Characteristics of Lake Ralph Hall, Upper Trinity Basin, Texas

Department of Environmental and Water Resources Engineering

GIS in Water Resources Fall/2014

Final Project

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12/5/2014

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1.0 Abstract

ArcGIS software was used to draw maps and find the characteristics of Lake Ralph Hall, Upper Trinity Basin, Texas by constructing a relationship between the storage volume, the surface area and the elevation of the water surface in one meter increments for the reservoir site. Comparison between the proposed reservoir specifications and the results of this study showed that the competed storage volume was almost identical to the actual reservoir volume, surface area was slightly larger than the actual surface area by 5.2%, and the time to fill the reservoir was less than actual time needed by 13.8%. This step validated the use of drawn maps for further analysis.

In addition to the lake characteristics, a flood frequency analysis was performed to determine the parameters of a 2, 5, 10, 50, 100-year flood event for the North Sulphur River near Cooper, TX where the reservoir is located. Data collected on peak annual stream flow from 1949-2013 will be used during the analysis. The frequency histogram illustrated a right tail with slightly positive skew 0.578. The design magnitude for the flood events and 90% confidence intervals were estimated for both the Extreme Value Type 1 (EV1) and Log Pearson Type 3 (LP3) models by using the Method of Moments (MOM) and Maximum Likelihood (ML) methods for determining parameters of models. Probability plots and the probability plot correlation coefficient (PPCC) test were utilized to evaluate the goodness of fit for the EV1 or LP3 model for the data. The goodness of fit of the EV1 model showed a straight line and fit better than the LP3. Both models passed the PPCC test with a 5% significance level with r values 0.985 and 0.986, respectively. The most conservative magnitude was provided by the EV1 model using ML and then the EV1 with MOM, whereas the LP3 appeared as the least conservative for estimating the flood frequency events. The volume of water expected during different flood events was extremely large compared to the original reservoir volume and thus conclude that the reservoir was not designed for flood control. To consider flood control of this reservoir, the new volume needed to be increased was estimated for different flood return periods. The new elevations of water surface and reservoir surface area were computed by using ArcGIS.

2.0 Introduction

1.1 Project Background:

Upper Trinity serves one of the fastest growing regions in North Texas. This area's population is expected to increase about 500% within 50 years, requiring approximately 136 million gallons of fresh water every day. Presently, Upper Trinity secures water from the City of Dallas and from Chapman Lake in northeast Texas. These water supplies will be adequate for about 15 years, after which new water sources will be needed. Lake Ralph Hall, a proposed new water supply lake on the North Sulphur River in Fannin County, will provide a safe, reliable water supply for the families and cities who rely on Upper Trinity. The proposed Lake is the most feasible and lowest cost source of new water available to Upper Trinity — and it can be built in time to avoid a water shortfall in about 25 years. Upper Trinity Regional Water District is predicting that demand for water will surpass available supplies sometime between 2025 and 2030. Here is some information about the proposed reservoir as shown in figure 1.

Reservoir Specifications:

- Volume = 180,000 acre-ft
- Surface Area = 7,605 acres
- Yearly Water Withdraw = 45,000 acre-ft
- Time to Fill Reservoir = Approximately 3 years
- Dam Location/PDF of Future Reservoir = http://www.cityofladonia.com/lake/LRHSitePlanLg.jpg

Figure 1 – Layout and specification of the proposed reservoir design (City of Ladonia Website).

1.2 Reservoirs Design:

The main objectives considered in reservoirs design include improving the reliability of industrial, municipal, and agricultural water supplies when and where it is needed. Another objective is protecting against floods as well as improving the quality of water.

Several factors should be considered in order to design, build, and operate a reservoir. In this report, two main factors will be considered such as calculating the height of the dam and the time needed to fill the reservoir. Reservoir storage capacity can be divided among three major uses, as shown in (figure 2),; the active storage, which is used for downstream flow regulation and for water supply, the dead storage required for sediment depositing, and flood storage reserved to reduce potential downstream flood damage during flood event.

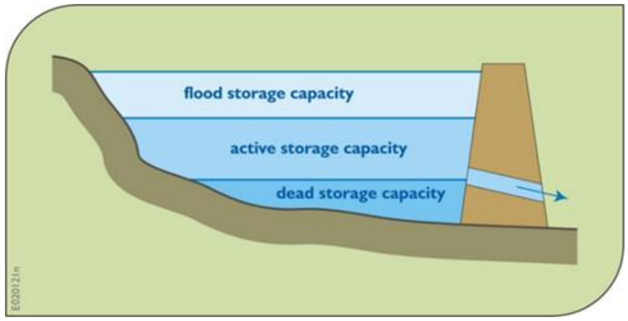
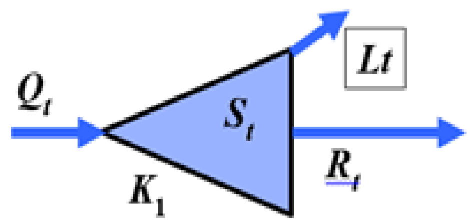


Figure – 2: Separated storage capacities of reservoirs (Loucks& Beek book)

The development and management planning process of water resource systems incorporate identification of the reservoirs needed, when needed, and where they are needed. There have been various methods used to determine reservoir capacities such as Mass Diagram Analyses and Sequent Peak Analyses. All models of reservoirs include the mass balance equation as shown in (figure 3) where the K is the reservoir capacity, the S_t is the initial storage volume, S_{t+1} is the final storage volume, Q_t is the inflow, R_t is discharge or release, and L_t is the evaporation and seepage losses.



$$\boxed{S_{t+1} = S_t + Q_t - R_t - L_t}$$

Figure – 3: The mass balance equation for calculating the reservoir capacity (K).

3.0 Research Questions

Two main research questions will be addressed as part of this project. The first question is to find out the most conservative flood zone capacity that can hold floodwater during a flood event. The second question is to estimate the time needed to fill the reservoir. The answers and results to these questions will be compared to the specifications of the proposed design in figure 1. Flood frequency analysis and powerful ArcGIS tools will be used to address these research questions.

4.0 Hypotheses

- Test whether or not the flood capacity zone can hold flood water events for a given X_T. The frequency flood analysis will be performed to generate different X_T for a set of return period such as 2, 5, 10, 50, 100 years.
- Test whether or not three years is enough to fill the reservoir. Average five years of historical daily mean flow data from 2009 to 2013 was used to determine how long for Reservoir to be filled.

