ENGINEERING-BASED NEW RESERVOIR DESIGN AND ENVIRONMENTAL SUITABILITY ANALYSIS WITH GEOSPATIAL TECHNOLOGY

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Abstract. As a follow up to the 2007 drought and water scarcity in Georgia and especially in North Georgia, there is a greater need of creating new water reservoirs. The main goal of this study is to use geospatial technology, engineering and environmental knowhow to find suitable locations in North GA for building a reservoir to serve primarily for drinking water supply and irrigation. Another objective is to design the reservoir with proper engineering applications and conduct an environmental impact analysis due to its construction. In order to determine reservoir suitable sites in North Georgia, a geospatial model was created with ArcGIS 9.3 Model Builder based on land use, DEM (Digital Elevation Model), Census Data, and orthoimagery. Buffers of different distances were created based on airport sites, population density, landfill and industrial waste sites, U.S forestry and national parks, railroads, and major roadways of North Georgia, which were designated as unsuitable areas for probable reservoir locations for environmental concerns. Peck's Mill Watershed, located in Lumpkin County was chosen as the most suitable location for building the reservoir. Then the suitable areas were surveyed using a DEM to find the best location to build a dam for the reservoir. The dam height was determined based on the amount of direct runoff coming from the above catchment area to the dam location and keeping in prospective to have the reservoir filled in four years maximum. A geospatial model was developed to calculate the runoff using the Soil Conservation Service (SCS) method (average intensity of rainfall and Curve Number). Based on the dam height, the reservoir impounding volume was calculated. The total runoff was divided with the proposed impounding volume to determine the years it will take to fill in the reservoir. Annual stream discharge of the Chestatee River (One mile downstream of the proposed dam) was also calculated to pump water from the river to fill the reservoir. The reservoir pool line of 405 meter was chosen with a probable filling time of 2.14 years by watershed runoff and water pumped from Chestatee River. After the reservoir design, flood pool line was calculated based on 100-year flood to find the environmental impact due to the reservoir.

INTRODUCTION

Due to the El-Niño and La-Nina effect from recent phenomenon of global warming and climate change, the global rainfall pattern is changing year to year (Panda, 2008). Drought conditions across the United States during 2007 dominated the Southeast, West, and Upper Great Lakes regions demonstrating unseasonal and erratic weather during March, May, August, and November. In that year, the northern Georgia went through a severe drought. The US National percent area for moderate to extreme dry conditions resulted in the United States increasing from 16% in January to 42% in August (NOAA) with widespread drought conditions throughout Georgia. According to Panda (2008), due to change in thermohaline circulation, the Northern Hemisphere's tropics and subtropics (a region between equator and 30^0 N) including Georgia become drier while Southern Hemisphere's similar region becomes wetter. With the expansion of urban sprawl in the southeast United States centering on Atlanta, GA, by 2030, almost all of north Alabama, north Georgia, most of South Carolina and Florida, a vast area of the gulf coast, and the entire southern Atlantic coast will be of urban land-use (Hammer et al., 2008). Therefore, demand for water will be immense in the area that includes northern Georgia. The sources for drinking water supply and water for other agricultural use would remain same or diminish if precautionary measures are not taken before hand.

Therefore, as a solution to Georgia's water shortages, it is essential to devise plan to build new reservoirs in drought prone area like north Georgia to arrest wasted runoff and make it available for drinking water supply and irrigation. Reservoirs, in general, are multipurpose. They are important for economic development and serve for flood control, water supply, irrigation, hydropower generation, navigation, recreation, and above all environmental management (TVA, 2010). Economic development through job creation is another important aspect of new reservoir construction. For example, Lake Lanier and Tennessee Valley Authority (TVA) generates thousands of jobs. The TVA last year provided approximately 26,000 jobs across the Tennessee valley and earned $4.2 billion dollars in capital investments across the Tennessee region (TVA, 2010).

Not only does a reservoir provide economic development and recreational benefits, but construction of a reservoir without proper decision support system would create environmental, economic, and social hazards. A reservoir can submerge huge amount of quality land, habitable locations, and ecologically important areas and displace people from their property. Engineering and surveying process is mostly used in fixing reservoir locations. Larger reservoirs create many environmental hazards than properly designed small reservoirs. Therefore, it is prudent to construct several smaller reservoirs instead of a single large reservoir so that the impact will be minimum but the main objective of meeting the increased water demand could be met. As we have very recently faced a precarious water scarcity in Atlanta, this study on designing smaller reservoirs in and around Atlanta could ease the water scarcity problem a great deal. Moreover, the emphasis on the use of geospatial technology on decision making would create less possibility of the destruction of ecosystem. Another major drawback on such new reservoir design comes from the land availability. According to US Fish and Wildlife Service - GA Ecological Services Branch website, "more than 90 percent of the land in Georgia is privately owned. Therefore, the future health of Georgia's land, water, and wildlife depends upon private landowners." As discussed above, the reservoirs would create humongous job opportunities for landowners whose land will be submerged with the reservoirs. They will reap the benefit from the reservoir if they own land in the ayacut area of the reservoir through irrigation or water seepage. The land cost surrounding the reservoir would certainly increase. Thus, private landowners would positively be motivated to participate in such new small reservoir designs in and around Atlanta.

