Water Resources Outlook

March 2011

Outlook for the U.S. Army Corps of Engineers Hydropower Program

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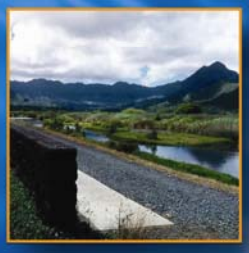

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Water Resources Outlook

Water is an essential resource in the U.S. economy. It plays a crucial role in supporting many economic activities and ensuring the quality of human life and the health of ecological systems. Despite this, the value of water may not be widely appreciated because only some water resources and water uses are easily visible or noticed while others are not.

Among the Institute for Water Resources (IWR) Future Directions program activities are the identification of emerging water challenges and opportunities and the tactical engagement of U.S. Army Corps of Engineers (USACE) senior leaders on these issues. Such critical thinking is an essential prerequisite to strategy development and planning.

IWR has developed this series of Water Resources Outlook papers, commissioned utilizing outside experts, to identify emerging issues and implications for the Nation. These issues and implications will be presented in the form of "provocation sessions" with external and internal subject matter experts and stakeholders and will inform the USACE strategic planning process.

Outlook for the U.S. Army Corps of Engineers Hydropower Program

This Outlook Paper examines the state of federal hydropower in the U.S. in the context of contemporary requirements for multi-use operations and other water users. The Corps of Engineers hydropower business is at a critical crossroads, where current decisions will determine its ability to contribute to renewable energy solutions in the 21st century. It is now facing unique challenges and opportunities. While the Corps is the largest owner/operator of hydropower in the U.S., it is highly constrained by the authorities given to it by Congress, by multiple, competing demands for water within river basins, and by the financial and regulatory environment within which it must operate. New ways of doing business will be needed if the Corps is to realize the new opportunities available to it today. If the Corps and other hydropower stakeholders can come together in pursuit of current opportunities, then hydropower has a bright future as part of renewable energy portfolios across the U.S. in the next century. The path forward depends in large part on whether new ways can be found to make hydropower compatible with the environment and competitive with other energy sources.

OUTLOOK FOR THE U.S. ARMY CORPS OF ENGINEERS HYDROPOWER PROGRAM

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DISCLAIMER

Views, opinions and/or findings contained in this report are those of the author and should not be construed as an official Department of the Army position, policy or decision unless so designated by other official documentation.

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Executive Summary

This Outlook Paper examines the state of federal hydropower in the U.S. in the context of contemporary requirements for multi-use operations and other water users. The Corps of Engineers' hydropower business is at a critical crossroads, where current decisions will determine its ability to contribute to renewable energy solutions in the 21st century. It is now facing unique challenges and opportunities. While the Corps is the largest owner/operator of hydropower in the U.S., it is highly constrained by the authorities given to it by Congress, by multiple, competing demands for water within river basins, and by the financial and regulatory environment within which it must operate. New ways of doing business will be needed if the Corps is to realize the new opportunities available to it today.

The hydropower industry in the U.S. is approximately a fifty-fifty mixture of federal and non-federal ownership (Section 1). Federal hydropower consists of projects built and operated by three agencies: the U.S. Corps of Engineers (Corps), the Department of Interior's Bureau of Reclamation (Reclamation), and the Tennessee Valley Authority (TVA). Power from federal hydropower projects is sold and distributed by Power Marketing Administrations (PMAs) that are part of the U.S. Department of Energy. Non-federal hydropower is regulated by the Federal Energy Regulatory Commission (FERC) under authority defined in the Federal Power Act. Ownership of non-federal projects is very diverse, ranging from large public utilities (e.g., Pacific Gas and Electric Co. or the New York Power Authority) to small rural electric cooperatives and independent power producers.

The Corps' Hydropower Program is one part of a broader water resources management mission that the Corps carries out. The Corps' water resources responsibilities include: coastal protection, disaster preparedness and response, environmental protection and restoration, flood protection, water supply, maintenance of navigable waters, recreational opportunities, and regulatory oversight. This very broad mission is generally pursued through the concept of Integrated Water Resources Management (IWRM).

The median age of all Corps projects is currently 47 years, and 90 percent of Corps projects are 34 years old or older. At these ages, it is reasonable to expect that failure rates of hydropower equipment will begin to increase, with associated decreases in performance. Generation trends and data on unit availability and forced outages confirm this expected trend. At some point in the life cycle of all mechanical equipment, replacement is inevitable, but within the fiscal constraints of the Corps, budgets for equipment replacement are very low. Dam removal is one alternative to replacement. This option continues to be pushed in the lower Snake River where it is seen as a solution to salmon restoration.

As described in Section 2, the challenges facing Corps Hydropower include:

- Aging infrastructure issues with growing investment needs;
- Pressures to reallocate reservoir storage to non-power uses;

- The need to restore aquatic ecosystems affected by Corps dams (environmental flows, water quality, endangered species management, etc.);
- An uncertain hydrologic future related to climate variability and change;
- Limited flexibility to react to opportunities for new development due to lack of Congressional authorities and/or appropriations; and
- Lack of access to revenue provided from its own power generation – while hydropower values are going up, funding returned to Corps projects via Congressional appropriations is either stagnant or declining.

Despite these challenges, there are important new opportunities for hydropower. These include:

- New recognition of the value of hydropower as a preferred source of renewable energy;
- A strong customer base that is showing increasing willingness to pay for modernization actions at Corps dams;
- Need for energy storage and flexible generation to provide ancillary benefits to the power grid of the future; and
- Availability of new technologies that improve environmental and energy performance, opening the door to new energy development.

Alternative futures for the Corps Hydropower Program (Section 3) can be summarized in three general strategies or paths forward: 1) maintain the status quo, 2) pursue privatization of federal hydropower assets, or 3) work aggressively to modernize the federal hydropower assets for which the Corps is responsible. The Status Quo path would continue the current trajectory of the Hydropower Program, with minimal changes in any aspect. Most importantly, Congressional budgets would most likely be flat or declining. New legislation authorizing direct funding through PMAs would not occur, but limited agreements for direct funding from federal power customers would provide some of the additional funding needed for O&M and equipment replacements.

The Privatization path would focus on finding non-federal sources of funding and, where possible, transferring hydropower assets from the federal to the private sector. This strategy is worth discussing here because it is often suggested as the solution to shortfalls of public funding. Asset transfers and other aspects of this path are problematic for many reasons. This path would likely involve some very contentious legislative and policy changes needed for implementation, putting the existing relations with preferred customers of federal power at risk.

The Modernization path may also require significant changes in authorities, financing, and management, but it has the best chance of long-term success. The Corps has already embarked on some of this, but much more is possible. Under the expanded Modernization path envisioned here, the Corps would participate in new interagency activities to unite the hydropower industry, deploy and test advanced technology, and develop policies to revitalize hydropower. Specific targets of opportunity for Modernization are the development of new tools to assess and manage both federal and non-federal hydropower assets; establishment of

standard practices to make hydropower operations more efficient, transparent, and cost-effective; and creation of new methods to certify environmentally sustainable hydropower.

The Status Quo path to the future is not sustainable, primarily because of the lack of funding sources which would be sufficient to keep up with the growing replacement needs for the Corps hydropower infrastructure. If no explicit decisions are made to pursue either Privatization or Modernization, it will in effect be a decision to maintain the status quo. Federal budgets will continue to decline, and no new authorities for direct customer funding will be established. If that happens, the current patterns of deteriorating performance are likely to continue. Federal hydropower will become even more of a low-priority byproduct of federal IWRM, rather than the highly valued renewable that it should be and was when the projects were originally constructed.

The Privatization path has many serious problems inherent to it, which make it impractical and unrealistic given the complexity of the Corps' multiple-use responsibilities. New legislation would be needed to deauthorize hydropower operations at many projects. Long-term federal power contracts would have to be phased out over time, and the loss of relatively cheap hydropower to preference customers is likely to be strongly opposed politically.

The best path forward for Corps Hydropower is a very active and aggressive Modernization process. However, this cannot be implemented unilaterally by the federal agency. Key elements of this path include finding new funding sources and getting new legislation passed for direct funding from customers through the PMAs. A strong and diverse political constituency for the changes needed to fully implement Modernization will be required to achieve success on this path. There are common interests that can be used to support the diverse constituency needed: for example, if advanced technologies with new environmental benefits are deployed in Modernization, then environmental NGOs may contribute new support. The new Hydropower MOU also offers hope that DOE can step in to play a constructive role in building this new path forward, especially if federal water projects can be reoperated to support new renewable, non-hydro energy sources. The Modernization path offers substantially more benefits than the others, but it will require new partnerships and a long-term commitment to change.

If the Corps and other hydropower stakeholders can come together in pursuit of current opportunities, then hydropower has a bright future as part of renewable energy portfolios across the U.S. in the next century. The path forward depends in large part on whether new ways can be found to make hydropower compatible with the environment and competitive with other energy sources. In a recent summary of the water conflicts in Georgia, Alabama, and Florida, Judge Paul Magnuson said, "The problems faced in the [Alabama-Coosa-Tallapoosa**]** basin will continue to be repeated throughout this country, as the population grows and more undeveloped land is developed. Only by cooperating, planning, and conserving can we avoid the situations that gave rise to this litigation." This is a serious warning that should not be ignored. The brightest future for Corps hydropower lies in stronger partnerships on funding solutions and in operational improvements, including the application of advanced technologies that offer improved energy and environmental performance.

Section 1: INTRODUCTION

1.1 Purpose and Scope

This Outlook Paper examines the state of the U.S. Army Corps of Engineers' federal hydropower program, in the context of contemporary requirements for multi-use operations and other water users. Changing conditions (including new policies for renewable energy, continuing growth in competing demands on water resources, and climate variability and change) pose serious challenges and opportunities for the federal hydropower industry, now and in the future. In response, federal hydropower managers should rethink their position within the energy sector of our country. This paper attempts to lay out available options and suggest possible ways that federal hydropower can maintain and grow its important contributions to the U.S. economy.

1.2 Background on Hydropower in the United States

The hydropower industry in the U.S. is a complex mixture of federal and non-federal ownership. To understand the role of federal hydropower as a national asset, it is necessary to first look at the total hydropower industry.

1.2.1 The national hydropower portfolio

Hydropower is the foundation of renewable energy in the U.S., a fact that is especially important now as national energy policies are shifting toward cleaner energy production. Hydropower provides substantial energy and non-energy benefits that affect all fifty states either directly or indirectly through the transmission grid. In 2007, the hydro industry (federal and non-federal) generated 248 billion kilowatts-hours (kWh) of electricity and accounted for 71 percent of total renewable generation (Gruenspecht, 2008). The non-hydropower renewables are a growing source of electricity, but as of 2007, the total generation from hydropower was still more than three times the total from all other types of non-hydro renewable energy combined (Figure 1-1).

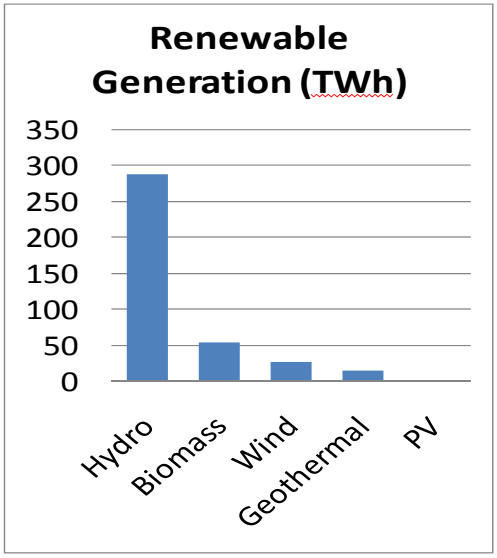

Figure 1-1 - Generation of electricity from renewable energy sources in the U.S. in 2007 (source: EIA, 2009)

In total, there are more than 93 GW of hydropower projects operating in the U.S. today, including conventional and pumped storage hydropower (PSH). Of this installed capacity, 77.4 GW is conventional hydropower, which is split approximately evenly between federal and non-federal projects (Table 1-1). Conventional hydropower refers to traditional project

Table 1-1. Numbers and sizes of existing federal and non-federal hydropower projects in the U.S. Non-federal projects are those subject to regulation by the Federal Energy Regulatory Commission (FERC).

	Number of Projects	***Number of Units***	***Total Capacity (GW)***	***Average Project Size (MW)***	***Average Units per Project***	***Average Unit Size (MW)***
Corps of Engineers	75	353	20.5	276	5	58
Bureau of Reclamation	58	194	14.8	255	3	76
Tennessee Valley Authority	30 113		5.5	183	4	49
Total Federal	***163***	***660***	***40.8***	***250***	***4***	***62***
FERC Licenses *	1012	-	53.5	53	-	-
FERC Exemptions	595	-	0.8	1.4	-	-
Total Non-federal *	***1607***		***54.3***	***34***		

* Includes approximately 18 GW of pumped storage projects.

designs that utilize a combination of hydrostatic head and flow through turbines to generate electricity. This is distinguished from the newer, hydrokinetic turbines that utilize only the kinetic energy in water velocity and not head (see Section 2.4.3). There are significantly more non-federal projects than federal projects, but federal projects tend to be larger in size on average. Some of the smaller, lower-impact, non-federal projects are exempt from FERC licensing, but are still subject to mandatory conditioning from state and federal resource agencies.

Federal hydropower consists of projects built and operated by one of three agencies: the U.S. Army Corps of Engineers (USACE or Corps), the Department of Interior's Bureau of Reclamation (Reclamation), and the Tennessee Valley Authority (TVA) (Figure 1-2). The Corps has the most projects, followed by Reclamation and then the TVA. The Corps currently operates 75 power plants with a total rated capacity of 20.5 GW. In addition to those federally owned power plants, there are another 90 non-federal power plants located at Corps dams that have an additional 2.3 GW of capacity (USACE, 2009).

Non-federal hydropower is regulated by the Federal Energy Regulatory Commission (FERC) under authority defined in the Federal Power Act. Ownership of non-federal projects is very diverse, ranging from large, public utilities (e.g., Pacific Gas and Electric Co. or the New York Power Authority) to small, rural electric cooperatives and independent power producers. FERC regulates non-federal hydropower development through a well-developed process of licensing.

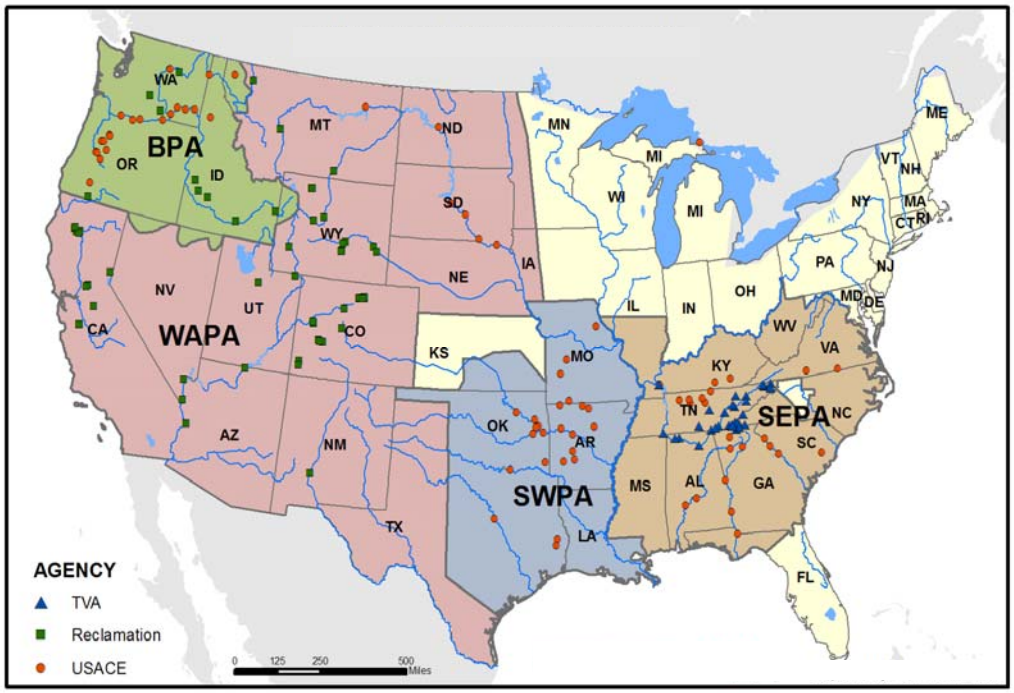

Figure 1-1 - Location of federal hydropower projects and Power Marketing regions in the U.S. (source: Oak Ridge National Laboratory WaterPower GIS database, 2010).

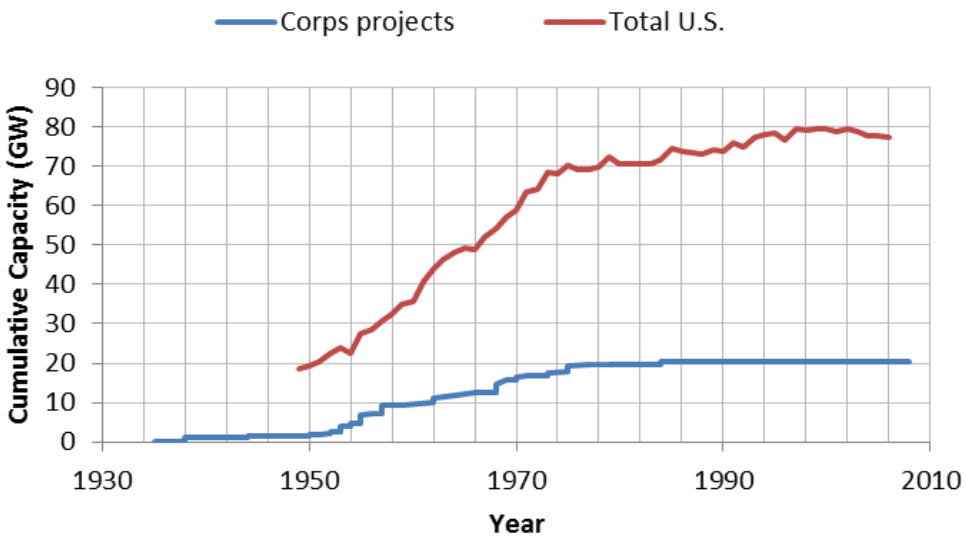

Figure 1-2 - Hydropower development over time in the U.S.

The first hydropower projects in the U.S. were built by non-federal entities in the late 1800s near irrigation districts in the West and small industrial mills in the East. The most active period of development was between 1950 and 1975 (Figure 1-3). The oldest Corps project is Bonneville Dam on the lower Columbia River, which came on line in 1938. The most recent Corps project to come on line was the RD Willis project in Texas in 1989. While federal dam construction essentially stopped in the 1980s, non-federal development continued between 1975 and 2000, but at a slower rate. Total installed capacity of conventional hydropower peaked between 1997 and 2002 at about 79 GW (EIA, 2007). It has been decreasing since 2002, due largely to dam removal initiatives across the nation. However, this trend may begin reversing as new incentives for renewable energy come into play (see Section 2.3).

1.2.2 Hydropower within the Corps of Engineers

The Corps' Hydropower Program is just one part of a broader water resources management mission that the Corps carries out. That broader mission is generally pursued through the concept of Integrated Water Resources Management (IWRM). The Global Water Partnership (GWP) has issued the following definition of Integrated Water Resources Management:

> *"IWRM is a process that promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."*

The Corps is the largest owner/operator of hydroelectric power plants in the United States and one of the largest in the world. The Corps' Hydropower Program plays a vital role in the stability of the nation's overall electric system far beyond the 3 percent of the nation's electric capacity which it provides. Average annual energy from Corps projects is about 68 billion kWh, and gross annual revenue returned to the U.S. Treasury from power sales from these projects is estimated at $3-4 billion per year. Development, operation, and maintenance of hydropower within the Corps is carried out in the context of a complex management framework that involves competing intra-agency mission activities, interactions with the federal Power Marketing Administrations (PMAs) and their customers, and regulatory constraints from outside the Corps. The Corps' competing mission activities affect funding availability and the priority with which hydropower needs are met.

