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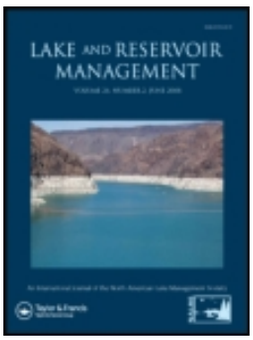

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Frameworks for amending reservoir water management

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Abstract

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Managing water storage and withdrawals in many reservoirs requires establishing seasonal targets for water levels (i.e., rule curves) that are influenced by regional precipitation and diverse water demands. Rule curves are established as an attempt to balance various water needs such as flood control, irrigation, and environmental benefits such as fish and wildlife management. The processes and challenges associated with amending rule curves to balance multiuse needs are complicated and mostly unfamiliar to non-US Army Corps of Engineers (USACE) natural resource managers and to the public. To inform natural resource managers and the public we describe the policies and process involved in amending rule curves in USACE reservoirs, including 3 frameworks: a general investigation, a continuing authority program, and the water control plan. Our review suggests that water management in reservoirs can be amended, but generally a multitude of constraints and competing demands must be addressed before such a change can be realized.

Key words: continuing authority, flood-control reservoir, general investigation, rule curves, water control plan, water level

Reservoirs are a valuable and widespread aquatic resource in the United States, with nearly every major river impounded somewhere along its reaches. Reservoirs number in the thousands nationwide and were constructed mainly in the early- to mid-20th century, with only limited construction in the last 2 decades (USACE 2009). Reservoirs are constructed for various purposes including flood control, hydroelectric power, water supply, navigation, fish and wildlife habitat, recreation, and others (Kennedy 1999). Commonly, reservoirs are built and managed to balance multiple purposes and fully utilize water resources. For the most part, the operation of reservoirs is not a matter of discretionary or subjective preference, but is tightly constrained (in most cases) by rules, regulations, laws (including treaties in some cases), and contractual agreements with vested stakeholders (e.g., power companies, water utilities, water rights holders), who in many cases have provided funding for the construction and operation of the project under a contract that specifies some aspect(s) of reservoir water management.

The allocation of water storage volume to meet the operational purposes of a reservoir is commonly regulated through a water control plan that includes schedules to guide reservoir volume and water level. These schedules are often called rule curves because they govern water levels throughout the year and indirectly guide releases. Rule curves can be designed to regulate storage for flood control, hydropower production, and other operating objectives, as well as a combination of objectives. Most reservoirs are operated according to rule curves established at the planning stage to provide long-term operation guidelines for reservoir managers. The rule curves are based on actual storage and do not generally account for year-to-year hydrological variability; however, most rule curves prescribe reservoir daily target volume or water level throughout the year as a relatively simple model that reservoir managers can apply and the public can understand (Fig. 1). Rule curves are usually established based on analyses of historic hydrological conditions through a complicated and data-intensive process. Traditionally rule curves were set based on the simulation of hypothetical curves to documented historical floods, but more recently they are based on optimization (Lund 1996) or other models (Rani and Moreira 2010).

Over time the purpose of the reservoir may change or new purposes may be added, regulatory requirements may proliferate, and public interests for the management of

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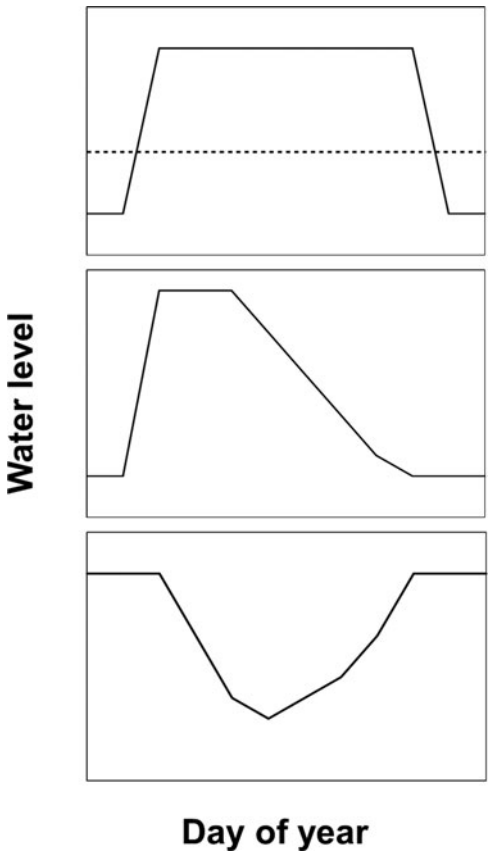

