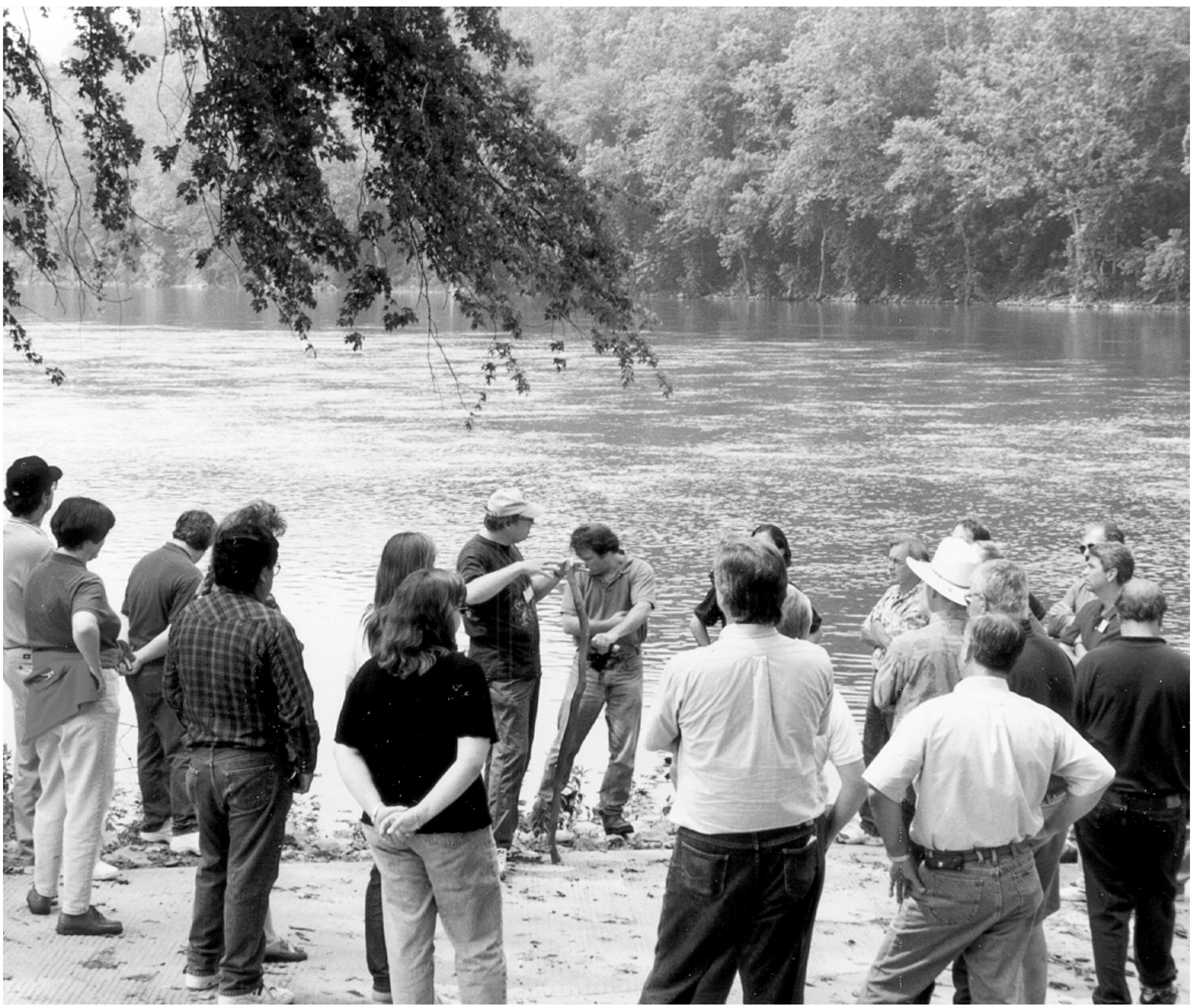
Part VI:

Implications for Source Water Assessments and for Land Management and Policy



A U.S. Fish and Wildlife Service class on "working at the watershed level" at the Potomac River near Sheperdstown, WV. Photo by Stephen Glasser

