CUMULATIVE WATERSHED EFFECTS: ISSUES AND ASSESSMENT

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CUMULATIVE WATERSHED EFFECTS:
ISSUES AND ASSESSMENT

Introduction

This report summarizes research on cumulative watershed effects (CWEs) and identifies how current knowledge about CWEs can be applied in timber harvesting plans (THPs).

Regulatory Requirements

The Forest Practice Rules (FPRs) define cumulative impacts by reference to the CEQA regulations contained in 14 CCR 15355, as follows:

> "Cumulative impacts" refer to two or more individual effects which, when considered together, are considerable or which compound or increase other environmental impacts.
>
> (a) The individual effects may be changes resulting from a single project or a number of separate projects.
> (b) The cumulative impact from several projects is the change in the environment which results from the incremental impact of the project when added to other closely related past, present, and reasonably foreseeable probable future projects. Cumulative impacts can result from individually minor but collectively significant projects taking place over a period of time.

Section 912.9 of the FPRs requires a determination of whether there are "any continuing, significant adverse impacts from past land use activities that may add to the impacts of the proposed project" and whether "the proposed project, as presented, in combination with past, present, and reasonably foreseeable probable future projects …" will "have a reasonable potential to cause or add to significant cumulative impacts …".

A critical issue in this determination is deciding what constitutes a "significant" impact. The FPRs define significant adverse impacts on the environment as "a substantial, or potentially substantial, adverse change in any of the physical conditions within the area affected by the project" and specify that "a social or economic change related to a physical change may be considered in determining whether the physical change is significant."

<u>CWE Research</u>

This review summarizes key cumulative effects concepts and results from research studies. For the purposes of this discussion, CWEs refer to the combined effect of multiple activities involving the processes of water and sediment transport (Reid 1998). Comments are limited to the impacts of multiple timber operations, which includes roading, yarding, log hauling, and site preparation. Where snow is not hydrologically significant, sediment resulting from timber operations is a much larger concern than increased peak flows (Rice 1981, 1989, 1990, Harr 1986). Lisle (1989) reported that CWEs are a sediment routing problem. Storage reaches, generally low-gradient, unconfined reaches of stream channels, are the most sensitive to impact, as well as the most productive for fish. Large increases in sediment loads affect channel morphology, including decreased depth and particle size and increased mobility and width. Studies in the Redwood Creek basin (Hagans et al. 1986, Weaver et al. 1986) and the Mokelumne River watershed (Euphrat 1992) have shown that most sediment comes from road systems —particularly from poorly designed crossings and inadequate construction and maintenance practices. In general, roads account for 75-95% of the total erosion from an area (Rice 1989).

Research conducted in the North Fork of Caspar Creek watershed has directly addressed cumulative watershed effects in California. This study was initiated in 1985 to determine the magnitude of CWEs. Approximately 50 percent of the North Fork was clearcut over about 7 years. Most of the logged units were cable yarded and new roads were built along the ridge lines. Nested watersheds with individual gaging stations measured sediment routing. None of the statistical tests performed on the sediment data revealed significant positive interactions that would indicate disproportionate disturbance effects at downstream gaging stations (Lewis 1998). In both pre and post-treatment, main stem gaging stations had higher unit area sediment loads than in the tributaries, which could reflect the greater availability of sediment stored in lower gradient reaches.

Hawkins and Dobrowolski (1994) attempted to create a large-scale model of watershed condition to predict land management effects on native trout throughout Northern California. The majority of the natural variation in trout abundance was not explained by any measured parameter, including land management. The magnitude of instream biological response to watershed disturbance associated with forest practices was small relative to nonanthropogenic factors.

Since CWEs span very long time frames, Ziemer et al. (1991a, 1991b) used Monte Carlo simulations to model CWEs on 5th order watersheds with varying management strategies. In these simulations, one basin was completely clearcut and roaded in 10 years, while another was cut at the rate of 1% each year with individual cut areas being widely dispersed throughout the watershed. Compared to the 1% strategy, the 10% strategy concentrated the timing of impacts and temporarily increased the potential damage to fish populations. The modeling indicated that current estimates of CWEs may underestimate their magnitude, because effects accumulate over much longer periods than previously considered.