Figure 1.-Rule curves commonly used in reservoir operations. Curves in the top panel are used in flood control and multipurpose reservoirs. Water levels are low during wet months and raised as precipitation subsides to accommodate various demands for the water. Conversely, water levels could be held stable (dashed line) if flood risk is low. The middle panel shows water level increases that are stored for a short time and slowly allowed to decrease to normal levels. This type of curve is commonly used in flood-control reservoirs and in maintaining conservation flows downstream. The bottom panel shows water recharging the reservoir during winter and spring and depleted again during the summer with consumptive uses such as agriculture.

the reservoir may intensify. Most of these changes may originate from increased environmental demands, but significant changes may also be instigated by recreational and water supply demand. These changes in societal objectives and demands have prompted reexamination and reregulation of many reservoir systems across the country, often accompanied by heightened levels of controversy and technical scrutiny. Examples include rule curves at Lake Lanier and John H. Kerr Lake, both in the Southeast and both involved in litigation regarding water allocation; Lake Heron and other reservoirs on the Rio Grande River in the Southwest involved in litigation concerning endangered species; and main-stem reservoirs in the Missouri River in the Midwest currently in litigation involving competition between navigation and environmental requirements.

Table 1.-List of general authorities applying to all USACE water development projects.

General Authority	Name of Act	Public Law #
Recreation	Flood Control Act 1944	79-534
Municipal and industrial water supply	Water Supply Act 1958	85-500
Fish and wildlife conservation	Fish and Wildlife Coordination Act 1958	85-624
Water quality	Clean Water Act 1972	92-500
Endangered species	Endangered Species Act 1973	93-205

The US Army Corps of Engineers (USACE) administers water storage, use, and discharge in many US reservoirs. Water management goals depend on each reservoir's congressionally authorized purpose. Although USACE projects are mandated to consider additional factors such as fish and wildlife habitat and recreational opportunities (Table 1), and the USACE's mission statement includes wildlife and environmental goals, the original authorization of the water development project (e.g., navigation, flood control) drives the USACE management and operation of the project, with additional emphases sometimes added before or after construction by congressional authorization. The process used by the USACE to first establish and subsequently amend rule curves is not well publicized and is not well understood by the public that uses the resource or is affected by its discharges, or by personnel from natural resources agencies charged with overseeing water quality, wildlife, and recreational needs.

As a result, questions and controversies arise as to how the rule curve might be amended. Fisheries managers, for example, may want to change seasonal water levels to inundate specific elevations for spawning habitat at certain times of the year. Recreational users may like to have a specific elevation at certain times of the year to provide the maximum enjoyment. Waterfowl managers may require reduced water levels at certain times of the year to provide forage for migratory waterfowl. Environmental managers may require increased discharge to maintain water quality in tailwaters. It is difficult for these user groups to ask for a change in a rule curve because they often do not understand what is required to implement change, nor are they aware of all the constraints imposed on the allocation of the resource. These constraints are sometimes embedded in the authorizing legislation, but in some cases they are part of interstate agreements, contracts, or treaties. Conversely, it is not possible for the USACE to implement changes that go beyond the authorization, compromise or conflict with an authorized purpose, or violate one or more of the legal agreements that

constrain reservoir operations. Sometimes the structure and the water do not necessarily "belong" to the USACE. Particularly in the West, local sponsors may own the structure (or a share of it) and control all or part of the storage volume under contract or other agreement. The USACE then cannot reallocate volume for other purposes without agreement from the local sponsor(s) and often from Congress, too. All parties must clearly understand the ramifications of a requested change, or of maintaining an outdated rule curve.

