Chapter 4: Using Management Measures to Prevent and Solve Nonpoint Source Pollution Problems in Watersheds

Management measures and associated management practices applied at harvest sites and along roads provide essential control of erosion and sedimentation, and it is important that all management measures and management practices applicable to a harvest site or road be applied to limit as much as possible the amount of soil erosion and the potential for water pollution that can result from forest harvesting activities.

The watershed perspective enables the practitioner to go beyond the effects from a single harvest area or individual road to consider all activities occurring within the watershed that could affect water resources. Each activity can have its own effect on water quality, and the watershed perspective views the effects due to harvesting and road construction within the context of the overall effects of forestry activities together with other activities such as recreational uses and conversions of land use. It is the collective effects of all of these activities that determine how water quality is affected, and these cumulative effects on water quality wouldn't normally be recognized if the effects arising from individual harvesting activities are considered alone.

Research has determined that the use of BMPs on forestland results in smaller increases in nutrients and suspended sediment load after logging than when BMPs are not used. This points to the need for a watershed approach to water quality management, and such an approach within the context of forest harvesting and road construction and use implies, at a minimum, the following:

- Applying management measures and management practices that are appropriate not only to the harvest site, but that take into consideration the current state of water quality in receiving waters, given all that is happening in the watershed, and the effect that forestry activities could have.
- The foreseeable future needs to be considered as well. Some effects of harvesting and road building can last beyond the duration of a harvest or the completion of road construction, and if other activities that could effect water quality are planned in the watershed in the timeframe during which those effects are expected to continue, mitigation of these long-term effects might be necessary.
- Maintenance of older roads built with outdated management practices (those dating from the 1950s to the mid-1970s), which can be significant sources of sediment, is an essential part of forested watershed management. Long-term management plans

for forest roads include their inventory, maintenance, and closure; and closure of unused, unneeded, and high-erosion-risk roads.

The EPA Watershed Approach

Watersheds are areas of land that drain to a single stream or other water resource. Watersheds are defined solely by drainage areas and not by land ownership or political boundaries.

Since 1991, the USEPA has promoted the watershed protection approach as a holistic framework for addressing complex pollution problems such as those from nonpoint sources. The watershed protection approach is a comprehensive planning process that considers all natural resources in the watershed, as well as social, cultural, and economic factors. The process tailors workable solutions to ecosystem needs through participation and leadership of stakeholders.

Although watershed approaches may vary in terms of specific objectives, priorities, elements, timing, and resources, all should be based on the following guiding principles.

- *Partnerships*. People affected by management decisions are involved throughout and help shape key decisions. Cooperative partnerships among federal, state, and local agencies and non-governmental organizations with interests in the watershed are formed. This approach ensures that environmental objectives are well integrated with those for economic stability and other social/cultural goals of the area. It also builds support for action among those individuals who are economically dependent upon the natural resources of the area.
- *Geographic focus*. Resource management activities are coordinated and directed within specific geographic areas, usually defined by watershed boundaries, areas overlaying or recharging groundwater, or a combination of both.
- *Sound management techniques based on strong science and data*. Collectively, watershed stakeholders employ sound scientific data, tools, and techniques in an iterative decision-making process. Typically, this includes:
  - Assessment and characterization of the natural resources in the watershed and the people who depend upon them.
  - Goal setting and identification of environmental objectives based on the condition or vulnerability of resources and the needs of the aquatic ecosystem and the people.
  - Identification of priority problems.
  - Development of specific management options and action plans.
  - Implementation, evaluation, and revision of plans as needed.

Operating and coordinating programs on a watershed basis makes good sense for environmental, financial, social, and administrative reasons. For example, by jointly reviewing the results of assessment efforts for drinking water protection, pollution control, fish and wildlife habitat protection, and other resource protection programs, managers from all levels of government can better understand the cumulative effects of various human activities and determine the most critical problems within each watershed. Using this information to set priorities for action allows public and private managers from all levels to allocate limited financial and human resources to address the most critical needs.

Establishing environmental indicators helps guide activities toward solving those high-priority problems and measuring success.

The final result of the watershed planning process is a plan that is a clear description of resource problems. Goals to be attained, and identification of sources for technical, educational, and funding assistance needed. The successful plan provides a basis for seeking support and for maximizing the benefits of that support.