CWE Assessment Methods Research

This section reviews methodologies that have been used to address CWEs and concludes with a brief discussion of what has been learned to date. Cumulative watershed effects (CWEs) have been discussed at length for at least two decades (Coats and Miller 1981), but fully defensible methodologies for approaching this complex problem have yet to be developed (Reid 1998). Natural systems are complex, natural variability of physical processes is extreme, and our knowledge of these processes is imperfect (McCammon 1991).

The initial strategy for addressing CWEs was to utilize proper on-site control measures to avoid or mitigate sediment production (Rice 1990). On-site control offers the closest linkage to cause and effect, direct mitigation of problem sites, and more direct estimation of associated risks (Rice 1989). Legal challenges (e.g., *EPIC vs. Johnson*, 1985), however, have required THPs in California to include a much more detailed CWE assessment, and BOF rules mandating CWE assessments were implemented in the fall of 1991.

Approaches for estimating CWEs in California have generally fallen into four categories: indices of land-use intensity, qualitative checklists, narrative discussions, and a research-based approach. The primary index of land use intensity is the US Forest Service Equivalent Roaded Area (ERA) method (Haskins 1986, USFS 1988, Kaplan-Henry and Machado 1991, Carlson and Christianson 1993). In this approach, basin characteristics are used to identify watershed sensitivity and assign a threshold ERA value. All logging related activities are assigned coefficients according to their estimated impact relative to that of a road, and each activity is assigned a rate of recovery. The percentage of a watershed covered by each type of activity at a similar stage of recovery is multiplied by the assigned coefficient to give an ERA value for that activity. The ERA values for all activities are summed to determine a total watershed ERA, which is then compared to the threshold value (Reid 1998). This approach provides a measure of ground disturbance, but does not directly relate to degraded channel conditions (Roby 1991), and Reid (1993) concluded that cumulative impacts can occur even when ERA is maintained at levels lower than the set threshold. McGurk and Fong (1995) found that only when ERAs were calculated for a 100-meter reach on either side of a watercourse was there a significant relationship to instream channel conditions.

CDF (1994) developed qualitative guidelines for use by RPFs on individual THPs to determine the likelihood of adverse CWEs. Current watercourse channel conditions are rated, impacts of past practices are evaluated, and potential impacts from the proposed project are developed based on the results of similar past activities. This approach relies on the user's expertise and experience, so results may not be reproducible (Reid 1993). However, it meets both BOF and CEQA procedural requirements and was upheld in the *East Bay Municipal Utility District vs. CDF and the BOF* lawsuit.

Many CWE assessments for THPs are simply narrative descriptions of topics specified in the BOF's Technical Rule Addendum No. 2. This includes disclosing where continuing significant impacts exist in a basin and, if necessary, a discussion of off-setting mitigations that will be used to reduce overall impacts to insignificant levels.

In some North Coast watersheds, *zero-net discharge* (Komar 1992) has been used to address CWEs. This requires estimating potential sediment production from the proposed project and from off-site problem sites. At best, these are crude estimations that depend to a large degree on climatic stress and actual on-the-ground implementation of practices.

Rice (1993) developed a procedure for estimating sediment related CWEs based on the results of the Critical Sites Erosion Study (Rice and Lewis 1991). In this approach, randomly located plots on roads and hillslope areas are used to estimate the volume of large events, based on relationships described in the CSES report, and surface erosion from the road plots. Estimated sediment production from the proposed project is then compared to existing sediment data for the watershed. In this analysis, cumulative effects are considered to be insignificant when anticipated sediment production is small compared to the range of natural variability in sediment flux.

