Evaluation of the Assessment, Integration of Findings, Data Gaps, and Future Work

Specific objectives of the aquatic resource assessment were to collect, assimilate, and analyze existing data with the purpose of identifying past, current, and future trends within the Southern Appalachian Assessment (SAA) area. The role of this assessment was to catalog and report information rather than form management decisions or recommendations based on that information. From the inception of this assessment, the aquatic resources team was directed to provide an analysis with a broad view of the aquatic resources across the entire region without limitation by national forest, national park, other federal ownership, state, or private land boundaries. This ambitious goal was begun with the realization of a need to balance the amount of information gathered against restricted financial resources and a short time frame. No such assessment has ever been completed by an interagency team working part-time with such limited resources.

Aquatic resource data collection sites were scattered, sometimes sparsely, across the SAA area. Where data did exist, they were often of questionable quality or derived from inconsistent sources. Definitive conclusions based on such limited data would be risky. Consequently, for many aquatic resources, the team could not determine with confidence the current status or likely future trends across the SAA as a whole. Where information was available and there was reasonable confidence in the data, aquatic resource status was discussed and future trends were projected. Specific findings from all chapters are summarized in the executive summary and chapter 1 of this document. The reader should recognize this assessment as an initial step toward gathering the detailed information required to document the current condition of aquatic resources over the SAA region.

The aquatic resource team faced other challenges throughout the development of the project. Each federal agency has its own mission and culture, and these differences are reflected in the various viewpoints presented in this report. The land cover TM satellite data – necessary for the completion of the aquatic technical report – were delayed, almost too late to be included in this report. Despite setbacks, delays, and limitations, the aquatic resource team worked diligently to meet the objectives of the assessment within the allotted time frame. This often required long hours and a great deal of dedication from the team members and people from the various agencies supporting the effort.

The assessment was a success and has yielded some valuable lessons and insights not only in terms of aquatic resources, but also in demonstrating that cooperative relationships between various agencies, through a shared common vision, can accomplish a formidable task. Each agency brought specific regional data to the process: water quality data from The U.S. Environmental Protection Agency (EPA); maps, streamflow, and water use data from the U.S. Geological Survey (USGS) and Tennessee Valley Authority (TVA); and land cover data from the USDA Forest Service, to name a few examples. The assessment would not have been successful without this sharing of data and resources.

In this final chapter, three major topics that span the questions in chapters 2 through 6 will be addressed: integration of findings; data gaps; and future work, including monitoring needs, research opportunities, and some ideas for future assessments.

Integration of Findings

Where possible, aquatic resource assessment findings were integrated with findings from the atmospheric, terrestrial, and social/cultural/economic assessments (SAMAB 1996a; SAMAB 1996b; SAMAB 1996c). Some integrated findings were reported in chapters 2 through 6 of this report. There are many more opportunities for integration of data and our findings with those from the three other technical teams. Further integrated analyses will be simplified because data will be accessible through the Internet. This section contains brief discussions of several additional findings that integrate data from two or more of the technical reports.

Recent Human Population Trends and Projected Wastewater Infrastructure Needs (1995-2005)

An analysis of human population trends and the anticipated wastewater infrastructure needs over the next 10 years indicates that areas with high population density (more than 168 persons per square mile) are generally also counties with projected wastewater infrastructure needs greater than $100 million (fig. 5.1.23). Moderately high-need counties ($10 million to $100 million) are also counties with relatively high population density or counties expected to experience a significant increase in population.

A notable exception to this relation concerns several counties in the southwestern portion of Virginia that have a relatively low population density and stable or declining growth, but which anticipate treatment and collection construction costs between $10 million and $100 million per county (fig. 5.1.23). This region of Virginia will likely have some of the highest per-capita costs for wastewater treatment in the SAA area because both human population densities and anticipated growth are low.

Interaction of Mining Impacts with Atmospheric Sulfate Deposition

Southwestern Virginia, specifically Wise, Dickenson, and Buchanan Counties, have the largest number of active mines per county (fig. 5.1.5). These counties are also in a region that has a high potential for adverse impacts due to atmospheric sulfate deposition (see Atmospheric Technical Report [SAMAB 1996a]). Because the historic and current mining activities in these counties have already impacted the water quality of several streams (fig. 5.1.4), it is not likely that the sulfate due to air deposition will result in further significant degradation. Other watersheds in the SAA area also have documented impacts due to past mining practices (fig. 5.1.4) that would probably mask some of the potential impacts due to deposition of atmospheric sulfate.

