REALLOCATION OF FEDERAL MULTIPURPOSE RESERVOIRS: PRINCIPLES, POLICY AND PRACTICE

George F. McMahon[1] and Michael C. Farmer[2]

AUTHORS: [1]Associate, Camp Dresser & McKee, 2030 Powers Ferry Road, Suite 325, Atlanta Georgia; [2]Assistant Professor, School of Public Policy, Georgia Institute of Technology, Atlanta, Georgia.
REFERENCE: Proceedings of the 2003 Georgia Water Resources Conference, held April 23-24, 2003, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Abstract. Most federal reservoirs placed in operation throughout the United States over the past 50 or 60 years serve multiple objectives, typically flood control, hydropower, navigation, recreation, water quality protection, irrigation and municipal and industrial (M&I) water supply. In the initial reservoir planning and design stage, federal agencies such as the U.S. Army Corps of Engineers (USACE) or the U.S. Bureau of Reclamation (USBR) decide on the scale of the project to be built based on demands for water and storage that prevail at the time and are expected to prevail after construction. A critical step in the planning process is the development of operating rules designed to conjunctively meet these many demands given the scope and scale of the existing project. One of the criteria applied to formulate such operating rules is contribution to National Economic Development (NED).

In the decades since their initial construction, relative demands for various services provided by federal reservoirs (expressed as society's willingness to pay for those services) have changed, in some cases substantially. These changes may prompt reallocation, or modifications to reservoir operating rules that better satisfy the more valuable emerging uses. Needed operational changes sometimes come at the expense of less valuable uses, even though these less valuable uses may constitute originally-authorized purposes of the project. Irrespective of any rights to water and/or to storage conveyed by federal law, significant questions of fairness (equity) and of economic efficiency arise with respect to the distribution of project benefits, costs and environmental impacts that occur if society chooses to reallocate or chooses not to reallocate. Fairness questions center on intergenerational equity and on sustainability while efficiency questions center on net economic surplus, or net benefits, aggregated across project uses. The authors examine as a case study the pronounced shift in public demand from hydropower to M&I water supply in the southeastern United States, to illustrate the potential disparities between the overarching principles that guide federal planning and the policies and procedures historically (and often successfully) used in practice to implement small, incremental reallocations. The normally small differences between objective principles and practical outcomes can accumulate over time to unacceptable proportions, foreclosing options for adaptive management of the nation's water resources infrastructure and threatening sustainability, equity and efficiency as a consequence.

INTRODUCTION

Over the past several decades federal water resource development agencies, particularly the U.S. Army Corps of Engineers (USACE), have come under increasing attack from various sectors for their management of the nation's water resource infrastructure. New economic, environmental and cultural demands have evolved since initial construction of multipurpose reservoirs that continue to supplant many of the original uses (purposes) many of these projects were built to serve. Federal water projects are in large part victims of their own success, as the economic growth induced by rural electrification, waterborne commerce, flood control and water supply has allowed society to afford new concerns for the environment and demands on water and storage largely unforeseen in their initial formulation.

Reallocation is an adaptive management mechanism better suited to reservoirs than to other types of public works infrastructure such as roads and bridges because

the uses to which reservoirs are put can change by simply changing the manner in which they are operated, a flexibility that may forego the need for structural modification. In practice, the measure of an operational shift is gaged normally by the amount of reservoir storage reallocated to various purposes; ideally, costs of reallocation should be apportioned based on storage dedicated to individual (separable) and common (joint) purposes. When it becomes apparent that demands on federal reservoirs have materially changed, the following questions arise:

- Whether the National Economic Development (NED) objective, defined in *Principles and Guidelines* (P&G) (USWRC, 1983) as "...increases in the net value of the national output of goods and services ... following project implementation" is relevant to reallocation of existing federal projects in the same way it has historically justified the construction of new projects;
- How NED and Environmental Quality (EQ) objectives factor into the Corps of Engineers' recently-articulated planning criterion (USACE-IWR, 1999) of Environmental Sustainability (ES), loosely defined as a "balancing of economic and environmental objectives;"
- At what point procedures governing incremental reallocations cease to be 'good enough' for equitable and efficient distribution of the benefits and costs of reallocation;
- Whether compensation by added or expanded purposes for reallocation is efficient or fair, and
- Whether the adaptations in management from reallocation contribute to sustainable water resource management, or conversely whether the costs of not reallocating are potentially unacceptable or cause irreversible harm.

Arguably, adaptive strategies to derive the greatest net economic benefit from the existing water resources infrastructure also can be the most sustainable management strategies, particularly if water and storage demands unmet by an economically inefficient operation must be supplied by constructing and operating new reservoirs, by creating new sources of supply by means of inter-basin transfers, or by severely curtailing demand. Each of these alternatives to reallocation likely contributes to a less equitable distribution of the economic burdens when less valuable uses enjoy disproportionate benefits, to larger and potentially irreversible environmental damages, or to other externalities and transboundary impacts. In those cases where a mere shift in operating rules avoids these costly alternatives to meet demand, failure to reallocate commits federal water projects to protect increasingly obsolete purposes at ever greater expense.

The goal of this research is to encourage Federal agencies to exploit reasonable opportunities to operationalize the guiding principles of federal planning traditionally applied to the formulation of new projects, and to apply these same principles to the reformulation of existing projects. When this avoids new capital-intensive responses to meet changing water demands, reallocation has the potential to conform to commonly-accepted notions of sustainability, conservation and conjunctive use in which social welfare is maintained or improved. Simply, the system uses fewer resources and consequently incurs lower social and environmental costs; so while efficiency, equity and sustainability are not always congruent social goals, reallocation is one instance where improvement to all three objectives is possible. For this reason, we argue that reallocation has the potential in many cases to be relatively free of controversy.

Lack of consensus on objectives often prevents full economic optimization except in the rarest and simplest cases. Planning is conducted increasingly by an iterative search for solutions acceptable to the greatest number, but not necessarily optimal to any. The rationale for accepting such a solution is usually a perceived equitable sharing of costs and benefits rather than maximization of any individual objective. Iterative extended-rational processes of this kind are known as *satisficing* processes (Pearce and Turner, 1990), and decision tools for evaluating alternatives are known as *satisficing models*. In the case of reallocation, a satisficing approach is unlikely to maximize economic welfare, sustainability or equity objectives but, as the name implies, may achieve a satisfactory compromise between them.