Given this lack of understanding, we believe the process used to amend existing rule curves needs to be better explained. The general perception toward amending rule curves is that "it would take an Act of Congress" to make a change. This perception may or may not be accurate, depending on the magnitude of the change requested. A clearer understanding of the process could promote productive cooperation among USACE personnel, natural resource managers, and the public. Our purpose is not to advocate changing reservoir operations to fit any particular use, but rather to explain the process behind how a change may be made. Whether or not to make a change would be completely case-specific. To this end, we review the policies and processes involved in amending rule curves in USACE reservoirs. We reviewed many USACE engineering regulations and manuals and we cite them in the text. These documents may be found at http://www.usace.army.mil/Library.aspx.

Frameworks for amending rule curves

Reviews of the scientific literature, legal literature, and interviews with USACE personnel revealed 3 frameworks available for amending rule curves, each with a unique process, scope, and varying degrees of flexibility. The framework used depends on the degree of flexibility afforded to the USACE by the authorized purpose(s) of the project. These frameworks are designated as general investigations, continuing authority program, and water control plan.

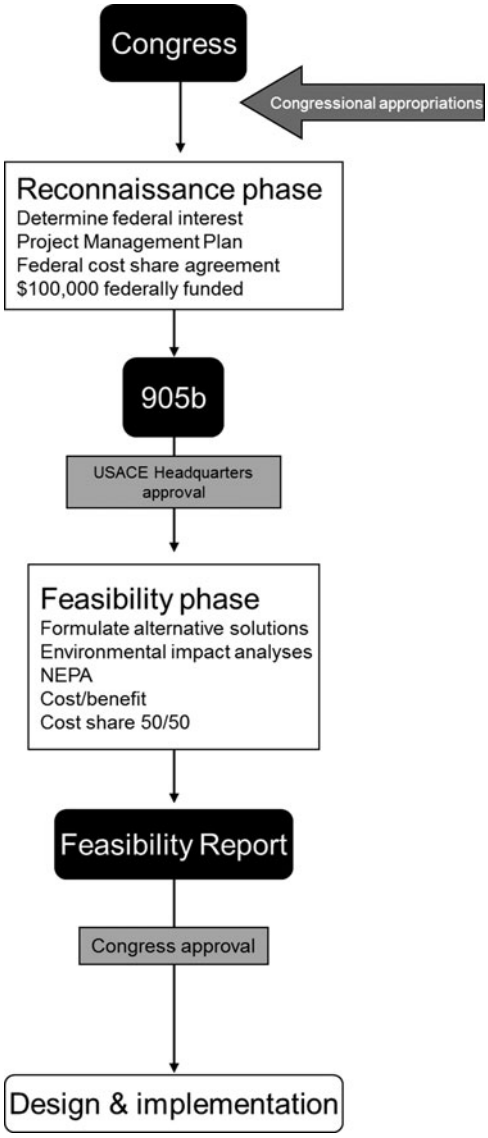

Figure 2.-Flowchart for the general investigation framework. This process is typically used for new projects, amending existing projects due to changed conditions, or reallocations in water use, and historically has been applied to flood control acts. Section 216 of the River and Harbor Act of 1970 identifies a general investigation process as an avenue for reevaluation of projects due to "significantly changed physical or environmental conditions."

General investigations

The general investigation (GI) framework is used to obtain congressional authorization for a new USACE project, or to recommend modifications to an existing water development project to the US Congress, to the extent that such an amendment exceeds the Chief of Engineers' discretionary authority. A GI is composed of 2 phases, a reconnaissance phase and a feasibility phase (Fig. 2), with implementation of the water development project resulting in a separate phase with separate funding. The GI process is initiated and authorized by the US Congress to investigate the feasibility of solving a water resource problem. Historically, GIs were authorized in flood-control acts. More recently, GIs have been authorized in rivers and harbors acts and omnibus water resource development acts. If a GI was previously done at the site, the River and Harbor Act of 1912 enables resolutions to be passed to review the water development project without a new GI, if the scope of the authorization is similar (Maass 1950, Carter and Stern 2011).