5.0 Data Source

1. Data collected on peak annual stream flow from 1950-2013 for the North Sulphur River will be used for flood frequency analysis as shown in (Figure 4).
   http://nwis.waterdata.usgs.gov/tx/nwis/peak?site_no=07343000&agency_cd=USGS&format=gif

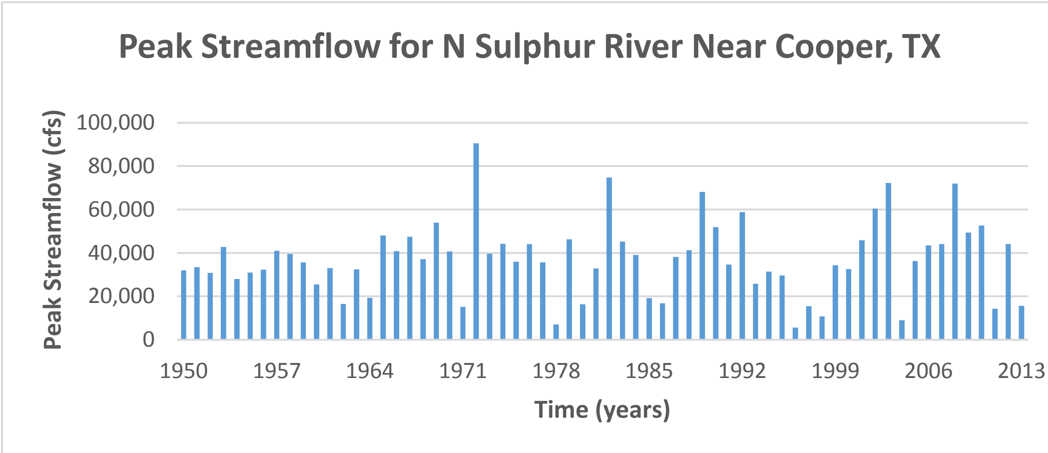


Figure – 4: Peak Streamflow for N Sulphur River from 1950 to 2013.

2. Historical data collected on annual streamflow from 1950 to 2013 for the North Sulphur River will be used for time series analysis as shown in (Figure 5).
   http://waterdata.usgs.gov/tx/nwis/dv/?site_no=07343000&agency_cd=USGS&referred_module=sw

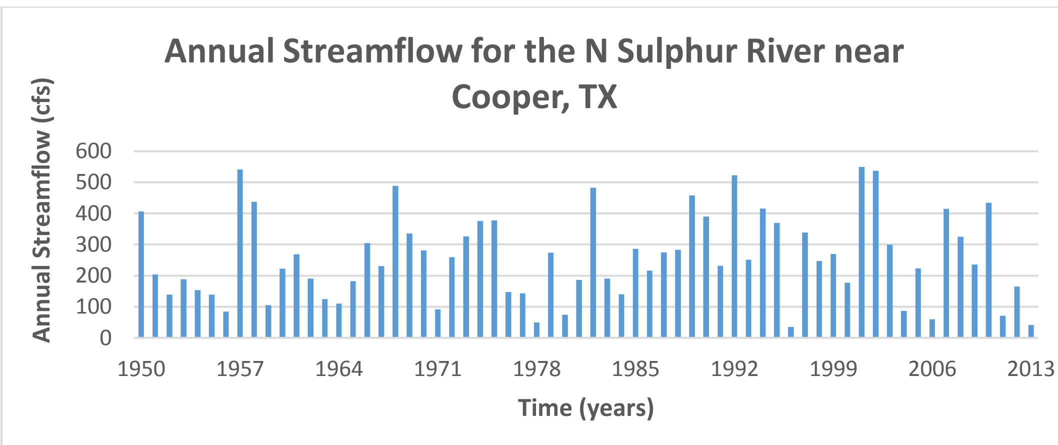


Figure – 5: Annual Streamflow for N Sulphur River from 1950 to 2013.

3. Data downloaded from ESRI Data Services and used in ArcGIS.
   http://elevation.arcgis.com/arcgis/services/ USA elevation data
   http://hydro.arcgis.com/arcgis/services/ Watershed delineation services

6.0 Methods

6.1 Mapping

6.1.1 Create Map in GIS showing dam location

- Get Topo/Map data from GIS online to locate Ladonia, TX and Dam location.
- Create new point shapefile showing Dam Location.

6.1.2 Watershed Delineation

- Download 30m resolution DEM.
- Extract general area around Ladonia, TX and the watershed.
- Use the "Fill" tool to fill in small depressions in the DEM.
- Use the "Flow Direction" tool to create a flow direction raster.
- Use the "Flow Accumulation" tool to create a flow accumulation raster.
- Use the "Snap Pour Point" tool to snap dam location to the nearest raster square with the highest flow accumulation.
- Use the "watershed" tool to create a rasterized watershed layer.
- Use the "Raster to Polygon" tool to convert the raster watershed to a polygon shapefile watershed.

6.1.3 Create Contours and Extract Specific Contours/Elevations

- Use the "Extract by Mask" to extract the smaller raster of just the watershed instead of the original raster file.
- Use the ArcToolbox -> Spatial Analyst Tools -> Surface -> Contour (Contour Interval = 1).
- Extract specific contours/elevations.
- Create a new line shapefile for each of those specific contours.

6.1.4 Obtain Streamflow Gage data and use to estimate how long to fill reservoir

- Average 5 years of daily flow data.
- Show hydrograph of 5 years of flow data and the average of those 5 years
- Calculate filling volume by multiplying the daily flow by time with some assumptions.
- Determine how long for Reservoir to be filled to different elevations and final elevation.
- Construct a relationship between the storage volume, the surface area and the elevation of the water surface.

6.1.5 Comparison of Proposed Reservoir Drawing and GIS Results

- Visually.
- Reservoir Volume.
- Reservoir Surface Area.
- Time to fill.