An increasingly important benefit of satisficing processes is that they reduce tensions and, we argue, reallocation provides better opportunities for tension-reducing consensus than other more structural approaches to meeting changing water demands. As an example, extensive research has shown that very modest reductions in system-wide hydropower benefits result from an operational shift from peaking to more continuous power generation at federal multipurpose

reservoirs in the Apalachicola-Chattahoochee-Flint, Alabama-Coosa-Tallapoosa, and Savannah River Basins (McMahon 2001). Yet these modest operational changes in the form of relaxed firm power commitments may satisfy a generous variety of instream flow uses by the States of Georgia, South Carolina, Alabama and Florida without drastic curtailments in more critical demands, i.e. those uses of water and storage for which no viable alternative supply sources exist. From a benefit-cost perspective, reallocation is clearly warranted, but fairness and equity gains emerge as well with relatively modest tradeoffs—losses to other concerns that can be compensated if necessary to achieve consensus. Reallocation arguably overcomes obstacles to consensus because it embeds three attractive qualities: (1) it is purely operational and non-structural, (2) it is reversible, i.e. can be undone at any time by reverting to the original operating rules and (3) it is adaptable, i.e. amenable to further operational changes as social preferences change in the future.

Failure to undertake reasonable reallocations leaves federal agencies vulnerable to charges of aimless and arbitrary practices that are out of step with the new world of environmentalism and sustainable development. Alteration of instream flows is the most common environmentalist complaint against large dams, rejoined by economists who freely challenge the relevance of federal water management practices and planning guidelines that largely exclude environmental quality from consideration as an economic good (Zilberman, 1994a; 1994b). These are serious charges to federal agencies responsible for a massive infrastructure that engages most regions and sectors of the American economy. Nonetheless the scope of federal concerns—flood control, hydropower, navigation, recreation, municipal and industrial water supply, water quality, and agricultural irrigation—has always been comprehensive and long-term, characteristic of integrated planning and sustainable water resource development. The tenet that reallocation can be approached with the same logic that applies in original project formulation may be something agencies choose to adopt on their own prerogative or as directed by Congress, whichever is appropriate. In either case, the changes are not so sweeping as to fundamentally alter the guiding principles of federal planning, since the changes themselves are drawn from principles that exist already and are merely extended to more decisions with potential to reduce controversy over federal water resource management in the process.

PRINCIPLES GUIDING FEDERAL WATER RESOURCE DEVELOPMENT

Most federal reservoirs constructed during the early and middle years of the last century were dedicated primarily to flood control, hydropower, and inland waterway navigation, with other purposes such as recreation and water quality benefitting more or less incidentally. While the importance of flood control has not abated and may have even increased in some areas, rural electrification and integration of energy markets in recent years have leveled the peaking increment of the load curve served by hydropower installations in the southeastern U.S., and have created cheaper substitutes for hydroelectric capacity as well. Overall, the share of the total load shouldered by hydropower has declined in all regions of the country as hydropower resources remain relatively fixed while demand for electricity grows. Growth of alternative modes of shipping and the increased expense and environmental opposition to channel maintenance dredging have diminished barge traffic, and inland waterways are generally relegated to transporting bulk cargo and large equipment impractical to move by truck or rail. While hydropower and navigation decline in importance, population growth in urban centers has created huge regional demand for municipal water supply and instream flows for waste assimilation. Highly productive and water-intensive farming practices have in many areas increased the irrigation demand. Public awareness of the essential role water plays in ecological diversity is also growing, adding to demand for higher instream flows for waste assimilation. Finally, a burgeoning recreation industry has grown around many of the largest federal reservoirs, augmenting the regional and national economic development contributions of these projects. Taken together, these shifts in public preferences in many cases overwhelmingly dictate modifications to reservoir operating rules and priorities.

Post rural electrification, the growth in demand for municipal and industrial (M&I) water supply relative to hydropower and other original purposes became apparent. Even before the end of World War II, the Flood Control Act of 1944 (FCA44 - P.L. 78-534, 1944) permitted “surplus storage,” i.e. unused storage or storage reserved for as-yet unrealized future demand

growth to be temporarily used for other purposes, including M&I water supply. Unfortunately FCA44 made no provisions to permanently include or allocate project costs to a water supply purpose, either when formulating new projects or when reformulating existing projects. The proliferation of FCA44-authorized reservoir withdrawal permits issued by the Corps and other federal agencies with little in the way of cost recovery fostered the perception of water supply 'freeloading,' principally at the expense of hydropower. The Water Supply Act of 1958 (WSA58 - P.L. 85-500, 1958) was widely viewed as an attempt to close this loophole through a series of procedural rules that, while not entirely consistent with the broader NED objective of the P&G, did allow small and permanent increments of storage to be reallocated from hydropower to water supply while recovering some project costs formerly assigned to power. We view WSA58 as one of a series of incremental attempts to update and resolve practical questions of the time rather than as a sweeping reversal in federal policy. This view is reinforced by examination of policies governing implementation of WSA58 (USACE, 1990) that prescribe practical cost-recovery mechanisms for small reallocations while leaving untouched the cost allocation procedures for formulation of new projects.

To date the rules and procedures adopted to implement WSA58 have proven adequate in most instances of incremental reallocations; yet we charge a rigid adherence to the same rules in the face of a more substantial shift in operational priorities potentially leads to seriously inefficient and inequitable outcomes inconsistent with overall P&G objectives. That is, a satisficing practice for small reallocations can lead to highly unsatisfactory outcomes for some of the more comprehensive re-orderings of operational priorities looming today. The digression is due to several factors, beginning with the emphasis on power benefits as the total measure of reallocation impact, compounded by oversimplified procedures for evaluating power benefits foregone due to reallocation. More serious, however, is the subsequent failure to simultaneously apply updated benefits accruing to all purposes to reapportion project costs, using the procedure central to the P&G known as the *Separable Costs Remaining Benefits* (SCRB) method (Federal Interagency River Basin Committee, 1950; 1958, a publication sometimes referred to as the "Green Book").

