Quivira National Wildlife Refuge

Water Resource Study

Prepared for

U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

1998

97-806-4

GEI Consultants, Inc.
Water Resources, Environmental, Geotechnical Engineering

Burns & McDonnell

QUIVIRA NWR WATER RESOURCES STUDY
TABLE OF CONTENTS

List Of Tables

List Of Figures

On or Follows **Page No.**

ACRONYMS

ASR	Aquifer Storage and Recovery
cfs	cubic feet per second
Corps	U.S. Army Corps of Engineers
CRP	Conservation Reserve Program
EPA	U.S. Environmental Protection Agency
GMD5	Big Bend Groundwater Management District No. 5
gpm	gallons per minute
KDHE	Kansas Department of Health and Environment
KDWP	Kansas Department of Wildlife and Parks
KDWR	Kansas Board of Agriculture - Division of Water Resources
KGS	Kansas Geological Survey
KWO	Kansas Water Office
MDS	minimum desired streamflow
MG	million gallons
MGD	million gallons per day
NRCS	Natural Resource Conservation Service
NWR	National Wildlife Refuge
O&M	operation and maintenance
OMR&E	operation, maintenance, replacement and energy
PET	Potential Evapotranspiration
PI	Plasticity Index
Refuge	Quivira National Wildlife Refuge
Service	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WaterPACK	Water Protection Association of Central Kansas

EXECUTIVE SUMMARY

This summary presents an overview of the Water Resources Study for the Quivira National Wildlife Refuge (Refuge). This study was performed for the U.S. Fish and Wildlife Service (Service) by Burns & McDonnell, Inc under Contract No. 1448-60181-97-C126. Discussed briefly below are the study objectives and the five specific tasks requested by the Service in their contract scope of work.

A. STUDY OBJECTIVES AND TASKS

The Refuge—located in Stafford and Rice counties in south-central Kansas—is a 32-square mile area of naturally occurring marshes, ponds and uplands that provides a variety of habitat for endangered species, waterfowl and wildlife. It has been altered by constructed canals and dikes that distribute water supplied by Rattlesnake Creek and groundwater upwelling. The Refuge water supply is highly variable, being too high on occasion in the spring and too low later in the growing season.

The Service has asked Burns & McDonnell to assist them by performing this Water Resource Study for the Refuge. The principle objectives of the study is to identify and evaluate structural and nonstructural options for implementing the most efficient and effective use of the available water resources.

The study tasks include:

- Task A—Identify and evaluate possible reservoir sites upstream of the Refuge which could store water in high flow periods for later release to meet Refuge demands and help maintain the State of Kansas' minimum desirable streamflow (MDS).
- Task B—Identify management strategies for using the Great Bend Prairie Aquifer as a storage reservoir.
- Task C—Identify and evaluate alternatives to provide additional operational flexibility for the Refuge's water diversion and conveyance system.

- Task D—Develop a computer model capable of quantifying the groundwater component that helps maintain surface water in Refuge units, particularly the Big Salt Marsh.
- Task E—Compare the alternatives evaluated in the preceding four tasks and make a recommendation for one or more of the water supply alternatives evaluated.

B. BACKGROUND INFORMATION

The investigation of these tasks was initiated after the background information was obtained and reviewed, the major evaluation criteria were selected, an operations model was developed, and the net water needs and the habitat availability on the Refuge were estimated. Background information reviewed and evaluated included:

- Geology
- Hydrogeology
- Water rights
- Water quality
- Environmental resources
- Cultural resources
- SWATMOD model

The review and evaluation of this background information for the Refuge and the Rattlesnake Creek Basin set the stage for the various analyses that followed. This review included the SWATMOD model that was developed for the Kansas Department of Water Resources, in concert with the Service, by the Kansas Geological Survey and Kansas State University. Data were obtained from and coordination maintained with various state, federal and local agencies for the duration of the water supply study. Data and information gathered as background were used to develop the evaluation criteria. Background information collected for the Refuge and Rattlesnake Creek Basin are summarized in Part I of this report.

C. EVALUATION CRITERIA

Burns & McDonnell's project team, in concert with the Service, developed criteria which were used to measure each alternative's beneficial and adverse features. As described in Part II, the major evaluation criteria used to select viable alternatives and guide the decision-making process are:

- Water supply capability
- Water quality
- Legal issues
- Policy and political issues
- Future availability
- Environmental issues
- Wetland habitat enhancement
- Cost estimates and economic comparisons

Each of these criteria could play an important role in the evaluation of an alternative's potential. For example, each water supply alternative must have the capability to supply all or part of the estimated water need. Water quality could become an issue if water treatment is required. Application of the Kansas Water Transfer Act guidelines may restrict intrabasin water transfers. Purchasing water rights from groundwater irrigators could become an politically sensitive issue. The future availability of a water supply may directly be tied to the Service's ability to implement the plan in a timely manner. An environmental "deficiency" or "fatal flaw" may be found. Wetland habitat on the Refuge should not be decreased by a water supply alternative, and would be a "fatal flaw" if threatened or endangered species habitat on the Refuge would be adversely impacted. Economic viability would be instrumental in the selection of an alternative.

D. OPERATIONS MODEL

An operations model of the Refuge and the Rattlesnake Creek Basin was developed to evaluate current conditions, the effectiveness of potential supplemental water supplies and other modifications at the Refuge. The model, which is described in Part III, simulates Refuge operation under current and proposed future conditions. Burns & McDonnell's Reservoir Network (RESNET) computer model was used to develop the operations model for the Refuge and the basin. The model is capable of simulating very complex stream and reservoir systems due to its network architecture. Since the model represents the system to be simulated as a circulating network, network solution techniques are used to optimize allocation of available water resources.

Since some of the alternatives being considered in this study include the development of off-site water supplies, the base operations model for the Refuge must be capable of simulating operation of the entire Rattlesnake Creek Basin.

E. REFUGE NET WATER NEEDS AND HABITAT AVAILABILITY

The water needs for the Refuge and the availability of wetland habitat for wildlife are established in Part IV. Net water needs are based on a comparison of operations modeling for the Refuge under baseline conditions and an ultimate water use scenario. The operations model includes physical data and desired operating criteria for the Refuge as reported by the Service.

Water for the Refuge is diverted from three points on Rattlesnake Creek—Little Salt Marsh, Darrynane Lake, and Rattlesnake Canal. Using the operations model, the median monthly diversion to the Refuge is about 450 acre-feet under existing conditions while the needed diversion amount is about 1,300 acre-feet per month.

Diverted waters are primarily used to create wetland habitat for shorebirds and waterfowl on the Refuge. The amount of available wetland habitat on the Refuge is considered to be a good measure of project benefits. Baseline conditions show that about 1,400 acres of wetland habitat are present on the Refuge 80 percent of the time but wetland habitat may increase to as much as 2,800 acres in a high water year. With additional water supplies, the amount of available wetland habitat can more than double to 5,800 acres.

F. TASK A - RESERVOIR SITING

Potential reservoir sites that could store water in high flow periods for later release to meet Refuge water demands and help maintain Kansas MDS requirements were initially identified using available mapping. As described in Part V, these potential sites are then screened using engineering and environmental criteria. Sites carried forward are examined in more detail using estimated potential yields and costs.

A total of 18 potential reservoir sites were identified in the Rattlesnake Creek Basin. These sites were screened in the field following review of each reservoir site by the project team. Nine of the potential sites were eliminated because of wetland presence, economics in terms of construction and oil and gas relocation costs, or other environmental parameters such as the presence of threatened or endangered species or cultural resources likely occurring. Four other reservoir sites were eliminated due to high water conveyance losses, the need for residential relocations, and their long distance from the Refuge.

All five of the remaining reservoirs were only marginally successful in providing a supplemental water supply to the Refuge when needed. In drier years, all of the water available for diversion from Rattlesnake Creek must be used directly on the Refuge, leaving no water available for storage in an upstream reservoir. Only in wet years, when supplemental water supplies are least valuable, can significant amounts of water be captured for reservoir storage. In addition, each of the potential reservoir alternatives either reduce wetland habitat on the Refuge or leave it unchanged.

Project construction costs range from a low of $1.4 million to a high of $18.0 million. Annual operation, maintenance, replacement and energy (OMR&E) costs range between $9,000 and $115,000 per year. Since none of these reservoir alternatives are capable of providing a reliable supplemental water supply to the Refuge, these alternatives have negligible benefits and corresponding benefit-cost ratios near zero. Cost data for the five reservoir alternatives are summarized in Table ES-1. Due to their limited benefits, none of the five potential reservoir alternatives warrant further consideration.

Table ES-1
SUMMARY OF ECONOMIC DATA FOR TASK A ALTERNATIVES

Reservoir Site	Construction Cost[1] ($ million)	Annual OMR&E Cost[2] ($/yr)	Benefit-Cost Ratio
1	1.4	9,000	0.00
2	13.1	83,600	-0.01
3	18.0	115,500	-0.01
6	14.0	88,200	-0.02
8	3.8	24,700	0.01

Note: 1. Costs in year 1998 dollars.
2. Costs in year 2000 dollars.

G. TASK B - AQUIFER RECHARGE

Two approaches for aquifer recharge in the Rattlesnake Creek Basin are considered in Task B (Part VI of this report):

- Conventional aquifer storage and recovery (ASR) for specific Refuge use where water is captured from available sources and stored in an aquifer for future use; water is recovered when needed by wells and delivered to the Refuge for use
- Enhancing natural recharge in the basin with the objective of raising groundwater levels that will increase the base flow in the creek; increased base flow could result in additional water supply to the Refuge.

Five aquifer storage locations suitable for ASR development were identified. These areas have experienced large groundwater level drawdowns, leaving a large portion of the aquifer's storage capacity available for recharge. As before, the water source is Rattlesnake Creek and the water available for storage are higher flows or above-base flows. Since high volume flow events in the basin are generally of short duration, large capacity diversion, treatment and storage facilities are required. Due to the potential for high conveyance loses, only one of the five aquifer storage locations—the one closest to the Refuge—was selected for detailed evaluation.

Water quality for Rattlesnake Creek is limited. Based on this limited data, the recharge water could degrade ambient groundwater quality. As a result, water treatment could be required to satisfy the State of Kansas' antidegradation policy for groundwater recharge. Captured water will also have to be monitored for the presence of pesticides and other potential contaminants.

The aquifer recharge and recovery alternative in the Rattlesnake Creek Basin is only marginally successful. In drier years, once again, all of the available water in Rattlesnake Creek must be used directly on the Refuge, leaving no water available for recharge. Only in wetter years can significant amounts of water be captured for aquifer recharge. Once captured, water stored can be withdrawn at a later date to supplement the supply to the Refuge. However, any water stored in the aquifer is exhausted rapidly and provides supplemental water to the Refuge for only a few months into the next period with average or less streamflow. In addition, little if any additional wetland habitat is developed on the Refuge by implementing an aquifer recharge alternative.

The estimated project cost for the ASR alternative is $17.0 million. Operation and maintenance costs are estimated to be $252,000 and energy is estimated to add another $300,000 annually. The benefit-cost analysis estimated a ratio of 0.03, well under the break-even point of 1.0. Aquifer recharge should not be pursued further in this investigation.

H. TASK C - REFUGE ALTERNATIVES

For Task C of the study, eight on-site and two off-site water management alternatives are evaluated for the Refuge. These alternatives, which are documented in Part VII of this report, include:

- Alternative 1—Raise dikes in Little Salt Marsh
- Alternative 2—Construct cross dikes in Little Salt Marsh
- Alternative 3—Develop additional water storage units
- Alternative 4—Line conveyance canals
- Alternative 5—Remove sediment from Little Salt Marsh
- Alternative 6—Construct bypass canal around Little Salt Marsh
- Alternative 7—Recontour additional areas to develop moist soil units
- Alternative 8—Fill borrow areas
- Alternative 9—Supplement water supply with Arkansas River water
- Alternative 10—Supplement water supply with groundwater wells.

Five of these alternatives (1, 2, 3, 5 and 6) would provide additional water storage and maintain existing storage on the Refuge. Alternatives 4 and 8 would conserve water for use in the management units. Alternatives 9 and 10 would provide a supplemental water supply to the Refuge. Alternative 7 would create additional management units on the Refuge. A brief description of each of these development alternatives is provided below. Economic data for each alternative are summarized in Table ES-2 at the end of this section.

1. Alternative 1—Raise Dikes in Little Salt Marsh

For Alternative 1, the dikes surrounding Little Salt Marsh are raised by two feet to increase the storage potential of the marsh by about 2,000 acre-feet. Increasing the storage capacity of the marsh allows the average water diversions to the Refuge to increase by about 7 percent, or about 500 acre-feet per year. Little impact would be seen on wetland habitat available at the Refuge 80 percent of the time. The additional storage in Little Salt Marsh can extend the length of surplus periods but cannot provide multi-year carryover storage during droughts.

2. Alternative 2—Construct Cross Dikes in Little Salt Marsh

Construction of a circular ring dike in Little Salt Marsh was considered in Alternative 2. This ring dike would increase the storage potential of the marsh, similar to Alternative 1, but would not inundate additional area. Two options were evaluated under this alternative: 1) raise the water level inside the ring dike by 2 feet, which allows this area to be filled by gravity flow; or 2) raise the water level inside the ring dike by 12 feet, which requires a pump station for filling. Development of the ring dike, and increased storage, will have only a modest impact on the amount of wetland habitat available at the Refuge 80 percent of the time. For the two scenarios described above, the 80th percentile wetland habitat would increase respectively by only 19 and 48 acres (1.4 and 3.4 percent) over the baseline value. The additional storage in Little Salt Marsh can extend the length of surplus water periods but cannot provide multi-year carryover storage during droughts.

3. Alternative 3—Develop Additional Water Storage Units

For Alternative 3, increasing the water storage capacity of five management units on the Refuge was assessed by either raising existing dikes or constructing new dikes. This additional water storage would be used for the management of downstream units. Implementation of this alternative would have no impact on the amount of wetland habitat available on the Refuge 80 percent of the time. As with most of the other storage alternatives, the additional storage provided cannot provide multi-year carryover storage during droughts.

4. Alternative 4—Line Conveyance Canals

The fourth alternative evaluated lining approximately 13 miles of major conveyance canals on the Refuge to improve the efficiency of water delivery to the various management units. Portions of the C-line, D-line, F-line, West, Rattlesnake and Darrynane Canals were to be lined. Although the quantity of optimum shorebird and waterfowl habitat are virtually unchanged, the amount of total wetland habitat available 80 percent of the time does increase by 21 acres (1.5 percent) over the baseline value. Conveyance canal water losses are highly dependent on antecedent conditions.

5. Alternative 5—Remove Sediment from Little Salt Marsh

The removal of about 100 acre-feet of accumulated sediment from Little Salt Marsh was considered in Alternative 5. This would restore the original storage capacity of the marsh. Little Salt Marsh is the first point of diversion from Rattlesnake Creek and provides the greatest volume of water storage on the Refuge. Although implementation of this alternative would increase the storage potential of the marsh slightly, it would have little impact on the available wetland habitat at the Refuge, especially during drier years when flows are reduced.

6. Alternative 6—Construct Bypass Canal Around Little Salt Marsh

The sixth alternative evaluated was the construction of a bypass canal to minimize the amount of sediment being deposited in Little Salt Marsh during flood events. Complete elimination of sediment deposition is not realistic, but the rate can be reduced by passing flood flows, which generally carry large volumes of sediment, around Little Salt Marsh. This alternative will have little impact on available wetland habitat at the Refuge. Bypasses occur during wetter periods when there is normally sufficient water available and the water bypassed is also available for diversion at Darrynane Lake and the Rattlesnake Canal.

7. Alternative 7—Recontour Additional Areas to Develop Moist Soil Units

This alternative evaluated the development of five moist soil areas by constructing one-foot high berms capable of storing 8- to 10-inches of water evenly over the entire area. Moist soil areas are filled in the spring to promote vegetation growth, allowed to dry during the summer, and filled again in the fall to provide habitat for waterfowl. Implementation of this alternative does not appreciably impact the wetland habitat at the Refuge, and does not impact the wetland habitat available on the Refuge 80 percent of the time.

8. Alternative 8—Fill Borrow Areas

The borrow areas in eight existing management units would be filled under Alternative 8. Large volumes of water fill the borrow areas before water spreads throughout each units' remaining area. Filling the borrow areas will mean less water is needed to develop various habitats in each unit. Even though the Refuge operations model was not run on this alternative, habitat areas that are available 80 percent of the time are not likely to change.

9. Alternative 9—Supplement Water Supply with Arkansas River Water

The development of a supplemental water supply for the Refuge from the Arkansas River is the subject of the ninth alternative. Water from the Arkansas River could be used on an as-available basis during and following runoff events. Four options with varying diversion capacities were evaluated under this alternative. Implementation of this alternative could have a significant impact on the amount of wetland habitat available at the Refuge 80 percent of the time resulting in 191 to 849 acres of additional habitat depending on diversion capacity. Supplemental water would be provided as needed, and Refuge personnel could manage the Refuge to provide more dependable quantity and quality of habitat.

10. Alternative 10—Supplement Water Supply with Groundwater Wells

The last alternative in Task C is the evaluation of a supplemental water supply to the Refuge using a series of wells along Rattlesnake Creek west of Little Salt Marsh. These wells would pump groundwater directly into Rattlesnake Creek, on an as-needed basis, for downstream diversion and use in Refuge management units. Five options, with varying maximum pumping capacities were evaluated for this alternative. Implementation of this alternative will have a dramatic impact on the amount of wetland habitat available at the Refuge 80 percent of the time. Depending on the total pumping capacity, the amount of wetland habitat would increase by approximately 870 to 2,770 acres(62 to 195 percent) over the baseline value.

Economic data for the ten alternatives evaluated under Task C are summarized in Table ES-2.

Table ES-2
SUMMARY OF ECONOMIC DATA FOR TASK C ALTERNATIVES

Alternative	Construction Cost[1] ($ million)	Annual OMR&E Cost[2] ($)	Benefit-Cost Ratio
1	1.4	0	0.00
2	3.3 - 8.1	0 - 48,000	0.05
3	2.3	0	0.00
4	1.9	0	0.10
5	0.9	23,900	0.05
6	3.6	0	0.00
7	1.1	0	0.00
8	0.8	0	0.00
9	7.0 - 16.9	190,000 - 880,000	0.09 - 0.29
10	1.4 - 5.3	85,000 - 200,000	3.63 - 3.91

Notes: 1. Costs in year 1998 dollars.
2. Costs in year 2000 dollars.

I. TASK D - REFUGE GROUNDWATER MODEL

A computer groundwater model was developed to quantify the subsurface flow contribution to Big Salt Marsh on the north side of the Refuge. As described in Part VIII, the model is used to quantify the area's water budget and to help evaluate alternatives for protecting the component of subsurface flow that helps maintain surface water in Big Salt Marsh. The study area boundary included the sand hills within the Rattlesnake Creek and focuses on Big Salt Marsh. MODFLOW, a U.S. Geological Survey three-dimensional, finite difference, groundwater flow model was selected for use.

The Big Salt Marsh model is developed to simulate steady-state conditions which can be viewed as annual "average" conditions. Although seasonal variations affect groundwater levels and water budgets, the steady-state model provides a good net annual water budget. The largest component is leakage from the aquifer upward into the marsh units and streams, about 98 acre-feet per day. The second component of flow is seepage from the sand hills that flows overland to the marsh, about 1 acre-foot per day.

Evapotranspiration has a much greater impact than regional pumping in lowering water level conditions in the Big Salt Marsh area. About 6 acre-feet per day is lost from the water budget due to pumping for an area around Big Salt Marsh, while evapotranspiration losses are estimated up to 43 acre-feet per day. Efforts to increase water supply to Big Salt Marsh includes methods to reduce evapotranspiration. However, the grassland habitat that currently exists in the sand hill area of the Refuge needs to be maintained.

The installation of two control structures and ditch cleaning should allow Refuge staff to improve control of flow in the Big Salt Marsh and North Flats area. A cost of about $17,000 would be incurred. Implementation of this alternative will not significantly impact water quality, since the same source of water is being used. Since implementation will not impact the available supply of water, the operations model was not used to evaluate habitat impacts.

J. TASK E - ALTERNATIVE COMPARISON

In Task E, Part IX of the study report, the alternatives evaluated in Tasks A through D are compared to identify the alternatives that are best suited to meeting the study's objectives. This was accomplished using a three-phase screening process. This process is described in the following sections.

1. Phase 1—Preliminary Alternative Screening

The first step in Phase 1 of the screening process was to develop the criteria that would be used to evaluate each of the 31 water supply or management alternatives. These criteria fall into five general categories, which are listed below along with their assigned weights.

Category	Assigned Weight
Hydrology	50
Engineering	15
Environmental	25
Socioeconomic	5
Land Use	5

These general evaluation categories were then subdivided into specific criteria that were used in the Phase 1 screening process. Each specific criteria was then allocated a portion of the total weight for their respective general category. The evaluation criteria were initially drafted by the Burns & McDonnell project team and then provided to the Service for comment.

After development of the evaluation criteria, a score between zero and ten—with zero being the least favorable and ten the most favorable—was assigned to each water supply/management alternative for each of these criteria. The product of the individual criteria scores and their respective weights were summed to yield a weighted total score for each alternative. These total scores, which ranged from a low of 136 to a high of 823, were used to identify the alternatives that were worthy of continued consideration.

The results of the Phase 1 preliminary alternative screening show that the top-rated alternatives are those that are capable of providing a supplemental water supply to the Refuge, specifically Alternatives 9 and 10 under Task C.

Review of the preliminary screening analysis also shows there is a marked distinction between on-site alternatives and off-site alternatives. Several on-site alternatives, when combined with a supplemental water supply, could enhance operation of the Refuge. Based on the preliminary screening analysis and discussions with the Service, the following on-site alternatives are carried through into Phase 3.

- Alternative 8—Fill borrow areas
- Alternative 3—Develop additional water storage units
- Alternative 1—Raise dikes in Little Salt Marsh
- Alternative 4—Line conveyance canals

2. Phase 2—Final Alternative Screening

For Phase 2 of the screening process, the three top-rated alternatives from Phase 1 were analyzed further to identify the water supply alternative with the highest development potential. These three alternatives are all options under Alternative 10, which supplement the existing water supply of the Refuge by development of groundwater wells. The only difference between these alternatives is the number of wells that would be installed. The three alternatives and their maximum monthly pumping capacity are listed below.

- Alternative 10-3—1,500 acre-feet per month
- Alternative 10-4—2,000 acre-feet per month
- Alternative 10-5—2,500 acre-feet per month

For the Phase 2 screening analysis, the operations model for the Refuge was modified to reflect management of the Refuge using the preferred moist soil management approach. Under this approach, approximately three-quarters of the existing Refuge management units were selected for management as moist soil units. With this modification, modeling showed that Alternative 10-3 provided the highest benefit-cost ratio of 3.54. For this reason, this alternative was selected as the preferred water supply alterative for the Refuge.

3. Phase 3—Water Supply Plans

Using the results of the screening under Phases 1 and 2, three water supply plans (WSP) were selected for more detailed evaluation. These three water supply plans are described below.

- WSP1—WSP1 provides for on-Refuge improvements only. The alternatives considered for implementation under this plan are those listed above, Alternatives 8, 3, 1, 4 under Task C. These alternatives would be implemented in the order listed.
- WSP 2—For WSP2, only development of a supplemental groundwater supply is included (Alternative 10-3). No on-Refuge improvements are included in this plan.
- WSP3—WSP3 is a combination of the other two plans.

The results of the Phase 3 analysis are summarized in Table ES-3.

Based on review of Table ES-3, the preferred development plan for the Refuge is WSP2. WSP2 includes development of a supplemental water supply for the Refuge by installation of groundwater wells along Rattlesnake Creek upstream of the Refuge. No on-Refuge improvements are included in WSP2.

Table ES-3
SUMMARY OF ECONOMIC DATA FOR WATER SUPPLY PLANS

Water Supply Plan	Alternative(s) Included	Construction Cost [1] ($ million)	OMR&E Cost [2] ($)	Benefit-Cost Ratio
WSP1a	8, 3	2.7	0	0.48
WSP1b	8, 3, 1	4.1	0	0.16
WSP1c	8, 3, 1, 4	6.0	0	0.18
WSP2	10-3	3.5	117,000	3.54
WSP3a	10-3, 8, 3	6.3	122,000	2.66
WSP3b	10-3, 8, 3, 1	8.5	136,000	2.35
WSP3c	10-3, 8, 3, 1, 4	11.4	145,000	1.91

Notes: 1. Cost in year 1998 dollars.
2. Cost in year 2000 dollars.

K. CONCLUSIONS AND RECOMMENDATIONS

The conclusions reached as a result of the investigations and evaluations conducted during this Water Resource Study, and recommendations for future action follow:

1. Conclusions

The conclusions reached during this study are presented below.

- None of the water supply or management alternatives evaluated in this study are considered to have significant environmental or social impacts. However, potential impacts are greatest due to development of an off-Refuge storage reservoir.
- No significant regulatory constraints are apparent that would preclude development of any of these alternatives.
- Development of additional water storage, whether on or off of the Refuge, will not by itself enhance the management of the Refuge to a significant degree.
- None of the on-Refuge alternatives, implemented by themselves, will significantly increase the availability of wildlife habitat at the Refuge. However, some of these improvements may enhance the operational flexibility of the Refuge or have other less tangible benefits that may warrant their continued consideration.
- The supply of water currently available from Rattlesnake Creek is not sufficient to adequately support the operation of the Refuge. In order to improve the water supply to the Refuge, and resulting availability of wetland habitat, a supplemental water source must be developed.
- Each of the alternatives that provide a supplemental water supply to the Refuge will have significant construction and annual OMR&E costs.

2 Recommendations

Given the conclusions reached during this study, the following recommendations for further action are offered for consideration by the Service.

- A supplemental water supply from groundwater wells should be considered the preferred development alternative at the Refuge.
- Begin discussions with potential funding sources, both public and private, to secure the funds necessary for continued study, construction and operation of the preferred water supply plan.
- Additional technical studies should be conducted to prove the feasibility of the proposed supplemental groundwater supply. These studies should include:
  - Soil borings
  - Test well installation and pumping
  - Water quality sampling and analysis

- Perform an environmental assessment of the preferred water supply plan. This should include coordination with appropriate regulatory agencies and the public.

INTRODUCTION

PURPOSE

The purpose of this report is to conduct an engineering study of water source alternatives for the Quivira National Wildlife Refuge (Refuge). Currently, the water supply for Quivira NWR is not adequate to meet the operating goals and to maintain adequate water levels in existing management units during dry weather. The overall objective of this project is to evaluate and recommend alternatives that improve water supply to the Refuge.

SCOPE

The scope of work for this project is divided into five major tasks, Tasks A through E. In addition to these major tasks, there are several general tasks that apply to the study as a whole. These general and specific tasks are described below.

- Collect and review available data and reports from U.S. Fish and Wildlife Service (Service), U.S. Geological Survey (USGS), U.S. Army Corps of Engineers (Corps), U.S. Environmental Protection Agency (EPA), Kansas Board of Agriculture - Division of Water Resources (KDWR), Kansas Water Office (KWO), Kansas Department of Health and Environment (KDHE), Big Bend Groundwater Management District No. 5 (GMD5), Kansas Geological Survey (KGS), Kansas Department of Wildlife and Parks (KDWP), WaterPACK, county agencies and local municipalities.
- Develop a base operations model for the Refuge (see Part III of this report).
- Estimate supplemental water needs of the Refuge (see Part IV of this report).

TASK A - RESERVOIR SITING

Task A of the study includes completion of the following subtasks. The work completed under Task A is documented in Part V of this report.

- Review maps to site potential reservoir sites in the Rattlesnake Creek watershed.
- Establish minimum acceptable criteria for use in screening alternative reservoir sites.

- Review available literature in environmental and cultural resources and threatened and endangered species and determine potential impacts at alternative reservoir sites.
- Perform field reconnaissance for up to 15 potential reservoir sites to determine construction feasibility and perform environmental and cultural resource reviews.
- Determine preliminary water quality releases required from each potential site based on discussions with federal and state agencies.
- Evaluate each site and determine the 2 percent firm yield considering water quality releases, state minimum desired streamflow, base flow and downstream water rights.
- Evaluate each side storage reservoir site to include a pump back from Rattlesnake Creek. Evaluate potential 2 percent firm yield considering pump back operations modeling, water quality releases, state minimum desired streamflow, base flow and downstream water rights.
- Modify operations model to include optimum reservoir alternative(s).
- Evaluate impacts on water supply with revised operations model.
- Evaluate impacts on habitat.
- Develop construction costs for each reservoir.
- Develop operations costs for each reservoir.
- Perform economics analysis considering tangible and intangible costs.
- Develop a matrix and rate each reservoir based on costs, benefits and environmental and cultural impacts.

TASK B - AQUIFER RECHARGE

Task B of the study includes completion of the following subtasks. The work completed under Task B is documented in Part VI of this report.

- Meet with GMD5 manager and discuss management strategies for the Great Bend Aquifer.
- Review existing predevelopment and later groundwater level maps and groundwater change maps of the watershed to determine potential areas available for recharge. Estimate potential recharge storage volumes.
- Review available stream/creek and groundwater level data to determine aquifer/creek interaction.
- Review existing water quality data on Rattlesnake Creek and adjacent groundwater.

- Develop a geologic cross-section along Rattlesnake Creek in areas of interest using available soil boring data.
- Review existing groundwater flow and water budget modeling by KGS.
- Determine feasibility of aquifer recharge in the Rattlesnake Creek watershed.
- If groundwater recharge looks feasible, the following work tasks are required:
  - Develop a groundwater recharge concept including facilities, potential locations, and operating conditions.
  - Develop a groundwater recharge recovery concept for the Refuge including facilities, potential locations, and operating conditions.
  - Modify operations model to include recharge and recovery system.
  - Evaluate impacts on water supply with revised operations model.
  - Evaluate impacts on habitat.
  - Develop construction costs for recharge and recovery system.
  - Develop operations costs for recharge and recovery system.
  - Perform economic analysis considering tangible and intangible costs.
  - Develop a matrix and rate the recharge and recovery system based on costs, benefits and environmental and cultural impacts.

TASK C - REFUGE ON-SITE/OFF-SITE ALTERNATIVES

Task C of the study includes completion of the following subtasks. The work completed under Task C is documented in Part VII of this report.

- Based on review of Refuge maps, surveys of marsh areas, canals and structures, area-capacity curves, elevations and bird habitat modeling, develop the following ten alternatives:
  - Construct dikes around Little Salt Marsh to store additional water.
  - Construct dikes inside Little Salt Marsh to store additional water.
  - Develop Units 14a and 14b, 28, 34 and 61 for additional water storage.
  - Line conveyance canals to improve delivery efficiencies.
  - Remove approximately 100 acre-foot of silt from Little Salt Marsh.

- Construct by-pass canal around Little Salt Marsh to minimize silt deposition in Little Salt Marsh during future flood events.
- Recontour additional area to develop moist soil units.
- Fill borrow areas with soil.
- Supplement water supply with Arkansas River water.
- Supplement water supply with groundwater.

- Modify operations model for each applicable alternative.
- Evaluate impacts on water supply with revised operations model for each applicable alternative.
- Evaluate impacts on habitat for each applicable alternative.
- Develop construction costs for each alternative.
- Develop operations costs for each alternative.
- Perform economic analysis considering tangible and intangible costs for each alternative.
- Develop a matrix and rate each applicable alternative based on costs, benefits and environmental and cultural impacts.