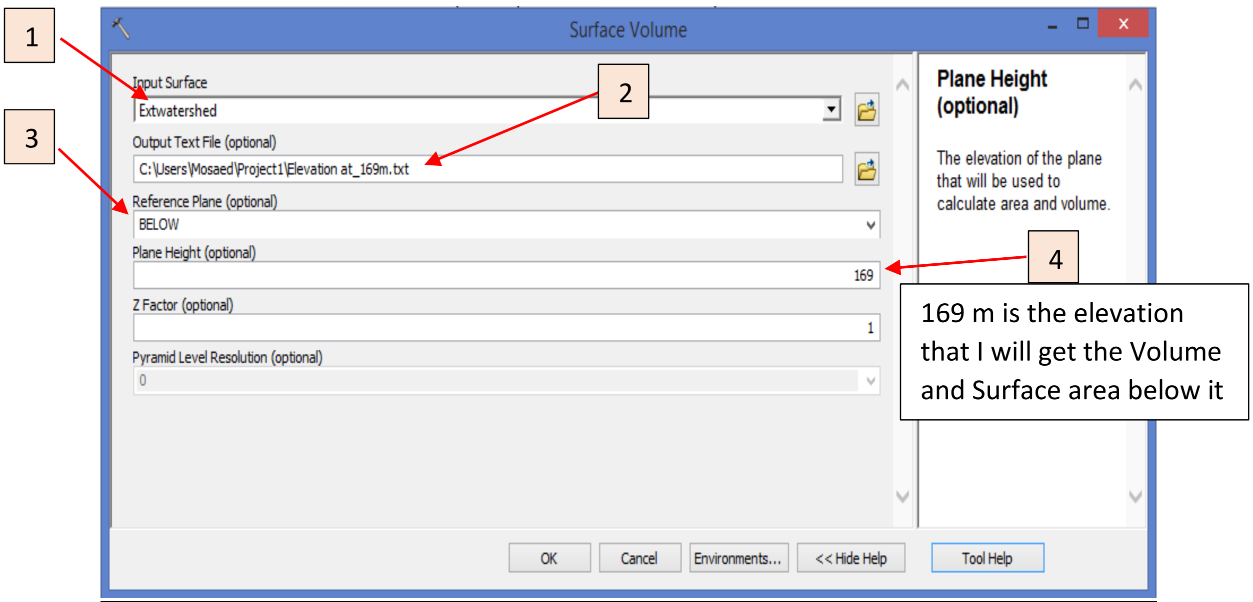
6.1.6 Use Surface Volume tool to calculate Reservoir Volumes and Surface Areas at different elevations

Surface Volume tool allows to calculate the area and volume of a raster, triangulated irregular network (TIN), or terrain dataset surface above or below a given reference plane.

To calculate Reservoir Volumes and Surface Areas considering different elevations in the Watershed, follow these steps:

- Go to: ArcToolbox -> 3D Analyst Tools -> Functional Surface -> Surface Volume
- Click the "Surface Volume" tool and enter in:
- Input Raster = Watershed DEM or TIN
- Specify an output file name (A Text File)
- Reference Plane = "Below"
- Specify Plane Height.
- No need to change Z factor or Pyramid Level Resolution!!!
- Run the tool and open the Text File that is created to get Volume and Surface Area.

An example:



<u>Sample Results</u>

Table

Elevation at 169m

Dataset	Plane_Height	Reference	Z_Factor	Area_2D	Area_3D	Volume
..s\Mosaed\Project1\Extwatershed	169	BELOW	1	34609308.583831	34644908.074294	225471152.83781

6.2 Reservoir filling

Historical data collected on daily mean flow from 2009 to 2013 for the North Sulphur River will be used to determine how long for reservoir to be filled to different elevations. Based on the water balance equation (Equation 1), we will assume that 50% of the mean flow will be released as environmental flows downstream (R) and evaporation and infiltration losses (L) because we do not have more information about the reservoir operation such as, firm yield and minimum environmental flow required. The rest of the flow will be stored. The simplified equation was used for this analysis as shown below (Equation 2).

$$S_{t+1} = S_t + Q_t + R_t + L_t \quad \dots (Eq.1)$$

$$S_{t+1} = S_t + Q_t - 0.5\, Q_t \quad \dots (Eq.2)$$

6.2 Flood Frequency Analysis

6.2.1 Frequency Histogram and Probability Plots:

The frequency histogram constructed to test the distribution of the data and allow for graphical visualization of how the data was distributed. This step served as a preliminary indicator for the appropriateness of later statistical tests. The number of classes used to classify the data was calculated by using M-Classes Formula (Sturges, 1926) which depends on the number of observations (N). For Probability Plots, two different plotting positions were assigned; the EV1 distribution and LP3 distribution. The data was ranked from largest to smallest and the plotting position (q_i) was computed with appropriate expression from Table 18.3.1. Both models showed a liner trend which indicates a well-fitting distribution. Equations used for plotting the frequency histogram and graphically evaluating the adequacy of EV1 and LP3 distributions to the data on probability plots are shown below.

Frequency Histogram and Probability Plots Equations:

$$M = 1 + 3.3\log(N) \ \text{ Sturges Formula Where, M: number of classes. } \ \text{N: number of observations}$$

$$qi = \frac{i-0.44}{N+0.12} \quad Gringorten\ Formula\ for\ EV1\ (Table 18.3.1)$$

$$qi = \frac{i-3/8}{N+1/4} \quad Blom's\ Formula\ for\ LP3\ (Table 18.3.1)$$

6.2.2 Probability Plot Correlation Coefficient (PPCC) Test:

The Probability Plot Correlation Coefficient (PPCC) was applied to the 64-year maximum annual stream flow data of N. Sulphur River. The PPCC test was performed for both the EV1 and LP3 to see if their distribution are acceptable for this data set at the 5% significance level and evaluate the goodness of fit for EV1 and LP3 considering a complete dataset. Equations used for performing the Probability Plot Correlation Coefficient (PPCC) Test are presented below.

Probability Plot Correlation Coefficient (PPCC) Test Equations:

$$r = \sum_{i}^{n} (X_i - \overline{X})(W_i - \overline{W}) \,/\, (\sum_{i}^{n} (X_i - \overline{X}) \ \sum_{i}^{n} (W_i - \overline{W}))\text{^}0.5$$

Test Statistic:

Reject distribution if $r < r_{N,\alpha}$: Critical Values of $r_{N,\alpha}$ obtain from table 18.3.3

PPCC Test Parameters for the EV1 Distribution Equations:

$$\alpha = \frac{1.2825}{S_X}$$

$$\beta = \overline{X}\text{- } 0.45 \text{ X } S_x$$

$$X_{Expected} = \beta - \frac{\ln(-\ln(1-q_i))}{\alpha}$$

PPCC Test Parameters for the LP3 Distribution Equations:

$$K_T = \frac{2}{C_{sy}}\left(1 + \frac{C_{sy}z}{6} - \frac{{C_{sy}}^2}{36}\right)^3 - \frac{2}{C_{sy}} \quad (Kite\ Eq: 9-52)$$

$$X_{Expected} = \mu + K_T \times \sigma$$

6.2.3 The Magnitude of the 2-5-10-50-100-Year Flood and Confidence Intervals:

The magnitude for the flood events, its standard error of estimate and the 90% confidence interval were estimated for the EV1 model by using the method of moment and maximum likelihood and for the LP3 model by using only the maximum likelihood method. Set of equations used for computing the magnitude of the 100-year flood event and its standard error are represented below.

