REALLOCATION OF STORAGE IN FEDERAL RESERVOIRS FOR FUTURE WATER SUPPLY

Prepared for:

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1.0 EXECUTIVE SUMMARY

Espey Consultants, Inc. (EC) in association with the Brazos River Authority (BRA) and the United States Army Corp of Engineers (USACE) was awarded a **Water Resources Grant** from the Texas Water Development Board (TWDB) to evaluate the potential for reallocation of federal storage in Texas to water supply. Regional Water Plans indicate that many regions will have populations that double by 2050 as well as significant shortfalls in water supply availability. Currently, more than 6 million acre-feet of water supply storage and 13.5 million acre-feet of flood control storage is available in USACE reservoirs in Texas. This project estimates a preliminary amount of water supply that could be available from the reallocation of storage. This report also develops a document to provide a summary of state and federal requirements for reservoir storage reallocation.

Federal Agency Requirements
USACE policy allows for the reallocation of up to 15 percent of the total storage capacity allocated to all authorized purposes or 50,000 acre-feet, authorized at the discretion of the Commander, USACE. Congressional approval is required to reallocate storage above 50,000 acre-feet or greater than 15 percent of the total storage of the reservoir. USACE requires a reallocation analysis be performed by the entity applying for reallocation. This document outlines the procedures and details required by the USACE for reallocation. Other federal requirements are also listed including 404 permitting issues, Federal Energy Regulatory Commission (FERC) permitting, etc. A decision flow chart is included in Figure 1 to illustrate the steps and decisions required to meet the federal requirements for storage reallocation.

State Agency Requirements
State requirements for reallocation include a new or amended water right application filed with the Texas Commission on Environmental Quality (TCEQ). The water right allows for the proper utilization of the reservoir yield created by reallocation of storage in the reservoir. The permitting process for reallocated storage is similar to the normal application process for a new appropriation of water for a water right or reservoir. Environmental and operational details are required as part of the permit application. Members of the Texas Parks and Wildlife Department (TPWD) staff will be reviewing reallocation water right permit applications for environmental and habitat concerns. An organization that has included reallocation of flood storage in a federal reservoir as a method of increasing water supply in the State Water Plan may also be able to seek financial assistance from the Texas Water Development Board. A decision flow chart is included in Figure 2 to illustrate the steps and decisions required to meet the state requirements for storage reallocation.

SUPER Reservoir Yield Analysis
The USACE performed SUPER Model runs for all but two USACE owned reservoirs in Texas. According to the SUPER Model summaries these reservoirs currently have a water supply dependable yield totaling 3,739,551 acre-feet per year, with the possibility of an increase to 4,082,433 acre-feet per year if all reservoirs were reallocated to the maximum USACE authorized limit (50,000 acre-feet or 15 percent of total storage). According to the SUPER model results, reallocation of USACE reservoirs in Texas could result in an additional 342,882 acre-feet of dependable yield per year.

WAM and Case Study
A virtual Water Availability Model (WAM) was developed utilizing the Water Rights Analysis Package (WRAP) to simulate a simplified river basin and demonstrate reservoir reallocation. The virtual model was utilized to evaluate stand alone reservoir yields, reallocation yields and yields from reallocation and reservoir system operations. The procedure used to model reservoir reallocation in the virtual river basin was also applied to a case study of the Little River Watershed in the Brazos River Basin. The virtual WAM analysis of the individual reallocated reservoirs showed a 3 to 11 percent increase in yield due to

reservoir reallocation. Reallocation of the case study reservoir system showed a yield increase of 5.3 percent.

Conclusion

Reallocation of USACE reservoirs can provide an effective use of water by converting storage to additional water supply. Every reservoir has its own defining characteristics in terms of environmental impacts, reservoir storage use, downstream flooding risks and costs associated with reallocation. Entities evaluating reallocation of a federal reservoir must work closely with the USACE, state agencies and officials to meet all of the state and federal requirements as outlined in this report. Reallocation of reservoir storage in USACE reservoirs is a very complicated and time consuming process; however, reallocation of existing storage to dependable yield can be extremely beneficial depending on the individual reservoirs and surrounding demand centers.

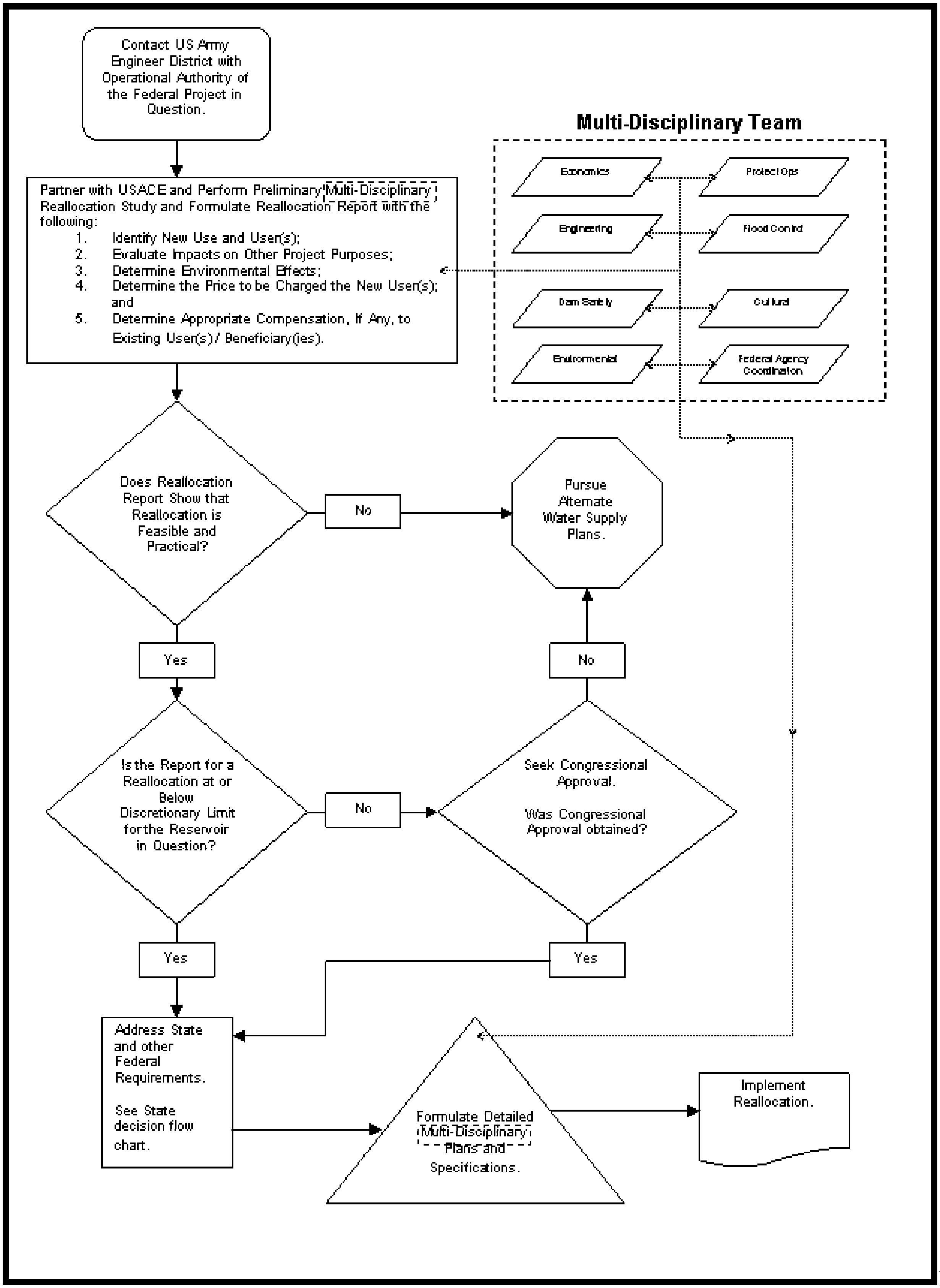

Figure 1: Federal Reallocation Requirement Flow Chart

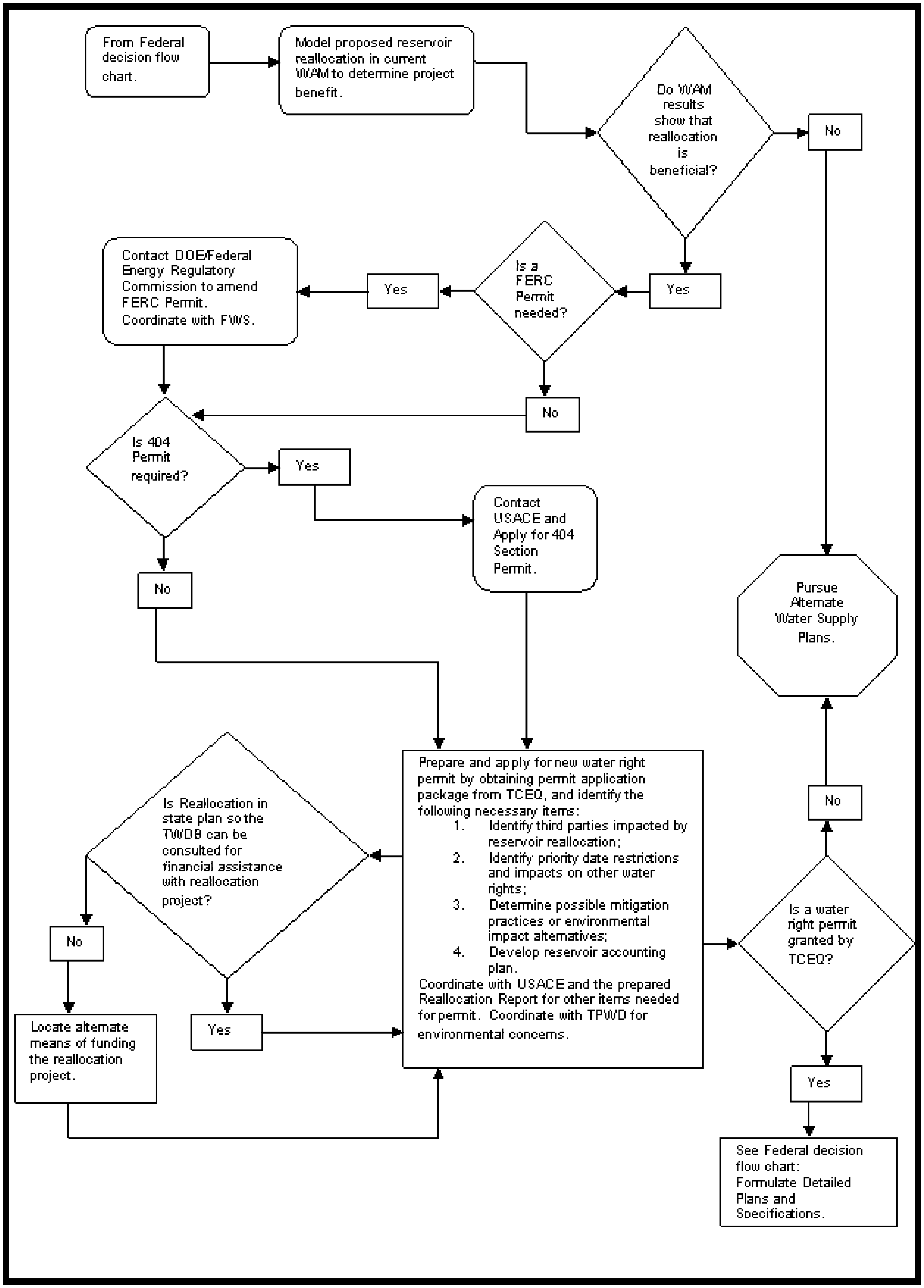

Figure 2: State Reallocation Requirement Flow Chart

2.0 PROJECT INTRODUCTION

Espey Consultants (EC) in association with Brazos River Authority (BRA) and the United States Army Corp of Engineers (USACE) was awarded a **Water Resources Grant** from the Texas Water Development Board (TWDB) to evaluate the potential for reallocation of federal storage in Texas to water supply. Regional Water Plans indicate that many regions will have populations that double by 2050 as well as significant shortfalls in water supply availability. Currently, more than 6 million acre-feet of water supply storage and 13.5 million acre-feet of flood control storage are available in USACE reservoirs in Texas. The storage needed for flood control may be reduced with time, due to federal, state and local programs that remove structures from flood plains and/or implement other types of flood control / management measures. Hydropower and hydropower head pools in USACE reservoirs contain more than 5.5 million acre-feet. Reallocation of a portion of the storage, particularly flood control storage, in existing federal reservoirs may provide a practical source of water supply. Reallocation of storage in existing reservoirs can provide additional water supply more rapidly than constructing new reservoirs, and with significantly less environmental and permitting issues.

This project estimates the amount of water supply that could be available from the reallocation of storage. This report will also include a guidance document that will provide a summary of state and federal requirements for reservoir storage reallocation. The guidance document will be an important tool that can be utilized as part of the State's Senate Bill One Water Planning process by entities that can take advantage of the additional water supply in existing federal reservoirs. As part of the project, EC assisted in the development of the guidance document identifying the issues associated with the state's permitting requirements for federal reservoir reallocation to water supply storage. The USACE has undertaken the task of putting together the document outlining federal requirements for the reallocation process.

The tasks set forth in this project are:

1. Develop a guidance document summarizing the permitting requirements of the State and Federal requirements for reallocation.
2. Estimate additional water supply yield available from reallocation of federal reservoirs in Texas.
3. Develop a virtual river basin utilizing the Water Rights Analysis Package (WRAP) to investigate the benefit of reallocation and system operations.
4. Develop a case study of the Little River Watershed in the Brazos River Basin utilizing the WRAP model and associated Water Availability Model (WAM) input file.
5. Final report.

3.0 FEDERAL GUIDELINES FOR REALLOCATION OF STORAGE IN DEPARTMENT OF THE ARMY FEDERAL RESERVOIRS FOR FUTURE WATER SUPPLY

3.1 BACKGROUND

In the past, flood control storage has been reallocated to water supply at several USACE reservoirs in Texas. Reallocation of flood control and other storage to water supply is an alternative to consider for meeting future water needs. However, the need for the water must be immediate to actually implement a reallocation. Reallocations of storage that would seriously affect the purposes for which the project was authorized, planned or constructed, or which would involve major structural or operational changes, will be made only upon approval of Congress. If the above criteria are not violated, it is USACE policy that up to 15 percent of the total storage capacity allocated to all authorized purposes or 50,000 acre-feet, whichever is less, may be allocated from storage authorized for other purposes at the discretion of the Commander, USACE. Table 1 provides storage capacities for the USACE reservoirs without reallocation as well as the maximum storages available for potential reallocation under discretionary authority assuming no major impacts on existing project purposes.

Analyses required for reallocation studies are frequently extensive, expensive, and time consuming. There is usually a reconnaissance study followed by a feasibility study. For reallocation, the current value of the storage in the project is to be repaid over a 30-year period. The cost of the reallocated storage is the higher of (1) benefits or revenues foregone as a result of the reallocation, (2) the replacement cost of an equivalent amount of storage in another or a new project, or (3) the updated cost in the federal project. The cost that usually governs is the updated cost of storage. Operations and maintenance costs are paid annually as the percent of the total useable project storage, which the reallocation represents. Any cost of project modification is paid by sponsor during the modification (e.g., relocating recreation facilities). The economic analysis to determine financial feasibility of the reallocation includes comparison of all reallocation costs to the cost of the least expensive alternative solution available to the sponsor. For any proposed reallocation, there should be a discussion of funding including the practical aspect of funds not being available and the need for 100% local sponsor costs if there is a need to expedite the process.

3.2 APPROVAL AUTHORITY

Per the Water Supply Act of 1958, reallocation is the reassignment of the use of existing storage space in a reservoir project to a higher and better use. Authority for the USACE to reallocate existing storage space to municipal and industrial (M&I) water supply is contained in Public Law 85-500, Title III, Water Supply Act of 1958, as amended (72 Stat. 319). Section 301(b) of this Act states

> ". . . it is hereby provided that storage may be included in any reservoir project surveyed, planned, constructed or to be surveyed, planned, and/or constructed . . . to impound water for present or anticipated future demand or need for municipal and industrial water supply."

Section 301(d) of the Act states

> "[M]odifications of a reservoir project heretofore authorized, surveyed, planned, or constructed to include storage as provided in subsection (b), which would seriously affect the purposes for which the project was authorized, surveyed, planned, or constructed, or which would involve major structural or operational changes, will be made only upon the approval of Congress as now provided by law."

Reallocation or addition of storage that would seriously affect other authorized purposes of the existing reservoir or that would involve major structural or operational changes requires Congressional approval. Provided these criteria are not violated, 15 percent of the total storage capacity allocated to all authorized project purposes (flood control, hydropower, navigation, water supply, etc.) or 50,000 acre-feet, whichever is less, may be allocated from storage authorized for other purposes. This amount may also be added to the project to serve as storage for M&I water supply at the discretion of the Commander. For reallocations up to 499 acre-feet, the Commander has delegated approval authority to the division commander. Reallocations that exceed the Commander's authority may be approved at the discretion of the Secretary of the Army if such reallocations do not require Congressional approval as described above. The approval of the reallocation report, however, does not signify an approval to reallocate storage. Such approval is governed by the final signature of the water supply agreement.

USACE Official Headquarters guidance on reallocations can be found in engineering regulation ER 1105-2-100 (Planning Guidance Notebook). Periodic Engineering Circulars and Policy Guidance Memorandums can also be issued on this procedure.

3.3 ECONOMICS

The cost of authorized M&I water supply storage in new and existing projects will be the total construction cost allocated to the water supply storage space. This cost will include, as appropriate, interest during construction and interest after the ten-year, interest-free period. The share of the user's cost of storage represented in the repayment agreement will be the same ratio as the share of the user's storage space is to the total water supply storage space. An agreement covering all costs allocated to water supply must be approved by both the non-federal sponsor and the Federal Government. This agreement must be approved before construction of a new project, modification of an existing project, or, if no modification is required, the initiation of the use of the storage space in an existing project.

If reallocation of hydropower storage is contemplated or it is anticipated that reallocation of other storage would impact hydropower storage and an economic question arises, the Power Branch of the USACE Northwestern Division (CENWD-ET-WP) should be contacted for assistance. This branch (the Hydropower System Economic Evaluation Center) is the official center of expertise for hydropower evaluation in the USACE. Also USACE engineering circular EC 1105-2-216 (Reallocation of Flood Control Storage to Municipal and Industrial Water Supply – Compensation Considerations) establishes policy and provides supplemental guidance on analyzing and implementing compensation requirements to existing water supply and/or hydropower users in the event flood control storage is reallocated to municipal and industrial water supply. Procedures and requirements are provided for the analysis and implementation of Dependable Yield Mitigation Storage (DYMS) to compensate water supply users and, where appropriate, to compensate hydropower users through operational changes.

The cost allocated to the non-federal sponsor for the capital investment for reallocated storage space will normally be established as the highest of the benefits or revenues foregone, the replacement cost, or the updated cost of storage in the federal project. The non-federal sponsor is also responsible for any specific construction and/or operational costs associated with the reallocation action including costs associated with the revision of the water control plan and environmental mitigation costs. The cost shall not, however, include the cost of past expenditures for replacement, rehabilitation and reconstruction. These later costs are excluded, as the price charged to the user will be at least the price of the storage space in a new project, which assumes the project is in a new state of repair.

Benefits foregone are generally estimated using standard USACE national economic development (NED) evaluation criteria in compliance with the Principles and Guidelines (P&G). The benefits foregone should be estimated for the remaining economic life of the project or 50 years, whichever is greater. For reallocations from hydropower storage that are within the discretionary authority of the Commander, benefits foregone may be obtained from in-house power value estimating procedures or otherwise in accordance with the P&G. For large reallocations, estimates should be calculated by the P&G procedures for evaluation of hydropower benefits.

Revenues foregone to hydropower are the reduction in revenues accruing to the U.S. Treasury as a result of the reduction in hydropower outputs based on the existing rates charged by the power marketing agency. Revenues foregone from other project purposes are the reduction in revenues accruing to the U.S. Treasury based on any existing repayment agreements.

If the reallocated storage is being taken from the flood control pool and adverse impacts warrant replacement measures, it is appropriate to use the replacement cost of equivalent protection. Examples of when replacement of flood control storage would be appropriate are when there is a real estate taking or when the value of the lost flood control storage is greater than the value of the added M&I storage. This would not be appropriate for reallocations within the discretionary authority of Commander, USACE, which by definition, do not have severe impacts.

Under the updated cost of storage procedure, the cost of the reallocated storage is determined through a three-step process:

(1) Cost at Time of Construction. Compute the cost of the reallocated storage at the time of construction by using the "Use of Facilities" cost allocation procedure.
(2) Midpoint of Construction. Determine the midpoint of the physical construction period.
(3) Update Cost. Using the appropriate index(s), update the cost from the midpoint of the construction period to the beginning of the fiscal year in which the contract for the reallocated storage is approved.

These three steps are displayed in detail in Table 4-4 of the USACE Water Supply Handbook (Revised IWR Report 96-PS-4).

All income and expenses (investment, operation, maintenance, replacement, etc.) associated with the water supply function will be separately identified in the official cost account record. When there is a loss of revenue from existing purposes or when there is an additional operation and/or maintenance expense to existing purposes because of the new water supply addition, such charges will be shown as a direct charge against the water supply function. All revenues lost to the project and downstream areas must be considered. This loss will affect the appropriate cost reductions in the existing project purposes and all revenues from the new addition will be credited to the new purpose. If hydropower revenues are being reduced because of the reallocation, the power marketing agency will be credited for the amount of revenues foregone to the U.S. Treasury because of the reallocation assuming uniform annual repayment. In instances where existing repayment agreements between the power marketing agency and their customer would result in a cost to the Federal Government to acquire replacement power to fulfill the obligations of the agreements, an additional credit to the power marketing agency can be made for such costs incurred during the remaining period of the agreements. Such credits should not actually be made for replacement costs until the costs are incurred and documented by the power marketing agency.

As a test of financial feasibility, the governing annual cost of storage derived as determined in the above paragraphs, should be compared to the annual cost of the most likely, least costly alternative that would provide an equivalent quality and quantity of water that the non-federal interest would undertake in the absence of using the federal projects. This analysis is to be included in the reallocation report.

There are many facilities and infrastructure issues that must be resolved when considering a reallocation in a USACE reservoir. A comprehensive accounting of facilities and infrastructure that will be affected by the proposed reallocation must be made along with contacts and information about the responsible public or private owners, operators, or agencies for each item. These items can include park facilities such as campgrounds, bathrooms, recreational vehicle facilities, boat ramps, swimming beaches, trail systems, and others. Other public and private infrastructure to be considered are project offices, interpretive centers, marinas, golf courses, roadways, bridges, pumping facilities, etc. This is not a comprehensive list and any cost estimates must be made for relocation, reconstruction, modifications, and compensation for loss of revenues for all of the affected sites on the project in question. This process will likely involve negotiations with both public and private concerns that own and/or operate the identified items. The distribution of costs for the above estimates should be included in the agreement covering all costs approved by both the non-federal sponsor and the Federal Government as discussed previously.

3.4 IMMEDIATE OR NEAR TERM NEED REQUIREMENTS FOR WATER SUPPLY

Under USACE policy, a reallocation report is separate from a reallocation action. A report may include future needs, but a reallocation action can only be in the context of satisfying immediate needs. An immediate need can be defined as the amount of storage for which the sponsor will make immediate payment. A reallocation action is not complete until a water supply agreement for those immediate needs is approved. When the need for reallocation or addition of storage at a project first arises, districts are encouraged to survey not only the immediate water needs but should include the water needs for the next 15 to 20 year planning horizon, although such need may be met through several reallocation actions over a period of several years. This entire need is to be put into one reallocation report. Agreements submitted after approval of the original reallocation report will be accompanied by the original approved report with information showing the changes in impacts, if any, since the time of the report. The new information will also determine the price of storage in the new agreement.

Whenever a reallocation is contemplated, a reallocation report must be prepared. This report can vary in length depending upon the size of the change and the issues encountered. The purposes of the report and the topics to be discussed are as follows:

(1) Identify and quantify the new use and user;
(2) Evaluate the impacts on other project purposes and users;
(3) Determine environmental effects;
(4) Determine the price to be charged the new user; and
(5) Determine appropriate compensation, if any, to existing users/beneficiaries.

A table containing a suggested outline for a reallocation report can be found in Box 4-1 of the USACE Water Supply Handbook. The text of the report will contain the major subject matter elements (not necessarily to be used as headings) as presented in the table referenced above. The level of detail should be commensurate with the amount of storage reallocated and/or the problems encountered because of the reallocation. A reallocation report may even serve as a reauthorization report. This would be expected in those reports recommending major changes. A detailed outline of a reallocation report, including examples, is provided in Appendix D of the USACE Water Supply Handbook.

3.5 ENGINEERING

Engineering services for investigation and calculations involved in reallocation studies from USACE reservoirs should be performed by the engineer district(s) with operational responsibility for the reservoir in question. For any engineering services not performed by the engineer district(s) with operational responsibility for the project in question, that district will be given the opportunity to specify criteria for and review all criteria set forth and any work performed by any other engineer district or contracted firms relating to reallocation projects in the responsible district(s) jurisdiction.

A yield analysis must be performed for any reallocation requested for consideration in a USACE Reservoir. This analysis will usually be used to make the first determination as to the feasibility of any reallocation proposal. Critical yield should be developed for existing top of conservation pool for the reservoir in question. Critical yields should be developed for any and all alternatives being considered for top of conservation pool elevation. The analysis should be performed using the latest and most comprehensive data sets and period of record information available at the time of study. Pool elevation probability data should be prepared and tabulated for alternative conservation pool levels under consideration. These previous guidelines are not the only guidelines that should be followed. Each individual request will bring with it, options and scenarios that will merit further or additional investigation and analysis.

For any proposed reallocation, a new assessment of flood damage reductions will be performed for the project in question. This assessment will encompass both upstream and downstream impacts from the proposed reallocation for the project in question. These results should be compared to the original reductions for the existing project and compared for feasibility. Applicable guidance for flood damage reduction studies can be found but should not be limited to the USACE engineering manual EM 1110-2-1619 (Engineering and Design Risk-Based Analysis for Flood Damage Reduction Studies).

Sedimentation impacts will be addressed for any potential reallocation under consideration. Assessment of potential increases or decreases in system sediment loads must be made and impacts evaluated from not only an operational or lifespan perspective but also relating to environmental and any other previously unconsidered pursuant impact issues. The USACE engineering manual EM 1110-2-4000 (Engineering and Design – Sedimentation Investigations of Rivers and Reservoirs) offers guidance on sedimentation modeling and analysis in USACE Reservoirs. The scope of the analysis should use the guidance offered in EM 1110-2-4000 but not be limited to it, and the scope should additionally use current sedimentation analysis criteria in use at the time the study is performed. This assessment should include, but need not be limited to, changes in chronological, seasonal and spatial depositional properties of the system(s) in question. Impacts based on these criteria may also impact previously mentioned areas of the overall reservoir system and, where warranted, should be considered in those assessments as well.

Impacts to the nature and cycle of shoreline erosion must be considered for any proposed reallocation in USACE reservoirs. An assessment should be made of the potential increase in shoreline erosion problems and impact on the reservoir. These studies should be carried out by or under the direction of the engineer district(s) with operational responsibility for the project in question in accordance with their specifications for such studies. Potential increases in shoreline erosion should also be considered when conducting sedimentation analysis as deposition of eroded shoreline material in other parts of the reservoir may need to be considered as impacts in the sedimentation analysis that is performed on the reservoir. Therefore, shoreline erosion and sedimentation analysis will be carried out in close association relating to the results and impacts of each process on the other. Agreement formulation for shoreline erosion impacts that are determined to occur based on the reallocation under consideration will be carried out with all of the involved and impacted parties, the USACE, and the entity requesting the reallocation. Plans will be developed, evaluated, and selected in accordance with the Water Resources Council's (WRC) Economic and Environmental P&G for Water and Related Land Resources Implementation Studies (dated 10 March 1983) as required by USACE engineering regulations ER 1105-2-100 (Planning Guidance Notebook) and ER 1165-2-130 (Water Resources Policies and Authorities - Federal Participation in Shore Protection).

3.6 DAM SAFETY IMPACTS AND REQUIREMENTS

The average age of USACE dams across the nation is approximately 50 years with 77 percent of them classified as high hazard dams. ER 1110-2-1156 states that "if there is certainty that one or more lives will be lost due to the failure of incorrect operation of the project, the project shall be classified as high hazard potential." The proximity of so many USACE dams to metropolitan areas places most of the dams in that category. These facts warrant that all aspects of dam safety must be given careful consideration under any proposed reallocations. All proposed modifications (including those for environmental or other purposes) must be evaluated to ensure there are no adverse impacts to project performance and must be approved by the Dam Safety Officer(s) for the USACE district(s) with jurisdiction over the project in question. Engineering investigations are required to support any proposed modifications to the dam, modifications to operations or increased frequency of higher elevations of increased storages being detained. All items affecting dam safety must be considered. These engineering investigations should include, but not be limited to, hydrologic/hydraulic investigations and geotechnical/structural investigations.

The dam foundation must be assessed for adequacy to changes in loadings created by any proposed reallocations. All other structural components of the dam and its attendant structures must be evaluated for proper sizing, placement, and applicable design when considered under any new operating criteria imposed by proposed reallocations. Existing riprap and other skin stabilization systems must be evaluated for adequacy of coverage and placement under new operational conditions to be encountered with any proposed reallocation. Applicable guidance for these items can be found in the following USACE engineering manuals: EM 1110-2-1911 (Engineering and Design: Construction Control for Earth and Rock-Fill Dams), EM 1110-2-2200 (Gravity Dam Design), and EM 1110-2-2300 (Earth and Rock Fill Dams: General Design and Construction).

An assessment must be made for adequate and appropriate hydraulic sizing and appropriate elevation of any project gates. Checks should be made for potential changes (both increases and decreases) in hydrologic frequencies for the structure. For the reservoirs in question, the relation of surface area and release capacity to storage content must be described. Characteristics of the control gates on the outlets and spillway must be known in order to determine constraints on operation. The top-of-dam elevation must be specified and the ability of the structure to withstand overtopping must be assessed. Determination of need for dam raise and/or spillway modifications must be addressed. Potential changes in fetch, run-up, and wave action should be studied with any inadequacies being addressed with appropriate solutions; such as dam raise to increase freeboard, which can vary from zero for structures that can withstand overtopping to two meters or more for structures where overtopping would constitute a major hazard. Type and sizing characteristics of the spillway must be assessed for adequacy based on any new operation criteria and with respect to any new computed frequency curves based on proposed reallocation. If under the new criteria imposed by the proposed reallocation the spillway can no longer carry the probable maximum flood (PMF) for which it was originally designed, then spillway modifications will need to be made to return it to this capacity. Unless the original spillway design was for the standard project flood (SPF) then this flood frequency should be used for the basis of any spillway modifications. More information and guidance for these issues can be found in USACE engineering manual EM 1110-2-1420 (Hydrologic Engineering Requirements for Reservoirs).

Another aspect of dam safety is management and monitoring of hydrostatic forces on and within the dam. Hydraulic piping, seepage, uplift, and sliding are common results of the hydrostatic load on dams. These phenomenons must be monitored and managed so they do not lead to failure of the dam or its systems. Grouting, installation of relief wells and installation of blanket drains are some of the many methods to relieve hydrostatic forces and reduce hydraulic gradient. These methods may be necessary for any proposed reallocation. Dams should be assessed prior to reallocation as well as continually monitored after reallocation for potential problems that can arise with increases in hydrostatic forces resulting from a reallocation. Various forms of instrumentation systems are available for the monitoring of dam conditions and should be implemented or expanded if preliminary dam safety studies of a reallocation deem them necessary. USACE guidance for these systems can be found in engineering manuals: EM 1110-2-1908 (Instrumentation of Embankment Dams), and EM 1110-2-4300 (Instrumentation for Concrete Structures).

