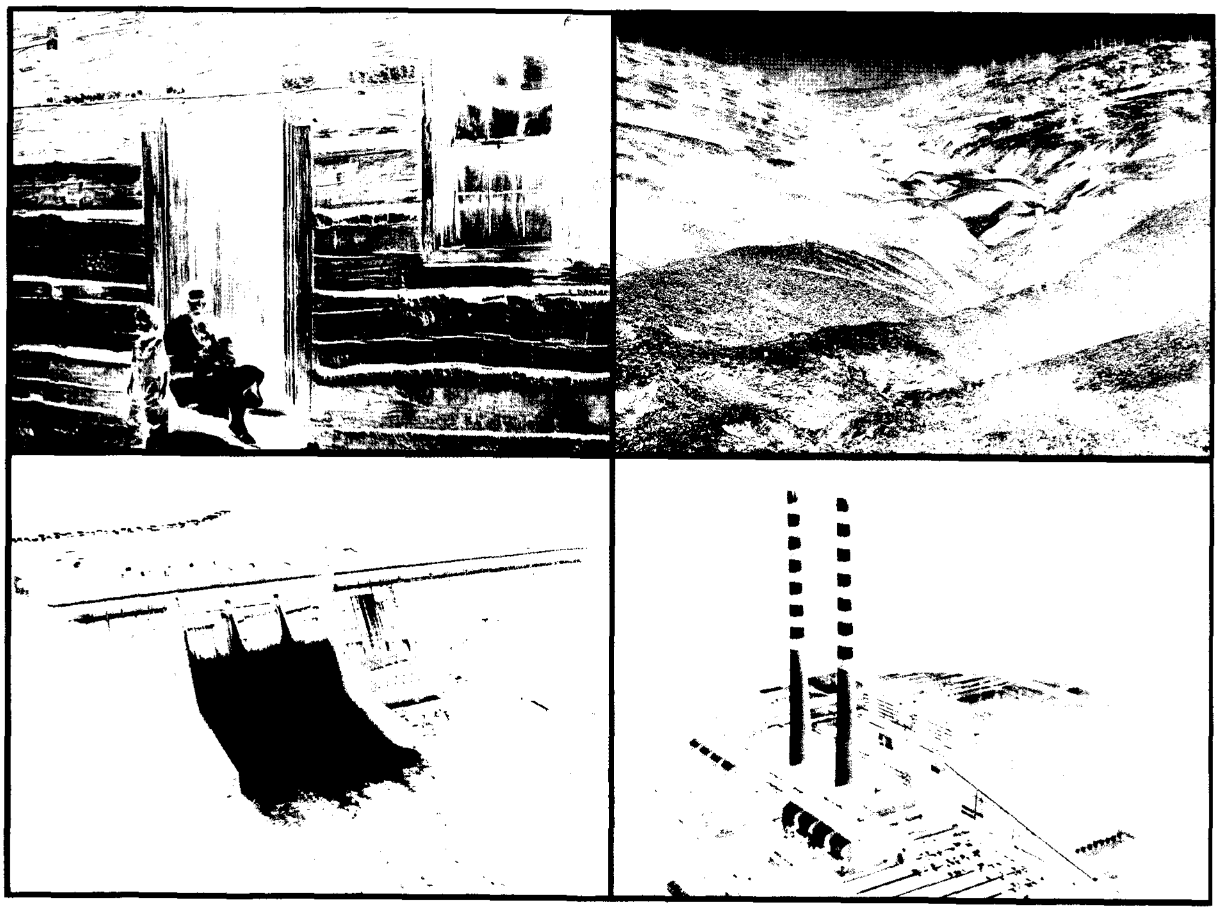
WORLD BANK TECHNICAL PAPER NO. 416

Work in progress
for public discussion

WTP416
Nov. 1998

Comprehensive River Basin Development

The Tennessee Valley Authority



Edited by
Barbara A. Miller and Richard B. Reidinger

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The World Bank
Washington, D.C.

First printing November 1998

ISSN: 0253-7494

Cover photos by TVA/Fleetwood. From left to right: "Women and children in log cabin typical of the Tennessee Valley in the 1930s," "Copper Hill, Tennessee in the 1930s; erosion was a major problem throughout the Valley," "Norris Dam on the Clinch River, built between 1933 and 1936," and "Cumberland Steam Plant."

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Library of Congress Cataloging-in-Publication Data

Miller, Barbara A., 1951–
Comprehensive river basin development : the Tennessee Valley Authority / prepared by Barbara A. Miller and Richard B. Reidinger.
p. cm. — (World Bank technical paper ; no. 416)
Based on papers presented at a World Bank sponsored seminar held on Feb. 13, 1997 in Washington, D.C.
Includes bibliographical references (p.).
ISBN 0-8213-4308-4
1. Tennessee Valley Authority—History. 2. Water resources development—Tennessee River Valley. 3. Reservoirs—Tennessee River Valley—Regulation. 4. Electric power—Tennessee River Valley. 5. Tennessee River—Power utilization. I. Reidinger, Richard B. II. World Bank. III. Title. IV. Series.
TC425.T2M55 1998
333.91'15'09768—dc21 98-33635
CIP

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FOREWORD

Water in its many aspects is now recognized as perhaps the major resource issue for the 21st century, and better river basin management is one of the primary challenges now facing World Bank client countries. During the coming century, this will require constructive attention and action by leaders, politicians, and technical specialists alike if water issues are to be resolved. Efficient river basin management must be comprehensive and is far more complex than building dams and control structures. It depends on the integration of a whole range of technical functions such as hydropower, irrigation, flood control, navigation, municipal and industrial water supply, and water quality, and also depends on institutional functions such as management, financing, water pricing, cost recovery, water use and allocation, and social impacts. River basin management is very different depending on the situation and the country or countries involved. Because of its importance for overall water resource management and strategy at the national and international level in many Bank client countries, comprehensive river basin management is one of the main tenets of the Bank's 1993 policy paper *Water Resources Management.*

The Tennessee Valley Authority (TVA) is perhaps the world's best-known example of comprehensive river basin development and management. It was the first experiment on a grand scale with comprehensive river basin management, and it was profoundly successful in many ways. This paper presents the story of TVA, the conditions under which it was established, and its achievements, problems, and lessons. This is not the definitive work on TVA, nor is it totally unbiased. Although there have been problems, TVA is portrayed as an effective river basin management agency that has had great benefits and has been instrumental in bringing the entire southeast region of the United States from abject poverty in the 1930s to a dynamic economy today. Now, however, the future of TVA is in doubt. The seeds of its possible destruction as a comprehensive river basin manager were sown at its inception and were at least partly recognized in its early years. The issues, problems, and solutions faced by TVA, then and now, are clearly presented in this technical paper. We hope TVA's experience will provide useful guidance to the Bank's clients and to others.

Alexander F. McCalla
Director
Rural Development Department
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PREFACE

The Tennessee Valley Authority, better known as TVA, has perhaps the best name recognition in the business of river basin management. It is considered by many outside the United States as the model for river basin development and management. It is also the oldest comprehensive river basin management agency in the world. Started during the Great Depression, it was born of crisis in 1933 in the southeastern region of the United States. It was an integral part of the "New Deal" to lift the nation out of economic depression.

Established to develop and manage the Tennessee River Basin, TVA was the first, and last, time that the United States government has established a comprehensive, independent agency to manage the water resources of an entire river basin as a "corporation clothed with the power of government but possessed of the flexibility and initiative of a private enterprise" (TVA 1983a p. 9). It was conceived as both a development agency to raise living standards in the Tennessee River Valley and a construction and management agency to build and operate dams and structures along the Tennessee River, whose drainage basin covers some 40,900 square miles (105,930 square kilometers) over seven states. TVA's primary functions—flood control, navigation, and power—have received the greatest notice, and TVA is still one of the few examples in the world where all river control structures in an entire large river basin are controlled or operated by a single agency to achieve basin-wide water management objectives. But other, less-well known aspects of its comprehensive operations, such as soil and water management, water quality control, malaria control, and fisheries and recreation management are what distinguish TVA from most other water resource agencies and attempts at river basin development in the United States and elsewhere.

TVA was fortunate to have as its first supporters and leaders some of the greatest visionaries of the time, including the U.S. President Franklin D. Roosevelt, who personally sponsored and led the creation of TVA. Many of the basic concepts that guided the establishment and early years of TVA, such as multipurpose and comprehensive river basin development, environmental management, and regional development were at least a generation ahead of their time. And the physical achievements were immense and fast: within about eight years, five major dams were completed. TVA was clearly "big government," but from the beginning it was effective, and that was an era when government was seen as good. Although not a formal part of the organizational structure, public participation and involvement were promoted by TVA for development of the region. It was "democracy on the march," the federal government reaching down to the very grassroots to help people help themselves.

Since its early successes, TVA has had to adapt to changing conditions, politics, economics, and perceptions. It has done many things right and some things wrong. Few would question that TVA and its programs have brought immense benefits to the Tennessee River Valley, and it has demonstrated the overwhelming value of a comprehensive, unified approach to management. But is the TVA model suited for modern times and conditions or for other countries or regions? Regardless of the answer, the experiences of TVA can offer useful lessons for the future of river basin development in many World Bank client countries.

The objective of this paper is to present a broad overview of TVA, including the forces that shaped its growth and development, institutions, and operational programs. While many important aspects of the organization are not discussed, some of the advanced analytical tools currently used to operate TVA's complex reservoir and power system are described. The intent is to summarize those aspects of TVA– particularly those related to water resources management– that could serve as a useful reference to Bank staff and client countries in evaluating the various institutional arrangements, operating programs, technological bases, and other conditions conducive to comprehensive river basin development.

This technical paper is based on presentations given at the World Bank-sponsored seminar "River Basin Management: Tennessee Valley Authority and the Murray-Darling Basin"on February 13, 1997 in Washington, D.C. Because of the strong interest expressed at the seminar, the presentation notes were expanded and this paper was the result. We would like to thank TVA for supporting presentation of the TVA story at the seminar, for kindly providing the photographs and many of the materials used in this report, and for assistance with permissions, revisions, and questions.

Our gratitude also goes to the present and former staff of TVA who made the seminar presentations: Mr. Jack L. Davis, Manger of TVA Watershed Planning and Development; Mr. Christopher Ungate, Manager of TVA Business/Generation Planning, Hydropower Operation; Dr. Vahid Alavian, former Leader of Environmental Hydraulics, TVA Engineering Laboratory, and Mr. H. Morgan Goranflo, specialist for TVA River System Operations. Dr. Barbara Miller, one of the authors of this technical paper, is the former manager of TVA Flood Risk Reduction. Altogether, these persons represent about 125 years of professional experience in river basin planning and management.

The reviewers of the draft paper shared many helpful and encouraging comments and insights, and we are indebted to Dr. Guy Le Moigne, Professor Peter Rogers, Dr. George Radosevich, Mr. Harald Frederiksen, and Mr. Douglas Olson. Our special thanks also go to Ms. Sandra Giltner whose editorial efforts and experience helped to shape and refine this paper.

This volume was sposored by the Water Resources Thematic group of the World Bank's Rural Development Family, and we would particularly like to thank Dr. Ariel Dinar and Ms. Liliana Monk for their support and assistance. The Bank's Learning and Leadership Center helped sponsor the original seminar that inspired this volume.

Finally, and most importantly, we would like to dedicate this paper to all the people at TVA, past and present, who over the years have worked with devotion and commitment for the improvement of the Tennessee Valley region. It is difficult for us today to imagine the conditions of the Tennessee Valley in the 1930s, when the region resembled many of the poorest of today's developing countries. In northern Alabama, for example, some 33 percent of the population living near the river had malaria. It is also hard for us to imagine the pervasive impact of TVA on the region and its people, poignantly expressed in the foreword to a book called *Tall Tales from Old Smokey*, whose author lived to see "the cook fireplace bow to the electric stove powered by TVA." But this was only the beginning. There was true human development for the region starting at the level of the most basic human needs. This was the commitment of TVA and its people.

ABSTRACT

Comprehensive River Basin Development: The Tennessee Valley Authority presents an overview of the history, institutions, and operational programs of the Tennessee Valley Authority (TVA), one of the world's first and most comprehensive river basin development initiatives. Beginning in 1933, TVA fostered the social and economic development of the Tennessee River Valley (a seven-state area in the southeastern United States) through the integration of a strong infrastructure, a healthy natural resource base, and human capacity. The infrastructure included a system of dams and reservoirs to support navigation, control floods, and produce power, coupled with an extensive transmission system to provide cheap electricity throughout the region. Intense efforts to improve agriculture, land use, and forestry practices helped to restore and maintain a healthy environmental base, while technical assistance and small-scale credit programs provided people with the tools to improve their own lives. This paper examines the circumstances that led to the creation and successful development of the agency, discusses current issues and challenges, and offers general lessons for comprehensive river basin management based on the TVA experience.

Executive Summary

The Tennessee Valley Authority (TVA) represents a successful example of comprehensive river basin development. Established more than 65 years ago to guide the development of the resources of the Tennessee River Basin, TVA continues to operate a wide variety of water, power, economic development, and environmental programs within the region. The integrated development of the watershed's resources, combined with TVA's unique institutional capacity, helped transform the Tennessee Valley from one of the poorest regions in the United States in 1933 into a region with a strong, diversified economy and a healthy environmental base.

This report presents an overview of TVA's growth and development, its institutions, and its operational programs. It is based on presentations given by current and past TVA staff as part of a 1997 World Bank-sponsored seminar on river basin management. The intent is not to provide an all-inclusive description of TVA, but (a) to summarize the conditions associated with TVA's conception and evolution that proved conducive to comprehensive river basin development and (b) to provide an overview of those aspects of the agency—particularly those related to water resources management—which could serve as a useful guide to Bank staff and client countries as they explore mechansims for using water resource development as a catalyst for the broader social and economic development of a region.

Historical Context: TVA Conception and Development

TVA was established by an Act of the U.S. Congress in May 1933 as part of President Franklin D. Roosevelt's "New Deal" to lift the United States out of the depths of the Great Depression. The concept of the agency was both unique and broad. TVA was to function as "a corporation clothed with the power of government but possessed of the flexibility and initiative of a private enterprise." The new agency would also "be charged with the broadest duty of planning for the proper use, conservation, and development of the natural resources of the Tennessee River Drainage basin. . . . ," a 40,900 square mile (105,930 square kilometer) area encompassing parts of seven states in the southeastern United States.

Over the 12-year period between its inception in 1933 and the end of World War II in 1945, TVA established its institutional framework, built broad-based local support for its programs, and constructed a physical infrastructure that would serve as the backbone for TVA's accomplishments. This infrastructure included a vast system of multipurpose dams and reservoirs to harness the Tennessee River and an extensive transmission system to provide cheap electricity throughout the region. Early and intense efforts to improve agriculture, land use, and forestry practices helped to restore and maintain a healthy environmental base, while access to small-scale credit and technical assistance programs provided the citizens of the Valley with the tools to improve their own lives. It was during these early years that it established what may become TVA's greatest legacy—the integration of a healthy natural resource base, a strong infrastructure, and human capacity to foster the social and economic development of a region.

Driving Forces

TVA emerged from the intersection of five major forces: need, champions, opportunity, vision, and tangible results.

The Need. The need for TVA arose from the dire social and economic conditions in the Tennessee Valley in the 1930s. Although rich in natural resources, the region was largely rural and undeveloped, poverty-stricken, and characterized by degraded environmental conditions. Per capita income was one of the lowest in the United States, few people had running water or electricity, and poor sanitary conditions resulted in some of the highest rates of disease and infant mortality in the country. In some areas near the Tennessee River, one out of every three people had malaria. Illiteracy rates were high and the quality of education was poor. Severe erosion, extensive deforestation, and exhausted mines were indicative of a deteriorating environment. Additionally, the navigation potential of the Tennessee River remained untapped due to hazardous shoals, while the heavy rainfall and steep slopes in the region subjected many areas to repeated and serious flooding. The people of the Tennessee Valley were trapped in a cycle of poverty. The natural resource base of the economy was deteriorating, which led to widespread poverty and further misuse of the region's resources. The social problems in the Valley could only be addressed by improving the economy, which depended on a healthy resource base. Development of the region's land, water, and forests was essential for economic revival.

Champions and Opportunity. In this historical context, three influential men provided the leadership, ideology, political will, and money to ensure the successful initiation of the agency. Gifford Pinchot, a leader in the early conservation movement, articulated the principals of multi-resource development, regional planning, and environmental balance that provided the conceptual framework for TVA. He also recognized that hydropower could provide the means to make multi-resource development economically viable. Senator George Norris, the author of the TVA Act, agreed with these principals and successfully argued for federal responsibility for hydropower development. However, it was Franklin Roosevelt, the newly inaugurated president in 1933, who took advantage of historical, political, and geographic circumstances to propose and sign the legislation to create TVA. As the Great Depression of the 1930s deepened and conditions in the Tennessee Valley worsened, Roosevelt sought an innovative program to revitalize the economy and boost morale. The creation of TVA represented a "bold experiment" to accomplish the unified development of a river basin. For the first time, a watershed was to be used as a planning unit and resources were to be developed for the benefit of the entire region. Flood control, navigation, and power generation were not ends in themselves, but the means to advance social and economic development. Roosevelt expressed his personal commitment to the agency by allocating presidential discretionary funds to TVA during the first few years of its life.

Vision. The practical implementation of this 'bold experiment' was left to the first board of directors, three men appointed by Roosevelt. Each man brought a different, but powerful, vision that contributed to the new agency. Arthur E. Morgan, the first chairman, advanced the concepts of regional planning and of using TVA as a vehicle for social and economic development. Board member Harcourt Morgan, an agriculturist by training, espoused the interdependency of people and nature. He instilled the practice at TVA of working at the grassroots level through state and local agencies, based on his belief that lasting change could only be accomplished by the farmers themselves, and that this change was best achieved through technical assistance from existing extension agencies. David Lilienthal, who was to become the most influential of the three board members, instituted the concept of centralized power generation by TVA and decentralized distribution through locally owned municipal electric systems and rural electric cooperatives. He promoted the vision that economic development depended on the provision of low-cost, accessible power. He understood that the lower the cost, the higher the demand. He also helped to create demand by providing inexpensive appliances and easy access to credit. He oversaw the construction of an extensive transmission system to ensure rural access to electricity. Low-cost power also attracted industry and set in motion an economic revival of the region.

Tangible Results. TVA's vitality as an institution was bolstered by its early, tangible, and, largely positive impact on the lives of the people of the Tennessee Valley. Two major dam construction projects were initiated the first year of the agency. Over the next 12 years, bolstered by the need to support World War II efforts, progress was remarkable: the navigation channel on the Tennessee River was completed; 26 dams were incorporated into the TVA water control system; TVA became the largest power producer in the United States; and the Tennessee Valley was essentially "on-line," supported by an extensive system of transmission lines and decentralized, locally owned distributors. Additionally, farm production levels tripled due to successful efforts to reduce soil erosion, improve farm practices, and introduce fertilizers. Industries seeking cheap electricity moved to the Valley. Although controversies arose over relocations required during dam building, the Valley residents were put back to work and the overall standard of living improved. TVA won the support of citizens and local governments and gained a national reputation for its work in water resources, land management, forestry, agriculture, and energy production.

Seeds of Success and Failure

By 1945, TVA had evolved into a strong organization with its physical infrastructure in place and an established institutional framework, mission, and constituency. Its early strengths, however, would provide the seeds for its greatest challenges as the agency matured and the external environment changed.

Institutional Framework. The organizational structure that emerged from TVA's first decade of operation and that would serve the agency for most of its 65 years included an appointed board of three directors, a general manager, and strong operating divisions. In general, the board's responsibility was to set policy, which was coordinated by a general manager and carried out by highly professional operating arms. These operating arms have typically included a power organization, a natural resources program (including water), and either an agriculture division (earlier years) or an engineering design or construction division (later years).

There have been important implications of this institutional structure. First, while policymaking at TVA has remained centralized, planning, management, and implementation have largely remained decentralized and the responsibility of the operating arms. There has never been a master development plan; rather, planning has been tied to operations and physical development programs. Second, the decisionmaking process between the operating arms has relied on self-coordination and "benign tension." Problems are resolved at the lowest possible working level and only "bubble" to higher levels if serious disagreements persist. Third, there is no means of scrutinizing recommendations from the operating arms, as the general manager has generally lacked the staff to conduct independent reviews.

The strengths of this institutional framework are that it has kept the agency action-oriented and grounded in doing real things to directly improve people's lives. This focus, coupled with a history of working through local agencies, has built widespread grassroots support for the agency. This framework was most successful prior to the 1950s when TVA's mission was clear and large-scale construction projects were under way.

Since the 1950s, this institutional structure has been less successful. The lack of centralized planning has hampered TVA's efforts to define new agency-wide missions, fierce competition often emerges between the operating arms during tight budget years, and there is no mechanism for external scrutiny or critical oversight. Efforts to correct these deficiencies began in 1988 when TVA initiated a series of organizational changes to increase the authority of the board of directors, increase competitiveness in the power arena, and run the agency more like a business. Restructuring efforts continue today.

Core Ideologies. TVA's core ideology has been based on four values, each of which is part of a dichotomy which continues to provide tension in the agency: professional expertise supported by statutory missions vs. grassroots democracy; and a multipurpose authority vs. a power company.

TVA has maintained a highly competent (although at times paternalistic) staff dedicated to directing development in the Valley. However, it has also established a precedent of working through local agencies and stimulating public participation to facilitate change. TVA cooperates with other federal agencies in the areas of flood control and navigation, works with states to support economic development, and involves local citizens and groups in a range of environmental projects. Public access phone lines and internet sites provide information on TVA activities and operations. TVA also utilizes a public review process around specific issues. Yet there is no direct representation of stakeholders in the management of TVA at high levels and no formalized mechanism for consensus-building.

TVA's greatest tension, however, has centered on its sense of itself as a comprehensive river basin development agency vs. a power company. Until recently, TVA's perception of itself, as well as the public's perception of TVA, has been that its core mission is to serve as a multipurpose agency. This theme has been the source of TVA's greatest accomplishments. Since 1947, however, the federal appropriations that support TVA's natural resources and economic development "nonpower" programs constitute only two percent of TVA's budget. The other 98 percent of TVA's budget is generated through power revenues.

Although, hydropower was originally seen as a by-product of navigation and flood control and as a means of improving economic conditions in the Valley, TVA's power-producing capabilities have steadily grown over the years. Initially, TVA won the court battle to bypass private utilities and established a monopoly by default as the sole supplier of electricity in the region. Then, in the 1940s TVA began building steam plants to meet the increased power demands during and after World War II. The turning point came in 1959 when TVA was granted the right to self-finance its power program. Subsequently, power has slowly become the dominant organization in TVA. The 1990s have brought another turning point, as power companies in the United States face the prospects of deregulation, and TVA's chairman has declared power production to be the agency's primary mission.

Constituencies. One of TVA's greatest strengths has been its strong base of local constituencies, including: grass-roots support; state and local governments; special interests (such as distributors, industries, and environmental groups) other federal agencies; and the Tennessee Valley Congressional Caucus. The TVA Caucus is composed of congressmen and women from the TVA region. Historically, members of the Caucus have held key positions on the congressional committees that control TVA's budget. TVA has depended on the Caucus to protect the agency's annual appropriations. The weakness of this approach is that TVA has not built broad-based support in Congress, and the Caucus' protective attitude has silenced constructive criticism of the agency. In 1992, many influential members of the Caucus lost their seats in Congress. Since then, TVA has had difficulty justifying its budget to congressmen and women that have no vested interest in TVA. Only recently has a strong TVA Caucus begun to coalesce in an attempt to save TVA's nonpower programs.

Distinguishing Characteristics. TVA distinguished itself as a multipurpose agency by the end of World War II and has continued to operate successfully for over 65 years. The concepts of comprehensive river basin management pioneered by the agency have served as models for the management of other river basins around the world. TVA's distinct characteristics remain its

- Focus on unified, regional development
- Multiple missions
- Autonomy
- High standards of professional excellence
- Grassroots participation and support
- Strong regional identity.

Water Resources Management

TVA is perhaps best known for its water resources management programs and large, multipurpose reservoir system. TVA's legal authority for its water programs derives from the TVA Act, which grants TVA broad multi-resource conservation and regional planning powers and the authority to build its own projects. TVA water, land, environmental, and other natural resources programs have historically been funded by U.S. Congressional appropriations as part of TVA's nonpower programs. In recent years, these appropriations have ranged from $90 to $140 million annually.[1] Due to downsizing of the federal government and the current controversy over TVA's nonpower programs, appropriations in fiscal year 1998 were reduced to $70 million. Appropriations for fiscal year 1999, as well as the future of TVA's natural resources management mission, remain uncertain at this writing.

The Tennessee River Basin lies in a seven-state area in the southeastern United States, centered around the State of Tennessee. Its drainage area is characterized by mountainous forests in its upper reaches and by rolling hills and farmland in its lower reaches. The region is one of the wettest in the U.S. and very vulnerable to flooding. Since its inception, flood management has been a primary focus of TVA activities and a primary consideration in the design of TVA's unique reservoir system.

The TVA water control system includes 54 TVA-owned dams and reservoirs that are operated as an integrated, multipurpose system. Major objectives are to provide for navigation, flood control, hydropower generation, summer recreation levels, and minimum flows for the maintenance of water quality and aquatic habitat. Additionally, the reservoir system supports fossil and nuclear generation by providing condenser cooling water and dissipating thermal waste loads.

Although all TVA projects serve multiple functions, major projects are categorized by the primary purposes for which they were built. Single-purpose, run-of-the-river projects produce hydropower. The mainstream multipurpose reservoirs on the Tennessee River primarily support navigation, provide limited flood storage, and generate hydroelectric power. The large, tributary multipurpose reservoirs located in the mountainaous regions were built to provide key flood control for the system, augment navigation flows, and produce power. Nonpower projects are smaller projects principally built for local flood control, recreation, and/or water supply purposes.

While TVA's large reservoirs were completed by the 1950s, the agency has continued to plan and implement smaller scale projects, such as local flood mitigation, water supply, recreation, and off-stream storage projects. These smaller projects are initiated on the basis of economic need, safety, and/or congressional mandate. While project planning and implementation rely heavily upon engineering, economic, and environmental analyses, TVA's approach is distinguished by the active involvement of local citizens and other agencies in the planning process.

The Power Program

The TVA power system, one of the largest in the United States, generates 4 to 5 percent of the country's electric power. Within its 800,000 square mile (207,000 square kilometer) service area, TVA meets the energy needs of nearly 8 million people. The backbone of the TVA power system is an extensive network of 17,000 miles (27,000 kilometers) of transmission lines.

The TVA power system generates approximately 28,000 megawatts (MW) of dependable capacity based on a generation mix that includes coal-fired, hydroelectric, nuclear, combustion turbine, and pumped storage facilities. Coal-fired plants supply the majority of the capacity (53 percent), while hydroelectric power accounts for 19 percent and nuclear for 20 percent of the remaining capacity. In general, the nuclear and coal-fired plants are used for base power loading, while hydropower and com-

[1] Please note that all dollar amounts are current U.S. dollars. A billion is 1,000 million.

bustion turbines are used to meet peak power demands.

By law, the TVA power system must be self-supporting from the revenues it produces and the capital it raises in public markets. In 1996, its operating revenues of nearly $6 billion accounted for 98 percent of TVA's budget. TVA's greatest financial challenge is an outstanding debt of approximately $27 billion, primarily incurred by the nuclear power construction program. Interest payments of close to $2 billion a year represent 35 percent of operating revenues.

Tremendous changes are occurring in the U.S. electric utility industry, such as the enactment of laws requiring open access through transmission systems and increasing trends toward deregulation. Over the past few years TVA has concentrated on preparing for these changes. TVA supports deregulation and has begun to position itself to operate in a more competitive environment by improving power system operations and reliability, strengthening financial management, and enhancing strategic planning. Perhaps TVA's most controversial change, however, has been the 1997 proposal to Congress to transfer TVA's nonpower programs to other federal agencies so that TVA can concentrate on power production.

Current Issues and Challenges

Discussions about TVA's future focus on two central issues: (a) the fate of TVA's natural resources and economic development programs, and (b) the future of TVA's power program in the face of deregulation and renewed discussions about privatization.

In January 1997, TVA Chairman Craven Crowell proposed to Congress that TVA divest itself of its congressionally funded nonpower programs in order to strip the agency to its "core energy business" and allow it to compete more effectively in a deregulated environment. Although TVA's history has been marked by controversy, this was the first time that a chairman proposed such a radical departure from TVA's original mission. The issue is being hotly debated by Congress, Valley residents, and other federal agencies. Public sentiment has been generally supportive of TVA and, for many, spinning off TVA's nonpower programs is giving away what justifies the agency in the first place. Nonetheless, in July 1997 Congress reduced TVA appropriations to $70 million for fiscal year 1998, a 34 percent reduction from the previous year. More significantly, the fiscal year 1998 budget stipulated that TVA would not get any federal funds in the future for its nonpower programs. At this writing, although the House of Representatives' Appropriations Committee has upheld this stipulation and has refused to hold formal budget hearings for next fiscal year, the Senate has approved $70 million for fiscal year 1999. The issue for fiscal year 1999 will be resolved in a congressional conference, although the long term fate of nonpower programs has not been resolved.

Regardless of the outcome of TVA's natural resources management mission, the future of TVA's power program in the face of deregulation is also being debated. TVA has positioned itself to be more competitive by upgrading power operations, improving financial management and customer relations, and reducing its debt. Critics of the agency, however, maintain that these changes have come at the cost of severe staff reductions and compromises in safety, that rate increases are inevitable, and TVA's large debt renders it noncompetitive with private utilities.

At the same time, talk of privatization has begun to resurface again. At the heart of the discussion is the question as to whether the federal government should legitimately be in the power business. Supporters of federal involvement in power production argue that the government has supplied remote or depressed areas which would not have been attractive to private industry and that the public good is still being served by federal utilities. Private utility companies, particularly in the Tennessee Valley, have fought federal power production since the 1930s. This battle continues as private utilities use lawsuits and intense congressional lobbying to thwart TVA's power program.

Over the past 65 years, TVA has continued to evolve in response to internal and external pressures. Although the future of the agency remains unclear, TVA has historically endured many attacks to its existence. Recent debates illustrate that while the public perceives TVA primarily as a comprehensive river basin development agency, low electric rates are essential to maintaining the economic vitality of the region. The dichotomy between TVA's resource management and power generation missions will continue to shape the future of the agency.

Lessons

TVA provides a successful example of comprehensive river basin development. While the development of TVA's institutions and operational programs can provide insight to World Bank staff and client countries, the applicability to other river basins will vary with local political, social, and economic conditions. Nonetheless, important lessons can be learned from the TVA experience.

1. *TVA emerged from a unique set of historical, political, and geographic circumstances.* The dire poverty in the Tennessee Valley, coupled with President Roosevelt's commitment to implementing an innovative New Deal program, lead to the creation of a unique regional agency with broad powers to develop the resources of a river basin. The TVA model has never been replicated in the United States, in part due to state's rights issues and opposition by other federal agencies. Similarly, in other countries where there are strong local governments and existing national institutions, the implementation of a strong regional authority might not be appropriate or even possible.

2. *The early success of the TVA depended on the strength of its champions, the vision of its first leaders, and its ability to show tangible results within a few years.* TVA's champions provided the conceptual framework, political will, and money to ensure the successful initiation of the Authority, while its first board of directors provided the vision to oversee the practical implementation of this 'bold experiment.' Concepts such as integrated land and water resource planning, maintenance of an ecological balance, collaboration with grass roots organizations, innovative technical assistance programs, small-scale credit programs, and provision of low-cost, accessible electricity to fuel economic development were well ahead of their time. TVA was also able to solidify its vitality as an institution and gain the support of Valley residents by completing major infrastructure projects and visibly improving the standard of living within a 12-year period.

