FINAL REPORT

EFFECT OF SMALL SURFACE WATER IMPOUNDMENTS ON WATER SUPPLY RESERVOIRS

report to

Texas Water Development Board

TWDB Contract No. 0704830751

February 2011

prepared by

R. J. Brandes Company
a wholly-owned division of TRC Environmental Corporation

in association with

URS Corporation

TRC/Brandes

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EXECUTIVE SUMMARY

This research study has been undertaken by R. J. Brandes Company (RJBCO), a wholly-owned division of TRC Environmental Corporation, under contract to the Texas Water Development Board (TWDB). This work was conducted in association with URS Corporation. M&E Consultants, LLC provided support with the collection of design data for the modeled NRCS structures. Dr. Raghavan Srinivasan of Texas A&M University provided SWAT model technical support throughout the project. This study was authorized by the TWDB on June 25, 2007, and it has been undertaken pursuant to Contract No. 0704830751 between the TWDB and RJBCO. Funding for the work has been provided through the TWDB's Research and Planning Fund.

The primary purpose of this study has been to investigate the potential effects of small surface water impoundments on the water supply provided by a major downstream reservoir. In the context of this work, small surface water impoundments have been defined primarily as those created by floodwater retarding structures that were constructed largely in response to flooding and extensive soil erosion that followed the drought of the 1950s across portions of Texas under the sponsorship of the federal government, namely the Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service) of the U. S. Department of Agriculture. The effects of other non-federal small impoundments and typical stock ponds on the water supply capabilities of a downstream reservoir also have been considered and analyzed in this study.

Small impoundments formed by NRCS structures and even stock ponds typically function as uncontrolled water storage reservoirs, subject to natural inflows during runoff events and evaporative losses during non-rainfall periods. Outflows generally occur as gravity discharges through low-flow outlets installed at some level above the bottom of the impoundments or as overflows through a spillway or similar structure.

By their nature, NRCS impoundments and stock ponds do result in some degree of consumptive loss of natural runoff that ultimately translates to some reduction in streamflows downstream. These losses typically occur as a result of: (1) the permanent storage of natural inflows in an impoundment when it has storage capacity available below its lowest outlet; (2) evaporative losses from the pool of water stored at or below the lowest outlet of an impoundment during extended dry periods; (3) evaporative losses from flood waters temporarily retained in an impoundment until they are gradually drained from storage over several days or weeks after a runoff event; (4) actual deliberate diversions of stored water from an impoundment; and (5) potentially increased channel losses downstream of an impoundment due to the attenuation of natural flows caused by the limited capacity of an impoundment's primary flow outlet.

As runoff is retained in small impoundments, even temporarily, attendant sediment loadings are reduced through settling. This, in turn, reduces the sediment loadings that are transported downstream and discharged into a downstream reservoir, thus having the effect of increasing the volume of the downstream reservoir that otherwise would have retained the sediment. The result is to extend the useful life of the downstream reservoir in terms of its storage capacity and its ability to capture and store inflows, and hence, to produce a useful water supply. Consequently, if a major water supply reservoir is located downstream of such small impoundments, some reduction in the inflows to the reservoir from what might have occurred naturally can be expected, but the effects of the small impoundments on the water supply capability of the reservoir are likely offset somewhat due to the retention of sediment in the small impoundments and the resulting reduced sediment loadings discharged into the downstream reservoir.

A significant portion of existing NRCS structures potentially may require upgrades to extend the useful life of their sediment pools and/or to comply with current state and federal dam safety standards. Actions for individual structures may involve different dam/impoundment management options, including no action (i.e., not extending structure life and in some cases not meeting current dam safety standards), removing (or breaching) existing structures, or performing upgrades to existing structures, and depending on which of these actions is implemented for a particular structure, the effect on the water supply capability of downstream reservoirs will likely be different.

Analyses of the effects of NRCS structures and small impoundments on the water supply capability of downstream reservoirs requires consideration of both hydrologic and sedimentation processes as they may be impacted by these structures and impoundments, and the Soil and Water Assessment Tool (SWAT) developed by the U.S. Department of Agriculture encompasses the necessary features for effectively simulating the most important watershed runoff and sedimentation processes. The SWAT model has been employed in this study to relate watershed, soil, and hydrologic characteristics to sediment loadings under different assumed conditions relating to the number and capacity of small impoundments and stock ponds that may exist upstream of a major water supply reservoir. Results from the SWAT model in terms of daily sediment loadings and inflows then have been used as the inputs to a reservoir operations model for the major water supply reservoir to assess the impacts on the reservoir's storage capacity and firm yield under different assumptions regarding the number and capacity of upstream small impoundments and stock ponds. This general study approach has been applied to two major water supply reservoirs, one located in eastern Texas and the other located in the more arid western Texas.

Cedar Creek Reservoir, in the Trinity River Basin, in the eastern central part of the state and Lake Coleman, in the Colorado River Basin, in the western central part of the state have been selected in this study as useful and representative test cases not only for evaluating the effects in general of NRCS structures and small impoundments on the water supply capability of downstream reservoirs, but also the effects of the different dam/impoundment management options that may be implemented in the future with regard to NRCS structures. Significant portions of the Cedar Creek Reservoir watershed area (20 percent) and annual runoff volume (23 percent) are subject to control by upstream NRCS floodwater retarding structures and other small dams. Furthermore, the Blackland Prairie soils conditions in this watershed are reasonably representative of a large number of other watersheds in the state with numerous NRCS-designed floodwater retarding structures. It is also important that an existing and calibrated SWAT runoff and sediment yield model is available for the Cedar Creek watershed. About half of the Lake Coleman watershed area (50 percent) and annual runoff volume (53 percent) are subject to control by upstream NRCS-designed floodwater retarding structures and other small dams. The watershed also is located significantly west of Cedar Creek Reservoir and therefore subject to more arid hydroclimatic conditions. It also is characterized by different soils conditions in a significantly different soils regime, which translates to different sedimentation conditions.

It should be noted that the Lake Coleman SWAT model could not be successfully calibrated to the limited and potentially unreliable hydrologic and sediment data available. The driving factors behind model results have been shown to be climatological data (precipitation, evaporation). Since historic climatological data for the Lake Coleman watershed are reasonably complete, the model results can be considered reasonable but qualitative. The results are most defensible when comparing one Lake Coleman model scenario to another rather than making a direct comparison between Lake Coleman model results and the more thoroughly calibrated Cedar Creek Reservoir results.

Results from operating the SWAT model of the Cedar Creek Reservoir and the Lake Coleman watersheds under 2055 conditions with daily climatological data corresponding to the 1947-2002 historical period confirm that the effect of upstream NRCS structures and small impoundments is to reduce both the inflows to the reservoirs and the sediment loadings that are discharged into the reservoirs, with these reductions varying depending on which dam/impoundment management actions are implemented for the NRCS structures in the future. Overall, the combined effect of the upstream NRCS structures and small impoundments on the water supply capability of Cedar Creek Reservoir under 2055 conditions is <u>to reduce its firm annual yield on the order of five to nine percent</u>, depending on which dam/impoundment management actions are implemented for the NRCS structures in the future and the assumed density of the sediment in the reservoir. For Lake Coleman, the combined effect of the upstream NRCS structures and small impoundments on the water supply capability of Lake Coleman under 2055 conditions is <u>to reduce its firm annual yield on the order of 20 to 40 percent</u>, again depending on which dam/ impoundment management actions are implemented for the NRCS structures in the future and the assumed density of the sediment in the reservoir.

These results indicate that the relative effects of the NRCS structures and other small impoundments on the inflows, sediment loadings and firm annual yield for Lake Coleman are somewhat greater than those indicated for Cedar Creek Reservoir. Factors that support these results include the following:

- The portion of the Lake Coleman drainage area that is controlled by structures is approximately 50 percent, whereas only about 20 percent of the Cedar Creek Reservoir watershed is controlled by structures.
- Rainfall affecting Lake Coleman in the western part of the state generally is less frequent and overall smaller in quantity than for Cedar Creek Reservoir in the eastern part of the state (average of about 25 inches per year versus about 41 inches per year), thus watershed and reservoir conditions generally are drier, and there is more opportunity for evaporative and seepage losses from the impoundments, which leads to greater capacity for capturing runoff when rainfall events do occur.
- The average net evaporation rate for the Lake Coleman watershed based on TWDB data (about 39 inches per year) is about double the average rate for Cedar Creek Reservoir (about 19 inches per year), which also translates to significantly higher evaporative losses per acre of water surface area within the Lake Coleman watershed.

From the overall results of this study, it is apparent that capturing of runoff in the upstream NRCS structures and small impoundments and the subsequent evaporation losses are much more effective with regard to reducing in the water supply capability of the downstream reservoirs than these upstream impoundments are with regard to extending the storage capacity of the downstream reservoirs through upstream sediment retention. While the net effect of these processes results in significant reductions in the inflows, sediment loadings and firm annual yield of both Cedar Creek Reservoir and Lake Coleman, the projected year-2055 storage capacities of the reservoirs do not appear to be appreciably affected by the sediment retention effects of the upstream NRCS structures and small impoundments, regardless of which dam/impoundment management actions are assumed to be implemented as the sediment pools of the structures become depleted.

However, it should be noted that the results of this study as relates to the effects of structure impacts on sediment transport are largely qualitative due to limited available data, specifically for sediment accumulation in the flood retarding structure pools. One recommendation is that additional sediment trap data for flood retarding structures be developed to evaluate consistency with the estimates presented in this report.

Analyses also have been performed to assess the effects of stock ponds on the water supply capability of Lake Coleman. Results from operating the SWAT model of the Lake Coleman watershed under 2055 conditions with daily climatological data corresponding to the 1947-2002 historical period indicate that the effect of upstream stock ponds is to reduce inflows to the reservoir between 13 and 17 percent for assumed stock pond areal densities of four and eight ponds per square mile of watershed. Overall, the effect of upstream stock ponds on the water supply capability of Lake Coleman under 2055 conditions is to reduce its firm annual yield on the order of 25 to 34 percent, relative to conditions with no stock ponds, for the two assumed areal densities of stock ponds within the watershed.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

APPENDIX A

OVERSIZED FIGURES

APPENDIX B

1.0 INTRODUCTION

1.1 BACKGROUND

This research study has been undertaken by R. J. Brandes Company (RJBCO), a wholly-owned division of TRC Environmental Corporation, under contract to the Texas Water Development Board (TWDB). The primary purpose of this work has been to investigate the potential effects of small surface water impoundments on the water supply provided by a major downstream reservoir. These effects have been addressed in terms of: (1) potential reductions in the firm supply of water available from the downstream reservoir due to the storage and evaporation of flows by the upstream small impoundments, and (2) the potential extended life of the downstream reservoir resulting from reduced sedimentation caused by the capturing of sediment in the upstream small impoundments.

In the context of this work, small surface water impoundments have been defined primarily as those created by floodwater retarding structures that were constructed largely in response to flooding and extensive soil erosion that followed the drought of the 1950s across portions of Texas under the sponsorship of the federal government, namely the Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service) of the U. S. Department of Agriculture. The effects of other non-federal small impoundments and typical stock ponds on the water supply capabilities of a downstream reservoir also have been considered and analyzed in this study.

For this research study, RJBCO has served as the prime contractor with the TWDB. Other members of the study team included:

URS Corporation – Austin, Texas
M&E Consultants, LLC – Heidenheimer, Texas
Dr. Raghavan Srinivasan – Texas A&M University, College Station, Texas

This work was authorized by the TWDB on June 25, 2007, and it has been undertaken pursuant to Contract No. 0704830751 between the TWDB and RJBCO. Funding for the work has been provided through the TWDB's Research and Planning Fund.

1.2 PROBLEM STATEMENT

Small impoundments formed by NRCS structures and even stock ponds typically function as uncontrolled water storage reservoirs, subject to natural inflows during runoff events and evaporative losses during non-rainfall periods. Outflows generally occur as gravity discharges through low-flow outlets installed at some level above the bottom of the impoundments or as overflows through a spillway or similar structure. Diversion or usage of water from these types of impoundments either is not made at all, or is relatively small, typically only for domestic and livestock purposes or for irrigation of small tracts. Diversions for irrigation of crops must be authorized by a surface water right issued by the State.

By their nature, NRCS impoundments and stock ponds do result in some degree of consumptive loss of natural runoff that ultimately translates to some reduction in streamflows downstream. These losses typically occur as a result of: (1) the permanent storage of natural inflows in an impoundment when it has storage capacity available below its lowest outlet; (2) evaporative losses from the pool of water stored at or below the lowest outlet of an impoundment during extended dry periods; (3) evaporative losses from flood waters temporarily retained in an impoundment until they are gradually drained from storage over several days or weeks after a runoff event; (4) actual deliberate diversions of stored water from an impoundment; and (5) potentially increased channel losses downstream of an impoundment due to the attenuation of natural flows caused by the limited capacity of an impoundment's primary flow outlet. Consequently, if a major water supply reservoir is located downstream of such small impoundments, some reduction in the inflows to the reservoir from what might have occurred naturally can be expected. The extent to which such reservoir inflows may be affected by upstream small impoundments, and the corresponding impact on the available water supply from the reservoir, have been addressed in this study, focusing primarily on the storage and evaporative losses associated with these impoundments under prescribed conditions for individual structures.

Another aspect of small impoundments related to their potential impacts on a downstream water supply reservoir pertains to sediment. As runoff is retained in these small impoundments, even temporarily, attendant sediment loadings are reduced through settling. This, in turn, reduces the sediment loadings that are transported downstream and discharged into a downstream reservoir, thus having the effect of increasing the volume of the downstream reservoir that otherwise would have retained the sediment. The result is to extend the useful life of the downstream reservoir in terms of its storage capacity and its ability to capture and store inflows, and hence, to produce a useful water supply. Sedimentation effects of upstream impoundments on the storage capacity of downstream water supply reservoir also have been considered in this study.

1.3 NRCS STRUCTURES

Per the National Inventory of Dams (U.S. Army Corps of Engineers, 2007), over 2,600 existing small dams in Texas have been designed and constructed by the NRCS. A significant portion of these NRCS dams, for reasons described below, potentially may require upgrades to extend the useful life of their structures and/or to comply with current state and federal dam safety standards. Actions to address this issue for individual dams may include no action (i.e., not extending structure life and in some cases not meeting current dam safety standards), removing (or breaching) existing structures, or performing upgrades to existing structures. Each of these actions can have relatively different effects on the available water supply from a downstream reservoir, and these effects have been considered and quantified in this study.

Because the status of NRCS structures in the future is somewhat indefinite and because there is a substantial number of these dams in certain watersheds across the state, they are of particular interest with regard to their potential impacts on downstream water supply reservoirs. Following are details pertaining to the design and operation of these NRCS structures and a discussion of the issues regarding these structures that will likely have to be addressed in the future.

1.3.1 Design of NRCS Structures

Existing NRCS dams in Texas have primarily been designed and funded under two federal programs:

- The Flood Control Act of December 22, 1944 (PL 78-534), which authorized the Secretary of Agriculture to "install watershed improvement measures to reduce flood, sedimentation, and erosion damages; further the conservation, development, utilization, and disposal of water; and the conservation and proper utilization of land".
- The Watershed Protection and Flood Prevention Act (PL 83-566), August 4, 1954, as amended, which authorized NRCS to cooperate with states and local agencies to carry out works of improvement for soil conservation and for other purposes including flood prevention; conservation, development, utilization and disposal of water; and conservation and proper utilization of land.

Federal design guidelines for dams to serve the above purposes have changed somewhat since 1944; with the initial Engineering Memorandum No. 3 being revised in 1956; and then replaced by Engineering Memorandum 27 in 1966. This memorandum was in turn replaced by Technical Release 60 in 1978.

The basic configuration of all NRCS-designed floodwater retarding structures is shown below.[1]

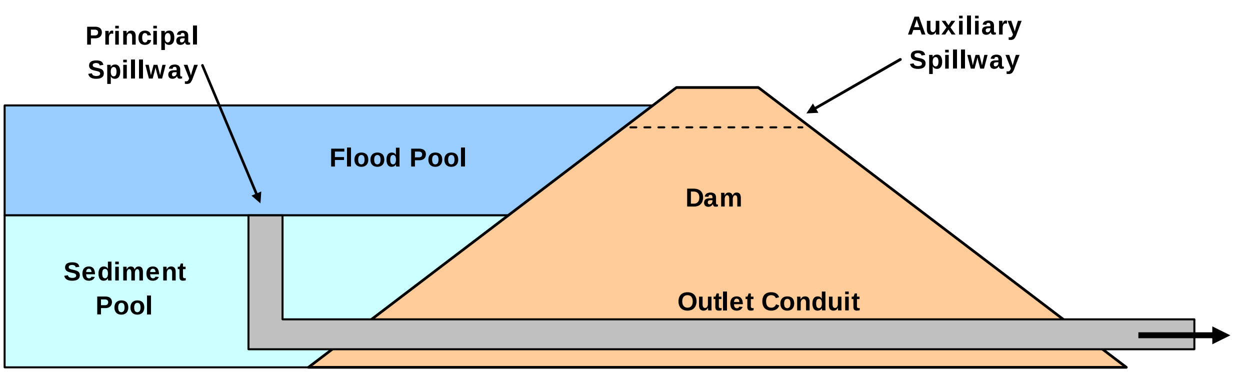

Figure 1-1 Key elements of NRCS floodwater retarding structure

As designed, inflows to the impoundment typically enter the sediment pool first. Depending on the volume of inflow relative to the volume of water and sediment accumulated in the impoundment at the beginning of the inflow event and the rate of inflow relative to the outlet flow capacity of the principal spillway, the inflows may be stored in the sediment pool and/or the flood pool. Water stored in the flood pool drains by gravity into the principal spillway and is discharged through the outlet conduit into the downstream channel. If the level of the water

[1] Tables and figures in this report normally follow their references in the text and are numbered according to major section numbers. However, oversized and some multi-page tables and figures are contained in separate appendices at the end of the report. Appendix A contains these tables sequentially numbered and preceded by A-, and Appendix B contains these figures sequentially numbered and preceded by B-.

stored in the flood pool exceeds the crest of the auxiliary spillway, then water in the flood pool also is discharged by gravity through the auxiliary spillway into the downstream channel.

At the end of an inflow event, water remains stored in the sediment pool where it is subsequently subjected to evaporation loss. Sediment in the stored water settles to the bottom and is accumulated in the sediment pool. When the volume of sediment fully occupies the sediment pool, the structure no longer functions as a sediment trap in accordance with one of its fundamental purposes, and the life of the structure is considered to be fulfilled with regard to reducing sediment loadings downstream. Decisions then can be made as to what modifications should be performed on the structure, if any, regarding its future operation and ability to function as originally designed.

1.3.2 Upgrades of NRCS Structures

There are two major issues that now have arisen with regard to NRCS structures that drive the potential or need for upgrading these structures: sediment accumulation and changes in hazard classification. These issues are discussed below, and they have been taken into consideration in the study analyses.

Sediment Accumulation **-** Prior to 1966, the standard for setting the elevation of the inlet of the principal spillway was that the reservoir volume below that elevation (intended for sediment storage) be equal to the estimated sediment yield from the watershed over a 50-year period. After 1966, the required volume below the principal spillway inlet was changed to the estimated sediment yield from the watershed over a 100-year period. Therefore, dams completed prior to 1960 (year 2010 minus 50 years) currently have a significant potential for having a full sediment pool, assuming no subsequent sediment removal. Once the sediment pool of a particular structure is full, the options are either: (1) to remove the sediment or raise the principal spillway (to create a new sediment pool); or (2) to breach the structure to eliminate its hydrologic impacts and liability. Federal (NRCS) standards would require that the reestablished sediment pool have a 100-year sediment capacity. Of course, there is a third option – that is to do nothing – which often is what happens in light of limited funding resources for either rehabilitation or breaching of the structure. Each of these options is considered in this study with regard to the effects of NRCS structures on downstream water supply reservoirs.

Changes in Hazard Class **-** The hazard classification of all regulated dams in Texas is defined by the estimated downstream consequences of dam failure; with a dam being designated “high” hazard if loss of life or excessive urban economic loss is expected, “significant” hazard if loss of life is possible or appreciable rural economic loss is expected, and “low” hazard if no loss of life or only minimal rural economic loss is expected (TCEQ Rules, §299.14). The hydrologic design criteria per both federal and state standards are much stricter for a high hazard structure than a low hazard structure. For example, for a high hazard structure, the design standard is safe passage (i.e. passage without overtopping of the unprotected dam crest) through the auxiliary spillway of the full probable maximum flood (PMF). For a low hazard structure, the design standard is much lower, requiring safe passage of a significantly lower (i.e., more frequent) flood event. Furthermore, with regard to existing NRCS structures, they typically were designed for a significantly smaller flood pool for low hazard structures versus high hazard structures.

The expansion of urban areas into historically agricultural regions of Texas has changed land use characteristics downstream of many existing NRCS structures. If development has occurred within the dam breach inundation zone downstream of an NRCS structure, then the hazard classification as a previously low or significant hazard dam is raised to the high hazard classification. Application of the resulting more stringent hydrologic design criteria requires that the spillway capacity of the structure be upgraded or that the dam be breached and eliminated. Upgrades based upon a change in hazard classification typically require a major (and very expensive) structural modification (raising the height of the dam, lengthening and/or raising the crest of the auxiliary spillway). Even breaching of a dam can be complicated and expensive.

2.0 STUDY APPROACH

2.1 GENERAL OVERVIEW

The most common measure of a reservoir's ability to produce a water supply is the quantity referred to as firm annual yield, which is typically expressed in units of acre-feet per year. This is the standard adopted for purposes of this study to evaluate the relative effects of small impoundments on major downstream water supply reservoirs. The firm annual yield is defined as the maximum annual quantity of water that can be withdrawn from a reservoir annually in a continuous monthly or seasonal pattern of use under hydrologic and climatic conditions corresponding to the most severe drought of record. For much of Texas, the drought of the 1950s represents the most severe drought of record; however, for a particular reservoir, it could be different. The critical drought of record for a particular reservoir can be determined through a reservoir operations analysis using varying reservoir inflows that reflect a long period of historical hydrologic conditions, including those representative of the drought of the 1950s.

The approach taken in this study has been to calculate the firm annual yield of a major water supply reservoir under varying hydrologic and sedimentation conditions that reflect not only a long period of historical streamflow variations but also the hydrologic and sedimentation effects of different assumed storage and operating conditions for upstream small impoundments and structures. The specific steps undertaken to make these analyses of these hydrologic and sedimentation effects on the reservoir's firm yield are listed in order in Table 2-1.

The fundamental tool that has been used to describe the hydrologic and sedimentation effects of different assumed conditions for upstream small impoundments and structures is a computer program with capabilities to simulate daily stormwater runoff and sediment transport throughout a watershed in response to prescribed daily climatological conditions and specified structure, watershed and soil characteristics. As described later, the program selected for this purpose is referred to as SWAT, the Soil and Water Assessment Tool developed by the U.S. Department of Agriculture. For these analyses, historical daily climatological conditions for approximately 60 years extending back from the mid-2000s have been used for the daily SWAT simulations. Under assumed conditions with the as-built storage capacity for all upstream small impoundments and structures in place, the total sediment accumulation volume for the 1970-2002 period[2] in each of the impoundments and structures within the watersheds of selected major water supply reservoirs has been determined from the results of the daily SWAT simulations. Based on these 33-year accumulated sediment volumes, the average annual sediment delivery and accumulation rate then has been calculated for each of the NRCS structures and/or other small impoundments included in the watersheds of the selected major water supply reservoirs. These average annual sediment delivery and accumulation rates then have been used to estimate the sediment storage condition of each individual impoundment and/or structure in the year 2006

[2] The period 1970 to 2002 was chosen for establishing historical sediment accumulation volumes because: 1) it represents a long enough period to be deemed representative of historical climatic and hydrologic conditions, and 2) it is a period during which most of the studied floodwater retarding structures had been built; i.e. the period was a representative period during which the studied structures existed.

Table 2-1 Basic steps applied for evaluating the effects of upstream small impoundments and structures on the water supply capability of a downstream major water supply reservoir

BASIC STEPS IN STUDY APPROACH

For selected watersheds with NRCS structures or small impoundments located upstream of a major water supply reservoir, perform the following steps to analyze the effects of these structures and/or small impoundments on the water supply capability of the downstream water supply reservoir based on different assumptions as to how the upstream sediment pools are modified once they are depleted and full of sediment:

1) For a baseline condition, operate a SWAT daily rainfall-runoff and sediment transport model of the watershed using daily climatological data extending back in time approximately 60 years to simulate the inflows to the downstream major water supply reservoir without any upstream structures and small impoundments in place.

2) Operate a SWAT daily rainfall-runoff and sediment transport model of the watershed using daily climatological data extending back in time approximately 60 years to simulate the daily storage fluctuations and sediment accumulation in the upstream structures and small impoundments represented at their as-built conditions.

3) Extract from the daily model results the 1970-2002 accumulated sediment volumes for each of the upstream structures and small impoundments and calculate the average annual sediment delivery and accumulation rate for each of the structures and impoundments.

4) Use these average annual sediment delivery and accumulation rates to estimate the sediment storage condition of each individual impoundments and/or structures for the year 2006 by starting with an empty sediment pool on the date each impoundment or structure was constructed and uniformly accumulating sediment in the pool year-by-year until the year 2006. If the sediment volume is less than the volume of the design sediment pool for a particular structure, then the design storage capacity of the sediment pool is reduced by this amount to produce the 2006 sediment pool capacity. If the estimated total sediment volume exceeds the volume of the design sediment pool for a particular structure, it is assumed that the design sediment pool storage capacity was reestablished through ongoing maintenance in 2006, and the 2006 sediment pool volume is set equal to the design sediment pool capacity.

5) Continue on a year-by-year basis with the sediment accumulation calculations beyond the year 2006 for each of the structures and small impoundments until the sediment storage capacity of each has been depleted and fully occupied with sediment. Based on one of three structure action alternatives (as described in the next section), adjust the sediment pool storage capacity for each of the structures and small impoundments.

6) For each of the structures and small impoundments, continue on a year-by-year basis with the sediment accumulation calculations beyond the year when the sediment pool became depleted and was adjusted through the year 2055. The end result of this step is the sediment storage condition of the sediment pool for each of the structures and small impoundments for each of the three structure action alternatives.

7) Operate the SWAT daily rainfall-runoff and sediment transport model of the watershed using daily climatological data extending back in time approximately 60 years to simulate the daily storage fluctuations and sediment accumulation in the upstream structures and small impoundments represented at their 2055 sediment storage conditions for each of the three structure action alternatives.

8) Extract from the daily model results the 1947-2002 daily inflows and sediment loadings to the downstream major water supply reservoir for each of the three structure action alternatives.

9) Using the calculated average annual daily sediment delivery and accumulation rate for the downstream major water supply reservoir based on the 1947-2002 sediment loadings, develop the adjusted stage-area-capacity relationship for the downstream major water supply reservoir to reflect year-2055 sedimentation conditions for each of the three structure action alternatives.

10) Using the 1947-2002 daily inflows from the daily rainfall-runoff model as inputs along with corresponding daily climatological data, apply an Excel spreadsheet daily reservoir operations model to the downstream major water supply reservoir with the year-2055 stage-area-capacity data to determine the firm annual yield of the reservoir for each of the three structure action alternatives and for the case without any upstream structures and small impoundments in place from Step 1.

by starting with an empty sediment pool on the date each impoundment or structure was constructed and uniformly accumulating sediment in the pool year-by-year until the year 2006. Similar sediment accumulation analyses then were undertaken into the future beginning in 2006 with the 2006 sedimentation pool volumes and proceeding on a year-by-year basis using the same average annual sediment delivery and accumulation rates for the individual structures and small impoundments. At the point in time in the future when the sediment pool of each of the impoundments or structures was determined to be filled with sediment, then one of three structure action alternatives (as described in the following section) was assumed to be implemented, with the corresponding sediment storage capacity of the impoundment or structure left in place. The sediment accumulation calculations for each of the impoundments and structures then were continued into the future through the year 2055. The end result of these analyses was the year-2055 sediment storage condition, and water storage capacity, for each of the individual impoundments and structures for each of the assumed structure action alternatives.

With the year-2055 sediment and water storage condition of each impoundment or structure established for each of the different assumed structure action alternatives, the effect of these different assumed structure action alternatives on the inflows and sediment loadings into downstream water supply reservoirs was analyzed. Again, daily simulations of stormwater runoff and sediment transport for the reservoir watersheds with all small impoundments and structures at their year-2055 sediment conditions were made using the SWAT model with daily climatic data extending from 1947 to 2002. Outputs from these simulations for a particular reservoir watershed in the form of the daily water and sediment outflows then were used as the daily inputs to an Excel spreadsheet daily reservoir operations model to calculate the resulting firm annual yield for the downstream water supply reservoir. These analyses were performed for each of the assumed structure action alternatives for the upstream impoundments and structures and for the assumed condition with no upstream impoundments and/or structures in place. Relative differences in the resulting firm annual yields among the different scenarios analyzed and with respect to the no-structures case have provided insight as to the effects of the small impoundments and structures, under different assumed future structure sedimentation conditions, on the water supply capability of the downstream reservoir.

2.2 NRCS STRUCTURE ACTION ALTERNATIVES

For analyzing the effects of upstream NRCS structures on the firm annual yield of a downstream major water supply reservoir, four different scenarios corresponding to different structure sedimentation conditions have been considered. These scenarios include a base condition (no structures) and three different dam/impoundment management options for the NRCS structures reflecting different levels of sediment storage as of the year 2055, approximately 50 years into the future beginning with actual 2006 conditions for individual structures.

The four scenarios examined are identified as Case I (No Structures), Case II (Structure Upgrades), Case III (Structure Removal), and Case IV (No Action). These are generally described below, and the derivation of their respective structure sedimentation conditions is described in more detail in Section 3.0.

Case I (No Structures) - The assumed structure condition is that no NRCS floodwater retarding structures exist upstream of the water supply reservoir. Runoff from the watershed is uninhibited by these types of structures.

Case II (Structure Upgrades) - The assumed structure condition reflects the estimated status of NRCS floodwater retarding structures in the year 2055 assuming that during the period 2006-2055 the structures would be upgraded as needed to represent initial design conditions. The upgrades would occur when the sediment pools are filled and would consist of full restoration of the sediment pool capacities.

Case III (Structure Removal) - The assumed structure condition reflects the estimated status of NRCS floodwater retarding structures in the year 2055 assuming that during the period 2006-2055 the structures would be removed (via a controlled breach) when their sediment pools become filled with sediment. Dam removal would be accomplished through a controlled breach by removal of a portion of the embankment so as not to cause downstream flooding, with no sediment pool remaining behind the embankment.

Case IV (No Action) - The assumed structure condition reflects the estimated status of NRCS floodwater retarding structures in the year 2055 assuming that during the period 2006-2055 no action is taken as the impoundments accumulate sediment. When the sediment pools become filled, it is assumed that the principal spillways would not function (zero outflow) and that the normal pool elevation would rise from the principal spillway crest elevation to the auxiliary spillway crest elevation.

For each scenario, the projected year-2055 sedimentation condition of individual structures within selected watersheds with downstream major water supply reservoirs was determined, beginning with actual year-2006 condition. Expected rates of sediment loadings and retention were applied over time until the sediment pool of the individual structures was fully occupied with sediment, at which time one of the scenario actions described above was engaged. The result of this process was the year-2055 sedimentation condition for each of the individual structures and the associated downstream water supply reservoir.

The hydrologic behavior of individual structures then was simulated on a daily basis subject to specified actual daily rainfall and evaporation conditions, and the resulting daily outflows from each of the structures were combined with other uncontrolled natural runoff to provide the corresponding total daily inflows to the downstream water supply reservoir under projected year-2055 conditions. Daily reservoir operation analyses then were performed using the daily inflows to the reservoir, with daily rainfall and evaporation, to determine the resulting firm annual yield of the water supply reservoir. This reservoir analysis process was repeated for each of the structure sedimentation scenarios described above using common climatological inputs.

2.3 SMALL STOCK POND EFFECTS

In addition to evaluating the effects of NRCS-type structures, analyses also have been undertaken to examine the potential impact of small stock ponds on the available supply of water from a downstream water supply reservoir. Rather than relate these analyses to specific stock ponds as they may have been constructed and currently exist within a particular watershed upstream of a water supply reservoir (these data typically do not exist), assumed conditions of stock pond areal densities and a typical pond size have been considered[3]. Stock pond areal densities of four and eight ponds per square mile were assumed for a selected watershed for the evaluation of water supply effects. A typical stock pond size also was assumed with the following dimensions:

Maximum Surface Area	0.76	acres
Maximum Storage Capacity	3.72	acre-feet
Maximum Depth	10.0	feet
Average Depth	5.0	feet
Maximum Top Width at Dam	150	feet
Maximum Top Width at Upper End	70	feet
Total Length of Pond	300	feet

In the analyses, outflows from the stock ponds were assumed to occur only when the ponds were full to their maximum storage capacity, and the only losses of stored water from the ponds were assumed to be due solely to evaporation. As the volume of water stored in a pond was diminished by evaporation, the available storage capacity then could impoundment stormwater inflows during the next rainfall event. No diversions or seepage losses from the ponds were assumed, and sedimentation within the ponds was not considered.

The hydrologic behavior of groups of individual stock ponds was simulated on a subwatershed basis subject to specified actual daily climatological conditions for one of the selected water supply reservoir watersheds that was analyzed for the effects of NRCS structures as described above. The resulting daily outflows from the groups of stock ponds were combined with other uncontrolled natural runoff to provide the corresponding total daily inflows to the downstream water supply reservoir under projected year-2055 conditions. Reservoir operation analyses then were performed using these daily inflows, with daily rainfall and evaporation, to determine the resulting firm annual yield of the water supply reservoir. Sedimentation conditions for the water supply reservoir were assumed to correspond to those simulated for Case I above, i.e., with no NRCS structures or small impoundments in place.

2.4 SELECTED STUDY WATERSHEDS

For purposes of evaluating the potential water supply effects of the different cases of upstream structure sedimentation conditions, two major water supply reservoirs and their respective watersheds have been considered; Cedar Creek Reservoir in the central-eastern part of the state and Lake Coleman in the central-western part of the state. The locations of these watersheds within Texas are identified on the aerial photograph in Figure 2-1. Figures 2.2 and 2.3 are similar aerial photographs of the Cedar Creek Reservoir and Lake Coleman watersheds, respectively, with the locations of individual small dams and reservoirs noted.

Cedar Creek Reservoir is located on Cedar Creek, a tributary of the Trinity River in the Trinity River Basin. Cedar Creek Reservoir and its associated watershed were selected for this study because a significant portion (20 percent) of the watershed is subject to control by upstream NRCS floodwater retarding structures and other small dams. The Blackland Prairie soils

[3] Based on professional judgment and experience with typical stock pond characteristics.