A reconnaissance study, which is part of the reconnaissance phase, identifies a water resource problem(s), determines whether the federal government has a legitimate stake in addressing it, and identifies a viable nonfederal sponsor for upcoming studies. The reconnaissance phase includes a 100% federally funded study, typically up to $100,000. If the study recommends continuing to a feasibility phase, then the reconnaissance phase includes the preparation of a project management plan for the feasibility study and the preparation and execution of a Feasibility Cost Sharing Agreement with a nonfederal sponsor (Wigington et al. 2007, Carter and Stern 2011; engineer regulation 1105-2-100)). Various requirements for becoming a nonfederal sponsor are outlined in 42 USC §1962.b. A sponsor must be a legally constituted public body with full authority and capability to perform the terms of its agreements and to pay damages, and can include a state or any other political subpart of a state or group of states; an Indian tribe; a port authority; or similar groups that have the legal and financial authority and capability to provide the funds and real estate requirements needed for a project. A nonprofit entity cannot be a sponsor. The reconnaissance phase typically takes 1 year, and results in a Section 905b report that details the cost of the feasibility study to the federal government and level of federal interest (engineer regulation 1105-2-100). The USACE Headquarters decides if the study continues on to a feasibility phase, but USACE Major Subordinate Commands have delegated authority to approve policy compliant 905b analysis (USACE, Feb 2013, pers. comm.[2]

Following a positive recommendation from the Section 905b report, the respective division commander approves moving on to the feasibility phase, which includes a feasibility study. The purpose of the feasibility study is to identify all potential solutions to the water resource problem, identify positive and adverse environmental impacts, and analyze cost/benefit ratios or cost effectiveness/incremental cost analysis for the proposed solutions. All USACE planning studies follow a 6-step process outlined in a planning and guidance framework (Water Resources Council 1983). It is beyond the scope of our review to explain details about this 6-step process, but in summary the feasibility study must compare alternative plans, coordinate with appropriate agencies having a stake in the project, and ensure the selected plan maximizes either the National Economic Development or the National Ecosystem Restoration policies. Locally preferred plans may also be considered. Federal interest is determined largely by a cost/benefit analysis corresponding to 6 main missions of the USACE: navigation, flood risk reduction, hurricane and storm damage reduction, water supply, hydroelectric power, and recreation. Alternatively, cost effectiveness/incremental cost analysis for the ecosystem restoration mission may be considered (engineer regulation 1105-2-100). However, many times a project has been authorized in the face of an undesirable cost/benefit analysis, often justified through employment benefits or local hardship (Reuss 1982).

This feasibility study is cost-shared 50% federal funds and 50% nonfederal sponsor (WRDA 1986) and is conducted by the USACE district in which the proposed project is located. If the project involves one of the original Mississippi River and Tributaries Projects, the report is submitted to the President of the Mississippi River Commission. Otherwise the report is submitted to the division commander, USACE Headquarters, and eventually the Assistant Secretary of the Army for Civil Works (engineer regulation 1105-2-100). The National Environmental Policy Act (NEPA) impact statement is conducted in this phase. Either an Environmental Assessment/Finding of "no significant impact" or an Environmental Impact Statement is required during this phase (USACE, Feb 2012, pers. comm.). The feasibility phase can take 2–3 years to complete and produces a report that becomes the foundation upon which the US Congress authorizes the recommended solution to the water resource problem. Upon endorsement of the feasibility report by the division commander to USACE Headquarters, the design and implementation phase can begin using GI funds. The construction process cannot begin until the project is authorized by the US Congress, funds are appropriated, a Project Partnership Agreement with the nonfederal cost sharing sponsor is negotiated, and the sponsor provides its share of the first year of construction costs. Because structural changes are not commonly required for an amendment to a rule curve, we do not describe this process in detail.

The GI is a well-defined way to amend rule curves through congressional approval. Section 216 of the River and Harbor Act of 1970 identifies a GI study as an avenue for reevaluation of projects due to "significantly changed physical or economic conditions." This is a long and expensive process, however, going through the US Congress and appropriations twice. John H. Kerr Lake in North Carolina and Virginia, and Philpot Lake in Virginia are undergoing a Section 216 GI study at an approximate cost of $5 million and $2 million, respectively. The master plan for the Missouri River basin is also being updated through a GI study at a cost of approximately $11 million (USACE, Feb 2012, pers. comm.).