The potential divergence between the P&G intent and WSA58 results requires a brief overview federal planning principles and the role of NED and other considerations in planning. The principle objective of federal water resource development defined in the P&G evolved from an embryonic quality of life statement in the Green Book, to NED as a co-equal objective with environmental quality in *Principles and Standards* (USWRC, 1971), to NED alone in the P&G, subject to legal and policy constraints:

> *"The Federal objective of water and related land resources project planning is to contribute to National Economic Development consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements."*

The following accounts are identified in the P&G, effects of which are used to compare alternative project implementation plans:

- The National Economic Development (NED) account displays changes in the economic value of the national output of goods and services [following project implementation].
- The Regional Economic Development (RED) account registers changes in the distribution of economic activity, i.e. income and employment.
- The Environmental Quality (EQ) account displays non-monetized effects on ecological, cultural, and aesthetic resources.
- The Other Social Effects (OSE) account includes relevant plan effects not included in the other accounts, e.g. community impacts, health and safety, displacement and resettlement, and consumption of energy and materials.

The recently-proposed Environmental Sustainability (ES) criterion has not yet been sufficiently defined to identify the types of effects that might be included in an ES "account."

The importance of SCRB to formulation of new projects and to reallocation of existing projects lies in its stated objective of "...all purposes sharing equitably in the benefits of multipurpose development," premised on the assumption that most purposes served by large reservoirs are to some degree conjunctive, and that economies of scope and of scale are achieved by large dams that serve multiple purposes compared to a series of smaller dams that each serve fewer or single

purposes. This notion can reasonably be challenged as well as defended on economic and environmental grounds (Takeuchi, 1997a; 1997b), to the degree that the cumulative economic and environmental impacts of large projects can be shown to be better or worse than a series of smaller projects. Setting aside this debate, proper application of SCRB prevents cross-subsidy among purposes, and ensures the cost to any purpose that participates in a multipurpose project does not exceed the go-it-alone cost to develop a separate project serving that purpose. The SCRB procedure consists of the following steps:

(1) Each included purpose is first allocated its separable costs, i.e. the specific costs to add that purpose;

(2) NED benefits, measured by public willingness-to-pay (WTP) for service but limited to lowest-cost alternative replacement, are assigned to each purpose, and

(3) Joint costs, i.e. the costs of facilities serving multiple purposes (e.g. dam, embankments, spillways, etc.), are apportioned among all purposes based on benefits (NED benefits minus separable costs) remaining to each.

Within the SCRB framework, economic efficiency is achieved when the marginal cost of adding new purposes or of increasing levels of service of existing purposes just equals the marginal gain in NED benefits. Project scale grows to accommodate expanded scope, i.e. each added purpose. By requiring that separable demand for each added purpose exceed the cost of the addition, SCRB ensures that no purpose subsidizes any other and that the costs of facilities are equitably allocated. To revise uses post-construction requires that any new or expanded purpose that reduces the capacity of the project to serve the original purposes must demonstrate a greater marginal gain in NED benefits to justify the reallocation.

The link between SCRB, traditional engineering economy, and neoclassical notions of economic efficiency is shown in Figure 1. Proper application of SCRB ensures a multipurpose project ideally will be sized so that the composite demand curve for all purposes (hydropower, navigation, etc.) intersects both marginal and average total (separable and joint) cost curves for the project. This illustrates the engineering economy property of lowest average cost of service as well as the correspondence of the P&G with various renditions of public goods in welfare economics.

An efficient initial allocation or reallocation locates the demand curve where the average cost of supply intersects composite demand at its lowest point for the project size.[1] The more conjunctive the uses of storage, the lower the costs of supply and the greater the net NED benefits or consumer surplus at the optimal scale, represented in Figure 1 by the differential area between the demand and supply curves. The goals of efficiency and equity embodied in the SCRB criterion that no purpose subsidize another are grounded in microeconomic theory as well. For the economist, the delivery of a good at the lowest point on the average cost curve has a special meaning. By definition, the bottom of the average cost curve intersects the marginal cost (or supply) curve for the dam, so storage initially allocated or later reallocated in accordance with SCRB assures supply equals demand, the basic condition for economic efficiency. It is unlikely, we argue, that this efficiency mechanism provided by SCRB is accidental as the WSA58 preamble in fact cites the NED-

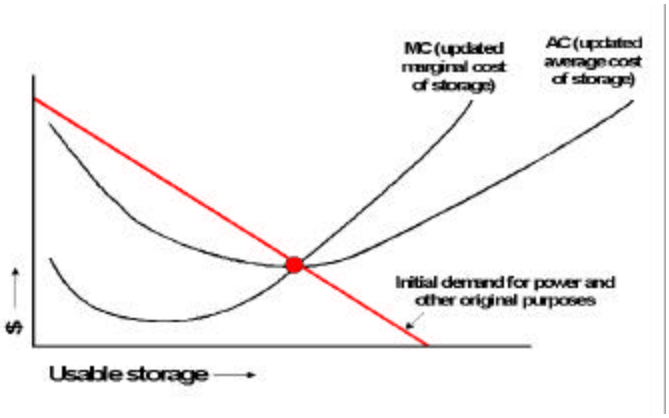

Figure 1. Initial reservoir storage allocation following SCRB.

[1]The envelope theorem assures that an array of annual cost (*AC*) curves enveloped within a large, long-run average cost curve touches the enveloping *AC* curve at just one point. In competitive markets, each supplier will realize the bottom of the long-run *AC* curve eventually. If there are few suppliers for a congestible good such as water supply provided by a federal dam, then the choice of scale is not necessarily the largest feasible project, a circumstance which in private markets drives oligopoly and monopoly formation. For public projects, the optimal size is a choice variable which, correctly chosen, scales up a project to where the average cost curve bottoms out at the intersection of the composite demand curve for all project outputs.

maximizing and equitable-sharing objectives of SCRB directly, a strong measure of the original intent of the legislation with respect to reallocation.

