Projected Reservoir Rating Curves and Their Utility for Water Planning in Texas[1]

John Zhu, Ph.D., P.G., D. Nelun Fernando, Ph.D., Holly Holmquist, Nathan Leber, and Carla G. Guthrie, Ph.D.

Texas Water Development Board, P. O. Box 13231, Austin, TX 78711-3231

ABSTRACT

This paper presents a method for projecting future reservoir elevation-area-capacity rating curves by calculating the distribution of sediment volume by lake elevation in reservoirs in Texas. We develop reservoir rating curves for the next 50 years, assuming a constant sedimentation volumetric rate as calculated at each elevational gradient for the predicting period. Projected rating curves can be used to simulate the impact of sedimentation on future reservoir firm yield and inform estimates of future available surface water for water planning purposes in Texas.

INTRODUCTION

Reservoir sedimentation is a natural and unavoidable process that reduces reservoir storage capacity. Sedimentation in reservoirs is also a significant problem affecting water availability in Texas (Texas Board of Water Engineers 1961). The International Boundary and Water Commission (IBWC) established the very first suspended sediment station in Texas on the Rio Grande at El Paso in 1889 (Texas Board of Water Engineers 1959). Investigations of reservoir sedimentation have been conducted based on reservoir volumetric surveys. According to Eakin and Brown (1936), the earliest studies on reservoir sedimentation in Texas were conducted for White Rock Lake and Lake Worth in 1910 and 1915, respectively. In 1991, the 72nd Texas State Legislature authorized the Texas Water Development Board (TWDB) to develop a non-profit, self-supporting reservoir volumetric survey program, the Hydrographic Survey Program. Since 1992, TWDB's Hydrographic Survey Program has completed 197 hydrographic surveys on 114 unique reservoirs. To date, most of Texas' major water supply reservoirs[2] have been surveyed multiple times, which allows for reasonable estimates of sedimentation rates. For example, hydrographic surveys of White River Lake conducted in 1971 by Freese and Nichols Inc. and in 1992 by TWDB (2003a), indicate that the lake loses approximately 1.3 percent of its capacity per year (approximately 600 acre-feet per year), one of the highest sedimentation rates among reservoirs in Texas. Per the 2022 State Water Plan (TWDB, 2022), the estimated three percent decline in the availability of surface water between 2020 and 2070 is primarily due to the sedimentation of reservoirs.

Sedimentation reduces a reservoir's storage capacity and therefore will, eventually, reduce its firm yield. Firm yield is the maximum annualized quantity of water that could be diverted without shortage from a reservoir every year including drought of record years, based on the historical hydrological record. Texas Administrative Code (Title 31) Rule §357.10

[1] This draft version is updated on November 21, 2024.

[2] Major reservoirs are defined as those reservoirs having original conservation volume 5,000 acre-feet or greater.

requires regional water planners to use firm yield *".... under a repeat of the Drought of Record using anticipated sedimentation rates....*," when estimating future water availability. What are anticipated sedimentation rates? How can a future reservoir elevation-area-capacity rating curve be developed? The goal of this study is to demonstrate a methodology for predicting future reservoir capacity and elevation-area-capacity rating curves to support water planning in Texas. The specific objectives of this study are 1) to examine sediment distribution in reservoirs, 2) to derive the distributed sediment volume along the vertical profile of the reservoir, and 3) to use this elevational sedimentation information to predict future rating curves.

DISTRIBUTION OF SEDIMENT IN A RESERVOIR

Sediment distribution in reservoirs can vary depending on the sediment load from contributing rivers, streams, and the local geomorphology. Sediment in a reservoir mainly comes from erosion in the reservoir catchment. Shoreline erosion due to wave action may also contribute to sedimentation. The mineral composition and particle size of the sediment are related to the nature of soils and geology in the catchment. Coarse materials are usually deposited at the river mouth where it enters the reservoir while fine particles settle farther into the body of a reservoir, usually in the lower elevations of the reservoir. If multiple rivers/streams flow into a reservoir, non-main stem streams will have a significant effect on sediment distribution within a reservoir (Abraham, et al 1999).

The TWDB models the distribution of post-impoundment sediment in reservoirs by analyzing acoustic signal returns from a multi-frequency depth sounder and sediment core samples as a part of the Hydrographic Survey Program's volumetric and sedimentation surveys. For more information please visit: https://www.twdb.texas.gov/surfacewater/surveys/index.asp.

Due to its varied climate, soil and geology, sediment distribution in Texas reservoirs varies significantly. Here are some typical examples: Per hydrographic surveys of Lake Buchanan and Granger Lake, more sediment was measured in the upstream area (upper reach) of Lake Buchanan (Figure 1), while more sediment was measured in the downstream portion (lower reach) of Granger Lake (Figure 2). When a reservoir is built at the confluence of two or more major streams, sediment distribution may differ in different arms of the reservoir. In Waco Lake, more sediment occurs in the southern arm implying that there are higher sediment flows in this reach of Waco Lake (Figure 3)[3]. Farmland activities in the Middle Bosque River and Hog Creek watersheds and municipal activities from the Waco area in the southeastern side may contribute to higher sedimentation in this arm. In addition to land use and land cover, the respective size of each tributary's contributing watershed, its hydrology, and the presence of upstream reservoirs that can trap sediment are some of the other factors that can lead to the variability of sediment transported by one tributary stream versus the other.

[3] The Texas Water Development Board conducts volumetric and sedimentation surveys using a multi-frequency (200 kHz, 50 kHz, and 12 kHz), sub-bottom profiling depth sounder. The 200 kHz signal is used to determine the current bathymetric surface. All three signal returns are analyzed to determine the reservoir bathymetric surface at the time of initial impoundment, i.e., pre-impoundment surface. Sediment core samples are collected throughout the reservoir and correlated with the acoustic signals in each frequency to assist in identifying the pre-impoundment surface. The difference between the current surface bathymetry and the pre-impoundment surface bathymetry yields a sediment thickness value at each sounding location. Sediment core locations are dispersed throughout the reservoir and selected to represent the various acoustic signatures seen in the data and to represent various depths and topographical features such as submerged river channels, floodplains, shallow slopes, and deep basins. The sediment core is analyzed and its physical characteristics including soil color, texture, relative water content, and presence of organic materials is noted. Many layers of sediment may be identified during analysis and each layer is classified as either pre-impoundment or post-impoundment. The pre-impoundment surface is identified by matching each sediment core with the acoustic signal returns. This information then serves as a guide for identifying the pre-impoundment surface along cross-sections where sediment cores were not collected. After the pre-impoundment surface is identified for all cross-sections a sediment thickness triangulated irregular network (TIN) model is created. To improve the accuracy of TIN models and reduce model inaccuracies such as intermittent representations of submerged stream channel connectivity or artificially-curved contour lines extending into the reservoir where reservoir walls are steep or the reservoir is relatively narrow the TWDB uses various anisotropic spatial interpolation techniques to improve bathymetric and sedimentation representation between survey lines. Reservoirs and stream channels are anisotropic morphological features where bathymetry at any particular location is more similar to upstream and downstream locations than to transverse locations. Using the survey data, polygons are created to partition the reservoir into segments with centerlines defining the directionality of interpolation within each segment. The interpolation routine applies an inverse-distance weighted algorithm to user defined parameters to add a high resolution, uniform grid of interpolated bathymetric elevation points throughout a majority of the reservoir. Each interpolation point also has a pre-impoundment elevation and sediment thickness. The sediment thickness TIN model is converted to a raster representation using a cell size of 2 feet by 2 feet to produce a sediment thickness map.