Hydropower is part of the Water Resources component of the Corps of Engineers' Civil Works mission that provides comprehensive engineering, management, and technical support to the nation in times of peace and war. The Corps' multi-purpose authorities allow hydroelectric power as an additional benefit from their projects built for other purposes, but hydropower is not the primary or sole purpose of any Corps projects. The responsibilities of the Corps in water resources are quite broad; in addition to hydropower, they include:

- Coastal protection
- Disaster preparedness and response
- Environmental protection and restoration
- Flood protection

Table 1-2 - Distribution of Corps of Engineers' hydropower projects among the Power Marketing areas of the U.S.

Region	*Number of Projects **	*Total Capacity (GW)*	*Average annual generation (TWh)*
Bonneville Power Administration	21	12.6	50.1
Southeastern Power Administration	22	3.5	6.0
Southwestern Power Administration	24	2.2	5.6
Western Area Power Administration	7	2.0	6.3

** One Corps project, St. Mary's Falls, is not associated with any PMA, therefore it is not counted in this table.*

- Water supply
- Maintenance of navigable waters
- Recreational opportunities
- Regulatory oversight

Although the Corps owns and operates all of its hydropower projects, electricity produced at their projects is sold and distributed by the PMAs, which are part of the U.S. Department of Energy (DOE) (Lane, 2007) (Figure 1-2). PMAs market power from federal water projects at the lowest possible rates to consumers consistent with sound business principles, so as to encourage the most widespread use of federal assets. There are four PMAs: Bonneville Power Administration (BPA), Southeastern Power Administration (SEPA), Southwestern Power Administration (SWPA), and the Western Area Power Administration (WAPA). Each of the four power marketing administrations is a distinct and self-contained entity within the DOE, much like a wholly owned subsidiary of a corporation. The power marketing program within the DOE began in the early 1900s, when excess hydropower produced at federal water projects was sold to repay the government's investment in the projects.

Currently, the Bonneville Power Administration is the only PMA that has authority to directly finance the operation and maintenance costs at Corps projects. Efforts are underway to enable SEPA, SWPA, and WAPA to have a similar direct-financing arrangement for Corps hydropower facilities in those regions (see Section 2.5.1 below for more details).

The Corps' Hydropower Program implemented out of the regional divisions and district offices of the Civil Works organization (Figure 1-4). Oversight is provided through four levels of authority, with the Department of Defense's Assistant Secretary of the Army for Civil Works at the top (Figure 1-5).

Figure 1-4 - Map of the U.S. Army Corps of Engineers Division structure (source: USACE, 2008).

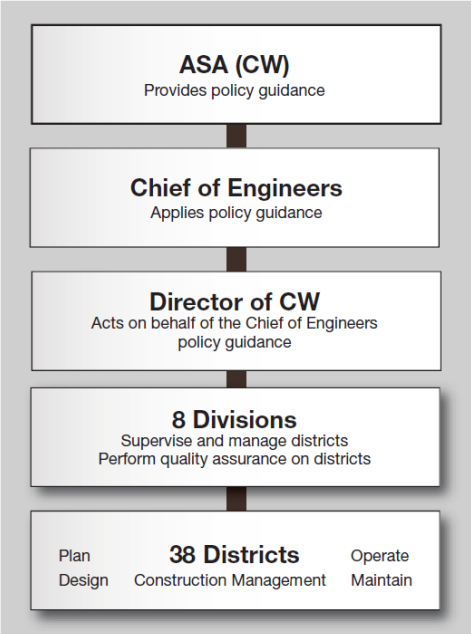

Figure 1-5 - Organizational structure of the Department of Army Civil Works Program (source: USACE, 2008).

The Corps has established topical networks of internal expertise called Communities of Practice (CoPs) that are comprised of staff who share common functional or business line interests (http://corpslakes.usace.army.mil/employees/strategicplan/cop.cfm). The CoPs serve as repositories of corporate knowledge and sources of information for solving current problems. The Hydropower CoP is active in holding periodic strategic planning meetings, including open forums at professional meetings such as the annual *HydroVision* conferences. The strongest center of expertise in hydropower for the Corps is at its Hydroelectric Design Center (HDC), located in the Portland District office in Portland, OR.

Section 2: CURRENT TRENDS AFFECTING HYDROPOWER

Many of the forces affecting hydropower in the U.S. are now in flux. For discussion purposes, these changes can be organized into five topics:

- Infrastructure condition and productivity
- Water resource availability and competing uses
- Evolving regulations and energy policies
- Emerging new technologies
- Patterns in federal funding

National energy policies are one of the most important current changes. For example, the Energy Independence and Security Act of 2007 (Pub. L. 110-140) contained numerous requirements and incentives for development of new types of renewable energy (Section 2.3). These new directions will have implications for the future mix of multiple water uses, including hydropower. All trends described affect the Corps' hydropower business directly or indirectly.

2.1 Infrastructure Condition and Productivity

Hydropower faces serious challenges with an aging infrastructure, and these are aggravated by the lack of funding for equipment replacement.

The U.S. has a serious problem with neglecting to upkeep the infrastructure that provides public services, including transportation, education, recreation, water, and sanitation. The American Society of Civil Engineers (ASCE) has been issuing periodic Report Cards on America's infrastructure to highlight the need to reinvest in critical public works, including dams and energy facilities (http://www.asce.org/reportcard/2009/grades.cfm). Their grade for dams and energy in 2009 were D and D+ respectively. Spending on dams and energy were $7.45B and $20.5B less than what ASCE deemed necessary. Hydropower is suffering from a similar underinvestment, and this underinvestment is starting to result in decreases in generation and other measures of productivity.

2.1.1 Generation patterns

The generation output from the nation's hydropower industry has very high year-to-year variability and a general downward trend (Figure 2-1). The range between the most recent minimum (217 TWh in 2001) and maximum (356 TWh in 1997) is 139 TWh, which is greater than the total output of all non-hydro renewable energy sources combined in 2007. This is a significant figure at a time when the nation is trying to encourage new renewable energy development. Conventional wisdom would say that this variability is simply a function of precipitation patterns that are not controllable. However, as discussed in the following sections

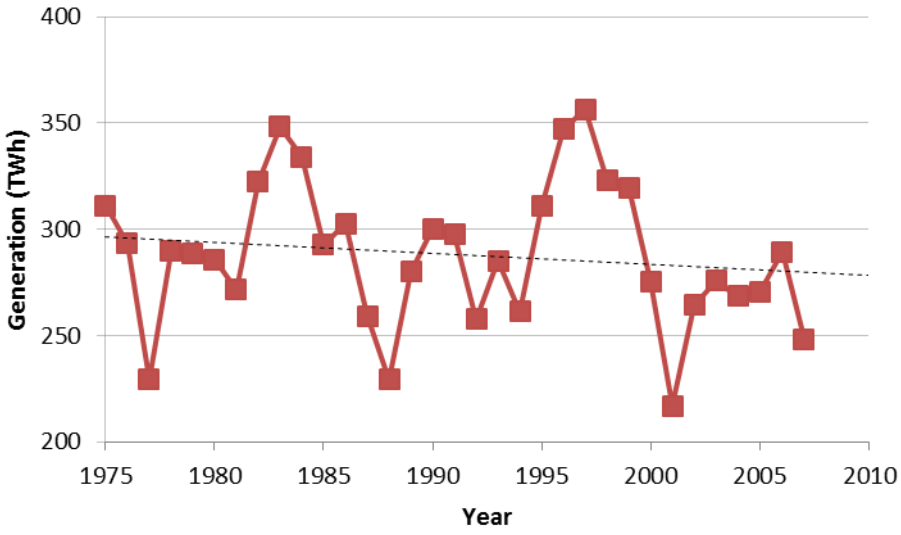

Figure 2-1 - Annual hydropower generation in the U.S. from all conventional hydropower projects through 2007 (source: EIA 2009 and data out of previous EIA reports).

of this report, there are other drivers for loss of production at hydropower projects, including environmental regulations, competition for water with nonpower uses, and climate change.

The average annual generation from all projects between 1975 and 2007 has been 288 TWh, with a coefficient of variation (CV) of 11.8 percent. Hydroelectric generation from Corps projects have been somewhat less variable compared to the whole industry, at least since 2000 (CV = 6.8 percent for Corps and 8.4 percent nationally for 2000-2008). Nevertheless, total generation from Corps hydropower projects has decreased over the last eight years, from 73.6 TWh in 2000 to 61.7 TWh in 2008 (source: unpublished Corps data).

2.1.2 Effects of aging infrastructure

The median age of all Corps projects is currently 47 years old, and 90 percent of Corps projects are 34 years old or older (unpublished data provided by the Corps' Hydropower Program). Given these numbers, it is not surprising that operation and maintenance issues are growing, and that equipment replacement and refurbishment are needed. Unit availability is falling in all divisions of the Corps (Figure 2-2 and GAO, 1996). An industry goal for unit availability is 95 percent or greater, a target which no division meets. It is especially notable that the Northwestern Division, where most of the Corps projects are located, has had the worst unit availability in the last two years, now below 85 percent. Total hours of forced outages across all Corps projects have been growing steadily since at least 1999 (Figure 2-3).

The situation in the Cumberland River System in Tennessee and Kentucky illustrates the challenges facing the Corps with respect to O&M. There are 28 generating units at nine Cumberland System power plants, managed out of the Nashville District office and Great Lakes

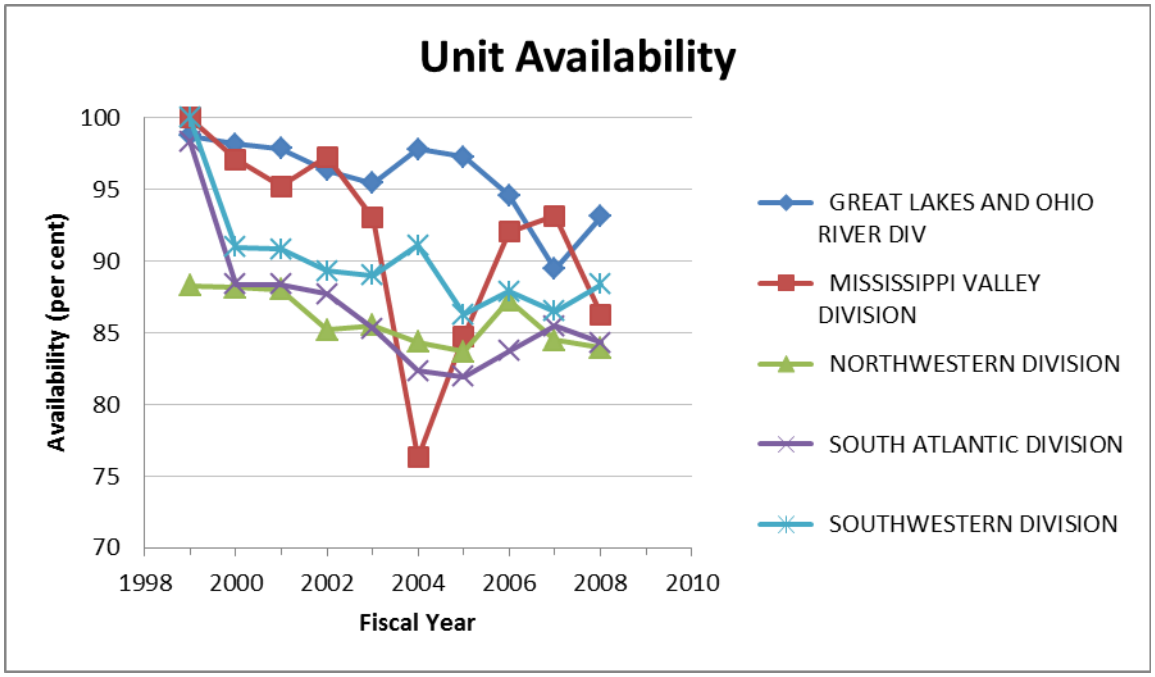

Figure 2-2 - Trends in unit availability by Corps divisions over the last decade (Source: unpublished Corps data).

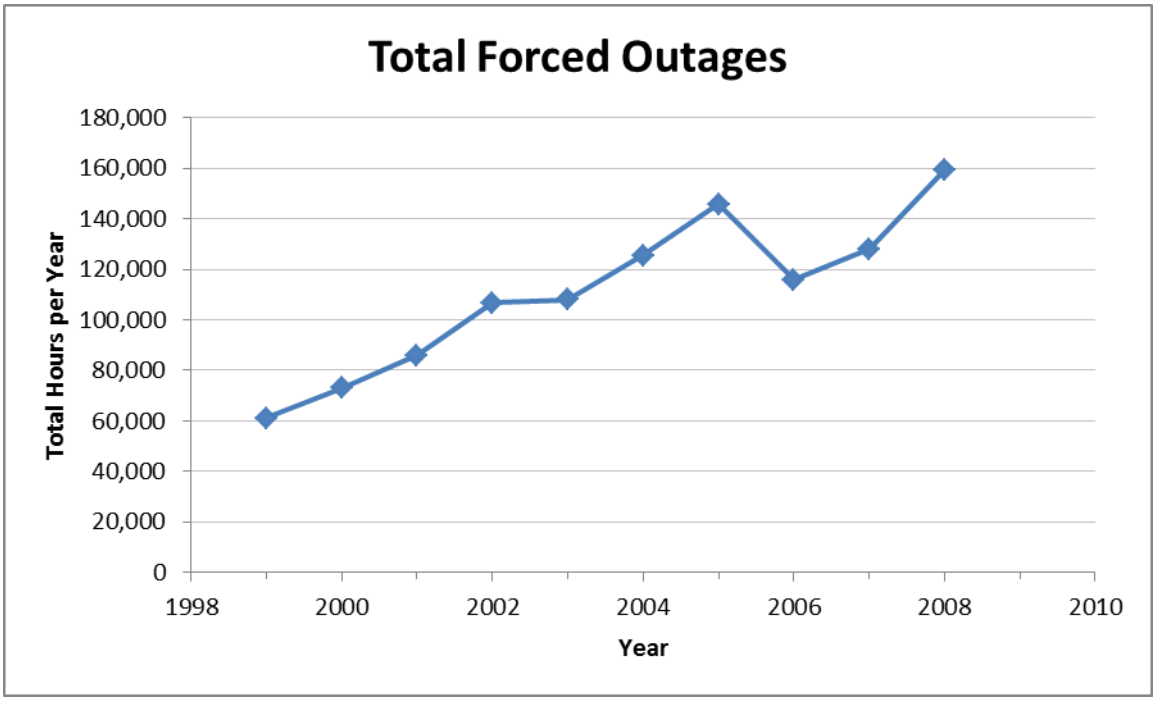

Figure 2-3 - Total hours of forced outages over all Corps projects for 1999 through 2008 (Source: unpublished Corps data).

Figure 2-4 - Examples of degradation of generator windings and blade damage representative at Corps projects.

and Ohio River Division. Almost none of the hydropower equipment there has been replaced since the plants were built 30 to 40 years ago (Sadler, 2007). These federal facilities have a capacity of more than 914 MW (4.5 percent of the Corps' total) and produce about $44 million per year in revenue for the U.S. Treasury in power sales through the SEPA. A recent reconnaissance assessment of plant life extensions and upgrades was completed on the system (MWH, 2008). It considered 342 individual work items for equipment replacement, repair, and upgrades, and identified $345 million of work needed over a 10-year period just for so-called "needs work orders" that are associated with actions to mitigate the risk of equipment failure and minimize revenue loss due to unscheduled outages. If all economically viable opportunities were pursued, the cost grows to $472 million. A team of the Corps, SEPA, TVA, and their power customers has been formed to further refine and prioritize these O&M needs. However, because of limited budgets and competition from other high-need government projects (Katrina recovery, dam safety issues in the Cumberland, etc.), available federal funding is very limited. New mechanisms for non-federal funding will be required if the backlog of hydropower needs are to be addressed.

It is normal for the frequency of O&M issues to increase as any type of product ages, including hydropower generating equipment. The life cycle of power plants will likely follow the theoretical "bathtub curve" of high, then low, then progressively higher failure rates and maintenance costs over time (Figure 2-5). As the age of the Corps' hydropower assets increases toward what might be a nominal 50-year maximum life expectancy, reliability will decrease and outages will increase.

One of the Corps' responses at the national level to the problem of aging infrastructure has been the establishment of the Hydropower Asset Management Partnership (hydroAMP), a joint venture of the Corps and Reclamation, plus HydroQuebec and BPA. The hydroAMP analytical framework supports risk-based decision-making in hydropower asset management, development of long-term investment strategies, coordination of O&M budgeting, and identification and tracking of organizational performance goals. Data comes from two sources:

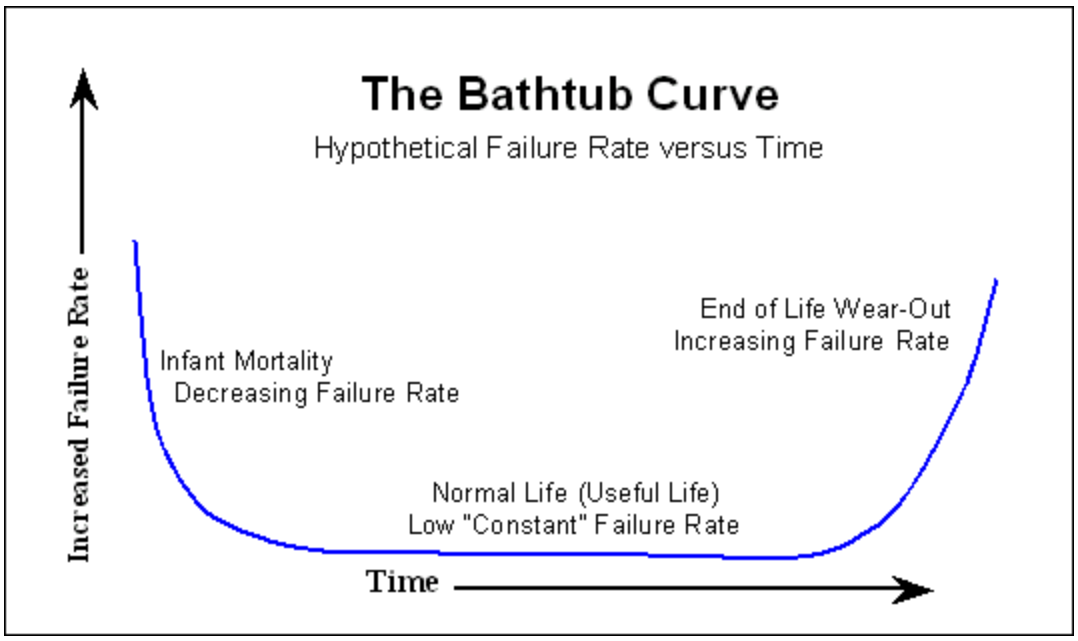

Figure 2-5 - Theoretical life cycle of failure rates over time. (Source: http://www.weibull.com/hotwire/issue21/hottopics21.htm)

1) routine test and inspection results obtained during routine O&M (Tier 1), and 2) non-routine tests/inspections as determined by condition indices or data quality indicators from the Tier 1 data. Data are maintained in a real-time, web-accessible format by the Corps' HDC.

In fiscal year 2009, the Corps also initiated a Hydropower Modernization Initiative (HMI) (MWH 2009), which will use risk assessment and net present benefit methods to identify the most pressing investment needs for hydropower rehabilitation efforts. Six projects that were studied in Phase I of the HMI are: Allatoona, Barkley, Center Hill, Ft. Randall, Old Hickory, and Wolf Creek. Initial results showed that 4,355 GWh of new energy could be generated through power plant rehabilitation, at a total cost of $599.2 million. Average energy increase across these six projects would be 8 percent per plant, ranging from a high of 12 percent at Center Hill to a low of 4 percent at Allatoona. This would be very cost effective energy development (2-3 cents/kWh), but funding will still be difficult to find even for these most competitive projects (Section 2.5).

2.1.3 Dam removal pressures

Initiatives to remove unneeded or environmentally damaging dams have been growing over the past two decades (ASCE, 1997; Graf, 2003). While many of these activities are focused on smaller, non-power dams, the general trend is also affecting federal and non-federal hydropower projects. American Rivers, one of the leading environmental non-governmental organizations advocating for dam removal, claims to have contributed to the removal of more than 150 dams across the country, most of them since 1999 when the first case of removal of a hydroelectric project occurred at Edwards Dam on the Penobscot River in Maine. Dam removal is rarely going to be a solution for the operational challenges of large, Corps hydropower projects, but it is being requested more frequently as an alternative to be considered in many environmental impact statements.