3.7 PROJECT OPERATION

When considering a reallocation in a USACE reservoir, the current plan of regulation must be assessed to determine if it is still applicable under the new conditions imposed by the reallocation. If it is determined that a new plan of regulation is warranted based on the results of the engineering and other investigations of the conditions after reallocation, then a plan must be developed. If a new plan of regulation is to be adopted, then a new water control manual must also be published. This new plan will reflect the changes to the plan of regulation of the project under study. USACE Guidance for accomplishing these tasks can be found in the engineering manual EM 1110-2-3600 (Engineering and Design Management of Water Control Systems) and in the engineering regulations ER 1110-2-240 (Engineering and Design Water Control Management) and ER 1110-2-8156 (Engineering and Design Preparation of Water Control Manuals).

3.8 ENVIRONMENTAL

An environmental assessment must be prepared for any reallocation actions to be undertaken on USACE reservoirs. This assessment should be prepared in accordance with the National Environmental Policy Act (NEPA) of 1969, the Council on Environmental Quality (CEQ) Regulations (40 Code of Federal Regulations [CFR] Parts 1500-1508), the USACE engineering regulation ER 200-2-3 (Environmental Quality Environmental Compliance Policies), and any other pursuant regulations, legislation, and accepted codes or guidelines in effect or commonly used at the time the reallocation is being considered. Any updates or superseding versions of the aforementioned guidance should be used. The assessment should include but not be limited to air and water quality considerations outlined in the Clean Air Act (CAA) (42 USC 7401 et seq., as amended) and the Clean Water Act (CWA) (33 USC 1251 et seq., as amended). Impacts to navigable waterways of the United States need to be considered, a Section 404 permit may be required. The USACE project manager working on the Reallocation Report will be able to determine if this permit is required. Impacts to endangered species must be considered and studied in accordance with the Endangered Species Act. ([ESA] 16 USC 1531-1543). Mitigation requirements must be determined for the project being considered for reallocation and should be based on the information and data compiled in the environmental assessment and any additional sources deemed relevant by all involved parties. If it is determined through the environmental assessment that an Environmental Impact Statement is needed then one will be prepared and factored into the agreement covering all costs allocated to water supply approved by both the non-federal sponsor and the Federal Government as previously discussed in the economics section (Section 1.3) of this document.

In all cases of environmental studies, the responsible engineer district(s) will be given the opportunity to specify criteria for any work as well as review all criteria set forth for any work. The district(s) will also have the opportunity to review any work performed by any other engineer district or contracted firms relating to environmental aspects of reallocation projects in the responsible district(s) jurisdiction.

3.9 CULTURAL

An inventory and assessment of any culturally significant, historical and archaeological sites or artifacts that would be affected by the actions of a reallocation in a USACE reservoir must be made. A course of action for any impacts will be determined and carried out in accordance with the National Historic Preservation Act of 1966 (NHPA [16 USC 470 et seq., as amended]), the Native American Graves Protection and Repatriation Act of 1990 (Public Law 101-601, 25 USC 3001 et seq.) and any other pertinent legislation or standard practices in use at the time for assessment of the aforementioned resources as deemed appropriate and applicable by all of the involved parties. Costs associated with any recommended alternatives will be considered in the agreement covering all costs allocated to water supply approved by both the non-federal sponsor and the Federal Government as previously discussed in the economics section (Section 1.3) of this document.

3.10 COORDINATION WITH OTHER FEDERAL AGENCIES

Involvement of other federal agencies may be required in many aspects of a reallocation study on any USACE reservoir. The engineer district(s) with operational responsibility for the project in question will coordinate the interaction with other federal agencies that are determined to have a stake in the potential reallocation or that will be affected by it. The degree of involvement should be determined by the agency as well as the nature of the issues that arise from the requested reallocation. Many federal agencies have jurisdictional overlaps both internally as well as with other agencies. When this is the case, all of the appropriate offices and agencies should be involved and given the opportunity to participate in the process for the requested reallocation. Some of the agencies that often are involved with issues affecting Department of the Army reservoirs are the United States Environmental Protection Agency (EPA), the United States Federal Emergency Management Agency, the United States Federal Energy Regulatory Commission (FERC), the United States Fish and Wildlife Service, and the United States Natural Resource Conservation Service to name a few. This is not meant to be an exhaustive list and should not be used as such.

4.0 STATE GUIDELINES FOR REALLOCATION OF STORAGE IN DEPARTMENT OF THE ARMY FEDERAL RESERVOIRS FOR FUTURE WATER SUPPLY

4.1 BACKGROUND

Several state agencies including the Texas Commission on Environmental Quality (TCEQ), Texas Water Development Board (TWDB) and Texas Parks and Wildlife Department (TWPD) were contacted to develop a document that includes the basic steps (in the State context) that would be required to reallocate storage in federal reservoirs for water supply. Relevant steps and/or issues for each of state agencies are described in the following sections.

4.2 TWDB REQUIREMENTS

The TWDB has no permit issues or environmental concerns that need to be addressed. The only requirements set forth by the TWDB involve requests for state funding to aid in completion of a reservoir reallocation. The requirement is that the Regional State Water Plan must include the option of reallocating reservoir storage for the purpose of increasing water supply[1]. This can be addressed by ensuring that the adopted Regional State Water Plan states that the entity in the region has listed reallocation of a specific or multiple reservoir system in the region plan as a method of increasing public water supply to meet projected water needs.

4.3 TCEQ REQUIREMENTS

Requirements for TCEQ are associated with standard water right permits and amendments to water rights. Reservoir reallocations would be applied for as a new water right permit or an amendment to an existing water right with a new priority date for the reallocated volume of water. The increased yield from reservoir reallocation is considered to be new water not previously permitted and must be permitted under a junior water right or junior amendment to an existing water right.

4.3.1 Necessary Forms and Documentation

In order to complete an application for reservoir reallocation and associated water rights, the agency requesting the reservoir reallocation would need to file a completed General Water Rights Permit Package Application (Form: TNRCC-10214) with TCEQ. The following information will be necessary for completion of this from:

- Applicants name, mailing address, customer reference number (CN), and lien holder information (File form No. TCEQ-10400). If one does not have a CN number, this form can be filed with the water right application,

- Type of storage reservoir and date of construction, location of dam structure, reservoir storage information, U.S. Natural Resources Conservation Service site name and number, if applicable, and drainage area above dam or diversion point,

- Requested water appropriations purpose, place of use, and volume; irrigation locations if applicable, diversion point description, location, and diversion rate; return flow location and quantity information, and designation of return location of surplus water,

[1] TWDB

- General information regarding water right facilities location and ownership, interbasin transfer requests, water conservation plan, and location of project with respect to distance from coast,

- Maps, plats, plans, photographs and drawings of reservoir, diversion, and dam sites need to be included as required by applicable Texas Administrative Code (TAC) Sections,

- Description of how this application addresses a water supply need in a manner that is consistent with the State Water Plan or the applicable approved Regional Water Plan for any area in which the appropriation is located, or describe conditions that warrant a waiver of the requirement and,

- The application is to be signed by applicant and notary public.

A description of the reallocation project will be part of the required water rights permit application mentioned above. The reallocation project description should detail the owner(s) of the reservoir and newly appropriated storage, the amount of storage reallocated to municipal and industrial use and the method of reallocation accompanied with the source of the allocated water. For example, the description could state whether the reservoir reallocation was performed by converting existing storage to water supply or by changing the normal reservoir elevation and modifying the existing dam structure. The project description should also provide information regarding diversion amounts, use types and locations, maximum diversion rates for the new diversion permits, and any other information not listed which is related to the new diversions.

To aid TCEQ in verification of the quantity of newly available firm yield created by the reallocation, the agency requesting the water permit should also provide WAM descriptions and analysis of the new storage and diversion as well as documentation regarding the change in the reservoirs sediment storage. Changes to the reservoirs sediment storage can be included with the permit application by providing a pro-rated sediment storage value which is related to the reallocated storage. Also, issues related to the sediment reserve's impact on conservation storage between multiple users or priority dates should be addressed in the application. The new water right application would be subject to environmental regulations; therefore, an environmental flow analysis should be considered as a necessary item to expedite the processing of the application. Considerations for environmental flows should address the effect of the reservoir reallocation and/or the changed operating rules for flood releases on in-stream flows downstream of the reservoir and freshwater inflows to bays and estuaries[2]. TCEQ staff would also require a component reservoir analysis if the reservoir being reallocated included multiple owners, multiple water right priorities or if the USACE owned part of the reservoir uses. TCEQ analysis would also require an evaluation of the impacts reallocation of storage would have to upstream and downstream water rights.

4.3.2 Additional Documentation

In some instances additional descriptive information and attachments may be needed. A reservoir accounting plan should be included in the water right permit application if:

- There are multiple users under different priority dates that will be using the reallocated storage,
- There are multiple users with the same priority dates,
- There is a single user operating under multiple water rights with varying priority dates,
- The reservoir is part of a system operation plan.

[2] TCEQ

Any permit granted by TCEQ would include a special condition requiring maintenance of the accounting plan. The accounting plan would need to be detailed in that it must show water supply use for all water rights involved with respect to priority dates, evaporation allocation, etc. Other details included with the accounting plan will vary depending on the water rights and environmental restrictions or concerns.

In the event that the reservoir reallocation will result in the need to upgrade the existing dam, TCEQ may require that the upgrade specifications and plans be submitted and reviewed by the Dam Safety Department. If the dam is federally owned, then TCEQ Dam Safety does not need to review upgrade plans and specifications. If the dam is privately owned (by landowner, corporation, city, etc.), including all dams that were/are approved by the Natural Resources Conservation Service (NRCS), then TCEQ Dam Safety requires that the plans, the specifications, and a letter describing the details of the dam upgrade be submitted for review and approval. Finally, documentation of agreements between the agency diverting the water supply and the USACE or other Federal sponsor should be included with the permit application. This may include the need for the requesting agency to purchase dependable yield mitigation storage[3] if the USACE requires such action[4].

4.3.3 Reallocation and Hydropower Requirements

Reallocation projects that involve reallocation of the hydropower pool have a separate set of circumstances that could include the subordination of hydropower rights. If reallocating the hydropower pool or requesting hydropower subordination, the TCEQ Surface Water Availability Team should be contacted for further consultation. Any reallocations involving hydropower on the reservoir, or reallocating the hydropower pool will also need to investigate the need for FERC permitting changes.

4.4 TPWD REQUIREMENTS

The primary focus of the TPWD will be to evaluate the impact of storage reallocation on environmental flows, habitat and fisheries, if applicable. In general, TPWD will coordinate with TCEQ staff in evaluations for changes in streamflows due to new water rights or amendments to existing water rights. TPWD also assist in providing recommendations for maintaining streamflows primarily for habitats. The method typically recommended by TPWD is an instream flow study at the new water right location. However, if a study is not available TCEQ and TPWD will evaluate environmental flows utilizing the Lyon's method. Another concern for TPWD is the effect of reservoir operations on fisheries in affected reservoirs. TPWD will evaluate the impact of the proposed reallocation on reservoir water level fluctuations.

4.4.1 Possible Permit Issues

TPWD does not require any permits for reservoir reallocation specifically. However, it is recommended that a study be performed to identify threatened and endangered species that may be impacted by the reservoir reallocation. In the event the reservoir reallocation would require disturbance or removal of the sands and gravels of the reservoir or surrounding stream and riverbeds, a "sand and gravel" permit from TPWD would be required[5].

The above information provides an overview of the necessary items to consider when performing a reservoir reallocation. Each reservoir situation is unique, therefore additional issues may arise. This

[3] Dependable yield mitigation storage is additional storage that must be purchased by the water user to mitigate the effects on other water users.
[4] TCEQ
[5] TPWD

document provides the basics needed to aid coordinating with the individual state agencies and provides some information on the necessary permits and environmental considerations.

5.0 METHODOLOGY AND ASSUMPTIONS

Reservoir reallocation yields were determined using two separate programs with separate methodologies and purposes. The USACE utilizes the SUPER Model to evaluate the current firm yields of the federal reservoirs in Texas. The SUPER Model is a computer program developed by the USACE to simulate the regulation of a multi-purpose system of reservoirs over a long period of record utilizing daily records. The basic inputs include (1) uncontrolled area daily accumulated local flows at each reservoir and control point in the modeled area and (2) a basin description file that describes reservoir characteristics, control point flood flow constraints, water supply requirements, low flow requirements and hydropower requirements. The basic outputs include simulated daily reservoir elevations, reservoir releases and control point flows. The SUPER program can only determine the critical period dependable yield for one reservoir at a time. The yield for the most upstream USACE reservoir in each basin was determined first. The modelers then worked downstream with a new yield run for each downstream reservoir by restricting the non-returnable pumpage for the upstream reservoirs to the computed yields from the previous runs for those reservoirs. The SUPER model does not account for water rights, Texas prior appropriation, or environmental flows in water right applications, etc. The assumptions for the SUPER model are different from those used in the WAM analysis and therefore the resulting amount of additional yield calculated can be substantially different.

The second approach to determine reservoir yield from reallocation of storage uses TCEQ permitting criteria and the Water Rights Analysis Package (WRAP). Reservoir capacities were updated based on sediment storage assumptions and current rating curves for the reservoirs involved in the case study. Reservoir reallocations were modeled in both a stand alone and system operations context by creating new water rights at each reservoir with junior priority dates representing the reallocated storage amount made available. The reservoir yield for a stand alone reservoir was calculated by adjusting the diversion at the reservoir to the maximum amount sustainable throughout the period of record. The reservoir yield for system operation was calculated by adjusting the diversion at a downstream location to the maximum amount sustainable throughout the period of record.

It is important to note that yield values from the SUPER Model will be different than those values determined by WRAP using the TCEQ WAM input data. The TCEQ WAM utilizes the Texas prior appropriation doctrine which does not allow an upstream reservoir to impound all available water unless it has seniority over the rest of the river basin. This is a legal framework established by Texas which can cause conflicts between the SUPER Model and WAM firm yield determination. When applying for a water right permit for a reservoir reallocation the results of the WAM analysis result are used by the TCEQ to determine the amount of water available for a new permit application.

6.0 EVALUATION OF RESERVOIR YIELDS BY USACE

6.1 BACKGROUND

Task 2 of this project was performed to evaluate the firm yields of all of the federal reservoirs in Texas. The firm yield evaluation included the determination of the firm yields with and without storage reallocation. The purpose of the evaluation is to evaluate how much additional yield could be made available across Texas for water supply purposes. This section details how the firm yields were calculated and reports the results of the analysis. The analysis performed in this task was completed by USACE personnel.

6.2 BRIEF DESCRIPTION OF THE SUPER MODEL

The SUPER Model is a computer program developed by the USACE to simulate the regulation of a multi-purpose system of reservoirs over a long period of record utilizing daily records. The basic inputs include (1) uncontrolled area daily accumulated local flows at each reservoir and control point in the modeled area and (2) a basin description file that describes reservoir characteristics, control point flood flow constraints, water supply requirements, low flow requirements and hydropower requirements. The basic outputs include simulated daily reservoir elevations, reservoir releases and control point flows. Table 2 provides data such as the date of impoundment, period of record, critical period and latest sediment survey for each reservoir. The SUPER Model was utilized to determine the firm yields of federal reservoirs in Texas.

6.3 FIRM YIELD SIMULATIONS

Each USACE reservoir required a separate computer run to calculate the firm yield. The SUPER program can only determine the critical period dependable yield for one reservoir at a time. Note that in this study the terms firm yield, critical period dependable yield, and dependable yield are synonymous. The yield for the most upstream USACE reservoir in each basin was determined first. The modelers then worked downstream with a new yield run for each downstream reservoir by restricting the non-returnable pumpage for the upstream reservoirs to the computed yields from the previous runs for those reservoirs. Since the upstream pumpage does not return to the system, the inflow into the downstream reservoir is the flow available to the downstream reservoir after the upstream demands are diverted. Numerous simulations were completed to determine the firm yield for existing and future conditions. Instream flow requirements are only considered insomuch as they are represented by the historical record used to make the runs.

6.4 EXISTING AND FUTURE SEDIMENTATION AND WATERSHED CONDITIONS

Future sedimentation for future time periods, such as 50 or 100 years, was estimated in the design stage for various projects, and yields were estimated based on those conditions. Over the years, different sediment distribution schemes were used in determining the required tops and bottoms of the conservation pools, and consequently in computing the initial and future yields. This ranged from assuming that sediment would deposit only in the lowest part of the reservoir to having the sedimentation distributed throughout a range of elevations including the conservation and flood control pools. For most of these prior studies, it was assumed that most of the sediment would deposit below the bottom of the conservation pool.

In this study, the most recent storage curves for each of the reservoir were used. The firm yield was determined by drawing the water surface down from the top of the conservation pool to the bottom of the conservation pool, or in some cases the bottom of the contract water supply pool. Consequently, the amount of storage allocated for sediment below this elevation had no effect on the yield, whether it was actually filled or not. The amount of storage allocated or projected for sediment storage in the conservation pool was only partially considered in the sense that any partially used-up sediment storage would be accounted for in the most recent storage curve. The remaining allocated or projected sediment storage in the conservation pool was still be used for available storage in the yield computations. It is recommended that in more detailed reallocation and yield studies that the distribution of projected sediment is accounted for throughout the full range of the elevation-storage curve for the reservoir.

The inflows used in the model were based strictly on the period of record inflows. Inflows were not adjusted for future land use or increased for future consumptive use upstream. Consequently, the yields computed in the current study represent currently available yields. This should be taken into account when comparing these newly computed yields to those from earlier studies. Some of the adopted yields from the previous studies considered that all allocated sediment storage was used up, while others assumed only initial storage capacity.

It should be noted that for several of the reservoirs in the Red River Basin, the elevation of the bottom of the conservation pool or water supply contract pool is set at the bottom of the reservoir. In these cases, the bottom of the conservation pool for the yield runs was adjusted to account for allocated sediment storage, taking into account the original and current storage capacity distribution of the reservoir. This was also done for the Guadalupe River Basin (Canyon Lake) where the bottom of the water supply contract pool overlapped the top of the sediment reserve. For these reservoirs, the computed yield comes closer to representing the yield at some point in the future when all sediment storage, or sediment reserve, is used up.

6.5 REALLOCATED FIRM YIELD SIMULATIONS

The USACE maximum reallocation authority limit was computed by subtracting the unused sediment reserve from the current storage between the outlet works invert and top of flood control pool. This calculation yielded the net usable storage which was then multiplied by 15 percent. If this volume was less than 50,000 acre-feet, it was added to the current storage in the conservation pool to get the maximum size of the new conservation pool. Otherwise, 50,000 acre-feet was added. For most of the reservoirs in this study, 50,000 acre-feet was used. To get the new pool elevation, the appropriate volume was added to the total storage at the top of the existing conservation pool resulting in the total storage at the top of the new pool. The elevation at the new top of conservation pool was then computed using the current elevation-total storage curve for the reservoir. The new conservation storage came out of the existing flood control storage. Once the new conservation storage elevations and volumes were determined (found in Table 1), new firm yield simulations were performed using the SUPER Model.

6.6 YIELD RESULTS ANLYSIS

As stated earlier, the yields determined in the SUPER Model simulations for current and reallocated conditions are found in Table 1. These results are for all of the reservoirs in Texas that the USACE owns, except O.C. Fisher and B. A. Steinhagen lakes. A graphical representation of the USACE Reservoir yield curves are found in Appendix A. The table also describes the elevation and conservation storage associated with each reservoir. The maximum increase in firm yield for an individual reservoir due to reallocation of storages was found in Lake Wright Patman. The yield increased from 242,991 acre-feet to 304,374 acre-feet or an increase of 61,383 acre-feet. The lowest amount of change in firm yield was 1,377 acre-feet and occurred in Lake Georgetown. According to the SUPER Model summaries these reservoirs represent a total of 4,082,433 acre-feet per year if all reservoirs were reallocated to the maximum USACE authorized limit. Reallocation of all USACE reservoirs could results in an additional 342,882 acre-feet per year.

The USACE yield curves can also be analyzed to determine the additional yield values over 50,000 acre-feet. The procedure to evaluate these curves is described below.

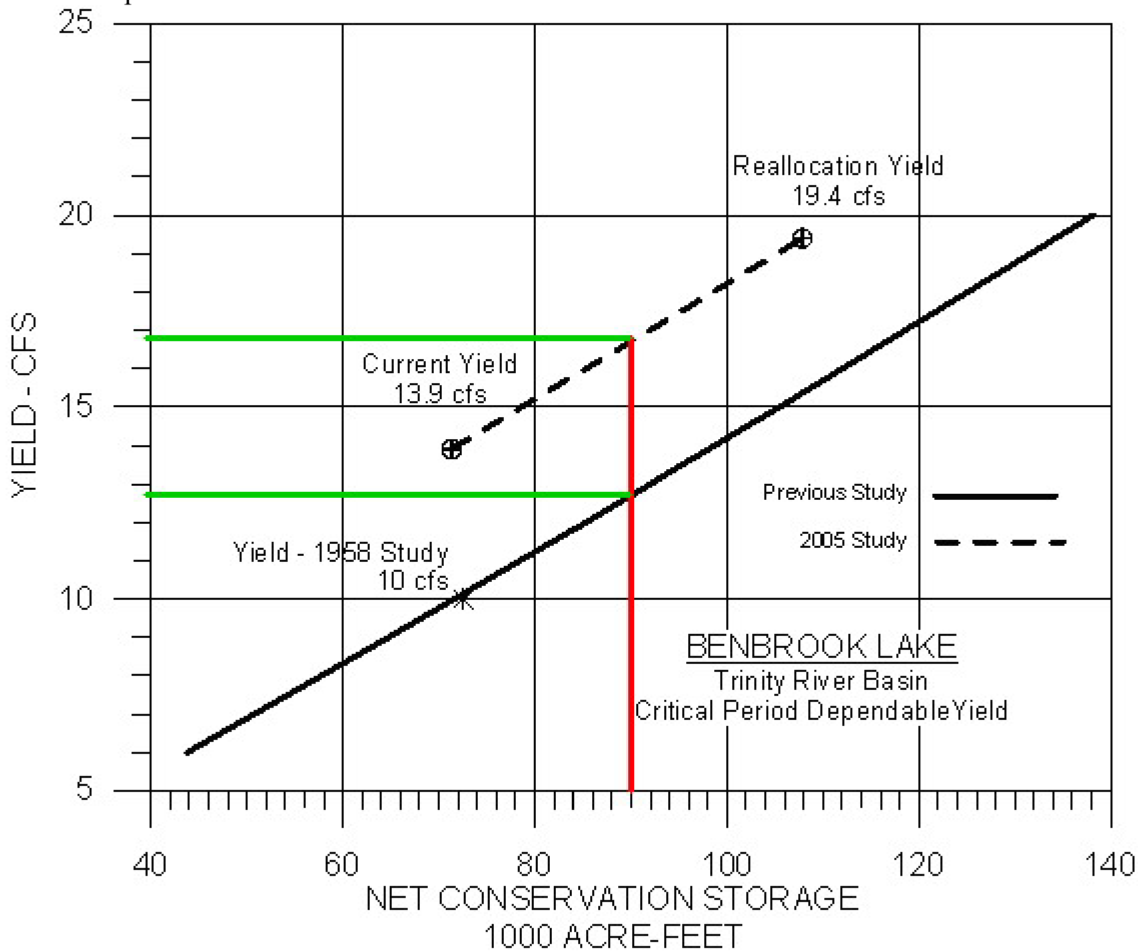

Figure 3: Ex. Benbrook Lake – Trinity River Basin

To estimate additional yield availability for storage volumes other than the 50,000 ac-ft or the 15 percent discretionary level from the supplied graphs use the following steps.

a. Choose a storage volume of interest.
b. Find this value on the x-axis of the graph. We will choose 90,000 ac-ft in this example.
c. Follow a perpendicular vertical line upwards from this value on the x-axis until it intersects the study curve you are interested in. In the above example this is the red line.
d. At the point it intersect the study curve in question follow a horizontal line back to the y-axis of the plot and read off the yield value you are looking for. In the above example this is either of the green lines. In the above example, the yields for 90,000 ac-ft are approximately 12.8 and 16.8 cfs for the previous and 2005 studies respectively.

Table 1: Critical Period Dependable Yields

	Current				USACE Maximum Reallocation Authority			
	Elevation at Top of Conservation	Conservation Pool Capacity	Dependable Yield [3,4]		Elevation at Top of Conservation	Conservation Pool Capacity	Dependable Yield [3,4]	
	(feet)	(acre-feet)	(cfs)	(ac-ft/yr)	(feet)	(acre-feet)	(cfs)	(ac-ft/yr)
Red River Basin								
Texoma	618.5 [1]	1,483,967 [1]	1880.0	1,361,989	The Water Resources Development of Act (WRDA) of 1986 allows for up to 150,000 ac-ft of storage for hydropower to be reallocated to water supply storage for Texas in blocks of 50,000 ac-ft. At the time of this report, a reallocation study is underway in Tulsa District, USACE. (1,361,989 plus 150,000)			
Pat Mayse	451.0	114,701	81.8	59,245	455.2 [2]	141,545	86.5	62,675
Cooper	440.0	273,072	166.5	120,599	442.5	323,138	180.0	130,572
Wright Patman	228.6 [1]	263,404 [1]	335.4	242,991	230.0 [1]	313,367 [1]	420.1	304,374
Lake O'the Pines	228.5 [1]	246,579 [1]	221.8	160,712	231.0 [1]	296,583 [1]	240.9	174,488
Trinity River Basin								
Benbrook	694.0	71,341	13.9	10,051	702.5	107,858	19.4	14,069
Joe Pool	522.0	175,800	36.5	26,450	527.0	215,755	42.2	30,548
Ray Roberts	632.5	798,870	163.0	118,087	634.2	850,035	170.4	123,474
Lewisville	522.0	543,988	129.4	93,745	523.7	594,055	135.7	98,323
Grapevine	535.0	147,030	32.6	23,653	541.5	196751	40.4	29,286
Lavon	492.0	443,845	157.7	114,236	494.2	492,550	166.0	120,248
Navarro Mills	424.0	55,843	28.5	20,647	429.4	84,164	38.8	28,113
Bardwell	421.0	46,122	16.8	12,192	425.7	64,288	21.1	15,276

[1] Based on seasonal pool elevation and average conservation storage.

[2] Existing drop inlet service spillway crest at elevation 451.0 will require modification.
[3] Dependable yields are based on capacity curves in Table 2.
[4] Yields are natural yields only, not subject to senior water rights.

Table 1 (cont'd): Critical Period Dependable Yields

	Current				USACE Maximum Reallocation Authority			
	Elevation at Top of Conservation	Conservation Pool Capacity	Dependable Yield [3,4]		Elevation at Top of Conservation	Conservation Pool Capacity	Dependable Yield [3,4]	
	(feet)	(acre-feet)	(cfs)	(ac-ft/yr)	(feet)	(acre-feet)	(cfs)	(ac-ft/yr)
Brazos River Basin								
Whitney	533.0	248,100	41.9 [5]	30,339 [5]	535.0	296,520	84.7 [6]	61,398 [6]
Aquilla	537.5	45,235	26.1	18,933	542.1	62,561	30.0	21,763
Waco	462.0	187,344	125.3	90,775	USACE maximum reallocation authority limit already met (90,775).			
Proctor	1162.0	50,091	30.8 [8]	22,313	1170.8	99,534	36.9 [8]	26,733
Belton	594.0	382,099	170.4	123,448	597.8	431,039	177.0	128,215
Stillhouse	622.0	226,033	101.2	73,316	629.2	275,331	106.7	77,315
Georgetown	791.0	36,986	22.9	16,590	802.5	54,481	24.8	17,967
Granger	504.0	52,524	31.5	22,821	509.6	82,186	40.5	29,374
Somerville	238.0	155,061	64.8	46,981	242.0	205,051	71.6	51,903
Neches River Basin								
Sam Rayburn	164.4	1,446,489	1,149.2	832,580	USACE maximum reallocation limit already met. (832,580)			
Colorado River Basin								
Hords Creek	1900.0	5,683	0.2	134	1905.6 [7]	8,948	0.2	180
Guadalupe River Basin								
Canyon	909.0	358,135	133.5	96,724	914.8	407,850	139.1	100,795
Total				**3,739,551**				**4,082,433**

11/16/2005

[5] Part of dependable yield attributable to 50,000 ac-ft contracted for water supply. Total yield is 207.8 cfs, and includes all releases from Possum Kingdom Lake.

[6] Part of dependable yield attributable to 100,000 ac-ft allocated for water supply. Total yield is 251.3 cfs, and includes all releases from Possum Kingdom Lake.

[7] Existing drop inlet service spillway crest at elevation 1900.0 will require modification.

[8] Sediment reserve not considered in computations for drawdown. Minimum pool at 1142.0.

Table 2: Miscellaneous Lake Data

	Date of Impoundment	Period of Record	Critical Drawdown Period (Existing Pool)	Acquisition Date for Area-Capacity Data Used to Develop Current Yield
Red River Basin				
Lake Texoma	1943	1938-2000	Jun 38 - Apr 40	2002
Pat Mayse	1967	1938-2000	Jul 52 - Mar 57	1984
Cooper	1991	1938-2000	Jun 53 – Jan 57	1957
Wright Patman	1956	1938-2000	Feb 72 – Oct 72	1997[1]
Lake O' Pines	1957	1938-2000	May 63 – Jan 65	2002
Trinity River Basin				
Benbrook	1952	1940-1992	Jul 51 - Mar 57	1998
Joe Pool	1986	1940-1992	May 50 - Apr 57	1985
Ray Roberts	1987	1940-1992	Oct 50 - Mar57	1985
Lewisville	1954	1940-1992	Oct 50 - Mar 57	1989
Grapevine	1952	1940-1992	Sep 50 - Mar57	2002
Lavon	1953	1940-1992	Jun 51- Mar 57	1965
Navarro Mills	1963	1940-1992	Jun 62 - Feb 65	1972
Bardwell	1965	1940-1992	May 53 - Mar 57	2001
Brazos River Basin				
Whitney	1951	1939-1997	May 77 - Aug 78	1959
Aquilla	1983	1939-1997	Jun 53 - Mar 57	2002
Waco	1965	1939-1997	May 53 - Mar 57	1995
Proctor	1963	1939-1997	Jun 77- Oct 81	2002
Belton	1954	1939-1997	May 47 - Mar 57	1994
Stillhouse	1968	1939-1997	May 47 - May 55	1995
Georgetown	1980	1939-1997	Jan 47 - Mar 57	1995
Granger	1980	1939-1997	Dec 53 - Mar57	2002
Somerville	1967	1939-1997	Jul 50 – Mar 57	1995
Neches River Basin				
Sam Rayburn	1965	1929-2001	Jul 69 – Oct 72	1971
Colorado River Basin				
Hords Creek	1948	1930-1999	May 75 – Sep 85	1968
Guadalupe River Basin				
Canyon	1964	1935-2001	Mar 57 – May 58	2002[1]

[1] Bottom of conservation pool was adjusted upward to account for future sediment storage.

7.0 VIRTUAL WAM MODEL

7.1 INTRODUCTION

Task 3 of the Brazos River Reallocation Project involves constructing a virtual river basin model and performing simulations using the Water Rights Analysis Package (WRAP) (June 2005 Version). A WAM (Water Availability Model) was developed for the virtual river basin using three separate reservoirs in one river basin. The purpose of the virtual river basin model is to develop a simple tool to determine if reservoir reallocation with and without system operations can provide increased water for water supply. This modeling exercise is simplistic and the input parameters for this model were similar to those used in some areas of the Brazos River.

7.2 VIRTUAL RIVER BASIN

The virtual river basin developed for the reservoir reallocation model consists of three reservoirs, water rights designed to establish and fill the three reservoirs, and a water right that diverts water from streamflow, reservoir storage and releases for determining the yields. The virtual model utilizes a small portion of data similar to the naturalized streamflow conditions and evaporation rates found in the Brazos River Basin WAM. These values were chosen to provide the natural fluctuation of real world hydrology that would represent a drought period as well as a wet period at one or more of the virtual reservoirs during the period of record modeled.

The virtual river basin simulations were developed to determine if reservoir storage reallocation with system operations would provide additional firm yield for water supply in a river system. As stated above, the virtual river basin is comprised of three reservoirs located on tributaries of a mainstem river. Reservoir A is the most upstream reservoir on a tributary that empties into the mainstem at Control Point 3 (CP3). Reservoirs B and C are also located upstream of CP3 but on different upstream tributaries. The mainstem is formed from the confluence of the three tributaries and is designated by Control Points 3 and 4. A diagram of the virtual river basin is shown in Figure 1. Naturalized flow data was input for Control Points 1, 2, 4 and 5 located downstream of Reservoir A, downstream of Reservoir B, at Control Point 4 and downstream of Reservoir C, respectively.