Several areas of moderate to high potential for sulfate deposition do not contain large numbers of mining operations. Here, observable impacts, such as decreased pH and acid neutralizing capacity or loss of acid-intolerant aquatic species due to atmospheric sulfate deposition are most likely. These areas are candidates for trend monitoring to better characterize the long-term impacts of atmospheric sulfate deposition on aquatic resources in the SAA area.

Roadless Areas and Wildernesses as Refuges for Terrestrial and Aquatic Plant and Animal Resources

Roadless areas and wildernesses potentially provide increased protection for the plants and animals that live in these areas. Nine federally listed T&E species in the heritage program EOR database occur in wildernesses in the SAA area – one amphibian, one bird, one mammal, and six plant species. Likewise, 19 federally listed T&E species occur in roadless areas 2 bird, 2 fish, 5 mammal, 1 mollusc, 1 other invertebrate, and 8 plant species.

Terrestrial viability concern and aquatic special concern species in the heritage program EOR database were also found in roadless areas and wildernesses. In roadless areas, 4 amphibian, 1 bird, 2 fish, 5 mammal, 1 reptile, 6 invertebrate, and 65 plant species were found. In wildernesses, 4 amphibian, 1 bird, 3 mammal, 2 mollusc, 9 other invertebrate, and 47 plant species were found.

Ten rare communities are represented in wildernesses, and 11 rare communities are represented in roadless areas.

Roadless areas and wildernesses do not appear to provide refuge for large numbers of federally listed T&E species, terrestrial viability concern species, or aquatic special concern species. However, these areas may protect more species than were represented in the heritage program database. Some species may be difficult to find in these areas. Other species may have been found but not reported to the heritage programs.

Roadless areas and wildernesses can provide protection for trout and a special kind of backcountry trout fishing experience. Roadless areas in the SAA area include 2,431 miles of potential wild trout streams. Wildernesses include an additional 846 miles of potential wild trout streams. Together, wildernesses and roadless areas include about 10 percent of the streams that potentially support wild trout.

Population Pressure on Aquatic Systems Due to Land Uses

Increasing human population density and the resulting intensive human uses of the landscape place high stresses on aquatic systems in many areas and have the potential for increasing pressure on aquatic systems due to nonpoint source pollution and habitat degradation. Population density in the study area has increased from 79.7 per square mile in 1970 to 101.8 per square mile in 1990; the area's population is projected to grow an additional 12.3 percent by the year 2010.

Land covers that may represent human activity (e.g., developed or barren, cropland, and pasture or herbaceous) already exceed 50 percent of the land area for many large watersheds (fig. 3.2.2). Very few large watersheds have less than 10 percent of these land covers. Although most of these areas are used intensively by humans, some barren lands such as rock outcrops and some herbaceous lands such as balds and rhododendron beds are areas of limited human use. Unfortunately, we could not resolve developed from barren and pasture from herbaceous land covers in the data set.

Intensive human activities occur both across the entire landscape (fig. 3.2.2) and in the riparian zone (fig. 3.3.2). Historically, riparian zones were largely forested, and human activities have reduced forest land cover in areas close to watercourses to less than 60 percent in many large watersheds (fig. 3.3.2), with smaller reductions in the rest of the study area. Areas with less than 60 percent forest cover in riparian zones (fig. 3.3.2) are concentrated in the great valley that runs through the Ridge and Valley province from the Shenandoah Valley to northwestern Georgia and into Alabama. The great valley may have been relatively unforested prior to European settlement. But the great valley is also a corridor of much human development and transportation, which can be expected to expand with human population.