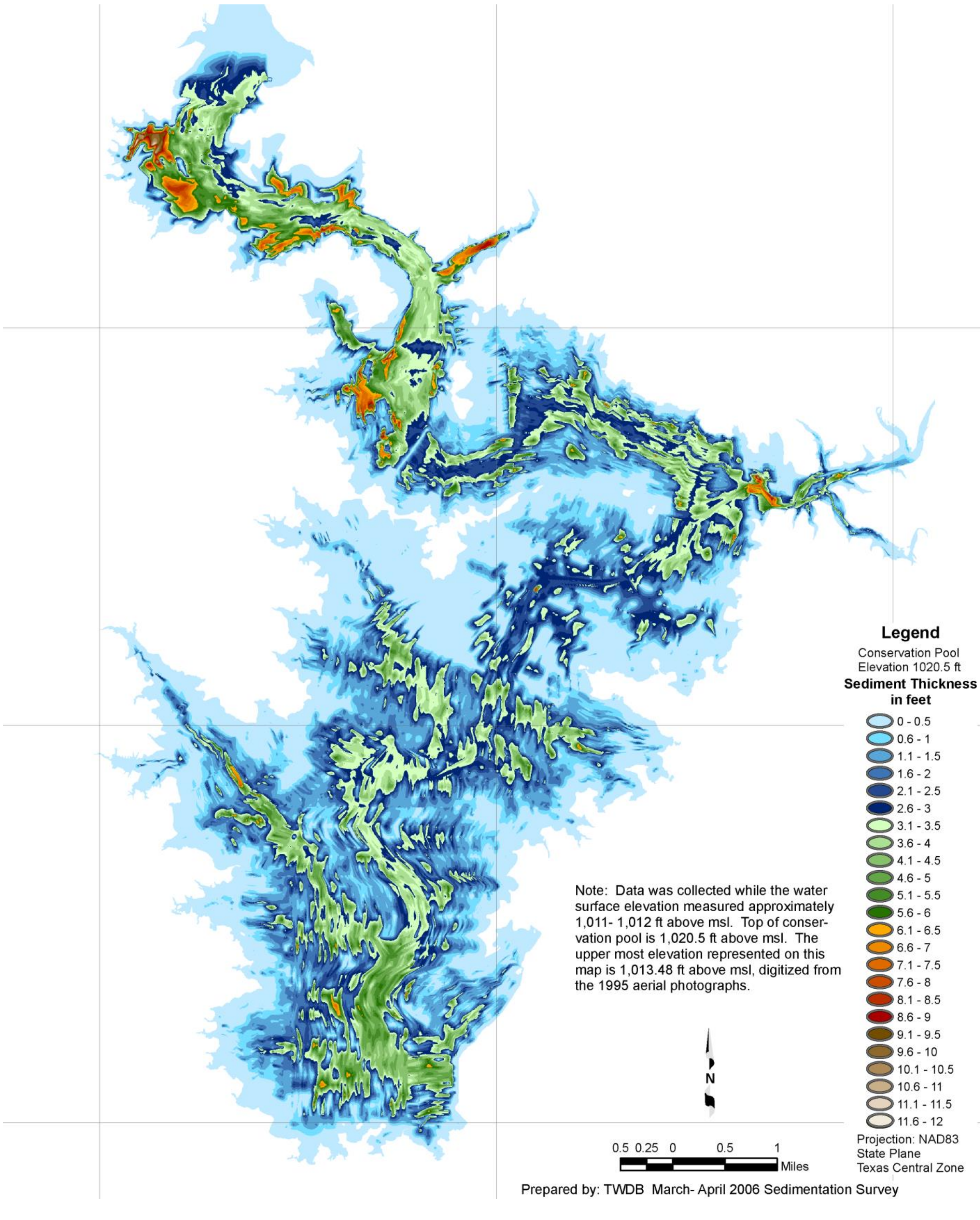

Figure 1. Sediment thickness map for Lake Buchanan (TWDB 2007b) shows more sediment (red and brown shading) accumulation in the upper reaches of the lake.