The Klamath River basin in southwestern Oregon and northern California promises to be the site of the largest set of hydropower dam removals in the nation to date. As with many other dam removal controversies, the one in the Klamath basin has revolved around salmon migration runs that have been in serious decline for many years. There are two major water resource development projects in the Klamath River: 1) Reclamation's Klamath Irrigation Project, and 2) PacifiCorps' Klamath Hydroelectric Project. In the upper basin, Reclamation facilities divert water out of the natural drainage, store it in reservoirs, and redistribute it through a complex network of irrigation systems that eventually discharge back into the main stem of the Klamath. The Klamath Hydroelectric Project consists of six powerhouses, dams, and diversions, plus one non-power reregulation dam, with a total capacity of 151 MW.

In September 2009, Secretary of the Interior Ken Salazar announced a comprehensive settlement plan with two parts: an agreement pertaining to removing hydroelectric projects with PacifiCorps and FERC, and a second but equally important agreement on basin restoration. The Klamath Hydroelectric Settlement Agreement with PacifiCorps will provide for the eventual removal of the lower four hydropower dams that have blocked salmon's migration runs. Removal and restoration activities would occur though 2020, if a first step determining removal feasibility is successful. Cost estimates range from a low of $100 million to an upper limit of $450 million, and no more than $200 million may come from PacifiCorps rate payers. The states of Oregon and California will also be providing substantial funding (California delivered their share, $250 million, in a state water bill passed in early Novermber 2009).

Dam removal alone will not be sufficient to restore the Klamath, because landuse impacts are a continuing stress to the river ecosystem. The second part of the comprehensive plan, the Klamath Basin Restoration Agreement (KBRA), will be the basis for increasing water flows for fish, improving the reliability of irrigation water delivery, conducting basin-scale habitat restoration, and making critical economic investments to ensure the economic viability of basin fishing and farming communities in the future. This critical second agreement is a good example of how factors beyond dam removal are required in ecosystem restoration.

The largest, most persistent and controversial dam removal case involving Corps hydropower projects is on the Snake River in Washington State. Four Corps locks and dams on the lower Snake River are at issue: Ice Harbor, Little Goose, Lower Granite, and Lower Monumental. These constitute a total rated capacity of more than 3 GW and an average annual generation of more than 7.8 TWh. These projects came into service between 1962 and 1975. The environmental driver for this controversy is primarily fish passage for migratory salmon, particularly species that have been listed as threatened or endangered under the Endangered Species Act (ESA). In addition to significant hydropower benefits, the four Lower Snake dams also provide important navigation benefits, providing transportation of agricultural commodities from the central regions of Washington, Oregon, and Idaho to coastal ports.

Another interesting case of dam removal is in the Penobscot River in Maine, associated with relicensing of non-federal dams owned by PPL Corporation. The Penobscot River Restoration

Project (see: http://www.penobscotriver.org/), which has been playing out since 2004, has produced a multi-party settlement agreement that will:

- provide for restoration of migratory fish to 500 miles of river,
- permit the sale of three dams, two of which will be removed, from PPL to a public trust,
- fund new monitoring to improve fish passage science, and
- enable a net increase in hydropower in the basin.

When fully implemented, the agreement will improve access to nearly 1,000 miles of historic habitat to enable the restoration of Atlantic salmon, river herring, and several other native sea-run fish. Energy increases will be achieved by repowering one dam and implementing operational improvements at others. Funding will come from a combination of private donations and state-federal grants, including $6.1 million recently awarded by the National Oceanographic and Atmospheric Administration (NOAA) out of the American Recovery and Reinvestment Act of 2009 (ARRA or Recovery Act). The Penobscot River case is a hopeful sign, showing how future river basin management can be achieved in a way where selective dam removal, environmental restoration, and new energy development can coexist.

2.2 Water Resource Availability

Water available for hydropower is decreasing as other competing uses have gained higher priority.

The water that flows through the nation's rivers is the fuel that drives hydropower, but there are growing demands for surface water resources. At the same time, climate variability and change are affecting the amount and timing of river flows. The combined effect of competing uses and climate change threatens to make less water available for hydropower generation, at least in some key parts of the country.

Hydropower is generally considered a non-consumptive water use, because water is released downstream where it remains available for other uses. The exception to this is that water stored in reservoirs may be subject to more evaporation than would otherwise occur. USGS estimated that the average daily use of water for hydropower in 1995 was 3,160,000 million gallons per day (mgd), or 2.6 times the average annual runoff in the lower 48 states (Solley et al.,1998). Water usage for hydropower can exceed runoff because it may pass through multiple power plants before it reaches the ocean. In comparison to hydropower, 1995 water use for irrigation, thermoelectric cooling, and public water supply were 134,000 mgd, 190,000 mgd, and 40,200 mgd, respectively. Although water use by hydropower is mostly non-consumptive, it is still by far the largest water user in the energy sector (DOE, 2006). Unfortunately, USGS has stopped reporting water usage for hydropower due to federal budget limitations and the difficulty of collecting accurate data.

In August 2004, federal agencies were directed to develop a coordinated, multi-year plan to improve research to understand the processes that control water availability and quality, and to

ensure an adequate water supply for the nation's future. The responsibility to develop this plan resides with the National Council for Science and Technology's Subcommittee on Water Availability and Quality (SWAQ), which has produced two key reports on the topic. The second SWAQ report identifies the challenges facing water resources in the U.S. and lays out a federal science strategy for meeting those challenges (NCST, 2007). One of the energy-related recommendations is to develop technologies for more efficient use of water in energy production, including hydropower, so that existing supplies can serve as many uses as possible.

2.2.1 Competition from other water uses

A previous Water Resources Outlook paper reviewed the trends and uncertainties affecting water resources and water supplies in the U.S. (Dziegielewski and Kiefer, 2007). It identified five important issues driving the need to develop new water supplies:

- population growth and geographical redistribution and associated economic growth,
- increasing demand for ecosystem services,
- global warming and climate change,
- water for energy production, and
- aging water supply infrastructure.

Of these five issues, Dziegielewski and Kiefer concluded that climate change and the need to provide more water for ecosystem restoration are the most likely to affect future water availability for other uses, such as hydropower. Although they generally dismissed pressures from population growth and economic development as less likely to be issues in the future, reallocation of water storage in Corps reservoirs is a rapidly growing trend. The Corps has discretionary authority to reallocate existing storage space from their conservation pools to new municipal and industrial (M&I) uses, derived from the Water Supply Act of 1958 (P.L. 85-500) and its amendments. However, exercising this authority is becoming an increasingly difficult process because of the complexity of competing use.

Water Storage Reallocation. The Lake Texoma Storage Reallocation Study is a good example of the stresses between hydropower and other water uses at Corps projects (USACE, 2006). Population growth and increasing demands for water in the Dallas-Fort Worth metropolitan area led to Congressional action in 1986 that authorized a reallocation of 300,000 acre-feet of reservoir storage from hydropower to water supply uses. Denison Dam, which forms Lake Texoma, is on the Red River, between Texas and Oklahoma. It creates a 2.5 million acre-foot storage reservoir, 1.5 million acre-feet of which were previously designated for hydropower use. There are two 35-MW generating units at the dam, producing an annual average of 235 GWh of electricity per year. The proposed reallocation would reduce reservoir storage available for hydropower by 23 percent, reduce downstream discharges, and reduce hydropower generation substantially, especially in dry years. The estimated value of foregone energy and capacity from the full reallocation was $1.6 million per year. Compared to those hydropower benefits, the estimated value of water supply uses of the 300,000 acre-ft was much higher: between $3 million and $6.5 million per year, depending on the evaluation methods used and who is doing the analysis (PMAs tend to value hydropower relatively higher than Corps analysts). Such shifts in water use are becoming common across the U.S.

When reservoir storage is reallocated to non-hydropower uses at a project, there are consequences to consumers of electricity, whether they pay for replacement power directly or indirectly. For example, SWPA has power sales contracts for Denison Dam's 70 MW capacity through 2018 with two rural cooperatives, Rayburn County Electric Cooperative and Tex-La Electric Cooperative of Texas. These small utilities depend on Denison Dam's output for 7 to 9 percent of their total capacity requirements. Some interpretations of existing power contracts argue that SWPA should be obligated to replace capacity and generation lost in the reallocation, but this seems to be an unresolved legal issue. Nevertheless, federal preference customers are likely to pay directly or indirectly, as PMAs can pass costs for replacement power back to those customers in their rates as an operating expense. Hydropower projects in this region are operated mainly to provide peaking power, making the electricity generated much more valuable, and the replacement costs higher. SWPA, their customers, and the Corps' Hydropower Analysis Center (HAC) continue to disagree on the appropriate methods to use in calculating replacement costs (SWPA, 2008). Regardless of the outcome, lost emission-free hydropower will most likely be replaced with natural gas generation, for a net increase in GHG emissions. So far, there is no mechanism to account for net carbon emissions in the economic development or environmental accounting in Corps planning processes.

The most important current example of water storage reallocation to M&I uses is in the Georgia-Alabama-Florida region, where the Atlanta metropolitan area continues to expand and demand more water. Two river systems are involved: the Alabama-Coosa-Tallapoosa (ACT) river basin, which drains southwesterly from Atlanta through Georgia and Alabama; and the Apalachicola-Chattahoochee-Flint (ACF) river basin, which drains to the south from Atlanta through Georgia, Alabama, and Florida (Figure 2-6). Intense and protracted negotiations have been going on in this region for more than 20 years in an attempt to find acceptable ways to reallocate available water resources among multiple uses, including cities, industry, agriculture, transportation, hydropower, recreation, and the environment. Twelve federal agencies, three state governments, and numerous non-governmental interest groups have been involved in these negotiations. In 1997, two River Basin Compacts were established to find water allocation formulas, but these compacts fell apart in 2003 due to failure to find an acceptable formula. This failure represented a significant lost opportunity to avoid future controversy.

The heart of the ACT-ACF water controversy is the use of water stored in two Corps multipurpose reservoirs: Lake Lanier, above Buford Dam in the upper part of the ACF basin, and Lake Allatoona in the ACT basin. These projects were originally authorized in the 1950s for flood control, hydropower, and navigation, but not water supply (Magnuson, 2009). Hydropower revenues paid for the majority of project costs (88 percent in the case of Buford Dam). Both river basins are potential sources of new M&I water supplies for the Atlanta area. Over the last 60 years, water supply uses of these water systems have been allowed to gradually increase under short-term "interim" water contracts between the Corps and local municipalities and water utilities. For example, in the cases of Lake Lanier and the Chattahoochee River at Atlanta, water

Figure 2-6 - Map of the Alabama-Coosa-Tallapoosa (ACT) and the Apalachicola-Chattahoochee-Flint (ACF) river basins in Georgia, Alabama, and Florida.

supply withdrawals have grown, respectively, from 10 and 230 mgd in the mid-1970s to 141 and 377 mgd now. These increases in water supply withdrawals have been supported by a gradual, "de facto" reallocation of storage in the conservation pool of Lake Lanier from hydropower uses to water supply. The Corps cooperated in meeting local economic development needs by permitting these new uses, but they never requested authorization from Congress as is required under the Water Supply Act.

In the most recent ruling on the ACF side of this controversy, the U.S. District Court in Jacksonville ruled that water supply was not an authorized use of Lake Lanier, that new water supply uses did seriously affect hydropower which was one of the authorized uses, and that reallocation could not occur unless Congress authorized it (Magnuson, 2009). The judge in the case, Paul A. Magnuson, gave the Corps and water users in the region three years to obtain new Congressional authorization. If it is not obtained, water management is to revert to the withdrawal levels that were occurring in the mid-1970s. Even Judge Magnuson admitted that such a loss in water supply for this region would have "draconian results." But he also firmly stated that the "Corps's failure to seek Congressional authorization for the changes it has

wrought in the operation of Buford Dam and Lake Lanier is an abuse of discretion and contrary to the clear intent of the Water Supply Act." The Congressional Research Service recently warned that the Corps may have exceeded its authorization for discretionary reallocations of water storage to new M&I uses in at least two other locations, Cowanesque Lake in Pennsylvania and Lake Texoma on the Texas-Oklahoma border (Carter, 2010). Resolution of the ACT-ACF water disputes will continue to be the most complex and hardest to solve situation, because of the number and diversity of interests involved. One of the major unresolved issues is how to evaluate the tradeoffs between lost hydropower generation and water supply benefits and to equitably compensate hydropower customers for the services that they will no longer have. Another unresolved issue is how to protect downstream aquatic ecosystems that are adversely affected by consumptive water withdrawals upstream.

Tradeoffs between water used for hydropower generation and water used for M&I applications are not simple one-to-one relations. The balance of the tradeoff depends in part on the spatial relation between hydropower plants and withdrawal points. Nevertheless, generation tends to be valued lower, all regulatory processes and project authorizations aside. Willingness to pay for M&I water is relatively higher, because available water is scarce and there are relatively cheap, for now, alternatives for replacing lost hydropower generation (e.g., natural-gas-fired power plants). At some time in the future, if national policies for managing green-house gas emissions are established, the value of hydropower may increase, but that time has not come yet.

Ecosystem Restoration. Ecosystem restoration is another important and growing use of water that is driving reallocation studies and affecting hydropower generation (e.g., Acreman and Dunbar, 2004; Poff, 2009). One of the ways that the Corps has become engaged in this trend is by establishing a partnership with The Nature Conservancy (TNC) called the Sustainable Rivers Project (SRP) (e.g., Hickey and Warner, 2005). The scope of Sustainable Rivers work is quite broad, ranging from dam removal to coastal zone management. Revising the environmental flow requirements below dams is at the heart of most restoration activities associated with hydropower (Harrison et al., 2007).

Section 216 of the River and Harbor Act of 1970 (Public Law 91-611) gives the Corps authorization to perform studies to modify the Water Control Plans that define operations at their water projects (e.g., Roos-Collins et al., 2007). A good example of ecosystem restoration activities under the cooperative SRP is the Kerr 216 Feasibility Study that is happening at the John H. Kerr Dam on the Roanoke River in Virginia and North Carolina (Whisnant et al., 2009). The purpose of the feasibility study is to review the operation of Kerr Dam and Reservoir and to report recommendations to Congress. From an ecosystem restoration point of view, the primary driver for the study is the fact that the dam's flood control operations have significantly changed the frequency and magnitude of high flows that are ecologically important in maintaining floodplain forests downstream of the dam. The hydropower plant at Kerr Dam also operates in a peaking mode, as dictated by SEPA. Peaking releases maximize the monetary value of hydropower, but also cause rapid swings between high and low flows in downstream aquatic habitats, which may damage fish resources. Alternative operating procedures that will stabilize

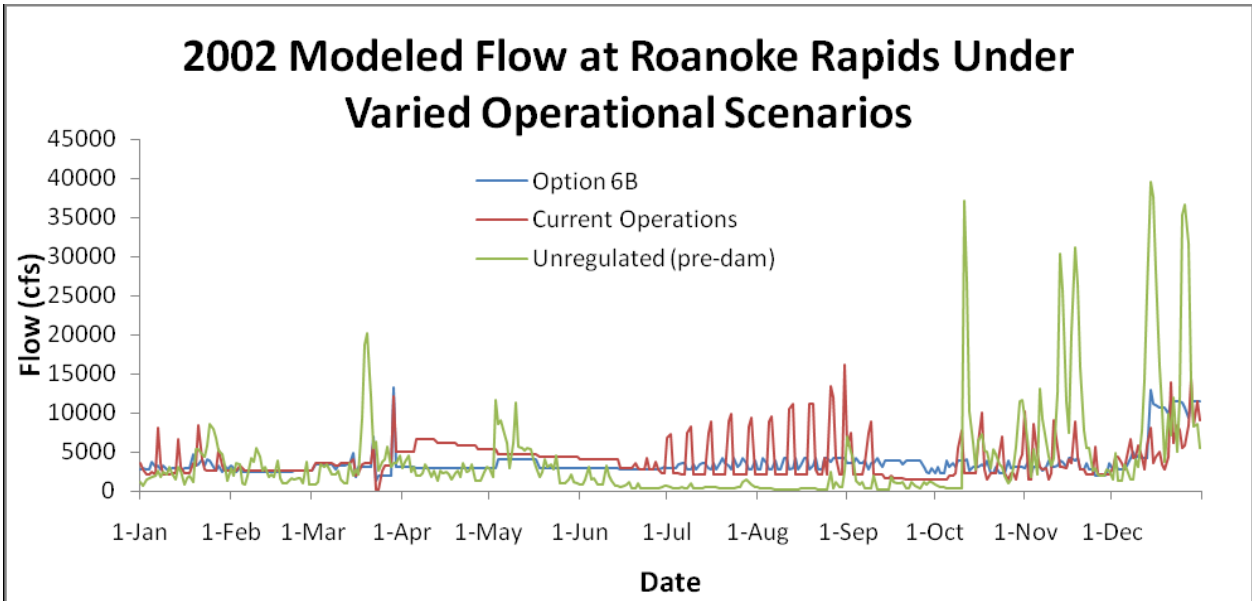

Figure 2-7 - Simulated daily flows in the Roanoke River under alternative operating regimes in an average water year, from the Kerr 216 study, with Option 6B being the favored alternative for ecosystem restoration (source: Whisnant et al., 2009).

short-term fluctuations in dam releases and restore both flood plain hydrology and habitat conditions for fish are being sought (Figure 2-7).

The operational changes needed to restore downstream ecosystems below Kerr Dam could have adverse effects on hydropower generation and associated revenues. In addition to Kerr Dam, there are two other downstream hydropower plants on the main stem of the Roanoke River, which are owned and operated by Dominion Power: Gaston Dam and Roanoke Rapids Dam.

Changes in releases from Kerr Dam would affect flows and generation at the two downstream Dominion projects. Power generated at Kerr is marketed to federal preference customers by SEPA at rates that are based on federal costs of operation and are significantly below market values in the PJM area. Less peaking generation at Kerr would mean that SEPA and its preference customers would have to replace cheap existing power with more expensive, open-market alternatives. Also, higher seasonal releases from Kerr designed to restore floodplain hydrology would exceed the maximum generation at Roanoke Rapids, resulting in spillage there that has no energy value. To date, the most balanced alternative for ecosystem and energy objectives is identified as Alternative 6B (Whisnant et al., 2009). Depending on water year type and electricity pricing assumptions, that alternative could result in up to 6 percent less hydropower generation and $1.1 million per year in revenue reductions to combined power customers (Whisnant et al., 2009). While not large, these tradeoffs are enough to cause opposition between energy and environmental interests.

The recommendations from the Kerr 216 Study will advise the Corps and ultimately Congress in the feasibility of modifying the structures or the structures' operation, and for improving the

quality of the environment in the overall public interest. Information developed during the study may become the basis for changes under existing or new authorities. These new authorities could be implemented by Congress or by the legislatures of the sponsors, the State of North Carolina and the Commonwealth of Virginia. The study provides the opportunity to integrate and assess different viewpoints from interested parties to achieve common beneficial goals.

2.2.2 Energy-Water Nexus

The term "Energy-Water Nexus" (EWN) refers to the fact that energy production and water resources are closely related to each other in many ways (DOE, 2006; Voinov, 2008) and often are inseparable. Many forms of energy production require water either directly, as a consumed resource, or indirectly to disperse waste heat or other pollutants. Likewise, water supply and water conveyance are major consumers of energy, especially in western states. It is well known that demand for both water and energy will continue to grow in the 21st century, but because of the EWN, limitations on either one will cause limits on the other.

Cardwell et al. (2009) described what the Corps' potential roles could be in the EWN arena, including rehabilitation and optimization of their own projects, development of expertise on water demand and energy-water linkages to share with others, and implementation of a systems perspective in planning and operations, applied to EWN issues. Better demand-side management of both water and energy are the most likely solutions, but these will require a new multi-agency initiative. Two aspects of this relation are discussed here: 1) water use by hydropower, and 2) headwater benefits, which refers to interactions between up- and downstream water developments and the fact that new upstream water storage reservoirs can result in additional hydropower generation at downstream power plants if storage operations shift river flows to more beneficial time periods.