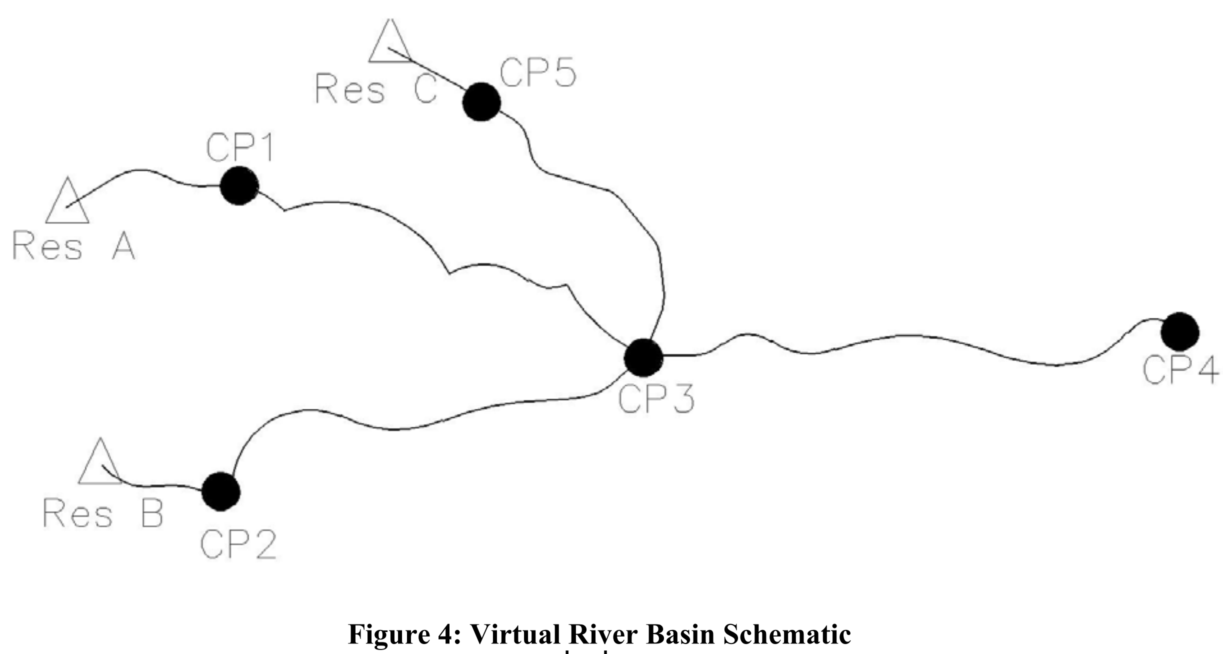

Figure 4: Virtual River Basin Schematic

7.3 MODELING SIMULATIONS

Four separate simulations of the virtual basin were developed. The first run was developed to determine the stand alone yield of each of the three reservoirs. The stand alone yields were determined by modeling diversions at each reservoir independently. A second run was developed to determine the increase in yield achieved by operating the reservoirs together as a system. This exercise was performed by modeling a diversion at a control point downstream of the reservoirs so that the reservoirs would release water to meet the maximized downstream diversion. Reservoir system operations can be beneficial because when one reservoir is in a time of drought other reservoirs in the system can be relied on where different hydrologic conditions exist (more rainfall in other areas of the basin). The increase in yield created by system operations was calculated by subtracting the sum of the stand alone reservoir yields from the total yield determined from system operations. The third simulation performed determined the benefit of reservoir reallocation on stand alone reservoir yields. This run is similar to the first run developed; however, it includes additional junior water rights, which represent reservoir reallocation. These junior water rights determine the yield produced from reallocation by diverting additional firm yield from the reservoir. The fourth simulation was developed to determine the combined benefit of reallocation and system operations. This run uses a single water right downstream of the reservoirs to divert the available firm yield from the system. The additional yield achieved from system operations of the reallocated reservoirs was calculated by subtracting the sum of the reallocated stand alone yields from the total diversion of the system operations of the reallocated reservoirs. These four simulations are described in more detail in the following sections.

7.3.1 Independent Reservoir Yield (with and without reallocation)

The determination of a stand alone yield for the three reservoirs in the virtual basin began with the base model in which all three reservoirs were established with independent water rights with similar priority dates. The maximum yield of each individual reservoir is determined by finding the maximum diversion for the water right from each reservoir that is sustainable throughout the period of record. The yield of the water right is defined as the maximum volume of water that can be diverted annually from the reservoir that does not cause the monthly storage in the reservoir to reach zero. In other words, the diversion amount of the water right was adjusted to take as much water out of the reservoir and still leave less than one percent of the storage in the reservoir (on a monthly basis). The diversion amount of the water right used to determine the individual firm yields was changed in an iterative process until less than one percent of the total storage of the reservoir remained.

Once the stand alone yields were calculated for each reservoir, reallocation of storage in the reservoirs was assigned. The reservoirs in the basin model were reallocated using the criterion detailed in Chapter 1 of this report. The USACE jurisdiction in federal reservoir reallocation is limited to the reallocation of 15 percent of a reservoir's total allocated storage or 50,000 acre-feet, whichever is less. The new reservoir storage capacities were estimated using that guideline. As stated earlier, the additional yield above the existing water right diversion authorizations (with and without reallocation) was modeled with a junior priority date. Special consideration was taken to ensure that the diversion of the additional junior yield would not decrease the amount of water other existing senior water rights had access to without the diversion of the additional yield. This was accomplished through the dual simulations option in WRAP which prevents the study reservoirs' senior water rights from refilling storage that was depleted by the additional junior yield.

In the virtual river basin, Reservoirs A, B, and C had reallocation increases in storage of 50,000, 50,000 and 9,750 acre-feet (15 percent of total allocated storage) respectively. Total additional storage through reallocation was 109,750 acre-feet. The reallocated storage volumes were input into the model with a junior water right priority date. The junior priority date will be important when utilized in the case study

(Little River) that is described in Chapter 8 of this report. The SA/SV (surface area and surface volume) records describing each of the reservoirs were changed to include the higher storage volume and surface area relationships. A sample of the WAM input and corresponding output tables for the virtual basin can be found in Appendix B. The maximum yield of each reallocated reservoir was determined in the same manner as the stand alone yield.

7.3.2 System Operation Yield (with and without reallocation)

The yield for the virtual basin using system operations was determined by using a hypothetical water right, which diverted on the mainstem downstream of all three reservoirs. The yield was calculated by adjusting the diversion at the downstream location to the maximum amount sustainable throughout the period of record. Additional yield above the existing water right authorization was modeled using a junior priority date. Special consideration was taken to ensure that the system operation would not decrease the amount of water existing water rights had access to without system operations. This was accomplished through the dual simulations option in WRAP which prevents the study reservoirs' senior water rights from refilling storage that was depleted by the additional junior system operation yield. The system operation diversion only has access to water that belongs to the reservoirs under current permits, plus any remaining unappropriated flow after all existing rights have diverted. The yield from system operations was compared to the cumulative stand alone yields to determine the increased yield made available by system operations. A variation of the system operation model, which accounted for reallocation of the individual reservoirs and operating them as a system was also created. A single downstream water right was also utilized to determine the yield of the reallocated reservoir system. The increased yield resulting from system operations of the three reservoirs with reallocated reservoir storage was determined by subtracting the cumulative individual yield amounts (from three reservoirs calculated in the simulations with reallocated storage) from the total yield of the system operations with reallocation included.

7.4 RESERVOIR YIELD ESTIMATION RESULTS

Using the yields determined from the WAM, the difference between the stand alone with no reallocation and the reallocation scenario were evaluated. Table 3 shows the yield results for the different simulations performed for the virtual basin as well as the total yield available under each operation scenario.

Table 3: Virtual Basin Firm Yield Analysis

	Base Yield (ac-ft/yr)	Reallocated Yield (ac-ft/yr)
Reservoir A	269,199	278,205
Reservoir B	563,801	608,838
Reservoir C	17,932	19,982
Stand Alone Cumulative Yield	850,932	907,025
System Yield	973,294	1,050,471
Total Increased Yield from (Sys)	122,362	143,446

The additional yields realized by reservoir reallocation are as follows. Reservoir A received an additional 9,006 acre-feet per year, Reservoir B received an additional 45,037 acre-feet per year and Reservoir C received an additional 2,050 acre-feet per year for a cumulative effect of 56,093 acre-feet per year of additional yield between the reservoirs. The additional yield realized through system operation of the reservoirs is 122,362 acre-feet per year before reallocation of the individual reservoirs. The additional yield realized by system operation of the reallocated reservoirs is 143,446 acre-feet per year. The combined effect of the reservoir reallocation and system operation provides the greatest availability of water in the system.

The yield analyses performed in this study are based upon a virtual system using parameters that while reflective of real world impacts; present only the methodology for how reservoir reallocation could be beneficial. The actual yield of a reservoir reallocation is greatly influenced by the amount of water already available in the system. Therefore, the actual increased yield realized in a particular case will vary depending upon the hydrologic condition of the region as well as other parameters present in the TCEQ WAMs for each river basin.

8.0 BRAZOS RIVER BASIN CASE STUDY

8.1 INTRODUCTION

Task 4 of the Brazos River Reallocation Project involves modifying the current version (May 25, 2004) of the Brazos WAM from TCEQ and applying the modeling procedures for reservoir reallocation which were developed in the virtual model and performing simulations using WRAP (June 2005 Version). The case study looks at the current yields of the five USACE owned reservoirs in the Little River Watershed of the Brazos River Basin and models reservoir reallocation and system operations to increase yield capacities.

8.2 LITTLE RIVER BASE SCENARIO

The Little River Watershed of the Brazos River Basin is located on the west side of the Brazos River and drains into the Brazos River near Hearne, Texas at the Milam/Robertson County Line. The Little River system is comprised of the Leon, Lampasas, and San Gabriel Rivers and their tributaries. The five USACE owned reservoirs are Lake Proctor located on the Leon River in Comanche County, Belton Lake located on the Leon River in Bell County, Stillhouse Hollow Lake located on the Lampasas River in Bell County, Lake Georgetown located on the North Fork San Gabriel River in Williamson County, and Granger Lake located on the San Gabriel River in Williamson County. Figure 5 shows a county map of the Little River Watershed including its major rivers and the five USACE owned reservoirs.

8.3 CASE STUDY RESERVOIR REALLOCATION

Four separate simulations of the modified Brazos WAM were performed. The first run was developed to determine the stand alone yield of each reservoir in the system. The second run was developed to determine the increase in yield achieved by operating the reservoirs together as a system. The third simulation performed determines the benefit of reservoir reallocation on stand alone reservoir yields. The fourth and final simulation determines the combined benefit of reallocation and system operations. These four simulations are described in more detail in the following sections.

The case study was initiated by inputting certain assumptions made in the USACE SUPER Model runs into the Brazos WAM simulations. The same assumptions were utilized in the WAM simulations to ensure that estimated yields from the SUPER runs could be compared to estimates based on the WAM runs. The case study models reservoir reallocation at Lakes Belton, Georgetown, Granger, Proctor, and Stillhouse Hollow. The following USACE SUPER Model assumptions were incorporated into the Brazos WAM:

1. Update the surface area and storage capacity relationship based upon current volumetric surveys from the Texas Water Development Board (TWDB).
2. Input the sediment storage capacity of each reservoir as inactive capacity in the WAM. These values taken from SUPER Model summary output from USACE.
3. Modified reservoir capacity records in the WAM to change reservoir conservation capacity to those used in the USACE SUPER Model simulations.

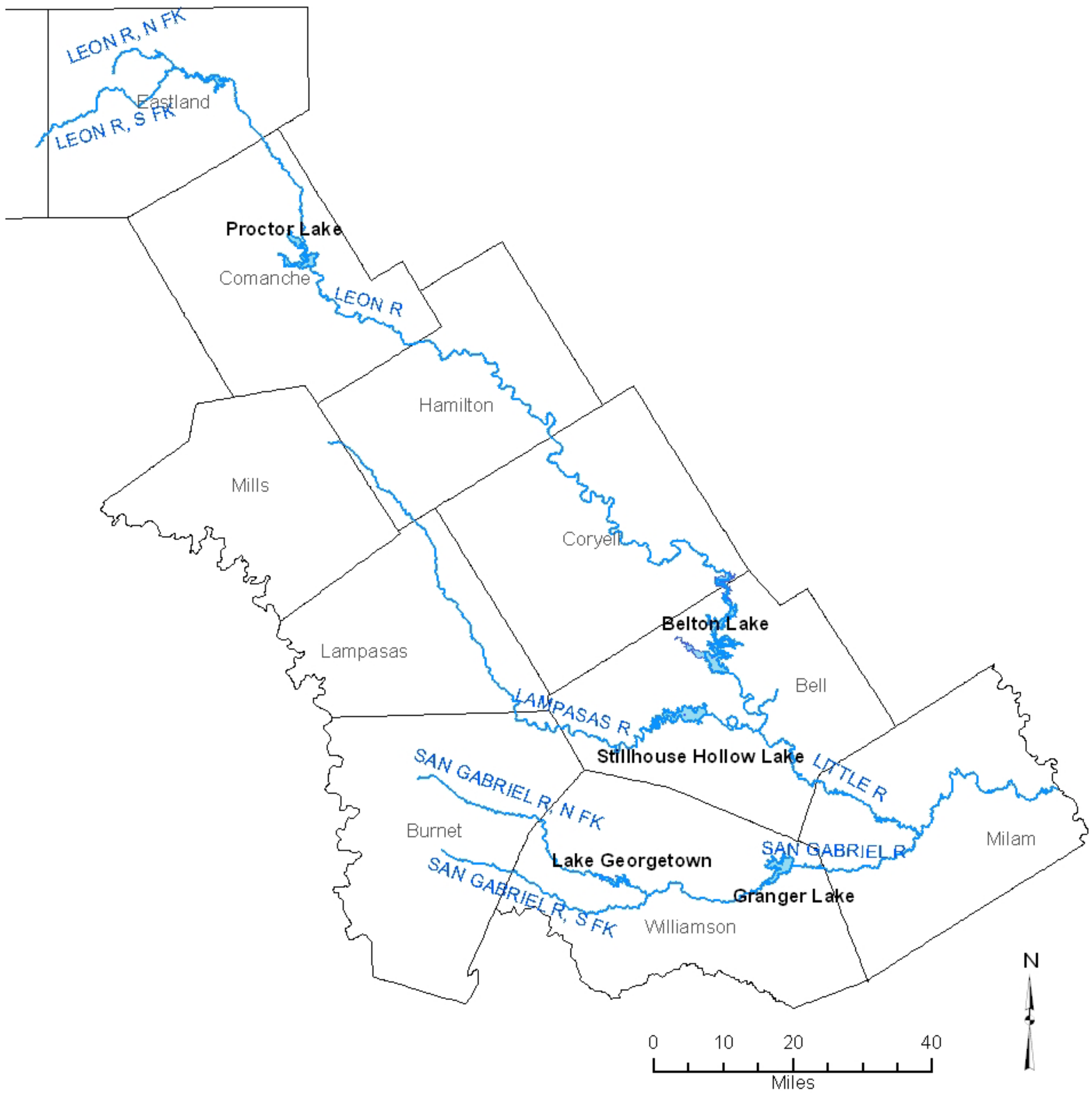

Figure 5: Little River System Map

With the USACE assumptions modeled in the four simulations of the Brazos WAM; the base stand alone yield of each reservoir and the base reservoir system yield was determined. These values will be used to determine the increased yield realized by reallocation of reservoir storage.

8.3.1 Independent Reservoir Yield (with and without reallocation)

The base stand alone yield of each reservoir was estimated by determining the maximum diversion that each reservoir can sustain throughout the period of record. This was done by adjusting the water right by increasing or decreasing the diversion until the resulting reservoir storage on a monthly context is less than one percent of the conservation storage. Once the stand alone yields were calculated for each reservoir, reallocation of storage in the reservoirs was assigned. The reservoirs were reallocated per the criterion outlined in Chapter 1. Table 4 shows the change in conservation pool capacity due to reallocation of flood storage. As stated earlier, the additional yield above the existing water right diversion authorizations (with and without reallocation) was modeled with a junior priority date. Special consideration was taken to ensure that the diversion of the additional junior yield would not decrease the amount of water other existing senior water rights had access to without the diversion of the additional yield. This was accomplished through the dual simulations option in WRAP which prevents the study reservoirs' senior water rights from refilling storage that was depleted from the additional junior yield.

Table 4: Pre- and Post-Reservoir Reallocation Conservation Pool Capacity

	Current Conservation Pool Capacity (acre-feet)	Reallocated Conservation Pool Capacity (acre-feet)	Change in Conservation Pool Capacity (acre-feet)
Proctor	50,091	99,534	49,443
Belton	382,099	431,039	48,940
Stillhouse Hollow	226,033	275,331	49,298
Georgetown	36,986	54,481	17,495
Granger	52,524	82,186	29,662

Results of the stand alone and reallocated stand alone yield simulations are found in Table 5. The modifications made to the Brazos WAM from the TCEQ to calculate the single reservoir reallocated stand alone yields can be found in Appendix C.

8.3.2 System Operation Yield (with and without reallocation)

WAM scenarios were created to evaluate the benefit of operating the five USACE reservoirs as a system both with and without flood reallocation. The reservoirs were reallocated per the criterion outlined in Chapter 1. In these WAM scenarios, the five USACE reservoirs release water to be diverted downstream at the United States Geological Survey (USGS) gage 08106500 located on the Little River near Cameron. Figure 6 illustrates the location of this diversion point with respect to the USACE reservoirs. All of the water rights for the five reservoirs were modeled at their authorized priority date at the downstream point on the Little River. The Lyons Method was utilized to develop instream flow requirements at the USGS Cameron gage for system operations. The Lyons Method defines the instream flow requirement as a percentage of the median daily-averaged flow by month, specifically, 40% of the median flows by month for October through February and 60% of the median flows by month for March through September. Using streamflow data from October 1953 to September 2005, the following instream flow requirements were calculated in ft^3/sec.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
381	398	538	748	1,150	863	339	179	193	192	200	303

Yield calculations were performed both with and without the instream flow requirements. The yield was calculated by adjusting the diversion at the downstream location to the maximum amount sustainable throughout the period of record. Additional yield above the existing water right authorization was modeled using a junior priority date. Special consideration was taken to ensure that the system operation would not decrease the amount of water existing water rights had access to without system operations. This was accomplished using the dual simulation option in WRAP which prevents the study reservoirs' senior water rights from refilling storage that was depleted by the additional junior system operation yield. The system operation diversion only has access to water that belongs to the reservoirs under current permits, plus any remaining unappropriated flow after all existing rights have diverted. Results of the system yield simulations are also found in Table 5. The modifications made to the Brazos WAM from the TCEQ to calculate the reallocated reservoir system operation yield can be found in Appendix D.

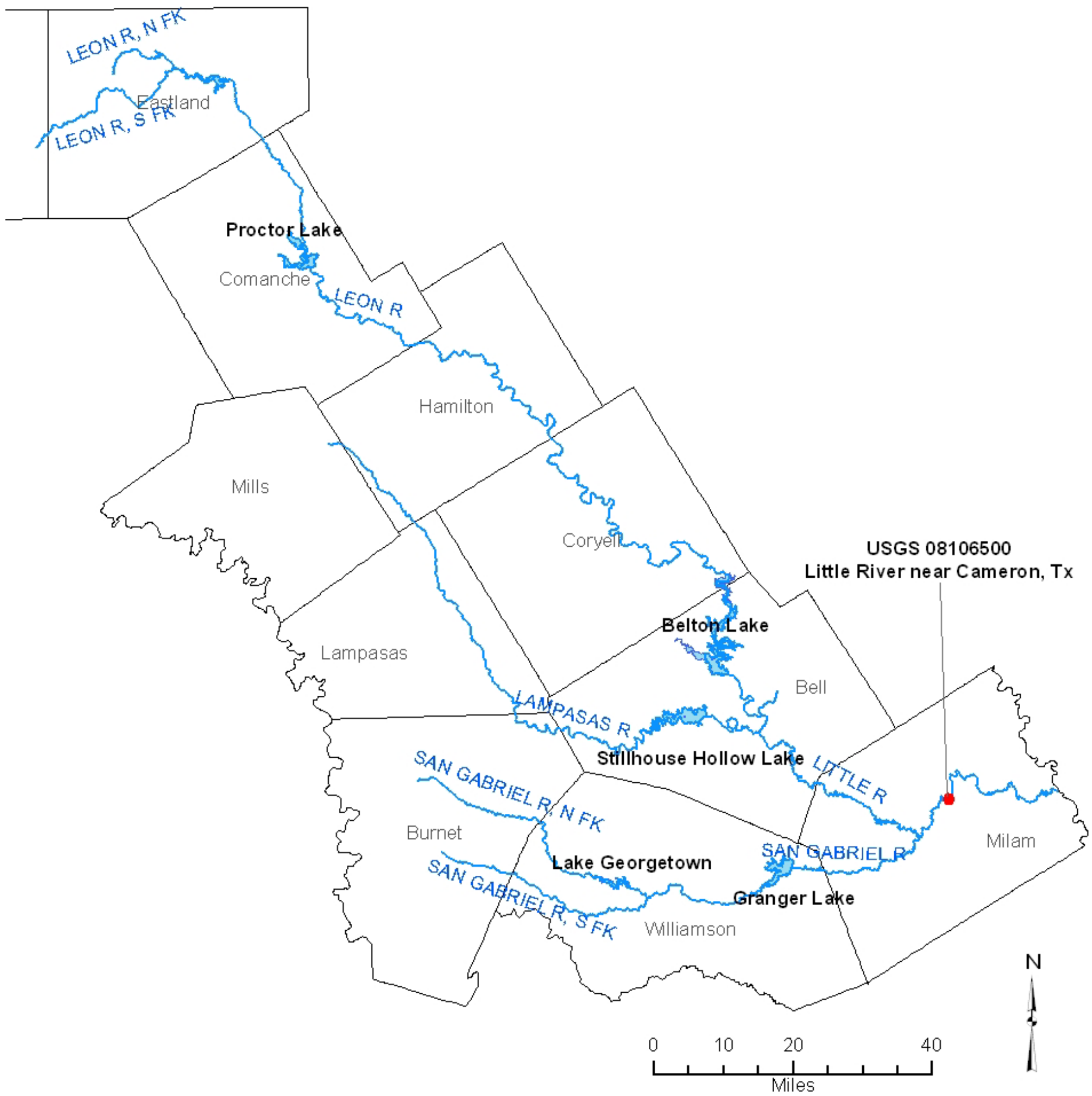

Figure 6: System Operations Simulation Diversion Point Location Map

8.4 RESERVOIR YIELD ESTIMATION RESULTS

The yield results of the different simulations performed on the Little River Watershed of the Brazos WAM as well as the total yield available under each operation scenario are shown in Table 5. The reallocation of storage resulted in an increase in the cumulative stand alone yield of 6,605 acre-feet per year. The additional storage added from reallocation (Table 4) was significant; however, the amount of water available during the drought conditions in the Little River System has limited the amount of increased yield achieved through reallocation.

Table 5: Reservoir Firm Yield Analysis

	Base Yield (ac-ft/yr)	Reallocated Yield (ac-ft/yr)	Benefit to Yield (ac-ft/yr)
Proctor	17,435	19,923	2,488
Belton	103,677	104,201	524
Stillhouse Hollow	62,445	65,450	3,005
Georgetown	11,503	11,760	257
Granger	16,819	17,150	331
Stand Alone Cumulative Yield	211,879	218,484	6,605
System Yield	215,979	227,432	11,453
System Yield with Instream Flow Restriction	213,579	224,832	11,253
Additional Yield from System Operations (without Instream Flow Restriction)	4,100	8,948	4,848

The additional yield realized through system operation of the reservoirs (between the cumulative stand alone yields and the system yield) is 4,100 acre-feet per year before reallocation of the individual reservoirs. The additional yield realized by system operation of the reallocated reservoirs is 8,948 acre-feet per year. When an instream flow restriction is placed at the USGS Cameron gage, the system yield is reduced by 2,400 acre-feet per year and the reallocated system yield is reduced by 2,600 acre-feet per year. One of the primary benefits of system operations is to take advantage of reservoirs that are experiencing times of wet weather while other reservoirs are in drought conditions. While any increase in reservoir yield is beneficial, the increase realized in this scenario is limited by the hydrology of the system. System operations will be much more significant across larger river basins. Larger river basins provide additional drainage area as well as larger areas for different hydrologic conditions.

9.0 CONCLUSIONS

This report was developed to outline the federal and state requirements and processes required to reallocate storage in federally owned reservoirs to water supply. Each reservoir is different and offers its own unique difficulties when trying to evaluate and implement storage reallocation. The USACE is limited in its reallocation capabilities in that it cannot reallocate reservoir storage by more than 15 percent of total reservoir storage or 50,000 acre-feet, which ever is greater without congressional approval. Reallocations of volumes larger than those previously mentioned require congressional action.

Reallocation of a federally owned reservoir is a complicated process that is specific to each reservoir. It will be necessary to work closely with the USACE to determine the details of each reallocation case. Due to the complexity of reallocation, associated federal costs, and the related state and environmental issues, it is very important to complete the necessary requirements on the federal and state level.

There are several benefits and disadvantages to reallocation of USACE reservoir storage to water supply. Each case will have to be evaluated separately to determine if the cost, benefits and/or disadvantages of the project will be acceptable for the increased water supply gained by that project.

Potential Benefits
Federal reservoir reallocation could result in the following benefits. Reservoir reallocation could provide an increase to available water supply for use due to the increased pool level and storage volume. The increased normal pool elevation could result in improved use for boating and other recreational activities on the reservoir by providing more areas of deep water for boater use. This may also improve the fishery habitats and recreational fishing as it would result in new fish habitats. Reservoir reallocation could result in the lowering of sedimentation pool creating additional storage for water supply use. Hydropower activity on a reallocated reservoir could benefit from increased head and additional reservoir volume.

Potential Disadvantages
Federal reservoir reallocation like other activities to increase water supply could result in some of the following disadvantages. Beach areas near the reservoir may need to be relocated as these areas may no longer be useable due to different water levels. A reservoir reallocation could provide some wildlife disadvantages in that an increased normal reservoir pool elevation could remove some natural wildlife habitats and vegetation. Pool elevation could also force current fish habitats to move to new areas of the reservoir and could potentially disrupt fishery habitats. The increased water level could cause increased shoreline erosion causing property damage and increased sediment in the reservoir. Landowners that have developed in lower lying areas could potentially be impacted. Flooding damage in the reservoir and downstream of the reservoir may be increased.

SUPER Reservoir Yield Analysis
The USACE performed SUPER Model runs for all but two USACE owned reservoirs in Texas. According to the SUPER Model summaries these reservoirs currently have a water supply dependable yield totaling 3,739,551 acre-feet per year, with the possibility of increasing to 4,082,433 acre-feet per year if all reservoirs were reallocated to the maximum USACE authorized limit (50,000 acre-feet or 15 percent of total storage). According to the SUPER model results, reallocation of USACE reservoirs in Texas could result in an additional 342,882 acre-feet of dependable yield per year.

WAM and Case Study
A virtual Water Availability Model (WAM) was developed and the Water Rights Analysis Package (WRAP) was used to simulate a simplified river basin and demonstrate reservoir reallocation. The virtual model was utilized to evaluate stand alone reservoir yields, reallocation yields and yields from

reallocation and reservoir system operations. The procedure used to model reservoir reallocation in the virtual river basin was also applied to a case study of the Little River Watershed in the Brazos River Basin. The virtual WAM analysis of the individual reallocated reservoirs showed a 3 to 11 percent increase in yield due to reservoir reallocation. Reallocation of the case study reservoir system showed a yield increase of 5.3 percent.

Conclusion

Reallocation of USACE reservoirs can provide an effective use of water by converting storage to additional water supply. Every reservoir has its own defining characteristics in terms of environmental impacts, reservoir storage use, downstream flooding risks and costs associated with reallocation. Entities evaluating reallocation of a federal reservoir must work closely with the USACE and state agencies and officials to meet all of the state and federal requirements as outlined in this report. Reallocation of reservoir storage in USACE reservoirs is a very complicated and time consuming process; however, reallocation of existing storage to dependable yield can be extremely beneficial depending on the individual reservoirs and surrounding demand centers.

10.0 REFERENCES

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EM 1110-2-1619 (Engineering and Design Risk-Based Analysis for Flood Damage Reduction Studies)

EM 1110-2-1908 (Instrumentation of Embankment Dams)

EM 1110-2-1911 (Engineering and Design: Construction Control for Earth and Rock-Fill Dams)

EM 1110-2-2200 (Gravity Dam Design)

EM 1110-2-2300 (Earth and Rock Fill Dams: General Design and Construction)

EM 1110-2-3600 (Engineering and Design Management of Water Control Systems)

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EM 1110-2-4300 (Instrumentation for Concrete Structures)

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ER 200-2-3 (Environmental Quality Environmental Compliance Policies)

ER 1105-2-100 (Planning Guidance Notebook)

ER 1165-2-130 (Water Resources Policies and Authorities - Federal Participation in Shore Protection)

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Other:

USACE Revised IWR Report 96-PS-4 (Water Supply Handbook)

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Council on Environmental Quality (CEQ) Regulations (40 Code of Federal Regulations [CFR] Parts 1500-1508)

Endangered Species Act. ([ESA] 16 USC 1531-1543)

National Environmental Policy Act (NEPA) of 1969

Water Resources Council's (WRC) Economic and Environmental Principles and

Appendix A
Reservoir Yield Curves for US Army Engineer District, Fort Worth

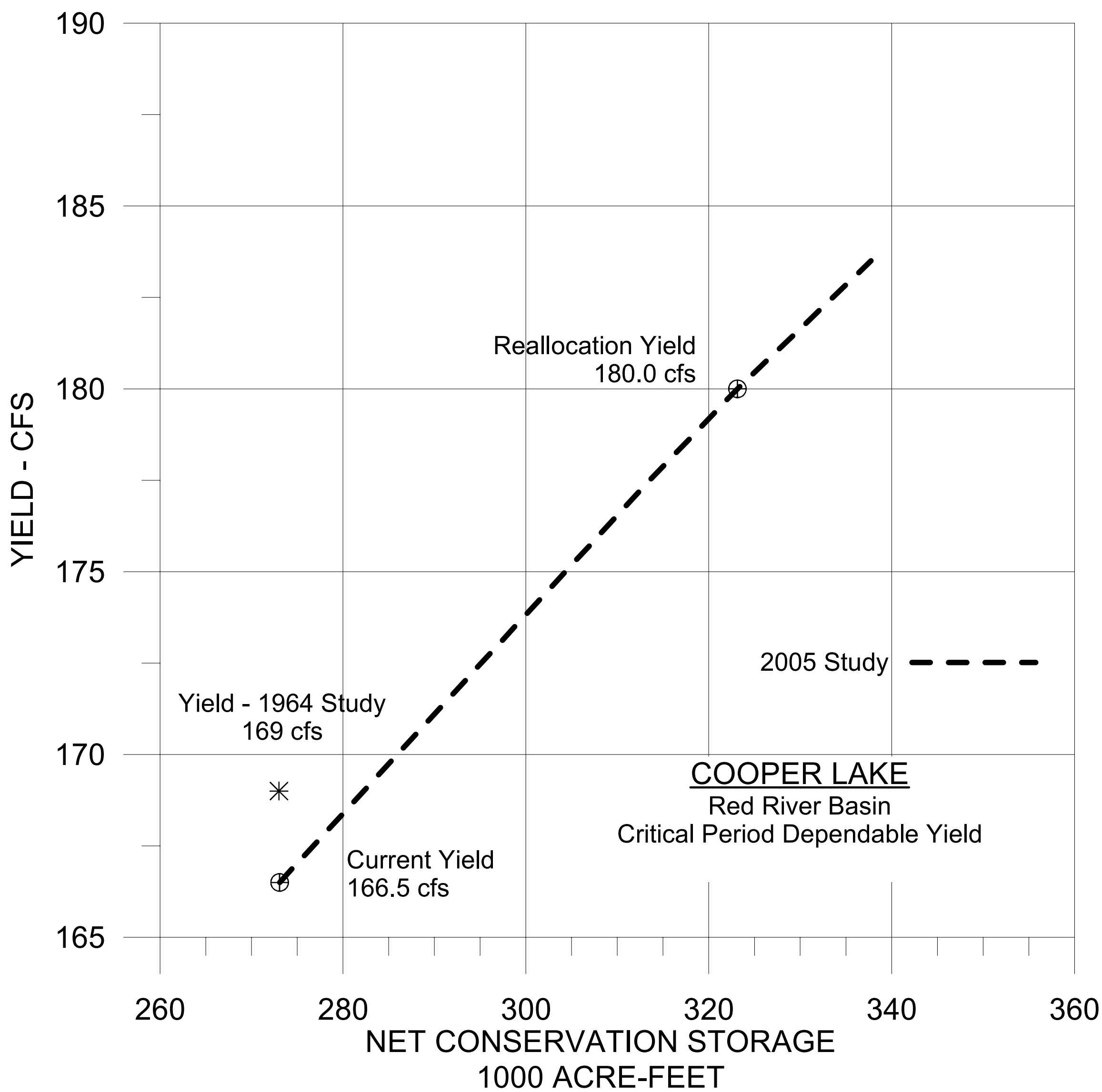

Figure A-1: Cooper Lake – Red River Basin

Notes:

1. Previous study yield curve is based on area-capacity curves derived from pre-impoundment (pre-1991) survey data. Sediment reserve accounted for.