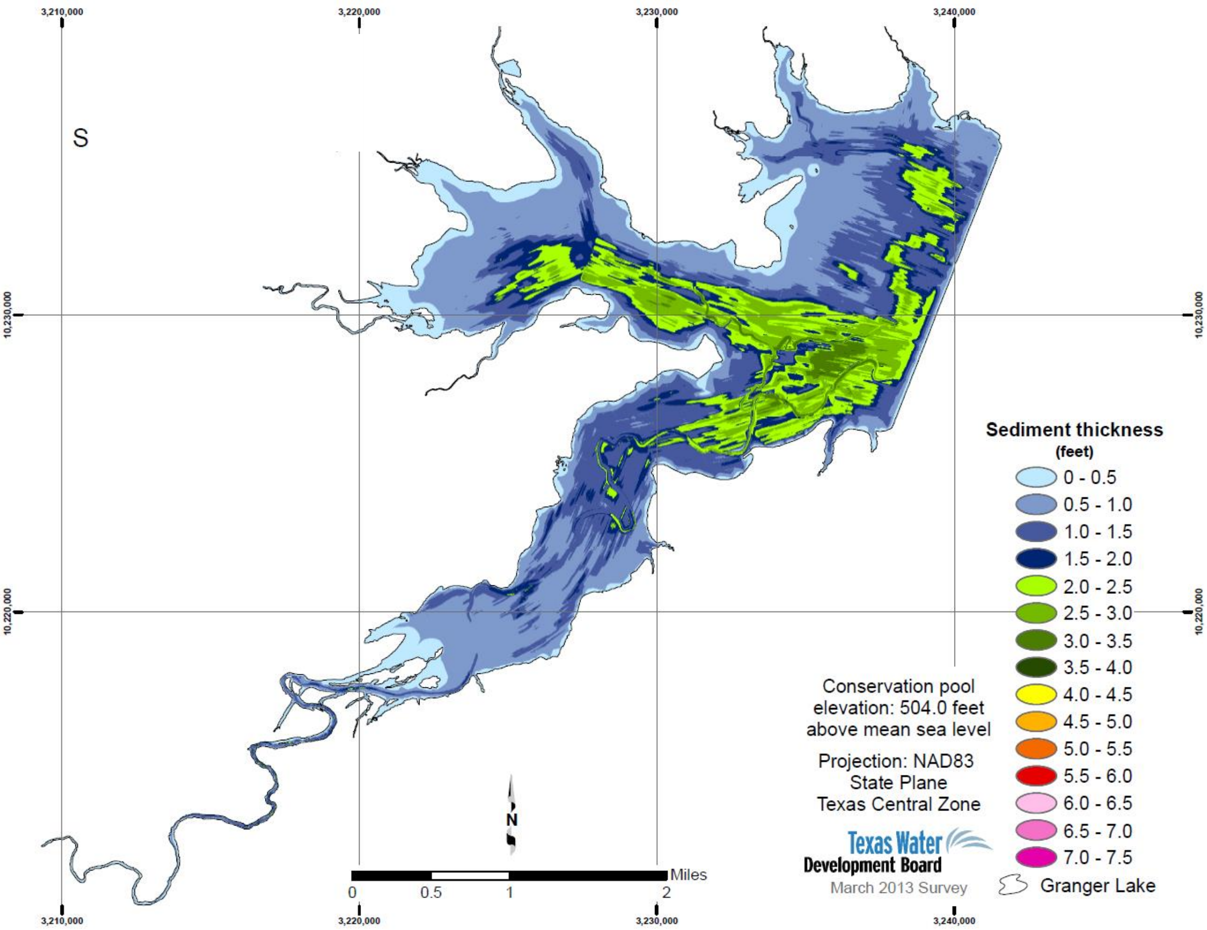

Figure 2. Sediment thickness map for Granger Lake (TWDB 2014) shows more sediment (green shading) accumulation in the lower portion of the lake.

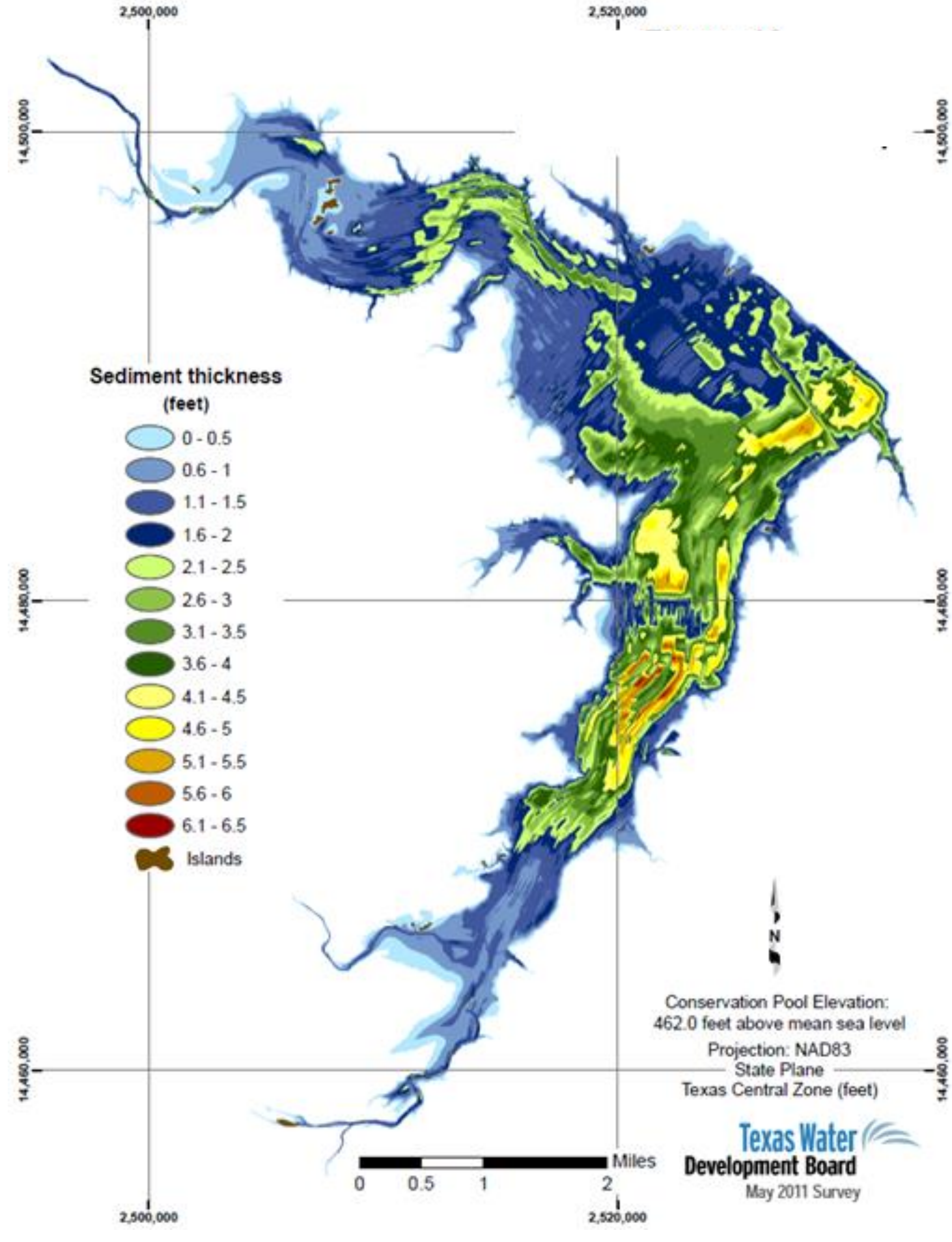

Figure 3. Sediment thickness map for Waco Lake (TWDB 2012) shows sediment accumulation (yellow and brown shading) predominantly in the southern arm of the lake with some accumulation (light green) in the lower portion of the northern arm of the lake.

How is sediment distributed vertically within a reservoir? We compared the sediment volume for each one-foot interval for all vertical elevations of a reservoir. Results indicate that sediment can be deposited anywhere in the lake depending on the source location, reservoir topology and shape of reservoir body. Conditions tend to vary across surveyed reservoirs, with no consistent pattern of sediment deposition. Figure 4 illustrates some typical patterns of sedimentation along the vertical gradient. Sediment volumes are higher at higher elevations in Lake Kemp [Figure 4(a)]; most sediment is deposited at lower elevations in Proctor Lake [Figure 4(b)]; sediment is nearly uniformly distributed at all elevations in Grapevine Lake [Figure 4(c)]; and sediment is deposited randomly throughout the vertical profile in Lake Worth [Figure 4(d)]. This finding suggests that sedimentation rates are not necessarily uniform across all elevations in a reservoir and should be assessed at all elevations, because the variation in sedimentation rates by elevation can affect reservoir yields.