EV1-MOM Equations:

$$\alpha = \frac{1.2825}{S_X}$$

$$\beta = \overline{X}\text{- } 0.45 \text{ X } S_x$$

$$X_T = \beta - \frac{1}{\alpha} ln\left[- ln\left(1 - \frac{1}{T}\right)\right] \quad where\ T = 2{,}5{,}10{,}50{,}100\ years$$

$$S(x_T) = \delta \frac{S_X}{\sqrt{N}}$$

$$\delta\ From\ Table\ 8.4\ (\ Kite\ page\ 104\ )$$

$$X_T^{U,L} = X_T \pm S(x_T)\, Z_{1-\frac{\alpha}{2}}$$

EV1-ML Equations:

$$F(\alpha) = \sum_i^N X_i\ e^{-\alpha X_i} - \left(\overline{X} - \frac{1}{\alpha}\right)\sum_i^N e^{-\alpha X_i} = 0\ (solved\ by\ Goal\ Seek\ Function\ with\ \alpha\ intial\ from\ MOM)$$

$$\beta = \frac{1}{\alpha}\ln\left(\frac{N}{\sum_i^N e^{-\alpha X_i}}\right)$$

$$S(x_T) = \delta \frac{S_X}{\sqrt{N}}$$

$$\delta\ From\ Table\ 8.5\ (\ Kite\ page\ 106\ )$$

$$X_T^{U,L} = X_T \pm S(x_T)\, Z_{1-\frac{\alpha}{2}}$$

LP3_MOM Equations:

$$K_T = \frac{2}{C_{sy}}\left(1 + \frac{C_{sy}z}{6} - \frac{{C_{sy}}^2}{36}\right)^3 - \frac{2}{C_{sy}} \quad (Kite\ Eq: 9 - 52)$$

$$\frac{\partial K_T}{\partial C_{sy}} = \frac{Z^2 - 1}{6} + \frac{4(Z^3 - 6Z)}{6^3} * C_{sy} - \frac{3(Z^2 - 1)}{6^3} * {C_{sy}}^2 + 4 \times \frac{Z}{6^4} * {C_{sy}}^3 - \frac{10}{6^4} \times {C_{sy}}^4 \ (\ Kite\ Eq: 9\_55)$$

$$\delta = \sqrt{\left(1 + K_T C_{sy} + \frac{K_T^2}{2} * \left(\frac{3C_{sy}^2}{4} + 1\right) + 3K_T \frac{\partial K_T}{\partial C_{sy}}\left(C_{sy} + \frac{C_{sy}^3}{4}\right) + 3\frac{\partial K_T}{\partial C_{sy}}^2\left(2 + 3C_{sy}^2 + 5\frac{C_{sy}^4}{8}\right)\right)}$$

$$S(_{y_T}) = \ \delta\ \frac{S_y}{\sqrt{N}}$$

$$S(XT) = \frac{XT(10^{syT} - 10^{-syT})}{2}$$

7.0 Results and discussion

7.1. Mapping

ArcGIS software was used to draw maps and find the characteristics of Lake Ralph Hall, Upper Trinity Basin, Texas by constructing a relationship between the storage volume, the surface area and the elevation of the water surface in one meter increments for the reservoir site.

7.1.1 Dam Location, Watershed Delineation and Contours Map

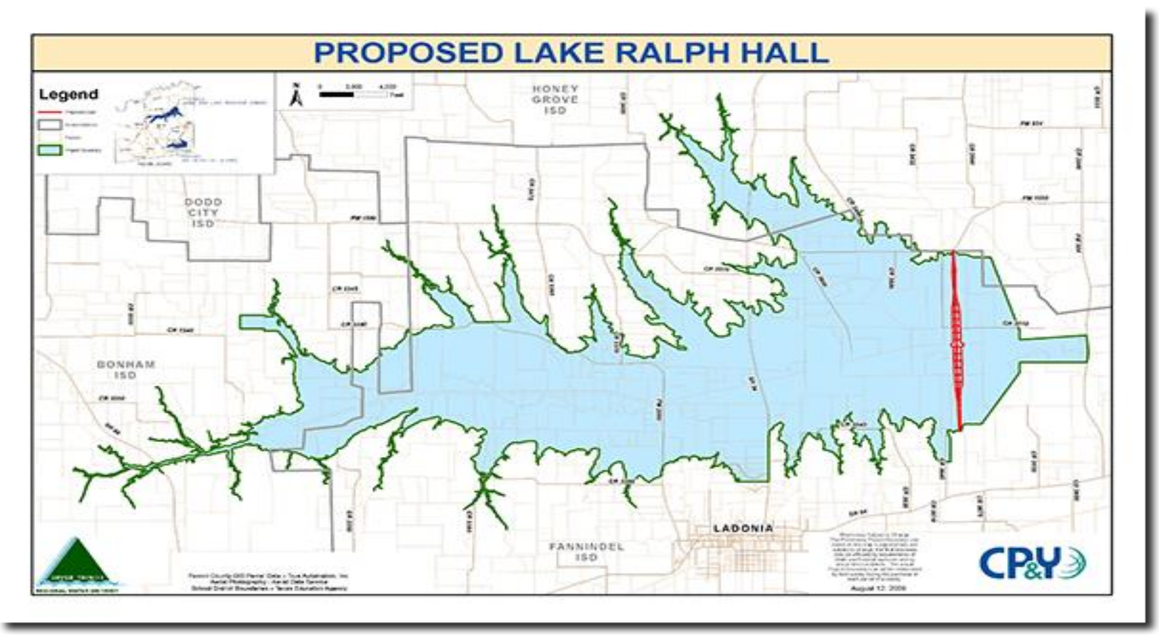


Figure 6 – Layout of the proposed reservoir design (City of Ladonia Website)