TASK D - REFUGE GROUNDWATER MODEL

Task D of the study includes completion of the following subtasks. The work completed under Task D is documented in Part VIII.

- Review existing groundwater reports and computer models to determine the suitability and potential use of conceptual framework, configuration, and aquifer parameters for the groundwater flow to the Big Salt Marsh.
- Develop a subregional model of the aquifer, compare to available data and calibrate as applicable, and run the model to quantify groundwater flow to Big Salt Marsh.
- Evaluate impacts on habitat for each applicable alternative.
- Develop construction costs for each alternative.
- Develop operations costs for each alternative.
- Perform economic analysis considering tangible and intangible costs for each alternative.
- Develop a matrix and rate each applicable alternative based on costs, benefits and environmental and cultural impacts.

TASK E - ALTERNATIVE COMPARISON

Task E of the study includes completion f the following subtasks. The work completed under Task E is documented in Pat IX of this report.

- Develop a matrix and rate each applicable alternative from Tasks A through D based on costs, benefits and environmental and cultural impacts.
- Select best alternatives of development of up to three water supply plans.
- Modify operations model for each applicable plan.
- Evaluate impacts on water supply with revised operations model for each applicable plan.
- Evaluate impacts on habitat for each applicable plan.
- Develop construction costs for each plan.
- Develop operations costs for each plan.
- Perform economic analysis considering tangible and intangible costs for each plan.

PART I

BACKGROUND INFORMATION

A. GENERAL

This section of the report describes general geologic, climatic, hydrologic, environmental and cultural conditions in the Quivira National Wildlife Refuge (Refuge) and Rattlesnake Creek Basin. It also describes the SWATMOD model developed for the U.S. Fish and Wildlife Service (Service) and other federal and state coordinating agencies. The Service is evaluating additional water supply alternatives for the Refuge. Additional water supply and modifications to Refuge operations are required to improve the maintenance of operating goals and adequate water levels in the management units.

Rattlesnake Creek and the Refuge are located in south central Kansas as shown in Figure I-1. The area is typically dry with limited water resources. The Refuge boundaries, management units and canals are shown in Figure I-2. The geology, hydrogeology, water rights, water quality, environmental resources, and cultural resources of the Refuge and the Rattlesnake Creek Basin are discussed below.

B. RATTLESNAKE CREEK BASIN

The Rattlesnake Creek Basin occupies approximately 1,317 square miles. The upper portion, about 15 percent, lies in the High Plains physiographic province which is a nearly flat alluvial plain with intermittent streams. The lower portion, about 85 percent, is part of the Great Bend Prairie physiographic province which is also a relatively flat alluvial plain (Sophocleous and McAllister, 1990). The Great Bend Prairie is poorly drained. Precipitation collects in depressions where it seeps into the ground or is lost through evapotranspiration (Latta, 1950).

1. Geology

The topography of Rattlesnake Creek Basin has evolved from eolian and stream activities. The land surface of the basin consists of loess deposits and eolian sand hills. Rattlesnake Creek winds through the basin flowing from the southwest to the northeast where it joins the Arkansas River. The higher portions of the basin consist of loess deposits and sand hills, whereas the lowest areas are marshes associated with

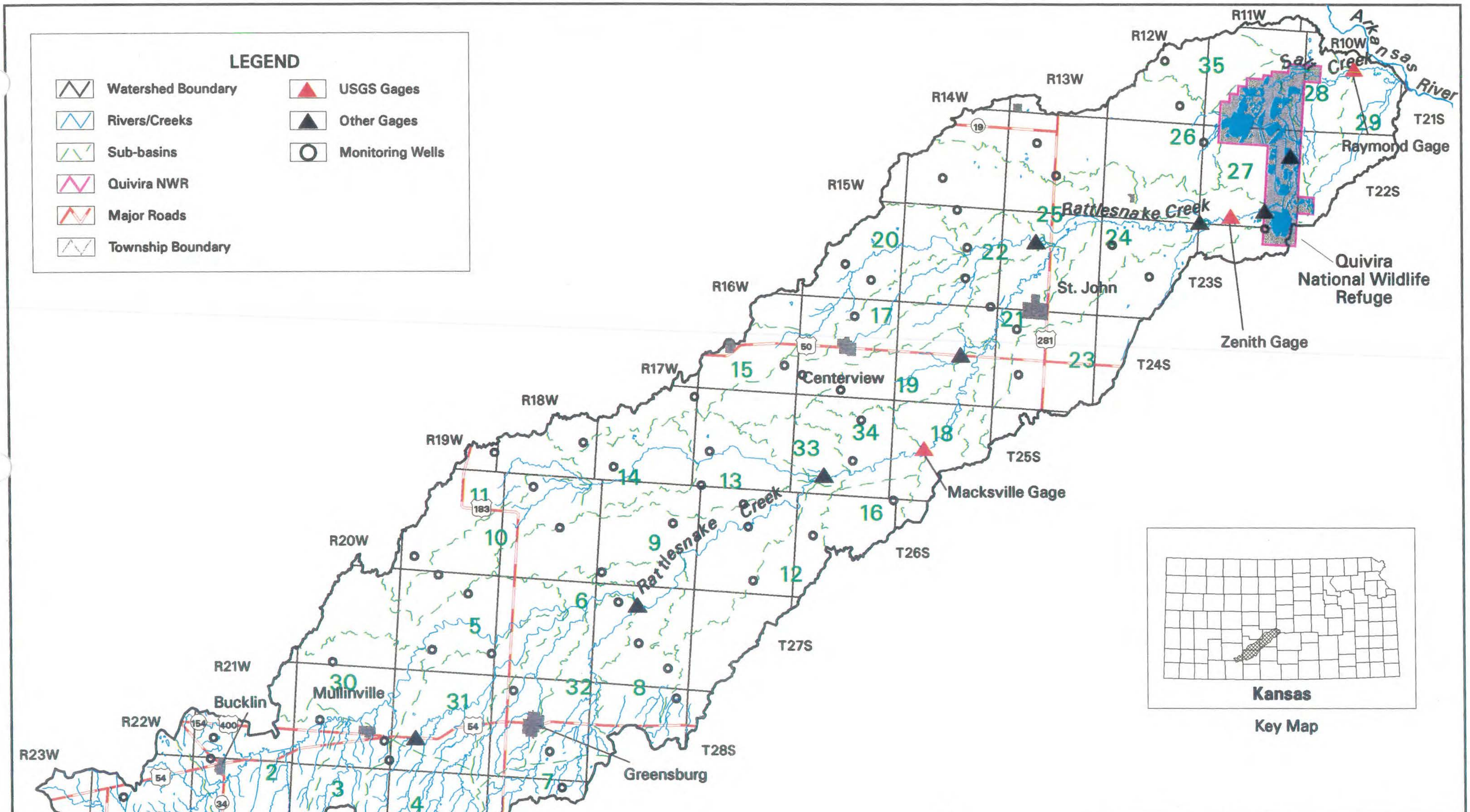
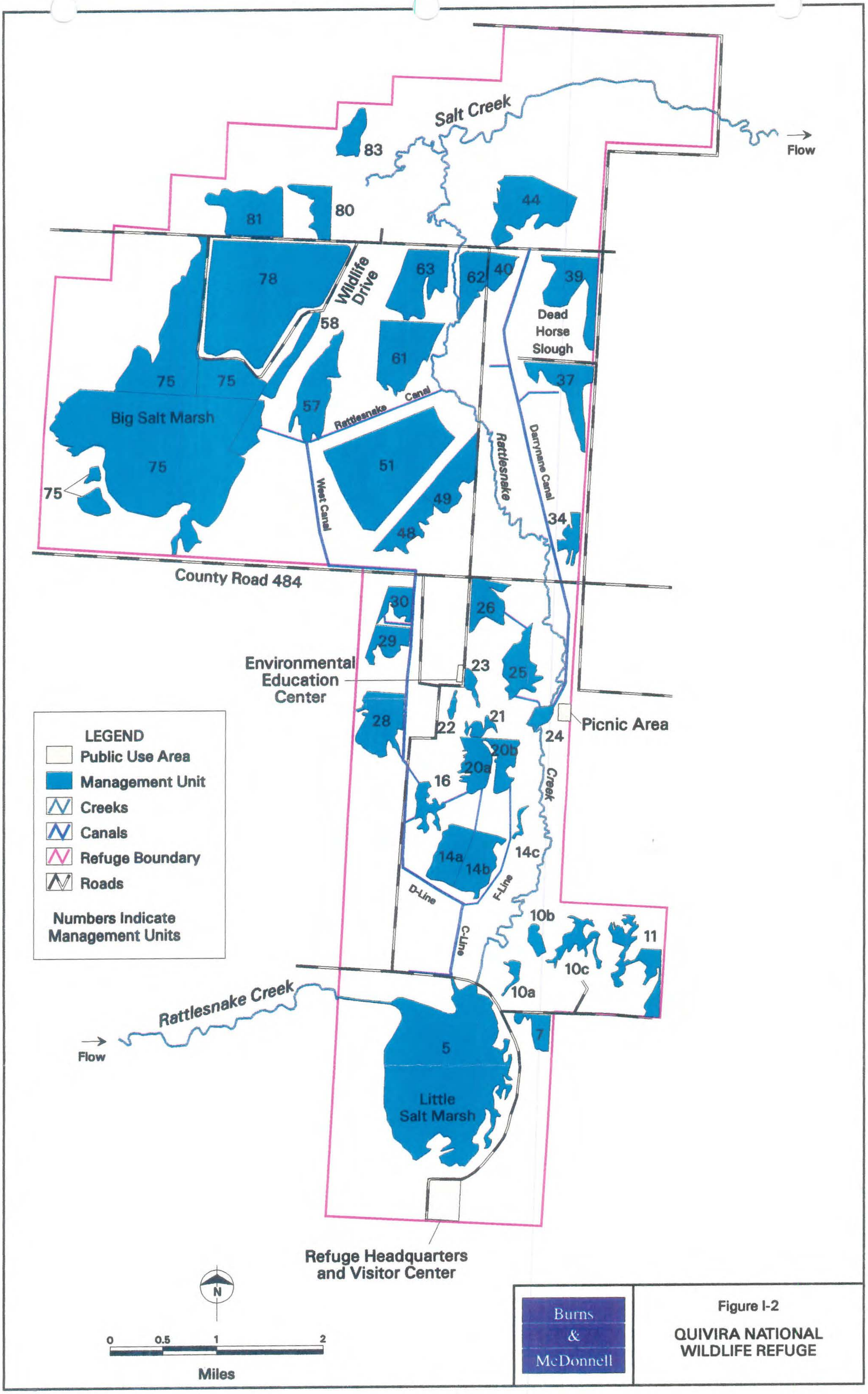


Figure I-1

RATTLESNAKE CREEK WATERSHED



Burns & McDonnell

Figure I-2

QUIVIRA NATIONAL WILDLIFE REFUGE

Rattlesnake Creek and Salt Creek. These deposits overlie the Mead Formation which is the primary aquifer in the basin (Sophocleous and McAllister, 1990).

The stratigraphy of the unconsolidated deposits and bedrock in the basin is shown in Table I-1. Starting from the surface, the stratigraphy of the unconsolidated deposits is (1) sand hills or dunes, (2) loess (a near-surface silt-clay bed), (3) alternating sandy silt-clay and sand and gravel lenses, and (4) a basal sand and gravel (Rosner, 1988). The underlying bedrock is composed of Cretaceous and Permian units.

Table I-1
GENERALIZED STRATIGRAPHIC SECTION OF RATTLESNAKE CREEK BASIN

System	Epoch	Unit	Maximum Thickness, feet
Quaternary	Holocene	Alluvium and Marsh Deposits	360
		Dune Sands	
	Pliestocene		
		Loess	
		Mead Formation	
Tertiary	Pliocene	Ogallala Formation	65
Cretaceous		Dakota Formation	380
		Kiowa Shale	
		Cheyenne Sandstone	
Permian		Undifferentiated Redbeds	350
		Cedar Hills Sandstone	200
		Salt Plain Formation	300
		Harper Sandstone	250

Note: Adapted from Fader and Stulken, 1978.

In some areas of the basin, the sand dunes are actively migrating in response to the wind carrying the sands and redepositing them. The stable dunes range from nearly level to gently rolling to moderately undulating and are composed of well sorted eolian sand (USDA, 1978).

The loess and weathered loess materials form a near-surface silt-clay bed with lower permeability than the underlying aquifer material, retarding the vertical migration of water into the aquifer sands and gravels. In some areas, the silty-clay bed is overlain by sand dunes.

The alluvium associated with Rattlesnake Creek ranges up to 20 feet thick and consists of poorly sorted sands and gravels derived from the underlying Mead Formation. Generally, the Rattlesnake Creek alluvium and the Mead Formation are indistinguishable (Latta, 1950).

The Tertiary deposits of the Ogallala Formation are similar to the Pleistocene alluvial deposits. These deposits underwent a period of erosion prior to the deposition of the Pleistocene Mead Formation. As a result of this erosion, only isolated remnants of the Ogallala Formation remain in the Rattlesnake Creek Basin and are not easily distinguished from the Mead Formation.

The surface features overlie alluvium deposited by the ancestral Arkansas River. This alluvium is composed of the early Pleistocene sediments of the Mead Formation. The Mead Formation consists of interbedded lenses of sand, gravel and silt. The Mead Formation, along with alluvium deposited by Rattlesnake Creek and its tributaries, form the Great Bend Prairie Aquifer.

The bedrock underlying the Rattlesnake Creek Basin consists of Permian and Cretaceous deposits. The Cretaceous age Kiowa Formation is composed of shale and sandstone. The highest area of the bedrock occurs north of the Zenith gaging station where the Kiowa Formation subcrops in a three square mile area. The lowest areas occur where bedrock channels are present. Figure I - 3 shows the configuration of the bedrock surface within the boundaries of Rattlesnake Creek Basin. Bedrock in the majority of the basin is comprised of Permian red bed deposits which consist of sandstone, siltstone, shale, salt, gypsum, anhydrite, and limestone (Sophocleous, et al, 1997). The Cedar Hills Sandstone subcrops in a northerly line just east of highway U.S. 281. The groundwater in these deposits is very saline and is the a major source of salinity in the overlying aquifer, marshes and streams.

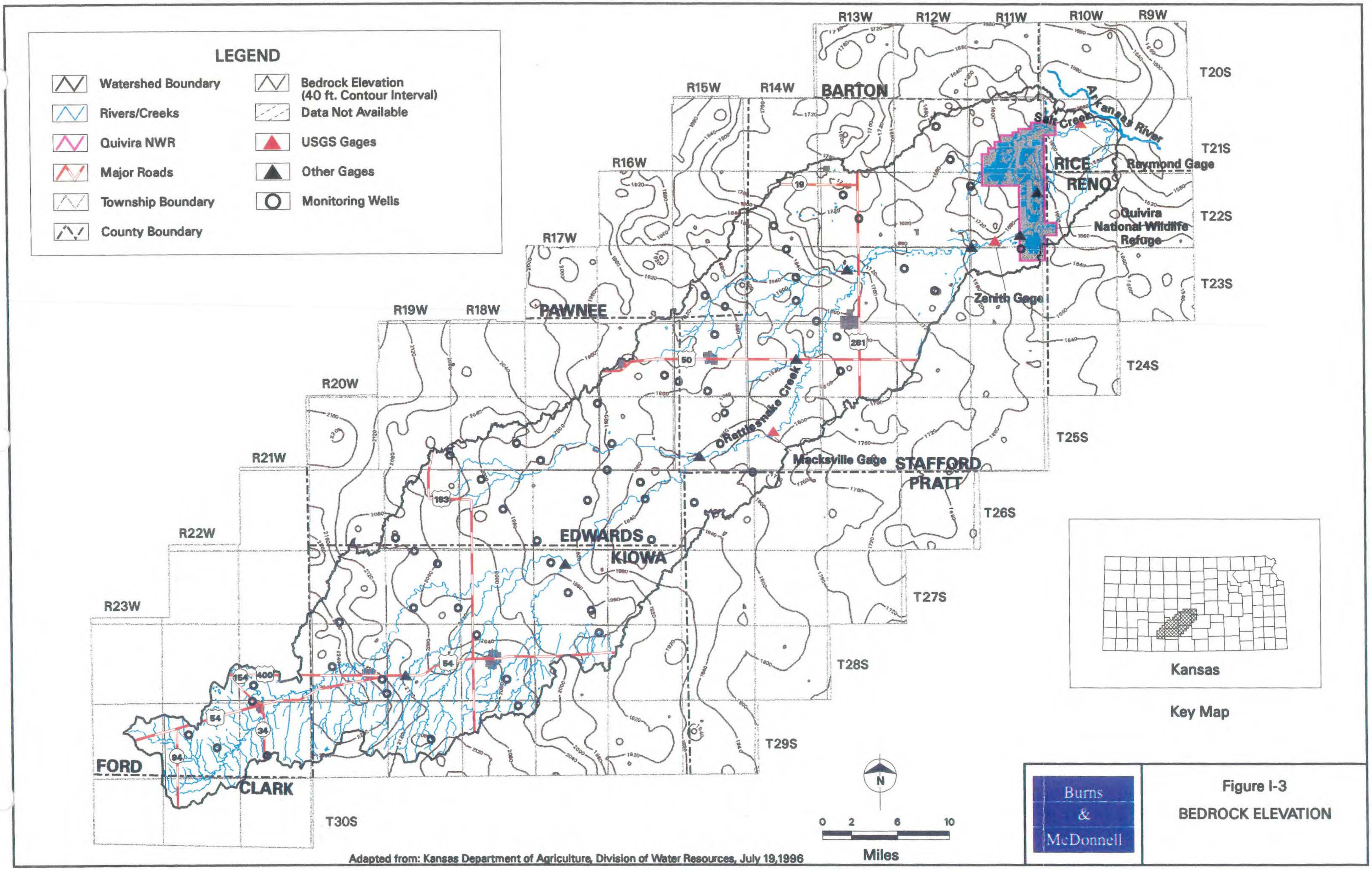


Figure I-3
BEDROCK ELEVATION

2. Hydrogeology

Rattlesnake Creek meanders from the High Plains region to the northeast through the Great Bend Prairie lowlands where it joins with the Arkansas River. There are approximately 60,200 acres of wetlands associated with Rattlesnake Creek and its tributaries (Ray and Coslett, 1972). Typically, these wetlands are the result of high water tables and are poorly drained. The surface water is highly mineralized and has high concentrations of salinity.

Rattlesnake Creek Basin represents the surface drainage for Rattlesnake Creek. The underlying groundwater basin does not match the surface water basin and varies with pumpage and recharge. At times, pumping may change groundwater gradients causing groundwater from outside the surface basin to flow into the region. Regional groundwater flow is generally to the northeast and may be impacted by groundwater levels outside the limits of the surface watershed.

Predevelopment water levels are shown in Figure I-4. These water levels are interpreted from groundwater data obtained during the 1940's from various sources (Sophocleous, 1990).

The general trend of the direction of groundwater flow has not changed. Increased pumping stresses on the aquifer have reduced water levels in portions of the aquifer. The 1996 water levels are shown in Figure I-5. The change in saturated thickness of the aquifer from predevelopment to 1996 is shown in Figure I-6. Review of Figure I-6 shows water levels have been reduced up to 30 feet in the areas where pumping stresses are significant.

Water enters the groundwater system as recharge underflow of groundwater from outside of the basin, through infiltration of precipitation, and percolation of surface runoff through Rattlesnake Creek and its tributaries. Groundwater exits the system as evapotranspiration, underflow out of the basin, baseflow in streams and marshes, and through well pumpage.

Underflow enters the basin from the southwest in Ford County and from the underlying bedrock. Inflow from the bedrock is predominantly from the Cedar Hills Sandstone at a rate of 5,000 to 10,000 acre-feet

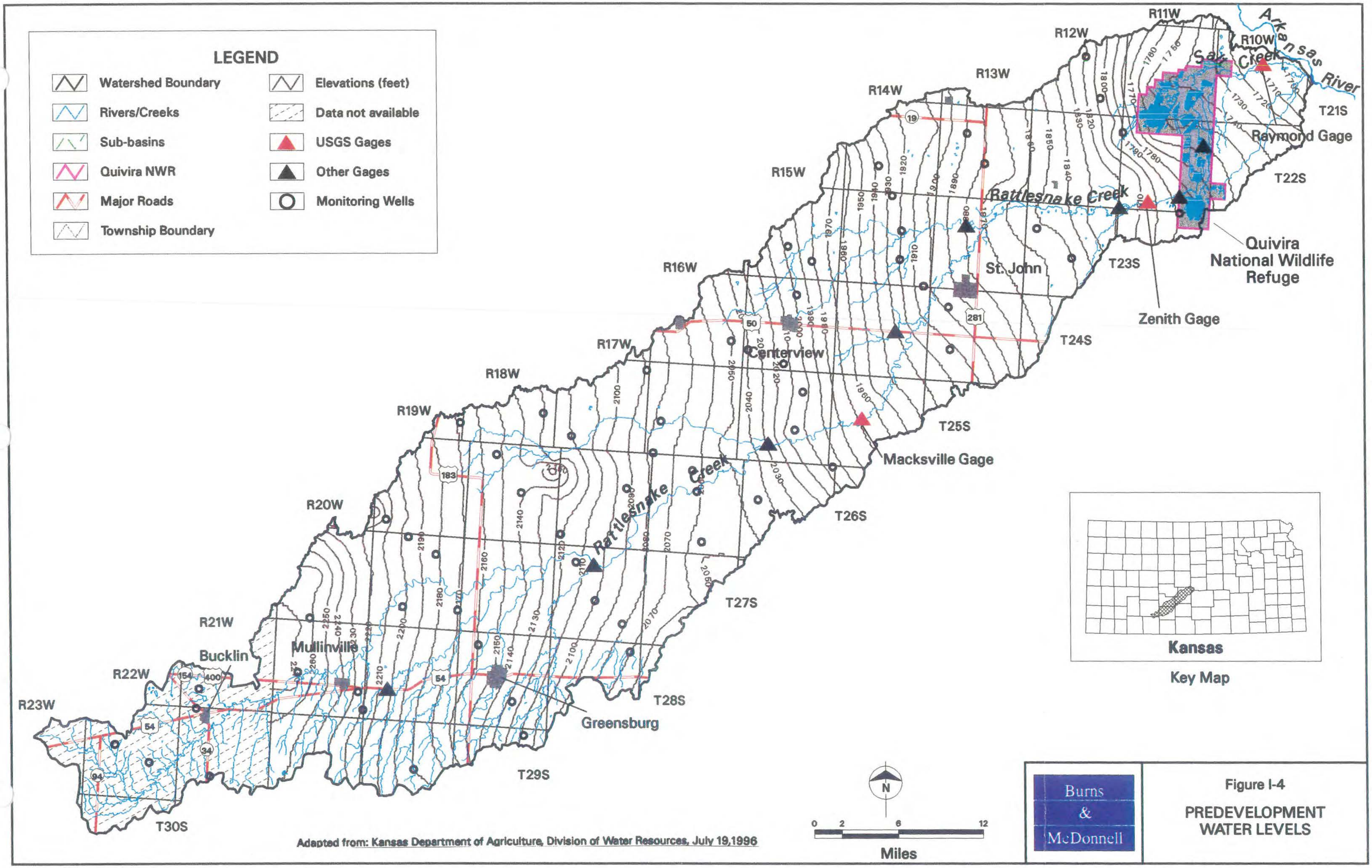


Figure I-4

PREDEVELOPMENT WATER LEVELS

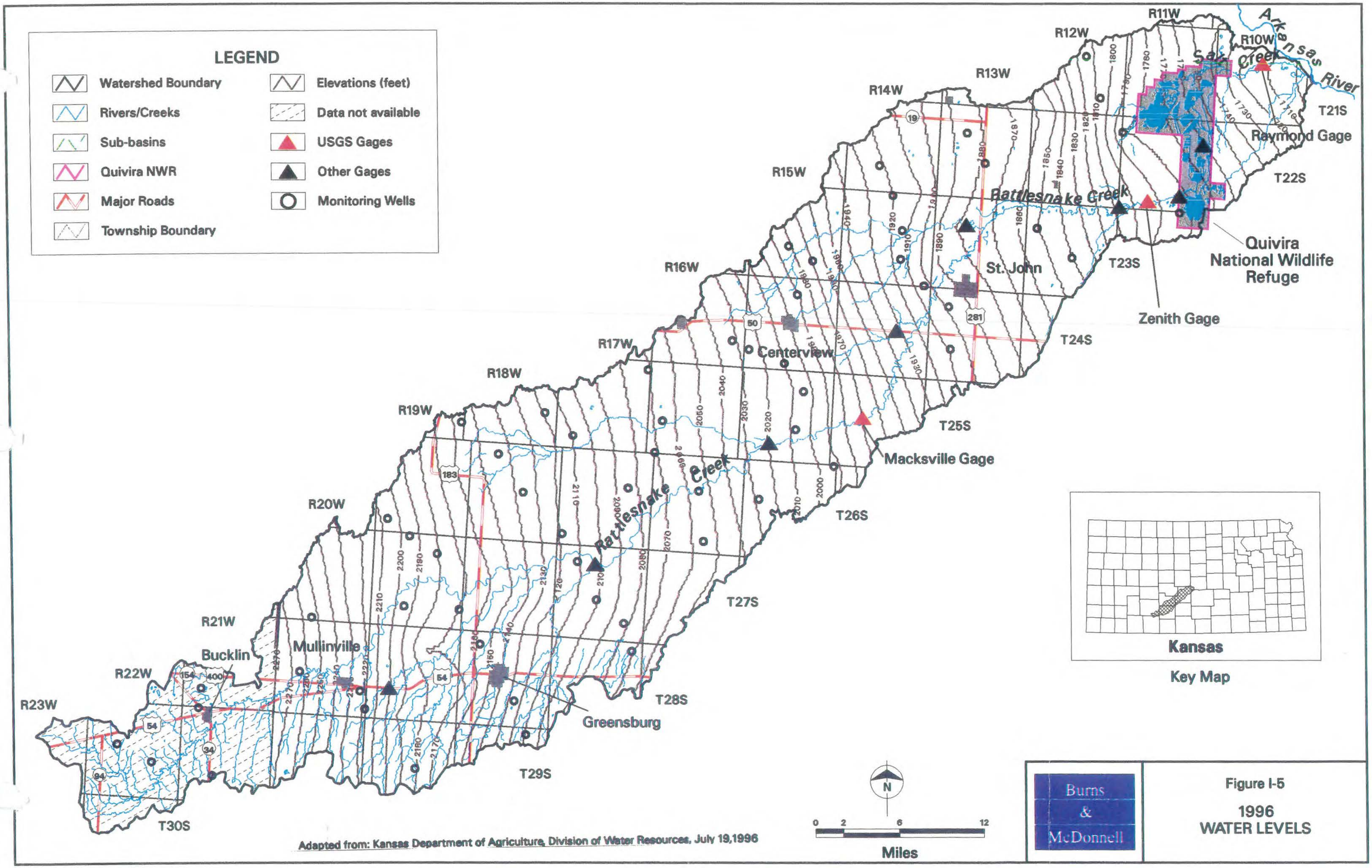
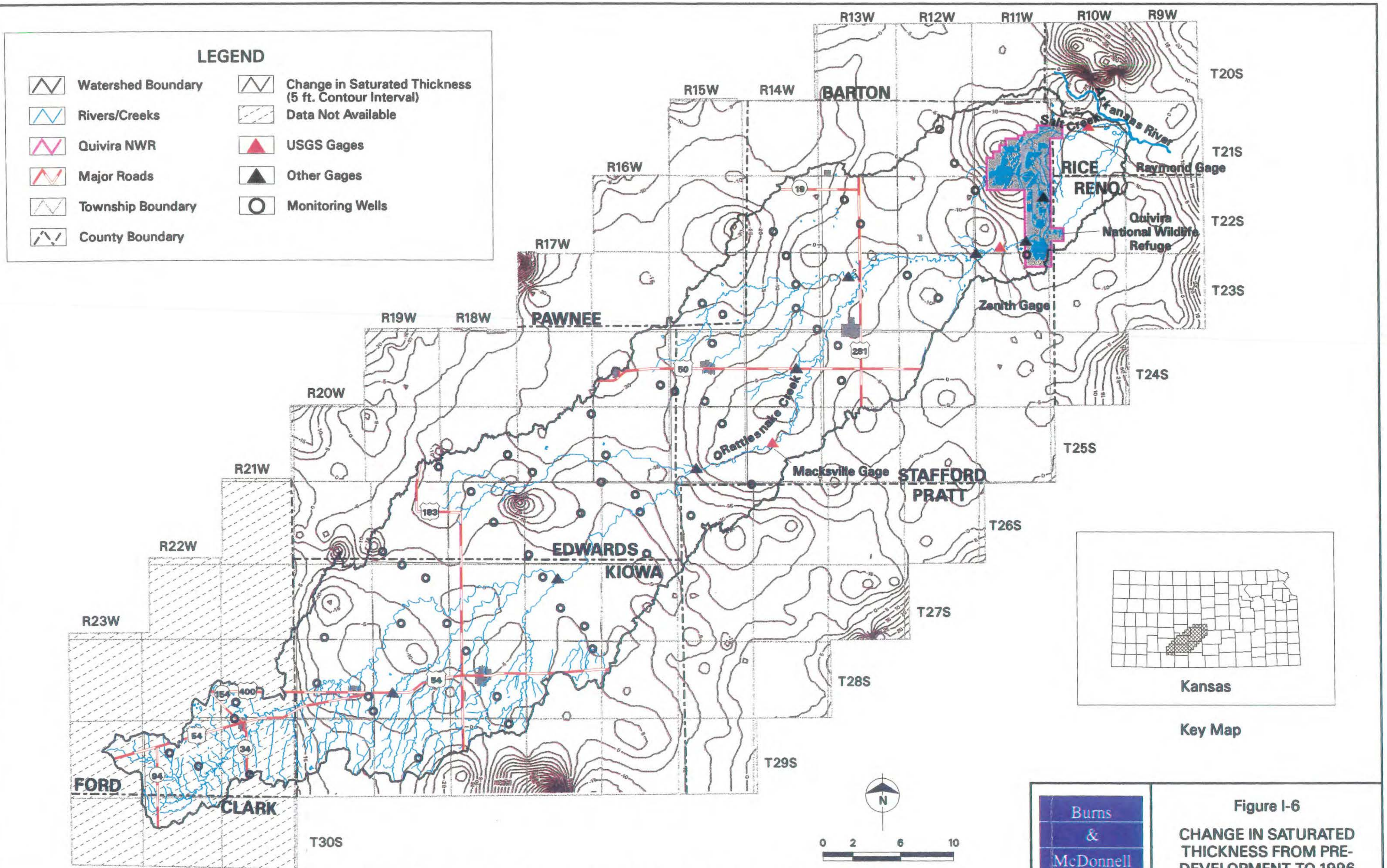


Figure I-5
1996 WATER LEVELS



Adapted from: Kansas Department of Agriculture, Division of Water Resources, July 19 1996

Burns & McDonnell

Figure I-6

CHANGE IN SATURATED THICKNESS FROM PRE-DEVELOPMENT TO 1996 per year (Fader and Stulken, 1978). Underflow leaves the basin near the northeast boundary in Rice, Reno, and Stafford Counties and to the southeast in Kiowa County (Sophocleous et al, 1997).

Precipitation is the primary source of recharge. The amount of precipitation varies across the basin and with the seasons. The rate of infiltration is affected by the soil type and the depth to the water table. Approximately five to ten percent of the average annual precipitation recharges to the aquifer.