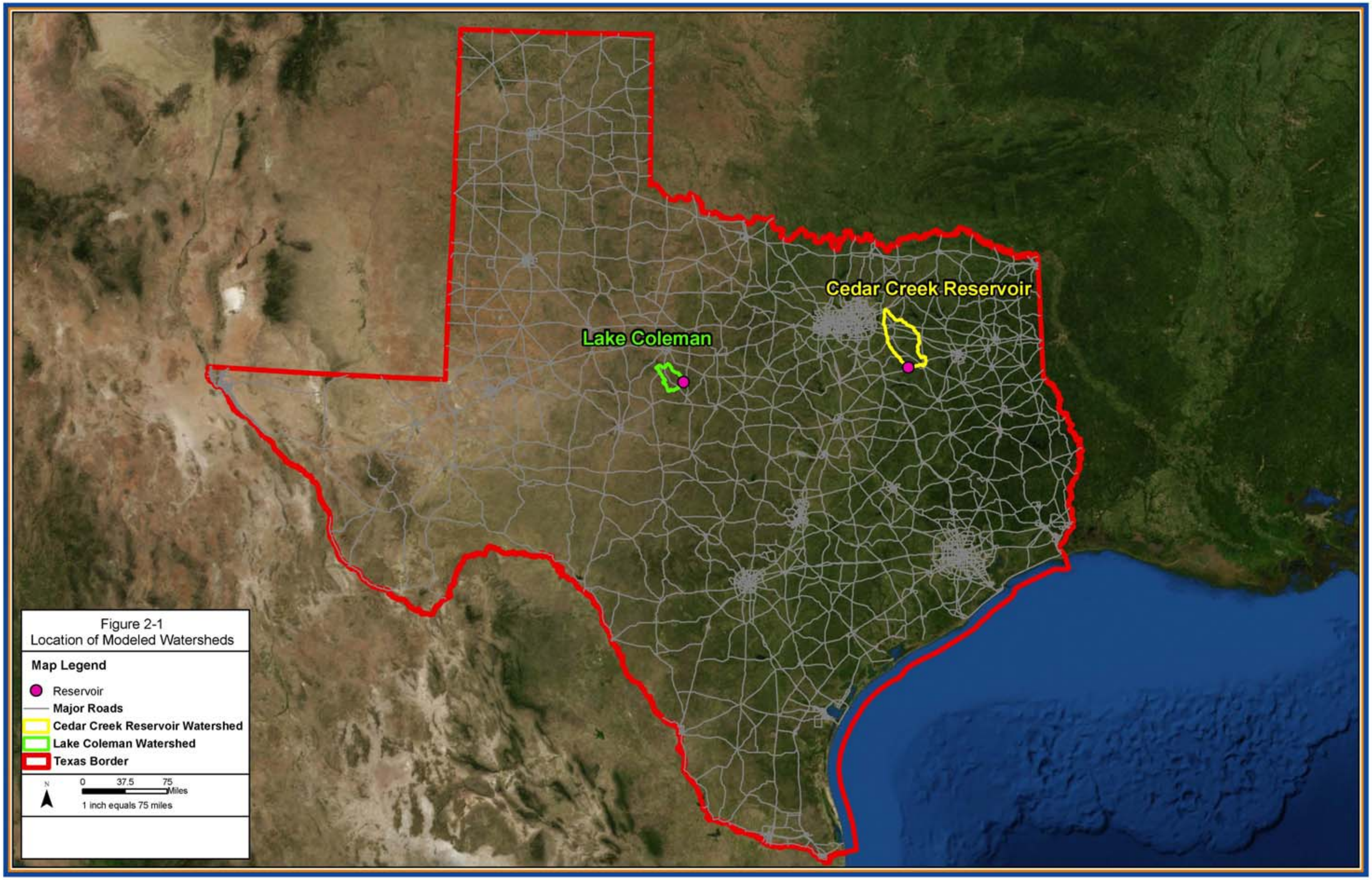

Figure 2-1 Location of Cedar Creek Reservoir and Lake Coleman watersheds within Texas.

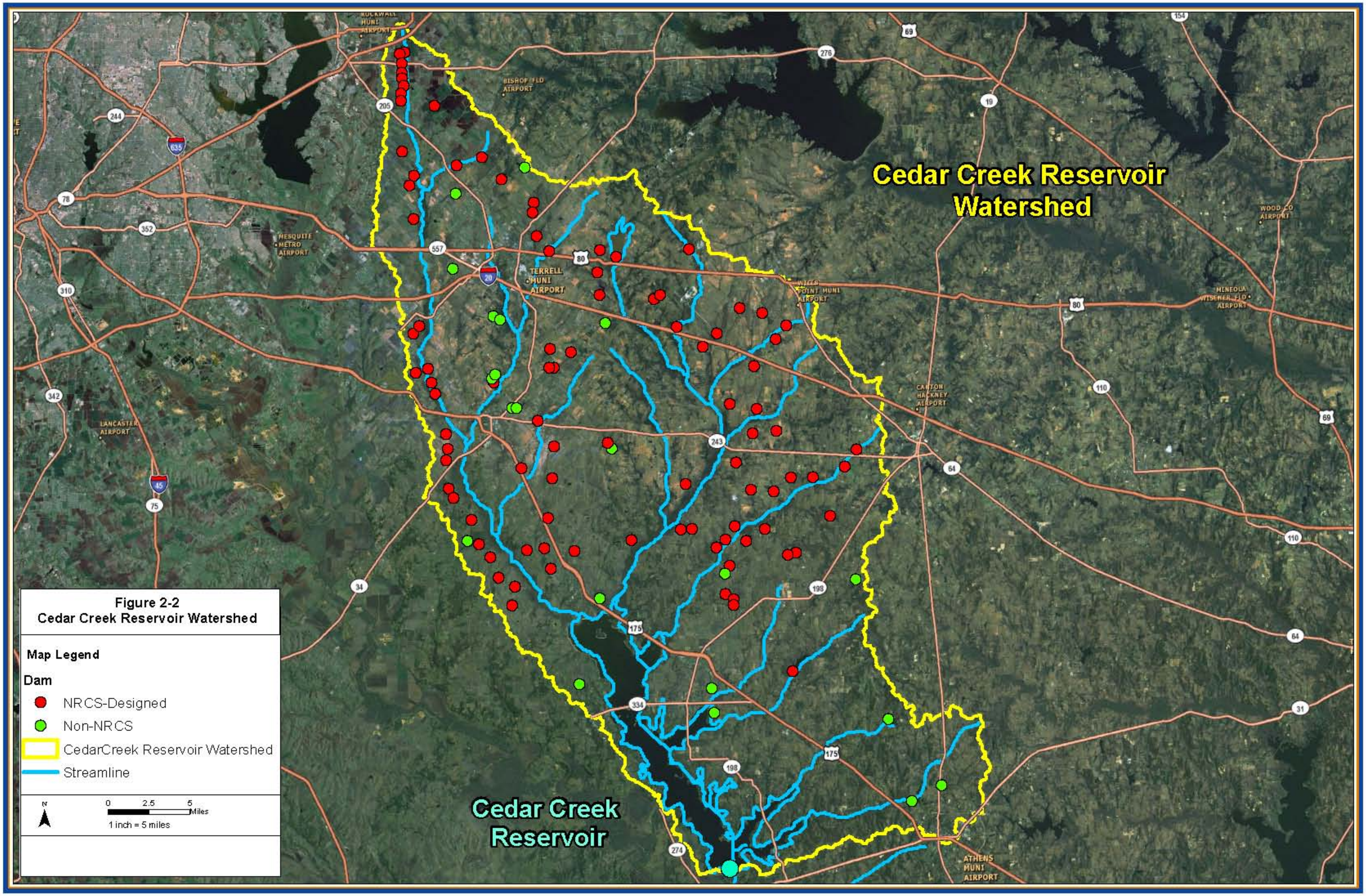

Figure 2-2 Cedar Creek Reservoir watershed with locations of small dam and reservoir structures identified.

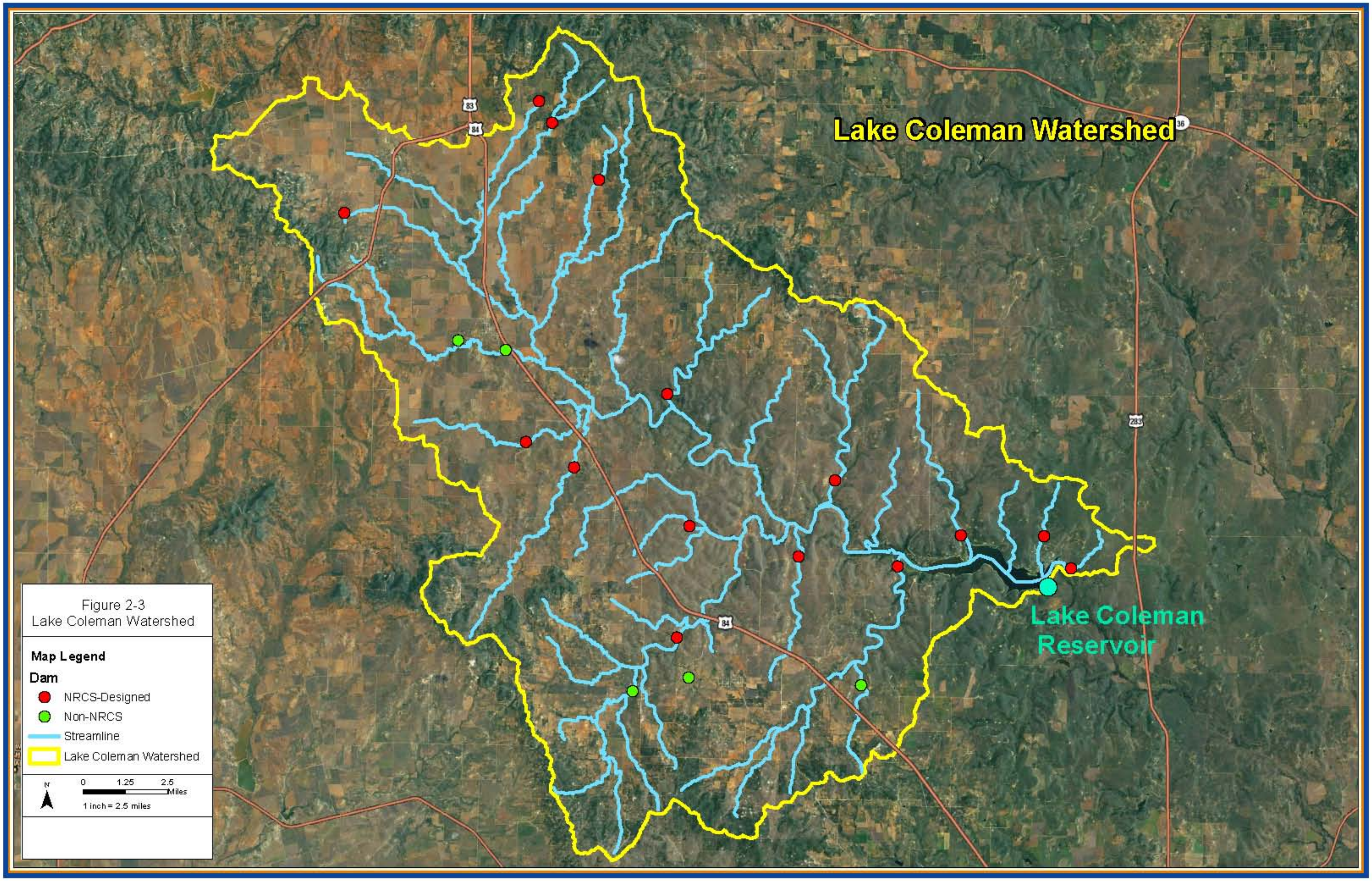

Figure 2-3 Lake Coleman watershed with locations of small dam and reservoir structures identified.

conditions in this watershed are reasonably representative of a large number of other watersheds in the state with numerous NRCS-designed floodwater retarding structures. It is also important to note that an existing runoff and sediment yield model was available for the Cedar Creek watershed (Nanrasimhan, B., Bednarz, S. and Srinivasan, R., 2008). This existing model had been calibrated to historical flows and available sediment yield information, and was documented.

Lake Coleman is located on Jim Ned Creek, a tributary of Lake Brownwood on Pecan Bayou. Pecan Bayou is a tributary of the Colorado River in the Colorado River Basin. About half of the Lake Coleman watershed is subject to control by upstream NRCS-designed floodwater retarding structures and other small dams. This watershed was selected because it is located significantly west of Cedar Creek Reservoir and therefore subject to more arid hydroclimatic conditions. It also is characterized by different soils conditions in a significantly different soils regime, which translates to different sedimentation conditions.

2.5 MODELING PROCEDURES

For performing the analysis of the potential effects of small impoundments on the water supply capability of a downstream major reservoir considering the sedimentation scenarios for NRCS structures as outlined above, specific watershed modeling criteria were identified as being essential. These include the following requirements:

- Simulation of daily stormwater flows and associated sediment loadings over a specified continuous period of time. Because each flood retarding structure has significant impacts on runoff generated by individual storm events, it was considered imperative that the model operate using a daily time step.
- Simulation of reservoir impoundment effects, including flow retention and attenuation and sediment removal.
- Simulation of channel flow losses in a manner that accounts for variations in the daily flow regime.
- Simulation of watershed erosion and sedimentation processes in a manner sensitive to soil parameters and flow regime.
- Ability to be readily calibrated using historical data.

The computer modeling program selected for simulation of watershed runoff and sedimentation processes in this study is the Soil and Water Assessment Tool (SWAT) developed by the U.S. Department of Agriculture (Neitsch, Arnold, Kiniry, Williams and King, 2002; Neitsch, Arnold, Kiniry, Srinivasan and King, 2002). This computer modeling program is considered to satisfy all of the above criteria. SWAT has the additional significant advantage that an existing detailed (and calibrated) SWAT model currently exists for the Cedar Creek watershed. The general SWAT modeling procedures utilized in the study are provided in the following sections.

2.5.1 Hydrologic Modeling

The generation of daily flows in SWAT is provided by a combination of an event-based runoff routine and a watershed storage routine for estimating base flows. Specified daily rainfall is the primary driver for generating runoff events.

2.5.1.1 Event-Based Runoff Model

The event-based runoff model consists of several subroutines that perform specific functions related to rainfall-runoff processes. The specific details of the source data specified for these subroutines are provided in Section 3.0.

Historical daily rainfall amounts from gages located within or proximate to the watershed being modeled are specified as the basic time-variable input to the runoff model. Rainfall amounts are distributed spatially to subwatersheds based upon proximity to the gages. Subwatersheds in the model are defined to conform with the natural tributary network, taking into consideration the location of small impoundments (NRCS structures and other reservoirs) of interest with regard to their potential impacts on a downstream water supply reservoir.

Direct runoff is estimated using curve numbers derived using standard NRCS methodology. The curve numbers are estimated spatially using hydrologic soil groups and land use types as described in the National Engineering Handbook-Section 4 (NEH-4) (NRCS, 1969) and Technical Release 55, Urban Hydrology for Small Watersheds (NRCS, 1986). Curve numbers are adjusted to account for antecedent soil moisture. Direct runoff is generally assumed to occur within the daily time step in response to the specified daily rainfall.

Routing of flows through small reservoirs is performed in a simplified manner consistent with the design criteria for NRCS structures. In summary:

- Subwatersheds are delineated within the watershed being modeled so as to include one or more small reservoirs.
- Reservoir parameters that affect flow routing are aggregated for all the small reservoirs in each subwatershed, including sediment pool and flood pool storage volumes and surface areas.
- The estimated volume of daily stormwater inflows into a small reservoir is compared to the available unused volume of sediment and flood pool storage capacity; if the inflow volume exceeds the storage capacity, the balance of the inflow is routed through the reservoir and discharged downstream.
- The daily rate for discharging stormwater stored in the flood pool is assumed to be one tenth of the total flood pool volume. This rate is consistent with NRCS design criteria.

In the SWAT model, evaporation and seepage losses from reservoirs are estimated based upon a daily accounting of reservoir surface area. The surface area for all small reservoirs included within a subwatershed is aggregated and tabulated as a function of the combined storage capacity at the principal spillway crest elevation (top of the sediment pool) and at the auxiliary spillway crest elevation (top of the flood pool). For other storage levels, the estimation of surface area is performed with a logarithmic interpolation. Evaporation loss is calculated as the product of a daily evaporation rate and the daily reservoir surface area. In SWAT, the daily evaporation rate is estimated based upon daily climatological data (solar radiation, air temperature, relative humidity, and wind speed) using the Penman-Monteith Method. Daily seepage loss through the reservoir bottom is similarly estimated as the product of the saturated hydraulic conductivity of local soils per the input SSURGO database and the daily reservoir surface area.

In SWAT, rainfall that occurs on a given day is added directly, without any losses, to the aggregate reservoir stored water volume. Rainfall volume is calculated as the product of the daily rainfall amount and the daily reservoir surface area. This surface area is subtracted from the remainder of the subwatershed area to prevent double-counting in the simulation of stormwater runoff from the subwatershed land area.

2.5.1.2 Watershed Storage Modeling

The SWAT model uses as inputs soil parameters available from the SSURGO spatial database for the watershed soils. SSURGO provides a representative soils profile (layers, by type, sequence from the surface, and thickness), with each layer defined by percent clay content, bulk density, available water capacity, and saturated hydraulic conductivity. The model uses these inputs to estimate soils field capacity and wilting point. Surface water estimated to enter the soil matrix (e.g., rain water infiltration) is accounted for daily. When the field capacity of the soil is exceeded, the water above field capacity is either percolated into groundwater, or discharged (with an exponential decay and time lag) to surface waters. Water percolating into groundwater is similarly accounted for, and released with further exponential decay and time lag into surface waters. This portion of the model estimates rainfall event recession curves and base flows.

Transmission losses into the bed and bank of natural channels are estimated within SWAT using the procedures in NEH-4, Chapter 19 “Transmission Losses” (Lane, 1983). In general the method involves the following steps:

- For each subwatershed, a representative natural channel cross-section is defined as a trapezoidal section with assigned roughness and bed slope.
- An average hydraulic conductivity is assigned to the cross-section based upon spatial NRCS soil survey data.
- A channel reach length is assigned for this section.
- Losses are estimated based an empirical equation that is a function of wetted perimeter (estimated based upon normal depth) and duration of wetting. The wetted perimeter varies with the estimated flow in the reach.

2.5.2 Sedimentation and Erosion

The Modified Universal Soil Loss Equation (MUSLE) (Williams, 1975) is used in the SWAT model to estimate the sediment yield from a given subwatershed. A lag equation is then applied to this yield to determine the quantity of sediment that enters a downstream reach or reservoir at a given time. If a reservoir is present in the subwatershed, the lag adjusted yield from the effective percentage of the watershed (the controlled portion of the subwatershed) enters the reservoir, while the remaining percentage enters the subwatershed reach. Once in the reservoir, the sediment either settles into the reservoir pool or leaves with the outflow from the reservoir. The sediment carried by the outflow from the reservoir then enters the reach. Additional sediment may be contributed to the reach by lateral and groundwater flow. Once in the reach, some sediment may settle out, or more sediment may be contributed by the reach. This will continue from reach to reach with sediment being added from additional subwatersheds.

All the above processes are modeled using user-selected parameters within empirical equations. Some of the parameter choices are based upon watershed, reservoir, or channel-specific data; some are largely based upon engineering judgment. The uncertainties associated with judgment-based parameter choices often must be addressed by sensitivity analyses within parameter ranges listed in SWAT model documentation.

2.5.2.1 Watershed Sediment Yield

Per the MUSLE, watershed sediment yield is a function of soil erodibility, watershed cover, support practices, watershed slope, and rock percentage. Soil erodibility is calculated in the SWAT model for each soil series polygon based on particle size, percent organic material, a soil structure factor, and a soil permeability factor, all associated with the soil series in the NRCS soil series database (SSURGO). The cover and management factor is assigned by SWAT based on cover type, derived from a GIS-based spatial land use file. For the SWAT models applied in this study, a value of “1” was assigned to the default support practice factor. The coarse fragment factor is based upon the percentage of rock in the surface soil layer, again based upon a value extracted from the SURGO database.

In the SWAT model, the amount of sediment released into the main channel of a subwatershed is estimated as an exponential decay function of the sediment yield (from MUSLE), input surface runoff lag coefficient, and subwatershed time of concentration. For the present study, it has been assumed that no sediment is contributed by lateral and groundwater flow to the stream reaches in either the Cedar Creek Reservoir or the Lake Coleman watersheds ,which is consistent with the manner in which these processes were addressed in the original calibration of the Cedar Creek watershed model (Nanrasimhan, Bednarz, and Srinivasan, 2008).

2.5.2.2 Channel Sedimentation/Erosion Processes

The basic method used in the SWAT model for estimating channel erosion and deposition encompasses the following steps:

- Channel reaches associated with subwatersheds as defined for purposes of applying the SWAT model are divided into reach segments, each defined by a representative hydraulic cross-section with a channel and an overbank, and an associated reach length.
- The maximum sediment concentration that can be transported through a channel reach segment is estimated as a function of a specified coefficient and exponent, each set by the user, and the peak channel velocity. The velocity is estimated each daily time step using

the representative subwatershed channel cross-section, the daily flow, and a normal flow calculation.

- The estimated sediment concentration in each channel reach segment as derived from sediment yield and transport calculations for upstream subwatersheds and reaches is compared to the previously determined maximum sediment concentration. If the estimated sediment concentration exceeds the maximum sediment concentration, deposition is assumed to occur in the reach segment. The volume of deposition is a function of the estimated channel reach segment volume. If the estimated sediment concentration is less than the maximum sediment concentration, degradation is assumed to occur within the reach segment. The amount of degradation is estimated as a function of an input channel erodibility factor and a channel cover factor.
- The amount of sediment leaving the entire reach for a subwatershed is estimated as the sum of erosion and deposition within the individual reach segments and the ratio of the full cross-section velocity to channel velocity.

2.5.3 Reservoir Sedimentation

Sedimentation processes in ponds and reservoirs in the SWAT model are based on a daily mass balance of estimated sediment inflow, outflow and change in storage within the pond or reservoir. The mass of sediment removed from a water body through settling in a given day is estimated as a function of concentration as follows:

- The initial suspended solid concentration is estimated based upon initial volume of suspended solids, volume of water stored at the beginning of the day, and volume of water entering on a given day.
- The suspended sediment concentration at the end of the day is estimated by an empirical exponential decay equation that is a function of an exponential decay constant, the time step (1 day), and mean sediment diameter (d50). The mean sediment diameter is estimated based upon data available within the SUURGO database considering percent clay, silt, and sand in the subwatershed surface layer.
- The amount of settling on a given day is estimated based upon the change in sediment concentration and the volume of water in the impoundment.
- The amount of sediment transported out of the water body on a given day is estimated by the final suspended sediment concentration times the daily outflow volume.

For evaluating the effects of sediment on the water supply capability of a downstream reservoir, an estimate of the volume of sediment accumulated in the reservoir is required. To convert the mass of sediment accumulated to a volume of sediment requires knowledge of the expected density of the sediment accumulated within the reservoir. No studies or data were available providing measured densities for deposited sediments within the primary water supply reservoirs or the flood retarding structure sediment pools within either of the subject watersheds. However, based upon recent reservoir studies conducted at Baylor University (Srinivasan, 2008), the sediment density used in the existing SWAT model for the Cedar Creek watershed is 35 pounds per cubic foot. This density reflects a soil/organics condition under near continuous submersion, which is not necessarily the condition for flood retarding structure sediment pools, especially in arid conditions. The analyses of sedimentation effects on water supply reservoirs in the present study were, therefore, performed assuming a likely minimum sediment density of 35 pounds per cubic foot and an alternative maximum sediment density of 100 pounds per cubic foot.

3.0 WATERSHED AND STRUCTURE MODELING

3.1 CEDAR CREEK RESERVOIR WATERSHED

3.1.1 Data and Information Sources

The SWAT model used for the analyses of the Cedar Creek watershed was previously developed by personnel from the Spatial Sciences Laboratory of Texas A&M University in cooperation with staff from the NRCS office in Temple, Texas (Nanrasimhan, Bednarz, and Srinivasan, 2008). Through this earlier study, the model was fully calibrated based on historic watershed flows and available sediment yield information. This earlier work is documented in the referenced report, which is attached as Appendix B to this report. The version of the SWAT program used for the model of the Cedar Creek Reservoir watershed was SWAT 2000.

The Cedar Creek watershed model was initially developed for the purpose of investigating the effect of alternative Best Management Practices (for cropland, pastureland, urban areas, and channels) on downstream sediment and nutrient loadings. The alternatives were analyzed using a calibrated model using climatological conditions for the years 1989 to 2002. Simulated streamflow in this study (Narasimhan, Bednarz, and Srinivasan, 2008) was calibrated for the period 1967-1987 using two USGS streamflow gage data records (Cedar Creek Gage 0806280 and King's Creek Gage 08062900) and Cedar Creek Reservoir stage/volume data. The calibrated model had R-squared values for these records, respectively of 0.81, 0.83, and 0.80. The sediment calibration of Cedar Creek Reservoir for the model considered the original (1966) as-built reservoir capacity, TWDB reservoir capacity surveys in 1995 and 2005, and 2006 Baylor University lake sediment and channel erosion surveys . After review of data showed inconsistencies between sedimentation rates 1966 to 1995 and 1995 to 2005, the model was calibrated to reproduce the average sedimentation rate for the period 1966 to 2005.

The basic information that provides inputs for the Cedar Creek SWAT model includes:

- USGS 1:24,000 topography
- NRCS SSURGO soils database
- USGS spatial land use data
- Historical daily rainfall and climatological data from the following stations:

  Rockwall
  Lake Ray Hubbard
  Terrell
  Wills Point
  Kaufman (gage 3 SE)
  Canton
  Crandall
  Athens, and

Trinidad Power Plant

- National Inventory of Dams
- National Hydrography Dataset

In the original Cedar Creek model, the dams upstream of Cedar Creek Reservoir were represented as impoundments using reservoir and dam structure dimensions derived from the National Inventory of Dams (NID). In this current study, the NID information for the NRCS-designed structures was supplemented with specific data obtained through review of the as-built drawings for the dams at the NRCS office in Temple, Texas. This information included primarily more accurate data describing the crest elevations for the principal and auxiliary spillways and the storage volumes and surface areas for the sediment pools and the flood pools.

A summary of available descriptive information for each of the structures included in the Cedar Creek Reservoir watershed as represented in the SWAT model is provided in Table 3-1.

3.1.2 SWAT Model Structure

The subwatersheds and the individual dams and reservoirs included in the SWAT model of the Cedar Creek Reservoir watershed are shown on the aerial photograph of the region in Figure A-1[4]. There are 106 subwatersheds and 116 dams and reservoirs considered in the model.

The basic elements of the Cedar Creek model include subwatersheds, streamflow routing reaches, reservoirs, and junctions at reach confluences. The basic network structure of the Cedar Creek SWAT model is presented in Figure A-2. No diversions or external sources of water (other than rainfall) are included in the model.

3.1.3 2006 Floodwater Retarding Structure Conditions

As noted earlier, in this study the initial modeling of floodwater retarding structures with the Cedar Creek SWAT model was performed with the sediment pool (normal pool) capacities and surface areas of these structures specified in accordance with their respective as-built conditions as derived from original design documents or available dam inspection reports. The existing structures within the Cedar Creek Reservoir watershed were constructed during the period from about 1940 to 1990. For analysis of the effects of the different assumed dam/impoundment management scenarios on the water supply capability of Cedar Creek Reservoir, the projected year-2055 sedimentation condition of the individual structures was required for each of the scenario alternatives. The initial task in the development of the different 2055 scenario sedimentation conditions was the estimation of the sedimentation condition of the existing structures in 2006. The activities involved in this process are described below:

<u>Aggregation of Structure Information</u> - As described in Section 2.0, as-built pond volume and surface area parameters were aggregated by subwatershed using the information presented in Table 3-1 for NRCS structures, coupled with the available NID-derived parameters for the non-NRCS designed structures. The resulting summary of subwatershed

[4] Figures with numbers preceded by A- are oversized and are contained in Appendix A of this report.

descriptions as included in the SWAT model is provided in Table 3-2. The percentage of subwatershed drainage area controlled by structures and the associated aggregate as-built sediment and flood pool surface areas and storage areas are indicated.

Performnce of As-Built SWAT Model Simulation - The SWAT model representing revised as-built structure conditions was operated with specified historical climatic conditions corresponding to the years 1945 through 2002 (per the simulation period in the previously constructed and calibrated model). Model results provided estimates of the quantity of sediment in tons trapped in the subwatershed aggregated normal pools (sediment pools) for each year of the simulation.

Determination of 2006 Structure Sediment Pool Conditions - The 1970-2002[5] average annual trapped sediment value from the SWAT model for the aggregate structure in each subwatershed was allocated to each individual structure within the subwatershed based on relative drainage area size. Then for each individual structure, the total sediment accumulation in tons was calculated over time beginning with the actual date of construction and extending to 2006. As described in Section 2.0, this sediment tonnage was converted to volume in acre-feet based on alternative sediment densities of 35 pounds per cubic feet and 100 pounds per cubic foot. If the estimated total sediment volume was less than the volume of the design sediment pool for a particular structure, then the design storage capacity of the sediment pool was reduced by this amount to produce the 2006 sediment pool capacity. If the estimated total sediment volume exceeded the volume of the design sediment pool for a particular structure, it was assumed that the design sediment pool capacity was reestablished through ongoing maintenance in 2006, and the 2006 capacity of the sediment pool was set equal to the design sediment pool capacity. Table 3-3 provides a summary of these calculations for each structure.

3.1.4 2055 Floodwater Retarding Structure Analyses

For each of the four different scenarios corresponding to different dam/impoundment management options described in Section 2.2, projections of year-2055 structure sedimentation conditions were made based on the 1970-2002 average annual sedimentation rates derived from the SWAT model simulations. Beginning with the actual 2006 sedimentation condition of each structure as derived above, the annual incremental decrease in the sediment pool storage capacity was calculated over time through the year 2055. At the point in time during the calculations when the sediment pool of each structure filled to its maximum capacity at the level of its primary spillway, adjustments were made in the sediment pool storage capacity in accordance with one of the different assumed dam/impoundment management options, and the pool sedimentation calculation process then was continued through the year 2055. The specific analyses undertaken to derive these 2055 structure sedimentation conditions are described in the following sections.

[5] As noted previously, the period 1970 to 2002 was chosen for establishing historical sediment accumulation volumes because: 1) it represents a long enough period to be deemed representative of historical climatic and hydrologic conditions, and 2) it is a period during which most of the studied floodwater retarding structures had been built; i.e. the period was a representative period during which the studied structures existed.

Table 3-1 Information available from NID and as-built drawings for structures in Cedar Creek Reservoir watershed

STRUCTURE NAME	NAT_ID	Year Completed	Designed by NRCS	Dam Height (feet)	Principal Spillway Elevation (feet msl)	Normal Storage Capacity (ac-ft)	Normal Surface Area (acres)	Auxillary Spillway Elevation (feet msl)	Auxillary Spillway Area (acres)	Auxillary Spillway Storage (ac-ft)	Top of Dam Elevation (feet msl)	Top of Dam Area (acres)	Top of Dam Storage (ac-ft)
CEDAR CREEK WS SCS GSS 101	TX09314	1984	√	19	389.0	15	2.0	394.0	9.3	39.5	396.9	19.4	87.0
CEDAR CREEK WS SCS GSS 102	TX09315	1984	√	16	392.0	11	2.3	394.0	15.7	68.0	399.4	17.7	83.4
CEDAR CREEK WS SCS GSS 103	TX09316	1984	√	10	400.0	3	2.2	403.0	6.0	14.6	405.0	10.5	31.8
CEDAR CREEK WS SCS SITE 101 DAM	TX02825	1969	√	33	443.2	200	96.0	453.0	500.0	3,286.0	456.8	660.0	5,019.0
CEDAR CREEK WS SCS SITE 102 DAM	TX02826	1969	√	22	476.7	87	25.0	485.5	123.0	705.0	488.5	179.0	1,345.0
CEDAR CREEK WS SCS SITE 103 DAM	TX02827	1968	√	29	470.6	60	81.0	478.0	228.0	1,318.0	482.0	335.0	2,429.0
CEDAR CREEK WS SCS SITE 104 DAM	TX02848	1968	√	30	470.2	200	60.0	480.0	223.5	1,580.0	483.8	366.0	2,757.0
CEDAR CREEK WS SCS SITE 105 DAM	TX02828	1968	√	25	461.3	55	19.0	469.5	55.0	353.0	471.9	71.3	500.2
CEDAR CREEK WS SCS SITE 105A DAM	TX02829	1967	√	25	446.8	33	10.0	457.0	53.0	315.0	460.0	73.0	506.0
CEDAR CREEK WS SCS SITE 109 DAM	TX02820	1973	√	23	421.7	86	21.0	430.0	65.0	433.0	432.9	88.2	673.0
CEDAR CREEK WS SCS SITE 11 DAM	TX00793	1966	√	27	522.6	200	53.0	529.5	141.0	870.0	532.3	190.0	1,288.0
CEDAR CREEK WS SCS SITE 110 DAM	TX02821	1968	√	29	405.2	174	48.0	414.5	140.0	1,011.0	417.4	177.0	1,460.0
CEDAR CREEK WS SCS SITE 111F DAM	TX06824	1983	√	27	432.4	26	8.0	442.5	33.0	222.0	445.5	48.0	339.0
CEDAR CREEK WS SCS SITE 113 DAM	TX02822	1973	√	29	409.2	109	30.0	419.5	94.0	729.0	422.9	125.6	1,117.0
CEDAR CREEK WS SCS SITE 114 DAM	TX02823	1973	√	27	396.0	64	19.0	406.8	76.0	560.0	410.2	100.0	853.0
CEDAR CREEK WS SCS SITE 117 DAM	TX04480	1978	√	34	375.6	75	20.0	388.5	104.0	837.0	394.0	163.4	1,468.4
CEDAR CREEK WS SCS SITE 120 DAM	TX04521	1976	√	28	382.5	38	11.0	392.5	37.0	265.0	395.0	46.0	369.0
CEDAR CREEK WS SCS SITE 121A DAM	TX04522	1976	√	22	366.5	28	10.0	374.5	36.0	206.0	377.5	52.0	338.0
CEDAR CREEK WS SCS SITE 122A DAM	TX06736	1989	√	23	402.2	44	16.0	414.5	76.0	593.0	417.5	96.0	850.0
CEDAR CREEK WS SCS SITE 123 DAM	TX02843	1965	√	30	483.0	88	23.0	495.0	155.0	1,122.0	499.0	230.0	1,883.0
CEDAR CREEK WS SCS SITE 124 DAM	TX02844	1965	√	22	470.5	67	29.0	481.5	98.0	733.0	485.2	138.4	1,180.6
CEDAR CREEK WS SCS SITE 126 DAM	TX02847	1965	√	25	451.5	23	8.0	464.0	49.0	336.0	467.0	65.5	516.0
CEDAR CREEK WS SCS SITE 127 DAM	TX02846	1966	√	24	442.0	94	24.0	452.0	86.0	554.0	455.1	121.6	898.9
CEDAR CREEK WS SCS SITE 128 DAM	TX02818	1966	√	25	431.2	164	38.0	440.5	139.0	960.0	443.5	195.0	1,471.5
CEDAR CREEK WS SCS SITE 129 DAM	TX02819	1965	√	20	436.8	75	24.0	444.0	85.0	438.0	446.7	124.1	727.6
CEDAR CREEK WS SCS SITE 130A DAM	TX02815	1966	√	25	365.3	24	65.0	406.5	43.6	280.0	409.5	64.1	458.3
CEDAR CREEK WS SCS SITE 130B DAM	TX03333	1966	√	20	381.5	28	10.0	390.6	47.0	277.0	393.6	64.8	465.3
CEDAR CREEK WS SCS SITE 131 DAM	TX02816	1965	√	30	384.5	82	22.0	396.0	73.0	575.0	399.1	97.4	851.5
CEDAR CREEK WS SCS SITE 134 DAM	TX02798	1965	√	36	448.5	121	33.0	464.0	205.0	1,738.0	468.3	305.7	2,830.1
CEDAR CREEK WS SCS SITE 135A DAM	TX02814	1966	√	22	442.5	17	7.5	451.0	39.0	202.0	454.1	56.6	361.6
CEDAR CREEK WS SCS SITE 135B DAM	TX02797	1966	√	22	439.7	38	14.5	451.0	98.0	580.0	453.8	234.0	1,675.0
CEDAR CREEK WS SCS SITE 135C DAM	TX02808	1966	√	37	405.0	108	35.0	418.0	228.0	1,617.0	421.4	301.5	2,557.0
CEDAR CREEK WS SCS SITE 136 DAM	TX02809	1965	√	30	405.2	63	18.4	417.0	63.8	513.0	419.9	79.9	732.9
CEDAR CREEK WS SCS SITE 137 DAM	TX02810	1965	√	33	389.3	62	14.0	401.0	52.0	412.0	404.0	69.0	590.0
CEDAR CREEK WS SCS SITE 138 DAM	TX02811	1968	√	29	391.3	89	21.0	401.6	72.0	542.0	404.9	102.0	838.0
CEDAR CREEK WS SCS SITE 139 DAM	TX02812	1968	√	30	395.4	44	11.0	403.5	39.0	239.0	406.2	97.0	360.0
CEDAR CREEK WS SCS SITE 140 DAM	TX02813	1960	√	31	388.6	200	56.0	402.5	249.0	2,163.0	406.7	310.0	3,200.0
CEDAR CREEK WS SCS SITE 143A DAM	TX05948	1985	√	45	404.0	3,768	353.5	410.4	520.0	6,560.0	414.0	625.0	8,447.0
CEDAR CREEK WS SCS SITE 14A DAM	TX00795	1971	√	26	510.6	108	24.0	518.0	60.8	414.8	520.5	81.0	610.0
CEDAR CREEK WS SCS SITE 15 DAM	TX03377	1971	√	23	485.3	124	33.0	492.5	77.0	532.0	495.5	102.0	847.0
CEDAR CREEK WS SCS SITE 16 DAM	TX00791	1969	√	20	487.6	199	67.0	495.0	226.0	1,264.0	497.8	325.0	2,080.0
CEDAR CREEK WS SCS SITE 16A DAM	TX00790	1969	√	28	506.0	200	113.0	513.5	360.0	2,011.0	516.7	512.0	3,110.0
CEDAR CREEK WS SCS SITE 18 DAM	TX03379	1971	√	28	479.8	197	42.0	490.0	134.0	1,048.0	493.1	172.0	1,530.0
CEDAR CREEK WS SCS SITE 19 DAM	TX03378	1973	√	26	465.6	199	63.0	474.0	170.0	1,281.0	478.0	264.0	2,147.0
CEDAR CREEK WS SCS SITE 1A DAM	TX00811	1971	√	27	557.4	99	32.0	564.0	100.0	531.0	567.3	137.0	935.0
CEDAR CREEK WS SCS SITE 1B DAM	TX00812	1971	√	22	564.8	46	14.0	571.5	40.0	218.0	573.9	52.0	330.0
CEDAR CREEK WS SCS SITE 2 DAM	TX00813	1971	√	25	557.2	50	13.0	564.7	39.0	233.0	568.6	54.0	410.0
CEDAR CREEK WS SCS SITE 3 DAM	TX00814	1971	√	29	548.5	63	13.0	556.0	40.0	262.0	559.1	58.0	405.0
CEDAR CREEK WS SCS SITE 31 DAM	TX04509	1974	√	23	432.7	21	14.0	439.0	37.0	209.0	441.1	52.0	303.0
CEDAR CREEK WS SCS SITE 32 DAM	TX04335	1977	√	19	433.4	73	17.0	440.5	36.0	263.0	443.1	47.0	368.0

Table 3-1 (cont'd.)