Chapter 21

Future Trends and Research Needs in Managing Forests and Grasslands as Drinking Water Sources

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Introduction

The management of forest and grassland watersheds for drinking water supplies has been, and will continue to be, a major activity of the Forest Service and other natural resource agencies. However, these watersheds will continue to support other uses, including providing timber products, recreation, mining, fisheries, grazing, and the conservation of biodiversity. In addition, relatively new uses like using forests for carbon and nutrient sequestration (DeLucia and others 1999) or the recycling of wastewater (Cole and others 1986, Sopper and Kardos 1973) will increase. The future is also expected to bring increased competition for existing water resources (Postel 1998) and changes from point source to watershed-based pollution management (U.S. EPA 1997). How these watersheds will be managed in this increasingly competitive, watershed-based, multiuse environment will be affected by site-specific knowledge of environmental change, technological change, and social and administrative considerations.

Environmental Change

It is widely believed that the Earth is undergoing a period of rapid global climate change that will significantly alter environmental conditions in many areas during the 21st century (Schlesinger 1997). Most global-scale climate models predict that in the next 50 years the Earth will be warmer, more humid, and have greater evaporation, precipitation, and runoff (Loaiciga and others 1995). However, not all areas will be affected equally, and large areas of the United States may actually experience more arid conditions. Projections based on historic hydrologic conditions and projected demands suggest that areas east of the Great Plains and in the Pacific Northwest will have water surpluses until 2040 (Guldin 1989). In contrast, much of the Colorado and the Rio Grande River basins, the Great Basin, parts of California, and the lower Mississippi Valley currently have or will have water shortages by 2040. Moreover, 11 out of 18 water resource regions of the Continental United States are currently diverting more than 20 percent of their streamflow for off-site uses and will be affected by changes in either streamflow or water demand (U.S. Department of Agriculture, Forest Service 2000). The availability of water is predicted to seriously constrain global food production by 2025 (Postel 1998). Water shortages and aquifer depletion already affect many of the World's most important food-producing regions, including the Western United States, northern China, the Punjab of India, and parts of Southeast Asia, Africa, and the Middle East.

In addition to global-scale change, local and regional environmental change can be expected to influence municipal water supplies. These changes can occur over years or decades and may include changes in land uses or increases in air pollution and atmospheric inputs. Increases in upstream water withdrawals or changes in the types of water uses (irrigation, snow making, etc.) can also modify water quality and temporal patterns of streamflow. Changes in the successional status of forest cover or the presence of exotic or noxious weeds can also affect source water quantity and quality (see chapter 11). Shifts in management practices can also influence local environmental conditions that affect municipal water supplies. Increased harvesting on steeper slopes, growing wood in high-input, short-rotation plantations, and intensively managing fisheries are some examples (see chapters 10, 17).

In response to the influence of local and regional environmental changes, assessments are now being developed to evaluate regional risks of specific environmental hazards (Graham and others 1991). A generic problem encountered when doing these assessments is the lack of ecosystem-specific information on the spatial and temporal variability of ecological and pollution-generating processes. Fortunately, technology advances in data acquisition and in the management of spatially explicit data using Geographical Information Systems (GIS) is rapidly improving this situation. Nevertheless, an administrative commitment to long-term environmental monitoring, data analysis, and

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synthesis is required to develop adequate assessments and verify ecological and resource management models.

Technological Change

The ability to provide safe drinking water depends on how technology is used to: (1) measure the quantity and quality of water, (2) run treatment plants and distribution systems, and (3) charge consumers for the water they use and the pollution they generate. Advances in the technology used to accomplish these tasks are expected to improve municipal water management. Meanwhile, other anthropogenic activities can be expected to create new chemicals, new pathogens, and presently unknown water-quality problems.