Cumulative Effects

The watershed approach is a useful mechanism for managing the resources within a defined geographical boundary, and it provides a basis for cumulative effects assessment as well. Though it is not a formal analytical framework for the evaluation of cumulative effects, the watershed approach shares with cumulative effects assessment (CEA) a consideration of all relevant activities and influences. Furthermore, a watershed is a natural geographic boundary for the analysis of cumulative effects on water quality because the influences of upstream activities can create a cumulative effect on downstream water quality.

Definition

Current environmental regulations provide at least two definitions of cumulative effects (CEs):

> Cumulative effect is the effect on the environment which results from the incremental effect of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time (40 CFR 1508.7).
>
> Cumulative effects are the changes in an aquatic ecosystem that are attributable to the collective effect of a number of individual discharges of dredged or fill material. Although the effect of a particular discharge may constitute a minor change in itself, the cumulative effect of numerous such piecemeal changes can result in a major impairment of the water resources and interfere with the productivity and water quality of existing aquatic ecosystems (40 CFR 230.11).

CEs can be very difficult to quantify and assess, and they are best understood by focusing on the mechanisms by which watershed processes are affected (Reid, 1993). Watershed processes are affected when a land use activity causes a change in the production and transport of one or more watershed products (water, sediment, organic material, chemicals, or heat). Most land use activities affect only one of four aspects of the environment—vegetation, soils, topography, or chemicals—and other watershed changes result from initial effects on these. Understanding CEs within a watershed context involves: (1) understanding how specific land uses affect vegetation, soils, topography, or chemicals; (2) determining to what extent these changes affect watershed processes; and (3) understanding how changes to vegetation, soils, topography, chemicals, and watershed processes affect particular resources and values.

Cumulative effects can be additive or synergistic (MacDonald, 2000). Additive effects are those in which each land use activity creates a discrete effect on an individual resource or value and the total effect is the sum of the individual effects. Synergistic effects are those in which the combined effect of individual activities on a resource or value are greater than the sum of their individual effects. Synergistic effects can occur through the interaction of different chemicals or types of effects on a single resource. Many times with synergistic effects, each effect is analyzed and determined to individually not be detrimental to a particular resource, but the combined or cumulative effect of the three activities do create a significant impact on a resource.

Assessment of CEs should also take into account whether they are on-site or off-site. On-site CEs can occur if a change persists long enough for later activities to affect the same resource or for the effects of off-site activities to be transported to the site of the change. The temporal dimension of on-site CEs is important to their assessment, while the spatial dimension is limited to the original site of the effect. Off-site CEs occur when a land use activity causes a change in a watershed process such that effects are created at a location other than where the original land use activity occurred. Off-site CEs occur when watershed processes are altered long enough for the off-site effects to accumulate over time; when watershed processes are affected at multiple sites in a watershed and the watershed products that are affected are transported to the same site, or when an off-site effect interacts with an on-site effect. Both the temporal and spatial dimension of off-site CEs are important to consider when analyzing them.

The Importance of Considering and Analyzing Cumulative Effects

Cumulative effects are of concern with respect to forest roads; forest road construction, use, and maintenance; and forest harvesting because the changes that can occur in watershed processes following these activities can persist for many years. This persistence increases the potential for cumulative effects to occur.

Traditionally, effect assessment has evaluated the likely effects of single actions on the environment. But single areas and ecosystems are often affected by more than single actions or projects. The collective effect of numerous small actions can cause serious degradation, though the effects of each small action by itself might be undetectable. Even after an area or ecosystem has been degraded, an analysis of the effects of an additional action might conclude that there would be only minor or no significant effect. An analysis of the additive effect of the single additional action—the cumulative effects—however, might conclude that the action could be detrimental (USEPA, 1992). Cumulative effects analysis also differs from many types of traditional environmental assessment in the need to predict the consequences of "reasonably foreseeable future actions."

The importance of cumulative effects assessment, then, lies in the difference between traditional effect assessment and cumulative effects assessment. Traditional effect assessment is performed with respect to the proposed disturbance, whereas cumulative effects assessment is performed with respect to valued environmental functions (USEPA, 1992). An assessment of an action might have little to no detectable significant effect in terms of pollutant additions or habitat loss, as determined by traditional effect assessment, but might have a clearly disturbing effect on ecosystem functioning as determined by cumulative effects assessment. As more habitat is lost or fragmented and pollutants are generated, environmental stewardship demands that we pay more attention to the collective effects of our actions on ecosystems and their functioning and place less stress on the absolute quantities of pollutants that are generated or habitat lost as a result of each action. Cumulative effects assessment is the means to do this.