Water Use Optimization in Hydropower. Improving the water-use efficiency of hydropower plants (i.e., kWh generated per unit of water passed through turbines) is one way to effectively decrease conflicts between energy and water uses. For example, TVA achieved a very significant increase in their water use efficiency through their Lake Improvement Program, which was active in the 1980s and early 1990s (Figure 2-8). Through 1997, TVA hydropower plants generated 34 percent more electricity with the same water availability after the LIP. Such improvements can be viewed as generating the same amount of energy with less water, which means water can be freed up for other uses, such as power, non-power, or storage. These types of improvements are beginning to be implemented elsewhere, including in the Columbia River Basin by BPA and in new R&D planned by the DOE.

Headwater Benefits. "Headwater Benefits" are an example of EWN relating to the interaction between upstream storage reservoirs and downstream hydropower plants. Under Section 10(f) of the Federal Power Act, an owner of a hydropower project is required to reimburse upstream headwater project owners for an equitable part of the benefits it receives (FERC: http://www.ferc.gov/industries/hydropower/gen-info/comp-admin/headwater.asp). Because an upstream storage reservoir regulates river flows, a hydropower project downstream is able to produce additional energy. The Federal Power Act instructs the Commission to determine headwater benefits received by downstream hydropower project owners.

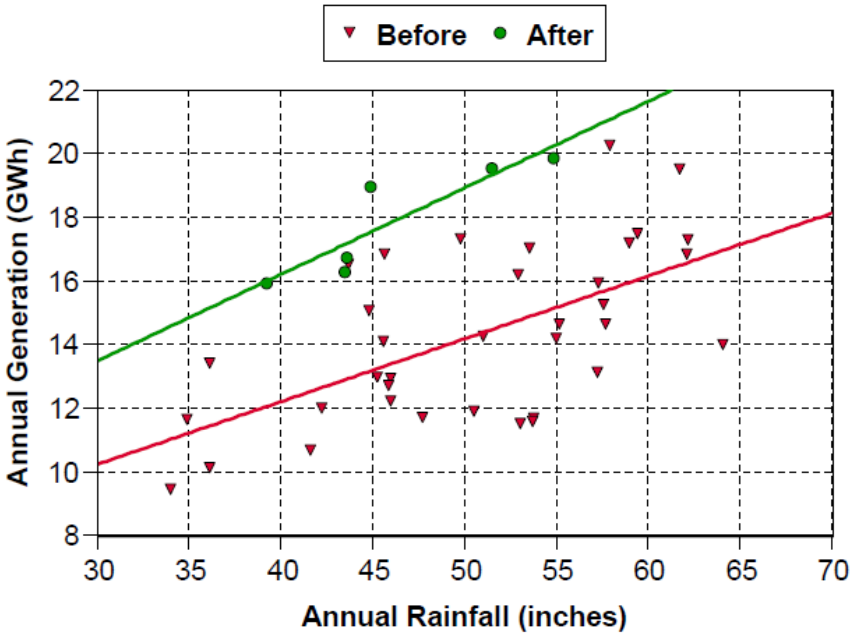

Figure 2-8 - Increases in water-use efficiency from the Tennessee Valley Authority's Lake Improvement Program (source: unpublished TVA data).

Many of the Corps storage reservoirs, be they power or non-power projects, provide headwater benefits to non-federal hydropower projects downstream. Where this occurs, FERC assesses charges to the corresponding downstream beneficiaries to recover costs of the upstream storage reservoirs. Funds collected by FERC under their Headwater Benefits Program are returned to the U.S. Treasury and credited to the sponsoring agency. The annual interest, depreciation and maintenance costs of the headwater project facilities that provide downstream power benefits constitute Section 10(f) costs. The headwater project owner, such as the Corps, generally provides these costs and allocations. The Commission uses the 10(f) costs in conjunction with the energy gains received at downstream hydropower projects to determine the Section 10(f) assessment, which is apportioned among all downstream hydropower beneficiaries. Only those costs identified as attributable to joint-use power facilities are included in the allocation formula (see: www.ferc.gov/industries/hydropower/gen-info/comp-admin/headwater.asp).

The FERC Headwater Benefit program is relevant to the Corps' Hydropower business for two reasons: 1) data requests, and 2) effects of changes to downstream hydropower operators when Corps' operations are changed. Regarding the first point, significant improvements could be made in interagency cooperation between FERC and the Corps in data exchange that would make HB estimation easier and less controversial. Regarding the second point, HB may not be positive for all cases of reoperation, which may trigger new regulatory proceedings, controversy, and conflict. A good example of this is the ACT-ACF, where reallocation of reservoir storage is leading to new consumptive uses of water that decreases the water available for power generation at downstream power plants owned by Alabama Power Company (APC). This has forced APC to request reductions in its HB charges and a change in how they are calculated.

Similar interactions may occur elsewhere in the country where reoperation is made in preparation for climate change.

2.2.3 Climate variability and change

Federal water resources agencies are becoming increasingly concerned about climate change and its potential effects on water resources in the United States (Brekke et al., 2009). The U.S. government's two principal water resources management agencies, the Corps and Reclamation, along with the two principal earth science data collection agencies, the U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA), wrote USGS Circular 1331, *Climate Change and Water Resources Management: A Federal Perspective* (Brekke et al., 2009). The purpose of the report was to explore strategies to improve water management by tracking, anticipating, and responding to climate change. The circular states that climate change has the potential to affect many water management sectors, including hydropower generation.

In the most recent national assessment of global climate change (Karl et al., 2009), the U.S. science community embraced the fact that climate change is already occurring; climate change is no longer an issue for debate, but rather an ongoing process that demands response. The following excerpt from *Effects of Climate Change on Energy Production and Use in the United States* (Climate Change Science Program Synthesis and Assessment Product 4.5) describes some possible impacts of climate change on hydropower.

> "There have been a large number of published studies on the climate impacts on water resource management and hydropower production (e.g., Miller and Brock 1988; Lettenmaier et al. 1999; Barnett et al. 2004). Significant changes are being detected now in the flow regimes of many western rivers (Dettinger 2005) that are consistent with the predicted effects of global warming. The sensitivity of hydroelectric generation to both changes in precipitation and river discharge is high, in the range 1.0 and greater (e.g., sensitivity of 1.0 means 1% change in precipitation results in 1% change in generation). For example, Nash and Gleick (1993) estimated sensitivities up to 3.0 between hydropower generation and stream flow in the Colorado Basin (i.e., change in generation three times the change in stream flow). Such magnifying sensitivities, greater than 1.0, occur because water flows through multiple power plants in a river basin. Climate impacts on hydropower occur when either the total amount or the timing of runoff is altered, for example when natural water storage in snow pack and glaciers is reduced under hotter climates (e.g., melting of glaciers in Alaska and the Rocky Mountains of the U.S.). Projections that climate change is likely to reduce snow pack and associated runoff in the U.S. West are a matter of particular concern.
>
> "Hydropower operations are also affected indirectly when air temperatures, humidity, or wind patterns are affected by changes in climate, and these driving variables cause changes in water quality and reservoir dynamics. For example, warmer air temperatures and a more stagnant atmosphere cause more intense stratification of reservoirs behind dams and a depletion of dissolved oxygen in hypolimnetic waters (Meyer et al. 1999). Where hydropower dams have tailwaters supporting cold-water fisheries for trout or

salmon, warming of reservoir releases may have unacceptable consequences and require changes in project operation that reduce power production.

"Evaporation of water from the surface of reservoirs is another important part of the water cycle that may be affected by climate change and may lead to reduced water for hydropower. However, the effects of climate change on evaporation rates is not straight-forward. While evaporation generally increases with increased air or water temperatures, evaporation also depends on other meteorological conditions, such as advection rates, humidity, and solar radiation. For example, Ohmura and Wild (2002) described how observed evaporation rates decreased between 1950 and 1990, contrary to expectations associated with higher temperatures. Their explanation for the decrease was decreased solar radiation. Large reservoirs with large surface area, located in arid, sunny parts of the U.S., such as Lake Mead on the lower Colorado River (Westenburg et al., 2006), are the most likely places where evaporation will be greater under future climates and water availability will be less for all uses, including hydropower.

"Competition for available water resources is another mechanism for indirect impacts of climate change on hydropower. These impacts can have far-reaching consequences through the energy and economic sectors, as happened in the 2000-2001 energy crises in California (Sweeney, 2002).

"Recent stochastic modeling advances in California and elsewhere are showing how hydropower systems may be able to adapt to climate variability by reexamining management policies (Vicuña et al., 2006). The ability of river basins to adapt is proportional to the total active storage in surface water reservoirs (e.g., Aspen Environmental Group and M-Cubed, 2005). Adaptation to potential future climate variability has both near-term and long-term benefits in stabilizing water supplies and energy production (e.g., Georgakakos et al., 2005), but water management institutions are generally slow to take action on such opportunities." (CCSP, 2007)

The Corps initiated a new program in the fiscal year of 2010 on Responses to Climate Change. The goal of the program is to develop and begin implementing practical, nationally consistent, and cost-effective approaches and policies to reduce potential vulnerabilities to the nation's water infrastructure resulting from climate change and variability. The Corps new work on climate change will be in close coordination with a wide variety of intergovernmental stakeholders and partners (e.g., Brekke et al., 2009). The program recognizes that the biggest challenge may be ensuring the robustness of operations and water management control activities associated with the existing capital stock. The effort will provide planning and engineering guidance, methods, and tools to ensure that future infrastructure is designed to be sustainable and robust to a range of potential changes.

One area of concern for water managers is how to plan investments when future hydrology may change. Traditional water resources planning methods and hydrologic frequency analysis assume that climate is stationary, which means the statistical properties of hydrologic variables in future time periods will be similar to past time periods. The validity of this assumption is challenged by anthropogenic climate change and our current understanding of decadal climate

variability (Milly et al., 2008). A workshop on Nonstationarity, Hydrologic Frequency Analysis, and Water Management was held in January 2010 to help initiate a dialog between water managers and scientists on methods to deal with climate uncertainty. The purpose was to discuss proposed decision rules under the assumption of nonstationarity in hydrologic frequency analysis (http://www.cwi.colostate.edu/NonstationarityWorkshop/index.shtml).

Another question for the water management agencies is how water management operations should adapt to a changing climate. A team of Corps water managers and hydraulic engineers developed a *Strategic Plan for Water Management Adaptation to Climate Change*. Some of the recommendations in the report include: implementation of a systems-based approach to river basin management, collaboration with stakeholders as part of an Integrated Water Resources Management (IWRM) approach, adoption of an adaptive management process that can update decisions given new information, and evaluation of potential climate change impacts on existing and proposed water management procedures.

As the science of climate change becomes more certain, responses are being incorporated into legislation. Recently, Congress authorized the Secretary of Energy to assess the effects of global climate change on hydroelectric generation at federal water projects (Omnibus Public Lands Management Act, Pub. L. 111-11). That assessment is one of the activities that will be addressed in new interagency coordination on conventional hydropower described in the next section.

2.3 Evolving Regulations and Energy Policies

The rules of the game are changing with new national policies and regulatory practices.

The U.S. is truly in a time of changing energy policies, driven now by a new administration and global pressures to de-carbonize the energy sector in response to concerns for climate change and for unstable energy markets. In 2001, then-President George W. Bush said, “America must have an energy policy that plans for the future, but meets the needs of today. I believe we can develop our natural resources and protect our environment.” Such good intent has been hard to realize in the past for more than just the last administration, but today, we are working harder than ever to reach those goals. As the nation’s oldest renewable energy source, hydropower has an important role to play in future energy policies.

Announcing new modernization awards from the American Recovery and Reinvestment Act, Secretary of Energy Steven Chu recently said, "One of the best opportunities we have to increase our supply of clean energy is by bringing our hydropower systems into the 21st century. With this investment, we can create jobs, help our environment and give more renewable power to our economy without building a single new dam." These types of statements indicate a strong shift in attitudes towards hydropower.

2.3.1 Changing markets and regulation

Over the last several decades, energy planning has moved from relatively simple least-cost planning within vertically diversified utilities to complex Integrated Resource Planning (IRP) that attempts to minimize total social costs, including environmental costs, in open, competitive markets (Raphals, 2001). Starting in 1992, FERC has been the guiding federal authority implementing these changes (Table 2-1). FERC's actions have had a significant effect on reducing the impediments to wholesale competition among energy suppliers. However, more reforms are proceeding to equalize access to transmission systems by increasing the clarity and transparency of rules for planning and use, as well as the ways that Open Access Transmission Tariffs are applied. The ownership and operation of transmission systems have been separated from those of power plants as these changes have been implemented. This has been done by forming Independent Systems Operators (ISOs) and Regional Transmission Operators (RTOs) across the country.

As energy markets and transmission systems have been evolving, two key events occurred. The first was the Western Energy Crisis of 2000-2001 when a convergence of factors (diminished power supplies due to drought conditions, inadequate infrastructure, and a flawed power market design) opened the door to market manipulation, which in turn led to an economic crisis of high energy prices and low availability (e.g., see www.ferc.gov/industries/electric/indus-act/wec.asp). The second was a large-scale blackout that occurred in August 2003 in the Midwest and northeastern states, ultimately affecting 50 million people in the U.S. and Canada (see www.oe.netl.doe.gov/hurricanes_emer/blackout.aspx).

Ultimately, the end result has been a new set of regulatory requirements designed to ensure transmission system reliability and resiliency, including new standards and associated enforcement mechanisms. Because hydropower generation can respond more quickly than most other energy sources and water reservoirs are a very efficient means to store energy, hydropower's value in these new markets is very high. The degree to which these changes affect federal hydropower is not clear, because in part of the long-term nature of federal power contracts.

2.3.2 Abatement of carbon emissions

Managing carbon dioxide emissions at the national and international levels continues to be a long-term challenge that is politically controversial. Solutions such as Cap-and-Trade policies or carbon taxes do not appear to be achievable in the next year or more, but at some time in the future, decarbonization of the energy sector in the U.S. is very likely. Lacking a clear national policy, individual states are taking actions of their own, led by California and the northeastern region.

Hydropower has generally been considered emission-free by its advocates, but that thinking is being challenged in several ways. Life cycle impact analysis of fuel cycles has been applied to all types of fuel cycles, including hydropower, and has measured emissions related to the construction processes, etc. More importantly, significant greenhouse gas (GHG) emissions from reservoirs have been found in some environments and at some large hydropower projects (Tremblay et al., 2005; Rosa et al., 2004). Natural carbon-cycle processes result in fluxes of

Table 2-1- Significant regulatory actions from FERC, restructuring energy markets and operation of transmission systems in the U.S. (Source: modified from FERC at http://www.ferc.gov/industries/electric/indus-act/competition.asp).

Year	*Action*
1992	The Energy Policy Act of 1992 was enacted, encouraging FERC to foster competition in the wholesale energy markets through open access to transmission facilities.
1996	FERC issued a series of orders designed to foster competition through better access to transmission facilities, namely Order No. 888.
1999	FERC issued Order No. 2000 which encouraged transmission utilities, including those that were not public utilities, to join a RTO.
2005	In August, the Energy Policy Act of 2005 (EPAct 2005) was enacted, reaffirming a commitment to competition in wholesale power markets as national policy. In December, FERC issues Order No. 668, which amended FERC's regulations to update the accounting requirements for public utilities and licensees, including RTOs and ISOs.
2006	FERC staff issued the Assessment of Demand Respond & Advanced Metering as required by EPAct 2005.
2007	In February, FERC issued Order No. 890, a final rule reforming its decade-old open-access transmission regulatory framework that will ensure transmission service is provided on a nondiscriminatory, just, and reasonable basis, as well as provide for more effective regulation and transparency in the operation of the transmission grid. In June, FERC issued an Advance Notice of Proposed Rulemaking seeking public comment on potential reforms to improve operations in organized wholesale power markets. The proposal will help the Commission identify challenges facing competitive wholesale power markets in RTOs and ISOs and propose workable solutions in those areas in which the Commission has jurisdiction. Specifically, the Commission sought comments on (1) the role of demand response in organized markets, (2) facilitating opportunities for long-term power contracts, (3) strengthening market monitoring, and (4) the responsiveness of RTOs and ISOs to customers and other stakeholders.
2008	In February, FERC issued a Notice of Proposed Rulemaking seeking public comment on new rules to improve operations in organized electric markets, boost competition and bring additional benefits to consumers. The proposed reforms are designed to ensure just and reasonable rates and to remedy undue discrimination and preference, and to improve wholesale competition in organized markets. They address demand response and market pricing during a period of reserve shortage, long-term power contracting, market-monitoring policies, and responsiveness of regional transmission operators and independent system operators to stakeholders and customers. In October, FERC issued Order No. 719 finalizing regulations that strengthen the operation and improve the competitiveness of organized wholesale electric markets through the use of demand response and by encouraging long-term power contracts, strengthening the role of market monitors and enhancing regional transmission organization (RTO) and independent system operator (ISO) responsiveness.
2009 In	July, FERC issued Order No. 719-A reaffirming regulations that strengthen the operation and improve the competitiveness of organized wholesale electric markets through the use of demand response and by encouraging long-term power contracts, strengthening the role of market monitors and enhancing regional transmission organization (RTO) and independent system operator (ISO) responsiveness.

carbon dioxide and methane from all water bodies. In man-made reservoirs, carbon cycles can be intensified when additional organic matter, such as flooded vegetation, decomposes. The biological processes that lead to GHG emissions from water bodies are highly site-specific, depending on the productivity of the local environment and the hydrology of the water body. This has been documented in large hydropower storage reservoirs built in tropical, forested ecosystems in several parts of the world, leading to the accusation that hydropower is associated with GHG emissions as great as coal-burning power plants. Non-governmental organizations (NGOs), such as the International Rivers Network, have been very vocal in raising awareness of this threat to the environment.

The most extensive field measurements have been conducted by research teams funded by Hydro Quebec, although some of their data come from water bodies in the U.S. (Figure 2-9). Results by Tremblay et al. indicate that GHG emissions from hydropower reservoirs are 35 to 300 times lower per unit energy than thermal generating plants. However, there are exceptions.

The significance of potential GHG emissions from hydropower reservoirs is that they may affect how new development is treated under regulations designed for carbon management in our energy sector. Although such emissions are not yet considered in the green energy certification systems that are available for hydropower (see the following section), they may be in the future, with consequences to certifying benefits of existing and future projects. For example, the International Hydropower Association (IHA) and UNESCO have initiated a GHG Research Project that produces methods for estimating hydropower-associated emissions. To date, IHA's proposed methodology is based on only two variables: a project's generation and its reservoir

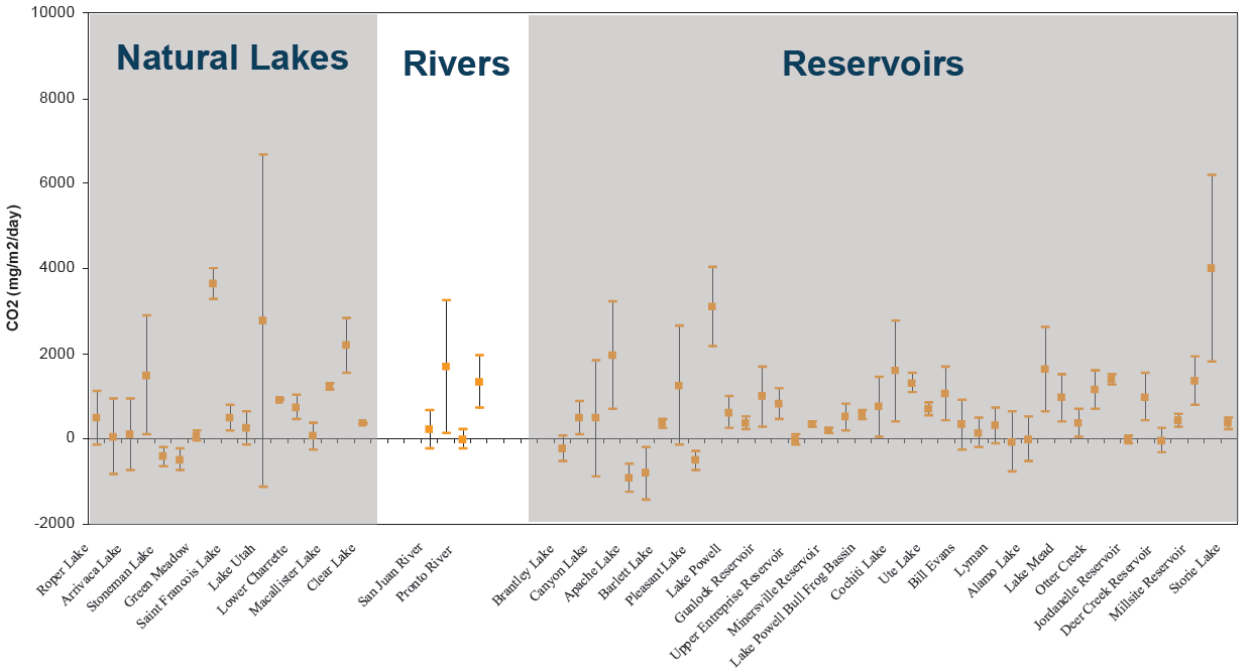

Figure 2- 9 - Carbon dioxide emission rates measured from natural lakes, rivers, and reservoirs in the southwestern U.S. (source: Tremblay et al., 2005; http://www.unesco.org/water/ihp/pdf/6_Tremblay.pdf).

size. It remains to be seen whether such a method can assess the variation among hydropower settings well enough to treat projects equitably. Given the scientific uncertainties, the DOE and EPRI are funding Oak Ridge National Laboratory (ORNL) for new research that will help resolve hydropower's role in GHG emissions.

