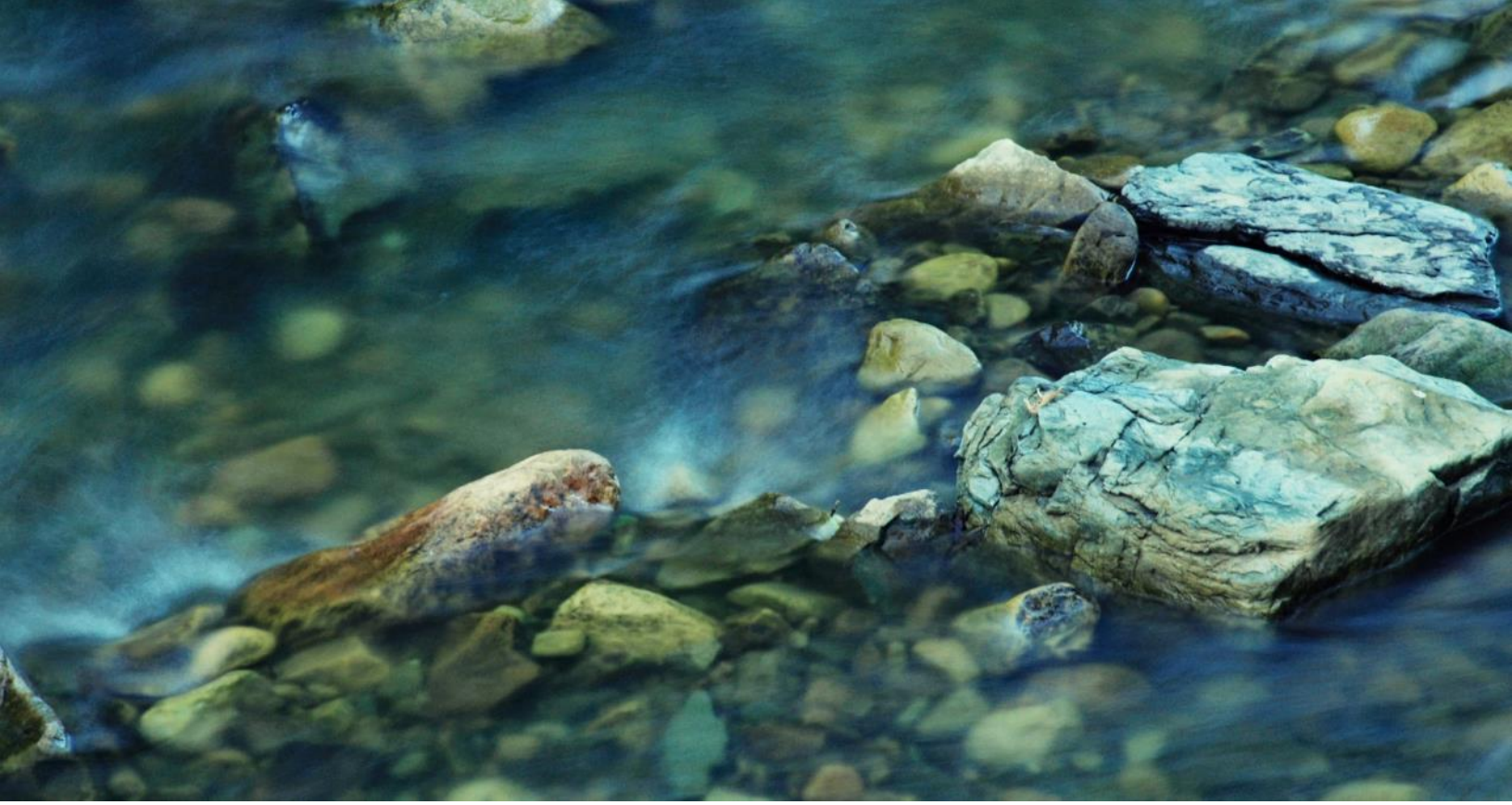

February 2020

ANCHOR QEA

Development of Basic Cost Model for Removal of Sediment from Reservoirs

Prepared for National Reservoir Sedimentation and Sustainability Team

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Prepared by
Anchor QEA, LLC
12596 West Bayaud Avenue, Suite 450
Lakewood, Colorado 80228

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1 Introduction

Water supply reservoirs across the United States are essential to the nation's economy and welfare but face a growing challenge in the form of ongoing buildup of sediment that has been eroded from upstream watersheds and carried into reservoirs by river flow. Without active management, the continued accumulation of sediment gradually displaces the water storage capacity of reservoirs, reducing effectiveness for water supply, power production, recreation, flood risk management, and other uses.