The high temperatures, dry weather, and wind cause the evapotranspiration rates to be high in this region. The average annual free-surface evaporation rate is approximately 64 inches per year (Sophocleous et al, 1997).

The estimated effective net annual recharge is shown in Figure I-7 and considers percolation of precipitation, pond seepage, evapotranspiration, transmission losses, and subsurface lateral flow during the pre-development period for each drainage sub-basin in the watershed. Transmission losses are flows of surface water from a river channel during high flow events. These rates are estimated from 1961 to 1970 conditions. The average annual precipitation rate for the region was 24 inches per year (Sophocleous et al, 1997). Generally, the most southwestern sub-basins exhibit the lowest rates of effective net recharge because of the greater depth to groundwater.

Rattlesnake Creek and its tributaries act as both sources and sinks of groundwater for the aquifer system. The approximate locations of gaining and losing reaches along Rattlesnake Creek are shown in Figure I-8. Typically, surface runoff of precipitation provides the flow of water in Rattlesnake Creek along the western portion of the creek. Much of this stretch of Rattlesnake Creek is composed of losing reaches where the flows infiltrate into the subsurface. This provides recharge into the aquifer. Further downstream near Macksville, Rattlesnake Creek becomes a gaining stream where the flows in more reaches are maintained by groundwater flowing into the channel. In the Refuge area, groundwater discharges into Rattlesnake Creek and the marshes, including Big Salt Marsh. Gaining reaches may become losing reaches as the conditions become drier and recharge to the aquifer is reduced. Additionally, losing reaches may change to gaining reaches during wet periods and recharge to the aquifer increases.

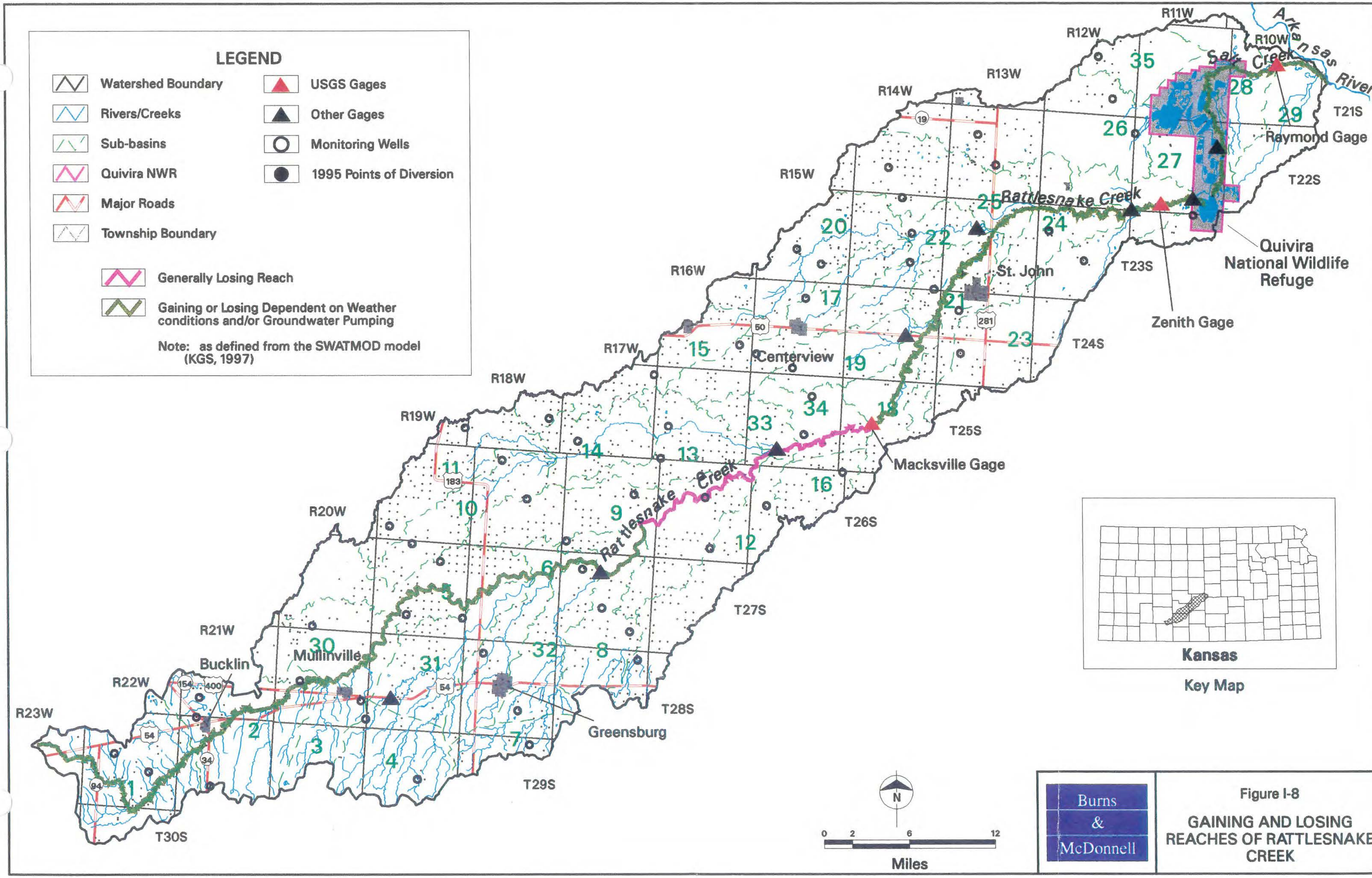


Figure I-8

GAINING AND LOSING REACHES OF RATTLESNAKE CREEK

The aquifer properties, hydraulic conductivity and storativity, are a measure of the capacity of a water bearing unit to yield water. The hydraulic conductivity of the Great Bend Prairie aquifer within the Rattlesnake Creek Basin ranges from 11 to 230 ft/day, and storage coefficient ranges from 0.0007 to 0.18 (Sophocleous et al, 1997). This range of hydraulic conductivity is typical for a good water producing aquifer. In areas where the aquifer is thickest, wells can yield 1,000 to 2,000 gpm (Fader and Stulken, 1978). This range of storage coefficient indicates that confined and unconfined conditions exist within the Rattlesnake Creek Basin. Values of storage coefficient greater that 0.01 indicate unconfined groundwater conditions. Lower values indicate semi-confined or confined conditions (Freeze and Cherry, 1979). A storage coefficient of 0.15 is a good representative value for the Great Bend Prairie aquifer indicating that much of the aquifer is unconfined (Fader and Stulken, 1978).

3. Water Rights

Water rights are issued by the Kansas Board of Agriculture - Division of Water Resources (KDWR) in accordance with the Kansas Water Appropriation Act and allows the owner of the right to lawfully divert water from a Kansas stream or aquifer. The groundwater in the basin is managed by Big Bend Groundwater Management District No. 5 (GMD5). GMD5 was formed in 1976 and preserves and manages the sustained yield of water for all users. Requests for groundwater rights are processed through GMD5 with final approval by KDWR. Requests for surface water rights are processed directly through KDWR.

Water rights in Rattlesnake Creek Basin are over-allocated and a moratorium restricting new water rights in the basin has been in-place since 1989. The basin is closed to development of additional wells except for domestic wells pumping less than 15 acre-feet per year. The basin has a net quantity of 304,307 acre-feet per year and an average authorized quantity of 230.1 acre-feet per year of water rights. These rights cover 16 vested rights (14 groundwater and 2 surface water), 4 surface water rights, and 1,455 groundwater rights (1,398 for irrigation, 19 for industrial, 21 for municipal, 14 for recreation, and 8 for stock watering) for a total of 1,591 points of diversion (as of January 1995).

Stored water discharged to a stream becomes part of the natural flow and is subject to all appropriation rights. The State of Kansas does not guarantee delivery of water from an upstream diversion point via the stream to a downstream water right owner. Loses in the stream due to pumpage by other water right owners, infiltration, uptake by habitat, evaporation, and aquifer recharge can occur and can drastically reduce or utilize all of a water right. The only method to guarantee the delivery of a water right is to pump the water from the point of diversion through a pipeline to the point of use.

4. Water Quality

Surface water quality data for Rattlesnake Creek and Arkansas River are available through STORET. Review of Rattlesnake Creek water quality shows severe salinity degradation of the water quality downstream of St. Johns. This is due to the percolation of groundwater through naturally occurring salt formations.

Review of water quality in the Arkansas River between Great Bend and Hutchinson, as listed in Table I-2, shows a notable increase in salinity downstream of the Salt Creek confluence. Chlorides, a major indicator of salinity, ranges from about 0 to 565 mg/L with a mean of about 99 mg/L at Great Bend and increases to a typical range of 27 to 1,700 mg/L with a mean of 560 mg/L at Hutchinson. Salt Creek is downstream of the Refuge, conveys high salinity water from the Refuge and Rattlesnake Creek to the Arkansas River, and is a major supplier of saline water into the Arkansas River.

5. Environmental Resources

The Rattlesnake Creek Basin extends from central Kansas, southwestward to near the Kansas-Oklahoma border. The region historically was part of the western tall grass prairies. It was dominated by a variety of warm season grasses and forbs, adapted to the limited rainfall conditions and periodic wildfires. Wildlife of the area included a variety of large and small mammals, most notably the American bison, large predators including wolves, bears, and mountain lions, and an abundant and diverse population of birds. Streams, rivers, and associated wetlands supported numerous types of furbearers, reptiles, amphibians, shorebirds, and waterfowl. However, the transient nature of water availability from season to season and year to year likely resulted in dramatic fluctuations in the diversity and population of these species.

Following settlement, the area was converted from prairie grassland to agriculture. Presently, cropland, both irrigated and non-irrigated, comprises the majority of land use throughout the basin. The principal

Table I-2
WATER QUALITY DATA SUMMARY
ARKANSAS RIVER

Parameter	Units	Great Bend Vicinity					Hutchinson Vicinity				
		No. of Samples	Sample Dates	Mean	Maximum	Minimum	No. of Samples	Sample Dates	Mean	Maximum	Minimum
Flow	cfs	287	3/44 - 5/75	1,166	27,400	2	249	9/59 -9/62	1066	15300	38
Flow - instanteous	cfs	223	7/57 - 8/95	446	950	0.05	-	-	-	-	-
Conductance	uS/cm	269	10/61 - 8/95	1,454	7,910	120	401	10/61 - 8/95	2,528	5,900	300
pH	-	253	10/61 - 8/95	7.9	12.0	6.7	343	10/61 - 8/95	7.8	9.1	6.9
Total Hardness	mg/L	168	10/61 - 9/75	551	1,110	84	178	10/61 - 9/75	404	805	-
Sodium	mg/L	168	10/61 - 9/75	153	350	5	177	10/61 - 9/75	371	1,110	23
Chloride	mg/L	168	10/61 - 9/75	68	130	0.7	255	10/61 - 4/92	564	1,700	27
Iron	ug/L	42	10/61 - 10/74	102	570	0	11	10/61 - 9/62	217	800	10
Manganese	ug/L	16	10/61 - 4/69	3.1	50	0	13	10/61 - 10/68	2	30	0
Flow	cfs	128	11/73 - 9/88	112	4,967	3	-	-	-	-	-
Conductance	uS/cm	213	11/73 - 12/96	1,298	3,100	200	40	5/90 - 11/96	2,398	3,600	742
pH	-	75	4/86 -12/96	7.8	8.7	-	41	3/90 - 11/96	8.3	8.7	7.4
Total Hardness	mg/L	213	11/73 - 12/96	375	1,111	65	40	3/90 - 11/96	328	583	117
Sodium	mg/L	212	11/73 - 12/96	133	330	4	40	3/90 - 11/96	321	506	64
Chloride	mg/L	202	11/73 - 12/94	129	565	4	28	5/90 - 11/94	524	762	160
Iron	ug/L	51	12/74 - 12/96	1,814	15,100	20	41	3/90 - 11/96	1,476	13,140	54
Manganese	ug/L	51	12/74 - 12/96	295	2,460	0	41	3/90 - 11/96	127	535	32
Flow	cfs	14	6/72 - 4/75	154	361	35					
Conductance	uS/cm	14	6/72 - 4/75	986	1,230	700					
Total Hardness	mg/L	14	6/72 - 4/75	372	456	268					
Chloride	mg/L	14	6/72 - 4/75	61	88	31					
Flow	cfs	21	4/71 - 6/77	208	1,080	14					
Total Hardness	mg/L	21	4/71 - 6/77	323	748	184					
Chloride	mg/L	21	4/71 - 6/77	75	160	22					

Note: Water quality data from STORET.

crops include winter wheat, milo/sorghum, and corn. Areas of warm and cool season grasses are also present and used for hay and pasture. Other tracts of warm season grasses, established as part of the Conservation Reserve Program (CRP), occur on lands of marginal use for agriculture and provide grasslands which remain largely undisturbed throughout the year. While areas of native, warm season grasses are common, few receive appropriate management to encourage diverse prairie communities and consist mainly of big bluestem, little bluestem, and Indian grass.

Woodlands were never common within the basin. They were mainly restricted to riparian corridors along larger streams in areas protected from prairie fires. Native woodlands consisted of cottonwood, willow, and American elm. With the current suppression of prairie fires by human activities, woodlands and shrub/scrub areas have become more prevalent. They still occur along riparian corridors but have expanded into the smaller and intermittent drainages. Abandoned farmsteads, fallow areas, or grasslands with little or no management develop into shrub/scrub areas of dogwood, honey locust, elm, hackberry, eastern red cedar, and osage orange. Additionally, many homes and farmsteads have associated shelter belts to protect them from the prevailing winds. Shelter belts are linear woodlots containing a variety of native, ornamental, and introduced shrubs and trees. Wooded fencerows adjacent to agricultural fields and along roadways are also present. Small, isolated woodlots also occur in some pasture areas if sufficient water is available, providing shade and shelter for livestock.

Although uncommon within the basin, wetlands within the basin are classified as emergent, shrub/scrub, and forested. Wetlands and hydric soils generally occur within streams and other drainageways, riparian corridors adjacent to streams, or in association with small man-made ponds and lakes; however, the majority of these areas do not contain hydric soils and would not be considered wetlands based on the 1987 U.S. Army Corps of Engineers Wetland Delineation Manual. Most of these areas are mapped as wetlands by the U.S. Fish and Wildlife Service, National Wetlands Inventory due to their meeting the wetland criteria established by the Service. Other isolated wetlands are scattered throughout the basin in small, depressional areas that retain surface runoff or are in areas with a high water table that periodically intercept the surface. Emergent wetlands consist of a variety of types of vegetation, including smartweed, sedges, rushes, bulrushes, and cattails. Shrub/scrub wetlands generally are dominated by willow. Forested wetlands contain a mix of cottonwood, willow, elm, and ash.

The variety of vegetative communities scattered throughout the basin creates a mosaic of habitats for wildlife. Dominated by cropland, the area provides abundant foraging areas with adjacent cover and nesting areas. The more visible and locally significant wildlife species occurring within the basin are whitetailed deer, coyote, eastern cottontail, black-tailed jackrabbit, wild turkey, bobwhite quail, ring-necked pheasant, mourning dove, prairie chicken, western meadowlark, brown-headed cowbird, common crow, turkey vulture, red-tailed hawk, American kestrel, scissortailed flycatcher, as well as a wide variety of songbirds, reptiles, amphibians, and small mammals.

The Rattlesnake Creek Basin is within the Central Flyway of North American waterfowl and shorebirds. Each spring and fall, hundreds of thousands of waterfowl and shorebirds pass through the basin as they migrate between their breeding and brood-rearing grounds in the northern Great Plains and Canada and their wintering grounds concentrated along the Texas/Louisiana Gulf Coast. During these periods, waterfowl and shorebirds make use of available water bodies, streams, and wetlands for resting, foraging, and drinking. Harvested grain fields and sheet-water are also used heavily for feeding during the migration periods. The more visible and important species include:

- Whooping cranes.
- Sandhill cranes.
- Canada, white-fronted, and snow geese.
- Mallard, pintail, bluewing and greenwing teal, American baldpate (wigeon), gadwall, Northern shoveler, scaup, ringneck, canvasback, and redhead ducks.
- White pelicans.
- American avocet.
- Greater and lesser yellowlegs.
- Numerous species of terns, gulls, sandpipers, phalaropes, and plovers.

Area waterbodies, wetlands, and streams also provide habitat during the summer months for a variety of avian and mammalian species. These include great blue, little blue, green and night herons; great, snowy, and cattle egrets; bitterns; white-faced ibis; cormorants; woodducks; mallards; bluewing teal; numerous species of rails; muskrat, beaver, raccoon, mink, and opossum.

Rattlesnake Creek is the primary perennial stream in the basin. Excluding some small stock ponds and runoff ponds for irrigated fields, most other streams and wetlands are intermittent or subject to periodically drying up. Therefore, aquatic resources in the area are largely limited to Rattlesnake Creek. Area streams, including Rattlesnake Creek, are characterized by sand bottoms, braided channels with alternating complexes of riffles, runs, and pools. During dry periods, surface water may be restricted mainly to the deeper pools and flowing water may be scarce; however, some short sections of streams are fed by springs or seeps and may contain water throughout even extended dry periods. Habitat within the streams includes log jams, tree-falls, undercut banks, brush piles, root wads, bare and vegetated sandbars, and overhanging trees. Common fish species expected to occur include: green sunfish, orange spotted sunfish, white crappie, largemouth bass, black bullhead, channel catfish, flathead catfish, common carp, red shiner, sand shiner, and mosquito fish. Seasonal low flows and high sediment loads due to runoff from agricultural lands combine to reduce fish species diversity and the overall quality of the stream fishery.

Federal and state listed threatened and endangered species occasionally occur throughout the basin. Seasonally, the federally threatened bald eagle and piping plover and the federally endangered peregrine falcon and whooping crane migrate throughout the area, foraging and resting in and around wetlands and other water bodies in the basin. Federally endangered interior least terns and state listed white-faced ibis also migrate through the area. However, these species also are known to nest within wetlands in the basin. The state listed Arkansas darter occurs around seeps and springs and in areas with a high water table.

The Rattlesnake Creek Basin encompasses portions of six counties; Edwards, Kiowa, Pratt, Reno, Rice, and Stafford. Only small portions of Pratt, Rice, and Reno counties are included, with Stafford, Edwards, and Kiowa comprising the majority of the basin. The population of these countries, according to the 1990 census, ranges from 3,557 in Edwards County to 62,551 in Reno County (39,770 person of this total are included in the incorporated area of Hutchinson, located approximately 25 miles east of the basin) (Hall and Slater, 1996). Residents within the basin are spread throughout the area, living on small family farms and in small towns. The larger towns in the basin include Stafford, St. John, and Greensburg, each with a population of approximately 2,000 people. Per capita annual income ranges from a low of $10,139 to $12,488 in Rice and Pratt Counties, respectively. Unemployment in the basin ranges from 7 percent in Kiowa, Pratt, and Reno Counties to 11 percent in Stafford and Rice Counties.

All these counties are predominantly agricultural. The few industries within the basin are mainly oriented toward farm and agricultural services. The majority of soils in these counties are classified by the Natural Resource Conservation Service (NRCS) as prime farmland, indicating they have the characteristics necessary to produce high yields of agricultural products. Primary crops include corn, milo/sorghum, winter wheat, and hay. Pasture and hayfields, including both cool and warm season grasses, are common. Livestock raised are primarily cattle. The majority of employment within each county is farming, ranging from 58 percent in Reno County to 74.5 percent in Edwards County.

A wide variety of recreational opportunities, both public and private, are provided within the basin. The Refuge, located at the north end of the basin, provides hunting, fishing, bird watching, and nature study opportunities. Several state fishing lakes in the basin provide hunting, fishing, and camping opportunities. Several thousand acres of private land are also available to the public through the Kansas Department of Wildlife and Parks'(KDWP) Walk-In Hunting Area program, providing additional hunting opportunities. White-tailed deer, pheasants, bobwhite quail, prairie chickens, and waterfowl are the most sought after species on both public and private lands. Additional opportunities are available on private lands for fishing along the larger streams in the basin and in private farm ponds. Abundant private land is also available for hunting. However, use is generally restricted to family members, neighbors, and guests. Other recreational attractions include the Kansas Cosmosphere & Space Center (Hutchinson); the Big Well, world's largest hand-dug well (Greensburg), and KDWP's visitor center and fish hatchery (Pratt).

6. Cultural Resources of the Rattlesnake Creek Basin

The cultural resources of the Rattlesnake Creek Basin and are essentially unknown. All of the cultural resources surveys conducted in the area were small scale, linear investigations in which no archaeological sites were recorded. In July 1997, a file search at the Kansas State Historical Society indicated that 24 archaeological sites are known within the Rattlesnake Creek Basin. Most of these sites were investigated by a professional archaeologist, but only after local informants disclosed their locations. Other sites were recorded by amateurs who submitted site forms to the Kansas State Historical Society. Possible historic sites in the area were identified by reviewing the historic county plat maps of Kiowa, Edwards, Rice, and Stafford counties and the General Land Office survey maps and notes. The data recovered from these few sites and their distribution across the landscape is summarized below to formulate a very general probability system for the cultural resources in the Rattlesnake Creek Basin. This probability study is biased in many aspects due to the lack of adequate sample surveys in the drainage basin.

Most of the evidence for prehistoric occupation of the basin was identified in sand dune blowouts. The continuous fluctuation of activity among sand dunes often make it difficult to identify cultural deposits or relocate those previously recorded. A few sites have been found in areas of more stable soil deposits, predominately light scatters of chipped stone debris on terraces or ridges. Based on the topographic setting of the recorded sites in the drainage basin, the areas with the highest probability for containing prehistoric sites are settings that are slightly elevated above the surrounding terrain. All of the recorded prehistoric sites are interpreted as limited activity areas or campsites, which are generally associated with hunting and gathering activities. Typically the behaviors evident at these sites are indicative of the exploitation of a few locally available resources. Due to the lack of raw resources such as stone outcrops or secondary deposits of gravels in the area and the scarce number of gallery forests reported in early historic accounts of the area, it is logical to assume that subsistence related resources would have been the most commonly exploited by the prehistoric population of the drainage basin.

Identified components of the Rattlesnake Creek drainage basin indicate that the basin has been occupied from the Archaic through the Historic period. Most of the prehistoric components are hunting camps dating from the Early to Late Ceramic stages and are associated with semi-sedentary peoples of the Central and Southern Plains. Ethnographic and archaeological evidence of these cultures indicate that small, special task groups would radiate out from the base camps or villages to exploit locally available resources. The short term occupation of the campsites associated with these subsistence based activities may or may not contain features such as hearths.

Historic Euroamerican farmsteads, generally distributed in broad rural communities, are likely to be the most common historic site found in the drainage basin. A review of the *Standard Atlas of Kiowa County, Kansas* (Geo. A. Ogle & Co. 1906) indicates that a rural community of farmers or homesteaders was established in the area. A visit to the area indicates that most of these sites have been abandoned. To date the only recorded historic site in the project area is a historic discard or dump area.

Twenty-four archaeological sites are recorded in the drainage basin. Seventeen of these sites are found in Kiowa County, with most of them situated along intermittent tributaries. Two of the four sites in Stafford County are on terraces of the main stream channel and the others are found in the upland sand dunes. The Edwards County portion of the drainage basin includes three widely distributed sites, ranging from the sand dunes to terraces along the stream channel. All of the sites are situated on slightly to moderately elevated terraces, ridges or dunes.

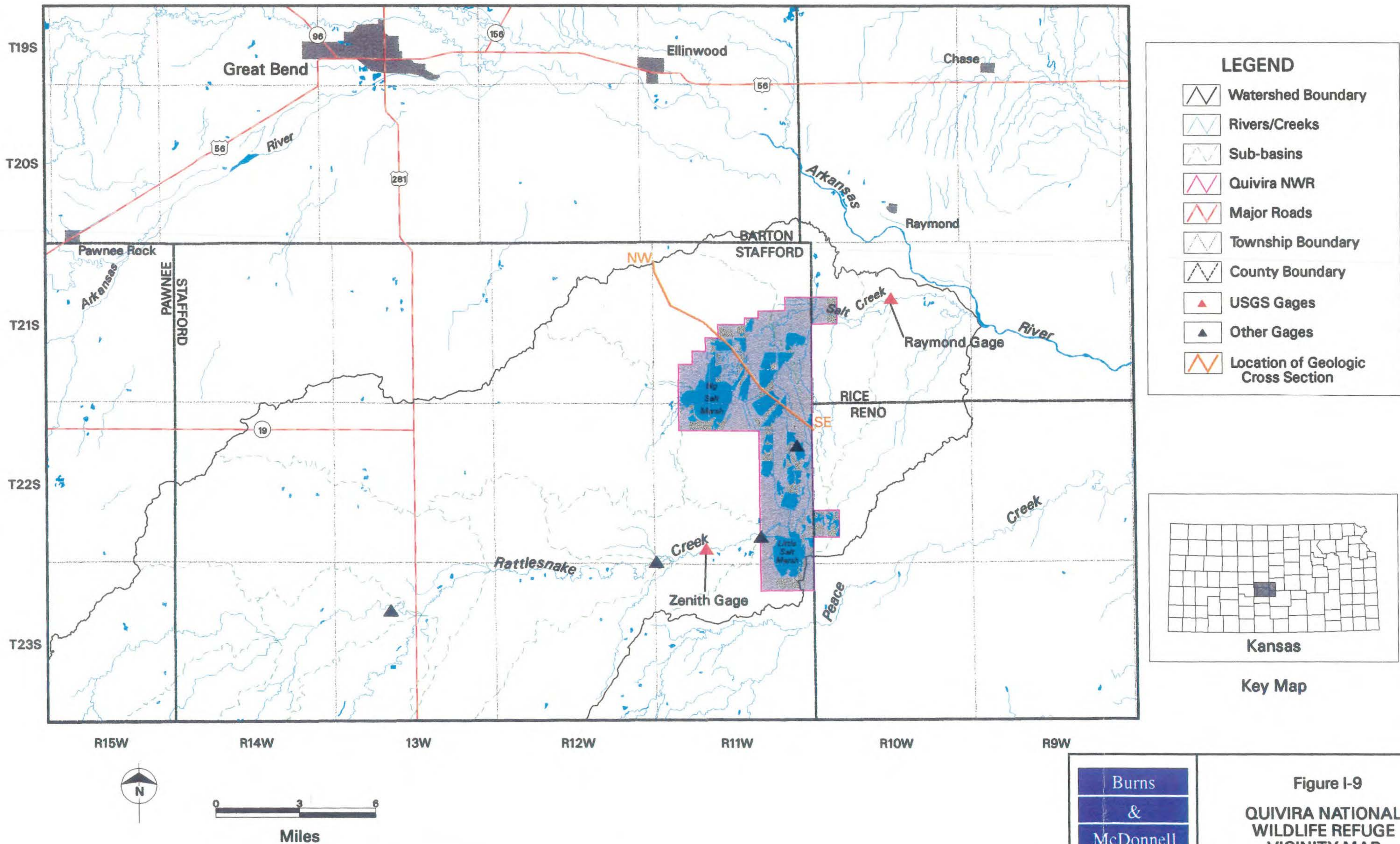
Although few of the sites recorded in the area have been determined as eligible for listing on the National Register of Historic Places, a high to moderate potential exists for the presence of such sites. In addition to the probability of significant sites in the basin, the research potential of the known sites is significant. Little is know about the campsites or subsistence based activities of the local archaeological cultures thus far identified in the area. Any archaeological investigations in the basin would contribute significantly to the understanding of the local prehistory and history.

C. QUIVIRA NATIONAL WILDLIFE REFUGE

Rattlesnake Creek enters the Refuge and flows into Little Salt Marsh as shown in Figure I-9. The creek continues to flow north out of Little Salt Marsh and across the eastern margin of the Refuge. This part of the lower basin, where Rattlesnake Creek joins with the Arkansas River, lies in Stafford County with small portions located in Barton, Rice, and Reno Counties. The confluence with the Arkansas River is located in Rice County. Extensive areas of marshes, including Big Salt Marsh, are associated with this portion of Rattlesnake Creek.

1. Geology

This portion of Rattlesnake Creek Basin is part of the Great Bend Prairie physiographic province and has similar properties to Rattlesnake Creek Basin. The higher portions of the study area consist of eolian sand hills, whereas the lower areas are marshes associated with Rattlesnake Creek (Sophocleous and McAllister, 1990). The Great Bend Prairie is poorly drained. Precipitation collects in depressions where it seeps into the ground or is lost through evapotranspiration (Latta, 1950).



Burns & McDonnell

Figure I-9

QUIVIRA NATIONAL WILDLIFE REFUGE VICINITY MAP

The stratigraphy of the unconsolidated deposits and bedrock in the vicinity of the Refuge is shown in Table I-3. Starting from the surface, the stratigraphy of the unconsolidated deposits is (1) sand hills or dunes, (2) a nearly continuous silt-clay bed, (3) alternating sandy silt-clay and sand and gravel lenses, and (4) a basal sand and gravel (Rosner, 1988). The underlying bedrock is composed of Cretaceous and Permian units.

Table I-3
GENERALIZED STRATIGRAPHIC SECTION OF REFUGE AREA

System	Epoch	Unit	Thickness feet
Quaternary	Holocene	Alluvium and Marsh	0-20
		Dune Sands	0-50+
	Pleistocene		
		Loess	0-40
		Mead Formation	50-200
Cretaceous		Dakota Formation	0-30
		Kiowa Shale	0-100
		Cheyenne Sandstone	0-80
Permian		Undifferentiated Redbeds	≤350
		Cedar Hills Sandstone	≤200
		Salt Plain Formation	≤300

Note: Adapted from Fader and Stulken, 1978.

A geologic cross section of the study area is shown in Figure I-10 as referenced in Figure I-9. Like the sand hills, the silt-clay bed is likely a wind-blown deposit and ranges up to 40 feet thick (Rosner, 1988). The loess and weathered loess materials form a silt-clay bed that underlies the sand dunes. This bed has lower permeability, which retards the vertical migration of water into the aquifer sands and gravels. A portion of the water recharged into the sand hills flows laterally through the dunes and seeps out along the edge of the dunes. The outflow then moves overland towards the salt marshes.