There is general agreement among watershed specialists that the above methods for addressing CWEs are often inadequate. In the past five years, there has been a movement towards using watershed analysis as a more defensible methodology for assessing CWEs — particularly when landscape level assessments are being completed. For example, Berg et al. (1996) concluded that watershed analysis is the best approach to address CWEs in the Sierra Nevada Mountains. This approach utilizes a screening procedure to determine key issues and concerns, as well as the intensity of analysis needed for the basin under review. Modules have been developed to inventory and understand processes linking mass wasting, surface erosion, riparian function, fish habitat, and watercourse channel assessment (WFPB 1995). Understanding linkages is a key component of assessing CWEs (Berg et al. 1996). Highly sensitive areas or areas with vulnerable downstream beneficial uses of water have prescriptions developed to reduce impacts to insignificant levels — thereby pro-actively reducing CWEs. Monitoring to track the effectiveness of the prescriptions is an important component of this process. CEQA mandated CWE questions, however, are not directly addressed with this approach alone. Additionally, this method does not provide for evaluating the potential of future activities to contribute CWEs (Reid 1998). Reid (1998) concludes that it should be possible to design a watershed analysis approach that will provide the kinds of information necessary to evaluate CWEs, but this has yet to be accomplished.

In the past two years, rapid sediment budgets have come to the forefront of CWE assessment for highly degraded watersheds. Sediment budgeting is a valuable tool for evaluating sediment sources and transport (Reid and Dunne 1996) that can be used in CWE analysis. If roads, landings, and crossings are found to be a significant and ongoing sediment source, a road and crossing inventory can be completed, and a program can be developed to reduce the number of high risk sites in an acceptable time frame (Weaver 1997). When combined with effective hillslope practices to reduce on-site erosion (for example, see Weaver and Hagans 1994) and a valid monitoring program to provide a feedback loop on prescription effectiveness, this approach is likely to be the most effective procedure to effectively deal with adverse CWEs (NCRWQCB 1997b). A rapid sediment budget has been recently completed for the Garcia River watershed as part of the TMDL process (NCRWQCB 1997a).

In highly sensitive or controversial situations, the best approach for addressing CWEs may be use several different techniques to provide a more robust answer (R. Ziemer, USFS-PSW, per. communication). If several techniques generate similar answers, then resource professionals will have more assurance that a reasonable result has been produced.

In what is likely to be the best synthesis of the scientific literature regarding cumulative effects, Beschta et al. (1995) offer several conclusions regarding CWEs. Among their findings are the following points:

1. Channel changes following periods of sedimentation or removal of riparian forests along unconstrained watercourse systems are likely to last decades to centuries.
2. Early CWE methodologies attempted to develop a threshold level, beyond which catastrophic changes would occur. Natural systems, however, rarely recognize discrete thresholds and can respond incrementally and interactively to change.
3. Limiting harvest to a certain percent of the basin per year to keep annual sediment levels below a set level is a simplistic approach that does not account for regional or watershed variability, harvest location, yarding system, roading, etc. and assumes a direct causal mechanism between harvest and the magnitude of impact. In most cases, it is not the fact that trees were harvested, but how they were harvested, where on the landscape, methods of roading and yarding, degree of riparian protection, and other factors that determine the impact of a forestry operation.
4. If the accumulation of individual impacts from various forest practices provides the mechanism for causing a particular cumulative effect, then the prevention of potentially adverse impacts at the project level is of fundamental importance to preventing CWEs.

5. CWEs are ownership blind, in that they occur across a wide variety of ownerships and land uses. Basins seldom experience only one type of land use. Urbanization, grazing, agriculture, and other land uses can be important contributors to CWEs. Therefore, other land uses must be incorporated into solutions for cumulative effects.

Sediment Production and Transport

Sediment transport is a natural function of stream systems, and periods of both aggradation and downcutting will occur even under natural conditions in response to varying storm magnitude and watershed conditions. The downstream impacts of sediment on stream conditions and beneficial uses is a matter of balance, and the appropriate question about cumulative impacts is whether management activities will cause or add to significant, adverse changes in downstream beneficial uses.

The usual expression of excess sediment is deposition in lower gradient stream reaches that fills pools and raises the streambed elevation. This can cause increased overbank flooding and stream bank erosion that, in turn, leads to accelerated streamside landsliding and even more sediment input to the stream. For this to happen, management related and natural sediment contributions must exceed the natural range of a stream's ability to move sediment without causing major changes in channel conditions. In other words, the equilibrium of the channel is shifted from supply dependent, where the stream has an excess of transport capacity, to a stream power dependent situation where there is more sediment than the stream can carry.