Problems in Cumulative Effects Analysis

Cumulative effects analysis, as conceived, is a powerful approach to assessing the overall effect of our actions on the environment and of managing those actions such that species and ecosystems continue to function properly. Unfortunately, many practical problems are associated with performing a cumulative effects analysis, including the following:

- Because total maximum daily load (TMDL) assessments calculate all point source and non-point source pollution for a watershed, a TMDL is essentially a cumulative effects analysis. Agencies responsible for implementing TMDL's have been hesitant to do so because of limitations in personnel, water quality data, and understanding of watershed dynamics. There is also a lack of available methodologies for tracking pollutants such as clean sediment (MacDonald, 2000).
- Ecosystems are complex and our knowledge of their workings is still limited, yet cumulative effects assessment involves identification of the ecosystem components of relevance that will be the focus of the cumulative effects analysis (Berg et al., 1996).
- The boundaries for cumulative effects assessment might be different from those relevant to other analyses, such as nonpoint source pollution or TMDL assessment. A single watershed might be appropriate for assessing nonpoint source pollution, but many watersheds might be involved in cumulative effects analysis for effects on forest conservation (Berg et al., 1996).
- Current guidelines published by the CEQ (1997) do not explicitly address natural processes, spatial variability, and temporal variability within project areas. Natural variability and rates of recovery can affect prediction and detection of cumulative impacts (MacDonald, 2000).
- Effects from individual projects often last for no longer than one human generation, whereas the time frame for changes in ecosystem processes that are the focus of cumulative effects assessment is typically an order of magnitude longer (Berg et al., 1996).
- The effects of most management activities diminish over time, and so then does the magnitude of possible cumulative effects. This leads to a problem of temporal scale related to determining the magnitude of human-induced cumulative effects relative to natural variability over a long time lag (MacDonald, 1997).
- The scale of cumulative effects analysis is very different from that used for traditional effect assessment, and effects due to individual projects might be undetectable using the analytical methods necessary for cumulative effects assessment. For instance, patterns on the landscape, such as whether 10,000 hectares are contiguous or not, are relevant for cumulative effects analysis; a small clear-cut, important at the local scale, might not appear in an analysis at a scale of thousands of hectares (Berg et al., 1996).
- When working at the scale necessary for cumulative effects assessment, areas that contain fragmented jurisdictions with multiple-agency oversight, differences in regulatory structure between jurisdictions and agencies, and conflicting interests and mandates are involved (Berg et al., 1996).
- To adequately assess the future consequences of multiple perturbations in a watershed, the status of ecosystem recovery from past perturbations must be estimated.

> Complexity of the analysis increases because recovery times for various components in a system are not necessarily identical, and knowledge is often inadequate to quantify recovery rates. For instance, "recovery" of stream flow magnitude and rate after timber harvest is largely a function of the rate of revegetation of the watershed. Sediment produced by roads associated with the timber harvest will typically take much longer to move through stream channels and "recover" to pre-road levels. Understanding of both types of recovery is needed and they cannot be substituted for each other.

Within the context of forestry activities and forested watersheds, the following difficulties are encountered when attempting to assess cumulative effects (Reid, 1993):

- The effects of forest management activities on streamflow has been studied extensively, yet it remains difficult to determine what effects a management activity will have on a stream because hydrologic response varies greatly with basin size, flow magnitude, season, climate, geology, and type and intensity of forest management activity. The results of studies done in one basin are therefore difficult to extrapolate to other basins. It can be important to determine whether forestry activities will have effects on watershed processes because of the potential consequences if the effects are substantial enough, but such a determination can be costly. It can also be costly, however, to take measures to prevent watershed effects from forestry activities when such effects might not materialize.
- Variability in storm intensity and runoff processes limit the ability to detect human-induced effects on streamflow. Even with years of monitoring data, it can be difficult to distinguish between human-induced effects and natural variability in watershed processes. The process of determining cause and effect is complicated by the fact that different activities can cause similar responses and one activity might not always elicit the same response.
- The dynamics of natural forest communities must be understood to interpret or predict the effects of changes, and natural disturbance frequencies, patterns, characteristics, recovery rates; these are not well understood. Monitoring would be a useful tool to increase our understanding of these dynamics, but the sequences of changes that can lead to CEs, or the combinations of changes that can lead to CEs are varied and can take long periods of time to take effect (e.g., 50 years). Monitoring these effects is often not possible due to the time frame involved.
- If a system responds incrementally, changes can be easily identified; but many changes, such as landslides or floods, do not occur incrementally. Instead, changes, such as loss of vegetation water storage and increased soil compaction, might be relatively benign and accumulate until some event, such as a 50-year storm, triggers a substantial response. These thresholds at which substantial and important CEs occur often cannot be predicted, and knowledge of them is based on studying them after they occur.
- The rate of recovery from land use depends on the type of land use and on the watershed processes that are affected.