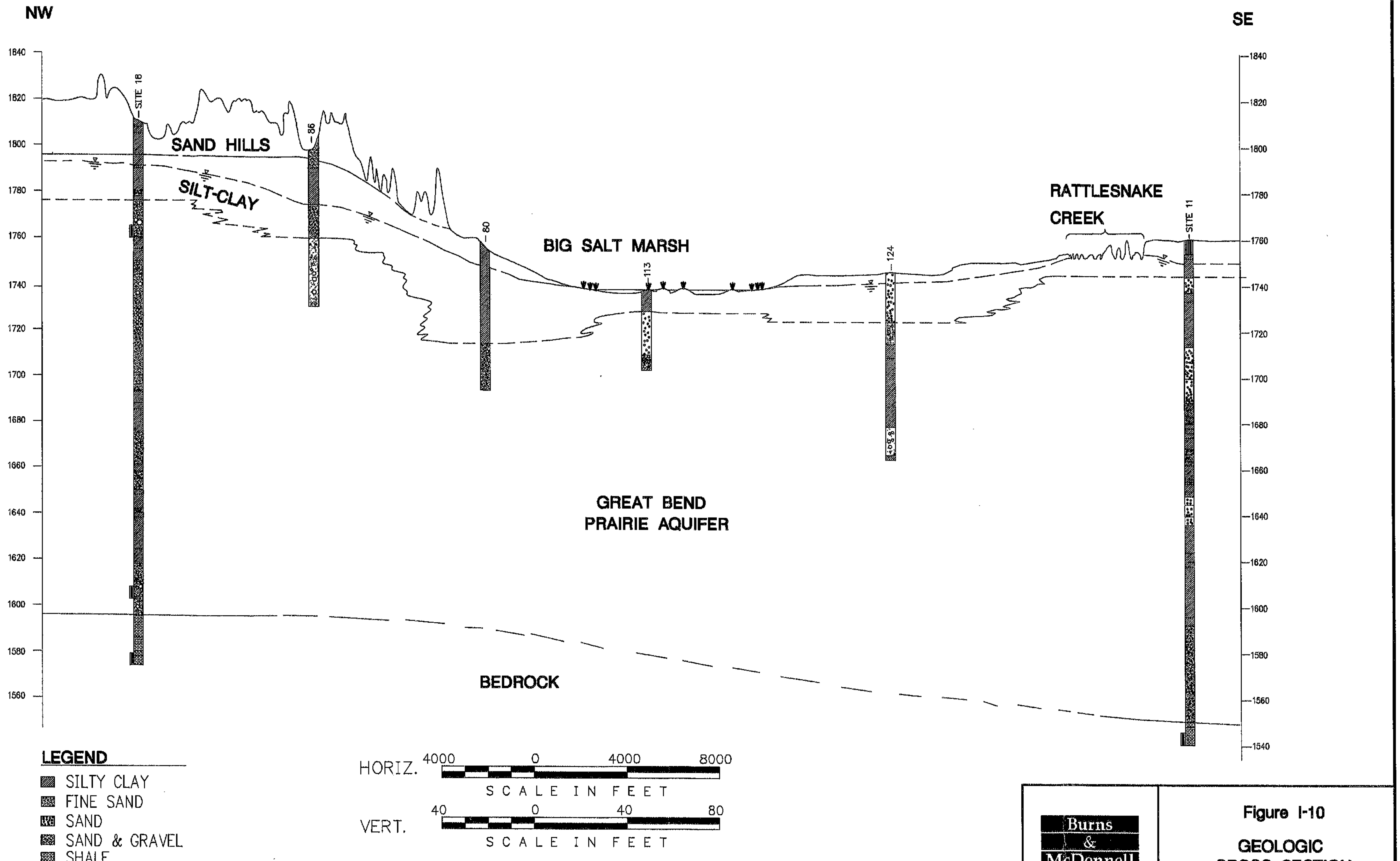


Figure I-10

GEOLOGIC CROSS SECTION

j:\USFWS\9780 ws\USFWS01.DWG 01-22-1998 14:15 MJC

The surface features overlie alluvium deposited by the ancestral Arkansas River and local streams, forming the Great Bend Prairie Aquifer. This alluvium is composed of the early Pleistocene sediments of the Mead Formation. The Mead Formation consists of interbedded lenses of sand, gravel and silt.

The bedrock in the area is relatively shallow and consists of Permian and Cretaceous deposits. The Cretaceous age Kiowa Formation is composed of shale and sandstone. The highest area of the bedrock occurs north of the Zenith gaging station where the Kiowa Formation subcrops in a three square mile area. The majority of the study area is comprised of Permian red bed deposits which consist of sandstone, siltstone, shale, salt, gypsum, anhydrite, and limestone (Sophocleous, et al, 1997). The Cedar Hills Sandstone subcrops in a northerly line just east of highway U.S. 281. The groundwater in these deposits is very saline and is a major source of salinity in the overlying aquifer, marshes and rivers.

2. Hydrogeology

Rattlesnake Creek Basin represents the surface drainage for Rattlesnake Creek. The underlying groundwater basin is not a closed system (Sophocleous, et al, 1997). Regional groundwater flow is generally to the northeast and is impacted by groundwater levels outside the limits of the surface watershed. The Refuge area is a discharge zone for groundwater exiting the Great Plains Prairie aquifer and the bedrock. Groundwater discharges into Rattlesnake Creek and the marshes, including Big Salt Marsh.

Water enters the groundwater system within the study area as underflow from outside of the study area limits, as inflow from the bedrock, through infiltration of precipitation, and percolation of surface runoff through Rattlesnake Creek and its tributaries. Groundwater exits the study area as evapotranspiration, underflow out of the study area, baseflow in streams and marshes, and through well pumpage.

The sandhills surrounding the marshes receive recharge from precipitation. Information from the Soil Survey of Stafford County, Kansas (USDA, 1978) indicates that the sandhills are poorly drained. The soil survey states, "The water table fluctuates from a depth of about one foot in wet seasons to a depth of five feet in dry season."

In this portion of Rattlesnake Creek Basin, the aquifer is overlain by a silt-clay bed that acts as a confining unit creating flowing artesian conditions in some areas. Boiling Springs is one of these areas. These springs are located to the southwest of Big Salt Marsh just within the boundaries of the Refuge. The saline waters of the springs are maintained by upwelling groundwater from the aquifer. The sandhills overlie a silt-clay bed that has a low permeability. When water percolates down through the sandhills and encounters the silt-clay unit it begins to flow laterally above the silt-clay. While some of this groundwater eventually passes through the silt-clay into the aquifer, a portion of it continues to flow laterally until it exits the sandhills and flows overland to the marshes.

3. Water Rights

The Refuge has certified surface water rights of 14,632 acre-feet per year from the Kansas Board of Agriculture - Division of Water Resources for the operation of up to 6,138 acres of wetlands. The water right, Water Right File No. 7,571, has a priority date of August 15, 1957. This right has a combined maximum diversion rate not to exceed 300 cubic feet per second (cfs) of surface water from three points of diversion within the Refuge. Additionally, the Refuge has stock water wells.

4. Water Quality

Limited water quality data for the Refuge provided by the Service is shown in Table I-4. Additional data, which is also very limited, for Little Salt Marsh and Big Salt Marsh was retrieved from STORET and reviewed as listed in Table I-5. Samples collected show the water to be high in conductance, chlorides and sodium and therefore high in salinity. Data for the Refuge are listed for Little Salt Marsh (Unit 5) and Big Salt Marsh (Unit 75) and Rattlesnake Creek on the southwest and northeast sections of the Refuge. The southwest section of Rattlesnake Creek represents the upstream side of the Refuge and the northeast section of Rattlesnake Creek represents the downstream side of the Refuge. Review of the data shows salinity, the key water quality parameter, varies greatly from 400 to 125,300 mg/L with a mean of about 8,400 mg/L.

Table I-4
WATER QUALITY DATA SUMMARY
QUIVIRA NWR

Parameter	Units	Little Salt Marsh					Big Salt Marsh				
		No. of Samples	Sample Dates	Mean	Maximum	Minimum	No. of Samples	Sample Dates	Mean	Maximum	Minimum
Conductance	uS/cm	6	7/88 - 6/94	6,362	7,430	5,130	6	7/88 - 6/94	10,295	18,980	1,080
pH	-	3	7/88 - 6/94	8.3	8.9	8.0	3	7/88 - 6/94	9.6	9.9	9.0
Total Hardness	mg/L	6	7/88 - 6/94	266	306	240	6	7/88 - 6/94	361	452	265
Sodium	mg/L	6	7/88 - 6/94	2,426	4,873	1,078	6	7/88 - 6/94	4,934	8,724	2,330
Chloride	mg/L	4	7/88 - 6/91	1,925	2,200	1,670	4	7/88 - 6/91	4,875	6,150	3,495
Iron	ug/L	4	6/91 - 6/94	1,260	1,990	553	4	6/91 - 6/94	683	1,330	114
Manganese	ug/L	4	6/91 - 6/94	150	185	110	4	6/91 - 6/94	81	130	36

Note: Water quality data from STORET.

Table I-5
QUIVIRA NWR WATER QUALITY DATA (1)

Parameter	Units	Little Salt Marsh (Unit 5)			Big Salt Marsh (Unit 75)			Rattlesnake Creek - SW			Rattlesnake Creek - NE		
		Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum
TDS (2)	mg/L	3,647	56,100	80	8,294	119,400	130	3,692	630,000	70	7,324	14,000	90
pH	-	8.3	9.5	4.9	8.7	10.8	5.4	8.1	9.3	4.9	8.2	9.5	4.9
Conductivity (3)	uS/cm	5,833	9,000	730	7,825	13,810	3,200	6,727	14,980	1,280	7,782	18,460	100
Salinity (4)	mg/L	5,700	60,800	400	10,500	125,300	800	7,900	14,000	500	9,600	16,600	1,000

Notes:
1. All data provided by Service.
2. Sampling conducted from March 1990 through July 1996.
3. Sampling conducted from January 1995 through July 1996.
4. Sampling conducted from May 1990 through September 1995.

5. Environmental Resources

Quivira NWR was approved for establishment on August 12, 1953. Purchase of property for the Refuge was approved by the Migratory Bird Commission, under authority granted by the Migratory Bird Treaty Act and the Migratory Bird Hunting Stamp Act, on May 3, 1955. The Refuge currently consists of 21,820 acres; the latest acreage was purchased in 1969. The Refuge contains numerous wetlands and management units ranging from less than one acre to over 1,500 acres in size. Together, over 6,000 acres of marshes and wetlands occur on the Refuge.

Non-wetlands on the Refuge consist of a variety of vegetative communities. These range from native warm season grasslands and riparian woodlands to cropland and pasture. Small woodlots and patches of shrub-scrublands create a mosaic of various types of wetlands and uplands which provide habitat for and are attractive to diverse wildlife communities.

Located in central Kansas, the Refuge is within the eastern part of the Central Flyway of migrating waterfowl and shorebirds. The Refuge is strategically located approximately midway between the U.S./Canadian border and the Gulf of Mexico. Semi-annually, waterfowl and shorebirds which breed in the northern Great Plains and as far north as northern Canada, migrate between their northern nesting grounds and wintering areas along the Gulf Coast and south into Central and South America. The primary management directive of the Refuge is to provide "protection and adequate food, water, and resting area for Central Flyway migratory waterfowl on their semi-annual migrations" (U.S. Department of the Interior, 1962). Additional objectives include providing nesting habitat for dabbling or puddle ducks and recreational opportunities for the public to enjoy Refuge fish and wildlife resources.

In meeting its directives, the Refuge has become a major stopping point for waterfowl migrating within the Central Flyway. Each year, thousands of shorebirds, ten-thousands of ducks, up to 100,000 sandhill cranes, and hundreds of thousands of geese use the Refuge. The Refuge provides an important stopping point for the federally endangered whooping crane and piping plover, as well as nesting habitat for the interior least tern. Bald eagle and peregrine falcon, federally threatened and endangered species, respectively, have also been observed on the Refuge. In all, over 250 species of birds have been observed on the Refuge.

Management units on the area provide abundant breeding habitat for waterfowl. Large tracts of grassland provide excellent nesting habitat. Wetlands and management units provide water and cover for foraging, rearing and fledging of young, and molting. Several species of waterfowl are known to nest on the Refuge including mallard, blue-winged teal, wood duck, and Canada goose.

Recreational opportunities are abundant on the Refuge. Approximately 8,000 acres of the Refuge are open to public hunting and all Refuge waters are open to public fishing. Photographic blinds and handicapped facilities are also available. Use by hunters can be heavy, particularly during the early portions of the waterfowl and upland bird seasons. Bird watchers also frequent the area, with use being the greatest when the whooping cranes and large flocks of sandhill cranes are present on the Refuge.

The Service has divided the Refuge into numerous management units, as shown in Figure I-2, to accomplish the directives established for the Refuge. These units are managed for various purposes and species throughout the year. The following discussion briefly describes the Service's current management of each unit. Units are discussed from the south end of the Refuge northward to help illustrate how water flows from unit to unit throughout the Refuge.

Unit 5 (Little Salt Marsh)
Little Salt Marsh is located on the south end of the Refuge, north of the Refuge headquarters (T22S & T23S R11W, portions of Sections 25, 26, 35, 36, 1 and 2). It is the second largest impoundment on the Refuge and is the most important source of water and water storage for wetland management. The unit is within a non-hunting area of the Refuge. Public facilities within the unit include a photography blind, handicap fishing access and a maintained road around the unit for visitors. The unit is comprised of large areas of open water interspersed with dense growths of cattails.

Little Salt Marsh is an impoundment of Rattlesnake Creek. Rattlesnake Creek flows into the marsh from the west and exits to the north. Water from Rattlesnake Creek is diverted and stored in the marsh. Stored water is released and delivered to other wetland units on the Refuge through a series of canals and diversion points along Rattlesnake Creek. Little Salt Marsh is the primary water storage and supply for the

Photograph 1: Little Salt Marsh looking Southwest from the northest portion of the Unit.

Photograph 2: Rattlesnake Creek looking north from outflow of Little Salt Marsh.

Refuge due to its size and location upstream of other basins and allows gravity flow of water to the other management units on the Refuge.

Little Salt Marsh is managed for a variety of bird species. It is used by waterfowl (year round), shorebirds (March through early June and late July through September), whooping cranes (late March through May and October through early December) and bald eagles (October through mid-March). Approximately 3.0 feet of water depth are required during the year. The desired management goal of this unit is to keep the surface water elevation at the spillway at 1783.0 feet year round to provide wildlife habitat while still allowing water transfers to other units.

Unit 7

Unit 7 is located on the south end of the Refuge, east of Little Salt Marsh (T22S R11W, NE 1/4 of Section 36). It is within a non-hunting area of the Refuge. The unit is comprised of a mix of open water and emergent vegetation, dominated by cattails. Water is supplied to this unit from Little Salt Marsh through control structure A-3. This unit is managed for a variety of bird species. It is used by waterfowl (September through mid-May), shorebirds (March through early June and August through September), egrets and ibis (early March through early October), and bald eagles (October through late March). The Service's desired water level in this unit is 3.5 feet of water in the fall, winter and spring and 3.0 feet of water in the summer.

Units 10a and 10b (Horseshoe Lake)

These units are located in the south central portion of the Refuge (T22S R11W, portions of the E ½ of Section 25). The units are within a hunting area of the Refuge. Both units are usually managed as a single unit. They are comprised of a mix of open water and emergent vegetation. Water is supplied to the units from Little Salt Marsh through structure A-1. Water drains from these units into Unit 10c. These units are managed for a variety of bird species. They are used by waterfowl (September through mid-May), shorebirds (March through early June and August through September), egrets and ibis (early March through early October), and bald eagles (October through March). The desired water level in these units is 3.5 feet of water in the fall, winter and spring and 3.0 feet of water in the summer. Refuge staff have indicated these units leak water to the north onto private ground.

Photograph 3: D-Line Canal looking west from intersection of D-, C-, and F-Line Canals.

Photograph 4: Unit 14b looking south from the northwest corner of the unit showing linear borrow areas adjacent to unit dikes.

(September through late May), shorebirds (March through May and August through early October), ibis (March through early October), and egrets (March through early October). Unit 14b has been proposed for management as a moist soil unit by using surplus water from Unit 14a after Unit 14a is filled. Management as a moist soil unit would involve filling the unit with 12 to 18 inches of water in the spring and then allowing the water to soak in, run-off, or evaporate naturally during the spring and summer. This promotes growth of species such as smartweeds, wild millets, and barnyard grass that provide high quality food for waterfowl. Vegetation is allowed to grow and mature during the summer. The unit would be refilled in the fall to provide habitat for migrating waterfowl. The desired water level in Unit 14b is 4.2 feet of water in the fall, winter and spring and 3.7 feet of water in the summer.

Unit 14c

Unit 14c is located northeast of Unit 14b in the central area of the Refuge, west of Rattlesnake Creek (T22S R11W, W 1/4 of the NE 1/4 of Section 24). It is located within a non-hunting area of the Refuge. The unit is comprised of a mix of open water and emergent vegetation. Water is supplied to this unit from the F-2 control structure on the F-line canal. This unit is used by waterfowl (September through late May), shorebirds (March through May and August through early October), and egrets (March through early October). The desired water level is 2.5 feet of water in the fall, winter and spring and 2.0 feet of water in the summer.

Unit 16

Unit 16 is located northwest of Unit 14a in the central area of the Refuge (T22S R11W, SW 1/4 of SE 1/4 of Section 14 and NW 1/4 of NE 1/4 of Section 23). It is located within a non-hunting area of the Refuge. The unit is comprised of a mix of open water and emergent vegetation. Water is supplied to Unit 16 from Unit 14a through control structure 14A2. This unit drains into the West Canal. This unit is used by waterfowl (September through mid-May), shorebirds (March through May and August through early October), and egrets (March through early October). The desired water level in Unit 16 is 6.5 feet of water in the fall, winter and spring and 6.0 feet of water in the summer.

Units 20a and 20b

Units 20a and 20b are located in the central area of the Refuge (T22S R11W, SW 1/4 of Section 13). The units are in a non-hunting area of the Refuge. Both units are managed jointly. There is a connection, but no control structure gate between the units. Units 20a and 20b are comprised of a mix of open water and emergent vegetation. Water is supplied to Units 20a and 20b from Units 14a and 14b, and Unit 20b from the F-line Canal. Units 20a and 20b drain into Unit 21 and Unit 24 - Darrynane Lake. These units are used by waterfowl (September through May), shorebirds (March through early June and late July through mid-October,) and egrets and ibis (March through early October). These units have the potential to be managed as moist soil areas using surplus water from Units 14a and 14b. The desired water level in these units is 3.2 feet of water in the fall, winter and spring and 2.7 feet of water in the summer.

Unit 21

Unit 21 is located north of Unit 20a in the central area of the Refuge (T22S R11W, SW 1/4 of SW 1/4 of Section 13). Unit 21 is in a non-hunting area of the Refuge. The unit is comprised of a mix of open water and emergent vegetation. Water is supplied to the unit from Units 20a and 24 through control structure 24D. Unit 21 drains into Unit 22. This unit is used by waterfowl (September through May), shorebirds (March through May and August through early October), egrets (March through early October), and white pelicans (March through October). The desired water level in this unit is 5.5 feet of water in the fall, winter and spring and 5.0 feet of water in the summer.

Unit 22

Unit 22 is located northwest of Unit 21 in the central area of the Refuge (T22S R11W, E ½ of NE 1/4 of Section 14). This unit is in a non-hunting area of the Refuge. There is an interpretive nature trail around the unit and a 335-foot boardwalk through the wetland portion. Unit 22 is comprised of a mix of open water and emergent vegetation. Water is supplied to this unit from Unit 21. Unit 22 drains into Unit 23. This unit is used by waterfowl (September through May), shorebirds (March through early June and August through early October), and egrets (March through early October). The desired water level in this unit is 2.5 feet of water in the fall, winter and spring and 2.0 feet of water in the summer.

Unit 23 (Park Smith Lake)

Unit 23 is located northeast of Unit 22 in the central area of the Refuge (T22S R11W, SW 1/4 NW of SW 1/4 of Section 12 and NE 1/4 of NE 1/4 of Section 13). This unit is in a non-hunting area of the Refuge and includes a public photograph blind on the west side of the unit. Unit 23 is comprised of a mix of open water and emergent vegetation. Water is supplied to this unit from Unit 22. Unit 23 drains northward into Unit 26. This unit is used by waterfowl (September through May), and shorebirds (early March through May and late July through early October). The desired water level in this unit is 2.3 feet of water in the fall, winter and spring and 1.8 feet of water in the summer.

Unit 24 (Darrynane Lake)

Unit 24 is located northeast of Unit 20b in the central area of the Refuge. Unit 24 is an impoundment of Rattlesnake Creek (T22S R11W, SE 1/4 of Section 13). The unit is in a non-hunting area of the Refuge. The unit is comprised of a mix of open water and emergent vegetation. Water is supplied to the unit from Rattlesnake Creek. Water from Unit 24 drains into Unit 25, and is also diverted into Darrynane Canal. Unit 24 is very important for the Refuge's water supply. It is generally kept full of water for distribution to other units when needed. Unit 24 is used by waterfowl (September through May), pelicans (March through October,) and egrets (early March through early late September). The desired water level in this unit is 3.9 feet of water in the fall, winter and spring and 3.4 feet of water in the summer.

Unit 25

This unit is located northwest of Unit 24 in the central area of the Refuge, west of Rattlesnake Creek (T22S R11W, E ½ of SW 1/4 of Section 12). The unit is in a non-hunting area of the Refuge. The unit is comprised of a mix of open water and emergent vegetation. Water is supplied to this unit from Unit 24. Unit 25 drains into Unit 26 or is released into Rattlesnake Creek. This unit is managed for a variety of bird species, and is a particularly important duck and goose area. This unit is used by waterfowl (September through May), shorebirds (March through early June and August through mid-October), egrets (early March through early October), sandhill cranes (late September through late December and late January through mid-April), and bald eagles (October through early April). The desired water level in this unit is 5.9 feet of water in the fall, winter and spring and 5.4 feet of water in the summer.

Unit 26

Unit 26 is located northwest of Unit 25 in the central area of the Refuge (T22S R11W, NW 1/4 of Section 12). The unit is in a non-hunting area of the Refuge. Unit 26 is comprised of a mix of open water and emergent vegetation. Water is supplied to this unit from Units 23 and 25. Unit 26 drains into Units 48 and 49. Unit 26 contains a large, deep borrow area that must be filled before other shallow areas of the unit can be flooded. This unit is used by waterfowl (September through May), shorebirds (March through May and late July through mid-October), and white pelicans (March through October). The desired water level in this unit is 3.5 feet of water in the fall, winter and spring and 3.0 feet of water in the summer.

Unit 28

Unit 28 is located west of Unit 22 in the central area of the Refuge (T22S R11W, NW 1/4 of Section 14) along the western boundary. It is currently managed as a hunting area. The unit is comprised of a mix of open water and emergent vegetation. Water is supplied to this unit from the West canal. This unit drains into Unit 29 or back into the West canal. Unit 28 is often managed jointly with Units 29 and 30. During any given year, one of these three units is managed for shorebirds, one for waterfowl, and one drained and disced to control cattails. Unit 28 would be used by waterfowl (September through May), shorebirds (March through May and August through early October), and egrets (March through early October), depending on its management for that particular season. The desired water level in this unit is 5.5 feet of water in the fall, winter and spring and 5.0 feet of water in the summer.

Unit 29

Unit 29 is located north of Unit 28 in the central area of the Refuge (T22S R11W, SW 1/4 of Section 11) and along the western boundary. It is currently managed as a hunting area. The unit is comprised of a mix of open water and emergent vegetation. Water is supplied to this unit from the West canal. Unit 29 drains into Unit 30. This unit is often managed jointly with units 28 and 30. During any given year, one of these three units is managed for shorebirds, one for waterfowl, and one drained and disced to control cattails. Unit 29 would be used by waterfowl (September through May), shorebirds (March through May and August through early October), and egrets (March through early October), depending on its management for that particular season. The desired water level in this unit is 4.5 feet of water in the fall, winter and spring and 4.0 feet of water in the summer.

Unit 30

Unit 30 is located north of Unit 29 in the central area of the Refuge (T22S R11W, Section 11, NW 1/4) along the Refuge western boundary. It is currently managed as a hunting area. This unit is comprised of a mix of open water and emergent vegetation. Water is supplied to this unit from the West canal. Unit 30 drains back into the West canal. This unit is often managed jointly with Units 28 and 29. During any given year, one of these three units is managed for shorebirds, one for waterfowl, and one drained and disced to control cattails. Unit 30 would be used by waterfowl (September through May), shorebirds (March through May and August through early October), and egrets (March through early October), depending on its management for that particular season. The desired water level in this unit is 2.5 feet of water in the fall, winter and spring and 2.0 feet of water in the summer.

Unit 34

Unit 34 was originally part of the Refuge Master Development Plan prepared when the Refuge was acquired, but it was never constructed. The site for Unit 34 is located northeast of Units 25 and 26 on the east-central side of the Refuge, east of Darrynane canal (T22S R11W SE 1/4 of Section 1). The area consists of a series of shallow depressions. Dikes were originally planned to impound the entire area, but these were never built; however, a water control structure and feeder ditch were constructed off the Darrynane Canal to flood the area. Approximately 30 acres can be flooded. Hunting is allowed on this site. The unit is currently managed as a moist soil unit with water provided to the area from the Darrynane Canal when available. This unit is primarily used by waterfowl (September through early June). The desired management goal of this unit would be to keep water levels at 1.5 feet year round.

Unit 48

Unit 48 is located north of Unit 30 in the central area of the Refuge (T22S R11W, the central area of Section 2). This unit and surrounding land is in a non-hunting area of the Refuge. Unit 48 is comprised of a mix of open water and emergent vegetation. Water is supplied to the unit from the West canal and from that pass through Unit 26. Water is often moved through both Units 48 and 49 to flood an un-numbered wetland unit south of the Rattlesnake Canal berm. Unit 48 is managed for a variety of bird species. This unit is used by waterfowl (September through May), shorebirds (March through early June and August through early October), egrets and ibis (March through early October), and white pelicans (March through

October). White-faced Ibis are known to nest in this unit. The desired water level in this unit is 3.9 feet of water in the fall, winter and spring and 3.4 feet of water in the summer.

Unit 49

Unit 49 is located at the northeast end of Unit 48 in the central area of the Refuge (T21S and T22S R11W, SE 1/4 of SE 1/4 of Section 35 and NE1/4 of Section 2). The wetland unit and surrounding land is within a non-hunting area of the Refuge. This unit is comprised of a mix of open water and emergent vegetation. Water is supplied to this unit from control structure 48E. Unit 49 drains into Unit 61. Water is often moved through both Unit 49 and Unit 48 to flood an un-numbered wetland unit south of the Rattlesnake Canal berm. Unit 49 is managed for a variety of bird species. This unit is used by waterfowl (September through May), shorebirds (March through early June and August through early October), and egrets and ibis (March through mid-October). White-faced Ibis are known to nest in this unit. The desired water level in this unit is 3.7 feet of water in the fall, winter and spring and 3.2 feet of water in the summer.

Rattlesnake Canal Berm Area (Unit 51)

This area includes two un-numbered units referred to as the Marsh Meadow in the original Refuge Master Development Plan. For easier reference, these units are referred to collectively as Unit 51 in the remainder of this report. Unit 51 is located south of Rattlesnake Canal berm (T21S R11W, portions of Sections 34 and 35). This unit is within a non-hunting area of the Refuge. The unit is fed by water from Units 48 and 49. The first portion of unit is 75 to 80 acres in size and is located south of Rattlesnake Canal berm area and east of the old township road between sections 34 and 35. The second management area is 50 to 60 acres in size, and is located south of Rattlesnake Canal berm area and west of the old township road between sections 34 and 35. The first unit is filled from excess surface water from Units 48 and 49 and drains back into Rattlesnake Canal through control structure RCC1. The second unit is filled from excess water from Rattlesnake Canal through control structure RCC2 and also drains into Rattlesnake Canal. These areas are managed as moist soil areas when water is available to flood them. They are used by waterfowl (September through May), shorebirds (March through May and August through early October), ibis (early March through mid-October) and egrets (March through mid-October). The desired water level over this area is 1.5 - 2.0 feet year round, with a minimum depth of 1.0 foot and a maximum depth of 3.0 feet.

Photograph 5: Unit 49 looking south from north end showing open water borrow area and typical vegetation.

Photograph 6: Unit 61 looking south from the north dike of the unit.

Unit 40

Unit 40 is located approximately two miles north of Unit 49 in the north-central portion of the Refuge (T21S R11W, east ½ of the NE 1/4). It is within a hunting area. This unit is comprised of a mix of open water and emergent vegetation. Water is supplied from Darrynane Canal through control structure 40C. Unit 40 drains northward into the Dead Horse Slough area and eventually into Salt Creek. This unit is managed for a variety of bird species. This unit is used by waterfowl (September through May), shorebirds (March through early June and August through early October,) egrets (March through early October), and white pelicans (March through October). The desired water level in this unit is 6.6 feet of water in the fall, winter and spring and 6.1 feet of water in the summer.

Unit 44

This unit, named Unit 44 for modeling purposes, is located north of Unit 40 (T21S R11W, S ½ of Section 24), and covers approximately 180 to 200 acres when flooded. Hunting is allowed on this unit. The area consists of small potholes, and old dikes constructed by hunting clubs prior to Refuge acquisition. The original Refuge Master Development Plan identifies two units, Units 44 and 45, in this area but neither have been constructed. For easier reference, this entire area is referred to as Unit 44 in the remainder of this report. This unit is filled with water from Unit 40 in the late fall, through control structure 40A. Drainage is into Salt Creek. The unit is comprised of a mix of open water, emergent vegetation, shrub/scrub, woodlots, and grassy uplands. It is primarily used by waterfowl (September through early June) when water is available. The desired water level is 1.5 feet year round.

Dead Horse Slough

This area is a natural slough wetland, named Unit 37 and 39 for modeling purposes, located in the northeast portion of the Refuge (T21S R10W & R11W, portions of Sections 13, 18, 24, 25, and 36). The portion of the slough on the Refuge is approximately three miles long, drains south to north and empties into Salt Creek. There is a water control structure at each of the two road culverts which cross the slough on the Refuge. These roads also serve as dikes which help flood approximately 60 to 70 acres of land. For easier reference in the remainder of this report, these two management areas are referred to as Unit 37 and 39 after their respective control structures. Water can be taken from Darrynane Canal, through control structure DCF when necessary, and put in Dead Horse Slough. These units are comprised of a mix of open water, emergent vegetation, shrub/scrub, woodlots, and grassy uplands. Bird use of the area includes waterfowl (September through May) egrets (March through mid-October) and ibis (early March through mid-October) when water is available. The desired water level is 1.5 feet year round.

Unit 57 (East Lake)

Unit 57 is located northwest of Unit 48 (T21S R11W, portions of Sections 27 and 34). Unit 57 and surrounding land is in a non-hunting area of the Refuge. This unit is comprised of a mix of open water and emergent vegetation. Water is supplied to the unit from control structure RCF on Rattlesnake Creek canal. Unit 57 drains into Unit 78, the floodplan area on the inside of Wildlife Drive. Unit 57 is managed for a variety of bird species. It is used by waterfowl (September through May), shorebirds (March through May and late July through early October), egrets and ibis (March through early October), and bald eagles (October through March). Refuge staff have recorded bald eagle roosts on the west side of Unit 57. The desired water level in this unit is 3.0 feet of water in the fall, winter and spring and 2.5 feet of water in the summer.

Unit 58

Unit 58 is located west of Unit 57, adjacent to the east side of Wildlife Drive (T21S R11W, portions of Sections 27, 33 and 34). The unit and surrounding land is within a non-hunting area of the Refuge. This unit is comprised of a mix of open water and emergent vegetation. Water is supplied to the unit from a control point on Big Salt Marsh. Unit 58 drains to Unit 78, the floodplan area on the inside of Wildlife Drive. This unit is managed for a variety of bird species. It is used by waterfowl (September through May), shorebirds (March through early June and August through mid-October), egrets and ibis (March through early October), bald eagles (October through March), interior least terns (mid-April through mid-September), and white pelicans (March through October). Refuge staff have recorded over 8,000 nesting egrets in this unit in past years. Unit 58 is considered a high wildlife use area due to its close proximity to Big Salt Marsh and the North Flats. The desired water level in this unit is 5.5 feet of water in the fall, winter and spring and 5.0 feet of water in the summer.

