends that monitoring be focused on key reaches of use by salmon and steelhead (biological hotspots). Band (2008) framed the challenge for monitoring need for Policy implementation:\

> "Monitoring and management of the finite water resource network calls for the development of a more advanced sensor network to monitor stream temperature, turbidity, suspended sediment transport in addition to flow. The State of California should be in the position to develop and implement this type of network in collaboration with federal agencies and the university system."

In other words, to fully deal with the questions of cumulative effects of water diversion and water supply, many similar data elements are needed to those of other processes like the Clean Water Act (TMDL), ESA (ITP) and the National Forest Management Act. For example, CDFG is currently attempting to issue Incidental Take Permits for agricultural operations in the Scott and Shasta river basins (CDFG, 2006a; 2006b) and many of the issues considered are those with which the current Policy concerns itself yet little coordination with SWRCB WRD is apparent in the ITP process.

The SWRCB WRD shows little technical capacity, other than that provided by consultants, and no track record of extensive field data collection. There is no commitment to a schedule for monitoring and the effectiveness monitoring section of the Policy shows bureaucratic reluctance. DWR shows a similar lack of capacity with regard to ground water monitoring and regulation. Consequently, the State should solicit emergency help from the U.S. Geological Survey to assess water supply and surplus availability (see Conclusion for discussion on the need to re-organize WRD and DWR.

Regardless of how data collection and agency coordination are structured, there needs to be a common database for sharing results, trend monitoring and implementation of adaptive management. KRIS projects submitted with these comments supply a great deal of useful data, including GIS information.

The SWRCB Water Rights Division should consider using this tool, already subsidized with over $1 million in public money.

If *Policy* implementation involves partnerships with private parties or groups, all raw data, computer codes for models and other related information must be available to the scientific community and to the public in electronic form. Without full transparency, no model or study output is scientifically valid (Collison et al., 2003) and history shows that public trust resources, such as salmon and steelhead, cannot be fully protected without the ability of the public to participate in oversight.

Band (2008) envisions using the data collected in the field to increase the predictive capacity of the flow model:

> "An integrated GIS-spatial watershed model that incorporates natural runoff production, stream routing and all water diversions and return flows should be developed……As part of an adaptive management approach, the modeling system would provide a formal set of expectations of different water resources policies in the watersheds."

Adaptive Management: The National Research Council (2004), in recommending that adaptive management be used to recover the endangered fishes of the Klamath basin, described it as follows:

> "Adaptive management is a formal, systematic, and rigorous program of learning from the outcomes of management actions, accommodating change, and improving management (Holling, 1978). Its primary purpose is to establish a continuous, iterative process for increasing the probability that a plan for environmental restoration will be successful. In practice, adaptive management uses conceptual and numerical models and the scientific method to develop and test management options."

Dr. Carl Walters (1997) is credited with having coined the term adaptive management and has followed 25 case studies of riparian and coastal ecosystem restoration projects around the world, but found "only seven of these have resulted in relatively large-scale management experiments, and only two of these experiments would be considered well planned in terms of statistical design." He notes that too little change in anthropogenic stressors is carried out in most cases so that natural variation and project effects are not distinguishable. "Various reasons have been offered for low success rates in implementing adaptive management, mainly having to do with cost and institutional barriers" (Walters, 1997). The cost of monitoring associated with Policy implementation is not estimated nor are sources of funding identified. The institutional barriers that might impede successful adaptive management are well described above.

If 500 or 1,000 illegal dams are removed, we would have the potential to make a difference on the problem and would also have an interesting and valid adaptive management exercise.

Instead of adaptive management, the SWRCB WRD has been exhibiting what NRC (2003) terms deferred action:

> "In the deferred-action approach, management methods are not changed until ecosystems are fully understood (Walters and Hillborn, 1978; Walters and Holling, 1990; Wilhere, 2002). This approach is cautious but has two notable drawbacks: deferral of management changes may magnify losses, and knowledge acquired by deferred action may reveal little about the response of ecosystems to changes in management. Stakeholder groups or agencies that are opposed to changes in management often are strong proponents of deferred action."