Riparian Areas as Habitats for Plants and Animals

Riparian habitat constitutes an estimated 2.3 million acres of the study area. For analysis, a riparian zone was assumed to be 100 feet on each side of streams and rivers. Of these acres, 69.8 percent are forested riparian habitats. Riparian areas are important habitat for wildlife and plants because these areas provide conditions and resources that are lacking in drier surrounding uplands, which may also be more subject to human activities such as logging, agriculture, or development. A total of 49 terrestrial plant and animal species from the SAA short list (see Terrestrial Technical Report SAMAB 1996b]) are associated with riparian habitats. Of these species, 10 species are federally listed threatened and endangered, with 81 percent of these EORs occurring on private lands. There are 24 viability concern species (equivalent to aquatic special concern species in section 2.4 of this report) associated with these habitats, with private lands containing 42 percent of the EOR occurrences, national forests 37 percent of the occurrences, and national parks 16 percent of the occurrences. Habitat needs of wildlife in riparian areas are carefully considered by many managers and landowners while planning their activities, but other owners and managers continue to adversely impact wildlife and plants dependent on riparian habitat. Several programs to assist agencies and landowners in management of riparian areas were described in section 4.2.

Data Gaps

In this report, “data gaps” refers to missing or incomplete data. Data gaps include aquatic resources for which little or no data exist. They also include gaps in the spatial distribution, timing, or quality of data collection or lack of certain critical information in data sets. Some data limitations have been discussed in the foregoing chapters. But others are universal to the sections and chapters of this report and will be discussed here.

A large-scale regional assessment requires data collection efforts involving all lands. Many data sets were available to the SAA for only small portions of the area (e.g., the benthic macroinvertebrate data of section 2.8). In several cases, several similar data sets could be combined to provide regional coverage, but such combinations must be done with great care (see discussion of meta-analysis in the section on future work below). Some data sets focused on public lands, such as those of the national parks and forests. Similar information about aquatic resources on privately owned lands is often lacking.

To produce trend information about aquatic resources also requires long-term data collection efforts with sampling occurring rather frequently over time. Statistical time-series analyses, impossible for the SAA, require more intensive sampling times than were available. However, the SAA should prove to be a useful benchmark for future analysis. Although long-term and large-scale monitoring efforts are massive and expensive, they are critical to addressing regional questions about trends in aquatic resources.

In many cases, data were available only as county summaries. For example, the amount of pesticide applied per year (fig. 5.1.19) was summarized for counties, precluding a more meaningful presentation as amounts applied in watersheds. Some data are collected only by counties, at times to protect privacy of individuals (e.g., fig. 5.1.6), and cannot be easily converted to watersheds. However, if data can be collected at finer spatial scales (e.g., points or farm fields), they can be aggregated to more meaningful land units like watersheds, and more accurate assessments would be possible.

For nearly all the data analyses, statistically valid regional sampling designs were lacking. Data sets must be statistically unbiased samples that is, randomly selected and independent observations from a population, which produce accurate estimates of parameters describing the entire population. For some data sets, for example, the EOR data set from the heritage program used to describe threatened, endangered, and special concern (TE&SC) species (section 2.4), samples were not random and probably not independent. Although the original studies were all appropriately designed, when aggregated into the regional data set, statistical validity was lost.

The second concern associated with statistical validity is that the population from which a sample is selected must be appropriate for the question at hand. All statistically valid samples consist of data collected to meet a specific objective or hypothesis. Although a sample may have been properly selected from a population that was correct for a particular question, that population and sample may be inappropriate for a different assessment question. Many data sets we encountered were of limited use because smaller, headwater streams were either not represented at all or were seriously undersampled compared to larger streams and rivers. In remote, rugged mountain areas, sampling of headwater streams is physically and logistically difficult, but is necessary for a statistically valid assessment of all aquatic resources.

Roughly half of the fish and mussel species known to occur in the SAA area were described in the chapter on status and trends of aquatic resources. The hundreds of fish and mussel species that are neither threatened or endangered nor important game fish exceeded our capabilities to summarize for this report. Greater knowledge of these species is critical to an assessment of biological diversity in the SAA area.

For many fish species, especially the other species discussed in section 2.6 and the species not treated in this report, the amount of information available varied from state to state. Recent books on "...Fishes of..." for North Carolina, Tennessee, and Virginia (Menhinick 1991; Etnier and Starnes 1993; Jenkins and Burkhead 1994) were invaluable to this effort. Similar volumes on the fishes of other states or mussels of the Southeast would have greatly assisted this effort. Late in the assessment processes, it was discovered that the fish distribution data in the Jenkins and Burkhead (1994) volume are now available in a computerized database maintained by the Virginia Department of Game and Inland Fisheries. Similar databases for the other states would be a valuable resource for agencies, private concerns, and individuals.

