TECHNICAL PROBLEMS ASSOCIATED WITH THE USE OF TOTAL MAXIMUM DAILY LOAD LIMITS FOR FOREST PRACTICES--REVISITED

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ABSTRACT: A 1989 white paper prepared by the author identified three key technical problems in setting Total Maximum Daily Load (TMDL) limits for forest watersheds. These were: setting defensible and achievable goals, calculating load allocations throughout a watershed to achieve those goals, and developing realistic compliance monitoring. In the decade since then, the number of waterbodies listed as water-quality limited has mushroomed. Were current technical problems anticipated ten years ago? An emerging understanding of forest systems and watershed responses to disturbance is relevant to the TMDL process. Experience from TMDL efforts and other watershed assessments involving forest management are cited to demonstrate the continuing issues and problems to be overcome. Suggested solutions are provided.
KEY TERMS: BMPs, forest practices, routing, TMDL

INTRODUCTION

In 1986 the Northwest Environmental Defense Center (NEDC) filed a complaint alleging that EPA had violated Section 303(d) of the Clean Water Act (CWA) by failing to develop Total Maximum Daily Load (TMDL) limits for water-quality limited streams in Oregon. This action by NEDC was one of the first legal challenges brought by environmental groups to force states to begin or to accelerate TMDL assessments. A July 1987 consent decree required that the Oregon Department of Environmental Quality develop TMDL limits for 11 waterbodies and further review 17 others.

The first waterbody addressed was the Tualatin River southwest of Portland, Oregon. Preliminary nutrient budgets indicated that municipal wastewater discharges were the major source of elevated phosphorus loads. Even with extraordinary point source controls, calculations showed that phosphorus concentrations in the Tualatin would continue to create nuisance algae problems. Forest management activities in the basin were identified as one of the potential nonpoint sources contributing to elevated phosphorus in the Tualatin.

During this first introduction of forest managers to TMDL development, concerns were raised about how operations might be affected and whether meaningful load limits were possible for forest practices. As a result, the National Council of the Paper Industry

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for Air and Stream Improvement (NCASI) prepared a white paper on TMDLs, summarizing our understanding of the TMDL process and its application to forest management (Ice 1989). The white paper identified three key technical concerns:

- setting defensible and achievable water quality goals
- determining appropriate load allocations throughout a watershed based on the stream's assimilative capacity, routing, and water quality needs
- developing realistic compliance monitoring strategies

SETTING DEFENSIBLE AND ACHIEVABLE WATER QUALITY GOALS

Nonpoint Source Activities and Water Quality Standards

The application of water quality standards to dynamic forest systems was, and remains, a difficult issue. Harper (1987) concluded that water quality "*standards were developed primarily to address point source type pollutants and [do] not reflect the variable conditions necessary to describe nonpoint sources.*" This observation may reflect that most streams interfacing nonpoint source activities are small, first and second order streams, while most point source activities discharge to larger, less dynamic streams.

Forest streams have water quality that varies naturally with weather and location. Some state water quality standards now recognize extreme hydrologic and weather conditions. In Oregon, dissolved oxygen criteria are adjusted to 95 percent of saturation if altitude and natural stream temperatures preclude achieving the basic criteria (Oregon DEQ 1995). Stream water temperature exemptions occur during flows that are below the 7Q10 level (lowest consecutive 7-day average flow with a 10-year recurrence interval) or when air temperatures are above the 90th percentile of the 7-day average maximum (Oregon DEQ 1995).

The Role of Disturbance in Maintaining Forest Stream Functions

Disturbance creates another scale of variation in water quality. Two of the most spectacular agents of disturbance in forests are fire and windthrow. The 1933 Tillamook Burn in coastal Oregon burned 240,000 acres and consumed nearly 12 billion board feet of timber (Lucia 1983). While records about the effects on water quality are lacking for the Tillamook Burn they are obvious for other fires. In the Entiat Experimental Forest in Washington, severe storms following a wildfire caused numerous debris torrents and flood-flow events. These increased soil transfer rates by a thousand times or more. Klock and Helvey (1976) reported that there was evidence from the alluvial fans of torrents occurring periodically for centuries, probably in response to wildfires. Hornbeck, Lawrence, and David (1996) found that nitrate concentrations in runoff from forest watershed can be influenced by catastrophic fires occurring as long as 180 years ago.