Increased competition for water resources and increased emphases on instream water quality are anticipated to increase the scrutiny of water supply and pollution management. Fortunately, recent advances in the technology used to acquire hydrologic data are greatly improving our ability to measure and monitor water resources. At the regional scale, advances in climate modeling and remote sensing have increased the ability to monitor precipitation and water resources over large areas. At the local scale, automated sensors and wireless communication systems are monitoring streamflows and water withdrawals, nutrient and pollution concentrations, stream channel morphology, and the migration of aquatic organisms. Moreover, real-time monitoring is currently being used to manage irrigation systems, water supply reservoirs, flood warning systems, and biotic migrations in rivers. Future developments are expected in the technology to monitor pesticides, special chemicals, and microbiological constituents. If pollution standards based on total maximum daily watershed loads replace standards based on average point-source discharges (U.S. EPA 1991), we would expect improvements in the technology for low-cost monitoring of temporal variations in water quality.

New technology and scientific understanding can be combined to improve the timing of land-use treatments. Recent examples of this type of management include: (1) the timing of streamwater withdrawal and release to minimize impacts on the migration of aquatic organisms (Benstead and others 1999, Bistal and Ruff 1996); (2) the timing of fertilizer application to growth phases of agricultural crops to minimize nutrient runoff (Matson and others 1998); (3) timing the abundance of grazing with the growing season of range and riparian vegetation (chapter 14); and (4) the scheduling of insecticide application to the life cycles of pests (Balogh and Walker 1992; chapter 13). The success of these life-history-based management schemes requires detailed knowledge of local environmental conditions; high-quality, spatially explicit monitoring; and institutional memory of past successes and failures.

While automated data collection techniques are essential to accurately monitoring hydrological and ecological processes, it will remain technically and economically impossible to monitor and treat for all contaminates, at all locations, at all times. Furthermore, without proper analysis, the automated collection of massive amounts of data can hinder rather than assist management. A major challenge for watershed management in the 21st century will be the development of spatially explicit analytical methods and institutional structures that can rapidly synthesize information about environmental conditions so managers can make informed, defensible decisions in a timely fashion. In response to this challenge, many natural resource organizations are developing data management and environmental decision-support systems (Lovejoy and others 1997, Spencer 1996). These decision-support systems will eventually integrate real-time hydrologic measurements with GIS and multiobjective decision models. Multiobjective models have been used for decades in the design and operation of reservoirs and water and wastewater distribution systems because they provide a formal and logical structure for organizing and synthesizing scientific, environmental, and social information (Hipel 1992). Nevertheless, their adoption as to real-time management tools will be a considerable challenge. Developing and verifying site-specific models to establish maximum daily pollutant load allocations for specific management practices or individual landowners will also be a major research and management challenge (U.S. EPA 1991, 1997). Moreover, just collecting real-time, water-quality information to be used in complex models can be a daunting task (Bistal and Ruff 1996).

Administrative Change

Because of high engineering and environmental costs associated with developing new water supplies, the emphasis in water management is shifting from the development of new sources toward the efficient and equitable use of existing supplies (Frederick 1993, Kneese 1993). Likewise, the costs and risks associated with transforming polluted water into potable water are increasing the emphasis on maintaining source water quality. In response to these shifts, the administrative structures and organizational relationships used to manage municipal water systems are also changing. One reflection of this change is the number of regional water management councils, stormwater utilities, waste management districts, and watershed restoration groups that have recently been established (Mann 1993, Shabman 1993, Taff and Senjem 1996) (see examples in appendices A, B). These new organizations typically develop to help manage the complexities associated with the mismatch between natural water regions, political districts, and the geography of water demand and wastewater generation.

While new organizational structures are developing in some regions, many traditional water and pollution management organizations are caught in a vicious cycle (World Bank 1993). Because of unreliable and poor-quality services, consumers are unwilling to support increase tariffs for water management and pollution control. Inadequate operating funds lead to further deterioration of services by the overextended agencies. To successfully deal with these problems, economists have championed “user-pays” and “market-based” approaches to water and pollution management for over 45 years (Busby 1955, Kneese 1993). For municipal water systems, this approach has typically meant establishing variable rate structures to promote conservation and/or the privatization of water management services. Several different market-based approaches have been promoted for pollution control, including the use of effluent charges, tradable effluent permits, tax on the use of substances that threaten water quality, and open competition for interbasin or interregion water or pollutant transfers (Mann 1993, Taff and Senjem 1996).