STRUCTURE NAME	NAT_ID	Year Com-pleted	Designed by NRCS	Dam Height (feet)	Principal Spillway Elevation (feet msl)	Normal Storage Capacity (ac-ft)	Normal Surface Area (acres)	Auxillary Spillway Elevation (feet msl)	Auxillary Spillway Area (acres)	Auxillary Spillway Storage (ac-ft)	Top of Dam Elevation (feet msl)	Top of Dam Area (acres)	Top of Dam Storage (ac-ft)
CEDAR CREEK WS SCS SITE 33 DAM	TX04510	1975	√	27	417.8	58	12.0	426.0	27.0	206.0	428.6	32.0	290.0
CEDAR CREEK WS SCS SITE 4 DAM	TX00815	1971	√	25	546.9	46	10.5	553.5	36.0	185.0	556.1	46.0	300.0
CEDAR CREEK WS SCS SITE 43A DAM	TX05806	1982	√	47	408.5	59	17.0	419.5	71.0	504.0	422.5	103.0	776.5
CEDAR CREEK WS SCS SITE 46REV DAM	TX05807	1982	√	20	497.8	27	8.0	505.2	29.0	144.8	508.0	45.0	253.0
CEDAR CREEK WS SCS SITE 47A DAM	TX06731	1985	√	21	473.2	154	51.0	482.5	177.0	1,244.0	485.5	247.0	1,879.0
CEDAR CREEK WS SCS SITE 5 DAM	TX00816	1971	√	25	540.0	56	14.0	547.0	36.0	220.0	549.3	45.0	319.0
CEDAR CREEK WS SCS SITE 50C DAM	TX04633	1979	√	26	473.7	109	65.0	484.0	340.0	2,197.0	488.1	485.0	3,775.0
CEDAR CREEK WS SCS SITE 55B DAM	TX06732	1978	√	22	449.9	46	14.6	456.5	53.0	265.0	459.5	76.5	465.0
CEDAR CREEK WS SCS SITE 57 DAM	TX03338	1962	√	23	447.8	325	96.0	456.0	264.0	1,788.0	459.9	342.5	3,000.0
CEDAR CREEK WS SCS SITE 58 DAM	TX03339	1962	√	19	450.7	62	17.0	457.5	47.0	273.0	460.5	62.0	483.0
CEDAR CREEK WS SCS SITE 59 DAM	TX03340	1962	√	15	444.2	35	13.0	450.0	42.0	186.0	452.4	53.4	300.0
CEDAR CREEK WS SCS SITE 6 DAM	TX00817	1971	√	26	528.8	71	23.0	535.5	50.0	295.0	538.6	62.0	442.0
CEDAR CREEK WS SCS SITE 60 DAM	TX03350	1962	√	35	431.4	1,834	350.3	436.7	592.4	4,254.0	443.7	900.0	7,500.0
CEDAR CREEK WS SCS SITE 61 DAM	TX03349	1954	√	31	397.8	120	39.4	407.0	118.8	782.0	413.5	?	?
CEDAR CREEK WS SCS SITE 63 DAM	TX04511	1975	√	17	386.3	30	10.0	395.5	36.0	240.0	397.7	47.0	339.0
CEDAR CREEK WS SCS SITE 64R DAM	TX06490	1988	√	21	382.9	64	20.0	391.5	63.0	424.0	394.9	80.0	680.0
CEDAR CREEK WS SCS SITE 65 DAM	TX04512	1975	√	21	378.0	48	21.0	387.5	92.0	587.0	391.1	156.0	952.0
CEDAR CREEK WS SCS SITE 66 DAM	TX04513	1975	√	20	376.2	25	9.0	384.0	48.0	239.0	386.4	62.0	382.0
CEDAR CREEK WS SCS SITE 68 DAM	TX04514	1975	√	16	377.3	17	6.0	385.0	16.0	103.0	387.9	23.0	152.0
CEDAR CREEK WS SCS SITE 68A DAM	TX05783	1982	√	26	380.0	12	4.0	389.5	12.0	77.0	392.6	17.0	121.0
CEDAR CREEK WS SCS SITE 69 DAM	TX04515	1975	√	31	381.8	86	20.0	395.0	71.0	678.0	398.6	96.0	971.0
CEDAR CREEK WS SCS SITE 7 DAM	TX00818	1971	√	24	532.2	45	12.0	539.0	30.0	186.0	541.1	35.0	252.0
CEDAR CREEK WS SCS SITE 70 DAM	TX04516	1974	√	25	366.3	110	34.0	375.0	101.0	673.0	378.0	132.0	1,021.0
CEDAR CREEK WS SCS SITE 71 DAM	TX04517	1974	√	27	376.5	65	18.0	387.0	65.0	493.0	390.3	81.0	729.0
CEDAR CREEK WS SCS SITE 72 DAM	TX06734	1977	√	24	363.5	52	13.0	370.5	39.0	233.0	373.2	49.0	352.0
CEDAR CREEK WS SCS SITE 73REV DAM	TX04924	1980	√	23	367.6	67	25.0	375.5	60.0	397.0	378.5	74.0	600.0
CEDAR CREEK WS SCS SITE 76 DAM	TX03334	1962	√	20	420.8	104	83.0	427.0	199.0	1,155.0	430.7	305.0	1,800.0
CEDAR CREEK WS SCS SITE 77A DAM	TX03335	1962	√	21	404.0	199	76.0	412.0	207.0	1,399.0	414.7	277.7	2,058.0
CEDAR CREEK WS SCS SITE 82 DAM	TX05784	1982	√	22	362.2	134	37.0	369.3	69.0	489.0	372.3	95.0	742.0
CEDAR CREEK WS SCS SITE 83 DAM	TX04518	1974	√	22	366.0	42	11.9	374.5	46.0	260.0	376.6	64.0	376.0
CEDAR CREEK WS SCS SITE 84 DAM	TX04519	1974	√	21	354.3	70	21.0	362.5	72.0	431.0	364.9	89.0	627.0
CEDAR CREEK WS SCS SITE 85 DAM	TX04520	1974	√	25	381.5	109	28.0	389.0	81.0	503.0	391.7	105.0	749.0
CEDAR CREEK WS SCS SITE 87A DAM	TX03341	1955	√	43	503.5	8,712	1,274.0	509.8	1,290.0	14,900.0	513.2	1,607.4	19,831.2
CEDAR CREEK WS SCS SITE 88 DAM	TX03342	1966	√	22	501.5	37	16.0	510.0	73.0	405.0	513.1	99.6	685.9
CEDAR CREEK WS SCS SITE 89 DAM	TX03343	1966	√	21	489.2	24	8.5	498.0	52.0	250.0	501.0	71.0	469.7
CEDAR CREEK WS SCS SITE 90 DAM	TX03344	1967	√	20	480.7	56	20.0	487.5	89.0	405.0	490.3	128.4	718.5
CEDAR CREEK WS SCS SITE 92 DAM	TX03346	1971	√	31	522.1	101	45.3	534.0	262.0	1,750.0	538.0	388.0	3,050.0
CEDAR CREEK WS SCS SITE 94B DAM	TX06735	1980	√	20	495.7	56	15.0	503.5	62.0	329.0	506.5	84.0	555.0
CEDAR CREEK WS SCS SITE 94C DAM	TX04479	1978	√	19	486.6	38	14.0	494.0	44.0	258.0	497.1	62.0	421.0
CEDAR CREEK WS SCS SITE 95A DAM	TX03347	1971	√	45	450.0	198	86.0	467.8	545.0	5,340.0	473.6	807.5	9,260.2
CEDAR CREEK WS SCS SITE 96 DAM	TX03348	1969	√	24	441.3	47	16.0	448.0	53.0	267.0	451.0	80.0	464.0
JOHN SANTERRE LAKE DAM	TX00239	1960		16		63	12.0		57.6	95.0			
KAUFMAN CITY LAKE DAM 1	TX03351	1900		10		180	45.0		216.0	259.0			
KAUFMAN CITY LAKE DAM 2	TX03352	1910		16		264	55.0		264.0	441.0			
KAUFMAN DAM NO 1	TX09050	1940		8		10	3.0		14.4	0.0			
KAUFMAN DAM NO 2	TX09049	1950		13		48	12.0		57.6	0.0			
KEMP LAKE DAM	TX03332	1926		35		300	35.0		168.0	469.0			
LEE LAKE DAM	TX00226	1956		23		90	12.0		57.6	110.0			
MABANK CITY LAKE DAM	TX00240	1926		24		216	47.0		225.6	216.0			

Table 3-1 (cont'd.)

STRUCTURE NAME	NAT_ID	Year Completed	Designed by NRCS	Dam Height (feet)	Principal Spillway Elevation (feet msl)	Normal Storage Capacity (ac-ft)	Normal Surface Area (acres)	Auxillary Spillway Elevation (feet msl)	Auxillary Spillway Area (acres)	Auxillary Spillway Storage (ac-ft)	Top of Dam Elevation (feet msl)	Top of Dam Area (acres)	Top of Dam Storage (ac-ft)
MEADOW WOOD LAKE NO 3 DAM	TX06890	1950		15		26	6.0		28.8	58.0			
MEADOW WOOD LAKE NO 4 DAM	TX07154	1960		23		40	12.0		57.6	112.0			
NOLAN LAKE DAM	TX05206	1977		28		72	21.0		100.8	180.0			
NORTH HAVEN CONSTRUCTION CO LAKE DAM	TX03372	1964		18		52	10.0		48.0	130.0			
PORTER LAKE DAM	TX03373	1966		16		108	15.0		72.0	196.0			
RICHARDS LAKE DAM	TX02817	1968		18		56	10.0		48.0	115.0			
ROBERTS LAKE DAM	TX03375	1970		18		48	10.0		48.0	108.0			
STARBRAND LAKE DAM	TX05205	1947		27		210	0.0		0.0	378.0			
STOUT DAM	TX09074	1960		17		12	2.0		9.6	0.0			
TAWAKONI BALANCING RESERVOIR LEVEE	TX03374	1963		31		998	59.0		283.2	1,168.0			
TERRELL COUNTRY CLUB LAKE DAM	TX03376	1905		16		645	0.0		0.0	1,217.0			
THOMAS LAKE DAM	TX00223	1959		37		1,053	0.0		0.0	1,900.0			
TONKERSLEY LAKE DAM	TX03345	1962		21		82	12.0		57.6	150.0			
VALLEY VIEW LAKE DAM	TX06396	1991		32		2,250	328.0		1,574.4	8,200.0			
WELLS DAM	TX03329	1955		16		96	20.0		96.0	243.0			
WEST LAKE DAM	TX04264	1973		26		370	0.0		0.0	504.0			
WILLIAMS DAM	TX09090	1990		10		19	5.0		24.0	39.0			
TOTAL						**28,900**	**5,190.9**		**14,845.7**	**102,815.7**		**15,570.5**	**132,774.0**

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Table 3-2 Summary of aggregated structures by subwatershed in Cedar Creek Reservoir watershed

Sub-watershed ID	Percent of Watershed Controlled by Structures	Aggregate Sediment Pool Surface Area (acres)	Aggregate Sediment Pool Volume (acre-feet)	Aggregate Flood Pool Surface Area (acres)	Aggregate Flood Pool Volume (acre-feet)
1	50%	132	530	371	2,130
2	19%	53	220	141	870
3	45%	24	108	61	415
4	30%	66	272	251	1,034
5	60%	180	564	586	3,275
6	4%	10	48	48	108
7	74%	138	640	381	2,861
8	0%	0	0	0	0
9	37%	133	1,287	561	2,753
10	89%	65	109	340	2,197
11	10%	20	73	138	502
12	1%	10	52	48	130
13	0%	0	0	0	0
14	14%	18	771	86	1,387
15	0%	0	0	0	0
16	0%	0	0	0	0
17	68%	81	200	228	1,318
18	66%	89	322	279	2,048
19	0%	0	0	0	0
20	65%	141	521	406	2,512
21	7%	1,331	8,499	1,562	16,110
22	79%	160	469	913	7,677
23	75%	96	310	500	3,286
24	20%	35	120	176	1,020
25	0%	0	0	0	0
26	0%	0	0	0	0
27	0%	0	0	0	0
28	5%	18	78	33	318
29	0%	0	0	0	0
30	0%	0	0	0	0
31	0%	0	0	0	0
32	15%	87	381	407	945
33	11%	50	468	131	1,178
34	0%	0	0	0	0
35	35%	48	174	140	1,011
36	39%	64	257	159	1,282
37	0%	0	0	0	0
38	21%	39	120	119	782
39	42%	84	249	388	2,745
40	28%	33	121	205	1,738
41	18%	16	50	190	593
42	8%	16	414	76	1,097
43	55%	38	164	139	960
44	91%	57	160	365	2,399
45	44%	6	106	16	103
46	0%	0	0	0	0
47	5%	22	239	0	302
48	19%	10	28	36	206
49	0%	0	0	0	0
50	17%	10	32	64	206
51	38%	221	827	559	3,551
52	39%	117	447	418	2,580
53	0%	0	0	0	0
54	0%	25	67	60	397

Table 3-2 (cont'd.)

Sub-watershed ID	Percent of Watershed Controlled by Structures	Aggregate Sediment Pool Surface Area (acres)	Aggregate Sediment Pool Volume (acre-feet)	Aggregate Flood Pool Surface Area (acres)	Aggregate Flood Pool Volume (acre-feet)
55	33%	163	390	412	2,610
56	0%	0	0	0	0
57	0%	0	0	0	0
58	0%	0	0	0	0
59	0%	0	0	0	0
60	0%	0	0	0	0
61	92%	354	3,768	520	6,560
62	0%	0	0	0	0
63	0%	0	0	0	0
64	24%	95	1,053	105	1,159
65	0%	0	0	0	0
66	12%	25	199	58	240
67	0%	0	0	0	0
68	0%	328	2,250	1,574	8,200
69	0%	0	0	0	0
70	2%	7	72	8	79
71	0%	0	0	0	0
72	76%	88	333	360	2,944
73	0%	0	0	0	0
74	8%	22	95	24	105
75	0%	0	0	0	0
76	0%	0	0	0	0
77	0%	0	0	0	0
78	0%	0	0	0	0
79	0%	0	0	0	0
80	36%	60	160	239	1,490
81	29%	39	139	180	1,397
82	0%	0	0	0	0
83	0%	0	0	0	0
84	0%	0	0	0	0
85	7%	47	296	226	216
86	0%	0	0	0	0
87	0%	0	0	0	0
88	0%	0	0	0	0
89	0%	0	0	0	0
90	17%	56	371	269	653
91	0%	0	0	0	0
92	0%	0	0	0	0
93	3%	5	19	24	39
94	0%	0	0	0	0
95	5%	12	63	13	70
96	0%	0	0	0	0
97	0%	0	0	0	0
98	0%	0	0	0	0
99	0%	0	0	0	0
100	0%	0	0	0	0
101	0%	0	0	0	0
102	0%	0	0	0	0
103	0%	0	0	0	0
104	65%	28	109	81	503
105	17%	28	117	120	503
106	0%	0	0	0	0
TOTAL		**5,098**	**28,931**	**14,793**	**100,791**

Shading indicates data were not available to update model, so existing model inputs were used.

Table 3-3 Summary of 2006 sediment pool storage calculations for structures in Cedar Creek Reservoir watershed

Structure Name	Sub-watershed ID	NRCS Drainage Area (acres)	Year Com-pleted	Years of Accum-ulated Sediment to 2006	Estimated Average Annual Sediment Loading (tons/yr)	Area Weighted Ave Annual Sediment Loading (tons/yr)	Sediment Loading From Construction to 2006 (tons)	As-Built Sediment Pool Storage Capacity (ac-ft)	Total Accumulated Sediment Volume 35 lbs/ft^3 (ac-ft)	Total Accumulated Sediment Volume 100 lbs/ft^3 (ac-ft)	2006 Sediment Pool Capacity 35 lbs/ft^3 (ac-ft)	2006 Sediment Pool Capacity 100 lbs/ft^3 (ac-ft)
CEDAR CREEK WS SCS GSS 101	33	482.5	1984	22	4,069	341	7,500	14.7	11.0	3.9	3.7	10.8
CEDAR CREEK WS SCS GSS 102	33	894.2	1984	22	4,069	632	13,900	11.0	20.4	7.1	Note [2]	3.9
CEDAR CREEK WS SCS GSS 103	33	3061.3	1984	22	4,069	2,163	47,586	3.0	69.9	24.5	Note [2]	Note [2]
CEDAR CREEK WS SCS SITE 101 DAM	23	482.5	1969	37	3,222	1,400	51,805	310.0	76.1	26.6	233.9	283.4
CEDAR CREEK WS SCS SITE 102 DAM	24	1118.8	1969	37	1,484	1,027	37,994	87.0	55.8	19.5	31.2	67.5
CEDAR CREEK WS SCS SITE 103 DAM	17	2334.5	1968	38	1,544	1,544	58,663	200.0	86.2	30.2	113.8	169.8
CEDAR CREEK WS SCS SITE 104 DAM	18	2622.2	1968	38	1,590	1,208	45,921	211.0	67.5	23.6	143.5	187.4
CEDAR CREEK WS SCS SITE 105 DAM	18	736.3	1968	38	1,590	339	12,894	55.0	18.9	6.6	36.1	48.4
CEDAR CREEK WS SCS SITE 105A DAM	24	497.5	1967	39	1,484	457	17,809	33.0	26.2	9.2	6.8	23.8
CEDAR CREEK WS SCS SITE 109 DAM	36	815.5	1973	33	1,023	363	11,978	86.0	17.6	6.2	68.4	79.8
CEDAR CREEK WS SCS SITE 11 DAM	2	1334.5	1966	40	2,128	2,128	85,106	220.0	125.0	43.8	95.0	176.2
CEDAR CREEK WS SCS SITE 110 DAM	35	1587.0	1968	38	1,973	1,973	74,976	174.0	110.2	38.6	63.8	135.4
CEDAR CREEK WS SCS SITE 111F DAM	28	414.2	1983	23	3,464	2,523	58,022	26.0	85.2	29.8	Note [2]	Note [2]
CEDAR CREEK WS SCS SITE 113 DAM	36	1395.3	1973	33	1,023	621	20,493	109.0	30.1	10.5	78.9	98.5
CEDAR CREEK WS SCS SITE 114 DAM	81	1039.2	1973	33	2,699	2,699	89,072	64.0	130.9	45.8	Note [2]	18.2
CEDAR CREEK WS SCS SITE 117 DAM	80	1847.3	1978	28	1,517	679	19,005	75.0	27.9	9.8	47.1	65.2
CEDAR CREEK WS SCS SITE 120 DAM	48	368.7	1976	30	4,347	1,996	59,886	38.0	88.0	30.8	Note [2]	7.2
CEDAR CREEK WS SCS SITE 121A DAM	48	434.2	1976	30	4,347	2,351	70,523	28.0	103.6	36.3	Note [2]	Note [2]
CEDAR CREEK WS SCS SITE 122A DAM	42	Note [1]	1989	17	3,144	34	578	44.0	0.8	0.3	43.2	43.7
CEDAR CREEK WS SCS SITE 123 DAM	39	1669.6	1965	41	3,896	1,365	55,969	78.0	82.2	28.8	Note [2]	49.2
CEDAR CREEK WS SCS SITE 124 DAM	39	1450.6	1965	41	3,896	1,186	48,627	67.0	71.4	25.0	Note [2]	42.0
CEDAR CREEK WS SCS SITE 126 DAM	39	621.0	1965	41	3,896	508	20,816	23.0	30.6	10.7	Note [2]	12.3
CEDAR CREEK WS SCS SITE 127 DAM	39	1023.4	1966	40	3,896	837	33,469	81.0	49.2	17.2	31.8	63.8
CEDAR CREEK WS SCS SITE 128 DAM	43	1416.3	1966	40	673	673	26,930	164.0	39.6	13.8	124.4	150.2
CEDAR CREEK WS SCS SITE 129 DAM	55	659.2	1965	41	2,261	355	14,555	75.0	21.4	7.5	53.6	67.5
CEDAR CREEK WS SCS SITE 130A DAM	55	492.3	1966	40	2,261	265	10,604	24.0	15.6	5.5	8.4	18.5
CEDAR CREEK WS SCS SITE 130B DAM	55	525.6	1966	40	2,261	283	11,321	28.0	16.6	5.8	11.4	22.2
CEDAR CREEK WS SCS SITE 131 DAM	55	854.0	1965	41	2,261	460	18,855	82.0	27.7	9.7	54.3	72.3
CEDAR CREEK WS SCS SITE 134 DAM	40	3558.2	1965	41	7,105	7,105	291,308	121.0	428.0	149.8	Note [2]	Note [2]
CEDAR CREEK WS SCS SITE 135A DAM	44	448.6	1966	40	5,384	453	18,118	14.0	26.6	9.3	Note [2]	4.7
CEDAR CREEK WS SCS SITE 135B DAM	44	999.8	1966	40	5,384	1,009	40,379	38.0	59.3	20.8	Note [2]	17.2
CEDAR CREEK WS SCS SITE 135C DAM	44	3883.8	1966	40	5,384	3,921	156,853	108.0	230.5	80.7	Note [2]	27.3
CEDAR CREEK WS SCS SITE 136 DAM	55	874.6	1965	41	2,261	471	19,307	63.0	28.4	9.9	34.6	53.1
CEDAR CREEK WS SCS SITE 137 DAM	55	656.0	1965	41	2,261	353	14,483	62.0	21.3	7.4	40.7	54.6
CEDAR CREEK WS SCS SITE 138 DAM	72	830.7	1968	38	4,387	656	24,925	89.0	36.6	12.8	52.4	76.2
CEDAR CREEK WS SCS SITE 139 DAM	72	372.6	1968	38	4,387	294	11,181	44.0	16.4	5.7	27.6	38.3
CEDAR CREEK WS SCS SITE 140 DAM	72	4352.5	1960	46	4,387	3,437	158,094	200.0	232.3	81.3	Note [2]	118.7
CEDAR CREEK WS SCS SITE 143A DAM	61	6555.8	1985	21	6,756	6,756	141,874	3,768.0	208.4	73.0	3,559.6	3,695.0
CEDAR CREEK WS SCS SITE 14A DAM	3	552.2	1971	35	3,341	3,341	116,926	108.0	171.8	60.1	Note [2]	47.9
CEDAR CREEK WS SCS SITE 15 DAM	7	785.5	1971	35	3,649	553	19,366	124.0	28.5	10.0	95.5	114.0
CEDAR CREEK WS SCS SITE 16 DAM	5	1684.9	1969	37	4,899	1,700	62,900	199.0	92.4	32.3	106.6	166.7
CEDAR CREEK WS SCS SITE 16A DAM	5	3170.9	1969	37	4,899	3,199	118,377	365.0	173.9	60.9	191.1	304.1
CEDAR CREEK WS SCS SITE 18 DAM	7	1579.6	1971	35	3,649	1,113	38,945	197.0	57.2	20.0	139.8	177.0
CEDAR CREEK WS SCS SITE 19 DAM	7	2814.4	1973	33	3,649	1,983	65,425	319.0	96.1	33.6	222.9	285.4
CEDAR CREEK WS SCS SITE 1A DAM	1	965.1	1971	35	2,169	458	16,015	99.0	23.5	8.2	75.5	90.8
CEDAR CREEK WS SCS SITE 1B DAM	1	339.8	1971	35	2,169	161	5,639	46.0	8.3	2.9	37.7	43.1
CEDAR CREEK WS SCS SITE 2 DAM	1	622.2	1971	35	2,169	295	10,325	50.0	15.2	5.3	34.8	44.7
CEDAR CREEK WS SCS SITE 3 DAM	1	400.8	1971	35	2,169	190	6,650	63.0	9.8	3.4	53.2	59.6
CEDAR CREEK WS SCS SITE 31 DAM	33	411.0	1974	32	4,069	290	9,292	55.0	13.7	4.8	41.3	50.2
CEDAR CREEK WS SCS SITE 32 DAM	33	382.4	1977	29	4,069	270	7,835	73.0	11.5	4.0	61.5	69.0

Table 3-3 (cont'd.)

Structure Name	Sub-watershed ID	NRCS Drainage Area (acres)	Year Com-pleted	Years of Accum-ulated Sediment to 2006	Estimated Average Annual Sediment Loading (tons/yr)	Area Weighted Ave Annual Sediment Loading (tons/yr)	Sediment Loading From Construction to 2006 (tons)	As-Built Sediment Storage Capacity (ac-ft)	Total Accumulated Sediment Volume 35 lbs/ft^3 (ac-ft)	Total Accumulated Sediment Volume 100 lbs/ft^3 (ac-ft)	2006 Sediment Pool Capacity 35 lbs/ft^3 (ac-ft)	2006 Sediment Pool Capacity 100 lbs/ft^3 (ac-ft)
CEDAR CREEK WS SCS SITE 33 DAM	33	322.9	1975	31	4,069	228	7,072	58.0	10.4	3.6	47.6	54.4
CEDAR CREEK WS SCS SITE 4 DAM	1	279.2	1971	35	2,169	132	4,634	46.0	6.8	2.4	39.2	43.6
CEDAR CREEK WS SCS SITE 43A DAM	32	903.9	1982	24	8,875	2,979	71,491	59.0	105.0	36.8	Note [2]	22.2
CEDAR CREEK WS SCS SITE 46REV DAM	9	393.8	1982	24	6,808	779	18,706	27.0	27.5	9.6	Note [2]	17.4
CEDAR CREEK WS SCS SITE 47A DAM	9	2573.2	1985	21	6,808	5,093	106,944	154.0	157.1	55.0	Note [2]	99.0
CEDAR CREEK WS SCS SITE 5 DAM	1	329.9	1971	35	2,169	156	5,474	56.0	8.0	2.8	48.0	53.2
CEDAR CREEK WS SCS SITE 50C DAM	10	5284.7	1979	27	5,372	5,372	145,056	109.0	213.1	74.6	Note [2]	34.4
CEDAR CREEK WS SCS SITE 55B DAM	20	Note [1]	1978	28	8,470	6	162	41.0	0.2	0.1	40.8	40.9
CEDAR CREEK WS SCS SITE 57 DAM	20	2593.0	1962	44	8,470	6,084	267,685	328.0	393.3	137.7	Note [2]	190.3
CEDAR CREEK WS SCS SITE 58 DAM	20	472.6	1962	44	8,470	1,109	48,792	57.0	71.7	25.1	Note [2]	31.9
CEDAR CREEK WS SCS SITE 59 DAM	20	247.1	1962	44	8,470	580	25,508	35.0	37.5	13.1	Note [2]	21.9
CEDAR CREEK WS SCS SITE 6 DAM	1	415.2	1971	35	2,169	197	6,890	71.0	10.1	3.5	60.9	67.5
CEDAR CREEK WS SCS SITE 60 DAM	79	5494.6	1962	44			0	1,834.0	0.0	0.0	Note [2]	Note [2]
CEDAR CREEK WS SCS SITE 61 DAM	38	1348.5	1954	52	3,944	3,944	205,075	120.0	301.3	105.5	Note [2]	14.5
CEDAR CREEK WS SCS SITE 63 DAM	80	403.9	1975	31	1,517	148	4,600	30.0	6.8	2.4	23.2	27.6
CEDAR CREEK WS SCS SITE 64R DAM	80	767.7	1988	18	1,517	282	5,078	57.0	7.5	2.6	49.5	54.4
CEDAR CREEK WS SCS SITE 65 DAM	80	631.9	1975	31	1,517	232	7,197	48.0	10.6	3.7	37.4	44.3
CEDAR CREEK WS SCS SITE 66 DAM	80	476.6	1975	31	1,517	175	5,428	25.0	8.0	2.8	17.0	22.2
CEDAR CREEK WS SCS SITE 68 DAM	45	325.3	1975	31	3,069	727	22,546	17.0	33.1	11.6	Note [2]	5.4
CEDAR CREEK WS SCS SITE 68A DAM	51	Note [1]	1982	24	4,526	2	45	12.0	0.1	0.0	11.9	12.0
CEDAR CREEK WS SCS SITE 69 DAM	52	746.2	1975	31	562	110	3,411	86.0	5.0	1.8	81.0	84.2
CEDAR CREEK WS SCS SITE 7 DAM	1	277.3	1971	35	2,169	131	4,602	45.0	6.8	2.4	38.2	42.6
CEDAR CREEK WS SCS SITE 70 DAM	52	1267.9	1974	32	562	187	5,983	110.0	8.8	3.1	101.2	106.9
CEDAR CREEK WS SCS SITE 71 DAM	52	804.7	1974	32	562	119	3,797	65.0	5.6	2.0	59.4	63.0
CEDAR CREEK WS SCS SITE 72 DAM	52	333.7	1977	29	562	49	1,427	48.0	2.1	0.7	45.9	47.3
CEDAR CREEK WS SCS SITE 73REV DAM	54	Note [1]	1980	26	0		0	67.0	0.0	0.0	Note [2]	Note [2]
CEDAR CREEK WS SCS SITE 76 DAM	51	2400.6	1962	44	4,526	1,829	80,470	338.0	118.2	41.4	219.8	296.6
CEDAR CREEK WS SCS SITE 77A DAM	51	2024.5	1962	44	4,526	1,542	67,862	273.0	99.7	34.9	173.3	238.1
CEDAR CREEK WS SCS SITE 82 DAM	51	946.2	1982	24	4,526	721	17,300	134.0	25.4	8.9	108.6	125.1
CEDAR CREEK WS SCS SITE 83 DAM	52	284.9	1974	32	562	42	1,344	42.0	2.0	0.7	40.0	41.3
CEDAR CREEK WS SCS SITE 84 DAM	51	567.7	1974	32	4,526	432	13,839	70.0	20.3	7.1	49.7	62.9
CEDAR CREEK WS SCS SITE 85 DAM	104	741.1	1974	32	3,181	3,181	101,777	109.0	149.5	52.3	Note [2]	56.7
CEDAR CREEK WS SCS SITE 87A DAM	21	8813.1	1955	51	3,926	3,229	164,704	8,300.0	242.0	84.7	8,058.0	8,215.3
CEDAR CREEK WS SCS SITE 88 DAM	21	774.1	1966	40	3,926	284	11,347	37.0	16.7	5.8	20.3	31.2
CEDAR CREEK WS SCS SITE 89 DAM	21	449.9	1966	40	3,926	165	6,595	24.0	9.7	3.4	14.3	20.6
CEDAR CREEK WS SCS SITE 90 DAM	21	572.9	1967	39	3,926	210	8,187	56.0	12.0	4.2	44.0	51.8
CEDAR CREEK WS SCS SITE 92 DAM	22	2416.8	1971	35	4,873	1,009	35,315	100.5	51.9	18.2	48.6	82.3
CEDAR CREEK WS SCS SITE 94B DAM	22	625.1	1980	26	4,873	261	6,785	47.0	10.0	3.5	37.0	43.5
CEDAR CREEK WS SCS SITE 94C DAM	22	433.4	1978	28	4,873	181	5,066	38.0	7.4	2.6	30.6	35.4
CEDAR CREEK WS SCS SITE 95A DAM	22	8197.5	1971	35	4,873	3,422	119,784	283.0	176.0	61.6	107.0	221.4
CEDAR CREEK WS SCS SITE 96 DAM	23	627.8	1969	37	3,222	1,822	67,411	47.0	99.0	34.7	Note [2]	12.3
JOHN SANTERRE LAKE DAM	100	351.1	1960	46			0	63.0	0.0	0.0	Note [2]	Note [2]
KAUFMAN CITY LAKE DAM 1	32	305.1	1900	106	8,875	1,005	106,582	180.0	156.6	54.8	23.4	125.2
KAUFMAN CITY LAKE DAM 2	32	865.9	1910	96	8,875	2,854	273,942	264.0	402.5	140.9	Note [2]	123.1
KAUFMAN DAM NO 1	32	163.6	1940	66	8,875	539	35,576	10.0	52.3	18.3	Note [2]	Note [2]
KAUFMAN DAM NO 2	32	454.6	1950	56	8,875	1,498	83,903	48.0	123.3	43.1	Note [2]	4.9
KEMP LAKE DAM	91	922.8	1926	80			0	300.0	0.0	0.0	Note [2]	Note [2]
LEE LAKE DAM	66	422.7	1956	50	5,734	5,734	286,679	90.0	421.2	147.4	Note [2]	Note [2]
MABANK CITY LAKE DAM	85	268.3	1926	80	1,111	1,101	88,051	216.0	129.4	45.3	86.6	170.7

TRC Brandes

Table 3-3 (cont'd.)