Continuing authority program

Many USACE activities and projects are not large enough in scope for congressional attention. Generally, when a need for a change in a water development project is identified, studies can be performed to analyze the feasibility of such a change. Those changes can be accomplished through already existing authority "to the extent possible" (engineer regulation 1165-2-119). Otherwise, changes must be submitted through

the GI framework. Project modifications authorized under a continuing authority program (CAP) are not transmitted to the US Congress for authorization. These water development projects use existing authority to enable small scale projects to move more quickly. The USACE has a special annual fund for CAP projects that fit the limited scope established by the continuing authorities. CAP funds are available every year, and funding for CAP projects is approved by the division commander. Only specific activities are eligible for authorization under CAP, including erosion stabilization, navigation improvements, sediment/dredge material management, flood control, aquatic ecosystem restoration, snagging, and project modifications for improvement of the environment (Carter and Stern 2011; engineer regulation 1105-2-100). Project modifications to improve the environment would be best suited for justifying the amendment of rule curves in existing reservoirs using CAP. The authority for CAP is given by Section 1135 of the Water Resource Development Act of 1986 (WRDA 1986), and expenditures for this type of project are capped at $5 million. All expenses associated with lands, easements, rights-of-way, relocations, and disposal areas are to be assumed by the nonfederal sponsor (engineering regulation 1105-2-100). Any costs of operations, maintenance, repair, replacement, and rehabilitation (OMRRR) that could potentially be needed by an amendment to the rule curve are to be assumed by the nonfederal sponsor after the project is constructed (Carter and Stern 2011; engineer pamphlet 1165-2-1). Initiating a CAP Section 1135 study requires a formal request to the district commander from an appropriate nonfederal sponsor stating an interest in participating in a CAP Section 1135 study to resolve a water resource problem. The division would then opt to initiate the required studies, subject to the availability of funds.

The Section 1135 process follows 2 phases: a feasibility phase and a design and implementation phase (Fig. 3). The feasibility phase has 2 main purposes: it determines the federal interest in the proposed water development project, and it provides opportunities to formulate alternative solutions to the identified problem (engineer regulation 1105-2-100). A report analogous to the Section 905b report of a GI study includes a justification of the project, legal sufficiency, impact analyses (e.g., NEPA), real estate plans, sponsor financing plans, cooperation requirements with local interests, and OMRRR plans.

If the project feasibility phase can be executed for less than $100,000, it can be entirely federally funded, and no CAP federal cost-share agreement is needed. The division commander approves the feasibility phase via a decision document stating whether the project should continue to the design and implementation phase. As with a GI, the water development project must optimize the National Ecosystem Restoration or National Economic Development goals; however, waivers can be submitted to deviate from these requirements if there is strong justification for a locally preferred plan.

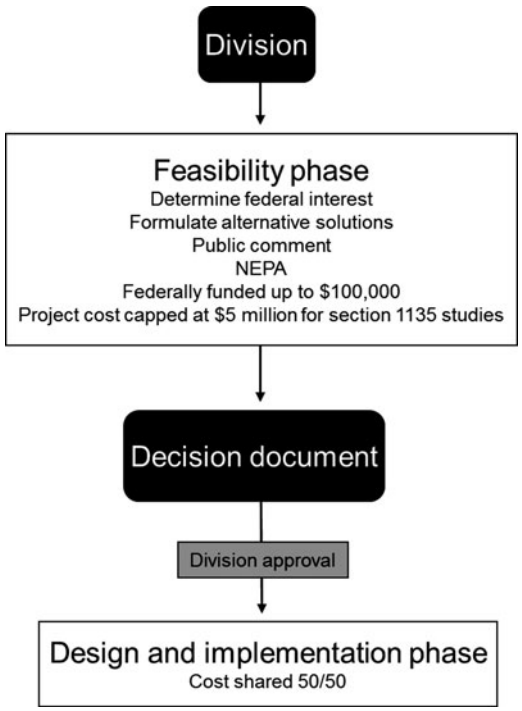

Figure 3.-Flowchart for the continuing authority program framework. Many USACE activities and projects are not large enough in scope for congressional authorization. Only erosion stabilization, navigation improvements, sediment/dredge material management, flood control, aquatic ecosystem restoration, snagging, and project modifications for improvement to the environment are eligible for authorization under this framework.