Not many studies have been conducted to determine the location and design of a multipurpose small reservoir using geospatial technology so that maximum environmental and economic benefit can be obtained from the new reservoir. The objective of this study is to develop a geospatial model to locate suitable reservoir sites in North Georgia and design the reservoir using engineering algorithms along with geospatial technology like geographic information system, remote sensing, and information technology. By using a DEM and a reservoir suitability map, a specific watershed called Peck's Mill watershed was chosen for determining direct runoff and the duration of time it would take to reach full pool at the 405 meter and 410 meter elevation contours. Once the full pool lines were determined, based on storm runoff, the flood pool line was calculated for the reservoir.

MATERIALS AND METHODS

Study area. The study area of this study involves the entire North Georgia (Figure 1). The reservoir suitability analysis was conducted over these Appalachian Counties of North Georgia. The entire area is ecologically very rich and environmentally sensitive. Therefore, highest precaution was taken to develop the model so that possible reservoir site would create the least environmental and social risk. The procedure of this geospatial model development is described later. With this suitability analysis, the Pecks Mill watershed, located at coordinates 34.53344 N and 83.91587 W in Lumpkin County was selected as the study site of new reservoir design. Peck's Mill watershed is a sub watershed totaling 2086.94 acres and is a part of 10-digit HUC Chestatee River basin (0313000105).

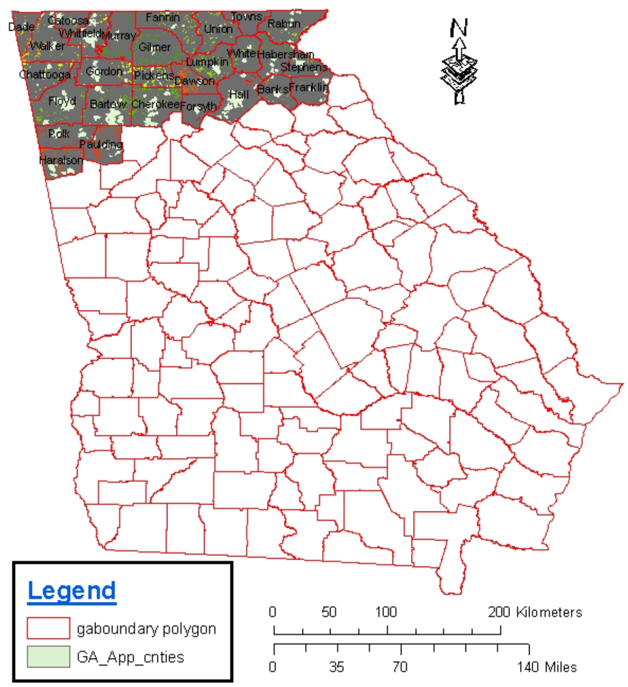

Figure 1: Appalachian counties of North Georgia.

Reservoir suitability analysis. Suitability analysis is one of the most crucial processes in environmental management. A reservoir set up would always jeopardize the ecology and landscape of any region if the site selection is not done with proper scientific procedure. Spatial heterogeneity of regions has important influence on ecological patterns and processes (Shugart, 1998) and GIS has a special role to play in decision making in such scenarios of new developments. Many landscape metrics in GIS environment are used to facilitate the investigation of the relation between new landscape structure and biodiversity (Wikramanayake et al. 2004; Bhagwat et al. 2005; Burel and Baudry 2005; Oja et al. 2005; Riitters 2005; Schindler et al. 2008). The suitability analysis model was created for North Georgia Counties to choose potential locations for reservoir construction with very low environmental, ecological, economical, and social disruption. In order to develop a reservoir suitability analysis, the following parameters were considered for the Environmental Protection Division's (EPD) regulations.

Under Georgia's ordinance, any new facility handling hazardous waste has to abide by the Department of Natural Resource's guidelines (Hall County, GA, 2010). If the hazardous waste facility is to be built within seven miles of a water storage facility (water reservoir), then the facility has to install spill and leak collection facilities to ensure that the impermeable surfaces do not harm the water supply (Hall County, GA, 2010). Also, limitations on hazardous and toxic materials based on regulations are applied. The regulation states that no landfills, waste disposal, hazardous and toxic waste facilities is located within the water supply watershed, and no industries or businesses classified as holding quantities of hazardous and toxic materials are located in the water supply watershed. Septic tanks only approved by the environmental health department are allowed within the water supply watershed. For fuel and chemical storage tanks, either above ground or sub surface fuel tanks and/or chemical storage tanks need to meet all Georgia Environmental Protection Division(GA-EPD) requirements (Georgia EPD, 2010).