Conclusion

When one studies Appendix E (Stetson Engineering, 2007a), it becomes apparent that Dr. Bob Gearheart's (2008) characterization of his experience with water rights in the Upper Klamath in Oregon apply to the *Policy* area: "water rights were 1) over allocated, 2) unmeasured, and 3) mostly unregulated." Implicit in the *Draft Policy* is that there is surplus water in North Coast streams in the geographic area in question. An accurate inventory of water resources might find that many or most streams are fully allocated, given changes in watershed hydrology and channel morphology in conjunction with existing levels of diversion and groundwater use. When the geographic extent and severity of the problem is fully assessed, one can see that Pacific salmon species will not thrive or even survive into the future without profound change in California water policy and management.

<u>Recommendations</u>: If the *Policy* goes forward under current agency framework:

- Only consider diversions after December 15.
- WRD works with USGS to set up gages for year around flow measurement region wide.
- No additional permits should be issued by WRD for streams that formerly supported juvenile salmonid rearing but now are dry.
- Full inventory of all use needs to be conducted on the ground in cooperation with USGS, including riparian rights, pre-1914 and illegal diversions within one year.
- WDR should stop post-permitting of illegal diversions and make fines sufficient to be a disincentive.
- Work cooperatively w/ CDFG using 5937 and get flows back. Don't reign in the wardens.
- DWR needs to work with USGS on collection of ground water data, share all data in the public domain and more actively manage the resource.
- DWR should re-establish Watermaster service so that it is done by a government agency not a private party due to public trust protection needs.
- WDR, DWR, CDFG and NOAA Fisheries need to create a participatory data management system that has all data for the region, including spatial data, and can be used for adaptive management.

In light of over-diversion, critical shortages of water for fish, inexorably rising demand for water, and the rampant lawlessness of both surface and ground water diversion, it is clear that we have a regional crisis. The data and the case studies above show that there is a complete dereliction of duty by the WRD and likely a similar lapse in management of ground water by DWR. In fact, much more profound reform is likely necessary, although there will be considerable opposition from agricultural interests and intransigent bureaucracies involved. What is really necessary is:

1) Change California Water Law to make riparian diversions require a permit,
2) Have Legislature request Attorney General investigation into lack of enforcement of SWRCB codes (1052, 1055), including illegal extraction of ground water that is connected to surface water (i.e. Big Springs, Shasta River)
3) Consolidate surface water and ground water management and Watermaster Service under one State agency that has public trust as its over-riding objective, such as CDFG or Cal EPA.
4) Integrate planning with TMDL (Regional Boards), ESA/CESA (CDFG, NMFS), watershed restoration efforts (NRCS/NGO's) and NFMA and Northwest Forest Plan (U.S. Forest Service/Bureau of Land Management) implementation to pool resources and all agencies and processes targeting Pacific salmon recovery.

Given the institutional incapacity of both the SWRCB WRD and DWR, it is hard to recommend either as a future lead agency under which water management would be carried out, and it is time to consider shifting authority. Regardless of how bureaucratic responsibility might be reallocated, the new perspective must be one of public trust protection as a priority and water supply allowed only when it does not harm fisheries and water quality. Also under any scenario the USGS is needed immediately to lead collection and analysis.

Urgent action is needed in reform of flow monitoring and regulation to avoid a wave of Pacific salmon stock losses due to climate change and recognized shifts in climatic regimes, such as the Pacific Decadal Oscillation (PDO) cycle (Hare et al., 1999). It is time for State agencies to uphold the law, to begin cooperative work to remediate over-diversion of surface and groundwater, and to not only prevent fish stock extinctions, but to aim for restoration that provide a harvestable surplus of fish.

I would be happy to discuss any aspect of my comments with your staff. Please see the references section of my comments for citations listed above.

Sincerely,

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