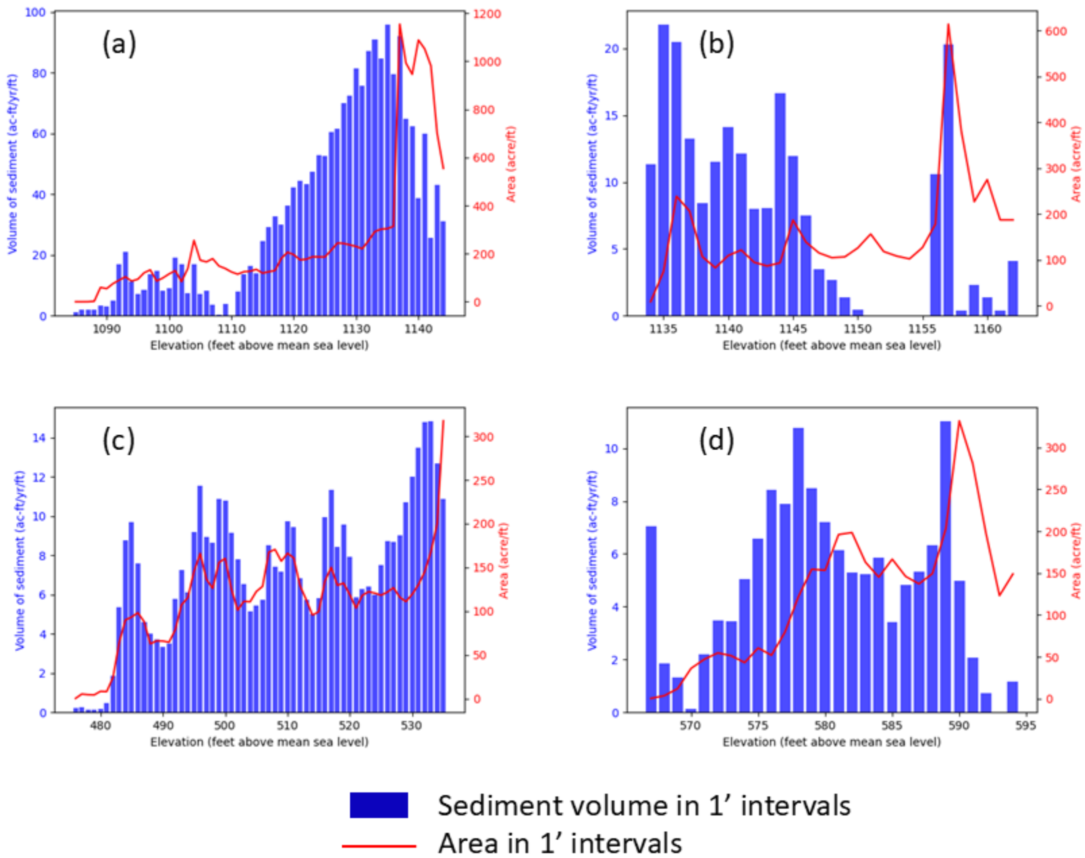

Figure 4. Examples of patterns of sedimentation along the vertical gradient for a) Lake Kemp; b) Proctor Lake; c) Grapevine Lake; and d) Lake Worth.

Generally, annual sedimentation rate, as measured per square mile, varies from reservoir to reservoir across the state of Texas. We use the TWDB reservoir hydrographic and sedimentation survey results for 80 reservoirs to depict a reservoir-specific sedimentation rate (Figure 5), depicted in units of acre-feet per year per square mile. The data appear to indicate that reservoirs in East Texas are subject to a higher sedimentation rate. Lake Athens and Monticello Reservoir, in East Texas, had the highest sedimentation rates. This high rate could be inaccurate because the original reservoir capacities may have been estimated using topographic maps, as suggested in the survey reports (TWDB, 2003d; 2003e). We obtained the catchment area for these 80 reservoirs from reservoir pertinent data maintained by the TWDB. Note, this is the total catchment area above the respective reservoir, without consideration of the effect of upstream reservoir(s) on sediment interception. In some cases, part of catchment may be non-contributing, but is not easily determined at this time. We acknowledge that the sedimentation rates depicted in Figure 5 are subject to revision based on our future data collection efforts and further study. Identifying why reservoir sedimentation rates vary across Texas was outside the scope of the current study.

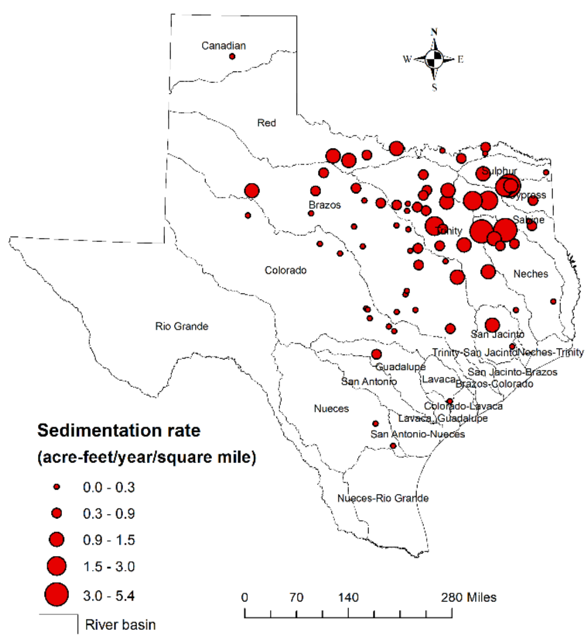

Figure 5. Reservoir sedimentation rates (acre-feet/year/square mile) at 80 surveyed reservoirs shows that several reservoirs in East Texas have high (3.0 – 5.0 acre-feet/year/square mile <) annual sedimentation rates.

METHODOLOGY FOR DETERMINING VOLUMETRIC ELEVATIONAL SEDIMENTATION RATES AND PROJECTING FUTURE RATING CURVES

Although the sedimentation rate for a reservoir usually refers to an average sedimentation rate for the entire reservoir, as discussed above, sediment can settle unevenly in a reservoir. Therefore, reservoir specific sedimentation volumetric rates vary along the elevational gradient. We refer to this variable volumetric sedimentation rate as the "volumetric elevational sedimentation rate", and the distribution plot of volumetric sedimentation rates along the elevational gradient is referred to as the "volumetric elevational sedimentation rate curve". A hydrographic survey of a reservoir may include both a sedimentation survey and a volumetric survey. We developed the elevational sedimentation curves by selecting two surveys among all available surveys for each lake evaluated.

The volumetric sedimentation rate is specific to each elevational interval in this study. For each elevation interval ΔEi, the volumetric elevational sedimentation rate (SVi) is computed by the following formulation:

$$SVi = (\Delta V_{1i} - \Delta V_{2i}) / T \qquad [1]$$

where SVi *– sedimentation volumetric rate (acre-feet per year) at elevation interval* ΔEi *from* $Ei\text{-}_1$ *to* Ei

ΔV_{1i} *– volume of survey 1 (previous survey) at elevation interval from* $Ei\text{-}_1$ *to* Ei
ΔV_{2i} *– volume of survey 2 (current survey) at elevation interval from* $Ei\text{-}_1$ *to* Ei
T *– duration between surveys 1 and 2 (in decimal year format).*

Taking Lake Granger as an example for computing the volumetric elevational sedimentation rate (Figure 6), we first examined the available survey data, and then selected the October 1995 survey and the March 2013 survey, with a time lapse of approximately 17.5 years, to develop the sedimentation curve. This selection was based on the following considerations: 1) longest duration between surveys, 2) similar survey technology used, and 3) sedimentation rate derived using the two surveys reflects the long-term trend.