While these market-based approaches have been widely promoted by economists, water resource managers have been less enthusiastic about their adoption (Brookshire and Neill 1992, Taff and Senjem 1996). The principal stumbling blocks are usually the technological and organizational requisites for monitoring and enforcing the complex and dynamic trade of water resources and pollutant effluent. Recently developed data acquisition technology allows pollution discharges and water withdrawals to be monitored continuously. It, therefore, is generally believed that these market-based, watershed-based approaches will increase in the near future as water-quality regulations based on watershed-wide maximum pollution loads are implemented.

Site-Specific Considerations

The social and environmental responses to changes that can affect municipal watersheds are complex because different ecosystems and processes respond at different rates and in different magnitudes (Schimel and others 1996). Furthermore, the risk and consequences of inaccurate decisions are not evenly allocated across the landscape or population (Frederick 1993). Therefore, site-specific research and monitoring are needed to develop local and ecosystem-specific understandings of the processes that effect water quality at a particular location**.** For example, removal of a road requires site-specific analysis, or the disturbance caused by road closure may accelerate rather than reduce erosion (Elliot and others 1996) (see chapter 9). Likewise, the impacts of grazing also require an understanding of the specific grazers and the local, seasonal cycle of rangeland vegetation (see chapter 14). The response of atmospheric deposition of nitrogen also depends on the level of nitrogen saturation of the receiving ecosystem and seasonal variations in plant growth and nitrogen use (Fenn and others 1998). Toxic algal blooms in lakes can occur in specific portions of some lakes and result from unique combinations of site-specific climatic events and management operations (James and Havens 1996) (see chapter 5, Hebgen Lake case study). The abundance and frequency of herbicide use also depend on site conditions and can range from never to several times each year (Balogh and Walker 1992) (see chapter 13). Furthermore, the width and composition of buffer zones needed to contain certain chemicals, reduce impacts of grazers, or maintain aquatic habitat also are ecosystem and problem specific. Water-quality changes due to ozone-induced stress on conifers are also closely related to location-specific forest cover changes (Graham and others 1991). Likewise, the impacts of accidental chemical spills or other historical legacies that alter water quality are site-specific and require local knowledge and institutional memory to be properly assessed and efficiently managed.

The importance of understanding the timing of specific environmental events and processes is an additional theme in many of the chapters in this report. For example, the amounts and impacts of recreation on site and water quality are regional, seasonal, and episodic (see chapters 6, 7, and 8). The use and, therefore, the potential influence of wildlife on water quality can also vary with seasonal and diurnal behavior and the abundance of specific populations (see chapters 15, 16, and 17). Grazing behavior also varies with season, species, and the age of individuals (chapter 14). Likewise, determining life histories and vectors of waterborne human pathogens is also essential for evaluating site-specific risks and management options.

The length of time that a particular activity affects water quality also varies with land use and site-specific characteristics. Sediment yields or concentrations following timber harvesting typically decrease as a negative exponential relationship while changes in nutrient concentrations occur in relatively brief pulses (see chapter 10). Sediment yields from roads typically peak in the first few years but can remain elevated for decades, while contamination from roadside fuel spills can last for years (see chapters 9, 11). Likewise, the residence time of fecal contamination in streams can be on the order of weeks to months (see chapter 2). Mining debris can acidify surface and subsurface water for decades or longer (see chapters 18, 19).

Developing methods and monitoring protocols to determine and predict environmentally critical time periods is an additional challenge that will require the interaction of scientific information, technology, and administrative structures. The future success of these interactions will depend on the availability of high-quality, spatially explicit, long-term environmental data. In many regions, assessments of municipal water supplies will provide invaluable baseline information for future managers.

Conclusion

The flow of water across the landscape and its collection and distribution through a municipal water system are complex and dynamic processes. Because of the complexities and risks involved, some basic level of water treatment and monitoring is always necessary. However, it is technically and economically impossible to monitor and treat for all contaminates, at all locations, at all times. Providing the necessary levels of watershed protection, treatment, and monitoring to sustain supplies has been, and will continue to be, a major challenge. The dramatic improvements in U.S. water quality that have occurred during the last few decades clearly demonstrate the success that integrated, continued management can have. It is hoped that this report will assist water resource managers to successfully identify critical problems and protect the best and restore the rest.