2.3.3 Increasing renewables

One of the important ways to de-carbonize our country's energy portfolio is to increase generation from renewable energy sources that do not emit carbon dioxide, such as wind, solar, geothermal, and hydropower. Hydropower resources in the U.S. have not been fully developed. Undeveloped resource types include:

- Upgrades in capacity and efficiency at existing power plants;
- Retrofitting new power plants into existing, non-powered dams;
- Development of new, environmentally compatible dams and diversions, large and small;
- New pumped storage hydropower projects;
- Extraction of excess energy from constructed waterways and water distribution systems; and
- Tidal and in-stream hydrokinetic projects that do not require dams or diversions.

Several attempts have recently been made to estimate how much undeveloped hydropower exists in the U.S. (Table 2-2). The EPRI published estimates of undeveloped water power resources in 2007 (Bahleda and Hosko, 2007) and published an update in late 2009. The DOE, with the help of Corps and Reclamation staff, also have done their own estimates in 2009, but with significantly different methods. The EPRI estimates in Table 2-2 represent a prediction of new development that will occur by 2025 under an aggressive energy policy scenario that includes favorable tax incentives, access to government-back loans, and positive treatment in renewable energy portfolios for hydropower. The DOE estimates are much less constrained – they represent an upper limit on development that is technically feasible but not limited by project economics, environmental impacts, or competing land uses. Obviously, there are significant uncertainties in both sets of estimates, but the most important aspect of these data is their conclusion that there remains substantial undeveloped hydropower potential in the U.S.

Another interesting aspect of the DOE estimates is the difference in estimated development potential for efficiency and capacity upgrades at federal versus non-federal dams. At existing federal hydropower plants, Corps/Reclamation staff estimate that 3.5 MW of new capacity is technically feasible to add, relative to 35 MW of installed capacity (~10 percent). At non-federal hydropower plants, DOE Lab and industry experts estimate that between 9 and 18 MW can be added, relative to 53.5 MW of installed capacity (17 percent to 34 percent). The discrepancy between these estimates is most likely due to differences in methodology, but it is also probable that federal projects can be upgraded more than 10 percent.

The Energy Policy Act of 2005 (EPAct) (Pub. L. 109-58) called for two studies of the undeveloped hydropower resources at existing federal facilities. Section 1840 of EPAct required the Secretary of the Interior to conduct a short-term inventory that identified potential

Table 2- 2 - Comparison of recent estimates of undeveloped hydropower potential in the United States (EPRI estimates are expected development by 2025; DOE estimates are technically feasible, but not constrained by economic, environmental factors, or time frame).

Resource Type	***EPRI (MW)***	***DOE (MW)***
Efficiency and capacity upgrades at existing dams	3	22
Retrofit existing non-powered dams	7	33
New, small dams or diversions	3	264
New large dams	0.5	n/a
Pumped storage projects	10	68
In-stream and tidal hydrokinetic projects	6	n/a
TOTALS	***30***	***467***

(uncompleted or authorized) hydropower projects that had been included in previous studies of Reclamation's surface water storage facilities (DOI, 2005). Section 1834 of EPAct 2005 called for a study to assess the potential for increasing hydropower at federally owned or operated non-powered dams. The second study identified 1,230 MW of new development in capacity increases, plus another 1,283 MW of additional generating capacity in refurbishment of existing power plants (DOI et al., 2007). Both these EPAct studies were limited by available time and data, so they were not conclusive on development feasibility of the sites identified. The 1834 study is currently being updated; a final report will be available before the end of 2010.

Although recent studies are showing that there are still significant undeveloped hydropower resources in the U.S., the most serious barrier to that development is the presence of relatively cheaper energy from natural-gas-fired power plants. Natural gas as a source of electricity is not renewable and does involve significant carbon emissions, but until there is a national policy limiting carbon emissions, it offers real economic advantages over hydropower.

If and when it happens, new hydropower development in the U.S. will most likely be accomplished by non-federal developers who will have to go through the FERC licensing process (Meier et al., 2010), because the federal water development agencies (e.g., Corps) are very unlikely to get Congressional authorization or appropriations for such new development. The FERC licensing process is very complex, time consuming, and uncertain, which imposes a significant barrier to new development of any kind. FERC instituted an Integrated Licensing Process several years ago to improve this process, but more improvement is needed. The Corps plays several different roles in non-federal hydropower licensing. The Corps is the federal agency responsible for issuing permits under Section 404 of the Clean Water Act, pertaining to discharge and disposal of dredged materials from rivers. When new development happens at an existing, non-powered dam owned by the Corps, the Corps also must issue a

so-called 408 permit that authorizes non-federal use of federal facilities. This requirement is related to Section 14 of the Rivers and Harbors Act and 33 USC 408 (33 CFR 209.170(b)], and it is a relatively new "discovery" that is delaying new developments (Meier et al., 2010). Currently, the Corps-related steps in non-federal permitting occur after a FERC license is issued, which adds additional delay and uncertainty on top of an already complex process. Negotiations between the Corps and industry have been going on for several years now to streamline these processes – this MOU is currently planned to be signed in April 2011.

2.3.4 Need for more energy storage

Energy planners and policy makers in the U.S. are waking up to the fact that we must find ways to increase our energy storage capacity (EAC, 2008a). Two issues are driving the new interest in energy storage technologies: 1) the need to maintain the resiliency and reliability of the nation's electricity transmission systems (the grid), and 2) the need to incorporate a large amount of intermittent renewable energy, from new sources like wind and solar energy. The first of these driving forces is related to growing energy demand, which is in turn driven by population growth and technology change. The second is driven by the changing national energy policy, described in preceding sections.

The term "Smart Grid" has gained wide-spread use to describe the electricity transmission and distribution systems of the future. DOE's definition for the Smart Grid is complex: it is "digital technology to improve reliability, security, and efficiency of the electric system: from large generation, through the delivery systems to electricity consumers and a growing number of distributed-generation and storage resources;" it is also, "the information networks that are transforming our economy in other areas are also being applied to applications for dynamic optimization of electric system operations, maintenance, and planning. Resources and services that were separately managed are now being integrated and rebundled as we address traditional problems in new ways, adapt the system to tackle new challenges, and discover new benefits that have transformational potential" (EAC, 2008b).

The FERC has been very active in development of new transmission system standards that will implement the vision of the Smart Grid, as required under Section 1305 of the Energy Independence and Security Act of 2007 (Pub. L. 110-140). The goals of these new standards are to:

- Ensure the cybersecurity of the grid;
- Provide two-way communications among regional market operators, utilities, service providers and consumers;
- Ensure that power system operators have equipment that allows them to operate reliably by monitoring their own systems as well as neighboring systems that affect them; and
- Coordinate the integration into the power system of emerging technologies such as renewable resources, demand response resources, electricity storage facilities and electric transportation systems.

While it will take time for the FERC's inoperability standards to be fully implemented, it is clear that flexible, dispatchable hydropower, including that from pumped-storage hydropower (PSH) projects, will be an extremely valuable part of it. PSH is a proven bulk energy storage

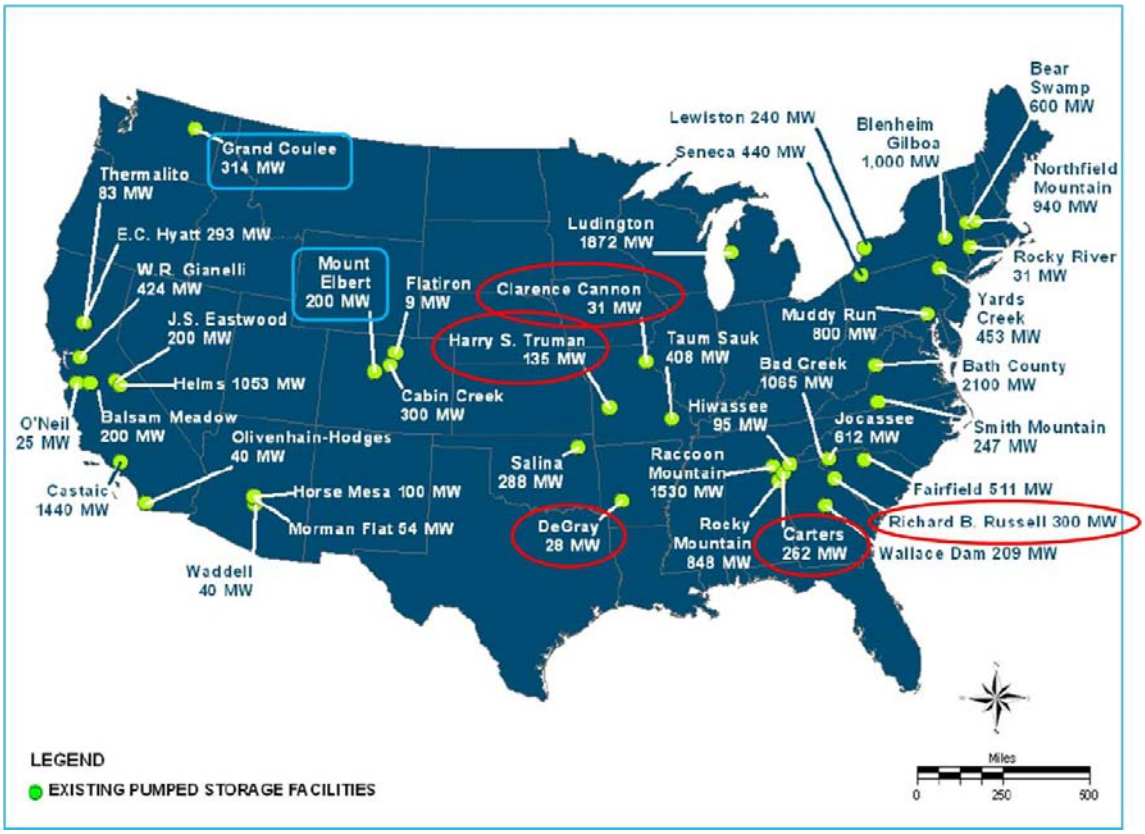

Figure 2-10 - Pumped storage hydropower projects in operations in 1993 the U.S., with Corps projects circled in red and Reclamation projects boxed in blue (source: MWH, 2009b).

technology that provides important ancillary service benefits to the grid, such as load balancing, frequency control, and reserve generation. There are more than 20 GW of PSH capacity in the U.S. today (Miller and Winters, 20), widely distributed across the country at 40 projects (Figure 2-10). Included in that total are five projects operated by the Corps that have reversible turbines that could be operated in a pumped-back storage mode, pumping water upstream from a lower to upper reservoir on main stem rivers. The total capacity of the Corps' pumped-back turbines is approximately 750 MW. However, the operation of many of the Corps fleet of reversible turbines is currently constrained due to a combination of issues, including fish entrainment, water availability, and equipment performance problems (excessive cavitation). Reclamation has two pumped storage projects. By far the most successful federal PSH project is the 1530-MW Raccoon Mountain project owned and operated by TVA.

The opportunities for non-federal pumped storage development were examined in a recent white paper by Miller and Winters (2009). There are more than 31 GW of new PSH projects in various stages of licensing being considered by FERC right now, most of which are in the western half of the U.S. The time to obtain a FERC license for large PSH may be as long as 10 years, so these new projects will not be coming on line for a decade or more.

2.3.5 Hydropower certification processes

Deregulation of the power industry in the U.S. has created new ways for consumers to exercise choice in energy markets, and these opportunities have led to the need for new types of public information on energy sources. Consumers have demonstrated a willingness to select energy sources with low environmental impacts. Several private-sector or non-governmental initiatives have proposed to establish new ways to evaluate and label energy sources relative to the environmental values of consumers. Such so-called "green energy" labeling systems are already being implemented in some parts of the country, beginning in California (e.g., see http://www.green-e.org/). This trend is likely to get stronger as deregulation provides the opportunity for more consumer choice.

The hydropower industry is the focus of at least two different certification approaches, one by the Low-Impact Hydropower Institute (LIHI) and a second by Scientific Certification Systems (SCS), both of which appeared in 1998. The LIHI certification process is based on a system of pass/fail criteria that evaluate whether projects are consistent with the best available recommendations of natural resource management agencies (Grimm, 2002). If agency recommendations are not available, then the LIHI criteria set performance standards that must be met. The LIHI Board of Directors makes the final decision on whether projects receive certification. The most important aspect of LIHI's success is that it was established by environmental organizations, and its board is composed almost completely by representatives of those organizations. Therefore, its certification decisions are an endorsement of the fact that at least some hydropower projects can be designed and operated in an environmentally compatible and renewable manner. LIHI is currently considering an upgrade of its criteria that will make them more objective.

The SCS certification approach is very different from that of LIHI. It uses quantitative measures of individual projects' design and emissions, then compares those to median values from a set of power supply alternatives (e.g., all the electricity sources in a NERC region). Projects that have aggregate scores better than the regional median are considered worthy of certification. Recently, Reclamation and WAPA have pursued the establishment of a certification process based on similar Life-Cycle Impact Assessment (LCIA) procedures within the American Society of Testing and Materials (ASTM) -- unfortunately, this ASTM procedure has not been finalized.

These two certification approaches are being used to highlight the advantages of hydropower, which is advantageous for this important renewable energy source. However, the two approaches are designed for very different purposes. The LIHI program is designed to make comparisons among hydropower projects and to distinguish those that do the best job of taking care of their local environments. The SCS-LCIA approach is designed to evaluate larger portfolios of energy production and to provide a basis for comparing one source of energy with others (e.g., hydro versus coal).

Future success in deregulated power markets will be influenced by consumer preferences and the systems that inform consumers. It is quite possible that future project owners may want to be certified by more than one program, because they inform different consumer values. Most importantly, it is in the interest of the hydropower industry to be engaged in the development of

certification programs. It may not be necessary or advisable to pick one certification approach over another, at least until more experience is gained.

A serious challenge for any certification program is the development of objective criteria that can be used to judge environmental performance in a consistent and cost-effective manner. Neither LIHI nor SCS-LCIA have entirely satisfactory solutions. The LIHI criteria are based too heavily on the recommendations of state or federal natural resource management agencies or on standards that have questionable defensibility. The SCS-LCIA applications to hydro to date have been very site-specific and not open to public view. As the saying goes, "the devil is in the details," and the details of hydropower certification are far from worked out.

Better understanding of environmental mitigation and environmental performance at hydropower projects is needed before any certification system will reach its full potential. If sets of "best management practices" or "best-available technologies" were available, then the establishment of standards for certification would be much easier. The DOE's Hydropower Program has worked on these issues in the past (Sale et al., 2006). The general research area of measuring the environmental performance of hydropower projects may be common ground where the DOE and non-governmental certification programs can work together.

2.4 Emerging New Technologies

Until recently, conventional wisdom has been that hydropower is a mature industry that has neither new development potential nor the need for research and development (R&D) investment. Nevertheless, new technologies that offer improvements in energy and environmental performance are emerging. These new technologies are opening the door to new types of development that do not require new dams or diversions. We appear to be entering a renaissance of hydropower in the U.S.

New technologies, including hardware and software, are making it possible to optimize hydropower for energy and environmental purposes.

2.4.1 Advanced turbine research

Two federal programs are examples of what can be done to improve hydropower technologies through new R&D: 1) the DOE-funded Advanced Hydropower Turbine Systems Program, and 2) the Corps' Turbine Survival Program in the Columbia River basin. The DOE's Advanced Turbine research program was conceived in 1994 and continued through 2005, at which point Congress and the Bush administration discontinued funding (Sale et al., 2006).

The most successful product of the DOE's turbine program has been the deployment of minimum-gap Kaplan turbines at Wanapum Dam on the mid-Columbia River (Brown and Garnant, 2006). Through a number of design modifications (Figure 2-11), the new, advanced turbine was able to achieve a 3 percent increase in water use efficiency and an overall increase in power output of 14 percent without changing fish passage mortalities.

The DOE Advanced Turbine program also produced an innovative runner design for sites that typically would be developed with Francis turbines – this new design was initially developed by joint work from Alden Research Laboratories and Natural Resoruces Energy Concepts. The so-called ACT (Alden-Concepts Turbine) runner has a unique helical design with an attached shroud and only two or three blades (Figure 2-12). The latest design and testing work that DOE is funding in 2010 is producing even more encouraging results, indicating that energy efficiencies exceeding 90 percent are possible with this design.

The Corps has also been working on new turbine designs for some time, for applications in the Columbia River basin (USACE, 2004). The first application of the so-called "Minimum Gap Runner," a form of Kaplan turbine that is more hydraulically efficient and therefore more fish-friendly, was installed at the Corps' Bonneville Dam on the lower Columbia River. The Corps' Turbine Survival Program (TSP) continues to actively pursue new turbine designs, the most recent of which will be installed at the Ice Harbor powerhouse on the Snake River.

2.4.2 Tools for integrated water management

The complexities of IWRM, whether it be part of a Corps planning activity or a FERC licensing proceeding for a non-federal project, have made computer modeling an integral part of studying hydropower development. These analytical tools are widely available in public domain or in proprietary forms. More important than the existence of the models is the fact that better ways to use them are evolving. With awareness of the diversity of uses for water, tools to support integrative approaches have been developed and are becoming more common in practice. In many cases, this includes participatory integrative approaches, where stakeholders contribute not only their expertise about the watershed, but also bring their values and interests to the negotiation table and collaborate to identify feasible solutions.

The Corps of Engineers is applying integrated approaches in partnership with The Nature Conservancy in their Sustainable Rivers Project (SRP). Many SRP sites, including the Savannah, Connecticut, Willamette, Roanoke, and the White-Black-Red river systems, include hydropower use. The SRP works to identify new ways to protect and restore freshwater and coastal habitats, while also maintaining or enhancing other benefits from the projects, such as flood control or hydropower.

In the 1990s, the Corps formally defined Shared Vision Planning as a methodology which incorporates a technical model, which is built collaboratively with stakeholders, into the tried-and-true Corps Planning Process. Models manage the complexity associated with the many issues of watershed management and support the development and testing of new alternatives, increasing the opportunity to find mutually acceptable options. Shared Vision Planning was codified during the National Drought Study (Werick and Whipple, 1994). Since then, it has been applied to several other cases at various scales, by the Corps and by other leads. The largest-scale application of Shared Vision Planning to date has been the Lake Ontario-St. Lawrence River system by the International Joint Commission (IJC). Regulations established in 1958 considered only three primary purposes: hydropower, commercial navigation, and water supply.