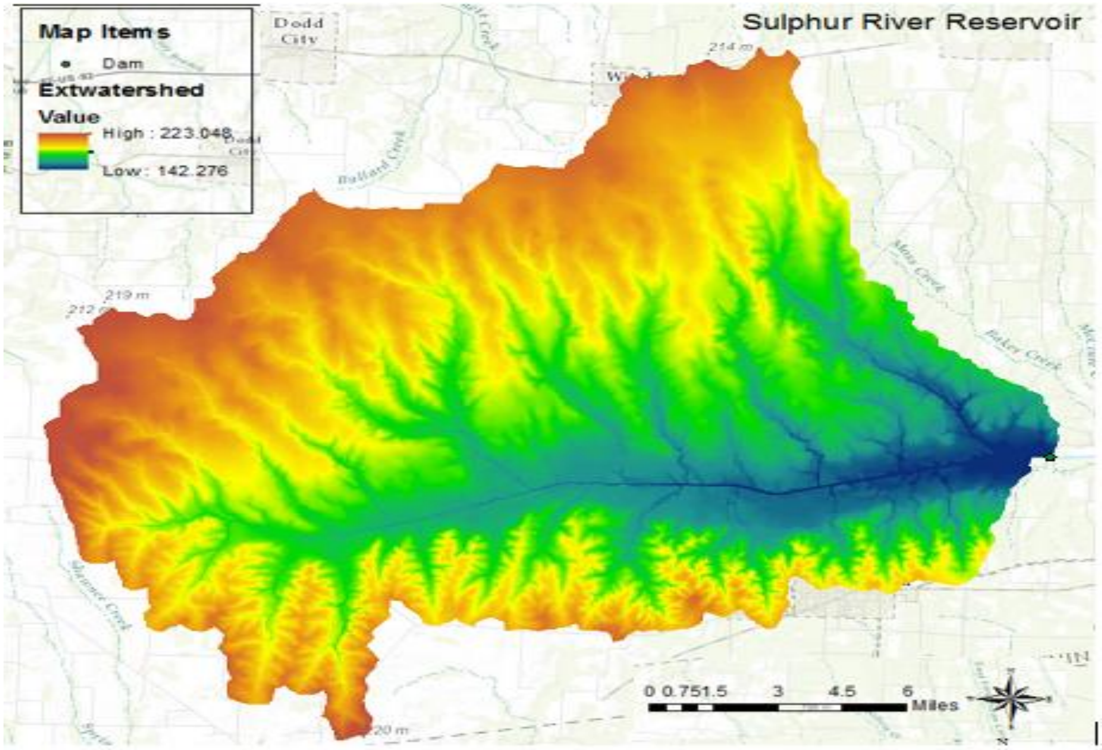


Figure 7 – Map created by GIS showing watershed and DEM.

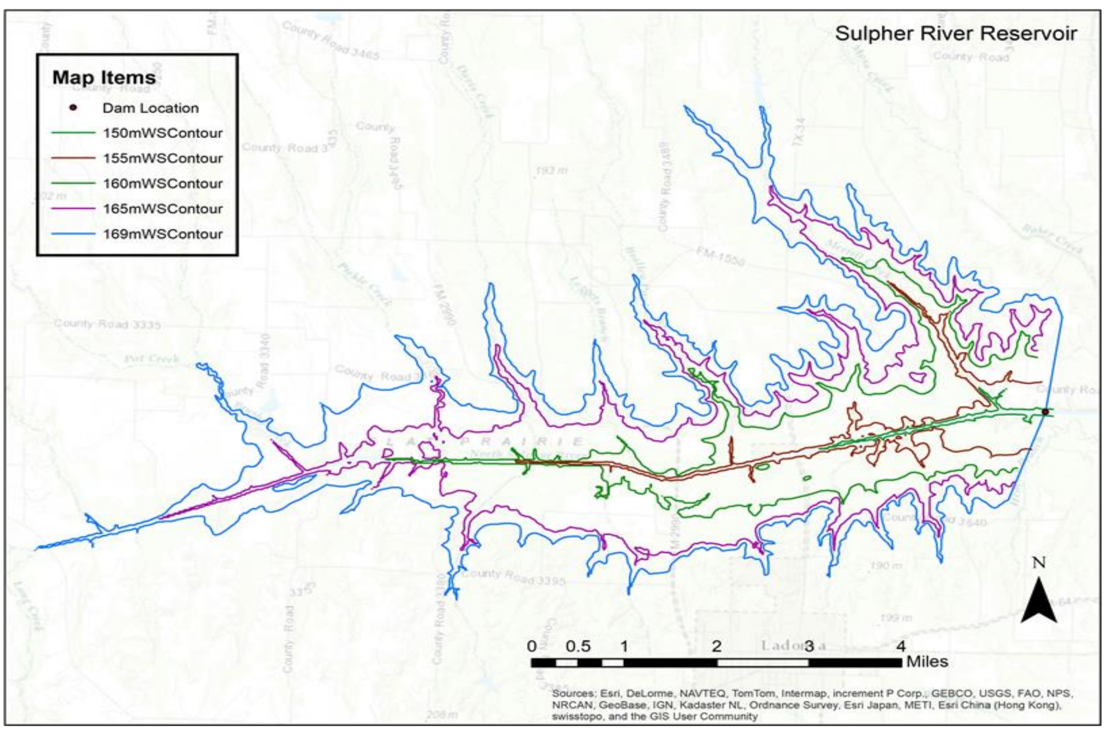


Figure 8 – Specific contours used to estimate time to fill the reservoir to those elevations

7.1.2 The elevation-area-capacity relationship

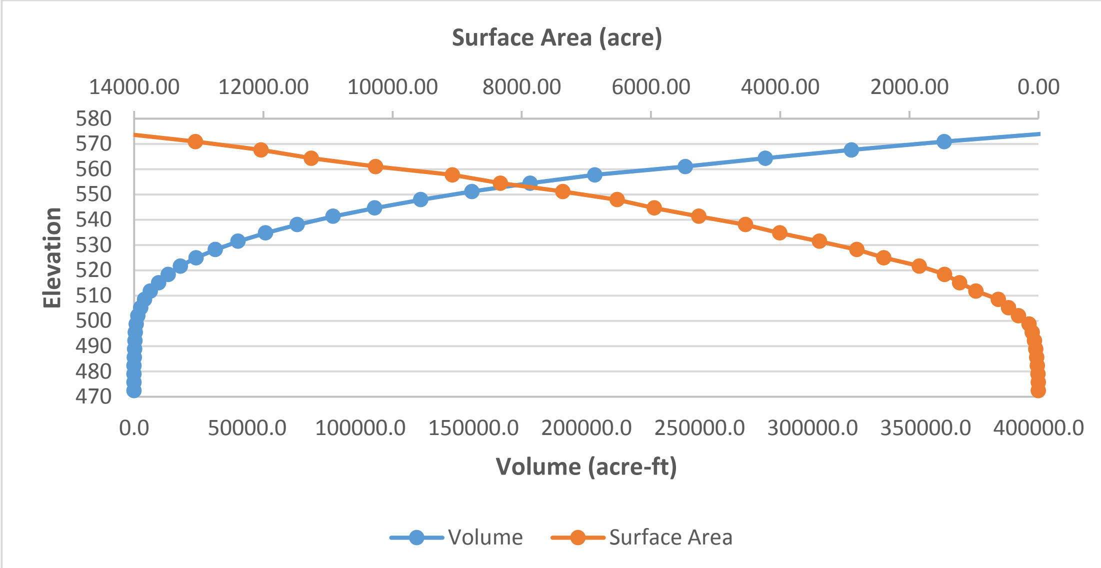


Figure – 9: A relationship between the storage volume, the surface area and the elevation of the water surface in one meter increments

7.1.3 Comparison of Proposed Reservoir Drawing and GIS Results.

To validate the data used to draw maps ArcGIS, comparison between the proposed reservoir specifications and the results of this study showed that the competed storage volume was almost identical to the actual reservoir volume, surface area was slightly larger than the actual surface area by 5.2%, and the time to fill the reservoir was less than actual time needed by 13.8% as shown in (Table 1) below.

