Total Maximum Daily Loads, Sediment Budgets, and Tracking Restoration Progress of the North Coast Watersheds[1]

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Abstract

One of the predominate water quality problems for northern coastal California watersheds is the impairment of salmonid habitat. Most of the North Coast watersheds are listed as "impaired" under section 303(d) of Clean Water Act. The Clean Water Act requires states to address impaired waters by developing Total Maximum Daily Loads (TMDLs) or implementing another program that will result in the attainment of water quality standards. TMDLs are an estimate of the maximum load necessary to meet water quality standards. In a general sense, a TMDL and its implementation plan is a water quality attainment strategy and provides a framework for assessing the watershed condition, evaluating the sources of pollution contributing to the water quality impairment, and developing a water quality restoration plan for the watershed.

Sediment budgets are useful tools to evaluate sediment impacts to water quality and channel morphology. As part of the TMDL development process, sediment budgets have been developed for twenty northern California watersheds. Anthropogenic activities such as logging and its associated road building, which commonly occur in this region, have dramatically increased sediment loading rates. TMDL studies estimate that is will take several decades or more for streams to transport the excess sediment out of the watersheds.

Tracking recovery of the watersheds from sediment impairments over time will be difficult. The Regional Water Board will use several tools to verify that progress is being made. These tools include sediment budgets, as well as monitoring hillslope and water quality conditions in the listed watersheds.

Key words: sediment budgets, targets, TMDLS, trend monitoring

Introduction

Over 40,000 water bodies in the United States do not meet the Clean Water Act goals of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters (USEPA 2009). Excessive sediment has impaired the beneficial uses of water for nearly 6,500 waterbodies (USEPA 2009). In the North Coast Region of the California Regional Water Quality Control Board, several salmonid species are listed under the Endangered Species Act. In particular, the Central California Coast Coho populations in the southern portion of the range appear to be either extinct or nearly so, including those in the Gualala, Garcia, and Russian rivers (Good et al. 2005). Although there are several factors involved in the decline of

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salmonids, the destruction and modification of habitat are the primary reasons for decline in the western United States (National Marine Fisheries Service 2007).

Anthropogenic activities such as logging and its associated road building, which commonly occur in northern coastal California, can dramatically increase sediment loading rates (Gomi et al. 2005, Reid 1993). The increased sediment supply can negatively impact salmonid habitat in several ways. Excessive fine sediment can prevent adequate water flow through salmon redds, the nest in the stream substrate formed by a female salmonid in which eggs are laid, fertilized and incubated. Excessive fine sediment in the redd can cause a high level of mortality by limiting the oxygen supply to salmon eggs and preventing the removal of metabolic wastes (Chapman 1988). Increases in sediment supply can also decrease the pool depth and pool size (Lisle and Hilton 1999), which reduces rearing habitat for salmonids. Decreases in clarity due to suspended sediment can cause direct effects, such as mortality, and indirect effects like decreases in growth rates due to reduced food supply (Newcombe 2003).

Excessive sediment can also impair drinking water supplies, which is another concern in some North Coast watersheds. Also, excessive sediment can lead to changes in stream channel morphology. Aggradation, the filling in of a stream channel by sediment which raises the level of the streambed, may lead to decreased channel capacity, which can cause an increase in flooding frequency, magnitude and duration (Knighton 1998). This increase in flooding can cause property damage or result in nuisance conditions by limiting access for landowners.

Sediment budgets are useful tools to evaluate sediment impacts to water quality and channel morphology. A sediment budget is an "accounting of the sources and disposition of sediment as it travels from its point of origin to its eventual exit from a drainage basin" (Reid and Dunne 1996). A variety of tools and data sources are used to create the sediment budget, including monitoring information, aerial photography analysis, simple calculations, spreadsheet analysis, and computer models.

This paper reviews the sediment budgets created for 20 North Coast watersheds. The paper then discusses a monitoring strategy that can track watershed recovery and will help determine when watersheds have been restored.

