Appendix A

Reservoir Sedimentation Economics Model (RSEM) User Guide

Contents

A.1 Initial Steps

A.1.2 Model Setup

Download the Reservoir Sedimentation Economics Model (RSEM) spreadsheet.

Open the spreadsheet.

Save a copy of the spreadsheet with the project name.

Open the **Inputs** worksheet and enter the reservoir name on Row 2 (cell C2).

Note that the formulas are locked. If you need to customize the model, unlock the model by using the password “RSEM-custom.”

The spreadsheet contains six colored tab worksheets to use for your modeling, and several locked down gray worksheets that perform the “back end” calculations for RSEM (Figure 1).

Figure 1. RSEM worksheets.

You will be using:

- **Inputs** are described and listed in Section A.2 *Sediment and Economic Inputs* of this User Guide. Provide the relevant details about your project here for both the without and with sediment management alternatives.

- **Economic Summary Results** and **Econ Graphs (comparison)** are described and listed in Section A.3 and A.4, respectively. Select the discounting approach and rate, and the graphs and tables will provide results based on your selection and the information from the **Inputs** worksheet.

- **Sediment Graphs (comparison)** are described in Section A.5. These graphs provide results for ten sedimentation profiles based on the information from the **Inputs** worksheet.

- **Yield & Area Graphs** are described in Section A.6. These graphs provide results of the reservoir sedimentation over time based on the information from the **Inputs** worksheet.

Calculation sheets are locked to prevent accidental corruption of the spreadsheet. However, the user can unlock these sheets if they want to modify the programming but do so at their own risk. The locked calculation worksheets are explained in Appendix B for future programming.

A.1.2 Model Defaults and User Overrides

Open the spreadsheet to the **Inputs** worksheet. This initial worksheet provides default values for all input parameters (Column C, white color). The individual default values will be used by the model except when overridden by user-provided values, entered in Column D. Therefore, you must provide values that are specific to your project in Column D. Three color cues are used: gray for values that you should provide, yellow for values that you could provide if you have the information, and white with red crossed out for values where RSEM uses the computed default values that should not be overridden. The model is set for the Muddy Creek Reservoir Case study (see Model Description, Section 2.2, *Muddy Reservoir Example*). These required inputs are displayed in ***red italics*** in the spreadsheet since they are specific to the Muddy Creek Reservoir and should be overridden for your project. Note that all user inputs are in Column D. Do not enter data in any other column. Values that RSEM will use are presented in Column E in pink (Figure 2).

	B	C	D	E	F	G	H
1					Legend for Column D (User Input)		
2	Reservoir Name:	*Muddy Creek Reservoir*			Recommended user input	Optional user input	~~Value that cannot be overridden~~
3	USER NOTE: Enter all values as positive numbers. Only enter "0" if the number is zero. Otherwise, leave the cell blank.						
4	USER NOTE: All *red italicized default values* in Column C are Muddy Reservoir specific and should be overridden with user input in Column D.						
5	INPUT PARAMETERS	Default Values	User Input	Value Used	Units		

Figure 2. Inputs heading and frozen Rows showing color scheme.

A.1.3 Notes

Please be aware of several key notes:

- Enter all values as a positive number, and only enter zero “0” if the number is zero. Otherwise, leave the cell blank. While there could be extenuating circumstances, the model would need to be customized for negative numbers.

- All units should be input as imperial measurements. RSEM converts imperial to metric for the input table for user reference.

- If you do not know a value, please enter and document an assumed value. You may want to run RSEM multiple times with different assumed values for a sensitivity analysis.

- For sedimentation analysis, RSEM always starts from the original dam and reservoir values—prior to any sedimentation. The age of the dam and reservoir starts from when the dam was originally placed in service. If the dam has been significantly enlarged, then consult with sedimentation experts to more accurately use RSEM.

- For economic analyses, RSEM starts with the present or current situation. Economic calculations use the number of years since the base year for economic analysis. For existing reservoirs, all costs and benefits that occurred prior to the beginning year of analysis are not considered.

- RSEM uses the lowest functioning dam outlet elevation throughout. If the dam has outlets at multiple elevations, enter the lowest elevation for the outlet(s) that is still in service.

- RSEM is set up to accommodate all levels of knowledge about the reservoir and sedimentation. Therefore, in general, the model has a forward dependency. Larger Row numbers (further down in the spreadsheet) will depend on what is entered in smaller row numbers (values entered higher up on the spreadsheet)—but overwritten larger row numbers will not change values that were entered in smaller row numbers. For example, annual percentage storage loss (Row 51) will contribute to the calculation of annual total sedimentation rate in Row 55, but if you override values in Row 55, then values entered in Row 51 will not be used.

A.2 Sediment and Economic Inputs

Enter the reservoir name on Row 2 in the **Inputs** worksheet (cell C2) where "Muddy Creek Reservoir" is in Figure 2.

Enter specific reservoir inputs in rows 7 through 47. Detailed explanations of these parameters are provided in the RESM Description, Section 3.1 *Reservoir Modeling*.

Enter reservoir sedimentation characteristics inputs in rows 49 through 74.

Enter reservoir benefits input data in rows 76 through 97. Detailed explanations are provided in Section 4.2 *Economic Benefits*.

Enter cost input data for planning, design, construction, operations, maintenance, replacement, and dam decommissioning in rows 99 through 131. Detailed explanations are provided in Section 4.4 *Economic Costs*.

Enter upstream sedimentation cost data in rows 133 through 137 and downstream channel degradation data in rows 139 through 145. Detailed explanations are provided in Sections 3.2 *Upstream Sedimentation Modeling* and 3.3 *Downstream Channel Degradation Modeling*.

Enter data inputs for the Without Sediment Management Alternative in rows 147 through 166. Detailed explanations are provided in Section 5.1 *Without Sediment Management Alternative*.

Enter data inputs for the With Sediment Management Alternative in rows 168 through 196. Detailed explanations are provided in Section 5.2 *With Sediment Management Alternative*.

A.2.1 Reservoir Age, Size, and Inflow Characteristics

A.2.1.1 Analysis Year and Reservoir Age

The first three rows are dedicated to the beginning years of the dam and reservoir (Figure 3).

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
7	Reservoir Age, Size, and Inflow Characteristics				
8	Base year for economic analysis (BYA)	2022		2022	year
9	Year that all dollar value inputs are indexed to (price level)	2021		2021	year
10	Present Dam and Reservoir Age (0 indicates a new dam and reservoir)	0	30	30	years

Figure 3. Beginning year and analyses in the Input worksheet.

- Row 8, **Base year for economic analysis (BYA)**. Enter the first calendar year of the period of analysis (POA) for which economic results will be presented. The base year of analysis is treated as year 0. Discounting begins in year 1 (base year + 1). Economic results are presented for four POAs: 50 years, 100 years, 200 years, and 500 years. The first year of any POA will be the value specified in Row 8. For example, if 2020 is input for Row 8, the 50-year POA will compute costs and benefits for the years 2020 through 2069. The default value is the current calendar year. You can override the default if you want to simulate an analysis that starts in the past or future. See RSEM Description, Section 4.1 *Considerations for Time-Equivalent Economic Evaluation.*
- Row 9, **Year that all dollar value inputs are indexed to (price level).** Enter the price level for all dollar values in RSEM. This is generally the most recent year for which applicable indices are available and does not have to be the same as the BYA. Note that you will have to perform indexing outside of RSEM.

> **Useful resources for indexing past dam and reservoir-related costs to real dollars are Reclamation's quarterly publication *Construction Cost Trends* (CCT) (Reclamation, 2021a), Reclamation's Operations and Maintenance (O&M) Index (Reclamation, 2019), and the Engineering News Record Construction Cost Index (ENR CCI) (Zevin, 2021). The Reclamation CCT consists of numerous categories and subcategories, including indices for different dam types and structures.**
>
> **For each cost input, the model user should use most appropriate index for that cost category (e.g., earth dams, concrete dams, ENR general construction, O&M, etc.).**

- Row 10, **Present dam and reservoir age.** Indicate if you are modeling a new or an existing reservoir. To model a newly constructed dam and reservoir, use zero (the default value). To model an existing reservoir, use the age of the reservoir in the specified BYA from Row 8. For example, if BYA is specified as 2022, and the reservoir was constructed in 2000, Present reservoir age should be specified as 22.

A.2.1.2 Reservoir Elevation Inputs

These values usually can be found in the engineering description of the new or existing reservoir (Figure 4). See RSEM Description, Section 3.1.1 *Reservoir Age, Size, Inflow, and Dam Characteristics,* Table 3-2. *User Inputs of Original Reservoir Elevations.*

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
11	Reservoir Elevation Inputs				
12	Top of live storage (full pool elevation)	6447.5		6,447.5	feet =
13	Top limit of sedimentation (where sediment will no longer deposits in the reservoir)	6440.0		6,440.0	feet =
14	Recreation pool elevation	6430.0		6,430.0	feet =
15	Normal water surface elevation	6373.0		6,373.0	feet =
16	Incremental sedimentation height limit above dam outlet	20.0		20.0	feet =
17	Sedimentation elevation limit for dam outlet funtion	6378.0		6,378.0	feet =
18	Top of dead storage	6358.0		6,358.0	feet =
19	Original streambed elevation	6287.0		6,287.0	feet =

Figure 4. Reservoir elevation inputs (in the Inputs worksheet).

- Row 12, **Top of live storage.** Enter the reservoir full pool elevation.
- Row 13, **Top limit of sedimentation (where sediment will no longer deposit in reservoir).** Once the simulated sedimentation elevation at the dam reaches this top limit, RSEM assumes that sediment trap efficiency becomes zero and that sediment will no longer deposit within the reservoir (i.e., inflowing sediments are assumed to pass through the reservoir to the downstream channel).
- Row 14, **Recreation pool elevation.** Enter the median reservoir water surface elevation during the typical recreation season. Data from several years should be evaluated (e.g., most recent 5-year period) to determine the median recreation pool elevation. Data from only a single year may not be representative of other years. Note that if the sedimentation reaches the recreation pool elevation, then RSEM will check to see if any boat ramps are buried and out of service.
- Row 15, **Normal water surface elevation.** Enter the median reservoir water surface elevation during the times when sediment is flowing into the reservoir. Reservoir sediment inflow is typically greatest during the rainy season and during spring snowmelt. Time periods when the reservoir inflow is typically greater than the mean-annual discharge also would identify periods of reservoir sediment inflow.
- Row 16, **Incremental sedimentation height limit above dam outlet.** Enter the threshold (in feet above the dam outlet) where dam decommissioning would be needed. This is the height limit where the dam outlet would be buried by sedimentation and no longer operational, even with forced sediment management. A high-hazard dam with severe sedimentation likely would require decommissioning. A low or significant hazard water storage dam with severe sedimentation could possibly be left in place with no remaining benefits.
- Row 17, **Sedimentation elevation limit for outlet function.** RSEM computes the elevation when sediment would bury the dam outlet to a level where the outlet can no longer function. RSEM computes this elevation by adding the value input in Row 16 to the dam outlet elevation or top of dead storage elevation, Row 18.

- Row 18, **Top of dead storage.** Enter the top elevation for dead storage, usually the invert (bottom) elevation of the dam outlet works.
- Row 19, **Original streambed elevation.** Enter the original streambed elevation at the location of the dam axis.

A.2.1.3 Original Reservoir Storage Capacity Inputs

Rows 20 through 23, **Original Reservoir Storage Capacity Inputs,** are required—even for existing reservoirs. RSEM uses these values to simulate the reservoir sedimentation in new and existing reservoirs. Users can compare simulated sedimentation profiles with measured profiles to calibrate sediment input parameters (Figure 5). See RSEM Description, Table 3-2. *User Inputs of Original Reservoir Storage Capacities (prior to any sedimentation)*.

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
20	Original Reservoir Storage Capacity Inputs				
21	Total storage volume at top of live storage	*20,950*		20,950	acre-feet =
22	Dead pool volume	*2,800*		2,800	acre-feet =
23	Live storage volume	18,150		18,150	acre-feet =

Figure 5. Original reservoir storage capacity inputs (in the Inputs worksheet).

- Row 21, **Total storage volume at top of live storage.** Enter the original reservoir storage capacity.
- Row 22, **Dead pool volume.** Enter the original storage capacity that is below the dam outlet (dead storage capacity).
- Row 23, **Live storage volume.** RSEM computes the live storage volume as the difference between the total storage capacity and the dead storage capacity. The user may enter the original live storage capacity, but must make sure the total of live and dead storage capacities (rows 22 and 23) match the total storage capacity in row 21.

A.2.1.4 Reservoir Inflow Characteristics

Rows 24 through 30, **Reservoir Inflow Characteristics,** describe the amount of water entering the reservoir (Figure 6). See RSEM Description, Table 3-3. *User Inputs of Reservoir Water Inflow*.

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
24	Reservoir Inflow Characteristics				
25	Mean annual reservoir inflow	*110,000*		110,000	acre-feet/yr =
26	Standard deviation of mean annual inflow	44,000		44,000	acre-feet/yr =
27	Reservoir live storage capacity to inflow ratio	0.17		0.17	
28	Annual coefficient of variation	0.40		0.40	
29	99% reliable yield (% of mean annual flow)	52%		52%	
30	Annual water volume delivered at 99% reliable yield	56,993		56,993	acre-feet/yr =

Figure 6. Reservoir inflow characteristics (in the Inputs worksheet).

- Row 25, **Mean annual reservoir inflow.** Enter the mean annual reservoir flow for the period of interest. This is usually based on stream gage records but could be adjusted to account for future climate change. RSEM uses this inflow value to compute the other parameters in this section (e.g., reservoir sediment trap efficiency) and provide default values based on the mean-annual reservoir inflow.

- Row 26, **Standard deviation of mean annual inflow.** Enter the standard deviation to account for the range of variation in the mean annual flow, which is usually based on the statistics of streamflow records.

Rows 27 through Row 30 are computed in RSEM, but you can override these values if your reservoir has other known issues that may provide a more accurate value.

- Row 27, **Reservoir live capacity to inflow ratio.** RSEM computes this as the ratio of live storage capacity (Row 23) to mean annual inflow (Row 25). The user should not override this value.
- Row 28, **Annual coefficient of variation.** RSEM computes this as the ratio of standard deviation (Row 26) to mean annual inflow (Row 25). The user should not override this value.
- Row 29, **99% reliable yield (% of mean annual flow).** RSEM computes this from reservoir yield curves, live reservoir storage capacity to inflow ratio (Row 27), and the coefficient of variation (Row 28).
- Row 30, **Annual water volume delivered at 99% reliable yield.** RSEM computes this as the product of the mean annual inflow and the 99% reliable yield. If the annual water volume delivered at 99% reliable yield is less than the reservoir storage volume, then the volume of storage that is available to generate benefits will be reduced. On the other hand, if the annual water volume delivered is greater than the reservoir storage, then RSEM assumes that all the remaining live storage capacity is available to generate benefits. RSEM assumes that the water storage benefits accrue from a single reservoir filling during the year—so 100% of the live storage would be available to generate benefits.

A.2.1.5 Original Reservoir Dimensions

Rows 31 through 37, **Original Reservoir Dimensions**. Please provide values for every input parameter where the data are available in this section. RSEM will estimate default values that may be used where data are not available (Figure 7). While RSEM can compute the other values in this section from Rows 32 and 33, **Reservoir length** and **Reservoir surface area at full pool,** RSEM assumes a hypothetical reservoir shape—which is a simplification. See RSEM Description, Table 3 4. *User Inputs of Original Reservoir Dimensions*.

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
31	Original Reservoir Dimensions				
32	Reservoir valley length at full pool	3.5		3.5	mi =
33	Reservoir surface area at full pool	653		653	acres =
34	Reservoir average surface width at the top surface of a full pool	1,540		1,540	feet =
35	Reservoir average depth at full pool	32		32	feet =
36	Reservoir average surface width at recreation pool	1,445		1,445	feet =
37	Reservoir surface area at the recreation pool elevation 6430 feet (from row 14)	601		600.6	acres =

Figure 7. Original reservoir dimensions (in the Inputs worksheet).

- Row 32, **Reservoir valley length at full pool.** Enter the original valley or canyon length of the full reservoir pool (prior to sedimentation). Do not enter the length of original stream channel which may be meandering within the valley or canyon.
- Row 33, **Reservoir surface area at full pool.** Enter the water surface area corresponding to the full reservoir pool. RSEM estimates the default surface area as the reservoir length times the average width. The average reservoir width is estimated as twice the dam crest length (Row 47). Overriding the default with a measured surface area is recommended. Google Earth could be used to measure the reservoir surface area.

Rows 34 through Row 37 are computed in RSEM, but you can override these values if your reservoir has other known issues that may provide a more accurate value.

- Row 34, **Reservoir average surface width at the top surface of a full pool.** RSEM computes this from the reservoir surface area and length.
- Row 35, **Reservoir average depth at full pool.** RSEM computes this as the ratio of total reservoir storage volume to surface area.
- Row 36, **Reservoir average surface width at recreation pool.** RSEM interpolates this from the reservoir pool elevations and computed average reservoir widths over the full range of reservoir depths.
- Row 37, **Reservoir surface area at the recreation pool elevation.** RSEM computes the surface area from the average reservoir width (Row 36) and the reservoir length at the recreation pool. The reservoir length at recreation pool elevation is computed from the elevation difference at the dam between the recreation pool (Row 14) and original streambed (row 19), and predam river slope (Row 65).

A.2.1.6 Boat Ramps/ Marinas

Enter the number of boat ramps (0,1, or 2) in Row 39. Default values will become active in rows 40 and 41, depending on the selected number of boat ramps. Enter the distance upstream from the dam in miles (Figure 8). This first version of RSEM can compute the economic impacts of sedimentation for up to two boat ramps. Future versions of RSEM may be able to simulate more than 2 boat ramps.

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
38	Boat Ramps / Marinas				
39	Number of boat ramps/marinas (choose up to 2)	2		2	
40	Boat ramp/marina #1 distance upstream from dam (min of 0.1)	2.8		2.8	mi =
41	Boat ramp/marina #2 distance upstream from dam (min of 0.1)	0.1		0.1	mi =

Figure 8. Boat Ramps/Marinas (in the Inputs worksheet).

A.2.2 Dam Characteristics

RSEM uses these reservoir dimension values to compute volume of dam material needed to be removed at the time of dam decommissioning (Figure 9).

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
43	Dam Characteristics				
44	Dam type (drop down list)	Earth		Earth	
45	Volume of dam material	811,782		811,782	yd^3 =
46	Hydraulic height	161		161	ft =
47	Dam crest length across river	770		770	ft =

Figure 9. Dam characteristics (in the Inputs worksheet).

- Row 44, **Dam type**. Select drop down list for earth, rock-fill, concrete gravity, concrete arch, concrete buttress. RSEM uses the dam type to help estimate the volume of material that composes the dam.
- Row 45, **Volume of dam material.** Enter the amount of dam material that would have to be removed at dam decommissioning. In the example case study, Muddy Creek Reservoir, the volume of earth material used to construct the dam was 1,302,0000 cubic yards.
- Row 46, **Hydraulic height.** Enter the elevation difference between the full reservoir water surface and original streambed.
- Row 47, **Dam crest length across river.** Enter dam length of the dam across the river canyon or valley.

A.2.3. Reservoir Sedimentation Characteristics

RSEM will compute the storage reduction from the original reservoir storage by applying an annual storage percent loss due to sedimentation (Figure 10). RSEM uses the values entered in this section to simulate the reservoir sedimentation profiles of the delta and reservoir bottom, channel aggradation upstream of the reservoir, and channel bed degradation downstream of the dam for the without- and with sediment management alternatives. The user can accept default values and run RSEM or override these default values.

To compare how these values will influence the results, run the model with multiple values.

A.2.3.1 Sediment Inflow Rate Inputs

See RSEM Description Section 3.1.2. *Upstream Sediment Supply Rate*.

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
49	**Reservoir Sedimentation Characteristics**				
50	**Sediment Inflow Rate Inputs**				
51	Annual storage percent loss due to sedimentation	0.50%		**0.50%**	**per year**
52	Fine sediment percentage (clay and silt)	*70%*		**70%**	Percentage of sediment grains < 0.062 mm
53	Coarse sediment percentage (sand and gravel)	30%		**30%**	
54	Initial fine sediment trap efficiency percentage	92%		**92%**	see Brune trap efficiency curve
55	Annual total sedimentation rate	98.6		**98.6**	acre-feet/yr =
56	Annual fine sedimentation rate	67.2		**67.2**	acre-feet/yr =
57	Annual coarse sedimentation rate	31.4		**31.4**	acre-feet/yr =

Figure 10. Sediment inflow rate inputs (in the Inputs worksheet).