Structure Name	Sub-watershed ID	NRCS Drainage Area (acres)	Year Com-pleted	Years of Accum-ulated Sediment to 2006	Estimated Average Annual Sediment Loading (tons/yr)	Area Weighted Ave Annual Sediment Loading (tons/yr)	Sediment Loading From Construction to 2006 (tons)	As-Built Sediment Storage Capacity (ac-ft)	Total Accumulated Sediment Volume 35 lbs/ft^3 (ac-ft)	Total Accumulated Sediment Volume 100 lbs/ft^3 (ac-ft)	2006 Sediment Pool Capacity 35 lbs/ft^3 (ac-ft)	2006 Sediment Pool Capacity 100 lbs/ft^3 (ac-ft)
MEADOW WOOD LAKE NO 3 DAM	14	166.7	1950	56	4,026	321	17,969	26.0	26.4	9.2	Note [2]	16.8
MEADOW WOOD LAKE NO 4 DAM	14	32.6	1960	46	4,026	63	2,884	40.0	4.2	1.5	35.8	38.5
NOLAN LAKE DAM	91	Note [1]	1977	29			0	72.0	0.0	0.0	Note [2]	Note [2]
N. HAVEN CONSTRUCTION CO LAKE DAM	12	112.5	1964	42	3,157	3,157	132,589	52.0	194.8	68.2	Note [2]	Note [2]
PORTER LAKE DAM	9	326.1	1966	40	6,808	645	25,815	108.0	37.9	13.3	70.1	94.7
RICHARDS LAKE DAM	55	136.5	1968	38	2,261	74	2,794	56.0	4.1	1.4	51.9	54.6
ROBERTS LAKE DAM	6	124.3	1970	36	7,274	7,274	261,875	48.0	384.8	134.7	Note [2]	Note [2]
STARBRAND LAKE DAM	33	141.4	1947	59	4,069	100	5,893	210.0	8.7	3.0	201.3	207.0
STOUT DAM	58	49.3	1960	46			0	12.0	0.0	0.0	Note [2]	Note [2]
TAWAKONI BALANCING RESERVOIR LEVEE	9	146.9	1963	43	6,808	291	12,501	998.0	18.4	6.4	979.6	991.6
TERRELL COUNTRY CLUB LAKE DAM	14	1823.4	1905	101	4,026	3,509	354,423	645.0	520.7	182.3	124.3	462.7
THOMAS LAKE DAM	64	1379.4	1959	47	11,199	11,199	526,358	1,053.0	773.3	270.7	279.7	782.3
TONKERSLEY LAKE DAM	21	102.8	1962	44	3,926	38	1,657	82.0	2.4	0.9	79.6	81.1
VALLEY VIEW LAKE DAM	68	3147.3	1991	15			0	2,250.0	0.0	0.0	Note [2]	Note [2]
WELLS DAM	52	370.6	1955	51	562	55	2,787	96.0	4.1	1.4	91.9	94.6
WEST LAKE DAM	42	226.2	1973	33	3,144	3,110	102,619	370.0	150.8	52.8	219.2	317.2
WILLIAMS DAM	93	625.7	1990	16	347	347	5,552	19.0	8.2	2.9	10.8	16.1
TOTAL		**135654.4**		**4462**	**421,264**	**158,482**	**6,394,915**	**29,427**	**9,396**	**3,288**	**18,518.8**	**26,747.7**

Note [1] - Did not locate.
Note [2] - Sediment pool full to design capacity in 2006; reset capacity to as-built condition.

3.1.4.1 Case I (No Structures)

To analyze runoff and sediment transport conditions for this case, the storage capacities of the sediment and flood pools of each structure within each model subwatershed were reduced to zero. In effect, this reduced the controlled drainage area within each subwatershed to zero. With these modifications, the SWAT model was operated to simulate daily inflows and sediment loadings for Cedar Creek Reservoir using the rainfall and climatological data for the period 1947 through 2002.

3.1.4.2 Case II (Structure Upgrades)

For this case, the average annual sedimentation rate for each structure as derived through the process described in Section 3.1.3 was applied to calculate the total sediment accumulation in tons over time beginning in 2006 and extending through 2055. This sediment tonnage was converted to volume in acre-feet based on alternative sediment densities of 35 pounds per cubic feet and 100 pounds per cubic foot.

If the estimated total accumulated sediment volume was less than the volume of the 2006 sediment pool for a particular structure, then the 2006 storage capacity of the sediment pool was reduced by this amount to produce the 2055 sediment pool capacity. If the estimated total sediment volume exceeded the volume of the 2006 sediment pool for a particular structure, it was assumed that the sediment pool capacity would be upgraded at the point in time when it became full to reestablish the original design sediment pool capacity. The reestablished sediment pool then would begin to accumulate sediment again at the specified sedimentation rate. For example, if the analysis showed that a sediment pool originally designed for 50 acre-feet of capacity filled with sediment in year 2020, the 50 acre-feet of capacity was reestablished in 2020, and sediment was allowed to accumulate again in the reestablished pool from 2020 to 2055. These analyses were performed for both an estimated minimum sediment density of 35 pounds per cubic foot and an estimated maximum sediment density of 100 pounds per cubic foot. The end result of these analyses was the year-2055 sedimentation condition for each of the structures in the Cedar Creek Reservoir watershed assuming two different sediment densities, i.e., 35 and 100 pounds per cubic foot. Table 3-4 summarizes these spreadsheet-based calculations for an assumed sediment density of 35 pounds per cubic foot.

The resulting estimated structure sedimentation conditions in year 2055 were used to aggregate subwatershed sediment pool storage and surface area for input to the Cedar Creek SWAT model. With these modifications, the SWAT model was operated to simulate daily inflows and sediment loadings for Cedar Creek Reservoir under year-2055 watershed conditions using the rainfall and climatological data for the period 1947 through 2002. Simulations based on sediment densities of 35 and 100 pounds per cubic foot were made.

3.1.4.3 Case III (Structure Removal)

The same procedures described above for Case II were applied for this Case III scenario to estimate the total volume of sediment in acre-feet potentially accumulated in each structure in the subwatersheds of the Cedar Creek Reservoir watershed during the period from 2006 through

Table 3-4 Summary of Case II (Structure Upgrades) 2055 sediment pool storage calculations for structures in the Cedar Creek Reservoir watershed (35 pounds/cubic foot density)

Structure Name	Average Annual Sediment Loading (tons/yr)	Sediment Loading From 2006 to 2055 (tons)	2006 Capacity @ 35lbs/ft^3 (ac-ft)	2015 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2025 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2035 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2045 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2055 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?
CEDAR CREEK WS SCS GSS 101	341	16,704	3.7	13.9	Yes	9.4		4.9		0.4		10.5	Yes
CEDAR CREEK WS SCS GSS 102	632	30,960	11.0	2.6		5.3	Yes	7.9	Yes	10.6	Yes	2.2	
CEDAR CREEK WS SCS GSS 103	2,163	105,987	3.0	1.4	Yes	2.8	Yes	1.2	Yes	2.6	Yes	1.0	Yes
CEDAR CREEK WS SCS SITE 101 DAM	1,400	68,607	233.9	215.4		196.9		178.3		159.8		141.3	
CEDAR CREEK WS SCS SITE 102 DAM	1,027	50,317	31.2	17.6		4.0		77.4	Yes	63.9		50.3	
CEDAR CREEK WS SCS SITE 103 DAM	1,544	75,645	113.8	93.4		73.0		52.6		32.2		11.7	
CEDAR CREEK WS SCS SITE 104 DAM	1,208	59,214	143.5	127.6		111.6		95.6		79.6		63.6	
CEDAR CREEK WS SCS SITE 105 DAM	339	16,627	36.1	31.6		27.1		22.6		18.1		13.6	
CEDAR CREEK WS SCS SITE 105A DAM	457	22,376	6.8	0.8		27.8	Yes	21.7		15.7		9.6	
CEDAR CREEK WS SCS SITE 109 DAM	363	17,785	68.4	63.6		58.8		54.0		49.2		44.4	
CEDAR CREEK WS SCS SITE 11 DAM	2,128	104,255	95.0	66.8		38.7		10.6		202.4	Yes	174.3	
CEDAR CREEK WS SCS SITE 110 DAM	1,973	96,679	63.8	37.8		11.7		159.6	Yes	133.5		107.4	
CEDAR CREEK WS SCS SITE 111F DAM	2,523	123,611	26.0	18.6	Yes	11.3	Yes	3.9	Yes	22.6	Yes	15.2	Yes
CEDAR CREEK WS SCS SITE 113 DAM	621	30,429	78.9	70.7		62.5		54.3		46.0		37.8	
CEDAR CREEK WS SCS SITE 114 DAM	2,699	132,258	64.0	28.3		56.6	Yes	20.9		49.2	Yes	13.5	
CEDAR CREEK WS SCS SITE 117 DAM	679	33,259	47.1	38.1		29.1		20.2		11.2		2.2	
CEDAR CREEK WS SCS SITE 120 DAM	1,996	97,814	38.0	11.6		23.2	Yes	34.8	Yes	8.4		20.0	Yes
CEDAR CREEK WS SCS SITE 121A DAM	2,351	115,188	28.0	24.9	Yes	21.8	Yes	18.7	Yes	15.7	Yes	12.6	Yes
CEDAR CREEK WS SCS SITE 122A DAM	34	1,665	43.2	42.7		42.3		41.8		41.4		40.9	
CEDAR CREEK WS SCS SITE 123 DAM	1,365	66,890	78.0	59.9		41.9		23.8		5.8		65.7	Yes
CEDAR CREEK WS SCS SITE 124 DAM	1,186	58,116	67.0	51.3		35.6		20.0		4.3		55.6	Yes
CEDAR CREEK WS SCS SITE 126 DAM	508	24,878	23.0	16.3		9.6		2.9		19.1	Yes	12.4	
CEDAR CREEK WS SCS SITE 127 DAM	837	40,999	31.8	20.8		9.7		79.6	Yes	68.6		57.5	
CEDAR CREEK WS SCS SITE 128 DAM	673	32,989	124.4	115.5		106.6		97.7		88.8		79.9	
CEDAR CREEK WS SCS SITE 129 DAM	355	17,395	53.6	48.9		44.2		39.5		34.8		30.1	
CEDAR CREEK WS SCS SITE 130A DAM	265	12,990	8.4	4.9		1.4		21.9	Yes	18.4		14.9	
CEDAR CREEK WS SCS SITE 130B DAM	283	13,868	11.4	7.6		3.9		0.1		24.4	Yes	20.7	
CEDAR CREEK WS SCS SITE 131 DAM	460	22,533	54.3	48.2		42.1		36.1		30.0		23.9	
CEDAR CREEK WS SCS SITE 134 DAM	7,105	348,149	121.0	27.0		54.1	Yes	81.1	Yes	108.2	Yes	14.2	
CEDAR CREEK WS SCS SITE 135A DAM	453	22,195	14.0	8.0		2.0		10.0	Yes	4.0		12.1	Yes
CEDAR CREEK WS SCS SITE 135B DAM	1,009	49,464	38.0	24.7		11.3		36.0	Yes	22.6		9.3	
CEDAR CREEK WS SCS SITE 135C DAM	3,921	192,145	108.0	56.1		4.3		60.4	Yes	8.6		64.7	Yes
CEDAR CREEK WS SCS SITE 136 DAM	471	23,074	34.6	28.4		22.2		16.0		9.7		3.5	
CEDAR CREEK WS SCS SITE 137 DAM	353	17,309	40.7	36.1		31.4		26.7		22.0		17.4	
CEDAR CREEK WS SCS SITE 138 DAM	656	32,140	52.4	43.7		35.0		26.4		17.7		9.0	
CEDAR CREEK WS SCS SITE 139 DAM	294	14,418	27.6	23.7		19.8		15.9		12.0		8.1	
CEDAR CREEK WS SCS SITE 140 DAM	3,437	168,404	200.0	154.6		109.1		63.7		18.2		172.8	Yes
CEDAR CREEK WS SCS SITE 143A DAM	6,756	331,038	3,559.6	3,470.2		3,380.9		3,291.6		3,202.2		3,112.9	
CEDAR CREEK WS SCS SITE 14A DAM	3,341	163,696	108.0	63.8		19.7		83.5	Yes	39.3		103.1	Yes
CEDAR CREEK WS SCS SITE 15 DAM	553	27,113	95.5	88.2		80.9		73.6		66.3		59.0	
CEDAR CREEK WS SCS SITE 16 DAM	1,700	83,301	106.6	84.1		61.6		39.1		16.7		193.2	Yes

Table 3-4 (cont'd.)

Structure Name	Average Annual Sediment Loading (tons/yr)	Sediment Loading From 2006 to 2055 (tons)	2006 Capacity @ 35lbs/ft^3 (ac-ft)	2015 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2025 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2035 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2045 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2055 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?
CEDAR CREEK WS SCS SITE 16A DAM	3,199	156,770	191.1	148.8		106.5		64.2		21.9		344.5	Yes
CEDAR CREEK WS SCS SITE 18 DAM	1,113	54,523	139.8	125.1		110.4		95.6		80.9		66.2	
CEDAR CREEK WS SCS SITE 19 DAM	1,983	97,146	222.9	196.7		170.4		144.2		118.0		91.8	
CEDAR CREEK WS SCS SITE 1A DAM	458	22,420	75.5	69.4		63.4		57.3		51.3		45.2	
CEDAR CREEK WS SCS SITE 1B DAM	161	7,895	37.7	35.6		33.5		31.3		29.2		27.1	
CEDAR CREEK WS SCS SITE 2 DAM	295	14,455	34.8	30.9		27.0		23.1		19.2		15.3	
CEDAR CREEK WS SCS SITE 3 DAM	190	9,310	53.2	50.7		48.2		45.7		43.2		40.7	
CEDAR CREEK WS SCS SITE 31 DAM	290	14,228	41.3	37.5		33.7		29.8		26.0		22.1	
CEDAR CREEK WS SCS SITE 32 DAM	270	13,238	61.5	57.9		54.3		50.8		47.2		43.6	
CEDAR CREEK WS SCS SITE 33 DAM	228	11,178	47.6	44.6		41.6		38.6		35.5		32.5	
CEDAR CREEK WS SCS SITE 4 DAM	132	6,487	39.2	37.4		35.7		33.9		32.2		30.4	
CEDAR CREEK WS SCS SITE 43A DAM	2,979	145,961	59.0	19.6		39.2	Yes	58.8	Yes	19.4		39.1	Yes
CEDAR CREEK WS SCS SITE 46REV DAM	779	38,192	27.0	16.7		6.4		23.1	Yes	12.8		2.5	
CEDAR CREEK WS SCS SITE 47A DAM	5,093	249,536	154.0	86.7		19.3		106.0	Yes	38.6		125.3	Yes
CEDAR CREEK WS SCS SITE 5 DAM	156	7,663	48.0	45.9		43.8		41.8		39.7		37.6	
CEDAR CREEK WS SCS SITE 50C DAM	5,372	263,250	109.0	38.0		75.9	Yes	4.9		42.8	Yes	80.8	Yes
CEDAR CREEK WS SCS SITE 55B DAM	6	284	40.8	40.7		40.6		40.5		40.5		40.4	
CEDAR CREEK WS SCS SITE 57 DAM	6,084	298,104	328.0	247.6		167.1		86.7		6.2		253.8	Yes
CEDAR CREEK WS SCS SITE 58 DAM	1,109	54,337	57.0	42.3		27.7		13.0		55.3	Yes	40.7	
CEDAR CREEK WS SCS SITE 59 DAM	580	28,407	35.0	27.3		19.7		12.0		4.3		31.7	Yes
CEDAR CREEK WS SCS SITE 6 DAM	197	9,647	60.9	58.3		55.7		53.1		50.5		47.9	
CEDAR CREEK WS SCS SITE 60 DAM	0	0	1,834.0	1,834.0		1,834.0		1,834.0		1,834.0		1,834.0	
CEDAR CREEK WS SCS SITE 61 DAM	3,944	193,243	120.0	67.9		15.7		83.6	Yes	31.4		99.3	Yes
CEDAR CREEK WS SCS SITE 63 DAM	148	7,271	23.2	21.3		19.3		17.4		15.4		13.4	
CEDAR CREEK WS SCS SITE 64R DAM	282	13,822	49.5	45.8		42.1		38.3		34.6		30.9	
CEDAR CREEK WS SCS SITE 65 DAM	232	11,376	37.4	34.4		31.3		28.2		25.1		22.1	
CEDAR CREEK WS SCS SITE 66 DAM	175	8,580	17.0	14.7		12.4		10.1		7.8		5.4	
CEDAR CREEK WS SCS SITE 68 DAM	727	35,637	17.0	7.4		14.8	Yes	5.1		12.5	Yes	2.9	
CEDAR CREEK WS SCS SITE 68A DAM	2	92	11.9	11.9		11.9		11.9		11.8		11.8	
CEDAR CREEK WS SCS SITE 69 DAM	110	5,392	81.0	79.5		78.1		76.6		75.2		73.7	
CEDAR CREEK WS SCS SITE 7 DAM	131	6,442	38.2	36.5		34.8		33.0		31.3		29.5	
CEDAR CREEK WS SCS SITE 70 DAM	187	9,161	101.2	98.7		96.3		93.8		91.3		88.8	
CEDAR CREEK WS SCS SITE 71 DAM	119	5,814	59.4	57.9		56.3		54.7		53.1		51.6	
CEDAR CREEK WS SCS SITE 72 DAM	49	2,411	45.9	45.3		44.6		44.0		43.3		42.6	
CEDAR CREEK WS SCS SITE 73REV DAM	0	0	67.0	67.0		67.0		67.0		67.0		67.0	
CEDAR CREEK WS SCS SITE 76 DAM	1,829	89,614	219.8	195.6		171.4		147.2		123.0		98.9	
CEDAR CREEK WS SCS SITE 77A DAM	1,542	75,574	173.3	152.9		132.5		112.1		91.7		71.3	
CEDAR CREEK WS SCS SITE 82 DAM	721	35,321	108.6	99.1		89.5		80.0		70.5		60.9	
CEDAR CREEK WS SCS SITE 83 DAM	42	2,059	40.0	39.5		38.9		38.4		37.8		37.2	
CEDAR CREEK WS SCS SITE 84 DAM	432	21,191	49.7	43.9		38.2		32.5		26.8		21.1	
CEDAR CREEK WS SCS SITE 85 DAM	3,181	155,846	109.0	66.9		24.9		91.8	Yes	49.8		7.7	
CEDAR CREEK WS SCS SITE 87A DAM	3,229	158,245	8,058.0	8,015.3		7,972.6		7,929.9		7,887.2		7,844.5	
CEDAR CREEK WS SCS SITE 88 DAM	284	13,900	20.3	16.6		12.8		9.1		5.3		1.6	
CEDAR CREEK WS SCS SITE 89 DAM	165	8,079	14.3	12.1		10.0		7.8		5.6		3.4	

Table 3-4 (cont'd.)

Structure Name	Average Annual Sediment Loading (tons/yr)	Sediment Loading From 2006 to 2055 (tons)	2006 Capacity @ 35lbs/ft^3 (ac-ft)	2015 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2025 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2035 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2045 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2055 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?
CEDAR CREEK WS SCS SITE 90 DAM	210	10,287	44.0	41.2		38.4		35.6		32.9		30.1	
CEDAR CREEK WS SCS SITE 92 DAM	1,009	49,441	48.6	35.3		21.9		8.6		95.7	Yes	82.4	
CEDAR CREEK WS SCS SITE 94B DAM	261	12,788	37.0	33.6		30.1		26.7		23.2		19.8	
CEDAR CREEK WS SCS SITE 94C DAM	181	8,866	30.6	28.2		25.8		23.4		21.0		18.6	
CEDAR CREEK WS SCS SITE 95A DAM	3,422	167,697	107.0	61.8		16.5		254.2	Yes	209.0		163.7	
CEDAR CREEK WS SCS SITE 96 DAM	1,822	89,274	47.0	22.9		45.8	Yes	21.7		44.6	Yes	20.5	
JOHN SANTERRE LAKE DAM	0	0	63.0	63.0		63.0		63.0		63.0		63.0	
KAUFMAN CITY LAKE DAM 1	1,005	49,269	23.4	10.1		176.8	Yes	163.5		150.2		136.9	
KAUFMAN CITY LAKE DAM 2	2,854	139,825	264.0	226.3		188.5		150.8		113.1		75.3	
KAUFMAN DAM NO 1	539	26,413	10.0	2.9		5.7	Yes	8.6	Yes	1.5		4.4	Yes
KAUFMAN DAM NO 2	1,498	73,415	48.0	28.2		8.4		36.6	Yes	16.8		44.9	Yes
KEMP LAKE DAM	0	0	300.0	300.0		300.0		300.0		300.0		300.0	
LEE LAKE DAM	5,734	280,946	90.0	14.2		28.4	Yes	42.6	Yes	56.7	Yes	70.9	Yes
MABANK CITY LAKE DAM	1,101	53,932	86.6	72.1		57.5		43.0		28.4		13.9	
MEADOW WOOD LAKE NO 3 DAM	321	15,723	26.0	21.8		17.5		13.3		9.0		4.8	
MEADOW WOOD LAKE NO 4 DAM	63	3,072	35.8	34.9		34.1		33.3		32.4		31.6	
NOLAN LAKE DAM	0	0	72.0	72.0		72.0		72.0		72.0		72.0	
N. HAVEN CONSTRUCTION CO LAKE DAM	3,157	154,687	52.0	10.3		20.5	Yes	30.8	Yes	41.0	Yes	51.3	Yes
PORTER LAKE DAM	645	31,623	70.1	61.5		53.0		44.5		35.9		27.4	
RICHARDS LAKE DAM	74	3,603	51.9	50.9		50.0		49.0		48.0		47.0	
ROBERTS LAKE DAM	7,274	356,441	48.0	47.8	Yes	47.6	Yes	47.4	Yes	47.2	Yes	47.1	Yes
STARBRAND LAKE DAM	100	4,894	201.3	200.0		198.7		197.4		196.1		194.7	
STOUT DAM	0	0	12.0	12.0		12.0		12.0		12.0		12.0	
TAWAKONI BALANCING RESERVOIR LEVEI	291	14,245	979.6	975.8		971.9		968.1		964.3		960.4	
TERRELL COUNTRY CLUB LAKE DAM	3,509	171,948	124.3	77.9		31.5		630.1	Yes	583.7		537.3	
THOMAS LAKE DAM	11,199	548,756	279.7	131.6		1,036.5	Yes	888.4		740.3		592.2	
TONKERSLEY LAKE DAM	38	1,846	79.6	79.1		78.6		78.1		77.6		77.1	
VALLEY VIEW LAKE DAM	0	0	2,250.0	2,250.0		2,250.0		2,250.0		2,250.0		2,250.0	
WELLS DAM	55	2,678	91.9	91.2		90.5		89.7		89.0		88.3	
WEST LAKE DAM	3,110	152,374	219.2	178.1		137.0		95.9		54.8		13.6	
WILLIAMS DAM	347	17,004	10.8	6.3		1.7		16.1	Yes	11.5		6.9	
TOTAL	**158,482**	**7,765,631**	**25,056**	**23,152**		**23,120**		**23,622**		**22,671**		**22,950**	

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2055, again considering alternative sediment densities of 35 pounds per cubic feet and 100 pounds per cubic foot. For this Case III, if the estimated total accumulated sediment volume was less than the volume of the 2006 sediment pool for a particular structure, then the 2006 storage capacity of the sediment pool was reduced by this amount to produce the 2055 sediment pool capacity. If the estimated total sediment volume exceeded the volume of the 2006 sediment pool for a particular structure, it was assumed that the structure was removed from the subwatershed and assumed not to be replaced.

For example, if the analysis showed that a sediment pool originally designed for 50 acre-feet of capacity filled with sediment in year 2020, the dam was assumed to be removed. Stormwater runoff would continue to flow past the site of the structure without any impoundment. These analyses were performed for both an estimated minimum sediment density of 35 pounds per cubic foot and an estimated maximum sediment density of 100 pounds per cubic foot. The end result of these analyses was the year-2055 sedimentation condition for each of the structures in the Cedar Creek watershed assuming two different sediment densities, i.e., 35 and 100 pounds per cubic foot. Table 3-5 summarizes these spreadsheet-based calculations for an assumed sediment density of 35 pounds per cubic foot.

The resulting estimated structure sedimentation conditions in year 2055 were used to aggregate subwatershed sediment pool storage and surface area for input to the Cedar Creek SWAT model. With these modifications, the SWAT model was operated to simulate daily inflows and sediment loadings for Cedar Creek Reservoir under year-2055 watershed conditions using the rainfall and climatological data for the period 1947 through 2002. Simulations based on sediment densities of 35 and 100 pounds per cubic foot were made.

3.1.4.4 Case IV (No Action)

For this case, the same procedures described above were applied to estimate the total volume of sediment in acre-feet potentially accumulated in each structure in the subwatersheds of the Cedar Creek Reservoir watershed during the period from 2006 through 2055, again considering alternative sediment densities of 35 pounds per cubic feet and 100 pounds per cubic foot. For this Case IV, if the estimated total accumulated sediment volume was less than the volume of the 2006 sediment pool for a particular structure, then the 2006 storage capacity of the sediment pool was reduced by this amount to produce the 2055 sediment pool capacity. If the estimated total sediment volume exceeded the volume of the 2006 sediment pool for a particular structure, it was assumed that this entire amount of sediment would remain within the structure and the principal spillway would become and remain inoperative. The 2055 available storage capacity in the structure then would be equal to total storage capacity below the auxiliary spillway crest elevation reduced by the total amount of sediment accumulated during the 2006-2055 period.

These analyses were performed for both an estimated minimum sediment density of 35 pounds per cubic foot and an estimated maximum sediment density of 100 pounds per cubic foot. The end result of these analyses was the year-2055 sedimentation condition for each of the structures in the Cedar Creek watershed assuming two different sediment densities, i.e., 35 and 100 pounds per cubic foot. Table 3-6 summarizes these spreadsheet-based calculations for an assumed sediment density of 35 pounds per cubic foot.

Table 3-5 Summary of Case III (Structure Removal) 2055 sediment pool storage calculations for structures in the Cedar Creek Reservoir watershed (35 pounds/cubic foot density)

Structure Name	Average Annual Sediment Loading (tons/yr)	Sediment Loading From 2006 to 2055 (tons)	2006 Capacity @ 35lbs/ft^3 (ac-ft)	2015 Capacity @ 35lbs/ft^3 (ac-ft)	Breached?	2025 Capacity @ 35lbs/ft^3 (ac-ft)	Breached?	2035 Capacity @ 35lbs/ft^3 (ac-ft)	Breached?	2045 Capacity @ 35lbs/ft^3 (ac-ft)	Breached?	2055 Capacity @ 35lbs/ft^3 (ac-ft)	Breached?	Breached During 2006 to 2055?
CEDAR CREEK WS SCS GSS 101	341	16,704	3.7	14.7	Yes	14.7	Yes	14.7	Yes	14.7	Yes	14.7	Yes	Removed
CEDAR CREEK WS SCS GSS 102	632	30,960	11.0	2.6		11.0	Yes	11.0	Yes	11.0	Yes	11.0	Yes	Removed
CEDAR CREEK WS SCS GSS 103	2,163	105,987	3.0	3.0	Yes	3.0	Yes	3.0	Yes	3.0	Yes	3.0	Yes	Removed
CEDAR CREEK WS SCS SITE 101 DAM	1,400	68,607	233.9	215.4		194.8		174.2		153.7		133.1		
CEDAR CREEK WS SCS SITE 102 DAM	1,027	50,317	31.2	17.6		2.5		87.0	Yes	87.0	Yes	87.0	Yes	Removed
CEDAR CREEK WS SCS SITE 103 DAM	1,544	75,645	113.8	93.4		70.7		48.0		25.4		2.7		
CEDAR CREEK WS SCS SITE 104 DAM	1,208	59,214	143.5	127.6		109.8		92.0		74.3		56.5		
CEDAR CREEK WS SCS SITE 105 DAM	339	16,627	36.1	31.6		26.6		21.6		16.6		11.6		
CEDAR CREEK WS SCS SITE 105A DAM	457	22,376	6.8	0.8		33.0	Yes	33.0	Yes	33.0	Yes	33.0	Yes	Removed
CEDAR CREEK WS SCS SITE 109 DAM	363	17,785	68.4	63.6		58.3		52.9		47.6		42.3		
CEDAR CREEK WS SCS SITE 11 DAM	2,128	104,255	95.0	66.8		35.6		4.3		220.0	Yes	220.0	Yes	Removed
CEDAR CREEK WS SCS SITE 110 DAM	1,973	96,679	63.8	37.8		8.8		174.0	Yes	174.0	Yes	174.0	Yes	Removed
CEDAR CREEK WS SCS SITE 111F DAM	2,523	123,611	26.0	26.0	Yes	26.0	Yes	26.0	Yes	26.0	Yes	26.0	Yes	Removed
CEDAR CREEK WS SCS SITE 113 DAM	621	30,429	78.9	70.7		61.6		52.4		43.3		34.2		
CEDAR CREEK WS SCS SITE 114 DAM	2,699	132,258	64.0	28.3		64.0	Yes	64.0	Yes	64.0	Yes	64.0	Yes	Removed
CEDAR CREEK WS SCS SITE 117 DAM	679	33,259	47.1	38.1		28.1		18.2		8.2		75.0	Yes	Removed
CEDAR CREEK WS SCS SITE 120 DAM	1,996	97,814	38.0	11.6		38.0	Yes	38.0	Yes	38.0	Yes	38.0	Yes	Removed
CEDAR CREEK WS SCS SITE 121A DAM	2,351	115,188	28.0	28.0	Yes	28.0	Yes	28.0	Yes	28.0	Yes	28.0	Yes	Removed
CEDAR CREEK WS SCS SITE 122A DAM	34	1,665	43.2	42.7		42.2		41.7		41.2		40.7		
CEDAR CREEK WS SCS SITE 123 DAM	1,365	66,890	78.0	59.9		39.9		19.8		78.0	Yes	78.0	Yes	Removed
CEDAR CREEK WS SCS SITE 124 DAM	1,186	58,116	67.0	51.3		33.9		16.5		67.0	Yes	67.0	Yes	Removed
CEDAR CREEK WS SCS SITE 126 DAM	508	24,878	23.0	16.3		8.8		1.4		23.0	Yes	23.0	Yes	Removed
CEDAR CREEK WS SCS SITE 127 DAM	837	40,999	31.8	20.8		8.5		81.0	Yes	81.0	Yes	81.0	Yes	Removed
CEDAR CREEK WS SCS SITE 128 DAM	673	32,989	124.4	115.5		105.6		95.7		85.9		76.0		
CEDAR CREEK WS SCS SITE 129 DAM	355	17,395	53.6	48.9		43.7		38.5		33.3		28.1		
CEDAR CREEK WS SCS SITE 130A DAM	265	12,990	8.4	4.9		1.0		24.0	Yes	24.0	Yes	24.0	Yes	Removed
CEDAR CREEK WS SCS SITE 130B DAM	283	13,868	11.4	7.6		3.5		28.0	Yes	28.0	Yes	28.0	Yes	Removed
CEDAR CREEK WS SCS SITE 131 DAM	460	22,533	54.3	48.2		41.5		34.7		27.9		21.2		
CEDAR CREEK WS SCS SITE 134 DAM	7,105	348,149	121.0	27.0		121.0	Yes	121.0	Yes	121.0	Yes	121.0	Yes	Removed
CEDAR CREEK WS SCS SITE 135A DAM	453	22,195	14.0	8.0		1.4		14.0	Yes	14.0	Yes	14.0	Yes	Removed
CEDAR CREEK WS SCS SITE 135B DAM	1,009	49,464	38.0	24.7		9.8		38.0	Yes	38.0	Yes	38.0	Yes	Removed
CEDAR CREEK WS SCS SITE 135C DAM	3,921	192,145	108.0	56.1		108.0	Yes	108.0	Yes	108.0	Yes	108.0	Yes	Removed
CEDAR CREEK WS SCS SITE 136 DAM	471	23,074	34.6	28.4		21.5		14.6		7.7		0.7		
CEDAR CREEK WS SCS SITE 137 DAM	353	17,309	40.7	36.1		30.9		25.7		20.5		15.3		
CEDAR CREEK WS SCS SITE 138 DAM	656	32,140	52.4	43.7		34.1		24.4		14.8		5.2		
CEDAR CREEK WS SCS SITE 139 DAM	294	14,418	27.6	23.7		19.4		15.0		10.7		6.4		
CEDAR CREEK WS SCS SITE 140 DAM	3,437	168,404	200.0	154.6		104.1		53.6		3.1		200.0	Yes	Removed
CEDAR CREEK WS SCS SITE 143A DAM	6,756	331,038	3,559.6	3,470.2		3,371.0		3,271.7		3,172.4		3,073.2		
CEDAR CREEK WS SCS SITE 14A DAM	3,341	163,696	108.0	63.8		14.7		108.0	Yes	108.0	Yes	108.0	Yes	Removed
CEDAR CREEK WS SCS SITE 15 DAM	553	27,113	95.5	88.2		80.1		72.0		63.8		55.7		
CEDAR CREEK WS SCS SITE 16 DAM	1,700	83,301	106.6	84.1		59.1		34.2		9.2		199.0	Yes	Removed
CEDAR CREEK WS SCS SITE 16A DAM	3,199	156,770	191.1	148.8		101.8		54.8		7.8		365.0	Yes	Removed
CEDAR CREEK WS SCS SITE 18 DAM	1,113	54,523	139.8	125.1		108.7		92.4		76.0		59.7		

Table 3-5 (cont'd.)