Timber harvesting practices that have contributed to large scale erosion and sediment production include:

- Skidding down draws and otherwise disrupting intermittent stream channels.
- Constructing Tractor roads without waterbars.
- Abandoning road and skid trail crossings without adequate (or, in some cases, any) drainage.
- Diversion of streams at road and skid trail crossings onto road surfaces and hillslopes.
- Placement of roads and skid trails on unstable terrain.
- Inadequate compaction and other poor road and landing construction practices that created unstable cuts and fills.
- Inadequate drainage design for runoff from road and landing surfaces.
- Placement of roads adjacent to watercourses and sometimes within the high flow channel.

These practices, and many other potentially damaging timber operations, are now prohibited by the FPRs. However, the question remains as to whether current operations can generate sufficient sediment or other changes, such as increased flow, that will accumulate to cause significant impacts to downstream beneficial uses. In this regard, a brief comparison of results from the Caspar Creek watershed studies and work in Redwood Creek offer a useful perspective and context to the discussion of watershed impacts.

Logging in the North Fork of Caspar Creek was conducted under the FPRs at (and, in two subwatersheds, exceeding) the maximum area allowed by harvest unit adjacency limits of rules, which were made even more restrictive after the study. After clear-cut harvesting of approximately half of the timber volume covering about half of the watershed area, average sediment production in the entire North Fork watershed increased by about 90 percent (Lewis, in press). This appears to be a large proportionate increase, but equates to an absolute annual increase of approximately 0.8 yd^3/ac on the harvested area, and half that on the watershed as a whole. To date, the rate of landsliding in the North Fork has been similar on both the clearcut and uncut areas, and much of the increase in sediment production appears to be coming from erosion in Class III watercourses, which now receive additional FPR protection from mandatory equipment exclusion zones. In contrast, the percent increase in sediment production in the South Fork of Caspar Creek following pre-FPR tractor logging in the early 1970s was 2 to 3 times greater than was observed in the North Fork (Lewis 1998), and the rate of landsliding was greatly increased in the harvested areas (Cafferata and Spittler 1998).

Redwood Creek is a large watershed (in which Caspar Creek would simply be a tributary) that experienced severe channel aggradation following extensive pre-FPR logging and a series of large storm events. Total, post-logging erosion from hillslopes (primarily in the form of gullies) in the 48,000 acre lower basin study area averaged about 6 yd^3/ac, and averaged 137 yd^3/ac in a few high erosion subwatersheds (Hagans and Weaver, 1987). This difference from the Caspar Creek results is large enough to be meaningful, despite differences in relative erodibility of the watersheds, measurement methods, time frames, and scale between studies. It is apparent that proper implementation of the FPRs can reduce sediment inputs from logging to levels that are much lower than those associated with past operations that have been associated with severe watershed degradation.

More recently, however, severe aggradation of channels in the Bear and Jordan Creek watersheds of Humboldt County have raised questions about the effectiveness of the rules in extremely unstable terrain. Additional work on the sites and causes of major erosion events is needed to determine the relationship of timber harvesting to sediment production in these, and other similar, North Coast watersheds, and what, if any, additions to the FPRs would serve to reduce sediment related impacts.

Cumulative Impacts Assessment Requirements

FPR requirements for assessing cumulative watershed effects include:

- A description of the watershed assessment area.
- Identification of information sources.
- Identification and a brief description of the location of past and reasonably foreseeable probable future projects.
- Identification and a description of the location of any known, continuing significant environmental problems caused by past projects.
- Identifying beneficial uses of water, as listed in applicable Water Quality Control Plans, that could be affected by the proposed project.
- Consideration of watershed effects that include sediment, water temperature, organic debris, chemical contamination, and peak flow.
- Consideration of listed watercourse conditions that could result from changes in stream flow or sediment transport.

The plan submitter is specifically required to declare whether there are any continuing, adverse impacts from past land use activities that could add to the impacts of the proposed project, and whether the proposed project in combination with past, present, and future projects would have a reasonable potential to cause or add to significant cumulative impacts.