- Row 51. **Annual storage percent loss due to sedimentation**. Enter the annual percentage storage loss based on reservoir survey results or other location-specific data. If data are not available, use of the default value is recommended. The default calculation depends on the original reservoir storage capacity (i.e., assume a loss of 0.5% per year if the storage capacity is less than 100,000 acre-feet and 0.1% per year if the storage capacity is greater than 100,000 acre-feet).
- Row 52. **Fine sediment percentage (clay and silt).** Enter the percentage of sediment inflowing each year that is considered clay or silt size. RSEM assumes that these fine sediments will deposit along the reservoir bottom downstream between the dam and delta. Clay and silt are usually defined as sediment smaller than a grain size of less than 0.062 millimeter (mm). If you change this definition, please document your assumed grain size in your model result documentations.
- Row 53. **Coarse sediment percentage (sand and gravel).** RESM computes the percentage of inflowing sediment that is considered coarse. RSEM assumes that coarse sediments will deposit in the delta and possibly along the upstream river channel. The percentages of fine and coarse sediment must equal 100%.
- Row 54. **Initial fine sediment trap efficiency percentage**. RSEM computes the initial fine sediment trap efficiency (Row 54) and decreases this value over time as the reservoir may fill with sediment. See the Model Description Section 3.1.7. *Sediment Trap Efficiency*.
- Rows 55 - 57. **Annual total, fine, and coarse sedimentation rate**. Defaults are computed based on the reservoir storage capacity, annual percent storage loss, and the percentage of fine and coarse sediment. You can override these calculations if you have reservoir-specific values. The values provided in Rows 55 to 57 are the important input parameters that are carried forward by the model in subsequent calculations. Default calculations are based on the inputs provided in Rows 51 through 54. If you enter a value in Rows 55 to 57, then the values in Rows 51 through 54 will not be used.

A.2.3.2 Reservoir Sedimentation Profile Slope Inputs

Specify the reservoir sedimentation slopes as a function of the predam river channel slope and delta topset slope (Figure 11and Figure 12). See RSEM Description Section 3.1.3. *Reservoir Sedimentation Profile Slopes*, Table 3 7. *User Inputs of Reservoir Sedimentation Profile Slope Parameters*.

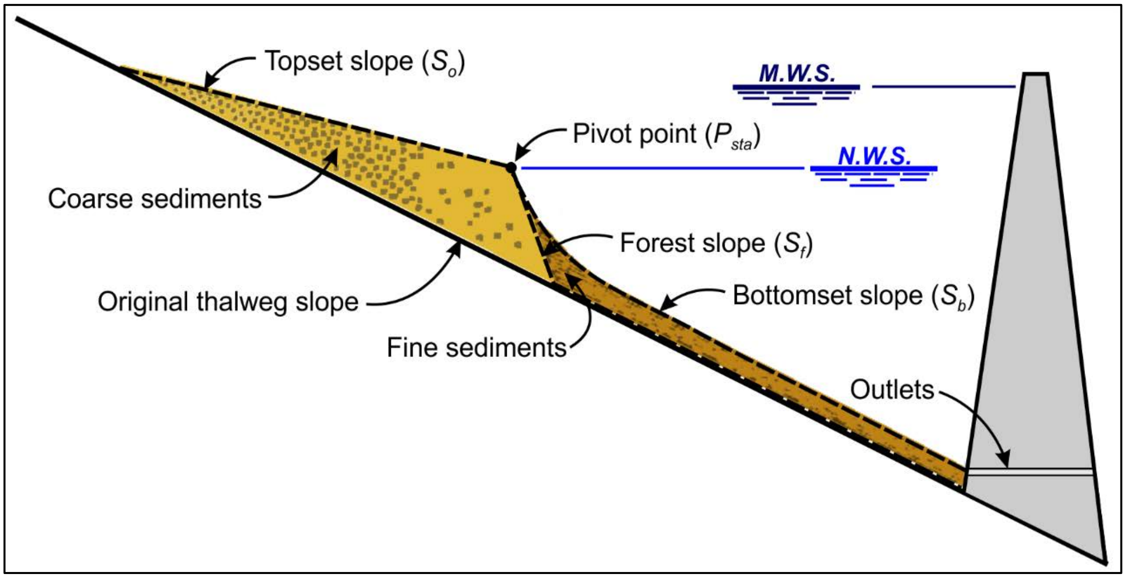


Figure 11. Reservoir sedimentation profile of the delta and reservoir bottom sediments (modified from Strand and Pemberton, 1982). The topset and foreset slopes define the delta profile and the pivot point between these two slopes is typically equal to the normal

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
58	**Reservoir Sedimentation Profile Slope Inputs**				
59	Delta topset slope factor	0.5		**0.50**	
60	Delta foreset slope factor	6.50		**6.50**	
61	Bottomset slope factor	*0.10*		**0.10**	
62	Reservoir profile plotting interval	12		**12**	years

Figure 12. Reservoir sedimentation profile slope inputs (in the Inputs worksheet).

- Row 59 and Row 60, **Delta topset and foreset slope factor**. The delta topset slope factor is specified as a multiple of the predam river channel slope. The foreset slope factor is specified as multiple of the topset slope. The default values for these Rows are typical for many reservoirs. However, override the default values with reservoir-specific data, if available.
- Row 61 **Bottomset slope factor**. The bottomset slope factor is specified as a multiple of the predam river channel slope. This value must be greater than zero and less than one. The default presented is for the Muddy Creek example, and these slope factors vary between reservoirs. If you do not know the value, it might be useful to run the model with several bottom slope factors between 0.1 and 0.9.

- Row 62 **Reservoir profile plotting interval**. RSEM will provide ten sediment profiles. If you use the default, you will have ten profiles over the life of the reservoir (until the dam decommissioning age) without sediment management (Row 155). If you want more frequent plotting intervals, then enter a smaller value. If you want to examine a certain year in the planning period, change the plotting interval to a whole integer factor of that year (e.g., for the 75th year, change the plotting interval to every 5 years or 25 years. Note that inputting a plotting interval larger than one-tenth of simulated reservoir life will result in one or more invalid profile plots for the without sediment management alternative. For example, inputting a profile interval of 20 years would generate 10 profile plots over 200 years. If the simulated dam decommissioning age is 100 years, the profile plots from years 120 through 200 will depict sedimentation beyond the life of the dam.

A.2.3.2 Predam River Channel and Degradation Parameters

Information about the predam river channel is needed to simulate the potential for downstream channel degradation due to the trapping of coarse sediment within the reservoir and the downstream release of clear water (Figure 13). See the Model Description Section 3.1.4. *Predam River Channel and Degradation Parameters* Table 3-9. *User Inputs of Predam River Channel and Degradation Parameters*.

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
63	**Predam River Channel and Degradation Inputs**				
64	Channel sinuosity (ratio of channel length to valley length)	1.1		1.1	
65	Longitudinal channel slope	0.00790		0.00790	
66	Average bankfull channel width	100		100	ft =
67	Average flow depth at bankfull discharge	4.0		4.0	ft =
68	Average channel roughness (Manning's *n* coefficient)	0.035		0.035	
69	Average streamflow velocity	9.5		9.5	ft/s =
70	Bankfull discharge	3,803		3,803	ft³/s =
71	Percentage of bed material that is armor size or coarser	10%		10%	
72	Armor layer thickness	0.5		0.5	ft =
73	Percentage reduction in the original downstream channel slope needed to achieve stability	5%		5%	
74	Percentage of original downstream channel slope that would remain after stability has been achieved	95%		95%	

Figure 13. Predam river channel and degradation inputs (in the Inputs worksheet).

- Row 64, **Channel sinuosity (ratio of channel length to valley length).** Enter the channel sinuosity as the ratio of channel length to valley length. The sinuosity is used to define the degree of channel meandering. RSEM uses sinuosity to compute the predam channel slope (Row 65). The channel and valley lengths, to compute sinuosity, can be measured from predam aerial photographs or maps of the reservoir or measured from river segments upstream from the reservoir delta. The default value of 1.1 is for a relatively straight river channel. A value of 3 would be considered highly sinuous or meandering. Typically, the sinuosity ranges from 1.1 to 2.
- To define the channel's water conveyance capacity at the bankfull discharge, enter values in Rows 65 through 68:

    - Row 65, **Longitudinal channel slope** (the default value is computed from **channel sinuosity** (Row 64), reservoir valley length (Row 32), and hydraulic height of the dam [Row 46]). The default value can be overridden if the location-specific channel slope is known.

    - Rows 66 and 67, **Average bankfull channel width and average flow depth at bankfull discharge.** RSEM uses the average channel width and flow depth to compute the cross-sectional area of the bankfull discharge. For natural streams channels, the average flow depth at the bankfull discharge is typically equal to the bank height. However, the average bankfull-flow depth could be less than the bank height of previously degraded channels.

    - Row 68, **Average channel roughness**. Enter the Manning's *n* roughness coefficient. Manning's n roughness coefficients typically range between 0.020 and 0.045.

- Row 69, **Average streamflow velocity**. RSEM computes the flow velocity using Manning's equation based on the average flow depth (Row 67), channel slope (Row 65), and channel roughness (Row 68).

- Row 70, **Bankfull discharge**. This is the flow conveyance capacity of the downstream channel. RSEM computes the default value from the cross-sectional area of flow and flow velocity (Row 69). To adjust this value, adjust the **channel slope** (Row 65), **average bankfull channel width** (Row 66), and/or **channel roughness** (Row 68) values.

- To compute channel degradation, enter values in Rows 71 through 74. See Model Description Section 3.3. *Downstream Channel Degradation Modeling* for these equations.

    - Row 71, **Percentage of bed material that is armor size or coarser**. Enter the percentage of the streambed material that is likely to remain along the streambed channel after the finer bed-material has eroded away because the coarse sediment supply has been trapped in the upstream reservoir. For streambed primarily composed of boulders and cobbles, the percentage could be as high as 50%. For sand-bed stream channels, the percentage could be quite low (less than 1%, or even zero).

    - Row 72, **Armor layer thickness**. Enter the minimum thickness the armor layer needs to be to resist channel degradation. The default is 0.5 feet (6 inches). You can override this with location-specific data or results from a detailed study.

- Row 73, **Percentage reduction in the original downstream channel slope needed to achieve stability**. Enter the percent the channel slope is reduced before the channel would be stable and stop degrading. The default value is 5%—indicating that the original channel slope would be reduced by 5% and become 95% of the original channel slope.

- Row 74 **Percentage of original downstream channel slope that would remain after stability has been achieved**. RSEM computes the remaining slope value from the previously defined percent reduction value (Row 73). The default value is 95%, indicating a loss of 5%. A value of 100% indicate would that there is already a stable slope. A value of 75% would indicate that the slope would be eventually reduced by 25% before achieving a stable slope and, therefore, 75% of the original slope would remain.

A.2.4 Reservoir Benefits

Unit reservoir benefits are entered so RSEM can compute and compare the economic benefits of the reservoir storage capacity over time under alternatives without- and with sediment management. RSEM considers different categories of benefits such as agricultural irrigation use, municipal and industrial (M&I) water use, fish and wildlife enhancement (F&W), flood risk, hydropower production, and recreation. See RSEM Description Section 4.3. *Benefits* for the background on estimating economic benefits. All monetary values should already be indexed to price level of year indicated in Row 9—which is copied in the parentheses in Row 76.

- Row 77, **Water Yield as a Percentage of Storage Capacity.** This yield is computed by RSEM and determines the amount of water that economic benefits are based on. See RSEM Description Section 3.1.1 *Reservoir Age, Size, Inflow, and Dam Characteristics.* RSEM computes this based on the live storage volume and the annual water volume delivered at the 99% yield capacity. Only override the default value with data resulting from a reservoir yield study.

A.2.4.1 Percentage of Consumptive Uses

Input consumptive use benefits in Rows 78 through 81 as shown in Figure 14. See RSEM Description, Table 4-2. *User Inputs of Percentage of Consumptive Uses.*

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
77	Water Yield as a Percentage of Storage Capacity	100%		100%	Reliability of storage
78	Percentage of Consumptive Uses			100%	
79	Agricultural irrigation use	60%		60%	
80	M&I water use	30%		30%	
81	Fish and wildlife and other	10%		10%	

Figure 14. Reservoir benefits (in the Inputs worksheet).

Rows 79 through 81 capture the percentage breakout of live storage volume by consumptive beneficial use. The sum of the percentage of consumptive use for irrigation, M&I, and fish and wildlife in these rows should equal 100%. Note that the percentage of consumptive use for fish and wildlife is an optional field as RSEM computes the percentage as the difference between 100% and the sum of irrigation and M&I consumptive use percentages. RSEM defaults for these percentages are:

- Agricultural irrigation use 60%
- M&I water use 30%
- Fish & wildlife and other 10%

Some hydrologically small reservoirs may fill multiple times within the year. However, RSEM does not account for annual benefits beyond the reservoir storage capacity.

A.2.4.2 Unit Values for Consumptive Use Benefits

The default benefit values in this section represent typical values for the 17 Western States. Depending on regions and reservoir sites, these values could be much higher or lower than the defaults (Figure 15). These values represent the marginal benefit per unit volume (i.e., the economic benefit of one additional unit from the mean compared to conditions without reservoir). Enter values that are indexed to the year specified in Row 9.

5	INPUT PARAMETERS	Default Values	User Input	Value Used	Units
82	**Unit Values for Consumptive Use Benefits**				
83	Agricultural irrigation use	$250.00		**$250.00**	/acre-foot/yr
84	M&I water use	$450.00		**$450.00**	/acre-foot/yr
85	Fish and wildlife and other	$100.00		**$100.00**	/acre-foot/yr
86	**Flood Risk Reduction**	$40.00		**$40.00**	/acre-foot/yr
87	**Weighted Average Benefit of Storage Capacity**	$335.00		**$335.00**	/acre-foot/yr

Figure 15. Unit Values for Consumptive Use Benefits (in the Inputs worksheet).

- Rows 83 to 85 **water use benefits**, enter unit values for agricultural, M&I, and fish & wildlife benefits in Rows 83 to 85.
- Row 86, **Flood Risk Reduction.** This is the value per acre foot of flood control provided by the reservoir. This value should represent avoided damages that could result from a flood. Consult the regional USACE office for the avoided flood damages by year that are associated with a given reservoir.
- Row 87. **Weighted Average Benefit of Storage Capacity**. RSEM computes this benefit based on inputs from Rows 79 (**Agricultural irrigation us**e) through 86 (**Flood risk reduction**). If you override the **Weighted Average Benefit of Storage Capacity,** then the values in Rows 79 through 86 (consumptive use values and flood risk) will no longer be used.

A.2.4.3 Hydropower Production

Hydropower is not a consumptive use. Note that the hydropower default is zero as most dams do not have hydropower (Figure 16). When the dam does include hydropower, look up the actual or planned energy production.

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
88	Hydropower Production				
89	Average annual energy production	0		0	MWh/yr
90	Average energy benefit rate	$48.00		$48.00	$/MWh
91	Annual hydropower energy benefit	$0		$0	/year =

Figure 16. Hydropower production (in the Inputs worksheet).

- Rows 89 and 90, **Average annual energy production and benefit rate.** Enter the average annual energy production and the average unit value of the energy (energy benefit per MWh). Index the value to the year specified in Row 9.

- Row 91, **Annual hydropower energy benefit.** RSEM computes the annual hydropower benefit as the product of average annual energy production (Row 89) and the energy benefit rate (Row 90). If you override the **annual hydropower energy benefit,** then the values in Rows 89 and 90 will no longer be used.

A.2.4.4 Recreation Use Benefits

The annual net recreation benefit is estimated as the net consumer surplus of a recreation visit multiplied by total annual recreation visitation (i.e., the difference between what consumers are *willing* to pay for a recreation experience and what they *actually* pay for that experience) (Figure 17). Note that these recreation values will depend on the reservoir and are indexed to the year specified in Row 9. Rely on an economic study or consult with an economist for these values. See RSEM Description, Section 4.4.3. *Recreation Benefits*.

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
92	Recreation Use Benefits in Base Year				
93	Average annual visitor days	58,800		58,800	visitor days/year
94	Benefit per visitor day (net consumer surplus)	*$45*		$45.00	/day
95	Benefit dependent on ALL boat ramps/marinas	50%		50%	
96	Benefit reduction from loss of 1 boat ramp/marina	20%		20%	
97	Maximum Annual Benefits Based on Inputs	$8,726,250		$8,726,250	/year

Figure 17. Recreation use benefits (in the Inputs worksheet).

- Row 93, **Average annual visitor days.** Enter the number of visitor days for the base year of analysis (Row 8).

- Row 94, **Benefit per visitor day (net consumer surplus).** Enter the unit recreation benefit per visitor day as the net consumer surplus value. The default value of $45 per day is based on a recent study for a small Reclamation reservoir in western Colorado that included boating, angling, and sightseeing activities and is considered representative of such reservoirs (Gaston, 2019). The user is encouraged to develop a recreation benefit specific to their reservoir.
- Row 95, **Benefit dependent on ALL boat ramps/marinas.** Enter an estimate of the percentage of recreation that depends on all boat ramps. The default assumption is that half of the recreation use depends on the availability of boat ramps.
- Row 96, **Benefit reduction from loss of 1 boat ramp/marina.** Enter the percentage of recreation loss if one boat ramp/marina is buried in sediment. As some boaters could go to the other boat ramp, the default assumption is that the loss of one boat ramp would be 20% of the total reservoir value.
- Row 97, **Maximum Annual Benefits.** Maximum benefits are the benefits attainable in the first year after the reservoir is filled to the full pool and prior to impacts from sedimentation. RSEM computes this based on inputs from the Reservoir Benefits section, Rows 77 through Row 96. This cannot be directly overridden as it is the total economic result. However, the values in Rows 93 through 96 can be changed to compute different maximum annual benefits.

A.2.5 Dam and Reservoir Planning, Design, and Construction Costs

The required lead time for a new reservoir construction can be long—from planning, design, land acquisition, and finally construction. Therefore, it is important to provide cost inputs at the price level indexed to the year specified in Row 9 (Figure 18). Since these steps require huge costs that incur in different time points, their present value would be different in an economic analysis. All monetary values should already be indexed to price level of year indicated in Row 9. See RSEM Description Section. 4.1.3 *Conversion of Nominal Dollars to Real Dollars* and Section 4.4.2 *Dam & Reservoir Planning, Design, and Construction Costs*.

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
100	Planning cost as percentage of construction cost	1%		**1%**	
101	Design cost as percentage of construction cost	5%		**5%**	
102	Planning cost	$174,334		**$174,334**	
103	Design cost	$871,671		**$871,671**	
104	Land acquisition cost	$5,000,000		**$5,000,000**	
105	Construction cost	$17,433,420		**$17,433,420**	
106	Additives for design and construction cost contingencies	$13,728,818		**$13,728,818**	
107	**Total of Planning, Design, Acquisition and Construction Cost***	**$37,208,244**		**$37,208,244**	**Enter total cost if known**
108	* Value includes contingencies for design, construction, and contracting				

Figure 18. R Reservoir planning, design and construction costs (in the Inputs worksheet).

- Row 100 and 101. **Planning and design cost as percentage of construction cost.** Defaults are based on Reclamation's experience that planning and design costs are roughly 6 percent of the overall construction cost. A different percentage may be entered if known.
- Row 107. **Total of Planning, Design, Acquisition and Construction Cost.** The simplest approach is to enter the total cost (sum of planning, design, acquisition and construction cost in Row 107) if known. If you do not know the total cost, then you can use the more detailed lines in Rows 102 through 105 to develop a best estimate for the total cost by entering values and entering contingency percentages in the next section, Design, Construction, and Contract Cost Additives. If you enter a total cost in Row 107, then the values in Rows 100 through 105 (planning, design, land acquisition, and construction costs) will no longer be used.

A.2.6 Design, Construction, and Contract Contingencies Cost Additives

This section lists the contingency costs for unlisted items, mobilization and demobilization, design contingencies, procurement strategy, overhead and profit (Figure 19). The increase to account for these additives is based on percentages of the total cost. The cost additives are used to compute the total dam and reservoir costs if you did not provide a total cost in Row 107 and are working with component costs. Cost additives are also applied to:

- Dam decommissioning costs (Row 130)
- Streambank protection costs for downstream channel degradation (Row 145)
- Annual forced sediment management cost (Row 163)

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
110	Increase for unlisted items	10%		10%	
111	Increase for mobilization and demobilization	5%		5%	
112	Increase for design contingencies	20%		20%	
113	Increase for procurement strategy	5%		5%	
114	Increase for overhead and profit	15%		15%	
115	Increase for construction contingencies	20%		20%	
116	**Total design, construction, and contracting increase**	75%		75%	

Figure 19. Design, Construction, and Contract Contingencies Cost Additives (in the Inputs worksheet).

- Row 110, **Increase for unlisted items.** Enter unlisted items percentage to account for the costs of minor items required to construct a project for which it is not practical to develop designs and quantities during early stages of a project.
- Row 111, **Increase for mobilization and demobilization.** Enter mobilization and demobilization percentage to account for the additional cost of contractor bonds and mobilizing (and de-mobilizing) contractor personnel and equipment to and from the project site, including initial project startup.

- Row 112, **Increase for design contingencies.** Enter design contingencies percentage to account for the cost of minor design and cost estimating refinements which are not practical to anticipate early in the project but typically arise as the project advances through final design.
- Row 113, **Increase for procurement strategy.** Enter procurement strategy percentage to account for the additional cost when solicitations will be advertised and awarded under other than full and open competition. Examples of these practices include Hub-zone, 8(a) competitive and negotiated procurement, small business set aside, Public Law 93-638 Indian Self-Determination Act, or Request for Proposal where award may be based on technical considerations.
- Row 114, **Increase for overhead and profit.** Enter overhead and profit percentage to account for the additional cost necessary to attract construction contractors for assuming the risk of performing the scope of work.
- Row 115, **Increase for construction contingencies.** Enter construction contingencies percentage to account for the additional cost to cover minor differences in actual and estimated quantities, unforeseeable difficulties at the site, changed site conditions, possible minor changes in plans, and other uncertainties.
- Row 116, **Total design, construction, and contracting increase**. RSEM computes the total percentage of these contingencies. If you enter a value in Row 116, then the values in Rows 110 through 115 will not be used. Consult a cost estimator or use the default percentages.