Structure Name	Average Annual Sediment Loading (tons/yr)	Sediment Loading From 2006 to 2055 (tons)	2006 Capacity @ 35lbs/ft³ (ac-ft)	2015 Capacity @ 35lbs/ft³ (ac-ft)	Breached?	2025 Capacity @ 35lbs/ft³ (ac-ft)	Breached?	2035 Capacity @ 35lbs/ft³ (ac-ft)	Breached?	2045 Capacity @ 35lbs/ft³ (ac-ft)	Breached?	2055 Capacity @ 35lbs/ft³ (ac-ft)	Breached?	Breached During 2006 to 2055?
CEDAR CREEK WS SCS SITE 19 DAM	1,983	97,146	222.9	196.7		167.5		138.4		109.3		80.1		
CEDAR CREEK WS SCS SITE 1A DAM	458	22,420	75.5	69.4		62.7		56.0		49.3		42.5		
CEDAR CREEK WS SCS SITE 1B DAM	161	7,895	37.7	35.6		33.2		30.8		28.5		26.1		
CEDAR CREEK WS SCS SITE 2 DAM	295	14,455	34.8	30.9		26.6		22.3		17.9		13.6		
CEDAR CREEK WS SCS SITE 3 DAM	190	9,310	53.2	50.7		47.9		45.1		42.3		39.6		
CEDAR CREEK WS SCS SITE 31 DAM	290	14,228	41.3	37.5		33.2		29.0		24.7		20.4		
CEDAR CREEK WS SCS SITE 32 DAM	270	13,238	61.5	57.9		53.9		50.0		46.0		42.0		
CEDAR CREEK WS SCS SITE 33 DAM	228	11,178	47.6	44.6		41.2		37.9		34.5		31.2		
CEDAR CREEK WS SCS SITE 4 DAM	132	6,487	39.2	37.4		35.5		33.6		31.6		29.7		
CEDAR CREEK WS SCS SITE 43A DAM	2,979	145,961	59.0	19.6		59.0	Yes	59.0	Yes	59.0	Yes	59.0	Yes	Removed
CEDAR CREEK WS SCS SITE 46REV DAM	779	38,192	27.0	16.7		5.2		27.0	Yes	27.0	Yes	27.0	Yes	Removed
CEDAR CREEK WS SCS SITE 47A DAM	5,093	249,536	154.0	86.7		11.8		154.0	Yes	154.0	Yes	154.0	Yes	Removed
CEDAR CREEK WS SCS SITE 5 DAM	156	7,663	48.0	45.9		43.6		41.3		39.0		36.7		
CEDAR CREEK WS SCS SITE 50C DAM	5,372	263,250	109.0	38.0		109.0	Yes	109.0	Yes	109.0	Yes	109.0	Yes	Removed
CEDAR CREEK WS SCS SITE 55B DAM	6	284	40.8	40.7		40.6		40.5		40.4		40.3		
CEDAR CREEK WS SCS SITE 57 DAM	6,084	298,104	328.0	247.6		158.2		68.8		328.0	Yes	328.0	Yes	Removed
CEDAR CREEK WS SCS SITE 58 DAM	1,109	54,337	57.0	42.3		26.0		9.8		57.0	Yes	57.0	Yes	Removed
CEDAR CREEK WS SCS SITE 59 DAM	580	28,407	35.0	27.3		18.8		10.3		1.8		35.0	Yes	Removed
CEDAR CREEK WS SCS SITE 6 DAM	197	9,647	60.9	58.3		55.4		52.5		49.6		46.7		
CEDAR CREEK WS SCS SITE 60 DAM	0	0	1,834.0	1,834.0		1,834.0		1,834.0		1,834.0		1,834.0		
CEDAR CREEK WS SCS SITE 61 DAM	3,944	193,243	120.0	67.9		9.9		120.0	Yes	120.0	Yes	120.0	Yes	Removed
CEDAR CREEK WS SCS SITE 63 DAM	148	7,271	23.2	21.3		19.1		16.9		14.7		12.6		
CEDAR CREEK WS SCS SITE 64R DAM	282	13,822	49.5	45.8		41.7		37.5		33.4		29.2		
CEDAR CREEK WS SCS SITE 65 DAM	232	11,376	37.4	34.4		30.9		27.5		24.1		20.7		
CEDAR CREEK WS SCS SITE 66 DAM	175	8,580	17.0	14.7		12.1		9.6		7.0		4.4		
CEDAR CREEK WS SCS SITE 68 DAM	727	35,637	17.0	7.4		17.0	Yes	17.0	Yes	17.0	Yes	17.0	Yes	Removed
CEDAR CREEK WS SCS SITE 68A DAM	2	92	11.9	11.9		11.9		11.9		11.8		11.8		
CEDAR CREEK WS SCS SITE 69 DAM	110	5,392	81.0	79.5		77.9		76.3		74.7		73.1		
CEDAR CREEK WS SCS SITE 7 DAM	131	6,442	38.2	36.5		34.6		32.6		30.7		28.8		
CEDAR CREEK WS SCS SITE 70 DAM	187	9,161	101.2	98.7		96.0		93.2		90.5		87.7		
CEDAR CREEK WS SCS SITE 71 DAM	119	5,814	59.4	57.9		56.1		54.4		52.6		50.9		
CEDAR CREEK WS SCS SITE 72 DAM	49	2,411	45.9	45.3		44.5		43.8		43.1		42.4		
CEDAR CREEK WS SCS SITE 73REV DAM	0	0	67.0	67.0		67.0		67.0		67.0		67.0		
CEDAR CREEK WS SCS SITE 76 DAM	1,829	89,614	219.8	195.6		168.7		141.8		115.0		88.1		
CEDAR CREEK WS SCS SITE 77A DAM	1,542	75,574	173.3	152.9		130.2		107.6		84.9		62.3		
CEDAR CREEK WS SCS SITE 82 DAM	721	35,321	108.6	99.1		88.5		77.9		67.3		56.7		
CEDAR CREEK WS SCS SITE 83 DAM	42	2,059	40.0	39.5		38.9		38.2		37.6		37.0		
CEDAR CREEK WS SCS SITE 84 DAM	432	21,191	49.7	43.9		37.6		31.2		24.9		18.5		
CEDAR CREEK WS SCS SITE 85 DAM	3,181	155,846	109.0	66.9		20.2		109.0	Yes	109.0	Yes	109.0	Yes	Removed
CEDAR CREEK WS SCS SITE 87A DAM	3,229	158,245	8,058.0	8,015.3		7,967.9		7,920.4		7,873.0		7,825.5		
CEDAR CREEK WS SCS SITE 88 DAM	284	13,900	20.3	16.6		12.4		8.2		4.1		37.0	Yes	Removed
CEDAR CREEK WS SCS SITE 89 DAM	165	8,079	14.3	12.1		9.7		7.3		4.9		2.4		

TRC Brandes

Table 3-5 (cont'd.)

Structure Name	Average Annual Sediment Loading (tons/yr)	Sediment Loading From 2006 to 2055 (tons)	2006 Capacity @ 35lbs/ft^3 (ac-ft)	2015 Capacity @ 35lbs/ft^3 (ac-ft)	Breached?	2025 Capacity @ 35lbs/ft^3 (ac-ft)	Breached?	2035 Capacity @ 35lbs/ft^3 (ac-ft)	Breached?	2045 Capacity @ 35lbs/ft^3 (ac-ft)	Breached?	2055 Capacity @ 35lbs/ft^3 (ac-ft)	Breached?	Breached During 2006 to 2055?
CEDAR CREEK WS SCS SITE 90 DAM	210	10,287	44.0	41.2		38.1		35.0		31.9		28.9		
CEDAR CREEK WS SCS SITE 92 DAM	1,009	49,441	48.6	35.3		20.4		5.6		100.5	Yes	100.5	Yes	Removed
CEDAR CREEK WS SCS SITE 94B DAM	261	12,788	37.0	33.6		29.7		25.9		22.1		18.2		
CEDAR CREEK WS SCS SITE 94C DAM	181	8,866	30.6	28.2		25.5		22.8		20.2		17.5		
CEDAR CREEK WS SCS SITE 95A DAM	3,422	167,697	107.0	61.8		11.5		283.0	Yes	283.0	Yes	283.0	Yes	Removed
CEDAR CREEK WS SCS SITE 96 DAM	1,822	89,274	47.0	22.9		47.0	Yes	47.0	Yes	47.0	Yes	47.0	Yes	Removed
JOHN SANTERRE LAKE DAM	0	0	63.0	63.0		63.0		63.0		63.0		63.0		
KAUFMAN CITY LAKE DAM 1	1,005	49,269	23.4	10.1		180.0	Yes	180.0	Yes	180.0	Yes	180.0	Yes	Removed
KAUFMAN CITY LAKE DAM 2	2,854	139,825	264.0	226.3		184.3		142.4		100.5		58.6		
KAUFMAN DAM NO 1	539	26,413	10.0	2.9		10.0	Yes	10.0	Yes	10.0	Yes	10.0	Yes	Removed
KAUFMAN DAM NO 2	1,498	73,415	48.0	28.2		6.2		48.0	Yes	48.0	Yes	48.0	Yes	Removed
KEMP LAKE DAM	0	0	300.0	300.0		300.0		300.0		300.0		300.0		
LEE LAKE DAM	5,734	280,946	90.0	14.2		90.0	Yes	90.0	Yes	90.0	Yes	90.0	Yes	Removed
MABANK CITY LAKE DAM	1,101	53,932	86.6	72.1		55.9		39.7		23.6		7.4		
MEADOW WOOD LAKE NO 3 DAM	321	15,723	26.0	21.8		17.0		12.3		7.6		2.9		
MEADOW WOOD LAKE NO 4 DAM	63	3,072	35.8	34.9		34.0		33.1		32.2		31.2		
NOLAN LAKE DAM	0	0	72.0	72.0		72.0		72.0		72.0		72.0		
N. HAVEN CONSTRUCTION CO LAKE DAM	3,157	154,687	52.0	10.3		52.0	Yes	52.0	Yes	52.0	Yes	52.0	Yes	Removed
PORTER LAKE DAM	645	31,623	70.1	61.5		52.1		42.6		33.1		23.6		
RICHARDS LAKE DAM	74	3,603	51.9	50.9		49.8		48.8		47.7		46.6		
ROBERTS LAKE DAM	7,274	356,441	48.0	48.0	Yes	48.0	Yes	48.0	Yes	48.0	Yes	48.0	Yes	Removed
STARBRAND LAKE DAM	100	4,894	201.3	200.0		198.6		197.1		195.6		194.2		
STOUT DAM	0	0	12.0	12.0		12.0		12.0		12.0		12.0		
TAWAKONI BALANCING RESERVOIR LEVEI	291	14,245	979.6	975.8		971.5		967.2		963.0		958.7		
TERRELL COUNTRY CLUB LAKE DAM	3,509	171,948	124.3	77.9		26.3		645.0	Yes	645.0	Yes	645.0	Yes	Removed
THOMAS LAKE DAM	11,199	548,756	279.7	131.6		1,053.0	Yes	1,053.0	Yes	1,053.0	Yes	1,053.0	Yes	Removed
TONKERSLEY LAKE DAM	38	1,846	79.6	79.1		78.5		78.0		77.4		76.9		
VALLEY VIEW LAKE DAM	0	0	2,250.0	2,250.0		2,250.0		2,250.0		2,250.0		2,250.0		
WELLS DAM	55	2,678	91.9	91.2		90.4		89.6		88.8		88.0		
WEST LAKE DAM	3,110	152,374	219.2	178.1		132.4		86.7		41.0		370.0	Yes	Removed
WILLIAMS DAM	347	17,004	10.8	6.3		1.2		19.0	Yes	19.0	Yes	19.0	Yes	Removed
TOTAL	**158,482**	**7,765,631**	**25,056**	**23,165**		**23,385**		**24,268**		**24,279**		**24,939**		

TRC/Brandes

Table 3-6 Summary of Case IV (No Action) 2055 sediment pool storage calculations for structures in the Cedar Creek Reservoir watershed (35 pounds/cubic foot density)

Structure Name	Average Annual Sediment Loading (tons/yr)	Sediment Loading From 2006 to 2055 (tons)	2006 Capacity @ 35lbs/ft^3 (ac-ft)	2015 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2025 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2035 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2045 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2055 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?
CEDAR CREEK WS SCS GSS 101	341	16,704	3.7	39.5	Yes	35.0		30.0		25.0		20.0	
CEDAR CREEK WS SCS GSS 102	632	30,960	68.0	59.6		50.4		41.1		31.8		22.5	
CEDAR CREEK WS SCS GSS 103	2,163	105,987	14.6	14.6	Yes	14.6	Yes	14.6	Yes	14.6	Yes	0.0	Yes
CEDAR CREEK WS SCS SITE 101 DAM	1,400	68,607	233.9	215.4		194.8		174.2		153.7		133.1	
CEDAR CREEK WS SCS SITE 102 DAM	1,027	50,317	31.2	17.6		2.5		705.0	Yes	691.4		676.3	
CEDAR CREEK WS SCS SITE 103 DAM	1,544	75,645	113.8	93.4		70.7		48.0		25.4		2.7	
CEDAR CREEK WS SCS SITE 104 DAM	1,208	59,214	143.5	127.6		109.8		92.0		74.3		56.5	
CEDAR CREEK WS SCS SITE 105 DAM	339	16,627	36.1	31.6		26.6		21.6		16.6		11.6	
CEDAR CREEK WS SCS SITE 105A DAM	457	22,376	6.8	0.8		315.0	Yes	309.0		302.3		295.5	
CEDAR CREEK WS SCS SITE 109 DAM	363	17,785	68.4	63.6		58.3		52.9		47.6		42.3	
CEDAR CREEK WS SCS SITE 11 DAM	2,128	104,255	95.0	66.8		35.6		4.3		870.0	Yes	841.9	
CEDAR CREEK WS SCS SITE 110 DAM	1,973	96,679	63.8	37.8		8.8		1,011.0	Yes	984.9		955.9	
CEDAR CREEK WS SCS SITE 111F DAM	2,523	123,611	222.0	188.6		151.6		114.5		77.5		40.4	
CEDAR CREEK WS SCS SITE 113 DAM	621	30,429	78.9	70.7		61.6		52.4		43.3		34.2	
CEDAR CREEK WS SCS SITE 114 DAM	2,699	132,258	560.0	524.3		484.7		445.0		405.3		365.7	
CEDAR CREEK WS SCS SITE 117 DAM	679	33,259	47.1	38.1		28.1		18.2		8.2		837.0	Yes
CEDAR CREEK WS SCS SITE 120 DAM	1,996	97,814	265.0	238.6		209.3		179.9		150.6		121.3	
CEDAR CREEK WS SCS SITE 121A DAM	2,351	115,188	206.0	174.9		140.4		105.8		71.3		36.8	
CEDAR CREEK WS SCS SITE 122A DAM	34	1,665	43.2	42.7		42.2		41.7		41.2		40.7	
CEDAR CREEK WS SCS SITE 123 DAM	1,365	66,890	1,122.0	1,103.9		1,083.9		1,063.8		1,043.8		1,023.7	
CEDAR CREEK WS SCS SITE 124 DAM	1,186	58,116	733.0	717.3		699.9		682.5		665.0		647.6	
CEDAR CREEK WS SCS SITE 126 DAM	508	24,878	336.0	329.3		321.8		314.4		306.9		299.4	
CEDAR CREEK WS SCS SITE 127 DAM	837	40,999	31.8	20.8		8.5		554.0	Yes	542.9		530.6	
CEDAR CREEK WS SCS SITE 128 DAM	673	32,989	124.4	115.5		105.6		95.7		85.9		76.0	
CEDAR CREEK WS SCS SITE 129 DAM	355	17,395	53.6	48.9		43.7		38.5		33.3		28.1	
CEDAR CREEK WS SCS SITE 130A DAM	265	12,990	8.4	4.9		1.0		280.0	Yes	276.5		272.6	
CEDAR CREEK WS SCS SITE 130B DAM	283	13,868	11.4	7.6		3.5		277.0	Yes	273.3		269.1	
CEDAR CREEK WS SCS SITE 131 DAM	460	22,533	54.3	48.2		41.5		34.7		27.9		21.2	
CEDAR CREEK WS SCS SITE 134 DAM	7,105	348,149	1,738.0	1,644.0		1,539.7		1,435.3		1,330.9		1,226.5	
CEDAR CREEK WS SCS SITE 135A DAM	453	22,195	202.0	196.0		189.4		182.7		176.0		169.4	
CEDAR CREEK WS SCS SITE 135B DAM	1,009	49,464	580.0	566.7		551.8		537.0		522.2		507.3	
CEDAR CREEK WS SCS SITE 135C DAM	3,921	192,145	1,617.0	1,565.1		1,507.5		1,449.9		1,392.3		1,334.7	
CEDAR CREEK WS SCS SITE 136 DAM	471	23,074	34.6	28.4		21.5		14.6		7.7		0.7	
CEDAR CREEK WS SCS SITE 137 DAM	353	17,309	40.7	36.1		30.9		25.7		20.5		15.3	
CEDAR CREEK WS SCS SITE 138 DAM	656	32,140	52.4	43.7		34.1		24.4		14.8		5.2	
CEDAR CREEK WS SCS SITE 139 DAM	294	14,418	27.6	23.7		19.4		15.0		10.7		6.4	
CEDAR CREEK WS SCS SITE 140 DAM	3,437	168,404	2,163.0	2,117.6		2,067.1		2,016.6		1,966.1		1,915.6	
CEDAR CREEK WS SCS SITE 143A DAM	6,756	331,038	3,559.6	3,470.2		3,371.0		3,271.7		3,172.4		3,073.2	
CEDAR CREEK WS SCS SITE 14A DAM	3,341	163,696	414.8	370.6		321.5		272.5		223.4		174.3	
CEDAR CREEK WS SCS SITE 15 DAM	553	27,113	95.5	88.2		80.1		72.0		63.8		55.7	
CEDAR CREEK WS SCS SITE 16 DAM	1,700	83,301	106.6	84.1		59.1		34.2		9.2		1,264.0	Yes
CEDAR CREEK WS SCS SITE 16A DAM	3,199	156,770	191.1	148.8		101.8		54.8		7.8		2,011.0	Yes
CEDAR CREEK WS SCS SITE 18 DAM	1,113	54,523	139.8	125.1		108.7		92.4		76.0		59.7	

Table 3-6 (cont'd.)

Structure Name	Average Annual Sediment Loading (tons/yr)	Sediment Loading From 2006 to 2055 (tons)	2006 Capacity @ 35lbs/ft^3 (ac-ft)	2015 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2025 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2035 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2045 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2055 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?
CEDAR CREEK WS SCS SITE 19 DAM	1,983	97,146	222.9	196.7		167.5		138.4		109.3		80.1	
CEDAR CREEK WS SCS SITE 1A DAM	458	22,420	75.5	69.4		62.7		56.0		49.3		42.5	
CEDAR CREEK WS SCS SITE 1B DAM	161	7,895	37.7	35.6		33.2		30.8		28.5		26.1	
CEDAR CREEK WS SCS SITE 2 DAM	295	14,455	34.8	30.9		26.6		22.3		17.9		13.6	
CEDAR CREEK WS SCS SITE 3 DAM	190	9,310	53.2	50.7		47.9		45.1		42.3		39.6	
CEDAR CREEK WS SCS SITE 31 DAM	290	14,228	41.3	37.5		33.2		29.0		24.7		20.4	
CEDAR CREEK WS SCS SITE 32 DAM	270	13,238	61.5	57.9		53.9		50.0		46.0		42.0	
CEDAR CREEK WS SCS SITE 33 DAM	228	11,178	47.6	44.6		41.2		37.9		34.5		31.2	
CEDAR CREEK WS SCS SITE 4 DAM	132	6,487	39.2	37.4		35.5		33.6		31.6		29.7	
CEDAR CREEK WS SCS SITE 43A DAM	2,979	145,961	504.0	464.6		420.8		377.1		333.3		289.5	
CEDAR CREEK WS SCS SITE 46REV DAM	779	38,192	144.8	134.5		123.0		111.6		100.1		88.7	
CEDAR CREEK WS SCS SITE 47A DAM	5,093	249,536	1,244.0	1,176.7		1,101.8		1,027.0		952.2		877.4	
CEDAR CREEK WS SCS SITE 5 DAM	156	7,663	48.0	45.9		43.6		41.3		39.0		36.7	
CEDAR CREEK WS SCS SITE 50C DAM	5,372	263,250	2,197.0	2,126.0		2,047.0		1,968.1		1,889.2		1,810.2	
CEDAR CREEK WS SCS SITE 55B DAM	6	284	40.8	40.7		40.6		40.5		40.4		40.3	
CEDAR CREEK WS SCS SITE 57 DAM	6,084	298,104	1,788.0	1,707.6		1,618.2		1,528.8		1,439.4		1,350.0	
CEDAR CREEK WS SCS SITE 58 DAM	1,109	54,337	273.0	258.3		242.0		225.8		209.5		193.2	
CEDAR CREEK WS SCS SITE 59 DAM	580	28,407	186.0	178.3		169.8		161.3		152.8		144.3	
CEDAR CREEK WS SCS SITE 6 DAM	197	9,647	60.9	58.3		55.4		52.5		49.6		46.7	
CEDAR CREEK WS SCS SITE 60 DAM	0	0	4,254.0	4,254.0		4,254.0		4,254.0		4,254.0		4,254.0	
CEDAR CREEK WS SCS SITE 61 DAM	3,944	193,243	782.0	729.9		671.9		614.0		556.0		498.1	
CEDAR CREEK WS SCS SITE 63 DAM	148	7,271	23.2	21.3		19.1		16.9		14.7		12.6	
CEDAR CREEK WS SCS SITE 64R DAM	282	13,822	49.5	45.8		41.7		37.5		33.4		29.2	
CEDAR CREEK WS SCS SITE 65 DAM	232	11,376	37.4	34.4		30.9		27.5		24.1		20.7	
CEDAR CREEK WS SCS SITE 66 DAM	175	8,580	17.0	14.7		12.1		9.6		7.0		4.4	
CEDAR CREEK WS SCS SITE 68 DAM	727	35,637	103.0	93.4		82.7		72.0		61.3		50.6	
CEDAR CREEK WS SCS SITE 68A DAM	2	92	11.9	11.9		11.9		11.9		11.8		11.8	
CEDAR CREEK WS SCS SITE 69 DAM	110	5,392	81.0	79.5		77.9		76.3		74.7		73.1	
CEDAR CREEK WS SCS SITE 7 DAM	131	6,442	38.2	36.5		34.6		32.6		30.7		28.8	
CEDAR CREEK WS SCS SITE 70 DAM	187	9,161	101.2	98.7		96.0		93.2		90.5		87.7	
CEDAR CREEK WS SCS SITE 71 DAM	119	5,814	59.4	57.9		56.1		54.4		52.6		50.9	
CEDAR CREEK WS SCS SITE 72 DAM	49	2,411	45.9	45.3		44.5		43.8		43.1		42.4	
CEDAR CREEK WS SCS SITE 73REV DAM	0	0	397.0	397.0		397.0		397.0		397.0		397.0	
CEDAR CREEK WS SCS SITE 76 DAM	1,829	89,614	219.8	195.6		168.7		141.8		115.0		88.1	
CEDAR CREEK WS SCS SITE 77A DAM	1,542	75,574	173.3	152.9		130.2		107.6		84.9		62.3	
CEDAR CREEK WS SCS SITE 82 DAM	721	35,321	108.6	99.1		88.5		77.9		67.3		56.7	
CEDAR CREEK WS SCS SITE 83 DAM	42	2,059	40.0	39.5		38.9		38.2		37.6		37.0	
CEDAR CREEK WS SCS SITE 84 DAM	432	21,191	49.7	43.9		37.6		31.2		24.9		18.5	
CEDAR CREEK WS SCS SITE 85 DAM	3,181	155,846	503.0	460.9		414.2		367.5		320.8		274.0	
CEDAR CREEK WS SCS SITE 87A DAM	3,229	158,245	8,058.0	8,015.3		7,967.9		7,920.4		7,873.0		7,825.5	
CEDAR CREEK WS SCS SITE 88 DAM	284	13,900	20.3	16.6		12.4		8.2		4.1		405.0	Yes
CEDAR CREEK WS SCS SITE 89 DAM	165	8,079	14.3	12.1		9.7		7.3		4.9		2.4	

Table 3-6 (cont'd.)

Structure Name	Average Annual Sediment Loading (tons/yr)	Sediment Loading From 2006 to 2055 (tons)	2006 Capacity @ 35lbs/ft^3 (ac-ft)	2015 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2025 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2035 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2045 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2055 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?
CEDAR CREEK WS SCS SITE 90 DAM	210	10,287	44.0	41.2		38.1		35.0		31.9		28.9	
CEDAR CREEK WS SCS SITE 92 DAM	1,009	49,441	48.6	35.3		20.4		5.6		1,750.0	Yes	1,736.7	
CEDAR CREEK WS SCS SITE 94B DAM	261	12,788	37.0	33.6		29.7		25.9		22.1		18.2	
CEDAR CREEK WS SCS SITE 94C DAM	181	8,866	30.6	28.2		25.5		22.8		20.2		17.5	
CEDAR CREEK WS SCS SITE 95A DAM	3,422	167,697	107.0	61.8		11.5		5,340.0	Yes	5,294.7		5,244.5	
CEDAR CREEK WS SCS SITE 96 DAM	1,822	89,274	267.0	242.9		216.1		189.4		162.6		135.8	
JOHN SANTERRE LAKE DAM	0	0	95.0	95.0		95.0		95.0		95.0		95.0	
KAUFMAN CITY LAKE DAM 1	1,005	49,269	23.4	10.1		259.0	Yes	245.7		230.9		216.2	
KAUFMAN CITY LAKE DAM 2	2,854	139,825	441.0	403.3		361.3		319.4		277.5		235.6	
KAUFMAN DAM NO 1	539	26,413	75.0	67.9		60.0		52.0		44.1		36.2	
KAUFMAN DAM NO 2	1,498	73,415	480.0	460.2		438.2		416.2		394.1		372.1	
KEMP LAKE DAM	0	0	469.0	469.0		469.0		469.0		469.0		469.0	
LEE LAKE DAM	5,734	280,946	110.0	34.2		110.0	Yes	34.2		110.0	Yes	0.0	
MABANK CITY LAKE DAM	1,101	53,932	86.6	72.1		55.9		39.7		23.6		7.4	
MEADOW WOOD LAKE NO 3 DAM	321	15,723	58.0	53.8		49.0		44.3		39.6		34.9	
MEADOW WOOD LAKE NO 4 DAM	63	3,072	35.8	34.9		34.0		33.1		32.2		31.2	
NOLAN LAKE DAM	0	0	180.0	180.0		180.0		180.0		180.0		180.0	
N. HAVEN CONSTRUCTION CO LAKE DAM	3,157	154,687	130.0	88.3		41.9		130.0	Yes	88.3		41.9	
PORTER LAKE DAM	645	31,623	70.1	61.5		52.1		42.6		33.1		23.6	
RICHARDS LAKE DAM	74	3,603	51.9	50.9		49.8		48.8		47.7		46.6	
ROBERTS LAKE DAM	7,274	356,441	108.0	11.8		108.0	Yes	11.8		108.0	Yes	0.0	
STARBRAND LAKE DAM	100	4,894	201.3	200.0		198.6		197.1		195.6		194.2	
STOUT DAM	0	0	29.0	29.0		29.0		29.0		29.0		29.0	
TAWAKONI BALANCING RESERVOIR LEVEI	291	14,245	979.6	975.8		971.5		967.2		963.0		958.7	
TERRELL COUNTRY CLUB LAKE DAM	3,509	171,948	124.3	77.9		26.3		1,217.0	Yes	1,170.6		1,119.0	
THOMAS LAKE DAM	11,199	548,756	279.7	131.6		1,900.0	Yes	1,751.9		1,587.4		1,422.8	
TONKERSLEY LAKE DAM	38	1,846	79.6	79.1		78.5		78.0		77.4		76.9	
VALLEY VIEW LAKE DAM	0	0	8,200.0	8,200.0		8,200.0		8,200.0		8,200.0		8,200.0	
WELLS DAM	55	2,678	91.9	91.2		90.4		89.6		88.8		88.0	
WEST LAKE DAM	3,110	152,374	219.2	178.1		132.4		86.7		41.0		504.0	Yes
WILLIAMS DAM	347	17,004	10.8	6.3		1.2		39.0	Yes	34.4		29.3	
TOTAL	**158,482**	**7,765,631**	**51,190**	**49,163**		**49,748**		**57,154**		**57,899**		**60,648**	

The resulting estimated structure sedimentation conditions in year 2055 were used to aggregate subwatershed sediment pool storage and surface area for input to the Cedar Creek SWAT model. Structures with inoperative principal spillways were incorporated with substantially changed conditions: 1) the normal pool (both volume and surface area) was expanded to include the flood pool (up to the elevation of the auxiliary spillway), reduced in storage capacity by the amount of sediment accumulated during the 2006-2055 period; and 2) the period for passage of flood flows through the structure was reduced from five days to one day. With these modifications, the SWAT model was operated to simulate daily inflows and sediment loadings for Cedar Creek Reservoir using the rainfall and climatological data for the period 1947 through 2002. Simulations based on sediment densities of 35 and 100 pounds per cubic foot were made.

3.1.5 Flow and Sediment Effects of Floodwater Retarding Structures

Results from operating the SWAT model of the Cedar Creek Reservoir watershed for year-2055 watershed conditions corresponding to the no structure case and to the different dam/ impoundment management options are summarized in Table 3-7. Average, maximum and minimum annual values for inflows to Cedar Creek Reservoir as simulated with the SWAT model based on 1947-2002 rainfall and climatological data are presented. Values for the two assumed sediment densities, i.e., 35 and 100 pounds/cubic foot, are provided. As shown, the highest levels of inflow to Cedar Creek Reservoir under 2055 watershed conditions occur with no structures in place within the watershed. Reductions in the annual average inflows on the order of five to seven percent are indicated for the different dam/impoundment management options.

Annual sediment volume loadings discharged to Cedar Creek Reservoir as simulated with the SWAT model also are presented in the table. These loadings reflect the effects of the different assumed dam/impoundment management options that were analyzed with the SWAT model using actual 1947-2002 daily rainfall and climatological data. Again, values for the two assumed sediment densities, i.e., 35 and 100 pounds/cubic foot, are provided. As expected, the highest sediment volume loadings on the reservoir are indicated for the case with no structures in place (Case I). Annual average sediment loadings discharged into Cedar Creek Reservoir for the different dam/impoundment management options are between 10 and 15 percent lower than the average annual sediment loadings with no structures in place (Case I), thus illustrating the effectiveness of the structures for capturing sediment.

The average annual values of the sediment volume loadings for each of the different assumed dam/impoundment management options and the different assumed sediment densities have been used to make hypothetical projections of the year-2055 conservation storage capacity of Cedar Creek Reservoir. These results are summarized in Table 3-8. For these projections, the most recent estimate of the conservation storage capacity of Cedar Creek Reservoir was used as the starting point for the sediment accumulation calculations. This quantity was 644,785 acre-feet as determined by the Texas Water Development Board based on a survey conducted in 2005 (TWDB, 2007a). Year-by-year accumulations of sediment in Cedar Creek Reservoir beginning in 2005 were determined using each of the average annual sediment loading values for the different dam/impoundment management options and sediment densities. While it is recognized that the resulting year-2055 storage capacities of Cedar Creek Reservoir do not represent the effects of actual sedimentation processes as they would occur over the 2005-2055 timeframe during which sediment storage in the upstream small impoundments and structures would be continuously changing, they do represent lake storage capacities that are reflective of the different assumptions regarding implementation of the dam/impoundment management options. This was considered to be of primary importance when evaluating the relative effects of the different dam/impoundment management options on the firm annual yield of Cedar Creek Reservoir. As shown in Table 3-8, the effect of the different dam/impoundment management options on the year-2055 storage capacity of the reservoir is not appreciable, and differences based on the different assumptions regarding sediment density also are relatively small.

Table 3-7 Annual inflows and sediment volume loadings for Cedar Creek Reservoir for different 2055 NRCS structure conditions based on 1947-2002 SWAT model simulations

ANNUAL INFLOWS TO CEDAR CREEK RESERVOIR UNDER 2055 STRUCTURE CONDITIONS BASED ON DAILY SWAT SIMULATIONS WITH 1947-2002 CLIMATIC DATA

Conditions Analyzed	Average Inflow		Maximum Inflow		Minimum Inflow	
	Simulated Value ac-ft	Percent Change From Case I	Simulated Value ac-ft	Percent Change From Case I	Simulated Value ac-ft	Percent Change From Case I
Sediment Density: 35 lbs/cubic foot						
Case I - No Structures	499,401	- -	947,952	- -	125,678	- -
Case II - Structure Upgrades	466,774	-7%	908,017	-4%	108,029	-14%
Case III - Structure Removal	479,073	-4%	923,691	-3%	114,304	-9%
Case IV - No Action	476,835	-5%	922,501	-3%	113,077	-10%
Sediment Density: 100 lbs/cubic foot						
Case I - No Structures	499,401	- -	947,952	- -	125,678	- -
Case II - Structure Upgrades	467,544	-6%	909,010	-4%	108,260	-14%
Case III - Structure Removal	469,863	-6%	912,019	-4%	109,640	-13%
Case IV - No Action	476,871	-5%	923,664	-3%	113,325	-10%

ANNUAL SEDIMENT VOLUME LOADINGS DEPOSITED INTO CEDAR CREEK RESERVOIR UNDER 2055 STRUCTURE CONDITIONS BASED ON DAILY SWAT SIMULATIONS WITH 1947-2002 CLIMATIC DATA

Conditions Analyzed	Average Loading		Maximum Loading		Minimum Loading	
	Simulated Value ac-ft	Percent Change From Case I	Simulated Value ac-ft	Percent Change From Case I	Simulated Value ac-ft	Percent Change From Case I
Sediment Density: 35 lbs/cubic foot						
Case I - No Structures	733	- -	1,611	- -	187	- -
Case II - Structure Upgrades	623	-15%	1,367	-15%	146	-22%
Case III - Structure Removal	662	-10%	1,445	-10%	160	-15%
Case IV - No Action	649	-11%	1,406	-13%	154	-18%
Sediment Density: 100 lbs/cubic foot						
Case I - No Structures	256	- -	564	- -	66	- -
Case II - Structure Upgrades	217	-15%	477	-15%	51	-22%
Case III - Structure Removal	220	-14%	484	-14%	52	-21%
Case IV - No Action	227	-12%	493	-13%	54	-18%

Table 3-8 Projected year-2055 conservation storage capacity for Cedar Creek Reservoir for different 2055 NRCS structure conditions based on average sediment loadings from 1947-2002 SWAT model simulations

Conditions Analyzed	Conservation Storage Capacity ac-ft	Percent Change From 2005	Percent Change From Case I	Percent Change From 35 lbs/cu foot
2005 TWDB Survey (TWDB, 2007a)	644,785	- -	- -	- -
Sediment Density: 35 lbs/cubic foot				
Case I - No Structures	609,771	-5.4%	- -	- -
Case II - Structure Upgrades	615,020	-4.6%	0.9%	- -
Case III - Structure Removal	613,106	-4.9%	0.5%	- -
Case IV - No Action	613,814	-4.8%	0.7%	- -
Sediment Density: 100 lbs/cubic foot				
Case I - No Structures	632,249	-1.9%	- -	3.7%
Case II - Structure Upgrades	634,118	-1.7%	0.3%	3.1%
Case III - Structure Removal	633,755	-1.7%	0.2%	3.4%
Case IV - No Action	633,687	-1.7%	0.2%	3.2%

3.2 LAKE COLEMAN WATERSHED

3.2.1 Data and Information Sources

Unlike the SWAT model used for the analyses of the Cedar Creek Reservoir watershed (which existed prior to this study), the Lake Coleman SWAT model had to be originally assembled as part of this study. The basic information that provides inputs for the Lake Coleman SWAT model includes:

- USGS 1:24,000 topography;
- NRCS SSURGO soils database
- USGS spatial land use data
- Historical daily rainfall and climatological data from the following stations:

  Coleman
  Novice
  Lawn, and
  Lake Abilene;
- National Hydrography dataset

The version of the SWAT program used for constructing the model of the Lake Coleman watershed was ArcSWAT2.1.6 linked with SWAT2005. In this version, model input parameters are linked to spatial databases using GIS software.

Information required for modeling of NRCS-designed structures within the Lake Coleman watershed was compiled from review of as-built drawings available at the NRCS office in Temple, Texas. This information included primarily data describing the crest elevations for the principal and auxiliary spillways and the storage volumes and surface areas for the sediment pools and the flood pools of each structure. Descriptive information for non-NRCS designed dams in the watershed was taken from the National Inventory of Dams. For some small dams, which were privately owned and not supported by NRCS, descriptive data either were insufficient or could not be located at all. These dams were not included in the SWAT model.