Upon the approval of the feasibility phase by the division commander, the project may move into the design and implementation phase. Costs that could possibly be related to amending a rule curve would be cost-shared 75% federal and 25% nonfederal by the requesting agency or appropriate nonfederal sponsor. Any construction would follow guidelines for construction of an individually authorized project (i.e., GI). It would not be common to make structural changes to a project for an amendment to the rule curve; thus, we do not detail the design and implementation stage, but more information about the construction process is provided in the engineering regulation 1105-2-100.

The process associated with implementing a Section 1135 study follows the 6-step planning and guidance procedures (Water Resources Council 1983; engineering regulation 1105-2-100 appendix E); however, division commanders have the option of simplifying and scoping the process at their discretion to fit the project, if the failure of the

project will not result in the loss of human life (engineer regulation 1105-2-100 appendix F). The process seems ideal for modifying a rule curve in an existing flood-control reservoir, which would require extensive flood-risk based evaluations; however, USACE divisions have been hesitant to use this process for amending rule curves. One problem with this approach is the enormous backlog of CAP requests. Before fiscal year 2010, Section 1135 CAP requests totaled $41 million in unstarted backlogged projects, with additional current projects often spilling into funding allocations for upcoming years (Carter and Stern 2011). Because of this backlog, amending rule curves through Section 1135 CAP requests could take years.

Water control plan

A third framework for amending rule curves is updating the water control plan (WCP). This type of action is acceptable to optimize the project for general authorities passed subsequent to the original authorizing act (Table 1; engineer regulation 1110-2-240 4.a, engineer pamphlet 1165-2-119).

The broad spectrum of USACE water development projects often requires specific seasonal or even daily water storage and release targets. The coordination of these activities within individual reservoirs and among multiple reservoirs to achieve management goals constitutes a WCP. The physical execution of the WCP is often detailed in a separate water control manual, containing specific instructions for project operation.

A WCP includes a summary of location, description, authorization, and purpose of individual or multiple reservoirs. Baseline meteorological and hydrological conditions, water quality, runoff, and flood stage information are also found in a WCP. Additionally, a WCP contains detailed information on objectives, benefits, and constraints of the overall purpose of the WCP. Charts detailing structures, project area, rule curves, hydrographs, discharge ratings, and frequency and duration curves for water control points are included in the WCP (engineer regulation 1110-2-3600, engineer regulation1110-2-240). The WCP provides plans for day-to-day operations management.

In accordance with the Water Supply Act of 1958, WCPs are mandated to be updated periodically to keep them applicable to social, economic, and physical conditions (public law 85-500). A main purpose of modifying a WCP is to enable a reservoir to run efficiently (engineer regulation 1110-2-240, engineer manual 1110-2-3600). Modifications are typically proposed and researched at the district level, and the updated WCP is approved by the division commander (engineer regulation 1110-2-240). This differs from the CAP program where program proposals and research occurs with division oversight and from a GI where approval is under the control

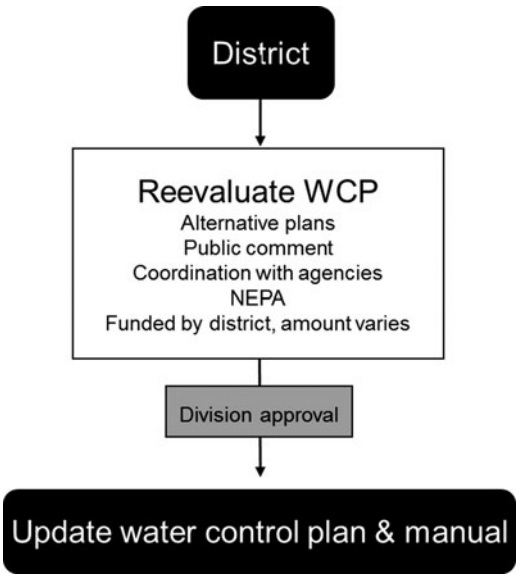

Figure 4.-Flowchart for the water control plan framework. The coordination of water storage activities within individual projects and among multiple projects to achieve management goals constitutes a water control plan. The Water Supply Act of 1958 mandates periodic reviews of the water control plan to keep it applicable to social, economic, and physical conditions.