A.2.7 Operation, Maintenance, and Replacement (OM&R) Costs

RSEM considers two types of operation and maintenance costs: annual costs (Row 119) and costs that recur every 5 years (Row 120) (Figure 20). RSEM assumes that OM&R costs remain the same throughout the life of the dam and reservoir. Some OM&R costs are significant and do not occur every year. For example, coating of spillway gates, rewinding of powerplant generators, replacement of valves, etc. The model user is free to annualize all OM&R costs or partition them as desired between annual costs and 5-year recurring costs.

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
119	Annual OM&R cost	$450,000		$450,000	per year
120	5-year recurring costs	$100,000		$100,000	per 5 years

Figure 20. Reservoir operation and maintenance costs (in the Inputs worksheet).

These OM&R costs are non-sediment related costs and apply to both the without-and with sediment management alternatives. In the without sediment management alternative, forced sediment management will eventually be required, and the associated costs are addressed in Rows 157 through 163: **Forced Sediment Management Parameters**. In the with sediment management alternative, OM&R costs to manage sediment are addressed in Rows 175 through 186, **Sediment Management Parameters.**

A.2.8 Dam Decommissioning Costs and Benefits

RSEM assumes that a high-hazard dam will have to be removed after sedimentation levels are so severe that the outlet can no longer function, and a sufficient number of years have passed to complete the dam removal planning. The large majority of Reclamation water storage reservoirs are behind high hazard dams. If the user believes a dam could be left in place after severe reservoir sedimentation, then the dam decommissioning cost could be set to zero. However, annual dam OM&R costs would continue.

The total dam decommissioning cost is based on the cost to remove the structure (dam removal unit cost times volume of dam material), sediment management (unit cost times the volume of reservoir sedimentation), river diversion cost to manage stream flows during demolition and construction activities, coffer dam cost to dewater the construction site, salvage benefits (enter as positive value), other river restoration costs, and the dam decommissioning cost additives. Note that the default values are for the example Muddy Reservoir and should be overridden for the reservoir being evaluated. All monetary values should already be indexed to price level of year indicated in Row 9 (Figure 21).

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
123	Dam removal unit cost	$3.00		$3.00	/yd^3 =
124	Sediment management unit cost	$10.00		$10.00	/yd^3 =
125	River diversion cost	$6,000,000		$6,000,000	
126	Coffer dam cost	$600,000		$600,000	
127	Salvage benefits (enter as positive value)	$0		$0	
128	Other river restoration costs	$0		$0	
129	Dam decommissioning cost before additives	$190,485,575		$190,485,575	
130	**Dam decommissioning cost with additive costs (see rows 109-116)**	$333,349,757		**$333,349,757**	
131	**Annual dam removal benefit**	$10,000		**$10,000**	

Figure 21. Reservoir operation and maintenance costs (in the Inputs worksheet).

- Row 123, **Dam removal unit cost**. Enter dollars per cubic yard of for the dam materials that will be removed.
- Row 124, **Sediment management unit cost.** Enter dollars per cubic yard for reservoir sediment.
- Row 125 and Row 126 **River diversion and coffer dam costs.** Enter costs needed to manage water during demolition and construction activities. Note that not all dam removals require a coffer dam.
- Row 127, **Salvage benefits**. Enter benefits from the sale or reuse of materials salvaged from the dam removal as a positive value.
- Row 128, **Other river restoration costs.** Enter the costs of constructing channel restoration features (e.g., logjams, riffles) to provide habitat, fishways, channel improvements, and planting of vegetation.
- Row 129, **Dam decommissioning cost before additives.** If you override the dam decommissioning cost (before adding the contingency percentages), then the values in Rows 123 through 128 (cost breakdowns) will no longer be used.

- Row 130, **Dam decommissioning cost with additives.** RSEM computes the total dam decommissioning cost from the cost before additives (Row 129) and the added percentage from all of the **Design, Construction, and Contract Contingencies Cost Additives** (Rows 116)**.** Like dam decommissioning costs before additives, putting your own value here will no longer use Rows 123 through 129. See RSEM Description, Section 4.6.3. *Dam Decommissioning* for the computations.
- Row 131, **Annual dam removal benefits.** Enter an estimated value for river restoration or fish passage benefits that would accrue yearly if the dam no longer existed. RSEM assumes that these benefits will begin accruing the year after the dam is decommissioned.

A.2.9 Upstream Sedimentation Costs

Delta aggradation upstream of the full reservoir pool can cause land devaluation and harm upstream infrastructure (e.g., highway, roads, railroads), and fish and boat passage. RSEM considers aggradation beyond a user defined threshold to compute the upstream sedimentation costs (Figure 22). RSEM estimates the delta area that is upstream of the full reservoir pool and that is thicker than the aggradation threshold (Row 134). This delta aggradation area is then used to estimate the cost of impacts to any upstream lands and infrastructure. The unit land devaluation cost, unit highway/railroad relocation costs, and cost for loss of fish and boat passage are listed in Rows 135 through 137. See RSEM Description, Section 3.2. *Upstream Sedimentation Modeling*.

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
133	**Upstream Sedimentation Costs (all dollar values should be indexed to 2021 price level)**				
134	Sedimentation threshold that would cause upstream land impacts	3.0		**3.0**	ft =
135	Lost value per unit area of land when rendered unusable due to inundation	$5,000		**$5,000**	/acre
136	Unit highway/railroad relocation cost due to inundation*	$2,000,000		**$2,000,000**	/mile
137	Annual fish and boat passage cost due to sedimentation*	$100,000		**$100,000**	/year
138	* Includes design, construction, and contracting additive costs				

Figure 22. Upstream sedimentation costs (in the Inputs worksheet).

- Row 134, **Sedimentation threshold that would cause upstream land impacts.** Enter the sedimentation thickness threshold where additional aggradation would start to incur economic losses or costs to lands, infrastructure, fish, or boats. The upstream most extent of delta sedimentation along the upstream river channel will likely be below this threshold, while areas farther downstream may be greater than the threshold. The location where the sedimentation thickness is just at the threshold will advance upstream over time with continued sedimentation.

Each year of simulation, RSEM estimates the length, width, and area of delta sedimentation that is above the full reservoir pool and that is greater than the sedimentation thickness threshold. Inputs provided in Rows 135 through137 are used to compute losses or costs from the impacts of upstream sedimentation.

- Row 135, **Lost value per unit area of land when rendered unusable due to inundation.** Enter the unit value per land area that is taken out of use or production due to increased ground water and flood stage from upstream reservoir sedimentation.
- Row 136, **Unit highway/railroad relocation cost due to inundation.** Enter the relocation cost per unit length for relocating transportation infrastructure, including design, construction, and other cost additives.
- Row 137, **Unit fish and boat passage cost due to sedimentation.** Enter the annual costs per unit length per year for maintaining or mitigating fish and boat passage. This cost includes design, construction, and other cost additives.

A.2.10 Downstream Channel Degradation Costs

Downstream channel degradation and subsequent bank erosion could impact fish and wildlife habitat, vulnerable streamside infrastructure, and property. The value of habitat, any streamside infrastructure, and property is highly variable and may be difficult to quantify. RSEM assumes that channel degradation, beyond a user-defined threshold, will eventually lead to streambank erosion. The estimated cost of this protection represents the economic cost incurred by downstream channel degradation (Figure 23). The cost of streambank protection is based on the unit cost of rock rip rap and the volume of rip rap needed. See RSEM Description, Section 3.3. *Downstream Channel Degradation Modeling*.

139	**Downstream Channel Degradation Costs (all dollar values should be indexed to 2021 price level)**				
140	Median rip rap rock size	0.9		**0.9**	ft =
141	Degradation threshold (min. vertical erosion when economic impacts begin)	2.0		**2.0**	ft =
142	Streambank side slope (*z* :1), Enter *z* value here	2.0		**2.0**	
143	Streambank protection factor	3.0		**3.0**	
144	Unit cost of streambank protection before additive costs (see rows 109-116)	*$50*		$50	$/yd^3$ =
145	**Unit cost of streambank protection with additive costs**	$88		**$88**	$/yd^3$ =

Figure 23. Downstream channel degradation costs (in the Inputs worksheet).

- Row 140, **Median rip rap rock size.** Enter the median rock size needed to protect the downstream channel banks for the expected streamflow velocities. RSEM computes the default rock size as a function of the average bankfull channel velocity. The median rock size is then used to compute the thickness of the rip rap rock layer, equal to 2 times the median rock size. You may override the median rock size if you have better design information.
- Row 141, **Degradation threshold**. Enter the vertical channel degradation (erosion) threshold where additional degradation would start to incur economic losses or costs to downstream lands, infrastructure, or habitat. Additional channel degradation, beyond this threshold, will start to cause streambank erosion and threaten lands, streamside infrastructure, and habitat. The volume of rock rip rap, and the installation cost, will both increase with channel degradation depth.

- Row 142, **Streambank side slope (z:1),** Enter z value here (z is the horizontal length needed for every increment of vertical rise, as illustrated in, Figure 3-8. *Streambank protection concept design for rip rap*. This value represents the horizontal component of the streambank protection slope. The greater the z value, the milder the bank slope, and the greater the volume or rock rip rap needed to protect the streambanks (Equations 36 to 41).
- Row 143, **Streambank protection factor.** Enter a factor between 1 and 4 to account for protection along the left and right channel banks and habitat degradation ($1 \leq F_{BP} \leq 4$). For example, to protect one streambank, enter 1. To protect both streambanks, enter 2. To account for habitat loss, the value could be as high as 3 (for one streambank) or 4 (for both streambanks).
- Row 144, **Unit cost of streambank protection before additive costs.** (see Section A3.6): Enter unit cost to purchase and place the estimated volume of rock rip rap. Each year of the simulation, RSEM computes the additional channel degradation and downstream extent, and the additional volume of rock rip rap needed to protect the streambanks. RSEM multiplies the increase in rock volume from the previous year by the unit cost for material, delivery, and installation
- Row 145, **Unit cost of streambank protection with additive costs.** Additional factors are applied to account for contingencies (See RSEM Description, Equation 42).

A.2.11 Without Sediment Management Alternative

Enter values in this section for a dam without proactive sediment management (Figure 24). Dam decommissioning can be a significant economic cost, so RSEM needs to estimate the timing and cost of dam decommissioning. After the reservoir dead storage capacity has filled with sediment (and before dam decommissioning), the dam outlet may become vulnerable to plugging by wood debris and sediment. Therefore, forced sediment management may be required to maintain dam operations and RSEM estimates these costs. Finally, the loss of one or two boat ramps to sedimentation will significantly reduce recreation benefits, so RSEM needs to estimate when and if this may occur.

A.2.11.1 Dam Decommissioning Age

RSEM simulates the year of dam decommissioning based on the year the dead storage is expected to fill with sediment (sediment design life) plus the additional years until the dam outlet becomes inoperable and enough planning and design has been accomplished (Figure 24). See RSEM Description, Section 3.1.9. *End of Sediment Design Life*.

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
147	Without Sediment Management Alternative				
148					
149	Dam Decommissioning Age				
150	Planned sediment design life	100		100	years
151	Simulated sediment design life (years to fill dead storage with sediment)	36			years
152	User-defined sediment design life (years to fill dead storage with sediment)	100		100	years
153	Add'l years until dam decommissioning (engineering, public invol., & financing)	20		20	years
154	Dam age when sediment is at height limit above outlet	48		48	years
155	Dam decommissioning age	120		120	years
156	Year of dam decommissioning	2142		2142	year

Figure 24. Dam decommissioning age (in the Inputs worksheet).

- Row 150, **Planned sediment design life**. Enter the originally planned sediment design life from the year the reservoir first began filling until the year when the reservoir dead pool storage is expected to fill with sediment. Typical values are 100 or 50 years. This value provides the default for the "user-defined sediment design life" in Row 152.
- Row 151, **Simulated sediment design life (years to fill dead storage with sediment)**. RSEM simulates the year that sedimentation would reach the outlet works (and fill the top of dead pool storage as defined in Row 18). This simulated year is based on sedimentation rates, the reservoir geometry, spatial distribution of the sediment, and the dam outlet elevation. This simulated value cannot be directly overridden here.
- Row 152, **User-defined sediment design life (years to fill dead storage with sediment).** The default value is the planned sediment design life from Row 150. For an existing reservoir, a better estimate can be made from reservoir surveys of the longitudinal sedimentation profile. For new reservoirs (or existing reservoirs without a sedimentation survey), enter the value from the reservoir sedimentation planning study, or enter the value computed by RSEM from Row 151. The spreadsheet cannot use this value as the default without creating a circular reference error.
- Row 153, **Additional years until dam decommissioning (engineering, public involvement, and financing).** Enter additional years, after the dead storage has filled with sediment, that would occur before the dam outlet becomes unreliable, an engineering plan has been developed for dam decommissioning, stakeholder agreement and permits have been obtained, and financing has been procured. Empirical evidence indicates that this value is typically 10 to 30 years for reservoirs with severe sedimentation. The RSEM default value is 20 years. Note that the additional years until dam decommissioning are added to the "value used" in Row 152 to determine the dam decommissioning age.
- Row 154, **Dam age when sediment is at height limit above outlet.** RSEM simulates the dam age when sediment levels would reach the top of the dead storage pool. This simulated value cannot be directly overridden but should be similar to the dam decommissioning age used in Row 155.
- Row 155, **Dam decommissioning age.** This is the dam age at decommissioning. This age is computed as the sum of Rows 152 and 153 and cannot be directly overridden. If the difference between this value and the computed value used in Row 154 is greater than

20 years, the user might consider changing the value in Row 152 to more closely agree with the amount of time for sedimentation to exceed the elevation limit specified in Row 17. Alternatively, the sediment height limit above the dam outlet can be modified in Row 16 to achieve this goal.

- Row 156, **Year of dam decommissioning.** This is the calendar year of dam decommissioning, computed as the sum of Rows 8 and 155. This value cannot be directly overridden.

A.2.11.2 Forced Sediment Management Inputs

After sediment has reached the dam outlet, RSEM assumes that forced sediment management will be used to keep the reservoir operational until dam decommissioning. RSEM assumes that the volume of "forced sediment management" initially will be small and then increase each year until the year before dam decommissioning (Figure 25). See RSEM Description, Section 3.1.9. *End of Sediment Design Life*.

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
157	Forced Sediment Management Parameters (all dollar values should be indexed to 2021 price level)				
158	Begin forced sediment removal	*10*		**10**	years after dead storage has filled with sediment
159	Maximum percentage of sediment inflow that will be removed in the year prior to dam decommissioning	25%		**25%**	Linear rate of increase assumed until the year prior to dam decommissioning
160	Forced fine sediment removal unit cost	$7.00		**$7.00**	/yd^3 = $9.16 /m^3
161	Forced coarse sediment removal unit cost	$7.00		**$7.00**	/yd^3 = $9.16 /m^3
162	Annual forced sediment management cost before additive costs	$278,379		**$278,379**	/yr
163	**Annual forced sediment management cost with additive costs**	$487,164		**$487,164**	/yr

Figure 25. Forced sediment management inputs (in the Inputs worksheet).

- Row 158, **Begin forced sediment removal**. Enter the number of years after the dead pool has filled with sediment when forced sediment management begins. RSEM assumes that forced sediment removal will be needed each year from the time it begins until the year prior to dam decommissioning. The default value is 10 years after the dead storage has filled with sediment. This assumes that a decade of sedimentation would occur above the dam outlet before operational problems would become noticeable and to formulate sediment removal plans to maintain reservoir operations.
- Row 159, **Maximum percentage of sediment inflow that will be removed in the year prior to dam decommissioning**. Enter the percentage of annual sediment inflow that will be removed during the last year of forced sediment removal. RSEM linearly increases the amount removed from the first year of forced sediment removal up to the defined maximum in the year prior to dam decommissioning. The concept is that a certain volume of sediment will have to be removed each year to keep the dam outlet operational. Because of continued sedimentation above the elevation of the dam outlet, the volume necessary to do this will have to increase each year. The default maximum percentage to be removed is 25%, which assumes that we are removing one-quarter of the incoming sediment in the final year before decommissioning. Inputting a value of zero assumes that there is no forced sediment management.
- Row 160 and Row 161, **Forced fine and coarse sediment removal unit cost.** Enter the unit cost of sediment removal for both fine and coarse sediment. The default values are

$7/yd3, but actual unit costs could be much greater. Removing sediment under forced sediment management can be more expensive than under planned sediment management, on a per unit basis. The unit removal cost for fine and coarse sediment can be similar, or quite different, depending on the specific circumstances.

- Row 162, **Annual forced sediment management cost before additive costs.** RSEM computes the default sediment removal cost for the last year of sediment management based on total removal volume, percentages of fine and coarse sediment, and the unit removal costs. If you override this RSEM default value, then the values in Rows 160 and 161 (unit costs and the percentage of forced sediment removal) will not be used.
- Row 163, **Annual forced sediment management cost with additive costs.** RSEM adds the sum of contingencies specified in Row 116 to the "value used" in Row 162. If you override the default value, then the value in Row 162 will not be used.

A.2.11.3 Boat Ramps/Marinas Lost

RSEM estimates the year, or dam age, that each boat ramp/marina may be lost to reservoir sedimentation. If only one boat marina is added in Row 39, then only one row will be active, and the year of loss is only computed for that one boat ramp/marina. (The unused row is grayed out if there is only one boat marina) (Figure 26).

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
164	Boat Ramps / Marinas Lost				
165	Dam age when boat ramp / marina #1 is lost	120		120	years
166	Dam age when boat ramp / marina #2 is lost	0		0	years

Figure 26. Boat ramps/marinas lost (in the Inputs worksheet).This example shows only one boat ramp, with the other potential boat ramp grayed out.

- Row 165 and Row 166, **Dam age when boat ramp/marina #1and #2 (if applicable) is lost.** RSEM simulates the dam age when either boat ramp/marina may be buried by sediment based on when the sedimentation level reaches the recreation pool elevation at the location of the boat ramp/marina (see **Sediment Graphs (comparison)** worksheet and Figure 27). You can also override these values if these years are known. The maximum dam age when the boat ramp is lost must cannot be more than the dam age at decommissioning.

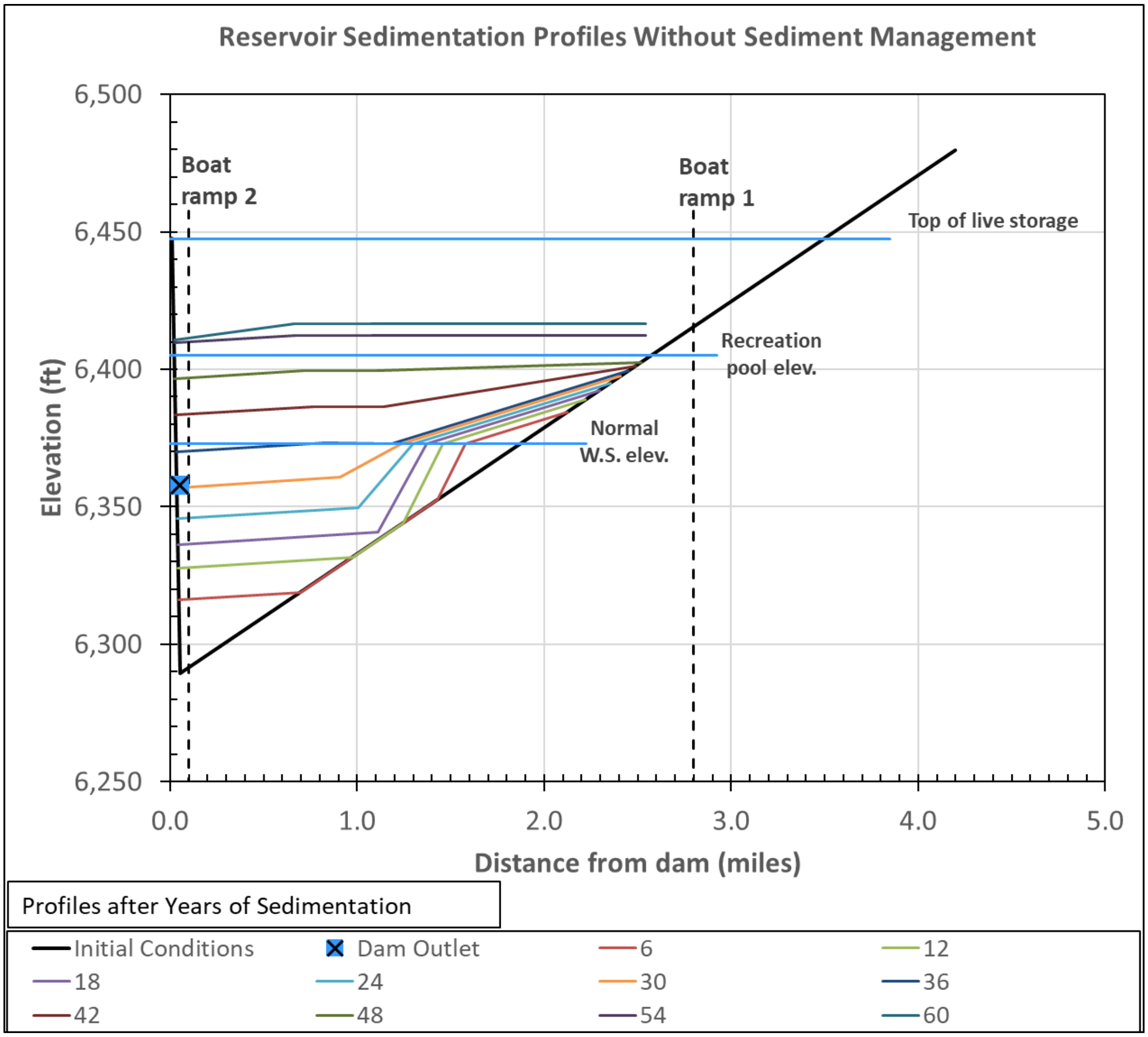


Figure 27. Note the year the sediment profile line first buries the boat ramp/marina at the recreation pool elevation.