The National Reservoir Sedimentation and Sustainability Team (NRSST), a collection of federal agencies, university researchers, technical experts, and other parties associated with reservoir use and management, has been exploring the problem of reservoir sediment management for several years. In June 2019, the NRSST released a white paper (NRSST 2019) that describes the various means by which sediment buildup in reservoirs can be managed and mitigated, as well as the technical, permitting, and economic challenges associated with doing so.

In some cases, regular removal of sediment can be the most viable option for long-term sustainability of reservoir storage capacity. This is especially likely in arid regions where reservoir water storage is considered too valuable to use for other forms of sediment management such as flushing or reservoir drawdown. For these cases, the costs of sediment removal will be a very important consideration.

This report presents a framework for early, order-of-magnitude-level cost estimating for cases where accumulated sediment needs to be removed from a lake or reservoir. Cost ranges were developed collaboratively between Anchor QEA, LLC, and Great Lakes Dredge and Dock Company, LLC, using experience gained over several decades of dredging lakes and reservoirs across the United States, including the following:

- Wilde Lake, Maryland
- Lake Decatur, Illinois
- John Redmond Reservoir and budgetary estimates for Tuttle Creek Lake, Kansas
- Lake Worth, Texas
- Cedar Lake and Lake Manawa, Iowa
- Waurika Reservoir, Oklahoma
- Fountain Lake, Minnesota
- St. Mary's River, Michigan
- Ashtabula River, Ohio
- Wiley Dondero Canal, St. Lawrence Seaway, New York

2 Cost Models for Four Sediment Removal Scenarios

Cost models for the following four different sediment removal scenarios are represented in Tables 1 through 4:

- Table 1 presents a cost model for mechanical excavation of accumulated sediments, after the lake or reservoir has been temporarily drained of water to allow equipment access.
- Table 2 presents a cost model for mechanical dredging of sediments, using portable barge-mounted excavators and transport barge equipment working over water.
- Table 3 presents a cost model for hydraulic dredging of sediments, using hydraulic cutter suction dredging equipment working over water, and pumping the sediments through pipelines to an upland placement location.
- Table 4 presents a cost model for hydraulic cutter suction dredging of sediments and pumping directly to nearby downstream locations.

Because overall project size influences unit costs, the tables have been further subdivided into three relative project sizes[1], as follows:

- Small-scale projects (generally defined here as projects requiring removal of up to 100,000 yd^3 (cubic yards)
- Medium-scale projects (removal of up to 1 million yd^3)
- Large-scale projects (removal of more than 1 million yd^3)

[1] Table 2, mechanical dredging, uses smaller volumes in its definition of project sizes.

3 Key Assumptions and Limitations

The cost ranges presented in Tables 1 through 4 are intended only as order-of-magnitude-level guidance for early planning purposes and for comparison from one project or methodology to another. Actual project-specific costs need to be developed on a site-by-site basis.

While cost ranges presented in the tables are reasonably representative of average or typical projects, not all situations fit that definition. For example, the tabulated cost models are not able to fully represent unique cases of particularly deep water reservoir excavation (water depths greater than 60 to 100 feet), nor projects that require material to be pumped long distances (e.g., more than 10 miles).

Furthermore, market conditions, availability of equipment, size of contracting pool, site access difficulties, presence of large woody debris, and other factors can play a significant role in project pricing beyond what is represented in this table.

The presence of chemical contamination in sediments would increase costs due to additional environmental protection measures being necessary, as well as more restrictive disposal endpoints.

Further assumptions and limitations are noted in Tables 1 through 4.