3. *TVA's greatest legacy has been the integration of a healthy natural resource base, a strong infrastructure, and human capacity to foster the social and economic development of a region.* An infrastructure based on a system of dams and reservoirs to support navigation, control floods, and produce power, combined with an extensive transmission system to provide cheap electricity throughout the region, served as the backbone for economic development. Intense efforts to improve agricultural, land use, and forestry practices helped to restore and maintain a healthy environmental base, while small-scale credit and technical assistance programs provided people with the tools to improve their own lives.

4. *TVA's institutional structure served the Authority well during its early years but has provided the seeds for its greatest challenges as the Authority has matured.* When its mission was clear and focused on infrastructure construction, TVA's hierarchical institutional structure streamlined decision making and kept the agency action-oriented. Today, two important deficiencies are apparent. There is no formalized mechanism for stakeholder participation in decisionmaking and there is no effective means to ensure critical oversight of the agency. Although TVA has historically worked closely with the states, local communities, and citizens, and utilizes a public review process around specific projects, there is no direct representation of stakeholders in the management of TVA or a formalized mechanism for consensus-building. There is also no well-established mechanism for internal, independent scrutiny of policies, while external congressional oversight has not always been consistent or rigorous.

5. *TVA's greatest tension has been between its missions as a resource development agency and as a power company.* As predicted in 1937, TVA's power organization has slowly become the dominant organization in the TVA. In 1997, TVA's chairman declared power production to be the agency's core business. TVA's power program is self-financing and generates more than 98 percent of the TVA's revenues. However, TVA's mission as a comprehensive river basin management agency has produced its greatest accomplishments. Although TVA's success as a river basin manager has given it a great deal of popular support, the future of its nonpower programs remains uncertain. While nonpower activities like flood control and environmental management provide immense benefits to the region, they are not self-financing or revenue generators. The long-term sustainability of agencies like TVA will depend upon finding innovative ways to finance resource management activities.

1. Conception and Development of the Tennessee Valley Authority

TVA was established by an act of the United States Congress in May 1933 within the first 100 days of Franklin Delano Roosevelt's new presidency. This act was part of Roosevelt's "New Deal" to help lift the United States out of the depths of the Great Depression. The concept of the Tennessee Valley Authority was both unique and broad. Roosevelt's vision was that TVA would function as "a corporation clothed with the power of government but possessed of the flexibility and initiative of a private enterprise" (TVA 1983a p. 9).

The new agency, he said, would also "be charged with the broadest duty of planning for the proper use, conservation, and development of the natural resources of the Tennessee River Basin and its adjoining territory for the general social and economic welfare of the nation. . . ." (TVA 1983a p. 9).

Over the next twelve years, between its inception in 1933 and the end of World War II in 1945, TVA embarked on an ambitious effort to establish its institutional framework, build broad-based local support for its programs, and construct a physical infrastructure that would serve as the backbone for its accomplishments. This infrastructure included a vast system of multipurpose dams and reservoirs to harness the power of the Tennessee River and an extensive transmission system to provide cheap electricity throughout the region. It was during these early years that TVA established what may become its greatest legacy—the integration of a healthy natural resource base, a strong infrastructure, and the human resources to foster the social and economic development of a region. The following section describes these early years, focusing on the principal factors that led to the establishment of TVA, the institutional and conceptual issues that guided its early development and laid the foundation for future successes and failures, and the attributes that emerged as TVA's distinguishing characteristics.

Principal Factors

Like many innovative projects, TVA emerged from the confluence of five main elements:

- Need
- Champions
- Opportunity (history, politics, and geography)
- Vision
- Tangible results (Miller 1997).

The Need

The need for TVA arose both from conditions in the Tennessee Valley as well as from conditions of the river itself. The Tennessee Valley encompasses the 105,930 square kilometers (40,900 square miles) of the Tennessee River Basin (please see figure 1 at the end of this volume). The Basin covers a seven-state area in the southeastern United States centered around the state of Tennessee, but with parts in Kentucky, Virginia, North Carolina, Georgia, Alabama, and Mississippi. Although rich in natural resources such as land, water, forests, and minerals, in the 1930s the Tennessee Valley lagged behind the rest of the United States in every economic indicator. At that time, the Valley was largely rural and undeveloped, poverty stricken, and characterized by severe soil erosion and deteriorating environmental conditions (TVA 1983a; TVA 1989).

Of the 2.3 million people living in the Tennessee Valley in the 1930s, more than 75 percent lived in rural areas compared with 44 percent nationally. Less than 25 percent of the population lived in urban areas, compared with a national average of 56 percent. Only two cities in the Valley—Chattanooga and Knoxville (both in Tennessee)—had populations greater than 100,000. Together with

L.W. Hine

Woman and children in a typical log cabin

In the 1930s, the Tennessee Valley was largely rural, undeveloped, and poor.

six other cities, these anchored the economy of the area. Settlement patterns throughout the remainder of the region were characterized by individual homesteads and crossroads communities that were often built around a general store, a church, and a school (TVA 1983b).

Poverty was widespread throughout the region in the 1930s. Per capita income was one of the lowest in the United States. At the beginning of the decade average annual farm income in the Tennessee Valley was about $639, less than half of the national average of $1,835. More than 20 percent of farms had incomes of less than $250, and in areas such as Norris, Tennessee, incomes were as low as $100 per year (TVA 1989).

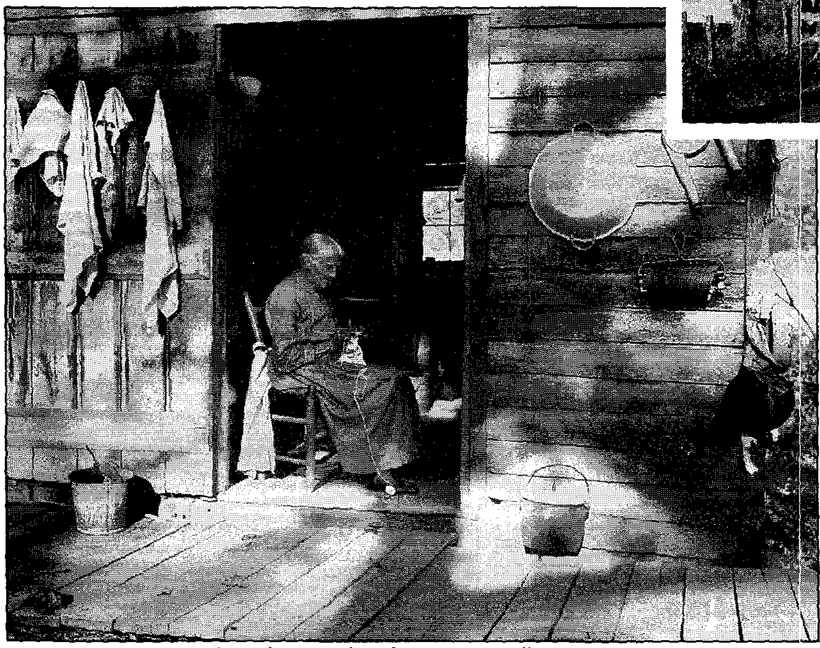
These impoverished conditions effected every aspect of life in the Valley. At a time when 13 percent of rural areas in the United States were electrified, only 4 percent of Valley farms had electricity and only 3 percent had running water. Poor sanitary conditions resulted in some of the highest rates in the nation for tuberculosis, typhoid, and infant mortality. One out of every three people in northern Alabama was infected with malaria. Poverty also resulted in relatively low-quality education. In 1930, the United States Office of Education ranked the seven Valley states among the 10 lowest in education quality. Illiteracy rates among adult residents were about 8 percent, almost twice the national average of 4.3 percent (TVA 1983b).

L.W. Hine

Straining sorghum near Anderson County, Tennessee

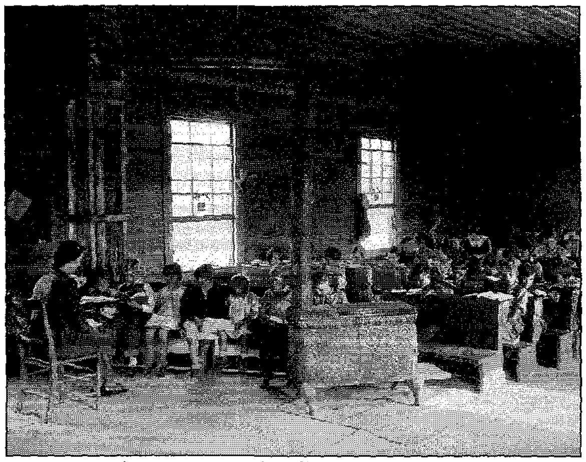
As the Depression deepened in the early 1930s, the deteriorating economic conditions of the region were also reflected in degraded environmental conditions, including eroded farmland, clear cut forests, and exhausted mines. Approximately 11 million acres, or 85 percent of the Valley's 13 million acres of cultivated land, had been damaged by erosion. Of this, 2 million acres were severely eroded and another 9 million visibly so. The natural conditions of steep slopes, heavy winter rainfall, and little winter snow cover contributed to the problem. Overuse of marginal lands, particularly on steep slopes, and heavy row cropping on unstable soils contributed equally to the severe erosion. The once-thriving forests and timber industry now produced trees of inferior quality and few

A country church near Loyston, Tennessee that would later be submerged by the waters of Norris Dam reservoir



Mrs. Sarah Wilson on her farm near Bulls Gap, Tennessee

Settlement patterns in the Tennessee Valley during the 1930s were characterized by individual homesteads and crossroads communities built around a general store, a church, and a school.



A typical one-room schoolhouse in rural Tennessee

Washday at the Stooksbury homestead near Andersonville, Tennessee

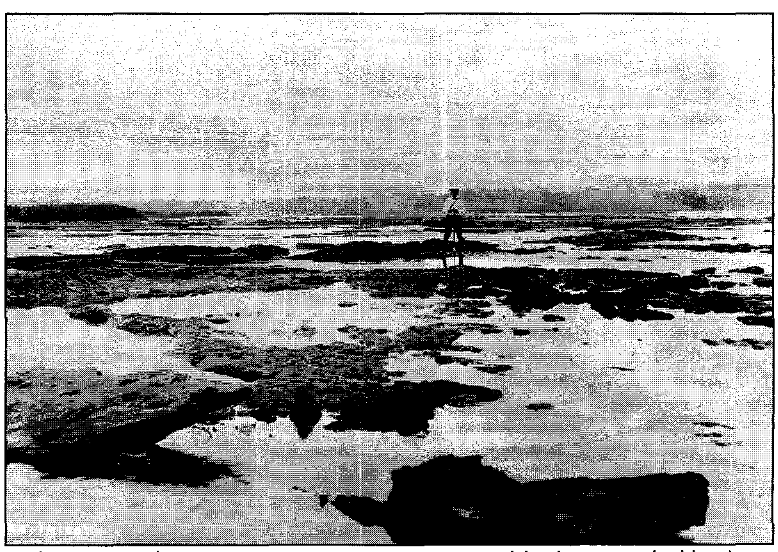
Copper Hill, Tennessee in the 1930s; erosion was a major problem throughout the Valley

employment opportunities. Similarly, many of the region's workable mines were nearly exhausted (TVA 1989).

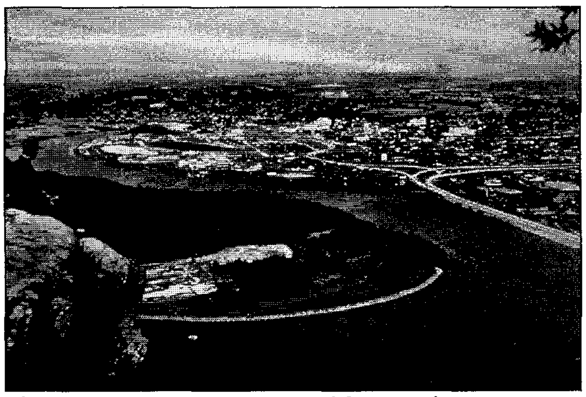
Conditions on the Tennessee River also contributed to widespread poverty in the area. As the fifth largest river in the United States (in terms of discharge) and a tributary of the Ohio and Mississippi Rivers, the Tennessee River had great potential to link the Valley with the extensive inland transportation system of the Mississippi River. The Tennessee River, however, was non-navigable due to hazardous shoals, seasonal variations in depth, and abrupt changes in gradient. Despite numerous attempts by the federal government (beginning in the 1820s) to overcome these obstacles, the Tennessee River remained unsuitable for long-distance transportation (TVA 1983b).

By far the most damaging aspect of the Tennessee River, however, was its great flood potential. The Tennessee Valley is one of the wettest regions in the United States. Prior to completion of the TVA reservoir system, most of the valleys in the Basin were subject to flooding. The majority of this flooding involved the inundation of farmland, resulting in crop damages. Floodplain encroachment by cities and towns, however, continued to increase potential damage. Chattanooga, a major urban area located within a narrow valley at the base of the upper Tennessee River Basin, was at the greatest risk of floods. In March 1867, the most widespread and devastating flood of record crested at a stage of 17.6 meters (58 feet) in Chattanooga, or about 8.5 meters (28 feet) above the top of the bank, thereby inundating most of the city (TVA 1983a). Additionally, the Tennessee River was also a major contributor to floods on the Ohio and Mississippi Rivers (Miller, Whitlock, and Hughes 1996).

By the 1930s the people of the Valley were trapped in a cycle of poverty. The natural resource base of the region, the foundation of the economy, was deteriorating, which led to widespread poverty and a public sector weakened by inadequate revenues. The Tennessee River, potentially a great resource itself, was non-



In the 1930s, the Tennessee river was non-navigable due to rocks like these at Muscle Shoals, Alabama



Chattanooga, Tennessee, viewed from Lookout Mountain

Chattanooga during the flood of record in March 1867

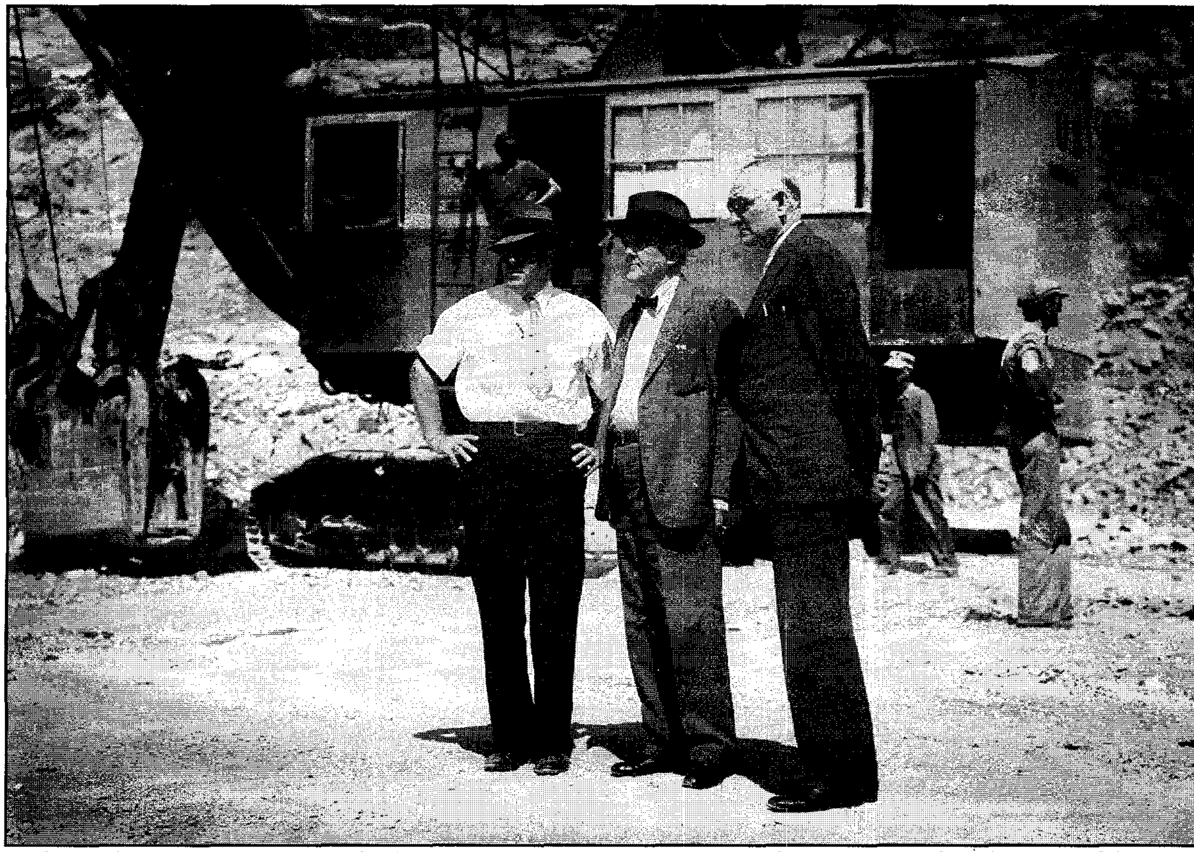
navigable and flooded regularly. It was recognized that the social problems in the Valley could only be addressed by improving the economy, which depended on a healthy resource base. Development of the region's land, water, and forests therefore appeared essential for economic revival. It was within this historical context that a program for multi-resource conservation and development was conceived (TVA 1983b).

The Champions

Although many people contributed to founding TVA, there were three very vocal and influential champions whose ideas and persistence were instrumental to making TVA a reality. These three men were Gifford Pinchot, whose ideas about multi-resource development provided the conceptual framework for TVA; George W. Norris, the author of the TVA Act; and Franklin Delano Roosevelt, the U.S. president who proposed and signed the legislation creating TVA (Davis 1997a).

Gifford Pinchot (1865–1946), who served as the first head of the U.S. Forest Service under President Franklin Roosevelt and later as Governor of Pennsylvania, was a leader in the early conservation movement. He promoted the concept of multiple use in conservation and recognized the significance of one resource to another. He saw a river as "a unit from its source to the sea" (TVA 1983 p. 5) that should be developed for all uses, and was one of the first persons to advocate planned conservation of the U.S. forests. He was also a friend of the great conservationist and former U.S. President Theodore Roosevelt and a link between this Roosevelt and U.S. President Franklin Roosevelt (a relative of Theodore Roosevelt). As early as 1910, when Franklin Roosevelt was a freshman New York legislator and chairman of the legislature's Forests, Fish and Game Committees, Pinchot influenced Roosevelt's thinking about conservation and comprehensive regional planning (TVA 1983a; Davis 1997a).

Pinchot also recognized that for multi-resource development to be successful, it must be economically viable. The advent of hydropower provided the economic grounding to the notion of a river system as an ecologically self-contained unit. Pinchot argued that only the government could successfully direct multipurpose projects dedicated to the public welfare and that, therefore, the best dam sites should remain under public oversight. Pinchot and others were able to place the concept of multiresource development at the center of policy debate in the early 1900s. In the process, conservationists and public officials elevated hydroelectric power to the level of navigation and flood control in the framework of federal responsibilities on the nation's waterways. This thinking became crucial during



Left to right: Project Engineer Fred Schlemmer, Senator George Norris, and A.E. Morgan (first chairman of the TVA Board of Directors) at the Norris Dam construction site, September 1933

the deliberations leading to the passage of the TVA Act and also influenced policy debates within the Authority during its first few years (Davis 1997a).

Senator George W. Norris (1861–1944) was a Republican from Nebraska who served in Congress for over 40 years. Throughout his career he remained an independent statesman. He was a very strong and vocal supporter of public ownership of utilities, particularly power utilities, despite the policies of his own Republican party. For several years and over several administrations, he led the fight as chairman of the Senate's Agriculture and Forestry Committee to preserve the hydroelectric dam and fertilizer facilities on the Tennessee River at Muscle Shoals, Alabama, as publicly owned facilities. The battle against private development of this site focused attention on the Tennessee River and became one of the catalysts for creating TVA. Senator Norris was the author of the TVA Act, and the first TVA dam constructed on the Clinch River was named Norris Dam in his honor (TVA 1983a; Davis 1997a).

Franklin Delano Roosevelt (1882–1945), a Democratic U.S. president who served for 12 years through the Great Depression and the beginning of World War II, had long-standing interests in the conservation of natural resources, regional planning and development, and the creation of urban settlements. Following the stock market crash of 1929, the United States fell into an economic depression, resulting in vast unemployment and deep despair across the country. In the fall of 1932, Franklin Roosevelt was elected president, partially on his promise of a "New Deal" for "the forgotten man." Influenced by Pinchot and other conservationists, he sought a bold experiment to serve as a model for the nation on how to organize and plan for the use of natural resources. Deeply disturbed by the facts of the depression and the high unemployment in the cities, he also sought a means to create employment in the country for unemployed urban workers and their families. A daring opportunist, Roosevelt took advantage of an historical moment to create an institution that symbolized his aspirations for the country and held out hope for revitalizing the economy (Hargrove 1994).

Opportunity: History, Politics, and Geography

By the spring of 1933, several historical, political, and geographic circumstances resulted in the creation of TVA. As the Depression deepened, conditions in the Tennessee Valley, already one of the poorest regions in the United States, worsened. Roosevelt was inaugurated in March 1933. Along with the Congress, he sought to initiate the New Deal within the first hundred days of his presidency by authorizing an unprecedented number of programs and policies designed to end the Depression and boost the morale of the American people. At the same time, Senator Norris proposed his seventh bill to create a regional federal agency in the Tennessee Valley. This bill not only addressed the issue of how to treat the federal properties at Muscle Shoals, but provided an avenue to test Pinchot's theories on multi-resource development. Roosevelt backed the idea; TVA could serve as a model for the nation on how to unify agriculture, forestry, and flood protection. In this vision, hydroelectric power was justified as a means for providing the energy to decentralize industry and create jobs throughout the region (Hargrove 1994). Roosevelt signed the TVA Act on May 18, 1933. He expressed his personal commitment to the Authority and to the principals of multi-resource development by directly allocating presidential discretionary funds to TVA during the first few years of its life. Freed of the congressional appropriations process, TVA was assured of adequate funding to initiate a strong design and construction program (Davis 1997a).

The TVA Act

The major sections of the TVA Act are summarized in table 1. The preamble to the Act set forth the purpose of TVA: "to improve the navigability and to provide for flood control of the Tennessee

U.S. President Franklin Roosevelt signs the TVA Act on May 18, 1933

Table 1. Summary of the Major Sections of the TVA Act (1933)

Section	Principal Aspects
1	Primary purposes and concept of unified resource development
2	Appointment and functioning of the TVA Board of Directors
3	Ability to operate outside of civil service laws; payment of prevailing wages
4	Rights as a corporation; power to acquire real estate; power to construct dams and reservoirs; instruction to provide nine foot navigation channel; power to acquire or construct power houses and structures, transmission lines, navigation projects and incidental works; power to unite power installations into one system by transmission lines; power to deed and lease real property
5	Power to produce, sell and demonstrate use of fertilizers; power, during times of war, to produce explosives and power for navigation facilities.
9a	Reservoir operating priorities set as flood control, navigation, and power generation as consistent with first two purposes; authority to generate, transmit, and market electric power.
10	Authority to sell power, giving preference to states, counties, municipalities, and cooperative organizations of citizens
12	Authority to construct transmission lines
13	In lieu of taxation, payments to states and counties from power proceeds
15a	Authority to issue bonds (maximum aggregate $50 million)
15e	Payments to U.S. Department of Treasury for reimbursement of appropriation investments in power facilities.
15f	Rules for determining power rates
22	Proper use, conservation, and development of natural resources of Tennessee River and adjoining territory; power to make surveys and general plans
23	Broad authority to maximize flood control, navigation, and power generation (as consistent first two purposes); properly use marginal lands; develop methods reforestation; provide for the social and economic well being of people in river basin
25	Power to acquire by condemnation lands, easements, or rights of way as necessary
26a	Requirement to submit plans to TVA and acquire approval for any dam, works, or other obstructions across, along, or in Tennessee river or tributaries that may affect navigation, flood control, or public lands
31	Act shall be liberally construed

Source: Authors.

River; to provide for reforestation and the proper use of marginal lands; to provide for agriculture and industrial development; . . . and for other purposes." Section 2 created a three-member board as the governing body. Board members were to be appointed by the president for nine-year staggered terms. One member was to act as chairman. The board was directed in Section 9a of the Act that the operating priorities of any dams and reservoirs were to be "for the purposes of promoting navigation and controlling floods . . . and so far as may be consistent with such purposes . . . for the generation of electric power." The construction of dams and the sale of hydroelectric power were authorized as by-products of the primary purposes of the Authority.

The broad multi-resource conservation and regional planning powers of TVA were set forth in Sections 22, 23, and 31 of the Act. Section 22 instructs TVA "to aid further the proper use, conservation, and development of the natural resources of the Tennessee River Basin and such adjoining territory as may be related. . . .and to provide for the general welfare of said citizens. . . ." Section 22 also authorized the president to make surveys and general plans to foster the "orderly and proper physical, economic, and social development. . . .of the area." TVA was subsequently assigned this responsibility by President Roosevelt through an Executive Order. Section 23 directed the president to propose appropriate legislation to enable TVA to maximize flood control, navigation, and power generation (consistent with flood control and navigation), seek the proper use of marginal lands and methods of reforestation, and bring about "the economic and social well-being of the people living in. . . .the river basin." To ensure that TVA's powers remained broad, Section 31 instructs that "this Act shall be liberally construed. . . ."

It is important to note that although Sections 22 and 23 expressed aspirations for comprehensive regional development, there were no specific powers embedded in the Act to achieve these goals. Nor did the Act provide guidance on the specific administrative and implementation mechanisms that were to be used to accomplish its mission. From the beginning there was ambiguity as to whether TVA was "an organization to do specific things for the development of natural resources or an agency for comprehensive planning for regional development" (Hargrove 1994 p.22).

Nonetheless, with the creation of TVA Roosevelt had provided a unique historical opportunity to unify the development of an entire river basin. For the first time, a complete river basin was used as a planning unit, overlapping the boundaries of seven states. The potential of the river and its tributaries could be developed for the benefit of the entire region and not for a small area or single purpose as previously customary. Also, flood control, navigation, and power generation were not ends in themselves, but the means to advance the social and economic well-being of the Valley. Additionally, all the purposes for which a river basin could be developed were under the administration of a single, grassroots agency with headquarters in the Valley and were not a branch of the central government in Washington. Thus, for the first time the opportunity was afforded in the Tennessee Valley to develop all the resources of the region to their fullest potential (Davis 1997a). The details of how to make

U.S. President Franklin Roosevelt, his wife, Eleanor, and A.E. Morgan at the Norris Dam construction site, September 1933 this happen, however, were left to the first TVA Board of Directors. For this reason, the personalities and vision of the first TVA Board of Directors were to have a profound impact on how TVA would evolve as an institution.

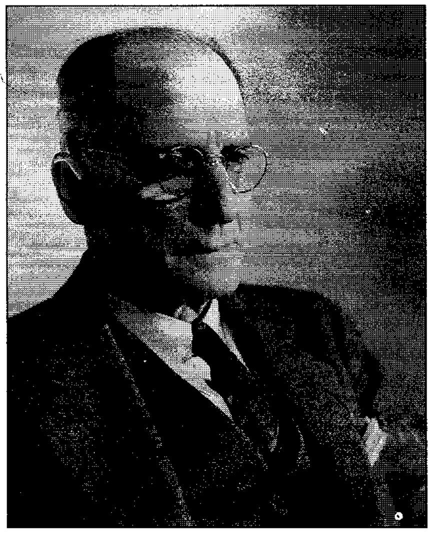
Vision: The First TVA Board of Directors

The first TVA Board of Directors, appointed by President Roosevelt in 1933, included Arthur E. Morgan (chairman), Harcourt A. Morgan, and David E. Lilienthal. The three men were vastly different in their approaches, experiences, and vision for TVA. Given the lack of practical guidance provided by the TVA Act, each had a unique contribution in setting TVA's agenda and future direction. Equally important, the tensions and disagreements among the three foreshadowed future contradictions in the core values and purposes of the Authority.

Arthur E. Morgan. A. E. Morgan, the first TVA chairman, was a construction engineer who had gained a national reputation for innovative dam design for the Miami Conservancy Project on the Ohio River. An intellectual, he was serving as the president of Antioch College at the time of his appointment. He was a staunch supporter of the concept of regional planning and saw the creation of small communities as a means of achieving a new society based upon humanitarian values. He firmly believed that society could be transformed through experimentation and demonstration and saw TVA as a unique opportunity to put his theories into practice (Morgan 1974). He wanted TVA to be involved in every aspect of the social and economic life of the people of the Valley. Although he provided great inspiration to the nascent organization and attracted many of the brightest thinkers in regional planning, he could also be dogmatic and paternalistic. He saw TVA's role as one of providing the moral and intellectual leadership to "properly" develop the Valley. This view of TVA was to contrast sharply with board member David Lilienthal's view and contributed to their contentious relationship. Eventually, in 1938, A. E. Morgan was fired by Roosevelt for the false and public accusations he made against Lilienthal (Hargrove 1994) and for public disagreements over the relationship between TVA and private utilities.

During the five years A. E. Morgan served TVA, however, he set a great many precedents that were to become deeply embedded in TVA culture. Based on his background and interests, he became responsible for the construction and planning aspects of the new agency. He oversaw the construction of TVA's first dam, Norris Dam, which was built in less than three years and under budget. He instituted a concept of "just-in-time" design and construction and set high standards for innovative dam design and integrated planning. He instituted an enlightened labor policy, including a six-hour workday (in order to employ more people) and equal pay for women. He developed the town of Norris, the dam work camp, as a model community for families, with libraries, hospitals, good schools, and affordable housing. He set up worker educational programs and demanded the absence of political patronage in hiring (Douglas 1986).

As one of A. E. Morgan's most lasting legacies, he oversaw the writing of *The Unified Development of the Tennessee River System* (TVA 1936). This document served as the blueprint for TVA's unique integrated, multipurpose reservoir system. Previously, the provision of flood control, which required leaving reservoir storage unfilled to capture flood flows, was seen as incompatible with the generation of hydropower, which required filling reservoirs to provide water for generation. TVA's unique system plan was able to accommodate flood control, navigation, and power generation by planning a series of dams on the mainstream of the Tennessee River, primarily for navigation and power generation. Large flood control storage and flow regulation, as well as water for power generation and water supply, would then be provided by high-head, deep storage reservoirs on the tributary rivers. To be operated as an integrated unit, the entire system could serve multiple purposes, which was not previously thought achievable. Moreover, the plan for unified development incorporated some very innovative concepts regarding land management. Recognizing that the "primary purposes of the unified control of the Tennessee River can best be achieved in part by construction of great engineering works, and in part by encouraging and guiding widespread changes in methods of agriculture and land use (TVA 1936), the plan included provisions for watershed protection, water control through improved forest and crop cover, and the development of recreational resources. The Tennessee River Valley provided an ideal location for this experimental approach. The Tennessee River was one of the few rivers in the eastern United States whose banks were not lined with major rail and highway systems. Inundation of large tracts of land by the construction of high-head dams was somewhat mitigated by the steep terrain in the tributary areas and the rural, non-industrial nature of the area (Davis 1997).

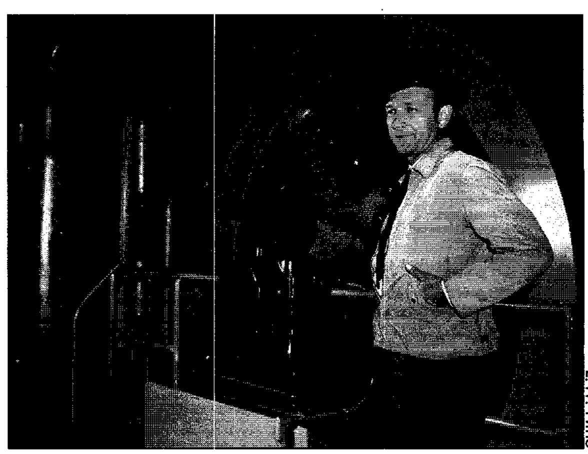


H.A. Morgan, one of the original TVA directors, who was previously president of the University of Tennessee

Harcourt A. Morgan. Harcourt Morgan (no relation to A.E. Morgan) was serving as the president of the University of Tennessee at the time of his appointment and previously served at the dean of agriculture at the same university. He was an agriculturist by training, with deep ties to local farm agencies, agriculture extension agents, and the farming community. Harcourt Morgan brought to TVA a concept called "a common mooring," which was based on the essential interdependency of people and nature. Land and water would flourish if properly cared for, but would result in soil erosion if misused (Hargrove 1994). Agriculture and industry should be balanced so that industrial growth did not upset the ecological balance against nature renewing itself (Hargrove 1994). Based on these values and experience, Harcourt Morgan became responsible for TVA's early agriculture and natural resources programs.