A.2.12 With Sediment Management Alternative

Enter these values for a reservoir with proactive sediment management program. This alternative may sustain the reservoir storage capacity over the long term or slow the rate of reservoir sedimentation. The user specifies the dam age when sediment management begins.

If dam decommissioning is eventually necessary, RSEM estimates the timing and cost of dam decommissioning. If reservoir sedimentation fills dead storage capacity, RSEM assumes that the selected sediment management program will be used as necessary to maintain the dam outlet and reservoir operations. RSEM evaluates the economics of sediment management by considering the capital equipment cost, unit operating costs, the annual volume of sediment removed or avoided, and the percentage of reservoir water used for sediment management. If reservoir sedimentation continues, but at a slower rate, RSEM estimates when sedimentation might bury boat ramps and reduce recreation benefits.

A.2.12.1 Dam Decommissioning Age

As in the without-sediment management alternative, RSEM simulates when the dam will be decommissioned based on the simulated sediment design life plus the additional years until dam decommissioning (Figure 28). See RSEM Description, Section 3.1.9. *End of Sediment Design Life*.

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
168	**With Sediment Management Alternative**				
169	**Dam Decommissioning Age**				
170	Simulated sediment design life	353		**353**	years
171	Dam age when sediment is at height limit above outlet	481		**481**	years
172	Additional years until dam decommissioning (engineering, public invol., & financing)	128		**128**	years
173	**Dam decommissioning age**	481		**481**	years
174	**Year of dam decommissioning**	2503		**2503**	year

Figure 28. Dam decommissioning age (in the Inputs worksheet).

- Row 170, **Simulated sediment design life.** RSEM simulates the year that sedimentation would reach the outlet works (and fill the top of dead pool storage as defined in Row 18). This simulated year is based on sedimentation rates, the reservoir geometry, spatial distribution of the sediment, and the dam outlet elevation. This default age can be overridden with estimates from reservoir sedimentation profile surveys and models studies.
- Row 171, **Dam age when sediment is at height limit above outlet.** RSEM simulates the dam age when sediment levels would reach the top of the dead storage pool. For some cases, sedimentation would not reach this level, and the default value of this Row will be "not Reached".
- Row 172, **Additional years until dam decommissioning.** Enter additional years after the dead storage has filled with sediment until the dam outlet is no longer operational and an engineering plan for dam decommissioning is developed along with stakeholder agreement, permits, and project financing. Empirical evidence indicates that this value is typically 10 to 30 years. For cases that sediment does not reach the sedimentation height limit indicated in Row 16, the default value of this Row will be 500 years (maximum years considered in RSEM).
- Row 173, **Dam decommissioning age** or **No dam decommissioning.** Depending on values on Rows 170 and 172, RSEM will either display the dam decommissioning age or stage that the dam will not be decommissioned within 500 years:
  - **Dam decommissioning age**: This is the dam age at decommissioning, computed by RSEM as the sum of Rows 170 and 172.

- **No dam decommissioning:** If sediment does not reach the height limit of sedimentation (Row 172 shows 500 years), this row would show no dam decommissioning cost.

- Row 174, **Year of dam decommissioning** or **No dam decommissioning.** Depending on values on Rows 170 and 172, this row can be shown in two ways:
    - Year of dam decommissioning. This is the calendar year of dam decommissioning, computed as the sum of Rows 8 and 173.
    - No dam decommissioning: If sediment does not reach the height limit of sedimentation (Row 172 shows 500 years), this row would show no dam decommissioning cost.

A.2.12.2 Sediment Management Inputs

RSEM computes the economic costs of sediment management depending on the annual sediment removal or avoidance volumes, capital costs, operation and maintenance costs, and frequency of capital placement. In this section, enter sediment management costs and removal amounts (Figure 29). Costs will generally be lower for planned management sediment removal than under forced sediment management. RSEM assumes the sediment management program will be adapted as necessary to keep the dam outlet and any reservoir water intakes or boat ramps functioning. Therefore, the forced sediment management under the without sediment alternative is not applicable. Note all monetary values should already be indexed to price level of year input in Row 9 and shown in Row 175. RSEM can simulate the economics for a range of sediment management alternatives, one at a time, by varying the unit costs and quantities of each alternative.

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units		
175	Sediment Management Parameters (all dollar values should be indexed to 2021 price level)				Sediment size	(yd^3/yr)	(m^3/yr)
176	Annual fine sediment removal	90%		90%	Fine	97,537	74,573
177	Annual coarse sediment removal	90%		90%	Coarse	45,629	34,886
178	Capital cost before additives	$600,000		$600,000			
179	Capital cost with additives (see rows 109-116)	$1,050,000		$1,050,000			
180	Equipment life (years)	30		30	years		
181	Sediment management begins at dam age	0		0	years		
182	Unit cost for fine sediment removal or avoidance	$5.00		$5.00	/yd^3 =		$6.54 /$m^3$
183	Unit cost for coarse sediment removal or avoidance	$5.00		$5.00	/yd^3 =		$6.54 /$m^3$
184	Annual sediment management cost before additives	$715,832		$715,832	/yr		
185	Annual sediment management cost with additives (exclusive of capital costs)	$1,252,706		$1,252,706	/yr		
186	Percentage of live reservoir storage used only for sediment management	0%		0%			
187	Annual downstream sediment mitigation cost (if sed. passed downstream)	$10,000		$10,000	/yr		

Figure 29. Sediment management inputs (in the Inputs worksheet).

- Rows 176 and 177, **Annual fine and coarse sediment removal.** Enter the percentage of annual incoming sediment that is removed under sediment management alternative.
- Row 178, **Capital cost before additives.** Enter the capital cost of sediment management. This could include the cost of mechanized equipment, dam gates, pipelines, tunnels, etc.

- Row 179, **Capital cost with additives (see Section A.3.6. Rows 109-116).** RSEM adds the sum of contingencies specified in Row 116 to the "value used" in Row 178. If you override the default cost, then the value in Row 178 will not be used.
- Row 180, **Equipment life (years).** Enter the expected service life of the capital equipment. RSEM assumes that capital costs will be incurred again at the end of the service life. For example, a hydraulic dredge might need to be replaced every 30 years while a low-level sluicing gate in the dam may need to be replaced every 75 years.
- Row 181, **Sediment management begins at dam age.** This is the year that RSEM will begin to simulate sediment management. The value should be equal or greater than the present dam and reservoir age (Row 10).
- Rows 182 and 183, **Fine and coarse sediment removal unit cost**. Enters the unit costs of sediment removal for both fine and coarse sediment. The default values are $5/yd^3, but actual unit costs could be much greater. The unit removal costs for fine and coarse sediment can be similar, or quite different, depending on the specific circumstances.
- Row 184, **Annual sediment management cost before additives**. RSEM computes the default based on total removal volume, percentages of fine and coarse sediment, and unit costs for sediment removal. If you override the default value, then the values in Rows 182 and 183 will not be used. Note that capital costs for sediment management are considered separately (see Rows 178 and 179).
- Row 185, **Annual sediment management cost with additives**. RSEM adds the sum of contingencies specified in Row 116 to the "value used" in Row 184. If you override the default value, then the value in Row 184 will not be used. Note that capital costs for sediment management are considered separately (see Rows 178 and 179).
- Row 186, **Percentage of live reservoir storage used only for sediment management.** Enter the portion of live storage dedicated to sediment management. This portion of live storage will be precluded from the reservoir storage yield available for beneficial.
- Row 187, **Annual downstream sediment mitigation cost (if sed. passed downstream).** Enter the annual OM&R cost to downstream water users to exclude sediment from infrastructure due to increased sediment loads along the downstream channel. This could include constructing and managing sediment settling basins, more frequent pump wear and replacement, etc. This input parameter may also be used to account for the net cost of water quality changes.

A.2.12.3 Beneficial Use of Removed Sediment

RSEM can consider revenue generated from beneficial uses of removed sediment, such as road base, soil augmentation, brick production, etc. (Figure 30).

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
188	Beneficial Use of Removed Sediment (revenue generation for use as road base, soil augmentation, brick production, etc.)				
189	Percentage of removed fine sediments put to beneficial use	0%		0%	
190	Percentage of removed coarse sediments put to beneficial use	0%		0%	
191	Unit value of fine sediment	$1.00		$1	/yd^3 =
192	Unit value of coarse sediment	$1.00		$1	/yd^3 =
193	Annual benefit of using removed sediment	$0		$0	/yr

Figure 30. Beneficial use of removed sediment (in the Inputs worksheet).

- Rows 189 and 190, **Percentage of removed fine and coarse sediments put to beneficial use**. Enter the percentage of removed sediments that can be used to generate economic benefit.
- Rows 191and 192, **Unit values of fine and coarse sediment**. Enter the unit values attributable to the beneficial use of the recovered sediments (Rows 189 and 190). The default values are $1/yd^3, but actual values could be much higher.
- Row 193, **Annual benefit of using removed sediment**. RSEM computes the annual benefits attributable to removed sediments as a function of volume put to beneficial use (Rows 189 and 190) and the unit value of that beneficial use (Rows 191 and 192). If the default annual benefit can be overridden with a known value, then the values in Rows 189 through 192 are not used.

A.2.12.4 Boat Ramps / Marinas Lost

RSEM estimates the year, or dam age, that each boat ramp/marina might be lost to reservoir sedimentation (Figure 31). If only one boat marina is added in Row 39, then only one row will be active, and the year of loss is only computed for that one boat ramp/marina. (The unused row is grayed out if there is only one boat marina).

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
194	Boat Ramps / Marinas Lost				
195	Dam age when boat ramp / marina #1 is lost	481		481	years
196	Dam age when boat ramp / marina #2 is lost	481		481	years

Figure 31. Sediment management inputs (in the Inputs worksheet). This example shows two marinas.

- Row 195 and Row 196, **Dam age when boat ramp/marina #1 and #2 (if applicable) is lost.** RSEM simulates the dam age when either boat ramp/marina might be buried by sediment based on when the sedimentation level reaches the recreation pool elevation at the location of the boat ramp/marina (see Sediment Graphs worksheet and Figure 27). You can also override these values if these years are known. The maximum dam age when the boat ramp is lost must cannot be more than the dam age at decommissioning.

A.2.13 Discounting Approach and Rate

There are various discounting approaches as noted in the RSEM Description, Section 4.2. *Discounting Benefits and Costs*. Rows 198 through 199 in the **Inputs** worksheet direct the user to select a discounting approach and rate in the Economics Summary Results worksheet (Figure 32) (Section A.3.1. of this User Guide).

5	INPUT PARAMETERS	Default Values	User Input	Values Used	Units
198	Discounting Approach and Rate				
199	Use the *Economic Summary Results* worksheet and *Discounting Approach and Rate Comparision Tool* to select the discounting approach and rate				

Figure 32. Redirect for the discounting approach and rate (in the Inputs worksheet).

A.2.14 Example input ranges for select cost and benefit categories

Example input values for sediment dredging costs are provided in rows 203 through 206. As an additional resource, Anchor QEA (member of the National Reservoir Sedimentation and Sustainability Team) produced the *Development of Basic Cost Model for Removal of Sediment from Reservoirs* (https://www.sedhyd.org/reservoir-sedimentation/Reservoir%20Sediment%20Removal%20Cost%20Model%20-%20Anchor%20QEA%20February%202020.pdf).

Approximate reservoir water storage benefits are provided in rows 208 through 214.

A.3 Economic Summary Results

The **Economic Summary Results** worksheet requires only two inputs: discounting approach and rate. The rest of this worksheet shows economic results.

All economic results portrayed in the figures within this chapter are based on the default values in the **Inputs** worksheet, the exponential discount approach, and a discount rate of 2.250%, unless otherwise stated.

A.3.1 Discount Approach and Rate Input

Cells for user input on this worksheet are those with a light gray background and blue font. The only inputs on this worksheet are in Row 8 (Figure 33).

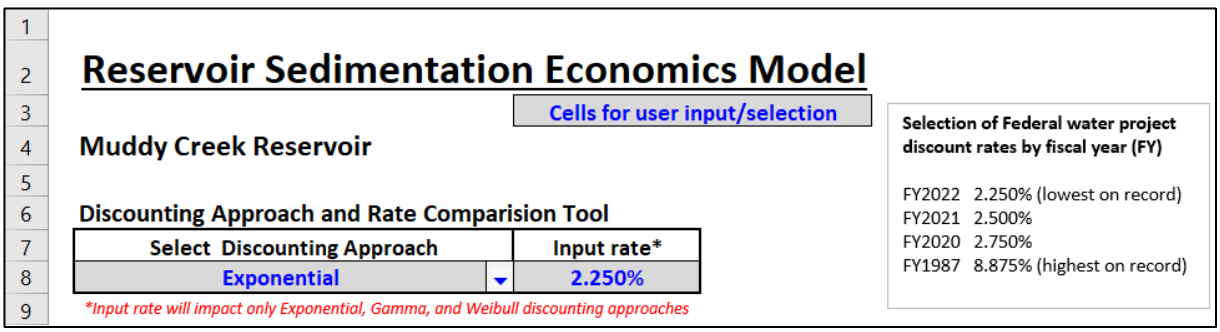


Figure 33. Discounting rate and approach (in the Economic Summary Results worksheet).

Check to make sure that the reservoir name is correctly spelled in Row 4. If it is not, go back to the **Inputs** worksheet and correct the name in Row 2 (Column C).

Select Discounting Approach. This is a dropdown menu where you can select among eight different discounting approaches. Note that the last selected approach option will show up in the drop-down box and will be used unless a different approach is selected.

Hint: Start using exponential discounting approach. Other approaches are provided but require expert knowledge of economics.

The exponential discounting approach should be treated as the default. This is the most commonly used discounting approach and will generate results most readily comparable with other models. Other discounting approaches may be appropriate, depending on decision process needs. Other approaches could be used for comparison, and these interpretations would require knowledge of economics or collaboration with an economist to meaningfully apply and interpret results. Note that these approaches require additional parameters to be defined, and there is a lack of consensus on the appropriate values these parameters should assume. The default parameters provided in RSEM are based on Harpman (2014).

Discount Rate. Type in the discount rate. Note that the last specified discount rate will show up in the input box and will be used unless another rate is input.

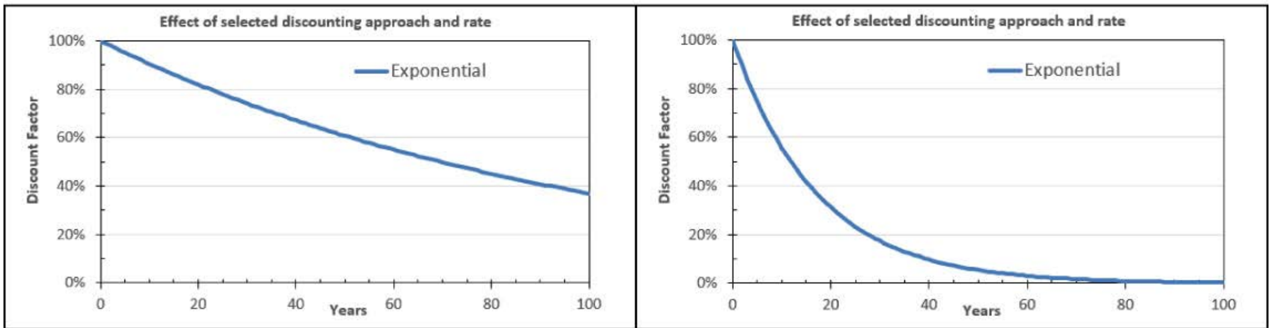
For Federal projects, use the current fiscal year's Federal water project discount rate or work with an economist. An informational table with a selection of historic rates is provided.

Selection of Federal water project discount rates by fiscal year (FY)	
FY2022	2.250% (lowest on record)
FY2021	2.500%
FY2020	2.750%
FY1987	8.875% (highest on record)

Note that choosing different discount rates will change the comparative graph of discount approaches in the Discount Chart worksheet. Rows 1 through 13 (columns I through M) provide a graph that shows the curve (effect) of the selected discounting approach and rate over 100 years (Figure 34).

The selected discounting approach affects the shape of the curve, while the rate affects the slope of the curve. The input rate will impact only Exponential, Gamma, and Weibull discounting approaches, while parameters for all other discounting approaches must be modified on the Discount Approaches & Factors worksheet. Contact the Technical Service Center's Economics Group if you want to change any factors within the various discounting approaches. Consult Appendix B.9 *Discount Approaches & Factors* for information on where to change alternative discount approach parameters.

The base year, price level, and dam age (Rows 11 through 13) are brought over from Rows 8 through 10 of the **Inputs** worksheet (Figure 35).



(A) Exponential discounting approach using 1.0% discount rate | (B) Exponential discounting approach using 6.0% discount rate

Figure 34. Discount factor over 100 years using the exponential approach and two different rates (in the Economic Summary Results worksheet). The rate dramatically affects the curve's slope.

10			
11	Base year	2022	From Inputs worksheet, Row 8
12	Price level	2021	From Inputs worksheet, Row 9
13	Dam age	0 years	From Inputs worksheet, Row 10

Figure 35. Discounting rate and approach (in the Economic Summary Results worksheet).

A.3.2 Reservoir Sediment Management Analysis Economics Results and Comparisons

RSEM **Economic Summary Results** are provided in the worksheet table (Rows 15 through 36). Example tables are presented in Figure 36 and Figure 37. All annualized values are computed using the exponential discounting approach, regardless of the discounting approach selected for present valuation. This is because there is no published method for annualizing time-inconsistent discounting approaches. If you use any discounting approach other than exponential, understand that results are valid for the present value over the POA, but the annualized values are not consistent with the selected discounting approach.

Reservoir Sediment Management Analysis Economics Results and Comparisons

All results stated at 2021 price level	Without Sediment Management				With Sediment Management			
Dam decommissioning occurs (yrs):	Dam age: 120	Analysis year: 120		Year: 2142	Dam age: 481	Analysis year: 481		Year: 2503
Period of Analysis (POA, yrs):	**50**	**100**	**200**	**500**	**50**	**100**	**200**	**500**
Years evaluated:	2022 - 2071	2022 - 2121	2022 - 2221	2022 - 2521	2022 - 2071	2022 - 2121	2022 - 2221	2022 - 2521
Present value over POA								
Cumulative benefits	$251,352,946	$304,663,024	$308,592,607	$308,597,907	$256,692,996	$343,304,578	$380,917,136	$385,435,489
Cumulative costs	$53,270,321	$57,974,661	$82,068,887	$82,068,887	$91,712,770	$109,497,585	$117,212,305	$118,157,172
Lost benefits due to sediment	$6,120,909	$40,317,749	$74,610,043	$79,229,583	$780,858	$1,676,195	$2,285,513	$2,392,001
Annualized value over POA*								
Annualized benefits	$8,239,548	$7,516,293	$6,870,777	$6,790,763	$8,414,599	$8,469,613	$8,481,074	$8,481,591
Annualized costs	$1,746,243	$1,430,284	$1,827,254	$1,805,943	$3,006,417	$2,701,398	$2,609,718	$2,600,074
Annualized lost benefits	$200,648	$994,673	$1,661,184	$1,743,464	$25,597	$41,353	$50,887	$52,636
Comparative metrics								
Benefit-cost ratio (BCR)	4.72	5.26	3.76	3.76	2.80	3.14	3.25	3.26
Net present value (NPV)	$198,082,625	$246,688,363	$226,523,720	$226,529,020	$164,980,226	$233,806,993	$263,704,831	$267,278,317
Annualized net benefits*	$6,493,305	$6,086,010	$5,043,523	$4,984,820	$5,408,182	$5,768,215	$5,871,356	$5,881,517

Figure 36. Economic results and comparisons for a new dam, which will be decommissioned at dam age 120, which corresponds with analysis year 120 (calendar year 2142). This figure depicts all defaults from Inputs worksheet, the exponential discounting approach, and a discount rate of 2.250%. Orange indicates the periods when the dam has been decommissioned (in the Economic Summary Results worksheet).

