It can be a dirty job! ~ How the NRCS Deals with Sedimentation

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Introduction

Sedimentation is a critical consideration for stream, river, and reservoir projects. Sedimentation analysis is a key aspect of design since many projects fail due to excessive erosion or deposition. This presentation includes an overview of the variety of analysis and design techniques employed by the Natural Resource Conservation Service (NRCS) in the planning, design and maintenance of watershed or river/stream projects. This presentation discusses the scope of the problem and provides an overview of the methods used to model and predict sedimentation.

NRCS and Work that is Impacted by Sedimentation

For more than 80 years, NRCS and its predecessor agencies worked and continue to work in close partnerships with farmers and ranchers, local and state governments, and other federal agencies to maintain healthy and productive working landscapes. NRCS provides America's farmers and ranchers with financial and technical assistance to voluntarily put conservation on the ground. The work includes the planning and design of a variety of water infrastructure projects including dams, waterways, and stream restoration.

All of these infrastructure projects provide important economic benefits. For example: across the nation, watershed dam projects provide an estimated annual benefit of $2.2 billion in reduced flooding and erosion damages, and improved wildlife habitat, recreation, and water supply for an estimated 47 million people. These projects provide additional benefits, such as improved water quality through sediment and erosion control. Watershed rehabilitation projects also can create rural economic growth and job opportunities. As of 2016, the United States National Inventory of Dams (NID) contained the records of 90,580 dams, of which NRCS aided with approximately 1/3 of this number.

All of these infrastructure projects require consideration of the potential effects of sedimentation. For example, when rivers and streams enter a reservoir, the reservoir traps most of the sediment carried by the stream rather than continuing downstream. Over a period of years these sediment deposits gradually displace the volume originally designated for water storage. Once the planned sediment storage is lost, the water storage volume designed as part of the beneficial purpose of the reservoir is impacted. As this water storage volume is lost, the beneficial uses that depend on storage – such as water supply and flood control – will decline and eventually be lost.

Watershed Projects and Sedimentation

Sedimentation adversely impacts reservoirs. On a world-wide average, the rate of reservoir storage lost to sedimentation is greater than the rate of storage added by construction. World-wide reservoir storage per capita peaked in the 1980s and is now back to 1965 levels due to sedimentation (Annandale 2013). Garcia estimated that the average annual reservoir storage capacity loss rate due to sedimentation is 0.2 percent in the United States (Garcia 2008). This is a serious infrastructure concern.

NRCS traditionally deals with the impacts of sedimentation in reservoirs in the planning phase. Dam planning and construction regulations require that significant implementation of soil conservation measures in the contributing watershed. NRCS implements a variety of techniques and practices to slow runoff, promote infiltration, stabilize gullies, and slow erosion under a variety of NRCS programs. These measure not only improve agricultural productivity but significantly reduce sedimentation into the reservoirs.

While the NRCS and its predecessor agencies long implemented soil conservation, even the best measures will not eliminate sediment flowing into and becoming trapped in reservoirs. Sedimentation prediction uses the following:

- Regional relationships
- Local measurements and observations
- Calculations (typically using modifications of RUSLE)

Specifics for these approaches are available in Soil Conservation Service (SCS) National Engineering Handbook Section 3 (NEH Section 3). Using these techniques, it is possible to estimate an adequate sediment storage for the project design life. The sediment pool is part of the planned reservoir volume.

NRCS planned most dams with a 50-year life and constructed many of these dams in the 1960s and 1970s. Of the 11,000 NRCS project dams, 4,300 have reached the end of their project life. In reviewing these projects, NRCS found that soil conservation practices in the watershed generally resulted in less sedimentation than originally planned but this is not the situation for all NRCS dams. Even when there is less sediment impacts, the loss of reservoir storage can still be a factor in rehabilitation efforts. This is particularly the case if the planned sediment storage capacity has been exceeded or current operation of the outlet works, or other withdrawal infrastructure have been impacted. When sedimentation must be addressed as part of NRCS rehabilitation efforts, the approach is to either dredge the dam or raise the embankment.