Application of SCRB assumes NED to be the sole objective of federal planning, with EQ—principally NEPA compliance (P.L. 91-190, 1970; USACE, 1988)—the primary constraint. The incipient ES criterion, calling for a balancing of NED and EQ considerations, appears on face to call this paradigm into question. However, because NED is a welfare-maximizing objective and SCRB provides a practical framework to achieve economic efficiency and equity, these objectives are likely to continue to play meaningful roles in future planning for sustainability, reasoning that efficient and equitable allocation of resources in the present is essential to maintaining the overall level of welfare in the future. And because democratic societies favor markets over authoritarian rules to allocate scarce resources, the most valuable economic uses of water and storage (usually those for which no good substitutes are available) will and should continue to prevail in selecting among alternative plans, possibly including reallocation, conservation, water imports/exports, or construction of new reservoirs. Where growth in M&I demand cannot be offset by conservation alone, a comparatively minor loss of hydropower benefits might make reallocation in combination with conservation an attractive alternative to the huge economic, environmental, and regulatory compliance costs of interbasin transfers and/or new reservoirs. An accurate determination of NED benefits provided by all purposes, followed by an updated SCRB cost allocation should lead to this same conclusion, i.e. that adaptive reallocation is the economically and environmentally preferable course of action that satisfies the ES criterion at least in a qualitative sense. The maturation of techniques for environmental valuation, moreover, may allow integration of environmental values in the NED account, and NED–EQ tradeoffs to be defined to a greater degree than they have historically been for evaluation of alternative plans (Stakhiv and Major, 1997).

POLICIES AND PROCEDURES FOR IMPLEMENTING REALLOCATION

While the preamble to WSA58 restates the equitable-sharing goal of SCRB, the legislation curiously does not mandate SCRB be applied to reallocation from hydropower to M&I water supply contemplated in the law. Instead, a simplified procedure was specified and subsequently codified in federal planning guidelines (USACE, 1990, *Op. Cit.*). The simplified procedures were justified by the need to avoid Congressional referral on minor reallocations and the difficulty of obtaining separate appropriations for detailed studies required to re-evaluate project benefits and to reallocate project costs. The simplified procedures, typically applied to small reallocations of. less than 50,000 acre feet or 15% of usable project storage, require compensation from new water supply users based on the highest of the following four costs:

- Revenues foregone from sale of power, equivalent to original amortized costs of storage
- Benefits foregone by power due to water supply
- Replacement costs of power, equivalent to benefits foregone
- Updated costs of storage reallocated.

The highest of the four costs is normally either power benefits foregone due to water withdrawals or updated replacement costs of storage reallocated in this case from power to water supply. Revenues foregone represent the extended amortization of original project costs allocated to power due to power sales reduced by additional water withdrawals. While the highest-cost criterion bears little resemblance to SCRB objectives, Figure 2 shows that the deviation between required compensation by water supply based on WSA58 criteria compared to an updated SCRB analysis can be small if the scale of the proposed reallocation—represented by the portion of storage space to be reallocated—is also small. In Figure 2, with total storage fixed and hydropower demand having declined over time (McMahon, 2001, *Op. Cit.*), NED benefits are maximized only when the encroaching water supply purpose shoulders the *updated* hydropower benefits foregone due to water supply, represented by area *A* in Figure 2. If power NED benefits are not updated, then compensation for benefits foregone is based on original power benefits, now inflated relative to current benefits, or areas $A + B$. Compensation for updated cost of storage in this case is represented by areas $A + B + C$ in Figure 2. Because of inflation, revenues foregone reflecting original costs of storage would never exceed present (updated) costs of storage and thus would never control.

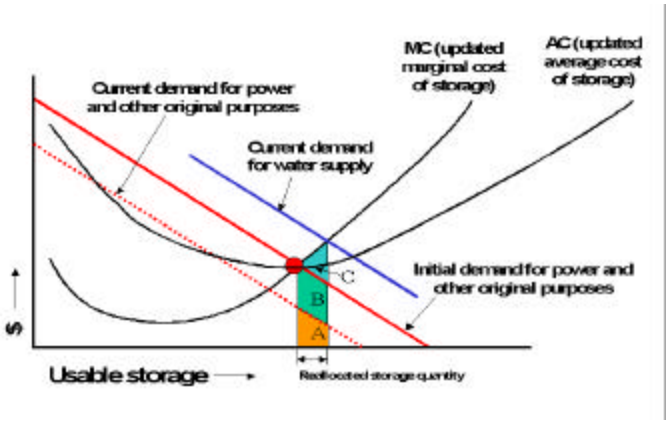

Figure 2. Reallocation cost assessment based on WSA58 procedures.

Inequitable price discrimination—whereby the last added user (water supply) is charged a higher marginal rate for storage than the first (hydropower)—is one consequence of the simplified WSA58 rules. Another issue in general arises out of compensation by water supply to power, a direct transfer of benefits amounting to a subsidy of power by water supply. There is no corresponding compensation of water supply benefits foregone due to power generation, for example. For small reallocations, these incongruities may be tolerable and even desirable if they avoid expensive reallocation studies likely to produce only small efficiency gains. For larger reallocations, however, these differences can rise to a level that significantly compromises the NED objective defined in the P&G and damages the equitable-sharing provisions of SCRB as well.

Policies to implement WSA58 are reasonable when the reallocation storage quantity is small because areas *A*, *B*, and *C* in Figure 2 are also small. These policies also allow reallocations to proceed without a comprehensive re-evaluation of NED benefits and SCRB cost allocation, with the implicit assumption that if the added water supply purpose is willing to reimburse the highest of the four costs, the benefits to water supply must be greater still. For more comprehensive reallocations impacting multiple project purposes, however, the shortcomings exhibited by the simplified procedures are pronounced, summarized as follows:

- Policies and procedures for implementing WSA58 are not generalized and provide no guidance for reallocation among purposes other than from hydropower to M&I water supply.
- The highest-cost criterion diverges considerably from SCRB when the reallocated storage quantity is large, and inadequate to guide adaptive management of the project in the long term.
- Strict interpretation of WSA58 policies leave federal agencies little discretion on referrals to Congress when any original project purpose is judged to be significantly impacted by reallocation, even when no hard economic data support such a finding. Because specific or Section 216 continuing authority funding (P.L. 91-611, 1970) for incremental reallocation studies is normally inadequate for comprehensive re-evaluation of project NED benefits and SCRB cost allocations, the determination of 'significant impact' is at best an educated guess predicated on the assumption that the viability (i.e. NED benefits in excess of separable costs) of the power purpose remains essentially unchanged since project construction—an increasingly improbable prospect for many older projects.