A summary of available descriptive information for each of the structures included in the Lake Coleman watershed as represented in the SWAT model is provided in Table 3-9.

3.2.2 SWAT Model Structure

The subwatersheds and the individual dams and reservoirs included in the SWAT model of the Lake Coleman watershed are shown on the aerial photograph of the region in Figure A-3 in Appendix A. There are 15 subwatersheds and 20 dams and reservoirs considered in the model.

The basic elements of the Lake Coleman SWAT model include subwatersheds, streamflow routing reaches, reservoirs, and junctions at reach confluences. The basic network structure of

Table 3-9 Information available from NID and as-built drawings for structures in Lake Coleman watershed

DAMNAME	NAT_ID	Year Com-pleted	Designed by NRCS	Dam Height	Normal Storage (Ac-ft)	Principal Spillway Elevation	Principal Spillway Surface Area (ac)	Auxillary Spillway Elevation (feet)	Auxillary Spillway Surface Area (Acres)	Auxillary Spilway Storage (Acre ft)	Top of Dam Elevation (feet)	Top of Dam Surface area (Acres)	Top of Dam Storage (acre-ft)
DANIELS DAM	TX02214	1964			32.0		13.0		24	120		413	194
HUGHES DAM	TX02219	1967			36.0		10.0		17	73		234	108
JIM NED CREEK WS SCS SITE 10 DAM	TX02155	1963	x	30.0	35.0	1728.8	11.0	1743.6	53.0	481.0	1748.7	71.8	804.3
JIM NED CREEK WS SCS SITE 11 DAM	TX02157	1963	x	52.0	53.0	1723.2	12.0	1758.0	148.0	2684.0	1763.8	173.1	3623.2
JIM NED CREEK WS SCS SITE 12 DAM	TX02159	1963	x	84.0	143.0	1782.8	23.0	1832.0	209.0	4987.0	1837.9	244.9	6334.5
JIM NED CREEK WS SCS SITE 12A DAM	TX02683	1963	x	72.0	200.0	1854.3	25.0	1892.0	140.0	3276.0	1897.5	163.8	4119.0
JIM NED CREEK WS SCS SITE 12C DAM	TX02163	1961	x	50.0	93.0	1859.4	19.0	1884.0	104.0	1420.0	1889.6	123.0	1724.3
JIM NED CREEK WS SCS SITE 12E1 DAM	TX02162	1965	x	64.0	200.0	1808.4	49.0	1918.2	318.0	5263.0	1926.2	428.7	5981.6
JIM NED CREEK WS SCS SITE 12F DAM	TX02158	1962	x	56.0	38.0	1804.0	9.0	1836.0	88.0	1508.0	1841.7	105.1	2064.2
JIM NED CREEK WS SCS SITE 15 DAM	TX02687	1960	x	27.0	59.0	2020.8	14.0	2032.0	50.0	380.0	2037.1	75.8	702.3
JIM NED CREEK WS SCS SITE 16 DAM	TX02686	1960	x	34.0	104.0	2060.0	26.0	2072.8	93.0	778.0	2077.8	131.3	1351.4
JIM NED CREEK WS SCS SITE 17 DAM	TX02685	1960	x	22.0	31.0	2050.0	12.5	2056.7	38.0	188.0	2061.7	66.7	460.8
JIM NED CREEK WS SCS SITE 17B1 DAM	TX02694	1970	x	31.0	108.0	2038.0	20.0	2051.6	67.0	679.0	2056.3	87.0	1044.0
JIM NED CREEK WS SCS SITE 19 DAM	TX02682	1960	x	28.0	200.0	1893.3	103.0	1903.6	373.0	2723.0	1908.8	565.8	5218.0
JIM NED CREEK WS SCS SITE 20 DAM	TX02161	1960	x	48.0	324.0	1907.2	48.0	1927.5	227.0	2820.0	1932.5	295.1	4143.8
JIM NED CREEK WS SCS SITE 21 DAM	TX02160	1963	x	92.0	185.0	1737.7	26.0	1787.0	202.0	5231.0	1798.5	268.6	7929.8
JIM NED CREEK WS SCS SITE 9 DAM	TX02154	1963	x	48.0	53.0	1698.3	10.2	1722.0	56.0	738.0	1727.5	0.0	80.5
LAKE LAWN DAM	TX02684	1912			201.0		103.0		494.4	2920.0		200.6	1137
LAKE STITH DAM	TX02693	1925			38.0		5.0		6	148		8	249
NOVICE CITY LAKE DAM	TX02213	1947			130.0		30.0		40.0	313.0		60.0	800.0
TOTAL					**2263.0**		**568.7**		**2747.1**	**36729.9**		**3715.7**	**48070.1**

the Lake Coleman SWAT model is presented in Figure A-4. No diversions or external sources of water (other than rainfall) are included in the model.

3.2.3 SWAT Model Calibration

3.2.3.1 Calibration of Watershed Hydrology

Calibration of the SWAT model for the Lake Coleman watershed was focused primarily on simulating reasonable estimates of the historical inflows to Lake Coleman. While there are no direct measurements of these inflows, estimates have been made in other studies. The most recent study was conducted by the Region F Water Planning Group as part of its planning activities for meeting future water demands in the region (Freese & Nichols, 2009).

These Region F inflows to Lake Coleman were estimated on a monthly basis for the period 1940-1998 by one of two methods. For the period 1940-1975 and the period 1997-1998, they reflect transformation of streamflow data from the nearest representative gage with a long-term record. This gage, identified as U.S. Geological Survey Gage No. 08127000, is on Elm Creek near the city of Ballinger. The drainage area upstream of this gage covers 450 square miles (versus 292 square miles for Lake Coleman), and there are 14 small dams located within this watershed, only one of which is an NRCS-designed floodwater retarding structure. The aggregate area controlled by flood retarding structures upstream of the Elm Creek gage is 14 square miles, about 3 percent of the watershed area. The Lake Coleman watershed has 21 dams, of which 15 (all NRCS-designed) were constructed for flood retention. The aggregate area controlled by flood retarding structures upstream of Lake Coleman is 113 square miles, which is about 50 percent of the watershed. For the period 1976-1996, the Region F inflows to Lake Coleman were derived through mass balance calculations using historical monthly data describing changes in storage for Lake Coleman, rainfall and evaporation at or near Lake Coleman, and diversions and releases from Lake Coleman.

While there are limitations associated with the Region F set of historical monthly inflows for Lake Coleman, they were derived using generally accepted procedures with what is likely the best available data. As noted in the Region F report (Freese & Nichols, 2009), these inflows to Lake Coleman are within about five percent of those originally developed for the Colorado Basin Water Availability Model (R. J. Brandes Company, *et al*, 2001), a deviation considered to be explained within the uncertainty of the hydrologic series itself.

The SWAT model of the Lake Coleman watershed was calibrated to match the Region F inflows to Lake Coleman primarily through varying two model parameters affecting model transfer of groundwater to base flow within their typical ranges: ALPHA_BF (base flow alpha factor) and GWQMIN (threshold depth of water in the shallow aquifer for return flow to occur). The best calibration was achieved using an ALPHA_BF factor of 0.048 and a GWQMIN factor of 1.0. The result of this calibration process is shown in Figure 3-1, which is a comparison plot of cumulative inflows into Lake Coleman over the period 1947-1998 based on the Region F inflows and inflows simulated with the SWAT model.

An additional calibration was performed for the SWAT model using historical 2000-2007 daily stage data for Lake Coleman as the calibration variable. For this analysis, the SWAT model was operated with actual daily rainfall and climatological parameters corresponding to the 2000-2007 period, and the daily storage in Lake Coleman was simulated subject to the simulated daily inflows and specified historical daily releases and diversions, or at least estimates of these quantities. The graph in Figure 3-2 shows the comparison between the actual measured Lake Coleman stage and that simulated with the SWAT model for this period. As shown, for the period after July 2002, the simulated daily stage of Lake Coleman from the calibrated SWAT model appears to match reasonably well with variations associated with individual rainfall events. It should be noted that Lake Coleman was assumed to be full at the beginning of the simulation for the 2000-2007 period, which is the reason that the simulated stage values differ significantly from the actual stage measurements prior to July 2002 when the actual storage in the reservoir was fairly low due to ongoing drought conditions. The problem with this overall calibration of the SWAT model is that there appears to be a significant dichotomy between the unit-area flows produced with this SWAT model and the corresponding unit-area flows measured at the Elm Creek gage. The SWAT unit-area flows are significantly lower than those measured at the Elm Creek gage. Similarly, the inflows to Lake Coleman from this SWAT model differ materially from the corresponding Region F inflows, which, of course, were derived from the Elm Creek gage.

It should also be noted that was some uncertainty with regard to the accuracy of the daily data used for specifying releases and diversions from Lake Coleman in the 2000-2007 SWAT model simulation. Furthermore, the measured stage data, which can be influenced by wind setup and local wave action, also may not accurately reflect the average stage over the entire surface of the reservoir, whereas the average is what is simulated with the SWAT model. The accuracy of the stage-area-volume relationship for Lake Coleman also can greatly affect the reported stage from the SWAT model simulation. These are some of the factors that may be part of the reason for some of the discrepancies observed in the model results.

The primary disagreement between the Region F inflow-calibrated SWAT model and the measured stage-calibrated SWAT model occurs in 1957, which is significant, because this includes the period at the end of the historic drought which typically determines reservoir yield. The SWAT model calibrated to match the Region F inflows to Lake Coleman simulates less runoff per square mile in 1957 (3.0 inches) compared to the corresponding gaged flows for the adjacent Elm Creek watershed (3.6 inches), despite having annual rainfall of 33 to 40 inches varying across the Lake Coleman watershed as opposed to 26 to 37 inches of annual rainfall across the Elm Creek watershed. This can be partially explained by the much greater capability for floodwater retention in the Lake Coleman watershed that leads to overall higher water losses (primarily through evaporation). However, it is also apparent that the SWAT model calibrated to match the Region F inflows to Lake Coleman does not accurately simulate inflows produced by individual intense rainfall events. Over 190 square miles of the Lake Coleman watershed lacks floodwater retention, yet flood peaks are severely attenuated throughout the watershed.

A number of attempts were made to resolve the dichotomy between the two calibrated models in order to create a SWAT model that both matched the 2000-2007 Lake Coleman stage record and was consistent with the full historic record of inflows to Lake Coleman as derived in the Region

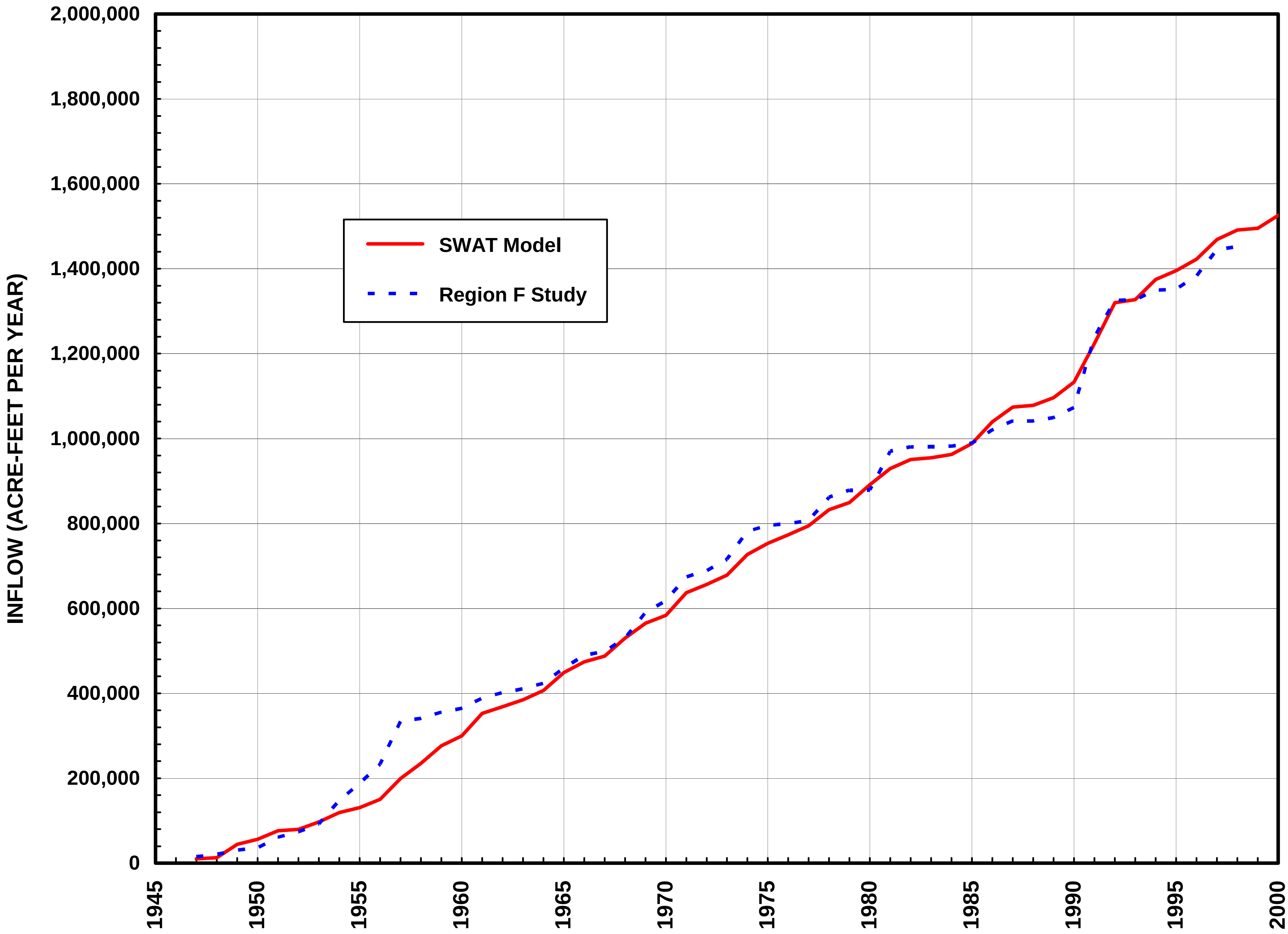

Figure 3-1 Comparison of 1947-1998 cumulative inflows to Lake Coleman based on the Region F Study and as simulated with the SWAT model

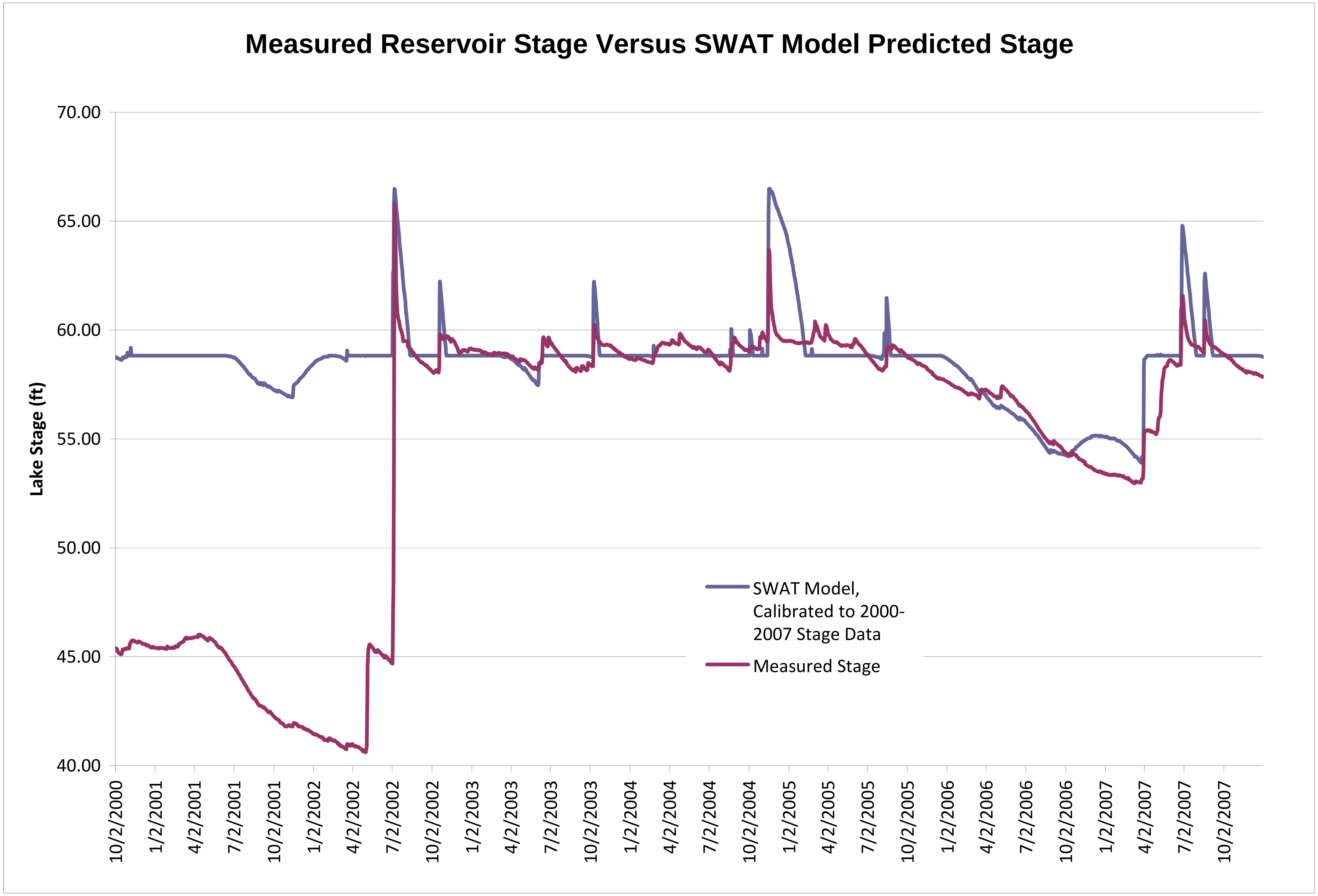

Figure 3-2 Comparison of daily stage of Lake Coleman from historical measurements and from SWAT model

F study. This effort proved to be unsuccessful. Because the stated purpose of this study is to investigate the effect of small impoundments, particularly NRCS floodwater retarding structures, on the water supply capability of a downstream reservoir and because of uncertainties associated with the model inputs necessary to accurately simulate the stage of Lake Coleman, the SWAT model calibrated to the Region F inflows to Lake Coleman was used for subsequent simulations. This allowed results to be more consistent with those from ongoing regional water supply planning activities.

3.2.3.2 Calibration of Watershed Sediment Yield

No site-specific field investigations or data were available for the Lake Coleman watershed upon which to base appropriate channel erosion/deposition parameters for use in the SWAT model. Consequently, several different strategies were attempted for calibration of sediment yield in the SWAT model, with very limited constructive results. The only information available for estimation of actual sediment yield for the watershed upstream of Lake Coleman included the following:

- The 2006 Texas Water Development Board volumetric survey of Lake Coleman
- The 1966 Lake Coleman as-built elevation-storage curve
- The Cedar Creek SWAT model, whose sediment yield parameters were calibrated to measured sedimentation data for that watershed

The design and as-built conservation storage capacity of Lake Coleman at a water surface elevation of 1717.5 feet above mean sea level, as the reservoir purportedly was constructed in 1966, was reported to be approximately 40,000 acre-feet (TWDB, 2006). The measured capacity at this elevation in 2006 was 38,076 acre-feet (TWDB, 2006), indicating an apparent 40-year accumulation of sediment of only about 2,000 acre-feet. This small difference was not deemed to be of sufficient accuracy to warrant use in calibration of the SWAT model. The primary concern was that the precise, rounded value (40,000 acre-feet) reported for the original conservation pool volume may not have been based on an accurate original reservoir site survey and that this inaccuracy may exceed in magnitude the estimated change in the actual storage capacity between 1966 and 2006.

Since field investigations were available for the Cedar Creek watershed that provided data that were used to establish appropriate channel erosion/deposition parameters in the Cedar Creek SWAT model, consideration was given to developing a multiple regression that related Cedar Creek SWAT model parameters to Cedar Creek watershed physical parameters. This regression relationship could then be applied to estimate corresponding Lake Coleman erosion/deposition parameters using Lake Coleman watershed-specific physical parameters. The SWAT model documentation indicates that the soil erodibility factor used in the universal soil loss equation and the D50 for a given area can be estimated based on SSURGO soils series data. Using ArcGIS, the SSURGO soil shapefile covering the Cedar Creek watershed was analyzed to develop area-weighted D50 and soil erodibility factor values for individual channel segments. These weighted values were then used in a regression analysis to attempt to predict the channel erodibility factor for the channel segment. Based on the regressions performed, it was concluded that there were no meaningful correlations between the area-weighted soil erodibility values and the calibrated channel erodibility factors; hence, this approach was abandoned as a potential means for establishing the sediment yield parameters for the Lake Coleman SWAT model.

In the absence of a meaningful approach for calibrating the Lake Coleman SWAT model for sediment yield, a sensitivity analysis was undertaken in order to better understand the impact of variations in the model parameters related to sediment yield. The SWAT model was operated using actual daily climatological data for the 1999-2007 period for successive simulations with the channel erodibility factor and the channel cover factor varied to the extent of the range of values used in the Cedar Creek SWAT model. The channel erodibility factor (Kch) varies between 0.0 and 1.0. A value of 0.0 indicates a non-erosive channel while a value of 1.0 indicates no resistance to erosion. The channel cover factor (Cch) also varies between 0.0 and 1.0 with a value of 0.0 indicating that a channel is completely protected from degradation by vegetative or other cover and a value of 1.0 indicating that there is no vegetative cover on the channel. The channel erodibility factors for all of the channel segments in the Lake Coleman model were originally set to 0.2, and the channel cover factors were set to 0.0 based on professional judgment. The effect of varying these parameters within their respective ranges is indicated by the results of the sensitivity analysis in Table 3-10.

Table 3-10 Effects of varying sediment yield parameters in the Lake Coleman SWAT model

Year	Sediment Inflow to Lake Coleman (Metric Tons)			
	Kch = 0.2 Cch = 0.0	Kch = 0.2 Cch = 1.0	Kch = 0.6 Cch = 1.0	Kch = 0.6 Cch = 0.2
1999	144	1,093	2,030	866
2000	5,576	23,610	42,540	19,000
2001	1,284	5,621	8,892	4,829
2002	19,680	92,080	153,000	73,390
2003	2,613	22,240	46,450	15,560
2004	29,360	88,830	162,400	68,400
2005	4,071	23,560	47,420	17,130
2006	294	3,583	5,648	3,046
2007	21,100	88,570	150,200	67,130

It was apparent from the results of the sensitivity analysis that different values of the channel erodibility factor and the channel cover factor could have a significant impact on the sediment yield produced by the SWAT model and that accurate estimation of sediment processes would require field investigations beyond the scope of this study. For purposes of proceeding with the analyses of small impoundments on the water supply capability of Lake Coleman, a single set of average values of the sediment yield parameters were used for all of the SWAT simulations to eliminate any effects of differences in these values.

3.2.4 2006 Floodwater Retarding Structure Conditions

As noted earlier, in this study the initial modeling of floodwater retarding structures with the Lake Coleman SWAT model was performed with the sediment pool (normal pool) capacities and surface areas of these structures specified in accordance with their respective as-built conditions as derived from original design documents or available dam inspection reports. The existing structures within the lake Coleman watershed were constructed during the period from about 1960 to 1970. For analysis of the effects of the different assumed dam/impoundment management scenarios on the water supply capability of Lake Coleman, the projected year-2055 sedimentation condition of the individual structures was required for each of the scenario alternatives. The initial task in the development of the different 2055 scenario sedimentation conditions was the estimation of the sedimentation condition of the existing structures in 2006. The activities involved in this process are described below:

Aggregation of Structure Information - As described in Section 2.0, as-built pond volume and surface area parameters were aggregated by subwatershed using the information presented in Table 3-9 for NRCS structures, coupled with the available NID-derived parameters for the non-NRCS designed structures. The resulting summary of subwatershed descriptions as included in the SWAT model is provided in Table 3-11. The percentage of subwatershed drainage area controlled by structures and the associated aggregate as-built sediment and flood pool surface areas and storage areas are indicated.

Performance of As-Built SWAT Model Simulation - The SWAT model representing revised as-built structure conditions was operated with specified historical climatic conditions corresponding to the years 1947 through 2007. Model results provided estimates of the quantity of sediment in tons trapped in the subwatershed aggregated normal pools (sediment pools) for each year of the simulation.

Determination of 2006 Structure Sediment Pool Conditions - The 1970-2002 average annual trapped sediment value from the SWAT model for the aggregate structure in each subwatershed was allocated to each individual structure within the subwatershed based on relative drainage area size. Then for each individual structure, the total sediment accumulation in tons was calculated over time beginning with the actual date of construction and extending to 2006. As described in Section 2.0, this sediment tonnage was converted to volume in acre-feet based on alternative sediment densities of 35 pounds per cubic feet and 100 pounds per cubic foot. If the estimated total sediment volume was less than the volume of the design sediment pool for a particular structure, then the design storage capacity of the sediment pool was reduced by this amount to produce the 2006 sediment pool capacity. If the estimated total sediment volume exceeded the volume of the design sediment pool for a particular structure, it was assumed that the design sediment pool capacity was reestablished through ongoing maintenance in 2006, and the 2006 capacity of the sediment pool was set equal to the design sediment pool capacity. Table 3-12 provides a summary of these calculations for each structure.

Table 3-11 Summary of aggregated structures by subwatershed in Lake Coleman watershed

Sub-watershed ID	Percent of Watershed Controlled by Structures	Aggregate Sediment Pool Surface Area (acres)	Aggregate Sediment Pool Volume (acre-feet)	Aggregate Flood Pool Surface Area (acres)	Aggregate Flood Pool Volume (acre-feet)	Top of Dam Surface Area (acres)
1	21%	21	88	109	1,219	72
2	41%	34	238	228	4,784	269
3	6%	20	108	67	679	87
4	0%	0	0	0	0	0
5	95%	12	53	148	2,684	173
6	99%	36	241	219	5,304	503
7	83%	23	143	209	4,987	245
8	69%	98	526	388	5,734	955
9	33%	19	93	104	1,420	123
10	0%	0	0	0	0	0
11	93%	48	288	227	2,820	295
12	72%	103	384	373	2,723	566
13	94%	108	632	500	148	209
14	11%	14	59	50	380	76
15	42%	39	135	131	966	198
TOTAL		**575**	**2,988**	**2,754**	**33,848**	**3,770**

3.2.5 2055 Floodwater Retarding Structure Analyses

For each of the four different scenarios corresponding to different dam/impoundment management options described in Section 2.2, projections of year-2055 structure sedimentation conditions were made based on the 1970-2002 average annual sedimentation rates derived from the SWAT model simulations. Beginning with the estimated 2006 sedimentation condition of each structure as derived above, the annual incremental decrease in the sediment pool storage capacity was calculated over time through the year 2055. At the point in time during the calculations when the sediment pool of each structure filled to its maximum capacity at the level of its primary spillway, adjustments were made in the sediment pool storage capacity in accordance with one of the different assumed dam/impoundment management options, and the pool sedimentation calculation process then was continued through the year 2055. The specific analyses undertaken to derive these 2055 structure sedimentation conditions are described in the following sections.

3.2.5.1 Case I (No Structures)

To analyze runoff and sediment transport conditions for this case, the storage capacities of the sediment and flood pools of each structure within each model subwatershed were reduced to zero. In effect, this reduced the controlled drainage area within each subwatershed to zero. With these modifications, the SWAT model was operated to simulate daily inflows and sediment loadings for Lake Coleman using the rainfall and climatological data for the period 1947 through 2007.

Table 3-12 Summary of 2006 sediment pool storage calculations for structures in Lake Coleman watershed

Structure Name	Sub-watershed ID	NRCS Drainage Area (acres)	Year Com-pleted	Years of Accum-ulated Sediment to 2006	Estimated Average Annual Sediment Loading (tons/yr)	Area Weighted Ave Annual Sediment Loading (tons/yr)	Sediment Loading From Construction to 2006 (tons)	As-Built Sediment Storage Capacity (ac-ft)	Total Accumulated Sediment Volume 35 lbs/ft^3 (ac-ft)	Total Accumulated Sediment Volume 100 lbs/ft^3 (ac-ft)	2006 Sediment Pool Capacity 35 lbs/ft^3 (ac-ft)	2006 Sediment Pool Capacity 100 lbs/ft^3 (ac-ft)
JIM NED CREEK WS SCS SITE 10 DAM	1	1,479	1963	43	3,922	2,087	89,750	35	132	46	Note [1]	Note [1]
JIM NED CREEK WS SCS SITE 9 DAM	1	1,300	1963	43	3,922	1,835	78,895	53	116	41	Note [1]	12
JIM NED CREEK WS SCS SITE 12A DAM	2	6,100	1963	43	815	520	22,357	185	33	11	152	174
JIM NED CREEK WS SCS SITE 12F DAM	2	523	1962	44	26,545	1,453	63,938	38	94	33	Note [1]	5
JIM NED CREEK WS SCS SITE 17B1 DAM	3	1,077	1963	43	25,439	25,439	1,093,881	200	1,607	563	Note [1]	Note [1]
JIM NED CREEK WS SCS SITE 11 DAM	5	6,129	1970	36	10,714	10,714	385,693	108	567	198	Note [1]	Note [1]
HUGHES DAM	6	2,786	1963	43	10,714	1,579	67,906	53	100	35	Note [1]	18
JIM NED CREEK WS SCS SITE 21 DAM	6	16,116	1963	43	10,714	9,134	392,783	56	577	202	Note [1]	Note [1]
JIM NED CREEK WS SCS SITE 12 DAM	7	9,891	1963	43	98,290	98,290	4,226,472	143	6,210	2,173	Note [1]	Note [1]
DANIELS DAM	8	573	1963	43	61,673	1,806	77,652	83	114	40	Note [1]	43
JIM NED CREEK WS SCS SITE 12E1 DAM	8	8,242	1965	41	61,673	25,978	1,065,117	263	1,565	548	Note [1]	Note [1]
NOVICE CITY LAKE DAM	8	8,673	1963	43	61,673	27,337	1,175,488	150	1,727	604	Note [1]	Note [1]
JIM NED CREEK WS SCS SITE 12C DAM	9	3,304	1961	45	81,928	81,928	3,686,775	93	5,417	1,896	Note [1]	Note [1]
JIM NED CREEK WS SCS SITE 20 DAM	11	7,393	1960	46	7,150	7,150	328,893	288	483	169	Note [1]	119
JIM NED CREEK WS SCS SITE 19 DAM	12	6,443	1960	46	3,239	3,239	148,978	384	219	77	165	307
JIM NED CREEK WS SCS SITE 15 DAM	14	1,036	1960	46	366	366	16,837	59	25	9	34	50
JIM NED CREEK WS SCS SITE 16 DAM	15	2,319	1960	46	3,525	2,616	120,359	104	177	62	Note [1]	42
LAKE LAWN DAM	13	7,502	1960	46	6,903	6,382	293,560	530	431	151	99	379
LAKE STITH DAM	13	613	1960	46	6,903	521	23,970	102	35	12	67	90
JIM NED CREEK WS SCS SITE 17 DAM	15	805	1960	46	3,525	908	41,779	31	61	21	Note [1]	10
TOTAL		92,302			489,630	309,283	13,401,082	2,958	19,689	6,891	2,215	2,297

Note [1] - Sediment pool full to design capacity in 2006; reset capacity to as-built condition.

3.2.5.2 Case II (Structure Upgrades)

For this case, the average annual sedimentation rate for each structure as derived through the process described in Section 3.2.4 was applied to calculate the total sediment accumulation in tons over time beginning in 2006 and extending through 2055. This sediment tonnage was converted to volume in acre-feet based on alternative sediment densities of 35 pounds per cubic feet and 100 pounds per cubic foot. The same procedures for adjusting the sediment pool capacities when the pools filled with sediment to their respective design capacities as applied for the Case II Cedar Creek structures (see Section 3.1.4.2) were also followed for the Lake Coleman structures. The end result of these analyses was the year-2055 Case II sedimentation condition for each of the structures in the Lake Coleman watershed assuming two different sediment densities, i.e., 35 and 100 pounds per cubic foot. Table 3-13 summarizes these spreadsheet-based calculations for an assumed sediment density of 35 pounds per cubic foot.

The resulting estimated structure sedimentation conditions in year 2055 were used to aggregate subwatershed sediment pool storage and surface area for input to the Lake Coleman SWAT model. With these modifications, the SWAT model was operated to simulate daily inflows and sediment loadings for Lake Coleman under year-2055 watershed conditions using the rainfall and climatological data for the period 1947 through 2007. Simulations based on sediment densities of 35 and 100 pounds per cubic foot were made.

3.2.5.3 Case III (Structure Removal)

The same procedures described above for Case II were applied for this Case III scenario to estimate the total volume of sediment in acre-feet potentially accumulated in each structure in the subwatersheds of the Lake Coleman watershed during the period from 2006 through 2055, again considering alternative sediment densities of 35 pounds per cubic feet and 100 pounds per cubic foot. For this Case III, if the estimated total accumulated sediment volume was less than the volume of the 2006 sediment pool for a particular structure, then the 2006 storage capacity of the sediment pool was reduced by this amount to produce the 2055 sediment pool capacity. If the estimated total sediment volume exceeded the volume of the 2006 sediment pool for a particular structure, it was assumed that the structure was removed from the subwatershed and assumed not to be replaced.

The end result of these analyses was the year-2055 Case III sedimentation condition for each of the structures in the Lake Coleman watershed assuming two different sediment densities, i.e., 35 and 100 pounds per cubic foot. Table 3-14 summarizes these spreadsheet-based calculations for an assumed sediment density of 35 pounds per cubic foot.

The resulting estimated structure sedimentation conditions in year 2055 were used to aggregate subwatershed sediment pool storage and surface area for input to the Lake Coleman SWAT model. With these modifications, the SWAT model was operated to simulate daily inflows and sediment loadings for Lake Coleman under year-2055 watershed conditions using the rainfall and climatological data for the period 1947 through 2007. Simulations based on sediment densities of 35 and 100 pounds per cubic foot were made.