Windthrow episodes, like the infamous 1962 Columbus Day Storm in the Pacific Northwest, can accelerate erosion and influence woody debris loads in streams. This storm, with winds of 170 mph on the Oregon Coast and 125 mph in the Willamette Valley, blew down an estimated 11 billion board feet across Oregon and Washington (Lucia 1963). Schwab (1983), in a landslide inventory for Rennell Sound on the Queen Charlotte Islands, British Columbia, found that debris torrents and mass failures in the forest were initiated by windthrow.

Some researchers even went so far as to suggest that catastrophic events, such as debris torrents, could benefit stream habitat for fish in some cases (Everest and Meehan 1981). These observations were highly criticized at the time. Today the role of natural disturbances is more clearly recognized. Short-term negative impacts from disturbances must be weighed against long-term benefits (Wootton 1996). Sediment pulses caused by landslides can move through streams, creating desirable off-channel habitat and spawning conditions (Benda et al. 1998). "Healthy" watersheds can have a mix of reach conditions. Different reaches in a watershed may simultaneously experience downcutting and deposition. First and second order streams should experience greater variations in conditions than higher order reaches. Redundancy and resilience become critical considerations for first and second order streams.

If human impacts are always within the scope of some natural events and these events are even beneficial in the long run, are human impacts always benign? No. Episodic disturbances may be less damaging than chronic and persistent disturbances (Harding et al. 1998). But watersheds have a capacity to adapt to both human and natural disturbances. Much of our concern about human impact is not about what will occur but when it will occur.

Identifying Actual Water Quality Needs in Forest Streams

The water quality which actually achieves beneficial uses can vary more than we commonly recognize. Monitoring of nutrients in the Yamhill Basin, near Portland, Oregon, found that *"...when samples taken on the same date were compared, water within the forestry land use class remained of high quality and free of algal blooms, although soluble and total P concentrations were the same as those found in other stream segments experiencing blooms and degradation. These observations, coupled with the high quality of the spring water, reflect the importance of additional variables on surface water quality, such as light, temperature, kinetic energy (flow velocity), and healthy riparian areas"* (Stewart 1997). In some cases, such as the eruption of Mt. St. Helens, water quality and habitat considered unfavorable for fish were found to be highly productive. This may have resulted from greatly increased instream primary production and an increase in high-quality macroinvertebrate food for fish.

Setting Achievable Goals

One frustration with TMDLs is that they often focus on the quality of water judged desirable for beneficial uses, without considering what is achievable. In the Tualatin Watershed, monitoring showed no relationship between phosphorus concentrations and level of forest management in headwater basins (Degenhardt and Ice 1996).

Further monitoring identified deep groundwater inputs as the source of high phosphorus concentrations in the summer (Tualatin Basin Technical Advisory Committee 1997), a product of Lake Missoula Flood deposits. Yet local agencies have been notified of pending lawsuits to enforce a water quality standard which can not be achieved.

DETERMINING REQUIRED LOAD ALLOCATION THROUGHOUT A WATERSHED

Spatial location is not only important for load generation, but also because it influences the routing of material and energy to downstream reaches. Inorganic sediment is often modeled as a conservative pollutant (not decaying and diminishing over time or distance), while biochemical oxygen demand is modeled as non-conservative. For a non-conservative pollutant, position is a critical component because time of travel and stream segment characteristics influence what fraction of the original contribution will be delivered downstream. All materials and energy are at least partially non-conservative.

Routing of materials and energy for forest systems remains a challenging problem. Holaday (1992) has shown that temperature changes in headwater tributaries may have little influence on main-stream temperatures. Zwieniecki and Newton (1999) found that small increases in stream temperature through buffered clearcuts returned to normal within 150 meters downstream. Load allocations should not be applied from mouth to headwaters in areas where headwater streams are not significantly contributing to water quality impacts.

COMPLIANCE MONITORING

Implementation of TMDLs requires compliance monitoring to insure that the load allocations and water quality goals are being met. Variability in natural systems make direct measurement of nonpoint source pollutant loads very difficult. For example, suspended sediment concentration can be influenced by factors such as the time since the last storm and the position on the hydrograph (rising or falling limb). In the Alsea Watershed Study near Toledo, Oregon, 36 percent of the suspended sediment for a 15-year period resulted from two storms (Moring 1975). Rice, Thomas, and Brown (1975) calculated that the number of samples required to detect a 10 to 20 percent change in suspended sediment for Caspar Creek in California and Needle Branch in Oregon may exceed the number of suitable magnitude events. However, if the goal is to detect a larger difference, such as 100 percent change, the number of samples required is an order of magnitude less. This is probably also biologically more relevant to designated beneficial uses.