2. Current and reallocation yields are based on area-capacity curves derived from 1957 survey data. Sediment reserve accounted for.

3. Reallocation yield represents maximum USACE discretionary authority.

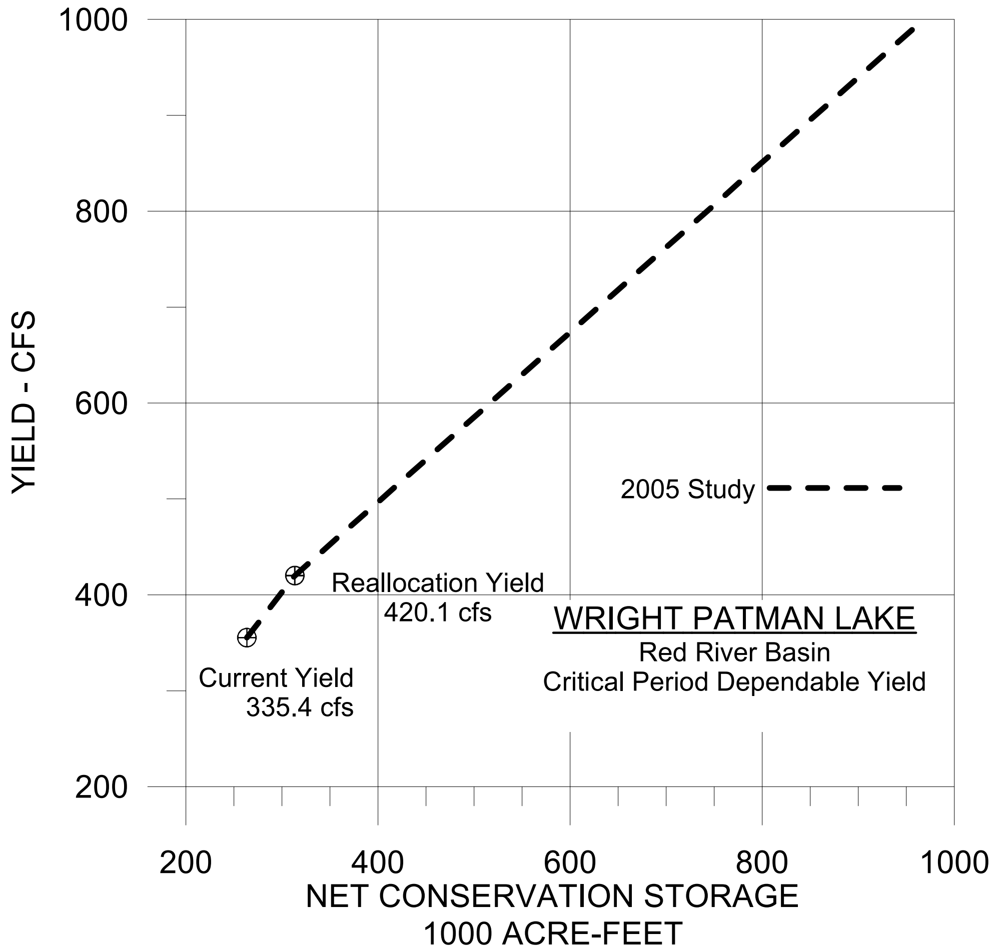

Figure A-2: Wright Patman Lake – Red River Basin

Notes:

1. Current yield based on Ultimate Rule Curve for reservoir operations.
2. Yield curve is based on area-capacity curves derived from 1997 survey data. Sediment reserve accounted for.
3. Reallocation yield represents maximum USACE discretionary authority.

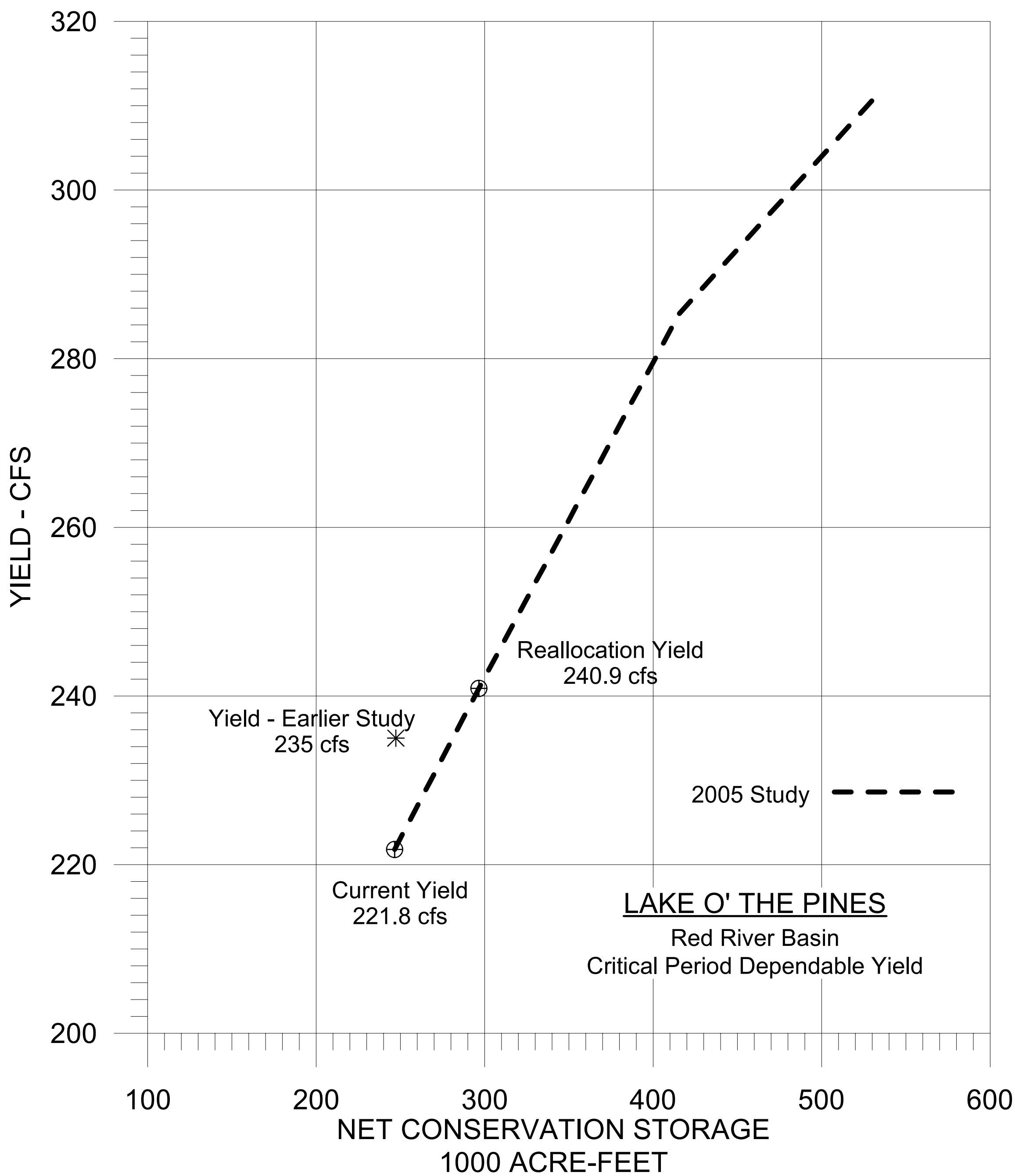

Figure A-3: Lake O' the Pines Lake – Red River Basin

Notes:

1. Current yield based on Season Rule Curve for reservoir operations.
2. Yield curve is based on area-capacity curves derived from 2002 survey data. Sediment reserve is only partially accounted for above elevation 201.0 (bottom of conservation pool).
3. Reallocation yield represents maximum USACE discretionary authority.

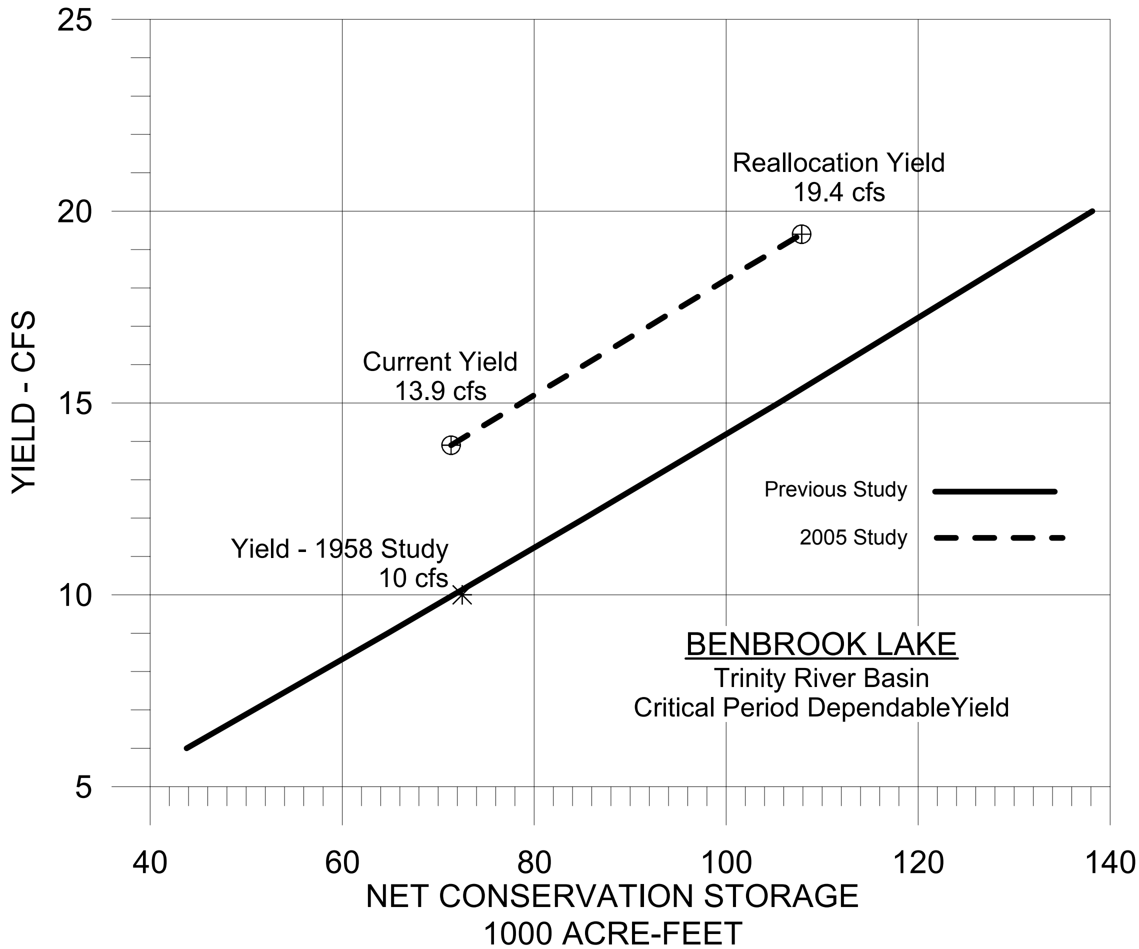

Figure A-4: Benbrook Lake – Trinity River Basin

Notes:

2. Previous study yield curve is based on area-capacity curves derived from pre-impoundment (pre-1952) survey data.

3. Current and reallocation yields are based on area-capacity curves derived from 1998 survey data.

4. Reallocation yield represents maximum USACE discretionary authority.

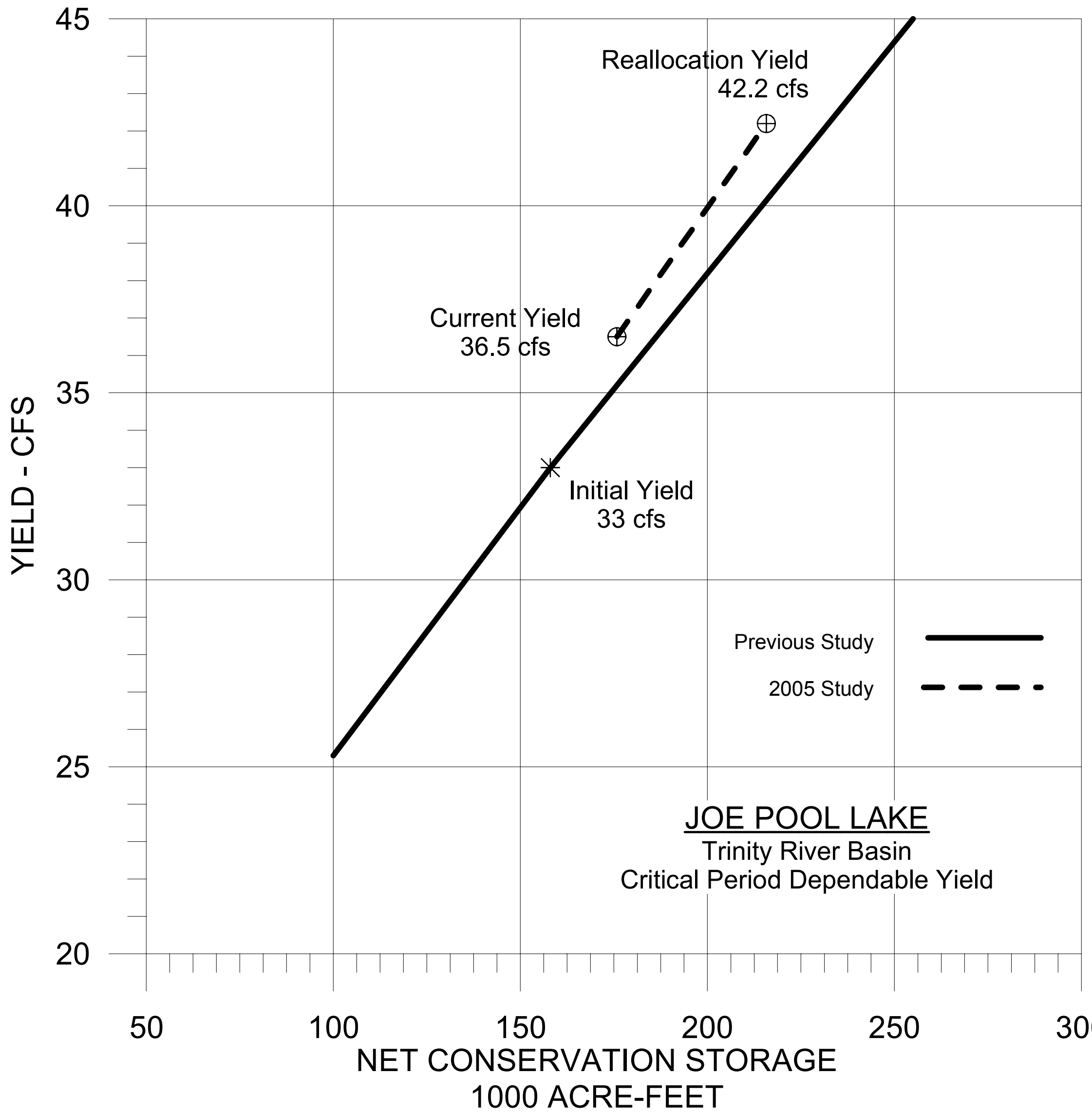

Figure A-5: Joe Pool Lake – Trinity River Basin

Notes:

1. Initial yield curve (previous study) is based on area-capacity curves derived from pre-impoundment (pre-1986) survey data, and does not account for future sedimentation.

2. Current and reallocation yields are based on area-capacity curves derived from 1985 survey data.

3. Reallocation yield represents maximum USACE discretionary authority.

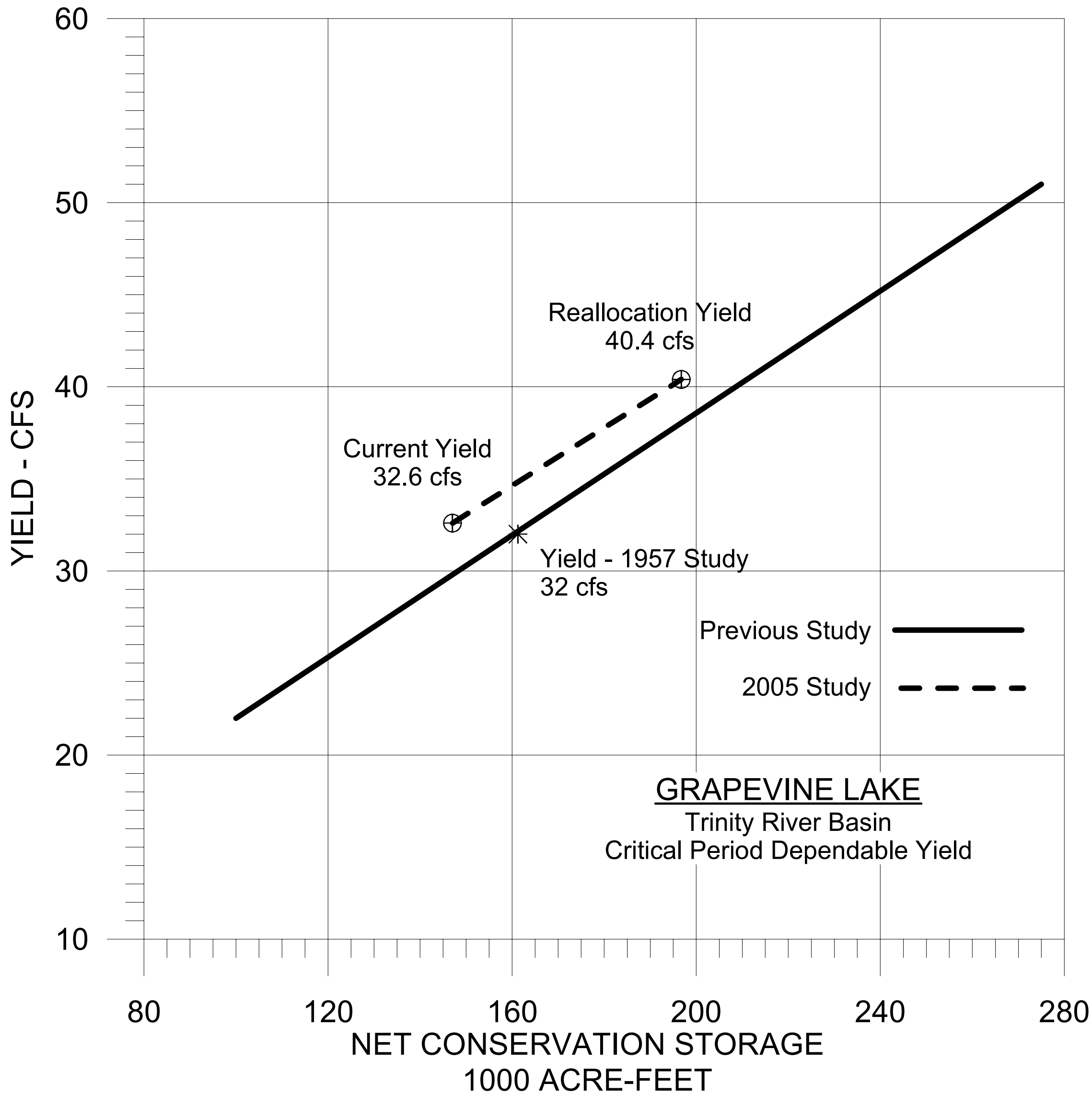

Figure A-6: Grapevine Lake – Trinity River Basin

Notes:

1. 1957 yield curve (previous study) is based on area-capacity curves derived from pre-impoundment (pre-1952) survey data, and does not account for future sedimentation.

2. Current and reallocation yields are based on area-capacity curves derived from 2002 survey data.

3. Reallocation yield represents maximum USACE discretionary authority.

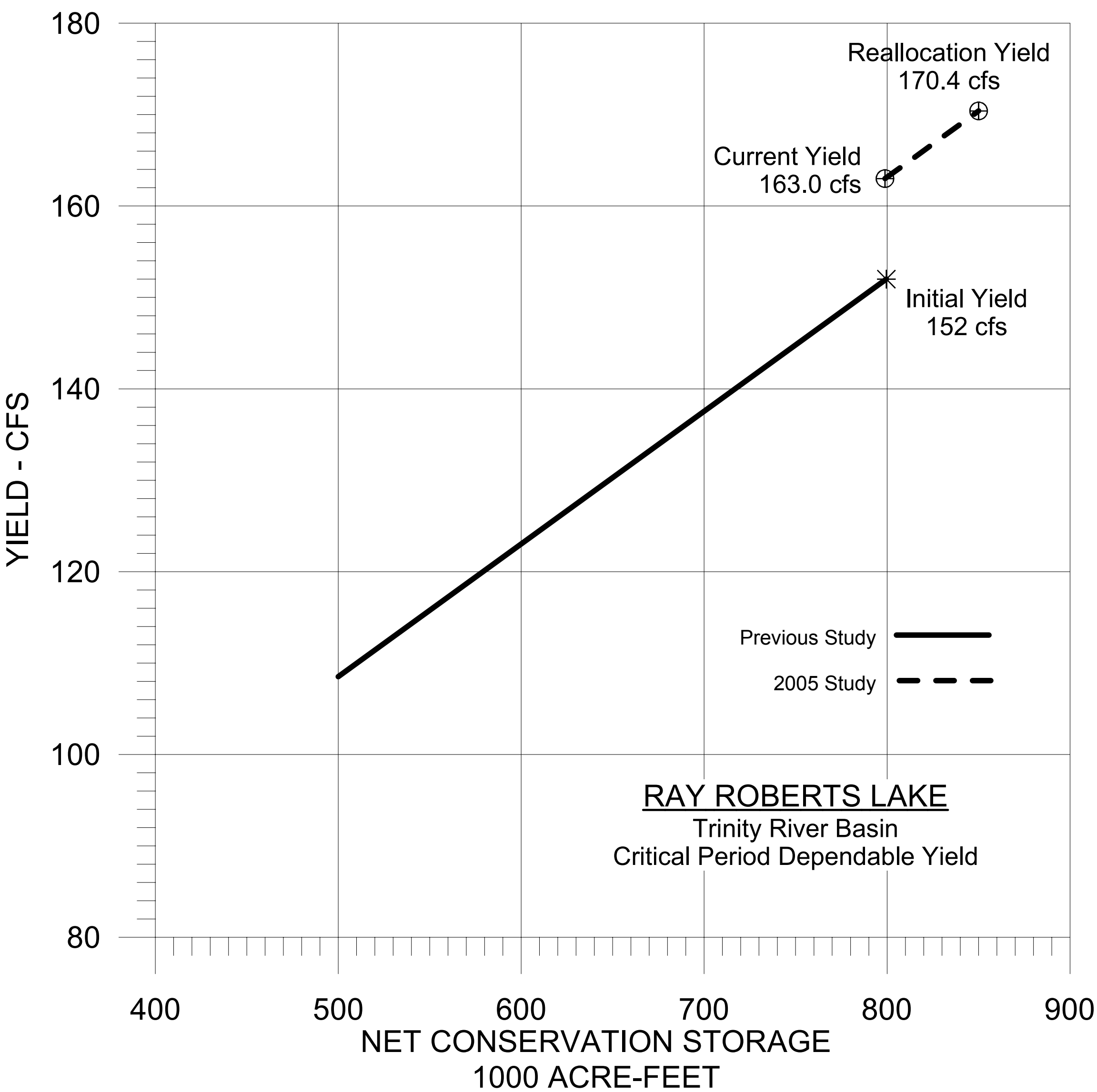

Figure A-7: Ray Roberts Lake – Trinity River Basin

Notes:

1. Initial yield curve (previous study) is based on area-capacity curves derived from pre-impoundment (pre-1987) survey data, and does not account for future sedimentation.

2. Current and reallocation yields are based on area-capacity curves derived from 1985 survey data.

3. Reallocation yield represents maximum USACE discretionary authority.

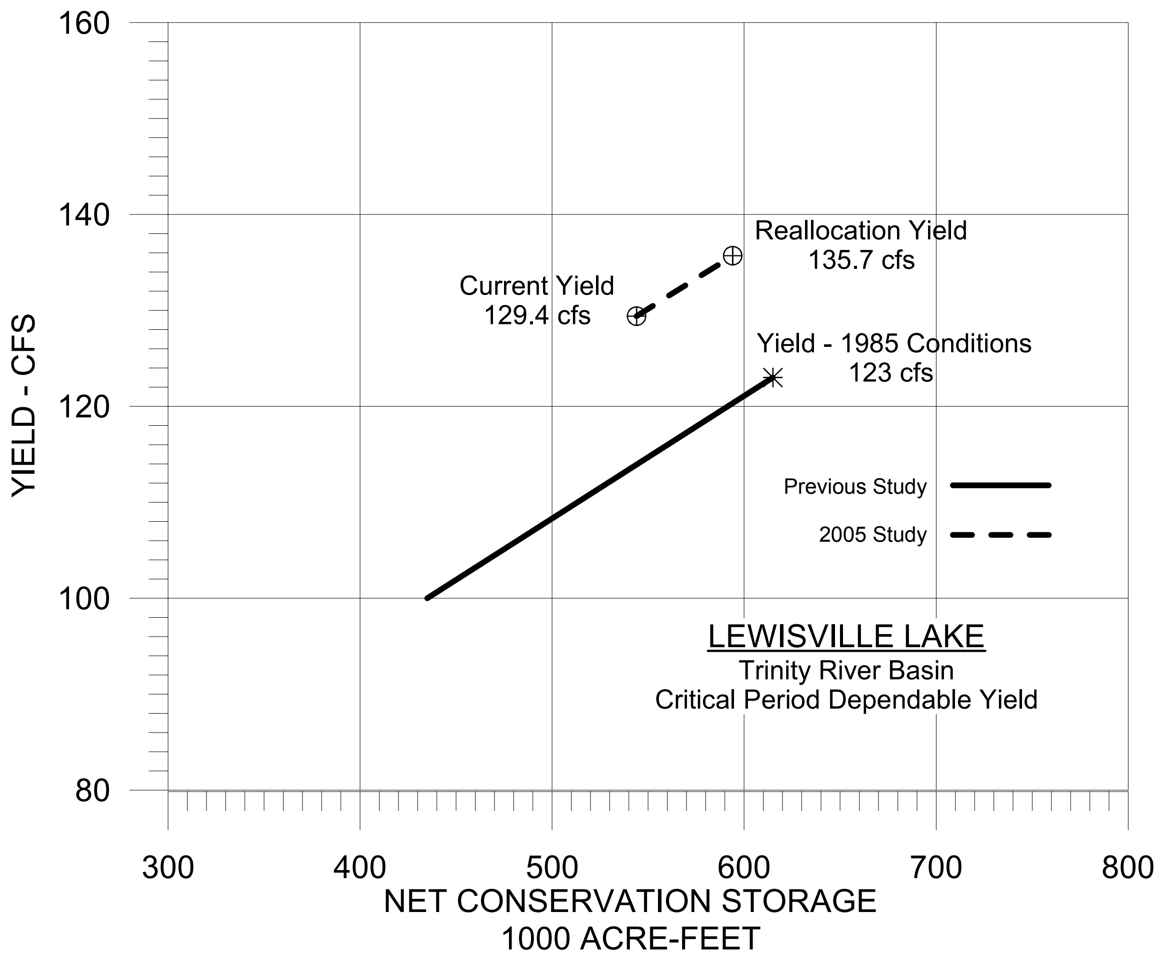

Figure A-8: Lewisville Lake – Trinity River Basin

Notes:

1. Initial yield curve (previous study) is based on area-capacity curves derived from pre-impoundment (pre-1954) survey data, and does not account for future sedimentation.

2. Current and reallocation yields are based on area-capacity curves derived from 1989 survey data.

3. Reallocation yield represents maximum USACE discretionary authority.

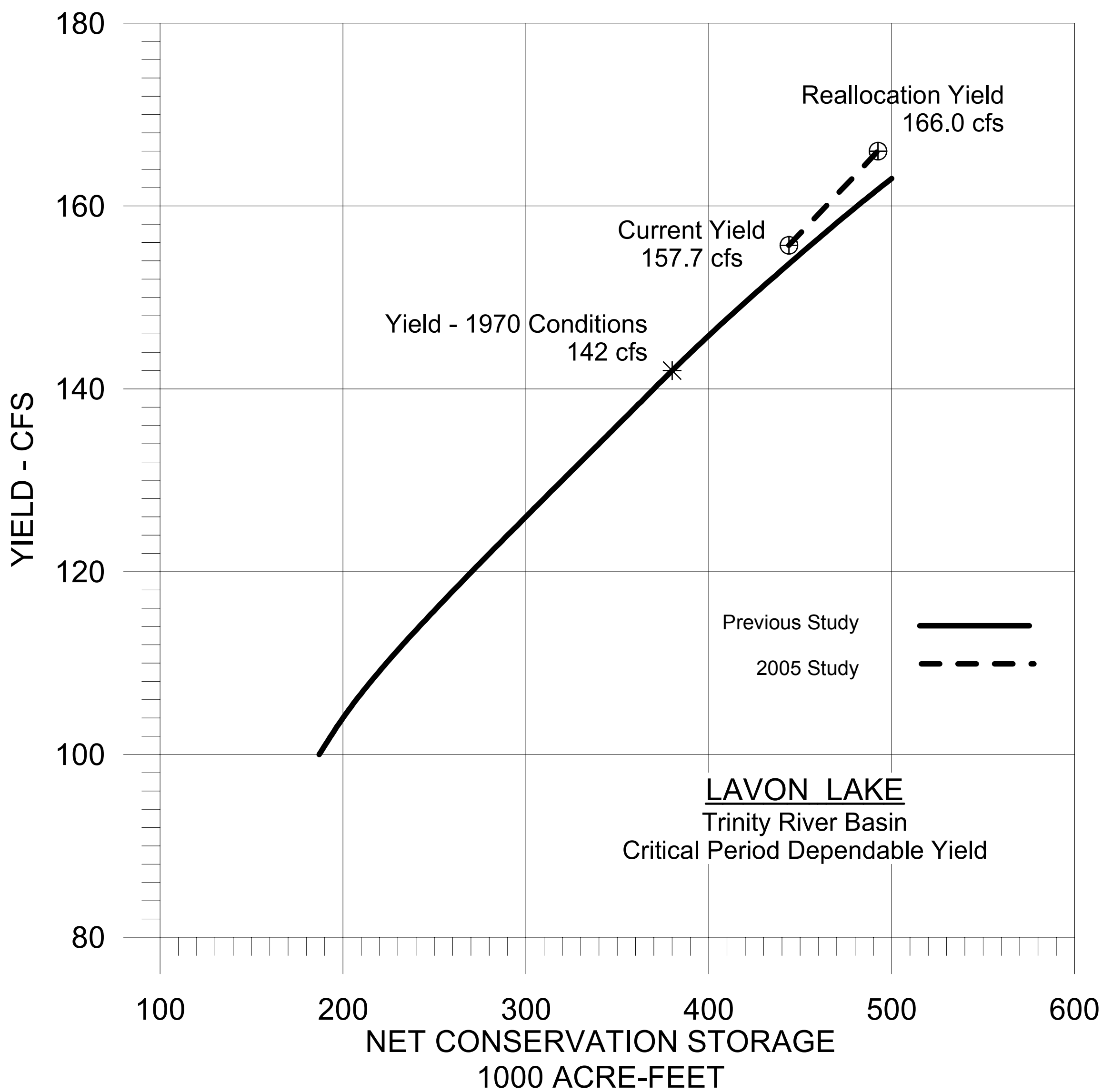

Figure A-9: Lake Lavon – Trinity River Basin

Notes:

1. Initial yield curve (previous study) is based on area-capacity curves derived from pre-impoundment (pre-1953) survey data, and does not account for future sedimentation.