Reservoir Sediment Management Analysis Economics Results and Comparisons

All results stated at 2021 price level	Without Sediment Management				With Sediment Management			
Dam decommissioning occurs (yrs):	Dam age: 120	Analysis year: 90		Year: 2112	Dam age: 211	Analysis year: 181		Year: 2203
Period of Analysis (POA, yrs):	**50**	**100**	**200**	**500**	**50**	**100**	**200**	**500**
Years evaluated:	2022 - 2071	2022 - 2121	2022 - 2221	2022 - 2521	2022 - 2071	2022 - 2121	2022 - 2221	2022 - 2521
Present value over POA								
Cumulative benefits	$227,284,381	$247,235,863	$247,279,664	$247,284,964	$259,413,601	$344,030,102	$377,724,873	$377,730,173
Cumulative costs	$14,310,821	$63,797,133	$63,797,133	$63,797,133	$54,419,150	$72,203,965	$85,375,509	$85,375,509
Lost benefits due to sediment	$38,915,723	$106,471,160	$144,649,236	$149,268,776	$6,786,503	$9,676,921	$14,204,027	$18,823,567
Annualized value over POA*								
Annualized benefits	$7,450,562	$6,099,517	$5,505,652	$5,441,559	$8,503,783	$8,487,512	$8,409,999	$8,312,033
Annualized costs	$469,120	$1,573,929	$1,420,436	$1,403,870	$1,783,903	$1,781,333	$1,900,875	$1,878,706
Annualized lost benefits	$1,275,688	$2,626,733	$3,220,598	$3,284,691	$222,467	$238,738	$316,251	$414,217
Comparative metrics								
Benefit-cost ratio (BCR)	15.88	3.88	3.88	3.88	4.77	4.76	4.42	4.42
Net present value (NPV)	$212,973,560	$183,438,730	$183,482,531	$183,487,831	$204,994,451	$271,826,137	$292,349,364	$292,354,664
Annualized net benefits*	$6,981,442	$4,525,588	$4,085,217	$4,037,689	$6,719,880	$6,706,180	$6,509,124	$6,433,327

Figure 37. Economic results and comparisons for a 30-year-old dam, which will be decommissioned at dam age 120, which corresponds with analysis year 90 (calendar year 2112). This figure depicts all defaults from Inputs worksheet, except for dam age, which is modified to 30 years. The selected discounting approach is exponential, and the discount rate is 2.250%. Note that in this case, the sediment management begins when the dam is already 30 years old, which reduces the dam age at decommissioning to 211 years, compared to 481 years in Figure 36. Orange indicates the periods when the dam has been decommissioned (in the Economic Summary Results worksheet).

A.3.3 Economic Comparison of Without and With Sediment Management

Three metrics are provided to compare the with and without sediment alternatives:

- Benefit-cost ratio (BCR)
- Net present value (NPV)
- Annualized net benefits (valid only for exponential discounting)

Each of these metrics are calculated for the four POAs under the two alternatives and reported in Rows 31 through 33 (Figure 36 and Figure 37).

These metrics are compared directly and summarized in Rows 38 through 44 in the table titled *Economic Comparison of Without and With Sediment Management* (Figure 38). The row heading "*Ann. NB greater by*"—found in the bottom row of Figure 38—is an abbreviation for "annual net benefits greater by" and indicates the extent to which the alternative with the higher NPV is greater than the competing alternative over the corresponding POA.

Note: The alternative with greater net present value (NPV) won't necessarily have the greater benefit-cost ratio (BCR). See explanation in the RSEM Description, Section 4.7. *Economic Results*.

Economic Comparison of Without and With Sediment Management

POA (years)	**50**	**100**	**200**	**500**
Greater B/C ratio	Without	Without	Without	Without
Greater NPV	Without	Without	With	With
NPV greater by	$33,102,399	$12,881,370	$37,181,111	$40,749,297
*Ann. NB greater by**	$1,085,123	$317,795	$827,833	$896,697

Figure 38. Economic comparison of without and with sediment management alternatives (in the Economic Summary Results worksheet).

A.3.4 Breakeven Analysis

This table presents the year that the net present value (NPV) for the with sediment alternative exceeds the NPV of the without sediment alternative—in other words, the minimum POA when with sediment management is cost effective, or "breaks even" (Figure 39).

Breakeven Analysis

Year at which "With" NPV exceeds "Without" NPV

Year basis	Breakeven year
Dam age	120
Analysis year	120

Figure 39. Breakeven analysis (in the Economic Summary Results worksheet).

In the new dam and reservoir example shown in Figure 39, the dam would need to be 67 years old for the with sediment alternative to break even—and then after the 67th year, the with sediment alternative would provide greater NPV. This concept is illustrated as the year where the NPV cross in the sixth graph on the **Econ Graphs (comparison)** worksheet (Section A.4. in this User Guide).

A.3.5 Retirement Fund Analysis

This table is presented in Rows 38 through 49 and in columns M through P. This table lists the amount of funding that would need to be set aside annually, beginning in the present year, to pay the dam decommissioning costs in the estimated year of decommissioning. Note that costs will be substantially higher under the without sediment management alternative as the dam age is less. Annual contributions to a retirement fund may approach zero under a comprehensive a sediment management program that begins with a new dam. If sediment management annually removes the entire inflowing mass or volume of sediment, then dam decommissioning would not be needed due to severe sedimentation.

Figure 40 shows the costs that should be set aside for a 30-year-old existing dam (either beginning with the dam's construction in 1992 or when the analysis year = 0 (2022 in this case).

Retirement Fund Analysis

Total dam decommissioning cost (2021$)	$333,349,757

Disc. rate: 2.250%

Decommissioning year

Year basis	Without	With
Dam age	120	481
Analysis year	120	481

Annual payment to dam retirement fund (2021$)

Payments begin in year:	Without	With
2022 (Dam age = 0)	$558,021	$169
2022 (Analysis year = 0)	$558,021	$169

Figure 40. Retirement fund analysis (in the Economic Summary Results worksheet).

A.4 Economics Graphs (comparison)

In the **Econ Graphs (comparison)** worksheet, five pairs of graphs and one direct comparison graph are presented to summarize the economic effects of reservoir sedimentation for both the without and with sediment management alternatives. A version of these graphs, where each is kept individual and can be independently copied into a report, can be found as one of the last (far right) worksheets in the workbook, labeled *Econ Graphs (individual)*.

All economic results portrayed in the graphs within this chapter are based on the default values in the **Inputs** worksheet, the exponential discount approach, and a discount rate of 2.250%.

Note that there are two horizontal (*x*) axes on each graph: the bottom axis depicting the analysis year and the top axis depicting the dam age. For a new dam, these axes will be the same, but for an analysis of an existing dam, the dam age will be greater than the analysis year.

The first and second pairs of graphs display annual economic costs and benefits under each alternative before discounting over a 500- and 200-year POA, Figure 41 and Figure 42, respectively. Costs are presented in red and benefits in blue. The final cost presented either graph represents dam decommissioning, which can be modified by the user for each alternative.

The third pair of graphs show the economic cost and benefits over a 200-year POA after discounting (Figure 43).

The fourth and fifth pairs of graphs show cumulative total economic benefits and costs up to 200 years before and after discounting (Figure 44 and Figure 45). These graphs display the results that are most important for determining economic feasibility. Without sediment management, the rate of increase in cumulative benefits (before discounting) diminishes over time. Cumulative costs significantly increase with dam decommissioning. With sediment management, the rate of change in cumulative benefits and costs tends to be more linear (before discounting). After discounting, the rate of change in cumulative economic costs and benefits is most rapid during the beginning part of the analysis and tend to diminish over time. A sufficiently long POA should capture the time in which cumulative benefits and costs are changing at a slow rate, or not at all.

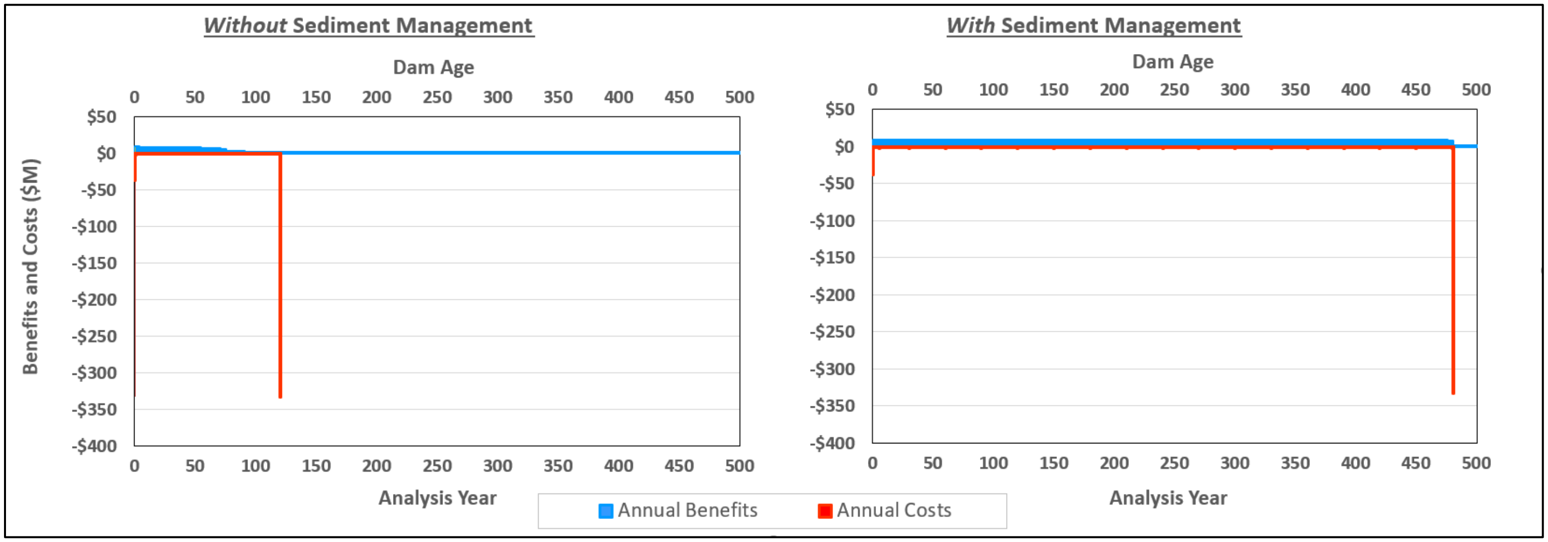


Figure 41. Costs and benefits over 500 years, before discounting (in the Economic Graphs (comparison) worksheet).

Figure 42. Costs and benefits over 200 years, before discounting (in the Economic Graphs (comparison) worksheet).

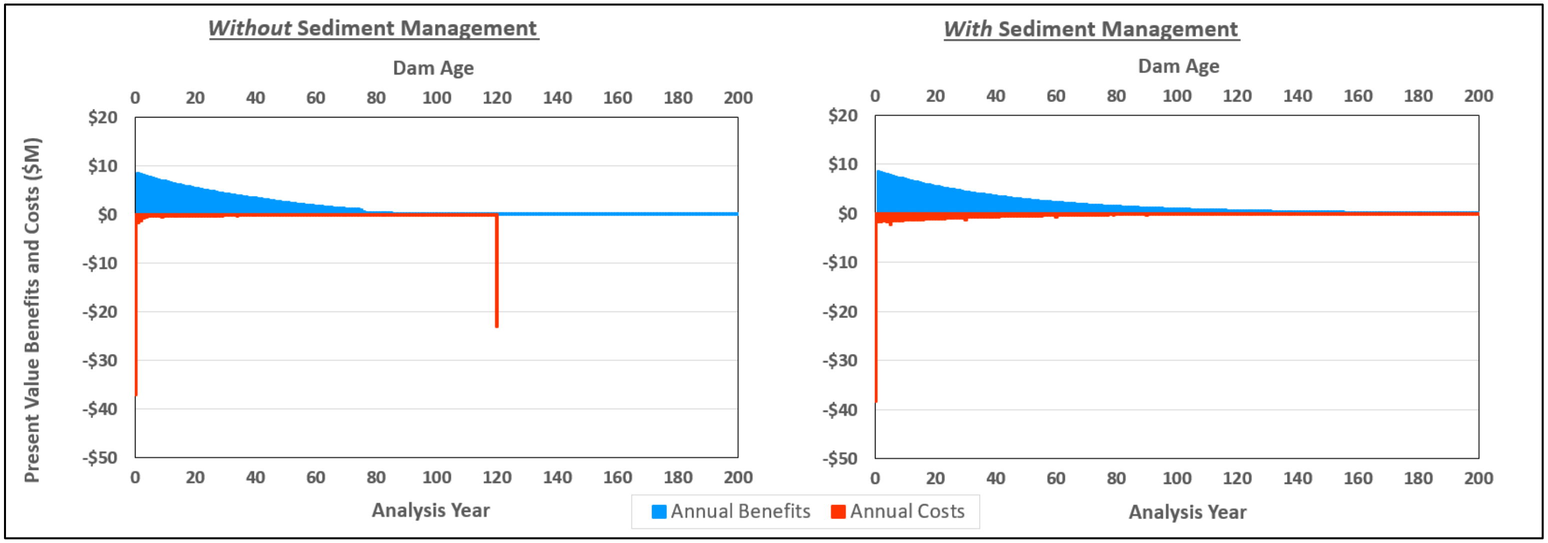


Figure 43. Costs and benefits over 200 years, after discounting (in the Economic Graphs (comparison) worksheet).

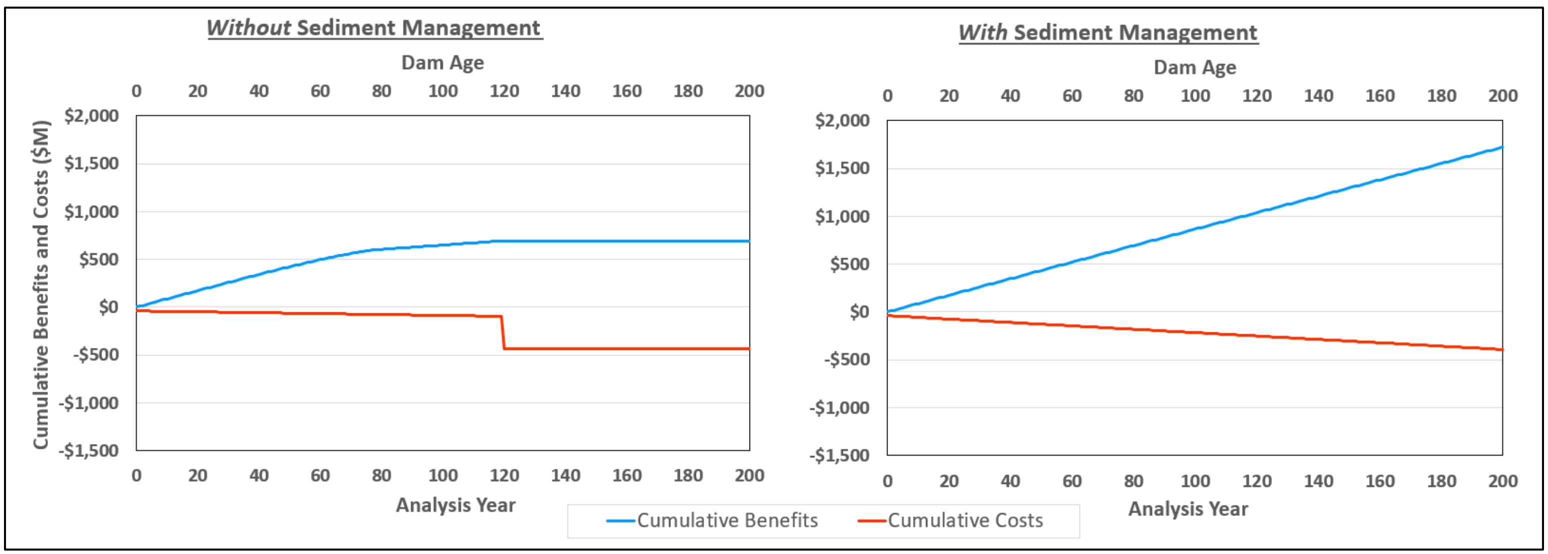


Figure 44. Cumulative economic benefits and costs over 200 years, before discounting (in the Economic Graphs (comparison) worksheet).

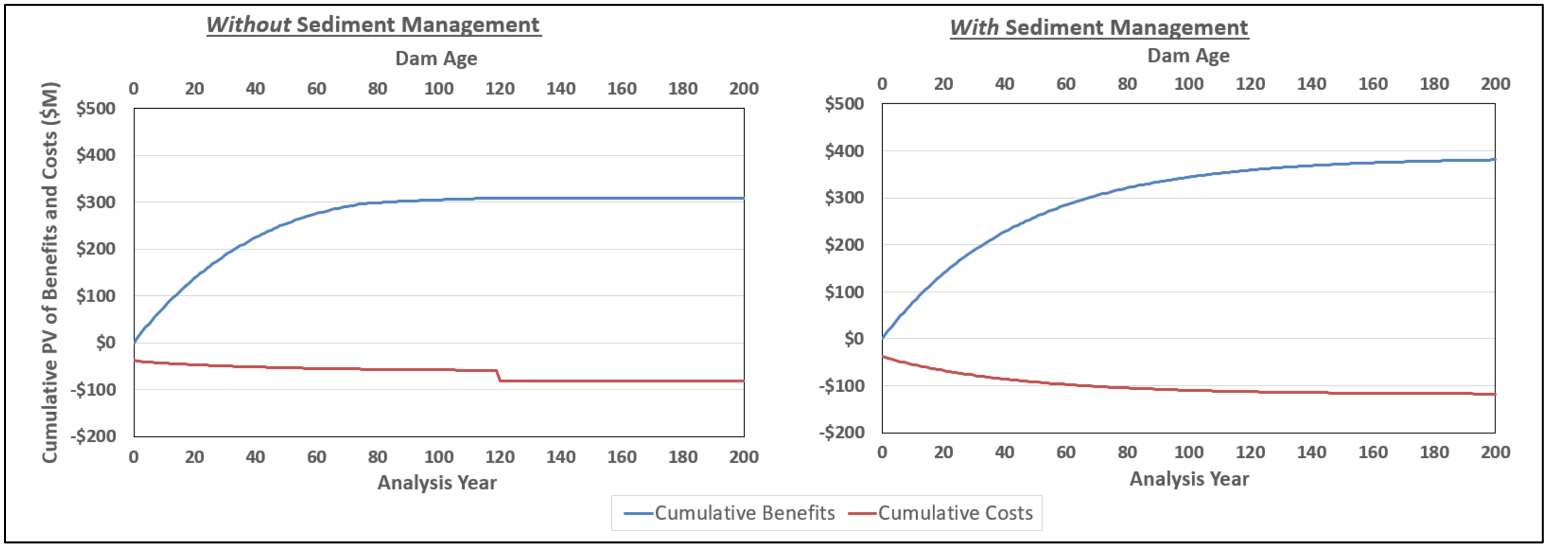


Figure 45. Cumulative economic benefits and costs over 200 years, after discounting (in the Economic Graphs (comparison) worksheet).

The sixth graph (the first presented as an individual graph on the worksheet) directly compares cumulative net present values. The point the two lines cross indicates the breakeven point of the two alternatives, i.e., the year that with sediment management overtakes without sediment management as the economically preferred alternative. In the example presented in Figure 46, the dam would have needed to be decommissioned at dam age 120 without sediment management, which also happens to be the breakeven point.

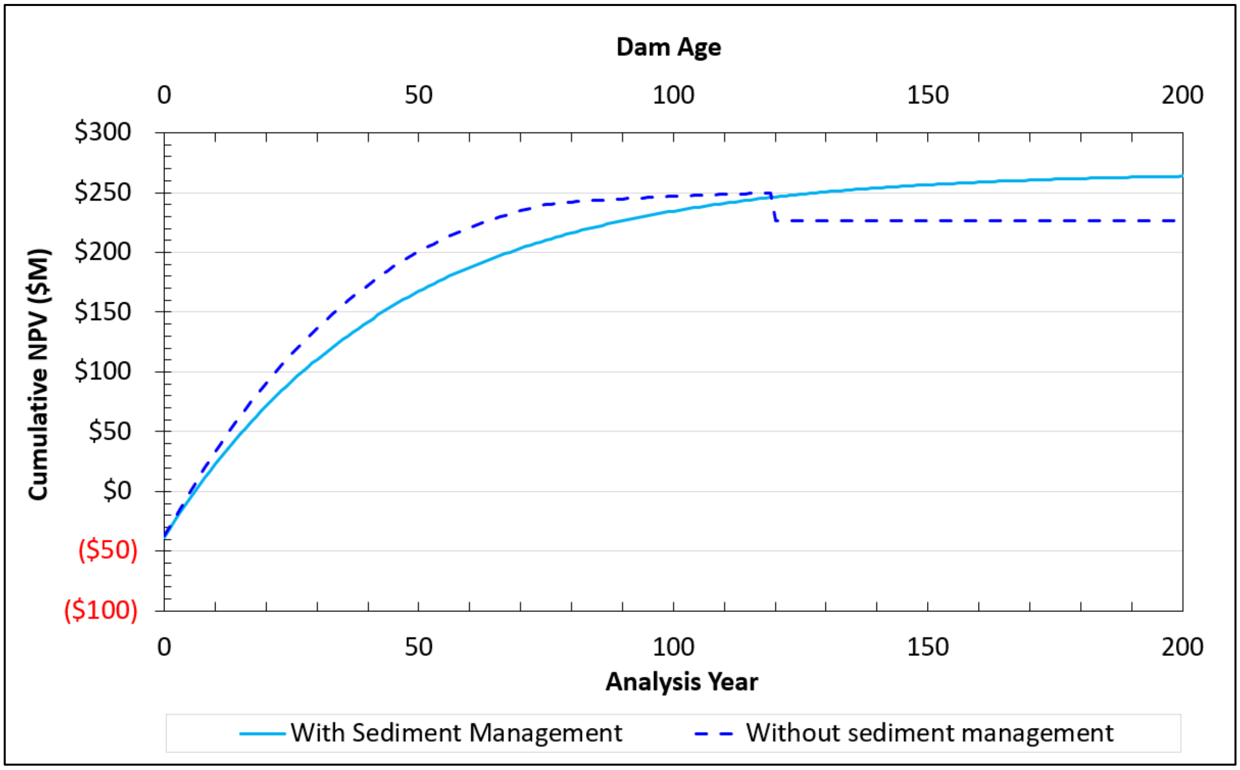


Figure 46. Cumulative net present value over 200 years (in the Economic Graphs (comparison) worksheet).