H.A. Morgan's most important contribution to TVA was instilling the philosophy and practice of working at the grass roots level through state and local agencies whenever possible. His experience in the field working with farmers had taught him that long lasting change could only be successfully accomplished by the farmers themselves. And this, he thought, was best achieved through farm demonstrations and by working with existing agencies already connected to the farm community. Lilienthal was later to articulate these concepts as "democracy at the grass roots" (Hargrove 1994 p. 27).

Both Arthur and Harcourt Morgan were leery of industrial development in the Valley and its potential to adversely impact the environment. Harcourt, however, believed that proper development could be attained by the people themselves, whereas Arthur maintained that common citizens required moral and intellectual leadership. A basic philosophical difference, which ultimately affected operational programs, emerged among the board members around this issue. While Arthur Morgan subscribed to the concept of elite leadership of the masses, Harcourt Morgan and Lilienthal believed in giving people the tools to improve their own lives (Hargrove 1994).



L.W. Hine

David E. Lilienthal, one of TVA's original directors, at Wilson Dam in the 1930s

David E. Lilienthal. When appointed to the TVA Board, Lilienthal was a 33-year old public-utility lawyer who had gained national recognition as a crusading member of the Wisconsin Public Service Commission. He was a strong advocate of utility regulation. He was ambitious, highly articulate, idealistic, intense, and combative. These traits were to serve him well in his protracted and contentious battles against private utilities in the Valley who sought to curtail TVA's power program (Neuse 1996; *Modern Marvels* 1997).

Lilienthal became responsible for TVA's power programs. His primary contribution was to develop an extensive decentralized system of power distribution through locally owned municipal electric systems and rural electric cooperatives. He instituted the concept of centralized power generation by TVA and decentralized distribution through locally owned distributors. He also defended and won court support for this concept when challenged by private utilities in the Valley. Led by Wendell Wilkie, chairman of the Commonwealth and Southern utility holding company, private utilities believed that TVA should be required to sell power through existing utilities. Lilienthal pushed the battle as high as the U.S. Supreme Court and upheld the right to sell power directly to public utilities. He also won the right for TVA to represent itself with its own lawyers in court—a unique right for a federal agency. Ultimately, TVA became the sole power producer in the Valley (Neuse 1996).

Lilienthal also brought to TVA the vision that economic development depended on the provision of low-cost power. He maintained that power supply should precede the demand and that the lower the cost, the greater demand. To help create demand, Lilienthal initiated TVA programs to provide low-cost appliances and to make credit easily available. He also pursued the construction of an extensive transmission system and provided assistance to rural cooperatives to ensure that farming areas had access to electricity. His boldness bore results and electric usage soared in the Valley (Hargrove 1994). Low-cost power was also essential to attracting industries to the Valley. As the economy of the Valley slowly revived, Lilienthal continued to advocate that low-cost, accessible power provide people the means to improve their own lives.

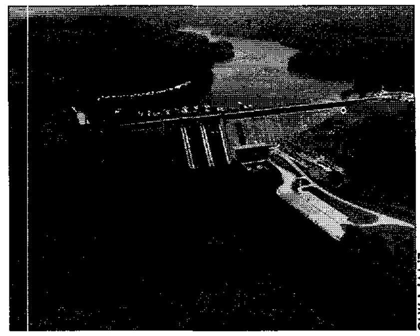
Tangible Results

TVA's viability as an institution was bolstered by its very early, visible, and for the most part positive impact on the lives of the people within the Tennessee Valley. Assured of funding directly from Roosevelt's presidential discretionary funds, TVA had two dam construction projects underway before its first year was out. Norris Dam, on the Clinch River, was the first project to be built. Through a massive construction effort with innovative design techniques, the dam was completed by 1936, in less than three years. Norris Dam was followed in quick succession by Wheeler, Pickwick, Guntersville, Chickamauga, and Watts Bar Dams on the mainstream of the Tennessee River. In approximately eight years (by 1941), five major dams had been completed, and five others were under construction.

With the onset of World War II, TVA was mobilized to assist the war effort and dam construction accelerated. On the mainstream of the Tennessee River, Ft. Loudon Dam was completed in 1943 and Kentucky Dam in 1944, thereby completing the nine-foot navigation channel on the Tennessee River and facilitating water transport from Knoxville, Tennessee to the Ohio and Mississippi Rivers (TVA 1983a; Davis 1997a). The war emergency dictated that subsequent dams be built with the objective of providing the most hydroelectric power in the shortest period of time with the smallest labor force. Large amounts of power were needed to produce aluminum at plants near Knoxville, nitrates at Muscle Shoals, and textiles at mills throughout the Valley, as well as to support uranium enrichment for the development of the atomic bomb as part of the Manhattan Project in Oak Ridge, Tennessee (*Modern Marvels* 1997). Consequently, large tributary dams, including Douglas, Cherokee, and Fontana Dams, were built with a great sense of urgency. Douglas Dam was completed in just 13 months and Cherokee Dam in 16 months. By 1945, a little more than a decade after creation of TVA, there were 26 dams in TVA's integrated water control system. This included 16 built by TVA, five acquired from others, and five operated by the Aluminum Corporation of America (ALCOA) (TVA 1945).

The construction of TVA's power system proceeded at the same rapid rate. By the late 1930s, the Tennessee Valley was essentially "on line." An aggressive transmission construction program, combined with the completion of a decentralized system of local municipal electric systems and rural cooperatives, ensured that power was distributed throughout the Valley. By 1945, TVA generated close to

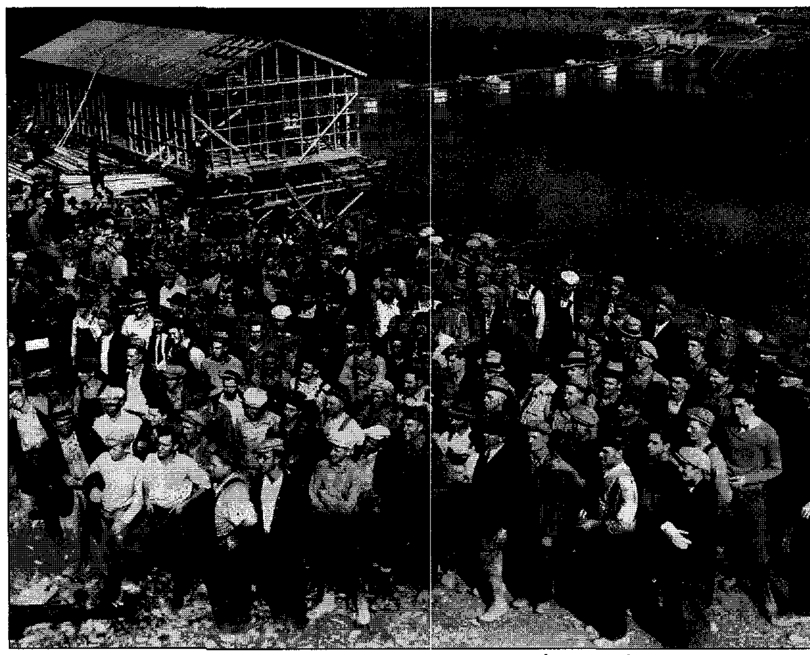
Norris Dam on the Clinch River, built between 1933 and 1936



L.W. Hine

L.W. Hine

Workers coming out of the test shaft at the Norris Dam site



L.W. Hine

Construction workers at the Norris Dam site

L.W. Hine

Engineers reviewing construction drawings at the Norris Dam site

Norris Dam, the first TVA project, was built in less than three years (1933–36) with a massive construction effort and the use of innovative design techniques. TVA put thousands of men and women back to work during the Depression.

12 billion kilowatt-hours and became the largest producer of power in the United States. Three-quarters of this power went to the war effort, which represented one-tenth of the power generated for war production in the United States (TVA 1945). By the 1950s, rural electrification was essentially completed (Ungate 1997).

During TVA's first decade, similar progress was made in the areas of agriculture and forestry. At its Muscle Shoals facility, TVA pioneered the development and use of phosphate fertilizers. By 1937, TVA began introducing these experimental fertilizers outside the Valley. Within the Valley, and using demonstration farms, TVA worked with local extension agents to induce farmers to try fertilizers and to experiment with new farming systems to control erosion, such as terracing, contour farming, and strip cropping. By 1943, there were some 15,000 demonstration farms in the Valley, and agricultural production levels had grown up to three times greater than before (TVA 1983a). Forestry efforts were focused on fire control, reforestation, implementation of management practices to increase yields, and development of techniques to reduce waste in woodcutting and processing. TVA also worked with the Civilian Conservation Corps and landowners to facilitate massive tree-planting efforts.

Although there was certainly controversy over the relocation required during TVA's early dam-building years, most people in the Tennessee Valley benefited from TVA's presence (*Modern Marvels* 1997). During the Depression, people were put back to work. In October 1933, TVA had 201 employees. By 1942, TVA employed nearly 40,000 workers, and the pay was generous by the standards of the time (Davis 1997a). Rural electrification efforts increased farm incomes dramatically (TVA 1983a), and cheap electricity attracted industries to the Valley (Hargrove 1994). Within little more than a decade, TVA won the broad-based support of local residents and local and state governments. It gained a national reputation for its work in water resources, land management, forestry, agriculture, and energy production. It also attracted some of the best and brightest minds in their fields to the Valley, beginning the development of a highly professional and committed staff (*Modern Marvels* 1997).

Seeds of Success and Failure

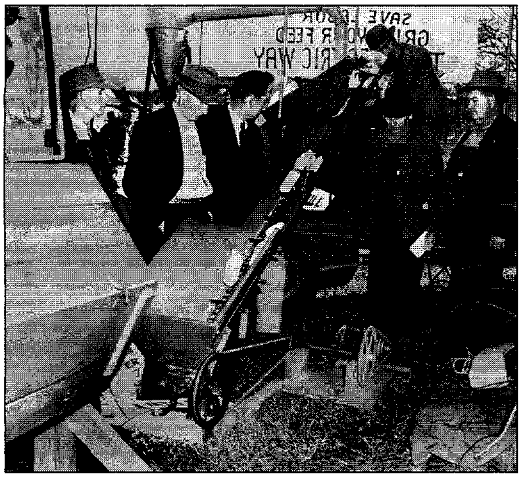
Between 1933 and 1945, TVA evolved into a strong organization with much of its physical infrastructure (reservoir and transmission systems) in place. It established its institutional framework, core ideologies, primary missions, and constituencies. Like many organizations, however, its greatest strengths in its early years would also prove to provide the seeds for its greatest challenges as the organization matured and the external environment changed (Miller 1997).

Institutional Framework

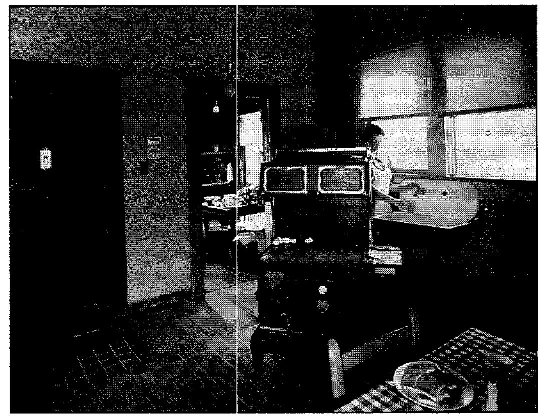
The overall organizational structure of TVA that emerged from its first decade of operation and served the Authority for many of its 65 years included:

- An appointed board of directors (three members)
- A general manager
- Strong operating divisions.

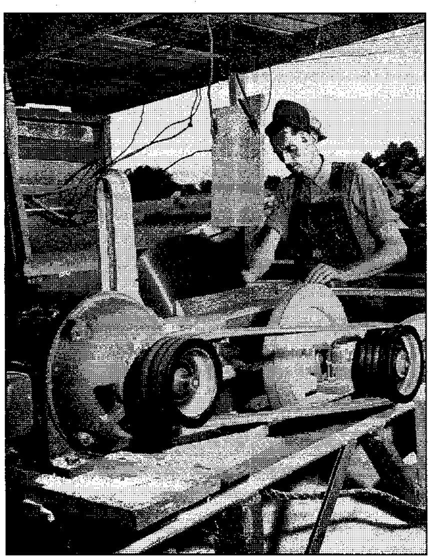
Although the details of the organizational structure and the relative strength of these three main arms have varied over time and also varied with the personalities and interests of the board members, the general structure has remained fairly constant until recently. The principal function of the TVA Board of Directors customarily has been to set policy. The general manager has primarily served as a facilitator and coordinator. Normally, the general manager has had a small staff and focused duties. The general manager has not had the means to conduct independent analyses or generate alternatives, but has largely functioned as a funnel for the ideas and programs proposed by strong operating divisions. Historically, although the specific titles have changed over time, the operating divisions have included a power organization, a division focused on natural resources (including water), and either an



Modern equipment and cheap electricity helped to improve farm incomes.

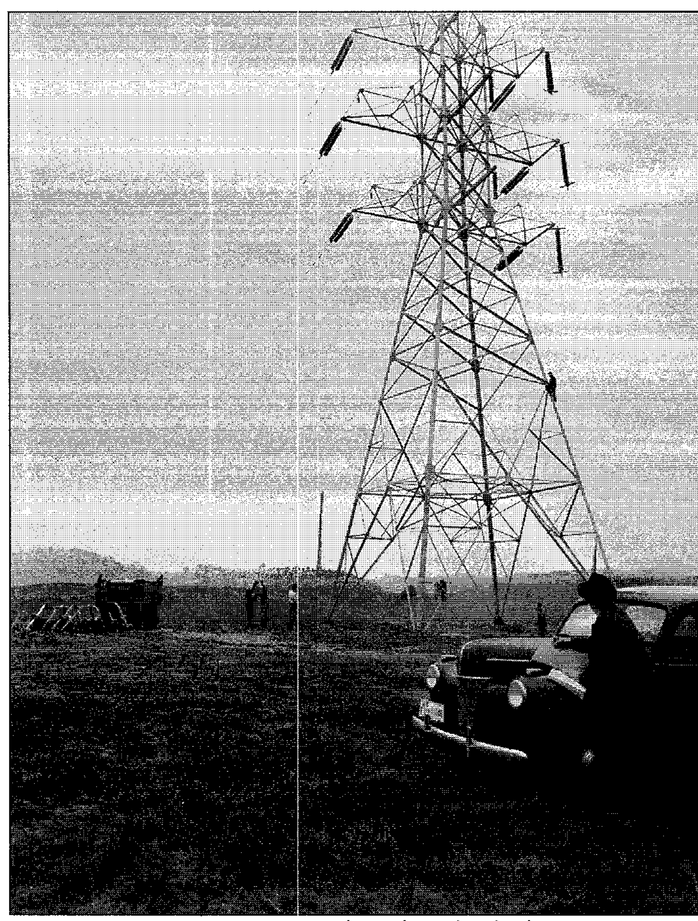


Rural home being electrified

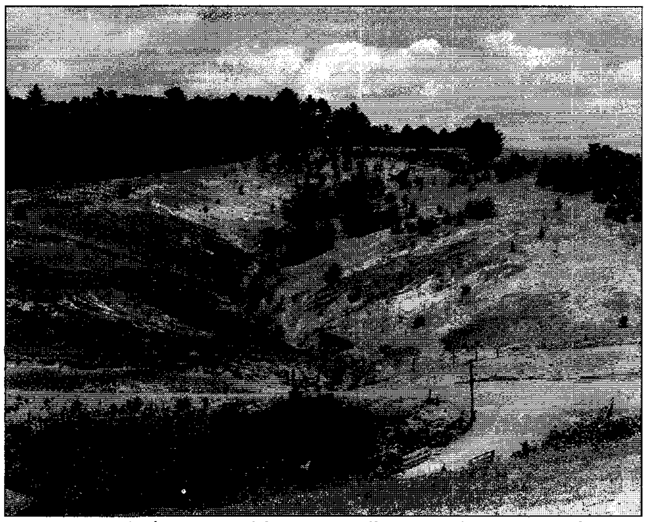


Access to electricity in rural areas powered small industries.

TVA's viability as an institution was bolstered by its early, tangible, and largely positive impact on the lives of residents of the Tennessee Valley in the 1930s and 1940s.

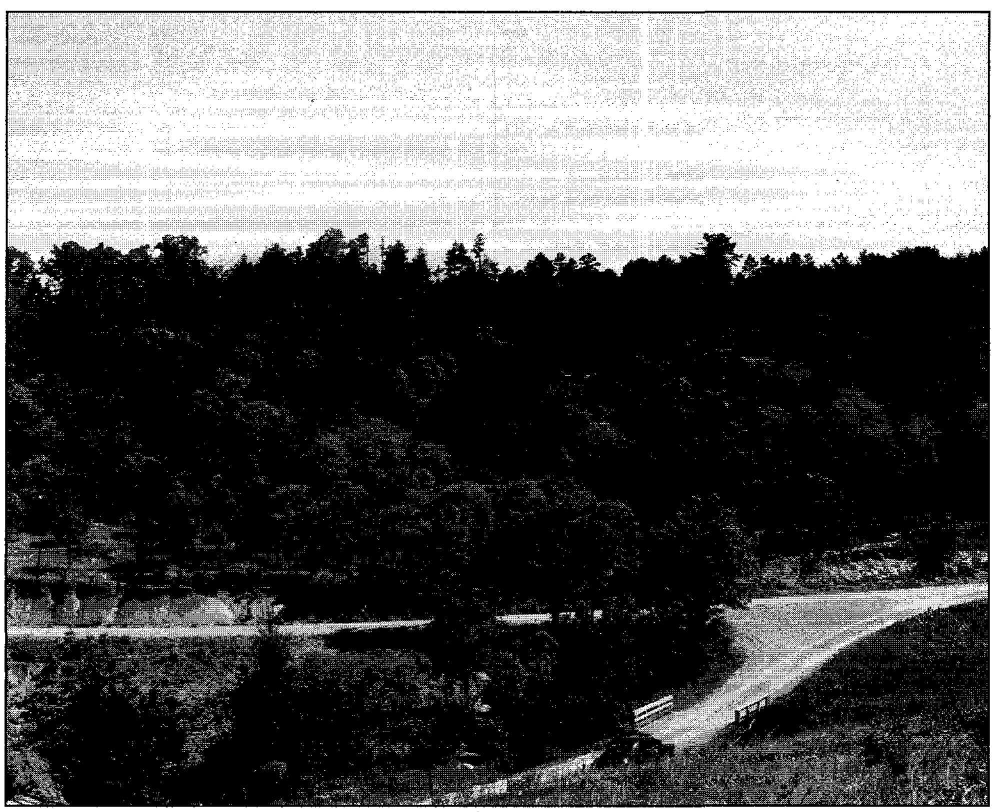


TVA power grid "on line" by the late 1930s



TVA provided pine and locust seedlings to the owner of this eroded land in Buncombe County, North Carolina, in the 1930s.

TVA recognized the importance of public participation in reforestation both to improve timber production and to protect watersheds. TVA worked with local forestry and agriculture agencies to promote tree planing on idle land.



The same tract of land, 20 years later

agriculture division (early years) or an engineering design and construction division (later years). The operating divisions have generally had highly competent technical staffs and have been responsible for their own planning and implementation of projects. In summary, the Board has generally set policy, which has been carried out by highly professional operating arms, guided and coordinated by a general manager (Hargrove 1994).

One implication of this overall structure is that while policymaking at TVA has remained centralized; planning, management, and implementation have however largely remained decentralized. Interestingly, although TVA carried out unified development of the Tennessee River Basin and implemented numerous social and economic development programs, it never had a master plan for the social and economic development of the region. It was strongly believed that planning should be tied to operations and folded into physical development programs. As such, each operating arm developed its own operational and strategic plans, and, except for a short period of time, there was no centralized planning division for the Authority as a whole.

A second implication was the emergence of a decisionmaking process between the operating arms that was characterized by self-coordination and benign tension (Hargrove 1994). In general, the operating arms were complimentary and worked cooperatively. Given the multi-purpose mission of the Authority and high level of staff competence, there was often genuine cross-departmental collaboration. Although tension often existed between the power and natural resources missions, these differences were kept in-house. To the extent possible, problems were resolved at the lowest working level possible and only bubbled up to the higher levels if serious disagreements occurred.

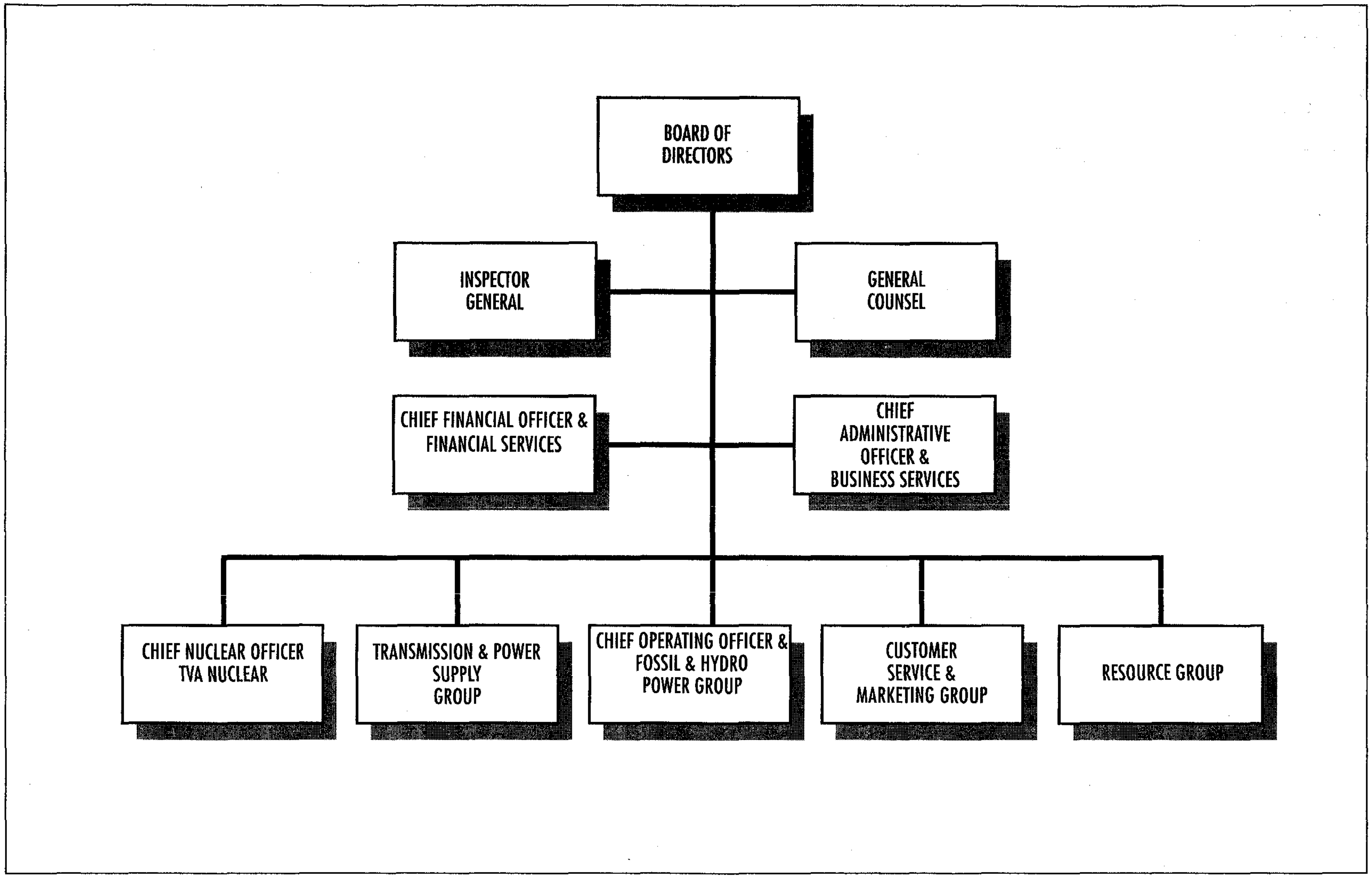
A third implication of TVA's overall institutional structure was that there was no means of conducting independent analyses or scrutinizing recommendations from the operating arms. The general manager for the most part lacked the staff to question proposals from below or develop an alternative set of approaches.

The strengths of this institutional framework were that it kept TVA grounded in operations and concentrated on doing real things that made a difference in the lives of the people of the Valley. It kept TVA action-oriented and focused on getting the job done. A small board of directors operating from the Valley combined with an emphasis on working through local agencies and government, also built widespread grassroots support for the Authority. This framework was most successful prior to the 1950s when TVA's mission was clear and large-scale dam and power plant construction projects were under way. A policy study conducted by Ruttan (1979) concluded that historically TVA had been most successful when it had responsibility for the development and execution of its own programs: electric power, navigation, flood control, recreation, development of fertilizers, or other specific contributions in technical fields such as forestry. TVA was less successful where the mission was less well-defined and cooperation with others was required, in areas such as rural and community development.

After the 1950s, as TVA began to search for new missions, some of the weaknesses of TVA's institutional approach began to emerge. There was no centralized planning division to assist TVA in defining new Authority-wide missions or a coherent strategy for the region (IIASA 1979). The strong nature and independence of the operating arms resulted in the pressure of centrifugal force on the center to relinquish power. The strongest division often won and, at times, there could be fierce competition over the congressional appropriated budget. Neither the Board nor the general manager's office could control departments without their full cooperation (Hargrove 1994). Additionally, as alternatives were screened by the operating divisions, the board was often unaware of the full range of options possible to address a given issue and there were no mechanisms to evaluate tradeoffs (IIASA 1979). Furthermore, because there was a strong belief that the operating arms were fully capable of discovering and correcting their own deficiencies, there was little room for external scrutiny or critical oversight. These weaknesses were to become most apparent in the late 1960s when TVA embarked upon an overly ambitious and costly nuclear power program.

Beginning in 1988 with the appointment of Marvin Runyon as chairman of the TVA Board of

Figure 2. Organization of the Tennessee Valley Authority as of June 1, 1996



Source: TVA.

Directors, the Authority has gone through a series of organizational changes to increase the authority of the board, increase competitiveness, run the Authority more like a business, and bring institute new management concepts, such as "total quality management." Runyon perceived that some of the virtues of TVA's decentralized organization and culture, while assets in the 1930s, had become serious liabilities in the 1980s (Hargrove 1994). A continual process of re-engineering, refocusing, and restructuring continues today under the chairmanship of Craven Crowell. One major institutional change has been the shift from the general manger concept to an executive committee overseeing operations. TVA's organization structure (as of 1996) is presented in figure 2.

Core Ideologies

In an interesting analysis of TVA and its leadership, Hargrove (1994) maintains that TVA, and the myth of itself it portrays, is based on the balancing of four values, each of which is part of a dichotomy: professional expertise supported by statutory missions versus a grassroots democracy and a multipurpose authority versus a power company.

On one hand, TVA has attracted and maintained a highly competent and dedicated staff. Particularly in the early years, working for TVA was more than a job; it was a mission. This bred within TVA culture a sense of self-confidence and belief that TVA could properly direct the development of the Valley. It also gave credence to the concept that operating organizations were willing and capable of discovering and correcting their own deficiencies and therefore were above external scrutiny. On the other hand, TVA has believed in and practiced grassroots democracy and has a long history of working through local and state agencies to facilitate change at the local level. TVA has had strong technical assistance programs in areas such as agriculture, forestry, floodplain management, and the clean water initiative, which have focused on stimulating local participation and building local capacity and a sense of ownership.

Perhaps TVA's greatest duality, however, is its sense of itself as a comprehensive river basin development authority versus as a power company. Until recently, TVA's perception of itself, as well as the public's perception of TVA, has been that its core mission is to develop and manage the resources of the basin. TVA's natural resource and social and economic development programs, which are referred to as nonpower programs, are supported through congressional appropriations. In reality, however, since 1947 federal appropriations for nonpower programs have constituted only 2 percent of TVA's budget (Hargrove 1994). The other 98 percent of TVA's budget is generated through power revenues.

In the TVA Act, hydropower generation was originally seen as a by-product of the core missions of navigation and flood control, and the distribution of electric power was a means of improving the economic conditions in the Valley. Yet as early as 1937, TVA officials warned that the temptation to earn money by the sale of electricity by a TVA cramped for appropriations might lead to the sacrifice of other purposes to the power program (Reeves 1937). Following the 1936 court battles where TVA won the right to supply power directly to local distributors and bypass private utilities, TVA became the sole supplier of electricity in the region. With private utilities now kept out of the Valley, TVA established a monopoly by default. This lead to an ever-expanding power program. In 1940, TVA began building it's first steam plant at Watts Bar, Tennessee, to meet the growing power demands imposed by the war effort. At that time, however, there was still, uncertainty about TVA's future as a power company following the close of the war. After World War II, however, the power demand continued to escalate and the scales tipped in favor of power. Between 1945 and 1950, the number of TVA electric power customers almost doubled. The Atomic Energy Commission demanded almost one-third as much energy as the rest of the Valley for its facilities in Oak Ridge, Tennessee and Paducah, Kentucky. The demand for power was outstripping the supply that TVA could provide by building dams, and in 1949 the Authority began building a series of large coal-fired plants (TVA 1983a). Eventually, thermal power production would far surpass TVA's hydropower generation and become the Authority's primary source of power.

The turning point for TVA as a power company came in 1959 when the it was granted the right to self-finance its power program. The federal government was reluctant to increase budget deficits and use appropriations to finance new thermal power plants. Following several years of negotiations, a self-financing amendment was finally passed that granted TVA the authority to issue bonds to fund the needed growth in the power system. In exchange for the privilege of self-financing, Congress barred TVA and its distributors from selling TVA power outside the areas in which it was being sold as of 1957. This so-called "fence" set TVA's power service area as an 80,000 square mile (207,000 square kilometer) area that is almost twice as big as the Tennessee River watershed. Once TVA's power program became self-financing, the Office of Power slowly became the dominant organization in TVA (Hargrove 1994). Today, TVA is one of the largest power producers in the United States and generates annual revenues close to $6 billion per year (TVA 1996).

The 1990s have brought another turning point for TVA, as power companies in the United States face the prospect of deregulation. To prepare for deregulation, for the first time in TVA's history its chairman, Craven Crowell, publicly declared that TVA's primary mission is power production. In early 1997, Crowell sent a recommendation to Congress that TVA remain a federal utility and turn its non-power programs over to other federal agencies (*Knoxville News-Sentinel*, Jan. 25, 1997). Due to congressinonal pressure and public outrage at the proposal, Crowell had to withdraw this recommendation. Nevertheless, the centrality of power production to TVA had been publically pronounced.

Constituencies

Over the years, TVA's primary constituencies have included:

- Tennessee Valley grassroots support
- State and local government
- Interest groups (distributors, industries, environmental, etc.)
- Tennessee Valley Congressional Caucus
- Other federal agencies.

Because of TVA's long history of grassroots work, residents of the Valley and state and local governments have generally remained staunch supporters of TVA, except over specific issues. Public dissatisfaction with TVA was most apparent over environmental issues in the 1970s. During this period, members of the public and some state and local governments strongly opposed the building of Tellico Dam in Tennessee. Protection of the snail darter, an endangered species, became a rallying point for the public and environmentalists, but special legislation in Congress finally allowed for completion of the dam. Additionally, during the 1970s the public expressed anger over TVA's resistance to implementing provisions of the Clean Air Act, and it was only after law suits with the Environmental Protection Agency that TVA committed to decreasing air pollution from its coal-fired plants. Subsequently, David S. Freeman was appointed to the TVA Board of Directors by U.S. President Jimmy Carter with instructions to establish TVA as an environmental leader (Hargrove 1994). Environmental management has since become a key component of TVA's activities, and the Authority has been recognized for its innovative programs to integrate environmental concerns with reservoir and power system operations. During recent uncertainties over the continuation of TVA's federally appropriated budget, the citizens of the Valley, as well as state and local governments, have been vocal supporters of the Authority.