Approaches to Cumulative Effects Analysis

Four general approaches for predicting cumulative effects include the use of analytical models, assessments of previous management activities, use of a collection of procedures that address specific anticipated impacts, and use of a checklist to indicate what cumulative effects might be expected to occur because of a land use activity. Models can be used to predict changes to physical or biological aspects of a watershed, or to predict the magnitude of change in a watershed process or characteristic that might trigger a particular type of impact (Reid, 1993). Models are useful because the cumulative effects of repeated timber harvests in a watershed could be estimated or monitored experimentally only in a study lasting several centuries (Ziemer and Lisle, 1991). While modeling does represent a simplification of nature and depends on a modeler's skill, modeling results can represent average conditions and explore the effects of large spatial and temporal scales. They can also be useful for conducting "what if" analyses, where the effects of different sequences of harvesting or precipitation events, for example, are explored. This characteristic of models contrasts sharply with monitoring studies, in which the unique sequence of events that occurs during a monitoring distorts the results.

Many models have been developed for specific locations and cannot easily be applied to other areas. The limitations of the models are stated in user's guides or instructions for use, but the models, nevertheless, are often put into general use regardless of whether the assumptions of the model are valid for a particular application or whether the methods of the model have been tested and validated (Reid, 1993). Many models are meant to be used to predict particular impacts, yet their methods are used to test for the likelihood of a variety of other possible impacts for which the method was not developed. Used properly, however, models can shed light on the importance of processes and variables to watershed behavior and treatment effects, but have limited value for precisely predicting watershed behavior (Reid, 1993). A large amount of data generally is required for modeling, and its acquisition can involve intensive monitoring. Data analysis also can be complex, and these factors have kept the use of models very limited (MacDonald, 1997).

Slightly less complicated than modeling would be an analysis involving a broad-scale assessment of previous management activities. Such a method would use one or more management indices to assess the relative likelihood of a cumulative effect, rather than explicitly modeling cause-and-effect (MacDonald, 1997). The EPA Synoptic Approach and the *Washington State Watershed Analysis Method* (described below) are examples of this level of analysis.

Another approach for assessing cumulative effects consists of a collection of procedures used to evaluate a variety of impacts. A relevant subset of impacts is generally considered. This approach provides flexibility in determining what impacts will be considered, but it provides no guidance on determining which impacts should be evaluated (Reid, 1993). The *Water Resources Evaluation of Non-point Silvicultural Sources* (WRENSS) (described below) method is an example of a procedure-based approach.

A third general approach consists of a checklist of items to consider during an assessment. A checklist provides guidance in determining what impacts to evaluate but does not provide methods for doing so (Reid, 1993). Checklists are useful for (1) identifying which issues to look at in more detail, (2) helping to ensure that a range of issues are considered, (3) providing a simple means to address the issue of cumulative effects assessment. Disadvantages associated with checklists include the strictly qualitative nature of the assessments, their lack of repeatability, and their lack of documentation (MacDonald, 1997). The California Department of Forestry questionnaire (described below) is an example of a checklist assessment method.

Each approach has its strengths and weaknesses, and a workable approach should be a combination of these separate approaches. For example, a checklist or expert system could be used to guide users through a decision tree to identify the impacts to be considered, and then a set of procedures could be selected to address them (Reid, 1993). Modeling could be employed to assess the sensitivities of the watershed to various treatment scenarios.

Five techniques that have been developed for assessing cumulative effects are described below.