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Chapter 22

Synthesis

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Introduction

Forest and grassland watersheds have traditionally been relied upon as sources of drinking water with relatively little contamination. Recent results from the National Water-Quality Assessment (U.S. Geological Survey 1999) reaffirm that, nationwide, water from forest and grassland watersheds is lower in many pollutants than that from watersheds dominated by urban or agricultural land use. These findings do not contradict the scientific evidence reviewed in this report, which shows that many types of common land-use practices and natural processes in forests and grasslands can introduce contaminants into water sources. Rather, taken together, these results indicate that although land-use practices in forests and grasslands can introduce contaminants, the characteristics and intensity of these practices, when applied over large areas, produce water that is cleaner in many respects than other, more intensive land-use practices. At the local level, forest and grassland management may cause significant problems for drinking water sources. For example, high-intensity activities such as logging, mining, or urban-style development in forests can cause considerable pollution as can uncontrolled events such as floods, landslides, or accidental chemical spills. At the regional level, contaminants from forests and grasslands, even where low in concentration, are part of the overall, cumulative load of water pollution. Thus, assessing the risk of contamination for drinking water systems with source areas in forests or grasslands is not fundamentally different from assessing risks in areas with other types of land uses. Regardless of land use, assessments should be done on a case-by-case basis, analyzing the natural processes and human activities that can reasonably occur in the source area to estimate the likelihood that contaminants will be transmitted to a drinking water intake.

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Drinking Water Contaminants and Treatments

Contaminants of concern for drinking water have been classified and standards for acceptable levels set by the U.S. Environmental Protection Agency (EPA). The relationship between specific forest and grassland best management practices and drinking water quality is complex and was not treated in detail in this report. Best management practices and the protection that they provide for water quality vary considerably from State to State and are evolving over time. As effects on human health from contaminants in drinking water become better understood and as new substances are released to the environment, changes in drinking water standards can be expected in the future. Standards for drinking water do not apply to source water before it has been treated to remove contaminants. Standards set under the Clean Water Act (Public Law 80–845) that apply to ambient water as it flows in a stream or lake are not intended to ensure that water is drinkable without treatment. Considerable treatment may be required to purify water that meets the ambient standard to make it comply with the drinking water standard. For examples of forest and grassland management practices that have been proposed to protect water quality, see U.S. EPA (1993), copies of which can be ordered from the Web at http://www.epa.gov/OWOW/info/PubList/publist4.html.

Drinking water treatment technology can be designed to reduce most contaminants in source water to an acceptable level before delivery to consumers. The cost of treatment, however, usually increases substantially as the amount of contamination in source water increases. Adopting appropriate land uses and management practices that do not contaminate source water has the potential to be more cost-effective than treatment of source water that has been contaminated.

Cumulative Effects

Although different types of land use are treated separately in this report, in an individual watershed many different land uses affect source water quality simultaneously. Land uses occur in complex patterns that overlap on the landscape and change over time. Relatively few studies have examined the cumulative effects of several land uses distributed over time and space. Most studies have focused on relatively small areas and short time periods. Some of the tools that are needed to analyze cumulative effects at large scales have only become available recently. More information is needed on the interactions among multiple land uses in complex and changing patterns because complexity is typical of watersheds in which land management is likely to affect public drinking water sources.

Effects of Natural Processes and Human Activities

Drinking water sources are affected by numerous natural and human-influenced processes that occur in watersheds. The processes by which water and contaminants move through watersheds are relatively well known. The risks these processes pose to source water can be severe, especially during extreme natural events such as floods and landslides.

Water quality may be affected where water is dammed, impounded, diverted, or augmented for a variety of human purposes that may or may not be related to drinking water use. These activities often alter flow rates and residence time of water. They change turbidity, sediment storage and transport, and oxygen content of water. Considerable information is available about effects of these manipulations on source water, but this information must be applied on a case-by-case basis. Removal of old dams may pose risks for drinking water sources downstream. Sediments and toxic contaminants or both in the material accumulated behind the dam can be mobilized. Few studies, however, have evaluated this risk.