The water use classification by GA-EPD includes drinking water supplies, recreation, fishing and propagation of fish, Wild River, Scenic River, and coastal fishing. Drinking water supplies, recreation, and fishing and propagation of fish are significant to our proposed water storage reservoir in North Georgia. For drinking water supplies, waters should not be impacted with municipal sewage, domestic sewage, and industrial waste to form sludge deposits (Georgia EPD, 2010) (paragraph 391-3-6-.03 (5) (a).) Oil, scum, and floating debris associated with domestic and municipal sewage should not impact the drinking water supply [4] (paragraph 391-3-6-.03 (5)(b).) Turbidity, color, and odor from municipal, industrial, and other discharges are not allowed to impact the water supply (Georgia EPD, 2010) (paragraph 391-3-6-.03 (5)(c).) Airports are other structures, which should be far away from the reservoirs. Reservoirs are suitable for bird flocks and they are deterrent to airport management. New reservoir should not submerge major roads as well as urban landscapes because of its high economic impact. Therefore, precautionary measures were taken to select suitable locations far away from such facilities already exist in North Georgia.

Spatial layers preparation for analysis. Figure 2 is the comprehensive automated geospatial model developed in ArcGIS 9.3 (ESRI, Redlands, CA) Model Builder platform for selecting the suitable locations for new reservoir set up in North Georgia. In determining a reservoir suitability model, layers based on environmental factors, aesthetic values, and conservation are important for providing a clear distinction between suitable and unsuitable areas. As discussed earlier, hazardous (super fund) sites, landfills, airports, North Georgia cities, and express ways (interstate highways) and rail road passing through North Georgia, and military bases were completely unsuitable for the reservoir design. Buffers (researchers defined) of different distances were created on these spatial vector layers downloaded from Georgia GIS Clearinghouse [http://data.georgiaspatial.org/login.asp] and other sources. The distances of each buffer were determined by personnel preference and basing on environmental laws enforced by the GA-EPD. The largest buffers of five miles were created for hazardous waste sites, landfills, and industrial complexes followed by one mile buffer for rural and urban population clusters, airports, roads, military bases, national forest parks and national war parks. All these individual buffered layers were unioned together to create a single unsuitable layer (Figure 2). As, our main goal was to protect natural habitats, we found the forest land (Chattahoochee National Forest (CNF)) and land owned by Georgia Department of Natural Resources (GA-DNR) were unsuitable locations for the proposed reservoir. Therefore, vector layers of CNF and GA-DNR land were collected and unioned with the buffered unsuitable layer. Finally, the entire unioned unsuitable vector layer was expunged from the North Georgia counties (study area) layer using the ERASE tool of ArcGIS 9.3 (Figure 2). Feature to Raster conversion tool of ArcGIS 9.3 was used to convert the reservoir set up suitable layer to a new suitable raster and was named as 'Suitable Raster 1'.

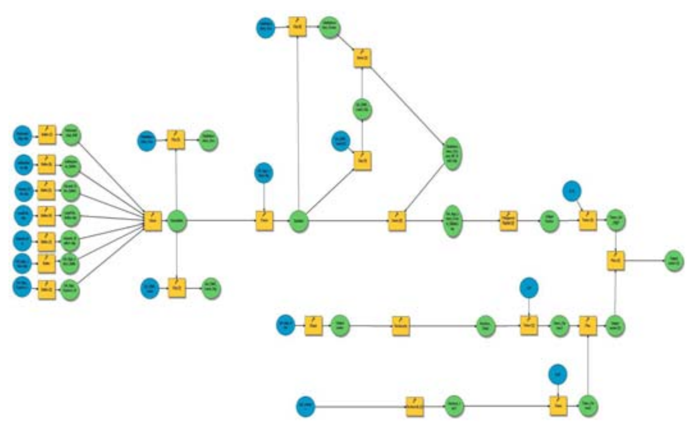

Figure 2: Schematic of the comprehensive geospatial model developed in ArcGIS 9.3 Model Builder for selecting suitable locations in North Georgia.

National Land Cover Dataset (NLCD) created through GAP analysis is best to find land cover for suitability decision making. USGS's GAP analysis maps dominant land-cover types at the landscape level for ecological and environmental management (Caicco et al. 1995; Scott et al. 1996). Therefore, land cover and vegetation raster, GLUT 2005 (Landsat-derived classification, Georgia Land Use Trend Program University of Georgia, College of Agricultural and Environmental Sciences, Natural Resources Spatial Analysis Laboratory [http://narsal.uga.edu/glut.html]) was collected for unsuitable land cover determination for reservoir design. Table 1 shows the list of land cover types used in this study and their respective suitability. The suitable land covers are equal to one (1) and unsuitable are equal to zero (0) (Table 1). Open water, urban areas, and special use lands were considered unsuitable land covers and forest, row crop, pasture lands and wetlands were considered suitable for the reservoir design purpose. The GLUT raster was reclassified in ArcGIS 9.3 to create the suitable land cover raster of North Georgia and was named as 'Suitable Raster 2'.