TVA's relationship to its other constituencies has been both a source of strength and weakness. Historically, one of TVA's strongest special interest groups has been the Tennessee Valley Public Power Association, an association of local distributors. In the face of deregulation, the Public Power Association for the first time has begun to oppose some of TVA's policies. Conversely, the Tennessee Valley Energy Reform Coalition, usually a vocal critic of TVA's power program, has recently voiced strong support for continuing TVA management of the Tennessee River. This group also opposes privatization of the TVA power program (*Knoxville News-Sentinel*, May 25, 1997).

TVA's greatest ally over the years has been the Tennessee Valley delegation to the U.S. Congress, also referred to as the TVA Caucus. This group is composed of over 30 congressmen and women (members of both the Senate and House of Representatives) from states and electoral districts within TVA's geographic reach. Members of the Caucus have historically held key positions on the congressional committees that control TVA's budget, and TVA has depended upon them to lead the fights to protect or restore the Authority's annual appropriations. As a result, TVA has not always built the broad-based congressional support it should have over the years. Furthermore, the TVA Caucus has often taken a "circle the wagons" approach in defending TVA, that has tended to silence constructive criticism of the Authority, both internally and externally. The significance of these deficiencies has become more apparent in recent years. Closer external scrutiny of the Authority may have helped to avoid the problems in TVA's nuclear power program and broader-based support would have proved useful during these times of government efforts to reduce the deficit and cut federal programs (Hargrove 1994). In the 1992 Republican Party landslide, many of the most influential members of the Caucus, who had been Democrats, lost their seats in Congress. Consequently, TVA has recently faced tough battles to justify its budget to Congresspersons who have no vested interest in TVA and would rather see that money spent in their own districts. It was only in 1997 that a TVA Caucus has begun to coalesce again in an attempt to save TVA's nonpower programs (*Knoxville News-Sentinel*, Feb. 7, 1997).

TVA has a history of both cooperation and conflict with other federal agencies. In areas such as forestry and navigation, TVA has worked cooperatively with agencies such as the U.S. Forest Service and the U.S. Army Corps of Engineers, respectively. On the other hand, in areas such as agriculture, soil conservation, and floodplain management, TVA has worked hard to establish its predominance over other federal agencies in the Valley. Consequently, some federal agencies have served as partners and supporters, and others as detractors.

Distinguishing Characteristics

By the end of World War II, in little more than a decade, TVA had established what would become its distinguishing characteristics as a unique multi-resource agency, including

- Focus on unified, regional development
- Multiple missions
- Autonomy
- High standards of professional excellence
- Grassroots participation and support
- Strong regional identity (Modern Marvels 1997; Alavian 1997).

TVA is the only agency of the Roosevelt era that remains an institution as of the late 1990s. It emerged from a unique set of historical, political, and geographical circumstances, and has operated successfully in the Tennessee Valley for over 65 years. No other regional agency exactly like TVA has been created within the United States; however, the concepts of comprehensive river basin development pioneered and practiced by TVA have served as a model for the management of other river basins in the United States and around the world (TVA 1989).

2. Water Resources Management

Although TVA has been responsible for a wide variety of programs in the Tennessee Valley, such as power production, economic development, environmental research, and natural resource conservation, it is perhaps best known for its water resources management programs. TVA owns 54 dams and reservoirs that are operated as an integrated unit for the benefit of the region. The reservoir system serves many purposes, including support for navigation, flood control, power generation, recreation, and water quality. One of TVA's great legacies has been the harnessing of the Tennessee River to foster the social and economic development of the Valley. This chapter provides an overview of the institutional and financial framework for TVA's water programs, the Tennessee River watershed, the uses and operations of the reservoir system, TVA's approach to water resources planning and projects, and the role of public input in TVA operations.

Legal, Institutional, and Financial Framework

TVA's legal authority for its water management programs is derived from the TVA Act (U.S. Congress 1933). As discussed, the Act grants TVA broad multi-resource conservation and regional planning powers to aid in "the proper use, conservation, and development of the natural resources of the Tennessee River drainage basin and . . . adjoining territory," as well as the power to authorize and build its own projects to meet these obligations. Section 9a of the Act also specifies that the operating priorities of TVA's dams and reservoirs are to be for navigation and flood control and for power generation as consistent with the first two priorities. In 1991, following an intensive public review process, TVA expanded its reservoir operating priorities to include recreation and the maintenance of minimum flows to improve water quality and aquatic habitat (TVA 1990a).

Because the Tennessee Valley is located in the eastern United States, issues related to access to and ownership of water are governed by the riparian doctrine. Under this doctrine, riparians have the right to utilize water as long as this use does not harm downstream riparians. As such, issues related to the ownership of water rights, which are important in the arid western region of the United States under the prior appropriation doctrine, are not as significant in the Tennessee Valley. Additionally, ample rainfall in the Tennessee Valley, coupled with minimal withdrawals and consumptive use of water (less than one percent of the mean annual flow is used consumptively), have minimized conflicts over water use. TVA's federal responsibilities for navigation and flood management give TVA the right to control the flow of water. Interestingly, although the public holds TVA accountable for the water quality of its lakes and streams, the states maintain responsibility for water quality and the issuance of discharge permits.

Administratively, TVA's water programs are currently the responsibility of the Water Management unit within the Resource Group (see figure 2). Currently, the Water Management unit oversees operational programs related to river system operations, water resources projects and planning, the clean water initiative, environmental compliance, and environmental chemistry.

TVA's water, land, environmental, and other natural resource management programs are funded by appropriations from the U.S. Congress as part of TVA's nonpower programs. In fiscal year 1997, total TVA federal appropriations were $106 million. Between 1987 and 1997, these appropriations have ranged from a low of $90 million to a high of $140 million. Since 1992, land and water stewardship activities have accounted for 60 to 80 percent of the appropriated budget. Given efforts to streamline the federal government and controversy over the future of TVA's nonpower programs, TVA appropriations for fiscal year 1998 are expected to be less than $100 million.

When TVA earned the right in 1959 to self-finance its power programs by issuing bonds, it became responsible for repaying the U.S. Treasury for the original appropriations for building that portion of

TVA projects that benefited power production. This cost allocation was decided by a congressional committee upon the completion of each multipurpose project. The money is paid annually, with interest, to the U.S. Treasury from power proceeds. Additionally, although TVA is exempt as a federal agency from paying taxes, it does make payments in lieu of taxes to local and state governments. These tax-equivalent payments represent five percent of gross power revenues and amounted to $256 million in 1996.

The Tennessee River Basin

The Tennessee River Basin lies in a seven-state area in the southeastern United States (please see figure 1 at the end of this volume). Its drainage area covers 40,900 square miles (105,930 square kilometers), mostly in the State of Tennessee, but with parts also in Kentucky, Virginia, North Carolina, Georgia, Alabama, and Mississippi. The Tennessee River begins in Knoxville, Tennessee, with the joining of the French Broad and Holston Rivers. It continues westward to Paducah, Kentucky, where it enters the Ohio River, only 46 miles (74 kilometers) upstream of the confluence of the Ohio and Mississippi Rivers. In terms of discharge, the Tennessee River is the fifth largest river in the United States and the seventh largest in North America.

The Tennessee River Basin is composed of two fan-shape basins connected, in the vicinity of Chattanooga, by a relatively narrow valley. The 21,400 square mile (55,430 square kilometer) area upstream, or east of Chattanooga, includes the slopes of the Blue Ridge and Great Smoky Mountains and is dominated by rugged forested areas. The remaining 19,500 square miles (50,500 square kilometers) downstream and west of Chattanooga, is dominated by relatively flatter open fields, woodlands, and rolling hills. Approximately 60 percent of the total watershed is forested, while the remaining 40 percent is open land and pasture.

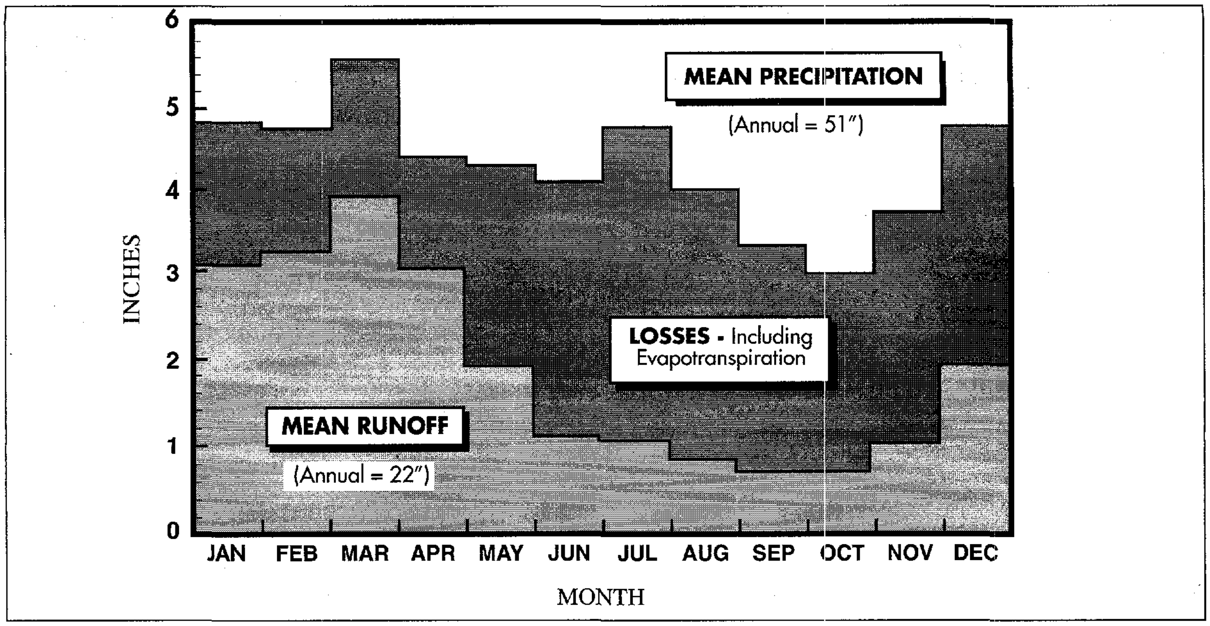
Table 2. Selected Tennessee River Basin Hydrological and Meteorological Statistics

Precipitation				**Runoff**			
Average Annual	1,295 mm	51 in	(1894-1993)	Average Annual	558 mm	22 in	(1894-1993)
Maximum Annual	1,651 mm	65 in	(1973)	Maximum Annual	863 mm	34 in	(1979)
Minimum Annual	914 mm	36 in	(1985)	Minimum Annual	279 mm	11 in	(1941)

Average Annual Natural Streamflow* +				**Temperature (daily average)**		
Chickamauga Dam (Upper Tennessee River System)				Jan.	-2.2°C/28°F (min)	8.3°C/47°F (max)
Average	971 m^3/s	34,300 cfs	(1903-93)	July	19.4°C/67°F (min)	30.6°C/87°F (max)
Median	960 m^3/s	33,900 cfs	(1933)			
Minimum	445 m^3/s	15,700 cfs	(1988)			
Maximum	1,455 m^3/s	51,400 cfs	(1929)			
Kentucky Dam (entire Tennessee River System)						
Average	1,883 m^3/s	66,500 cfs	(1903-93)			
Median	1,863 m^3/s	65,800 cfs	(1971)			
Minimum	880 m^3/s	31,100 cfs	(1941)			
Maximum	2,797 m^3/s	98,800 cfs	(1979)			

*Natural streamflow is the flow that would have occurred had there been no dams and is indicative of overall hydrologic conditions.
Note: 1 inch = 25.4 millimeters; 1 cfs = 0.028 cms; °F = °C x 1.8 + 32
Source: Miller and others 1993 and TVA 1995a.

Figure 3. Tennessee River Basin Mean Monthly Rainfall & Runoff, 1890-1994



Source: TVA.

Hydrologic Overview

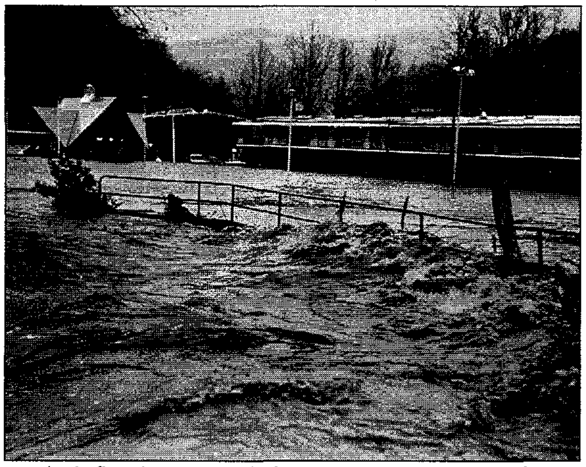
The Tennessee River Basin is one of the wettest regions in the United States. The Gulf of Mexico and the Caribbean Sea, located only a short distance to the south, are major sources of moisture. As there is no significant barrier between the Basin and the Gulf, prevailing winds from the south and west bring this moisture across the Basin. The Basin is also subject to heavy rainfall from dissipating hurricanes moving across the southeastern United States. General hydrologic and meteorological statistics are summarized in table 2.

The long-term (1894–1993) average annual precipitation for the Basin is 51 inches (1,290 millimeters) per year. The heaviest rainfall concentrations occur in the mountainous highlands of the eastern region, where annual precipitation often exceeds 90 inches (2,286 millimeters). Approximately half of the annual rainfall is received in winter and early spring, from December until mid-April. March is typically the wettest month; while September and October are likely to be the driest. As shown in figure 3, monthly average rainfall ranges from 3 to 5.6 inches (76 to 142 millimeters).

Long-term mean annual runoff in the Tennessee River is approximately 22 inches (560 millimeters), or roughly 40 percent of the average annual rainfall over the drainage area. Monthly average runoff varies from a high of almost 4 inches (25 millimeters) in March to a low of less than 1 inch (25 millimeters) in September and October. Generally, runoff is heaviest in the winter and early spring (December–May) when the vegetation is dormant and the ground is saturated. As the growing season commences, infiltration and evapotranspiration increase, and runoff decreases substantially through the summer and early fall (June–October) (Miller and others 1992).

Flood Potential

The high rainfall and runoff rates in the Tennessee Valley have rendered the area vulnerable to flooding. In general, flood-producing storms occur on an area within the Tennessee River Basin on the average of about once every two years. The major flood season in the Valley is December through mid-April, with the highest frequency of storms occurring in March. Widespread cyclonic storms with



Flash flooding in Gatlinburg, Tennessee, a popular tourist area in the Smoky Mountains

Flooding along the Tennessee River

High rainfall and runoff rates in the Tennessee Valley render the area vulnerable to flooding. Flood management is a major priority for TVA.

heavy, persistent rainfall occur more frequently during the winter season. Dormant vegetation and ground conditions favor a high rate of runoff during the same period. The worst winter storms can cover the entire Valley for several days. It is not unusual for one large winter storm to be followed by another even larger storm, three to five days later. Conversely, the worst summer storms tend to be short, intense, and relatively localized, resulting from thunderstorms or decadent tropical storms that have moved inland. These summer storms generally effect a smaller portion of the Valley, with heavy rains typically covering an area of 3,000 square miles (7,770 square kilometers) or less—roughly the size of a tributary reservoir drainage basin (TVA 1961).

Prior to the completion of the TVA reservoir system, most valleys in the Basin were subject to periodic flooding, resulting in inundation of farmland and in crop damage. However, Chattanooga, a major urban area located within a narrow valley at the base of the upper Basin, has always been at greatest risk from floods. During the flood of record, which occurred in March 1867, floodwaters rose about 28 feet (8.5 meters) above top of bank and inundated most of the city (TVA 1933a). Reducing the flood risk at Chattanooga became a major priority in the design of the TVA reservoir system and remains a major operating priority today.

Prior to the construction of Kentucky Reservoir, the Tennessee River was also a major contributor to Ohio and Mississippi River floods. Although the Tennessee River drainage area is only slightly more than 4 percent of the Mississippi River Basin above Columbus, Kentucky, it has historically contributed more flow than indicated by the ratio of drainage areas. The highest contribution, more than 30 percent, occurred in the 1897 flood, which was the highest known flood on the lower Tennessee River.

Although TVA flood management efforts have substantially reduced the magnitude and frequency of damage-producing floods in the Valley, risks from flooding persist. There is currently about a 20 percent annual chance of minor flood damage and a 5 percent chance of substantial flood damage at Chattanooga. Chattanooga's vulnerability is influenced by the fact that thirty-foot floodwalls, which were part of the city's original flood protection plan, have not been constructed. Other flood-prone urban areas on regulated streams, such as Knoxville, Kingsport, Lenior City, Clinton, Charleston-Calhoun, and the low-lying agricultural areas surrounding Savannah, are still vulnerable to damage during large floods. Additionally, because TVA dams regulate less than 10 percent of the total stream miles in the Valley, the communities and farms on unregulated streams remain subject to periodic flooding.

Reservoir System and Uses

There are 54 TVA-owned dams and reservoirs in the TVA water control system. Fifty-three of these dams are located in the Tennessee River Basin and one in the Cumberland River Basin. Additionally, there are 14 dams that are owned by other entities but whose releases are integrated into the TVA system. These include four dams owned by Tapoco, a wholly owned subsidiary of the Aluminum Company of America (ALCOA), two owned by Nantahala Power and Light, a wholly owned subsidiary of Duke Power, and eight dams on the Cumberland River owned by the U.S. Army Corps of Engineers. Due to a canal that connects Barkley Reservoir on the lower Cumberland River and Kentucky Reservoir on the lower Tennessee, the operation of these two systems must be coordinated. A schematic of the TVA's water control system is shown in figure 4, while table 3 provides an overview of major dam and reservoir projects.

The TVA reservoir system is operated as an integrated, multipurpose system. Major objectives are to provide for navigation, flood control, hydropower generation, summer recreation levels, and minimum flows for the maintenance of water quality and aquatic habitat. Additionally, the reservoir system supports fossil and nuclear generation by providing condenser cooling water and dissipating thermal waste loads. A summary of major TVA programs and their characteristics is provided in table 4.

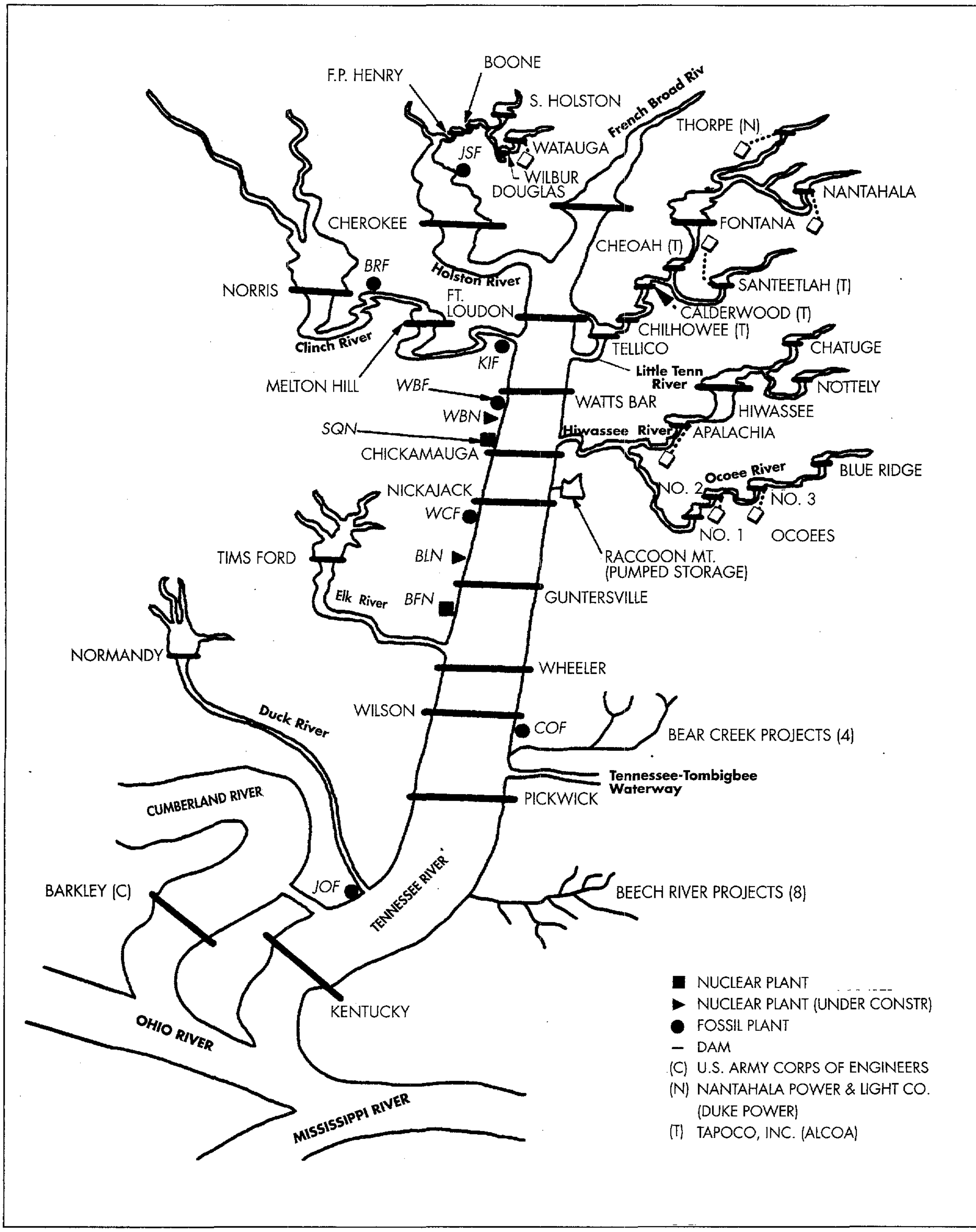
Although all 54 TVA-owned projects serve multiple functions, major projects fall into four primary categories: single purpose power projects, mainstream multipurpose reservoirs, tributary multipurpose reservoirs, and nonpower projects. The eight single-purpose power projects have small reservoirs (that is, run-of-the-river) with minimal storage capacity. The nine mainstream multipurpose reservoirs on the Tennessee River primarily support navigation, provide limited flood storage, and generate hydroelectric power. The 13 multipurpose tributary reservoirs were primarily built for flood control, flow augmentation for navigation, and power generation. These tributary reservoirs, primarily located in the mountainous regions upstream of Chattanooga, provide key flood storage capacity for the system. The 22 nonpower projects are smaller projects principally built for local flood control, recreation, or water supply purposes (Goranflo 1997). Additionally, TVA operates one pumped storage facility at Raccoon Mountain and a small detention dam to support power plant operations at John Sevier Fossil Plant.

Flood Management

Since its inception, flood control has been a primary focus of TVA activities. TVA has historically met these responsibilities through a dual approach to flood management that combines a system of multipurpose dams and reservoirs with a floodplain management program to encourage appropriate shoreline development. The former approach was designed to "keep the water away from the people," while the latter focused on "keeping the people away from the water." Early in TVA's history, it recognized that such a dual approach was necessary to maintain long-term and sustained reductions in flood damage potential, as the newly regulated shorelines provided attractive areas for development and it was difficult for the public to understand the flood control limitations of the reservoir system (Miller, Whitlock, and Hughes 1996).

Reservoir System Flood Control Capabilities. The TVA reservoir system was designed with flood control as one of its primary purposes. Available flood control storage in the system varies with the time of year and potential flood threat. The system provides its maximum flood storage capacity on January 1, the beginning of the flood season, with a detention capacity of approximately 11 million acre-feet (14 billion cubic meters), equivalent to 5.3 inches (135 millimeters) of runoff over the Basin. On March 15, towards the end of the flood season, the system has a storage capacity of about 10 million acre-feet (12 billion cubic meters), or 4.7 inches (119 millimeters) of runoff. A storage capacity of 2 million acre-feet (2.6 billion cubic meters), or about 1 inch (25 millimeters) of runoff, is reserved during the summer to pass summer storms (TVA 1961; TVA 1995a).

Figure 4. The TVA Water Control System



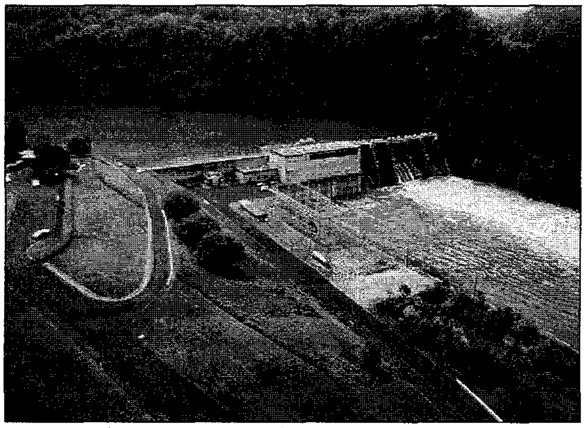
Source: TVA Reservoir System Operations Business Unit, Miller and Others 1993.

Table 3. Major TVA Dam and Reservoir Projects

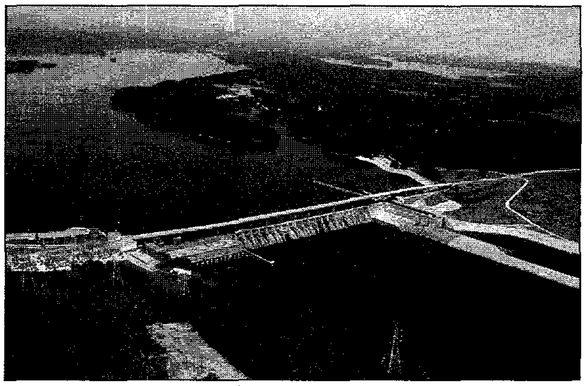
	Dam Height m	Dam Height ft	Dam Length m	Dam Length ft	Reservoir Length km	Reservoir Length mi	Drawdown Range m	Drawdown Range ft	Flood Storage, *million* cu m	Flood Storage, *million* cu yd	Winter Net Dependedable Capacity, megawatts	Construction Span	Note
Tennessee River													
Fort Loudoun	38	125	1,277	4,190	98	61	1.8	6	137	179	140	1940-43	
Watts Bar	34	112	902	2,960	155	96	1.8	6	468	612	175	1939-42	
Chickamauga	39	129	1,768	5,800	95	59	2.1	7	426	557	124	1936-40	
Nickajack	25	81	1,148	3,767	74	46	0.6	2	0	0	96	1964-67	
Guntersville	29	94	1,213	3,979	122	76	0.6	2	200	262	108	1935-39	
Wheeler	22	72	1,933	6,342	119	74	1.8	6	431	564	384	1933-36	
Wilson	42	137	1,384	4,541	26	16	0.9	3	66	86	629	1918-24	
Pickwick Landing	34	113	2,352	7,715	85	53	1.8	6	516	675	228	1934-38	
Kentucky	63	206	2,567	8,422	297	184	1.5	5	4,948	6,472	175	1938-44	
Racoon Mountain Pumped-Storage	70	230	2,591	8,500	2	1.2			0	0	1,532	1970-78	
Clinch River													
Norris	81	265	567	1,860	208	129	18.3	60	1,818	2,378	57	1933-36	
Melton Hill	31	103	311	1,020	71	44	1.5	5	0	0	75	1960-63	
French Broad River													
Douglas	62	202	520	1,705	69	43	18.3	60	1,544	2,020	58	1942-43	
Holston River													
South Holston	87	285	488	1,600	39	24	16.5	54	358	468	22	1942-50	
Boone	51	168	517	1,697	53	33	16.5	54	114	149	68	1950-52	
Fort Patrick Henry	29	95	225	737	16	10	1.5	5	0	0	36	1951-53	
Cherokee	53	175	2,060	6,760	95	59	15.8	52	1,249	1,634	75	1940-41	
Watauga River													
Watauga	101	331	282	925	26	16	13.4	44	275	360	38	1942-48	
Wilbur	23	77	114	375	3	2	1.5	5	0	0	11	1912	
Little Tennessee River													
Fontana	146	480	721	2,365	47	29	39.0	128	716	937	172	1942-44	
Tellico	39	129	987	3,238	53	33	1.8	6	148	194	-	1979	a,b
Hiwassee River													
Chatuge	46	150	1,017	3,336	21	13	6.7	22	115	150	5	1941-42	
Nottely	61	199	1,193	3,915	32	20	13.4	44	123	161	9	1941-42	
Hiwassee	94	307	419	1,376	35	22	22.6	74	334	437	95	1934-40	
Apalachia	46	150	399	1,308	16	10	2.4	8	0	0	72	1941-43	
Ocoee River													
Blue Ridge	53	174	473	1,553	18	11	30.5	100	0	0	11	1925-30	
Ocoee 1	41	135	256	840	13	8	6.1	20	0	0	22	1910-11	
Ocoee 2	9	30	137	450	1	0.8	-	-	0	0	18	1912-13	
Ocoee 3	34	110	187	612	11	7	6.7	22	0	0	27	1941-42	
Elk River													
Tims Ford	53	175	482	1,580	55	34	7.0	23	271	354	35	1966-70	
Duck River													c
Normandy	34	110	835	2,741	27	17	4.9	16	59	101	-	1976	a,b
Caney Fork River													
Great Falls	28	92	244	800	35	22			0	0	21	1941-42	

Note:
a. Tellico Dam closed 1979 and Normandy Dam closed 1976
b. Non Power Dam
c. Columbia Dam is unfinished but has not beeen cancelled

Source: TVA 1994.

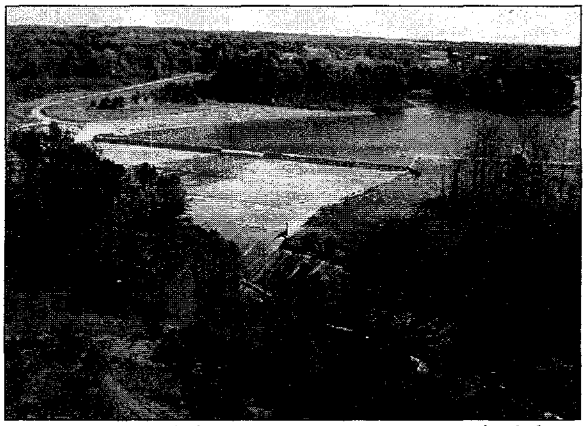


Ft. Patrick Henry is a single-purpose power project on the Holston River.



Watts Bar Dam, a multipurpose mainstream project on the Tennessee River, provides limited flood storage capacity, supports navigation, and generates hydroelectric power.

Multipurpose tributary reservoirs, such as the Norris Reservoir, were built to support flood control, augment flows for navigation, and generate power. These large tributary reservoirs provide key flood control storage for the system.



Upper Bear Creek, a nonpower project, was built for local flood control, recreation, and water supply.

The TVA's reservoir system, which includes 54 TVA-owned projects, is operated as an integrated unit, although most projects can be categorized by the primary purpose for which they were built.