The volumetric elevational sedimentation rate curve for a reservoir is unique for each reservoir. Therefore, we develop this curve for each reservoir.

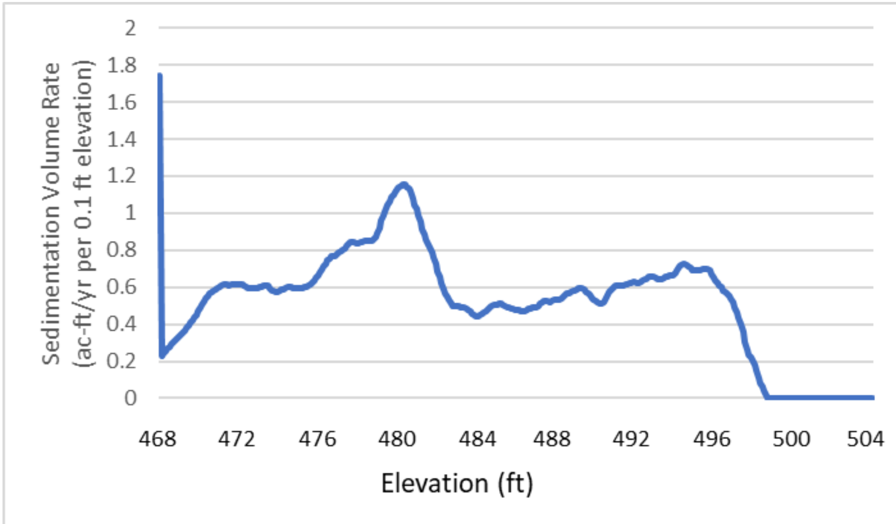

Figure 6. Volumetric elevational sedimentation rate curve for Granger Lake computed using the volumetric elevational sedimentation rate method and the 1995 and 2013 TWDB sedimentation surveys. The volumetric sedimentation rate is depicted at 0.1-foot vertical intervals.

We next project future reservoir elevation-area-capacity rating curves, based on the distribution of sediment volume by elevation. We assume that the volumetric elevational sedimentation rates will remain constant during the projection period, which is usually a 10-year period (e.g., from 2030 to 2040). The projection for the first timestep uses information from the latest survey. The projection for subsequent timesteps (e.g., 2050) uses the projected rating curve (e.g., 2040).

Projected future reservoir volume from the latest survey or projection at elevation Ei is:

$$Vi = Vi_{-1} + \Delta V_{2i} - SVi * T \qquad [2]$$

Where,

Vi – projected volume at elevation Ei (acre-feet)
Vi_{-1} – projected volume at elevation Ei_{-1}
ΔV_{2i} – volume of latest survey or projection at elevation interval from Ei_{-1} to Ei
SVi – volumetric elevational sedimentation rate (acre-feet per year) at elevation interval ΔEi from Ei_{-1} to Ei
T – duration between latest surveys or projection to the new projecting year

The projections are developed decade by decade from 2020 to 2080. The first projection decade (i.e., 2020) is based on the latest survey. All other projections are based on the previous projection (*e.g.*, the rating curve for 2040 is based on the 2030 projected rating curve, the rating curve for 2050 is based on the 2040 projected rating curve, etc.). This method always results in the lowest elevations of a reservoir filling in, which increases the lowest elevation of the reservoir with each passing year. Therefore, the lowest section of the volumetric elevational sedimentation rate curve needs to be omitted when projecting the rating curves for subsequent decades. For instance, if the reservoir's lowest elevation went from 100 feet in 2030 to 101 feet in 2040, the lowest elevation of the sediment curve must be raised up to 101 feet when projecting the 2050 rating curve from the 2040 curve. In the 2050 curve, the volumetric elevational sedimentation rate at 101 feet will be the sum of the 2040 curve's volumetric elevational sedimentation rate from 100 feet to 100.9 feet (e.g., 5 ac-ft/year) plus the 2040 curve's volumetric elevational sedimentation rate at 101 feet (e.g., 1 ac-ft/year). Thus, the 2050 curve's volumetric elevational sedimentation rate at 101 feet will be all sediment below and at 101 feet (e.g., 6 ac-ft/yr). This process is repeated for all projections (i.e., 2040, 2050, ……, 2080).

We use the reservoir volume change to compute the area change because the reservoir volume change (ΔVi) at a certain elevation interval (ΔEi) from Ei_{-1} to Ei is a product of area change (ΔAi) multiplied by the same elevation interval (ΔEi):

$$\Delta Vi = \Delta Ai * \Delta Ei \quad or \quad \Delta Ai = \Delta Vi / \Delta Ei \qquad [3]$$

Hence, projected area (Ai) at elevation Ei is the previous area (A_2i) minus the area change (ΔAi) from equation [3] (see Figure 7).

$$Ai = A_2i - \Delta Ai \qquad [4]$$

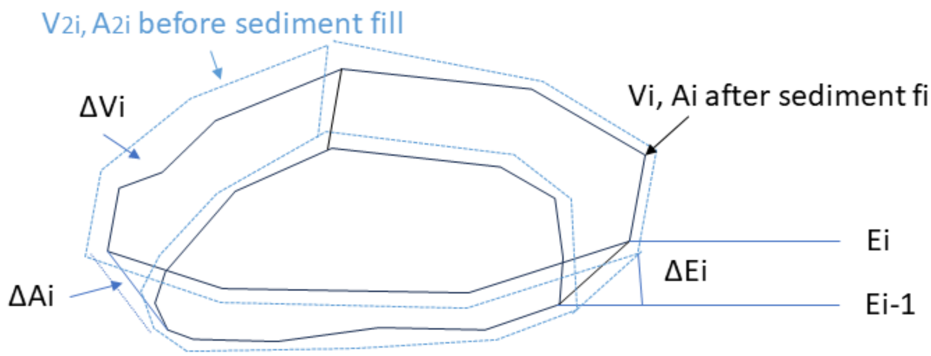

Figure 7 A diagram illustrating sediment filling depicts the change in reservoir volume (ΔVi) and change in area (ΔAi) at elevational intervals from Ei_{-1} to Ei.

Factors that need to be considered when selecting hydrographic and/or sedimentation surveys of a reservoir to compute volumetric elevational sedimentation rates for projecting future rating curves:

1. Time between two consecutive surveys should be long enough to avoid short-term sudden changes of sedimentation due to human activities or short-term climate variations that may cause short term changes in sedimentation (e.g., increased erosion due to flood events). Ideally, the gap between the two surveys should be 10 years or greater.
2. When multiple surveys are available, a simple regression may be derived on capacity against time. Selected surveys should be close to the regression trend line, so that the computed volumetric elevational sedimentation rate represents the general trend of silting of the reservoir. When the regression trend line is a non-linear, selected surveys should be consistent with the latest trend (i.e., trend in recent years), to give a best estimate of projected future reservoir capacity and rating curves.