PROJECT REFORMULATION CASE STUDY

A striking example of the urgent need for substantial revision of project NED benefits and SCRB analysis to inform reallocation is provided by Lake Lanier, a Corps multipurpose reservoir located on the Chattahoochee River that serves as the principle water supply source for the metropolitan Atlanta area. A recent re-evaluation of M&I water supply, hydropower, and reservoir recreation NED benefits (McMahon, et.al., 2001) reveals a profound shift in demands on the project since it was placed in service in 1957. Factors contributing to this shift include:

- Rapid growth in regional population and employment over the past two decades (current population over 4 million, projected to reach 8 million by 2030).
- Location of the Atlanta population center in the headwaters of the Chattahoochee and Etowah River Basins, both of which are regulated by two federal multipurpose reservoirs: Lake Allatoona on the Etowah and Lake Lanier on the Chattahoochee; as a consequence no

significant surface water supply alternatives to these reservoirs exist.

- Piedmont-mountain watersheds with little potential for groundwater supply augmentation.
- Heavy development and recreational use of Lakes Allatoona and Lanier, both consistently ranked in the top ten most visited Corps lakes nationally.
- Intensive economic and environmental competition for water resources in the adjoining Savannah and Tennessee River Basins, and substantial legal and regulatory impediments to importation of water from these basins.

Normally, NED benefits are based on consumer willingness to pay for reservoir outputs, limited to least-cost replacement alternatives. In these circumstances, the NED benefits of M&I water supply could not be based on the cost of alternative supplies, because no alternative sources exist within the Chattahoochee Basin. Interbasin transfers are precluded not only by prohibitive facilities costs[2] and the prevailing legal and regulatory climate, but by the greater NED and environmental impacts of major diversions from federal reservoir systems in the Savannah and Tennessee River Basins as well, each with significant demands on storage and substantially more power generating capacity than Lanier. Consequently, the NED benefits of reallocation were estimated based on the value of water supply reliability, i.e. society's willingness to pay to avoid water shortages.

In contrast, determination of hydropower NED benefits based on non-federal (thermal) energy and capacity replacement costs was fairly straightforward, but nonetheless revealing. The proliferation of non-utility generators and inexpensive combustion turbines accompanying industry moves toward deregulation has substantially leveled system load and reduced replacement costs of the mix of thermal capacity resources traditionally displaced by hydropower. Concurrently, hydropower dependable capacity (load-carrying ability) has also greatly diminished relative to installed capacity, due to the fact that most federal hydropower installations in the southeast were originally sized to operate dependably through a critical drought only a few hours during weekday peak load periods, displacing primarily low-cost combustion turbines. With deregulation and market integration, however, combustion turbines now routinely operate from 8 to 12 hours during peak load periods and on weekends as well, requiring displacing hydro generation to be spread out over much longer periods. Hydrologic limitations on water availability and turbine-generator mechanical limitations potentially reduce dependable capacity by half or more (of installed) when attempting to shoulder such a wide peak. At Lanier, for example, the study determined dependable capacity in the current system load to be only about 35% of installed capacity, even before reallocation. With only two main units, each with limited hydromechanical operating range, operation at such a low plant factor (ratio of average load to installed capacity) is impractical and almost no capacity benefit is in reality provided by the project. Reallocation would therefore have virtually no impact on capacity benefits, and because all releases from Lanier's conservation storage would still be made through the turbines after reallocation, energy losses from Lanier and the entire system of federal reservoirs downstream were only about 4%—a function of the additional net water withdrawals from the system occasioned by reallocation.

Recreation NED benefits were estimated by comparing expected reservoir visitation and direct spending with and without reallocation. Indirect spending was also evaluated, but separately accounted for as regional (RED) benefits. Frequency and severity of reservoir drawdown were determined by reservoir system operational simulation using the USACE HEC-5 model (USACE-HEC, 1998), comparing the most recent baseline USACE water control plan with an alternative operating rule accommodating a variety of new priorities and constraints currently under negotiation by the States of Georgia, Florida and Alabama in ongoing Apalachicola-Chattahoochee-Flint (ACF) River Basin water allocation negotiations.

[2]A regional water utility manager who had just completed a major water piping project to return highly-treated wastewater to Lake Lanier as a conservation strategy estimated the minimum facilities cost of interbasin transfer from Lake Hartwell in the Savannah Basin (nearest Lake Lanier) at more than 7 times the value of hydropower benefits lost at Lanier. This 'next-best' alternative to reallocation was prohibitively expensive even without factoring in environmental and property acquisitions costs, without considering the hydropower losses from the Savannah reservoir system with more than 10 times Lanier's generating capacity, or recreation losses from Lake Hartwell with nearly 40% more conservation storage than Lanier.

The impacts of reallocation on commercial navigation and water quality were also qualitatively assessed in the study. The additional quantity of water diverted as a consequence of reallocation is too small (< 1% in the critical drought) to present a meaningful tradeoff between M&I water supply and navigation benefits. Navigation NED benefits are the transportation cost savings achieved by reduced delays and/or larger or more fully-loaded vessels due to flow regulation by the federal projects in the ACF Basin. Water quality is affected by both the timing and the quantity of reservoir releases for all project purposes. Relative change in streamflow quantity due to reallocation is most pronounced immediately downstream of dam, decreasing moving downstream. However, the shift in operational priorities from hydropower to water supply on the timing and reliability of instream flows qualitatively benefits water quality and biological diversity in the following two ways:

- The shift from peaking to more continuous power releases associated with maintaining minimum instream flows (MIFs) required for waste assimilation and reliable functioning of water intakes also reduces sediment loading and streambank erosion.
- The shift to power releases conjunctive with non-power uses conserves water in storage and maintains higher reservoir levels, the principle factor contributing both to a gain in recreation benefits and to increased reliability of water supply and instream flows supporting other economic and environmental objectives.