Stream Projects and Sedimentation

The success of any constructed channel reach is based on its ability to transport the inflowing water and sediment load without excessive sediment deposition or scouring on the channel bed. Excess scour can cause banks to fail while excess deposition can reduce flood carry capacity and cause flooding. Even a bank protection project is generally ineffective if the bed is unstable. Therefore, a critical step of any channel design project is a sediment impact assessment. Sediment impact assessments can widely range in effort and output. These assessments use visual or qualitative techniques for relatively simple projects or numerical models that incorporates solution of the sediment continuity equation for more complex projects. A final sediment impact assessment should be viewed as a closure loop at the end of the design process to:

- Validate the efficacy of the design channel geometry and guide designers to needed changes in the design or approach
- Identify flows which may cause aggradation or degradation over the short term (these changes are inevitable and acceptable in a dynamic channel)
- Recommend minor adjustments to the channel design to ensure dynamic stability over the medium- to long-term.

The type of sediment impact assessment employed affects the certainty of the result as well as the precision of an assessment as to whether the channel will aggrade, degrade, or remain stable. The choice of the appropriate technique to assess the sediment impact of a proposed project includes an assessment of not only the project goals and watershed condition but also an assessment of the impact of project failure. Visual and qualitative assessments are typically only appropriate for sites where there is low risk and minimal change to an otherwise stable system. These can be accomplished with the aid of primarily judgment-based tools. As a project complexity increases and where there is a higher risk to life and property, more analytical approaches are usually employed. While there is a wide selection of different analytical techniques, they all typically require the calculation of hydraulic parameters such as velocity and shear stress for the range of natural discharges. They all require data determined from field observations and measurements as well as calculations. Such assessments may require a non-trivial investment of time, but that time may be well spent when compared to the impacts of a project not performing as intended. Table 1 below illustrates some typical sediment impact analysis for different project types and watershed conditions.

Table 1: Selection guidance for sediment impact assessment technique

Project Type	Site / Watershed Assessment	Risk to life, property, or project investment	Suitable Sediment Impact Assessment
Bank stabilization. No significant change to cross section, slope, or planform.	Relatively stable watershed and site.	Low	Confirm that there is no significant change in the local hydraulic conditions from pre to post project and note watershed stability.
Bank stabilization. No significant change to cross section, slope, or planform.	Moderately active watershed and site.	Moderate	Assess stable channel grade at design flows. Field check indications of future channel evolutionary change
Bank stabilization. No significant change to cross section, slope, or planform.	Moderately active watershed and site.	High	Rating Curve comparison of above and through site
Channel modification. Small change to cross section, slope, or planform.	Moderately active watershed and site.	Low	Rating Curve comparison of above and through site as well as pre and post project
Channel Modification. Significant change to cross section, slope, or planform.	Moderately active watershed and site.	Moderate	Sediment Budget analysis with SAM or spreadsheet-based type analysis
Channel Modification. Significant change to cross section, slope, or planform.	Active watershed and site.	High	Long term numerical modeling with HEC-RAS type analysis

The selection of the appropriate methodology requires a firm understanding of the assumptions, accuracy, data requirements, and limitations of the approach. NRCS guidance in NEH-654 provides more details and guidance in the specific techniques.

Conclusion

Sedimentation is a critical component in the planning, design and operation of any watershed or stream/river project. A variety of analysis techniques are used. While no model or assessment eliminates all possibility of a project not performing as intended, the use of the appropriate tool as discussed in NEH-654 and NEH Section 3 reduces the possibility of poor project performance.

References

Annandale, G. (2013). *Quenching the Thirst, Sustainable Water Supply and Climate Change*, Create Space Independent Publishing Platform, North Charleston, SC, 231 pages.

Garcia, M. H. (2008). *Sedimentation engineering: processes, measurements, modeling and practice*, American Society of Civil Engineers.

U.S. Department of Agriculture – Soil Conservation Service, National Engineering Handbook, Section 3, Sedimentation (NEH Section 3).

U.S. Department of Agriculture – Natural Resources Conservation Service, National Engineering Handbook, Part 654, Stream Restoration Design Handbook (NEH-210-VI-654 or NEH-654).