of USACE Headquarters, and ultimately, the US Congress. Unless initiated by the USACE, a formal request must be sent to the USACE from an appropriate nonfederal sponsor (e.g., local department of natural resources) asking for a reevaluation of the water control plan (USACE 2001). The process (Fig. 4) of revising a WCP is highly dependent on the nature of the project in question. The diversity of USACE water development projects prevents defining concrete requirements for updating a WCP; however, general guidelines do exist such as NEPA analyses, public comment, and coordination with appropriate agencies. Decision records of all studies performed seem to fulfill most requirements for a WCP update, but their application may be more or less dependent on the nature of the project (engineer manual 1110-2-3600, engineer regulation 1110-2-240; Wigington et al. 2007; USACE, Feb 2012, pers. comm.). Some changes to the WCP can be made through a categorical exclusion with minimal effort (USACE, Feb 2012, pers. comm.). A categorical exclusion enables an action that has no effect on the environment to be performed without any further impact analysis under NEPA (e.g., environmental assessment or environmental impact statement). USACE personnel interviewed, ranging from high-level administrators to district engineers, was often found to reject the possibility of an update to the WCP as a vehicle to amend a rule curve (USACE, Feb 2012, pers. comm.). According to internal documents, however, rule curves are directed to be considered along with the WCP (engineer regulation 1165-2-119, engineer regulation 1110-2-240).

Conclusions

This review examined the frameworks that exist for revising rule curves in USACE reservoirs. The general investigation, continuing authority program, and water control plan are each feasible approaches, depending on the project. The level of difficulty (and time required) decreases with each respective framework. Both the GI and the CAP frameworks would involve updating the WCP, but a separate review of the WCP would not involve a GI or CAP. The process involved with a CAP Section 1135 and changing the water control plan are complicated and mostly unfamiliar to non-USACE natural resource managers, although they can be effective alternatives for amending rule curves.

Judging from interviews with USACE personnel, it is apparent that most districts and higher level USACE officials are hesitant to consider the possibility of permanently amending reservoir operations without congressional approval (i.e., GI study), but some executive personnel indicated that it was possible. Flatt and Tarr (2011) conducted a legal review of the flexibility potential of the USACE to amend operations in the face of changing environmental conditions. They found that the legal system in which water development laws were passed originally intended flexibility where rigidity is now found. Customary decisions and historical activity may play a more significant role in determining operating procedures in water development projects than does an interpretation of the current legal framework.

One of the major roadblocks to exercising the flexibility originally intended is the language found in many laws stating that operations can be modified provided they do not "significantly" alter the original authorization. Significance is not defined in those laws, although more information on the discretionary authority of the Chief of Engineers is found in engineer regulation 1105-2-100 appendix G. The lack of a definition for significance by the US Congress enables the protection of the chevron doctrine, which when used in court affords federal agencies the benefit of the doubt when they interpret vague and conflicting legislative requirements (Stewart 1975, Ballweber and Jackson 1996, Flatt and Tarr 2011). The USACE does interpret conflicting requirements in balancing uses from multiple stakeholders and requirements from multiple laws, and thus they would be entitled to such protection. Laws and policies that create the framework for the current USACE civil works programs are convoluted, pieced together, and are sometimes conflicting (Whisnant et al. 2009). These laws and policies are often subject to individual interpretation in decision making, which is in turn subject to judicial review. Hence, USACE personnel are understandably hesitant to try new and untested procedures to accomplish a change in reservoir operations.

Our review is not intended as a "silver bullet" to cut through current political and procedural avenues. Amending rule curves involves many stakeholders with many competing interests often regarding old water development projects. Tradition and original purposes require serious consideration and should not be taken lightly; however, our review is intended to provide an improved understanding into the processes required for a management action desired by environmental managers or other groups affected by rule curves. Having clear alternatives and encouraging flexibility in reservoir operations to change rule curves should promote productive communication and cooperation among USACE, resource management agencies, and multiple stakeholders.

Acknowledgments

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