A.5 Sediment Graphs (comparison)

The **Sediment Graphs (comparison)** worksheet presents three pairs of graphs to summarize the simulated results of reservoir sedimentation under the without and with sediment management alternatives. A version of these graphs, where each is kept individual and can be independently copied into a report can be found as one of the last (far right) worksheets in the workbook, labeled *Sediment Graphs (individual)*.

All sedimentation results portrayed in the graphs within this chapter are based on the default values in the **Inputs** worksheet.

The first pair of graphs show a series of ten longitudinal reservoir sedimentation profiles representing a range of time increments over the life of the reservoir (Figure 47). The default reservoir plotting interval is equal to the dam age at decommissioning divided by ten. You can manipulate these graphics by changing plotting interval in the **Inputs** worksheet, Row 62, **Reservoir profile plotting interval** (Section A.2.3.2. *Reservoir Sedimentation Profile Slope* in this User Guide).

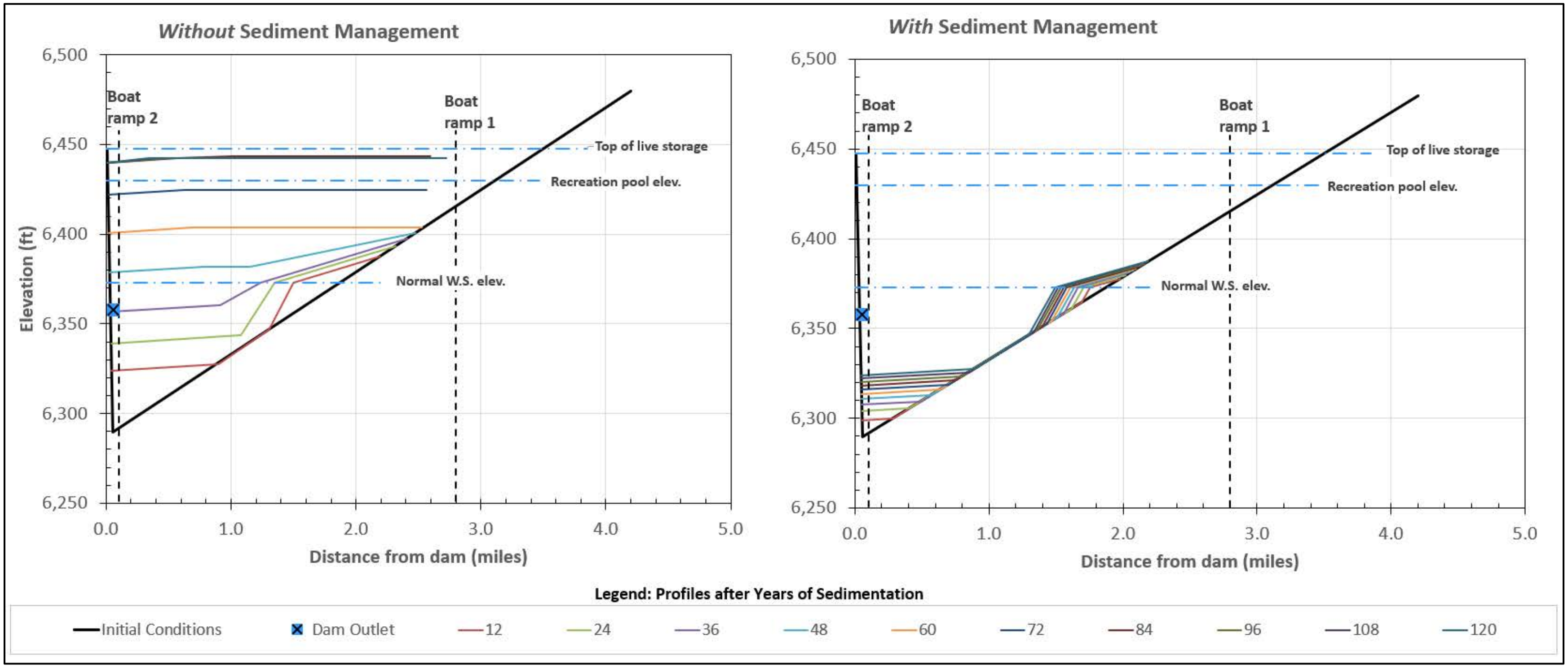


Figure 47. Reservoir sedimentation profiles for the ten profile years (in the Sediment Graphs (comparison) worksheet).

Coordinates for boat ramps and surface levels

Boat ramp 1

Sta (mi)	Elev (ft)
2.8	6200
2.8	6457.5

Boat ramp 2 Elev (ft)

Sta (mi)	Elev (ft)
0.1	6200
0.1	6457.5

Recreation pool elev.

Sta (mi)	Elev (ft)
0	6,430
3.47	6,430

Plotting position (mi) past original reservoir bottom:

Miles	3.5
10% adj.	0.35

Normal W.S. elev.

Sta (mi)	Elev (ft)
0	6373
2.23	6373

Top of live storage

Sta (mi)	Elev (ft)
0	6447.5
3.85	6447.5

Figure 48. Table in Sediment Graphs (comparison) worksheet displaying the calculation of plotting coordinates based on inputs from the Inputs worksheet.

Columns AB through AE contain a list of coordinates used to display the profiles graphs. Do not change these values here. Only change these within the Inputs worksheet or there will be inconsistent values (Section A.2.1. Reservoir Age, Size, and Inflow Characteristics in this User Guide) (Figure 48).

The second pair of graphs show reservoir storage and sedimentation volumes over time (Figure 49). Once the dam is decommissioned, the storage and sediment volumes remain constant, thus the lines are horizontal. This might not be a realistic assumption and should be noted in your result documentation.

The third pair of graphs show downstream channel degradation profiles (Figure 50). Using the features of Excel, the axes scales can be changed to better display the reach of interest.

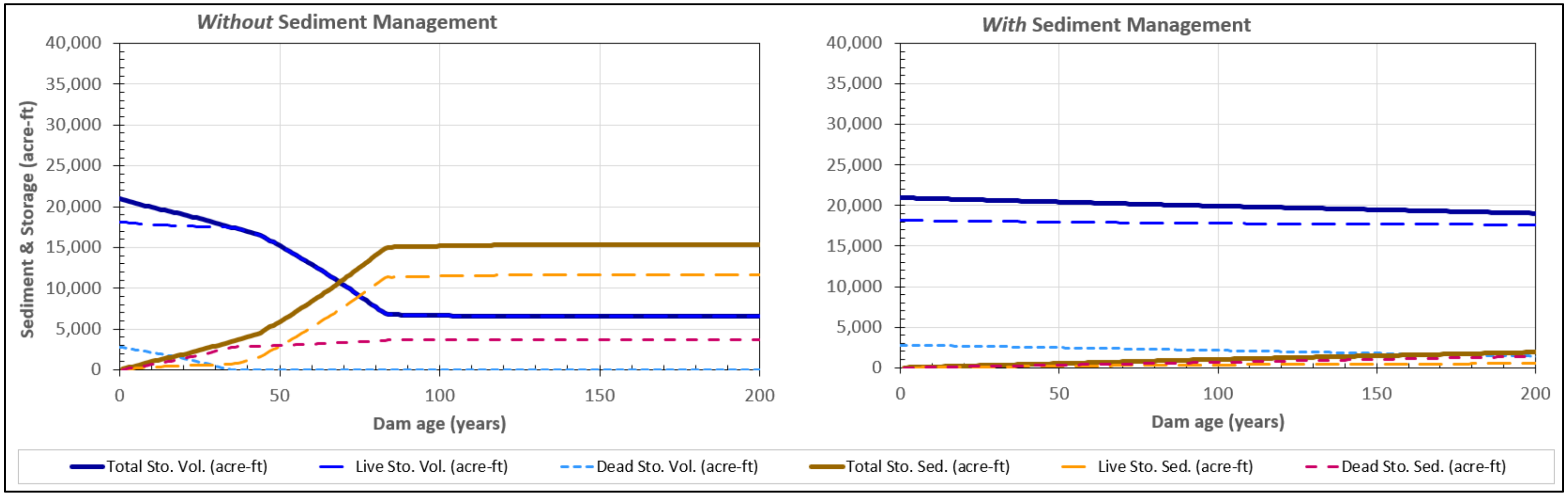


Figure 49. Changes in reservoir storage capacity and sedimentation over time (in the Sediment Graphs (comparison) worksheet).

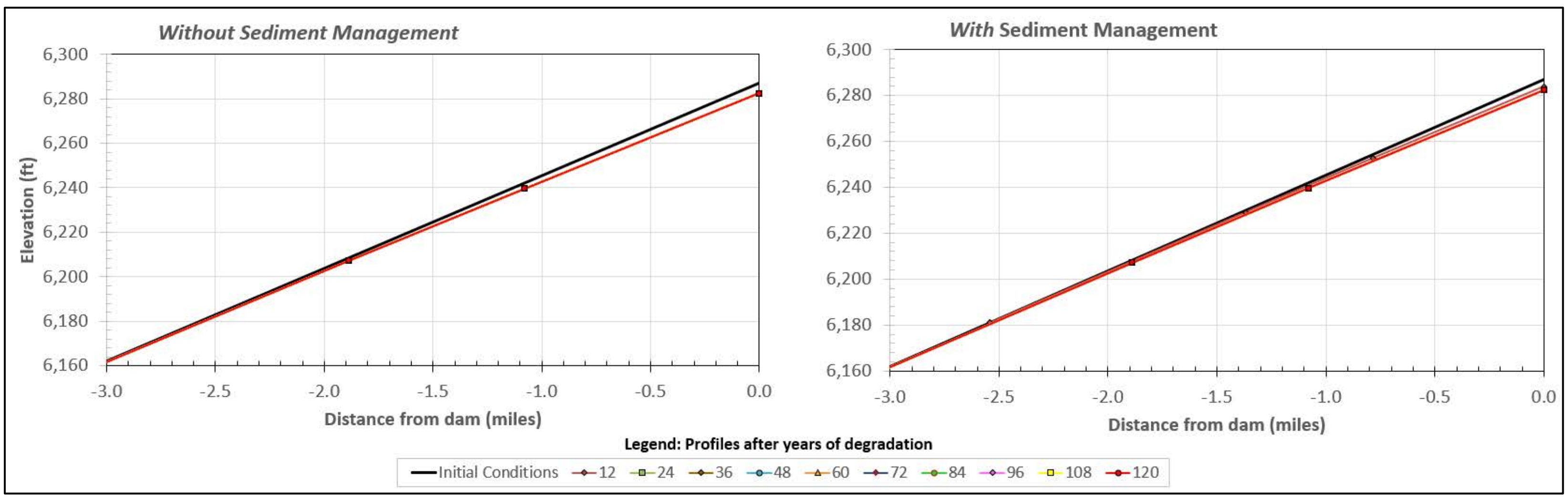


Figure 50. Channel degradation profiles for the ten profile years (in the Sediment Graphs (comparison) worksheet).

A.6 Yield and Area Graphs

The **Yield & Area Graphs** worksheet presents additional graphs that provide insight into the drivers of economic benefits.

All results portrayed in the graphs within this chapter are based on the default values in the **Inputs** worksheet

Figure 51 depicts water yield from storage under the without and with sediment alternatives, while Figure 52 depicts recreation surface area under the two alternatives. Both outputs are graphed over a 500-year POA. These graphs can be visually inspected to ensure that RSEM is simulating reservoir operations as expected. Note that based on the RSEM defaults, the dam is decommissioned at dam age 120 under the without sedimentation alternative and at dam age 481 under the with sediment management alternative.

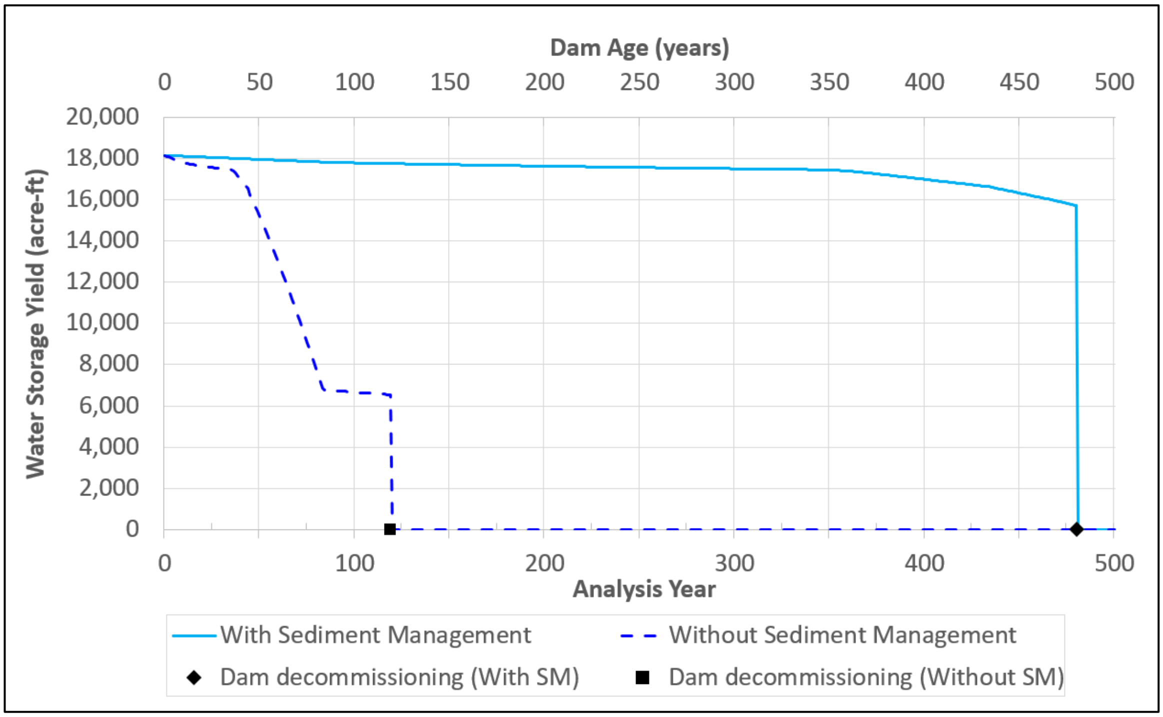


Figure 51. Delivered water yield from storage (in the Yield & Area Graphs worksheet).

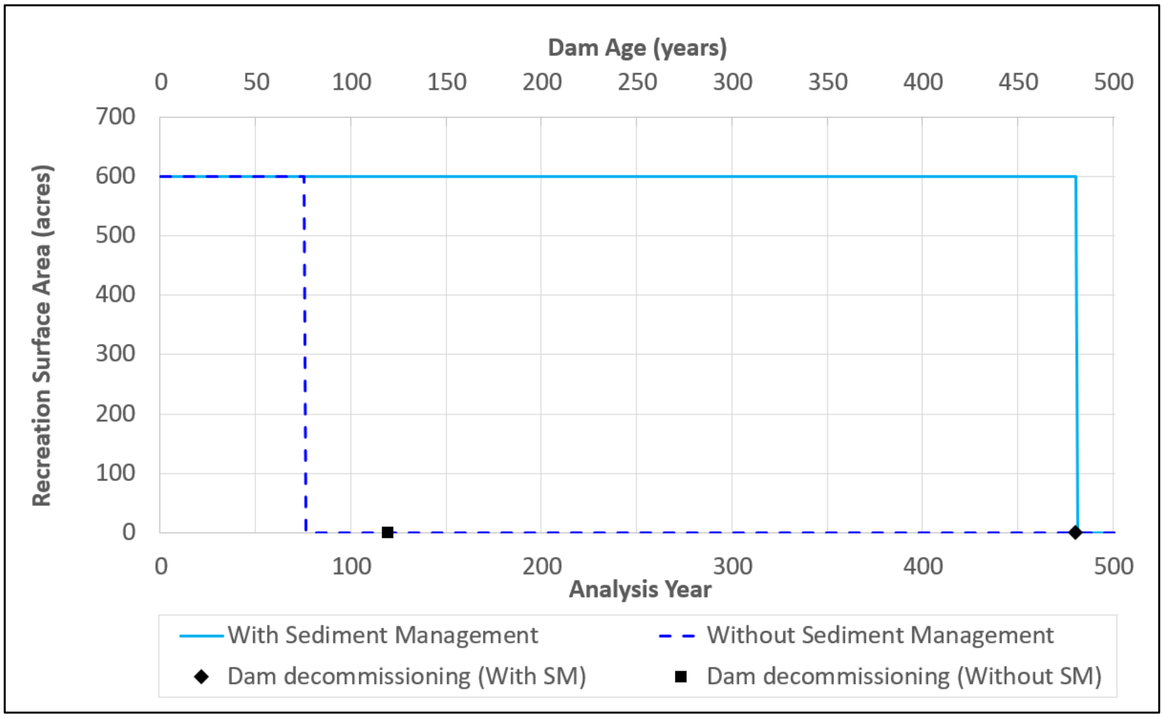


Figure 52. Recreation surface area (in the Yield & Area Graphs worksheet).

Appendix B

RSEM Spreadsheet Organization

Contents

Introduction

The model has been programmed in an Excel spreadsheet with 20 separate worksheets. The spreadsheet allows for easy data input and graphing of results. The relationship between the various worksheets is illustrated in Figure 1. The user provides sediment and economic data to the input and **economic summary results** worksheets. A series of sediment worksheets simulate reservoir sedimentation over time and another series of economic worksheets simulate the benefits, costs, net present values, and summary parameters. The 20 worksheets are individually described in Sections B.1 through B.20.

The overall spreadsheet does provide opportunities for customizing the programming for specific reservoirs. Program formulas are locked to prevent accidental changes. The password to unlock cells is provided in subsequent sections of this appendix, but users who attempt to modify the spreadsheet do so at their own risk.

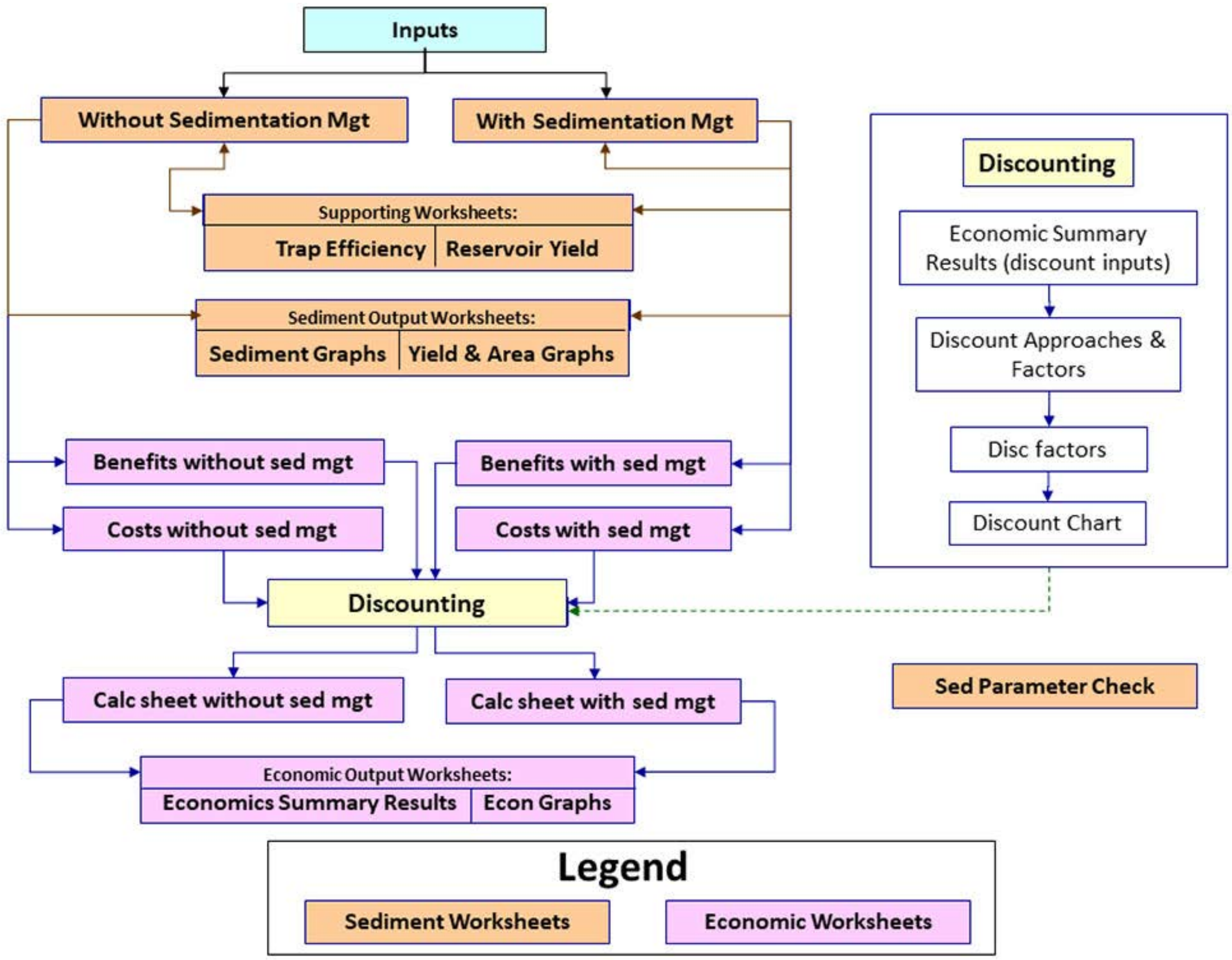


Figure 1.– Relationship of worksheets within the spreadsheet program.