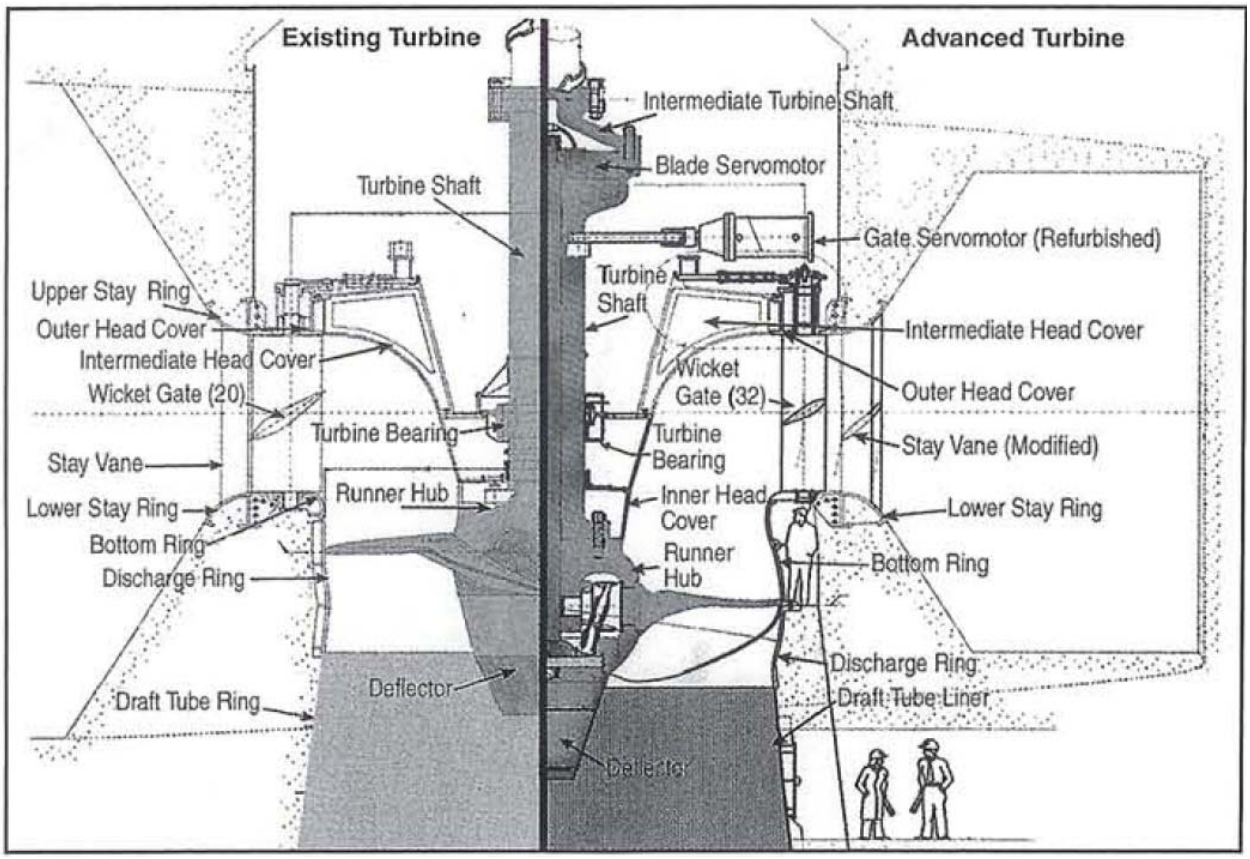

Figure 2-11 - Modifications made in Kaplan turbines at Wanapum Dam in cooperative research and development between the U.S. Department of Energy and Grant County Utility District (source: Brown and Garnant, 2006).

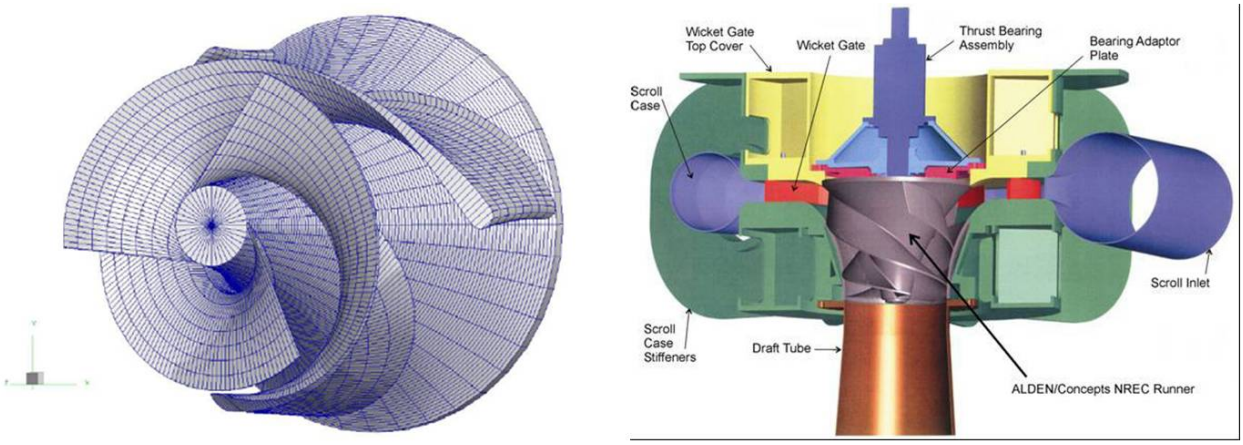

Figure 2-12 - Helical design of the Alden fish-friendly turbine.

In the Shared Vision Planning effort that the IJC initiated in 2000, experts, stakeholders and policy-makers negotiated and recommended a revised operating plan that balanced the additional interests that the rivers system now serves, including: recreational boating, environmental preservation, and to some degree, changing priorities among shoreline property owners (IWR 2009). IWR reports are available to introduce its methodology and benefits *(A Shared Vision Planning Primer* (Cardwell et al., 2009)), or to provide guidance *(How to Conduct a Shared Vision Planning Process* (Creighton, 2010)).

The use of Shared Vision Planning and other collaborative modeling processes is growing. Shared Vision Planners and others who use Collaborative Modeling for water resources management (including academics, consultants, states, and local agencies) have formed a community of practice to promote and advance the field both within the U.S. and internationally. One initiative in this community is to measure the benefits of these processes as compared to conventional approaches. Those who have been involved in these processes have observed benefits such as increased trust and understanding between stakeholders, more informed decision making, and easier implementation of recommendations, but these have been challenging to measure. The community is also working to increase training and mentorship opportunities, and to increase political support for this approach. See Stephenson, et al. (2007); Cardwell et al. (2009); and Lorie (2010) for more information about these efforts.

2.4.3 Hydrokinetics

The push for new sources of renewable energy has led to a re-examination of how energy is produced from water. The kinetic energy in ocean waves and water currents in tidal estuaries and rivers is being looked at for new types of water power projects. A recent assessment of water power development potential by EPRI (Bahleda and Hosko, 2007) estimated that as much as 30 MW of new capacity may be developed by 2030 from all types of hydrokinetic technologies (tidal and in-stream). The Department of Energy maintains a website describing the different types of hydrokinetic devices (www1.eere.energy.gov/windandhydro/hydrokinetic/).

Figure 2-13 - Photo of the installation of the first in-stream hydrokinetic turbines licensed by FERC: (a) Hydro Green's installation downstream of the Corps Lock & Dam No.2 on the upper Mississippi River, near Hastings, MN, and (b) Verdant Power's installation in tidal zone of the East River in New York City. (source: Hydro Green Energy, LLC, and Verdant Power Company).

The state of engineering of these devices currently requires relatively high current velocities to have efficient generation, on the order of 6 to 7 feet per second. There is a great deal of licensing activity at FERC for tidal and in-stream hydrokinetic development. As of the beginning of November 2009, FERC had issued preliminary permits for 128 in-stream hydrokinetic projects, 29 tidal hydrokinetic projects, and 18 ocean wave projects. FERC was also processing preliminary permit applications for another 48 sites at that time. The vast majority of these potential developments are in large inland rivers, such as the Mississippi, Ohio, and Missouri rivers. Most these types of developments are in located in the tailwaters of existing dams.

There are two operational hydrokinetic projects in the U.S. (Figure 2-13). The first hydrokinetic device deployed in a tidal river setting was by Verdant Power Company in the East River of New York City, NY. The first in-river deployment of a modern hydrokinetic device occurred in August 2009 on the upper Mississippi River near Hastings, MN, by Hydro Green Energy, LLC. Both are small capacity, essentially experimental devices.

2.5 Patterns in Federal Funding

There is significant stress between providing low-cost hydropower and maintaining reliable generation.

Recent trends in federal funding have been problematic for hydropower because of limited budgets and competing national priorities. The current situation is ambiguous – there is chronic underfunding of O&M needs at both federal and non-federal projects, but because of the interest in renewable energy, there have been some unprecedented increases in budgets for some types of new development and for R&D. In discussing budgets, it is important to distinguish between funding for construction, O&M, and R&D, because the trends and constraints differ for each.

2.5.1 Federal hydropower

The President's budget request for the Corps' Civil Works Program, where the hydropower business line is located, has increased from fiscal year 2009 to fiscal year 2010, from $4.7 billion to $5.1 billion. Four of the Corps' primary water resources mission areas have larger budget allocations than Hydropower in the 2010 budget: Navigation with $1.8 billion, Flood Control with $1.6 billion, Aquatic Ecosystem Restoration with $546 million, and Recreation with $283 million (Figure 2-14). In comparison, Hydropower was allotted only $230 million in the 2010 budget, of which $200 million was for O&M and $30 million was for construction (this for a federal business line that returns $3-4 billion per year to the federal treasury). Construction funds are the only budget items that can be used from Congressional appropriations for replacement of major equipment, such as older turbines or generators that are in poor condition; O&M funds cannot be used to fund equipment replacements. Several business lines (Flood Control, Navigation, and Ecosystem Restoration) have budget requests for investigations that are larger than Hydropower's total for construction ($30M). Hydropower has no specific budget item for Investigations, but the budget request does include $3 million for a long-term plan for management of hydropower projects and $5 million to evaluate responses to potential climate change impacts – those funds are listed under O&M.

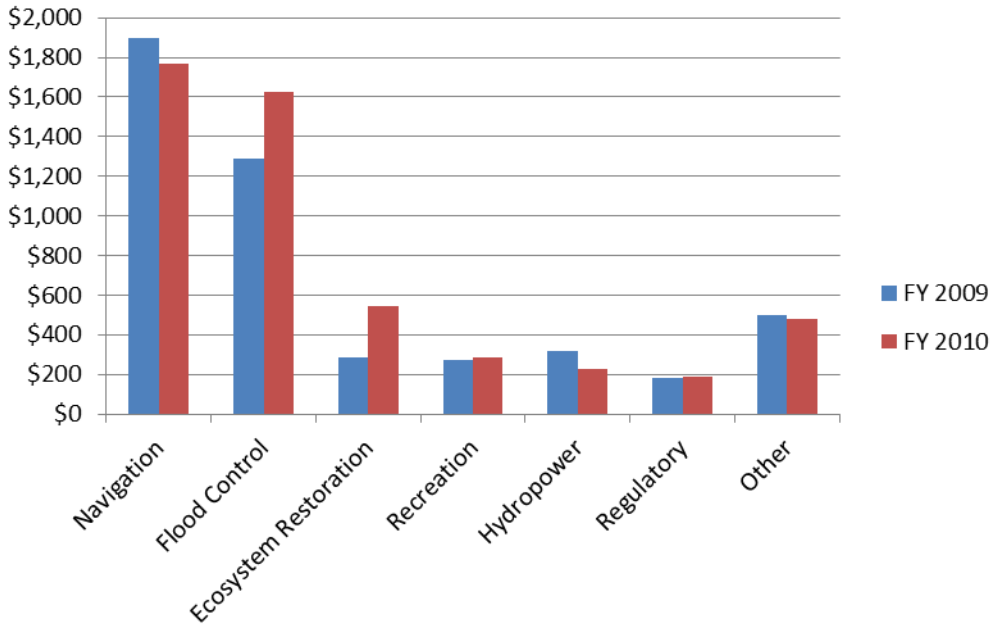

Figure 2-14 - FY 2009 and FY 2010 budget requests for the U.S. Army Corps of Engineers (millions of dollars).

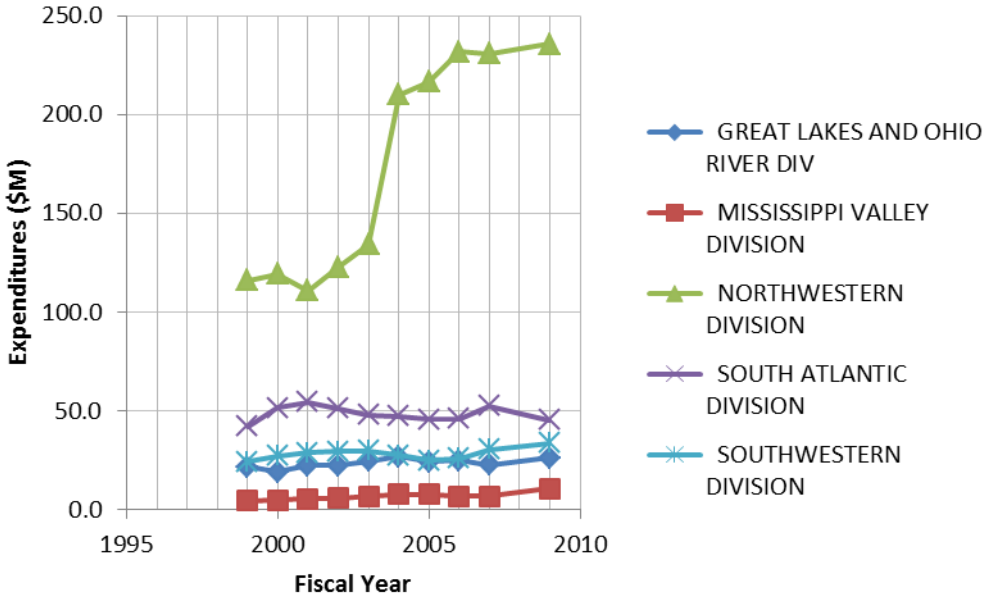

Figure 2-15 - Annual expenditures for Corps of Engineers hydropower, by Division (source: unpublished Corps data).

Based on budget allocations, Hydropower is clearly not a priority for the Corps. Its position among other missions has fallen behind both Ecosystem Restoration and Recreation in recent budgets. Nevertheless, the situation has been worse in the past; in the fiscal year 2002 budget, Hydropower received just $133 million or 4 percent of the total. Most of the growth in Hydropower budgets has been in the Northwestern Division, where work on the Columbia River projects is a high priority (Figure 2-15). Most of the Corps' 75 multipurpose reservoirs, including 353 generating units, are located in the Pacific Northwest. In total, the Corps' owns 24 percent of the hydroelectric capacity in the U.S. and generates 3 percent of the total electric power capacity in country. One way to put the Corps' hydropower budget in perspective is to calculate dollars spent per unit energy produced. If the Corps hydropower projects produce 70 TWh per year and their appropriated budget is $230 million, that translates to approximately $3.28/MWh. The EUCG (formally Electric Utilities Cost Group), an international organization that maintains current benchmarking data, has estimated the best-practices estimate of annual O&M costs at $50/MWh.

The Recovery Act has provided a significant new source of funding that may be used for some federal hydropower costs, at least in some regions that do not have authority to directly fund. For example, $34 million from ARRA are being used by the Kansas City District of the Corps to repair structural damage caused by a turbine blade failure at the Stockton power plant (Figure 2-4b).

The Corps and Reclamation have at times been accused of pursuing a strategy of "break-down maintenance," where equipment is only repaired or replaced when it fails (English, 2008). This is neither accurate nor intentional practice, but it is forced *de facto* when Congressional appropriations do not keep up with O&M needs. The accusations of a "break-down maintenance" policy illustrate some of the stresses between federal power customers, who have justifiable needs for cheap, clean energy, and the federal power producers, who have to operate with declining budgets. Finding ways to fully fund the combination of routine O&M plus modernization needed for federal hydropower projects may be the most pressing need driving improved policies and management. PMAs are required by law to sell federal hydropower at rates that end up being significantly below open-market rates. They do so in long-term contracts that cannot be easily changed. Preferred customers benefit from these relatively low rates and put pressure on the federal power producers to keep the O&M cost that factors into rates as low as possible. Congress is also part of the problem, because they routinely put language in appropriations bills that prohibit the use of federal funds to study PMA energy rates.

There is a serious need to improve how federal hydropower is funded – to find a solution will require all interested parties cooperate in achieving that goal. A range of potential solutions have been suggested over the last several decades. For example, The National Performance Review (NPR) that was initiated under the Clinton administration examined this problem and came up with the following recommendations:

1. *The Secretary should encourage Power Marketing Administrations (PMAs) in the Southeast, Southwest, western areas, and Bonneville to be more aggressive in promoting energy conservation programs with their subscriber utilities. These utilities should be permitted to sell PMAs' electric power saved under conservation programs to other*

customers. Sale of the saved PMA power should be at market rates. The preferred utilities and the Treasury should share in the proceeds from the sale of saved PMA power. The opportunity to sell PMA power at market rates should be an incentive for utilities to expand or start up new energy conservation programs with their customers.

2. *The Secretary should establish a new rate policy for PMAs in the Southeast, Southwest, western areas, and Bonneville. The new policy should require that PMAs recover full operating costs, including differentials in interest rate financing, of each PMA hydroelectric facility. Annual repayment rate studies are conducted by PMAs and can be used as a basis for analysis by DOE. By establishing PMA electrical power rates that cover all operating costs, the federal government will eliminate direct taxpayer subsidy of PMAs and also take responsible steps toward reducing the federal deficit. Debt restructuring may be considered as an alternative to rate reform.*

3. *Congress should remove the Energy & Water Development Appropriations Act prohibition against expending federal funds to conduct studies of market rates or other non-cost-based methods for the pricing of hydroelectric power by federal PMAs. Any market-based electrical rate studies conducted by DOE should be made available to the public. Any market rate studies should apply to the southeastern, southwestern, western, and Bonneville PMAs. While TVA is not a PMA, it is also protected under the restrictive legislation. In fairness, TVA should not be excluded from the study. The government needs to be able to collect and analyze market information that is necessary to carry out its mission and act in the best interest of the country as a whole. Any such studies should be conducted by DOE using available resources.*

These recommendations from a previous administration have generally not been adapted, nor are they the only approach to improving the current situation. Some customers are now providing direct funding for O&M, such as in the case of the City of Jonesboro, Arkansas (SWPA, 2008). Solutions other than rate changes are also possible, such as increasing Congressional appropriations to support direct federal funding of O&M and replacement of aging equipment. At a time of high federal budget deficits though, that will be difficult. Alternatively, there could be adjustments to the budget allocations within the Civil Works Program to increase support for the hydropower infrastructure, if that were politically possible. There is fairly wide-spread agreement that the Corps Hydropower Program is under-funded, but there is no agreement on the solution.

2.5.2 Other agencies

Aside from the operations of the PMAs that are independent parts of the department, the DOE does not directly fund the construction or operation of hydropower projects. However, even that is changing a bit with ARRA and growing budgets for renewable energy (below). Between the late 1970s and 2005, the DOE had a Hydropower Program that focused on technology development and environment mitigation (Sale et al., 2006). In fiscal year 2005, Congressional appropriations for the DOE's Hydropower Program were zeroed out, but they were restored in 2007 to establish a new Water Power Program. Budget growth for DOE has been rapid since then: $10 million, $40 million and $50 million in fiscal years 2007, 2008, and 2009, respectively.

These funds are being used to rebuild a robust, applied R&D program that covers conventional hydropower as well as newer ocean and hydrokinetic technologies (DOE, 2009).

In addition to its appropriated funds in fiscal year 2009, the DOE Water Power Program also received an additional $32 million in ARRA funds to support a new Hydropower Facility Modernization solicitation for non-federal facilities. Subsequent contracts were established at seven projects where substantial increases in hydropower generation will be achieved at costs of less than $0.04 per installed MW. These projects are providing new insights into the return on investments at existing hydropower plants.