Technological advances in field instruments, including portable continuous nephelometers and programmable pumping samplers, are also allowing us to detect smaller changes today than in the past. Advances in small electronic thermographs are especially remarkable. New, low-cost instruments can easily be programmed for months of near-continuous stream temperature monitoring and the data are then easily downloaded directly to a portable computer or other device. This is resulting in thousands of stations being deployed throughout forest watersheds. Patterns of stream temperature response to management and natural variations due to position in the watershed or climate are being identified.

Assessment approaches which can integrate background variations in water quality in a meaningful way are also being sought. Macroinvertebrates, as biological integrators of stream conditions, are being used more frequently to assess watershed conditions (Barbour, Gerritsen, and White 1996). For this approach the critical question remains, "What metric indicates an impact?" NCASI is supporting development at Idaho State University of a macroinvertebrate "tool" designed to identify elevated sediment loads. Similarly, the River Stability Index proposed by Rosgen (1999) is designed to provide a tool for assessing the effects of accelerated sediment yields on the physical and biological functions of the river, using integrating physical stream characteristics.

CONCLUSIONS

The three technical problems identified in 1989 (setting defensible and achievable goals, calculating load allocations throughout a watershed, and realistic compliance monitoring schemes) are clearly still with us. In 1989 there was some consensus that Best Management Practices (BMPs) were the tool of choice to control nonpoint sources, even for water-quality limited streams. That still seems to be true. The use of BMPs greatly simplifies compliance monitoring but it adds requirements for testing BMP effectiveness at different time and space scales and across watershed conditions. Watershed assessments and analyses are now seen as means toward refining BMPs for site-specific conditions.

What we probably underestimated in 1989 was the explosive expansion in assessment work loads that would result from mushrooming state 303(d) lists, a trend which has the potential to overwhelm state environmental agencies and landowners. In Oregon the 303(d) list has gone from 96 in 1988 to 1,168 in 1998 (See Table 1).

Table 1. Waterbodies on the 303(d) List in Oregon

Year	Number of Waterbodies
1986	28*
1988	96
1990	110
1992	128
1994/96	869
1998	1,168

* Original 11 streams for TMDL assessments and 17 streams for further evaluation, based on consent decree

Greenfield (1999) found that TMDL development can be cheap, fast, and accurate, but only two at a time. Court mandates and resource limitations may make these decisions for states. The Washington Department of Ecology recently calculated the cost of conducting TMDLs for the 666 waterbodies listed in that state as of 1996 (Wrye 1998).

The annual cost to the state is estimated to be $6.7 million over the next 15 years. This workload has caused both state and forestry interests to look at more efficient alternatives.

The emergence of Geographic Information Systems, access to inexpensive remote sensing data, and complementary watershed modeling tools was also not anticipated. Models like Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) (Lahlou et al. 1998) and Watershed Analysis Risk Management Framework (WARMF) (Chen et al. in press) provide tools that can be readily applied to broad watershed planning, although they have limits for forest watershed applications. The Distributed Hydrologic Soil and Vegetation Model (DHSVM), a spatially explicit model which can currently only address hydrology, has received wide attention (Storck et al. 1998). It provides a tool for testing alternative management scenarios but has some limitations, including a voracious need for data and watershed information. Rule-based attribute adjustments, such as modifying soil depth with geomorphic position, may improve watershed model performance.

Field assessments and inventories, such as those used in the Washington state Watershed Analysis procedure (Washington Forest Practices Board 1997), remain important watershed evaluation tools. Watershed analysis has proven useful in identifying appropriate management practices, but continues to be viewed with skepticism by agencies. Testing and refining these methods, which translate landscape conditions and stream types into site-specific BMPs, will improve nonpoint source controls.

Even with watershed analysis there are substantial costs ($3.50 to $5.00/acre). One approach to lower these is to apply findings from a few intensively evaluated basins to similar watersheds. Idaho, Oregon, Washington, and the USDA Forest Service have all considered this option. One of the most refined efforts of this type is by Plum Creek Timber Company, which is using geomorphic guilds (based on parent geology, landtype associations, valley bottom geomorphology, and stream order) to extrapolate the findings of intensive watershed analysis in subbasins throughout larger watersheds (Watson et al. 1998).

In summary, the basic technical questions haven't changed as much as our sophistication in asking questions and measuring change. There is a work overload facing water resource professionals, but the emergence of new integrative assessment methods, basin-scale data and modeling tools, and streamlined approaches to TMDL development (such as multiple-basin assessments) may be of assistance. The development and application of TMDLs for forest watersheds and monitoring their success remains a difficult problem; often best addressed through site-specific controls and field assessments.

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