1. EPA The Synoptic Approach

The Synoptic Approach was developed by EPA for the evaluation of cumulative effects on wetlands for section 404 permit review. It does not provide a precise, quantitative assessment of cumulative effects, but is used to rate cumulative effects on resources of interest (Berg et al., 1996). The Synoptic Approach has two major steps—definition of the synoptic indices and selection of landscape indicators.

Synoptic Indices

Four synoptic indices are used for assessing cumulative effects and relative risk—function, value, functional loss, and replacement potential. The function index refers to the total amount of a particular function a wetland provides within a landscape subunit without consideration of the ecological or social benefits of that function. Landscape elements function within landscapes through physical, chemical, and biological processes to provide habitat, cleanse water, prevent flooding, and perform other functions. The value index refers to the value of ecological functions with respect to public welfare. Tangible benefits (e.g., hunting, camping, timber, carbon dioxide sequestration) and intangible benefits (e.g., aesthetic, existence value) can both be included, as well as future value as the future benefit of the functions performed. Note that the value index does not represent economic value since market factors are not considered. The functional loss index represents cumulative effects on a particular valued function that have occurred within a landscape subunit. A complete loss, where an ecosystem element is changed into something else entirely, is a conversion. A partial loss, where ecosystem element type is the same but functioning is altered, is degradation. In the course of a cumulative effects assessment, future loss is considered per the Council on Environmental Quality's regulations (40 CFR 1508.7). Functional loss depends on the characteristics of a particular effect, including the type of effect; its magnitude, timing, and duration; and ecosystem resistance, or the sensitivity of the ecosystem element to disturbance. The replacement potential index represents the ability to replace an ecosystem element and its valued functions. Functional replacement through ecological restoration or natural recovery are both considered. Protection of ecosystem elements and functions is critical for risk reduction if their replacement potential is judged to be low (USEPA, 1992).

Landscape Indicators

Landscape indicators are first-order approximations that represent some particular synoptic index. Quantifying specific synoptic indices for large landscape subunits would be difficult if not impossible, so the Synoptic Approach uses landscape indicators of actual functions, values, and effects (USEPA, 1992).

As an example, a particular management concern might be nonpoint source sediment loading to streams. Nonpoint source sediment loading would then be the synoptic index used in the Synoptic Approach. Since it would be difficult to quantify this over a large area, total area harvested might be chosen as a landscape indicator for forest harvesting. Total harvested area would be the data used to determine cumulative nonpoint source sediment loading effects on the area of concern.

The Synoptic Approach is an ecologically based framework in which locally relevant information and best professional judgment are combined to address cumulative effects. It is not, however, meant to be used to assess the cumulative effects of specific actions. Rather, it is really meant to be used to augment site-specific review processes and to improve best professional judgment. It is probably most effectively used at extremely large landscape scales, such as the state level (Berg et al., 1996). The approach is valuable because it is flexible enough to cover a broad spectrum of management objectives and constraints—the specific synoptic indices and landscape indicators used in an application can be chosen based on the particular goals and constraints of the assessment—and it certainly need not be limited to assessing effects on wetlands. The process allows managers to weigh the need for precision against the constraints of time, money, and information (USEPA, 1992).

2. Washington State Watershed Analysis

The Washington State Watershed Analysis method is used to develop forest plans for individual watersheds based on current scientific understanding of the significant links between physical and biological processes and management activities. The first step in use of the method is screening a watershed to qualitatively define and assess areas of sensitivity to environmental change within the watershed. If any area is found to be sensitive, then the area and the causal mechanism must be addressed by a management plan appropriate to the problem. The management plan will define more precisely the potential effects of management actions and management alternatives. The method uses separate assessment modules for mass wasting, surface erosion, hydrologic change, riparian function, stream channel assessment, fish habitat, water supply/public works, and routing through the fluvial system (Berg et al., 1996).

The Washington State Watershed Analysis process is a collaborative one that involves both scientists and managers, and its products generally are area-specific management prescriptions and monitoring recommendations (Berg et al., 1996).

3. Water Resources Evaluation of Nonpoint Silvicultural Sources (WRENSS)

The WRENSS is a process-based approach to evaluating timber management impacts (Reid, 1993). It consists of a series of procedures for evaluating separate impacts, though it is not intended specifically to address CEs. The original focus of the method was water quality and consideration of the effects of timber management and roads. While its procedures do not address resources other than water quality, it would be possible to add additional methods to evaluate impacts on particular resources and to assess the effects of other land uses. Use of the method can be complex and time consuming.