Table 1: GLUT land cover types used in reservoir set up suitability analysis (0 represents unsuitable and 1 represents suitable)

Land Cover Types	Suitability for reservoir design
Open Water	0
Low Intensity residential	0
High Intensity residential	0
Commercial/industrial/transportation	0
Bare rock/sand/clay	0
Mining/gravel pits	0
Transitional	0
Deciduous forest	1
Evergreen forest	1
Mixed forest	1
Pasture/hay	1
Row crops	1
Urban/recreational grasses	0
Forested wetlands	1
Emergent herbaceous wetlands	1

Slope is also another major factor in finding suitable locations for reservoir design. Because we did not want a reservoir (Dams) cannot be constructed in very high slope area (more than 20 degree). The DEM was converted into a slope grid by using the slope tool in spatial analysis. The reclassify tool of ArcGIS 9.3 was used to designate slopes greater than 20 degrees as unsuitable (0) and used to designate slopes less than 20 degrees as suitable (1). The new suitable raster created from the slope raster was named as 'Suitable Raster 3'.

Weighted overlay. All the three suitability raster layers (Suitable Raster 1 (Buffer), Suitable Raster 2 (LULC) and, Suitable Raster 3 (Slope)) were merged together on weighted basis to create a final reservoir set up suitable location layer. The basis for weighted analysis was to provide importance to land cover and slope factors. Researcher defined weights of 0.45 (LULC), 0.4 (Slope), and 0.15 (Buffer) were used through the Times tool of ArcGIS 9.3. Finally all the weighted layers were unioned together using the Plus tool to create a weight based water reservoir set up suitable location raster. Once the final suitable raster was created, areas with large continuous suitable land mass were selected. Our study found a large patch of land suitable for reservoir construction in the Peck's Mill watershed of Lumpkin County (Figure 3). Peck's Mill Watershed was moderate to most suitable based on the Reservoir Suitability map (Figure 3).

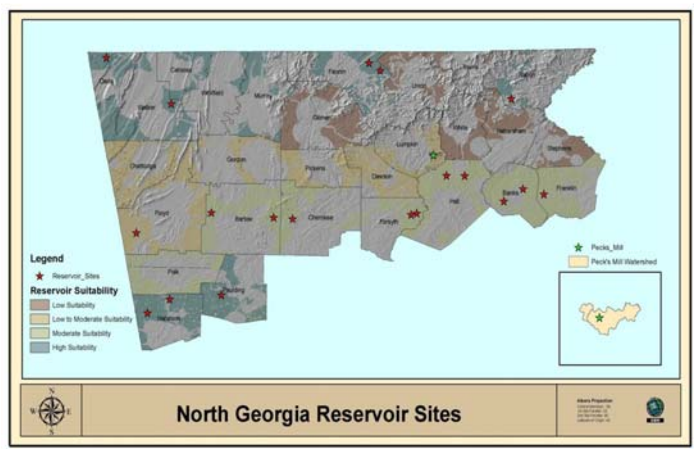

Figure 3: Suitable locations for possible reservoir sites in North Georgia.

SPATIAL ANALYSIS FOR RESERVOIR ENGINEERING DESIGN

Subwatershed delineation. Once, we had the best location for setting up the water reservoir obtained, our next goal was to conduct proper engineering design. The most important factor for designing a water reservoir is to quantify the amount of runoff from the watershed to the proposed dam location. Peck's Mill watershed is part of the upper Chestatee River watershed in portions of Lumpkin and White Counties, northeast Georgia (Figure

3). It is a 10-digit HUC (0313000105) watershed and a subwatershed of Lake Sidney Lanier Watershed in northeast Georgia. The Chestatee River is a major tributary of the Chattahoochee River, which flows into Lake Lanier. It begins at the confluence of Dicks Creek and Frog town Creek in northeastern Lumpkin County of Georgia and flows down by the county seat and town of Dahlonega. Initially, the DEM and the GLUT LULC layer were used to find a suitable location for the dam locations. Proper care was taken to select the dam location by finding high elevation in both sides of a creek which has a great amount of low elevation in the upstream to be suitable for reservoir. The dam location was selected with a major objective of economical dam construction and larger impounding area development. Figure 3 shows the preferred dam location in the Peck's Mill watershed.

ArcSWAT (http://swatmodel.tamu.edu/software/arcswat) was used to delineate sub watersheds in the Chestatee River basin and the suitable location for dam construction in Peck's Mill area was chosen as an exit point. Thus, a subwatershed was created for the proposed dam site explaining the drainage area that would contribute runoff to fill the reservoir. A DEM for Lumpkin County was used in ArcSWAT as the sourceDEM. Peck's Mill subwatershed was selected from the developed subwatershed map of the Chestatee watershed and exported as the final study area boundary layer to be used in rest of the analysis.