2. Current and reallocation yields are based on area-capacity curves derived from 1965 survey data.

3. Reallocation yield represents maximum USACE discretionary authority.

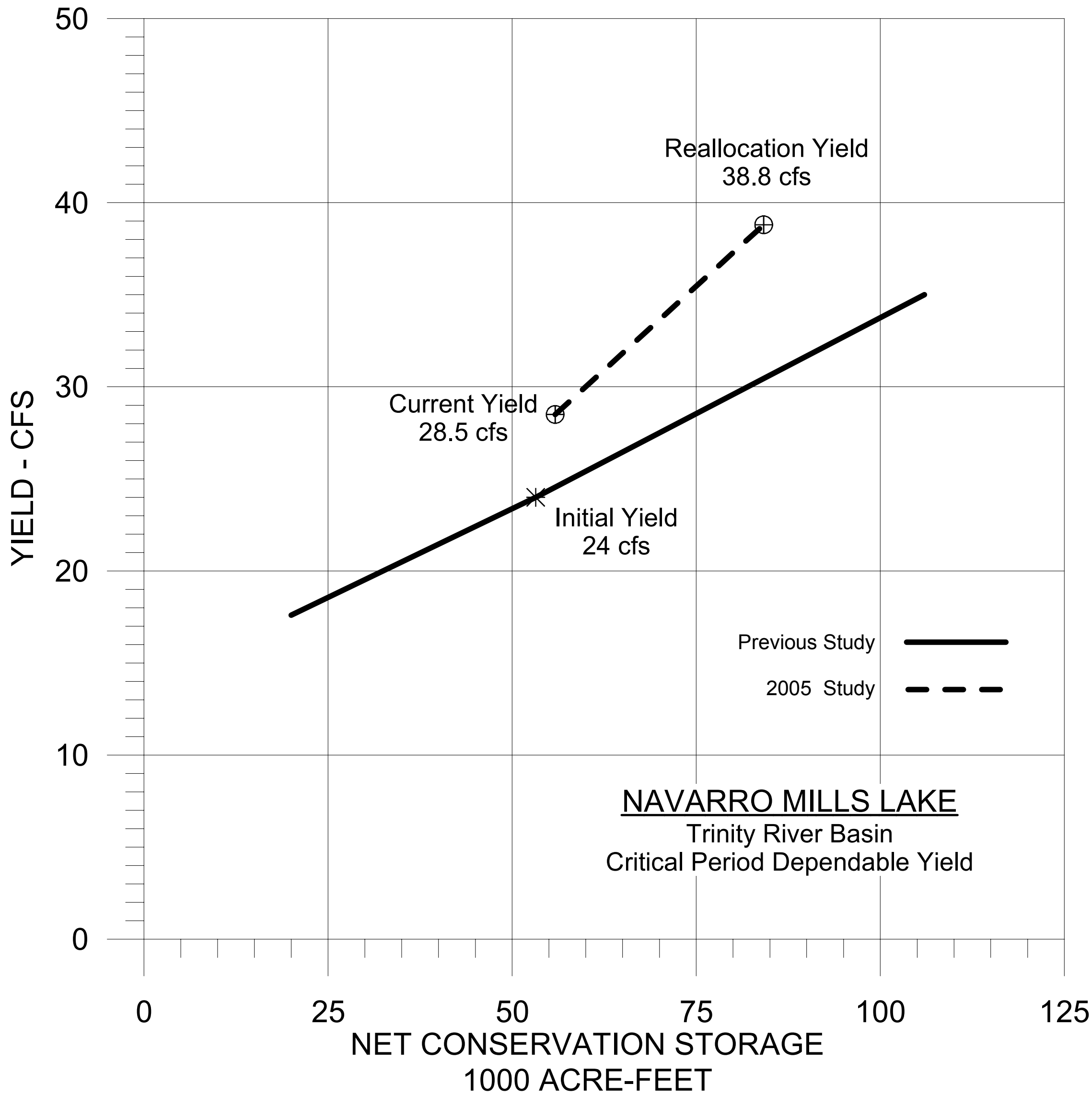

Figure A-10: Navarro Mills Lake – Trinity River Basin

Notes:

1. Initial yield curve (previous study) is based on area-capacity curves derived from pre-impoundment (pre-1963) survey data, and does not account for future sedimentation.

2. Current and reallocation yields are based on area-capacity curves derived from 1972 survey data.

3. Reallocation yield represents maximum USACE discretionary authority.

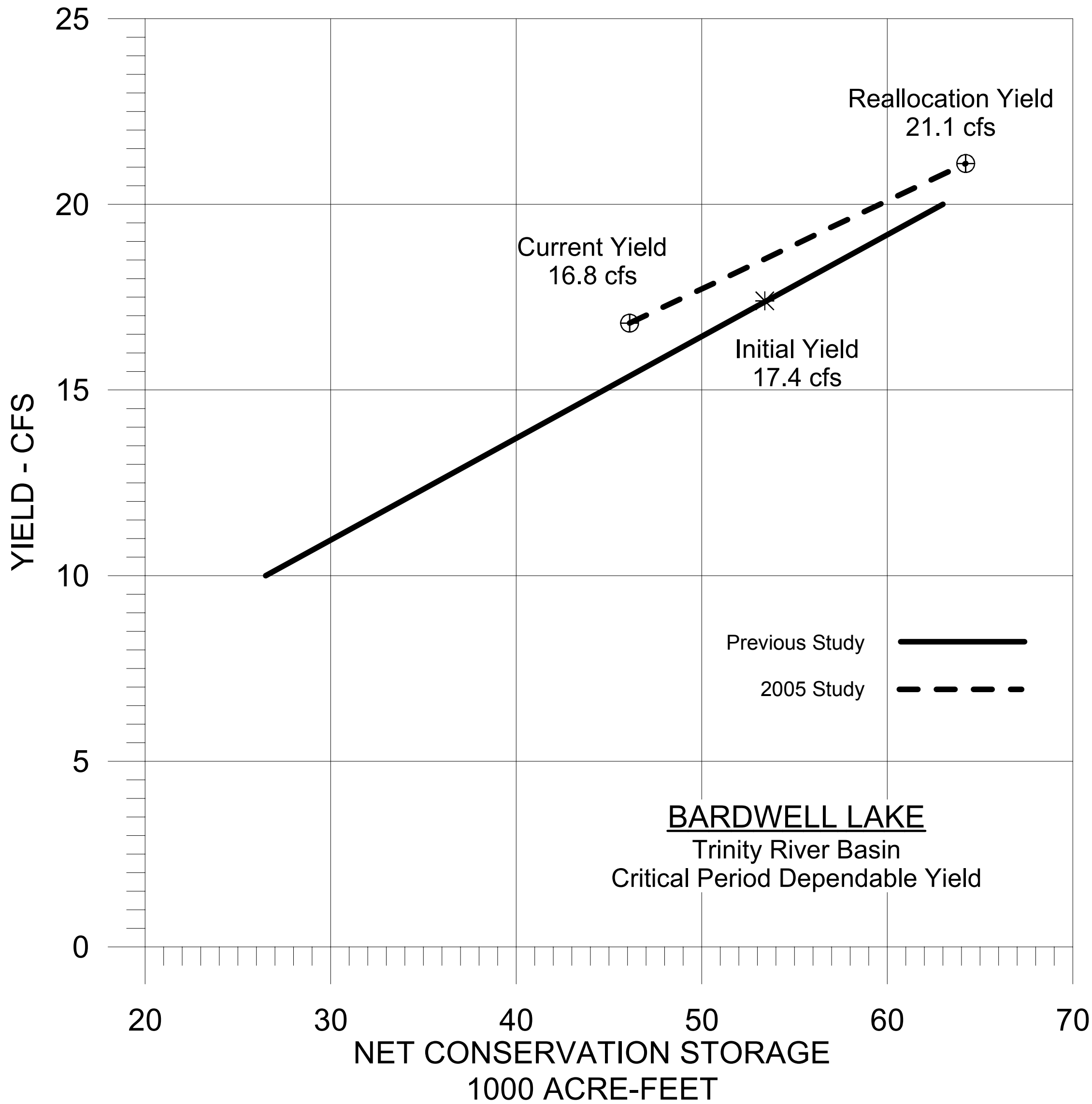

Figure A-11: Bardwell Lake – Trinity River Basin

Notes:

1. Initial yield curve (previous study) is based on area-capacity curves derived from pre-impoundment (pre-1965) survey data, and does not account for future sedimentation.
2. Current and reallocation yields are based on area-capacity curves derived from 2001 survey data.
3. Reallocation yield represents maximum USACE discretionary authority.

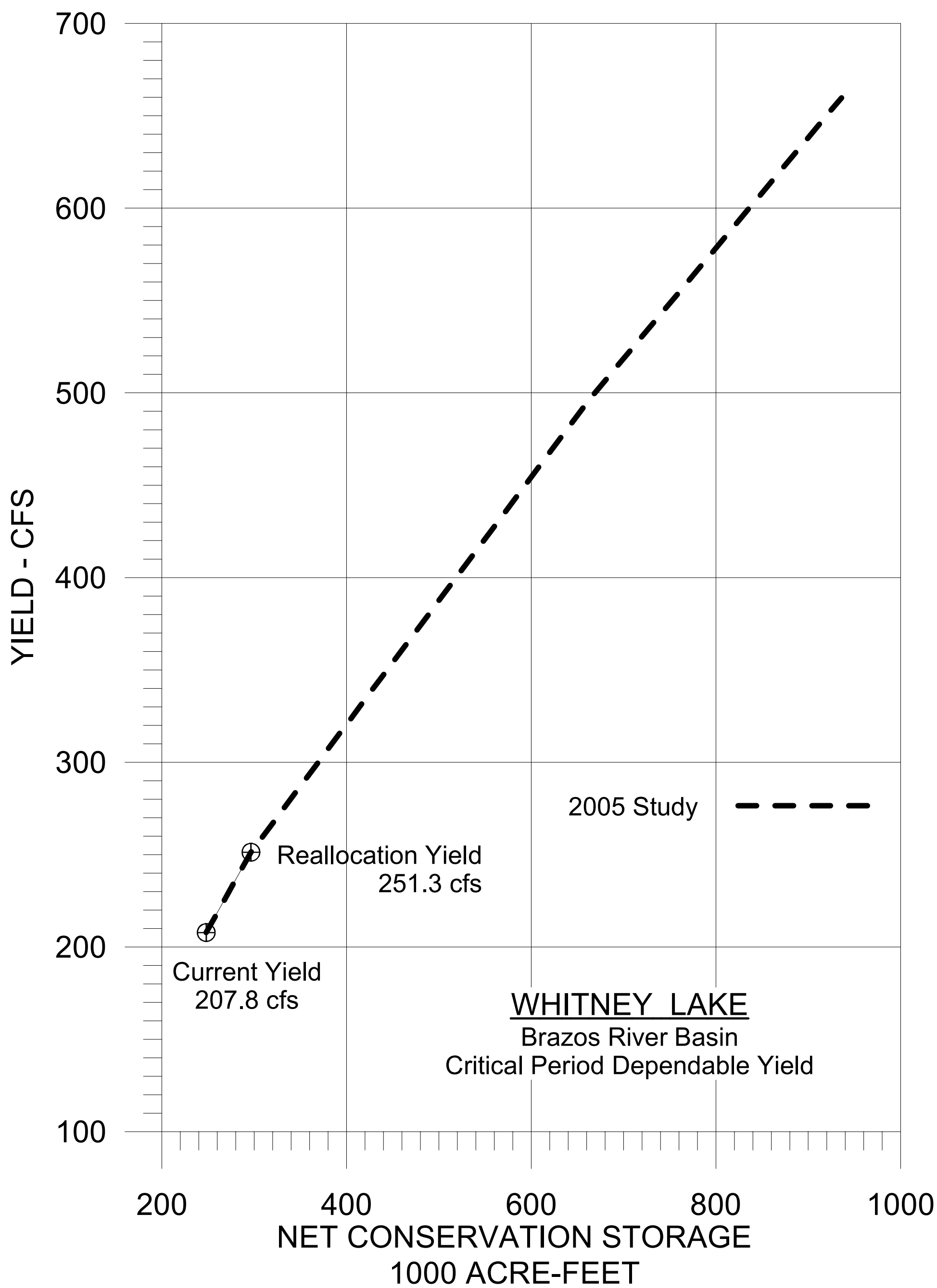

Figure A-12: Whitney Lake – Brazos River Basin

Notes:

1. Yield is total yield, not just that attributable to 50,000 acre-feet contract water supply pool, and includes all releases from Possum Kingdom Lake. Note yield in Table 1, Chapter 1 is for 50,000 ac-ft.

2. Current and reallocation yields are based on area-capacity curves derived from 1959 survey data.

3. Reallocation yield represents maximum USACE discretionary authority.

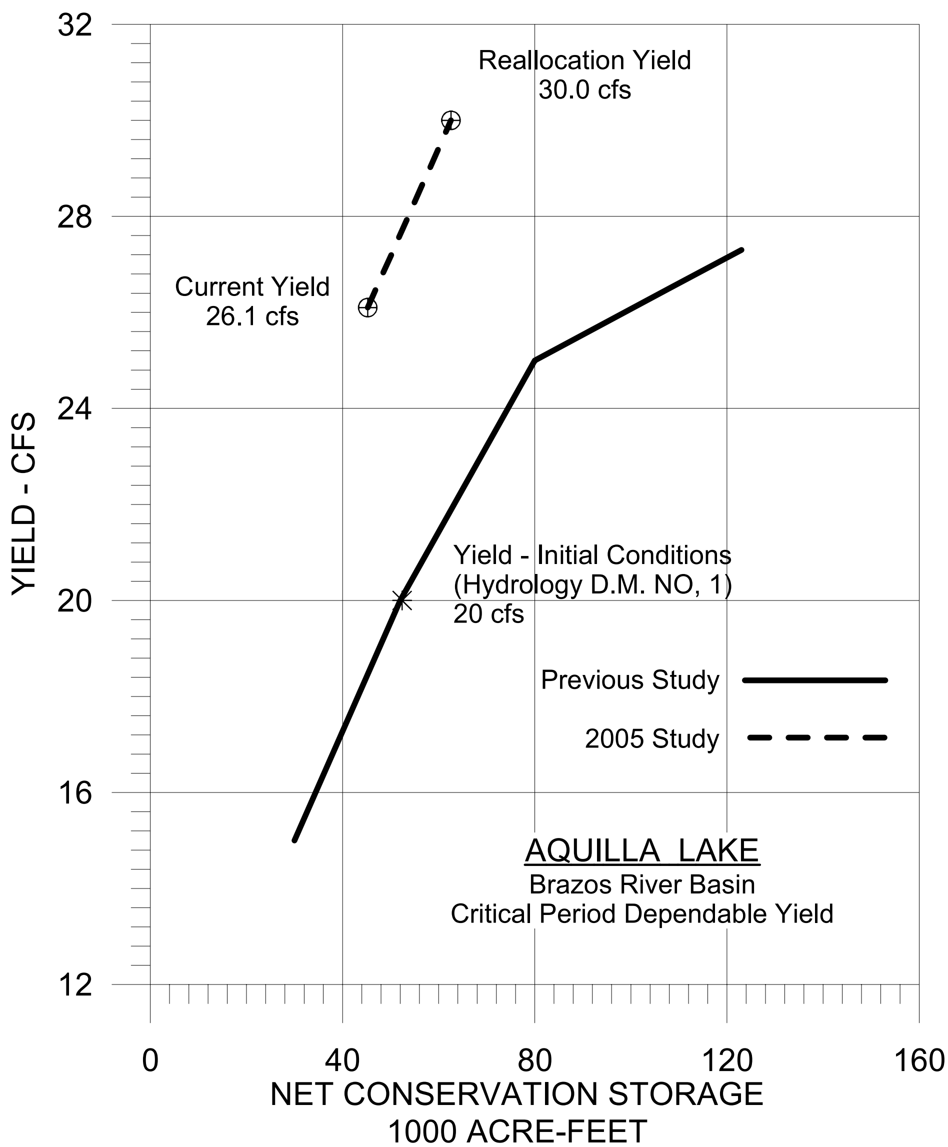

Figure A-13: Aquilla Lake – Brazos River Basin

Notes:

1. Previous study yield curve is based on area-capacity curves derived from pre-impoundment (pre-1983) survey data.

2. Current and reallocation yields are based on area-capacity curves derived from 2002 survey data.

3. Reallocation yield represents maximum USACE discretionary authority.

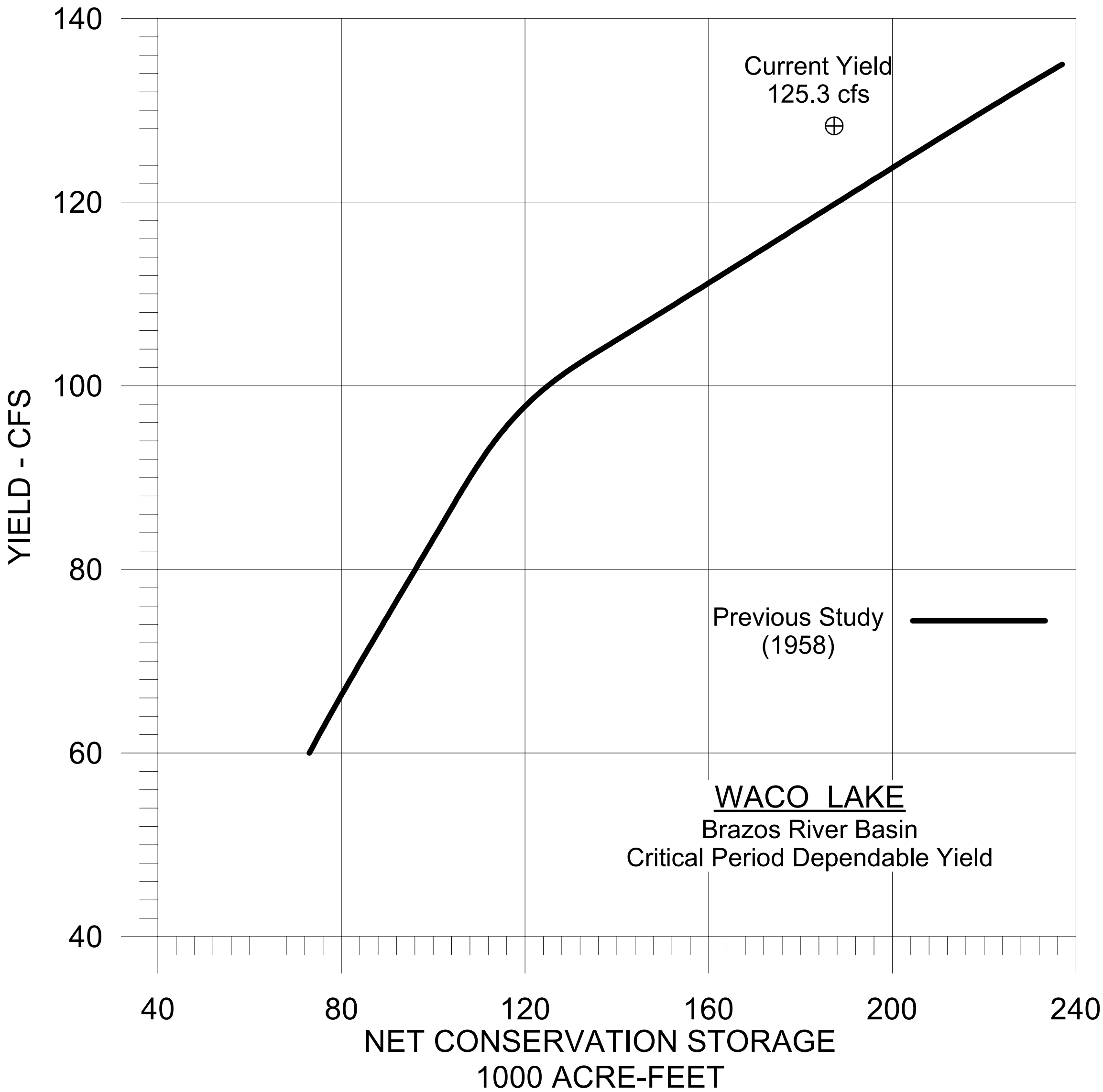

Figure A-14: Waco Lake – Brazos River Basin

Notes:

1. Previous study yield curve is based on area-capacity curves derived from pre-impoundment (pre-1965) survey data.

2. Current and reallocation yields are based on area-capacity curves derived from 1995 survey data.

3. Current yield represents maximum USACE discretionary authority.

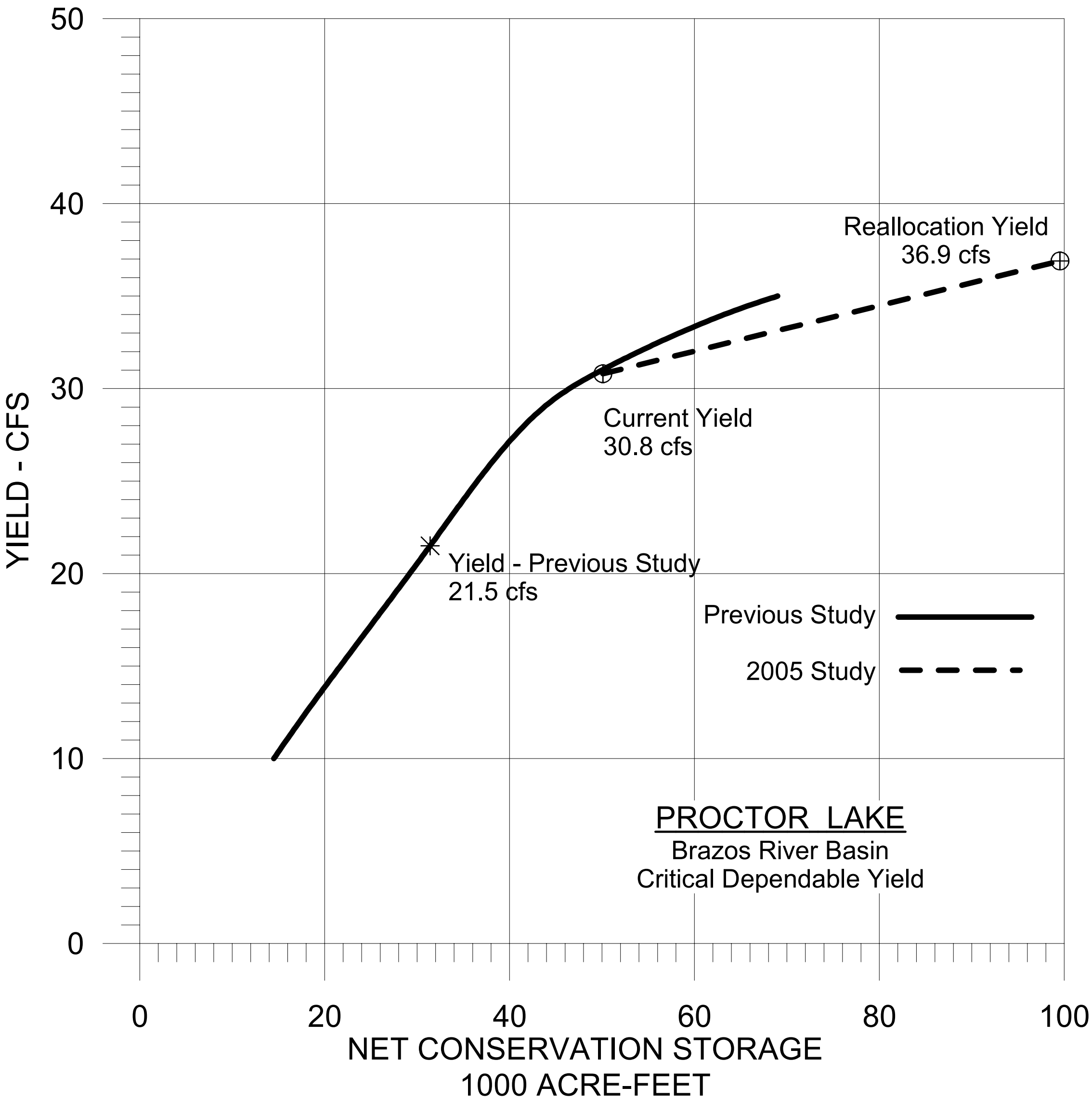

Figure A-15: Proctor Lake – Brazos River Basin

Notes:

1. Previous study yield curve is based on area-capacity curves derived from pre-impoundment (pre-1963) survey data.

2. Current and reallocation yields are based on area-capacity curves derived from 2002 survey data.

3. Reallocation yield represents maximum USACE discretionary authority.

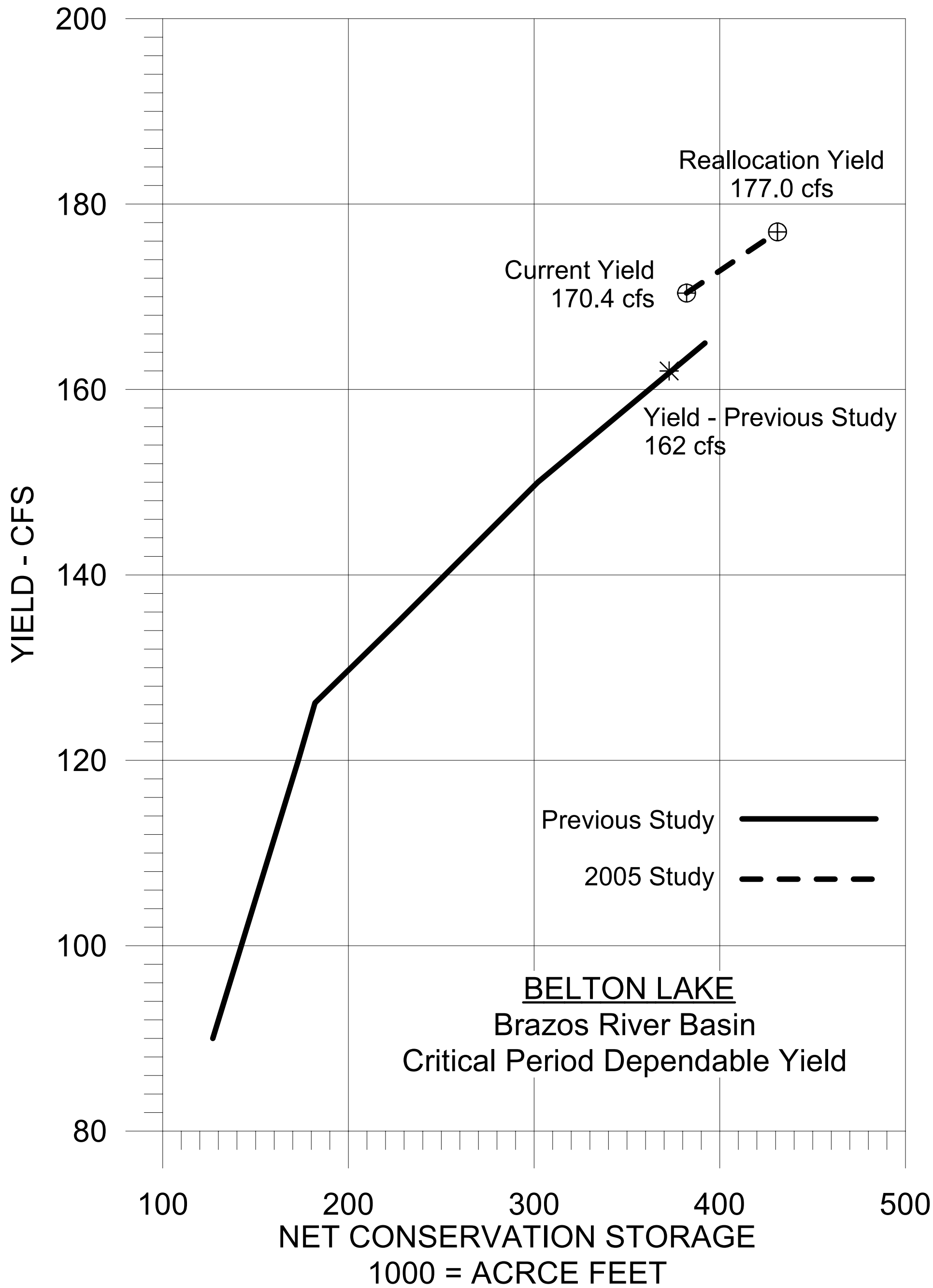

Figure A-16: Belton Lake – Brazos River Basin

Notes:

1. Previous study yield curve is based on area-capacity curves derived from pre-impoundment (pre-1954) survey data.
2. Current and reallocation yields are based on area-capacity curves derived from 1994 survey data.
3. Reallocation yield represents maximum USACE discretionary authority.