B.1 Inputs

Model input data are entered in the **Inputs** worksheet. These data describe characteristics of the reservoir, dam, sedimentation, benefits, costs, and alternatives without and with reservoir sediment management. The section headings on the **Inputs** worksheet are listed below:

- Reservoir Age, Size, and Inflow Characteristics
- Dam Characteristics
- Reservoir Sedimentation Characteristics
- Reservoir Benefits
- Dam & Reservoir Planning, Design, and Construction Costs
- Design, Construction, and Contract Contingencies Cost Additives
- Operations, Maintenance, and Replacement (OM&R) Costs
- Dam Decommissioning Costs and Benefits
- Upstream Sedimentation Costs
- Downstream Channel Degradation Costs
- Without Sediment Management Alternative
- With Sediment Management Alternative

The reservoir name is entered in cell C2. The model provides suggested default values in column C. Please be careful not to change values or formulas in this column. The default values can be overridden in column D. The values used by the model simulation are presented in column E. These values (column E) are obtained from any user data provided in column D. When user data are not provided in column D (blank cells), the model uses the suggested default values identified in column C. The details of the **Inputs** worksheet are described in Appendix A. RSEM User Guide.

Except for column D and cells C2–D2, this worksheet is protected and may be unlocked using the password: RSEM22. There are many complex interactions among cells in this and the other worksheets. Model users attempting programming modifications do so at their own risk.

The discounting approach and rate specified in the **Economic Summary Results** worksheet (see Section A.3.1. Discount Approach and Rate Input).

B.2 Economic Summary Results

This worksheet is where the discounting approach and rate are specified and includes the following economic output data:

- Net present values of benefits and costs, which are linked to values in the two calculation worksheets: without and with sediment management ("Calc_sheet without sed mgt" and "Calc_sheet with sed mgt").
- Annualized values are computed from the net present values and the discounting factors ("Discount Approaches & Factors" worksheet). Annualized values are only valid when exponential discounting approach is selected.

The significance of the economic results is described in Appendix A, Section A. 3 Economic Summary Results.

Except for cells B8‒E8, this worksheet is protected and may be unlocked using the password: RSEM22. There are many complex interactions among cells in this and the other worksheets. Model users attempting programming modifications do so at their own risk.

B.3 Economic Graphs (comparison)

Annual economic benefits and costs are presented in a series of comparative graphs in this worksheet. All benefits and costs presented in these graphs are linked to values in the two calculation worksheets: without and with sediment management ("Calc_sheet without sed mgt" and "Calc_sheet with sed mgt"). Graphs, without and with reservoir sediment management, are presented side-by-side for easy comparison:

- Bar graphs of annual benefits and costs, before discounting, over the entire period of analysis (500 years).
- Bar graphs of annual benefits and costs, before discounting, over the first 200 years of analysis.
- Bar graphs of annual benefits and costs, after discounting, over the first 200 years of analysis.
- x-y graphs of cumulative benefits and costs, before discounting, over the first 200 years of analysis.
- x-y graphs of cumulative benefits and costs, after discounting, over the first 200 years of analysis.

In addition, the following comparative graphs are provided:

- Cumulative net present value versus time for the alternatives without and with reservoir sediment management.
- Cumulative present value of benefits versus time for the alternatives without and with reservoir sediment management.
- Present value of annual benefits versus time for the alternatives without and with reservoir sediment management.

The significance of these economic graphs is explained in Appendix A, Section A. 4.

Individual versions of these same side-by-side graphs are provided in the "Economic Graphs (individual)" worksheet in case model users need larger size versions for reports or presentations.

B.4 Sediment Graphs (comparison)

Reservoir sedimentation results are presented in a series of comparative graphs in this worksheet. All values plotted in these graphs are linked to values in the two sedimentation management worksheets: without and with sediment management ("Without Sediment Mgt" and "With Sediment Mgt"). Graphs, without and with reservoir sediment management, are presented side-by-side for easy comparison:

- Longitudinal profile graphs of reservoir sedimentation after ten different time periods. Any plotted profiles beyond the simulated sediment design life may not be valid (see row 2 of this worksheet)
- Graphs of reservoir sedimentation and storage capacity over the first 200 years of the analysis period.
- Longitudinal profile graphs of river channel elevation versus distance downstream from the dam show the extent of degradation after ten different time periods.

The significance of these sediment graphs is explained in Appendix A, Section A. 5.

Individual versions of these same side-by-side graphs are provided in the **Sediment Graphs (individual)** worksheet in case the model user needs larger size versions for reports or presentations.

Columns AB through AH (rows 5–30) are used to help plot the location of boat ramps 1 and 2, recreation pool elevation, normal water surface elevation, and top of live storage elevation. Values in these columns and rows are imported from the **Inputs** worksheet and constant values from the "Without Sedimentation Mgt" worksheet.

B.5 Yield & Area Graphs

Separate graphs are provided showing changes in reservoir water storage yield over time and recreation surface area over time. For each graph, conditions are plotted under both the without and with sediment management alternatives. The water storage yield and recreation surface area values are all plotted from the two benefits worksheets: without and with sediment management ("Benefits without sed mgt" and "Benefits with sed mgt"). Data for the time of dam decommissioning are plotted from to values in the **Inputs** worksheet.

The significance of these water yield and surface area graphs is explained in Appendix A, Section A. 6.

B.6 Without Sediment Mgt

Reservoir sedimentation and downstream channel degradation are simulated in this worksheet for the alternative without sediment management. This worksheet is very similar to, but independent of, the "With Sediment Mgt" worksheet. The first 9 rows of the worksheet are devoted to values that are constant over time. These values are linked to values in the **Inputs** worksheet. The worksheet columns of these first 9 rows are described in Table 1.

Table 1. Without Sediment Management worksheet columns devoted constant values

Worksheet Columns	Description
A-E	Reservoir elevation characteristics and the hydraulic height of the dam
F_K	Reservoir inflow rates of water and sediment and the geometric factors related to the delta topset and foreset
L_O	Longitudinal slope and factors used to compute the delta topset and foreset slopes, bottomset slope, and the limiting slope of potential downstream channel degradation
P_U	Longitudinal slopes of the reservoir valley, delta topset, delta foreset, bottomset, stable channel slope after channel degradation, and the decrease in channel slope
V_Z	Original channel sinuosity, reservoir lengths, depth-averaged widths below the full reservoir pool and below the dead storage pool, original full pool surface area, and original recreation pool surface area
AA_AE	Parameters used to compute channel bed armoring, including average bankfull channel width, bed-material armor size, amor layer thickness, and channel degradation limit from possible armoring
AF_AK	Depth-averaged reservoir widths below the top of live storage (full reservoir pool) and below the dead storage pool and parameters for a linear equation to interpolate the depth-averaged reservoir width below other reservoir elevations
AS_AY	Upstream delta length where sedimentation thicknesses are below the threshold of significant effects
BO_BR	Longitudinal station for the upstream extent of dead storage
BS_BU	Longitudinal station for the upstream extent of live storage
DD_DG	Recreation pool elevation, longitudinal stations of boat ramps, and year that boat ramps may become buried by sedimentation.

Table 2. Without Sediment Management worksheet columns devoted to the annual simulation of reservoir sedimentation and downstream channel degradation

Worksheet Columns	Description
A to B	Reservoir age and the volume of any sediment removed during forced management
C to L	Simulation of coarse delta sedimentation including the volume, maximum delta thickness, topset and foreset lengths, and the longitudinal station of the delta pivot point
M to Y	Simulation of fine bottomset sedimentation including the volume, maximum thickness at the dam, thickness at the delta foreset, and longitudinal length
N to Q	The initial assumption is made that the fine bottomset sediments extend from the dam all the way upstream to the delta foreset (see Section 3.1.5 Reduced Storage Over Time, Case 2, equations 16-17) The column headings for these initial estimates and are highlighted in gray Negative thicknesses of the delta aren't real and mean that the case 2 assumption is not valid
R to T	The next assumption is made that the fine bottomset sediments at the dam do not extend far enough upstream to reach the delta foreset (see Section 3.1.5 Reduced Storage Over Time, Case 1, equations 13-14) The columns headings for these adjustments and are highlighted in green
U to X	Final determination (choice of Case 1 or Case 2) for fine sediment thickness at the dam and delta foreset and longitudinal length of the bottomset sediment based on a comparison of the bottomset slope factor (cell O6) and the minimum bottomset slope factor for each year (column X) The columns headings for final the values and are highlighted in yellow
Z to AF	Simulation of downstream channel degradation including the longitudinal slope limit, erosion depth at dam, longitudinal lengths where the maximum degradation below the dam has reduced to ½, ¼, and near 0, and the volume of streambank protection along one channel bank
AG to AT	Reservoir sedimentation profile plotting points at the dam centerline, upstream dam face, upstream extent of bottomset, delta foreset toe, delta pivot point, and upstream extent of delta topset
AU to AV	Length and surface area of sedimentation impacts upstream from the reservoir pool
AW	Recreation surface area which reduces over time with reservoir sedimentation

Worksheet Columns	Description
AX to BN	Simulation of sedimentation volumes in both live and dead storage pools computed in parts: bottomset at the dam and below the delta foreset, delta foreset toe, delta pivot point, and delta topset
BO to BS	Total sedimentation in the dead and in the live storage pools
BT to BV	Simulation of remaining reservoir storage capacity in both the dead and live storage pools
BW to CB	Simulation of reservoir sediment trap efficiency as a function of the storage capacity to inflow ratio (the "Trap Efficiency" worksheet is utilized for this simulation)
CC	Simulation of depth-averaged reservoir width
CD to CF	Column list of reservoir sedimentation profile plotting points for selected simulation years
CG to CO	Calculated downstream channel profile plotting points at the dam centerline and three downstream locations where degradation has reduced to ½, ¼, and near 0
CP to CR	Column list of downstream channel degradation profile plotting points for selected simulation years
CS to DG	Simulation of reservoir sedimentation at boat ramps utilizing profile interpolation at the bottomset, delta foreset, and delta topset

Rows 10 through 512 of this worksheet are used for the annual simulation of reservoir sedimentation, recreation surface area, and downstream channel degradation over the 500-year analysis period (Table 2).

This worksheet is protected and may be unlocked using the password: RSEM22. There are many complex interactions among cells in this worksheet. Model users attempting programming modifications do so at their own risk.

B.7 With Sediment Mgt

Reservoir sedimentation, recreation surface area, and downstream channel degradation are simulated in this worksheet for the alternative with sediment management. This worksheet is very similar to, but independent of, the “Without Sediment Mgt” worksheet. The first 9 rows of the worksheet are devoted to values that are constant over time. These values are linked to values in the **Inputs** worksheet. The worksheet columns of these first 9 rows are described in Table 3.

Table 3. With Sediment Management worksheet columns devoted constant values

Worksheet Columns	Description
A to D	Reservoir elevation characteristics and the hydraulic height of the dam
E to J	Reservoir inflow rates of water and sediment and the geometric factors related to the delta topset and foreset
K to N	Longitudinal slope and factors used to compute the delta topset and foreset slopes, bottomset slope, and the limiting slope of potential downstream channel degradation
O to T	Longitudinal slopes of the reservoir valley, delta topset, delta foreset, bottomset, stable channel slope after channel degradation, and the decrease in channel slope
U to Y	Original channel sinuosity, reservoir lengths, depth-averaged widths below the full reservoir pool and below the dead storage pool, original full pool surface area, and original recreation pool surface area
Z to AD	Parameters used to compute channel bed armoring, including average bankfull channel width, bed-material armor size, amor layer thickness, and channel degradation limit from possible armoring
AE to AJ	Depth-averaged reservoir widths below the top of live storage (full reservoir pool) and below the dead storage pool and parameters for a linear equation to interpolate the depth-averaged reservoir width below other reservoir elevations
AR to AX	Upstream delta length where sedimentation thicknesses are below the threshold of significant effects
BN to BQ	Longitudinal station for the upstream extent of dead storage
BR to BT	Longitudinal station for the upstream extent of live storage
DC to DF	Recreation pool elevation, longitudinal stations of boat ramps, and year that boat ramps may become buried by sedimentation.

Rows 10 through 512 of this worksheet are used for the annual simulation of reservoir sedimentation and downstream channel degradation over the 500-year analysis period (Table 4).

Table 4. With Sediment Management worksheet columns devoted to the annual simulation of reservoir sedimentation and downstream channel degradation

Worksheet Columns	Description
A	Reservoir age
B to K	Simulation of coarse delta sedimentation including the volume, maximum delta thickness, topset and foreset lengths, and the longitudinal station of the delta pivot point
L to X	Simulation of fine bottomset sedimentation including the volume, maximum thickness at the dam, thickness at the delta foreset, and longitudinal length
M to P	The initial assumption is made that the fine bottomset sediments extend from the dam all the way upstream to the delta foreset (see Section 3.1.5 Reduced Storage Over Time, Case 2, equations 16-17) Negative thicknesses of the delta aren't real and mean that the case 2 assumption is not valid
Q to S	The next assumption is made that the fine bottomset sediments at the dam do not extend far enough upstream to reach the delta foreset (see Section 3.1.5 Reduced Storage Over Time, Case 1, equations 13-14)
T to W	Final determination (choice of Case 1 or Case 2) for fine sediment thickness at the dam and delta foreset and longitudinal length of the bottomset sediment based on a comparison of the bottomset slope factor (cell N6) and the minimum bottomset slope factor for each year (column W)
Y to AE	Simulation of downstream channel degradation including the longitudinal slope limit, erosion depth at dam, longitudinal lengths where degradation has reduced to ½, ¼, and near 0, and the volume of streambank protection along one channel bank
AF to AS	Calculated reservoir sedimentation profile plotting points at the dam centerline, upstream dam face, upstream extent of bottomset, delta foreset toe, delta pivot point, and upstream extent of delta topset
AT to AU	Length and surface area of sedimentation impacts upstream from the reservoir pool
AV	Recreation surface area which reduces over time with reservoir sedimentation
AW to BM	Simulation of sedimentation volumes in both live and dead storage pools computed in parts: bottomset at the dam and below the delta foreset, delta foreset toe, delta pivot point, and delta topset
BN to BR	Total sedimentation in the dead in live storage pools

Worksheet Columns	Description
BS to BU	Simulation of remaining reservoir storage capacity in both the dead and live storage pools
BV to CA	Simulation of reservoir sediment trap efficiency as a function of the storage capacity to inflow ratio (the “Trap Efficiency” worksheet is utilized for this simulation)
CB	Simulation of depth-averaged reservoir width
CC to CE	Column list of reservoir sedimentation profile plotting points for selected simulation years
CF to CN	Calculated downstream channel profile plotting points at the dam centerline and three downstream locations where the maximum degradation below the dam has reduced to ½, ¼, and near 0
CO to CQ	Column list of downstream channel degradation profile plotting points for selected simulation years
CR to DF	Simulation of reservoir sedimentation at boat ramps utilizing profile interpolation at the bottomset, delta foreset, and delta topset

This worksheet is protected and may be unlocked using the password: RSEM22. There are many complex interactions among cells in this worksheet. Model users attempting programming modifications do so at their own risk.

B.8 Discount Chart

This worksheet provides a chart (graph) of the discount factors versus time for the range of discounting approaches available in RSEM. The graph will change as the interest rate is changed in **Economic Summary Results** worksheet or other parameters are changed in the "Discount Approaches & Factors" worksheet. The graph may be useful in an economic report to document the discounting approaches considered. For information about the discounting approaches and rates, see Section 4.4.1 Discounting Benefits and Costs and Appendix A, Section A.3.1. Discount Approach and Rate Input.

B.9 Discount Approaches & Factors

This worksheet describes the various discounting approaches and their parameters. The discounting approach and rate selected in the **Economic Summary Results** worksheet is displayed in cells B1 through E3 of the "Discount Approaches & Factors" worksheet. The various discounting approaches and parameters are presented in Rows 7 through 32 of the worksheet (Table 5). The discount factors (weights) for each discounting approach and for each year of the analysis period are presented in Rows 34 through 537 (Columns B through K). For more information about the various discounting approaches, see Section 4.4.1 Discounting Benefits and Costs.

Table 5. Discount Approaches & Factors worksheet columns that describe the discounting approaches, parameters, and sources

Worksheet Columns	Description
B	Discounting approaches
C	Discounting variables
E to I	Discounting variable descriptions
J	Default parameter values from Harpman (2014)
K	Alternative, or override, discounting values
L	Discounting values used by RSEM
M to R	Notes and reference sources
S to T	Discounting equations

This worksheet is protected and may be unlocked using the password: RSEM22. There are many complex interactions among cells in this and the other economic worksheets. Model users attempting programming modifications do so at their own risk.

B.10 Calc_sheet without sed mgt

Benefits and costs are discounted in this worksheet for the alternative without sediment management. This worksheet is very similar to, but independent of, the "Calc_sheet with sed mgt" worksheet.

Rows 4 through 504 of this worksheet are used to simulate the economic benefits and costs over the period of analysis. The economic simulation includes discounting and evaluation of net annual benefits, lost benefits, and the cumulation of annual benefits and costs. The columns of the worksheet are described in Table 6. For each analysis year, the discount factors are imported from the "Discount Approaches & Factors" worksheet. The benefit values are imported from the "Benefits without sed mgt" worksheet. The cost values are imported from the "Costs without sed mgt" worksheet.

Table 6. "Calc_sheet without sed mgt" worksheet columns devoted to the annual simulation of discounted benefits and costs

Worksheet Columns	Description
A to D	Actual year, analysis year, dam age (in years), and the discount factor for each year
F to I	Annual benefits, annual costs, net annual benefits, and lost benefits (all before discounting)
K to N	Discounted annual benefits, annual costs, net annual benefits, and annual lost benefits
O to Q	Discounted and cumulative benefits, costs, and lost benefits
S to U	Data (before discounting) shown for graphing purposes: annual costs (shown as negative), cumulative benefits, and cumulative costs
W	Discounted annual costs (shown as negative for graphing purposes)
Y to Z	Discounted and cumulative benefits and costs
AB to AD	Discounted and cumulative benefits, costs, and net present values

This worksheet is protected and may be unlocked using the password: RSEM22. There are many interactions among cells in this and other worksheets. Model users attempting programming modifications do so at their own risk.

B.11 Calc_sheet with sed mgt

Benefits and costs are discounted in this worksheet for the alternative with sediment management. This worksheet is very similar to, but independent of, the “Calc_sheet without sed mgt” worksheet.

Rows 4 through 504 of this worksheet are used to simulate the economic benefits and costs over the period of analysis. The economic simulation includes discounting and evaluation of net annual benefits, lost benefits, and the cumulation of annual benefits and costs. The columns of the worksheet are described in Table 7. For each analysis year, the discount factors are imported from the “Discount Approaches & Factors” worksheet. The benefit values are imported from the “Benefits with sed mgt” worksheet. The cost values are imported from the “Costs with sed mgt” worksheet.

Table 7. “Calc_sheet with sed mgt” worksheet columns devoted to the annual simulation of discounted benefits and costs

Worksheet Columns	Description
A to D	Actual year, analysis year, dam age (in years), and the discount factor for each year
F to I	Annual benefits, annual costs, net annual benefits, and lost benefits (all before discounting)
K to N	Discounted annual benefits, annual costs, net annual benefits, and annual lost benefits
O to Q	Discounted and cumulative benefits, costs, and lost benefits
S to U	Data (before discounting) shown for graphing purposes: annual costs (shown as negative), cumulative benefits, and cumulative costs
W	Discounted annual costs (shown as negative for graphing purposes)
Y to Z	Discounted and cumulative benefits and costs
AB to AD	Discounted and cumulative benefits, costs, and net present values
AF to AG	For alternative comparison purposes: the cumulative net present value, without sediment management, and the difference in cumulative net present values between alternatives with and without sediment management

This worksheet is protected and may be unlocked using the password: RSEM22. There are many interactions among cells in this and other worksheets. Model users attempting programming modifications do so at their own risk.