Components	Proposed Reservoir Specifications (Original)	Reservoir built by this report	Comments
Visually	Figure 6	Figure 8	Almost Identical
Reservoir Volume	180,000 acre-ft	178,000 acre-ft	Elevation of water surface is around 555 ft above the sea level
Reservoir Surface Area.	7,605 acres	8,000 acres	Difference = 5.2% due to different DEM resolutions

Table 1: General Properties.

7.2 Reservoir Filling

Average five years of historical daily mean flow data from 2009 to 2013 was used to determine how long for Reservoir to be filled. As shown in (Figure 10), the reservoir will be filled within 31 months after construction which is less by 13.8% than the approximate time in the design proposal as shown in (Table 2). The reason of this difference is due to the start time of each approach (Wet/Dry Seasons).

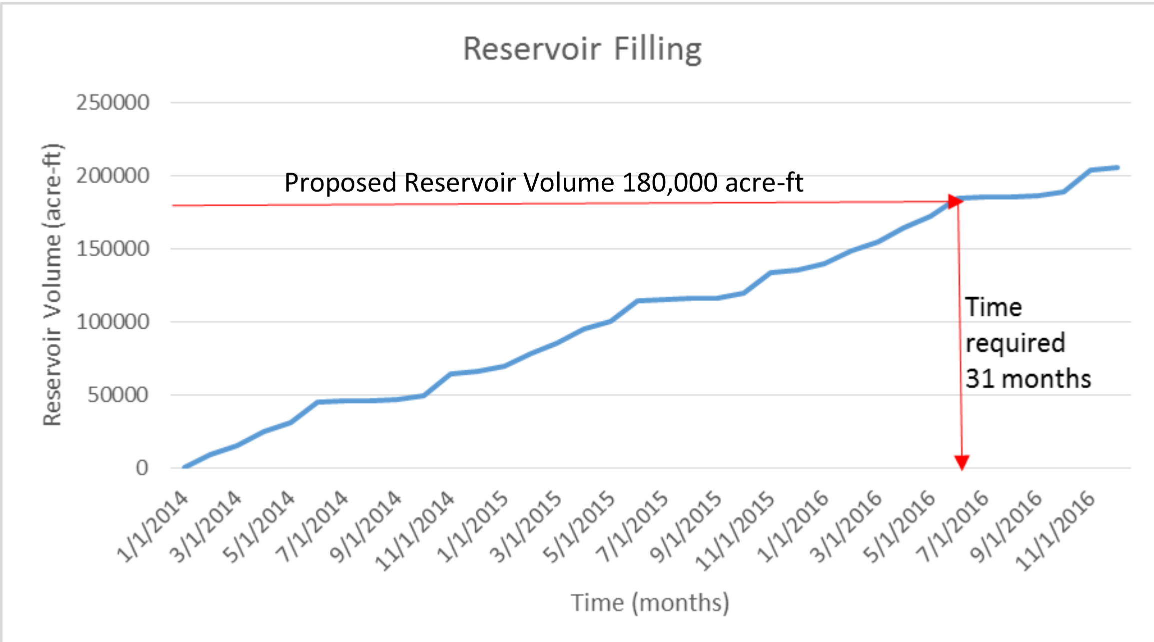


Figure – 10: The reservoir filling with time

Component	Proposed Reservoir Specifications (Original)	Reservoir built by this report	Comment
Time to fill	Approximately 36 months	31 months	This difference is due to the start time of each approach. (Wet/Dry Seasons) as shown in (Figure 10)

Table 2: General Properties.

7.3 Flood Frequency Analysis

7.3.1 Frequency Histogram and Probability Plots

According to M-Class method, the frequency histogram was classified into seven bins (Figure 11). The data represent a right tail with positive coefficient of skew 0.578 (Table 3). After that, Probability plots and the probability plot correlation coefficient (PPCC) test were utilized to evaluate the goodness of fit for the EV1 or LP3 model for the data as shown in (Figure 12 and 13). The linearity observed in EV1 probability plot suggest graphically that EV1 model could fit the data better than the LP3 and further testing is needed. Thus, the EV1 model is expected to give more accurate data than LP3.

Flow Data Statistics	Value (cfs)
Average	37,214
Mode	44,100
Maximum	90,600
Minimum	5,600
Standard Deviation	17,043
Coefficient of Skew	0.5776

Table 3: General Properties.

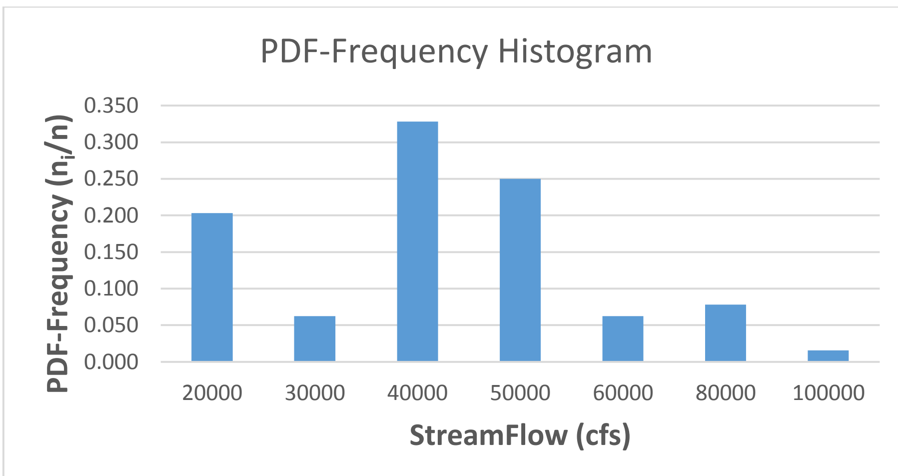


Figure 11 – Frequency histogram of maximum annual streamflow.