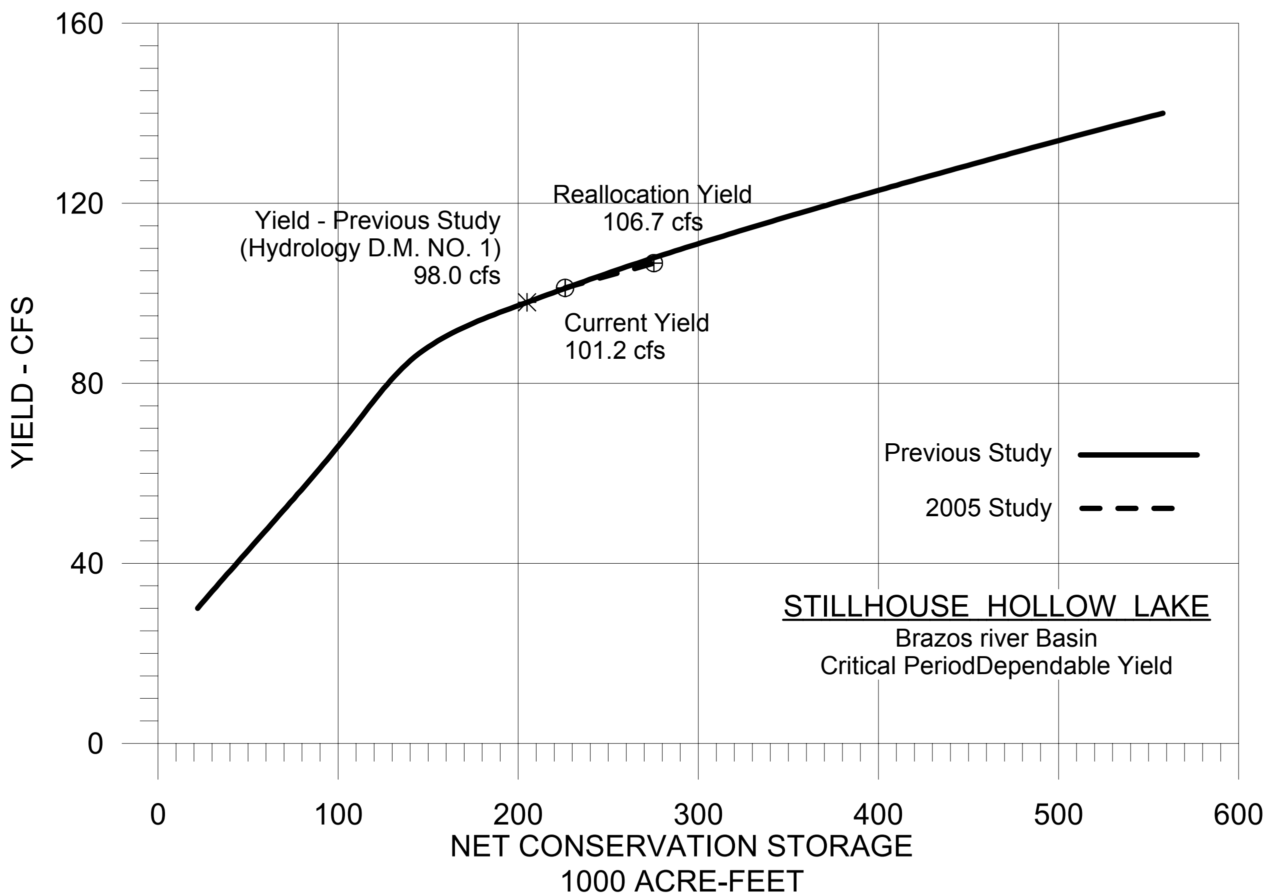

Figure A-17: Stillhouse Hollow Lake – Brazos River Basin

Notes:

1. Previous study yield curve is based on area-capacity curves derived from pre-impoundment (pre-1968) survey data.

2. Current and reallocation yields are based on area-capacity curves derived from 1995 survey data.

3. Reallocation yield represents maximum USACE discretionary authority.

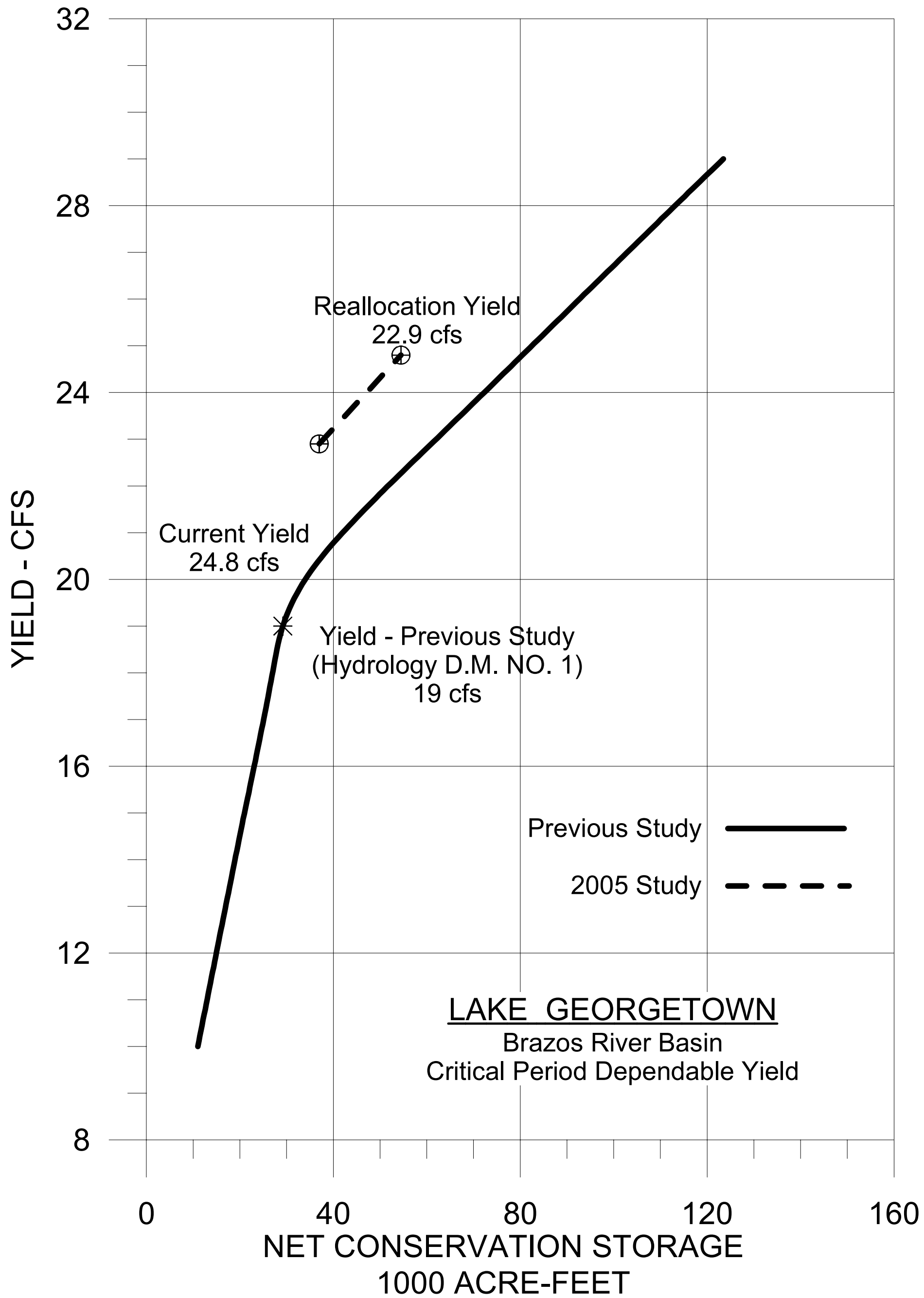

Figure A-18: Lake Georgetown – Brazos River Basin

Notes:

1. Previous study yield curve is based on area-capacity curves derived from pre-impoundment (pre-1980) survey data.

2. Current and reallocation yields are based on area-capacity curves derived from 1995 survey data.

3. Reallocation yield represents maximum USACE discretionary authority.

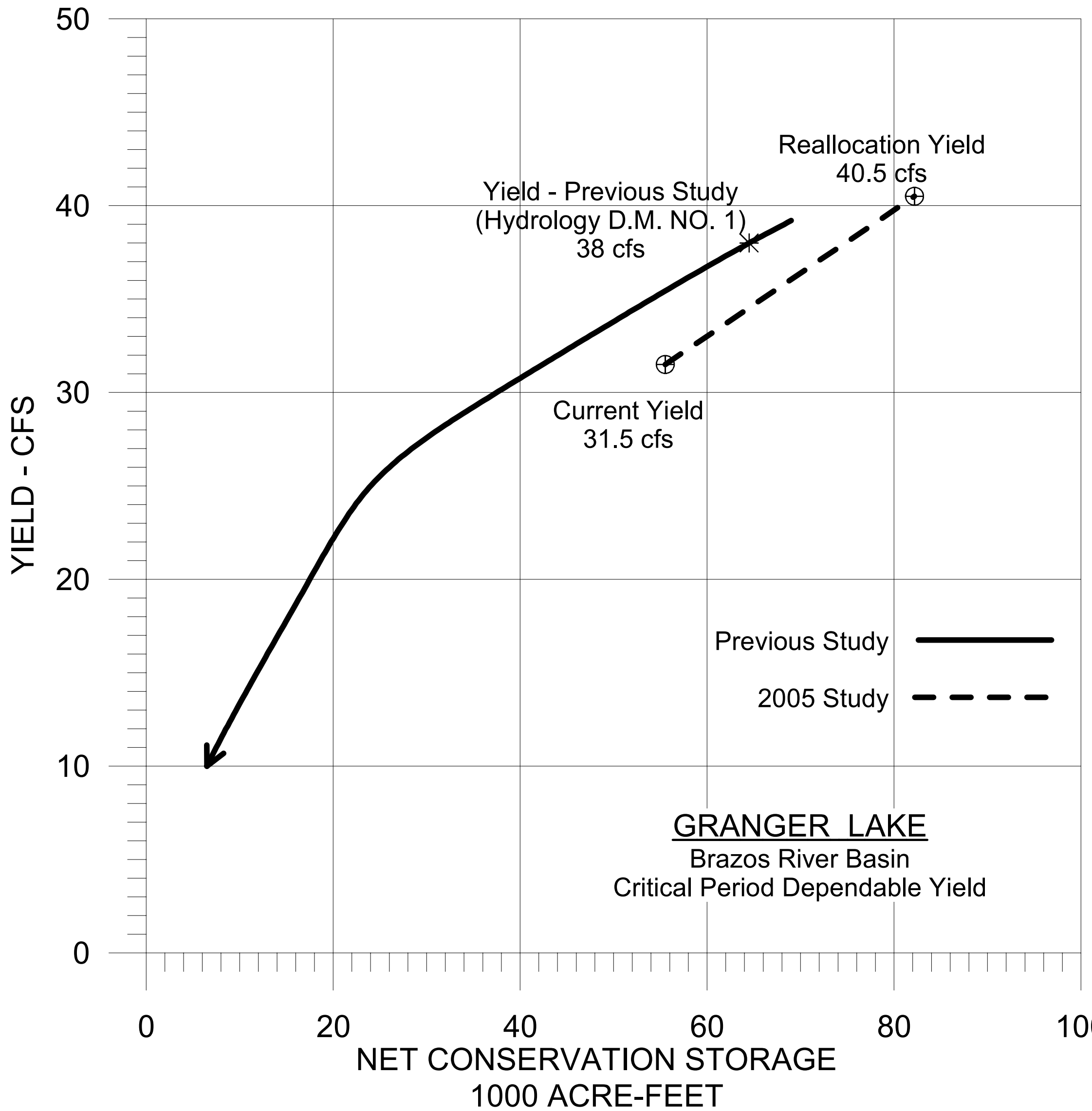

Figure A-19: Granger Lake – Brazos River Basin

Notes:

1. Previous study yield curve is based on area-capacity curves derived from pre-impoundment (pre-1980) survey data.

2. Current and reallocation yields are based on area-capacity curves derived from 2002 survey data. Sediment reserve accounted for.

3. Reallocation yield represents maximum USACE discretionary authority.

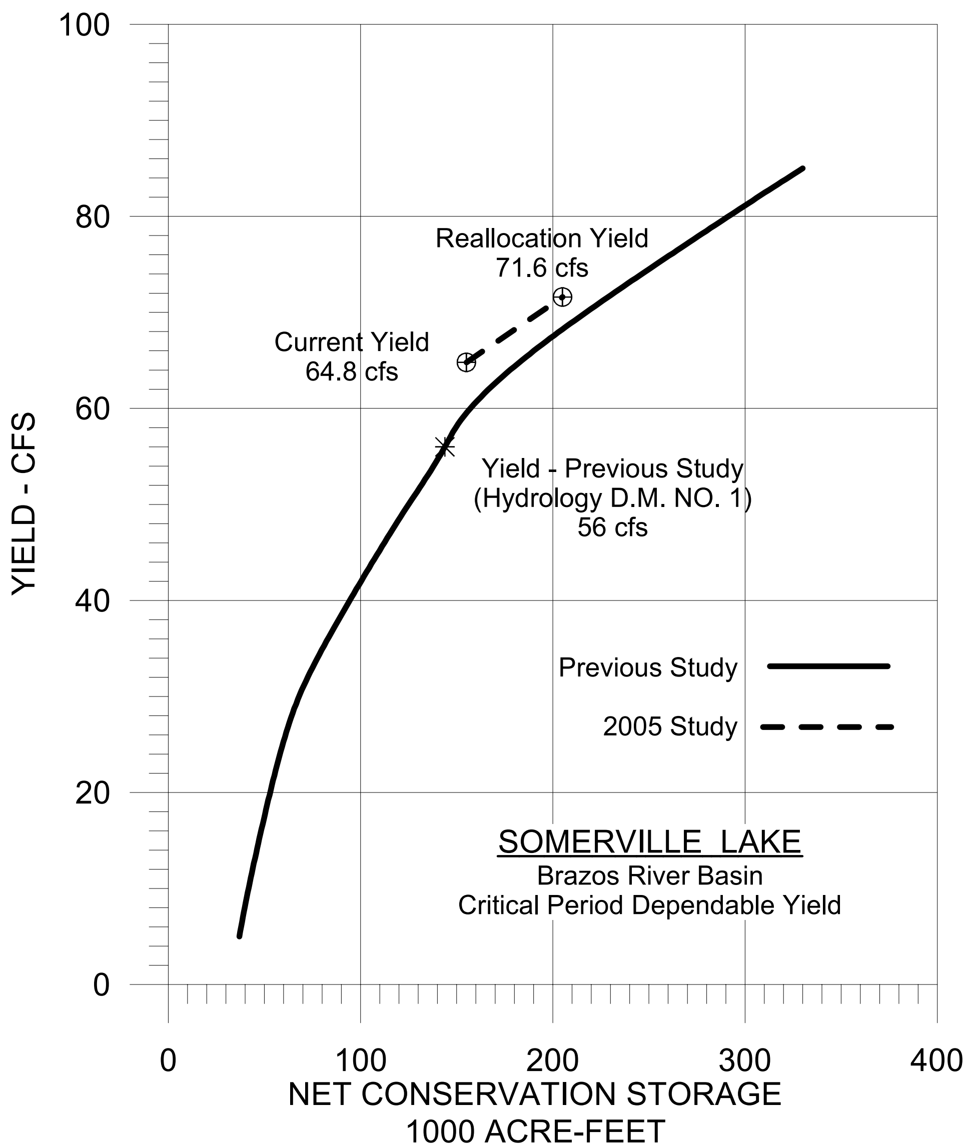

Figure A-20: Somerville Lake – Brazos River Basin

Notes:

1. Previous study yield curve is based on area-capacity curves derived from pre-impoundment (pre-1967) survey data
2. Current and reallocation yields are based on area-capacity curves derived from 1995 survey data.
3. Reallocation yield represents maximum USACE discretionary authority.

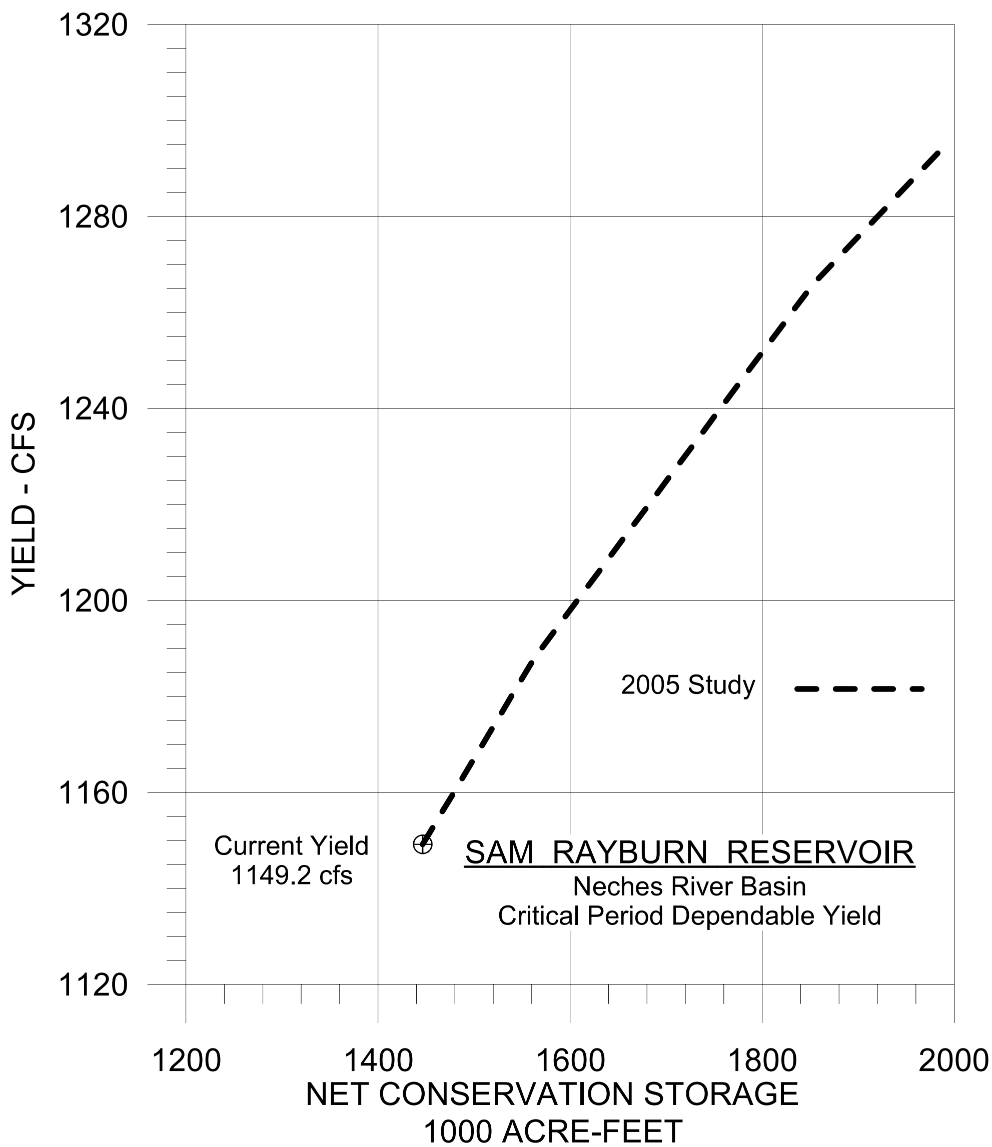

Figure A-21: Sam Rayburn Reservoir – Neches River Basin

Notes:

1. Previous study yield curve is based on area-capacity curves derived from pre-impoundment (pre-1965) survey data.
2. Current and reallocation yields are based on area-capacity curves derived from 1971 survey data.
3. Reallocation yield represents maximum USACE discretionary authority.

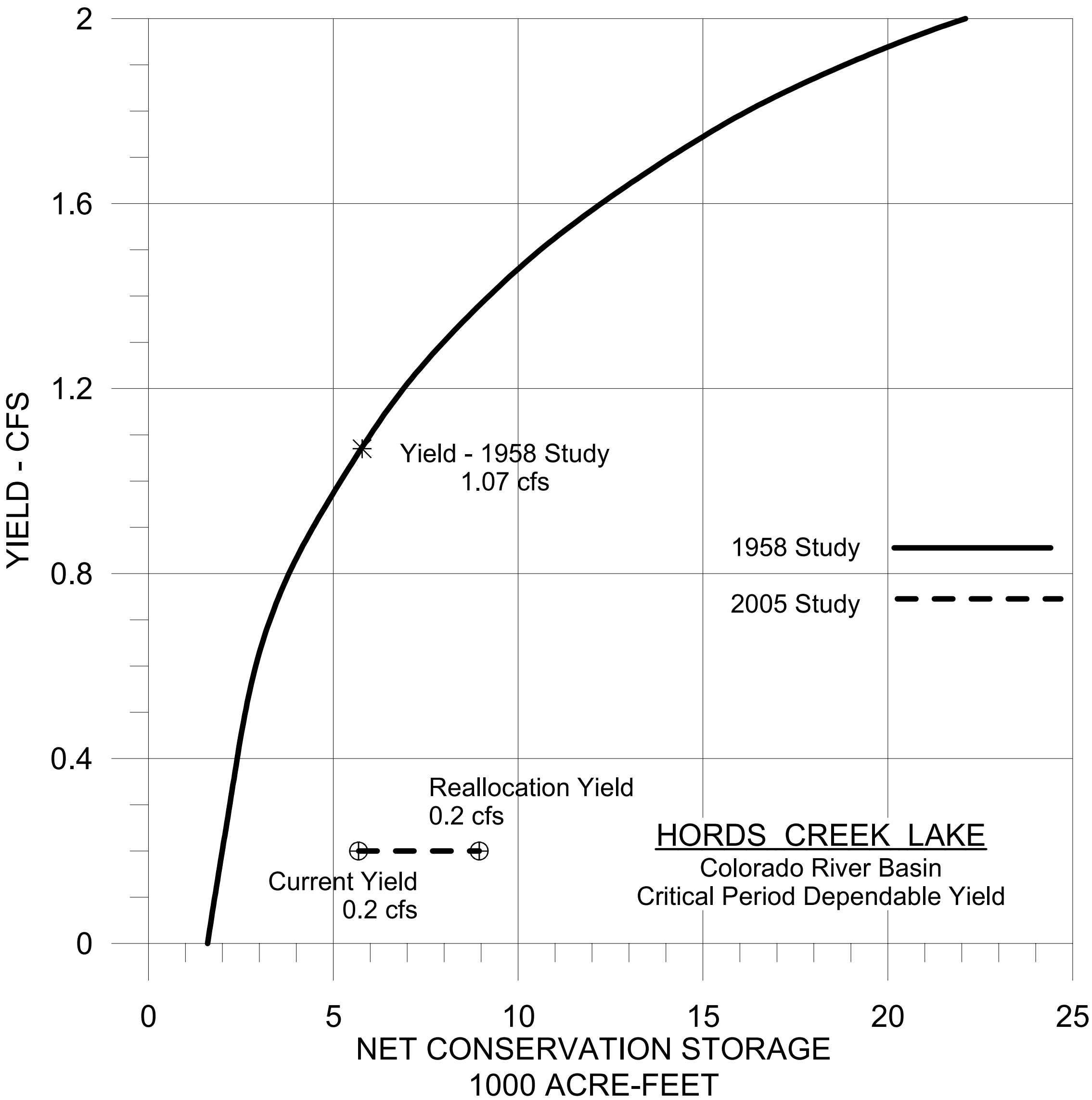

Figure A-22: Hords Creek Lake – Colorado River Basin

Notes:

1. Previous study yield curve is based on area-capacity curves derived from pre-impoundment (pre-1948) survey data.

2. Current yield is based on area-capacity curves derived from 1968 survey data.

3. Current yield represents maximum USACE discretionary authority.

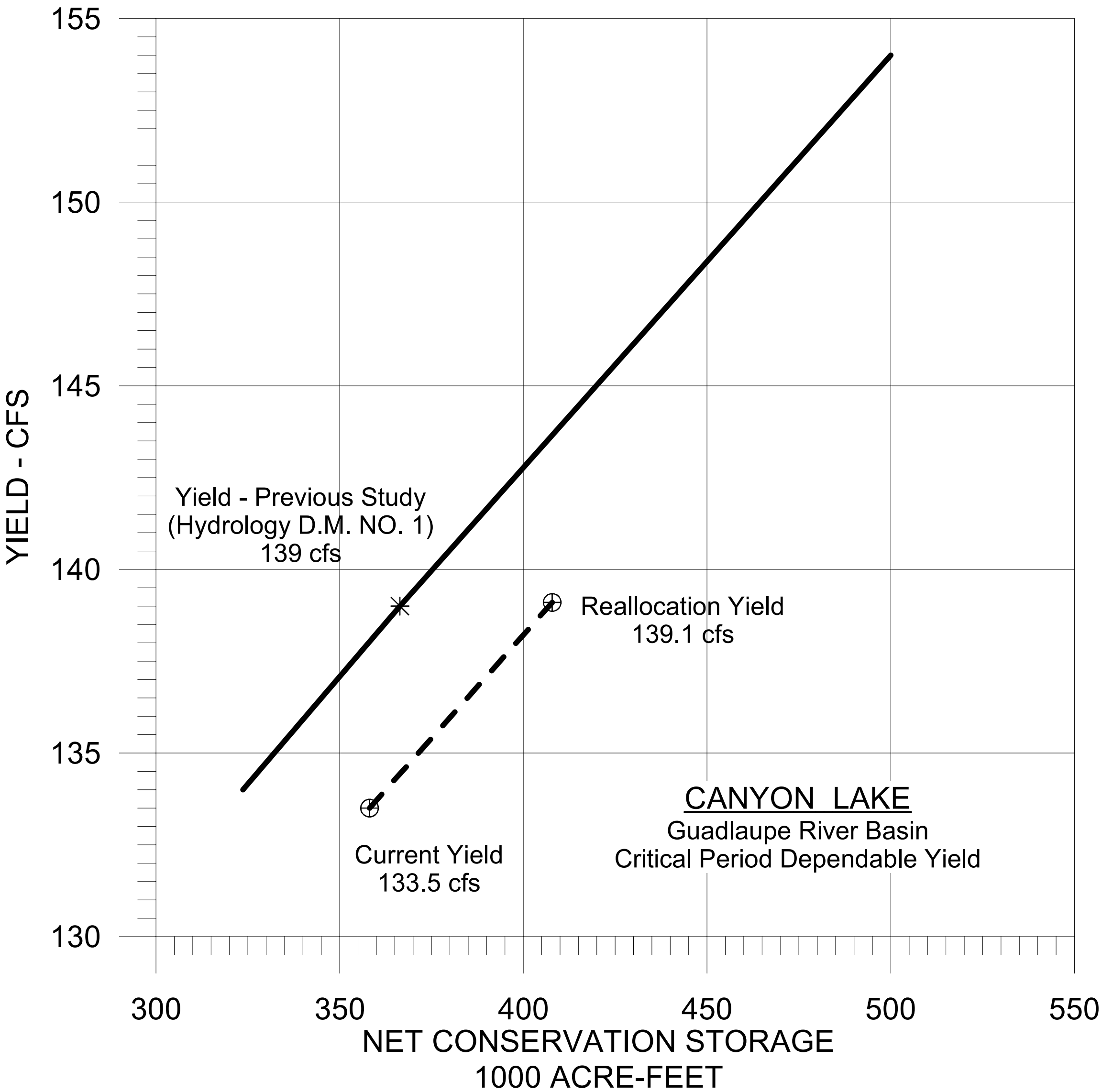

Figure A-23: Canyon Lake – Guadalupe River Basin

Notes:

1. Previous study yield curve is based on area-capacity curves derived from pre-impoundment (pre-1964) survey data.

2. Current and reallocation yields are based on area-capacity curves derived from 2002 survey data.

3. Reallocation yield represents maximum USACE discretionary authority.

Appendix B

Virtual Basin Stand Alone Reservoir Reallocation Sample Input and Output Data

```
T1Virtual River Basin WAM Model
T2Task 3 - EC Project No. 4027
T3 REALLOCATION OF RESERVOIRS A, B & C
**     WITH MUNICIPAL USE COEFFICIENT
**     TYPE 1 RIGHT
**
**
JD     5    2000       8      -1      -1
JO     1
RO     3   RES-A   RES-B   RES-C
**
**  Use Coefficients
UC  MUN1   0.066   0.064   0.071   0.077   0.092   0.100   0.115   0.104   0.092   0.079   0.070   0.068
**  Control Point Records
CP  RESA    CP1                     7             CP1
CP  RESB    CP2                     7             CP2
CP  RESC    CP5                     7             CP4
CP   CP1    CP3                     0
CP   CP2    CP3                     0
CP   CP5    CP3                     0             CP4
CP   CP3    CP4                     7             CP4
CP   CP4    OUT                     0
**
**  Water Right (WR) records, with supporting SO and WS records.
**
WR  RESA  269199    MUN1    1940   1         0.0      CP1                    WR-01
WS RES-A  430000                               0
SO                                                                                                        3
WR  RESB  563801    MUN1    1942   1         0.0                             WR-02
WS RES-B  450000                               0
SO                                                                                                        3
WR  RESC   17932    MUN1    1943   1         0.0                             WR-03
WS RES-C   65000                               0
SO                                                                                                        3
**
WR  RESA    9006    MUN1    1990   1         0.0      CP1                   WR-01A
WS RES-A  480000                               0
SO                                                                                                        2
WR  RESB   45037    MUN1    1991   1         0.0                            WR-02A
WS RES-B  500000                               0
SO                                                                                                        2
```

```
WR  RESC    2050    MUN1    1992   1         0.0                         WR-03A
WS RES-C   74750                               0
SO                                                                                                           2
**
**RES-A HAS PROPERTIES OF LAKE PROCTOR
**RES-B HAS PROPERTIES OF LAKE BELTON
**RES-C HAS PROPERTIES OF LAKE GRANGER
**
**  SV/SA Records
SV RES-A      0.     10.    182.   1302.   7792.  13122.  20147.  29787.  59387. 374200. 433000. 485000.
SA            0.      8.    100.    460.   1160.   1520.   2010.   2810.   4610.  14010.  15410.  21000.
SV RES-B      0.     40.    650.   1100.   1800.  20900.  58700. 123500. 218100. 304170. 457600. 500600.
SA            0.     17.     63.    110.    200.   1760.   3270.   5290.   7580.   9261.  12258.  16000.
SV RES-C      0.     76.    960.   2200.   3460.   5310.   7030.  10310.  23950.  46600.  65500.  90000.
SA            0.     16.    180.    344.    500.    750.    980.   1230.   1828.   3280.   4400.   6500.
**
ED
```

Virtual Basin Output Table

DIVERSIONS (AC-FT) FOR WATER RIGHT WR-01

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	17802.74	17263.26	19151.43	20769.86	24815.94	26973.85	31019.93	28052.80	24815.94	21309.34	18881.69	18342.22	269198.97
2001	17802.74	17263.26	19151.43	20769.86	24815.94	26973.85	31019.93	28052.80	24815.94	21309.34	18881.69	18342.22	269198.97
2002	17802.74	17263.26	19151.43	20769.86	24815.94	26973.85	31019.93	28052.80	24815.94	21309.34	18881.69	18342.22	269198.97
2003	17802.74	17263.26	19151.43	20769.86	24815.94	26973.85	31019.93	28052.80	24815.94	21309.34	18881.69	18342.22	269198.97
2004	17802.74	17263.26	19151.43	20769.86	24815.94	26973.85	31019.93	28052.80	24815.94	21309.34	18881.69	18342.22	269198.97
MEAN	17802.74	17263.26	19151.43	20769.86	24815.94	26973.85	31019.93	28052.80	24815.94	21309.34	18881.69	18342.22	269198.97

Virtual Basin Output Table

DIVERSIONS (AC-FT) FOR WATER RIGHT WR-02

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	37285.44	36155.57	40110.09	43499.68	51973.64	56493.09	64967.05	58752.81	51973.64	44629.54	39545.16	38415.30	563801.00
2001	37285.44	36155.57	40110.09	43499.68	51973.64	56493.09	64967.05	58752.81	51973.64	44629.54	39545.16	38415.30	563801.00
2002	37285.44	36155.57	40110.09	43499.68	51973.64	56493.09	64967.05	58752.81	51973.64	44629.54	39545.16	38415.30	563801.00
2003	37285.44	36155.57	40110.09	43499.68	51973.64	56493.09	64967.05	58752.81	51973.64	44629.54	39545.16	38415.30	563801.00
2004	37285.44	36155.57	40110.09	43499.68	51973.64	56493.09	64967.05	58752.81	51973.64	44629.54	39545.16	38415.30	563801.00
MEAN	37285.44	36155.57	40110.09	43499.68	51973.64	56493.09	64967.05	58752.80	51973.64	44629.54	39545.16	38415.30	563801.00

Virtual Basin Output Table

DIVERSIONS (AC-FT) FOR WATER RIGHT WR-03

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	1185.88	1149.95	1275.72	1383.53	1653.05	1796.79	2066.31	1868.67	1653.05	1419.47	1257.76	1221.82	17932.00
2001	1185.88	1149.95	1275.72	1383.53	1653.05	1796.79	2066.31	1868.67	1653.05	1419.47	1257.76	1221.82	17932.00
2002	1185.88	1149.95	1275.72	1383.53	1653.05	1796.79	2066.31	1868.67	1653.05	1419.47	1257.76	1221.82	17932.00
2003	1185.88	1149.95	1275.72	1383.53	1653.05	1796.79	2066.31	1868.67	1653.05	1419.47	1257.76	1221.82	17932.00
2004	1185.88	1149.95	1275.72	1383.53	1653.05	1796.79	2066.31	1868.67	1653.05	1419.47	1257.76	1221.82	17932.00
MEAN	1185.88	1149.95	1275.72	1383.53	1653.05	1796.79	2066.31	1868.67	1653.05	1419.47	1257.76	1221.82	17932.00

Virtual Basin Output Table

DIVERSIONS (AC-FT) FOR WATER RIGHT WR-01A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	595.59	577.54	640.71	694.85	830.21	902.41	1037.77	938.50	830.21	712.90	631.68	613.63	9006.00
2001	595.59	577.54	640.71	694.85	830.21	902.41	1037.77	938.50	830.21	712.90	631.68	613.63	9006.00
2002	595.59	577.54	640.71	694.85	830.21	902.41	1037.77	938.50	830.21	712.90	631.68	613.63	9006.00
2003	595.59	577.54	640.71	694.85	830.21	902.41	1037.77	938.50	830.21	712.90	631.68	613.63	9006.00
2004	595.59	577.54	640.71	694.85	830.21	902.41	1037.77	938.50	830.21	712.90	631.68	613.63	9006.00
MEAN	595.59	577.54	640.71	694.85	830.21	902.41	1037.77	938.50	830.21	712.90	631.68	613.63	9006.00

Virtual Basin Output Table

DIVERSIONS (AC-FT) FOR WATER RIGHT WR-02A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	2978.40	2888.14	3204.03	3474.80	4151.71	4512.73	5189.63	4693.23	4151.71	3565.05	3158.91	3068.65	45037.00
2001	2978.40	2888.14	3204.03	3474.80	4151.71	4512.73	5189.63	4693.23	4151.71	3565.05	3158.91	3068.65	45037.00
2002	2978.40	2888.14	3204.03	3474.80	4151.71	4512.73	5189.63	4693.23	4151.71	3565.05	3158.91	3068.65	45037.00
2003	2978.40	2888.14	3204.03	3474.80	4151.71	4512.73	5189.63	4693.23	4151.71	3565.05	3158.91	3068.65	45037.00
2004	2978.40	2888.14	3204.03	3474.80	4151.71	4512.73	5189.63	4693.23	4151.71	3565.05	3158.91	3068.65	45037.00
MEAN	2978.40	2888.14	3204.03	3474.80	4151.71	4512.73	5189.63	4693.23	4151.71	3565.05	3158.91	3068.65	45037.00

Virtual Basin Output Table

DIVERSIONS (AC-FT) FOR WATER RIGHT WR-03A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	135.57	131.46	145.84	158.17	188.98	205.41	236.22	213.63	188.98	162.27	143.79	139.68	2050.00
2001	135.57	131.46	145.84	158.17	188.98	205.41	236.22	213.63	188.98	162.27	143.79	139.68	2050.00
2002	135.57	131.46	145.84	158.17	188.98	205.41	236.22	213.63	188.98	162.27	143.79	139.68	2050.00
2003	135.57	131.46	145.84	158.17	188.98	205.41	236.22	213.63	188.98	162.27	143.79	139.68	2050.00
2004	135.57	131.46	145.84	158.17	188.98	205.41	236.22	213.63	188.98	162.27	143.79	139.68	2050.00
MEAN	135.57	131.46	145.84	158.17	188.98	205.41	236.22	213.63	188.98	162.27	143.79	139.68	2050.00

Virtual Basin Output Table

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT RESA

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	69.	241.	177.	663.	1524.	1439.	830.	1073.	579.	0.	4003.	20136.	30733.
2001	6849.	81072.	18464.	23321.	151543.	20015.	5469.	64302.	6916.	13546.	3651.	3876.	399024.
2002	2580.	1966.	1540.	116725.	61705.	29338.	3239.	1101.	46395.	66618.	6388.	4543.	342139.
2003	3043.	2389.	10675.	4051.	7614.	2417.	121.	38.	1296.	3356.	212.	614.	35825.
2004	8859.	10605.	10566.	9619.	41902.	22190.	21320.	9466.	9805.	24786.	35351.	55791.	260261.
MEAN	4280.	19254.	8284.	30876.	52858.	15080.	6196.	15196.	12998.	21661.	9921.	16992.	213596.