3. The technology being used in reservoir volumetric and sedimentation surveys has advanced significantly in recent decades. Therefore, it is preferable to select surveys that used similar technology when computing the volumetric elevational sedimentation rate.
4. If there is no clear trend in sedimentation rate, a more conservative projection based on surveys that yield a higher volumetric sedimentation rate over a lower volumetric sedimentation rate is preferred, because it will lead to a smaller reservoir firm yield and provide a more conservative estimate of future available surface water.

By this method, volumetric elevational sedimentation rate curves for 80 (as of 2024) reservoirs in Texas were developed based on the available survey data. Using these volumetric elevational sedimentation rate curves, we developed projected rating curves for these 80 reservoirs. These ratings curves are developed at 0.1-foot elevation for the full elevation range in each reservoir. Figure 8 illustrates the existing rating curves from surveys (solid lines) and the projected full rating curves (dashed lines) for Granger Lake.

Regional Water Planning Groups in Texas are required to consider anticipated reservoir sedimentation rates when they simulate reservoir firm yields using the state's Water Availability Models (WAMs). Rating curves for the WAM can only have 12 elevation and area data pairs. When simplifying the full rating curve for the WAM, the lowest and highest elevation points of the full rating curve are used as is. The intermediate elevation points are set to equal elevation intervals, the magnitude of which is determined by dividing the elevation difference between the highest and lowest elevation points by 11. We developed simplified projected rating curves (i.e., rating curves for 12 elevation points, suited for input to the WAMs) for 80 major water supply reservoirs for the water planning decades 2030 through 2080 and shared these at https://www.twdb.texas.gov/surfacewater/data/projectedratingcurves/index.asp.

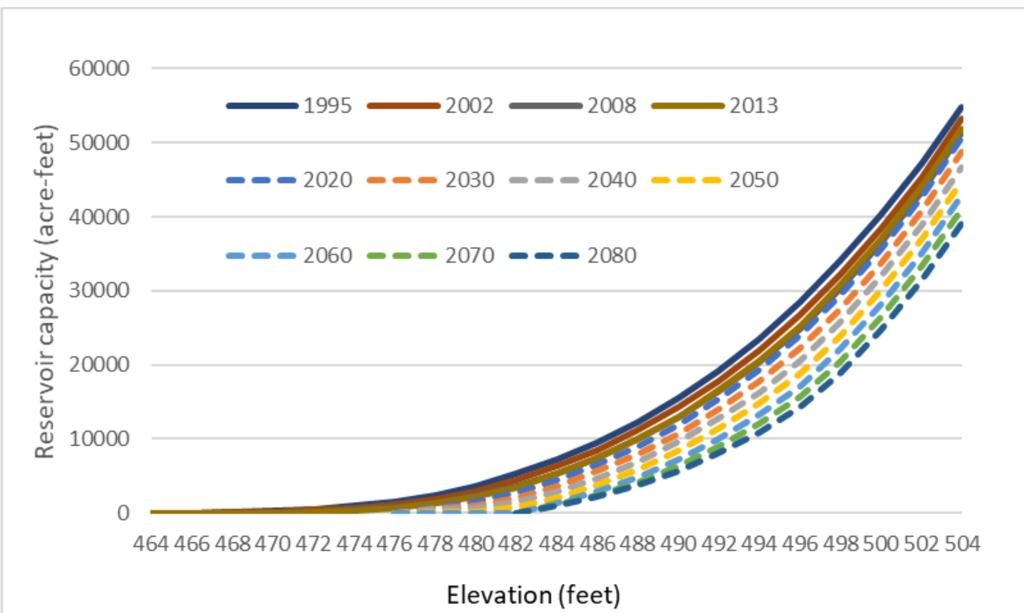

Figure 8. Existing (TWDB 2003b, 2003c, 2009b, 2014) and projected rating curves (for 2020 to 2080) for Granger Lake. ***Using the elevational sedimentation volumetric rate method, Granger Lake is projected to lose 12,805 acre-feet, or 24.7 percent of total capacity from 2013 to 2080.***

ESTIMATION OF RESERVOIR FIRM YIELD BY PROJECTED RATING CURVE

As mentioned before, sedimentation of reservoirs reduces conservation storage capacity and may affect firm yield. We used the projected rating curves to assess the impact of sedimentation on reservoir firm yield for all decades from 2020 through 2080. The Texas Commission on Environmental Quality's (TCEQ) WAM RUN 3 was used to compute reservoir firm yield with revised reservoir capacity, area-volume rating, inactive pool capacity, seasonal pool capacity, and/or the storage related diversion algorithm (drought index card) as they are related to the rating curve updates. Using the projected rating curves, we simulated firm yields for future decades using the TCEQ WAM for the respective river basin. Reservoir firm yield at Joe Pool Lake and Richland-Chambers Reservoir are simulated using the TCEQ Trinity WAM Run 3 (version 2023). Reservoir firm yield at Alan Henry Reservoir, Granger Lake and Possom Kingdom Lake are simulated using the TCEQ Brazos WAM Run 3 (version 2008, without the Brazos River Authority's Systems Operation).

Results for Granger Lake indicate that the reduction in reservoir firm yield associated with a reduction in reservoir capacity follows a non-linear relationship (Figure 9). When the capacity of Granger Lake reduces from 54,892 acre-feet to 39,016 acre-feet (29 percent loss) from 1995 through 2080, firm yield decreases from 17,455 acre-feet per year to 10,834 acre-feet/year, or approximately 38 percent (Figure 9 and Figure 10).

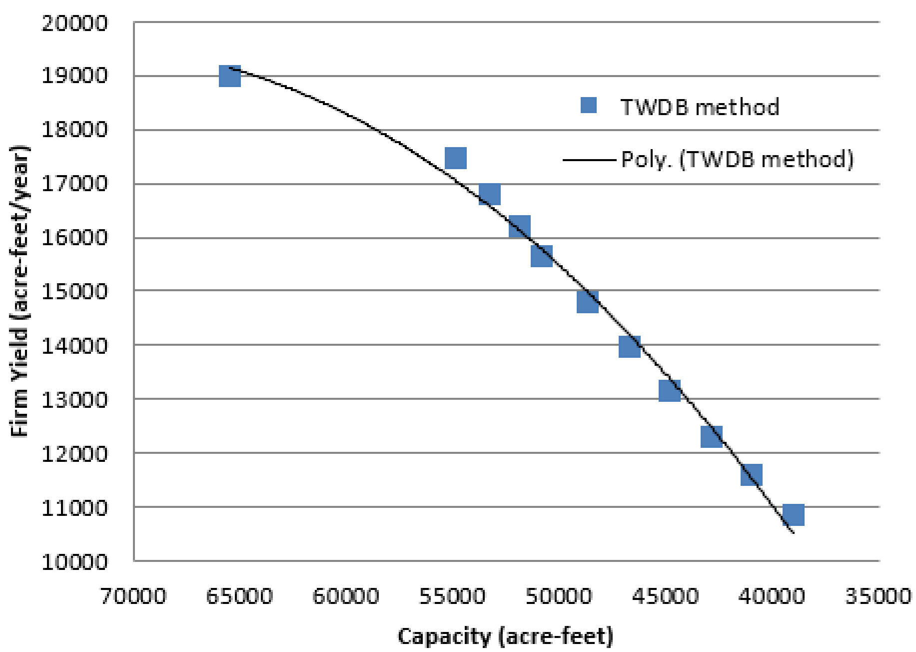

Figure 9. Firm yield versus capacity for Granger Lake ***(blue squares represent firm yield while the black line shows the best regression between firm yield and capacity)***