Runoff calculation using SCS Curve Number method. United States Department of Agriculture (USDA) - Soil Conservation Services (SCS) has the algorithm designed for calculating the runoff using the Curve Number (CN) values of the watershed (USDA, 1986). The runoff curve number is based on the area's hydrologic soil group, land use land cover, treatment and hydrologic condition of a watershed (USDA, 1986). The runoff calculation equation based on CN method is

$$Q = \frac{(P - I_a)^2}{P - I_a + S} \quad (1)$$

where Q = depth of runoff, in inches; P = depth of rainfall, in inches; I_a = initial abstraction (surface storage), in inches, or the amount of water before runoff, such as infiltration, or rainfall interception by vegetation; and it is generally assumed that $I_a = 0.2S$; and S = maximum potential retention, in inches. S is calculated using the CN values as shown in equation 2.

$$S = \frac{1000}{CN} - 10 \quad (2)$$

According the Georgia Storm Water Management Manual, the SCS-CN method is best used for drainage areas less than 2000 acres and applied to storage facilities and outlet structures (GA Storm Water Management Manual, 2010). Our study area of 2086.94 acres is slightly higher than this limit but we considered using the SCS-CN method in our calculation.

Curve number (CN) values are determined from soil type and antecedent moisture conditions (AMC I, II, III) (USDA, 1986). A county soil map was downloaded from NRCS soil data mart. The hydrologic code was obtained from the soil layer. Curve numbers for hydrologic soil-cover complexes are associated with land use and hydrologic soil groups. Antecedent moisture conditions II (AMC II) was used for determining soil moisture conditions for runoff. AMC II is normal soil conditions before a storm event occurs. AMC I is for dry soil conditions and AMC III is for saturated soils. It is important to determine which AMC to use because curve numbers (CN) are different for each AMC (USDA, 1986).

Hydrologic soil groups (A, B, C, D) depict the potential runoff based on texture, bulk density, clay mineralogy, soil structure, and organic matter. Group A hydrologic soil group has a low potential for runoff. This group is composed of nearly 90 % sand and only 10 % clay. Loamy sand, sandy loam and/or loam if aggregated are categorized as group A. Group B hydrologic soil group have moderately low runoff potential. Group B is composed of 10% to 20% clay and 50% to 90% sand, loamy sand, sandy loam, and/or loam. Group C hydrologic soil groups have moderate runoff. The amount of clay is 20% to 40% and the sand is 50%. Group D hydrologic soil group has a high potential for runoff. Water movement through the soil is slowed more so than the previous hydrologic soil groups. Group D has more than 40% clay and less than 40% sand, loamy sand, sandy loam, and/or sand (Soil Survey Division Staff, 1993).

A soil layer for Lumpkin County, downloaded from NRCS soil data mart, was used to obtain the hydrologic soil group and curve number information. As discussed, different land use condition along with the soil hydrologic group type represent different CN values and these values are provided in National Engineering Hand Book (Mockus, 1972). The county soil vector map was converted from a feature polygon shapefile to a raster using the Feature to Raster conversion tool in ArcGIS 9.3 using hydrologic soil group attribute as the conversion field. The GLUT LULC and hydrologic soil group rasters were combined by using the combine tool to form new combined raster grid file. A new attribute field was created to hold the CN values of different grid in the watershed. The curve number values for the Peck's Mill watershed were collected and a If-Then-Else VB expression was written in Map Algebra to populate proper CN values (30-100) relating to the land use and soil hydrologic group types. Then, the new raster became the Peck's Mill CN Raster grid. Raster calculator was used to develop the maximum potential retention (S) raster from the CN raster using Equation 2. The initial abstraction (surface storage) raster was created from the maximum potential retention (S) raster using the expression $I_a = 0.2S$ in Raster Calculator of ArcGIS 9.3.

Precipitation data was collected from the Dahlonega NOAA weather station. Hourly precipitation during 2000-2008 was downloaded for Peck's Mill watershed. The designed storm event (100 yr/24 hr) data for the Lumpkin County was extracted from the USDA NRCS web site, http://www.ga.nrcs.usda.gov/technical/software/climate.html for calculating the flood pool line determination of the proposed watershed. A designed storm is a selected storm event, described in terms of the probability of occurring once within a given number of years, for which drainage or flood control improvements are designed and built. The designed 100 yr/24 hr storm event data was the essential parameter to use as P in the SCS-CN equation for this reservoir design study. The designed P for flood pool line calculation was 9.2 inches. The storm event, 100 yr/24 hr, was used to determine the flood pool line for two reservoir scenarios, 405 meters and 410 meters, if 9.2 inches of rain fell within a 24 hour period. As the study area was encompassed within a single county, a precipitation raster was created from the study area boundary vector file using the precipitation attribute of 9.2 inches.