Virtual Basin Output Table

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT RESB

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	996.	1663.	989.	29932.	6950.	99388.	46945.	7587.	1881.	5539.	170862.	212352.	585084.
2001	85433.	247420.	217898.	131663.	415931.	159878.	83851.	52654.	41697.	59228.	18562.	14970.	1529186.
2002	10838.	9568.	8060.	289513.	266993.	187714.	22282.	27728.	184907.	146978.	49047.	29579.	1233206.
2003	22426.	14568.	20902.	31507.	20963.	8787.	3513.	857.	8294.	7820.	2627.	4666.	146929.
2004	47767.	118001.	108410.	68535.	538052.	107753.	21072.	8616.	10510.	9524.	8355.	32725.	1079319.
MEAN	33492.	78244.	71252.	110230.	249778.	112704.	35532.	19488.	49458.	45818.	49891.	58858.	914745.

Virtual Basin Output Table

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT RESC

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	500.	500.	599.	500.	500.	1199.	500.	500.	500.	500.	500.	500.	6793.
2001	500.	500.	599.	500.	500.	599.	500.	500.	500.	500.	500.	500.	6194.
2002	100.	100.	50.	50.	0.	0.	25.	0.	100.	100.	50.	50.	625.
2003	500.	500.	500.	500.	500.	500.	500.	500.	500.	500.	500.	500.	5994.
2004	10989.	10989.	10989.	10989.	10989.	10989.	10989.	10989.	10989.	10989.	10989.	10989.	131868.
MEAN	2517.	2517.	2547.	2508.	2498.	2657.	2502.	2498.	2517.	2517.	2508.	2508.	30295.

Virtual Basin Output Table

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT CP1

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	69.	241.	177.	663.	1525.	1440.	830.	1074.	579.	0.	4005.	20148.	30751.
2001	6853.	81119.	18475.	23335.	151632.	20027.	5472.	64340.	6920.	13554.	3653.	3878.	399258.
2002	2582.	1967.	1541.	116793.	61741.	29355.	3241.	1102.	46422.	66657.	6392.	4546.	342339.
2003	3045.	2390.	10681.	4053.	7619.	2418.	121.	38.	1297.	3358.	212.	614.	35846.
2004	8864.	10611.	10572.	9625.	41926.	22203.	21332.	9472.	9811.	24801.	35372.	55824.	260413.
MEAN	4283.	19266.	8289.	30894.	52889.	15089.	6199.	15205.	13006.	21674.	9927.	17002.	213721.

Virtual Basin Output Table

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT CP2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	996.	1663.	989.	29935.	6951.	99398.	46950.	7588.	1881.	5540.	170880.	212374.	585145.
2001	85442.	247446.	217921.	131677.	415974.	159895.	83860.	52659.	41701.	59234.	18564.	14972.	1529345.
2002	10839.	9569.	8061.	289543.	267021.	187733.	22284.	27731.	184926.	146993.	49052.	29582.	1233334.
2003	22428.	14570.	20904.	31510.	20965.	8788.	3513.	857.	8295.	7821.	2627.	4666.	146944.
2004	47772.	118013.	108421.	68542.	538108.	107764.	21074.	8617.	10511.	9525.	8356.	32728.	1079431.
MEAN	33495.	78252.	71259.	110241.	249804.	112716.	35536.	19490.	49463.	45823.	49896.	58864.	914840.

Virtual Basin Output Table

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT CP5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	500.	500.	600.	500.	500.	1200.	500.	500.	500.	500.	500.	500.	6800.
2001	500.	500.	600.	500.	500.	600.	500.	500.	500.	500.	500.	500.	6200.
2002	100.	100.	50.	50.	0.	0.	25.	0.	100.	100.	50.	50.	625.
2003	500.	500.	500.	500.	500.	500.	500.	500.	500.	500.	500.	500.	6000.
2004	11000.	11000.	11000.	11000.	11000.	11000.	11000.	11000.	11000.	11000.	11000.	11000.	132000.
MEAN	2520.	2520.	2550.	2510.	2500.	2660.	2505.	2500.	2520.	2520.	2510.	2510.	30325.

Virtual Basin Output Table

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT CP3

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	1565.	2404.	1766.	31098.	8976.	102038.	48280.	9162.	2960.	6040.	175385.	233022.	622696.
2001	92795.	329065.	236996.	155512.	568106.	180522.	89832.	117499.	49121.	73288.	22717.	19350.	1934803.
2002	13521.	11636.	9652.	406386.	328762.	217088.	25550.	28833.	231448.	213750.	55494.	34178.	1576298.
2003	25973.	17460.	32085.	36063.	29084.	11706.	4134.	1395.	10092.	11679.	3339.	5780.	188790.
2004	67636.	139624.	129993.	89167.	591034.	140967.	53406.	29089.	31322.	45326.	54728.	99552.	1471844.
MEAN	40298.	100038.	82098.	143645.	305192.	130464.	44240.	37196.	64989.	70017.	62333.	78376.	1158886.

Virtual Basin Output Table

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT CP4

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	1565.	2404.	1766.	31098.	8976.	102038.	48280.	9162.	2960.	6040.	175385.	233022.	622696.
2001	92795.	329065.	236996.	155512.	568106.	180522.	89832.	117499.	49121.	73288.	22717.	19350.	1934803.
2002	13521.	11636.	9652.	406386.	328762.	217088.	25550.	28833.	231448.	213750.	55494.	34178.	1576298.
2003	25973.	17460.	32085.	36063.	29084.	11706.	4134.	1395.	10092.	11679.	3339.	5780.	188790.
2004	67636.	139624.	129993.	89167.	591034.	140967.	53406.	29089.	31322.	45326.	34728.	99552.	1451844.
MEAN	40298.	100038.	82098.	143645.	305192.	130464.	44240.	37196.	64989.	70017.	58333.	78376.	1154886.

Virtual Basin Output Table

End-OF-PERIOD STORAGE (AC-FT) FOR RESERVOIR RES-A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
2000	460022.6	441677.5	418450.5	396168.6	370752.5	343357.0	306710.7	275897.6	246860.9	221790.2	205671.1	206096.8	324454.7
2001	193412.1	257149.7	254888.9	256462.8	382693.4	373211.3	342538.6	375694.4	354054.0	345551.3	326881.8	310517.0	314421.3
2002	293040.5	275421.8	254450.6	351397.7	385951.2	383875.0	349211.8	317739.5	336635.0	381569.2	364773.3	349577.8	336970.3
2003	332439.1	314699.7	304591.5	283830.4	264080.2	236013.9	200587.7	167204.0	139863.4	119426.3	98692.9	80312.1	211811.8
2004	70650.5	63240.4	53417.4	40531.1	56101.4	48653.8	36629.8	16062.7	3.3	2703.4	17803.7	54472.9	38355.9
MEAN	269912.9	270437.8	257159.8	265678.1	291915.7	277022.2	247135.7	230519.7	215483.3	214208.1	202764.5	200195.3	245202.8

Virtual Basin Output Table

End-OF-PERIOD STORAGE (AC-FT) FOR RESERVOIR RES-B

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
2000	459399.0	422545.8	377659.6	360743.4	309299.7	349036.8	322191.1	261632.0	203279.0	159086.0	289141.6	460686.7	331225.0
2001	500000.0	500000.0	500000.0	500000.0	500000.0	500000.0	500000.0	481440.6	461822.5	472895.0	446254.6	418588.0	481750.0
2002	387192.7	356204.0	318591.5	500000.0	500000.0	500000.0	446304.1	406323.4	500000.0	500000.0	500000.0	487018.2	450136.2
2003	467476.0	440059.4	416221.8	397475.5	361025.7	305171.3	235568.5	168460.7	119210.8	77475.6	36810.7	0.6	252079.7
2004	7557.8	86714.6	151663.6	171887.4	500000.0	500000.0	442916.3	383155.6	333721.4	291722.7	249560.8	241125.9	280002.2
MEAN	364325.1	361104.8	352827.3	386021.2	434065.1	430841.6	389396.0	340202.5	323606.7	300235.8	304353.6	321483.9	359038.7

Virtual Basin Output Table

End-OF-PERIOD STORAGE (AC-FT) FOR RESERVOIR RES-C

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVG
2000	73429.8	73261.7	71303.8	70456.0	68407.7	68633.9	65255.4	61194.6	57646.4	55638.0	56456.2	56184.1	64822.3
2001	55198.0	54763.5	54293.8	53627.0	52317.4	51298.5	48636.1	45178.5	42621.2	41718.7	40244.4	39217.7	48259.6
2002	37547.4	35868.4	33895.0	33184.9	31307.5	28872.1	25888.0	22933.4	21140.7	19582.0	18003.0	16660.7	27073.6
2003	15713.7	14613.0	13555.6	12119.2	10702.5	8716.9	6574.2	4465.1	2991.6	1799.0	858.6	0.5	7675.8
2004	9840.7	19748.3	29401.8	38290.1	48310.4	55851.7	62117.8	69196.6	74750.0	74750.0	74650.8	74750.0	52638.2
MEAN	38345.9	39651.0	40490.0	41535.4	42209.1	42674.6	41694.3	40593.6	39830.0	38697.5	38042.6	37362.6	40093.9

Virtual Basin Output Table

DIVERSION SHORTAGES (AC-FT) FOR WATER RIGHT WR-01

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MEAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Virtual Basin Output Table

DIVERSION SHORTAGES (AC-FT) FOR WATER RIGHT WR-02

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MEAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Virtual Basin Output Table

DIVERSION SHORTAGES (AC-FT) FOR WATER RIGHT WR-03

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MEAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Virtual Basin Output Table

DIVERSION SHORTAGES (AC-FT) FOR WATER RIGHT WR-01A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MEAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Virtual Basin Output Table

DIVERSION SHORTAGES (AC-FT) FOR WATER RIGHT WR-02A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MEAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Virtual Basin Output Table

DIVERSION SHORTAGES (AC-FT) FOR WATER RIGHT WR-03A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MEAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Virtual Basin Output Table

DIVERSION SHORTAGES (AC-FT) AT CONTROL POINT RES-A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MEAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Virtual Basin Output Table

DIVERSION SHORTAGES (AC-FT) AT CONTROL POINT RES-B

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MEAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Virtual Basin Output Table

DIVERSION SHORTAGES (AC-FT) AT CONTROL POINT RES-C

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MEAN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Virtual Basin Output Table

EVAPORATION (AC-FT) FOR RESERVOIR RES-A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	1648.0	745.1	3611.7	1479.8	1294.0	958.4	5418.1	2895.2	3969.2	3048.4	608.4	754.7	26431.0
2001	1135.4	-506.9	932.8	282.7	-333.5	1621.1	4083.8	2155.3	2910.1	26.6	2806.9	1284.7	16399.0
2002	1658.7	1743.8	2719.1	-1687.2	1505.2	3537.7	5844.6	3582.3	1853.1	-338.4	3670.7	783.1	24872.7
2003	1783.6	2287.2	990.8	3347.0	1718.6	2606.6	3489.4	4430.3	2990.7	1770.9	1431.9	38.6	26885.6
2004	122.2	174.1	596.6	1040.9	685.0	1761.4	1285.8	1042.2	218.6	64.1	114.3	166.3	7271.5
MEAN	1269.6	888.7	1770.2	892.6	973.9	2097.0	4024.3	2821.1	2388.3	914.3	1726.4	605.5	20372.0

Virtual Basin Output Table

EVAPORATION (AC-FT) FOR RESERVOIR RES-B

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	1333.0	-527.7	2561.0	-126.4	2268.6	-1355.2	3634.1	4700.3	4108.5	1537.9	-1897.4	-677.1	15559.6
2001	1010.8	-1084.4	-861.2	-1084.4	175.4	175.4	5390.4	7766.9	5189.4	-39.3	2498.5	1153.1	20290.6
2002	1969.3	1512.9	2358.6	-2549.0	893.1	4050.7	5820.9	4262.8	1265.0	414.6	3046.0	1076.8	24121.7
2003	1704.1	2941.4	1425.3	3278.6	1287.3	3635.6	2958.7	4518.7	1418.8	1360.7	587.6	-8.4	25108.4
2004	-54.0	-199.8	146.7	1336.6	-2341.8	6395.1	7998.8	4930.8	3818.8	3328.1	-542.2	-324.5	24492.6
MEAN	1192.6	528.5	1126.1	171.1	456.5	2580.3	5160.6	5235.9	3160.1	1320.4	738.5	244.0	21914.6

Virtual Basin Output Table

EVAPORATION (AC-FT) FOR RESERVOIR RES-C

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	498.2	-613.8	1135.8	-194.4	705.8	-1029.6	1575.4	2478.1	2205.7	926.1	-1720.2	-590.0	5377.1
2001	164.2	-347.5	-352.5	-375.3	-32.9	-384.0	859.4	1874.7	1214.8	-179.8	572.3	164.7	3178.1
2002	448.8	497.4	601.9	-781.7	35.4	433.2	706.5	872.3	50.6	76.9	227.5	30.8	3199.6
2003	125.0	318.9	135.4	394.2	74.1	482.9	339.6	526.3	131.0	110.3	38.4	-4.0	2672.1
2004	-172.6	-200.1	-86.0	559.0	-873.3	1445.5	2420.4	1827.9	2036.4	2077.1	-1302.3	-788.7	6943.3
MEAN	212.7	-69.0	286.9	-79.6	-18.2	189.6	1180.3	1515.9	1127.7	602.1	-436.9	-237.4	4274.0

Appendix C
Little River Case Study Stand Alone Reservoir Reallocation Model - Changes to TCEQ Brazos WAM Run 3

Edits to the BWAM3.dat WRAP input file for modeling reallocation in the Task 4 Case study - Reallocation of reservoir system in Little River Watershed.
The following modeling is for the stand alone firm yield calculations using the dual simulations option with reallocation.

```
** EC MODIFIED PROCTOR'S STORAGE TO MATCH CORPS SUPER SUMMARIES
WR515931   2685.    MUN219631216   1   2  0.0000                        C5159_1   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                               3
**WSPRCTOR  59400.                            0
WR515931    735.    MUN219631216   1   2  0.0000                        C5159_2   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                               3
**WSPRCTOR  59400.                            0
WR515931   1147.    MUN219631216   1   2  0.0000                        C5159_3   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                               3
**WSPRCTOR  59400.                            0
WR515931   1772.    MUN219631216   1   2  0.0000                        C5159_4   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                               3
**WSPRCTOR  59400.                            0
WR515931   1671.    MUN219631216   1   2  0.0000                        C5159_5   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                               3
**WSPRCTOR  59400.                            0
WR515931      0.    IND219631216   1   2       0                        C5159_6   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                               3
**WSPRCTOR  59400.                            0
WR515931   5948.    IRR219631216   1   2       0                        C5159_7   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                               3
**WSPRCTOR  59400.                            0
WR515931   5700.    IRR219631216   1   2       0                        C5159_8   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                               3
**WSPRCTOR  59400.                            0
WR515931      0.    MIN219631216   1   2       0                        C5159_9   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                               3
**WSPRCTOR  59400.                            0
WR515931      0.   UNIFO19631216   1   2       0                       C5159_10   C515965159001
```

```
WSPRCTOR  55457.                           5366
SO                                                                                                        3
**WSPRCTOR  59400.                              0
** EC ADDED TO INCLUDE REALLOCATION USING CORPS REALLOCATION VALUES
WR515931      0.    MUN220060101   1   2       0                        C5159_11   C515965159001
WSPRCTOR 104900.                           5366
SO                                                                                                        2
**



** EC MODIFIED BELTON'S STORAGE TO MATCH CORPS SUPER SUMMARIES
WR516031  10000.    MUN219530824   1   2  0.0000                         C2936_1   C293662936001
WSBELTON  10000.                              0
SO                                                                                                        3
WR516031   2000.    MUN219540823   1   2  0.0000                         C2936_2   C293662936001
WSBELTON  12000.                              0
SO                                                                                                        3
WR516031   7056.    MUN219631216   1   4  RBLSH1  102191                 C5160_1   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                        3
**WSBELTON 457600.                              0
WR516031   1245.    MUN219631216   1   2  0.0000                         C5160_2   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                        3
**WSBELTON 457600.                              0
WR516031   3432.    MUN219631216   1   4  RBLSH1  101761                 C5160_3   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                        3
**WSBELTON 457600.                              0
WR516031   2016.    MUN219631216   1   4  RBLSH1  101741                 C5160_4   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                        3
**WSBELTON 457600.                              0
WR516031  27735.    MUN219631216   1   4  RBLSH1  103513                 C5160_5   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                        3
**WSBELTON 457600.                              0
WR516031   7745.    MUN219631216   1   4  RBLSH1  103512                 C5160_6   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                        3
**WSBELTON 457600.                              0
WR516031    540.    MUN219631216   1   2  0.0000                         C5160_7   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                        3
```

```
**WSBELTON 457600.                               0
WR516031   1758.    MUN219631216   1    4  RBLSH1  100451                 C5160_8   C516065160001
WSBELTON 434500.                            52401
SO                                                                                                          3
**WSBELTON 457600.                               0
WR516031   4549.    MUN219631216   1    4  RBLSH1  100455                 C5160_9   C516065160001
WSBELTON 434500.                            52401
SO                                                                                                          3
**WSBELTON 457600.                               0
WR516031   1758.    MUN219631216   1    4  RBLSH1  100451                C5160_10   C516065160001
WSBELTON 434500.                            52401
SO                                                                                                          3
**WSBELTON 457600.                               0
WR516031   5424.    MUN219631216   1    4  RBLSH1  101551                C5160_11   C516065160001
WSBELTON 434500.                            52401
SO                                                                                                          3
**WSBELTON 457600.                               0
WR516031  17484.    MUN219631216   1    4  RBLSH1  113181                C5160_12   C516065160001
WSBELTON 434500.                            52401
SO                                                                                                          3
**WSBELTON 457600.                               0
WR516031  10469.    MUN219631216   1    4  RBLSH1  104702                C5160_13   C516065160001
WSBELTON 434500.                            52401
SO                                                                                                          3
**WSBELTON 457600.                               0
WR516031   5411.    MUN219631216   1    2  0.0000                        C5160_14   C516065160001
WSBELTON 434500.                            52401
SO                                                                                                          3
**WSBELTON 457600.                               0
WR516031    200.    MUN219631216   1    2  0.0000                        C5160_15   C516065160001
WSBELTON 434500.                            52401
SO                                                                                                          3
**WSBELTON 457600.                               0
WR516031   2365.    IND219631216   1    2  0.0000                        C5160_16   C516065160001
WSBELTON 434500.                            52401
SO                                                                                                          3
**WSBELTON 457600.                               0
WR516031   1070.    IRR219631216   1    2  0.0000                        C5160_17   C516065160001
WSBELTON 434500.                            52401
SO                                                                                                          3
**WSBELTON 457600.                               0
WR516031     0.0    MIN219631216   1    2  0.0000                        C5160_18   C516065160001
WSBELTON 434500.                            52401
SO                                                                                                          3
**WSBELTON 457600.                               0
```

```
WR516031     0.0   UNIFO19631216   1   2  0.0000                        C5160_19   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                       3
**WSBELTON 457600.                               0
** EC ADDED TO INCLUDE REALLOCATION USING CORPS REALLOCATION VALUES
WR516031      0.    MUN220060101   1   2  0.0000                        C5160_20   C516065160001
WSBELTON 483440.                           52401
SO                                                                                                       2
**

** EC MODIFIED STILLHOUSE'S STORAGE TO MATCH CORPS SUPER SUMMARIES
WR516131   6973.    MUN319631216   1   4  RBLSH1  102051                 C5161_1   C516165161001
WSSTLHSE 226063.                              30
SO                                                                                                       3
**WSSTLHSE 235700.                               0
WR516131   2092.    MUN319631216   1   2  0.0000                         C5161_2   C516165161001
WSSTLHSE 226063.                              30
SO                                                                                                       3
**WSSTLHSE 235700.                               0
WR516131   4880.    MUN319631216   1   2  0.0000                         C5161_3   C516165161001
WSSTLHSE 226063.                              30
SO                                                                                                       3
**WSSTLHSE 235700.                               0
WR516131  53823.    MUN319631216   1   2  0.0000                         C5161_4   C516165161001
WSSTLHSE 226063.                              30
SO                                                                                                       3
**WSSTLHSE 235700.                               0
WR516131      0.    IND319631216   1   2  0.0000                         C5161_5   C516165161001
WSSTLHSE 226063.                              30
SO                                                                                                       3
**WSSTLHSE 235700.                               0
WR516131      0.    MIN319631216   1   2  0.0000                         C5161_6   C516165161001
WSSTLHSE 226063.                              30
SO                                                                                                       3
**WSSTLHSE 235700.                               0
WR516131      0.    IRR319631216   1   2  0.0000                         C5161_7   C516165161001
WSSTLHSE 226063.                              30
SO                                                                                                       3
**WSSTLHSE 235700.                               0
** EC ADDED TO INCLUDE REALLOCATION USING CORPS REALLOCATION VALUES
WR516131      0.    MUN320060101   1   2  0.0000                         C5161_8   C516165161001
WSSTLHSE 275361.                              30
SO                                                                                                       2
**
```

```
** EC MODIFIED GEORGETOWN'S STORAGE TO MATCH CORPS SUPER SUMMARIES
WR516231   4764.    MUN319680212   1   4  R51621  104893                 C5162_1   C516265162001
WSGRGTWN  37010.                             24
SO                                                                                               3
**WSGRGTWN  37100.                              0
WR516231   2041.    MUN319680212   1   4  R51621  104892                 C5162_2   C516265162001
WSGRGTWN  37010.                             24
SO                                                                                               3
**WSGRGTWN  37100.                              0
WR516231   3198.    MUN319680212   1   4  R51621  102641                 C5162_3   C516265162001
WSGRGTWN  37010.                             24
SO                                                                                               3
**WSGRGTWN  37100.                              0
WR516231   3607.    MUN319680212   1   4  R51621  102642                 C5162_4   C516265162001
WSGRGTWN  37010.                             24
SO                                                                                               3
**WSGRGTWN  37100.                              0
WR516231      0.    IND319680212   1   2  0.0000                         C5162_5   C516265162001
WSGRGTWN  37010.                             24
SO                                                                                               3
**WSGRGTWN  37100.                              0
WR516231      0.    MIN319680212   1   2  0.0000                         C5162_6   C516265162001
WSGRGTWN  37010.                             24
SO                                                                                               3
**WSGRGTWN  37100.                              0
WR516231      0.    IRR319680212   1   2  0.0000                         C5162_7   C516265162001
WSGRGTWN  37010.                             24
SO                                                                                               3
**WSGRGTWN  37100.                              0
** EC ADDED TO INCLUDE REALLOCATION USING CORPS REALLOCATION VALUES
WR516231      0.    MUN320060101   1   2  0.0000                         C5162_8   C516265162001
WSGRGTWN  54505.                             24
SO                                                                                               2
**

** EC MODIFIED GRANGER'S STORAGE TO MATCH CORPS SUPER SUMMARIES
WR516331   6566.    MUN319680212   1   4  R51631                         C5163_1   C516365163001
WSGRNGER  52525.                              1
SO                                                                                               3
**WSGRNGER  65500.                              0
WR516331   6721.    MUN319680212   1   4  R51631  102991                 C5163_2   C516365163001
WSGRNGER  52525.                              1
SO                                                                                               3
**WSGRNGER  65500.                              0
```

```
WR516331   5659.    IND319680212   1   2  0.0000                         C5163_3   C516365163001
WSGRNGER  52525.                             1
SO                                                                                              3
**WSGRNGER  65500.                             0
WR516331      0.    IND319680212   1   2  0.0000                         C5163_4   C516365163001
WSGRNGER  52525.                             1
SO                                                                                              3
**WSGRNGER  65500.                             0
WR516331     20.    MIN319680212   1   2  0.0000                         C5163_5   C516365163001
WSGRNGER  52525.                             1
SO                                                                                              3
**WSGRNGER  65500.                             0
WR516331    874.    IRR319680212   1   2  0.0000                         C5163_6   C516365163001
WSGRNGER  52525.                             1
SO                                                                                              3
**WSGRNGER  65500.                             0
** EC ADDED TO INCLUDE REALLOCATION USING CORPS REALLOCATION VALUES
WR516331      0.    MUN320060101   1   2  0.0000                         C5163_7   C516365163001
WSGRNGER  82187.                             1
SO                                                                                              2
**


**  EC ADDED - UPDATED SA/SV RECORDS TO MOST RECENT SURVEYS
**  EC RECONSTRUCTED SA/SV RECORD FOR BELTON LAKE BASED UPON TWDB 1994 SURVEY AS PROVIDED BY CORPS OF ENGINEERS
SVBELTON      0.     49.    197.   1192.   2013.  20962.  58558. 126330. 222430. 302090. 447055. 513015.
SA            0.     23.     57.    220.    325.   1651.   3194.   5238.   7890.   9809.  12688.  13660.
**  EC RECONSTRUCTED SA/SV RECORD FOR LAKE GEORGETOWN BASED UPON TWDB 1995 SURVEY AS PROVIDED BY CORPS OF ENGINEERS
SVGRGTWN      0.    114.    300.    697.   1299.   3159.   4789.   8200.  13480.  24388.  43970.  55380.
SA            0.     27.     68.    127.    177.    286.    363.    498.    681.    998.   1490.   1770.
**  EC RECONSTRUCTED SA/SV RECORD FOR GRANGER LAKE BASED UPON TWDB 2002 SURVEY AS PROVIDED BY CORPS OF ENGINEERS
SVGRNGER      0.     14.    191.   1355.   3475.   6064.  12384.  26215.  44749.  66525.  77045.  82690.
SA            0.     24.     99.    332.    740.    993.   1531.   2514.   3675.   5020.   5500.   5789.
**  EC RECONSTRUCTED SA/SV RECORD FOR LAKE PROCTOR BASED UPON TWDB 2002 SURVEY AS PROVIDED BY CORPS OF ENGINEERS
SVPRCTOR      0.      2.     54.    282.   1234.   3408.   7737.  13930.  28996.  55457.  75722. 106212.
SA            0.      9.    122.    322.    601.    884.   1333.   1756.   2555.   4537.   5520.   6680.
**  EC RECONSTRUCTED SA/SV RECORD FOR LAKE STILLHOUSE BASED UPON TWDB 1995 SURVEY AS PROVIDED BY CORPS OF ENGINEERS
SVSTLHSE      0.     17.    452.   3041.   9214.  13828.  39250.  68006. 101285. 163675. 226063. 281193.
SA            0.      5.    127.    339.    668.    884.   1831.   2631.   3443.   4991.   6429.   7349.
```

Appendix D

Little River Case Study Reallocated System Yield Model – Changes to TCEQ Brazos WAM Run 3