Methods used to accomplish these requirements, as previously described, usually include an inventory or some other form of identifying and evaluating projects, past impacts, and stream channel conditions. Approaches vary from cursory to complex, and inventories of assessment area conditions range from what the RPF remembers to a Washington State DNR level II watershed analysis. And even the most sophisticated inventory approaches are not sufficient without a thoughtful discussion of how the inventory findings are connected to conclusions about cumulative impacts.

Too often, CWE assessments suffer from a lack of connection between information about watershed conditions and conclusions about potential future impacts. For example, descriptions of landslide frequency or size and other evidence of erosion in areas of past road construction and harvesting should be discussed in relation to the potential impacts of proposed activities. And the required listing of projects should be linked to a discussion of how much of the watershed has been affected by these plans and whether they have resulted in previous adverse impacts.

Baseline Conditions

Current channel conditions reflect an on-going balance between sediment loads and stream transport capacity, and establish the baseline for evaluating sensitivity of the stream to additional sediment inputs. In addition, the evaluation of impact significance is often complicated by channel responses to unusual natural events. This can be looked at in two ways. One is that natural events set the base level against which the effects of future project impacts must be judged. Another possibility is that past project impacts may contribute to the effects of large storm events on hillslopes and in channels. For example, a large storm flow that fills downstream pools with sediment from upstream sources would create conditions that are more sensitive to impacts from future management activities, whether the upstream sources were natural or management related. If this sediment came from natural sources, the impacts of future projects on beneficial uses would need to be judged in relation to the new, more sensitive channel conditions. However, if the upstream sediment originated from management activities, it could result in a finding of significant, adverse impacts without additional projects that, at a minimum, would need to be combined with the impacts of proposed and future projects in subsequent CWE evaluations.

Incremental Effects

There is speculation that even small increases in sediment production, such as have been found in the North Fork of Caspar Creek, can accumulate to cause significant downstream impacts (Reid 1998). This may be the case for specific habitat conditions, such as increased fine sediments in spawning gravels as a result of chronic road erosion, but the connection to major changes in downstream sediment storage is not convincing. In the Redwood Creek example, 75% of the reported hillslope erosion came from a few subwatersheds, which indicates that erosion events with significant downstream consequences are likely to be large and readily apparent. However, small additions to an already degraded condition can have significant impacts on affected beneficial uses by contributing to the existing condition.

Recovery Rates

Preventing significant downstream sediment accumulations is primarily a matter of not exceeding a stream's ability to transport sediment through lower gradient reaches. Sediment from land management activities can be controlled by regulating practices to reduce on-site impacts, by repairing existing problems to off-set the impacts of new projects, and by limiting the rate at which new, sediment producing activities are introduced into a watershed relative to recovery from earlier activities. Types of improvements in practices have been identified above, so this discussion will concentrate on the effects of entry rates.

Slowing entry rates reduces the proportion of a watershed that is at risk of producing management related sediment at any one time. The effects of harvest areas and roads need to be considered separately because harvest areas are generally undisturbed between entries, while roads recover differently and are often used on a more frequent basis.

The total amount of harvest related sediment and the proportion of sediment production between harvest areas and roads will vary depending on logging systems and road location, type, design, and use and with differences in watershed sensitivity. Following are some generalizations about sediment production, erosion susceptibility, and recovery times that are suggested as a very general framework for thinking about relative impacts.

Harvest Areas – Near recovery to original or new baseline within 10 years:

- Sheet and rill erosion – Small proportion of total hillslope sediment production. Recovery to near zero in 3 to 5 years with majority in first 2 years.
- Gully erosion – Moderate proportion of hillslope sediment production. Usually develop within 10 years.
- Mass movement erosion – Largest source of hillslope sediment. Usually occurs within 10 years of harvest.