In addition to the new Water Power Program in DOE's Energy efficiency and Renewable Energy Office, DOE's Office of Electricity Delivery and Energy Reliability received $4.5 billion in fiscal year 2009 for a new program to modernize transmission systems, enhance stability and reliability of the energy infrastructure, and conduct energy storage R&D. Interconnection of hydropower systems and other renewables will be part of this program.

Hydropower activities in other agencies such as DOE are now more relevant to the Corps, because in March 2010, a new Memorandum of Understanding (MOU) was established on interagency cooperation in hydropower. The Hydropower MOU addresses a wide range of important topics, including:

- Energy resource assessments, including new, integrated basin-scale opportunity assessments
- Improved regulatory processes and certification of environmentally compatible hydropower projects
- Technology development and deployment,
- Renewable energy integration and energy storage, and
- Information exchange.

Section 3: ALTERNATIVE PATHS FORWARD

The Corps currently has a leadership role within the U.S. hydropower industry, if for no other reason than because it is responsible for the largest share of the nation's installed capacity of hydropower (Table 1-1). The challenges and constraints facing both the Corps and the rest of the industry are formidable, as explained in Section 2. Future directions can be simplified into three strategies or paths forward: 1) maintain the status quo, 2) pursue privatization of federal hydropower assets, or 3) work aggressively to modernize the federal hydropower assets for which the Corps is responsible (Table 3-1). These strategies may not be mutually exclusive, but they are useful in illustrating the available options and associated consequences to the Corps Hydropower business. In this section, the alternatives and consequences are described with respect to the major trends affecting hydropower.

The ***Status Quo*** path would continue the current trajectory of the Hydropower Program with minimal changes in any aspect. Most importantly, Congressional budgets would most likely be flat or declining. New legislation authorizing more direct funding through PMAs would not occur, but limited agreements for direct funding from federal power customers, such as that with the City of Jonesboro (SWPA, 2008), would provide some of the additional funding needed for O&M and equipment replacements. However, because total funding would not keep up with program needs, the Status Quo strategy is not sustainable in the long term.

The ***Privatization*** path would focus on finding non-federal sources of funding and, where possible, transferring hydropower assets from the federal to the private sector. This strategy is worth discussing here because it is often suggested as the solution to shortfalls of public funding. Asset transfers and other aspects of this path are problematic for many reasons. However, the fact that there already are approximately 90 non-federal hydropower plants licensed by FERC and operating at Corps dams means that joint operations are feasible. Nevertheless, some very contentious legislative and policy changes would be needed if this path were to be successful.

The ***Modernization*** path may also require significant changes in authorities, financing, and management, but it has the best chance of long-term success. The Corps has already embarked on one modernization initiative, the HMI, that is conducting a risk-based assessment of the net benefits of new hydropower investments (MWH, 2009), but the HMI is only part of the Modernization path envisioned here. Many other aspects are part of this path, ranging from finding new sources of funding to full implementation of the new Hydropower MOU with the DOE and DOI.

Some of the key features of these three paths are listed in Table 3-1. More details are presented in the remainder of this section.

Table 3-1 - Summary of key aspects of alternative strategies for the future of the Corps hydropower program (see text for details).

Aspect of the Paths	**Alternative Paths Forward**		
	Status Quo	***Privatization***	***Active Modernization***
Partnerships	Minimal changes in directions and internal/external relations; concentration on in-house solutions via the Community of Practice (CoP).	Transfer operation and maintenance of hydropower equipment to private sector or federal power customers as non-federal owners.	Expand connections between Corps CoP and non-federal industry; work actively on all MOU initiatives to maximize interagency cooperation.
Policies and Regulation	Some improvement via MOUs but no change in 408 permitting for new development; non-federal development discouraged by lack of efficient regulation within Corps and between agencies.	New development and equipment upgrades/replacement subject to FERC licensing, led by private sector developers; conflicts possible with non-power purposes .	Update MOU with FERC; develop top-down, standard approaches for new development, especially 408; implement joint and concurrent FERC licensing and Corps permitting; new authority for direct funding from all PMAs.
Funding	Flat/declining federal budgets for O&M combined with rising costs to maintain aging equipment mean increased risk of performance shortfalls.	Increase rates to cover maintenance and replacement costs; channel new revenue through private sector to recapitalize infrastructure.	Mix of funding mechanisms including direct from both Congress and customers and a shift in internal budget allocation within Corps across missions
RDD&D	Lack of funding limits opportunities except in BPA; little technology transfer; competency and skills of staff with new technology erodes.	Rely on private sector and other agencies for all hydro R&D; continued erosion of Corps staff/capabilities.	Cooperative, interagency demonstration and testing of new technologies; active technology transfer among private and federal entities in both directions
Enabling clean energy	Operating flexibility continues to erode and ability to support does not increase; increased wear aggravates aging equipment problem.	Reinvestment from private sector expands/restores operational flexibility to maximize grid services.	Restore all assets to good condition and increase operational flexibility, subject to environmental protection; expand and restore operation of reversible turbines.
Climate adaptation	Few updates of water control plans and manuals for climate change issues; operation in reactive rather than proactive mode.	Non-power uses predominate and hydropower uses only what is available after other uses are met; climate adaptation actions only for non-power uses.	Initiate river-basin-specific planning that will provide updated Guidance Memoranda for all projects, addressing options for climate change adaptation actions and other current issues.
Predicted Outcome	Not sustainable; continued deterioration of the sustainability of Corps hydropower assets due to lack of funding; increasing risks of performance failures.	Not practical or realistic; too much new legislation would have to be passed to allow this to happen; rising power rates would be opposed by current customers.	Best prospects for success; rejuvenation of hydropower in Corps with benefits to relations with PMAs, NGOs, customers, and the national renewable energy portfolio.

3.1 Partnerships

The Corps is very experienced and successful in building partnerships, especially at the District, project, and local levels. The importance of two-way partnership is clearly established in the Corps' Partnership Philosophy. However, in the area of hydropower, there is room for improvement. Hydropower in the U.S. suffers from being split among many different ownerships, ranging from federal to non-federal, large to small, publically regulated utilities to private independent power producers (IPPs). Information flow among these different parts of the industry is not nearly what it could be. Industry-oriented research organizations, such as EPRI and CEATI (of which the Corps is currently a member), generally consider their products proprietary, which excludes those who cannot afford membership fees from new knowledge. Given the pressures from the current state of the national economy and from the competitive energy markets that are evolving, many members of the hydropower industry either cannot afford fees or choose not to pay for access to new information. The result of under-investment in R&D means that improved practices and advanced technology are not adapted quickly. Although the Corps and Reclamation have increased bilateral interagency cooperation lately, the interactions between federal and non-federal sectors is minimal, especially with regard to technology development. The industry sometimes also suffers from the "not-invented-here" syndrome, where too much time and effort is expended reinventing or reverse-engineering technology, rather than buying and adopting good ideas from others.

A Memorandum of Understanding (MOU) was established in March 2010 between the DOE, the Corps, and Reclamation to establish a new partnership on hydropower. This Hydropower MOU commits to work on a number of initiatives, including:

- Energy resource assessments, including new, integrated basin-scale opportunity assessments,
- Improved regulatory processes and certification of environmentally compatible hydropower projects,
- Technology development and deployment,
- Renewable energy integration and energy storage, and
- Information exchange.

The Hydropower MOU is a promising step in building new partnerships, but so far it has been slow to develop, in part because it is a top-down effort initiated in Washington, D.C., and staffed primarily by headquarters staff who are limited in number and burdened with many other priorities. Individual Corps District offices generally do a good job of building and maintaining partnerships in many ways, but those tend to be locally driven, not nationally coordinated.

Another important outreach activity that the Corps recently initiated is discussions with its vendor community (Roll et al., 2009). In January 2008, a discussion forum was held in Portland, OR, between Corps representatives and key manufacturers and suppliers of hydropower equipment to identify current issues and areas for improvement in commercial acquisitions. Such interactions are very commendable, but measurable actions on issues identified are even more important, and these are less apparent to date. Relations with vendors are likely to

become even more critical in the future if a new wave of development, replacement, and rehabilitation happens and demand exceeds supplies.

3.1.1 Status Quo of partnerships

The Status Quo path for partnerships would entail minimal changes in current directions and in both internal and external relations. The Corps would likely continue to rely on its internal CoP for hydropower solutions, along with their centers of expertise at their HDC and HAC. Activities under the Hydropower MOU would likely remain centered at Headquarters, limiting the benefits and contributions that could come from the distributed knowledge and experience of the Hydropower CoP. Other good partnership initiatives like the Sustainable Rivers Project would continue, but would likely be limited by tight budgets and procedural delays (e.g., slowly developing Water Supply studies such as that at the 216 Feasibility Study at the John H. Kerr project; Section 2.2.1).

3.1.2 Privatizing partnerships

Partnerships would take on a different meaning and direction in the Privatization path. If hydropower assets were transferred to non-federal owners/operators, Corps staff would have to focus more of their attention on making this transfer process happen smoothly and in a way that did not jeopardize other authorized water uses. The 408 approval process (Section 2.3.3) would be a very important step in this, requiring much more staff time both at Headquarters and in the districts. Existing power customers would likely oppose any transfers that resulted in increased costs of energy or loss of preference, so many existing partnerships between the Corps and its customers could be aggravated in a privatization process.

One program that might lead to new public-private partnerships is a recently expanded program called Energy Saving Performance Contracting (ESPC) that is managed through the DOE's Federal Energy Management Program (FEMP). ESPCs were originally designed to support energy efficiency improvements at federal facilities, but they are now applicable to improvements in renewable energy generation. In an ESPC partnership, private financing pays for improvements at a federal facility, such as a power plant, and the private sector contractors who implement the improvements are repaid by the government from future energy sales. The feasibility of such an approach at a federal hydropower project would depend heavily on how excess energy (i.e., new energy produced from efficiency improvements) is treated in existing power contracts (Section 2.5.1). Early attempts to develop ESPCs at federal hydropower plants have also run into issues of liability that are as yet unresolved.

3.1.3 Modernizing partnerships

Modernization of partnerships would mean a significant expansion in the Corps' currently existing outreach and relationship-building activities in the hydropower arena. This would require either increasing the hydropower staff at Headquarters who are active in outreach, or increasing the support to Corps staff at District and Corps labs so that they have time and assigned responsibilities for building new partnerships. As explained in the following sections, realization of the full benefits of modernization cannot be done unilaterally by the Corps; rather, diverse partnerships will be needed with other federal agencies (e.g., the MOU members), the PMAs, federal power customers, the non-federal hydropower industry, and NGOs. An active

Modernization path will require both new funding and new legislation, which will in turn require supportive constituencies.

The Corps can play a much stronger role in unifying the hydropower industry in the U.S. if it expands its hydropower partnerships. Some very encouraging movement is happening in this direction right now. This type of expanded interagency collaboration should be strongly supported and expanded to other federal organizations with hydropower involvement, such as TVA and the PMAs. Improving federal relations is necessary, but it is not enough to unify the industry. New initiatives are needed to strengthen relations among the federal sector, non-federal sector, and non-governmental interest groups. The Corps' CoP can benefit from more, two-way interactions with the private sector. At the recent HydroVision 2010 conference, an open meeting of the CoP was held with very strong attendance – such events should be repeated and expanded. More open program reviews that include stakeholders outside the Corps should be considered in order to increase feedback and participation in performance evaluations.

Additional opportunities exist within the international hydropower community. For example, although the International Energy Agency (IEA) has had a Hydropower Annex for many years, the U.S. has not been a member of it. This is unfortunate, because technology development and adaptation of advanced hydropower technologies are greater in other countries and we could learn from them. Since the DOE is the lead federal agency for IEA involvement, the lack of participation there is not directly the Corps' fault. Nevertheless, all federal agencies should expand their outreach activities both domestically and internationally in the future in order to overcome communication barriers that tend to hinder the U.S. hydropower industry.

3.2 Policies and Regulations

The magnitude of new hydropower development now envisioned by the industry and the DOE (Section 2.3.3) will not be realized unless the institutional barriers to such development are reduced. Current barriers include: the long, expensive, and uncertain licensing process for non-federal hydropower that is regulated by FERC; the energy policy incentives at federal and state levels in which hydropower does not fully participate; and the overlapping and often redundant regulatory authorities that are active in water resources management.

Although hydropower has not previously had access to the same incentives as non-hydro renewables such as wind and solar energy, that trend is starting to be reversed in some important ways (Ernst and Young, 2010). For example, both the timing limits and the hydropower eligibility for the Production Tax Credit (PTC), the Investment Tax Credits (ITC), and Clean Renewable Energy Bonds (CREBs) have been expanded with respect to hydropower this year. Hydropower has also been included in other new programs, such as the Advanced Energy Investment Credit for manufacturing facilities and the Department of Treasury grants for renewable energy projects. There is also a growing alignment of federal agency leaders in the DOE, DOI, and FERC who are committed to lowering barriers to hydropower along with those to other forms of renewable energy.

These new directions in energy policies will definitely help non-federal development activities, and many of those activities will be at federal dams that do not have hydropower, such as the Corps navigation projects along the Ohio, Missouri, and Mississippi rivers. Unfortunately, those new policies will not help with the problem of how to fund replacement, rehabilitation, and modernization of existing federal power plants (Section 2.1.2). Federal power customers are willing to fund economically justified improvements in some cases at existing federal power plants, but their funding capabilities are not likely to cover all needs.

If Congressional appropriations do not cover all equipment replacement/rehabilitation needs, the ultimate fix to the challenges of aging infrastructure at federal facilities will have to come from direct funding by federal power customers. Some solutions to this are being found, such as the Jonesboro Memorandum of Agreement in Arkansas and the SWPA region (SWPA, 2008). Congressional action may be needed to establish any new ways of doing business among the federal power producers and their customers. Two specific changes that could help this situation would be: 1) legislative changes that would allow all the PMAs to directly fund replacements from their power revenues, and 2) establishment of a trust fund within each PMA, similar to the Inland Waterway Trust Fund (IWTF), which provides funding for construction and rehabilitation of locks and dams.

An area where the Corps has administrative flexibility that could be used to streamline hydropower licensing is the process by which non-federal development at federal dams is permitted. Currently, a prospective developer must obtain a FERC license and then get Corps approval for any modifications they propose to make at the dam. The Corps and FERC are working on a new MOU to improve this process. Progress is needed in this area to handle the large number of proposed developments that are being stimulated by the push for more renewable energy.

A new type of integrated river basin planning focused on the dual objectives of energy and the environment may be arising out of the DOE Waterpower Program and the Hydropower MOU – this type of an effort could ease the regulatory burden on new hydropower development. This would be a potential new area for interagency cooperation in which the Corps could be a key player. Early discussions have started among the DOE, environmental NGOs, and industry members to evaluate the feasibility of such a new process, which might be envisioned as an expanded version of the river basin studies that are called for in the Federal Power Act. The energy issue covered would be the screening of sites for new hydropower at both new and existing locations. The environmental issues examined would be the need for and feasibility of limited dam removal and the opportunities for ecological restoration, either through operational improvement of existing facilities or new non-flow mitigation. If such planning could consolidate existing plans and lead to the identification of new, environmentally compatible development sites, then subsequent regulatory process may be facilitated. This would be similar to power plant siting studies that were done in some states (e.g., Maryland) and river basins (e.g., New England River Basins Commission) in the past. It would also be related to the watershed approach identified in the Corps' current 5-year development plan, but it goes farther than that by including new, non-federal power development issues. Creative thinking such as this is needed if the development burdens facing hydropower are to be reduced.

3.2.1 Status quo of policies and regulation

Under a Status Quo path, current efforts between the Corps and FERC to update their MOU on hydropower licensing may lead to some improvement in regulatory processes, but it is not likely to produce significant change on the requirement for 408 permitting for new development. Therefore, non-federal development of new hydropower at federal faculties is likely to continue to face serial processes of first getting a FERC license and then getting Corps approval. Such a long and uncertain process adds significant cost to developers, which is a barrier to progress (Meier et al., 2010).

3.2.2 Privatizing policies and regulation

If new development and/or equipment replacement/rehabilitation were turned over to private developers, such as in the case of the ESPC program, the two-stop process of FERC licensing followed by Corps 408 approval would continue to be required. Possible conflicts between non-federal control of power generation and other non-power project purposes would have to be carefully considered, and the liability issues of private redevelopment within operating federal facilities would have to be resolved. Working out the details of these new ways of doing business will be difficult.

3.2.3 Modernizing policies and regulation

Under an active Modernization path, many new improvements can be made in how the Corps interacts with the hydropower industry as a whole. Many of these changes can be made administratively, without the need to wait for Congressional action. These should include an updated MOU with FERC on hydropower licensing that implements a joint process for concurrent FERC licensing and Corps permitting. Standardized, top-down approaches should be developed for new non-federal projects at federal facilities, and these should be implemented through one central Corps unit in order to eliminate the variability across Districts. Progress toward that end should be measured and reported on annually. Other policy changes will require new Congressional authority, such as a mechanism for direct funding from all PMAs (next section).

3.3 Funding

Chronic underfunding of the Corps' Hydropower business line is the most problematic aspect of all the challenges currently being faced (Section 2.5). The recently completed Phase 2 HMI report (MWH, 2010) evaluated 54 of the Corps' projects and more than 1200 individual power train assets for their replacement/rehabilitation needs (BPA projects were excluded from the analysis because they are self-funded). Over a 20-year planning horizon starting in 2012, MWH estimated that if no action is taken on modernization projects, these 54 hydropower projects will incur a $7B loss of benefits, based on a risk-based calculation of net present benefits foregone through outages and equipment failure. On an average annual basis, that equates to $350M/yr of lost hydropower benefits that can be expected annually for the next two decades. Several different investment alternatives were considered to reduce risks and recover benefits in the Phase 2 HMI report, the most aggressive of which would require $3.7B of new funding over 20 years, ramping up to a sustained level of $200–260M/yr for a decade. This option would not eliminate all risks or lost benefits; it would only stabilize their growth at approximately $900M

around 2030. The most recent Congressional appropriations of only $30M/yr for construction activities is far below those investment needs. While current power customers may eventually make up some of the funding gap, federal funding will also be needed if this progressive deterioration is to be controlled or reversed.

The underfunding of Corps Hydropower has other effects beyond the risks of equipment failures and outages. It limits the availability of Corps staff to solve pressing problems, such as new relationship building, cooperative R&D, planning for climate change, and regulatory reform. When federal hydropower projects are operating reliably and generating clean renewable electricity, one of their benefits is to offset carbon emissions that would otherwise come from fossil-fuel generation. These GHG benefits apply to many people beyond just the customers who purchase federal power, and therefore some public funding is justified.

The requirement that the Corps and PMAs produce hydropower "at the lowest possible rates to consumers consistent with sound business practices" is based in the Flood Control Act of 1944 (16 U.S.C. §825s). Maintaining competitive rates sufficient to cover operating costs and repay the federal investment in the hydropower dams and transmission systems amid drought, legal challenges, and customer pressure is a significant challenge, but one more factor should be considered: that "sound business practices" should also account for the unavoidable need to replace aging equipment. Some solution to this need must be found in the next several years.

3.3.1 Status quo of funding

A Status Quo path forward for hydropower will mean flat or declining federal budgets for O&M combined with rising costs to maintain aging equipment. The customers of federal power will likely provide some direct funding for rehabilitation and replacement of deteriorating equipment, but they will not be able to provide the total investments needed to protect federal hydropower assets. In such a scenario, the current trends in low unit availability and rising forced outages will continue and worsen. Overall, the contributions that Corps hydropower could make to the nation's renewable energy portfolio will not be realized.

3.3.2 Privatizing funding

The Privatization path has the potential to find new sources of funding, which is badly needed for asset management of Corps hydropower facilities. However, if the costs for new equipment are recovered through increased electricity rates in any way, this change would likely disrupt relations with the current preferred customers for federal power (public bodies and cooperatives). Nevertheless, Privatization would be one way to recapitalize the Corps' hydropower infrastructure.