For amphibians, turtles, and the remaining invertebrate groups, information about distribution of all species, including those at risk, is especially sparse because there are few biologists who are experts about these species.

Some otherwise good data sets, particularly those that contain information about biological organisms collected at various sites across the region, were not usable because the sample sites have never been adequately geo-referenced. That is, although the location information would allow one to return to the site with the help of a good map (usually a 1:24,000 USGS quadrangle sheet), this information has not been converted to the format that a GIS would require.

Although the location of reservoirs and many of their water quality properties are well known, knowledge about the organisms in reservoirs is often poor. In many cases, the species that are present are not even known. Quantitative estimates of reservoir fish populations are notoriously difficult to obtain. Frequently, an estimate from a single cove expanded to the entire reservoir or a qualitative estimate must suffice. For other aquatic species groups, even less information is available.

The sedimentation impact of soil-disturbing agriculture was estimated for this report by two analyses methods: a statistical sample of points that are under agricultural use in counties, and satellite land cover data. But other land uses and active mines contribute sediment to streams, and models or data to estimate sediments produced from noncultivated land and mines are lacking. Data on location of roads and headwater streams are also inadequate or a valid assessment of impacts of roads and land uses on streams and waterbodies.

Most of these data gaps present opportunities for future work, particularly further research and monitoring, which will be discussed in the next section.

Future Work

From the perspective of the assessment process, research and monitoring needs stand out as ideas for future work. Research and monitoring will be discussed together in this section because these two topics are intertwined. But monitoring and research have different meanings to the various agencies involved in the SAA. One agency's monitoring need is another agency's research opportunity. For some agencies, monitoring and research are essentially the same thing, and for others, such as the Forest Service, these are two distinct activities carried out by different branches of the agency. The research activity of designing, testing, and analyzing monitoring programs further ties research to monitoring. This section will also address some future needs for GIS analysis and future uses of this assessment and assessments that may follow.

Need for GIS Analysis

Development of GIS data and tools for aquatic resource analysis has lagged development for terrestrial and human resource analysis, perhaps because aquatic applications appear less obvious and more difficult. Base GIS data on topography, streams, waterbody boundaries, and roads are needed at the 1:24,000 scale for all lands. Headwater streams that are not represented as blue lines on the 1:24,000 USGS quadrangle sheets must be delineated in the GIS. The USGS, National Park Service, Forest Service, and TVA are in the process of constructing these data layers for the SAA area.

Refinements, corrections, and additions to exiting databases would expedite use of these essential data. Upstream and downstream linkages, stream orders, and stream names are incomplete for the GIS data set of the RF3 file. Additional information on the type of surface (paved, gravel, soil) for all roads is critical to assessment of the sediment load entering streams from this major sediment source. Many existing data sets (e.g., biological and habitat data, point source discharges, and water supply points) should be amended with accurate geo-referencing (i.e., latitude and longitude) to link sample points to the RF3 database in a GIS.

Solving the problem of properly delineating watersheds and aggregating nested watersheds in the GIS is an active area of current work that will be of benefit to future analysis of aquatic GIS resource information. Accurately delineating watersheds requires highly detailed digital elevation models and has been done for small watersheds in limited areas. But to do so for an area the size of the SAA area is computationally formidable. With accurately defined watershed boundaries, data from several data layers that fall within watershed boundaries can be selected and models that link aquatic resources, land base characteristics, and stressors can be developed.

Monitoring Needs and Design

Monitoring is defined simply as the repeated measurement of characteristics at one or more sites for comparison over time to detect change or comparison with established references to detect differences. Monitoring can be conducted at spatial scales that range from very specific sites to the globe. In this discussion, we are primarily concerned with monitoring studies of aquatic resources conducted at regional scales. Many fine monitoring studies do not have formal statistical designs, but other monitoring studies are designed to be statistically valid so that powerful conclusions can be drawn.

Regional scale monitoring efforts are potentially massive undertakings. Three such efforts, EMAP and R-EMAP, NAWQA, and RAT, were mentioned in the introduction to chapter 2. These programs are largely efforts of single agencies (EPA, USGS, and TVA, respectively), although one R-EMAP effort, the Mid-Atlantic Highlands Assessment (MAHA), is an interagency effort. Effective regional monitoring efforts will increasingly depend on interagency cooperation. The differing missions of cooperating agencies will require some compromise and make monitoring design a challenge. Nevertheless, when agencies pool their monitoring needs and resources and agree on study design, efficiencies can be realized.