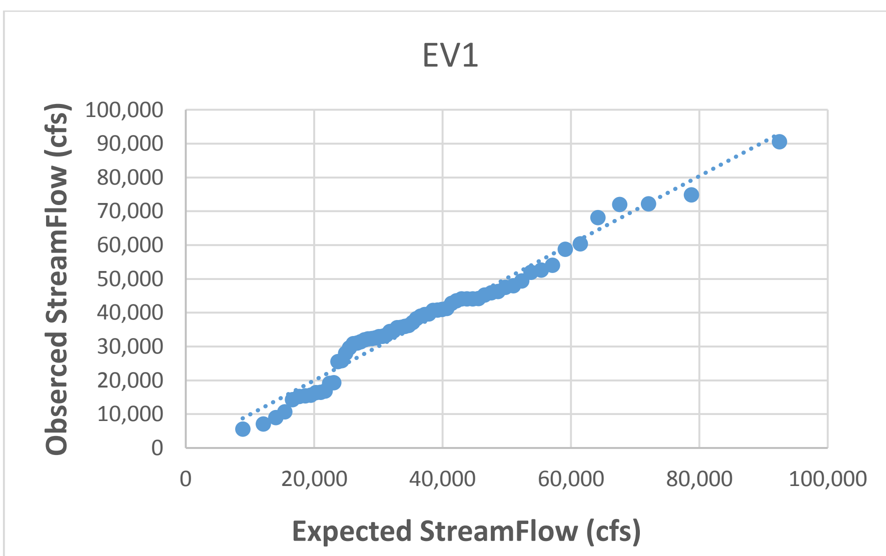


Figure 12- Probability plot_ EV1.

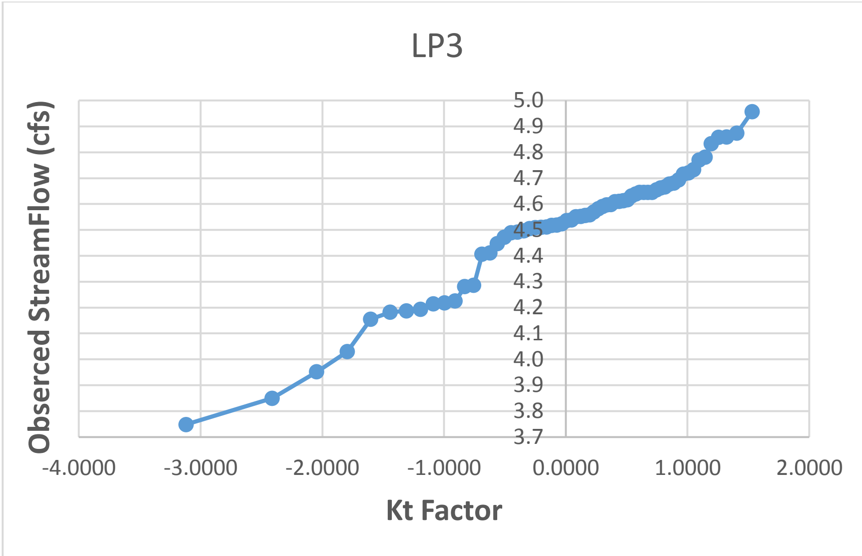


Figure 13 – Probability plot_ LP3.

7.3.2 Probability Plot Correlation Coefficient (PPCC) Test

The probability Plot Correlation Coefficient (PPCC) was applied to evaluate the goodness of fit for EV1 and LP3 models to the streamflow dataset by measuring the linearity observed in the probability plots. Both models passed the PPCC test with a 5% significance level with r values 0.985 and 0.986, respectively as shown in (Table 4). The LP3 model had the highest r value for the PPCC test compared to the EV1 model. The increased critical $r_{N,\alpha}$ value helped confirm this model as a potentially good estimator because it made it more difficult for the LP3 model to pass the PPCC test. One of the advantages that the LP3 has is that it helps reduce positive skewness when datasets are converted into the log-space. In addition, the LP3 is the standard model used in the United States when performing flood frequency analysis and as such may be preferred.

Model	Pearson Correlation Coefficient (r)	$r_{N,\alpha}$	Decision Rule Reject if $r < r_{N,\alpha}$	comments
EV1	0.985	0.969	DO NOT REJECT	The observations are drawn from the fitted distributions EV1
LP3	0.986	0.981	DO NOT REJECT	The observations are drawn from the fitted distributions LP3

Table 4- PPCC Test Result for EV1 and LP3 Models.

7.3.3 The Magnitude of the 2-5-10-50-100-Year Flood events and Confidence Intervals

The magnitude for the 2-5-10-50-100-year flood events, its standard error of estimate and the 90% confidence interval were estimated for the EV1 and LP3 models by using different methods for determining parameters of distributions such as MOM and ML. There are differences in the design event magnitudes and 90% confidence intervals for EV1 and LP3 due to the fact that different assumptions and estimation producers were used for MOM and ML. The final results of the design event magnitudes and confidence interval in table using different distribution and methods for determining parameters of models with different return periods are shown below (Table 5, Table 6 and Table 7). These results indicated that the most conservative magnitude was provided by the EV1 model using ML and then the EV1 with MOM, whereas the LP3 appeared as the least conservative for estimating the flood frequency events.

T(years)	X_T(cfs)	X_T^L(cfs)	X_T^U(cfs)
100	90,674	76,079	105,270
50	81,396	66,801	95,991
10	59,449	44,854	74,045
5	49,477	34,882	64,072
2	34,416	19,820	49,011

Table 5 – The magnitudes and 90% confidence interval For EV1_MOM

T(years)	X_T(cfs)	X_T^L(cfs)	X_T^U(cfs)
100	97,788	83,625	111,952
50	87,370	73,206	101,533
10	62,725	48,562	76,888
5	51,527	37,364	65,691
2	34,614	20,451	48,778

Table 6 – The magnitudes and 90% confidence interval For EV1_ML

T(years)	X_T(cfs)	X_T^L(cfs)	X_T^U(cfs)
100	76,722	55,214	98,230
50	73,122	56,878	89,366
10	60,634	54,564	66,703
5	52,424	47,579	57,270
2	36,186	31,156	41,215

Table 7 – The magnitudes and 90% confidence interval For LP3_MOM

The LP3 was underestimating for flood in October of 1971, 90,600 (cfs). However, the LP3 model is the standard flood analysis model in the USA while the EV1 model is the default flood analysis model in Europe. In fact, choosing the best design alternative is a fundamental problem for governments. There are several factors should be considered in order to choose the most suitable design such as flood damage reduction and expected annual flood damage. To improve the current estimates and those made in the future, it is recommended that more recent data from the 1990s be incorporated into all the models to account for changes in climate and environment of the river.