3.3.3 Modernizing funding

The Modernization path forward would most likely require a mix of funding mechanisms including direct funding from both Congress and customers and a shift in internal budget allocation within the Corps across missions. To a degree, this is already happening within the BPA region and in parts of the WAPA region. Given the current federal budget situation, it will be very difficult to get increases in the Corps' overall Civil Works budget, but the stakeholders of

Corps hydropower should mobilize to support that. A trust fund similar to the IWTF should be considered, at least for the PMAs that do not currently have direct funding authority (SWPA and SEPA), because such a mechanism could stabilize the funding available for rehabilitation and replacement. More importantly, the funding needs for replacement of aging equipment should be explicitly incorporated into the "sound business practices" that are used in setting rates for federal hydropower. Action to do that must come from the PMAs and the DOE, but the Corps could help initiate interagency discussions on the topic.

3.4 Research, Development, Demonstration, and Deployment

The full scope of technology development extends from basic research to demonstration and deployment, hence the all-encompassing term RDD&D (research, development, demonstration, and deployment). New technologies or practices do not become fully adopted until the uncertainties of costs, benefits, and effectiveness are fully understood. Resolving these types of uncertainties requires multiple demonstration and testing applications in different settings. Typically, the later stages in the RDD&D continuum are not well funded, especially when total budgets are limited. It is likely that both federal agencies and industry will be constrained by limited fiscal budgets for the foreseeable future, which means that no one entity is likely to be able to cover all of the necessary steps in RDD&D. For that reason, as well as others, significant new cooperation in technology development will be needed in the hydropower arena in the future, especially with respect to demonstration and testing.

Significant opportunities exist for developing new, more efficient technologies in hydropower, especially in areas that involve increases in both energy and environmental performance, which are critical to new development. The DOE Hydropower Program and the Corps have worked well together in the past on advanced turbine research, and they should return to that type of cooperation. The stage is set for this under the new MOU being developed by the DOE and the federal water agencies (previous section). The top-priority areas for conventional hydropower research that have been identified by the industry are in Table 3-2. Demonstrations and deployment are the most likely areas of cooperation between the DOE and other federal dam owners. The results from ARRA-funded projects may be useful in this area.

Basic knowledge-building research on environmental flow requirements is one particular area where cooperative R&D will be especially valuable (Poff, 2009). Scientific uncertainty is high in this area, especially as we are undergoing a paradigm shift toward natural flow regimes (Richter et al., 2003; Harrison et al., 2007). The biological response of fish resources to flow alternations is a long-term process that cannot be observed in a single sampling season. Simple management concepts like minimum flows and rule curves do not fit well with creating flow variability downstream, which is now recognized as important for ecological integrity. New water management approaches and operating procedures will be needed to achieve the type of flow variability that will produce more "naturalized" flow regimes. The Corps has a good start on this problem in the Sustainable Rivers Project which they have established in cooperation with the Nature Conservancy. However, in regard to hydropower, it is critical that studying energy-environment tradeoffs be a strong element of this research. Studying environmental flow

Table 3-2 - Research, development, demonstration, and deployment needs identified by the non-federal hydropower industry (modified from EPRI, 2009).

Research Area	*Description*
Technology Development	Develop, demonstrate, and deploy new turbine designs with reduced fish passage mortality
	Develop, demonstrate, and deploy new turbine designs with high efficiency aeration capability
	Develop advanced materials and coatings for turbine applications that are friction-reducing and resistant to cavitation and biofouling
Standard Practices	Develop standard practices to reduce the high cost of regulatory compliance
	Develop standard practices to optimize overall plant efficiencies and production
	Develop standard practices to optimize O&M expenses and results
Greenhouse Gas Emissions	Develop improved methodology for estimating GHG emissions from hydropower reservoirs
	Develop methodology for allocating GHG emissions across multiple water uses
Markets	Quantify full ancillary benefits of hydropower (conventional and pumped-storage), including support for other renewables
	Quantify effects of different energy market structures on ancillary benefits
	Quantify additional O&M costs to hydropower associated with providing ancillary benefits, including support for other renewables
Education	Develop cooperative efforts to establish new undergraduate and graduate education programs in hydropower
	Develop cooperative efforts to establish new primary and secondary education programs in hydropower
	Develop cooperative efforts to establish new education programs in hydropower for the general public
Environmental Issues	Develop improved methodology for establishing reasonable in-stream flow requirements, especially for peaking plants
	Develop, demonstrate, and deploy hydro-environmental technologies for aeration and fish passage
	Develop, demonstrate, and deploy systems for optimizing hydro-environmental technologies

requirements should not be just about ecosystem restoration – it should also address the problem of making hydropower operations more sustainable (e.g., Jager and Smith, 2008).

A key element in cooperative RDD&D among federal entities must be a commitment to open public information and active outreach to disseminate results to all interested parties, from

environmental NGOs to all members of the hydropower industry. If the Corps chooses to participate in private consortiums such as CEATI and EPRI, as it now does, it should take steps to ensure that research products become public. The results of cooperative RDD&D must be easily available to everyone if they are to support the rejuvenation of our industry.

Research that leads to new methods that measure the full value of hydropower is extremely important to the future success of both federal and non-federal hydropower. This will be the basis for better education and decision-making in areas ranging from risk assessments to EISs. Both the benefits and the impacts of hydropower have long-term elements that are too often disregarded in planning decisions, but this problem can be solved.

3.4.1 Status quo of RDD&D

Due to a lack of funding for Corps hydropower R&D, the Status Quo path forward would involve few new opportunities for developing new technology, except in the BPA region where the combination of direct funding and the need to protect endangered species supports and requires action. Activities such as the installation of new turbines at the Ice Harbor project on the Snake River will provide unique opportunities for new science and engineering, even under the Status Quo path. However, the full range of benefits from a proactive technology transfer program and the opportunity to gain experience and expertise with new technology will not happen under this type of future.

3.4.2 Privatizing RDD&D

Under a Privatization path, development and maintenance at Corps facilities would gradually transfer to private sector entities. This may accelerate the erosion of Corps staff capabilities with respect to hydropower technologies, but because other non-power project purposes would continue, Corps capabilities would still be required for water resource management.

3.4.3 Modernizing RDD&D

A Modernized future for the Corps would expand cooperative interagency demonstration and testing of new technologies and increase technology transfer among private and federal entities. Corps staff would be supported to interact more with the non-federal hydropower industry. The turbine survival program developed in the Columbia River system would be expanded to other regions in order to solve nagging problems such as those that are keeping some of the Corps' reversible turbines from being operated. The benefits of such new initiatives would be realized within the Corps as staff members gain new experience and expertise, and in the non-federal industry as Corps experiences with managing hydropower assets are shared.

3.5 Enabling Clean Energy

Hydropower can play an important role in supporting other renewable energy development, such as wind and solar, but it can only do so if it maintains its operational flexibility. Recent Congressional testimony by BPA illustrates this well, describing how the existing hydropower system in the Columbia River is being managed to serve as a virtual storage battery of energy that can be used when needed to balance the variable output from wind in the region (Mainzer, 2009). As intermittent renewables like wind and solar grow throughout the country, the need for

load balancing from hydropower will also grow. However, operational flexibility of Corps hydropower projects is currently decreasing, due to a combination of deteriorating equipment condition (Section 2.1) and new environmental protection requirements (ecological flow needs and fish passage requirements; Section 2.2). New pumped storage hydropower will also be a good tool in renewables integration, but only if the barriers to new development can be overcome.

The ancillary benefits of hydropower, including load balancing, frequency control, and reserve generation are very real, but they have proven difficult to measure and even harder to value and be paid for. Many Corps projects currently operate in a mode of Automatic Generation Control (AGC) whereby they directly support the stability of transmission systems. However, neither the Corps nor the PMAs receive compensation for these benefits. Available data to describe existing benefits is largely lacking, which makes progress in understanding it very difficult. Better management of ancillary benefits from hydropower is a necessary part of enabling the integration of more renewable energy. The best first step that the Corps could take in this direction is to measure and document the ancillary services that its projects are providing now, including quantifying dispatchable energy (peak versus base loads), number and duration of projects on AGC, and marketing of peak power from Corps projects. Better management of ancillary benefits, and the subsequent enabling of non-hydro renewables, can then be founded upon this information base, which does not currently exist. Compensation for the ancillary benefits from Corps hydropower may be a source of revenue that can help address the funding shortfalls discussed above (Sect. 2.5 and 3.3).

3.5.1 Status quo for clean energy

Under a Status Quo future, the full ancillary benefits of Corps hydropower will not be realized, because operating flexibility is likely to decrease. The existing Corps projects with reversible turbines will not be brought into full operation, because the necessary funding will not be available. Many Corps projects will remain on AGC, but the associated increased in wear on equipment will incur additional O&M costs, further aggravating funding problems.

3.5.2 Privatizing clean energy

There are undeveloped opportunities for pumped storage hydropower at some Corps projects (e.g., LBST, 2007). Under a Privatization future, new ways to develop these types of projects may be found.

3.5.3 Modernizing clean energy

Increased funding and stronger partnerships under an active Modernization path will give the Corps the resources it will need to study ancillary benefits and to find new ways to contribute to the integration of non-hydro renewables into the grid. All existing reversible turbines at Corps projects will be brought into full operation. A new Corps R&D program on ancillary benefits should focus on first measuring current benefits, and then better managing them. The DOE WaterPower Grid Services project is one specific research activity that the Corps should join as soon as it can.

3.6 Preparing for a changing climate

Improving water management practices, including those at hydropower projects, in order to be prepared for climate variability is a win-win prospect, because even if climate change does not occur as predicted, the resulting better management practices will allow available water to be put to the best uses. Too many of the Corps' Operating Manuals are out of date, which risks operational decisions based on outmoded information. For example, in the case of Buford Dam in the ACT river basin (Section 2.2.1), the Operating Manual has not been updated in 50 years or more. Many things have changed in 50 years, ranging from the growth of water needs to our understanding of climate variability and change.

The November 18, 2009, court decision that found the Corps liable for improper maintenance of the Mississippi River–Gulf Outlet may have implications for how the Corps addresses climate change in its planning documents. In the past, the Corps did not consider climate change impacts in its policies or project planning. Because of this court case, it may have to do so.

The fact that the Corps has established a technical group to work on adaptation to climate change and, more importantly, that it has allocated substantial funding to this work (Section 2.5.1) is encouraging. Additional information will come from the Section 9505 study led by the DOE on the effects of climate change on federal hydropower operations. However, the questions remain, will the current research activity be put into practice, and if so, when?

3.6.1 Status quo relative to climate change

The Status Quo path would most likely mean that there would be few updates of water control plans and manuals for climate change issues and changing hydrology. Reservoir operations would generally continue in a reactive rather than proactive mode. Without updates of water control plans, the risks of surprises from extreme hydrology and competing water uses will be much higher.

3.6.2 Privatization relative to climate change

A Privatization path would not likely change current water management practices at Corps facilities in preparation for a changing climate, because such operational change would still require federal studies of non-power water uses. A disengagement of federal interests in hydropower at Corps dams would tend to increase the priority of non-power uses and could end up being counterproductive to energy interests.

3.6.3 Modernization relative to climate change

The Modernization path forward would mean that sufficient work priority and funding resources would be dedicated to not just research but also to the application of knowledge on changing hydrology. The Corps could initiate river-basin-specific planning that would provide updated Guidance Memoranda for all projects, addressing climate change adaptation actions and other current issues.

Under an active Modernization path, the Corps should begin a national effort to update all Operating Manuals, not just for climate variability and change, but also for current and future

economic conditions and water needs. Corps policies and procedures require that water control plans and manuals be kept up to date [ER1110-2-240, section 6 (USACE 1982 updated 1987, 1994)], and Section 8(b) of that ER requires a Guidance Memorandum for each reservoir/water control center that should be updated every 10 years to ensure that it meets current needs. Although these documents are not always kept up to date, progress is being made in that direction. Unfortunately, it is a slow and expensive process. Nevertheless, it should not be put off simply because it is too hard to handle. The Corps should consider committing to a comprehensive schedule that would move through all river basins at a fixed pace in order to ensure that all basins are addressed over a 10-15 year period. Because the operation of multipurpose projects will determine generation outputs, the updating of Guidance Memoranda should be coordinated with the long-term power sales contracts by the PMAs.

3.7 Predicted Outcomes of Alterative Paths

The Status Quo path into the future is not sustainable, primarily because funding is insufficient to keep up with the growing replacement needs for the Corps hydropower infrastructure. If no explicit decisions are made to pursue either Privatization or Modernization, it will in effect be a decision to maintain the status quo. Federal budgets will continue to decline, and no new authorities for direct customer funding will be established. If that happens, the current patterns of deteriorating performance are likely to continue. Federal hydropower will become even more of a low-priority byproduct of federal IWRM, rather than the highly valued renewable that it should be and was when the projects were originally constructed.

The Privatization path has many serious problems inherent to it, which make it impractical and unrealistic given the complexity of the Corps' multiple-use responsibilities. New legislation would be needed to deauthorize hydropower operations at many projects. Long-term federal power contracts would have to be phased out over time, and the loss of relatively cheap hydropower to preference customers is likely to be strongly opposed politically.

The best and possibly the only responsible path forward for Corps Hydropower is a very active and aggressive Modernization process. However, this cannot be implemented unilaterally by the federal agency. Key elements of this path include finding new funding sources and getting new legislation passed for direct funding from customers through the PMAs. A strong and diverse political constituency for the changes required to fully implement Modernization will be needed to achieve success on this path. There are common interests that can be used to support the diverse constituency needed: for example, if advanced technologies with new environmental benefits are deployed in Modernization, then environmental NGOs may contribute new support. The new Hydropower MOU also offers hope that the DOE can step in to play a constructive role in building this new path forward, especially if federal water projects can be reoperated to support new renewable, non-hydro energy sources. The Modernization path offers substantially more benefits than the others, but it will require new partnerships and a long-term commitment to change.

Section 4: CONCLUSIONS

Fifty years ago, the hydropower industry in the U.S. was in the midst of a unique period of expansion. Today, the industry is in another unique period, with extraordinary opportunity as well as major challenges. Driven by the current interest in renewable energy sources, federal support for hydropower is greater than it has been since the growth periods of the 1950s and 1960s. The hydropower industry has set a strategic goal of doubling generation from hydropower by 2030, and there is strong support for that type of goal in other federal agencies and in industry. National energy planning is seriously looking at such ambitious objectives as providing 80 percent of the nation's electricity from renewable sources – and hydropower is in that mix.

All parts of the hydropower industry must work together if we are to take advantage of the current opportunities. If we cannot do so, we are likely to return to the downward trends that we have seen in recent years (Section 2.1). If we step up and embrace these opportunities, then hydropower has a bright future as part of renewable energy portfolios across the U.S. in the next century. The path forward depends in large part on whether we can learn lessons from the past half-century and find ways to make hydropower compatible with the environment and to become more competitive with other energy sources.

The Corps' current vision with regard to hydropower is to "be the premier stewards of entrusted hydropower resources " (http://operations.usace.army.mil/hydro.cfm). Their mission is to provide reliable power services at the lowest possible cost, consistent with sound business practices, and in partnership with other federal generators, PMAs, and preference customers. This vision and mission are challenging, but they may not be challenging enough to capitalize on all the opportunities of today or to overcome today's challenges. For example, there is no reference to the rest of the non-federal hydropower industry or to all of the governmental and non-governmental environmental interests that are involved with hydropower and other water uses at federal facilities.

Judge Paul Magnuson said recently, "The problems faced in the ACF basin will continue to be repeated throughout this country, as the population grows and more undeveloped land is developed. Only by cooperating, planning, and conserving can we avoid the situations that gave rise to this litigation." This is a serious warning that should not be ignored. The brightest future for Corps hydropower lies in stronger partnerships on funding solutions and in operational improvements, including the application of advanced technologies that offer improved energy and environmental performance.

Section 5: REFFERENCES

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Appendix A. Glossary and Acronyms

ACF	Apalachicola-Chatahoochee-Flint river basins in Alabama, Florida, and Georgia
ACT	Alabama-Coosa-Tullapoosa river basins in Alabama and Georgia
ACT Alden-Concepts	Turbine
AGC	Automatic Generation Control
APC	Alabama Power Company
ARRA	American Recovery and Reinvestment Act
ASCE	American Society of Civil Engineers
ASTM	American Society of Testing and Materials
BPA	Bonneville Power Administration
CDM	Company name; not an acronym
CEATI	Centre for Energy Advancement through Technology Innovation
Corps	U.S. Army Corps of Engineers
CoP Community	of Practice
CFR	Code of Federal Regulations
CREBs	Clean Renewable Energy Bonds
CV	coefficient of variation, generally the standard deviation divided by the mean
DOE	U.S. Department of Energy
EAC	Electricity Advisory Committee for the U.S. Department of Energy
EIA	Energy Information Agency, a branch of the U.S. Department of Energy
EIS	Environmental Impact Statement
EPRI	Electric Power Research Institute
ESA	Endangered Species Act
ESPC	Energy Saving Performance Contracting, a program of the U.S. Department of Energy
EUCG	Organization name for EUCG, Inc. (formerly known as the Electric Utility Cost Group)
EWN	Energy- Water Nexus, a term referring to the interrelations between water resources and energy production
FEMP	Federal Energy Management Program
FERC	Federal Energy Regulatory Commission
GHG greenhouse	gas
GW gigawatts	
GWh gigawatt-hours	
GWP	Global Water Partnership
HAC	Hydropower Analysis Center, part of the U.S. Army Corps of Engineers
HB	Headwater Benefit Program of the Federal Energy Regulatory Commission
HDC	Hydroelectric Design Center, part of the U.S. Army Corps of Engineers
HMI	Hydropower Modernization Initiative of the U.S. Army Corps of Engineers

hydroAMP	Hydropower Asset Management Partnership, including the U.S. Army Corps of Engineers, the Bureau of Reclamation, Bonneville Power Administration, and HydroQuebec
IEA	International Energy Agency
IHA	International Hydropower Association
IJC	International Joint Commission
IPP	Independent Power Producer
IRP	Integrated Resource Planning
ISOs	Independent Systems Operators
ITC Investment	Tax Credit
IWR	Institute for Water Resources, part of the U.S. Army Corps of Engineers
IWRM	Integrated Water Resources Management
IWTF	Inland Waterways Trust Fund
kWh Kilowatt-hours	
LCIA	Life Cycle Impact Assessment
LIHI	Low Impact Hydropower Institute
LIP	Lake Improvement Program of the Tennessee Valley Authority
M&I	municipal and industrial, as in water uses
mgd	million gallons per day
MOU	Memorandum of Understanding
MW megawatts	
MWH megawatt-h	ours
NCST	National Science and Technology Council
NERC	North American Electric Reliability Corporation
NGO Non-govern	mental organization
NOAA	National Oceanographic and Atmospheric Administration
NPR	National Performance Review, a Clinton Administration initiative
O&M	Operation and maintenance
OMB	Office of Management and Budget
ORNL	Oak Ridge National Laboratory
OSTP	Office of Science and Technology Policy
PG&E	Pacific Gas and Electric Company
PJM	PJM Interconnection, a regional transmission organization in mid-eastern U.S.
PMA	Power Marketing Administrators
PPL	Company name; not an acronym
PSH	Pumped storage hydropower
PTC Production	Tax Credit
R&D	research and development
RDD&D	Research, development, demonstration, and deployment
Reclamation	Bureau of Reclamation, part of the U.S. Department of Interior
RTO	Regional Transmissions Operator
SCS	Scientific Certification Systems
SEPA	Southeastern Power Administration

SRP Sustainable Rivers Project
SWPA Southwestern Power Administration
TNC The Nature Conservancy
TSP Turbine Survival Program
TVA Tennessee Valley Authority
TWh Terawatt-hours
UNESCO United Nations Environmental
USACE U.S. Army Corps of Engineers
USC United States Code
USGS U.S. Geological Survey of the U.S. Department of Interior
WAPA Western Area Power Administration

Water Resources Outlook

IWR Future Directions

IWR's Future Directions program activities include the identification of emerging water challenges and opportunities and the tactical engagement of USACE senior leaders on these issues. Such critical thinking is seen as an essential prerequisite to strategy development and planning.

IWR employs a variety of approaches to encourage strategic thinking, including the development of Water Resources Outlook papers and the conduct of topic specific and broad strategy provocation sessions with senior leaders from the U.S. Army Corps of Engineers and the Office of the Assistant Secretary of the Army for Civil Works.

Future Directions activities include:

Engaging Senior Leaders
Strategic Planning
Policy Development

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