Table 4. Major TVA Programs and Characteristics

Program	General Information
1. Reservoir Operations	Major Dams & Reservoirs: 32 TVA[a] 4 Tapoco, Inc. (Subsidiary of Alcoa) 8 Cumberlands (U.S. Army Corps of Engineers) Water Surface: 259,383 hectares (640,927 acres) Shoreline: 18,013 km (11,195 miles)[a,b]
2. Navigation	Length of Waterway: 1,022 km (635 miles)[c] Channel Depth: 3.35 m (11ft) Traffic (1989): 39.1 million metric tons(43.1 million tons) Private Investment (1933-1989): $6.5 billion
3. Flood Control	System Detention Capacity Jan 1: 14.5 billion m3 (11,751,869 ac-ft) Mar 15: 13.0 billion m3 (10,543,390 ac-ft) Summer: 3.3 billion m3 (2,676,399 ac-ft) Total Damages Averted (Since TVA): ~$3.5 billion
4. Power Production	System Installed Capacity (1996): 28,123 MW[d] 53% Coal-Fired 19% Hydroelectric[e] 20% Nuclear 8% Combustion Turbine Average Annual Hydropower Generation: 14 million MWhf Power Service Area (1990): Area: 207,200 sq km (80,000 sq miles) Population: ~8 million Tennessee River Watershed (1990): Area: 105,960 sq km (40,910 sq miles) Population: 5.0 million
5. Water Quality	Lake Improvement Plan: Minimum Flow Requirements at Tributary & Main River Projects Dissolved Oxygen (DO) Enhancements at Selected Projects
6. Recreation	Public Access and Recreational Lands: 102,268 hectares (252,702 acres) Recreation Visits (1990): 20.2 million Value of Development & Equipment (1990): $1.002 billion Target Summer Recreation Levels: 10 Tributary Projects
7. Fisheries (Sport)	Fishing Trips (1986): 17.1 million Catch: 6.8 - 9.1 million kilograms/year (15.0-20.1 million lb/yr) Cost of Goods & Services: $400 million/year

Notes:

a. Includes Great Falls in the Cumberland Valley & Nolichucky; does not include Raccoon Mountain (pumped storage project); Columbia (construction deferred); four dams in Bear Creek water control system; eight dams in Beech River Project; and two dams at Bristol Project.
b. At normal maximum pool level.
c. Does not include the tributaries Melton Hill (with lock) 44 miles and Tellico (with an open canal linking it to Fort Loudoun Lake) 33 miles.
d. Installed capacity in service. Source: TVA 1996 Annual Report.
e. Includes Pumped-Storage, 405 MW of dependable capacity from Army Corps of Engineers dams on the Cumberland river system.
f. TVA-owned hydro plants only.

Source: TVA 1986, 1990, 1992, 1996.

Table 5. TVA Reservoir System Flood Control Storage

Time of Year	Detention Storage			
	Above Chattanooga		Total System	
	billion m³	*million acre-feet*	*billion m³*	*million acre-feet*
January 1	7.8	6.3	14.0	11.3
March 15	6.4	5.2	12.4	10.0
June 1	1.9	1.6	2.6	2.1

Note: 1 acre-foot = 1,233 cubic meters
Source: TVA 1995.

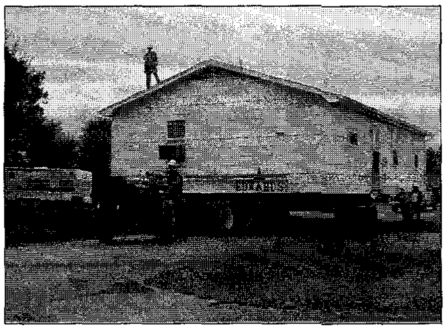
The reservoir system in the eastern portion of the Basin was primarily planned to protect Chattanooga from flooding. This portion of the Basin is drained by the Tennessee River's five largest tributaries, the Hiwassee, Clinch, Little Tennessee, French Broad, and Holston Rivers, and by 180 miles (290 kilometers) of the mainstream itself. The multipurpose tributary reservoirs in the upper system provide approximately 5 million acre-feet (6.6 billion cubic meters) of storage, more than 7.5 inches (191 millimeters) on January 1, and 4 million acre-feet (5.5 billion cubic meters), or approximately 6 inches (152 millimeters), on March 15. Almost 90 percent of this storage is provided by 5 major reservoirs (Norris, Cherokee, Douglas, Fontana, and Hiwassee Reservoirs), each of which is located on one of the major tributary rivers.

The three main river reservoirs above Chattanooga (Chickamauga, Watts Bar, and Ft. Loudon-Tellico) provide only 955,300 acre-feet (1.2 billion cubic meters) of storage, or 2.4 inches (61 millimeters) of runoff on January 1, a relatively small amount of the total upper system flood storage. These mainstream reservoirs, however, play an essential part in reducing the flood crest at Chattanooga as they provide regulation of the otherwise uncontrolled 7,400 square mile (19,170 square kilometer) area between Chattanooga and the tributary dams.

The principal purpose of flood control storage in the main river projects below Chattanooga is to regulate floods below each of the dams on the Tennessee River and on the lower Ohio and Mississippi Rivers. Kentucky Reservoir, the largest flood storage reservoir in the system, provides as much as 4 million acre-feet (5 billion cubic meters)—or 10 inches (254 millimeters) of runoff over its watershed—of detention storage on January 1. This represents more than 30 percent of the available flood storage in the entire TVA reservoir system. During flood events on the lower Ohio and Mississippi Rivers, TVA works cooperatively with the U.S. Army Corps of Engineers to take advantage of this storage in the Tennessee system, by minimizing releases from Kentucky Reservoir until the flood crest has passed on the Ohio or Mississippi. Flood storage in Kentucky can be used to reduce flood crests by as much as 2 to 3 feet (0.6 to 0.9 meters) on the Mississippi River at Cairo, Illinois.

Flood storage in the remaining five mainstream reservoirs below Chattanooga is less than 1 million acre-feet (1.2 billion cubic meters) combined. This storage supplements storage in Kentucky Reservoir and serves to regulate floods immediately below these dams (Alavian 1994; TVA 1961).

Flood Risk Reduction Activities. To complement TVA's reservoir system flood control capabilities, TVA initiated in 1953 the first regional floodplain management program in the United States. This program was based on the concept that flood damages could be substantially reduced over time by local governments controlling land use in the floodplain, through measures such as zoning, subdivision ordinances, and building codes. The objective was to incorporate flood risk considerations into the overall planning and economic development of a community. TVA's role was to provide technical and engineering assistance in this process (TVA 1961; TVA 1983c). Over time, this concept broadened



Relocation of homes outside the floodplain avoids repeated flood damages.

In-place elevation is used to reduce damage of existing property located in flood-prone areas.

Chickamauga levee, a local flood project in Chattanooga, Tennessee, reduces urban flood damage.

Environmental and beneficial uses of floodplains are encouraged in the Tennessee Valley.

TVA's approach to flood management combines a system of dams and reservoirs with a floodplain management program that encourages appropriate use of the floodplain to reduce damage.

to include environmental as well as flood protection aspects. Today, the concept of floodplain management is widely accepted and implemented throughout the United States. It serves as the cornerstone of the U.S. National Flood Insurance Program and is a key element in current efforts to formulate a national flood mitigation strategy (Natural Hazards Center 1992; Interagency Floodplain Management Review Committee 1994).

TVA's floodplain management programs have generally been directed toward three primary objectives (Miller, Whitlock and Hughes, 1996):

- Avoid flood damages through appropriate location of new development
- Reduce flood damages in existing floodprone areas through mitigation planning and projects
- Protect and enhance the environmental and beneficial uses of floodplains.

To meet these objectives, TVA has historically engaged in six primary flood risk reduction activities:

- Development and application of flood risk information
- Floodplain management technical assistance
- Flood hazard mitigation planning and projects
- Public education and awareness
- Stewardship of TVA lands and facilities
- Provision of operational support during flood control emergencies.

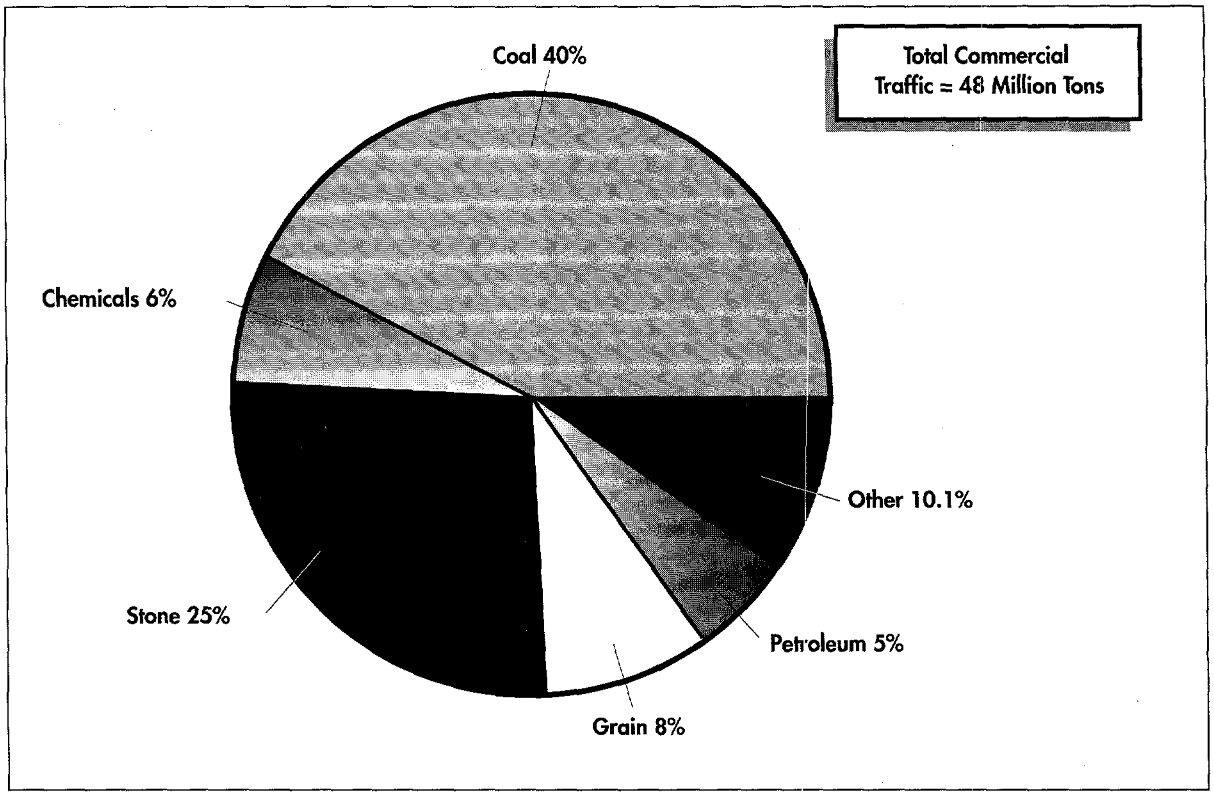
Between 1953 and 1994, these activities were conducted throughout the Tennessee River Basin. The TVA reservoir system regulates less than 10 percent of the total stream miles in the Tennessee Valley. TVA's floodplain management programs, therefore, were directed towards serving the more than 350 Valley communities on unregulated streams that suffered from local flooding problems. Beginning in 1994, however, agency streamlining and budget constraints necessitated that TVA's floodplain management programs focus on serving only those communities along regulated TVA rivers.

Flood Management Benefits. Between 1936 and late 1998, the TVA reservoir system averted close to $4.4 billion dollars of damages in Chattanooga, the urban center that accounts for approximately 90 percent of damages along the Tennessee River. Of the 50 flood events that had the potential to cause damages in that city, only 13 of these storms resulted in actual damages. In all cases, the TVA reservoir system reduced the flood crests, from a minimum of 1.6 feet (0.5 meters) in 1939 to a maximum of 21.8 feet (6.6 meters) in 1957. The average crest reduction over the past 60 years has been 11.3 feet (3.1 meters).

Additionally, from 1936 until late 1998, the TVA reservoir system averted approximately $440 million in damages to smaller urban areas and agricultural crops along the Tennessee's regulated streams. Since 1945, regulation of the Tennessee River has also been used to avert over $200 million of damages along the Ohio and Mississippi Rivers through flood crest reductions at Cairo, Illinois. Consequently, the TVA reservoir system has benefited the region with over $5 billion of averted damages (TVA 1995a).

The dollar benefits of TVA's pioneering programs in floodplain management to influence appropriate shoreline development, however, are more difficult to precisely quantify. One difficulty lies in the fact that the true value of the program results from what has not occurred—floodprone areas that have been left vacant and developments that have not been built. Another important factor is that TVA's influence has largely been indirect based on provision of technical expertise, education, and persuasion to assist communities in implementing floodplain regulations. TVA has no direct regulatory authority and no control over local land use and floodplain ordinances. Although most of the major damage centers in the Valley have floodplain regulations in force, many communities in the region continue to resist any type of land use controls.

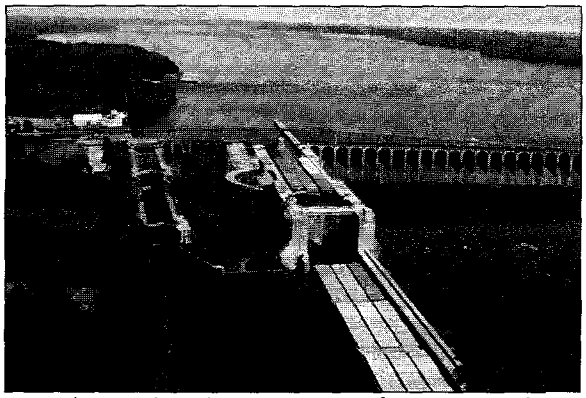
Figure 5. TVA Navigation Traffic, 1995



Source: TVA 1995c.

Given more than a 50 percent growth in the Tennessee Valley's population since the 1950s, it is not surprising that development in the region's floodplains has increased. Based on flood insurance estimates and other information, the flood risk (value of contents and structures within identified flood hazard areas) in the Valley was thought to approach $10 billion in 1994 (TVA 1994). How much larger the flood risk in the Valley would have been had TVA's technical expertise and presence not been available can only be roughly approximated. It has been estimated that without TVA's flood risk reduction programs, this $10 billion of flood risk in 1994 would have been almost doubled (TVA 1977, TVA 1994).

Despite TVA's efforts, there is still considerable flood damage potential in the Valley that will probably increase. The TVA reservoir system can only minimize the impacts of floods. The system cannot prevent floods from occurring, nor is it designed to control all floods. Furthermore, development pressures in the floodplain continue to increase, placing more people and structures at risk. Increased flood risk results from improper location of new development along streams without adequate floodplain controls. Flood risk also increases because floodplain development is not prohibited along streams with adequate floodplain controls. In these circumstances, structures and infrastructure are placed to minimize exposure to frequent flood events (for example, less than 100- or 500-year magnitude), but are subject to flooding from large, infrequent floods. Although it is impossible for TVA to prevent an increase in the region's flood damage potential, given the proper resources, it can continue to minimize the rate of increase.



Wilson Lock and Dam are part of TVA's 650 mile (1,050 kilometer) navigation system

Navigation

Improvement of navigation of the Tennessee River was one of the fundamental objectives of the TVA Act. TVA was responsible for planning and constructing the lock and dams in the Tennessee River system. Today, the Authority continues to operate the reservoir system to maintain minimum channel depths, oversee navigation system improvements, and provide technical assistance to ports, municipalities, private industry, and other federal agencies in order to improve water transportation.

The Tennessee River is an integral part of the Interconnected Inland Waterways System of the United States. This system, that extends from the Great Lakes to the Gulf of Mexico, includes the Mississippi, Missouri, Illinois, Ohio, Tennessee, and Arkansas River systems. The Inland Waterways System connects TVA with 21 other states.

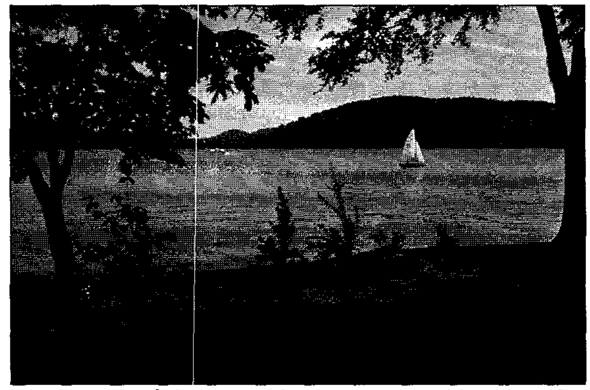
The Tennessee River provides a navigable channel for its entire length from Knoxville, Tennessee, to Paducah, Kentucky, a distance of 650 miles (1,050 kilometers), through a series of nine locks and dams on the mainstream of the river (see figure 4). Commercial navigation is also available on portions of the Clinch River through the Melton Hill Lock and Dam, as well as the lower portions of the Little Tennessee and Hiwassee Rivers. The minimum channel depth is 11 feet (3.4 meters), which provides sufficient depth for vessels with a 9-foot (2.7-meter) draft. The minimum channel width in dredged cuts is 300 feet (90 meters) with some widening on bends. Most locks in the system are 110 by 600 feet (33 by 180 meters), considered a standard for modern barge traffic of low to medium traffic levels. Newer locks, such as the one constructed at Pickwick Dam and planned for Kentucky Dam, are larger, measuring in the range of 110 feet by 1,000 feet (33 meters by 300 meters).

In 1995, commercial barge traffic on the Tennessee River reached a total of 48 million tons. The three largest ports in the system, in order of importance, are Decatur, Alabama; Chattanooga, Tennessee; and Guntersville, Alabama. As illustrated in figure 5, the principal commodity transported on the river is coal, which constitutes 40 percent of the total traffic. This coal is primarily bound for TVA steam plants and barge-rail transloaders from where it is shipped to other southern utilities or coastal ports for export. Stone, sand, and gravel, which constitute approximately 20 percent of the river traffic, are used in waterway improvement projects, cement and stone manufacturing, and other large-scale construction projects. Grain is shipped inbound for use in the production of vegetable oils, bread, corn syrup, animal feed and other commodities. The remaining commodities shipped on the river include petroleum, chemicals, forest products, iron and steel, salt, and newsprint (TVA 1993).

The growth of commercial navigation on the Tennessee River waterway has contributed significantly to the economic development of the region. Since the full navigation channel was completed, private industry has invested almost $8 billion in waterfront plants, terminals, and distribution facilities. Approximately 52 percent of this investment has occurred within the past 17 years, since 1980. Industries along the waterway provide direct employment for approximately 31,000 Valley residents (TVA 1993).

Maintenance and operation of the Tennessee River waterway is the joint responsibility of TVA, the U.S. Coast Guard, and the U.S. Army Corps of Engineers. TVA's reservoir operations ensure that the navigation channel is maintained. On mainstream reservoirs, lake level policy prescribes a normal minimum level that ensures a navigable depth of 9 feet (2.7 meters). Tributary reservoirs also provide conservation storage for navigation. Under normal weather conditions, tributary releases for flood control and power generation provide sufficient streamflow to maintain minimum navigation depths.

During dry years, however, special tributary releases may be needed to satisfy navigation requirements. Additionally, TVA performs maintenance on the lock walls, makes capital improvements at the locks, and furnishes the power to operate the locks. TVA also provides technical assistance to local, state and federal agencies, as well as private industries, to support navigation development.



Swimming, fishing, and boating are popular uses of TVA's reservoirs.

The Coast Guard installs and maintains navigation aids, such as the lights and buoys that mark the commercial navigation channel on the Tennessee River and its tributaries. TVA marks the secondary channels used by recreational boaters and fisherman. The Corps of Engineers operates the navigation locks, performs lock machinery maintenance, and dredges the commercial navigation channels.

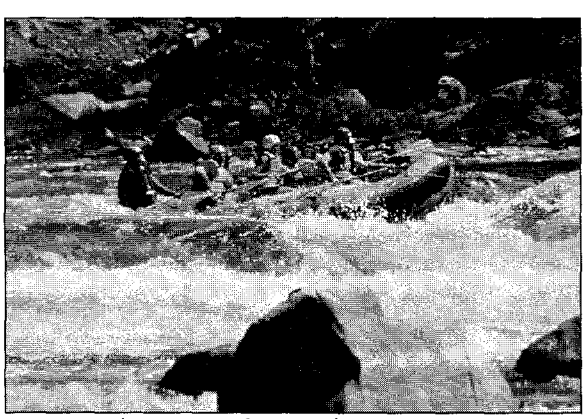
Power Generation

Today, TVA operates 29 hydropower facilities within its reservoir system. Net winter dependable hydropower capacity is approximately 3,768 megawatts (including Cumberland River projects), which represents nearly 14 percent of TVA's total generating capacity. Additionally, TVA operates a pumped-storage facility at Raccoon Mountain, with an installed capacity of 1,530 megawatts, which constitutes roughly 5 percent of TVA's capacity. Together, hydropower generation and pumped-storage account for roughly 19 percent of TVA's installed generating capacity (TVA 1996).

TVA reservoirs are operated to maximize hydropower generation to the extent possible in light of satisfying other multipurpose uses. Hydroelectric power is the most economical form of electricity available in the TVA system because incremental costs for hydropower (the costs that vary with production levels) are very low. In comparison, incremental costs for nuclear units are 16 times higher, coal-fire units roughly 30 times higher, and gas and oil-fired combustion turbines approximately 75 to 100 times higher (TVA 1990a).

In the TVA power system, hydropower is used primarily for peaking purposes, to provide additional power quickly during those times of the day when power demands are highest. Hydropower is ideal for this role, as it can be started and brought to full load more quickly than other sources of generation. A more complete discussion of the TVA power system is provided in the following chapter.

Hydropower system generation averages about 14 billion kilowatt-hours per year. Generation in any given year, however, is highly dependent on hydrology and can range from 8 billion kilowatt-hours in a dry year to as much as 18 billion kilowatt-hours in a wet year. Similarly, the economic benefit derived from the hydropower system varies greatly with hydrology, as well as with other system and economic factors. During an "average" hydrologic year, hydropower generation can be valued (based on 1993 economics, valuation procedures, and replacement costs) on the order of $350 million per year. Incremental benefits, however, can vary from $62 million in a wet year, such as 1990, to a loss of $147 million in a dry year, such as 1986 (Miller and others 1993).



Whitewater rafting on the Ocoee River

In addition to hydropower generation, the reservoir system supports thermal power generation by providing condenser cooling water and dissipating thermal waste loads from the fossil and nuclear plants in the system. Particularly during hot summer periods, this function can be critical to keeping TVA power plants in compliance with state environmental requirements.

Recreation

The recreational value of TVA's lakes and rivers has increased tremendously over the years. The region's numerous lakes afford opportunities for a variety of water-oriented activities, including swimming, fishing, water skiing and boating. More than 11,000 miles (18,000 kilometers) of shoreline surround TVA's lakes and provide ample occasion for camping, hiking, picnics, sightseeing, nature-watching, and fishing. Kentucky Lake, TVA's largest and most popular lake, has recorded as many as 5 million visitor days per year. Investments in recreation facilities on TVA's mainstream and tributary lakes are valued at more than $1 billion (TVA 1990a).

Recreation on major streams and rivers in the Tennessee Valley has also become increasingly popular in recent years. Fishing, canoeing, kayaking and rafting have become important activities. The whitewater slalom events of the 1996 Summer Olympic Games, which were held on the Ocoee River in the Tennessee Valley, highlighted the importance of recreation in the area. Since 1996, the Ocoee has hosted several other international kayaking events, and the whitewater rafting industry is estimated to add more than $30 million a year to the area economy (TVA 1996). To support the popularity of these whitewater sports, TVA provides additional releases from hydropower dams on pre-designated weekends and other times. The cost of lost power revenues for these releases is reimbursed to TVA through rafting, canoeing and kayaking user fees.

In the late 1980s, during a series of public meetings to assess TVA's reservoir operating priorities, the residents of the Valley expressed a strong desire for increased recreational opportunities on TVA's lakes and below its dams to support tourism and economic growth. As a result, TVA incorporated recreation as one of its primary operating objectives. With the implementation of the TVA Lake Improvement Plan (TVA 1990b; TVA 1991), TVA designated target summer recreation levels at ten tributary dams. TVA attempts to reach these levels 90 percent of the time, based on hydrologic conditions. To reach and maintain these levels, tributary lakes are filled more aggressively in the spring and unrestricted drawdown is delayed until August 1 (as opposed to June 1 under previous operating guidelines). The costs for these changes, roughly $2 million in lost power revenues, are paid from TVA's appropriated budget, as are TVA's other regional economic development programs. Additionally, TVA committed itself to working with local communities and whitewater outfitters to reach agreements for more special releases to support recreational floating activities on popular tailwaters below TVA dams.

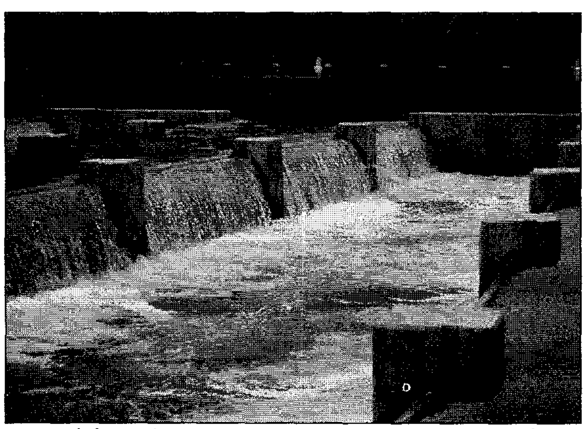
Water Quality

Overall, the Tennessee River is considered to be a clean river. In general, there is no one pervasive water quality concern in TVA reservoirs, but a there are a collection of concerns affecting various uses. Most of these concerns, however, can be related to two major water quality issues. The first issue relates to point and nonpoint pollution, which tends to effect specific reservoirs and specific water uses. A related issue is that of toxic substances, which have been found in sediments and fish in reservoirs with otherwise good water quality. The second primary water quality issue is the occurrence of low dissolved oxygen (DO) levels in the tailwater areas below TVA dams. Low DO levels can stress aquatic life and limit the ability of the water to assimilate wastes.

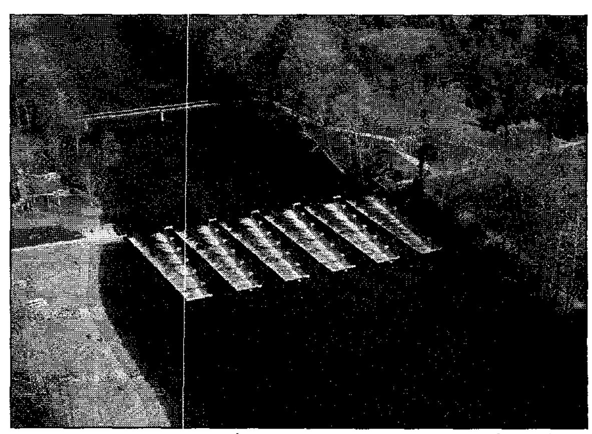
Although TVA is held accountable by the public for the quality of its lakes and rivers, it has no regulatory authority over point and nonpoint source pollution. Point source discharges of pollutants are controlled by the U.S. Environmental Protection Agency and state governments. Nonpoint source pollutants, which can contribute as much as five times more DO-consuming wastes than point sources, are the principal cause of water quality concerns in the Tennessee Valley. Nonpoint source pollution results from a variety of activities in the watershed related to agriculture (that is, runoff from fertilizer and pesticide applications, erosion and animal wastes), mining (sedimentation and acidification from tailings), land development, and urbanization (storm sewers, combined storm and sanitary sewer overflows, and septic systems). Preventing pollutants from entering the water depends primarily on the actions of state and federal regulatory agencies and the conduct of local communities and individuals.

Low DO levels, particularly in the tailwater reaches below TVA dams, result from the characteristics of TVA reservoirs and the operation of the dams. Most of TVA's large storage reservoirs are deep and become stratified in the summer. The cold bottom layer of the reservoir (hypolimnion) tends to become depleted of oxygen levels, particularly late in the summer. Most of the hydropower dams in the TVA system have a single outlet, which draws from this deeper, oxygen depleted level in the reservoir. Consequently, the waters released from TVA dams are cold and often low in DO. Additionally, the use of hydropower for peaking purposes often resulted in concentrated releases during the peak hours of demand and long periods of no release during other times. This resulted in low water depths below dams and degradation of the aquatic habitat in tailwater reaches.

The public meetings held in the late 1980s as part of TVA's Reservoir Review (TVA 1990a) indicated that support for improved water quality was widespread in the Tennessee Valley. TVA's Lake Improvement Plan (TVA 1990b) resulted in several efforts to address low DO and nonpoint source pollution problems. TVA committed to address low DO and aquatic habitat problems directly through a combination of minimum flow releases and a reservoir release improvements program. Minimum flow requirements were established at 12 tributary dams, and the releases were to be achieved by "pulsing," running hydroturbines for short periods of 30 to 60 minutes a day up to six times a day to ensure a continuous supply of water. These efforts recovered over 180 miles of aquatic habitat below TVA dams. To improve minimum DO levels to target levels between 4 and 6 milligrams per liter (depending on the dam), TVA committed to aerating releases at 16 dams. At some of these dams, it was assumed that TVA's endeavors were supplemented by state efforts to control nonpoint source pollution. TVA



A labyrinth re-aerating weir simulates a natural waterfall to increase dissolved oxygen levels.



Re-aerating weirs also maintain constant pool levels below dams used for hydropower pulsing.

TVA has pioneered the use of re-aerating weirs to improve aquatic habitat and dissolved oxygen levels in the tailraces below dams.

employed a range of aerating methodologies to meet its objectives, including installation of aeration equipment in the headwaters upstream of dams, construction of re-aerating weirs downstream of dams, and development and experimentation with auto-venting turbines. The costs of this Reservoir Releases Program ($43 million in capital costs for aeration equipment and $4 million annual operations and maintenance costs), as well as the $50,000 annual cost for minimum flows, are paid from power funds (Brock 1997).

To address complex nonpoint source pollution issues, TVA also started a Clean Water Initiative to influence local, state, and federal agencies, as well as individuals, to improve water quality efforts in the watershed. Under this initiative, river action teams have been formed in several of the region's subwatersheds. These teams utilize a combination of technical assistance, demonstration projects, public education programs, media campaigns, and other grassroots activities to focus public attention on critical issues and motivate citizens and governments to action. The ultimate responsibility for controlling nonpoint source pollution lies with the states.

Other Reservoir Uses

Although the TVA reservoir system is operated primarily for the purposes of flood control, navigation, power generation, recreation, and water quality, there are several other incidental benefits derived from the system. The reservoir system is also used for water supply, weed and vector control, maintenance of public health, support of economic development, and support of wildlife, fisheries, and threatened and endangered species. There is some use of TVA streams, rivers, and reservoirs for municipal and industrial water supply, but it is relatively small. Public water systems, which serve about 80 percent of the Valley residents, use about 450 to 550 million gallons per day (28,000 to 35,00 cubic meters per day). Roughly half of this demand is satisfied through groundwater and the other half from surface water. The remaining 20 percent of Valley residents used individual wells. Over 300 industrial water systems also withdraw water for industrial processes and cooling. However, the total water withdrawn for both industrial and municipal purposes amounts to only about two to three percent of the annual average flow of 64,000 cubic feet per second (1,800 cubic meters per second) at the mouth of the Tennessee River (TVA 1990a). Consumptive use is even less, as close to 75 percent of this water is returned to the system. Furthermore, irrigation demand in the Valley is small and not expected to grow.

Because malaria was once widespread along the Tennessee River, the reservoir system is still operated to control mosquitoes. During the summer breeding season, some mainstream reservoirs are fluctuated by one foot on an alternating basis to strand and drown mosquito eggs. TVA also supports public health efforts by maintaining minimum flows past large cities, such as Knoxville and Chattanooga, to facilitate waste assimilation. Similarly, reservoir operators work with biologists, fisheries specialists, and other environmental scientists to schedule special operations for weed control, to support fish spawning, to support recovery efforts for threatened and endangered species, and to improve wildlife habitat. Special nonpower projects, such as the Beech River and Bear Creek projects, have also been built and operated to facilitate local economic development efforts. Finally, the TVA Water Management business unit works closely with the Land Management business unit efforts to effectively manage TVA lands and shorelines.