Unit 61

Unit 61 is located east of Unit 57 in the north central portion of the Refuge (T21S R11W, SW 1/4 of Unit 26 and NW 1/4 of Section 35). The unit and surrounding land is within a non-hunting area of the Refuge. This unit is comprised of a mix of open water and emergent vegetation. Water is provided to the unit from the Rattlesnake Canal. This unit drains into units 63 and 57. This unit is managed for a variety of bird species and is a major wildlife use area. Over 25,000 ducks use this wetland during peak migrations. This unit is used by waterfowl (September through May), shorebirds (March through early June and August through mid-October), egrets and ibis (early March through early October), sandhill cranes (late September through December and late January through mid-April), and bald eagles (late September through early April). The desired water level in this unit is 5.0 feet of water in the fall, winter and spring and 4.5 feet of water in the summer.

Unit 62

Unit 62 is located northeast of Unit 61 in the north central portion of the Refuge, east of Rattlesnake Creek (T21S R11W, east ½ of the NW 1/4 of Section 26). The unit and surrounding land is within a non-hunting area of the Refuge. Water is supplied to Unit 62 by the Darrynane Canal to Unit 40. Units 62 and 40 are managed jointly. Unit 62 is comprised of a mix of open water and emergent vegetation. This unit is managed for a variety of bird species and is a major wildlife use area. Unit 62 is used by waterfowl (September through May), shorebirds (March through early June and August through mid-October), and egrets (March through early October). The desired water level in this unit is 8.5 feet of water in the fall, winter and spring and 8.0 feet of water in the summer.

Unit 63

Unit 63 is located north of Unit 61 in the north central portion of the Refuge (T21S R11W, NW 1/4 of Section 26). This unit and surrounding land is in a non-hunting area of the Refuge. Water is provided to this unit through a control structure from Unit 61. This unit is comprised of a mix of open water and emergent vegetation, consisting mostly of cattails. A large borrow area is present in this unit. Unit 63 is generally managed as a moist soil area using surplus water from Unit 61. This unit is managed for a variety of bird species and is a major wildlife use area when water is present. The unit is used by waterfowl (September through May), shorebirds (March through early June and August through mid-

October), egrets and ibis (early March through early October), and sandhill cranes (late September through December and late January through mid-April). The desired water level in this unit is 4.7 feet of water in the fall, winter and spring and 4.2 feet of water in the summer.

Unit 75 (Big Salt Marsh)

Unit 75 is located southwest of Unit 58 on the north side of the Refuge near the western boundary (T21S & T22S R11W, portions of sections 28, 29, 32, 33, 4 and 5) and is the largest impoundment on the Refuge. Big Salt Marsh and the land surrounding the unit are in a non-hunting area of the Refuge. Water is provided primarily through the West canal entering from the east side of Big Salt Marsh. Additional water flows into the marsh from drainage out of the sand hills northwest of the marsh, off the Refuge. Big Salt Marsh drains into Units 80 and 81 (North Flats). Much of the Big Salt Marsh is open water when full. This unit is managed for a variety of bird species and is a major wildlife use area. Federally endangered interior least terns, piping plovers , whooping cranes and federally threatened bald eagles use this wetland. Over 40 whooping cranes were observed using this and adjacent units during 1996. This unit is used by waterfowl (September through May), shorebirds (March through May and August through mid-October), sandhill cranes (late September through December and late January through mid-April), egrets and ibis (March through September), bald eagles (late September through early April), least terns (late March through September), and whooping cranes (mid-March through April and October through November). The desired water level in this unit is 4.5 feet of water in the fall, winter and spring and 4.0 feet of water in the summer.

Unit 78 (Interior of Wildlife Drive)

Unit 78 is located within the interior area of the Wildlife Drive, adjacent to Big Salt Marsh, on the north portion of the Refuge (T21S R11W, portions of Sections 27, 28, 33 and 34). The unit and surrounding land is within a non-hunting area of the Refuge. Water is provided primarily through control structures from Units 57, 58 and 75. The vegetation in this unit consists of moist soil species, grasses, scattered shrubs and occasional open water pools. Mud flats area also scattered throughout the unit. Unit 78 is managed for a variety of bird species, particularly shorebirds. The unit is burned annually to improve shorebird habitat. Federally endangered least terns, piping plovers, whooping cranes and bald eagles use this wetland. Unit 78 is used by waterfowl (September through May), shorebirds (March through May and


Photograph 7: Big Salt Marsh looking west from where Wildlife Drive turns north.


Photograph 8: Big Salt Marsh looking north at the portion of the Marsh contained within Wildlife Drive.

August through early October), sandhill cranes (mid-September through December and late January through late April), egrets and ibis (March through September), bald eagles (late September through March), least terns (late March through September), whooping cranes (mid-March through April and October through November), and white pelicans (March through October). The desired water level in this unit is 5.2 feet of water in the fall, winter and spring and 4.7 feet of water in the summer.

Unit 80 and 81 (North Flats)

Units 80 and 81 are located northeast of Big Salt Marsh on the north portion of the Refuge (T21S R11W, SE 1/4 of Section 21 and W ½ of Section 22). They are currently managed as hunting areas. Water is provided primarily from Units 78. The vegetation in these units is sparse, consisting primarily of grasses, emergent wetland and moist soil species, and occasional salt cedars. Salt and mud flats are present throughout the units. These units are used by a variety of bird species, but are particularly important to shorebirds. Federally endangered least terns are known to nest on these units and piping plovers may also nest here from late March through September. Electric fence enclosures are erected prior to the nesting season to prevent egg predation and human disturbance. The fences are removed after the terns have left. Other endangered species that use these wetlands include whooping cranes (mid-March through April and October through late November), and bald eagles (October through March). These units are managed for a variety of bird species. They are used by sandhill cranes (January through mid-April and late September through December), waterfowl (September through May), and shorebirds (March through May and late July through early October). These units require a constant water depth of 0.70 feet year round.

Unit 83 (North Lake)

Unit 83 is located near the north-central boundary of the Refuge (T21S R11W, W1/2 of SE 1/4 of Section 15, and W1/2 of NE 1/4 of Section 22). It is currently managed as a hunting area. Water is provided to this unit from the surface runoff of Units 80 and 81 and from groundwater. Water drains from this unit into Salt Creek. This unit is managed for a variety of bird species. These include waterfowl (September through May), shorebirds (March through early June and late July through early October), least terns (April through September), sandhill cranes (February through mid-April and October through December), whooping cranes (mid-March through May and October through November), white pelicans (March

Photograph 9: North Lake area looking west from point where foot-access path crosses Salt Creek.

Photograph 10: Salt Creek looking east as it leaves the Refuge.

through October), and bald eagles (October through March). The desired water level in this unit is 2.0 feet of water in the fall, winter and spring and 1.5 feet of water in the summer.

6. Cultural Resources

Only one cultural resource site (the Comanche Site) is recorded within the Refuge. Even though the known cultural resources within the Refuge are limited to one site, it is projected that the same patterns for these resources are evident throughout the basin and are found within the Refuge. The Comanche Archaeological Site (14SF301) is a multicomponent prehistoric site that is listed on the National Register of Historic Places. The name of this site is erroneous as there is no evidence that the Comanche ever occupied the site. A review of the artifact assemblage indicates that this site was occupied from the Early Ceramic stage to the Great Bend aspect of the Late Ceramic stage (500 to 1500 A.D.). Even though no other sites have been recorded in the Refuge, the resources available suggest that the potential is very high that additional sites are present. It is projected that most of these sites are small campsites, likely not considered eligible for listing on the National Register of Historic Places; however, other significant cultural resources, similar to the Comanche site, may be present. Based on the limited number of significant sites in the drainage basin, it is assumed that such sites are rare in the area.

D. SWATMOD MODEL

A comprehensive computer model of the Rattlesnake Creek Basin, know as SWATMOD, was developed for the KDWR and other cooperating agencies, including the Service, Kansas Geological Survey and Kansas State University. The purpose of this model is to allow KDWR and the other interested parties to evaluate long-term water management strategies for the Rattlesnake Creek Basin (Sophocleous and Koelliker, 1997).

The SWATMOD model is capable of simulating surface-water runoff, ground-water movement, and stream-aquifer interactions on a continuous basis for the entire Rattlesnake Creek Basin. The model was build by linking a surface-water model, SWAT, with a ground-water model, MODFLOW. Custom computer routines were developed to link the two models and to provide a decision support system that can be used to modify basin management assumptions using a user-friendly, graphical interface.

For the purposes of model development, the Rattlesnake Creek Basin was divided into 35 subbasins. These subbasins are shown in Figure I-1. Within each subbasin, data on precipitation, evapotranspiration, soils, and cropping patterns were collected and formatted for use in the SWAT model. Execution of the SWAT model provides estimates of daily surface runoff, stream flow and percolation for the selected 40-year simulation period, calendar years 1955 through 1994. The percolation estimates generated by SWAT are then passed to MODFLOW.

The MODFLOW ground-water model uses a finite difference approximation of a layered aquifer system. For the Rattlesnake Creek Basin model, the aquifer system that underlies the basin is segmented into a rectangular grid with a half-mile spacing. For each grid cell, data on aquifer properties, such as saturated thickness and transmisivities, were collected and formatted for use in MODFLOW. The other key input to MODFLOW is data on water pumped from each well in the basin. MODFLOW, which operates using a monthly time step, uses the percolation estimates generated by SWAT and the other aquifer properties to calculate ground-water flow, and aquifer-stream interactions. The monthly streamflow estimates that come from the SWATMOD model are extracted from MODFLOW's stream package. These estimates form the basis for the streamflow data used in this study.

The combined SWAT/MODFLOW model, SWATMOD, was calibrated and validated using available streamflow data for Rattlesnake Creek. These data have been collected by the USGS at their Zenith stream gage, which is located on Rattlesnake Creek just upstream of the Refuge. These recorded streamflow data were compared to predicted values to validate the results of the SWATMOD model.

Due to the variability of streamflow in Rattlesnake Creek, most water use in the Rattlesnake Creek Basin comes from groundwater. Each permitted well within the basin is represented in the MODFLOW portion of the SWATMOD model. Since the Refuge is located at the lower end of the Rattlesnake Creek Basin and is the only major appropriator of surface water in the basin, the MODFLOW model does not attempt to administer surface water rights in any way. Nearly all of the flow in Rattlesnake Creek, up to the Refuge's water right, is assumed to be available for diversion by the Service.

The SWATMOD decision support system allows users to easily modify basin management assumptions including land use by subbasin and permitted groundwater withdrawals. However, since it is difficult to accurately predict future management policies for the Rattlesnake Creek Basin, all of the analyses conducted in this study are based on the baseline SWATMOD model. Under these baseline conditions, basin land use and irrigation well withdrawals are assumed to remain constant at their current levels throughout the 40-year simulation period.

E. COORDINATING AGENCIES

This project is coordinated with numerous state and federal agencies and local entities. Initial input and data were requested from and monthly progress reports were provided to the following agencies:

- U.S. Fish and Wildlife Service (Service).
- U.S. Geological Survey (USGS).
- U.S. Army Corps of Engineers (Corps).
- U.S. Environmental Protection Agency (EPA).
- Kansas Board of Agriculture - Division of Water Resources (KDWR).
- Kansas Water Office (KWO).
- Kansas Department of Health and Environment (KDHE).
- Big Bend Groundwater Management District No. 5 (GMD5).
- Kansas Geological Survey (KGS).
- Kansas Department of Wildlife and Parks (KDWP).
- Water Protection Association of Central Kansas (WaterPACK).

The Rattlesnake Creek Basin/Quivira Partnership (Partnership), was developed in 1994 between the Service, KDWR, GMD5, and WaterPACK. According to the Partnership Agreement, the goals of the Partnership are "to work in a cooperative manner to develop and implement solutions to problems in the Rattlesnake Creek Basin; to use a community involvement approach to address issues in the Rattlesnake Creek Basin; to provide lines of communication between KDWR, Subasin Water Resources Management Program, Basin Management Team, residents and water users in the basin."

The primary issues identified by the Partnership include the following:

- Fluctuations of aquifer levels in basin result in flows that are inadequate in some years or portions of some years to allow objective level management of Quivira National Wildlife Refuge.
- Groundwater withdrawals, especially during drought conditions, reduce surface water flows.
- Irrigation demands for water often coincide with demands of water at the Refuge.
- Partnership members desire, through management of available water supplies, to assure adequate water for all users, to sustain profitable agriculture and abundant wildlife and habitat to insure an acceptable standard of living for basin residents.

Continued coordination with the above-listed agencies will be maintained to implement the Service's selected alternative or plan. These agencies will provide technical support, answer regulatory questions and issue permits for the construction of the selected project(s).

PART II

EVALUATION CRITERIA

A. GENERAL

This section of the report describes the major evaluation criteria applied to each water supply alternative to guide the decision-making process, screen out undesirable alternatives and select viable alternatives for the Service. Major evaluation criteria include the following:

- Water supply capability
- Water quality
- Legal issues
- Policy and political issues
- Future availability
- Environmental issues
- Wetland habitat enhancement
- Cost estimates and economic comparisons

B. WATER SUPPLY CAPABILITY

Each potential water supply alternative must have the capability to supply all or a part of the projected water need. Water supply capability may be indicated by the following terms:

- Firm yield and substantial yield
- Safe peaking ability
- Ability to meet demands
- Water rights
- Integrated (conjunctive) use

The interpretation of several terms may vary slightly depending on whether a surface water or groundwater source is involved.

1. Firm Yield

The firm yield of a surface water reservoir is sometimes considered to be the yield of the reservoir during the most severe drought of record as determined by a reservoir inflow/outflow operational study. This is typically how the state of Kansas determines reservoir firm yield. Another approach is to consider the firm yield as one with a two percent chance of interruption as caused by a drought condition with a one-in-50-year recurrence cycle.

By contrast, the firm yield of an individual groundwater well is normally considered to be the pumping rate which will not cause incrustation damage to the well or aquifer formation (assuming adequate recharge from rainfall or rivers is available). Such yield is normally established by well screen entrance velocities and aquifer characteristics, including water chemistry, rate of drawdown, and static groundwater level.

The Big Bend Groundwater Management District No. 5 (GMD5) practices water management based on "sustainable yield" or the long-term yield of a supply source. Sustainable yield accounts for the hydraulic connection between surface water and groundwater, while allowing for reasonable raising and lowering of the water table.

2. Safe Peaking Ability or Firm Capacity

"Safe" peaking ability may be determined by time of use or frequency of use or other conditions. For mechanical components, such as pumps or wells, "safe" peaking ability (or firm capacity) is figured as the available flow with the largest unit considered to be out of service. For this study, temporary loss of a mechanical component is acceptable and mechanical systems are concepted for maximum capacity with no additional capacity for "safe" peaking ability or firm yield.

3. Ability to Meet Demands

The ability of a water supply to meet total water demands may be considered collectively with other sources or as a separate project. The supply of water from small, multiple water sources may often times be extended to meet total water demands by integrated, optimized operation.

4. Water Rights

The KDWR controls water rights in Kansas. Water rights specify a maximum annual amount that may be used and a maximum rate of diversion. Historically, water rights were issued with no consideration of actual supply. Currently, new water rights are only issued if sustainable yield criteria are met.

5. Integrated Use

Based on discussions with the State of Kansas, new water rights may be obtained, with conditions, that would allow the Service to use preset quantities of water from groundwater and surface water sources.

Such a permit would allow the Service to manage the operations of their water supplies to maximize use and storage excess runoff from surface water sources for use during drought conditions.

C. WATER QUALITY

The quality of raw water from a water supply alternative and the quality of water required for the management units are important variables because water treatment could be required which would impact an alternative's feasibility. Water supply alternatives involving aquifer recharge may need treatment of recharge water to meet requirements by the Kansas Department of Health and Environment (KDHE). KDHE typically looks at each recharge application on a case-by-case basis with the general guideline that the recharge water should not degrade water quality in the aquifer. At this time, KDHE has no minimum water quality standards for aquifer recharge and subsurface storage.

D. LEGAL ISSUES

The Kansas Water Transfer Act may apply to one water supply alternative. The purpose of this law is "to determine whether the benefits to the State for approving the transfer outweighs the benefits to the State for not approving the transfer."

E. POLICY AND POLITICAL ISSUES

Policy issues that need to be considered include the purchase of water rights from groundwater irrigators. Political issues associated with each water supply alternative will be considered since any significant opposition could cause long-term delays, substantial cost increases, litigation and the eventual canceling of a project.

F. FUTURE AVAILABILITY

Future availability of a water supply may be related to the ability of the Service to execute the plan given a number of regulatory, social, economic and political constraints. For example, in today's regulatory climate with wetlands issues and emphasis on environmental concerns, entering into a planning phase with the goal of constructing a new reservoir may likely be a very difficult, time-consuming process with no assurance of success. Other factors, also need to be considered, such as continuing development and the need for water by other communities which could eliminate remaining available water supplies over the next 10 to 50-year period.

G. ENVIRONMENTAL ISSUES

Environmental issues associated with each alternative will be evaluated to determine if a possible environmental "deficiency" or "fatal flaw" might exist. Typical fatal flaws deal with the presence of federal endangered species or wetlands or other significant environmental impacts.

Various environmental areas of concern might involve the following:

- Relocations (dwellings, churches, and cemeteries)
- Land or right-of-way required for project
- Timber removal
- Inundation of rivers and streams
- Wetlands
- Cultural resources
- Biological resources
  - Federal endangered species
  - Federal threatened species
  - State endangered species
  - State rare species
- State forest and natural areas

H. WETLAND HABITAT ENHANCEMENT

The primary purpose of this study is to identify and evaluate alternative projects that can increase the quantity, quality, and dependability of available wildlife habitat at the Refuge, particularly for migratory bird species that are dependent on wetlands. Although the creation of additional wetland habitat is desirable, it is more important to provide a consistent amount of habitat on a dependable basis. Increased amounts of wetland habitat one year may benefit individuals for that year but the negative impacts that result from reduced habitat in subsequent years can outweigh these short-term benefits. Therefore, the amount of dependable habitat available at the Refuge is used as the primary measure of project benefits.

Under current conditions, both the quantity and quality of habitat available at the Refuge vary from year to year and season to season. In order to quantify the amount of dependable wetland habitat provided with each potential improvement project, a habitat duration score is developed for each project. This score is derived from the operation simulations for each alternative. The operations model for the Refuge is discussed in Part III of this report. The operations model provides estimates of storage in each management unit each month during the 40-year simulation period. From this information, the total amounts of optimum shorebird and waterfowl habitat and total wetland habitat acreage are determined for each month during the critical management period, September through April. Optimum shorebird and waterfowl habitats are defined as those portions of each management unit with water depths of 1 to 4 inches and 10 to 18 inches, respectively. These habitat values are then analyzed to determine the 80th percentile values. The 80th percentile values are those which are available 80 percent of the time, or 4 out of every 5 years on average.

A value is developed for waterfowl and shorebird habitat for use in the benefit-cost analysis. Changes in acres of habitat are evaluated for each water supply alternative compared to the current baseline condition.

The value for Refuge habitat is based on annual visitor use days and an estimate of daily expenditures n the area. The Refuge does not directly receive revenues from hunters and tourists. User fees and visitor expenditures contribute to the economics of the local communities and the State of Kansas and the federal government through the purchase of goods, services supplies, and their assessed taxes.

Estimated visitor use of the Refuge and associated expenditures were obtained from the Service's "Banking on Nature: The Economic Benefits to Local Communities of National Wildlife Refuge Visitation" (Laughland and Caudill, 1997). The Refuge, located within Region 6, is classified as a "medium hunting use" area, and is estimated to provide 38,400 visitor days annually. Annual visitation is divided into several activity categories, as shown in Table II-1.

Annual hunting visitors days on the Refuge are reported to be 14,700. This number is an annual total and does not separate different types of hunting, such as big game, small game, or migratory bird. However, expenditures for different types of hunting do vary. All hunting is attributable to small game (upland birds, rabbits, etc.) or migratory bird (ducks, geese, doves). Big game hunting is not permitted on the Refuge. Approximately 75 percent of the total hunting days are in pursuit of migratory birds (11,000 visits) and 25 percent are pursuing small game (3,700 visits) (Hilley, 1998).

Table II-1
VISITOR USE DAYS FOR QUIVIRA NATIONAL WILDLIFE REFUGE

	Total Visitor Days	Visitor Days by Activity					
		Visitor Center	Nature Trails	Small-game Hunting	Migratory Bird Hunting	Fishing	Other
Kansas Residents	28,800	4,950	11,550	2,775	8,250	150	1,125
Non-Residents	9,600	1,650	3,850	925	2,750	50	375
Total	38,400	6,600	15,400	3,700	11,000	200	1,500

Kansas residents comprise seventy-five percent of the users for all Refuge activities (Hilley, 1998). This is significant because in-state users would typically spend less on a recreation day within their state than out-of-state visitors. Table II-2 provides a summary of the visitor use by residents and non-residents, the estimated expenditures per recreation day for the various activities, and the total expenditures attributable to each activity and the Refuge.

Using estimated visitor days and the expenditures for each activity, a total of $840,100 (1992 dollars) is annually expended for recreational activities at the Refuge. While the Refuge contains a variety of habitat types, it is assumed that visitors are primarily drawn to recreational opportunities provided by wetlands. These recreational opportunities include nature trails through the marshes, bird watching, waterfowl hunting, and the interpretive visitors center. When marsh habitat is present, the large numbers of waterfowl and shorebirds, particularly whooping cranes and large flocks of sand hill cranes and waterfowl, are the main attractions to Refuge visitors. Only small game hunting is not directly related to wetland or marsh habitat since these activities are still available on the Refuge even when marshes are dry. Expenditures for small game hunting are therefore removed from the above listed total, leaving a total of $756,960 per year for recreational opportunities provided by marsh habitat on the Refuge.

About 1,500 acres of marsh habitat are estimated to be available 80 percent of the time during the high use period from September through April (as discussed in greater detail in Part IV.C.1.). The 80 percent quantity is selected to represent the amount of habitat that would be available to consistently attract waterfowl, sand hill cranes, whooping cranes, and shorebirds to the Refuge. Use of the Refuge by wildlife, numbers and variety appropriate for the amount of habitat present, on a consistent basis is responsible for the number of estimated user days. It is assumed that, all things remaining constant, increased habitat will result in increased visitor days and visitor expenditures. For example, no change in whooping crane use of the Refuge or major reduction in waterfowl numbers would occur. Annual habitat value is determined by dividing the annual expenditures due to the Refuge ($756,950) by the acres of marsh habitat available 80 percent of the time (1,500 acres). This results in an annual habitat value of $504 per acre (1992 dollars) of marsh. The habitat value of an acre of marsh at the Refuge is inflated to 1998 dollars at 3.5 percent per year to a value of $618 per acre per year. No other costs have been included since all marsh habitat being

Table II-2
EXPENDITURES FOR RECREATIONAL ACTIVITIES AT QUIVIRA NATIONAL WILDLIFE REFUGE

	Location	Total Visitor Days	Spending per Day	Total ($)
Kansas Residents	Visitor Center	4,950	$12.27	60,737
Non-Residents		1,650	$47.69	78,689
Kansas Residents	Nature Trails	11,550	$12.27	141,719
Non-Residents		3,850	$47.69	183,607
Kansas Residents	Small-game Hunting	2,775	$12.97	35,992
Non-Residents		925	$51.00	47,175
Kansas Residents	Migratory Bird Hunting	8,250	13.04	107,580
Non-Residents		2,750	55.60	152,900
Kansas Residents	Fishing	150	$13.55	2,033
Non-Residents		50	$55.46	2,773
Kansas Residents	Other	1,125	$12.27	13,804
Non-Residents		375	$47.69	17,884
	TOTAL	**38,400**		**844,890**

considered lies within the Refuge. The dollar value for the marsh habitat only considers the additional economic benefit derived from the land and the habitat it provides (Laughland and Caudill, 1997).

A second data source is for the State of Kansas (U.S. Department of the Interior/U.S. Department of Commerce, 1996) which estimates the 1998 habitat value at approximately $296 per acre per year. This value uses recreational days and expenditures for Kansas to calculate an expenditure per day of recreational activities. These values are then multiplied by the number of various user days at the Refuge (Laughland and Caudill, 1997). Non-resident and resident use as well as all types of hunting are considered. This data also reflects state-wide usage and is not specific to a national wildlife refuge. These limitations decrease the overall value of the data to the Quivira NWR and are not used in this study.

I. COST ESTIMATES AND ECONOMIC COMPARISONS

Cost estimates for construction and operation, maintenance, replacement and energy (OMR&E), present value analysis and other cost allowances are used to compare each viable improvement project to determine the most economically feasible and best alternative.

Cost estimates for alternatives developed during this study will require the conceptual design of facilities for the purpose of determining preliminary sizes and quantities of materials and components. Unit cost data and component cost information from historical projects are used in the estimates. Determination of OMR&E costs require preliminary consideration of how each plan will function in relation to existing facilities. All costs are developed for an Engineering News Record (ENR) construction cost index of 5909.18 for the Kansas City regional area for December 1997.

1. Project Costs

Project costs for each alternative include construction costs, contingencies, land or right-of-way costs, environmental mitigation costs, and other costs. Project costs are often used for the general comparison of alternatives in present-day dollars without consideration of the time value of money.

Project cost estimates are required for the purpose of comparing each potential Refuge improvement projects to determine the most economically viable alternatives. The unit costs used in this evaluation are listed in Table II-3. Estimates of costs per unit of available flow are based on total project cost divided by a 20-year period (based on present value estimates from year 2000 through 2019). This time frame is used for all alternatives to allow the alternatives to be evaluated on an equal basis.

Table II-3
UNIT COSTS

Item	Units	Cost
Intake and Pump Station:		
4 MGD	$	500,000
10 MGD	$	1,000,000
20 MGD	$	1,500,000
35 MGD	$	2,000,000
Well, Pump, Motor	$	75,000
Piping Valves, Meters, Fence	$	10,000
Electrical Power Supply	$	30,000
Piping:		
12" PVC	$/LF	20
16" PVC	$/LF	25
16" Ductile Iron	$/LF	56
24" Ductile Iron	$/LF	84
30" Ductile Iron	$/LF	105
36" Ductile Iron	$/LF	126
Crossings:		
Creek/Stream 300' long	$/LF	370
Highway Crossings 600' long	$/LF	700
Railroad Crossings 600' long	$/LF	700
Land	$/acre	2,000
Right-of-Way	$/ft	1.00
Contingency	%	20
Other Costs	%	20
Move soil with scraper (one mile haul)	$/CY	$2.00
Move soil with trucks (one mile haul)	$/CY	$4.25
Move clay liner with trucks (two mile haul)	$/CY	$5.25
Move clay liner with trucks (five mile haul)	$/CY	$7.25
General earthwork	$/CY	$2.50
Dike construction	$/CY	$0.75
Compact impervious core for dike	$/CY	$1.00
Line canal with 6" clay layer	$/CY	$10.00
Dredging (manual)	$/CY	$4.00
Concrete Box Culvert (three - 12' x 4')	Each	$45,000
Concrete Box Culvert (one - 12' x 4')	Each	$17,500
Concrete Spillway (6" x 20' x 300')	$ LS	$15,000

Table II-3
UNIT COSTS (continued)

Item	Units	Cost
Sheet Pile:		
10 feet high for one mile	$/LF	$110
15 feet high for one mile	$/LF	$165
Gravel Road 30 feet width	$/LF	$63
Gravel Road 20 feet width	$/LF	$42
Gravel Road 10 feet width	$/LF	$21
Guard rails	$/LF	$15
Inverted siphons:		
24" Diameter concrete pipe	$/LF	$40
24" Diameter 45 deg. concrete fittings	Each	$450
48" Diameter concrete pipe	$/LF	$80
48" Diameter 45 deg. concrete fittings	Each	$700
Stop log structure (4-feet wide)	Each	$2,000+800/LF Height
Gated control structure (3 bays, 10' wide, 12' height)	Each	$180,000
Gated control structure (3 bays, 5' wide, 12' height)	Each	$100,000
Control structure (3 bays, 10' wide, 8' height)	Each	$160,000
Control structure for other canals (2 bays, 5' wide, 7' height)	Each	$70,000
Gated control structure (3 bays, 10' wide, 17' height)	Each	$200,000
Warm season prairie grass seed	$/AC	$1,200
Rip Rap (1-foot boulders)	$/SY	$22
Rip Rap (2-foot boulders)	$/SY	$44
Pump Station (4-10 MGD Pumps)	Each	$1,000,000
Pump Station (4-20 MGD Pumps)	Each	$1,200,000

a. Construction Cost Estimates

Construction cost estimates are the primary components of project costs from which many related costs are determined. Estimates of construction costs are based on the application of unit or component costs, as derived from historical projects, to the number and size of components and quantities of materials associated with each plan.

Contingencies of 20 percent for construction are included as part of the project cost estimates. Contingencies are cost allowances for items or conditions which are not known or anticipated for the project at this point in time.

b. Land and Right-of-Way Costs

Land and right-of-way costs associated with each alternative are estimated from historical information. A contingency allowance is included in the costs to account for some escalation of prices created by the need for land and right-of-way by various projects.

Right-of-way costs for the pipeline alternatives are based on the acquisition of a permanent 50-foot-wide easement with a temporary 50-foot-wide construction easement (for a total of 100 feet, including severance costs). Permanent easements are used for the right-of-way-access along the pipeline route for future repairs and operation and maintenance activities. Temporary construction easements are used during construction and revert back to the landowner after pipeline construction is complete.

c. Environmental Mitigation Costs

Cost estimates for various types of environmental mitigation will be included in each water supply alternative. Typical cost allowances may include fish and wildlife mitigation, wetlands mitigation, and archaeological resource mitigation.

d. Other Costs

Other costs associated with each project include the fees and expenses associated with the technical, professional and special services required to execute the delivery of each plan. Such costs include environmental, technical, geotechnical and hydrogeologic studies; land and right-of-way appraisals and negotiations, design and resident engineering fees, construction materials testing, legal fees, project insurance, land surveying and legal descriptions, project design surveying, operation and maintenance (O&M) manuals, additional management O&M personnel, and personnel training all are estimated at 20 percent.

2. Operation, Maintenance, Replacement and Energy Costs

Operation, maintenance, replacement and energy (OMR&E) costs are used along with capital costs in the economic comparison of alternatives. Such costs, which are usually budgeted for on an annual basis, are on-going project costs related to facility operation which extend over the life of each project. An energy cost of $0.095 per kilowatt-hour is used in this study.

3. Present Value Analysis

Present value analysis will be performed on each potential improvement project to permit an economic comparison of project costs and OMR&E costs of all the various phases of each alternative in 1998 dollars. Present value computations cover the study period of 20 years from years 2000 through 2019 for the purpose of comparing all project alternatives. Inflation of costs is figured at an annual rate of 4 percent and the discount rate for bringing costs back to 1998 is figured at a discount rate of 7 percent. The cost of debt service is figured at an annual interest rate of 7 percent.

4. Benefit-Cost Analysis

Benefit-cost analysis will be performed on each potential improvement project to permit a comparison of alternatives. Benefits for this analysis are the 20 year present value of the annual additional habitat acreage (acreage for alternative minus 1,500 acres from baseline analysis) at the 1998 unit cost of $618 per acre. The present value is calculated at an inflation rate of 4 percent and a discount rate of 7 percent. Costs for this analysis are the 20 year present value of the alternative. The benefit/cost ratio is the benefit present value divided by the cost present value. Benefit/cost rates of 1 or greater are typically considered feasible project.