As we have all three rasters (S, I_a, and P) created, we used the Raster Calculator to develop the Runoff (Q) raster using the formula in equation 1. The new Runoff raster provided the runoff values, in inches, for each cell of 30 x 30 m (900 sq. m. or 0.2224 acres) of the Peck's Mill watershed. Thus, total area of the watershed, in acres, was calculated using the statistics tool of ArcGIS 9.3. Then, finally, the total amount of runoff in acre-ft (by converting the inches of runoff to feet) was calculated for the entire watershed.

ENGINEERING DESIGN FOR RESERVOIR IMPOUNDING AREA

Once the total amount of water harvested from direct runoff was calculated for the watershed, the analysis for the reservoir impounding area was performed. It was initially decided that two scenarios of 405 m and 410 m pool line would be considered for analysis. It was concluded by analyzing the DEM of the study area. With our preliminary geospatial analysis, we found that with both the pool lines less amount of costly land in Lumpkin County will be submerged. With two pool line levels, the volume and impounding area of the reservoir were calculated using the 3D Analyst tool in ArcGIS 9.3. The time needed to fill the reservoir with runoff from the watershed was computed by dividing the volume of the reservoir impoundment by the total amount of runoff volume. The 410 m pool line level would certainly take longer time to fill than the 405 m. Since time may be a factor, then perhaps an inflow from the Chestatee River may be needed and could be pumped to the reservoir. The annual volume of inflow in Chestatee River at a location closest to the proposed reservoir was also calculated. The Chestatee River discharge was used as a factor for calculating the time it needed to fill the new proposed reservoir by adding the amount the annual runoff. This calculation obviously resulted in a reduced duration of time for the reservoir to reach full capacity.

RESULTS AND DISCUSSIONS

Figure 3 shows the possible suitable locations for new reservoir set up in North Georgia. Twenty one probable sites were found in the Appalachian Counties of Georgia. Our main goal was to facilitate drinking water supply to residents of Atlanta and the surrounding areas. Five prospective reservoir sites (two in Forsyth County, two in Hall County, and one in Lumpkin County) were closer to Atlanta. However, the cost of land acquisition was the lowest (the analysis is not shown in the study) in the Peck's Mill Creek watershed location in Lumpkin County. Therefore, it was the chosen site.

The runoff was determined by the Soil Service Conservation (SCS-CN) method. The SCS-CN method not only was used to calculate yearly runoff but also used to calculate runoff during a 100 yr/ 24 hr storm event. The storm data and SCS-CN method were combined to predict the height of flood. As discussed in the Materials and Methods section, individual rasters were created to support the final runoff raster grid development using Equation 1. Figures 4, 5, and 6 are the CN, maximum potential retention (S) raster, and initial abstraction (surface storage) raster. Figure 4 suggests that the higher curve numbers (78, 92, and 98) are in the lowest elevation areas. A very large amount of area in the watershed is represented by low CN of 55, which means the watershed is in a good hydrologic condition to facilitate less runoff. This is due to the soil type and a good vegetation cover in the watershed. This suggests that the reservoir will take longer time to fill than ones proposed in locations with very high CN values.

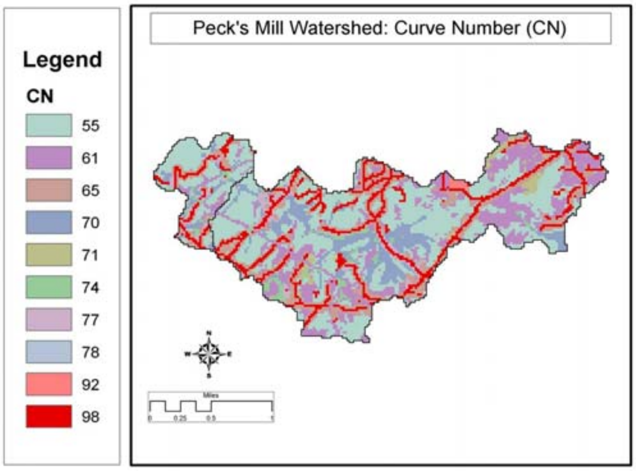

Figure 4: The Curve Number raster for the Peck's Mill Watershed.

The S-raster shown in Figure 5, provides the opposite picture of the Figure 4. That means when the curve numbers are lower, the maximum retention value is higher. Larger area in the watershed has the maximum potential retention capacity.

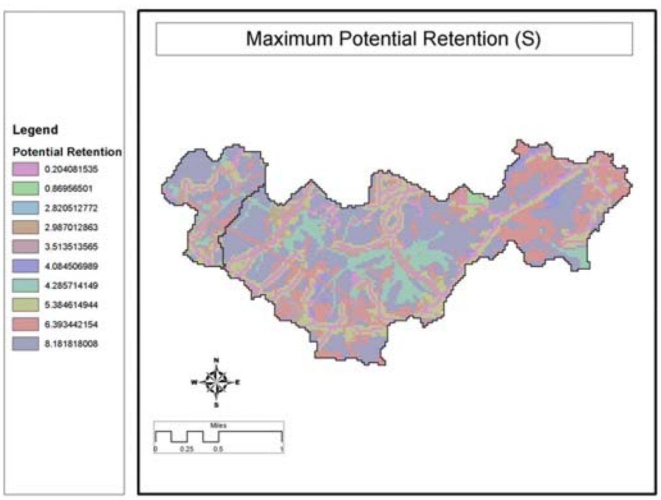

Figure 5: The maximum potential retention (S) raster for the Peck's Mill Watershed.