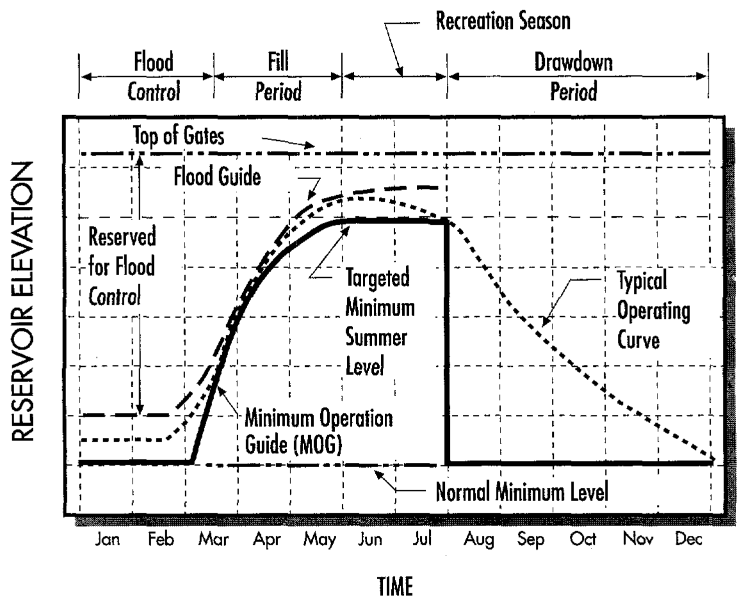
Reservoir Operations

TVA's large reservoir system is operated as an integrated unit. Operations are both unique and complex. While reservoir guide curves provide seasonal targets to maximize system benefits, sophisticated scheduling and forecasting processes are used to route water on a daily basis.

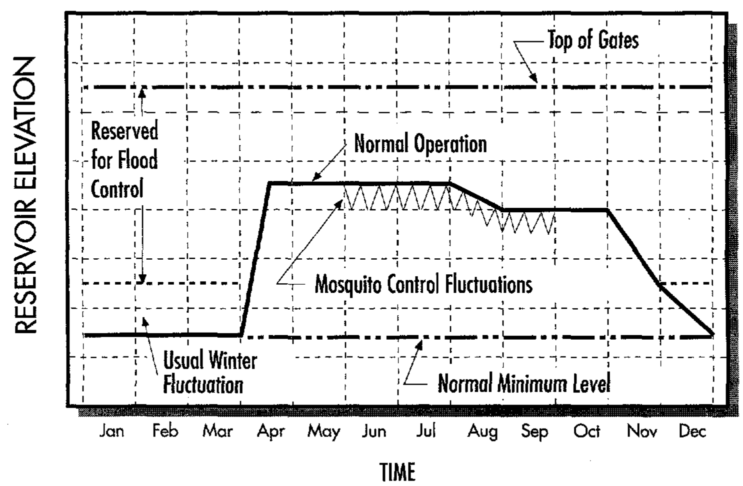
Annual Operating Cycle

Typical operating curves for TVA tributary and mainstream reservoirs are presented in figure 6. On the tributary reservoirs, operations are closely allied with the annual hydrologic cycle and can be cat-

Figure 6. Typical TVA Reservoir Operating Levels



TRIBUTARY RESERVOIR OPERATIONS



MAINSTREAM RESERVOIR OPERATIONS

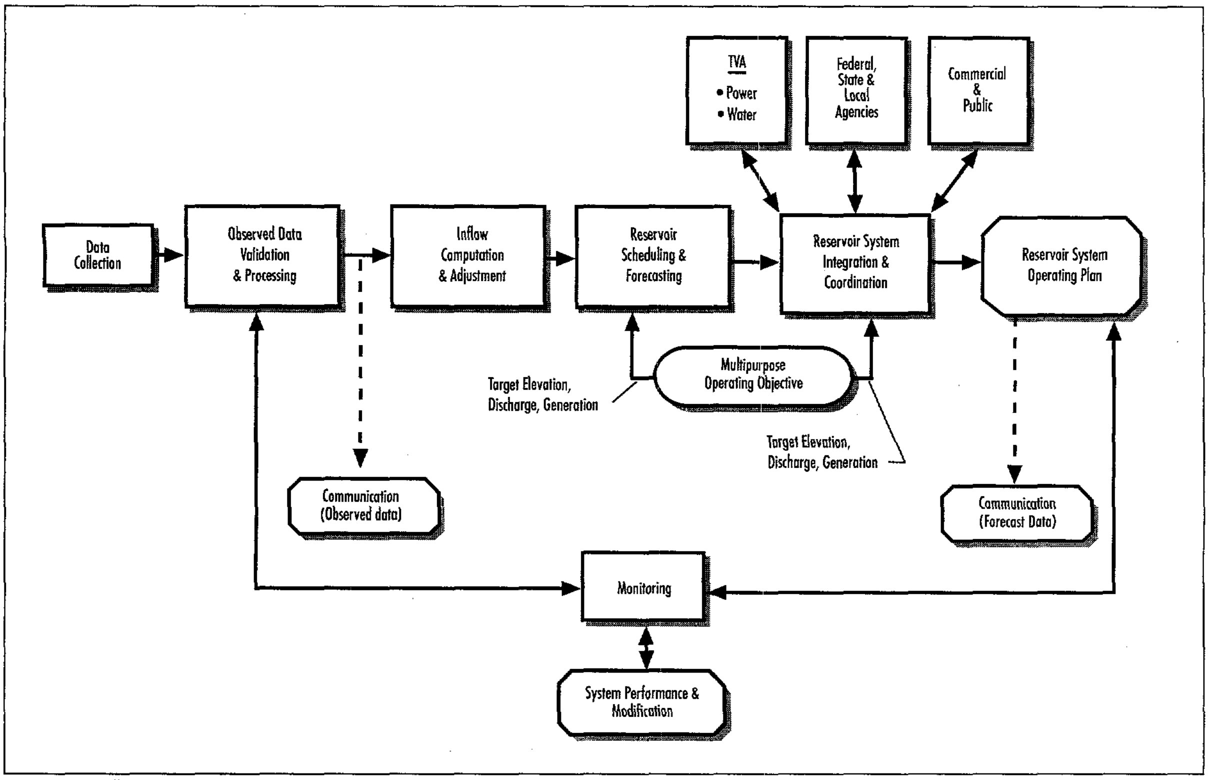
On tributary reservoirs, low lake levels provide storage capacity for the winter flood season. Spring rains are used to rapidly fill the reservoirs after mid-March in an attempt to reach targeted minimum summer levels by June. Lake levels are generally held high until the end of July for recreation purposes, then gradually lowered through late-summer and fall in preparation for the next flood season. This results in flow *augmentation* for power production, water supply, and other needs.

Water levels on mainstream reservoirs fluctuate only a few feet during the year, because adequate water depths must be *maintained in the navigation* channel to the next dam upstream.

Normal summer pool level is generally achieved on *mainstream reservoirs*, but is achieved in only 90 percent of the years on multipurpose tributary reservoirs. Tributary levels are drawn below normal minimum level infrequently during periods of unusual drought and high power demand, or for maintenance purposes.

Source: TVA River System Operations Business Unit, Miller and others 1993.

Figure 7. Overview of TVA Daily Scheduling and Forecasting Process



Source: Miller 1993.

egorized into four main periods: winter flood season, fill period, recreation season, and drawdown season. During the winter flood season (January 1 to March 15), lake levels are held below the flood guides to provide storage capacity for high winter flows. Between March 15 and June 1, spring rains are used to rapidly fill the reservoirs in an attempt to reach summer recreation target levels. During this fill period, an attempt is made to keep lake levels below the flood guides and above the minimum operation guides. If elevations are maintained within this zone, there is a 90 percent probability that June 1 recreation target levels will be achieved. During the summer, lake levels are normally held high (above targeted minimum summer recreation levels) until the end of July. Lake levels are then gradually lowered through the drawdown period (August 1 to December 31) in preparation for the next flood season. On the tributary projects, reservoir elevations can fluctuate as much as 75 feet (23 meters) between winter and summer pool levels.

Operations on the mainstream reservoirs generally follow a similar, though simplified pattern. Due to topography and navigation requirements, the mainstream projects are designed to vary only a few feet between normal winter and summer levels. Guide curves are generally followed more closely at these projects. To help control mosquitoes, lake levels are fluctuated by one foot each week during the late spring and summer at some mainstream projects (Miller 1993).

TVA's use of reservoir operating guides is unique in the United States. Most other major reservoir systems, such as those maintained by the U.S. Army Corps of Engineers, operate within specified zones or pools. Permanent flood storage and surcharge pools are generally maintained above normal operating levels in these reservoirs. TVA's seasonal preservation of flood storage detention optimizes the use of flood control capacity, lowering lake levels to provide the maximum capacity during the period when the threat from flooding is the highest and filling the reservoirs to provide for summer recreation and hydropower generation as the probability of flooding declines. This unique approach to flood detention is possible due to the seasonal nature of the floods in the Valley and the fact that the reservoirs can be operated on an annual operating cycle (that is, there is no carry-over required from year to year to provide for other multipurpose uses such as recreation).

Daily Scheduling and Forecasting

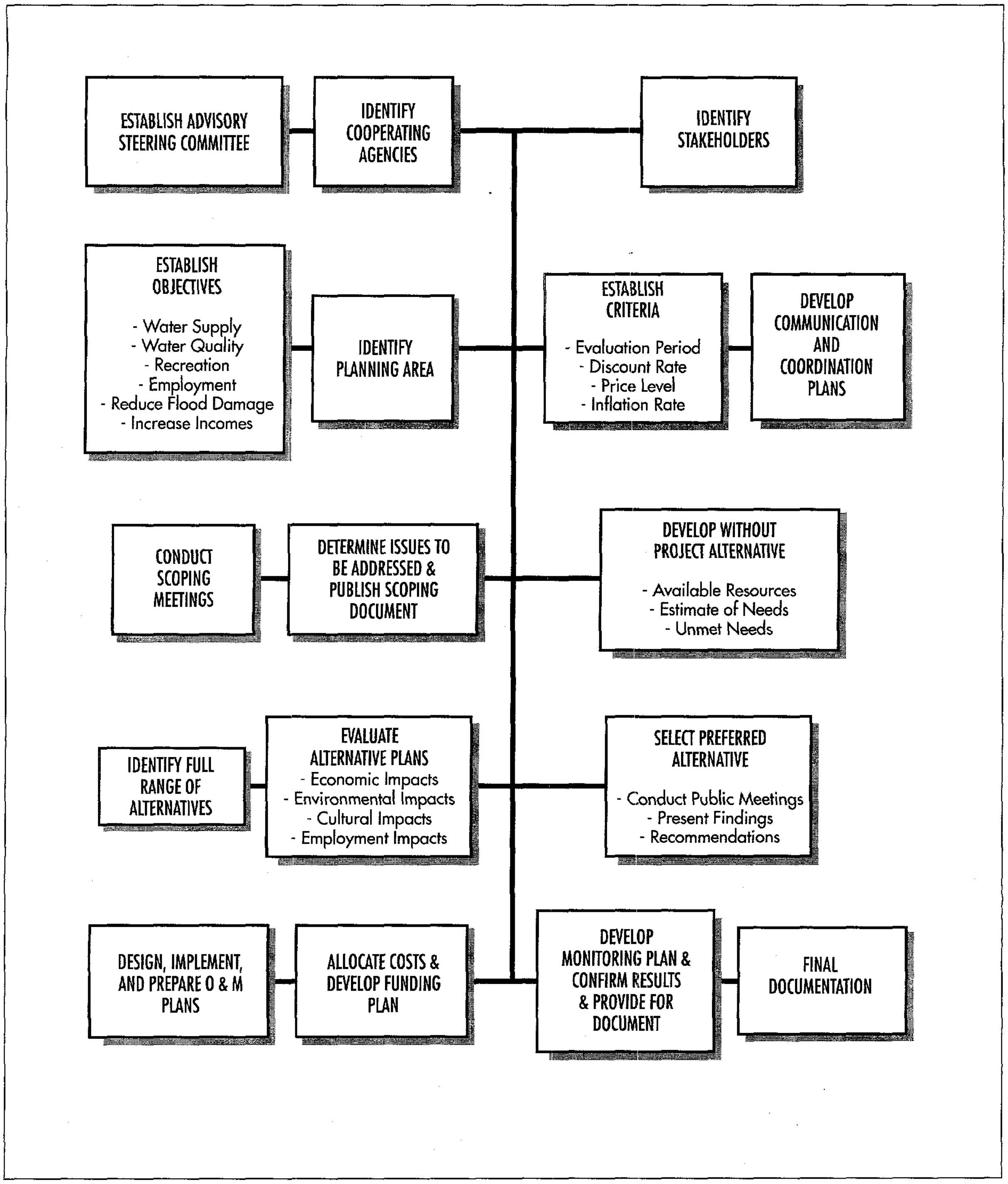
TVA's reservoir operating guides provide seasonal goals to maximize multiple system benefits while ensuring the orderly filling of reservoirs during the spring and lowering of reservoirs during the summer and fall. The daily scheduling process, however, is more complex. On a daily basis, TVA schedules water releases from 35 of its own dams over more than 800 stream miles (1,290 kilometers). TVA also schedules or coordinates releases from four additional dams belonging to ALCOA and eight U.S. Army Corps of Engineers dams on the Cumberland River. The daily scheduling process must account for numerous factors, such as the amount of water in storage, travel time through the system, uncontrolled inflow, weather conditions, power demand, and seasonal operating targets. Utilizing advanced computers, mathematical models, and an extensive data collection system, river control managers determine on a daily basis the rate and total quantity of water to be released from each dam to satisfy the multiple purposes of the system. As shown in figure 7, major elements of TVA's scheduling and forecasting process include: (a) data collection; (b) data validation and processing; (c) inflow computation; (d) reservoir scheduling and forecasting; (e) reservoir system integration and coordination; (f) communication and dissemination of the reservoir system operating plan; and (g) monitoring (Goranflo 1997; Miller 1993).

TVA's data collection system consists of 292 precipitation gauges and 74 streamflow gauges in the Tennessee and Cumberland River Basins, as well as hourly elevation and discharge records at major dams. Using a combination of computer programs and manual inspection, this observed data is processed and validated early each morning by the river system operations staff for the previous 24-hour period. Observed data is updated at regular intervals throughout the day, ranging from every 2 to 6 hours, depending on the type of data and gage system. During periods of high rainfall or streamflow, information is processed on a more frequent basis. Based on observed rainfall data, empirical hydrologic models are then used to estimate the quantity and timing of local flow into each reservoir in the system for a 10- to 12-day forecast period. Using an interactive computer system, hydrographs are adjusted so that the predicted data matches observed reservoir and stream inflow data as closely as possible and, therefore, accurately reflects current hydrologic conditions. Inflow estimates are primarily based on observed rainfall (that is, 'rain-on-the-ground'); however, if additional rainfall is expected, the incremental impact of predicted rainfall is also determined. During periods of high flow, inflow computations are repeated at least every 6 hours based on the most currently available observed data.

Once the local flow into each reservoir has been computed, reservoir forecasters utilize a computerized system to route the flow through each reservoir and determine projected daily dam releases, hydropower generation, and lake levels for the next 10 to 12 days. These initial schedules for individual reservoirs are based on forecasters' judgment and knowledge of operating conditions, including reservoir targets, constraints, special operations, expected power system requirements, or the previous day's operations. The preliminary forecasts are finalized based on additional information, integration of all reservoirs, and reservoir-power system coordination.

While initial forecasts are being developed for individual reservoirs, overall system conditions and needs are used to formulate a general operating strategy and multi-day system plan. The system plan must account for power system conditions and expected needs for hydropower generation, observed and forecast weather conditions, and expected operations in the Cumberland, Ohio, and Mississippi River Basins. Additionally, current reservoir system conditions must be compared with overall seasonal targets, multipurpose operating objectives and constraints, scheduled hydro plant maintenance, other planned special operations, and emergency requests.

Figure 8. The TVA Water Resources Planning Process



Source: Davis 1997.

The results of the preliminary system plan are then used to coordinate and integrate the more detailed forecasts developed for individual projects. Through an iterative process, a solution is converged upon that balances overall power requirements, long- and short-term multipurpose reservoir system objectives, and the detailed inflow and special conditions at each project or groups of projects. The final operating plan, which summarizes the daily inflow, elevation, discharge, and generation expected at each project for the 10-day forecast period, is usually completed before noon. Additional or more detailed hourly plans may be generated as needed.

Observed data, system information, and the final multi-day operating plan, are disseminated electronically to appropriate TVA organizations. Pertinent information is also distributed externally to the U.S. Army Corps of Engineers, the National Weather Service, and local press agencies. Additionally, in light of TVA's commitment to public involvement, the public can directly access information concerning streamflow conditions, lake levels, and water release schedules via an automated telephone system or computer link. System performance and conditions are continuously monitored throughout the day. Additional reservoir system routings and scheduling modifications may be required in response to unanticipated changes in hydrology, power system needs, or emergency conditions, such as toxic spills or accidents.

During flood control operations, reservoir system scheduling and forecasting follow the general processes described above, but on a continuous 24-hour basis. Additionally, during a flood event, flood control takes precedence over all other multipurpose objectives, including power generation. It is only during the flood recovery stage, as reservoirs are being returned to normal operating levels, that efforts are made to minimize spill and maximize power generation as consistent with the timely recovery of flood storage capacity (Miller, Whitlock, and Hughes 1996).

Water Resources Planning and Projects

The Plan for the Unified Development of the Tennessee River (TVA 1936) laid out the basic structure of TVA's large reservoir system. The majority of TVA's large dams were completed by the 1950s. Since that time, TVA has been involved in the planning and construction of several smaller-scale water resources projects. The nature of these individual projects varies. Examples include the planning and construction of: a flood mitigation project in Spring City, Tennessee water supply facilities near Tupelo, Mississippi, recreational facilities on the Ocoee River, and off-stream storage for irrigation at Belle Mina, Alabama. Such projects are initiated for a variety of reasons, including economic need, public safety, and congressional mandate.

TVA evaluates and plans these individual projects based on engineering analysis, economics, environmental impact, and public participation. Economic analyses are based on national guidelines for benefit/cost analysis. As outlined in figure 8, what distinguishes TVA's water resources planning approach are the intense efforts to involve local citizens and groups in the planning process (Davis 1997b). Through experience, TVA has found that water resources projects are best implemented through a combination of a strong project manager and a task force composed of local stakeholders and interested local, state, and federal agencies. The project management approach has been to operate with a small staff to maintain flexibility and reserve the largest share of expenditures for project implementation (Davis 1997b).

Partnership With The People

The success of TVA's water resources programs can in part be attributed to its commitment to working cooperatively with other federal, state, and local agencies and with the residents of the Valley. Over the years, the nature of this cooperation has taken many forms, including: formal cooperative agreements and memorandum of understanding with specific agencies or groups; the formation of and participation in special task forces comprised of interested agencies, local governments, environmental groups, and citizens; the formation of local planning committees; use of public meetings and other forums to gather public input; use of the National Environmental Policy Act (NEPA) public review process; and joint funding and implementation of projects with other agencies or local governments.

For example, TVA works closely with other federal agencies such as the U.S. Army Corps of Engineers in the areas of navigation and flood control under formal cooperative agreements. States, such as North Carolina, have worked directly with TVA to raise lake levels to encourage tourism and development in economically depressed areas. Environmental groups such as Trout Unlimited have worked cooperatively with TVA through special task forces to continuously improve the reservoir releases program. Special task forces have also been used at Tims Ford and Kentucky Reservoirs to devise plans to protect endangered species and delay drawdowns to improve fish spawning. As part of the NEPA process, TVA's Reservoir Review (TVA 1990a) and subsequent Lake Improvement Plan (TVA 1991) relied heavily upon public input and review to adjust reservoir operating priorities to reflect public concern for improved water quality and increased recreation opportunities. TVA programs, such as the Clean Water Initiative, continue the tradition of working at the grassroots level to influence and motivate local action to control nonpoint source pollution. In this role, TVA serves as a catalyst to form local coalitions and then provides technical support and seed funding, if appropriate, to support the coalition's efforts. TVA's River System Operations business unit maintains a 24-hour public access telephone line, as well as computer link-ups, for individuals to access streamflow and dam release information. It should be noted, however, that although TVA is open to fine-tuning operations at individual projects to accommodate special needs, the overall principal remains that the reservoir system must be operated as a unit for the greatest benefit of the entire region.

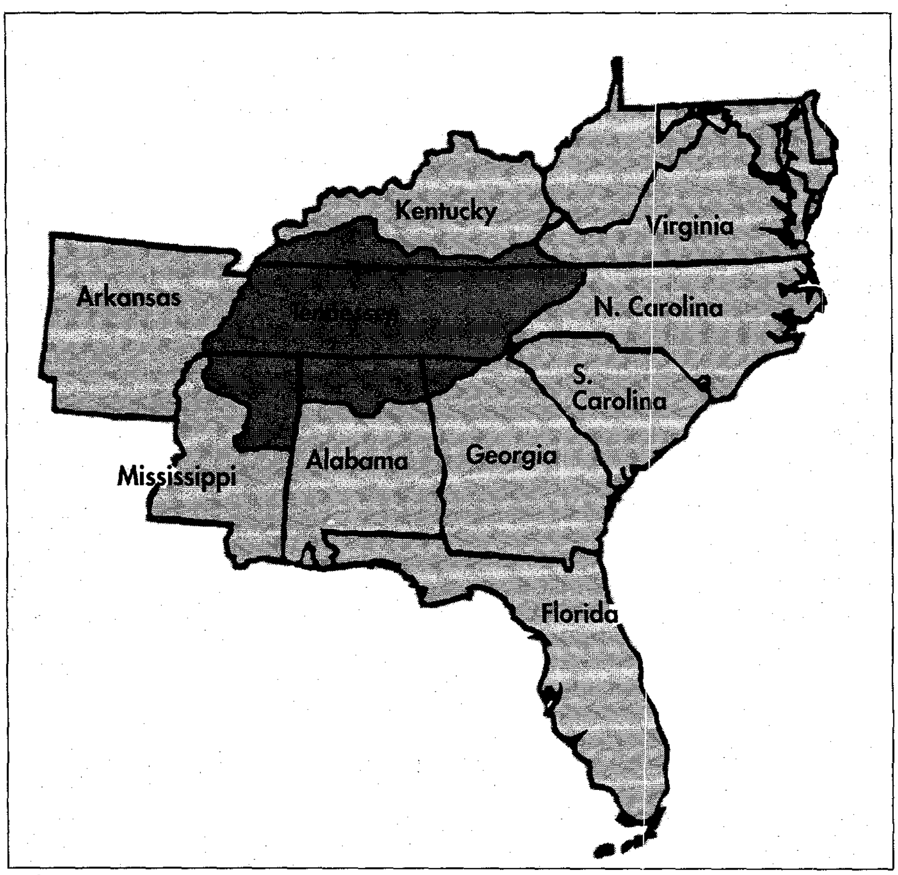
It should also be noted that although TVA has historically worked closely with local and state governments and private citizens and has involved the public around specific projects, there is no formalized mechanism for public participation in managing or setting policy at TVA. The TVA Board of Directors holds open meetings and follows the National Environmental Policy Act environmental review process when appropriate, but there is no elected or appointed council, parliament, or representative body of Valley residents and officials to directly influence decision making at the Authority. If the public wishes to influence policies or actions of the Authority, they must exert public pressure through the press and utilize the political system by voicing their concerns to congressmen and women, who in turn can influence the TVA Board of Directors.

3. The Power Program

The TVA power system, one of the largest producers of electricity in the United States, generates 4 to 5 percent of the country's electric power (TVA 1995b). The TVA power service area covers an area of 80,000 square miles (207,000 square kilometers) in the southeastern United States, including most of Tennessee and parts of Mississippi, Kentucky, Alabama, Georgia, North Carolina, and Virginia (figure 9). This area, which is almost twice as large as the Tennessee River Basin, was established in 1959 by Congress as part of the TVA Self-Financing Amendment and is referred to as a "fence," an area outside of which TVA may not sell power. Within the power service area, TVA provides power to 160 municipal and rural cooperative power distributors and directly serves 67 federal and large industrial customers. The municipalities and rural cooperatives represent 82 percent of TVA power sales and 88 percent of its revenue. Power is distributed through a network of 17,000 miles (27,000 kilometers) of transmission lines. The system supplies the energy needs of nearly 8 million people.

The TVA power system includes 11 coal-fired plants, 29 hydroelectric projects, 3 nuclear power plants, 48 combustion turbines, and 1 pumped storage facility. In 1996 the system provided 28,123 megawatts of net winter dependable generating capacity (table 6). The majority of the capacity (53 percent) is supplied by coal-fired plants. Hydroelectric power, including pumped storage, accounts for 19 percent of the capacity. In 1996, five nuclear power units were operating, and for the first

Figure 9. The TVA Power Service Area



Source: TVA 1996

Table 6. Selected TVA Power System Statistics, 1996

Dependable Generating Capacity[1]

	(MW)	%
Fossil (coal-fired)	15,012	53
Hydroelectric	5,298[2]	19
Nuclear (units in service)	5,545	20
Combustion Turbine	2,268	8
Total Capacity	28,123	

[1] Net winter dependable capacity
[2] Includes Pumped-Storage and 405 MW of dependable capacity from Army Corps of Engineer dams on the Cumberland River System under a marketing arrangement with the Southeastern Power Administration.

System Input - Generation
(Millions of Kilowatt-Hours)

Fossil (Coal-fired)	97,046
Hydroelectric[1]	16,107
Nuclear	35,426
Combustion Turbine	217
Total Net Generation:	148,796
Purchased	4,929
Net Interchange & Wheeling	(7,849)
Total System Input:	145,876

[1] Includes Pumped Storage

System Output - Sales
(Millions of Kilowatt-Hours)

Municipalities & Cooperatives	117,035
Industries Directly Served	16,599
Federal Agencies	6,966
Total Sales:	140,600
Other	1,172
Losses	4,104
Total System Output:	145,876

System Peak Loads

	Date	Megawatts
Summer	1995	25,496
Winter	1996	25,995

Operating Highlights

Annual Load Factor	63.89
Nuclear Capacity Factor	85.1
Fossil Equivalent Forced Outage Rate	7.0
Number Transmission Line Interuptions	1,300

Source: TVA 1996.

time in TVA's history, nuclear capacity (20 percent) exceeded hydroelectric capacity (TVA 1996). A description of TVA's thermal power plants is provided in table 7, while information on hydropower dams is presented in the previous chapter in table 3.

In general, the nuclear and coal-fired plants are used for base power loading, while hydroelectric, combustion turbines, and some coal-fired plants are used to meet peak power demands. In the summer, peak power demand occurs in the late afternoon or early evening, while the winter usually has two peaks, one in the morning and another in the early evening (figure 10). The TVA power system is referred to as a summer-peaking system, as summer (July, August, September) cooling requirements for air-conditioning are generally greater than heating demands during the winter (January, February, and March) (Miller and others 1993).

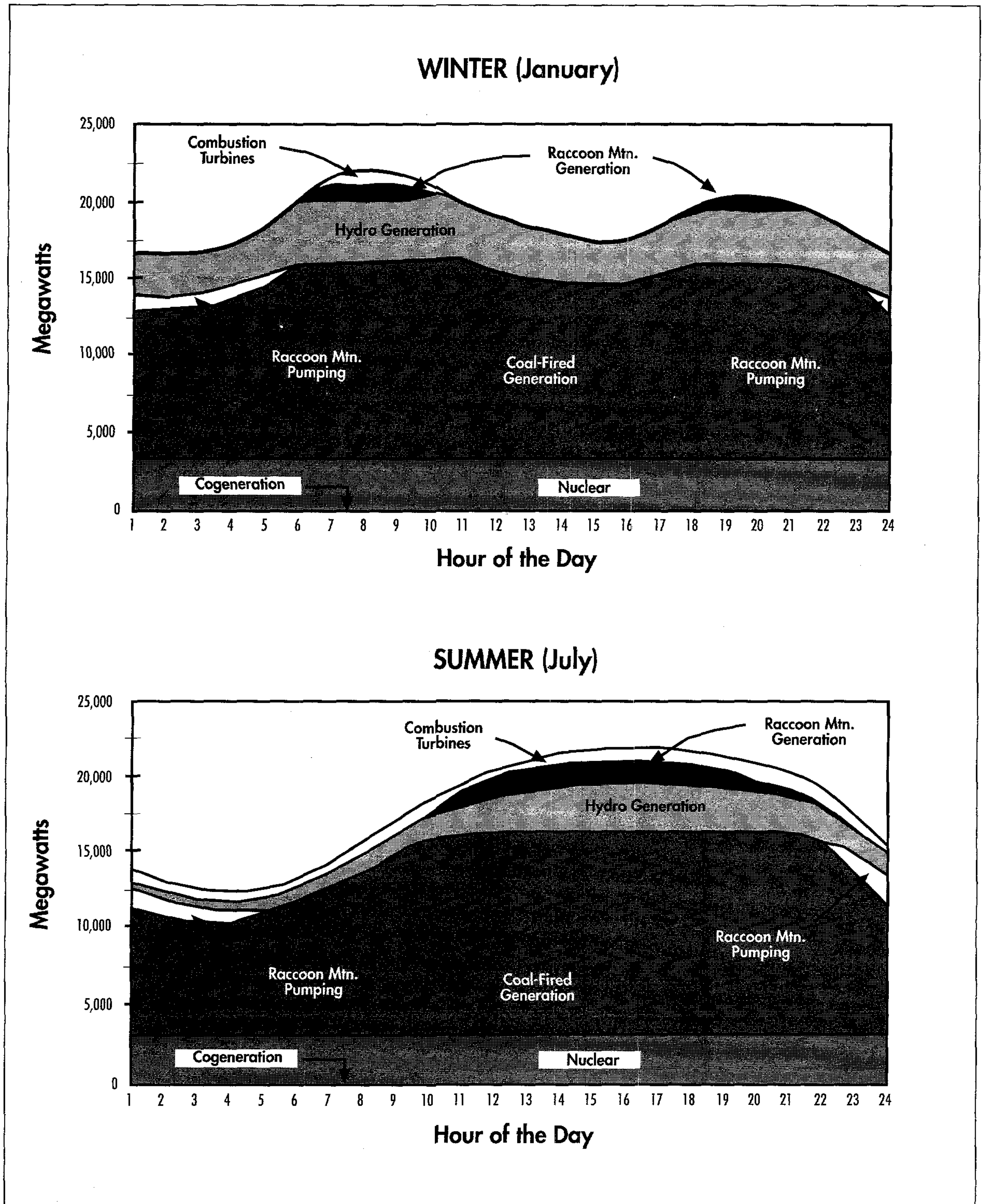
Table 7. TVA Thermal Power Plants, 1997

	Number of units	Winter Net Dependable Capacity *megawatts*	Coal Burned at Full Capacity *metric tons/hr*	*short tons/hr*	Design	Construction Span	Note
Coal-Fired Plants							a
Allen	3	753	300	272	-	1956-59	
Bull Run	1	881	316	287	-	1962-67	
Colbert	5	1,204	518	470	-	1951-73	
Cumberland	2	2,546	1,020	925	-	1968-73	
Gallatin	4	1,018	422	383	-	1953-59	
John Sevier	4	712	280	254	-	1952-57	
Johnsonville	10	1,254	572	519	-	1949-59	
Kingston	9	1,456	615	558	-	1951-55	
Paradise	3	2,240	1,051	954	-	1959-70	
Shawnee	10	1,389	522	474	-	1951-57	b
Widows Creek	8	1,615	734	666	-	1950-65	
Nuclear Plants							
Browns Ferry	3	2,175	-	-	Boiling Water Reactor	1966-77	c
Sequoyah	2	2,300	-	-	Pressurized Water Reactor	1969-80	
Watts Bar	2	1,165	-	-	Pressurized Water Reactor	1974-96	d
Bellefonte	2		-	-	Pressurized Water Reactor	Currently Deferred	
Combustion Turbines							
Allen	20	565	-	-	-	1942-50	
Colbert	8	435	-	-	-	1950-52	
Gallatin	4	352	-	-	-	1951-53	
Johnsonville	16	942	-	-	-	1940-41	

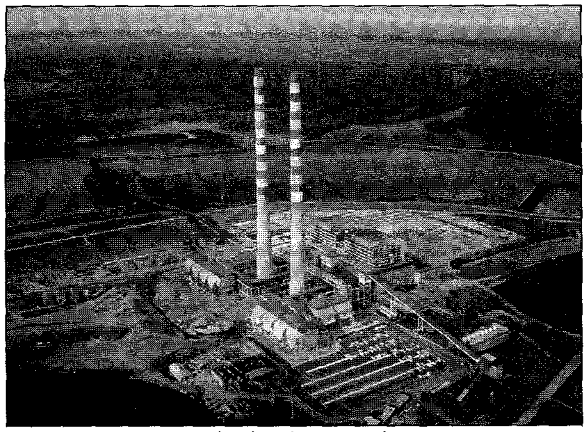
Note:
a. Watts Bar Coal-Fired Plant, which was built from 1940 to 1945, was placed in storage in 1982.
b. Unit 10 was converted to an atmospheric fluidized bed combustion (AFBC) unit in 1988.
c. 1997 update: Only two units in operation.
d. 1997 update: Watts Bar Unit 1 on-line, Watts Bar Unit 2 deferred.