Intermixed urban and wildland uses, developed administrative sites, and concentrated recreational sites share a number of similar risks for source water. Runoff from impervious surfaces and improperly functioning sewerage treatment facilities can contaminate surface water, while poorly performing septic systems and leaking underground fuel storage tanks can pose risks for both surface and ground water. Systems that are old, inadequately designed, and/or poorly maintained represent the highest risks. Forms of concentrated recreation that involve direct water contact, such as bathing beaches, may have a high potential for contaminating surface water but have been little studied.

Dispersed recreation activities that attract people to spend time near water bodies, but lack developed sanitary facilities, can introduce fecal organisms, presumably including pathogens, into surface waters. However, few studies have been done to determine thresholds above which dispersed use contaminate source water excessively. Many other potential effects of dispersed recreation on drinking water sources, such as risks associated with pets and off-road vehicles, are poorly understood and need further research.

Roads and other utility corridors pose risks of contamination because they concentrate many human activities. Roadside recreation facilities are often centers of dispersed recreation. Roads also support transport of chemicals, some of them toxic. Chemicals may be spilled during accidents; the highest risk of water contamination is where roads cross streams. Utility corridors present similar risks due to incidents such as pipeline failures or transformer fires that may spill chemicals. Road and corridor construction, maintenance, and use have been shown to contribute sediments to streams because they have elevated erosion rates and can increase the risk of landslides on unstable terrain. Proper engineering design, construction and maintenance of roads and utility corridors, as well as emergency preparedness can reduce but not entirely eliminate these risks to source waters.

Many researchers have studied the impacts on water quality from manipulating forest vegetation for purposes such as timber and fiber production including growing trees, harvesting them, and reestablishing forest vegetation. The primary contaminant to source water from these activities is sediment associated with soil disturbance during harvesting and regeneration and erosion from roads. Enrichment of streamwater by nitrate after forest harvesting has been reported in some parts of the country. Mounting evidence suggests that this response in some regions may be explained by mobilization of long-term accumulations in forest soils of nitrogen compounds that were deposited from air pollution. The degree and areal extent of this effect needs further study.

Most modern pesticides and herbicides that are currently used on forests and grasslands are immobilized and degraded in soils to the extent that they pose little contamination risk to source water if required application precautions are followed. Even though the use of pesticides that resist breakdown in the environment has largely been discontinued, some of these substances may persist in the landscape as a result of past use. They may pose problems for source water, especially if deposits of these chemicals in soils or sediments are mobilized by disturbance.

Prescribed fire is normally conducted under conditions when fire severity is low and impact on source water quality under these conditions also is low. Wildfires, however, can be severe. When they occur on steep or erodible terrain and are followed by intense rainfall, they can produce large sediment loads that pose problems for source waters. The causes of high nitrate levels in streams after fires in areas with high air pollution, and the effects of fire retardant chemicals on source water need further study. The effectiveness of emergency rehabilitation practices to stabilize watersheds after severe wildfires also needs more investigation.

Land management that results in domestic or wild animals being concentrated near surface water can contaminate source water, but in most cases the risk of transmission to source water is little understood. Domestic grazing animals, such as cattle, have been shown to introduce sediment and fecal organisms into surface waters. Streamside buffers and other practices that reduce contact between grazing animals and surface water can reduce contamination risks. Although many wildlife species are known to carry pathogens, relatively little is known about the risk that wildlife-carried pathogens pose for source water. The few studies of wildlife effects on water quality mainly involve ungulates, such as elk and deer that pose risks analogous to domestic grazing animals when wild ungulates reach high concentrations near surface waters. Fish hatcheries can introduce fecal matter and chemicals if these substances are flushed from hatchery facilities to source waters. Less-intensive forms of fisheries management, such as altering fish habitat by introducing large woody debris and restoring habitat for anadromous fish runs, may also have effects on source water but these aspects have been little studied. Large concentrations of water birds can introduce pathogens into surface water, and measures are sometimes taken to discourage water bird congregations near drinking water intakes.