Edits to the BWAM3.dat WRAP input file for modeling reallocation in the Task 4 Case study - Reallocation of reservoir system in Little River Watershed.
The following modeling is for the system firm yield calculations with reallocation.

```
**  EC ADDED DUMMY CP's TO MODEL SYSTEM OPERATIONS
CP5159DP     OUT                        2    NONE    NONE    -3.   0.0000
CP5160DP     OUT                        2    NONE    NONE    -3.   0.0000
CP5161DP     OUT                        2    NONE    NONE    -3.   0.0000
CP5162DP     OUT                        2    NONE    NONE    -3.   0.0000
CP5163DP     OUT                        2    NONE    NONE    -3.   0.0000
CP5159CI     OUT                        2    NONE    NONE    -3.   0.0000
CP5160CI     OUT                        2    NONE    NONE    -3.   0.0000
CP5161CI     OUT                        2    NONE    NONE    -3.   0.0000
CP5162CI     OUT                        2    NONE    NONE    -3.   0.0000
CP5163CI     OUT                        2    NONE    NONE    -3.   0.0000
**


**  EC ADDED DUMMY CP's WITH LARGE FLOWS TO MODEL SYSTEM OPERATIONS
CI5159CI 9999999 9999999 9999999 9999999 9999999 9999999
CI       9999999 9999999 9999999 9999999 9999999 9999999
CI5160CI 9999999 9999999 9999999 9999999 9999999 9999999
CI       9999999 9999999 9999999 9999999 9999999 9999999
CI5161CI 9999999 9999999 9999999 9999999 9999999 9999999
CI       9999999 9999999 9999999 9999999 9999999 9999999
CI5162CI 9999999 9999999 9999999 9999999 9999999 9999999
CI       9999999 9999999 9999999 9999999 9999999 9999999
CI5163CI 9999999 9999999 9999999 9999999 9999999 9999999
CI       9999999 9999999 9999999 9999999 9999999 9999999
**


**
**  EC MODIFIED PROCTOR'S STORAGE TO MATCH CORPS SUPER SUMMARIES AND USED DUAL SIMULATION TO MODEL SYSTEM OPERATIONS
**    First simulation determines the amount of streamflow depleted in the base run.
WR515931   2685.    MUN219631216   1   2  0.0000                         C5159_1   C515965159001
WSPRCTOR  55457.                           5366
SO                                                                                                  1
**WSPRCTOR  59400.                               0
WR515931    735.    MUN219631216   1   2  0.0000                         C5159_2   C515965159001
WSPRCTOR  55457.                           5366
SO                                                                                                  1
**WSPRCTOR  59400.                               0
WR515931   1147.    MUN219631216   1   2  0.0000                         C5159_3   C515965159001
WSPRCTOR  55457.                           5366
```

```
SO                                                                                                           1
**WSPRCTOR  59400.                               0
WR515931   1772.    MUN219631216   1   2  0.0000                         C5159_4   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                                           1
**WSPRCTOR  59400.                               0
WR515931   1671.    MUN219631216   1   2  0.0000                         C5159_5   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                                           1
**WSPRCTOR  59400.                               0
WR515931      0.    IND219631216   1   2       0                         C5159_6   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                                           1
**WSPRCTOR  59400.                               0
WR515931   5948.    IRR219631216   1   2       0                         C5159_7   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                                           1
**WSPRCTOR  59400.                               0
WR515931   5700.    IRR219631216   1   2       0                         C5159_8   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                                           1
**WSPRCTOR  59400.                               0
WR515931      0.    MIN219631216   1   2       0                         C5159_9   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                                           1
**WSPRCTOR  59400.                               0
WR515931      0.   UNIFO19631216   1   2       0                        C5159_10   C515965159001
WSPRCTOR  55457.                            5366
SO                                                                                                           1
**WSPRCTOR  59400.                               0
**
**  Calculate the total streamflow depletion in the first simulation/base run for water right 5159.
WR5159CI              19631216                               Compute Dep 5159  SYSTEM
TO     6     1.0     ADD                                      C5159_1    CONT
TO     6     1.0     ADD                                      C5159_2    CONT
TO     6     1.0     ADD                                      C5159_3    CONT
TO     6     1.0     ADD                                      C5159_4    CONT
TO     6     1.0     ADD                                      C5159_5    CONT
TO     6     1.0     ADD                                      C5159_6    CONT
TO     6     1.0     ADD                                      C5159_7    CONT
TO     6     1.0     ADD                                      C5159_8    CONT
TO     6     1.0     ADD                                      C5159_9    CONT
TO     6     1.0     ADD                                     C5159_10
SO                                                                                                           4
**
```

```
**  From an imaginary point, divert an amount equal to the total streamflow depletions in the first simulation/base run
in the second simulation.
**   The diversion will be limited by the previous diversion.
WR5159CI 9999999        19631216                                  Depletion 5159  SYSTEM
SO                                                                                                  5
**
**  From the river, divert the lumped streamflow depletion from the first simulation/base run (using the previous
diversion).
WR515931                19631216          1.0000  5159DP         Lumped Dep 5159  SYSTEM
TO     6     1.0     ADD                                  Depletion 5159
SO                                                                                                  2
**
**  END MODELING OF LAKE PROCTOR
**




**
**  EC MODIFIED BELTON'S STORAGE TO MATCH CORPS SUPER SUMMARIES AND USED DUAL SIMULATION TO MODEL SYSTEM OPERATIONS
**    First simulation determines the amount of streamflow depleted in the base run.
WR516031  10000.    MUN219530824   1   2  0.0000                         C2936_1   C293662936001
WSBELTON  10000.                              0
SO                                                                                                  1
WR516031   2000.    MUN219540823   1   2  0.0000                         C2936_2   C293662936001
WSBELTON  12000.                              0
SO                                                                                                  1
WR516031   7056.    MUN219631216   1   4  RBLSH1  102191                 C5160_1   C516065160001
WSBELTON 434500.                          52401
SO                                                                                                  1
**WSBELTON 457600.                              0
WR516031   1245.    MUN219631216   1   2  0.0000                         C5160_2   C516065160001
WSBELTON 434500.                          52401
SO                                                                                                  1
**WSBELTON 457600.                              0
WR516031   3432.    MUN219631216   1   4  RBLSH1  101761                 C5160_3   C516065160001
WSBELTON 434500.                          52401
SO                                                                                                  1
**WSBELTON 457600.                              0
WR516031   2016.    MUN219631216   1   4  RBLSH1  101741                 C5160_4   C516065160001
WSBELTON 434500.                          52401
SO                                                                                                  1
**WSBELTON 457600.                              0
WR516031  27735.    MUN219631216   1   4  RBLSH1  103513                 C5160_5   C516065160001
WSBELTON 434500.                          52401
SO                                                                                                  1
```

```
**WSBELTON 457600.                              0
WR516031   7745.    MUN219631216   1   4  RBLSH1  103512                 C5160_6   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                     1
**WSBELTON 457600.                              0
WR516031    540.    MUN219631216   1   2  0.0000                         C5160_7   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                     1
**WSBELTON 457600.                              0
WR516031   1758.    MUN219631216   1   4  RBLSH1  100451                 C5160_8   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                     1
**WSBELTON 457600.                              0
WR516031   4549.    MUN219631216   1   4  RBLSH1  100455                 C5160_9   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                     1
**WSBELTON 457600.                              0
WR516031   1758.    MUN219631216   1   4  RBLSH1  100451                C5160_10   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                     1
**WSBELTON 457600.                              0
WR516031   5424.    MUN219631216   1   4  RBLSH1  101551                C5160_11   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                     1
**WSBELTON 457600.                              0
WR516031  17484.    MUN219631216   1   4  RBLSH1  113181                C5160_12   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                     1
**WSBELTON 457600.                              0
WR516031  10469.    MUN219631216   1   4  RBLSH1  104702                C5160_13   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                     1
**WSBELTON 457600.                              0
WR516031   5411.    MUN219631216   1   2  0.0000                        C5160_14   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                     1
**WSBELTON 457600.                              0
WR516031    200.    MUN219631216   1   2  0.0000                        C5160_15   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                     1
**WSBELTON 457600.                              0
WR516031   2365.    IND219631216   1   2  0.0000                        C5160_16   C516065160001
WSBELTON 434500.                           52401
SO                                                                                                     1
**WSBELTON 457600.                              0
```

```
WR516031   1070.    IRR219631216   1   2  0.0000                        C5160_17   C516065160001
WSBELTON 434500.                           52401
SO                                                                                              1
**WSBELTON 457600.                               0
WR516031     0.0    MIN219631216   1   2  0.0000                        C5160_18   C516065160001
WSBELTON 434500.                           52401
SO                                                                                              1
**WSBELTON 457600.                               0
WR516031     0.0   UNIFO19631216   1   2  0.0000                        C5160_19   C516065160001
WSBELTON 434500.                           52401
SO                                                                                              1
**WSBELTON 457600.                               0
**
**  Calculate the total streamflow depletion in the first simulation/base run for water right 2936 and 5160.
WR5160CI                19631216                                Compute Dep 5160  SYSTEM
TO     6     1.0     ADD                                         C2936_1    CONT
TO     6     1.0     ADD                                         C2936_2    CONT
TO     6     1.0     ADD                                         C5160_1    CONT
TO     6     1.0     ADD                                         C5160_2    CONT
TO     6     1.0     ADD                                         C5160_3    CONT
TO     6     1.0     ADD                                         C5160_4    CONT
TO     6     1.0     ADD                                         C5160_5    CONT
TO     6     1.0     ADD                                         C5160_6    CONT
TO     6     1.0     ADD                                         C5160_7    CONT
TO     6     1.0     ADD                                         C5160_8    CONT
TO     6     1.0     ADD                                         C5160_9    CONT
TO     6     1.0     ADD                                        C5160_10    CONT
TO     6     1.0     ADD                                        C5160_11    CONT
TO     6     1.0     ADD                                        C5160_12    CONT
TO     6     1.0     ADD                                        C5160_13    CONT
TO     6     1.0     ADD                                        C5160_14    CONT
TO     6     1.0     ADD                                        C5160_15    CONT
TO     6     1.0     ADD                                        C5160_16    CONT
TO     6     1.0     ADD                                        C5160_17    CONT
TO     6     1.0     ADD                                        C5160_18    CONT
TO     6     1.0     ADD                                        C5160_19
SO                                                                                              4
**
**  From an imaginary point, divert an amount equal to the total streamflow depletions in the first simulation/base run
in the second simulation.
**   The diversion will be limited by the previous diversion.
WR5160CI 9999999        19631216                                  Depletion 5160  SYSTEM
SO                                                                                              5
**
```

```
**  From the river, divert the lumped streamflow depletion from the first simulation/base run (using the previous
diversion).
WR516031                19631216          1.0000  5160DP         Lumped Dep 5160  SYSTEM
TO     6     1.0     ADD                                 Depletion 5160
SO                                                                                                      2
**
**  END MODELING OF LAKE BELTON
**




**
**  EC MODIFIED STILLHOUSE HOLLOW'S STORAGE TO MATCH CORPS SUPER SUMMARIES AND USED DUAL SIMULATION TO MODEL SYSTEM
OPERATIONS
**    First simulation determines the amount of streamflow depleted in the base run.
WR516131   6973.    MUN319631216   1   4  RBLSH1  102051                C5161_1   C516165161001
WSSTLHSE 226063.                              30
SO                                                                                                      1
**WSSTLHSE 235700.                              0
WR516131   2092.    MUN319631216   1   2  0.0000                         C5161_2   C516165161001
WSSTLHSE 226063.                              30
SO                                                                                                      1
**WSSTLHSE 235700.                              0
WR516131   4880.    MUN319631216   1   2  0.0000                         C5161_3   C516165161001
WSSTLHSE 226063.                              30
SO                                                                                                      1
**WSSTLHSE 235700.                              0
WR516131  53823.    MUN319631216   1   2  0.0000                         C5161_4   C516165161001
WSSTLHSE 226063.                              30
SO                                                                                                      1
**WSSTLHSE 235700.                              0
WR516131      0.    IND319631216   1   2  0.0000                         C5161_5   C516165161001
WSSTLHSE 226063.                              30
SO                                                                                                      1
**WSSTLHSE 235700.                              0
WR516131      0.    MIN319631216   1   2  0.0000                         C5161_6   C516165161001
WSSTLHSE 226063.                              30
SO                                                                                                      1
**WSSTLHSE 235700.                              0
WR516131      0.    IRR319631216   1   2  0.0000                         C5161_7   C516165161001
WSSTLHSE 226063.                              30
SO                                                                                                      1
**WSSTLHSE 235700.                              0
**
**  Calculate the total streamflow depletion in the first simulation/base run for water right 5161.
```

```
WR5161CI                19631216                                Compute Dep 5161  SYSTEM
TO     6     1.0     ADD                                         C5161_1    CONT
TO     6     1.0     ADD                                         C5161_2    CONT
TO     6     1.0     ADD                                         C5161_3    CONT
TO     6     1.0     ADD                                         C5161_4    CONT
TO     6     1.0     ADD                                         C5161_5    CONT
TO     6     1.0     ADD                                         C5161_6    CONT
TO     6     1.0     ADD                                         C5161_7
SO                                                                                                    4
**
**  From an imaginary point, divert an amount equal to the total streamflow depletions in the first simulation/base run
in the second simulation.
**   The diversion will be limited by the previous diversion.
WR5161CI 9999999        19631216                                  Depletion 5161  SYSTEM
SO                                                                                                    5
**
**  From the river, divert the lumped streamflow depletion from the first simulation/base run (using the previous
diversion).
WR516131                19631216          1.0000  5161DP         Lumped Dep 5161  SYSTEM
TO     6     1.0     ADD                                  Depletion 5161
SO                                                                                                    2
**
**  END MODELING OF LAKE STILLHOUSE HOLLOW
**



**
**  EC MODIFIED GEORGETOWN'S STORAGE TO MATCH CORPS SUPER SUMMARIES AND USED DUAL SIMULATION TO MODEL SYSTEM OPERATIONS
**    First simulation determines the amount of streamflow depleted in the base run.
WR516231   4764.    MUN319680212   1   4  R51621  104893                 C5162_1   C516265162001
WSGRGTWN  37010.                             24
SO                                                                                                    1
**WSGRGTWN  37100.                              0
WR516231   2041.    MUN319680212   1   4  R51621  104892                 C5162_2   C516265162001
WSGRGTWN  37010.                             24
SO                                                                                                    1
**WSGRGTWN  37100.                              0
WR516231   3198.    MUN319680212   1   4  R51621  102641                 C5162_3   C516265162001
WSGRGTWN  37010.                             24
SO                                                                                                    1
**WSGRGTWN  37100.                              0
WR516231   3607.    MUN319680212   1   4  R51621  102642                 C5162_4   C516265162001
WSGRGTWN  37010.                             24
SO                                                                                                    1
```

```
**WSGRGTWN  37100.                              0
WR516231      0.    IND319680212   1   2  0.0000                        C5162_5   C516265162001
WSGRGTWN  37010.                            24
SO                                                                                                    1
**WSGRGTWN  37100.                              0
WR516231      0.    MIN319680212   1   2  0.0000                        C5162_6   C516265162001
WSGRGTWN  37010.                            24
SO                                                                                                    1
**WSGRGTWN  37100.                              0
WR516231      0.    IRR319680212   1   2  0.0000                        C5162_7   C516265162001
WSGRGTWN  37010.                            24
SO                                                                                                    1
**WSGRGTWN  37100.                              0
**
**  Calculate the total streamflow depletion in the first simulation/base run for water right 5162.
WR5162CI                19680212                                Compute Dep 5162  SYSTEM
TO     6     1.0     ADD                                         C5162_1    CONT
TO     6     1.0     ADD                                         C5162_2    CONT
TO     6     1.0     ADD                                         C5162_3    CONT
TO     6     1.0     ADD                                         C5162_4    CONT
TO     6     1.0     ADD                                         C5162_5    CONT
TO     6     1.0     ADD                                         C5162_6    CONT
TO     6     1.0     ADD                                         C5162_7
SO                                                                                                    4
**
**  From an imaginary point, divert an amount equal to the total streamflow depletions in the first simulation/base run
in the second simulation.
**   The diversion will be limited by the previous diversion.
WR5162CI 9999999        19680212                                  Depletion 5162  SYSTEM
SO                                                                                                    5
**
**  From the river, divert the lumped streamflow depletion from the first simulation/base run (using the previous
diversion).
WR516231                19680212          1.0000  5162DP         Lumped Dep 5162  SYSTEM
TO     6     1.0     ADD                                  Depletion 5162
SO                                                                                                    2
**
**  END MODELING OF LAKE GEORGETOWN.
**

**
```

```
**  EC MODIFIED GRANGER'S STORAGE TO MATCH CORPS SUPER SUMMARIES AND USED DUAL SIMULATION TO MODEL SYSTEM OPERATIONS
**    First simulation determines the amount of streamflow depleted in the base run.
WR516331   6566.    MUN319680212   1   4  R51631                         C5163_1   C516365163001
WSGRNGER  52525.                         1
SO                                                                                                     1
**WSGRNGER  65500.                         0
WR516331   6721.    MUN319680212   1   4  R51631  102991                 C5163_2   C516365163001
WSGRNGER  52525.                         1
SO                                                                                                     1
**WSGRNGER  65500.                         0
WR516331   5659.    IND319680212   1   2  0.0000                         C5163_3   C516365163001
WSGRNGER  52525.                         1
SO                                                                                                     1
**WSGRNGER  65500.                         0
WR516331      0.    IND319680212   1   2  0.0000                         C5163_4   C516365163001
WSGRNGER  52525.                         1
SO                                                                                                     1
**WSGRNGER  65500.                         0
WR516331     20.    MIN319680212   1   2  0.0000                         C5163_5   C516365163001
WSGRNGER  52525.                         1
SO                                                                                                     1
**WSGRNGER  65500.                         0
WR516331    874.    IRR319680212   1   2  0.0000                         C5163_6   C516365163001
WSGRNGER  52525.                         1
SO                                                                                                     1
**WSGRNGER  65500.                         0
**
**  Calculate the total streamflow depletion in the first simulation/base run for water right 5163.
WR5163CI               19680212                                Compute Dep 5163  SYSTEM
TO     6     1.0     ADD                                        C5163_1    CONT
TO     6     1.0     ADD                                        C5163_2    CONT
TO     6     1.0     ADD                                        C5163_3    CONT
TO     6     1.0     ADD                                        C5163_4    CONT
TO     6     1.0     ADD                                        C5163_5    CONT
TO     6     1.0     ADD                                        C5163_6
SO                                                                                                     4
**
**  From an imaginary point, divert an amount equal to the total streamflow depletions in the first simulation/base run
in the second simulation.
**   The diversion will be limited by the previous diversion.
WR5163CI 9999999        19680212                                  Depletion 5163  SYSTEM
SO                                                                                                     5
**
**  From the river, divert the lumped streamflow depletion from the first simulation/base run (using the previous
diversion).
```

```
WR516331                19680212          1.0000  5163DP         Lumped Dep 5163  SYSTEM
TO     6     1.0     ADD                                  Depletion 5163
SO                                                                                              2
**  END MODELING OF LAKE GRANGER
**






************** SYSTEM OPERATIONS MODELING ************************************
**  EC MODIFICATIONS
**  STSTEM OPERATION MODELING WITH REALLOCATION STARTS HERE
**  EC ADDED THE FOLLOWING SYSTEM OPERATION MODELING IN THE SECOND SIMULATION FOR PROCTOR, BELTON, STILLHOUSE,
GEORGETOWN, AND GRANGER.
**
**  Refill reservoirs with water from the first simulation/base case.
WR515931      0.        21111111                                       C5159_RF1  SYSTEM
WSPRCTOR 104900.                          5366
SO                        5159DP                                                                2
WR516031     0.0        21111111                                       C5160_RF1  SYSTEM
WSBELTON 483440.                         52401
SO                        5160DP                                                                2
WR516131      0.        21111111                                       C5161_RF1  SYSTEM
WSSTLHSE 275361.                            30
SO                        5161DP                                                                2
WR516231      0.        21111111                                       C5162_RF1  SYSTEM
WSGRGTWN  54505.                            24
SO                        5162DP                                                                2
WR516331      0.        21111111                                       C5163_RF1  SYSTEM
WSGRNGER  82187.                             1
SO                        5163DP                                                                2
**
**  Return flow from dummy control points to river basin.
WR5159DP 999999.        22222222          1.0000  515931            C5159_DPRETQ  SYSTEM
SO                                                                                              2
WR5160DP 999999.        22222222          1.0000  516031            C5160_DPRETQ  SYSTEM
SO                                                                                              2
WR5161DP 999999.        22222222          1.0000  516131            C5161_DPRETQ  SYSTEM
SO                                                                                              2
WR5162DP 999999.        22222222          1.0000  516231            C5162_DPRETQ  SYSTEM
SO                                                                                              2
WR5163DP 999999.        22222222          1.0000  516331            C5163_DPRETQ  SYSTEM
SO                                                                                              2
```

```
**
**  Refill reservoirs with unappropriated streamflow.
WR515931      0.        33333333                                          C5159_RF2  SYSTEM
WSPRCTOR 104900.                           5366
SO                                                                                                     2
WR516031     0.0        33333333                                          C5160_RF2  SYSTEM
WSBELTON 483440.                          52401
SO                                                                                                     2
WR516131      0.        33333333                                          C5161_RF2  SYSTEM
WSSTLHSE 275361.                             30
SO                                                                                                     2
WR516231      0.        33333333                                          C5162_RF2  SYSTEM
WSGRGTWN  54505.                             24
SO                                                                                                     2
WR516331      0.        33333333                                          C5163_RF2  SYSTEM
WSGRNGER  82187.                              1
SO                                                                                                     2
**
**  System diversion at the Little River at Cameron USGS gage.
WRLRCA58      0.    MUN344444444   2                                    SYSTEM_LRCA  SYSTEM
WSGRNGER  82187.                              1
WSGRGTWN  54505.                             24
WSSTLHSE 275361.                             30
WSBELTON 483440.                          52401
WSPRCTOR 104900.                           5366
SO                                                                                                     2
**
** Final refill of reservoirs.
WR515931      0.        55555555                                          C5159_RF3  SYSTEM
WSPRCTOR 104900.                           5366
SO                                                                                                     2
WR516031     0.0        55555555                                          C5160_RF3  SYSTEM
WSBELTON 483440.                          52401
SO                                                                                                     2
WR516131      0.        55555555                                          C5161_RF3  SYSTEM
WSSTLHSE 275361.                             30
SO                                                                                                     2
WR516231      0.        55555555                                          C5162_RF3  SYSTEM
WSGRGTWN  54505.                             24
SO                                                                                                     2
WR516331      0.        55555555                                          C5163_RF3  SYSTEM
WSGRNGER  82187.                              1
SO                                                                                                     2
**
****************************** END OF SYSTEM OPERATION MODELING ****************************************
```

```
**  EC ADDED - UPDATED SA/SV RECORDS TO MOST RECENT SURVEYS
**  EC RECONSTRUCTED SA/SV RECORD FOR BELTON LAKE BASED UPON TWDB 1994 SURVEY AS PROVIDED BY CORPS OF ENGINEERS
SVBELTON      0.     49.    197.   1192.   2013.  20962.  58558. 126330. 222430. 302090. 447055. 513015.
SA            0.     23.     57.    220.    325.   1651.   3194.   5238.   7890.   9809.  12688.  13660.
**  EC RECONSTRUCTED SA/SV RECORD FOR LAKE GEORGETOWN BASED UPON TWDB 1995 SURVEY AS PROVIDED BY CORPS OF ENGINEERS
SVGRGTWN      0.    114.    300.    697.   1299.   3159.   4789.   8200.  13480.  24388.  43970.  55380.
SA            0.     27.     68.    127.    177.    286.    363.    498.    681.    998.   1490.   1770.
**  EC RECONSTRUCTED SA/SV RECORD FOR GRANGER LAKE BASED UPON TWDB 2002 SURVEY AS PROVIDED BY CORPS OF ENGINEERS
SVGRNGER      0.     14.    191.   1355.   3475.   6064.  12384.  26215.  44749.  66525.  77045.  82690.
SA            0.     24.     99.    332.    740.    993.   1531.   2514.   3675.   5020.   5500.   5789.
**  EC RECONSTRUCTED SA/SV RECORD FOR LAKE PROCTOR BASED UPON TWDB 2002 SURVEY AS PROVIDED BY CORPS OF ENGINEERS
SVPRCTOR      0.      2.     54.    282.   1234.   3408.   7737.  13930.  28996.  55457.  75722. 106212.
SA            0.      9.    122.    322.    601.    884.   1333.   1756.   2555.   4537.   5520.   6680.
**  EC RECONSTRUCTED SA/SV RECORD FOR LAKE STILLHOUSE BASED UPON TWDB 1995 SURVEY AS PROVIDED BY CORPS OF ENGINEERS
SVSTLHSE      0.     17.    452.   3041.   9214.  13828.  39250.  68006. 101285. 163675. 226063. 281193.
SA            0.      5.    127.    339.    668.    884.   1831.   2631.   3443.   4991.   6429.   7349.
```

Appendix E
TWDB Comments to Draft Report

ATTACHMENT 1

TEXAS WATER DEVELOPMENT BOARD
Contract No. 2004-483-533
Review of Draft Report entitled "Reallocation of Storage in Federal Reservoirs for Future Water Supply"

1. The Draft Report needs an Executive Summary section at the beginning of the report (including a conclusions summary subsection within it).

2. Please clarify how the instream flow/environmental flow requirements are considered when determining the yield.

3. Address, or if addressed then clearly describe how the following components in Task 1 were addressed:
   Subtask a.
   - Cost of relocated facilities
   - Real estate requirements

   Subtask b.
   - Incorporation of reallocated water supply into the WAM

   Subtask c.
   - Decision flow chart

4. The Report must include an examination and guidance document for *Flood Control Impacts, both upstream and downstream*, as required by Task 1 part a.

5. Include criteria for estimating additional water supply availability for *congressional level* reallocation with flood storage capacity *over the discretionary limit of 50,000 ac-ft*, as required by Task 2 part a.

6. Section 3.3 should also discuss impacts, if any, to changes in the flood control aspects of the reservoir due to reductions in flood storage.

7. Please include information on the investigation and document on other potential benefits of storage reallocation as required in Task 4 of the Scope of Work.

8. Include the results of Task 1 as required by Task 4, part a (*The results of Tasks 1, 2 and 3 will be applied in Brazos River Basin*). For example, *flood control, dam safety or shoreline erosion impacts and agreements*.

9. List the advantages and disadvantages of storage reallocation as required in Task 5.

10. Provide an initial estimate of additional water that could be achieved if the storage in federal reservoirs over 25,000 ac-ft in Texas were reallocated to water supply and how that additional water relates to the overall demands in the State as required in Task 5." Table 1 of the Draft Report provides current Dependable Yield values and estimated Dependable Yield values with reallocation for individual reservoirs. Include a state-wide estimate of additional water that

could be achieved by reallocation of federal reservoirs and the relationship to overall demands in the State.

11. Report body itself needs a conclusion section.

12. Report needs an overall methodology/assumptions section.

13. Please identify whether any additional modifications (customizations) that were made to the WAM models beyond those specifically described in the report body, if applicable.

14. Clarify which WAM model version or version generation was used to perform analyses.

15. Please include the following in the Report:
    a. A summary report and decision flowchart to help determine the feasibility of reallocating storage in federal reservoirs.
    b. An estimate of the total amount of water available from reallocation of all federal reservoirs in Texas. Table 1 in the report is inadequate for this purpose.

The following comments are from the Texas Commission on Environmental Quality (TCEQ) and include a copy of a memo provided to the Consultants by TCEQ because the draft report comments refer to the memo.

TCEQ Memo

Issues regarding Reallocation in federal reservoirs:

Hydrology Issues

1. Water Availability:

a. Reallocation could be submitted as a new application or as an amendment to an existing authorization in the same reservoir.

b. Priority date of the application. The application will have a new priority date, which is the filing date of the application. The additional reallocated water would be considered a new appropriation of water and will be subject to availability criteria. Note that in most circumstances, the application will be modeled such that depletions of storage caused by the new water right cannot be refilled at a senior priority date (DUAL SIM option) and this will be included as a special condition in the permit.

c. If, after reallocation, multiple users under different water rights will own conservation storage, or, if the storage in the reservoir has multiple priority dates, an accounting plan/water balance that includes the proposed priority order of diversions may be required before a permit authorizing diversion of additional water could be issued. The accounting plan must be detailed enough so that staff can evaluate the plan to determine whether the operation will affect senior and superior water rights. TCEQ cannot grant a new authorization that could affect downstream water rights.

d. How will sediment storage be accounted for? There may have been a sediment estimate for the entire flood pool when the reservoir was originally constructed. The application must include the pro-rated sediment storage, if any, that would apply to the reallocation of that flood storage. Additionally, issues relating to the sediment reserve in the conservation pool and allocation of that sediment reserve among the water right owners in the reservoir should be addressed in any application for reallocated storage as this could affect the water availability analysis.

e. If the reallocated storage will be used as part of a system operation with reservoirs authorized under other permits, the accounting plan should include any/all other reservoirs and also include any/all other diversions from those reservoirs.

f. Some USACE contracts require dependable yield mitigation storage. It is our understanding that dependable yield mitigation storage is considered when flood control storage is reallocated. When flood storage is reallocated, existing water users with contracts for dependable yield could be affected. So, the new user would be required to purchase not only storage required for their own use, but a portion of the storage required to mitigate effects on other water users. The total amount of storage, including any dependable yield mitigation storage must be specified in the application.

Permitting Issues
1. Documentation of any agreements/contracts with the USACE (or other federal sponsor) must be provided.

2. Documentation that proposed reservoir operations for the new water use would be consistent with federal operating plans, the rights/operations of other permit holders owning water in the reservoir and operations of other reservoirs that could be affected.

Environmental Issues
1. The application could be subject to environmental requirements over and above those required by federal agencies.

2. What effect would the reallocation and/or changed operating rules for flood releases have on instream flows downstream of the reservoir?

3. What effect would the reallocation and/or changed operating rules for flood releases have on freshwater inflows to bays and estuaries?

Other comments
1. In regards to the issue of subordination of hydropower rights, we are only aware of one reservoir (Toledo Bend reservoir) that includes a separate authorization for hydropower use. In other reservoirs in Texas either the hydropower is not permitted (federal) or hydropower use is incidental to releases from a particular reservoir for other uses. Therefore, a request for hydropower subordination would be considered as a request to subordinate the other authorized uses as well.

TCEQ Draft Report Comments:

1. Please expand on the need for a reservoir accounting plan and emphasize that some detail would be required, for instance the need to allocate evaporation depths among the priority pools. Also, the accounting plan would not just be required if there were multiple users with different priority dates, the accounting plan would be required if there was a single user with multiple priority dates, or multiple users with the same priority dates. If the reservoir were part of a system operation plan, an accounting plan would also be required.

2. Although issues related to reallocation of sediment storage were discussed in the section on federal requirements, certain information would be required to be submitted as part of the state permitting process as well. Reference TCEQ memo Item #d under Hydrology Issues (attached).

3. Some proposed reallocation projects involve reallocation of the hydropower pool. These types of reallocations involve a separate set of issues (see Other Comments in the TCEQ memo) and this should be mentioned in the report).

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4. In the references section, please cite the TCEQ memo as follows (this document was produced by the Team and forwarded by Kathy Alexander): Surface Water Availability and Interstate Compacts Team, Texas Commission on Environmental Quality. "Issues related to reallocation of flood control storage in federal reservoirs." E-mail to David Harkins from Kathy Alexander. 6 June 2005.

5. It should be noted more explicitly in the report that the assumptions used in generating firm yields using the SUPER model are different than those that would be used in the Texas permitting framework. For example, in Texas, prior appropriation does not permit the most upstream reservoir to impound the area daily accumulated local flows, unless that reservoir is the senior water right in the basin. Thus, the firm yield values (Texas permitting framework vs. USACE model) are sometimes in conflict. The guidance document should perhaps emphasize this aspect so future applicants requesting new appropriations of state water are not caught unaware.

6. Task 3(c) indicates that the modeling scenarios would be performed using the WAM that is currently used by TCEQ. The TCEQ Brazos WAM was not used for this analysis.

7. After reviewing the WAM code in Appendix B, it appears that only a five year period was used for the flows. The report contains little specificity as to how the flows were developed, stating that "data similar to naturalized flows" (Draft Report Page 18) were used. Do the modified flows represent a drought sequence, which should be the case if one is calculating firm yields? Were gaged and not naturalized flows used? The report mentions that the flows "were chosen to provide the natural fluctuation of real world hydrology". Expanded discussion of how the flows were developed and whether the flows are representative of a drought sequence (necessary to calculate a firm yield) should be included in the text.

8. For the virtual model (Task 3), the method used for determining water available for the new water right (based on reallocation) is inconsistent with Texas' prior appropriation requirements (See page 54 of Appendix B). The model should have been run using the Dual Simulation approach, or in the alternative using TS records to limit depletions from the senior portion of each reservoir to only the amount that could have been impounded if the junior depletions and storage did not exist. This is to make sure that the water right associated with the senior reservoir cannot make priority calls to ref ill reservoir storage depleted by the junior priority diversions. This is also mentioned as Item #b under Hydrology Issues in the TCEQ memo.

9. The text (5.3) states that the second simulation (modeling system operations) was performed by modeling releases from reservoir storage to a downstream control point. The model code for this simulation is not included in the Appendix and it would be useful to include it for evaluation purposes. It is difficult to evaluate the technical information provided because the appendices do not contain enough of the WAM code to make the evaluation.

10. The modeling procedures for the virtual model are inconsistent with the modeling procedures used for the case study (Section 6.1). See comment 8. The case study uses a more correct approach, but why was the most updated version of the WAM code (Dual simulation) not used for this study for both the virtual reservoirs and the case study?

11. The final item in Task 4 (Scope of Work) does not appear to have been accomplished. Modeling the system operations of the reservoirs by a firm diversion based on releases from storage (where weighting factors, multipliers or other methods of analysis that ensure utilization of all interruptible water are not used) is not equivalent to an analysis of utilizing interruptible water transferred by pipeline from other reservoirs.

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12. Task 4 indicates that the existing WAM developed by the TCEQ would be used. Based on the information in Appendices C and D, it is unclear whether this was done. If different flows and different modeling assumptions were used for the reservoirs, then the model should not be referred to as the TCEQ WAM because those assumptions (in particular those used by the USACE SUPER model) are inconsistent with prior appropriation. It is also unclear whether other alterations were made to the model. This information should be included explicitly so that the report results can be replicated.

13. Was any analysis performed to evaluate the effects of the system operation on other water rights in the basin? If there were any measurable effects additional modeling would need to be done to mitigate the effect. If there were no effects, this should be stated in the text. This type of analysis would be one of the basic components of a water availability assessment for an application for either reallocation and/or system operations.

14. It appears that no environmental flow restrictions were included in either the virtual model or the case study runs. At minimum, a Lyon's value or the consensus based criteria should be used to limit diversions and/or impoundment of additional water at the reservoirs and/or limit diversions at the downstream point in the analysis for the second, third and fourth simulations for both the virtual simulation and the case studies. This is because inclusion of environmental restrictions would likely affect the results of the firm yield analysis. The report indicates correctly on page 11, Section 3.3.1, that the reallocation is subject to environmental limits and that including an environmental flow analysis as part of the application would be helpful.