5. Potential Funding Sources for Refuge

Over the past years, the Refuge has become an important resource for several species listed as federally threatened (bald eagle) or endangered (whooping crane, piping plover, interior least tern). Recovery plans have been prepared for all of these species by the Service. These plans present the life history and current status of the respective species and outline the procedures to be implemented to facilitate recovery of the species to population levels sufficient for down listing. Additionally, recovery plans provide costs for implementation of recovery procedures. The Whooping Crane Recovery Plan (U.S. Fish and Wildlife Service, 1994) contains several recovery tasks under which the proposed project could potentially receive funding. These tasks include: manage habitat; manage vegetation; protect habitat; identify, protect, manage, and create habitat; and create wetland habitat. While none of these tasks are specifically described for Quivira NWR, they note a requirement of over $450,000 per fiscal year, continuously for no defined duration to fulfill these tasks. Likewise, the recovery plans for the piping plover, interior least tern, and bald eagle have separate costs assigned for similar tasks for each of these species (U.S. Fish and Wildlife Service, 1983; 1990; 1994). It may be possible that the proposed project, which would provide important habitat for each of these species, would be eligible for funding as part of the projects necessary for recovery of each species.

The Whooping Crane Recovery Plan provides evidence that humans value whooping cranes. Such evidence includes publications in a variety of media for sale and entertainment about whooping cranes. Additionally, the report sites several instances where bird watchers and tourists, numbering in the tens-of-thousands, are willing to spend money, directly and indirectly, to view whooping cranes. In 1982 and 1983, visitors at Arkansas National Wildlife Refuge near Arkansas, Texas on the Gulf Coast, an important wintering area for whooping cranes, noted they would be willing to pay an average of $4.47 for an annual Refuge visitors permit and an average of $16.33 annually to support private foundations responsible for whooping crane conservation (U.S. Fish and Wildlife Service, 1990). Refuge personnel indicated heavy use of the area by bird watchers and other interested parties during periods when whooping cranes were present. These findings illustrate the potential to implement various types of programs, such as user fees or donations, for public funding of Refuge projects designed to provide habitat for whooping cranes and viewing opportunities for the public.

In addition to project funding through governmental programs and the public, funds may also be available from private organizations. Ducks Unlimited is one agency specifically dedicated to the preservation of North America's wetlands and waterfowl. Its mission statement is "to fulfill the annual life cycle needs of North American waterfowl by protecting, enhancing, restoring and managing important wetlands and associated uplands" (Ducks Unlimited, 1998). Initially concentrating on protecting, restoring, and enhancing breeding habitat, Ducks Unlimited has expanded its emphasis to include important habitat throughout all the North American flyways, including resting and wintering areas. The Refuge has become a significant resource to migrating waterfowl within the Central Flyway. As the proposed project would enhance and manage important existing waterfowl habitat, funds from this organization may be available.

PART III
OPERATIONS MODEL

A. GENERAL

This section of the report describes the development of an operations model of the Quivira National Wildlife Refuge (Refuge) and Rattlesnake Creek Basin to evaluate the effectiveness of potential supplemental water supplies and other modifications at the Refuge. This computer model is used to simulate operation of the Refuge under current and proposed future conditions. The formulation of the operations model is described below, along with a discussion of significant assumptions and other data used in the model.

B. RESNET COMPUTER MODEL

The operations model for the Refuge was developed using Burns & McDonnell's Reservoir Network (RESNET) computer program. The RESNET model is capable of modeling very complex stream and reservoir systems due to its network architecture. Since the model represents the system to be simulated as a circulating network, network solution techniques can then be used to optimize allocation of available water resources (Foster, 1989).

C. RATTLESNAKE CREEK BASIN

Since some of the alternatives under investigation in this study include development of off-site water supplies, the base operations model for the Refuge must also be capable of simulating operation of the entire Rattlesnake Creek Basin. The collection and synthesis of data used in the operations model that is applicable to the entire basin is described below.

1. Streamflow

The streamflow data used in the operations model are extracted from the Kansas Division of Water Resources' (KDWR) SWATMOD model for the Rattlesnake Creek Basin. The SWATMOD model is an integrated computer model that simulates surface-water runoff using the SWAT model, ground-water flow using the MODFLOW model, and the interactions between the two using custom computer programs (Sophocleous and Koelliker, 1997). A general discussion of the SWATMOD model is provided in Part 1.

In their hydrologic unit map series, the U.S. Geological Survey (USGS) has divided the Rattlesnake Creek Basin into 29 subbasins. To facilitate modeling of the surface-water system in the basin, 6 of the original 29 subbasins were divided into 2 separate subbasins. As a result, the SWATMOD model uses 35 subbasins to represent the surface-water system in the Rattlesnake Creek Basin. The 35 subbasins used in the SWATMOD model are shown on Figure I-1.

For the operations model, the Rattlesnake Creek Basin was simplified. Streamflow at only twelve locations was extracted from the SWATMOD model. These twelve locations and associated data are listed in Table III-1. Figure III-1 shows schematically how the 35 SWATMOD subbasins were grouped to yield the 12 sets of flow data used in the operations model.

Table III-1
SWATMOD STREAMFLOW DATA USED IN OPERATIONS MODEL

Operations Model Node No.	Stream	SWATMOD			
		Subbasin	Row	Column	Stream
10	Rattlesnake Creek	2	19	37	58
20	Rattlesnake Creek	5	23	67	90
30	South Branch	31	25	66	167
40	Rattlesnake Creek	6	27	75	173
50	East Fork	32	29	73	205
60	Rattlesnake Creek	9	29	100	225
70	Unnamed Tributary	13	27	101	255
80	Rattlesnake Creek	34	33	114	264
90	Rattlesnake Creek	21	22	142	294
100	Wild Horse Creek	22	21	142	331
110	Rattlesnake Creek	23	32	164	348
200-630	Rattlesnake Creek	28	26	184	378

The streamflow data extracted from SWATMOD are representative of baseline conditions. The following basin parameters are assumed to remain static, at current values, for the entire 40-year simulation period used in the model:

- Distribution of agricultural crops and other land uses by subbasin.
- The number, location, and permitted diversion or pumping rates for all basin water rights.
- No reservoir development or extensive conservation programs.

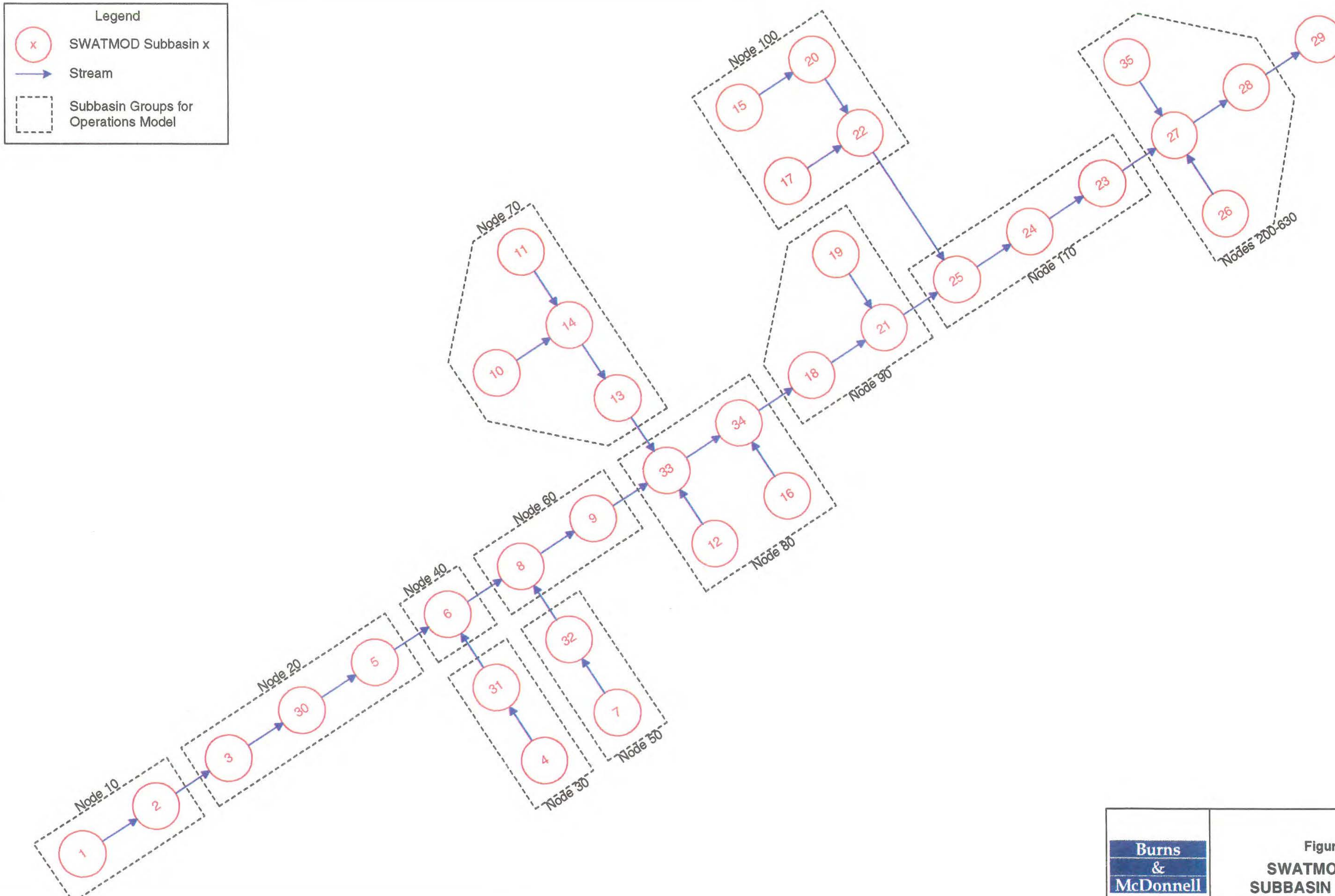
Streamflow in the Rattlesnake Creek Basin varies significantly, both seasonally and annually. This annual variability is illustrated in Figure III-2, which shows the annual flow in Rattlesnake Creek near the upstream boundary of the Refuge. Review of this figure shows that Refuge inflow from Rattlesnake Creek is less than 10,000 acre-feet in most years.

The flow data used in the operations model is the unregulated inflow at each node. The unregulated portion of the flow at each node is the incremental inflow that occurs between the current node and any upstream nodes in the basin. The unregulated inflow at each node was calculated from the total flow data extracted from the SWATMOD model. Negative incremental flows indicate a stream reach that is losing flow to the groundwater system. This occurs often for some stream reaches and occasionally at others.

2. Reservoir Evaporation

No major reservoirs exist in the Rattlesnake Creek Basin upstream of the Refuge; however, water supply alternatives being considered in this study include construction of new supply reservoirs. In order to evaluate these alternatives in the operations model, net monthly reservoir evaporation is estimated.

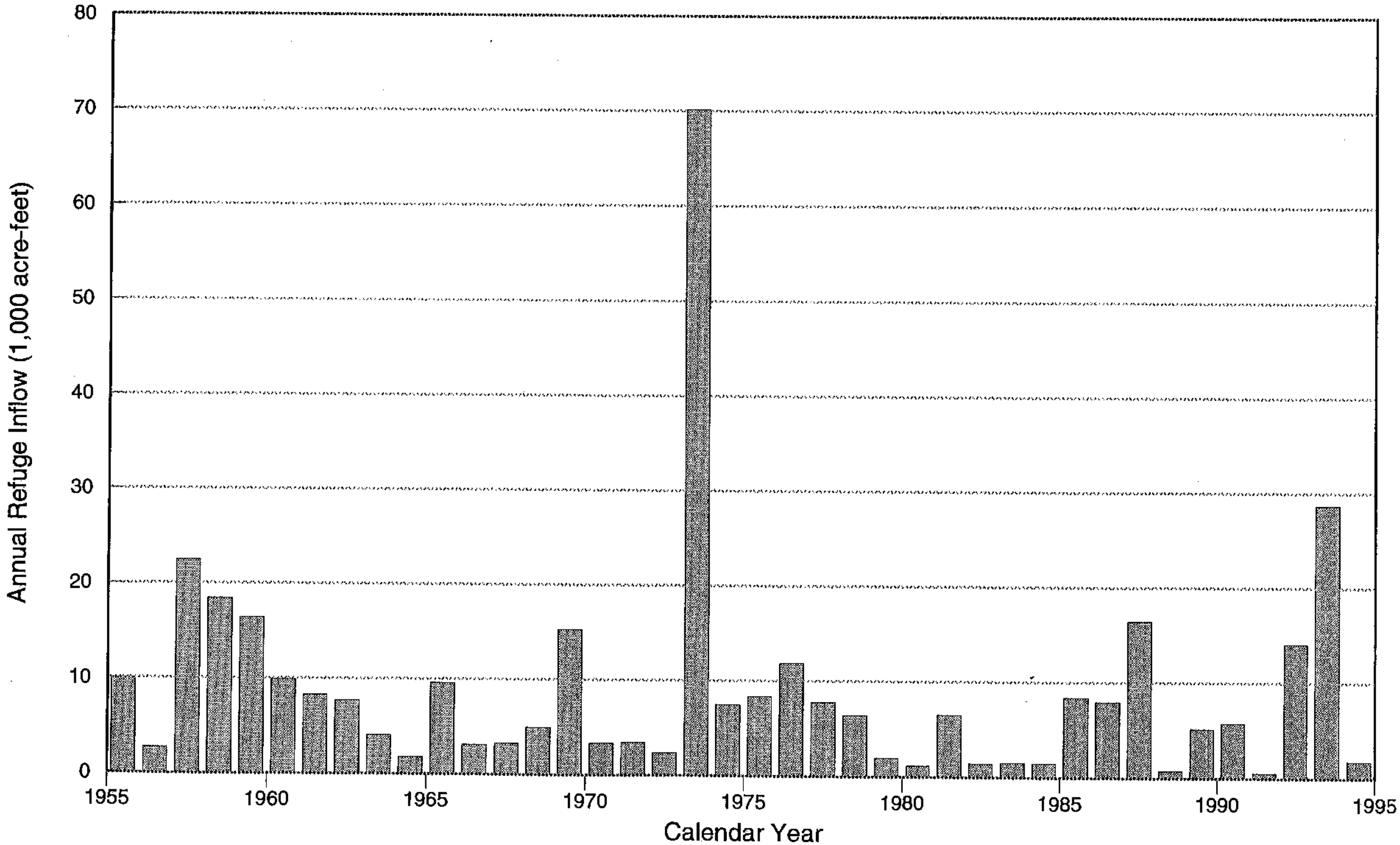
No long-term pan evaporation records are available at stations in or near the Rattlesnake Creek Basin. For this reason, reservoir evaporation estimates are developed using Burns & McDonnell's ETCALC evaporation model. The ETCALC model uses the Penman equation and monthly climatological data to estimate gross and net evaporation. The climatological data required includes data on temperature, precipitation, solar radiation, relative humidity, wind speed, barometric pressure, and cloud cover. Most of these same data are required for use in the SWAT portion of the SWATMOD model and were provided in an electronic format along with this model. The SWAT model is a daily model so the monthly climatological data used in the ETCALC model are developed by averaging or totaling, as appropriate, these daily data. Table III-2 lists average monthly values for these data. The actual climatological data used in the ETCALC model are listed in tables provided in the Appendix.



Burns & McDonnell

Figure III-1

SWATMOD MODEL SUBBASIN SCHEMATIC



Notes
1. Calculated from monthly flow data extracted from KDWR SWATMOD model of Rattlesnake Creek Basin.
2. Flow data are for Rattlesnake Creek at outlet of Subbasin 23, which is near where Rattlesnake Creek enters the Quivira National Wildlife Refuge.

Burns & McDonnell

Figure III-2

ANNUAL INFLOW QUIVIRA NWR

Table III-2
CLIMATOLOGICAL DATA

Month	Temperature (°F)	Precipitation (inches)	Percent Sunshine	Relative Humidity (%)	Solar Radiation (Langleys)	Wind Speed (mph)	Barometric Pressure (millibars)
Jan	30.6	0.60	61	77.5	213.6	12.0	971.3
Feb	35.5	0.88	61	77.6	282.8	12.5	970.0
Mar	45.0	1.86	61	75.9	370.1	14.2	966.8
Apr	56.3	2.49	64	74.1	459.6	14.2	965.6
May	65.9	4.19	65	77.9	510.1	13.3	965.6
Jun	75.6	3.94	70	75.6	576.2	12.9	965.6
Jul	81.0	3.10	76	72.8	571.0	12.2	967.3
Aug	79.2	2.45	75	75.3	502.4	11.7	967.7
Sep	70.2	2.60	68	77.8	417.5	12.3	968.5
Oct	58.9	2.16	65	74.2	318.0	12.4	969.2
Nov	44.0	1.09	59	76.0	223.5	12.7	969.5
Dec	34.2	0.84	58	76.2	184.0	12.2	970.7

The average annual and summertime (May–October) lake evaporation (from 1956 to 1970) for the Rattlesnake Creek Basin are respectively 58 and 42 inches (NOAA, 1982). These average values are representative of reservoir evaporation rates for the central portion of the Rattlesnake Creek Basin. Evaporation rates tend to increase toward the southwest end of the basin and decrease toward the northeast end of the basin, which is where the Refuge is located. The ETCALC model was calibrated to yield these average values for the same 15-year period. Using the coefficients estimated during model calibration, the ETCALC model is executed for the entire period of record from 1955 to 1994. The resulting average monthly and annual gross and net reservoir evaporation for the basin are listed in Table III-3. The actual monthly evaporation data are listed in tables in the Appendix. Net evaporation is gross evaporation less direct precipitation. Only 70 percent of the precipitation that falls directly on a reservoir is assumed to offset evaporation.

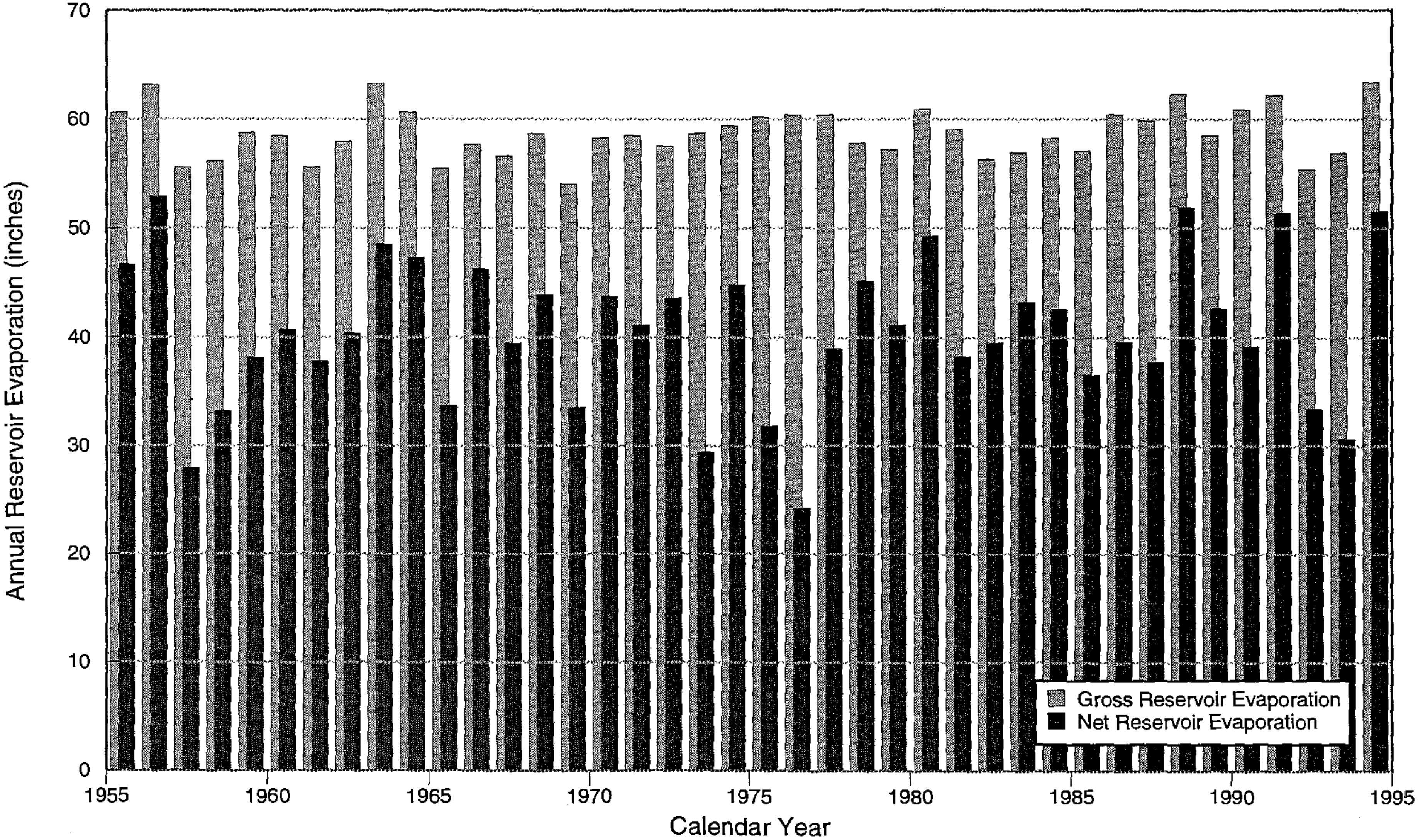
Table III-3
AVERAGE MONTHLY AND ANNUAL RESERVOIR EVAPORATION

Month	Average Reservoir Evaporation (inches)	
	Gross	Net
Jan	1.67	1.27
Feb	2.05	1.42
Mar	3.42	2.14
Apr	4.93	3.19
May	6.37	3.58
Jun	8.12	5.35
Jul	9.49	7.32
Aug	8.43	6.73
Sep	6.00	4.19
Oct	4.28	2.73
Nov	2.34	1.57
Dec	1.67	1.09
Annual	58.77	40.58

Calculated annual reservoir evaporation rates are shown graphically in Figure III-3. Review of this graph shows that annual gross evaporation ranges between about 54.1 inches in 1969 and 63.4 inches in 1994. Net evaporation is more variable since it is also dependent on precipitation amounts. Annual net evaporation ranges from a minimum of about 24.2 inches in 1976 to a maximum of approximately 52.9 inches in 1956.

D. QUIVIRA NWR

The main focus of the operations model is to simulate operation of the actual management units on the Refuge. The following sections describe the data used in the operations model that is specific to the Refuge.



Notes
1. Calculated using Burns & McDonnell's ETCALC evaporation model.
2. The ETCALC model was calibrated using reported evaporation rates for the central portion of the Rattlesnake Creek Basin. Reservoir evaporation rates for the extreme southwest and northeast ends of the basin are slightly higher and lower, respectively.

Burns & McDonnell

Figure III-3

ANNUAL RESERVOIR EVAPORATION RATTLESNAKE CREEK BASIN

1. Local Inflow

Although not a major component of the water supply to each management unit, each unit does receive runoff in response to precipitation events within its own watershed. This local inflow is estimated for each unit using the simple drainage area ratio procedure described below.

In the SWATMOD model for the Rattlesnake Creek Basin, the Refuge is located in portions of Subbasins 27 and 28. The incremental streamflow generated in these two subbasins is estimated for each month in the simulation period by subtracting the flow in Rattlesnake Creek at the outlet of Subbasin 23 from that at the outlet of Subbasin 28. Although Figure III-1 shows that Subbasins 26 and 35 are tributary to Subbasin 27, neither are believed to produce significant runoff because of their sandy soils and undulating topology. The total areas of Subbasins 27 and 28 are estimated to be approximately 46.2 and 30.5 square miles, respectively, for a total of 76.7 square miles. The monthly incremental flow values for Subbasins 27 and 28 are divided by 76.7 square miles to estimate runoff per unit area.

In concert with the unit runoff analysis described in the preceding paragraph, the local drainage area for each management unit is also estimated. These drainage area estimates are listed in the Appendix. The local inflow to each management unit is then estimated by multiplying the local drainage area of each unit by the monthly unit runoff values for Subbasins 27 and 28.

A number of limitations in the methodology used to estimate local inflow to the management units exist and are as follows:

- The primary purpose of the SWATMOD model is to estimate the impacts of varying management practices in the upper Rattlesnake Creek Basin on streamflow and ground-water levels. For this reason, the Refuge itself (that is, Subbasins 27 and 28) are not modeled in any detail in the SWATMOD model. For example, the many management units of the Refuge are modeled as a single large impoundment.

- In order for the calculated incremental runoff values to be truly representative of "natural" conditions, the Refuge area would have to be modeled assuming that none of the management units exist.

Due to these limitations, the local inflow estimates to the management units are somewhat suspect; however, as stated above, local inflow is not a major component of the water supply to the Refuge. Therefore, these limitations do not significantly impact the results of the operations modeling.

2. Management Unit Evapotranspiration

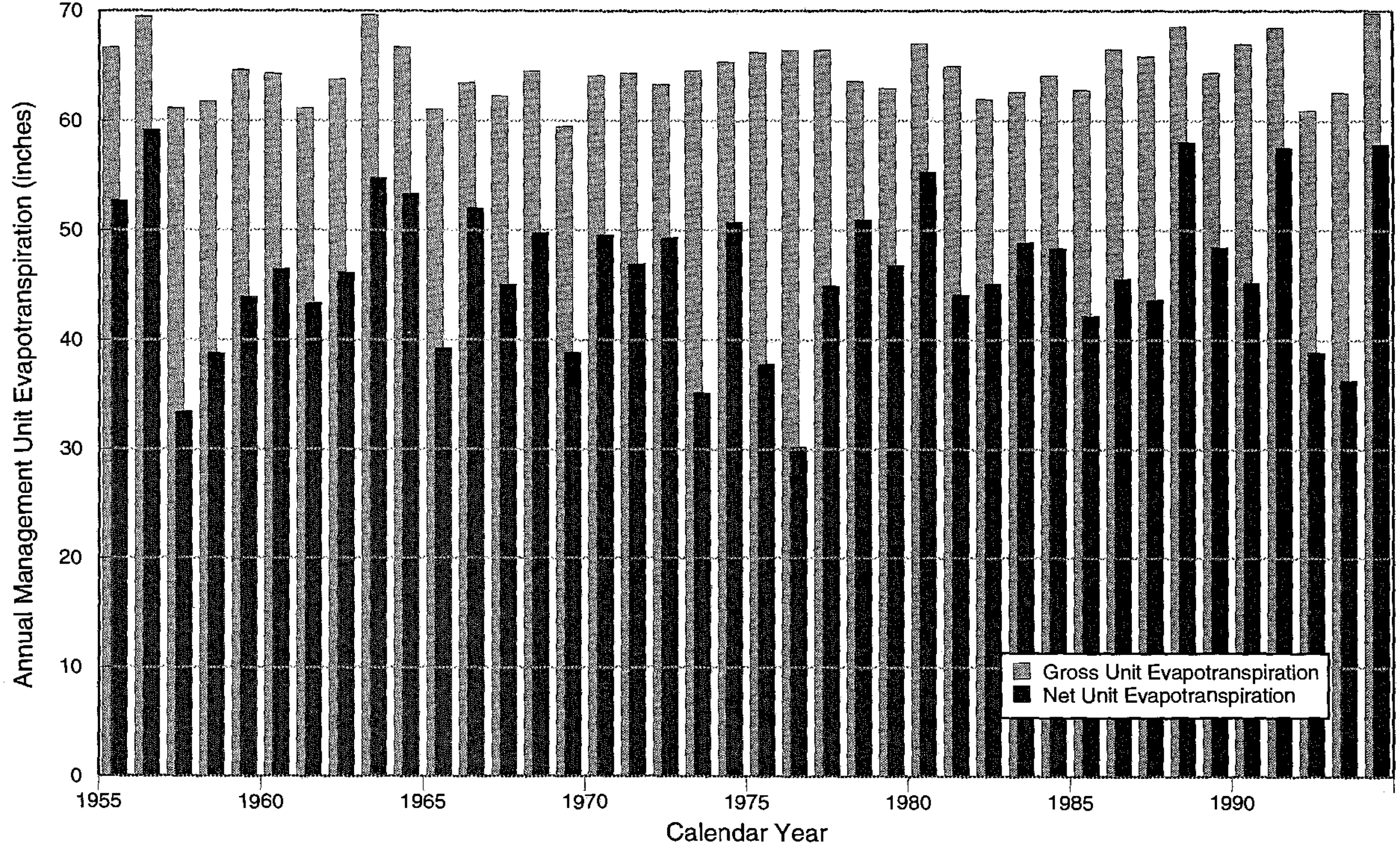
Because of their shallow depths and abundant wetland vegetation, evapotranspiration from the management units of the Refuge is estimated to be slightly higher than evaporation from a typical reservoir. Sophocleus and Koelliker (1997) report an average evapotranspiration rate of 64 inches per year. This value is approximately 10 percent higher than the estimated average reservoir evaporation of 58 inches per year used to calibrate the ETCALC model; therefore, the gross evapotranspiration rates used for the management units are estimated to be 10 percent higher than those used for an upstream reservoir.

The average annual net evapotranspiration rate for the management units is shown in Table III-4 to be 46.4 inches. This value is about 14 percent higher than the same value for a reservoir. Figure III-4 is a graph that shows annual estimated gross and net evapotranspiration rates from the Refuge management units.

3. Management Unit Physical and Operating Data

Physical and operating data for the various management units on the Refuge are obtained from the Service. These include the following types of data:

- Pool elevation, surface area and storage.
- Maximum (full pool) water surface elevations.
- Desired, or target, management levels.
- Locations of control structures.
- Operating procedures.



<u>Note</u>
Calculated from reservoir evaporation estimates developed using Burns & McDonnell's ETCALC evaporation model. These gross evaporation estimates were increased by 10 percent to account for shallow nature of management units and adundant vegetation.

Burns & McDonnell

Figure III-4

ANNUAL MANAGEMENT UNIT EVAPOTRANSPIRATION QUIVIRA NWR

Table III-4
AVERAGE MONTHLY AND ANNUAL MANAGEMENT UNIT EVAPOTRANSPIRATION

Month	Average Management Unit Evapotranspiration (inches)	
	Gross	Net
Jan	1.84	1.43
Feb	2.25	1.62
Mar	3.76	2.48
Apr	5.42	3.68
May	7.01	4.21
Jun	8.93	6.16
Jul	10.44	8.27
Aug	9.26	7.57
Sep	6.60	4.78
Oct	4.70	3.15
Nov	2.57	1.80
Dec	1.84	1.25
Annual	64.62	46.40

Table III-5 lists the current target water levels for each management unit. Additional physical and operating data for each unit are reproduced in tables contained in the Appendix.

The target water levels listed in Table III-5 reflect the current management of the Refuge under conditions where water is often in short supply during the late summer and early fall. At that time, it is desirable to re-flood many of the management units in preparation for the fall migration season. Since there is no guarantee that the flow in Rattlesnake Creek will be sufficient to accomplish this re-flooding, the management units are currently maintained at levels above optimum through the late spring and summer to ensure that there is some wetland habitat available even in a dry year. The base operations model utilizes the current management practices at the Refuge. A more optimum management plan for the Refuge is discussed later in Part IX.