4 Use of Cost Model Tables

The following two examples illustrate the use of the cost model tables for two theoretical cases:

Example 1: Mechanical dredging of reservoir with anticipated 75,000 yd^3 of sediment needing removal and disposal on site

- Use Table 2, Cost Model for Mechanical Dredging Through Water, and apply the column "Medium-Scale Project 25,000 to 100,000 yd^3."
- Table 2 lists several individual unit costs for the dredging, hauling, and disposal process. The total of these individual unit costs for on-site disposal is $32 to $85 per yd^3. Note that costs for off-site disposal would be quite a bit higher.
- Total of individual unit costs is 75,000 yd^3 multiplied by $32 to $85 per yd^3, or $2.4 million to $6.4 million (rounded).
- Also include additional costs, as listed for the following items:
  - Equipment mobilization and demobilization: $250,000 to $500,000
  - Preparation of placement/disposal area (if necessary): $20,000 to $30,000
  - Design, project management, and construction management: $1 million to $2 million

Summing up the low and high limits of the given ranges, using the values listed above, gives a total project estimate ranging from **$3.7 million to $8.9 million**. These values could be further rounded to $4 million to $9 million.

Example 2: Hydraulic dredging of reservoir with anticipated 2 million yd^3 of sediment for downstream direct placement

- Use Table 4, Cost Model for Hydraulic Dredging with Downstream Direct Placement, and apply the column "Large-Scale Project More than 1 million yd^3."
- Table 4 lists individual unit costs for dredging as well as for regrading of materials along the river channel (for cases where this is necessary). The total of these individual unit costs is listed as $3 to $7 per yd^3.
- Total of individual unit costs is 2 million yd^3 multiplied by $3 to $7 per yd^3, or $6 million to $14 million.
- Also include additional costs, as listed for the following items:
  - Equipment mobilization and demobilization: $1.5 million to $3 million
  - Design, project management, and construction management: $1 million to $2 million

Summing up the low and high limits of the given ranges, using the values listed above, gives a total project estimate ranging from **$8.5 million to $19 million**.

5 Additional Resources for Further Information

Several additional resources are also available for obtaining information on costs of sediment removal from reservoirs. These include, but are not limited to, the following:

American Society of Professional Estimators, 2012. *How to Estimate the Cost of Mechanical Dredging*. ASPE Technical Paper. Based in part on USACE Technical Letter 1110-2-573, "Construction Cost Estimating for Civil Works," Appendix D: Preparation of Dredge Cost Estimates. Available at: https://cdn.ymaws.com/www.aspenational.org/resource/resmgr/Techical_Papers/13_June_TP.pdf.

Doody, J.P., and B.S. Cushing, 2001. "An Evaluation of Environmental Dredging for Remediation of Contaminated Sediment." *Handbook of Complex Environmental Remediation Problems*. Editors, J. Lehr, M. Hyman, T. Gass, and W. Seevers. New York: McGraw-Hill.

Morris, G.L., and J. Fan, 1998. *Reservoir Sedimentation Handbook*. New York: McGraw-Hill.

U.S. Environmental Protection Agency (USEPA), 2000. *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*. USEPA 540-R-00-002. Prepared by the U.S. Army Corps of Engineers Hazardous, Toxic, and Radioactive Waste Center of Expertise (Omaha, Nebraska) and the USEPA Office of Emergency and Remedial Response (Washington, DC). Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi/10001YOR.PDF?Dockey=10001YOR.PDF.

6 Reference

NRSST (National Reservoir Sedimentation and Sustainability Team), 2019. *Reservoir Sediment Management: Building a Legacy of Sustainable Water Storage Reservoirs*. NRSST White Paper. June 2019.