Mining has the potential to contaminate source water with sediments, acids, toxic metals, and other introduced chemicals from mining residues and ore processing. Many of these effects may be abated or mitigated during active mining but can pose long-term risks to source water if mines are not properly decommissioned after mining ceases. Oil and gas exploration and extraction can cause risks from spills of oil and drilling fluids and cross-contamination of aquifers if well casings are not properly sealed. Abandoned wells that are not adequately capped may be used for illegal dumping that can contaminate source water.

Implications of Scientific Uncertainty

Evaluating risks associated with managing forests and grasslands that are sources of public drinking water requires close collaboration among managers, scientists, and the public. Clearly, the most current scientific findings need to be considered in this process, but the participants in this joint effort will need to recognize that science alone cannot solve many management problems. An appropriate role for science is to provide the public, in the case of government-owned land, or the responsible party, in the case of private land, with a better understanding of the effects of land-use decisions on drinking water sources.

As should be apparent from this report, there are many situations in which scientific studies provide limited or, in cases where knowledge is scant, almost no basis for evaluating risks of some activities to public water sources. To cite a few examples: the risks to source water from dispersed recreation, from the deposition of nitrogen compounds from air pollution, or from newly discovered pathogens might prove to be difficult to estimate with current knowledge. When contaminant sources are suspected, but their effects on source water are highly uncertain, it is prudent to implement backup activities such as monitoring of water quality at source water intakes. Monitoring may offer additional benefits beyond limiting the immediate risk to human health. It can also allow landowners and land managers to learn from experience; they can adjust future management practices on the basis of past results and can help to reassure the public that their water source is being protected even where predictions of land-use effects cannot be made precisely. To deal with large, uncontrolled events with severe consequences, such as floods or accidental chemical spills, emergency preparedness measures should be instituted. In this way, public water supplies can be protected by minimizing damage from such potential catastrophes.

Gaps in scientific knowledge about the effects of forest and grassland management on drinking water sources indicate areas in which future research can provide large potential benefits for land managers. Some examples emerged in the preparation of this report. There has been very little research on the risk that land management activities may introduce disease organisms into source water. Research is needed on the potential to transmit pathogens to source water from urban-wildland intermixed development, from water contact activities such as swimming as well as recreational pursuits that occur in areas without developed sanitary facilities, and from management that concentrates animals near source water. Animals that may transmit pathogens include water birds and other wildlife, as well as domestic animals such as livestock and pets. Research is needed on how land management activities such as timber and fire management in areas of high nitrogen deposition from air pollution may affect the release of nitrates into source water. There is a need for research on how forest and grassland management practices affect the economic costs and benefits of providing safe drinking water and to whom costs and benefits may accrue.

Implications for Source Water Assessments

The Forest Service and other government agencies are developing relatively new management approaches, such as ecosystem management and sustainability, to ensure the long-term viability of species and human communities that depend on public land. A key objective of these practices is to consider a broad spectrum of values in land management. Source water assessments are consistent with this approach because they increase the public's awareness of source water protection as a value to be included in land management. Teams that perform source water assessments should be composed of individuals from a wide variety of disciplines and should draw upon a wide spectrum of public opinion to ensure that the many relevant points of view are included in the analyses. In addition, these teams should make an effort to integrate across disciplines because many risks to source waters arise at the intersection of activities traditionally considered to be the subject of separate disciplines. For example, an impoundment constructed for the sole purpose of storing source water could become a source of contamination if it attracted large numbers of water birds to feed or roost on the reservoir or drew large numbers of recreationists to enjoy its shores.

Assessments should consider activities that take place in sensitive parts of the landscape that have strong linkages to surface water. Activities in these sensitive areas should be examined carefully for contaminant risk, especially during floods. Examples of areas with strong hydrological linkages to surface water are: active stream channels or lakebeds, riparian areas, floodplains, and areas near wetlands, springs, and seeps. Surface water moves quickly through the landscape. Contaminants that reach surface water can reach drinking water intakes rapidly, with relatively little time for transformation or removal by natural processes. When incidents such as chemical spills contaminate surface water, fast action may be needed to protect drinking water. Once the source of surface contamination is contained, however, the rapid movement of surface water tends to flush away contaminants quickly. Where possible, potential contaminant sources should not be permitted in these areas, and vegetated buffer strips should be retained in these zones.