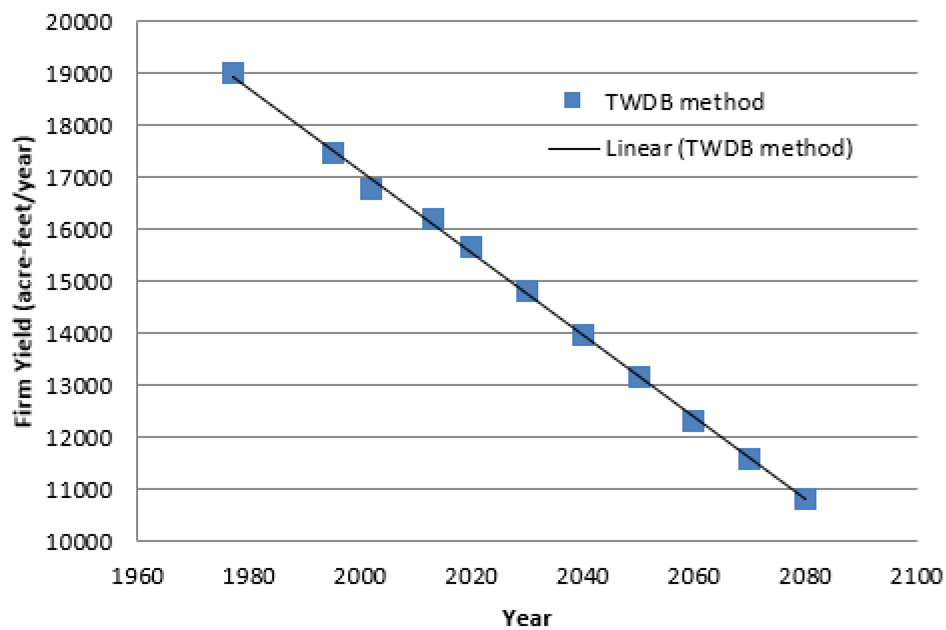

Figure 10. Firm yield versus decades since impoundment for Granger Lake *(blue squares represent firm yield while the black line shows the best regression for firm yield over time)*

The WAM Run 3 simulation does not incorporate future potential changes to naturalized flow or net reservoir evaporation; only changes to reservoir sedimentation are accounted for in the simulation. This allows for the isolation of reservoir firm yield change attributable to sedimentation. Future projected reservoir firm yields at Joe Pool Lake, Richland-Chambers Reservoir, Alan Henry Reservoir, and Possum Kingdom Lake show consistent declines over five decades due to sedimentation. Table 1 shows the change in reservoir firm yield for the decades 2020 through 2080 as a result of reservoir sedimentation, with Alan Henry Reservoir having the steepest decline in firm yield due to sedimentation. Other potential changes which might affect firm yield (such as a new drought of record or a change in evaporation patterns) are not considered.

Table 1 Firm yields for select reservoirs computed using projected rating curves.

Lake	Firm Yields (acre-feet per year)						
	2020	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**
Joe Pool Lake	13,834	13,393	12,908	12,400	11,887	11,377	10,890
Richland-Chambers Reservoir	239,799	236,774	234,142	231,391	228,520	225,685	222,873
Alan Henry Reservoir	10,484	9,767	9,026	8,308	7,561	6,818	6,074
Possum Kingdom Lake	302,389	298,281	294,162	290,058	285,943	281,801	277,650

COMPARISON OF THE VOLUMETRIC ELEVATIONAL SEDIMENTATION RATE METHOD WITH OTHER METHODS

Other methods have been used to project reservoir capacity and rating curves with the consideration of sedimentation, such as the empirical area reduction method and the areaincrement method (Borland W.M, and Miller C.R., 1958). These methods include, but are not limited to, trapezoidal, conic, or prismoidal formulations (Taube 2000). Taking the trapezoidal formulation as an example, volume (V_i) from elevation i-1 to elevation i is computed by the following formulation:

$$V_i = V_{i-1} + (E_i - E_{i-1}) * (A_i + A_{i-1})/2$$

where V_{i-1} *is volume at elevation i-1*

E_i, E_{i-1} *are elevation i and elevation i-1, respectively*

A_i, A_{i-1} *are areas at elevation i and elevation i-1, respectively*.

The total volume for a reservoir is the sum of all incremental volumes. In order to project the future capacity, an operator would reduce reservoir area by a constant for all elevations until the total capacity reaches the projected total capacity, which is the previous total capacity at the top of conservation pool minus the total sediment volume for the projection period computed by general/overall sedimentation rate. By the trapezoidal method, the capacity reduction at Granger Lake will be 192.7 acre-feet per year. Although the total capacity at 504 feet, the top of conservation pool elevation, is the same as that calculated using the elevational sedimentation volumetric rate method discussed above, the volumes estimated by the trapezoidal method are consistently higher than the volumes estimated by the volumetric elevational sedimentation rate method below 500 feet for 2050 projection, for example (Figure 11). As a result, firm yields computed by these rating curves are higher than those computed by the rating curves generated by the volumetric elevational sedimentation rate method (Figure 12).

Each method has advantages and disadvantages. Advantages of the trapezoidal method include that it is easy to understand and has consistent volume and area change. The disadvantages are the reservoir shape assumption and constant area reduction at all elevations. Constant area reduction means constant volume change, which is not necessarily consistent with the actual sediment distribution in a reservoir, as discussed in the previous section. An advantage of the volumetric elevational sedimentation rate method is the incorporation of varied volumetric sedimentation rates along the vertical profile. Disadvantages include the need to have at least two sedimentation surveys of reservoirs, and the potential drawback that the two surveys selected for the analysis may not represent the long-term sedimentation trend at the reservoir. It is also true that the vertical distribution of sedimentation may change over time.