Sediment budgets and total maximum daily loads

Under section 303(d) of the Clean Water Act, states are required to identify all water bodies that do not meet water quality standards. For those "impaired" water bodies, the states must develop and implement Total Maximum Daily Loads (TMDLs) or implement another program that will result in the attainment of water quality standards. A TMDL "shall be established at a level necessary to implement the applicable water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality" (Clean Water Act, §303(d)(1)(C)). In a general sense, a TMDL and its implementation plan is a water quality attainment strategy, which provides a framework for assessing the watershed condition, evaluating the sources of pollution contributing to the water quality impairment, and developing a water quality restoration plan for the watershed. The North Coast Region of the California Regional Water Quality Control Board has 61 percent of the region's area listed for sediment impairment under Clean Water Act Section 303(d) (CRWQCB 2008).

A key component of TMDLs is the source assessment. For sediment TMDLs, the source assessment typically takes the form of a sediment budget that identifies and estimates the hillslope sources of sediment. Due to the significant yearly variation in sediment loads in northern coastal California, which can range over several orders of magnitude, the sediment budgets rely on long-term estimates of sediment input. These estimates are often derived by using sequential aerial photographs to evaluate the occurrence of major sediment sources such as landslides. The sequential photographs often bracket significant storm events (for example, 1964, 1986, 1997 and 2003 storms). Therefore, the sediment budgets “average” the estimated sediment delivery over the air photo period.

While calculating the TMDL on a daily basis is a legal requirement, U.S. Environmental Protection Agency (USEPA) recognizes that it is impractical for land managers to measure sediment loads, or sediment discharges, on a daily basis. Therefore, sediment TMDLs are expressed as an average annual load which should be evaluated as a long-term (for example, 10 to 15 year) running average (USEPA 2007a). Furthermore, USEPA expects progress toward the TMDL to be evaluated by estimating the total sediment load relative to the natural load (USEPA 2007a), which is why the loading capacity is often expressed as a ratio relative to the natural loads, in addition to being provided as an absolute load. The underlying assumption is that while sediment delivery is very episodic, which makes the determinations of progress towards the TMDL very difficult, the ratio of total sediment to natural is not as sensitive to episodic events.

To date, 20 sediment TMDLs have been completed for North Coast Region watersheds. The estimated sediment loads and the TMDL, in other words the loading capacity, are shown in *table 1*. Comparisons between the sediment loads from TMDLs are difficult because different methods and categories were used to identify the sources and volumes of sediment reaching streams. However, some general conclusions can be reached. The road system is often the major source of sediment averaging 57 percent of the management-related sediment load. Logging sources of sediment averaged 24 percent of the management-related sediment load. Agriculture and grazing were very minor sources of sediment in these watersheds, while mining sources of sediment were important in some watersheds (for example, the Scott River watershed).

To provide a better understanding of sediment discharges from the 1970s through the 1990s from logging activities, Strauss (2002) reviewed the TMDL sediment budgets for several watersheds where the primary land use was logging. Seven watersheds were identified for this exercise: Noyo River, Ten Mile River, Albion River, and Big River, and portions of the Van Duzen River, South Fork Eel River, and Gualala River. The results indicated that 43 percent of the sediment delivered to streams was from natural or background sources, 1 percent was from specific sources other than silviculture and the remaining 56 percent was associated with timberland management. The amount attributed to logging was always substantial, ranging from 43 to 70 percent, and most of the logging-related sediment was associated with roads, but other processes like landslides from logging units were significant.