The present value of NED benefit changes due to reallocation from operational priorities observed in the Corps' current ACF Basin Water Control Plan (WCP) to a new set of operational priorities accommodating water security interests at stake in the ongoing ACF basin Compact negotiations are summarized in Table 1.

Table 1. Lanier NED update results summary

Purpose	Present value of NED benefit change due to reallocation (millions)
M&I water supply	19,100
Hydropower	(21)
Reservoir recreation	174
TOTAL	**19,300**

The NED benefits accruing to M&I water supply presented above are conservatively low. This is partially due to the benefits transfer approach used to estimate water supply reliability values, which in this case assumed that the Atlanta area, despite lacking California's water conservation infrastructure and institutions, can nonetheless suddenly adapt to pervasive water shortages and do so with equal efficiency. Moreover the NED benefits of reallocation reflect only a portion of the opportunity costs of not reallocating, because the Regional Economic Development (RED) impacts—measured by changes in income and employment—of capping Atlanta's water demand growth have been estimated to be orders of magnitude greater than the lost NED benefits. It is difficult to imagine that a loss to the regional economy of this magnitude would not be felt in the national economy as well.

A revised SCRB analysis for the power purpose was performed based on updated NED benefits for the baseline condition. The analysis, using updated cost of storage (UCS), annual operation, maintenance and repair (OM&R) costs, and allocated or separable hydropower facilities costs, is summarized in Table 2. This analysis reveals that power has become a marginalized purpose of Lake Lanier, i.e. no longer produces NED benefits in excess of allocated costs. In addition, the breakdown of WSA58 procedures in major reallocations become apparent. In this case, reallocation of all usable project storage to M&I water supply is warranted by the revised SCRB analysis, with water supply reimbursing the present value of power benefits foregone due to reallocation, or $21 million. The study conclusively demonstrates that power is already a marginalized purpose and cannot be significantly impacted by reallocation, that recreation benefits gained by reallocation exceed by nearly an order of magnitude the hydropower losses, and that EQ impacts are neutral to marginally positive. The most significant finding, of course, is the huge gain in NED water supply benefits—nearly a thousand times the hydropower losses—due to reallocation. Taken together, the findings indicate that no Congressional referral is warranted because no authorized purpose is significantly impacted, and that the reallocation should be administratively implemented following appropriate NEPA compliance procedures. Application of the WSA58 rules, on the other hand, require referral to Congress based on the incorrect presumption of significant impacts to power purpose.

Assuming Congressional approval, compensation from the water supply purpose would then be required based on updated cost of storage currently allocated to power, in excess of $314 million—nearly 15 times the power benefits foregone.

The SCRB update shows that the simplified WSA58 procedures can prevent reasonable adjustment to the highest and best uses when confronting the need for major operational change. As the Lanier case study

Table 2. Updated power purpose SCRB cost allocation

Benefit/cost category	Benefits/costs (thousands)
PV power benefits (i=$6^{5}/_{8}$%, n=57 years)	$74,144
PV updated cost of storage (UCS)	$250,206
Annual OM&R	$7,000
PV OM&R	$102,932
PV (UCS + OM&R)	$353,138
Allocated (separable) costs to power (89%)	$314,293
PV remaining benefits	**($240,149)**

demonstrates, however, full application of P&G effects accounting along with SCRB can adequately guide major reallocations, despite institutional inexperience along these lines. By employing the full planning process, therefore, the outcomes of reallocation can be substantially improved and the most beneficial and sustainable outcomes assured, fully within the framework of existing federal policy. This conclusion calls into question recent proposals for discarding the underlying principles of federal planning before putting them to the test on some of the Nation's most immediate water allocation problems.

As evolving economic and social demands call for major reallocations around the nation, the inadequacy of policies designed for incremental reallocations but applied to major reallocations will become more obvious as the consequences become more severe. The Lanier example shows that even from a purely economic perspective, the opportunity costs of failing to treat effectively the problem in a timely manner are clearly unacceptable. Yet planners can avoid this quagmire if they apply to the reallocation process the same comprehensive planning and cost allocation procedures that they already use to formulate new projects. In his way, the fairness and efficiency goals of the P&G and SCRB can be achieved, resulting in mutually beneficial outcomes that might avert some disputes altogether or reduce them at least to manageable proportions so that consensus is possible.

PROPOSED SUSTAINABILITY GUIDELINES FOR REALLOCATION

While we do not contend that efficiency and equity are sufficient for sustainability, it seems reasonable that a grossly inefficient application of resources that deteriorates wealth likely will limit options available to future generations. This observation alone of course does not operationalize sustainability nor demonstrate how a reallocation process informed by NED and SCRB is likely to promote it.

One definition of sustainability has been recently proposed by an American Society of Civil Engineers (ASCE, 1998) Task Committee:

> *"Sustainable water resource systems are those designed and managed to fully contribute to the objectives of society, now and in the future, while maintaining their ecological, environmental and hydrological integrity."*