Table 3-13 Summary of Case II (Structure Upgrades) 2055 sediment pool storage calculations for structures in the Lake Coleman watershed (35 pounds/cubic foot density)

Structure Name	Average Annual Sediment Loading (tons/yr)	Sediment Loading From 2006 to 2055 (tons)	2006 Capacity @ 35lbs/ft^3 (ac-ft)	2015 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2025 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2035 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2045 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?	2055 Capacity @ 35lbs/ft^3 (ac-ft)	Sediment Removed?
DANIELS DAM	1,806	88,487	83.0	59.1		35.2		11.4		70.5	Yes	46.6	
HUGHES DAM	1,579	77,381	56.0	35.1		14.2		49.4	Yes	28.5		7.6	
JIM NED CREEK WS SCS SITE 10 DAM	2,087	102,273	35.0	7.4		14.8	Yes	22.2	Yes	29.6	Yes	2.0	
JIM NED CREEK WS SCS SITE 11 DAM	10,714	524,971	53.0	17.3	Yes	34.7	Yes	52.0	Yes	16.3	Yes	33.7	Yes
JIM NED CREEK WS SCS SITE 12 DAM	98,290	4,816,212	143.0	130.3	Yes	117.6	Yes	104.9	Yes	92.2	Yes	79.5	Yes
JIM NED CREEK WS SCS SITE 12A DAM	520	25,476	167.2	160.3		153.4		146.5		139.7		132.8	
JIM NED CREEK WS SCS SITE 12C DAM	81,928	4,014,489	93.0	32.7	Yes	65.3	Yes	5.0	Yes	37.6	Yes	70.3	Yes
JIM NED CREEK WS SCS SITE 12E1 DAM	25,978	1,272,944	263.0	182.5	Yes	102.0	Yes	21.5	Yes	203.9	Yes	123.4	Yes
JIM NED CREEK WS SCS SITE 12F DAM	1,453	71,204	38.0	18.8		37.6	Yes	18.4		37.1	Yes	17.9	
JIM NED CREEK WS SCS SITE 15 DAM	366	17,935	34.3	29.4		24.6		19.7		14.9		10.1	
JIM NED CREEK WS SCS SITE 16 DAM	2,616	128,208	104.0	69.4		34.8		0.2		69.6	Yes	35.0	
JIM NED CREEK WS SCS SITE 17 DAM	908	44,503	31.0	19.0		7.0		26.0	Yes	14.0		2.0	
JIM NED CREEK WS SCS SITE 17B1 DAM	25,439	1,246,516	108.0	95.6	Yes	83.2	Yes	70.8	Yes	58.5	Yes	46.1	Yes
JIM NED CREEK WS SCS SITE 19 DAM	3,239	158,694	165.1	122.3		79.5		36.6		377.8	Yes	335.0	
JIM NED CREEK WS SCS SITE 20 DAM	7,150	350,343	288.0	193.5		98.9		4.4		197.8	Yes	103.3	
JIM NED CREEK WS SCS SITE 21 DAM	9,134	447,590	185.0	64.2		128.4	Yes	7.6		71.9	Yes	136.1	Yes
JIM NED CREEK WS SCS SITE 9 DAM	1,835	89,904	53.0	28.7		4.5		33.2	Yes	9.0		37.7	Yes
LAKE LAWN DAM	6,382	312,706	98.7	14.3		459.9	Yes	375.5		291.1		206.8	
LAKE STITH DAM	521	25,533	66.8	59.9		53.0		46.1		39.2		32.3	
NOVICE CITY LAKE DAM	27,337	1,339,510	150.0	88.5	Yes	27.0	Yes	115.6	Yes	54.1	Yes	142.6	Yes
TOTAL	**309,283**	**15,154,878**	**2,215**	**1,428**		**1,576**		**1,167**		**1,853**		**1,601**	

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Table 3-14 Summary of Case III (Structure Removal) 2055 sediment pool storage calculations for structures in the Lake Coleman watershed (35 pounds/cubic foot density)

Structure Name	Average Annual Sediment Loading (tons/yr)	Sediment Loading From 2006 to 2055 (tons)	2006 Capacity @ 35lbs/ft^3 (ac-ft)	2015 Capacity @ 35lbs/ft^3 (ac-ft)	Breached?	2025 Capacity @ 35lbs/ft^3 (ac-ft)	Breached?	2035 Capacity @ 35lbs/ft^3 (ac-ft)	Breached?	2045 Capacity @ 35lbs/ft^3 (ac-ft)	Breached?	2055 Capacity @ 35lbs/ft^3 (ac-ft)	Breached?	Breached During 2006 to 2055?
DANIELS DAM	1,806	88,487	83.0	59.1		32.6		6.1		83.0	Yes	83.0	Yes	Removed
HUGHES DAM	1,579	77,381	56.0	35.1		11.9		56.0	Yes	56.0	Yes	56.0	Yes	Removed
JIM NED CREEK WS SCS SITE 10 DAM	2,087	102,273	35.0	7.4		35.0	Yes	35.0	Yes	35.0	Yes	35.0	Yes	Removed
JIM NED CREEK WS SCS SITE 11 DAM	10,714	524,971	53.0	53.0	Yes	53.0	Yes	53.0	Yes	53.0	Yes	53.0	Yes	Removed
JIM NED CREEK WS SCS SITE 12 DAM	98,290	4,816,212	143.0	143.0	Yes	143.0	Yes	143.0	Yes	143.0	Yes	143.0	Yes	Removed
JIM NED CREEK WS SCS SITE 12A DAM	520	25,476	167.2	160.3		152.6		145.0		137.4		129.7		
JIM NED CREEK WS SCS SITE 12C DAM	81,928	4,014,489	93.0	93.0	Yes	93.0	Yes	93.0	Yes	93.0	Yes	93.0	Yes	Removed
JIM NED CREEK WS SCS SITE 12E1 DAM	25,978	1,272,944	263.0	263.0	Yes	263.0	Yes	263.0	Yes	263.0	Yes	263.0	Yes	Removed
JIM NED CREEK WS SCS SITE 12F DAM	1,453	71,204	38.0	18.8		38.0	Yes	38.0	Yes	38.0	Yes	38.0	Yes	Removed
JIM NED CREEK WS SCS SITE 15 DAM	366	17,935	34.3	29.4		24.0		18.7		13.3		7.9		
JIM NED CREEK WS SCS SITE 16 DAM	2,616	128,208	104.0	69.4		31.0		104.0	Yes	104.0	Yes	104.0	Yes	Removed
JIM NED CREEK WS SCS SITE 17 DAM	908	44,503	31.0	19.0		5.6		31.0	Yes	31.0	Yes	31.0	Yes	Removed
JIM NED CREEK WS SCS SITE 17B1 DAM	25,439	1,246,516	108.0	108.0	Yes	108.0	Yes	108.0	Yes	108.0	Yes	108.0	Yes	Removed
JIM NED CREEK WS SCS SITE 19 DAM	3,239	158,694	165.1	122.3		74.7		27.1		384.0	Yes	384.0	Yes	Removed
JIM NED CREEK WS SCS SITE 20 DAM	7,150	350,343	288.0	193.5		88.4		288.0	Yes	288.0	Yes	288.0	Yes	Removed
JIM NED CREEK WS SCS SITE 21 DAM	9,134	447,590	185.0	64.2		185.0	Yes	185.0	Yes	185.0	Yes	185.0	Yes	Removed
JIM NED CREEK WS SCS SITE 9 DAM	1,835	89,904	53.0	28.7		1.8		53.0	Yes	53.0	Yes	53.0	Yes	Removed
LAKE LAWN DAM	6,382	312,706	98.7	14.3		530.0	Yes	530.0	Yes	530.0	Yes	530.0	Yes	Removed
LAKE STITH DAM	521	25,533	66.8	59.9		52.2		44.6		36.9		29.3		
NOVICE CITY LAKE DAM	27,337	1,339,510	150.0	150.0	Yes	150.0	Yes	150.0	Yes	150.0	Yes	150.0	Yes	Removed
TOTAL	**309,283**	**15,154,878**	**2,215**	**1,691**		**2,073**		**2,371**		**2,785**		**2,764**		

3.2.5.4 Case IV (No Action)

For this case, the same procedures described above were applied to estimate the total volume of sediment in acre-feet potentially accumulated in each structure in the subwatersheds of the Lake Coleman watershed during the period from 2006 through 2055, again considering alternative sediment densities of 35 pounds per cubic feet and 100 pounds per cubic foot. For this Case IV, if the estimated total accumulated sediment volume was less than the volume of the 2006 sediment pool for a particular structure, then the 2006 storage capacity of the sediment pool was reduced by this amount to produce the 2055 sediment pool capacity. If the estimated total sediment volume exceeded the volume of the 2006 sediment pool for a particular structure, it was assumed that this entire amount of sediment would remain within the structure and the principal spillway would become and remain inoperative. The 2055 available storage capacity in the structure then would be equal to total storage capacity below the auxiliary spillway crest elevation reduced by the total amount of sediment accumulated during the 2006-2055 period.

These analyses were performed for both an estimated minimum sediment density of 35 pounds per cubic foot and an estimated maximum sediment density of 100 pounds per cubic foot. The end result of these analyses was the Case IV year-2055 sedimentation condition for each of the structures in the Lake Coleman watershed assuming two different sediment densities, i.e., 35 and 100 pounds per cubic foot. Table 3-15 summarizes these spreadsheet-based calculations for an assumed sediment density of 35 pounds per cubic foot.

The resulting estimated structure sedimentation conditions in year 2055 were used to aggregate subwatershed sediment pool storage and surface area for input to the Cedar Creek SWAT model. Structures with inoperative principal spillways were incorporated with substantially changed conditions: 1) the normal pool (both volume and surface area) was expanded to include the flood pool (up to the elevation of the auxiliary spillway), reduced in storage capacity by the amount of sediment accumulated during the 2006-2055 period; and 2) the period for passage of flood flows through the structure was reduced from five days to one day. With these modifications, the SWAT model was operated to simulate daily inflows and sediment loadings for Lake Coleman under year-2055 watershed conditions using the rainfall and climatological data for the period 1947 through 2007. Simulations based on sediment densities of 35 and 100 pounds per cubic foot were made.

3.2.6 Flow and Sediment Effects of Floodwater Retarding Structures

Results from operating the SWAT model of the Lake Coleman watershed for 2055 watershed conditions corresponding to the no structure case and to the different dam/impoundment management options are summarized in Table 3-16. Average, maximum and minimum annual values for inflows to Lake Coleman as simulated with the SWAT model based on 1947-2002 rainfall and climatological data are presented[3]. Values for the two assumed sediment densities, i.e., 35 and 100 pounds/cubic foot, are provided. As shown, consistent with the Cedar Creek Reservoir results, the highest levels of inflow to Lake Coleman under 2055 conditions occur with no structures in place within the watershed. Reductions in the annual average inflows to Lake

[3] The 1947-2002 period was used to extract and analyze results from the Lake Coleman SWAT model to be consistent with the analysis period used for Cedar Creek Reservoir.

Table 3-15 Summary of Case IV (No Action) 2055 sediment pool storage calculations for structures in the Lake Coleman watershed (35 pounds/cubic foot density)

Structure Name	Average Annual Sediment Loading (tons/yr)	Sediment Loading From 2006 to 2055 (tons)	2006 Capacity @ 35lbs/ft^3 (ac-ft)	2015 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2025 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2035 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2045 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?	2055 Capacity @ 35lbs/ft^3 (ac-ft)	Filled With Sediment?
DANIELS DAM	1,806	88,487	83.0	59.1		32.6		6.1		120.0	Yes	96.1	
HUGHES DAM	1,579	77,381	56.0	35.1		11.9		72.8	Yes	51.9		28.7	
JIM NED CREEK WS SCS SITE 10 DAM	2,087	102,273	35.0	7.4		481.0	Yes	453.4		422.7		392.1	
JIM NED CREEK WS SCS SITE 11 DAM	10,714	524,971	53.0	2,684.0	Yes	2,542.3		2,384.9		2,227.5		2,070.1	
JIM NED CREEK WS SCS SITE 12 DAM	98,290	4,816,212	143.0	4,987.0	Yes	3,687.3		2,243.2		799.1		0.0	Yes
JIM NED CREEK WS SCS SITE 12A DAM	520	25,476	167.2	160.3		152.6		145.0		137.4		129.7	
JIM NED CREEK WS SCS SITE 12C DAM	81,928	4,014,489	93.0	1,420.0	Yes	336.7		1,420.0	Yes	336.7		0.0	Yes
JIM NED CREEK WS SCS SITE 12E1 DAM	25,978	1,272,944	263.0	5,263.0	Yes	4,919.5		4,537.8		4,156.1		3,774.4	
JIM NED CREEK WS SCS SITE 12F DAM	1,453	71,204	38.0	18.8		1,508.0	Yes	1,488.8		1,467.4		1,446.1	
JIM NED CREEK WS SCS SITE 15 DAM	366	17,935	34.3	29.4		24.0		18.7		13.3		7.9	
JIM NED CREEK WS SCS SITE 16 DAM	2,616	128,208	104.0	69.4		31.0		778.0	Yes	743.4		705.0	
JIM NED CREEK WS SCS SITE 17 DAM	908	44,503	31.0	19.0		5.6		188.0	Yes	176.0		162.6	
JIM NED CREEK WS SCS SITE 17B1 DAM	25,439	1,246,516	108.0	679.0	Yes	342.6		679.0	Yes	342.6		0.0	Yes
JIM NED CREEK WS SCS SITE 19 DAM	3,239	158,694	165.1	122.3		74.7		27.1		2,723.0	Yes	2,680.2	
JIM NED CREEK WS SCS SITE 20 DAM	7,150	350,343	288.0	193.5		88.4		2,820.0	Yes	2,725.5		2,620.4	
JIM NED CREEK WS SCS SITE 21 DAM	9,134	447,590	185.0	64.2		5,231.0	Yes	5,110.2		4,976.0		4,841.8	
JIM NED CREEK WS SCS SITE 9 DAM	1,835	89,904	53.0	28.7		1.8		738.0	Yes	713.7		686.8	
LAKE LAWN DAM	6,382	312,706	98.7	14.3		700.0	Yes	615.6		521.9		428.1	
LAKE STITH DAM	521	25,533	66.8	59.9		52.2		44.6		36.9		29.3	
NOVICE CITY LAKE DAM	27,337	1,339,510	150.0	313.0	Yes	313.0	Yes	313.0	Yes	313.0	Yes	0.0	Yes
TOTAL	**309,283**	**15,154,878**	**2,215**	**16,227**		**20,536**		**24,084**		**23,004**		**20,099**	

Table 3-16 Annual inflows and sediment volume loadings for Lake Coleman for different 2055 NRCS structure conditions based on 1947-2002 SWAT model simulations

ANNUAL INFLOWS TO LAKE COLEMAN UNDER 2055 STRUCTURE CONDITIONS BASED ON DAILY SWAT SIMULATIONS WITH 1947-2002 CLIMATIC DATA

Conditions Analyzed	Average Inflow		Maximum Inflow		Minimum Inflow	
	Simulated Value ac-ft	Percent Change From Case I	Simulated Value ac-ft	Percent Change From Case I	Simulated Value ac-ft	Percent Change From Case I
Sediment Density: 35 lbs/cubic foot						
Case I - No Structures	38,167	- -	104,902	- -	7,308	- -
Case II - Structure Upgrades	27,746	-27%	95,350	-9%	2,832	-61%
Case III - Structure Removal	33,716	-12%	100,621	-4%	5,482	-25%
Case IV - No Action	32,919	-14%	100,176	-5%	4,947	-32%
Sediment Density: 100 lbs/cubic foot						
Case I - No Structures	38,167	- -	104,902	- -	7,308	- -
Case II - Structure Upgrades	27,550	-28%	95,277	-9%	2,844	-61%
Case III - Structure Removal	33,511	-12%	100,604	-4%	5,447	-25%
Case IV - No Action	32,753	-14%	100,098	-5%	4,850	-34%

ANNUAL SEDIMENT VOLUME LOADINGS DEPOSITED INTO LAKE COLEMAN UNDER 2055 STRUCTURE CONDITIONS BASED ON DAILY SWAT SIMULATIONS WITH 1947-2002 CLIMATIC DATA

Conditions Analyzed	Average Loading		Maximum Loading		Minimum Loading	
	Simulated Value ac-ft	Percent Change From Case I	Simulated Value ac-ft	Percent Change From Case I	Simulated Value ac-ft	Percent Change From Case I
Sediment Density: 35 lbs/cubic foot						
Case I - No Structures	8.9	- -	45.0	- -	0.1	- -
Case II - Structure Upgrades	4.0	-55%	24.4	-46%	0.0	-77%
Case III - Structure Removal	6.7	-25%	39.1	-13%	0.0	-52%
Case IV - No Action	5.1	-43%	26.8	-40%	0.0	-66%
Sediment Density: 100 lbs/cubic foot						
Case I - No Structures	3.1	- -	15.8	- -	0.0	- -
Case II - Structure Upgrades	1.4	-55%	8.5	-46%	0.0	-76%
Case III - Structure Removal	2.3	-27%	12.5	-21%	0.0	-52%
Case IV - No Action	1.6	-48%	8.8	-44%	0.0	-67%

Coleman between 14 and 28 percent are indicated for the different dam/impoundment management options.

The results from the Lake Coleman SWAT simulations indicate that the relative effect of the NRCS structures and other small dams on inflows to Lake Coleman is substantially greater than that indicated for Cedar Creek Reservoir. As previously shown in Table 3-7, the percentage reduction in the average annual inflows to Cedar Creek Reservoir due to the structures was on the order of 5 to 7 percent for the different dam/impoundment management options, whereas the values in Table 3-16 for Lake Coleman range between 12 and 28 percent. There are several factors that support these relative inflow differences. First of all, the portion of the Lake Coleman drainage area that is controlled by structures is approximately 50 percent, whereas only about 20 percent of the Cedar Creek Reservoir watershed is controlled by structures. Rainfall affecting Lake Coleman in the western part of the state generally is less frequent and overall smaller in quantity than for Cedar Creek Reservoir in the eastern part of the state (average of about 25 inches per year versus about 41 inches per year), thus watershed and reservoir conditions generally are drier, and there is more opportunity for evaporative and seepage losses from the impoundments, which leads to greater capacity for capturing runoff when rainfall events do occur. Furthermore, the average net evaporation rate for the Lake Coleman watershed based on TWDB data (about 39 inches per year) is about double the average rate for Cedar Creek Reservoir (about 19 inches per year), which also translates to significantly higher evaporative losses per acre of water surface area within the Lake Coleman watershed. This effect is offset somewhat, however, by the fact that the combined normal pool water surface area of the NRCS and other small impoundments in the Lake Coleman watershed (about 0.9 square miles) covers only about 0.3 percent of the total Lake Coleman drainage area, whereas, for Cedar Creek Reservoir, about 0.8 percent (or about 8.0 square miles) of the reservoir's drainage area is covered by the combined normal pools of the NRCS and other small impoundments.

Annual sediment volume loadings discharged to Lake Coleman as simulated with the SWAT model also are presented in Table 3-16. These loadings reflect the effects of the different assumed dam/impoundment management options that were analyzed with the SWAT model using actual 1947-2002 daily rainfall and climatological data. Again, values for the two assumed sediment densities, i.e., 35 and 100 pounds/cubic foot, are provided. As expected, the highest sediment volume loadings on the reservoir are indicated for the case with no structures in place (Case I). Average annual sediment loadings discharged into Lake Coleman for the different dam/impoundment management options are between 25 and 55 percent lower than the average annual sediment loadings with no structures in place (Case I). This significant level of sediment loading reductions is reflective of the reductions in inflows to Lake Coleman indicated in the table with the small impoundments in place (Cases II, II and IV).

The average annual values of the sediment volume loadings for each of the different assumed dam/impoundment management options and the different assumed sediment densities have been used to make hypothetical projections of the year-2055 conservation storage capacity of Lake Coleman . These results are summarized in Table 3-17. For these projections, the most recent estimate of the conservation storage capacity of Lake Coleman was used as the starting point for the sediment accumulation calculations. This quantity was 38,094 acre-feet as determined by the Texas Water Development Board based on a survey conducted in 2006 (TWDB, 2007b). Year-by-year accumulations of sediment in Lake Coleman beginning in 2006 were determined using each of the average annual sediment loading values for the different dam/impoundment management options and sediment densities. While it is recognized that the resulting year-2055 storage capacities of Lake Coleman do not represent the effects of actual sedimentation processes as they would occur over the 2006-2055 timeframe during which sediment storage in the upstream small impoundments and structures would be continuously changing, they do represent lake storage capacities that are reflective of the different assumptions regarding implementation of the dam/impoundment management options. This was considered to be of primary importance when evaluating the relative effects of the different dam/impoundment management options on the firm annual yield of Lake Coleman. As shown in Table 3-17, the effect of the different dam/impoundment management options on the year-2055 storage capacity of the reservoir is relatively small for all options, and differences based on the different assumptions regarding sediment density also are not appreciable.

Table 3-17 Projected year-2055 conservation storage capacity for Lake Coleman for different 2055 NRCS structure conditions based on average sediment loadings from 1947-2002 SWAT model simulations

Conditions Analyzed	Conservation Storage Capacity ac-ft	Percent Change From 2006	Percent Change From Case I	Percent Change From 35 lbs/cu foot
2006 TWDB Survey (TWDB, 2007b)	38,094	- -	- -	- -
Sediment Density: 35 lbs/cubic foot				
Case I - No Structures	37,754	-0.9%	- -	- -
Case II - Structure Upgrades	37,956	-0.4%	0.5%	- -
Case III - Structure Removal	37,845	-0.7%	0.2%	- -
Case IV - No Action	37,918	-0.5%	0.4%	- -
Sediment Density: 100 lbs/cubic foot				
Case I - No Structures	37,975	-0.3%	- -	0.6%
Case II - Structure Upgrades	38,046	-0.1%	0.2%	0.2%
Case III - Structure Removal	38,010	-0.2%	0.1%	0.4%
Case IV - No Action	38,039	-0.1%	0.2%	0.3%

The fact that very little difference is indicated in the conservation storage volume among the no-impoundments case and the different dam/ impoundment management cases for Lake Coleman relates directly to the relatively small sediment volume loadings simulated with the SWAT model as listed in Table 3-16. If the original as-built storage capacity of Lake Coleman truly was 40,000 acre-feet in 1966, then the calculated amount of sediment accumulation in the reservoir through the year 2006 based on the TWDB's survey is about 1,900 acre-feet, which translates to an average annual loading of only about 48 acre-feet per year. While this is a relatively small rate of sedimentation, it nonetheless is somewhat greater than the average annual sediment loadings simulated with the SWAT model, which suggests that the Lake Coleman SWAT model maybe should have been calibrated using this small rate of sedimentation to start with. Regardless, the sedimentation effects on Lake Coleman are generally fairly small.

3.2.7 Effects of Stock Ponds on Lake Coleman Inflows

The analyses of the effects of small stock ponds on the water supply capability of a downstream reservoir as described in Section 2.3 were conducted for the watershed upstream of Lake Coleman. For each of the subwatersheds included in the SWAT model of the Lake Coleman watershed, stock pond areal densities of four and eight ponds per square mile were assumed based on 90 percent of the total drainage area of each subwatershed. For each pond areal density, the combined surface areas and storage capacities of the calculated number of ponds within each subwatershed were aggregated to represent a single pond. Because of their configuration and shape, some of the subwatersheds were divided into smaller areas to better reflect more realistic pond locations. As noted in Section 2.3, each individual pond was assumed to have a maximum surface area equal to 0.76 acres and a maximum storage capacity equal to 3.72 acre-feet. The numbers of stock ponds and the aggregated maximum pond surface areas and storage capacities for each of the subwatershed areas as represented in the Lake Coleman SWAT model are listed in Table 3-18. Data are provided for both pond areal densities of four and eight ponds per square mile

Table 3-18 Aggregated stock pond surface areas and storage capacities for each subwatershed in the Lake Coleman SWAT model for different assumed areal densities of stock ponds

Stock Pond ID In SWAT Model	Sub-watershed Location ID	Sub-watershed Drainage Area (sq miles)	90% of SW Area Controlled by Stock Ponds (sq miles)	Case I-4: 4 Ponds/Sq Mile			Case I-8: 8 Ponds/Sq Mile		
				Number of Stock Ponds In Area	Max Pond Area (acres)	Max Pond Capacity (ac-ft)	Number of Stock Ponds In Area	Max Pond Area (acres)	Max Pond Capacity (ac-ft)
1.1	1	7.06	6.36	25	18.9	95.4	51	38.6	194.6
1.2	1	7.06	6.36	25	18.9	95.4	51	38.6	194.6
1.3	1	7.06	6.36	25	18.9	95.4	51	38.6	194.6
2.1	2	36.26	32.63	131	99.2	499.8	261	197.7	995.8
3.1	3	14.43	12.99	52	39.4	198.4	104	78.8	396.8
3.2	3	14.43	12.99	52	39.4	198.4	104	78.8	396.8
4.1	4	19.78	17.80	71	53.8	270.9	142	107.6	541.8
5.1	5	10.14	9.12	36	27.3	137.4	73	55.3	278.5
6.1	6	29.72	26.75	107	81.1	408.2	214	162.1	816.5
7.1	7	18.59	16.73	67	50.8	255.6	134	101.5	511.2
8.1	8	44.60	40.14	161	122.0	614.3	321	243.2	1224.7
9.1	9	15.71	14.14	57	43.2	217.5	113	85.6	431.1
10.1	10	13.34	12.01	48	36.4	183.1	96	72.7	366.3
11.1	11	12.38	11.15	45	34.1	171.7	89	67.4	339.6
12.1	12	14.06	12.65	51	38.6	194.6	101	76.5	385.3
13.1	13	13.56	12.20	49	37.1	186.9	98	74.2	373.9
14.1	14	15.06	13.55	54	40.9	206.0	108	81.8	412.1
15.1	15	5.86	5.28	21	15.9	80.1	42	31.8	160.2
15.2	15	5.86	5.28	21	15.9	80.1	42	31.8	160.2

The Case I version (no NRCS structures or other small impoundments) of the SWAT model for the Lake Coleman watershed was modified to create two different models; one with stock ponds distributed at an areal density of four ponds per square mile (referred to as Case I-4) and one with stock ponds distributed at an areal density of eight ponds per square mile (referred to as Case I-8). As noted earlier, the simulation of these stock ponds with the SWAT model accounted only for the storage of stormwater inflows in the ponds and the subsequent evaporation of these stored inflows from the stock ponds. Daily inflow volumes in excess of the available pond storage capacities were spilled and routed downstream. Sedimentation processes were not simulated.

Results from operating the daily SWAT models with stock ponds incorporated using actual daily 1947-2007 climatological data are presented in Table 3-19 in terms of the average, maximum and minimum annual inflows to Lake Coleman. These values are based on the daily simulated inflows for the period 1947-2002, and the corresponding Case I inflow values are included in the table for comparative purposes. As shown, the effect of the stock ponds is to reduce the average annual inflows to Lake Coleman by 13 percent for an areal pond density of four ponds per square mile and by 17 percent for an areal pond density of eight ponds per square mile.

Table 3-19 Summary of annual inflows to Lake Coleman as simulated with the SWAT model for different assumed areal densities of stock ponds

Conditions Analyzed	Average Inflow		Maximum Inflow		Minimum Inflow	
	Simulated Value ac-ft	Percent Change From Case I	Simulated Value ac-ft	Percent Change From Case I	Simulated Value ac-ft	Percent Change From Case I
Case I - No Structures or Ponds	38,167	- -	104,902	- -	7,308	- -
Case I-4 - 4 Ponds/Sq Mile	33,187	-13%	103,465	-1%	3,098	-58%
Case I-8 - 8 Ponds/Sq Mile	31,584	-17%	105,608	1%	1,896	-74%

4.0 WATER SUPPLY ANALYSES

The effects of the different dam/impoundment management cases and the assumed stock pond scenarios on the inflows to Cedar Creek Reservoir and Lake Coleman have been evaluated with respect to the firm annual yield of the reservoirs. For this purpose, an Excel spreadsheet program was constructed to perform reservoir operation simulations on a daily basis taking into consideration specified reservoir inflows for each of the cases, historical daily rainfall and evaporation rates, and specified daily diversions or withdrawals from the reservoirs in amounts equivalent to the firm annual yield corresponding to the different conditions analyzed.

It should be noted that the original Scope of Work for this study called for the firm yield analysis of each of the major water supply reservoirs considered in the study to be performed using the TCEQ's Water Availability Model (WAM) for the respective river basin in which each reservoir is located. Since the SWAT model generates the inflows to these major water supply reservoirs on a daily basis, it was decided during the course of the work that it would be less complicated and more straightforward to simply use these daily inflows directly as the daily inputs to the reservoir operation simulations, rather than having to recode the WAM data input files and possibly adjust the naturalized flows used in the WAMs. Hence, standalone, Excel-based spreadsheet programs were developed to represent and simulate the time-varying operation and behavior of Cedar Creek Reservoir and Lake Coleman using a daily time step. These reservoir operation programs then were used to determine the firm yields of the reservoirs using the SWAT-generated inflows corresponding to the different dam/impoundment management cases and assumed stock pond scenarios described in Section 3.0. Since only the relative differences in the firm yields of the water supply reservoirs as influenced by the different upstream pond and sedimentation conditions were of concern to the evaluations in this study, the use of the spreadsheet programs, rather than the WAMs, was considered appropriate and consistent with the study purpose. However, it is important to note that the firm yield values calculated for Cedar Creek Reservoir and Lake Coleman in this study do not reflect passage of any inflows for downstream senior water rights; hence, they may overstate the actual yield of the reservoirs under prior appropriation conditions. But, again, since only the relative magnitudes of firm yield have been considered and examined in this study, this limitation does not influence study results.

Simulations with the reservoir operations program have been performed for each reservoir assuming year-2055 reservoir sedimentation conditions using the corresponding simulated daily reservoir inflows from the SWAT models for historical climatic conditions corresponding to the 1947-2002 period. This period encompasses the drought of the 1950s, which typically is the critical drought of record for most parts of Texas that determines a reservoir's firm annual yield. Historical daily rainfall and evaporation data for this same period also have been input to the reservoir operations program for each of the reservoirs.

Details regarding the application and operation of the reservoir operations program for Cedar Creek Reservoir and Lake Coleman and the resulting firm annual yield quantities for the different conditions analyzed are presented in the following sections.

4.1 CEDAR CREEK RESERVOIR

The first step in the process of applying the reservoir operations program was to establish appropriate stage-area-capacity data for the reservoir corresponding to each of the different dam/impoundment management cases that were analyzed with the SWAT model. As described in Section 3.1.5, sediment loading results from the SWAT simulations were analyzed to produce estimates of the maximum conservation storage capacity in Cedar Creek Reservoir for the year 2055 for each of the cases considered and for each of the assumed sediment densities, i.e., 35 and 100 pounds per cubic foot. These quantities are presented in Table 3-8. For each of these maximum conservation storage values, stage-area-capacity data were derived for the reservoir based on the vertical distribution of storage over the depth of the reservoir as measured during the TWDB 2005 survey. The stage-area-capacity data from this survey are illustrated graphically in Figure 4-1, and the corresponding depth-storage distribution curve is shown on the plot in Figure 4-2. Percentage values from this curve were applied to the maximum conservation storage value for each of the cases to develop complete sets of stage-area-capacity data over the entire depth of the reservoir. For simplicity, it was assumed that the depth distribution of the surface area of the reservoir did not change for the different cases. The sets of stage-area-capacity data were specified as inputs to the reservoir operations model.

For withdrawals from Cedar Creek Reservoir assumed during the process of determining the reservoir's firm annual yield, a municipal pattern of use was specified in the reservoir operations model. This is consistent with the authorized use of water from the reservoir. This pattern exhibits somewhat higher withdrawals during the summer months than during the winter months.

Results from the reservoir operations model for the case without any structures or small impoundments in the Cedar Creek Reservoir watershed (Case I) and for the different dam/impoundment management cases are presented in Table 4-1 in terms of firm annual yield. Values are reported for each of the two assumed sediment densities.

Table 4-1 Firm annual yield of Cedar Creek Reservoir under 2055 conditions for different dam/impoundment management cases

Conditions Analyzed	Sediment Density 35 Pounds/cubic foot		Sediment Density 100 Pounds/cubic foot	
	Firm Annual Yield ac-ft/year	Percent Change From Case I	Firm Annual Yield ac-ft/year	Percent Change From Case I
Case I - No Structures	291,550	- -	296,335	- -
Case II - Structure Upgrades	268,465	-8%	270,490	-9%
Case III - Structure Removal	278,050	-5%	278,380	-6%
Case IV - No Action	275,995	-5%	279,475	-6%

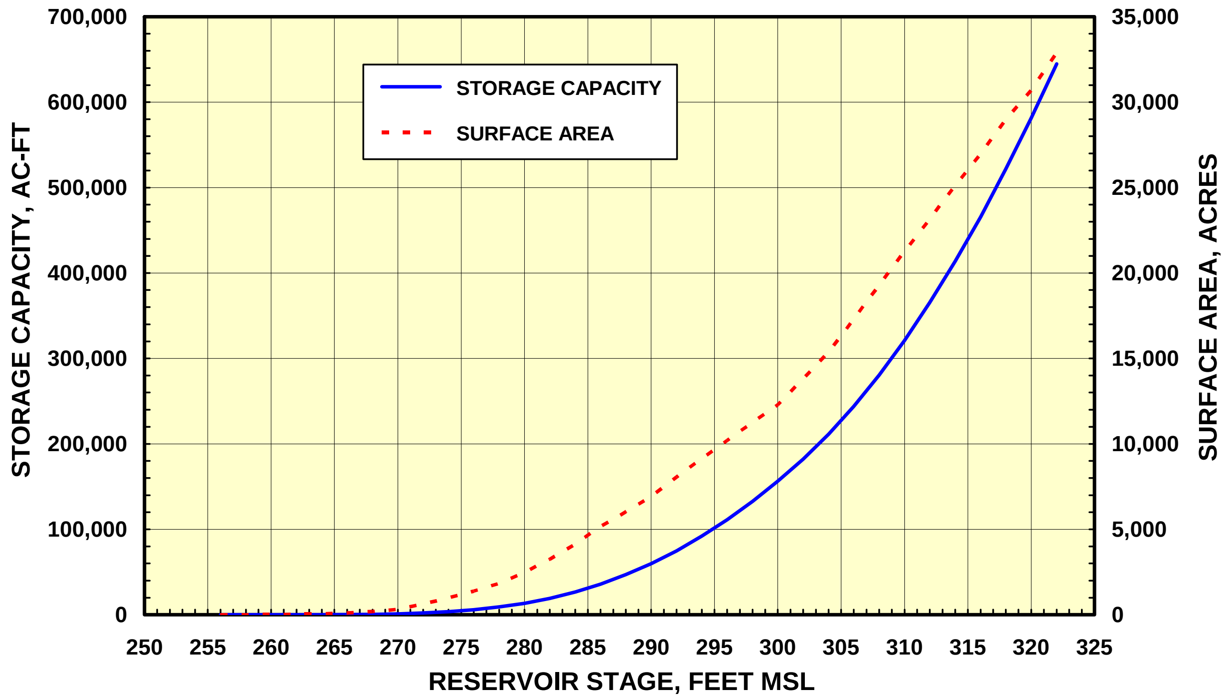

Figure 4-1 Stage-Area-Capacity curves for Cedar Creek Reservoir based on TWDB 2005 survey

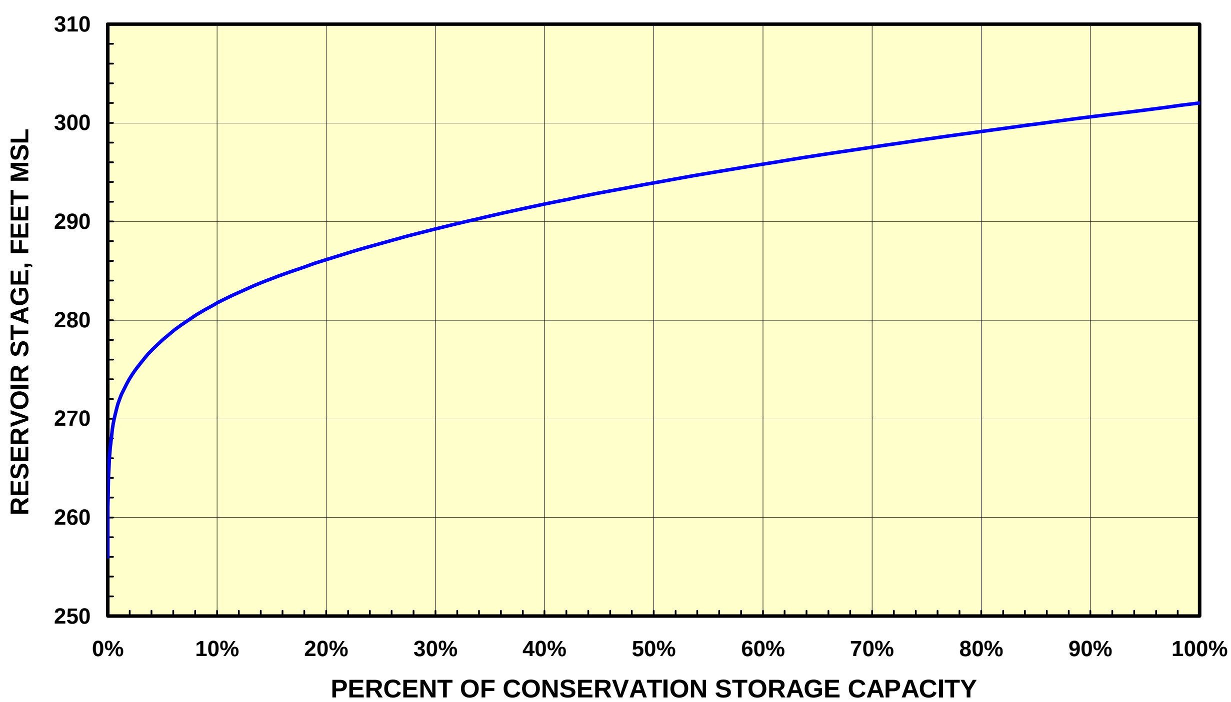

Figure 4-2 Distribution of storage capacity in Cedar Creek Reservoir based on the TWDB 2005 survey

As shown in the table, the firm annual yield values for Cedar Creek Reservoir are less with the NRCS structures in place within the watershed compared to conditions with no structures (Case I). A nine percent reduction in the no-structures yields is indicated for Case II with all of the structures upgraded to their original design capacity as they become filled with sediment. If the structures are removed when they become filled with sediment (Case III), the impact relative to the no-structures yield is a reduction of five or six percent, whereas if nothing is done when the structures become filled with sediment, the impact still is six percent.