The method is based on computer simulation modeling that delivers graphs and tables as results that are used to estimate changes in evapotranspiration, flow duration, and soil moisture from different logging plans. Temperature changes are incorporated using a separate model, the Brown model, and sediment modules include methods for estimating surface erosion, ditch erosion, landsliding, earthflow activity, sediment yield, and channel stability.

Application of the method to CE analysis would require the identification of likely environmental changes generated by a project, likely downstream impacts, and the mechanisms generating them.

4. California Department of Forestry Questionnaire

The California Department of Forestry and Fire Protection developed a questionnaire for use by registered professional foresters to assess potential cumulative watershed effects (CWE) from timber management. Completion of the questionnaire involves a four-step process: (1) perform a resource inventory in the assessment area; (2) judge whether the planned timber operation is likely to produce changes to each of those resources; (3) identify the effects of past or future projects; and (4) judge whether significant cumulative effects are likely from the proposed operation. Onsite and downstream beneficial uses, existing channel conditions, and adverse effects from past projects are identified and listed during the first step. The area for analysis is one of manageable size relative to the timber harvest—usually an order 3 or 4 watershed. During the assessment, the user rates the magnitude of a variety of potential effects from the proposed and future projects, and combined past, present, and future projects. The assessment serves as an indicator of need for further review.

Responding to the questionnaire relies on the qualitative observations and professional judgment of the person filling out the forms. The questionnaire is designed to be used within the time constraints of the development of timber harvest plans and serves primarily as a checklist to be certain that all important issues have been considered. Its strength lies in its flexibility: the checklist can be easily altered to accommodate a wide variety of situations and harvesting conditions.

The California Department of Forestry questionnaire addresses a wide variety of uses and effects and includes many that are not related to water quality, e.g., recreational, aesthetic, biological, and traffic uses and values, but it provides only qualitative results. The questionnaire is the only CWE evaluation method that uses an assessment of more than one type of effect from more than one type of mechanism, and it is one of few that incorporates an evaluation of effects that accumulate due to past, present, and future actions (Berg et al., 1996).

5. Phased Approach to Cumulative Effects Assessment

MacDonald (2000), put forth a conceptual process for assessing cumulative effects. The process is an attempt to overcome some of the problems with other approaches to cumulative effects analysis (CEA), including problems in defining key issues, specifying the appropriate spatial and temporal scales, and determining the numerous interactions and indirect effects to analyze. The assessment is broken down into three phases: scoping, analysis, and management.

- The scoping phase is further broken down into steps in which the issues, resources, time scale, spatial scale, risk, and assessment effort are identified for the cumulative effects analysis. The analysis phase is likewise subdivided into five substeps.
- In the analysis phase researchers identify and analyze cause-and-effect mechanisms; natural variability and resource condition; past, present and future activities; relative impacts of past, present and future activities; and validity and sensitivity of the overall cumulative effects analysis.
- The management phase identifies possibilities for mitigation and restoration, as well as key data gaps and monitoring needs.

Figure 4-1 illustrates MacDonald's process for assessing cumulative effects.