Table 1—*Sediment load estimates from northern California TMDLs.*

Watershed	**Size (km^2)**	**Natural (t/km^2)**	**Management (t/km^2)**	**Total (t/km^2)**	**Total (relative to natural)**	**TMDL (t/ km^2)**	**TMDL (relative to natural)**	**Reference**
Albion River	111	96	152	249	2.58	144	1.50	USEPA 2001a
Big River	469	110	110	220	2.00	138	1.25	USEPA 2001b
Eel River, North Fork	749	291	140	430	1.48	364	1.25	USEPA 2002
Eel River, Middle Fork	1950	201	29	230	1.14	211	1.05	USEPA 2003a
Eel River, South Fork	1785	378	331	708	1.88	472	1.25	USEPA 1999b
Eel River, Upper Main	1782	109	54	162	1.49	136	1.25	USEPA 2004
Eel River, Middle Main	1349	181	83	264	1.46	226	1.25	USEPA 2005
Eel River, Lower Main	774	251	272	523	2.08	315	1.25	USEPA 2007a
Garcia River	295	57	427	483	8.52	193	3.41	USEPA 1998a
Gualala River	774	133	294	427	3.21	166	1.25	USEPA 2001c
Mad River	1243	313	553	867	2.77	376	1.20	USEPA 2007b
Mattole River	767	1016	1786	2802	2.76	1261	1.24	USEPA 2003b
Navarro River	816	410	271	681	1.66	512	1.25	USEPA 2000a
Noyo River	293	130	74	204	1.57	165	1.27	USEPA 1999a
Redwood Creek	738	532	1131	1664	3.13	666	1.25	USEPA 1998c
Scott River	2106	157	105	262	1.67	196	1.25	CRWQCB 2005
Ten Mile River	311	109	111	220	2.02	137	1.25	USEPA 2000b
Trinity River	4978	379	197	575	1.52	474	1.25	USEPA 2001d
Trinity River, South Fork	2414	239	130	369	1.54	258	1.08	USEPA 1998b
Van Duzen River	1111	596	157	753	1.26	642	1.08	USEPA 1999c
Average	1241	284	320	605	2.29	353	1.34	
Median	795	220	155	429	1.77	242	1.25	

For most northern coastal TMDLs, the loading capacity has been set at or near 1.25 relative to the natural background sediment loads (*table 1*). Since estimates of current sediment loading in these northern coastal watersheds average 2.29 relative to natural background, significant reductions in sediment discharges are required to meet the TMDLs. On average, it's estimated that the management-related sediment load must be reduced by 69 percent to meet water quality standards.

These TMDLs and their associated sediment budgets are for large watersheds and many of the sediment budgets were the first attempt to analyze sediment source information at a watershed scale. It's expected that further research will increase the understanding of sediment sources and sediment loads.

Recent research has identified sediment sources that were not included in most TMDL sediment budgets. For example, Reid et al. (2010) found that gullies were a significant source of sediment following logging in the Caspar Creek watershed. Furthermore, Klein et al. (2011) recently compared turbidity, which is closely related to suspended sediment, for 28 watersheds in northern coastal California, some of which are on the 303(d) list for sediment. Watersheds with high harvest rates for the last fifteen years had turbidity levels approximately eight times greater than nearly pristine old-growth watersheds. This study indicates that logging activities continues to contribute sediment to impaired water quality conditions and that the impact of logging may have been underestimated in previous sediment budgets.

Tracking watershed recovery

Monitoring can have many different forms based on its objectives. Monitoring related to water quality regulation can be classified into the following categories: implementation monitoring, upslope effectiveness monitoring, instream effectiveness monitoring and compliance and trend monitoring (CRWQCB 2006). This paper is focused on compliance and trend monitoring, which describes monitoring that is intended to determine if water quality standards are being met. Specifically, this paper focuses on the parameters that can be used to determine the water quality conditions for cold water fish such as coho and to determine when a waterbody has recovered from sediment impacts. When monitoring data indicates that water quality standards are being met, the data can then be used for delisting from the 303(d) list.

The 303(d) Listing Policy adopted by the California State Water Resources Control Board (2004) establishes a standard methodology for assessing data and information for both listing and delisting purposes that utilizes a weight of evidence approach. While one of several approaches can be used, sediment delistings will likely use a situation-specific weight of evidence approach. This approach requires that delisting recommendations are supported by (1) data or information that affords a substantial basis in fact from which the decision can be reasonably inferred, (2) data and information demonstrates that the water quality standard is attained, and (3) a demonstration that the approach used is scientifically defensible and reproducible (CSWRCB 2004). Other approaches that can be used to delist waterbodies include demonstrating that numeric water quality objectives are not exceeded, nuisance conditions no longer exist or adverse biological response is no longer evident.

Water quality standards include the designated beneficial uses of water, water quality objectives to protect those designated uses, federal and state anti-degradation policies, and policies adopted by the State and Regional Water Boards. Water quality standards are generally contained in the Water Quality Control Plan for the North Coast Region (Basin Plan). The Basin Plan is one regulatory tool used by the Regional Water Board staff to implement the federal Clean Water Act and the state Porter-Cologne Water Quality Control Act to protect water quality. The cold freshwater habitat beneficial use appears to be the most sensitive beneficial use to excessive sediment. The water quality objectives related to sediment are narrative.