Ecological classifications that stratify or partition large regions into relatively homogeneous landscape units are useful for design of monitoring programs because stratifications are statistical tools for reducing variability in data. Different ecological classification systems are in use by different agencies, largely because the systems were devised by respective agency scientists to meet agency objectives (Bailey 1995; Maxwell and others 1995; Omernik 1995). Each classification system can be useful for reducing variability in particular monitoring studies, depending on objectives, variables measured, and sampling design. If federal and state resource agencies can agree on common definitions and boundaries for ecological classification at scales important for aquatic resources, coordination of monitoring studies and their results will be easier.

Although tight coordination of monitoring efforts among agencies is certainly of benefit to all, there are tradeoffs. If all monitoring efforts of agencies were pooled into a single region-wide monitoring effort, the risk is quite high that critical information would be missed by the resulting design. The value of a diversity of efforts and multiple sample designs is that more problems and successes can be detected. That is why the combination of monitoring efforts represented by the suite of NAWQA, RAT, and R-EMAP is potentially powerful.

New tools and improved monitoring methods and sampling designs are continuing needs. In some cases, methods are needed that more accurately and precisely measure the variable of interest because increased precision increases statistical power (i.e., the ability to statistically detect a difference) of any monitoring design. Modifications of sampling design can also increase statistical power, and each completed study provides information that can be used to design the next monitoring effort.

For many monitoring studies, an array of reference streams that represent different ecological regions, stream sizes, elevations, and aquatic habitat types in the SAA area would be valuable for monitoring efforts. These sites could document the natural range of chemical, physical habitat, and biological community condition (fish, benthic macroinvertebrates, and other organism groups) for healthy and relatively unimpacted areas. Such a set of reference streams provides a baseline against which other sites can be compared.

Some specific monitoring needs follow directly from the data gaps identified above. Integrated physical habitat, biological, and chemical monitoring is needed at more sites to fully answer questions such as those posed by the SAA. Lower-order streams, from first – (ephemeral) and second – (intermittent) to third – (small perennial) and fourth-order streams, which dominate many watersheds, are under-represented in many monitoring studies. Finally, quality control and full documentation are needed to maximize the utility of aquatic resource data for further analysis.

Research Opportunities

Researchers will find many opportunities for further research in the pages of this report and in the data sets available on the Internet and CD-ROM. The following paragraphs outline a few of the opportunities identified by the aquatic resources team.

Expanded research is needed that links multiple aquatic resources to their watershed and regional environments. This research would include development of predictive models that relate landscape factors such as watershed and riparian land cover, land use, human population patterns, topography, and geology to direct instream measures of instream aquatic habitat and biological integrity (fish, benthos, and other organisms). In the past, few models that relate watershed habitat to aquatic organisms have been attempted because the linkages seem conceptually too distant and data and analysis capabilities were lacking (see Flebbe and others [1988] for an exception). Related research is needed to devise ways to link aquatic resources across disparate spatial and temporal scales.

Basic research is needed to establish physical, chemical, and biological responses to multifarious stressors. For example, invasion by gypsy moth presents a complex set of consequences that are difficult to track in chemical and biological responses. Defoliation by gypsy moth can paradoxically both increase and decrease food sources for aquatic organisms. Likewise, control of gypsy moth has paradoxical consequences for stream insects and fish. Acidification, hemlock wooly adelgid, land use, riparian management, recreational use of riparian areas, and other human activities may simultaneously produce several different, and perhaps conflicting, responses by aquatic resources.

Sediment is produced from all lands and the amount varies depending on land cover, land use, road density, and other factors. A fundamental need is for research to produce models that can predict amounts of sediment produced from the land, based on remotely sensed land cover information. The Universal Soil Loss Equation (USLE) model used in this report was designed for plot studies in agricultural land and is not adequate for all land cover types. Research currently underway to develop new models is critical to consideration of sediment sources in future assessments and planning.