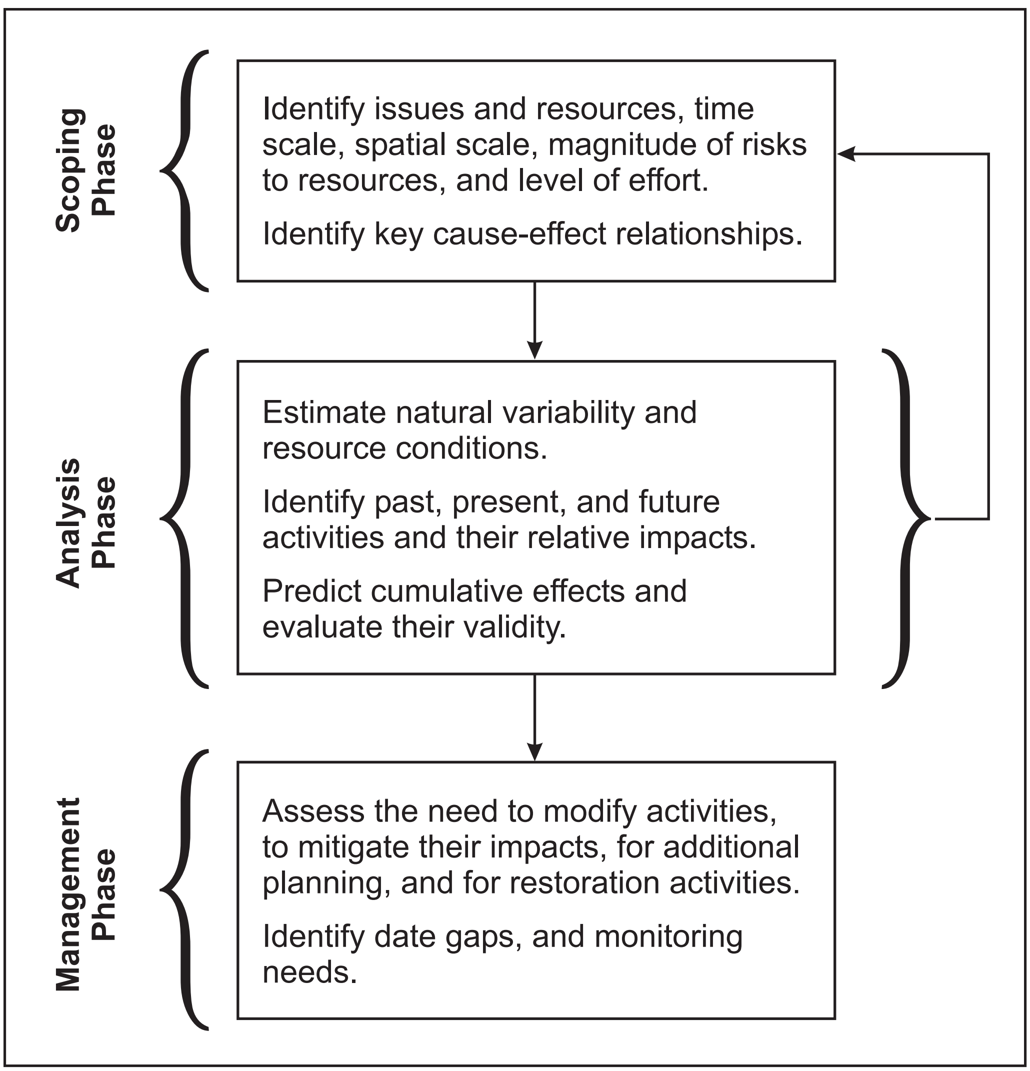

Figure 4-1. Representation of MacDonald's process for assessing cumulative effects (after MacDonald, 2000).

The President's Council on Environmental Quality (CEQ) published guidelines for performing CEA (CEQ, 1997). The CEQ methodology is broken down into three groups of steps that are designed to be integrated into three components of an environmental impact assessment (EIA). The EIA components relevant to CEA are scoping, describing the affected environment, and determining the environmental consequences.

- In the scoping component of an EIA, the CEA steps are to identify significant issues and define assessment goals; establish spatial boundaries of the CEA; establish temporal scale of the CEA; and identify other activities that affect natural and human communities.
- The affected environment component of the EA should incorporate the following CEA steps: characterize the resources, ecosystems and human communities and their resilience to stress; define stresses and regulatory thresholds for measuring stresses; and define baseline conditions for the area defined in the CEA.
- The environmental consequences component of the EIA should identify CEA cause-and-effect relationships between human activities and resources; determine the significance of cumulative effects; develop alternatives to minimize or mitigate significant cumulative effects; monitor cumulative effects and adapt management accordingly.

CEQ lists seven primary methods to develop baseline data and analytical models for cumulative effects analysis (CEA):

- Questionnaires, interviews, and panels to gather initial information
- Checklists to review important activities that may contribute to cumulative effects
- Matrices to tally cumulative effects
- Networks and system diagrams to qualitatively analyze effects of multiple activities on multiple resources in the analysis
- Modeling to quantify the cause-and-effect relationships within the CEA
- Trends analysis to use baseline data to extrapolate future cumulative effects
- Overlay mapping (GIS) to perform spatial analysis and identify areas of high and low impact.

Appendices to the CEQ report provide examples of each method and how it is might be used in CEA. The report is available on the World Wide Web at <http://ceq.eh.doe.gov/nepa/ccenepa/ccenepa.htm>.