Table III-5
MANAGEMENT UNIT OPERATING LEVELS

Node No.	Node Name	Management Unit Pool Elevations (feet)			
		Pond Bottom	Target (Sep–Apr)	Target (May–Aug)	Full
200	Unit 5—Little Salt Marsh	1780.0	1783.0	1783.0	1783.0
210	Unit 7	1774.0	1778.0	1777.5	1778.0
220	Units 10a and 10b	1774.0	1778.5	1778.0	1779.0
230	Units 10c and 11	1754.0	1774.0	1773.5	1775.0
250	Unit 14a	1772.0	1778.0	1777.5	1778.0
260	Unit 14b	1772	1776.2	1775.7	1776.7
270	Unit 14c	1774.0	1776.5	1776.0	1777.0
280	Units 20a and 20b	1767.0	1770.2	1769.7	1770.7
300	Unit 24—Darrynane Lake	1765.0	1768.9	1768.4	1769.4
320	Unit 21	1764.0	1769.5	1769.0	1770.0
330	Unit 25	1762.0	1767.9	1767.4	1768.4
340	Unit 16	1768.0	1774.5	1774.0	1775.0
350	Unit 28	1762.0	1767.5	1767.0	1768.0
360	Unit 29	1757.0	1761.5	1761.0	1762.0
370	Unit 30	1756.0	1758.5	1758.0	1759.0
390	Unit 22	1764.0	1765.5	1763.8	1764.3
400	Unit 23—Park Smith Lake	1762.0	1764.3	1763.8	1764.3
410	Unit 26	1758.0	1761.5	1761.0	1762.0
420	Unit 48	1750.0	1753.9	1753.4	1754.4
430	Unit 49	1750.0	1753.7	1753.2	1754.2
440	Unit 51—Rattlesnake Canal	1745.0	1747.0	1746.5	1748.0
455	Unit 34	1752.0	1753.5	1753.0	1754.0
460	Unit 37—Dead Horse Slough	1745.0	1746.5	1746.0	1747.0
470	Unit 39—Dead Horse Slough	1736.0	1737.5	1737.0	1738.0
510	Unit 61	1740.0	1745.0	1744.5	1745.5
520	Unit 63	1736.0	1740.7	1740.2	1741.2
530	Unit 57—East Lake	1740.0	1743.0	1742.5	1743.5
540	Unit 75—Big Salt Marsh	1736.0	1740.5	1740.0	1740.8
550	Unit 58	1736.0	1741.5	1741.0	1742.0
560	Unit 78—Wildlife Drive	1735.0	1740.2	1739.7	1740.2
570	Unit 81	1736.0	1736.7	1736.7	1736.7
580	Unit 80	1734.0	1736.7	1736.7	1736.7
590	Unit 83—North Lake	1734.0	1736.7	1736.2	1736.7
600	Unit 40	1736.0	1742.6	1742.1	1742.6
610	Unit 62	1735.0	1743.5	1743.0	1744.0
620	Unit 44	1734.0	1735.5	1735.0	1736.0

E. BASE OPERATIONS MODEL

As discussed in Section B above, Burns & McDonnell's RESNET computer model was used to develop the operations model for the Rattlesnake Creek Basin and the Refuge. This model requires that the basin be represented as a circulating network, a series of nodes joined by links. The nodes, links and other model parameters used in the base operations model are discussed below. The base operations model simulates the Refuge and Rattlesnake Creek Basin under existing conditions. This base operations model is modified as necessary to evaluate the various water supply and other alternatives considered in this study. Where applicable, these model modifications are described in subsequent sections of this report.

1. Model Nodes

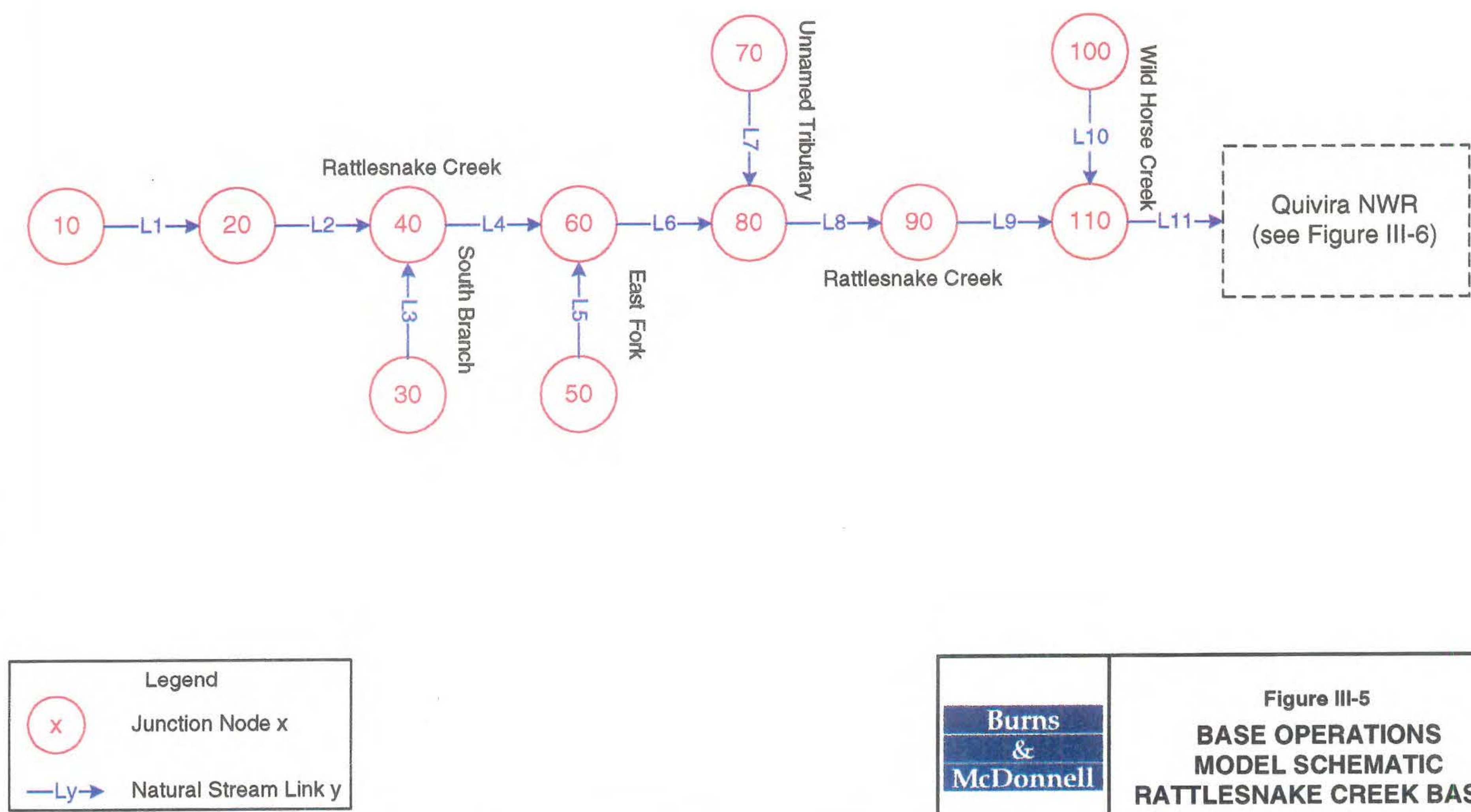
The base operations model contains 55 nodes. Eleven of these nodes represent the flow system in the upper Rattlesnake Creek Basin and the remaining 44 nodes represent features within the Refuge. All of the 11 upper basin nodes and 8 of the nodes for the Refuge are junction nodes. Junction nodes are placed at any location where flow data are available or measurements are required. At junction nodes, the flow into the node must be equal to the flow out of the node in each model time step.

The remaining 36 nodes in the base operations model, all of which are within the Refuge, are storage nodes. Storage nodes are used to represent the various management units of the Refuge, which have the ability to store varying quantities of water. At storage nodes, the amount of water discharged may be greater or less than inflow if water is being released from or added to storage, respectively. Storage nodes also may lose water each month due to evapotranspiration.

Table III-6 is a list of all of the nodes included in the base operations model. Additional descriptive data on these nodes are provided in the Appendix. The schematic diagram for the base operations model is shown in two parts due to its complexity. Figures III-5 and III-6 respectively show schematics for the upper Rattlesnake Creek Basin and the Refuge portions of the operations model. Each node is assigned a node number for easier reference. These node numbers were assigned in increments of ten to allow for insertion of new nodes later, if necessary, without disturbing the numbering sequence.

Table III-6
SYSTEM NODES, BASE OPERATIONS MODEL

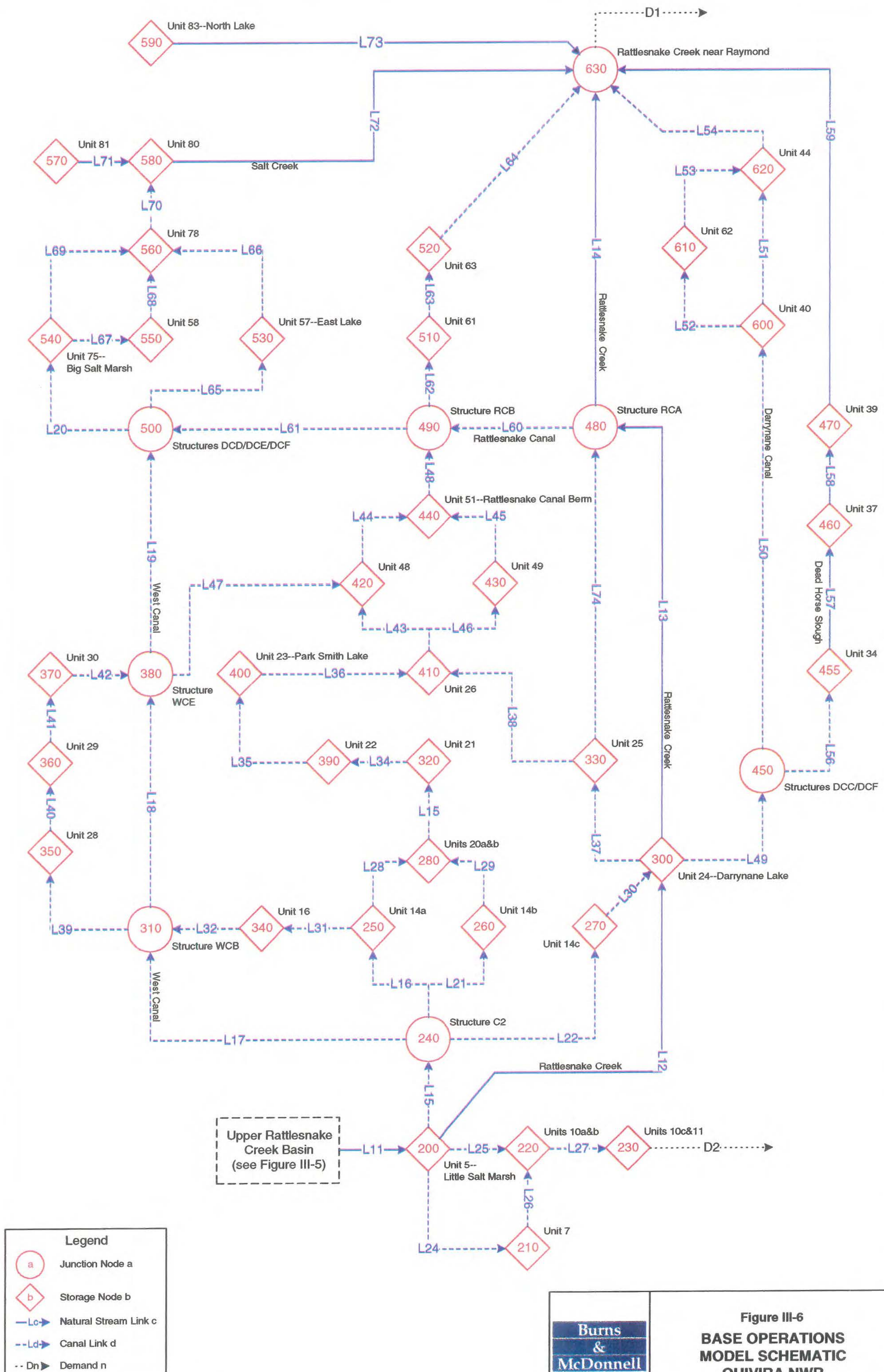
Node No.	Description	Node No.	Description
10	Rattlesnake Creek above Mullinville	380	West Canal at Structure WCE
20	Rattlesnake Creek above S. Branch	390	Unit 22
30	S. Branch, Rattlesnake Creek	400	Unit 23—Park Smith Lake
40	Rattlesnake Creek above E. Fork	410	Unit 26
50	E. Fork, Rattlesnake Creek	420	Unit 48
60	Rattlesnake Creek near Hopewell	430	Unit 49
70	Unnamed Tributary	440	Unit 51—Rattlesnake Canal Berm Area
80	Rattlesnake Creek near Macksville	450	Darrynane Canal
90	Rattlesnake Creek near St. Johns	455	Unit 34
100	Wild Horse Creek	460	Unit 37—Dead Horse Slough
110	Rattlesnake Creek below Zenith Gage	470	Unit 39—Dead Horse Slough
200	Unit 5—Little Salt Marsh	480	Rattlesnake Creek at Rattlesnake Canal
210	Unit 7	490	Rattlesnake Canal at Structure RCB
220	Units 10a and 10b	500	Junction of West and Rattlesnake Canals
230	Units 10c and 11	510	Unit 61
240	C-line Canal at Structure C-2	520	Unit 63
250	Unit 14a	530	Unit 57—East Lake
260	Unit 14b	540	Unit 75—Big Salt Marsh
270	Unit 14c	550	Unit 58
280	Units 20a and 20b	560	Unit 78—Interior of Wildlife Drive
300	Unit 24—Darrynane Lake	570	Unit 81—North Salt Flats
310	West Canal at Structure WCB	580	Unit 82—North Salt Flats
320	Unit 21	590	Unit 83—North Lake
330	Unit 25	600	Unit 40
340	Unit 16	610	Unit 62
350	Unit 28	620	Unit 44—Salt Flats
360	Unit 29	630	Rattlesnake Creek near Raymond
370	Unit 30		



Burns & McDonnell

Figure III-5

BASE OPERATIONS MODEL SCHEMATIC RATTLESNAKE CREEK BASIN



Burns & McDonnell

Figure III-6

BASE OPERATIONS MODEL SCHEMATIC QUIVIRA NWR

2. Model Links

Each node in the operations model is connected to one or more of the other nodes by links. Links can represent natural stream reaches, man-made canals and ditches, or overland flow. There are 74 links incorporated into the base operations model. Twenty of these links represent natural stream reaches and the remaining 54 are man-made canal or overland flow segments. The links used in the base operations model are also shown in Figures III-5 and III-6.

The flow in links is unidirectional. Each link has an associated minimum and maximum flow rate, and unit cost of flow. The minimum flow in all links is set to zero. The maximum flow rate for natural stream links is set to an arbitrarily high number, 10 million acre-feet per month. This is equivalent to approximately 165,000 cubic feet per second (cfs). All other links have maximum flow rates set at 15,000 acre-feet per month, or approximately 250 cfs. Detailed specifications on each model link are listed in tables in the Appendix.

Service personnel at the Refuge report that significant losses from canals can occur at times; however, there is little if any quantitative data on canal losses. The RESNET model has to ability to model link losses, but only as a fixed percentage of the flow each month. To account for these reported canal losses, the links that represent the major canals were assigned a loss rate of 10 percent. These links are identified in Table III-7.

Table III-7
BASE OPERATIONS MODEL LINKS WITH LOSSES

Link No.	Link Name
15	C-line Canal
17	D-line Canal
18	West Canal
19	West Canal
20	West Canal
22	F-line Canal
49	Darrynane Canal
50	Darrynane Canal
60	Rattlesnake Canal
61	Rattlesnake Canal

3. Model Demands and Spills

The operations model for the Refuge and Rattlesnake Creek Basin is distinctly different than the model for a typical water supply system. A typical water supply system model will have one or more point demands, such as the raw water supply for a municipal water system or a diversion structure for an irrigation district. The reservoirs in a typical system store water for subsequent release to satisfy these demands. In the operations model for the Refuge, there are no point demands, in the usual sense. The system "demands" at the Refuge are for water in storage for use by wildlife.

In the base operations model of the Refuge, there are only two actual model demands. The points of diversion for these two demands are located at the two system outlets, the outlet of Unit 11 (Node No. 230) and at Rattlesnake Creek near Raymond (Node No. 630). These are arbitrarily large demands with a low priority whose only purpose is to allow the management units to be drawn down when desired. Without these drawn down demands, the RESNET model would never discharge water from the Refuge unless every management unit were completely full. Maintaining the management units full is generally not desirable, even when excess water supplies are available.

The two system outlets are also identified as spill nodes. In the RESNET model, a spill node is a safety valve of sorts that provides an outlet for excess flow. Although it is good modeling practice to designate each system outlet as a spill node, because of the drawdown demands discussed above, it is doubtful there will every be any modeled "spills" from the model.

4. Management Unit Storage Priorities

The operations model uses specified monthly storage levels and priorities to allocate water to the management units each month. For the purposes of assigning storage priorities, each management unit is divided into four storage zones. These zones are described as follows:

- Very Low Zone—This is the lowest zone in each unit and extends from the pond bottom to an elevation one foot less than the target level for the current month.
- Low Zone—The second zone extends from the top of the Very Low Zone up to 0.5 foot less than the target level for the current month.

- Normal Zone—The top of the normal zone is the target pool level for the current month. From this level, this zone extends down 0.5 foot to the top of the low zone.
- Full Zone—The full zone for each management units is the pond volume above the current month's target level up to the spillway crest or top of the stop log slots.

Each storage zone has an assigned storage priority. Storage priorities decrease as levels increase. That is, the very low zone has the highest storage priority and the full zone the lowest. This ensures that the operations model will fill each unit from bottom to top.

Since the primary water supply to the Refuge is Rattlesnake Creek, the management units on the south end of the Refuge are normally filled before those on the north. This policy tends to keep water stored at higher elevations where it can flow to lower units by gravity when desired. To mimic this policy in the operations model, storage priorities within each zone decrease as one moves from south to north.

The storage priorities used in the operations model are designed to fill the management units in a balanced fashion. The very low zone in each unit, starting at the south end of the Refuge, is filled first. Then the low and normal zones are filled in turn until all units are full to their target levels, or there is no water left to allocate. The operations model does not normally store water in the management units above the current month's target level.

Data on the assigned storage zones and priorities for each month and management unit are included in the Appendix.

PART IV

REFUGE NET WATER NEEDS AND HABITAT AVAILABILITY

A. GENERAL

This section of the report discusses the water needs for the Quivira National Wildlife Refuge (Refuge) and the availability of wetland habitat for wildlife. Net water needs are based on a comparison of operations modeling for the Refuge under baseline conditions and an ultimate usage scenario. The operations model includes physical data and desired operating criteria for the Refuge as provided by the Service. Detailed information on the operations model is discussed in Part III of this report.

B. REFUGE DIVERSIONS

The primary water supply at the Refuge is Rattlesnake Creek. The Refuge diverts water from Rattlesnake Creek at three locations, Little Salt Marsh, Darrynane Lake and Rattlesnake Canal. For the purposes of these water diversion estimates, total diversions are defined to be the sum of the following:

- Diversions from Little Salt Marsh to Unit 7 through Structure A-3.
- Diversions from Little Salt Marsh to Units 10a and 10b through Structure A-1.
- Diversions from Little Salt Marsh into the C-line canal through Structure C-1.
- Net evaporation from Little Salt Marsh.
- Net increases in storage in Little Salt Marsh.
- Diversions from Darrynane Lake to Unit 25 through Structure 24C.
- Diversions from Darrynane Lake into the Darrynane Canal through Structure DCA.
- Net evaporation from Darrynane Lake.
- Net increases in storage in Darrynane Lake.
- Diversions from Rattlesnake Creek into the Rattlesnake Canal through Structure RCA.

Since Refuge diversion include changes in storage in Little Salt Marsh and Darrynane Lake, negative diversions are possible during periods when water is released from storage.

1. Baseline Diversions

Baseline water diversions are estimated for the Refuge using the base operations model. In this model, all management units, canals and other water delivery facilities are left in their current states. No additional development upstream of the Refuge, that would impact the magnitude and distribution of streamflow in Rattlesnake Creek, is assumed. Under these conditions, the operations model is executed to estimate monthly diversions during the period of record for the model, calendar years 1955 through 1994. These baseline water usage estimates represent the quantities of water that would have been diverted to the Refuge each month if it had been in existence for the entire 40-year simulation period.

Due to the variability of flow in Rattlesnake Creek, simulated monthly diversions at the Refuge vary greatly from month to month. Table IV-1 summarizes the minimum, maximum, and average monthly and annual diversions to the Refuge under baseline conditions. As shown in this table, total annual baseline diversions range from about 1,200 to 14,900 acre-feet per year with an average of approximately 6,800 acre-feet per year.

Table IV-1
BASELINE DIVERSIONS TO QUIVIRA NWR [1]

Month	Baseline Diversions [2]		
	Minimum	Maximum	Average
Jan	45	846	220
Feb	40	783	219
Mar	-8	6,418	546
Apr	41	3,766	508
May	68	4,822	802
June	71	7,475	1,361
July	50	3,735	633
Aug	49	6,201	820
Sept	44	3,417	659
Oct	45	4,200	563
Nov	45	1,335	266
Dec	45	907	238
Annual	1,159	14,876	6,832

Notes: 1. Units are acre-feet per month or year.
2. Simulated diversions to Quivira NWR under existing conditions.

The diversion statistics listed in Table IV-1 are derived from monthly diversion estimates produced by the base operations model. As mentioned in Part III, the base operations model is designed to mimic operations of the Refuge under the current management philosophy. Under a more optimum management plan, which would manage many of the Refuge units as moist soil units (see discussion in Part IX), diversions would be somewhat less than those shown. Also, the operations model assumes any or all water in Rattlesnake Creek is available for diversion to the Refuge whenever desired. For this reason, simulated annual diversions to the Refuge may, in some years, exceed the Service's current water right of 14,600 acre-feet per year. The operations model does not limit diversions to the Refuge based on current water rights.

2. Ultimate Diversions

A second set of water diversion estimates are generated with the operations model under an ultimate usage scenario. Under this scenario, water diversion estimates are representative of the quantities of water that would have been diverted to the Refuge if an adequate supply was always available. This condition is simulated with the operations model by introducing an artificial import to Little Salt Marsh, equivalent to 5,000 acre-feet per month. This supplemental supply is in addition to the natural inflow to the Refuge from Rattlesnake Creek and local runoff. The size of this import is chosen arbitrarily to ensure that the supply of water to the Refuge would always be greater than the quantities needed each month.

Monthly and annual statistics on ultimate water diversions are summarized in Table IV-2. Under this scenario, annual diversions range from about 12,300 to 24,900 acre-feet per year with an average of approximately 19,000 acre-feet per year.

3. Net Water Needs

The net water needs for the Refuge are calculated by subtracting total monthly diversions under baseline conditions from those with ultimate usage conditions. Note that these net water need estimates are valid only for a supplemental supply that would not impact the inflow to the Refuge from Rattlesnake Creek, such as an import from outside of the basin. An upstream reservoir in the Rattlesnake Creek Basin would have to supply quantities of water close to the ultimate water diversions of the Refuge.

Statistics on the net water needs at the Refuge are summarized in Table IV-3. Review of this table shows the net annual supplemental supply requirements at the Refuge range from 0 to about 18,100 acre-feet per year, with an average of approximately 9,200 acre-feet per year.

Table IV-2
ULTIMATE DIVERSION TO QUIVIRA NWR [1]

Month	Ultimate Diversions [2]		
	Minimum	Maximum	Average
Jan	13	3,329	661
Feb	-28	74	728
Mar	-184	2,492	1,168
Apr	-475	3,139	716
May	-75	1,057	348
June	80	3,646	1,973
July	312	4,603	2,935
Aug	246	3,877	2,758
Sept	-410	5,159	4,019
Oct	18	2,854	1,409
Nov	-86	1,619	808
Dec	-85	1,099	525
Annual	12,323	24,925	19,049

Notes: 1. Units are acre-feet per month or year.
2. Diversions to Quivira NWR if an excess supply was always available.

Table IV-3
SUPPLEMENTAL SUPPLY (USAGE) TO QUIVIRA NWR [1]

Month	Supplemental Diversions [2]		
	Minimum	Maximum	Average
Jan	-598	2,728	441
Feb	-811	1,517	509
Mar	-6,602	2,416	622
Apr	-4,241	3,097	1,207
May	-4,618	729	-454
June	-7,385	3,415	618
July	-1,701	4,546	2,302
Aug	-5,995	3,828	1,937
Sept	-3,482	4,991	3,360
Oct	-4,182	2,636	846
Nov	-1,295	1,570	546
Dec	-992	1,054	292
Annual	-2,318	23,040	12,217

Notes: 1. Units are acre-feet per month or year.
2. Calculated from differences between monthly diversions under baseline and ultimate conditions.

Figure IV-1 shows durations for the baseline, ultimate and net water needs of the Refuge. Review of the median values (50th percentile) shows that the median monthly diversion to the Refuge is about 450 acre-feet under existing conditions while the needed diversion amount is about 1,300 acre-feet per month.

C. AVAILABILITY OF WETLAND HABITAT

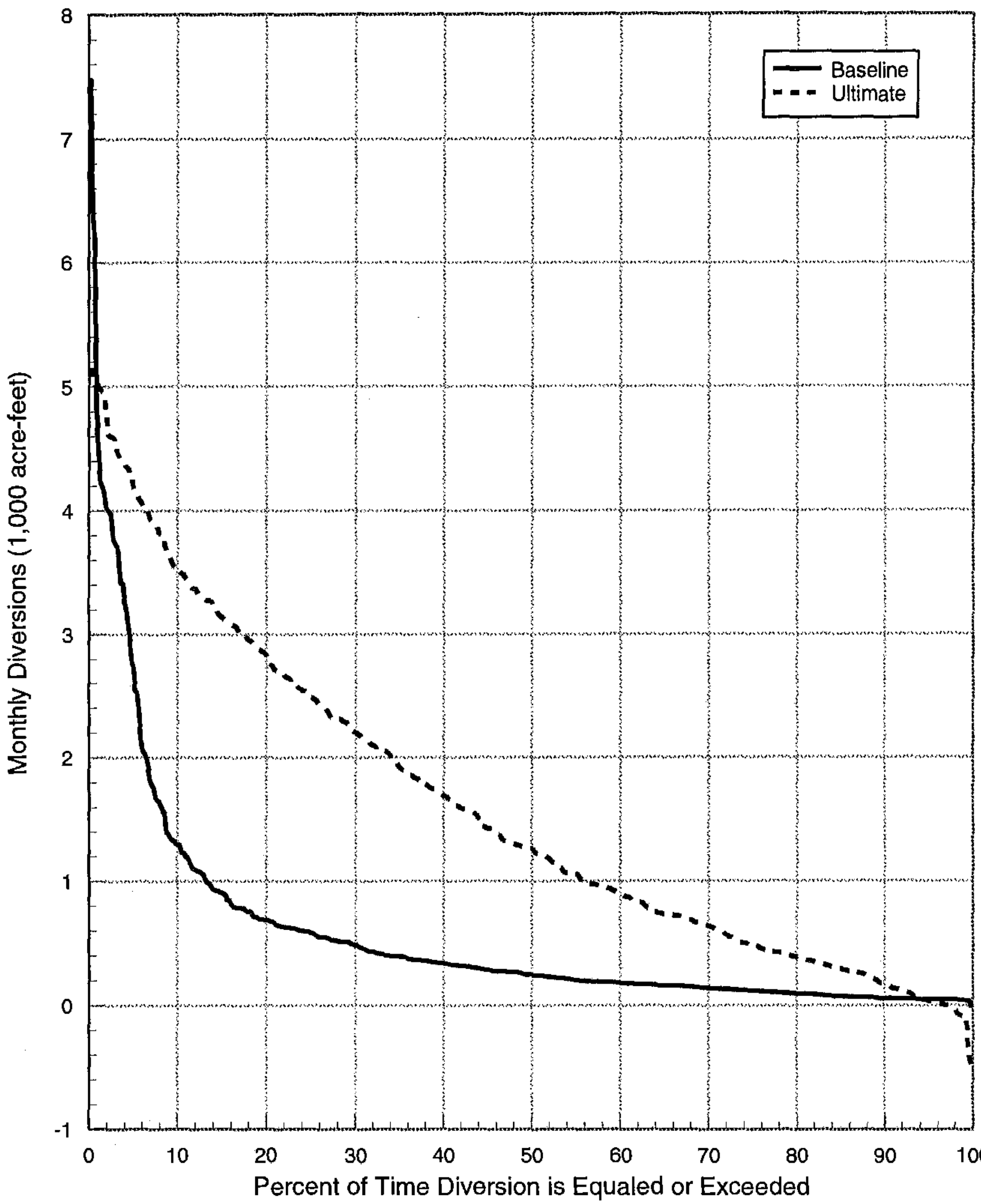
The water diverted to the Refuge is used primarily to create wetland habitat for shorebirds and waterfowl. Therefore, as discussed in Part II, the amount of available wetland habitat on the Refuge is considered to be a good measure of project benefits. The amounts of wetland habitat available under baseline and ultimate water usage are presented below.

The quantities of optimum shorebird and waterfowl habitat at the Refuge are estimated from the results of the operations modeling. The operations model provides estimates of management unit contents each month. These storage values are analyzed to yield quantities of optimum shorebird and waterfowl habitat. Optimum shorebird habitat is defined as wetland areas with water depths between one and four inches. Similarly, optimum waterfowl habitat consists of wetland areas with water from 10 to 18 inches deep.

At the Refuge, the primary migration season extends from early September through the end of April. It is during this eight-month period when it is most critical to maintain consistent quantities of quality wetland habitat. The remaining four months of the year, May through August, are considered to be the off season at the Refuge. Comparisons of available wetland habitat focus on the primary migration season only.

1. Baseline Wetland Habitat

Monthly statistics on the availability of wetland habitat at the Refuge under baseline conditions are presented in Table IV-4. Under current baseline conditions, the available optimum habitat falls to near zero during dry years for both shorebirds and waterfowl. Peak habitat ranges up to approximately 700 acres for shorebirds and 1,000 acres for waterfowl. Average habitat areas are respectively 358 and 602 acres for shorebirds and waterfowl. Total wetland habitat ranges from about 700 acres in a dry year to a maximum of 6,000 acres, with an average of a 2,800 acres.



Notes:
1. Based on total simulated diversions to Quivira National Wildlife Refuge for period 1/1955 through 12/1994.
2. Total diversions are the sum diversions from Rattlesnake Creek at Little Salt Marsh, Darrynane Lake and the Rattlesnake Canal.
3. Ultimate water usage scenario assumes virtually unlimited supply of water to Little Salt Marsh.