B.12 Benefits without sed mgt

Annual benefits, before discounting, are computed in this worksheet for the alternative without sediment management. This worksheet is very similar to, but independent of, the "Benefits with sed mgt" worksheet.

Rows 4 through 504 of this worksheet are used to simulate the various reservoir benefits over the period of analysis. The columns of the worksheet are described in Table 8. Reservoir benefits may include water storage, hydropower, and recreation. Another benefit may include river restoration resulting from dam removal. These benefits are described below:

- Water storage benefits are computed as the product of delivered yield from live storage and the weighted benefit per unit storage volume (see **Inputs** worksheet, cell E87). Values for the available live storage are imported from the "Without Sedimentation Mgt" worksheet (column BU). The water yield delivered from live storage is computed as the product of available live storage and the yield percentage from the **Inputs** worksheet (cell E77).

- Annual hydropower benefits are assumed to be constant, so long as live reservoir storage capacity remains. This assumption may be generally true for hydropower capacity. However, the assumption may not be as true if peaking energy production is linked to reservoir storage capacity.

- Annual recreation benefits are computed as the product of the recreation visitor days per year and the benefit per visitor day (net consumer surplus) from the **Inputs** worksheet (cell E94). Each year of simulation, the recreation visitor days per year are reduced from the initial value (at analysis year 0) by multiplying the ratio that recreation surface area is reduced from its initial value. The recreation visitor days per year may also be reduced over time if one or more boat ramps/marinas are lost to reservoir sedimentation. Values for the recreation surface area are imported from the "Without Sedimentation Mgt" worksheet.

- Annual river restoration benefits from dam removal are assumed to be constant (see **Inputs** worksheet, cell E131), starting the year after dam removal.

For each analysis year, the various reservoir benefits are computed, the total benefit is computed, along with the benefits lost to sedimentation.

Table 8. "Benefits without sed mgt" worksheet columns devoted to the calculation of annual benefits

Worksheet Columns	Description
A to C	Actual year, analysis year, and dam age
D to E	Available live reservoir storage capacity and the water yield delivered from this capacity
F to H	Reservoir recreation capacity with operational boat ramps/marinas, surface area, and visitor days per year
I to M	Annual reservoir benefits (before discounting) for water storage, hydropower, recreation, restoration from dam removal, and the total reservoir benefits
N	Annual benefits lost to reservoir sedimentation (initial benefits minus current benefits)

This worksheet is protected and may be unlocked using the password: RSEM22. There are many interactions among cells in this and other worksheets. Model users attempting programming modifications do so at their own risk.

B.13 Benefits with sed mgt

Annual benefits, before discounting, are computed in this worksheet for the alternative with sediment management. This worksheet is very similar to, but independent of, the “Benefits without sed mgt” worksheet.

Rows 4 through 504 of this worksheet are used to simulate the various reservoir benefits over the period of analysis. The various columns of the worksheet are described in Table 9. Reservoir benefits may include water storage, hydropower, and recreation. Other benefits may include beneficial use of removed sediment and river restoration resulting from dam removal. These benefits are described below:

- Water storage benefits are computed as the product of delivered yield from live storage and the weighted benefit per unit storage volume (see **Inputs** worksheet, cell E87). Values for the available live storage are imported from the “With Sedimentation Mgt” worksheet (column BT). The water yield delivered from live storage is computed as the product of available live storage and the yield percentage from the **Inputs** worksheet (cell E77). Water yield may also be reduced by the percentage of reservoir storage used for sediment management (**Inputs** worksheet, cell E186).

- Annual hydropower benefits are assumed to be constant, so long as live reservoir storage capacity remains. This assumption may be generally true for hydropower capacity. However, the assumption may not be as true if peaking energy production is linked to reservoir storage capacity.

- Annual recreation benefits are computed as the product of the recreation visitor days per year and the benefit per visitor day (net consumer surplus) from the **Inputs** worksheet (cell E94). Each year of simulation, the recreation visitor days per year are reduced from the initial value (at analysis year 0) by multiplying the ratio that recreation surface area is reduced from its initial value. The recreation visitor days per year may also be reduced over time if one or more boat ramps/marinas are lost to reservoir sedimentation. Values for the recreation surface area are imported from the “With Sedimentation Mgt” worksheet.

- Annual river restoration benefits from dam removal are assumed to be constant (see **Inputs** worksheet, cell E131), starting the year after dam removal.

For each analysis year, the various reservoir benefits are computed, the total benefit is computed, along with the benefits lost to sedimentation.

Table 9. "Benefits with sed mgt" worksheet columns devoted to the calculation of annual benefits

Worksheet Columns	Description
A to C	Actual year, analysis year, and dam age
D to E	Available live reservoir storage capacity and the water yield delivered from this capacity
F to H	Reservoir recreation capacity with operational boat ramps/marinas, surface area, and visitor days per year
I to N	Annual reservoir benefits (before discounting) for water storage, hydropower, recreation, beneficial use or removed sediment, restoration from dam removal, and the total reservoir benefits
O	Annual benefits lost to reservoir sedimentation (initial benefits minus current benefits)

This worksheet is protected and may be unlocked using the password: RSEM22. There are many interactions among cells in this and other worksheets. Model users attempting programming modifications do so at their own risk.

B.14 Costs without sed mgt

Annual costs, before discounting, are computed in this worksheet for the alternative without sediment management. This worksheet is very similar to, but independent of, the "Costs with sed mgt" worksheet.

Rows 4 through 504 of this worksheet are used to simulate the various costs related to dam construction, OM&R, and sedimentation impacts over the period of analysis. The columns of the worksheet are described in Table 10. The various costs evaluated by RSEM are listed below:

- Planning, design, construction & land acquisition costs for the dam and reservoir. This cost is only for a new reservoir and assigned to the dam age at 0 years. The cost is obtained from the **Inputs** worksheet (cell E107).

- Annual and 5-year recurring OM&R costs. These costs begin at the dam age of 1 year and are assumed to be constant throughout the remaining life of the dam and reservoir. Values are obtained from the **Inputs** worksheet (cells E119 and E120).

- Upstream-impact cost related to the inundation of lands and associated buildings and infrastructure. The annual cost is computed as the difference in the cumulative costs (column J) from a given year and the preceding year. Each year, the cumulative cost is computed as the product of the land area experiencing significant sedimentation and the unit value of the land. The land areas with significant sedimentation are obtained from the "Without Sedimentation Mgt" worksheet (column AV). The unit land value is considered constant and obtained from the **Inputs** worksheet (cell E135).

- Upstream-impact cost related to the relocation or elevation of highways and railroads. The annual cost is computed as the product of the incremental length of significant upstream delta advancement and the unit value of highway and railroad construction. The cumulative length of significant upstream delta advancement is imported from the "Without Sedimentation Mgt" worksheet (column AU). The unit value for highway and railroad construction is considered constant and obtained from the **Inputs** worksheet (cell E136).

- Upstream-impact cost related to providing fish and boat passage. This cost begins when there is significant upstream delta advancement and is assumed to be constant throughout the remaining life of the dam and reservoir. The annual cost is obtained from the **Inputs** worksheet (cell E137).

- Downstream impact costs related to channel degradation and streambank protection. The annual cost is computed as the difference in the cumulative costs (column N) from a given year and the preceding year. Each year, the cumulative cost is computed as the product of the necessary streambank protection volume and the unit cost of constructed streambank protection. The streambank protection volumes are obtained from the "Without Sedimentation Mgt" worksheet (column AF). The unit streambank protection cost is considered constant and obtained from the **Inputs** worksheet (cell E145).

- Forced Sediment Management cost to keep dam outlets, and other facilities, functioning. This cost begins a certain number of years after the dead storage pool has filled with sediment. The cost is initially small and then linearly increases to a maximum, the year prior to dam decommissioning.

- Dam decommissioning cost is applied as a one-time cost after the reservoir has experienced severe sedimentation and enough time has passed for dam decommissioning preparations. The decommissioning cost is obtained from the **Inputs** worksheet (cell E130).

- Total annual cost is the sum of the individual costs.

Table 10. "Costs without sed mgt" worksheet columns devoted to the calculation of annual benefits

Worksheet Column(s)	Description
A to E	Analysis year, analysis year, dam age, forced sediment management year, and a switch to indicate if the project is still in service (project life = 1) or decommissioned (project life = 0)
F	Planning, design, construction and & land acquisition costs for the dam and reservoir
G to H	Annual OM&R cost and 5-year recurring OM&R cost
I	Cumulative length of significant upstream delta advancement
J	Cumulative upstream-impact cost related to the inundation of lands and associated buildings and infrastructure
K	Annual upstream-impact cost related to the inundation of lands and associated buildings and infrastructure
L	Upstream impact cost related to the relocation or elevation of highways and railroads
M	Upstream impact cost related to providing fish and boat passage
N to O	Cumulative and annual downstream impact costs related to channel degradation and streambank protection
P	Forced sediment management cost to deep dam outlets, and other facilities, functioning
Q	Dam decommissioning cost at the end of the project life
R	Total annual cost
T to AB	Costs from columns F, G, H, K, L, M, O, P, and Q presented as negative values for possible plotting purposes

This worksheet is protected and may be unlocked using the password: RSEM22. There are many interactions among cells in this and other worksheets. Model users attempting programming modifications do so at their own risk.

B.15 Costs with sed mgt

Annual costs, before discounting, are computed in this worksheet for the alternative with sediment management. This worksheet is very similar to, but independent of, the "Costs without sed mgt" worksheet.

Rows 4 through 504 of this worksheet are used to simulate the various costs related to dam construction, OM&R, and sedimentation impacts over the period of analysis. The columns of the worksheet are described in Table 11. The various costs evaluated by RSEM are listed below:

- Planning, design, construction and & land acquisition costs for the dam and reservoir. This cost is only for a new reservoir and assigned to the dam age at 0 years. The cost is obtained from the **Inputs** worksheet (cell E107).
- Annual and 5-year recurring OM&R costs. These costs begin at the dam age of 1 year and are assumed to be constant throughout the remaining life of the dam and reservoir. Values are obtained from the **Inputs** worksheet (cells E119 and E120).
- Upstream-impact cost related to the inundation of lands and associated buildings and infrastructure. The annual cost is computed as the difference in the cumulative costs (column I) from a given year and the preceding year. Each year, the cumulative cost is computed as the product of the land area experiencing significant sedimentation and the unit value of the land. The land areas with significant sedimentation are obtained from the "With Sedimentation Mgt" worksheet (column AU). The unit land value is considered constant and obtained from the **Inputs** worksheet (cell E135).
- Upstream-impact cost related to the relocation or elevation of highways and railroads. The annual cost is computed as the product of the incremental length of significant upstream delta advancement and the unit value of highway and railroad construction. The cumulative length of significant upstream delta advancement is imported from the "With Sedimentation Mgt" worksheet (column AT). The unit value for highway and railroad construction is considered constant and obtained from the **Inputs** worksheet (cell E136).
- Upstream-impact cost related to providing fish and boat passage. This cost begins when there is significant upstream delta advancement and is assumed to be constant throughout the remaining life of the dam and reservoir. The annual cost is obtained from the **Inputs** worksheet (cell E137).
- Downstream impact costs related to channel degradation and streambank protection. The annual cost is computed as the difference in the cumulative costs (column M) from a given year and the preceding year. Each year, the cumulative cost is computed as the product of the necessary streambank protection volume and the unit cost of constructed streambank protection. The streambank protection volumes are obtained from the "With Sedimentation Mgt" worksheet (column AE). The unit streambank protection cost is considered constant and obtained from the **Inputs** worksheet (cell E145).
- The capital cost for planned sediment management and the annual cost to help maintain reservoir storage capacity. These costs begin with the beginning of sediment management. Years since the capital cost investment are tracked and the capital cost is

repeated at the end of the service life. The capital cost is obtained **Inputs** worksheet (cell E179). Annual costs are assumed to be constant and the sum of the reservoir sediment management cost and the cost of downstream sediment mitigation. These annual costs are obtained from the **Inputs** worksheet (cells E185 and E187).

- Dam decommissioning cost is applied as a one-time cost after the reservoir has experienced severe sedimentation and enough time has passed for dam decommissioning preparations. The decommissioning cost is obtained from the **Inputs** worksheet (cell E130).
- Total annual cost is the sum of the individual costs.

Table 11. "Costs with sed mgt" worksheet columns devoted to the calculation of annual benefits

Worksheet Column(s)	Description
A to D	Analysis year, analysis year, dam age, and a switch to indicate if the project is still in service (project life = 1) or decommissioned (project life = 0)
E	Planning, design, construction and & land acquisition costs for the dam and reservoir
F to G	Annual OM&R cost and 5-year recurring OM&R cost
H	Cumulative length of significant upstream delta advancement
I	Cumulative upstream-impact cost related to the inundation of lands and associated buildings and infrastructure
J	Annual upstream-impact cost related to the inundation of lands and associated buildings and infrastructure
K	Upstream impact cost related to the relocation or elevation of highways and railroads
L	Upstream impact cost related to providing fish and boat passage
M to N	Cumulative and annual downstream impact costs related to channel degradation and streambank protection
O to Q	Years since the pervious capital cost for sediment management, capital cost, and annual sediment management cost to help preserve reservoir storage capacity
R	Dam decommissioning cost at the end of the project life
S	Total annual cost
U to AD	Costs from columns E, F, G, J, K, L, N, P, Q, and R presented as negative values for possible plotting purposes

This worksheet is protected and may be unlocked using the password: RSEM22. There are many interactions among cells in this and other worksheets. Model users attempting programming modifications do so at their own risk.

B.16 Trap Efficiency

This worksheet supports the "Without Sediment Mgt" and "With Sediment Mgt" worksheets by estimating the reservoir sediment trap efficiency (ratio of sediment deposition to sediment inflow). The graph presented by Morris and Fan (1998, Figure 10.15) is used to estimate the sediment trap efficiency as a function of the reservoir storage capacity to mean annual inflow ratio. Morris and Fan adapted this curve from Brune (1953). Values for the capacity-inflow ratio and the sediment trap efficiency were digitized from the median curve for normal ponded reservoirs and presented in columns A and B (rows 4 through 20) of the worksheet. RSEM uses this worksheet to predicts the initial trap efficiency and how the trap efficiency changes over time.

RSEM uses the same mean annual reservoir inflow throughout the simulation. However, the reservoir storage capacity will reduce over time with continued sedimentation. As the storage capacity reduces, so too will sediment trap efficiency and more inflowing sediments will pass through the reservoir.

As a demonstration of the worksheet function, the initial total capacity-inflow ratio (dam age of 0 years) is imported to cell A23, and also cell A26, from the **Inputs** worksheet (cells E21 and E25). The interpolated trap efficiency is displayed in cells B23 and B26. Cells A25–B27 are used to help with the interpolation. Lookup functions are used to determine the upper and lower capacity-inflow ratios (from cells A4–A20) that bracket the initial ratio. These upper and lower ratios are displayed in cells A25 and A27. Lookup functions are also used to find the trap efficiencies (from cells B4–B20) that correspond to the upper and lower ratios and these trap efficiencies are displayed in cells B25 and B27. A semi-log interpolation procedure is used to predict the sediment trap efficiency corresponding to the initial capacity-inflow ratio and the result is displayed in cells B26 and B23.

The same semi-log interpolation procedure is used to predict the sediment trap efficiencies for each year of the simulation. However, the interpolations are performed directly from the "Without Sediment Mgt" worksheet (columns BW through CB) and the "With Sediment Mgt" worksheet (columns BV through CA). Lookup functions are used in these two worksheets to find the upper and lower capacity-inflow ratios, in the "Trap Efficiency" worksheet, that bracket the inflow-capacity ratio for a given year. Lookup functions are also used to find the trap efficiencies that correspond to the upper and lower ratios. Semi-log interpolation is then performed to predict the trap efficiency for a given year.

This worksheet is protected and may be unlocked using the password: RSEM22. There are many interactions among cells in this and other worksheets. Model users attempting programming modifications do so at their own risk.

B.17 Reservoir Yield

This worksheet supports the **Inputs** worksheet by estimating the reservoir water yield that can be obtained from the storage capacity. The reservoir water yield depends on the water storage volume, which in turn depends on the amount and variability of reservoir inflows and the operational policies of the reservoir. Therefore, the water storage volume may be less than the storage capacity. The greater the annual variability of reservoir inflow, the lower the reliability of reservoir yield. The greater the ratio of reservoir storage to mean annual inflow (MAF), the greater the reliability of reservoir yield.

The graph presented by Annandale (2013, Figure 3.2) is used to estimate the 99% reliable yield as a function of the coefficient of variation for reservoir inflow and live reservoir storage capacity to mean annual inflow ratio. Digitized values from the curves in this graph (MAF, CV, and Yield) are tabulated in cells M36–O69. The coefficient of variation (CV) for reservoir inflow is the ratio of the standard deviation to mean annual inflow. A coefficient of variation of 0.4 is common for many rivers, but values often range from 0.2 to 1.4 and sometimes beyond this range (Annandale, 2013).

Parabolic equations were developed to interpolate values along a series of curves representing a given ratio of reservoir live storage capacity to mean annual inflow (3, 1, 0.5, and 0.25 MAF). A linear equation was also developed to interpolate along the run-of-river curve. Parameters for these equations are displayed in cells P9–R13.

The initial live reservoir storage capacity to inflow ratio (Cap) and coefficient of variation (CV) are imported from the **Inputs** worksheet (cells E27 and E28). The reservoir water yield (cell Q16) is linearly interpolated between live reservoir storage capacity to inflow ratios, using the table of Cap and CV values (cells O18–Q23). The Cap values of this table (cells O19–O23) are fixed. The CV values (cells P19–P23) match the imported CV value in cell P16. The yield values (cells Q19–Q23), corresponding to the Cap values, are interpolated for the specific CV values using the equation parameters (cells P9–R13).

This worksheet is protected and may be unlocked using the password: RSEM22. There are many interactions among cells in this and other worksheets. Model users attempting programming modifications do so at their own risk.

B.18 Economic Graphs (individual)

Annual economic benefits and costs are compared in a series of individual graphs in this worksheet. This worksheet contains graphs that are very similar to the graphs in the "Economic Graphs (comparison)" worksheet. Individual versions of these side-by-side graphs are provided here in case the model user needs larger size versions for reports or presentations.

All benefits and costs presented in these graphs are linked to values in the two calculation worksheets: without and with sediment management ("Calc_sheet without sed mgt" and "Calc_sheet with sed mgt"). Separate graphs, without and with reservoir sediment management, are presented next to each other for easy comparison:

- Bar graphs of annual benefits and costs, before discounting, over the entire period of analysis (500 years).
- Bar graphs of annual benefits and costs, before discounting, over the first 200 years of analysis.
- Bar graphs of annual benefits and costs, after discounting, over the first 200 years of analysis.
- x-y graphs of cumulative benefits and costs, before discounting, over the first 200 years of analysis.
- x-y graphs of cumulative benefits and costs, after discounting, over the first 200 years of analysis.

In addition, the following comparative graphs are provided:

- Cumulative net present value versus time for the alternatives without and with reservoir sediment management.
- Cumulative present value of benefits versus time for the alternatives without and with reservoir sediment management.
- Present value of annual benefits versus time for the alternatives without and with reservoir sediment management.

The significance of these economic graphs is explained in Appendix A, Section A. 4.

B.19 Sediment Graphs (individual)

Reservoir sedimentation results are presented in a series of comparative graphs in this worksheet. This worksheet contains graphs that are very similar to the graphs in the **Sediment Graphs (comparison)** worksheet. Individual versions of these side-by-side graphs are provided here in case the model user needs larger size versions for reports or presentations. All values plotted in these graphs are linked to values in the two sedimentation management worksheets: without and with sediment management (“Without Sediment Mgt” and “With Sediment Mgt”). Graphs, without and with reservoir sediment management, are presented side-by-side for easy comparison:

- Longitudinal profile graphs of reservoir sedimentation after ten different time periods.
- Graphs of reservoir sedimentation and storage capacity over the first 200 years of the analysis period.
- Longitudinal profile graphs of river channel degradation, downstream from the dam, after ten different time periods.

The significance of these sediment graphs is explained in Appendix A, Section A. 5.

Columns AB through AH (rows 5–30) are used to help plot the location of boat ramps 1 and 2, recreation pool elevation, normal water surface elevation, and top of live storage elevation. Values in these columns and rows are imported from the **Inputs** worksheet and constant values from the “Without Sedimentation Mgt” worksheet.

B.20 Sed Parameter Check

This worksheet provides a tool for graphing sediment modeling parameters, versus time, from the both the “Without Sediment Mgt” and “With Sediment Mgt” worksheets. The tool may be helpful for checking simulation results and possible debugging.

The user selects a specific sediment parameter from the drop-down list in cell B2. A comparative graph of the selected parameter versus dam and reservoir age is presented for alternatives without and with sediment management.

A table of sediment parameters for each year of the model simulation is presented in columns A–C of the worksheet (rows 4 through 505). The sediment parameters from the “Without Sediment Mgt” worksheet are presented in column B while parameters from the “With Sediment Mgt” worksheet are presented in column C.