TVA 1994.

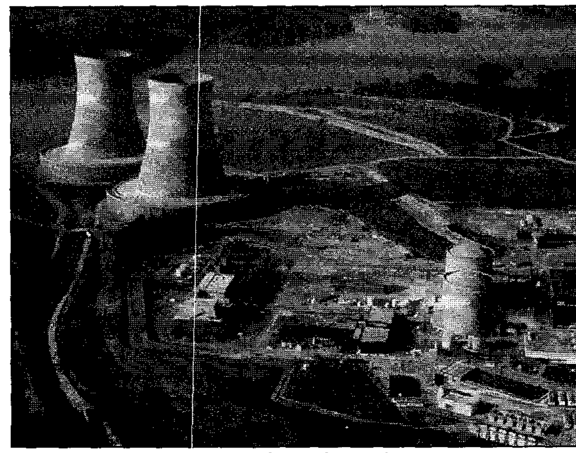
Figure 10. Representative TVA Power Load and Supply Curves



Source: TVA.



Cumberland steam plant



Sequoyah nuclear plant

TVA is one of the largest power producers in the U.S., with coal-fired, nuclear, hydroelectric, combustion turbine generation, and pumped storage facilities.

Finances

The book value of power system assets is $34 billion. These assets include $6.3 billion in deferred nuclear generating units at Watts Bar and Bellefonte Nuclear Power Plants (TVA 1996).

By law, the TVA power system must be self-supporting from the revenues it produces and capital it raises in public markets. Financial highlights for the TVA power system for 1996 are provided in table 8. Total operating revenues for the year were nearly $5.7 billion, with a net income of $61 million. Total sales (system output) were approximately 146 billion kilowatt-hours. The average revenue per kilowatt-hour was $0.04, while aggregate fuel costs per kilowatt-hour of net thermal generation were $0.01.

TVA power rates are among the lowest in the country. Following large rate increases in the 1970s and early 1980s, TVA's rates have remained constant since 1987. By its own account, TVA is the second lowest-cost power producer among the nation's 50 largest electric utilities (TVA 1996). The cost of electricity for residential customers in the TVA region is $0.06 cents per kilowatt-hour compared with a national average of $0.08 per kilowatt-hour. Residents of Tennessee, who represent the core of the TVA power service area, also use more electricity on the average than residents in any other state in the country.

In 1996 the Authority paid approximately $2 billion in interest expenses on a total outstanding debt of $27.3 billion (long and short term). This debt was primarily incurred for TVA's nuclear power construction program. The interest payments represent nearly 35 percent of TVA's $5.7 billion operating revenues.

TVA's debt is not guaranteed by the U.S. Government, but since TVA is closely linked to the government, investors and rating agencies have traditionally believed that TVA has the implied support of the government. Furthermore, the requirements of the Power Bond Resolution (please see next section) almost guarantee investors of repayments; TVA is required to set rates sufficient to repay indebt-

Table 8. TVA Power Program Financial Highlights, 1996

Financial Summary

	$ millions
Operating Revenues	5,693
Operating Expenses	(3,656)
Operating Income	2,037
Other Expenses, Net	(10)
Interest Expense	(1,966)
Net Income	**61**
Total Assets	**34,029**
Capitalization	
Long-Term Debt	25,570
Proprietary Capital	4,028
Total Capitalization	**29,598**

Income Statement

	$ millions
Operating Revenues	
Sales of Electricity	
Municipalities and Cooperatives	4,980
Industries Directly Served	452
Federal Agencies	172
Other	89
Total Operating Revenues	**5,693**
Operating Expenses	
Fuel and Purchased Power, Net	1,278
Operation and Maintenance	1,218
Depreciation and Amortization	904
In-Lieu of Tax Payments	256
Total Operating Expenses	**3,656**
Operating Income	**2,037**
Other Expense, Net	(10)
Income Before Interest Expense	2,027
Interest Expense	
Interest on Debt	1,965
Amortization on Debt Discount, Issue, and Reacquisition, Net	118
Allowance for Funds Used During Construction	(117)
Net Interest Expense	**1,966**
Net Income	**61**

Outstanding Debt

	$ millions
Short-Term Debt	
U.S. Treasury Notes	-
Held by the Public	4,024
Total Short-Term Debt	**4,024**
Long-Term Debt	
Held by the Public-Senior	19,403
Held by Federal Financing Bank-Senior	3,200
Held by the Public-Subordinate	1,100
Total Long-Term Debt	**23,703**
Unamortized Discount and Other Adjustments	(383)
Net Long-Term Debt	**23,320**
Total Debt	**27,344**

Source: TVA 1996.

edness. This implied government support and strict requirements have secured favorable interest rates for TVA in domestic and international capital markets (Davis 1997a). TVA bonds have maintained a AAA rating from Moody's Investment Services, largely because TVA remains "a wholly owned corporate agency and instrumentality of the federal government," and, therefore, while TVA bonds are not guaranteed they carry important support (*Knoxville News-Sentinel* April 13, 1997).

Although TVA does not pay taxes, its 1996 in-lieu-of tax payments to local and state governments amounted to $256 million, or nearly 5 percent of its operating revenues.

Historical Perspective

The box on the following page presents the highlights of TVA's power program since World War II. By the 1950s, TVA had accomplished its basic mission. It had facilitated the unified development of the resources in the Tennessee Valley, constructed the majority of its large dams and reservoirs, abated the most glaring abuses of forest and agricultural lands, completed rural electrification, established its right as the sole power producer in the Valley, and completed a vast network of transmission lines. As discussed previously, two important events concerning the power system occurred during this time. In 1949, as power demands in the Valley began to outstrip the available supply from hydroelectric facilities, TVA initiated the construction of a series of large coal-fired plants. In 1959, Congress passed the Self-Financing Amendment that granted TVA the right to finance its power program from its own revenues. The Amendment enabled TVA to issue revenue bonds, which were to be secured and repaid by power sales, to private investors. These bonds would not be guaranteed by the U.S. Treasury. Power rates were to be set by TVA at a level sufficient to cover operating expenses and to repay debt and past appropriations. Repayment of past appropriations included the cost of previously built thermal plants, hydropower plants, transmission lines, and the proportion of dams allocated to power benefits. To allay fears of neighboring utilities, the Amendment also established the "fence," an area outside of which TVA and its distributors cannot sell power. This power service area is defined as those areas TVA was serving in 1957, and, therefore, includes both a geographic area (approximately 80,000 square miles or 207,000 square kilometers) shown in figure 9, as well as 14 other public and private utilities to whom TVA was selling power at the time.

Having won the right to finance its power program, TVA embarked upon an ambitious effort to construct coal-fired plants. Construction was initiated on nine of TVA's 11 fossil plants between 1949 and 1959. The remaining two fossil plants were constructed in the 1960s. To raise capital for this growth, TVA adopted in 1959 the "Power Bond Resolution" to provide economic protection to bondholders (Davis 1997a). The Resolution is binding legal document that specifies the terms and conditions upon which TVA can issue debt securities in public markets. It specifies that:

- The TVA Board of Directors has sole authority to set rates
- TVA must meet certain financial covenants and tests
- The TVA Board of Directors is required to set power rates sufficient to ensure compliance with such financial covenants and tests
- The repayment of the government investment in TVA is subordinate to the public bond repayment.

The 1960s were a time when TVA searched for a new, clearly defined mission. During this period, an Office of Tributary Area Development was created to work closely with local governments throughout the Basin in an attempt to establish TVA's leadership in social and economic development. The program was not always successful, however, and resulted in a series of separate, locally beneficial projects as opposed to a comprehensive plan for the Basin. In 1963, TVA established the "Land Between the Lakes" as a model for land management and environmental education. Six new dams were initiated during 1960-72. Many, such as Tellico, Normandy, and Columbia, had economic development as one of their motivating forces. For the first time, project benefit/cost ratios were based on economic development and not just flood control, navigation, and power generation (Hargrove 1994).

Box 1. TVA Power Program Post-WWII Historical Highlights

1950s: Mission Complete

- 53 fossil units and 4 dams added before 1960
- Rural electrification completed by 1950s
- Self-financing amendment 1959
- Large-scale efforts to construct 9 coal-fired plants 1940s-1950s

1960s: Search for a New Mission

- 2 additional fossil plants initiated 1960-68
- 6 dams initiated 1960-72
- Land Between the Lakes 1963
- 17 nuclear units at seven plants initiated 1966-75

1970s: Seeds of Change

- Last new fossil unit on-line 1973
- Browns Ferry Nuclear Plant fire 1977
- Clean Air Act agreement with EPA 1978
- Dam building ends with closure of Tellico Dam 1979
- Reservoir Release Improvements Program initiated in 1981
- Electric rates quadruple 1972-80
- 8 nuclear units deferred and then canceled 1980-84
- 36% cut in employment 1981-87

1980s-1990s: Power Program Retrenchment

- All nuclear units shut down 1985-88
- Electric rates double 1980-88
- In-house construction group abolished 1988
- Electric rates frozen 1988-97
- 24 % cut in employment 1988
- 2 nuclear units returned to operation 1988
- 27 % cut in employment 1992
- 3 nuclear units operating 1994
- 16 % cut in employment 1994
- 5 nuclear units operating 1995; 3 units deferred indefinitely; 1 unit for coal gasification

1990s: Preparing for Deregulation

- Creating the corporate TVA 1988-94
- Energy Policy Act of 1994
- Mission "providing energy and related services" 1994
- GAO and Palmer Bellevue reports 1995
- TVA proposes to take down the fence 1995
- "...the Party's Over" "It's Time to Sell TVA" 1995
- Klug Amendments to appropriations bills 1995-96
- Equal Access Transmission (Federal Energy Regulatory Commission Orders 888, 889) 1996
- TVA proposes to eliminate federal appropriations for nonpower programs 1997
- Bristol, Virginia chooses an IOU wholesale supplier 1997

Source: Ungate 1997.

While TVA's natural resource programs searched for new missions, the power program continued to grow. The 1960s were a period of unprecedented economic growth in the Valley, and TVA anticipated that electric power needs would continue to grow at the same rapid rate. The price of coal was beginning to increase, and the costs of addressing environmental concerns relating to the effects of strip mining and air pollution from coal-fired plants had escalated. A new form of energy, nuclear power, appeared to offer a continuous, low-cost, and less environmentally harmful source of power. Consequently, between 1966 and 1975, TVA planned and ordered equipment for 17 nuclear reactor units at seven nuclear power plants (Ungate 1997). Construction of the first nuclear power plant at Browns Ferry, Alabama, began in 1966. This program marked a dramatic shift to nuclear energy as the dominant source of TVA power. During this era, TVA's commitment to nuclear power was larger than any other utility in the world (Hargrove 1994).

The 1970s marked the beginning of great changes for TVA. The last new fossil unit was brought on-line in 1973, while the era of dam building ended with the controversial closure of Tellico Dam in 1979. Environmentalists, farmers, and some state and local governments strongly opposed the dam, and the ensuing battle created a great credibility gap between TVA and the public. Controversy and public anger at TVA was further increased over a series of environmental issues related to power production, including strip mining, air pollution, and the nuclear power program. Prior to the 1970s, TVA had operated autonomously from state and federal regulations. With the passage of the Clean Air Act in 1969, TVA was pitted against the regulatory obligation of states to uphold federal environmental laws. After lengthy battles and lawsuits with the Environmental Protection Agency, TVA committed itself to expensive options to decrease air pollution from its coal-fired plants (Hargrove 1994). Courts could no longer protect TVA against other federal agencies. In 1977, President Jimmy Carter appointed S. David Freeman to the TVA Board of Directors with instructions to establish TVA as a leader in the environmental arena.

In the 1970s, problems began to emerge with TVA's nuclear power program. To finance the program, in 1970 Congress raised TVA's debt limit from $1.75 billion to $3.5 billion. In 1976, the debt ceiling was raised to $15 billion, and it doubled again in 1979 to $30 billion (where it rests as of mid-1998). Congress did not question these changes until public concerns for nuclear safety were heightened by a fire at Browns Ferry Nuclear Plant in 1977 and electricity rates began to increase. The 1970s were marked by high inflation and rising interest rates. Coal-fired plants became more costly to run due to increases in the price of coal and the additional costs associated with complying with environmental regulations. The nuclear plants were also more complicated and took longer to build than anticipated, particularly to meet safety standards and the new environmental regulations on thermal pollution. Although nuclear power plants were far more complex, TVA approached building them with the same attitude—just in time design—as its dam and coal-fired construction programs. Additionally, there was no standardized building approach and each nuclear unit was uniquely designed. Consequently, cost overruns began to mount in the nuclear program, at the same time that the cost of operating coal-fired plants rose dramatically. By 1977, the actual costs of constructing the Browns Ferry and Sequoyah Nuclear Plants had tripled from original estimates, while estimated costs at Watts Bar and Bellefonte had doubled (Hargrove 1994). In response to these circumstances, the first rate increase for residential customers occurred in 1967. Between 1972 and 1980, TVA electric rates quadrupled (Ungate 1997).

At the same time, the oil embargo and U.S. energy crisis of the 1970s had resulted in reductions in power demand. Initially, TVA made no attempt to re-evaluate its nuclear building program in light of potential changes in future demand. Based on its historical experience, TVA still operated from the premise that if you "build load . . . everything will come to it" (Willis 1990) and that cheap power was essential to the economy of the region. Hargrove (1994) argues that during this period TVA was hampered by its decentralized management structure, lack of congressional oversight, and independence in financing. The TVA Board of Directors lacked any independent means of evaluating recommendations proposed by the power program. The budget process was the only planning process TVA used, and the annual budget was prepared to satisfy the U.S. Office of Management and Budget, not as a means to control management. Congress did not scrutinize TVA's plans, and, as a government corporation, the TVA power program was not regulated by the Federal Energy Regulatory Commission. TVA was also able to continuously raise its debt limit to finance nuclear construction program.

The 1980s and 1990s have been a time of retrenchment for the TVA power program. In response to cost overruns and problems with the nuclear power program, rising electric rates, reduced power demand, and increased concern from the public and Congress, TVA deferred and canceled eight nuclear units between 1980 and 1984. This marked the end of the massive nuclear construction efforts, and TVA employment was cut by 36 percent between 1981 and 1987. Because of safety infractions in operations and construction, all nuclear units were shut down between 1985 and 1988 (Hargrove 1994). Electric rates, however, continued to rise and doubled between 1980 and 1988 (Ungate 1997).

In 1988, Marvin Runyon was appointed by President Ronald Reagan as the new chairman of TVA. At that time, electric power rates were frozen, TVA's in house construction group was abolished, and employment was cut another 24 percent. Electric rates remained frozen for the ten year period, between 1988 and 1997. During that period TVA employment has steadily declined. Staff were cut by another 27 percent in 1992 and 16 percent again in 1994. As of mid-1998, TVA employs some 15,500 people compared with 34,000 in 1988. By 1995, however, TVA brought back safely on-line or completed construction of five nuclear units at its Browns Ferry, Sequoyah, and Watts Bar nuclear power plants. These five units are in operation today. TVA has recommended that the four remaining units be deferred indefinitely or not be completed by TVA itself. To date, TVA has invested a total of $19 billion in its nuclear power program of which $6.3 billion is tied up in its deferred units. Although TVA's nuclear power plants supply one-fifth of generating capacity, they represent two-thirds of the Authority's plant investment (*Knoxville News-Sentinel*, April 13, 1997).

An Evolving Power Program

The future of TVA's power program is being influenced by national trends towards deregulation of the electric power industry. TVA is positioning itself to operate in a more competitive environment by improving power system operations, strengthening financial management, and enhancing strategic planning.

Preparing for Deregulation

Tremendous changes are occurring in the U.S. electric utility industry. These national changes have had a tremendous impact on TVA power program as it prepares to operate in a more competitive environment. Historically, TVA and regulated electric utilities have had well-defined and protected markets or service areas. Additionally, utilities have controlled their transmission systems and been able to choose whose power they purchase for resale, whose they transport or "wheel" through their service area, and how much they charge for wheeling. New laws regarding open access and trends toward deregulation, however, are changing the ground rules for electric utilities (TVA 1995). The National Energy Policy Act of 1992 and related Federal Energy Regulatory Commission regulations issued in 1996 have introduced the concept of open access, whereby wholesale customers and suppliers will have equal access to all of the nation's transmission systems. Although TVA is not regulated by the Federal Energy Regulatory Commission, it has taken steps to voluntarily comply with the Commission's regulations. The TVA has now offers transmission service patterned after the open-access tariff but consistent with the TVA Act and Energy Policy Act of 1992. It has adopted a code of conduct based on Federal Energy Regulatory Commission standards. In addition, TVA has separated transmission system operations from wholesale off-system power marketing and is participating in the national electronic information system OASIS (TVA 1996).

Nationally, there have also been numerous moves towards deregulating the electric power industry to increase competition and allow consumers the opportunity to choose their power supplier. In 1996, seven states approved plans for pilot programs or full-scale retail competition within the next two years. In 1997, legislation was introduced within U.S. Congress to require retail competition in electricity nationwide over the next three to five years (*Knoxville News-Sentinel* May 18, 1997).

Publicly, TVA has announced support of deregulation of the electric utility industry and has taken several steps to prepare for a more competitive environment, including efforts to:

- Hold power rates constant
- Improve power operations and reliability
- Manage debt
- Expand marketing and advertising efforts
- Participate in global markets
- Recommend removal of the TVA "fence"
- Recommend dissolution of nonpower programs (TVA 1996).

Following large increases in power rates in the 1980s, TVA held power rates constant for a ten-year period beginning in 1988. This was accomplished by cutting operating costs by $800 million, reducing the work force by more than 50%, and impoving employee productivity.

Since 1993, the power system has focused on improving operations and reliability. New management techniques have introduced performance measures to focus work efforts and accountability. Capacity factors at the fossil plants have been increased by 20 percent, and in 1995 all 59 fossil units were operated at the same time. The hydropower system has initiated a modernization program that will add approximately 536 megawatts of capacity to the system by refurbishing and upgrading 88 hydropower units at 24 dams by the year 2010. To date, completed hydropower modernization projects have improved turbine efficiency by an average of five percent. In 1996, TVA completed Watts Bar Nuclear Plant Unit 1 and restarted Browns Ferry Nuclear Plant Unit 3, thereby increasing the net winter dependable capacity by 2,200 megawatts or nine percent. For the first time, TVA had five nuclear units in operation.

Perhaps one of TVA's most serious problems is dealing with its $27 billion debt and related interest payments that totaled $2 billion in 1996. To address this issue, TVA has imposed an internal debt ceiling of $28 billion (a $30 billion ceiling is mandated by Congress), and 1997 was the first year in 35 years in that TVA will not borrow additional money for capital expenditures. Additionally, TVA has broadened its investor base by selling bonds to global, national, and regional investors. A five-year financial plan has also been developed to reduce this debt, that includes debt repayments of $50 million and $250 million over the next two years (*Knoxville News-Sentinel* February 7, 1997).

In anticipation of consumer choice of the electric power provider, TVA has implemented an aggressive marketing and advertising strategy. A customer service and marketing group was formed to focus on improved customer relations, economic development, technology advancements, and energy marketing. More flexible contracts and more choices in energy services are being provided. Economic development efforts are focused on creating power demand. TVA served as a catalyst in the formation of the Public Power Alliance, a business partnership to help members launch new businesses/services and to increase their competitiveness. For the first time, TVA used paid television advertisements as well as advertising in other ways.

Recognizing the increasing globalization of the electric utility industry, TVA has begun to look at international markets. In 1996, TVA signed agreements with China's Ministry of Water Resources, Ministry of Electric Power, and Lishui Hydro & Power Corporation to assist the Chinese in developing the Han and Li rivers and to improve their coal-fired plants. Recently, TVA has also worked in Egypt, the Republic of Georgia, and India.

The TVA "fence," limits TVA's power service area to those areas it was serving in 1957. Open access, therefore, could enable other utilities to come into TVA's area, but the language of the legislation creating the "fence" might prohibit TVA from offering service to their customers. The "anti-cherry picking" provisions of the National Energy Policy Act of 1992 offer some protection to TVA. These provisions acknowledge that 80 percent of TVA power sales are to wholesale distributors, and exempt TVA from having to transmit or wheel power from neighboring utilities to wholesale customers within the TVA service area. Neighboring utilities, however, maintain that this provision leaves distributors within the TVA region little option but buy power from TVA (*Knoxville News-Sentinel* May 18, 1997). At the retail level, TVA would still be subject to increased competition. TVA has decided that it is to its advantage to eliminate the "fence" in order to enter the emerging competitive environment on an equal footing with other suppliers.

The most controversial recent change in TVA came with a January 1997 proposal to Congress by the current Chairman Craven Crowell that TVA should focus its efforts on power production and transfer its nonpower responsibilities (that is, water, land, and environmental management) to other federal agencies. The following chapter discusses this proposal in more detail.

Strategy for the Future

In 1996, TVA completed a multi-year process to prepare an integrated resource plan for the future. Entitled Energy Vision for 2020 (TVA 1997), this plan identifies and selects resources to meet the Tennessee Valley's electric power needs for the next 25 years. The plan was prepared by TVA staff and consultants, coupled with public involvement through a series of public meetings, a 17-member review group that represented a range of public viewpoints, and acceptance of written comments on the draft plan.

Vision 2020 took into account public concerns regarding factors such as TVA's debt, the nuclear program, power rates, the ability to remain competitive, the privatization of TVA, the environment, and the use of specific resource options such as renewable energy sources. Based on these stakeholder issues, TVA developed 42 evaluation criteria to reflect public values, as well as TVA's goal and objectives. The main goals were to achieve, competitively priced power, opportunities for economic growth, and a quality environment rich in natural resources.

The plan had both short-term and long-term components. In the short-term plan (to the year 2005) it was estimated that TVA would need an additional 3,500 megawatts of capacity to meet the Valley's energy needs during that period. Key recommendations included:

- TVA should not by itself complete the remaining four nuclear units on deferred status. Browns Ferry Unit 1 and Watts Bar Unit 2 should continue in inoperative or deferred status. The two units at the Bellefonte Plant should be converted, in partnership with outside entities, to a combined cycle plant that uses natural gas or gasified coal as its primary fuel source. Elimination of large capital outlays on nuclear plants will help TVA manage its debt and remain competitive.
- TVA should purchase up to 2,700 megawatts of power from outside sources to meet base load and peak power demands.
- The Authority should invest in siting and pre-engineering work for combustion turbines or other facilities using different technologies.
- TVA's hydropower plants should be modernized to add 100 megawatts to existing capacity.
- Cost-effective biomass cofiring (for example, use combination of coal and wood waste products at generating facilities) should be implemented.
- Implement three types of customer-service options: demand-side management, beneficial electrification to improve efficiency, and off-system sales.

The long-term plan (to the year 2020), recommends that TVA look at a portfolio or bundle of resource options. The portfolio is designed to increase flexibility; balance cost, rates, environmental impacts, debt, and economic development; and, manage risk. Resource options include

- Supply side options, including purchasing power from outside sources, use of innovative approaches and renewable energy sources (for example, wind, biomass, photovoltaics), and partnering with others to convert Bellefonte Nuclear Plant to a coal gasification project

- Customer service options, including demand-side management and beneficial electrification. These efforts should add 900 to 2,000 megawatts, or 14 to 31 percent of additional capacity
- Environmental controls, including fuel switching and the use of scrubbers at TVA coal-fired plants to further reduce the emission of sulfur and other pollutants.

4. Current Issues and Challenges

The future of TVA is once again being debated within the Authority, the Tennessee Valley, and the U.S. Congress. The debate focuses around two central issues: (a) the fate of TVA's natural resources and economic development programs, and (b) the future of TVA's power program in the face of deregulation and renewed discussions about privatization.

Natural Resources Programs

In January 1997, TVA Chairman Craven Crowell proposed that TVA divest itself of the nonpower programs that are funded through congressional appropriations (*Washington Post*, February 4, 1997). These nonpower programs include TVA's traditional responsibilities for water management (including flood control), navigation, water quality, land management, environmental research, and social and economic development activities. Chairman Crowell maintained that divestiture of these nonpower programs, which constitute only two percent of TVA's total budget, would achieve two desirable results. First, it would strip the Authority to its "core energy business" and allow it to prepare more effectively to compete with private utilities in a deregulated environment. Second, it would end allegations by TVA critics that the Authority is federally subsidized and therefore has an unfair advantage over private utilities (*Knoxville News-Sentinel*, March 9, 1997). Crowell recommended that other state or federal agencies take over these natural resources activities, that economic development activities be refocused and embedded in power marketing programs, and that environmental management activities become self-supporting. Crowell maintained that these changes would support efforts to reduce the national budget and streamline the federal government (*Knoxville News-Sentinel*, February 5, 1997).

TVA's history has been marked by controversy and numerous debates about its future, yet this is the first time that a chairman had proposed such a radical departure from TVA's original mission. Historically, the TVA Board has fought to maintain its appropriated budget and strongly defended its mission as a resource development agency. The TVA Caucus in Congress has voiced strong opposition to the proposal, and, although TVA has certainly had its critics, there was a litany of support for the Authority to continue its natural resources missions. Widespread support has been voiced by the general public through a series of meetings, as well as from groups as diverse as the environmental group American Rivers, the Board of Directors of the Tennessee Valley Public Power Association, (which represents the 160 municipal and rural cooperatives TVA supplies with power), area governors, local businesses, boat operators, and Cherokee Native Americans. The general sentiment has been that although TVA has not always done things well, few organizations could have done better. Some even feel that Crowell has "it backward—that it is TVA river management and other nonpower functions, and not its electric system, that is worth keeping" (*Knoxville News-Sentinel*, May 25, 1997). For many, spinning off TVA's nonpower programs is giving away what justifies TVA in the first place. As a result of congressional pressure and widespread public support for TVA's continued management of natural resources programs, Chairman Crowell publicly withdrew this controversial proposal in July 1997 (*Knoxville News-Sentinel* July 10, 1997).

As of the spring of 1998, the future of TVA's nonpower programs continued to remain uncertain. U.S. President Bill Clinton has recommended that TVA continue to receive federal funds, and a new federal audit by the General Accounting Office confirmed that much of the work done by TVA's nonpower programs is not done or funded by other private power companies. The federal government's Office of Management and Budget, reversing an earlier position, also reported that shifting TVA's nonpower programs to other federal agencies would not save money. Supporters of the Authority, particularly the TVA Caucus, are using this information to continue to fight for federal funding for TVA.

Despite these efforts, Congress reduced TVA appropriations for fiscal year 1998 to $70 million, a 34 percent reduction from the previous year. More significantly, the FY98 budget stipulated that TVA would no longer receive federal funds for nonpower programs in the future. Yet the debate has continued during the preparation of the fiscal year 1999 budget. Although the House of Representatives has upheld the stipulation for no future funding and has refused to hold budget hearings, the Senate has included $70 million for TVA in its version of the budget. The issue for fiscal year 1999 will be resolved in a congressional conference, while options regarding the long term fate of TVA's natural resources mission continued to be discussed. The range of options under consideration include, continued federal funding for TVA, financing of nonpower programs through TVA's power program, transfer of nonpower programs to other federal agencies, and granting the U.S. Army Corps of Engineers federal funds to contract to TVA to manage the nonpower programs. Congress members have also put forth proposals to improve the management of TVA, such as increased congressional oversight of the Authority and expansion of the TVA board from three to 15 members, along the lines of most corporations. (*Knoxville News-Sentinel*, May 5, 1997; February 15, 1998; April 22, 1998; May 17, 1998; May 23, 1998).

Power Program

The future of TVA's power program is also the subject of ongoing debate. As discussed previously, the primary challenge facing the power program is the prospect of deregulation of the electric power industry. To prepare for a more competitive environment, TVA has taken aggressive steps to transform itself from a traditional federal agency to a more corporate-like environment. It has cut operating expenses, reduced its workforce by more than 50 percent since the 1980s to current levels of around 15,500, instituted performance measures, and now holds its employees and managers accountable for meeting performance standards. It has held power rates constant for ten years and attempeted to manage its debt by capping it at $28 million and making annual repayments. Power operations and reliability have been improved, while marketing and advertising efforts have been expanded. TVA publicly supports deregulation and has recommended that Congress remove the "fence" that prohibits TVA from selling power outside of its defined service area. It has even proposed ending tax-subsidized programs (that is, its nonpower programs) to maintain a competitive edge (*Knoxville News-Sentinel*, May 23, 1997). TVA has also continued to raise capital by selling bonds regionally, nationally, and internationally. TVA bonds have maintained a high rating (Aaa) by investement services largely because TVA remains a wholly owned corporate agency and instrumentality of the federal government, and while TVA bonds are not guaranteed, they carry important support (*Knoxville News-Sentinel*, April 13, 1997).

Critics of the Authority, however, maintain that these changes at TVA have come at a cost and that the Authority may not be competitive with private utilities. Reducing operating costs and repaying the debt has resulted in drastic staff reductions, as well as cutbacks that might ultimately effect plant performance and safety (*Knoxville News-Sentinel*, May 25, 1997). Some argue that increases in rates, as much as 10 to 15 percent, are inevitable (*Knoxville News-Sentinel*, May 18, 1997). Others suggest that TVA's debt, largely incurred by its nuclear construction program, render it non-competitive. Professional investment services have said TVA's cost generating structure is disadvantaged by substantial investments in nuclear power plants, which supply only one-fifth of TVA's generating capacity, yet represent two-thirds of plant investment (*Knoxville News-Sentinel*, April 13, 1997). According to a 1995 study TVA commissioned on its competitive future, TVA's greatest asset in a deregulated environment might not be its generating units, but its 17,000 miles (27,000 kilometers) of transmission lines that could become a major thoroughfare for power transfer through the region (*Knoxville News-Sentinel*, May 25, 1997).

As predicted by critics of TVA, in July 1997 TVA did have to propose a rate increase (5.7 percent for residential customers and 5.8 percent for commercial customers) effective October 1, 1997. TVA presented the rate increase as part of a plan to retire at least half of its $27 billion debt by 2007.

Significantly, another component of the plan called for laying off more than 1,000 employees. TVA estimates that the proposed rate increase and decrease in employment will enable TVA to realize an additional $10 to $15 billion in revenues by 2007, and thereby help it to reduce its debt to $13.8 billion, its lowest level since 1981. Critics of the Authority are concerned about the fairness of the rate increases, since no independent regulatory body reviews TVA rates (*Knoxville News-Sentinel,* July 23, 1997).

Some of TVA's distributors are also beginning to show dissatisfaction. Many distributors have 20-year contracts with TVA that don't allow them to buy cheaper power. The contracts also require a 10-year notice if they would like to terminate the contract. Earlier this year, Bristol, Virginia, a long-time TVA customer, contracted with another supplier for its electric power. In 1993, Four-County Electric Power Association gave TVA a 10-year notice and entertained bids from other suppliers. A law suit between Four-County and TVA ensued that was only resolved when TVA agreed to continue with its plans to build a lignite plant in the county. The largest five distributors in the Valley, including distributors in Knoxville, Memphis, Chattanooga, and Hunstville, are evaluating their energy options for the future.