Tables

Table 1
Cost Model for Mechanical Excavation After Temporary Removal of Water

Approximate cost ranges identified for key cost elements

	Small-Scale Project Up to 100,000 yd^3	Medium-Scale Project 100,000 to 1 million yd^3	Large-Scale Project More than 1 million yd^3	Notes
Individual unit costs				
Material excavation, using land-based excavators	\$10–\$15/yd^3	\$5–\$10/yd^3	\$5/yd^3	
Material stockpiling/dewatering, if necessary	\$10–\$20/yd^3	\$5–\$15/yd^3	\$5–\$10/yd^3	
Processing or screening, if needed to improve reuse potential of material	\$15–\$30/yd^3	\$10–\$25/yd^3	\$5–\$20/yd^3	May include mechanical separation by grain size (to produce reusable fill) and/or mechanical dewatering
Hauling material by truck to placement/disposal area	\$5–\$10/yd^3 (on site)	\$5–\$10/yd^3 (on site)	\$5–\$10/yd^3 (on site)	
	or \$15–\$60/yd^3 (off site)	or \$15–\$60/yd^3 (off site)	or \$10–\$50/yd^3 (off site)	
Reclamation of placement/disposal area	\$5/yd^3	\$5/yd^3	\$5/yd^3	Limited grading, soil cover, and/or planting
Total of individual unit costs (on-site disposal)	**\$45–\$80/yd^3**	**\$30–\$65/yd^3**	**\$25–\$50/yd^3**	
Total of individual unit costs (off-site disposal)	**\$55–\$130/yd^3**	**\$40–\$115/yd^3**	**\$30–\$90/yd^3**	
Additional costs				
Equipment mobilization and demobilization	\$50,000–\$200,000	\$100,000–\$400,000	\$250,000–\$500,000	
Temporary water barrier, cofferdam, and/or water diversion	\$50,000–\$100,000	\$100,000–\$250,000	\$250,000–\$500,000	Temporary barrier; earthen berm; sheetpiling. Costs will increase with greater water depths.
Preparation of placement/disposal area, if necessary	\$10,000–\$20,000	\$20,000–\$30,000	\$30,000–\$60,000	Landfill, cell preparation, or re-use as cover
Design, project management, and construction management (percentages based in part on guidance from USEPA [2000])	\$2–\$3 million	\$6–\$10 million	\$7.5–\$15 million	Consistent with cost estimating guidance in USEPA (2000). Also includes site investigations and characterization. Complex environmental permitting or approvals may require additional cost.

Notes on use of Basic Cost Model:
The cost ranges presented here are intended only as order-of-magnitude level guidance for early planning purposes and for comparison from one project or methodology to another. Actual project-specific costs need to be developed on a site-by-site basis.
Market conditions, availability of materials, size of contracting pool, site access difficulties, and other factors could play a significant role in project pricing beyond what is represented in this table.
Presence of chemical contamination in sediments would increase costs due to additional environmental protection measures being necessary and more restrictive disposal endpoints.

Table 2
Cost Model for Mechanical Dredging Through Water

Approximate cost ranges identified for key cost elements

	Small-Scale Project Up to 25,000 yd^3	Medium-Scale Project 25,000 to 100,000 yd^3	Large-Scale Project More than 100,000 yd^3	Notes
Individual unit costs				
Dredging via crane-mounted clamshell bucket	$10–$20/yd^3	$5–$20/yd^3	$5–$15/yd^3	
Material offloading by excavator	$5–$10/yd^3	$5–$10/yd^3	$5–$10/yd^3	
Material stockpiling, management, and/or drying	$10–$15/yd^3	$5–$15/yd^3	$5–$10/yd^3	
Water collection and management	$2–$4/yd^3	$1–$3/yd^3	$1–$2/yd^3	Removal and management of free water from sediment, if necessary
Processing or screening, if needed to improve reuse potential of material	$15–$30/yd^3	$10–$25/yd^3	$5–$20/yd^3	May include mechanical separation by grain size (to produce reusable fill) and/or mechanical dewatering
Hauling material by truck to placement/disposal area	$5–$8/yd^3 (on site)	$5–$8/yd^3 (on site)	$3–$7/yd^3 (on site)	
	or $15–$60/yd^3 (off site)	or $15–$60/yd^3 (off site)	or $10–$50/yd^3 (off site)	
Reclamation of disposal/placement area	$2–$4/yd^3	$1–$4/yd^3	$1–$3/yd^3	Limited grading, soil cover, and/or planting
Total of individual unit costs (on-site disposal)	**$49–$91/yd^3**	**$32– $85/$yd^3$**	**$25–$67/yd^3**	
Total of individual unit costs (off-site disposal)	**$59–$143/yd^3**	**$42–$137/yd^3**	**$32–$110/yd^3**	
Additional costs				
Equipment mobilization and demobilization	$100,000–$250,000	$250,000–$500,000	$500,000–$1 million	
Preparation of placement/disposal area, if necessary	$10,000–$20,000	$20,000–$30,000	$30,000–$60,000	
Design, project management, and construction management (percentages based in part on guidance from USEPA [2000])	$500,000–$1 million	$1–$2 million	$1–$2 million	Consistent with cost estimating guidance in USEPA (2000). Also includes site investigations and characterization.