Figure 6 shows a larger area with initial abstraction by infiltration, depression storage, and rainfall interception. Most of the initial abstraction was due to rainfall interception which happens with large area of vegetation cover. This suggests the superior quality of the watershed. Again, we have taken care not to submerge hose quality land cover types.

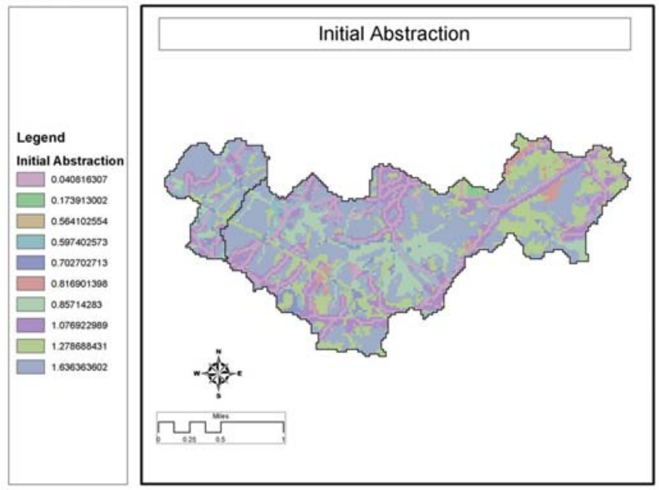

Figure 6: The initial abstraction (I_a) raster for the Peck's Mill Watershed.

Figure 7 is the runoff map of the watershed shown in runoff values converted to cubic meter. Cells with varying runoff volumes are present in the watershed. It ranges from 0.5 cubic meters to 26,491 cubic meters.

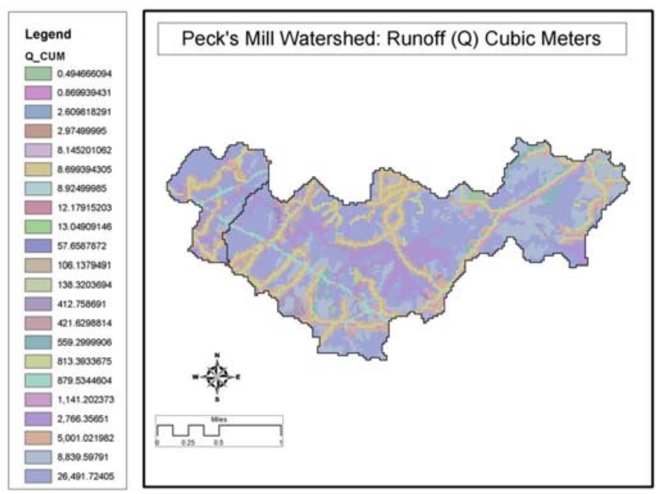

Figure 7: The runoff (Q) raster for the Peck's Mill Watershed

Figures 8 and 9 represent the impounding area map for the proposed reservoir with 405 m and 410 m height, respectively, generated with the help of watershed DEM. Both figures also show the proposed dam site in the northwest corner of the watershed. The area represented in blue is the impounding area of the reservoir. The 405 m and 410 m height reservoirs have impounding areas of 112 acre and 216 acre, respectively. The red line surrounding the impounding area in blue is the flood pool line, in case of a 1 m or 2 m rise in the water level from the spillway level during flood. The reservoirs also show flood pool lines based on SCS-CN method calculations. Calculations to determine the duration of time for the 112 acre and 216 acre reservoirs to reach full capacity, and to determine the estimation of flood pool lines based on a storm event are shown in below equations (3 – 5).

$$\text{Time } (t_2) = \frac{\text{Volume of Reservoir } (m^3)}{\text{Volume of Runoff } (m^3) + \text{Inflow } (m^3)} \tag{4}$$

$$\text{Rise (m)} = \frac{\text{Volume of Storm Runoff } (m^3)}{\text{Area of Reservoir } (m^2)} \tag{5}$$

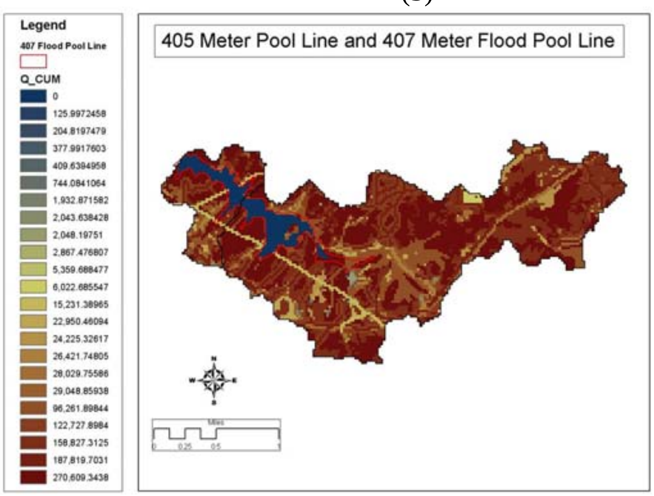

Figure 8: Map of proposed Peck's Mill reservoir showing the dam site and impounding area for 405 m pool line and 407 m flood pool line.