Cumulative effects of multiple land management activities in watersheds are of concern to many in the Southern Appalachians and elsewhere. Research progress on this subject is slow and difficult. A dependable database of turbidity or total suspended solids determinations, collected with consistent methods from a large number of streams of different sizes, would provide the basis for some of this needed research. Several data sources identified in this assessment–headwater stream monitoring on national forest and other public lands; turbidity analyses of the raw water intake stream, required for every public drinking water system; and sediment deposition rates for reservoirs–could contribute to research on cumulative effects.

Relatively new basic research to link aquatic resources with the social, cultural, and economic domain of human activity should be expanded. Historically, aquatic ecology has been conducted as if humans were not part of the aquatic system. At best, creel surveys were conducted to determine how many game fish were removed. But humans are part of the aquatic system, whether by introducing bait fish, removing game fish, stocking, hiking, horseback riding, mountain biking, waterskiing, and any number of other activities. Whether we like it or not, aquatic systems exist within a social, cultural, and economic context, and management of aquatic systems does and should consider the human context. New and exciting research is underway in these areas, including ecological economics, recreation research, and human dimensions research.

Meta-analysis is a rather new field of research that "uses formal statistical procedures to retrieve, select, and combine results from previous separate studies" (Wachter 1988). Many of the analyses presented in this report would properly be considered meta-analyses. But the tools for meta-analysis are not fully developed. Further research into methods by which results from different studies can be combined is critical because future regional assessments are likely to rely on data sets collected from different sources.

Regional Assessments

Identification of additional analysis, monitoring, and research needs is one of the most important outcomes of the aquatic resource assessment. Meeting these needs will ensure that similar questions can be answered more fully in future assessments. Although the SAA aquatic resources team was tasked to answer five specific questions, outlined in the executive summary at the beginning of this report, most of the questions could be recast into the first: What are the status and trends of aquatic resources? Four key questions that concern status and trends might be addressed in future assessments of aquatic resources in the region:

- What is the full range of condition for all aquatic resources of the region? More information is needed to know more about tiny pristine streams and polluted large rivers, game fish, and threatened and endangered species and everything in between.

- What is the reference condition? If problem areas are to be identified or an aquatic resource is to be restored, clear, measurable, and attainable standards are needed.
- Where do the aquatic resource problems or concerns exist? There is a need to develop and apply screening techniques that are sensitive to the wide array of stressors and effects to ensure that all problem areas are identified.
- Where is the condition of aquatic resources improving over time? There is a critical need to evaluate the effectiveness of aquatic resource management efforts and to measure, with known confidence, changes in aquatic systems over time for large areas.

Those involved in the SAA wish to see the effort begun in the summer of 1994 continue in some way. No doubt, individual agencies will build on the aquatic resource information collected for the SAA. The Forest Service, for one, has already begun the forest planning process, prescribed by the National Forest Management Act, for five national forests with land in the SAA area. The SAA will be part of the planning process, providing the context and an important information base for individual forest plans. Those involved in the assessment have proposed that the multiple agency collaboration initiated with the SAA be continued and perhaps expanded to include other state, federal, and local agencies, which may have been less involved than the agencies represented by the authors of this report. Repeating this assessment, with improvements, at intervals in the future will be invaluable to future planning and management.

Information gathered for the SAA will be used by many groups for many purposes. Government agency planners at all levels – federal, state, regional, and local – should find information they can put to use. Agencies like the Forest Service can determine the array of TE&SC and other species at risk that should be considered in planning for a national forest, ranger district, or management area activity. Private citizens, companies, citizen groups, and special interest groups will all find information of value to their own planning and stewardship of aquatic resources. Agencies and private concerns can more easily determine the array of possible stressors for a particular project area than was possible before the assessment. Schools and young students will probably be leaders in use of the vast data sets available to them on the Internet or on CD-ROM. And researchers will find plenty to improve and expand on in future publications and reports.

This assessment is the first of several regional assessments of aquatic resources either underway or planned for the eastern United States. Several agencies cooperating in the SAA will participate in other assessments and have indicated their willingness to support and expand future cooperative assessments. These new assessments will build on and benefit from information shared on sources of data and the lessons learned. Some assessments, such as the MAHA, already underway, overlap geographically with the SAA area and will more directly benefit from shared data and analyses. Eventually, as these overlapping regional assessments are completed, opportunities for integrating the results across assessments expand dramatically. And eventually, a new SAA will build on the combined experiences and successes.