Some sensitive areas may be linked by gravity to surface water. Steep slopes and areas with unstable geomorphology close to water bodies carry high risks. Activities that disturb the soil surface or remove significant portions of the vegetation in these sensitive areas may cause high erosion rates or landslides that may increase sediment loads for drinking water sources downslope.

Some sensitive zones may also have strong biological linkages to surface water. Both wild and domestic grazing animals are strongly attracted to surface water, especially in arid areas or during droughts when forage may be concentrated near water. Water bird populations and migratory fish can likewise be drawn from long distances to suitable habitat in or near water. Management actions that cause high animal concentrations in or near drinking water sources need to be carefully examined for their potential to introduce contaminants.

Some sensitive parts of the landscape have strong linkages to ground water that is used for drinking water sources. Recharge areas that have high infiltration of water to aquifers are particularly susceptible to contamination. Ground water and its contaminants usually move very slowly. This may allow long warning times for systems that rely on ground water, e.g., when contaminants are detected in ground water moving towards drinking water wells. However, once an impurity is introduced into an aquifer, contamination may be essentially permanent because ground water movement may take a very long time to flush away impurities. Exceptions exist where underground conduits such as caves, permit rapid underground flows, making predictions of underground contaminant movement very uncertain. Facilities such as septic systems, leach fields, underground fuel tanks, and dumps in sensitive aquifer recharge areas are potential contamination sources and need careful maintenance and monitoring. Illegal dumping of toxics in recharge areas may go undetected until it reaches a well, producing potentially serious consequences for health and disruption of water supply.

Not all contaminants pose the same risks. Contaminants such as toxic substances and pathogens that can cause serious health problems if they are consumed in drinking water obviously deserve a high priority in assessing risk. Contaminants that do not pose a direct threat to health but may make water less palatable, or may interfere with or increase the cost of treatment such as clean suspended sediment, color, odor, or taste should logically not receive as high a priority as health-threatening contaminants, but the economic cost of treating these nonhealth-threatening contaminants should be included in analyses.

Source Water Protection as a Priority for Land Management

In principle, providing safe drinking water to protect human health is a high priority in our society. In practice, this priority is often not well represented in land-use decisions. As was suggested in chapter 4, appropriate land-use practices that protect clean source water may be more cost-effective for society as a whole than removing pollutants after the fact. However, decisions about land uses and their effects on water are often made piecemeal and potential savings often are not realized. Source water assessments can help to forge the connection between land use and drinking water protection by better informing land managers and the public about that linkage. For society to fully benefit, other mechanisms may need to be established that more closely link the outcomes of land management to its effect on drinking water sources. In chapter 4, an example was cited of how a water utility provided an economic incentive for land managers upstream to control contaminants. Many other legal, institutional, or economic arrangements could potentially produce similar, positive effects on source water quality. Managers of land and of drinking water systems should be encouraged to cooperate to protect drinking water safety at the local level, but more fundamental and far-reaching changes may be required at the policy level to enhance incentives that encourage such cooperation and to overcome obstacles that inhibit it.

The human values that drive economic and political decisions affecting drinking water sources are reflections of the values held by the general public. Over time, the values that people place on natural resources can be expected to change and the purposes that public lands serve will likewise change. A challenge for land managers and the public will be to see that, as new patterns of land uses arise in the future, the importance of safe sources of drinking water to protect human health is given due consideration among the competing uses of forests and grasslands.

We hope that land managers, scientists, and the public will draw upon the basic scientific information in this report and apply it to their local watersheds as they participate in source water assessments in their State. We expect that they will also draw upon their own experience and use their best professional judgement to decide what portions of this work are most relevant to their particular setting within their individual source areas. In doing so, they may find important factors and interactions at work in their particular watersheds that we have overlooked, and will reveal future research needs. We look forward to the results of their analyses, because they will advance the understanding of the relationship between land management and source water quality. Their efforts will be an important next step toward better protection of drinking water sources in future land management decisions.

Literature Cited

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