CHIEF OF ENGINEERS
ENVIRONMENTAL ADVISORY BOARD
Army Science Board Subcommittee

Lieutenant General Todd T. Semonite 17 AUG 2020
Commanding General and Chief of Engineers
U.S. Army Corps of Engineers
441 G Street NW
Washington, DC 20314-1000

Subject: Sustainable Sediment Management at U.S. Army Corps of Engineers Reservoirs

Dear LTG Semonite:

The Chief of Engineers' Environmental Advisory Board (EAB), a Subcommittee of the Army Science Board, evaluated sediment management issues at Corps of Engineers' (Corps) reservoirs from a national perspective. The EAB recommends that long-term ecosystem health and the sustainability of reservoir project benefits could be improved by re-establishing sediment continuity through reservoirs and the whole riverine system. Sediment continuity is achieved when the sediment generated from the watershed and upstream river channels is allowed to pass through or around a dam to the downstream river corridor. The EAB recommends the following specific actions. The Corps should:

1. Recognize the downstream channel system and receiving coastal systems as preferred beneficial uses for reservoir and dredging sediments, subject to the principles discussed in the attached document.

2. Expand the footprint for assessing cost-benefits of reservoir sediment management measures to include both downstream and upstream river corridors.

3. Analyze storage lost to sedimentation as a reallocation, with an assessment of lost benefits and associated increased costs both upstream and downstream of the project footprint.

4. Highlight existing sediment passage pilot projects and implement new projects that demonstrate different management options.

5. Hold reoccurring reservoir sediment management training courses. The Regional Sediment Management (RSM) program has produced and held two such courses, one for regulators, managers, and planners (held in 2017) and one for engineers (held in 2018).

Taking these steps can help to enhance upstream and downstream ecosystems and encourage the adoption of cost-effective, environmentally-sound reservoir sediment management practices which will extend the useful life of Corps reservoir projects. These steps are congruent with and build upon current Corps initiatives such as the Environmental Operating Principles (EOPs), Environmental Flows, Sustainable Rivers, and the Corps' RSM and Engineering with Nature programs.

The attached document provides general background and additional justification for each of the five recommendations. This EAB study was led by Dr. Rollin Hotchkiss with significant contributions by Dr. Melinda Daniels, who are available to answer any questions. We hope the recommendations will be useful and look forward to working with your staff on implementation.

Sincerely,

Mary C. Barber, PhD
Chair, Environmental Advisory Board
Subcommittee of Army Science Board

Attachment

CF:
Chief, Planning & Policy Division
Chief, Environmental Division
Chief, Operations & Regulatory Division
Chief, Engineering & Construction Division
Director, ERDC Environmental Laboratory

ATTACHMENT.

Sustainable Sediment Management at U.S. Army Corps of Engineers Reservoirs

Introduction & Background

The Corps is the largest operator of dams in the United States. Each Corps dam was planned, designed and built to provide specific benefits to the American public, including navigation, flood risk reduction, hydropower generation, recreation, and water supply. Most Corps dams have operated for more than 50 years, with some approaching 100 years of operation. Corps dams and reservoirs provide crucial benefits to the nation, especially during times of flooding or drought.

Corps dams and reservoirs were designed with an understanding of dynamic river processes and accounted for a certain amount of sedimentation over their economic design life (much shorter than the actual life of the structure). Planners and Designers have accounted for a rate of sedimentation by identifying a volume of future sediment storage, called the inactive pool or dead pool. Sedimentation occurs throughout the pool, however, and thus can impact conservation pool storage or flood control storage, depending on reservoir operations and incoming sediment timing and magnitude. Once deposited, sediment can also move throughout the pool. As this sediment accumulates over the design life of 100 years or more, it can result in a "reduction in the reliability of water supply, burial of dam outlets and intakes for water supply and power production, damage to hydropower and pumping equipment, burial of boat ramps or marinas, navigation impairment, reduction in the surface area for lake recreation, and increased flood stages upstream" (Randle et. al 2019). Deposition upstream from the reservoir and scour downstream from the dam can also cause well-documented ecosystem and infrastructure damage far from the dam location (George et al. 2016, Kondolf et al. 2014).

Even planned for, the Corps recognizes that dams interrupt the downstream movement of sediment. For example, Regulatory Guidance Letter (RGL) 18-01 (USACE 2018) states:

> Dams and other obstructions disrupt the sediment transport that is critical to sustaining the habitat of riverine and riparian species, including the variations in sediment sizes that are important for habitat heterogeneity for different life stages of aquatic organisms. Stream reaches immediately downstream of a dam or other obstruction become starved of sediment which can lead to stream bank erosion or channel incision. In coastal areas, disruption of sediment transport by dams can contribute to the loss of shoreline habitats because of reduced sediment deposition in those areas.