Roads – Initial period of recovery following construction, then continued erosion potential depending on location, type, construction methods, drainage design, maintenance frequency and methods, and storm size:

- Road surface erosion – Moderate proportion of total road erosion. Except in cases of drainage diversions, sediment production decreases to somewhat constant rate within 5 years unless graded or otherwise modified. A continuing source of fine sediments.
- Road cut erosion – Small proportion of total road erosion. Declines to somewhat constant rate within 10 years, depending on maintenance methods.
- Road fill erosion – Large proportion of road related erosion, primarily from mass failures and gullies. Declines to episodic failures initiated by large storm events.
- Road crossing erosion – Large proportion of total road erosion. Failure of seriously undersized or flawed designs within a few years. Subsequent failures dependent on storm size that exceeds capacity and upstream activities that plug culverts or increase flow.

Harvest areas can be expected to recover to near pre-logging levels within about 10 years. This includes shallow mass movements in areas susceptible to landsliding when the overall root strength of harvested and new vegetation is at a minimum.

The hazard of sediment production from permanent roads can also be looked at as a constant after about 10 years, although actual amounts will vary by road type and storm size – with less frequent, episodic events associated with large storms. Older (legacy) roads constructed near streams, in unstable areas, without adequate drainage, or having large amounts of perched fill material are likely to have much higher erosion rates. Overall, higher rates of surface erosion and failures due to poor design or execution are most likely during the first few years. Following this initial "settling in" period, continued sediment inputs are most likely to come from a relatively constant amount of background erosion associated with on-going use of the permanent road system. Exceptions include failures initiated by very large storms and continued bleeding of material from large erosion events.

At present, the only explicit limitations on rate of harvest are the FPR adjacency requirements, which result in at least a 5 year period between harvest of adjacent units or an average height of the 5 feet in the new stand with a 3 year minimum in the Coast District. Assuming the 5-year minimum re-entry period and 4 entries to completely harvest a watershed, this would limit the harvest of an entire watershed to about 15 years. In this hypothetical example, over half the watershed would be within the 10 year window of highest risk for mass movement at the same time, while about 10 percent of the watershed would be subject to the highest risk of surface erosion. This is similar to the situation at North Fork Caspar Creek, where half of the area was logged in about 7 years and the increase in sediment production has been relatively small. However, the impacts of a similar rate of harvest in more unstable or erodible terrain, or the occurrence of a very large storm, could lead to higher sediment yields. At a minimum, the potential impacts of such a high rate of harvesting should be addressed in the CWE assessment.

Control Strategies

The current FPRs contain sufficient authority to obtain adequate cumulative impacts assessment for THPs. Implementation of these rules, however, could be improved with training and development of background information on conditions that indicate a need for additional information during the review process.

How much sediment is too much for a stream system to handle will depend on its ability to transport more sediment and the magnitude of changes in sediment production from proposed THP activities. As described in the literature summary above, identifying thresholds at which significant impacts may be expected is complicated by the relatively gradual nature of responses to progressive changes in channel conditions, variations and lag times in channel conditions relative to hillslope conditions, and the influence of infrequent storm events. As a result, the test of significance for cumulative impacts has generally been based on a comparison of current channel and hillslope conditions with expected project impacts. The hazard of relying strictly on current conditions in evaluating project effects is that significant impacts may not be addressed until after they become apparent.

In general, a description of the overall watershed impacts of the listed past projects should be required in the THP along with a clear discussion of how information about past impacts, the proposed plan, and future projects is combined to reach the final conclusions about cumulative impacts on beneficial uses. In cases where a watershed analysis has been completed or is underway, the additional information about current channel conditions and sediment sources can be used to determine if the stream is responding to natural or management related impacts and to determine the present sensitivity of the stream to additional sediment inputs. The results of watershed analysis can also be used to identify the locations of high-risk areas and appropriate prescriptions. This can be viewed as a pro-active way to address “future impacts” from road building and harvesting.

In site specific situations, CDF can also require:

1. Intensive hillslope monitoring to provide a feedback loop on impacts and needed changes in practices.
2. Basing the approval of future THPs on monitoring results.
3. Timely completion of offsetting mitigation projects.

For example, intensive hillslope monitoring of completed THPs, including those completed in the last 5 years, can be used to determine the on-the-ground implementation and effectiveness of prescriptions and mitigation measures. Approval of future plans could then be based on incorporating successful mitigation measures and the development of improved methods to solve on-going problems.

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