The definition suggests, in the absence of a codified scientific theory, that sustainability can potentially be described using traditional concepts of welfare economics (Loucks, 1997), much as NED benefits are expressed, though there is considerable controversy among economists as to how to operationalize sustainability from welfare measures alone. For example, survivability—assuring that future welfare will always exceed a minimum subsistence level—may be described by welfare functions as follows:

$$W(k,y) \geq W_{min}$$

for time period y and decision or planning alternative y. Minimum water quality affecting millions of people or minimum flows critical to basic human or ecosystem needs at any time are plausible indicators of subsistence-level welfare. Survivability, however does not fully prescribe sustainability, and some scholars have proposed a *non-declining welfare* criterion, e.g.:

$$\{W(k,y+1) - W(k,y)\} > 0 \text{ for all } y$$

This is a rather strict criterion that allows everyone to suffer greatly to avoid even a small decline in welfare

between two periods, even if welfare levels later recover. It raises questions as to the degree to which planners are responsible to mitigate temporary dips in welfare from unforeseen circumstances such as droughts or floods, or whether continued welfare improvement, particularly of the kind driven by continued economic growth, is even possible (Meadows et. al., 1994). This pragmatic observation underlies the utilitarian objective of *maximizing the gross sum of welfare benefits over time*:

$$Max \; \mathring{a}_y \, W(k,y)$$

This measure however might conceivably allow welfare to fall below subsistence level over time. For engineering projects commissioned to protect present and future objectives, a more satisfactory baseline sustainability definition that captures the main concerns of each of these three definitions is as follows:

$$Max \; \mathring{a}_y \{W(k,y+1) - W(k,y)\}$$

s.t.

$$W(k,y) \; ³ \; W_{min} \text{ (survivability)}$$

Establishing a rough equivalence between 'sustainability' and 'maintaining quality of life,' this criterion characterizes policies that either maximize cumulative gains or minimize cumulative reductions in welfare as the more sustainable over time. It may be noted as well that this criterion offers no incentive for maximizing present welfare at the expense of future welfare, thus heeding Ophuls' (1992) admonition to balance "...present utility against future regrets." The criterion neither rewards gains nor penalizes declines, instead adding net improvements (gains and losses) in welfare over time, checked by declines that approach the survivability constraint however defined in a given case.

The search for an optimal solution is not realistic in most cases, but the policy choices seldom present themselves in this fashion in any case. With NED calculations to measure welfare benefits in any time period (perhaps buttressed by non-welfare survival constraints mandated by law), two competing reservoir operating rules can be immediately compared using this sustainability criterion. While not functioning as a stand-alone policy objective independent of all other concerns, the criterion potentially allows sustainability to be placed more on a par with NED in decision-making and consensus-building. The possibility of such a sustainability criterion factoring into a policy debate can be seen in a comparison of two early proposals for operation of Lake Lanier conducted by Farmer (2001) prior to the additional information from the NED report detailed above. In the conflict between Georgia and Florida, Florida suggested an environmental sustainability proposal premised on the best probability of exceeding a desired instream flow target lying above a required minimum flow critical to species survival. Georgia offered a proposal that moved most of the way toward this goal while ensuring that other water demands such as M&I and water supply and agricultural irrigation could also be met. While the Florida proposal did exceed the *desired* flow target more of the time than the Georgia proposal, the gain came at the expense of violating the critical *required* minimum flow much more often and for much longer periods of time. These violations risk acute health and safety crises from water quality deficiencies as well as threaten irreversible harm to the aquatic biota. Fusing Farmer's with the NED analysis above, we get a very strong potential sustainability improvement by following the NED-maximizing plan represented by reallocation. Reallocation brings about substantial improvements in welfare (reflected by NED benefits) in each time period and assures minimum survival flow is always maintained. This coincidence is neither accidental nor unexpected.

In this model, the decisionmaking framework and NED welfare-maximizing objective embodied in the P&G can provide the basic underpinnings of sustainable water resource development, provided heretofore externalized and nonmarket EQ, RED and OSE effects can be more fully incorporated within NED. Advances and growing experience in contingent valuation, travel cost, hedonic regression, and satisficing modeling techniques would appear to now make this possible. The problem of accommodating sustainable development principles in federal water resource development has been characterized (Loucks, 2000) as "...not so much a different planning paradigm [as] an extended set of evaluation factors—different criteria and weights on objectives to reflect a perceived shift in public preferences." The existing P&G/NED/SCRB framework appears highly adaptable to this problem, and reallocation contributing to NED in the broadest sense thus constitutes an effective sustainable water resource management strategy.

The authors suggest the following specific steps to operationalize sustainability in reallocation planning:

- Prioritize the most critical economic and environmental life-support uses (i.e. reallocate first to supply those uses for which there are no substitutes to water or substitute sources of water).
- Integrate NED and EQ objectives in part by applying best available environmental valuation, full-cost and/or energy-materials accounting techniques to reallocation and to the likely alternatives to reallocation, enabling some environmental quality impacts to be counted among NED effects. In the Lanier case, for example, one approach to estimating the minimum environmental benefits of reallocation relative to alternatives such as construction of new reservoirs is the life-cycle energy and materials costs these alternatives would incur.
- Build on an extended accounting of NED effects and establish by satisficing process a reallocation framework plan for assessing (1) the impacts of reallocation, (2) methods, procedures and criteria for implementation, and (3) procedures for monitoring and adjusting project operation as demands on water and storage change over time. The reallocation framework plan may include the following and possibly other elements:
    - Water control plan for implementation of the reallocation
    - Procedures for monitoring, enforcement and storage-use accounting
    - Negotiation framework, dispute resolution mechanism
    - Updated project benefits and project cost allocation
    - Adjustments for changes in reservoir yield (i.e. due to sedimentation, climate change, demand growth, etc.)
    - Provisions for renegotiation

CONCLUSIONS AND RECOMMENDATIONS

Reallocation of reservoir operational priorities can significantly reduce stress on highly competitive uses of water and highly valued parts of the environment. Moreover, unlike structural approaches to meeting changing demands, no evidence has been presented that conjunctive water management resulting from reallocation precludes water trading or forecloses future options for environmental protection. Rather, it is inflexibility in applying policies and procedures designed to address a specific need to today's more generalized, complex and interdependent water allocation problems that makes these types of improvement all the more difficult. This research draws distinctions between the over-arching principles intended to ensure federal water projects are formulated to meet all of society's needs in the long-term, and those policies and procedures devised decades ago to expeditiously ameliorate some of the specific problems of the time.

As competition among multiple economic and environmental uses intensifies, federal reservoirs will have to be managed more conjunctively and more sustainably in the future, and the federal planning framework must evolve accordingly as well. Existing multipurpose reservoirs in need of reallocation afford excellent opportunities to adapt existing principles, policies and procedures to the new realities; the need is immediate, the economic and environmental costs are likely to be substantially less than for alternatives to reallocation (as shown by the Lanier example), and the risks of irreversible consequences are minimal.