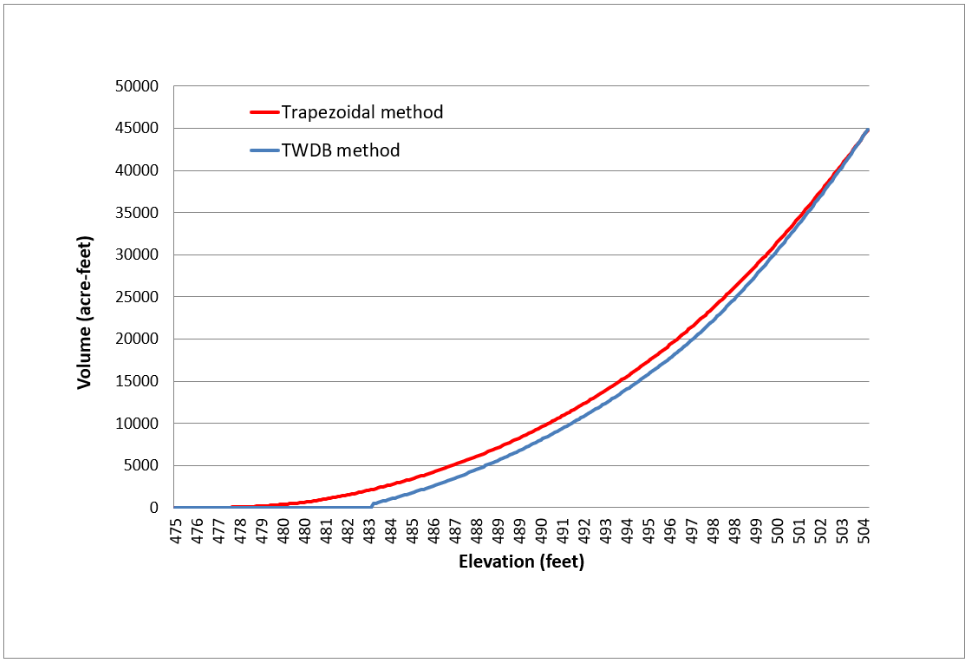

Figure 11. Estimated capacity for Granger Lake along the elevation gradient as determined by the trapezoidal method (red line) and the volumetric elevational sedimentation rate method (blue line) for 2050. The volumes below 500 feet with the trapezoidal method are about 1000–1500 acre-feet more than the volumes estimated with the volumetric elevational sedimentation rate method.

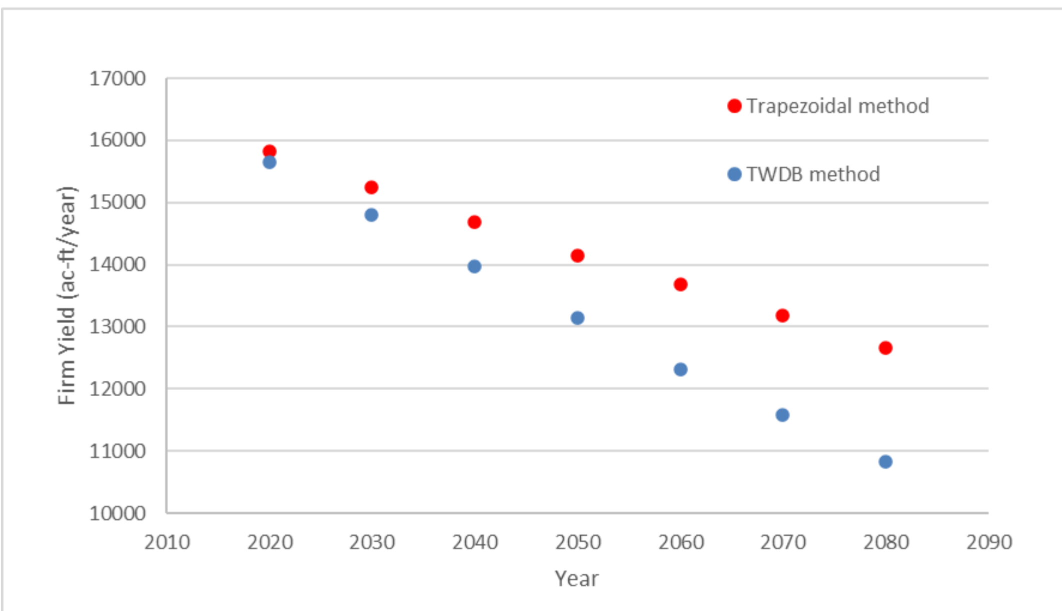

Figure 12. Granger Lake firm yields using rating curves by trapezoidal method (red *points*) and the volumetric elevational sedimentation rate method (blue point*s*). By 2070, firm yield calculated by trapezoidal method is 1,589 acre-feet per year (about 14 percent) more than the firm yield estimated by the volumetric elevational sedimentation rate method.

DISCUSSION AND RECOMMENDATIONS

Sedimentation in reservoirs is a concerning problem in Texas. Sediment reduces a reservoir's storage capacity and, therefore, may affect its ability to store and yield water for beneficial use. To estimate reservoir firm yield for Texas' 50-year water planning horizon, future reservoir capacity and rating curves are projected based on a detailed understanding of sedimentation characteristics in a reservoir.

We find that sediment distribution varies inside a reservoir and volumetric sedimentation rates vary at different elevations along a reservoir's elevational gradient. This suggests that a method that accounts for the variability of sedimentation by elevation is needed when estimating a reservoir's future capacity and associated rating curve. Based on available hydrographic and sedimentation surveys, we developed volumetric elevational sedimentation curves for 80 Texas reservoirs. Using these rating curves, and assuming a constant total volumetric sedimentation rate over a future time horizon, reservoir rating curves for the next 50 years were developed, specifically for 2030, 2040, 2050, 2060, 2070, and 2080. We have shared these rating curves at https://www.twdb.texas.gov/surfacewater/data/projectedratingcurves/index.asp for regional water planning groups in Texas to consider and utilize when estimating future reservoir firm yields for each planning decade.

Reservoir sedimentation processes are dynamic. The natural sedimentation rate is not a constant rate due to changes in climate, weather pattern, and land use. The method we propose assumes that over a projection decade the volumetric sedimentation rate will remain constant at all elevations except at the lowest elevation in reservoir. We acknowledge that the distribution of sedimentation by elevation can vary over time. Whether the filling up of the lowest elevations of a reservoir, and the increase in volumetric sedimentation rate over time at the lowest elevations in a reservoir, are physical processes applicable to all reservoirs needs to be determined. Assessing the sensitivity of reservoir capacity loss to these assumptions will be the subject of future study. We recognize that further study is needed to identify and implement improvements to the methodology we propose. Nevertheless, this method provides regional water planning groups with an easy-to-use, physically based method for estimating future reservoir firm yields. Furthermore, it yields a reservoir firm yield that appears to be more conservative than the firm yield estimates derived using other methods — such as the empirical area reduction method — for accounting for reservoir sedimentation.

While we suggest that projected firm yields for planning periods be derived using projected rating curves whenever possible, for reservoirs that have only a single hydrographic survey and no sedimentation survey, projected rating curves cannot be derived by the volumetric elevational sedimentation rate method. Water planners may still use other analytical methods, such as trapezoidal or conic formulations to compute future rating curves. In such cases, all available information on area-capacity and the sedimentation rate must be obtained by field surveys or by other reliable sources. The Texas State Soil and Water Conservation Board (TSSWCB) published comprehensive sediment yield data for Texas in 1991 (TSSWCB 1991), which may be a good reference for estimating sedimentation for a reservoir with no hydrographic survey data.

As a foundation for estimating the future capacity of a reservoir, detailed volumetric and sedimentation surveys are critical. Therefore, we recommend that reservoir owners have volumetric and sedimentation surveys completed at regular intervals for their respective reservoirs.

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