The MacDonald (2000) and CEQ (1997) guidelines share many similar components. The spatial and temporal boundaries of the CEA are defined first, along with the resources that will be impacted by cumulative effects. Detailed analysis of cause-and-effect relationships follows, and baseline data is developed to describe present conditions. Both methods include monitoring and mitigation steps toward the end of the process. MacDonald's framework differs from the CEQ methodology by including natural variability in systems, consideration of past and future activities, sensitivity analysis of predictive models, and an up-front determination on the level of effort that is appropriate for the assessment. MacDonald's refinements help address some of the hurdles to CEA implementation that have hampered past efforts.

Forest Watershed Management: An Example

The Umatilla National Forest, located in the Blue Mountains of southeast Washington and northeast Oregon, covers l.4 million acres of diverse landscapes and plant communities (USDA-FS, 1999). The forest has some mountainous terrain, but mostly consists of V-shaped valleys separated by narrow ridges or plateaus. The landscape also includes heavily timbered slopes, grassland ridges and benches, and bold granite outcroppings. Elevations range from 1,600 to 8,000 feet above sea level.

The Forest is administered by the Forest Supervisors Office in Pendleton, Oregon, along with four Ranger Districts located in Pomeroy and Walla Walla, Washington, and Ukiah and Heppner, Oregon. The actual on the ground management of the forest resources is accomplished at the Ranger District level by the District Ranger and staff, while the Forest Supervisor oversees management and administration. The Forest is challenged daily with protecting both the productivity and the aesthetic values of the land. Managing to provide many resources, benefiting many people "for the long run" is the key principle guiding the Umatilla Management Team.

Because water from the Blue Mountains is important for so many uses, proper management of the watersheds in the Umatilla National Forest is strongly emphasized. The goals of the watershed management program are as follows:

- To maintain streams that are cold, clean, and free of excessive sediments and human-caused pollution.
- To keep stream banks, channels, wetlands, and adjacent floodplains healthy.
- To restore damaged lands to their previous, productive condition.
- To maintain near-natural amounts of runoff water.

The Umatilla National Forest Plan includes important direction for achieving these goals. The plan envisions a basic three-point program for managing forest watersheds:

1. Inventory Basic Watershed Resources

Proper management of a forest watershed demands a good understanding of basic components—soil, water, climate, and vegetation. Managers at the Umatilla National Forest upgrade the resource information base for the forest by conducting the following inventories and surveys:

- Soil
- Water
- Fishery resources
- Potential watershed improvement projects
- Riparian zones (areas adjacent to streams and lakes)

These watershed surveys provide vital information for improving the management of surface water resources.

2. Apply Best Management Practices

The Umatilla National Forest has developed "best management practices"—policies, standards, and methods of operation designed to reduce harmful effects on water while still allowing use of other resources. Maintaining stream surface shading to prevent fish-bearing waters from overheating during the summer is an example of general practices applied throughout the forest. Others are developed specifically for a particular activity.

Forest managers work together in the project planning stages to identify the nature and risk of potential hazards to water resources. As a result, projects can be modified to avoid problem areas and reduce water resource damage.

The forest's watershed management program emphasizes the prevention of problems before they occur. However, it is sometimes necessary to treat watershed problems resulting from past practices. Such treatments might include restoring wet meadows, recontouring gullied lands, or stabilizing eroding stream banks.

Recently, a program to control and treat the acidic wastewater draining into a forest stream where salmon and steelhead spawn was begun in the Umatilla National Forest. These wastes, produced by abandoned gold mines, are now treated in man-made bogs, where toxic metals and other harmful substances are filtered out. Initial results have shown a dramatic recovery in water quality.

3. Monitor and Analyze Results

An extensive water-monitoring program has been developed for the Umatilla National Forest. It measures success in achieving the goal of maintaining healthy and abundant water resources. Monitoring stations are strategically placed at forest management projects to measure

- Stream flow
- Water temperature
- Suspended sediment and turbidity
- Shape and condition of stream channels and riparian areas
- Precipitation, snow pack and other climatic factors
- The soil's ability to infiltrate and hold precipitation
- Physical, chemical and biological components of water quality

These measurements provide a better understanding of how management activities affect water resources and whether our efforts are effective in maintaining high water quality.