A substantial unfunded project backlog is listed among concerns prompting recent calls for economic review of new federal water projects, for rewriting or discarding federal water resource development policies and procedures, and even for dissolving the Corps' Civil Works mission altogether. Unfortunately little notice appears to have been taken of substantial opportunities to improve the operation of existing multipurpose reservoirs, despite the attractiveness of reallocation as a means of alleviating, at very low cost, some of the most immediate and severe stresses on the Nation's water resource infrastructure. We assert that the underlying principles of federal planning are sound and provide, through reallocation, a practical framework for adaptive and sustainable water resource management in the future. Careful adjustments to policies and institutions can potentially usher in a new era of adaptive water management in the United States. Conversely, without a clear understanding of how increasingly complex and interdependent demands on federal water projects might better be met in the future, wholesale abandonment of these principles and radical alterations to institutions may engender enormous socioeconomic and environmental risks. Only when the limitations of current policy and institutional capabilities are fully

explored and understood can efforts to improve them be successful.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of the Atlanta Regional Commission and the Cobb County-Marietta Water Authority.

REFERENCES

American Society of Civil Engineers, Task Committee on Sustainability Criteria and Working Group UNESCO/IHP IV Project M-4.3 (1998). *Sustainability Criteria for Water Resource Systems.* Water Resources Planning and Management Division. Washington DC.

Farmer, Michael C. (2001). Getting the SMS to work in the real world: a case study in moral pragmatism. *Ecological Economics.* August, 256-281.

Federal Interagency River Basin Committee (Departments of Agriculture, Army, Commerce, Interior, Labor, HEW, and the Federal Power Commission), Subcommittee on Evaluation Standards (1950, revised 1958). *Proposed Practices for Economic Analysis of River Basin Projects*.

Loucks, D.P. (1997). Quantifying trends in system sustainability. *Hydrological Sciences Journal*, Special Issue on Sustainability, IAHS Press, Wallingford, UK, 42(4), 513-530.

Loucks, D.P. (March 2000). Sustainable water resource management. *Water International,* IWRA, 25(1), 3-10.

McMahon, George F. (May 2001). *The Marginalization of Federal Hydropower*. Doctoral Dissertation, Georgia Institute of Technology, Atlanta GA.

McMahon, G.F., Wade, W.W., Roach, B., Farmer, M.C. and Fredrich, A.J. (November 2001) *Lake Lanier National Economic Development Update: Evaluation of Water Supply, Hydropower and Recreation Benefits*. Draft Report to the Atlanta Regional Commission, Atlanta GA.

Meadows, D.H., Meadows, D.L., and Randers, J. (1994). *Beyond the Limits: Envisioning a Sustainable Future*. Universe Books.

Ophuls, William and Boyan, A. Stephen (1992). *Ecology and the Politics of Scarcity Revisited*. W.H. Freeman.

P.L. 78-534, 1944; Flood Control Act of 1944. (58 Stat. 887, 33 U.S.C. 701-1).

P.L. 85-500, Section 301, 1958; Water Supply Act of 1958. (72 Stat. 319, 43 U.S.C. 390b).

P.L. 91-190, 1970; National Environmental Policy Act of 1969. (83 Stat. 853, 42 U.S.C. 4332).

P.L. 91-611, Section 216, 1970; River and Harbor and Flood Control Act of 1970. (84 Stat. 1819, 33 U.S.C. 426-2nt).

Pearce, David W. and Turner, R. Kerry (1990). *Economics of Natural Resources and the Environment.* The Johns Hopkins University Press.

Stakhiv, E. and Major, D. (1997). Ecosystem Evaluation, Climate Change and Water Resources Planning. In K. Frederick, D. Major and E. Stakhiv (eds.), *Climate Change and Water Resources Planning Criteria*. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Takeuchi, K. (1997a) Least marginal impact rule for reservoir development. *Hydrological Sciences–Journal–des Sciences Hydroliques*, Special Issue: Sustainable Development of Water Resources, International Association of Hydrological Sciences, 42(4), pp. 583–597.

Takeuchi, K. (1997b). On the scale diseconomy of large reservoirs in land occupation. In D. Rosbjerg, N.E. Boutayeb, A. Gustard, Z.W. Kundzewicz, and P.F. Rasmussen (eds.), *Sustainability of Water Resources under Increasing Uncertainty*. IAHS Publication No. 240, 519-527.

U.S. Water Resources Council (December 21, 1971). *Proposed Principles and Standards for Planning Water and Related Land Resources*. Washington, D.C.

U.S. Water Resources Council (March 10, 1983). *Principles and Guidelines for Water and Related Land Resources Implementation Studies*. Washington, D.C.

U.S. Army Corps of Engineers, Hydrologic Engineering Center (October 1998). *HEC-5: Simulation of Flood Control and Conservation Systems*. User's Manual, Version 8.0, Davis CA.

U.S. Army Corps of Engineers, Institute for Water Resources (May 1999). *SustainableDevelopment: Concepts, Goals and Relevance to the Civil Works Program.* IWR Report 99-PS-1. Alexandria, VA.

U.S. Army Corps of Engineers (March 1988). *Procedures for Implementing NEPA*. ER 200-2-2, Washington, DC.

U.S. Army Corps of Engineers (28 December 1990). *Planning Guidance*. ER 1105-2-100., Washington, DC.

Zilberman, David (1994a). "Introduction." In D. Zilberman (ed.), *Review of Principles and Guidelines*. Department of Agricultural and Resource Economics, University of California, Berkeley, CA.

Zilberman, David (1994b). "Incorporation of Environmental and Quality Considerations in Principles and Guidelines." In D. Zilberman (ed.), *Review of Principles and Guidelines. Department of Agricultural and Resource Economics*, University of California, Berkeley, CA.

NOTATION

The following symbols are used in this paper:

AC = average cost
MC = marginal cost
r = social discount rate or cost of funds
$W(k,y)$ = welfare resulting from decision k in period y
W_{min} = minimum welfare for survival