Finally, as TVA continues to prepare for a more competitive, deregulated electric industry, talk of privatization has resurfaced again. TVA has long been a candidate for privatization. As early as 1953, President Dwight E. Eisenhower expressed interest in selling TVA. Similar sentiments were voiced by prominent republican politicians in the 1960s. Conservative organizations such as the Cato Institute and Citizens Against Waste have long advocated disbanding federal bureaucracies like TVA. Today, as private companies vie for the most competitive position in a deregulated environment, coalitions of conservative groups and private utilities have launched aggressive media campaigns and lobbying efforts to convince the U.S. Congress to sell TVA. Globally, there has also been a shift toward privatizing electric utilities as a means of cutting government spending and increasing competition. Countries such as Great Britain, Argentina, Bolivia, and the Philippines have either auctioned off government power plants or encouraged private industry to build new ones.

Although the privatization of TVA is not thought imminent, at the heart of the discussions is the debate as to whether the federal government should legitimately be in the power business. The ten federal electric utilities within the United States supply about a quarter of the nation's electric power. TVA is the largest federal utility. Four of these utilities, including the Bonneville Power Administration, merely distribute power, while others such as the Army Corps of Engineers and the Bureau of Reclamation own and operate hydropower dams. Supporters of federal involvement in electric power production argue that the government has supplied remote or depressed areas that would not have been attractive to private industry and has shown how rates could be lowered when power was produced for people and not profit. The public good, they maintain, is still being served by federal utilities (*Knoxville News-Sentinel,* May 18, 1997). TVA and supporters of the Authority estimate that the sale of TVA to a for-profit company would result in rate increases on the order of 20 percent or more (*Knoxville News Sentinel,* August 4, 1997; June 9, 1997).

Private utility companies, particularly in the Tennessee Valley, have long fought federal production of power. In the 1930s, private power companies in the Tennessee region bitterly fought the creation of TVA. They engaged the new Authority in a series of legal battles that culminated in the February 17, 1936 Supreme Court decision that upheld the government's right to build dams to improve navigation and sell power from those dams. Again in 1959, when TVA fought for the right to self-finance its power programs, private utilities won a concession to "fence" TVA's power service area and prevent it from competing in neighboring regions. (TVA's power service area is defined by those areas it was serving in 1957, and, therefore, includes both a geographic area, as well as 14 other utilities to whom TVA was selling power at the time. Strictly speaking, TVA can sell power through the geographic "fence" as long as it is to the original 14 utilities.)

These battles continue today. Southern utilities like Duke Power have twice sued TVA in federal court, claiming TVA had "laundered" power, selling it outside TVA "fence." These lawsuits primarily concern the 14 utilities that TVA maintains it has the right to sell power, because it sold power to them in 1957. In one case, TVA was restricted from further sales because the entity to whom it was selling power was a subsidiary of one of the original 14 utilities. The second case is still pending (*Knoxville News-Sentinel*, May 18, 1997). In response, TVA has filed a formal complaint with the Justice Department that private companies are smearing TVA's name and "undermining TVA's ability to compete." In its complaint, TVA has invoked a provision of the TVA Act that forbids "any conspiracy, collusion, or agreement" designed to thwart the federal power agency. The FBI is currently investigating the matter. Although TVA continues to sell power to these 14 original utilities, one can expect further challenges—and rebuttals by TVA.

Since its inception 65 years ago, TVA has continued to evolve and change in response to internal and external pressures. Although the future of the Authority remains unclear, it has endured many attacks. Recent public and congressional debates illustrate that the public's perception of TVA's mission remains as comprehensive river basin development agency. At the same time, the importance of low electric rates in supporting the economic development of the region also remains a central issue. It appears that the dichotomy between these core values will continue to shape the future of TVA. It is also clear that the physical infrastructure that TVA built beginning in the 1930s—the system of multipurpose dams and reservoirs to harness the power of the Tennessee River and the extensive transmission system to provide cheap electricity throughout the region—remain its greatest asset. TVA's legacy continues to be the integration of a healthy natural resource base, a strong infrastructure, and sound human resources, all dedicated to fostering the social and economic development of a region.

5. Lessons

TVA successfully guided the unified development of the natural resources of the Tennessee River Valley. The growth and development of TVA's institutions and operational programs can provide insight to World Bank staff and client countries in the implementation of comprehensive water resource management policies and practices. The relevance of the TVA approach to other river basins, however, will vary considerably with the local political, social, and economic environment. Nonetheless, there are some important lessons that can be learned from the TVA experience.

1. *TVA emerged from a unique set of historical, political, and geographic circumstances.* The deep poverty and dire need in the Tennessee Valley, coupled with President Roosevelt's commitment to implementing an innovative New Deal program, lead to the creation of a unique regional agency with broad reaching authority to accomplish the unified development of an entire river basin. The TVA model has never been replicated in the United States, in part due to state's rights issues and opposition by other federal agencies. Similarly, in other countries where there are strong local governments and existing national institutions, the implementation of a strong regional authority might not be appropriate or even possible.

2. *The early success of TVA depended heavily on the strength of its champions, the vision of its first leaders, and its ability to show tangible results within a few years.* TVA's most prominent champions provided the conceptual framework, political will, and money to ensure the successful initiation of the Authority. TVA's first board of directors provided tremendous vision to oversee the practical implementation of this "bold experiment." Concepts such as integrated land and water resource planning, maintenance of an ecological balance, collaboration with grassroots organizations, innovative technical assistance programs, small-scale credit programs, and provision of low-cost, accessible electricity to fuel economic development were well ahead of their time. TVA was also able to solidify its vitality as an institution and gain the widespread support of the Valley's citizens by completing major infrastructure projects and visibly improving the standard of living of the region within a 12-year period.

3. *TVA's greatest legacy has been the integration of a healthy natural resource base, a strong infrastructure, and human resources, all to foster the social and economic development of a region.* TVA's infrastructure, which includes a system of dams and reservoirs to harness the Tennessee River and an extensive transmission system to provide cheap electricity throughout the region, served as the backbone for regional economic development. Similarly, early and intense efforts to improve agricultural, land use, and forestry practices helped to restore and maintain a healthy environmental base. Technical assistance and demonstration programs throughout the Valley, coupled with the wide range of professionals, who were attracted to the new Authority, helped to build human capacity. Although some TVA leaders and programs have been paternalistic in their approach to development, the prevailing attitude has been to provide people with the tools to improve their own lives.

4. *TVA's institutional structure served it well during its early years but has provided the seeds for its greatest challenges as the Authority has matured and economic and political conditions have changed.* TVA's institutional structure has traditionally included an appointed board of three directors, a general manager, and strong operating arms. More recently, the general manager has been replaced by an executive committee. During the early years, when its mission was clear and focused on infrastructure construction, this hierarchical structure streamlined decision making and kept the TVA action-oriented. In more recent years, however, this structure has revealed two important deficiencies.

There is no formalized mechanism for stakeholder participation in decisionmaking, and there is no effective means to ensure critical oversight of the Authority. TVA has historically worked very closely with the states in the regions, local agencies, and grassroots citizen's organizations and utilizes a public review process around specific projects. Yet there is no direct representation of key stakeholders and beneficiaries in the management of TVA at high levels or a formalized mechanism for consensus building. Although beneficial to TVA's rapid early development, these two deficiencies have left it vulnerable to loss of political support and inadequate oversight of internal policies and decisions. There is no well-established mechanism for internal, independent scrutiny of policies, while external congressional oversight has not always been consistent or rigorous.

5. *TVA's greatest tension has been between its missions as a comprehensive resource development agency and as a power company.* As predicted in 1937, TVA's power organization has slowly become the dominant organization in TVA. In 1997, TVA's chairman declared power production to be the Authority's core business. TVA's power program is self-financing and generates more than 98 percent of TVA's revenues. However, TVA's mission as an agency that manages multiple resources as an integrated unit has produced its greatest accomplishments. Although TVA's success as a river basin manager has given it a great deal of popular support, the future of its nonpower programs remains uncertain. While nonpower activities like flood control and environmental management provide immense benefits to the region, they are niether self-financing nor revenue generators. The long-term sustainability of agencies like TVA will depend upon finding innovative ways to finance resource management activities.

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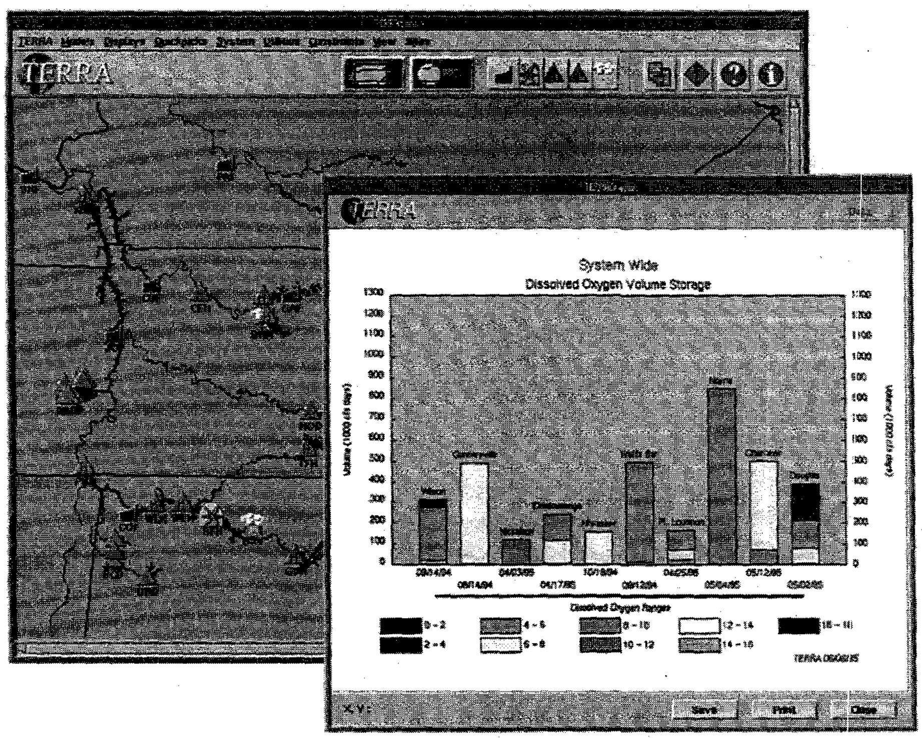
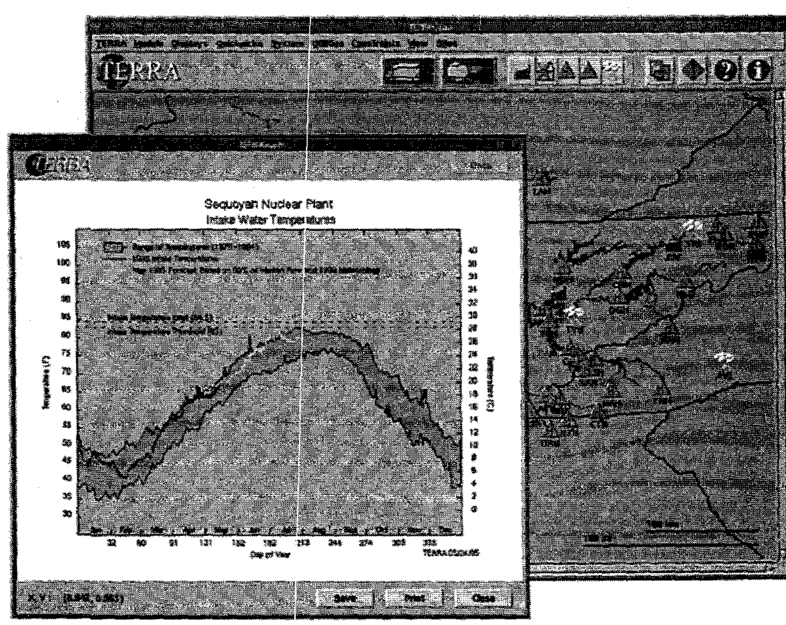
APPENDIX 1.
THE TVA-EPRI RIVER RESOURCE AID (TERRA)

TVA-EPRI River Resource Aid (TERRA)



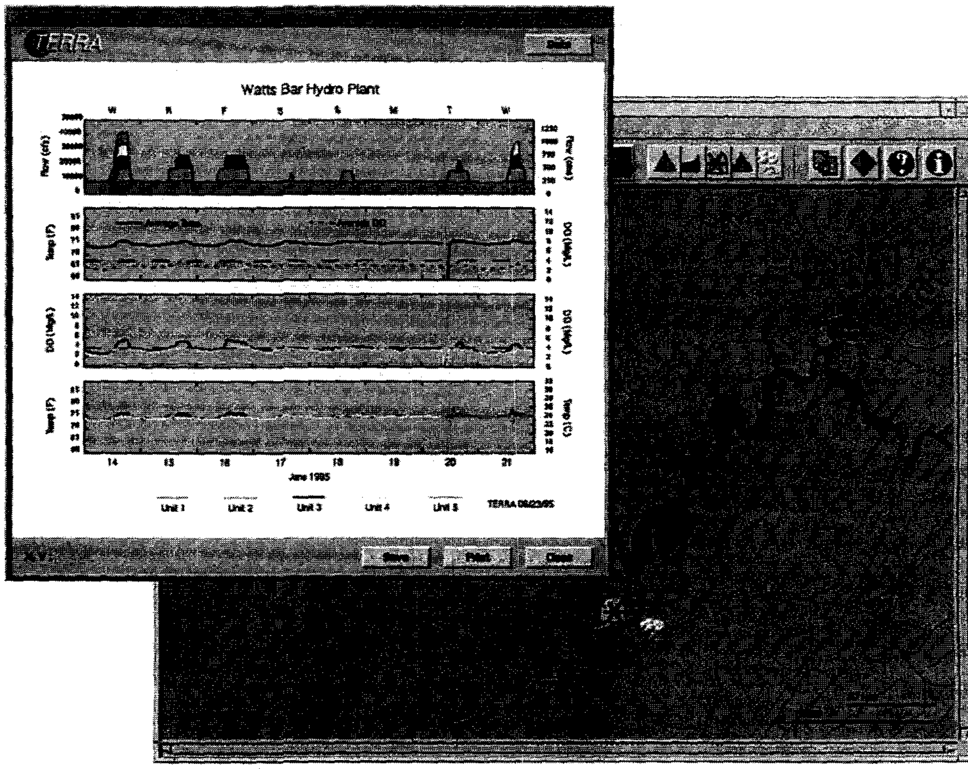
The Tennessee Valley Authority (TVA), the Electric Power Research Institute (EPRI), and the Center for Advanced Decision Support (CADSWES) have developed decision support software to help utilities coordinate power and reservoir operations while protecting water quality, meeting water supply needs, and managing reservoir levels. The TVA-EPRI River Resource Aid (TERRA) has been developed to integrate tracking, display, and modeling tools into a computer system accessible at widely dispersed decision-making locations. TERRA provides a common set of historical, current, and forecast data to assist in rapidly resolving problems in operation, forecasting, and planning of power and reservoir systems.

TERRA uses a geographic information system (GIS) background map of the Tennessee River Valley, which includes portions of seven states. TERRA is adaptable to other reservoir systems by reconfiguring the GIS background map and other system features.



Site-specific or system-wide displays are available for reservoir, power system, and environmental parameters. Example uses:

1) User can track and project the reservoir system's seasonal cold water availability for power plants.
2) Schedules for plant outages are available to facilitate planning of seasonal activities, taking advantage of down times.



TERRA monitors compliance with a set of constraints and commitments that guide daily reservoir operations. Current, 3 to 5 day, and 6 to 10 day weather forecasts are on-line for predicting power demands and water temperatures. TERRA allows operators to run hydrothermal "scheduling" models and predict intake and downstream water temperatures at power plants. The system displays results for decision-makers responsible for daily reservoir and power operations so they can efficiently resolve conflicts and interact with those responsible for environmental compliance.

The system is highly adaptable, and it will continue to evolve in response to users' needs. TERRA is designed for application to your reservoir and power systems.

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APPENDIX 2.
RIVERWARE

■ The Center for Advanced Decision Support for Water and Environmental Systems ■

RiverWare

August 1998

RIVERWARE: RIVER BASIN MODELING FOR TODAY AND TOMORROW

RiverWare™ is a general river basin modeling package that enables you to build and manage your own river basin models and to modify those models as features, uses and policies change. Its integrated functions allow seamless switching from one task to another. Its customization options make it flexible enough for any application.

With RiverWare, you may never need another river basin management software package. RiverWare is designed to meet your riverbasin modeling and management needs now and in the future.

With RiverWare you can . . .

- Model Any Basin. Select generic basin features from a palette, name the features, and link them together to create your basin topology.
- Customize Your Model. Select the appropriate physical process equations for each basin feature. Choose units for entering and displaying data.
- Create your own data icons for holding special data for policies or user-defined functions. Configure plots and spreadsheet-like views of the data.
- Express Operating Policy as Dynamic Data. Get maximum flexibility and ease of use thanks to RiverWare's ability to express operating policy as user-defined data. Because policy is not compiled into the code, you have easy access to create it and modify it.
- Simulate or Optimize. Switch easily between pure simulation, rulebased simulation, and optimization. RiverWare's integration of these modeling approaches in one package makes it possible.
- Schedule, Forecast, and Plan. Manage daily scheduling, mid-term forecasting, and long-range planning by using RiverWare's flexible and innovative utilities. Easily modify the model to apply to new design studies or the analysis of operating policies.
- Use Your Model with Ease. Enjoy intuitive interaction and informative messaging to achieve better modeling results, more quickly, for users with a wide range of experience and expertise.
- Update Your Model to Meet Future Needs. Use RiverWare's data-centered design to its fullest by updating any aspect of your model as needs change. To complement your changing needs, RiverWare developers will provide updated, enhanced versions of the model compatible with changing compilers and operating systems. In short, RiverWare makes obsolescence obsolete.

CREATE YOUR MODEL

RiverWare's graphical user interface (GUI) makes it easy to build a river basin model to your exact specifications. Select the features of your river basin from the palette and create links between them to create the basin topography. Then, for each feature, enter or import data and use the methods menu to select the engineering algorithms you want to apply. Because RiverWare offers several options for solving the system, you only need to build the model once to use pure simulation, rule-driven simulation, or optimization and to handle the full range of tasks-scheduling, forecasting, planning, design, and analysis studies.

Basin Features & Engineering Processes

As you build a model, you select the appropriate methods for modeling physical processes on each feature. Changing the processes for physical processes are:

- **Storage Reservoir** - Calculates mass balance, including evaporation, precipitation and bank storage; releases; regulated and unregulated spill; sediment accumulation.
- **Power Reservoir** - Calculates storage reservoir processes plus turbine releases, hydropower and energy, and tailwater elevation.
- **Slope Power Reservoir** - Calculates storage and power reservoir processes plus wedge storage and reservoir routing.
- **Pump Storage Reservoir** - Calculates power reservoir processes plus pumping power and energy.
- **Inline Pump/Generator** - Calculates pumping/generating power and energy, turbine/pump flow.
- **River Reach** - Routes flow and calculates gains and losses.
- **Confluence** - Calculates mass balance at a river confluence.
- **River Gage** - Specify measured or forecasted flows.

- **Water Users** - Calculates depletion (consumption), groundwater and surface water return flow.
- **AggDiversions** - Aggregates water users and models simple diversions.
- **Diversion** - Models gravity or pumped diversion structure.
- **Aggregate Delivery Canal** - Models off-line delivery canals.
- **Groundwater Storage** - Models temporary aquifer storage for return flows.
- **Canal** - Models bi-directional flow between reservoirs.
- **Thermal Object** - Calculates economics of thermal power system.
- **Data Object** - Evaluates user-defined expressions.

Water Quality

Model water quality along with water quantity processes:

- Model temperature, total dissolved solids, and dissolved oxygen in reservoirs and reaches.
- Select from a simple, well-mixed reservoir or a two-layered reservoir model.
- Choose from several water quality routing methods either with or without dispersion.

User-Selectable Methods

Physical processes in your basin are modeled according to specific algorithms or methods you select, based on time step size, data availability, desired resolution, or an institutional need to use a particular method. Some examples of categories of physical processes and their methods are:

- Power Generation - Plant Power Method, Unit Generator Power Method, Peak Base Power Method, Empirical Power Plant Method
- Tailwater (TW) Calculation - TW Base Value Only, TW Base Value Plus Lookup Table, TW Stage Flow Lookup Table
- Reach Routing Methods - Time Lag, Impulse Response, Muskingum, Muskingum-Cunge, Kinematic Wave and Storage Routing

VIEW YOUR MODEL

When it comes to viewing a river basin model, RiverWare's combination of object-based topology and customized spreadsheet views gives users the best of all possible worlds.

Open Object

Each basin feature, or object, can be opened by double-clicking its icon on the workspace to reveal a list of all the data variables (slots) associated with the feature and a list of all user-selected methods. Each slot can be opened to show time series or table data. Enter or import data, customize display format and data units, and change the input/output status of the data in the Open Slot view.

Spreadsheet-like View

RiverWare's Spreadsheet Control Table (SCT) gives users a customized spreadsheet format view of all the time series data in the model. Think of it as opening a window into data on all features in the basin at once. What's more, you can configure multiple SCTs to get different views of the model, and easily switch from one view to another with the click of a mouse.

From the SCT, you can:

- View any time series data in the model, in any order.
- Change the input/output status of values.
- View the data in time-aggregated form.
- Change data values.
- Set special operating flags.
- Execute runs.

RUN YOUR MODEL

RiverWare offers users the ultimate package of integrated solutions for river basin management. With the same model, RiverWare can provide both prescriptive and descriptive solutions. Choose from pure simulation, rulebased simulation, or optimization and easily change the start and end times of the run, or the time step size, on the graphical Run Control Panel.

Pure Simulation

RiverWare's simulation algorithm can solve upstream, downstream, or any well-determined combination of these in a single run. Input/output data combinations are very flexible, allowing various combinations of, for example, storage, pool elevation, releases, energy, and inflows as inputs that drive the simulation.

Value-Added Features:

- Time steps solve in data-driven order, so targets can be met and upstream releases can be calculated at prior time steps to meet downstream demands.
- The object-oriented modeling approach makes it easy to find where your model may be over- or underdetermined.
- Advanced diagnostic utilities give detailed information about the progress of the solution at each time step, making it easy to analyze runs.

Rulebased Simulation

Rulebased simulation allows you to specify if-then operating policy statements to drive the simulation instead of using data input values. These prioritized rules are created through a graphical editor and can include complex algorithms and call customized or predefined functions. The rules are interpreted and executed when the simulation needs additional data. The most valuable benefit of RiverWare's rulebased simulation is that the rules represent policies as dynamic data, which can be viewed and modified outside the compiled code.

Value-Added Features:

- Create your own libraries of functions to simplify rule writing.
- Test the rules for correct syntax before making a run.
- Turn rules on and off and change priorities easily through the graphical Rule Editor.

- Write comments and diagnostic messages in your rules to enhance analysis of the results.

Water Accounting

Create storage, flow, and diversion accounts and track the legal ownership of water through your basin.

Value-Added Features:

- View and configure account information globally or on each feature.
- Separate "physical" and "paper" water; you define reconciliation of paper accounts with modeled water quantities. Represent water rights, accruals, carryovers, and exchanges.
- Solve accounts "after the fact" or use in your operating rules to drive the simulation account data.

Optimization

The realities of water resource management demand that system operators balance multiple-often conflicting-objectives and operations. RiverWare's preemptive goal programming optimization mode provides a valuable tool for trading off multiple objectives.

Both experts and nonexperts can employ this sophisticated optimization technique.

Manage Reservoirs for Multiple Objectives

- Water supply
- Flood control
- Navigation
- Recreation
- Water quality
- Hydropower

RiverWare's Optimization Works: Automatically

When you make an optimization run, RiverWare automatically generates the physical constraints-such as mass balance, topological connections, and upper/lower bounds-from the model you've constructed. Enter your prioritized policy objectives and constraints through a graphical Constraint Editor, and they are automatically linearized. The linear program (LP) is generated for each goal and sent to a powerful, fast commercial solver. Objectives are met in order of priority, and the solution is returned to the objects.

The LP solver treats each successive constraint as an objective, finding the best solution and setting that solution as a constraint while meeting lower-priority objectives. The result: the best solution given your prioritized goals. The optimal values of the decision variables are then displayed in the slots. A post-optimization simulation run is automatically set up, so you have an exact prediction of the basin's operation with the optimal reservoir releases.

Value-Added Features:

- A multi-objective system without the "penalty matrices" or "objective weights" of conventional multi-objective optimization.
- The satisfaction of each objective is automatically distributed evenly over all reservoirs and all time steps to avoid unacceptable solutions.
- Select the best linearization method for each variable and specify the approximated points (e.g., piecewise).
- Turn objectives on and off, or change priorities, through the graphical Constraint Editor.

MORE USEFUL FEATURES

Data Management Interface (DMI)

RiverWare's DMI utility provides the ultimate flexibility to share data with other applications and analysis tools, other agencies, and other system users. It allows you to customize and automate loading and exporting data and setting up runs for specific applications through external programs tailored to your needs and executed through RiverWare's GUI. The DMI also allows you to:

- Load inputs from any external sources-including real-time or relational databases, outputs from other models, and flat files.
- Export data to spreadsheets, analysis tools, databases, official schedules, other models, e-mail, and more.
- Extend or redefine start and end run times.
- Automatically load initial conditions, hydrologic forecasts, and special operating constraints in a single menu selection from RiverWare's DMI interface-enabling near-real-time operation.

Multiple Run Management

Set up many runs at concurrent or consecutive time horizons and change data inputs or policies (rule sets or constraint sets). The Index Sequential Option automatically permutates historical inflow data for planning studies.

Advanced Diagnostics

Improve analysis of your runs by printing optional informational messages on specified objects, slots, time steps, methods, and controllers. These messages are integrated with RiverWare's warning and error messages to give you exact problem diagnosis.

Subbasins

Define and name arbitrary groupings of features in your model as subbasins, which can be used in expressions, policies, and DMIs. Use this feature with DMIs to allow several operators to schedule different subbasins and to bring the results together into one model.

Expression Slots

Want to know the total power generation in your system? The average inflows over the run? Create your own algebraic expressions on a Data Object, using RiverWare's slots and subbasins as variables. Build the expressions in RiverWare's Graphical Expression Editor.

Snapshot Manager

RiverWare's Snapshot Manager automatically saves details of each run, based on the data you choose. Change the scenario, make another run, and keep selected results for comparison. Data are kept on Snapshot Data Objects and are created and modified through the Snapshot Manager interface.

Output Options

The Plotting Manager allows you to plot one or many variables, from successive runs-with no limit to the number of plots. View and print the plots or export data in flat files or spreadsheet-readable files.

Batch Mode

Need to call in on the weekend to make a run via modem? RiverWare's Batch Mode utility lets you make a run, enter data, and look at the results in batch mode through its RiverWare Command Language (RCL).

SOME CURRENT APPLICATIONS

Tennessee Valley

The Tennessee Valley Authority is using RiverWare in simulation and optimization for daily scheduling of more than 40 reservoirs and hydroplants at a six-hour timestep. Their operating considerations include controlling floods, maintaining navigable depths,

protecting aquatic communities, providing suitable levels and releases for recreation, and achieving economical hydropower generation schedules.

Colorado River

The Bureau of Reclamation has replaced both its long-term policy and planning model (Colorado River Simulation System) and its mid-term operations model (24-month Study) for the Colorado River with RiverWare rulebased simulation models. These models are used for policy negotiations, to estimate future salinity mitigation needs, as well as to set the monthly target operations for the entire river basin.

Upper Rio Grande

An interagency team including the Corps of Engineers, Bureau of Reclamation, and the U.S. Geological Survey (USGS) is developing a daily timestep operations model of the Upper Rio Grande Basin using RiverWare's rule-based simulation and water accounting. The model must keep track of native water and San Juan-Chama transbasin diversion water to fulfill compact deliveries, international treaty obligations, Indian water rights, and private rights and contracts.

San Juan Basin

An operations model of the San Juan River Basin in Arizona, Colorado, and New Mexico has been developed in a joint Bureau of

Reclamation and USGS effort. The model is driven by operating policies to meet water supply demands, flood control, target storages, and filling criteria in its reservoirs as well as improved habitat for the endangered humpback chub and Colorado squawfish.

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Licensing

RiverWare is licensed by the University Technology Corporation, 3101 Iris Avenue, Suite 250, Boulder, Colorado 80301. For more information about RiverWare and licensing, contact:

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RiverWare was developed by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES). The modeling tool evolved from a joint research project sponsored by the Tennessee Valley Authority and the U.S. Bureau of Reclamation.

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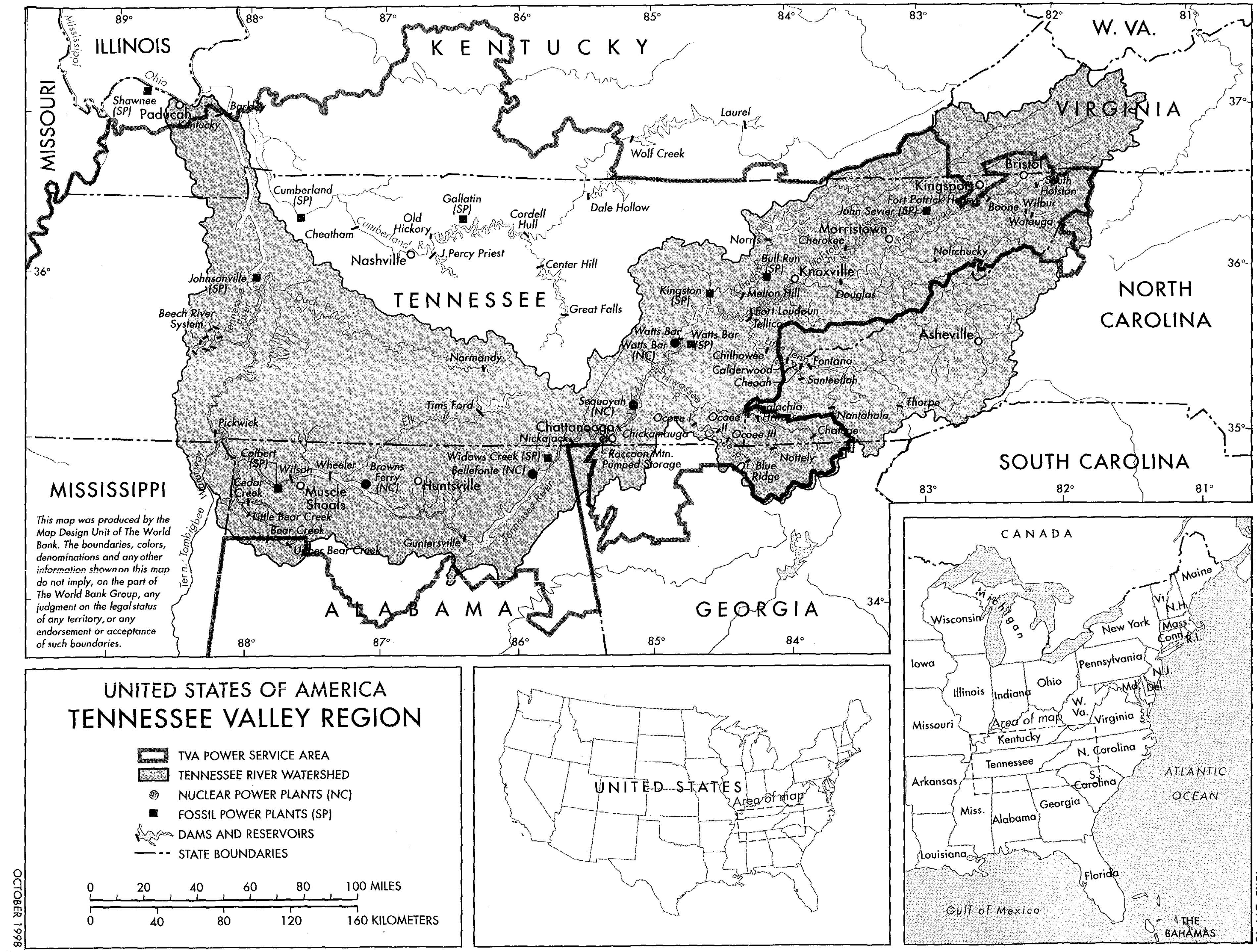
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