4.2 LAKE COLEMAN

As with Cedar Creek Reservoir, the first step in the process of applying the reservoir operations program to Lake Coleman was to establish appropriate stage-area-capacity data for the reservoir corresponding to each of the different dam/impoundment management cases and the stock pond scenarios that were analyzed with the SWAT model. The estimates of the maximum conservation storage capacity in Lake Coleman for the year 2055 for each of the watershed conditions considered and for each of the assumed sediment densities, i.e., 35 and 100 pounds per cubic foot are presented in Table 3-17. For each of these maximum conservation storage values, stage-area-capacity data were derived for the reservoir based on the vertical distribution of storage over the depth of the reservoir as measured during the TWDB 2006 survey. The stage-area-capacity data from this survey are illustrated graphically in Figure 4-3, and the corresponding depth-storage distribution curve is shown on the plot in Figure 4-4. Percentage values from this curve were applied to the maximum conservation storage value for each of the watershed conditions analyzed to develop complete sets of stage-area-capacity data over the entire depth of the reservoir. Again, for simplicity, it was assumed that the depth distribution of the surface area of the reservoir did not change for the different cases. The sets of stage-area-capacity data were specified as inputs to the reservoir operations model.

For withdrawals from Lake Coleman assumed during the process of determining the reservoir's firm annual yield, the same municipal pattern of use used for Cedar Creek Reservoir withdrawals also was specified in the reservoir operations model. As with Cedar Creek Reservoir, this is consistent with the authorized use of water from Lake Coleman.

Results from the reservoir operations model for the case without any structures or small impoundments in the Lake Coleman watershed (Case I) and for the different dam/impoundment management and stock pond cases are presented in Table 4-2 in terms of firm annual yield. Values are reported for each of the two assumed sediment densities.

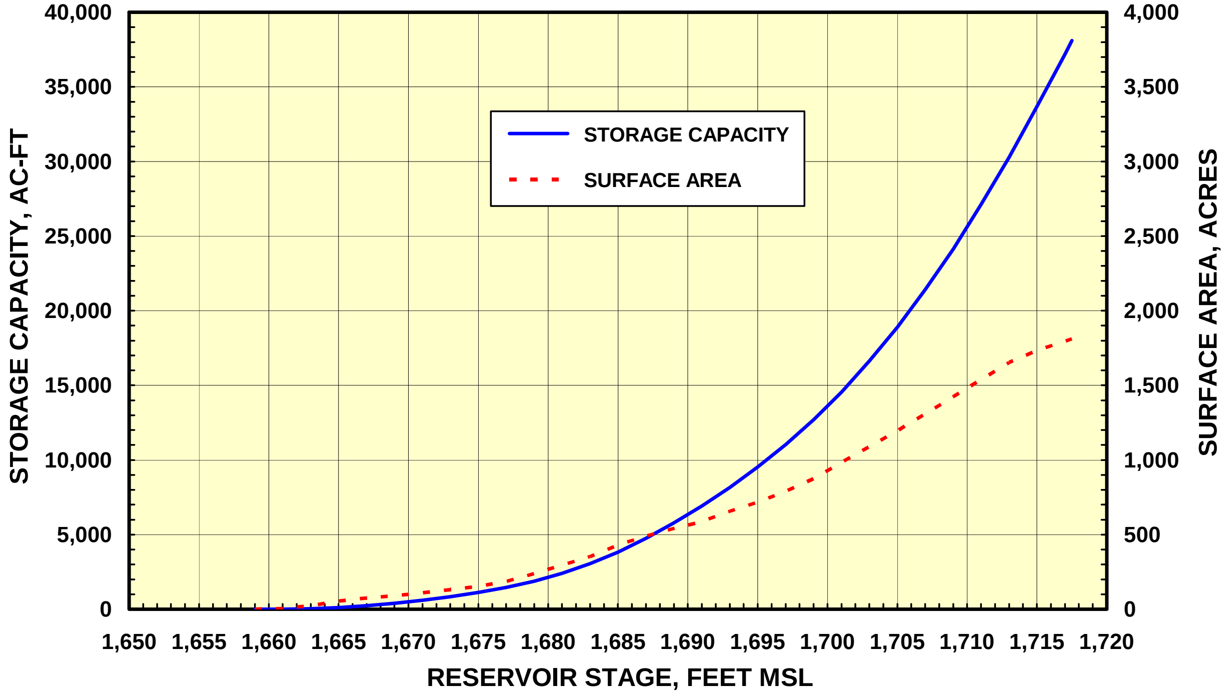

Figure 4-3 Stage-Area-Capacity curves for Lake Coleman based on TWDB 2006 survey

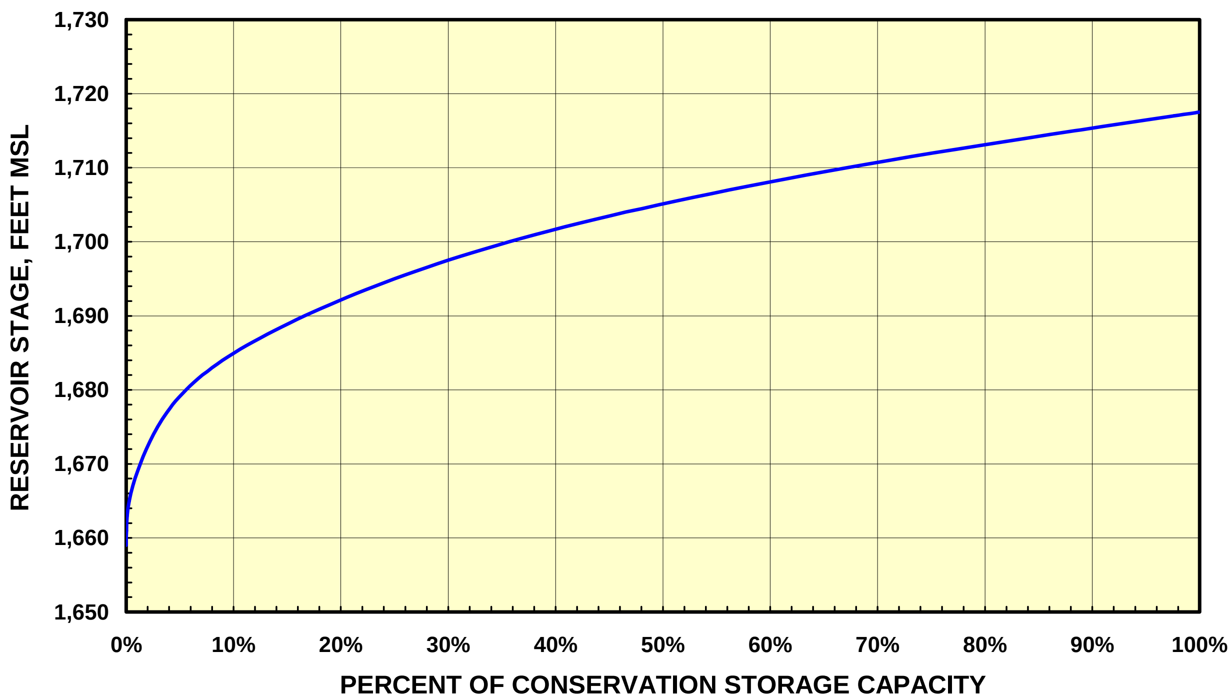

Figure 4-4 Distribution of storage capacity in Lake Coleman based on the TWDB 2006 survey

Table 4-2 Firm annual yield of Lake Coleman under 2055 conditions for different dam/impoundment management cases and stock pond scenarios

Conditions Analyzed	Sediment Density 35 Pounds/cubic foot		Sediment Density 100 Pounds/cubic foot	
	Firm Annual Yield ac-ft/year	Percent Change From Case I	Firm Annual Yield ac-ft/year	Percent Change From Case I
Case I - No Structures	21,140	- -	21,175	- -
Case II - Structure Upgrades	12,625	-40%	12,430	-41%
Case III - Structure Removal	17,695	-16%	17,670	-17%
Case IV - No Action	17,075	-19%	16,945	-20%
Case I-4 - 4 Stock Ponds/Sq Mile	15,947	-25%	15,983	-25%
Case I-8 - 8 Stock Ponds/Sq Mile	14,052	-34%	14,089	-33%

As shown in the table, similar to the Cedar Creek Reservoir results, the firm annual yield values for Lake Coleman are less with the NRCS structures in place within the watershed compared to conditions with no structures (Case I). The yields for Case II with all of the structures upgraded to their original design capacity as they become filled with sediment are about 40 percent less than the yields with no structures in the watershed. If the structures are removed when they become filled with sediment (Case III), the impact relative to the no-structures yields is a reduction of 25 percent, and if nothing is done when the structures become filled with sediment, the impact is about 33 or 34 percent. As indicated, the relative reductions in yield with the structures in place for Lake Coleman are considerably greater than those for Cedar Creek Reservoir, a direct result of the corresponding greater relative reductions in inflows to Lake Coleman as noted in Section 3.2.6.

5.0 OBSERVATIONS AND CONCLUSIONS

Following is a summary of observations and conclusions based on the results of this study of the the potential effects of small impoundments, including NRCS structures and stock ponds, on the water supply capability of a downstream reservoir.

- Small impoundments formed by NRCS structures and even stock ponds typically function as uncontrolled water storage reservoirs, subject to natural inflows during runoff events and evaporative losses during non-rainfall periods. Outflows generally occur as gravity discharges through low-flow outlets installed at some level above the bottom of the impoundments or as overflows through a spillway or similar structure.
- By their nature, NRCS impoundments and stock ponds do result in some degree of consumptive loss of natural runoff that ultimately translates to some reduction in streamflows downstream. These losses typically occur as a result of: (1) the permanent storage of natural inflows in an impoundment when it has storage capacity available below its lowest outlet; (2) evaporative losses from the pool of water stored at or below the lowest outlet of an impoundment during extended dry periods; (3) evaporative losses from flood waters temporarily retained in an impoundment until they are gradually drained from storage over several days or weeks after a runoff event; (4) actual deliberate diversions of stored water from an impoundment; and (5) potentially increased channel losses downstream of an impoundment due to the attenuation of natural flows caused by the limited capacity of an impoundment's primary flow outlet.
- As runoff is retained in small impoundments, even temporarily, attendant sediment loadings are reduced through settling. This, in turn, reduces the sediment loadings that are transported downstream and discharged into a downstream reservoir, thus having the effect of increasing the volume available for storage in the downstream reservoir. The result is to extend the useful life of the downstream reservoir in terms of its storage capacity and its ability to capture and store inflows, and hence, to produce a useful water supply.
- Consequently, if a major water supply reservoir is located downstream of such small impoundments, some reduction in the inflows to the reservoir from what might have occurred naturally can be expected, but the effects of the small impoundments on the water supply capability of the reservoir are likely offset somewhat due to the retention of sediment in the small impoundments and the resulting reduced sediment loadings discharged into the downstream reservoir.
- A significant portion of existing NRCS structures potentially may require upgrades to extend the useful life of their sediment pools and/or to comply with current state and federal dam safety standards. Actions for individual structures may involve different dam/impoundment management options, including no action (i.e., not extending structure life and in some cases not meeting current dam safety standards), removing (or breaching) existing structures, or performing upgrades to existing structures, and

depending on which of these actions is implemented for a particular structure, the effect on the water supply capability of downstream reservoirs will likely be different.

- Analyses of the effects of NRCS structures and small impoundments on the water supply capability of downstream reservoirs requires consideration of both hydrologic and sedimentation processes as they may be impacted by these structures and impoundments, and the Soil and Water Assessment Tool (SWAT) developed by the U.S. Department of Agriculture encompasses the necessary features for effectively simulating the most important watershed runoff and sedimentation processes.
- Cedar Creek Reservoir in the eastern central part of the state and Lake Coleman in the western central part of the state provide useful and representative test cases not only for evaluating the effects in general of NRCS structures and small impoundments on the water supply capability of downstream reservoirs, but also the effects of the different dam/impoundment management options that may be implemented in the future with regard to NRCS structures.
- Significant portions of the Cedar Creek Reservoir watershed area (20 percent) and runoff volume (23 percent) are subject to control by upstream NRCS floodwater retarding structures and other small dams. Furthermore, the Blackland Prairie soils conditions in this watershed are reasonably representative of a large number of other watersheds in the state with numerous NRCS-designed floodwater retarding structures. It is also important that an existing SWAT runoff and sediment yield model is available for the Cedar Creek watershed.
- About half of the Lake Coleman watershed area (50 percent) and runoff volume (53 percent) are subject to control by upstream NRCS-designed floodwater retarding structures and other small dams. The watershed also is located significantly west of Cedar Creek Reservoir and therefore subject to more arid hydroclimatic conditions. It also is characterized by different soils conditions in a significantly different soils regime, which translates to different sedimentation conditions.
- Results from operating the SWAT model of the Cedar Creek Reservoir watershed under 2055 conditions with daily climatological data corresponding to the 1947-2002 historical period confirm that the effect of upstream NRCS structures and small impoundments is to reduce inflows to the reservoir, with these reductions varying between five and seven percent depending on which of the dam/impoundment management actions is implemented for the NRCS structures in the future.
- Results from operating the SWAT model of the Cedar Creek Reservoir watershed under 2055 conditions with daily climatological data corresponding to the 1947-2002 historical period confirm that the effect of upstream NRCS structures and small impoundments is to reduce sediment loadings discharged into the reservoir, with these reductions varying between 10 and 15 percent depending on which of the dam/impoundment management actions is implemented for the NRCS structures in the future.
- Reductions in the future sediment loadings on Cedar Creek Reservoir due to upstream NRCS structures and small impoundments result in small increases in the year-2055 conservation storage capacity of the reservoir of less than one percent and vary slightly

depending on which of the dam/impoundment management actions is implemented for the NRCS structures in the future.

- Overall, the combined effect of the upstream NRCS structures and small impoundments on the water supply capability of Cedar Creek Reservoir under 2055 conditions is <u>to reduce its firm annual yield on the order of five to nine percent</u>, depending on which of the dam/impoundment management actions is implemented for the NRCS structures in the future and the assumed density of the sediment in the reservoir.
- Results from operating the SWAT model of the Lake Coleman watershed under 2055 conditions with daily climatological data corresponding to the 1947-2002 historical period also confirm that the effect of upstream NRCS structures and small impoundments is to reduce inflows to the reservoir, with these reductions varying between 12 and 28 percent depending on which of the dam/impoundment management actions is implemented for the NRCS structures in the future.
- Results from operating the SWAT model of the Lake Coleman watershed under 2055 conditions with daily climatological data corresponding to the 1947-2002 historical period also confirm that the effect of upstream NRCS structures and small impoundments is to reduce sediment loadings discharged into the reservoir, with these reductions varying between 25 and 55 percent depending on which of the dam/impoundment management actions is implemented for the NRCS structures in the future.
- Reductions in the future sediment loadings on Lake Coleman due to upstream NRCS structures and small impoundments result in small increases in the year-2055 conservation storage capacity of the reservoir of generally less than one-half percent and vary slightly depending on which of the dam/impoundment management actions is implemented for the NRCS structures in the future.
- Overall, the combined effect of the upstream NRCS structures and small impoundments on the water supply capability of Lake Coleman under 2055 conditions is <u>to reduce its firm annual yield on the order of 20 to 40 percent</u>, depending on of the which dam/ impoundment management actions is implemented for the NRCS structures in the future and the assumed density of the sediment in the reservoir.
- Results from the analysis of Cedar Creek Reservoir and Lake Coleman indicate that the relative effects of the NRCS structures and other small impoundments on the inflows, sediment loadings and firm annual yield for Lake Coleman are substantially greater than those indicated for Cedar Creek Reservoir. Factors that support these results include the following:
    - The portion of the Lake Coleman drainage area that is controlled by structures is approximately 50 percent, whereas only about 20 percent of the Cedar Creek Reservoir watershed is controlled by structures.
    - Rainfall affecting Lake Coleman in the western part of the state generally is less frequent and overall smaller in quantity than for Cedar Creek Reservoir in the eastern part of the state (average of about 25 inches per year versus about 41 inches per year), thus watershed and reservoir conditions generally are drier, and there is more opportunity for evaporative and seepage losses from the impoundments, which leads to greater capacity for capturing runoff when rainfall events do occur.

  - The average net evaporation rate for the Lake Coleman watershed based on TWDB data (about 39 inches per year) is about double the average rate for Cedar Creek Reservoir (about 19 inches per year), which also translates to significantly higher evaporative losses per acre of water surface area within the Lake Coleman watershed.

- From the overall results of this study, it is apparent that capturing of runoff in the upstream NRCS structures and small impoundments and the subsequent evaporation losses are much more effective with regard to reducing in the water supply capability of the downstream reservoirs than these upstream impoundments are with regard to extending the storage capacity of the downstream reservoirs through upstream sediment retention. While the net effect of these processes results in significant reductions in the inflows, sediment loadings and firm annual yield of both Cedar Creek Reservoir and Lake Coleman, the projected year-2055 storage capacities of the reservoirs do not appear to be appreciably affected by the sediment retention effects of the upstream NRCS structures and small impoundments, regardless of which dam/impoundment management actions are assumed to be implemented as the sediment pools of the structures become depleted.

- However, it should be noted that the results of this study as relates to the effects of structure impacts on sediment transport are largely qualitative due to limited available data, specifically for sediment accumulation in the flood retarding structure pools. One recommendation is that additional sediment trap data for flood retarding structures be developed to evaluate consistency with the estimates presented in this report.

- Results from operating the SWAT model of the Lake Coleman watershed under 2055 conditions with daily climatological data corresponding to the 1947-2002 historical period indicate that the effect of upstream stock ponds is to reduce inflows to the reservoir, with these reductions varying between 13 and 17 percent for assumed stock pond areal densities of four and eight ponds per square mile of watershed, respectively.

- Overall, the effect of upstream stock ponds on the water supply capability of Lake Coleman under 2055 conditions is <u>to reduce its firm annual yield on the order of 25 to 34 percent,</u> relative to conditions with no stock ponds, for assumed stock pond areal densities of four and eight ponds per square mile of watershed, respectively.

6.0 REFERENCES

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APPENDIX A

OVERSIZED FIGURES

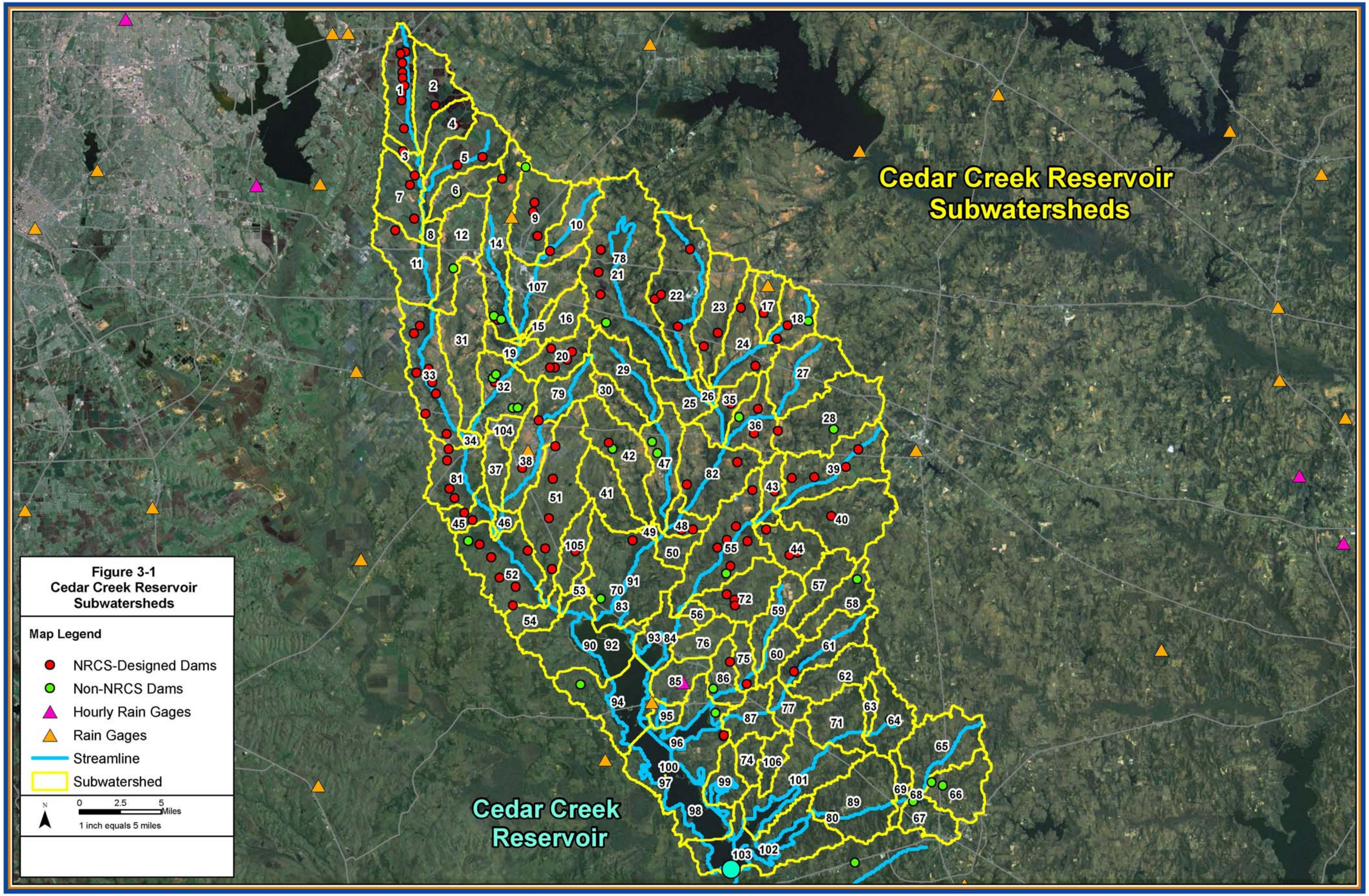

Figure A-1 Subwatersheds and structures included in SWAT model for Cedar Creek Reservoir watershed

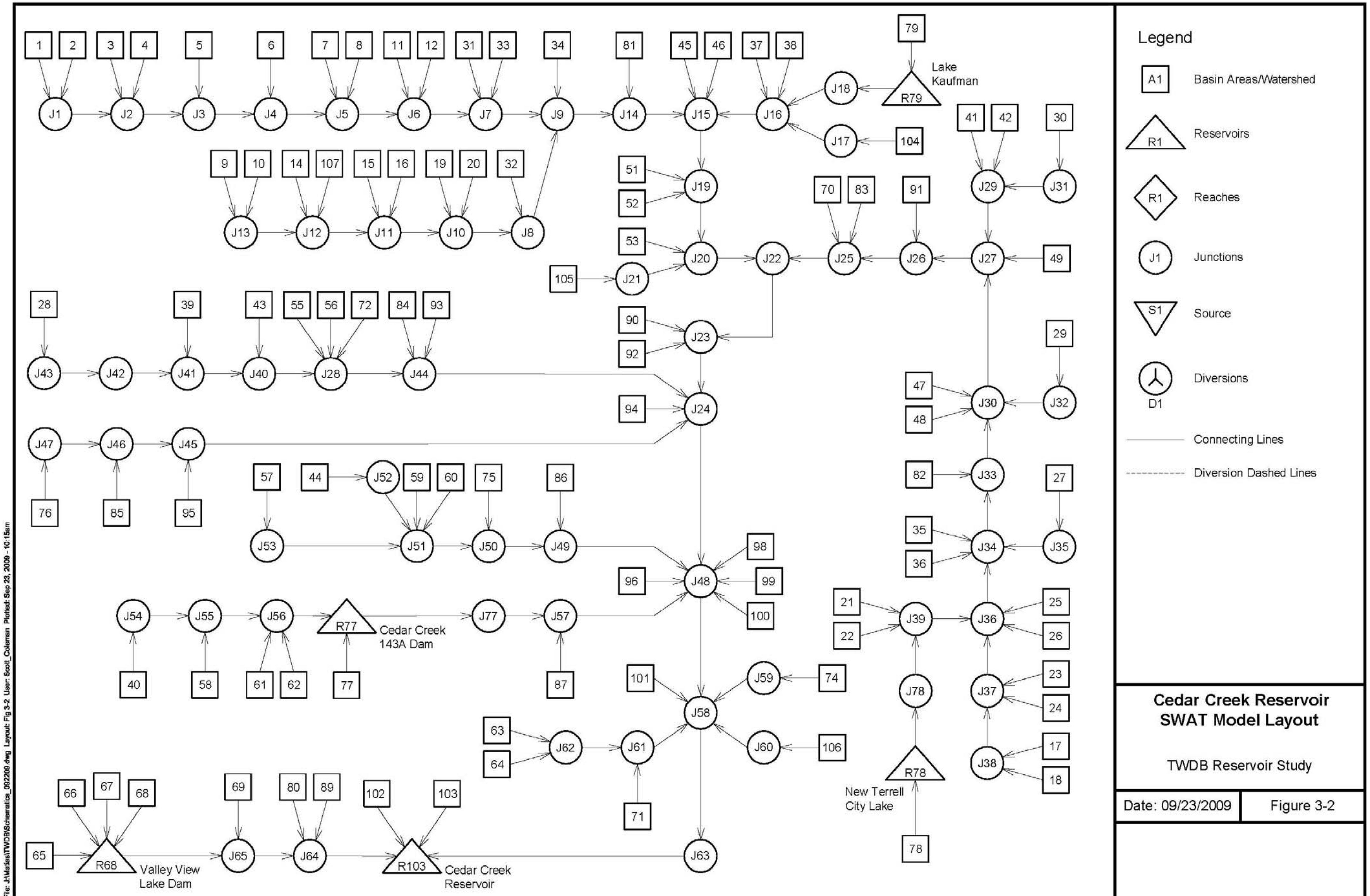

Figure A-2 Network structure of SWAT model for Cedar Creek Reservoir watershed

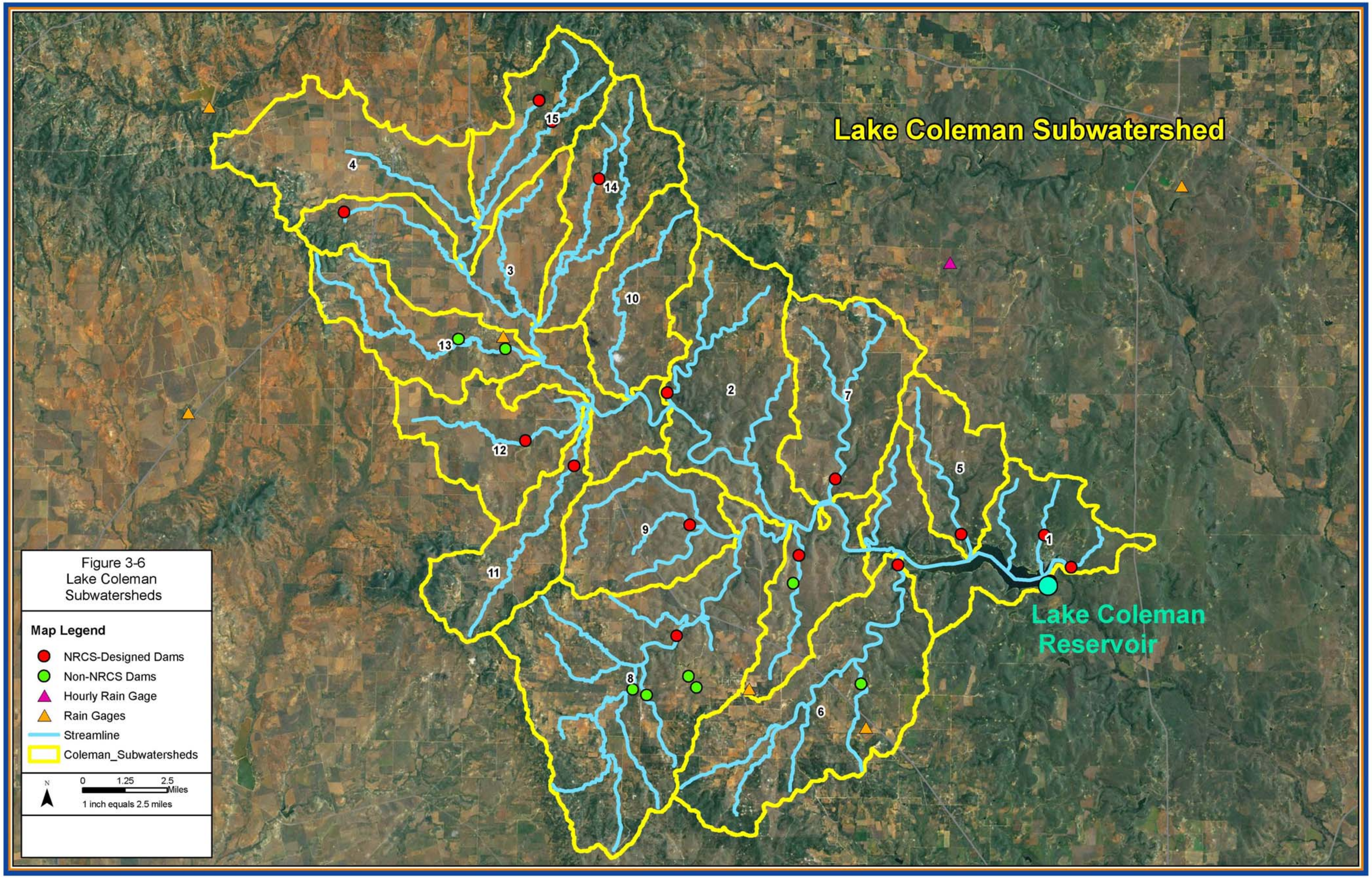

Figure A-3 **Subwatersheds and structures included in SWAT model for Lake Coleman watershed**

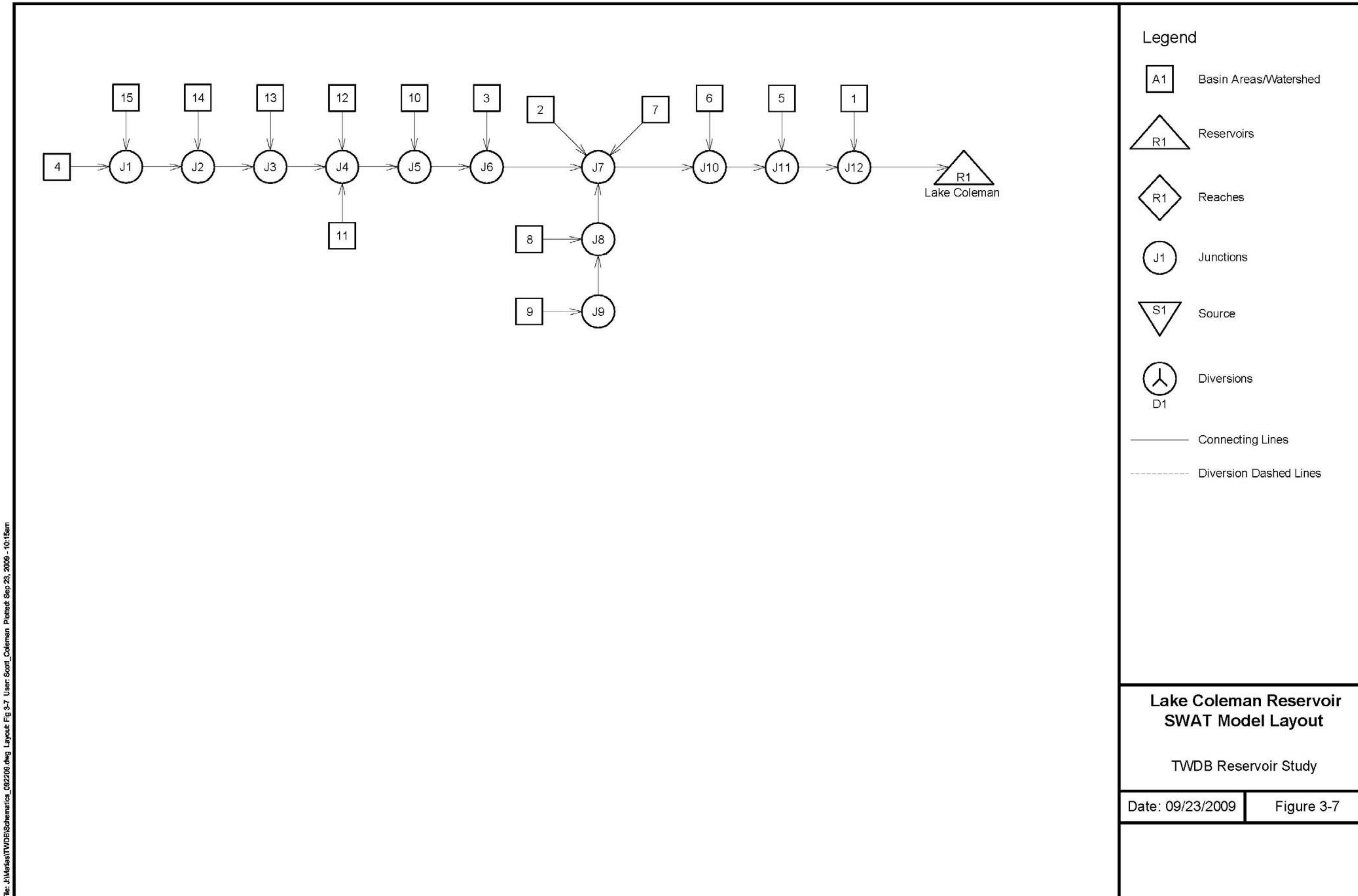

Figure A-4 Network structure of SWAT model for Lake Coleman watershed

APPENDIX B

Technical Memorandum

Cedar Creek Watershed: SWAT Model Development, Calibration, and Validation

Nanrasimhan, B., Bednarz, S. and Srinivasan, R.

April 2, 2008