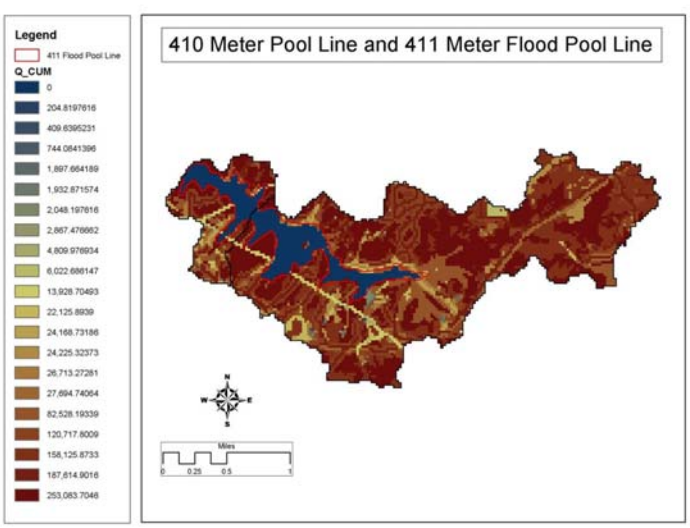

Figure 9: Map of proposed Peck's Mill reservoir showing the dam site and impounding area for 410 m pool line and 411 m flood pool line.

For the 216 acre reservoir, the time it would take to reach the 410 meter pool line is calculated to be approximately 16.26 years based only on the runoff coming from the watershed. This would not be feasible since water demands may needed sooner than 16.26 years. If inflow in the amount 1.44 X 10^5 m^3 is added by pumping water from the Chestatee River to 4.76 X 10^4 m^3, runoff, then the total volume of runoff and inflow would equal to 1.92 X 10^5 m^3. The volume of the reservoir, 7.75 X 10^5 m^3 was divided by 1.92 X 10^5 m^3. The calculated result for the duration of the reservoir to reach full pool is 4.0 years. For the 112 acre reservoir, the time is less because there is more runoff to consider because the reservoir is smaller. The same method of calculation is applied for calculating the amount of time for the reservoir to fill when an inflow is added to the storage capacity. The estimated time for the 112 acre reservoir to reach full capacity is 8.6 years. If we add the pumped water from Chestatee River to the runoff amount, it will take 2.14 years to fill the 112 acre reservoir to reach full capacity at the 405 meter pool line.

Not only was the duration of time to reach full capacity for both reservoirs calculated, but the flood pool lines were also calculated based on a 100 yr /24 hr storm event. The amount of runoff above both pool lines, 405 m and 410 m, had to be determined. Based on 9.2 inches (in) of rain during a 24 hour period, there is 1.00 X 10^6 m^3 of runoff for the 112 acre reservoir. This volume of storm runoff is divided by the area, 4.56 X 10 m^2, of the 112 acre reservoir. The result is a 2.20 m rise in elevation. For the 216 acre reservoir, the calculation is based on the 112 acre reservoir. The storm runoff is 9.62 X 10^5 m^3 and area is 8.78 X 10^5 m^2. The storm runoff is divided by the area to result in flood rise. The flood rise in elevation is 1.02 m. The red line surrounding the reservoir impounding area was constructed with these results.

CONCLUSION

From this study, it was found that geospatial technology has the best potential to undertake complex environmental related engineering design problems to analyze and provide results required for decision-making. This study provides a new tool to design reservoirs with less damage to environment with enough decision support for cost-effectiveness. The comprehensive geospatial model developed in ArcGIS ModelBuilder to locate potential reservoir sites could be easily replicated by other researchers or engineers for reservoir suitability analysis decision making. The study found that a new reservoir can be built in Lumpkin County to ease the water woes in Metro Atlanta and it does not require much reconnaissance survey.

Some other aspects of hydrologic designing challenge may be considered to reduce the future water woes of

Atlanta. Instead of constructing costly and environmental unfriendly reservoirs, low cost reservoir spurs can be constructed on Chattahoochee River and its major tributaries in the Upper Chattahoochee 8-digit HUC watershed. The obstructed water can be diverted to water reservoirs or water treatment plants for water supply. A future study is under progress to find suitable spur design locations in Upper Chattahoochee watershed.

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