Notes on use of Basic Cost Model:

The cost ranges presented here are intended only as order-of-magnitude level guidance for early planning purposes and for comparison from one project or methodology to another. Actual project-specific costs need to be developed on a site-by-site basis.
Market conditions, availability of materials, size of contracting pool, site access difficulties, and other factors could play a significant role in project pricing beyond what is represented in this table.
Presence of chemical contamination in sediments would increase costs due to additional environmental protection measures being necessary and more restrictive disposal endpoints.

Table 3
Cost Model for Hydraulic Dredging to On-Site or Local Repository

Approximate cost ranges identified for key cost elements

	Small-Scale Project Up to 100,000 yd^3	Medium-Scale Project 100,000 to 1 million yd^3	Large-Scale Project More than 1 million yd^3	Notes
Individual unit costs				
Hydraulic dredging, by 14- to 18-inch cutter suction dredge or similar	$15–$20/yd^3	$8–$15/yd^3	$2–$8/yd^3	Typical size range of portable cutter suction dredges: 14-inch (small class); 14- to 18-inch (medium class); greater than 18-inch (large class)
Mechanical dewatering or grain size separation	$15–$30/yd^3	$10–$25/yd^3	$5–$20/yd^3	Passive dewatering approaches (as with open cells or geotubes) may lessen costs.
Reclamation of disposal/placement area	$2–$4/yd^3	$1–$4/yd^3	$1–$3/yd^3	Limited grading, soil cover, and/or planting
Total of individual unit costs (on-site disposal)	**$32–$54/yd^3**	**$19–$44/yd^3**	**$8–$31/yd^3**	
Additional costs				
Equipment mobilization (including pipelines) and demobilization	$100,000–$250,000	$500,000–$1 million	$1.5-$3 million	Includes setup of pipelines and pumps. Price will vary on pipeline length and need for booster pump(s).
Preparation of placement/disposal area, if necessary	$10,000–$20,000	$20,000–$30,000	$30,000–$60,000	
Design, project management, and construction management (percentages based in part on guidance from USEPA [2000])	$1–$2 million	$2–$6 million	$2–$6 million	Consistent with cost estimating guidance in USEPA (2000). Also includes site investigations and characterization.

Notes on use of Basic Cost Model:
The cost ranges presented here are intended only as order-of-magnitude level guidance for early planning purposes and for comparison from one project or methodology to another. Actual project-specific costs need to be developed on a site-by-site basis.
Market conditions, availability of materials, size of contracting pool, site access difficulties, and other factors could play a significant role in project pricing beyond what is represented in this table.
Presence of chemical contamination in sediments would increase costs due to additional environmental protection measures being necessary and more restrictive disposal endpoints.

Table 4
Cost Model for Hydraulic Dredging with Downstream Direct Placement

Approximate cost ranges identified for key cost elements

	Small-Scale Project Up to 100,000 yd^3	Medium-Scale Project 100,000 to 1 million yd^3	Large-Scale Project More than 1 million yd^3	Notes
Individual unit costs				
Hydraulic dredging, by 14- to 18-inch cutter suction dredge or similar	$6–$10/yd^3	$3–$6/yd^3	$2–$4/yd^3	Relatively less wear on equipment involved with direct downstream placement.
Regrading of placed materials, if necessary along river channel	$2–$4/yd^3	$1–$4/yd^3	$1–$3/yd^3	Using standard earthwork equipment working from shore
Total of individual unit costs	**$8–$14/yd^3**	**$4–$10/yd^3**	**$3–$7/yd^3**	
Additional costs				
Equipment mobilization (including pipelines) and demobilization	$100,000–$250,000	$500,000–$1 million	$1.5-$3 million	Includes setup of pipelines and pumps. Price will vary on pipeline length and need for booster pump(s).
Design, project management, and construction management (percentages based in part on guidance from USEPA [2000])	$250,000–$750,000	$750,000–$1.5 million	$1–$2 million	Consistent with cost estimating guidance in USEPA (2000). Also includes site investigations and characterization.

Notes on use of Basic Cost Model:
The cost ranges presented here are intended only as order-of-magnitude level guidance for early planning purposes and for comparison from one project or methodology to another. Actual project-specific costs need to be developed on a site-by-site basis.
Market conditions, availability of materials, size of contracting pool, site access difficulties, and other factors could play a significant role in project pricing beyond what is represented in this table.
Presence of chemical contamination in sediments would increase costs due to additional environmental protection measures being necessary and more restrictive disposal endpoints.