On the other hand, elevated soil erosion and sediment production due to human activities and extreme natural events can impair surface waters. The U.S. Environmental Protection Agency 2016 National Summary of Impaired Waters and TMDL Information, lists sediment as the sixth most frequent cause of impacted waters for Section 303(d) listed waters. The causes of sediment impairment in order of frequency (high to low) are: siltation (62% of sediment-related impairment), a combination of sedimentation and siltation (33% of sediment-related impairment), and for the remaining 5%, sediment, sedimentation, solids (suspended and bedload) fine sediment, bottom deposits, and particle distribution (embeddedness). Sediment is not inherently a pollutant, but extremes in sediment concentrations, whether too low or too high, lead to less desirable environmental outcomes. In this sense, natural levels of sediment discharge from dams could therefore be a desired environmental outcome. At the same time, because sediment sources can be contaminated, the quality and level of contamination of the sediment must be evaluated whenever a management intervention is considered.

Some watersheds have been disturbed by human activities leading to increased sediment loading to rivers and streams. In these situations the reservoir may have been a source of "free" water quality treatment for decades, i.e. the sediment trapping in the reservoir may help offset increases in sediment loading by other human activities. Unless sediment trapping for downstream water clarity is a specifically-authorized purpose for the project, the reservoir should not be expected to sacrifice long-term sustainability of the actual authorized purposes for temporary water clarity improvements downstream. Rather, the reservoir should be allowed and expected to pass sediment downstream at the annual rate it enters the reservoir under appropriate circumstances.

Recommendation 1 - Recognize the Downstream Channel as a Preferred Beneficial Use

Large watersheds with many dams have a documented history of wide-spread impacts from sediment starvation. Such is the case on the Missouri River (NRC 2011), the Colorado River (Ward et al. 2016), the Kansas River (Shelley et al. 2016), and the Mississippi River (Kondolf et al. 2014; Kesel 2003, 1989, 1988). On the flip side, restoring natural sediment loads to a river system may result in an ecological uplift (Martin et al. 2017, Sumi et al. 2012) or negative impacts if not managed carefully (Espa et al. 2019).

The Corps encourages the beneficial use of dredged sediment where possible, and districts are "encouraged to consider options that provide opportunities for aquatic ecosystem restoration" in ER 1105-2-100 (USACE 2000). The most straight-forward beneficial use for the sediment is to replenish the sediment deficit in the downstream channel. Section 1179(a) of the Water Resources Development Act of 2016, as amended, states that sediment management plans for the Missouri River Basin reservoirs, for example, should "identify beneficial uses for sediment, including discharging to the downstream channel."

The EAB recommends that the downstream channel system and receiving coastal systems be explicitly recognized and evaluated as beneficial uses for the reservoir material. In most cases, discharging sediment to the downstream channel will be the least expensive option as well.

The following principles should be considered when making sediment releases to maximize the environmental benefits and minimize or prevent negative environmental impacts:

- Match the timing (seasonality, discharge level, duration) of sediment passage measures with pre-damming natural sediment regimes as much as possible. Analyze the modern reservoir release and downstream ecosystem sediment regime to identify deviations from the natural sediment regime.
- Sediment releases/bypassing should not have long-term negative impacts on the native ecosystem downstream.
- Do not release sediments with appreciably elevated levels of contamination relative to the sediments downstream. (In these cases, the federal interest will likely favor continued sediment trapping.)
- Attempt to match the concentration of sediment discharges to more natural conditions to benefit the ecological needs of the system.
- The most downstream reservoir in a closely-spaced series can satisfy the sediment deficit in the downstream river by accounting for the trapping by proximal upstream reservoirs.

Recommendation 2 - Expand the Footprint for Reservoir Sedimentation Analyses

Decades of experience have demonstrated that the effects of sediment trapping in reservoirs can extend far upstream and downstream from the original project boundary. Sediment tends to deposit near the confluence of the reservoir multi-purpose pool level and the upstream channel, which forms the familiar reservoir delta. Delta progression proceeds both upstream (new Harrison, 1983) and into the reservoir and effects can impact upstream land use and infrastructure, and have within-reservoir environmental and recreational impacts in addition to degrading primary project purposes. Increased sediment may also increase invasive plants issues in turn increasing project O&M and exacerbating issues related to the delta formation as vegetation slows waters and traps sediment. These deltas can have negative impacts on recreation fishery recruitment and in turn reduce recreational use as the fishery declines. Increased sediment storage often facilitates increased nutrient levels and may encourage harmful algal blooms (new Utah Division of Water Resources, 2010).

Reservoir sediment trapping of sediments can cause sediment starvation for miles downstream (new National Research Council, 2011). Trapping of sediments has led to bed degradation with associated damage to bridge piers, levee toes, water intake structures, and other river-side infrastructure. In addition, a lack of coarse sediments degrades spawning habitats and sand-bar habitats for birds. Trapping fine sediments causes unnaturally clear water releases downstream. Lack of turbidity allows non-native fish to outcompete and prey upon native species and leads to wetland loss (new Kondolf et al. 2014).

The EAB recommends that as sediment management alternatives are evaluated, the footprint for analysis be expanded to include the damages (and prevented damages) upstream and downstream in addition to the lost benefits in the reservoir itself. A comprehensive accounting for the real impacts of reservoir sedimentation will allow for better decision making and more accurate placement of reservoir sediment management among other federal priorities.