7.3.4 New Reservoir Volumes

The volume of water expected during different flood events was extremely large compared to the original reservoir volume and thus conclude that the reservoir was not designed for flood control. To consider flood control of this reservoir, the new volume needed to be increased was estimated for different flood return periods by EV1 model using ML method as shown in (Table 8). The new elevations of water surface and reservoir surface area were computed by using ArcGIS considering the results of EV1 model using ML which provides the most conservative magnitudes as shown in (Figure 14).

T(years)	Flood Flow X_T(cfs)	(A)Flood Volume (acre-ft)	(B)Original Reservoir Volume	(A+B)New Reservoir Volume
100	97,788	155,189	180,000	335,189
50	87,370	138,655	180,000	318,655
10	62,725	99,544	180,000	279,544
5	51,527	81,773	180,000	261,773
2	34,614	54,933	180,000	234,933

Table 8 – Original (without flood control) and new (with flood control) reservoir volumes

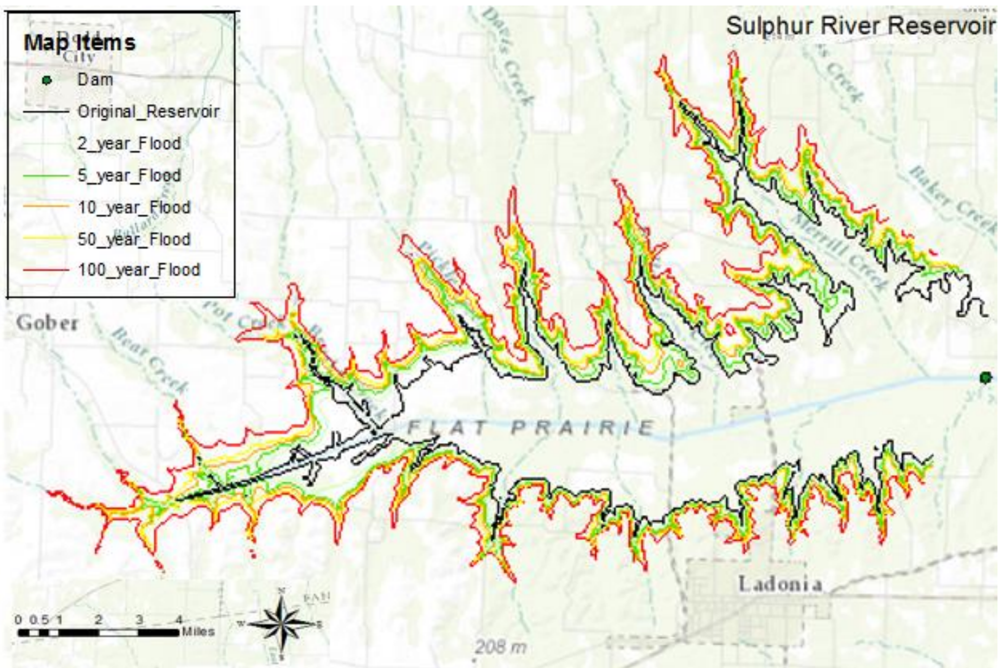


Figure 14 – Reservoir layout for different flood control capacities

8.0 Future Work

- Develop a flood hydrograph since the instantaneous peak discharge reported by the USGS is for a single instant of time, not for a whole day.
- Doing a better water balance using the TWDB evaporation and precipitation data.
- Time Series Analysis (AR(1), AR(2), ARMA(1,1)) for the N. Sulphur River to generate synthetic data from 2015 to 2018 and predict the reservoir filling after construction.

  * Data Source:
  http://waterdata.usgs.gov/tx/nwis/dv/?site_no=07343000&agency_cd=USGS&referred_module=sw

9.0 Conclusion

The validation of using the maps drawn by ArcGIS software for further analysis was proofed by comparing between proposed reservoir drawing and GIS Results. A relationship between the storage volume, the surface area and the elevation of the water surface in one meter increments for the reservoir site was constructed. Comparison between the proposed reservoir specifications and the results of this study showed that the competed storage volume was almost identical to the actual reservoir volume, surface area was slightly larger than the actual surface area by 5.2%, and the time to fill the reservoir was less than actual time needed by 13.8%.

A flood frequency analysis was performed to determine the parameters of a 2, 5, 10, 50, 100-year flood event for the North Sulphur River near Cooper, TX where the reservoir is located. The frequency histogram demonstrated a right tail with slightly positive skew 0.578. Probability plots and the probability plot correlation coefficient (PPCC) test were utilized to evaluate the goodness of fit for the EV1 or LP3 model for the data. The goodness of fit of the EV1 model showed a straight line and fit better than the LP3. Both models passed the PPCC test with a 5% significance level with r values 0.985 and 0.986, respectively. The most conservative magnitude was provided by the EV1 model using ML and then the EV1 with MOM, whereas the LP3 appeared as the least conservative for estimating the flood frequency events. The volume of water expected during different flood events was extremely large compared to the original reservoir volume and thus conclude that the reservoir was not designed for flood control. To consider flood control of this reservoir, the new volume needed to be increased was estimated for different flood return periods. The new elevations of water surface and reservoir surface area were computed by using ArcGIS. To improve the current estimates and those made in the future, it is recommended that more recent data from the 1990s be incorporated into all the models to account for changes in climate and environment of the river.

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Nomenclature (in order of occurrence)

M	Number of classes
N	Number of Observations
q_i	Plotting Position
X_i	Observations Values
Y_i	Lognormal values of observation, Base 10
$\overline{X}$	Mean of Expected Values
μ	Mean of Y values
S_x	Standard deviation of the observations
S_y	Standard deviation of Y values
C_s	Coefficient of Skewness of Xi
C_{sy}	Coefficient of Skewness of Yi
α,β	Model Parameters
K_T	Frequency Factor
W_i	Expected Values- PPCC Test
$\overline{W}$	Mean of Expected Values- PPCC Test
r	Pearson Correlation Coefficient
T	Return Period of Event
δ	Standard Error Parameter
$S(X_T)$	Standard Error of The Estimate
X_T	Magnitude of Flood Event
X_T^U	Lower Confidence Limit for XT
X_T^L	Upper Confidence Limit for XT