Regional Water Board staff reviewed the scientific literature related to sediment impacts on freshwater salmonid habitat to help interpret the narrative sediment-related water quality objectives. The Desired Conditions Report (CRWQCB 2006) identifies numeric targets which are directly measurable by known monitoring methods. The targets provide a means of assessing attainment, or recovery toward attainment, with the narrative water quality objectives for sediment in regards to the beneficial use of cold water fish, and specifically the freshwater habitat needs for salmonids. Non-attainment of these desired conditions, however, is not independently enforceable. The desired condition values would only be enforceable if they are specifically incorporated into a permit or if they are formally adopted as water quality objectives in the Basin Plan.

The desired conditions are intended to be used by the Regional Water Board and other agencies, organizations, and interested individuals to assess and monitor sediment impacts to water quality. Stakeholders, landowners, and other resource agencies are encouraged to monitor instream conditions and compare their data to these indices where applicable.

Since the relationship of water quality with sediment cannot be described by a single parameter, it is important to track a suite of parameters to assess watershed recovery and to determine when water quality standards are being met. There are five general categories of data and information needed to track the recovery of sediment impaired waterbodies (*table 2*). The three primary categories are channel substrate, channel morphology, and water column. Two other categories, hillslope and biological, can provide supporting evidence on watershed recovery.

The targets for the sediment monitoring parameters primarily come from the desired conditions report (CRWQCB 2006). However, other sources are also used for establishing appropriate targets, including approved TMDLs (for example, hillslope targets from USEPA 1999a) or Recovery Plans (for example, biological targets from NMFS 2010). The targets are based on current knowledge and may need to be modified depending on further research. Furthermore, some reports identify parameters whose targets are “increasing tends” (for example, increasing trend in variation along the thalweg elevation (CRWQCB 2006)). Further information on monitoring methods can be found in the referenced reports.

Table 2—*Trend monitoring categories and targets.*

Category	Parameter	Target	Reference
Channel Substrate	Substrate composition: Percent Fines < 0.85 mm	≤ 14 % of substrate is small fines	CRWQCB 2006
	Substrate composition: Percent Fines < 6.40 mm	≤ 30 % of substrate is small fines	CRWQCB 2006
	Embeddedness	≤ 25 % of gravels and cobbles are embedded	CRWQCB 2006
	Pool filling with fine sediment (V*)	≤ 20 % of the pool volume is filled with fines	CRWQCB 2006
Channel Morphology	Primary Pools	≥ 40% of reach is primary pools	CRWQCB 2006
	Large Woody Debris: small streams	> 11 key pieces/ 100 m	CRWQCB 2006
	Large Woody Debris: large streams	> 4 key pieces/ 100 m	CRWQCB 2006
Water Column	Suspended Sediment and Turbidity	Water Quality Objectives	CRWQCB 1994
Hillslope	Stream crossings with diversion potential	≤ 1 % of stream crossings have diversion potential	USEPA 1999a
	Stream crossings with failure potential	≤ 1 % of stream crossings have failure potential	USEPA 1999a
	Hydrologic connectivity of roads	≤ 1 % of the road network is connected to streams	USEPA 2003b
Biological	Spawning Adults (coho)	20 to 40 per km	NMFS 2010
	Juvenile Density (coho)	0.5 to 1.0 fish per m^2	NMFS 2010

Water column parameters in *table 2* already have water quality objectives in the Basin Plan. Regional Water Board staff does not propose to revise the standards or establish desired conditions, because further research is needed. However, several approaches appear promising, including examining turbidity exceedences (Klein et al. 2011) or using the Severity Index (Newcombe 2003) to determine water quality impacts. Also, it should be noted that suspended sediment and turbidity monitoring is helpful for monitoring trends and validating sediment budgets.

Conclusions

The sediment budgets developed for TMDLs confirm that many streams in the north coast region have suffered impacts from large inputs of sediment from anthropogenic activities. Much of the management source of sediment comes from logging and the roads that are used to access the timber. Substantial effort is needed to reduce sediment loads in these watersheds. Establishing trend monitoring programs is critical to measuring the progress of watershed recovery in these impaired watersheds. Since the relationship of water quality with sediment cannot be described by a single parameter, it is important to track a suite of parameters to assess watershed recovery and to determine when water quality standards are being met.

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