Recommendation 3 - Analyze Storage Lost to Sedimentation as a Reallocation

Without intentional action, reservoir pools will by default be reallocated to sediment storage over time. Formal pool reallocation between other authorized purposes are executed only after a pool reallocation study. We recommend that a similar study be done for Corps reservoirs to assess the economic and environmental effects of reallocating storage away from existing authorized purposes to sediment. The economic and environmental benefits that will be lost should be quantified so that either (1) sediment sustainability actions can be justified and implemented, or (2) a plan to optimally redistribute remaining benefits until a final project decommissioning is implemented.

In addition to the value of lost benefits, the economic and environmental consequences of reservoir sediment trapping should include the increase in O&M costs related to acute sediment deposition, the costs of downstream sediment starvation, the costs of upstream delta progression, and the costs of project decommissioning.

The EAB recommends that such a "reallocation" style assessment be performed at Corps reservoirs. Where indicated to be in the federal interest by the results of this sustainability/ reallocation study, maintenance for the lake project should include maintenance of the reservoir pools with appropriate cost sharing of maintenance costs.

Cases may exist where continued sediment trapping with associated decay of storage capacity is deemed as the best option. Reservoirs trapping contaminated sediments or reducing dredging needs in downstream navigation channels may fall into this category. The full costs of continued sediment trapping must be included in such a determination, including the increased O&M the project will see under continued sedimentation, upstream and downstream ecological and geomorphological effects of the sediment trapping, and the cost to eventually decommission the project, as well as the loss in benefits from authorized purposes. In these cases, a reallocation schedule should be created to optimally redistribute remaining storage amongst the authorized purposes.

Recommendation 4 - Implement Reservoir Sediment Sustainability Pilot Projects

International examples attest that reservoirs can pass sediments downstream through a variety of means such as drawdown flushes, hydrosuction, dredging with downstream discharge, bypass tunnels, and turbidity current venting (Morris and Fan 1998). Unfortunately, very few reservoirs in the United States have adopted these management strategies. This lack of adoption reinforces the current misconception that dams must trap sediment and cannot release it downstream.

In December 2014, the multi-agency Advisory Committee and Water Information (ACWI) passed a resolution on reservoir sediment management encouraging "all Federal agencies to develop long-term reservoir sediment-management plans for the reservoirs that they own or manage by 2030." (ACWI 2014). ACWI also recommends starting with one or two such plans per year in order to work through the methodologies and inform the larger effort. The EAB supports this recommendation by ACWI and recommends that the Corps implement pilot projects which demonstrate sediment management strategies that pass sediment downstream. These projects could be implemented with federal funding through various authorities such as Section 204 or 1146 on a short-term basis. Following a fully federal pilot phase and the creation of a reservoir sustainability plan, long-term implementation could be accomplished with appropriate cost-sharing by non-federal sponsors.

As a practical matter, the Corps may want to perform a high-level initial screening and prioritization. We suggest that such a prioritization include an estimation for upstream and downstream impacts on ecosystems and infrastructure, with an initial focus on known existing impacts to priority species and ecosystems (e.g. T&E species and rapidly degrading receiving coastal wetland systems). We advise against a prioritization based solely on percent loss in reservoir storage capacity, which could be misleading as to where the needs and opportunities are greatest.

Recommendation 5 - Hold Reoccurring Reservoir Sediment Management Training

Currently, no regularly offered Corps training classes cover reservoir sediment management. As a result, many regulators are unsure how to permit these actions and engineers are unsure how to design cost-effective, environmentally-acceptable solutions.

In 2017 the Regional Sediment Management (RSM) program hosted a three-day training workshop titled: "Reservoir Sediment Management Workshop for Regulators, Planners, and Managers" (Shelley et al. 2018). In 2018, RSM hosted a five-day training workshop titled: "Reservoir Sediment Management and Analysis for Engineers Workshop" (Shelley et al. 2019). The EAB recommends that both of these workshops be repeated on a regular basis (perhaps alternating years).

Conclusion

Reservoir sediment trapping has led to undesirable geomorphological and ecological conditions in river and coastal systems and has negatively impacted river-related infrastructure. Downstream river corridors and receiving coastal ecosystems are being deprived of the sediments essential to proper ecosystem functioning and shoreline defense, upstream river corridors are experiencing aggradation, groundwater rise, and flooding, and the reservoirs themselves are losing water storage capacity.

The Environmental Advisory Board recommends the Corps take the following steps:

1. Expand the footprint for assessing cost-benefits of reservoir sediment management to include both downstream and upstream river corridors.

2. Analyze storage lost to sedimentation as a reallocation, with an assessment of lost benefits and associated increased costs both upstream and downstream of the project footprint.

3. Implement reservoir sediment sustainability pilot projects that demonstrate different management options.

4. Recognize the downstream river and coastal systems as preferred beneficial uses for reservoir sediments, subject to the principles discussed in this document.

5. Hold reoccurring reservoir sediment management training courses.

Taking these steps will encourage the adoption of cost-effective, environmentally-sound reservoir sediment management practices that will improve the ecosystems upstream and downstream of reservoirs and facilitate long-term reservoir sustainability.

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