Burns & McDonnell

Figure IV-1

DIVERSION DURATIONS QUIVIRA NATIONAL WILDLIFE REFUGE

Table IV-4
AVAILABLE WETLAND HABITAT—BASELINE CONDITIONS

Month	Shorebird (1–4 inches)		Waterfowl (10–18 inches)		Total Wetland	
	Range	Average	Range	Average	Range	Average
Jan	177 - 684	376	110 - 1,019	625	940 - 6,000	2,871
Feb	173 - 682	366	144 - 1,029	623	991 - 5,825	2,878
Mar	170 - 683	377	154 - 1,017	631	995 - 5,941	2,934
Apr	133 - 681	377	117 - 1,055	663	904 - 5,839	2,957
Sep	85 - 626	300	11 - 1,019	534	692 - 5,305	2,450
Oct	97 - 684	334	12 - 1,021	553	726 - 5,995	2,572
Nov	131 - 681	354	42 - 1,054	578	825 - 5,950	2,662
Dec	145 - 682	378	82 - 1,035	608	888 - 5,952	2,732
Sep–Apr	85 - 684	358	11 - 1,054	602	692 - 6,000	2,757

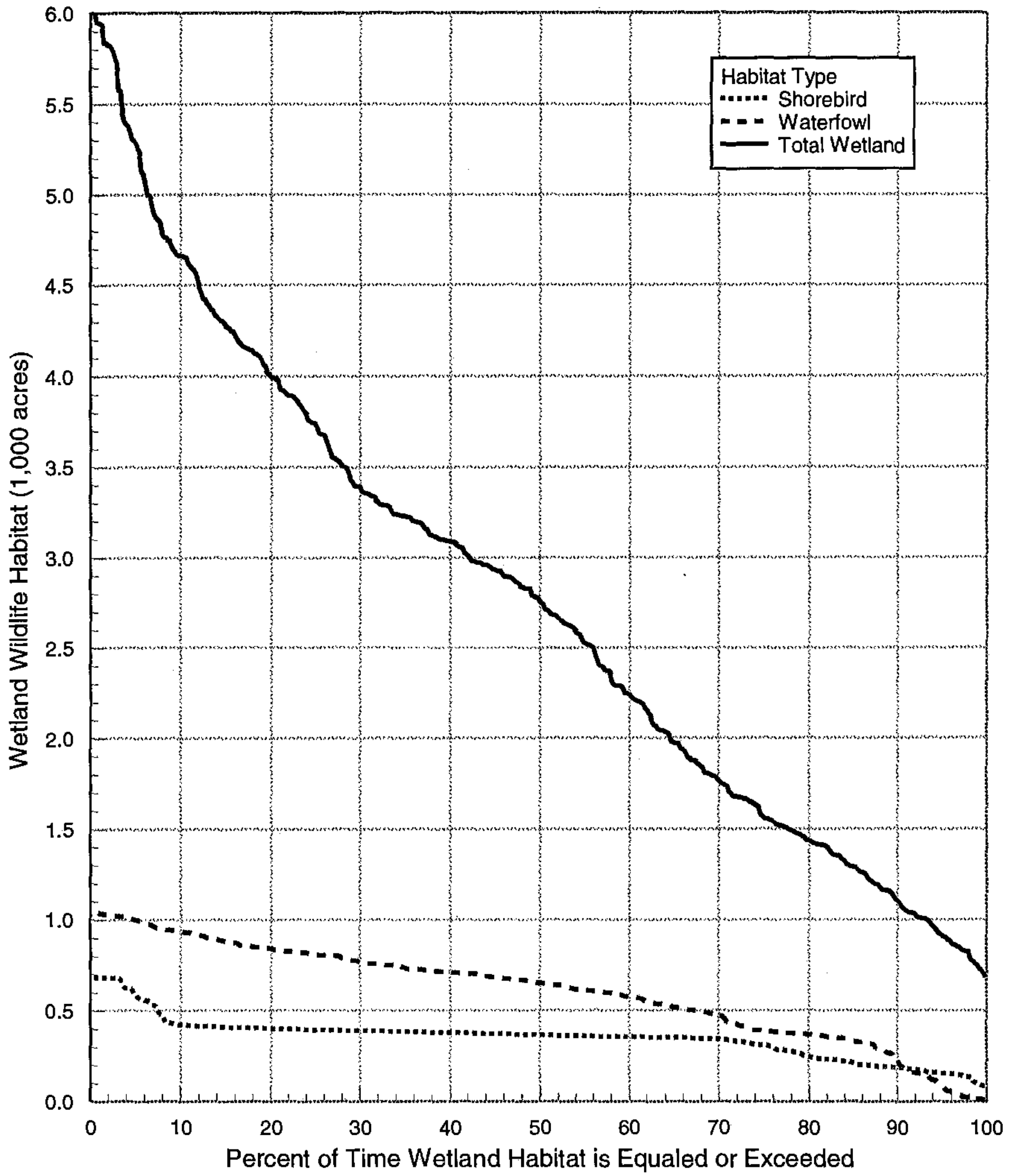
Note: All wetland habitat values in acres. Statistics include data for primary migration season, September through April only.

The durations of available wildlife habitat under baseline conditions are shown in Figure IV-2. Review of this figure shows the 80th percentile habitat areas to be as follows:

- Shorebird: 237 acres.
- Waterfowl: 354 acres.
- Total Wetland: 1,416 acres.

2. Ultimate Wetland Habitat

While the wetland habitat statistics shown in Table IV-4 are representative of current conditions, Table IV-5 lists these same statistics under conditions with an unlimited water supply. These values are representative of the maximum potential habitat at the Refuge. The minimum, maximum, and average habitat areas do not vary significantly from one another or from month to month since it is assumed that surplus water is always available. Under these conditions, the contents of each management unit stays relatively stable. Average areas of wetland habitat with surplus water supplies are respectively 675 and



Notes:

1. Developed from operations modeling for Quivira NWR for period 1/1955 through 12/1994 under baseline conditions. Includes data for months of September through April only.
2. Optimum shorebird and waterfowl habitats defined as wetland areas 1-4 inches and 10-18 inches deep, respectively. Total wetland habitat is the sum of the surface areas of all ponded water in all management units, regardless of depth.

Burns & McDonnell

Figure IV-2

WETLAND HABITAT DURATIONS BASELINE CONDITIONS

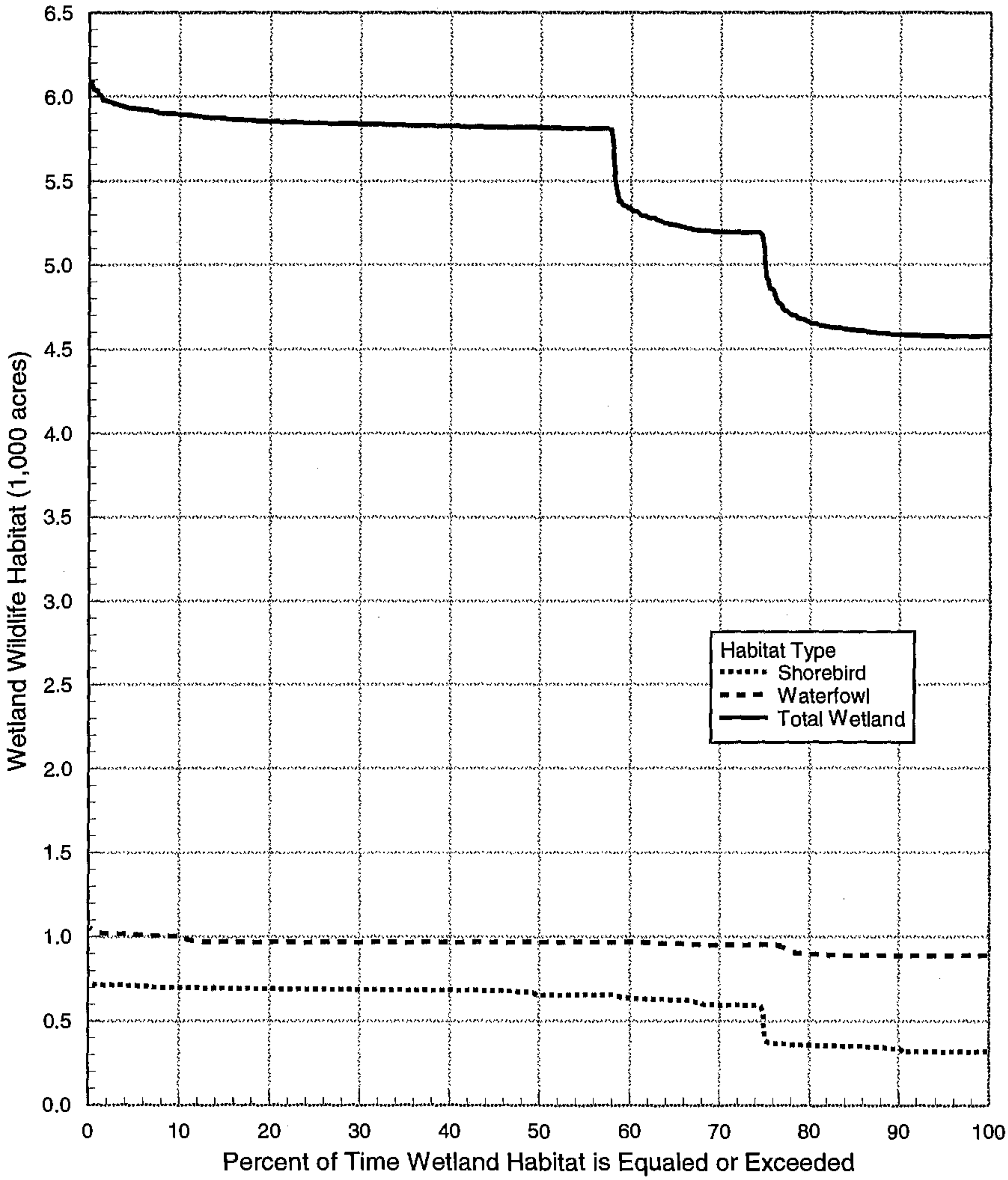
972 acres for shorebirds and waterfowl. These represent increases of 89 and 61 percent, respectively, over the corresponding averages under baseline conditions. The average amount of total wetland habitat more than doubles to 5,772 acres.

Table IV-5
AVAILABLE WETLAND HABITAT—ULTIMATE USAGE CONDITIONS

Month	Shorebird (1–4 inches)		Waterfowl (10–18 inches)		Total Wetland	
	Range	Average	Range	Average	Range	Average
Jan	622 - 719	691	968 - 1,015	973	5,316 - 6,039	5,845
Feb	653 - 715	692	968 - 1,012	974	5,817 - 6,010	5,862
Mar	653 - 716	688	968 - 1,017	975	5,814 - 5,980	5,866
Apr	653 - 700	680	968 - 1,043	978	5,812 - 6,015	5,864
Sep	549 - 653	606	937 - 1,034	956	5,099 - 5,341	5,208
Oct	646 - 719	673	968 - 1,026	974	5,721 - 6,088	5,835
Nov	653 - 714	681	968 - 1,021	973	5,811 - 6,046	5,846
Dec	653 - 716	690	968 - 1,016	972	5,815 - 6,036	5,853
Sep–Apr	549 - 719	675	964 - 1,034	972	5,099 - 6,088	5,772

Note: All wetland habitat values in acres. Statistics include data for primary migration season, September through April only.

The durations of available wetland habitat at the Refuge with ultimate water usage are shown in Figure IV-3. Review of this figure illustrates how nearly constant wetland acreages can be maintained with adequate water supplies.



Notes:
1. Developed from operations modeling for Quivira NWR for period 1/1955 through 12/1994 with ultimate water usage. Includes data for months of September through April only.
2. Optimum shorebird and waterfowl habitats defined as wetland areas 1-4 inches and 10-18 inches deep, respectively. Total wetland habitat is the sum of the surface areas of all ponded water in all management units, regardless of depth.

Burns & McDonnell

Figure IV-3

WETLAND HABITAT DURATIONS ULTIMATE WATER USAGE

PART V

TASK A - RESERVOIR SITING

A. GENERAL

This section of the report discusses potential surface water storage sites in the Rattlesnake Creek Basin. The investigative approach or site selection process includes preliminary screening and the use of engineering and environmental characteristics in the development of potential water yields and costs for reservoir construction.

Potential reservoir sites are identified initially using available mapping and then screened for suitability based on engineering and environmental criteria. Sites carried forward in the screening process are compared in greater detail to estimate potential yields and parametric criteria to estimate costs.

B. INVESTIGATIVE APPROACH -- SITE SELECTION

1. Identification of Reservoir Sites

Preliminary identification of reservoir sites is based on the following:

- Map study to locate potential reservoir sites.
- Review of construction materials availability.
- Assessment of geologic conditions affecting construction.

During the map study, potential surface water storage sites are identified based on review of 7½-minute USGS topographic quadrangle maps. The availability of construction materials and assessment of geologic conditions affecting construction are based on available regional geologic and soils information, and previous reports on potential reservoir sites.

2. Review of Geologic Conditions

The Rattlesnake Creek Basin is located in the Great Plains physiographic province in south-central Kansas. The basin is in an area referred to as the Great Bend Prairie because of its location relative to the great bend of the Arkansas River between Dodge City and Wichita. Rattlesnake Creek flows through the Great Bend Prairie from the southwest (originating in Kiowa and Ford Counties) to the northeast, where it flows into the Arkansas River (in Rice County).

The Great Bend Prairie is an alluvial plain which has been covered by aeolian (wind-deposited) sand. The alluvium and dune sand are both recent depositional features. Except for small areas within the basin, the topography is characterized by dune sand. The topography is relatively flat, with some irregular areas containing higher sand hills. Many small, undrained basins exist. Areas of more moderate relief are flat to hummocky and are drained by tributaries to Rattlesnake Creek and by Rattlesnake Creek itself.

Bedrock in the region is sedimentary in origin and ranges from Cretaceous to recent in age. Outcrops are rare throughout the basin and generally found along stream channels. The Pleistocene Meade Formation is the most prominent bedrock in the basin, consisting of lightly cemented sandstone, with silt and caleche found in the upper part of the formation. The caleche is most often exposed along stream channels in the basin. The bedrock is covered by recent alluvial sands and gravels. Most of the alluvial deposits within the basin are covered by recent dune sands, except along the stream channels. Bedrock can be 50 feet or more below the ground surface, except along stream channels where it is locally higher. Groundwater is generally shallower in the eastern portion of the basin.

Because of the variable depth of bedrock within the basin and the fact that the bedrock can be deep (compared to the overall height of the embankments considered), selection of damsites is performed independent of the geologic conditions and concentrated on topographic features that would allow construction. It is likely that bedrock, if shallow enough to influence the construction of a dam at a specific location, is relatively permeable; therefore, foundation treatment consisting of a cutoff trench or wall is assumed necessary to reduce seepage beneath the dam regardless of the foundation conditions. Although seepage through and underneath the dam often can be controlled to a significant extent by construction methods, loss of stored water through the soils covering the reservoir basin will likely occur, considering the predominance of sandy soils within the basin.

Many small, closed basins exist in the Rattlesnake Creek Basin, among the sand dune deposits, that locally trap water after precipitation. Most of this water is lost through infiltration into the soils, or through evaporation and transpiration; therefore, any new reservoir sites within the Rattlesnake Creek Basin also will tend to lose stored water in this fashion, unless it can be transferred relatively quickly downstream. The potential is high for loss of water in transit from a reservoir to a downstream point of use.

3. Identification of Potential Reservoir Sites

A reconnaissance-level map study is used to identify the locations for 18 potential reservoir sites or impoundments in the Rattlesnake Creek Basin as shown in Figure V-1. Surface water storage appears to be feasible at these sites, based on topographic, geographical, and geological factors. Several sites include two or more variations of reservoir elevation and storage. Information on these sites is listed in Table V-1. Sites are considered to be "acceptable" if they meet the general criteria of storing greater than 1,000 acre-feet of water. Site 1 has less than 1,000 acre-feet of storage and is included since the site is on property adjacent to the Refuge. In order to achieve the Refuge water supply objectives, a combination of several storage sites, as well as other alternatives, may be needed.

Only two potential reservoir sites are located on the main stem of Rattlesnake Creek. One of these sites is an enlargement of the existing Gossell Lake. The more common type of reservoir site identified in the basin is characterized by shallow, incised valleys and wide flood plains, pond and lake enlargements, and broad depressions predominantly bordered by high ground. Most of the sites are "off-channel" and are not located on Rattlesnake Creek.

The environmental and land ownership issues associated with reservoir siting are not initially considered in potential reservoir site identification. Environmental factors are applied in the subsequent screening process.

During preliminary screening, storage volumes for the sites are estimated based on the water surface area, scaled from 7½-minute USGS topographic quadrangle maps, multiplied by an estimate of the average depth of the reservoir. The contours of the topographic maps covering the watershed range from 5-foot

Table V-1
POTENTIAL RESERVOIR SITES

Map Index No.	Surface Area (ac)	Depth Range (ft)	Approx Vol (ac-ft)	Max Emb Height (ft)	Tot Emb Length (ft)	Drainage Area [1]	Maximum Water El (ft.)	Type [2]	Pipe Dist (ft)	Pumping (HP)	Pipe Dia.(in)
1	200	4 to 7	1,000	10	300	NA	1795	c	500	50	16
2	380	10 to 13	3,800	10	1,600	36+ sq mi	1910	b or d	13,300	2,040	30
3a	510	9 to 10	4,600	20	1,650	<5 sq mi	1930	d	10,700	1,790	36
3b	560	9 to 20	7,200	20	2,800	<5 sq mi	1935	d	10,700	2,490	42
4	150	11 to 16	1,600	15	1,900	8 sq mi	2005	e	2,700	340	20
5	260	4 to 7	1,600	10	3,200	NA	1815	c	300	50	20
6a	340	4 to 15	4,400	15	2,100	< 10 sq mi	1960	b or d	5,900	1,030	36
6b	170	8 to 10	1,700	10	1,200	< 10 sq mi	1955	b or d	6,500	620	24
6c	690	4 to 20	11,100	20	4,000	< 10 sq mi	1965	b or d	5,000	1,810	54
7	120	4 to 10	800	10	1,350	14 sq mi	1935	b or d	3,800	270	16
8a	200	4 to 11	1,400	10	4,400	NA	1865	c	2,200	250	20
8b	770	4 to 15	7,700	15	5,500	NA	1870	c	2,200	780	48
9	110	9 to 12	1,300	10	310	NA	2100	a			
10	90	9 to 12	900	15	1,250	NA	2110	c	1,900	180	16
11	280	13 to 19	3,800	40	2,650	NA	2300	c	500	290	30
12	240	11 to 15	3,100	20	550	50+ sq mi	2220	a			
13	220	18 to 24	4,800	30	1,400	15 sq mi	2270	a			
14	210	16 to 24	4,200	40	1,450	5.5 sq mi	2280	a			
15	160	9 to 13	1,800	20	2,750	NA	2300	c	300	120	20
16	100	14 to 19	1,600	25	4,250	NA	1925	c	4,500	580	20
17a	1,640	4 to 20	19,700	20	6,000	NA	1905	d	8,000	3,120	72
17b	2,220	5 to 25	31,100	25	7,200	NA	1910	d	7,800	4,560	90
18	750	4 to 11	4,500	15	4,700	NA	2105	c	500	220	36

Notes:
1. Not applicable (NA) if pumped inflow from Rattlesnake Creek will most likely be used, whether by direct flow or pumping.
2. a - On the Rattlesnake Creek channel.
   b - Off-channel; however, inflow does not require pumping and flow downstream will reach Rattlesnake Creek.
   c - Off-channel. Inflow involves a short pipeline.
   d - Off-channel. Inflow involves a long pipeline.
   e - Off-channel. Piped inflow and outflow.

intervals, for approximately half of the drainage basin at its downstream end, to 10- and 20-foot contours progressing upstream. The maximum water surface elevations are estimated at defined contour lines.

Subsequent analysis shows the initial storage volumes were over-estimated at certain identified sites. This over-estimation does not have a significant effect on the initial screening since most of the sites are eliminated from further study due to environmental considerations and their physical location within the basin.

4. Topographic and Geologic Factors

The topography and geology of the Rattlesnake Creek Basin present challenges to reservoir siting. Most of the basin consists of a broad, flat plain of sandy soil, with very gradual variation in relief near streambeds; however, the upstream fringes of the basin have considerably more topographic relief. The surface soils in the majority of the basin are windblown sand.

Water from any surface water storage site is subject to significant losses, both in storage and in the stream releases or conveyance to the delivery point. While sites high in the basin are generally deeper and would experience less evaporation loss, inflows are low and conveyance losses between the storage reservoir and the Refuge could significantly reduce the volume of delivered water from these sites. Suitability of the potential reservoir sites is also affected by their proximity to construction materials.

Sites in the downstream third of the basin can generally be characterized as broad, shallow depressions, often on a tributary stream and including the stream's flood plain. These sites have the advantage of storing runoff from a large portion of the basin and releasing it close to the Refuge, thereby helping to minimize transit losses due to seepage and other factors.

Losses into the groundwater system could potentially be recovered by wells or increased base flow; however, not all of the groundwater underlying the Rattlesnake Creek Basin flows towards the Refuge or could be pumped by groundwater users before reaching the Refuge. Groundwater in the upstream part of the basin, within Kiowa County and extending south, migrates away from the Refuge, while groundwater

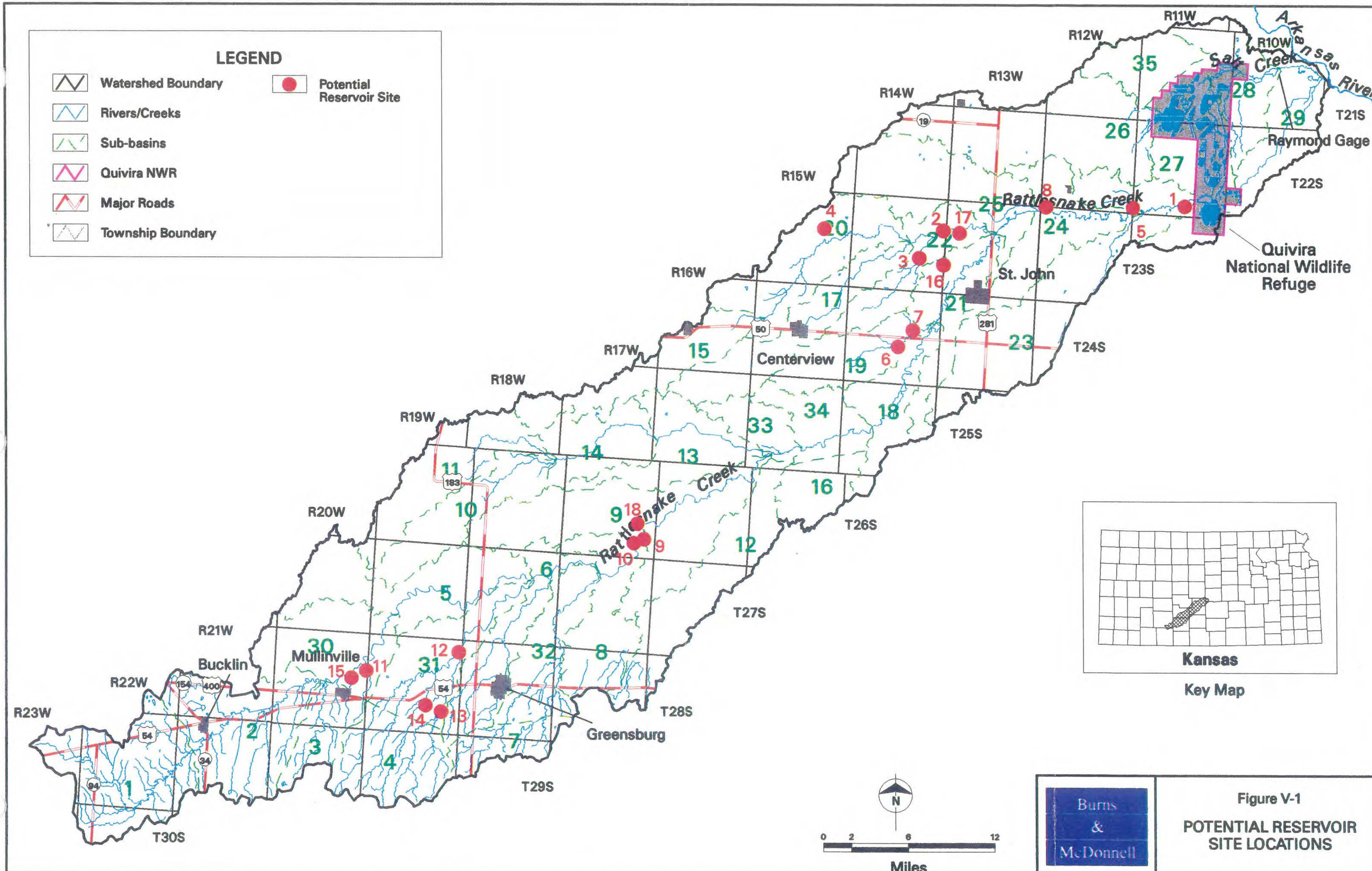


Figure V-1

POTENTIAL RESERVOIR SITE LOCATIONS

in the part of the basin downstream of the Edwards and Kiowa County lines migrates northeast toward the Refuge.

Developing storage projects in the upstream portion of the basin may involve restricting outflow from these sites to the times of the year during which Rattlesnake Creek has continual flow and conveying it to another storage site downstream from which outflows could be scheduled, as needed. This would help to minimize conveyance losses.

5. Contributing Drainage Area

Of the 18 potential reservoir locations, 14 sites are off-channel reservoirs and require significant water volumes to be pumped from Rattlesnake Creek. Small to moderately-sized reservoir sites, which collect inflow from both a tributary stream and from the perennial portion of Rattlesnake Creek, have the greatest chance of achieving the estimated storage volume. This assumption is based on the small contributing drainage areas above these sites and is confirmed by streamflow estimates extracted from the SWATMOD model. Large portions of the Rattlesnake Creek Basin do not contribute sufficient surface runoff. These non-contributing areas may justify reduction of the estimated storage volumes at the largest sites.

6. Configuration Factors

Embankment dams would be used to create storage at the 18 identified sites and would range in length from relatively short dams in a narrow, defined channel to very long embankments in flood plains. Certain sites require several smaller embankments to enclose an area with insufficient topography. Very long embankments are considered acceptable if relatively large storage volumes could be developed. Sites involving ring dikes to create an impoundment may be excessively costly per acre-foot of storage developed and are not considered in the map study.

Most of the sites are off-channel and the reservoirs would be filled by pumping water from Rattlesnake Creek. The distance between the point of diversion and the storage reservoir is an important cost factor. Sites requiring long pipelines are not screened out initially. A rough estimate of pumping horsepower to fill off-channel storage reservoirs is developed for the initial screening. This estimate is based on pumping the reservoir volume during a 30-day period (that is, the entire storage would be filled by "flood skimming"); the pipe diameter is based on a velocity of 12 feet per second; friction and static head loss are calculated to estimate total pumping head.

7. Other Considerations

The presence of existing structures at the damsite or in the reservoir "take area" may adversely affect project feasibility. Such structures include residences, roads, pipelines, oil wells, cemeteries and railroads. Many of these structures can probably be relocated, avoided, or abandoned, and the presence of these structures is not used to screen out any sites during the map study.

8. Identification of Construction Materials

Natural Resource Conservation Service (NRCS) soil surveys are reviewed for the following counties in the Rattlesnake Creek Basin: Kiowa, Edwards, Pawnee, Stafford, Pratt, and Reno. Information on Ford County is incomplete because the soil survey is no longer in print, and information on Rice County is not available. The latter two counties make-up a small portion of the basin at the extreme ends and the absence of such information is not considered significant.

Each soil survey report is reviewed to identify potential materials for construction. Construction materials are divided into three categories: sand, gravel, and fine-grained soils. Because of the geologic history of the Rattlesnake Creek Basin, sands are abundant throughout the basin. Gravels are limited in quantity and areal extent and are found primarily along stream channels. Because of the abundance of granular materials and their limited use for construction of embankments and levees or to line canals, their locations are not identified. Embankments and lined canals should be constructed of relatively impermeable materials to limit loss of water through seepage. Such materials should be predominantly fine-grained soils having moderate plasticity and low permeability; therefore, construction materials identified in this initial screening of information are limited to relatively impermeable materials, such as clay and silt.

The engineering properties of soils in the region are summarized in each of the NRCS soil survey reports. Based on these summaries, materials are identified that have a minimum of 35 percent silt or clay-size particles (passing the No. 200 sieve) and a plasticity index (PI) of 10 or more. Soil profiles in the surveys are limited to 5 or 6 feet in depth. Only those soil types that meet these criteria for the entire depth and those that did not have interlayered sands are included in the analysis. Those soils having shallow bedrock or groundwater conditions are also eliminated from consideration. Soils with groundwater within 5 feet of the ground surface are not included as part of this initial screening, even if the high groundwater is only present for part of the year.

The review of potential borrow areas is limited to the area within the Rattlesnake Creek Basin, with the following exception; at the north end of the basin, impermeable materials are limited within the basin, but appear abundant just south of the basin boundary in Stafford County along the Peace Creek drainage. These materials are included in the study because it could be less costly to borrow material from a nearby source (for reservoirs in the lower basin) than from a source within the basin, even though it could be further from the potential damsite.

Each index sheet of the soil survey report is reviewed to locate potentially acceptable construction materials. Only borrow areas 40 acres or larger are included in this initial screening.

9. Results of Preliminary Screening

The 18 identified storage sites and the potential borrow areas for construction materials are screened to identify surface water storage sites worthy of further reconnaissance-level or more detailed evaluation. The screening was performed during a 3-day field trip to the project area from September 9 through 12, 1997. The results of the reservoir screening are discussed below.

Screening team assembled at the Quivira NWR on September 9, 1997. The team included water resources specialists, engineers, and environmental scientists from Burns & McDonnell and GEI.

On September 9, 1997, the 18 potential surface storage sites (similar to Figure V-1) were discussed with the team. Sites 4, 7, 11, and 15 were eliminated from any further consideration because of wetlands, likely construction challenges, materials quantities, and expected water yield.

A "windshield" survey of the 14 remaining sites was conducted on September 9 and 10, 1997. This activity consisted of visual surveys from county roads around the alternative sites. Environmental conditions on each site were noted where possible, including land use, cultural resource potential, potential for threatened and endangered species or their habitats, wetlands, soils, roads, residences, utilities, and oil wells.

On September 9, 1997, a Burns & McDonnell representative met with the Kansas Department of Wildlife and Parks (KDWP) to discuss the agency's position on the water supply study and issues pertaining to threatened and endangered species. KDWP's formal written response to the water supply project was presented in a letter dated September 9, 1997. KDWP's primary concern was the potential impoundment of Rattlesnake Creek for a water supply reservoir. A state endangered fish species, the Arkansas darter, occurs in this watershed. Any impoundments could reduce the species' habitat and cause further declines in populations. KDWP would not permit a project that was on the main channel of Rattlesnake Creek; however, KDWP would be more inclined to permit an off-channel reservoir site, as long as impacts to threatened and endangered species were not a factor.

Following the initial screening of all 14 remaining sites, these 14 sites were further screened on September 10, 1997, based on results of the initial field reconnaissance. Several variables were considered in this screening, including the expected amount of earthwork, potential size and cost of the outlet works and spillway; road and utility relocations, residential relocations; water supply pipeline length; wetlands; cultural resource potential; threatened and endangered species potential; and distance from the Refuge.

After discussing these issues, the screening team determined that Sites 5, 9, 10, 14, and 16 should be dropped from further consideration. This decision was based on different factors for each site. Site 5 was dropped due to outlet works and spillway construction costs, wetlands issues, and the extensive oil facility development. Sites 9 and 10 were eliminated due to high-quality springs potentially containing Arkansas darters in the potentially impounded areas, the density of known archaeological sites in these areas and the high potential for additional sites. After visiting Site 14, it was determined that no real differences existed among Sites 12, 13, and 14; therefore, Site 14 was dropped because it is farthest of the three sites from the Refuge and would ultimately have the greatest conveyance loss and provide the lowest yield. Site 16 was eliminated from further consideration because of the large amount of earthwork required compared to expected water yield.

After the initial discussions, Sites 1, 2, 3, 6, 8, 12, 13, 17, and 18 were retained for additional evaluation. An impact matrix table (Table V-2) was created. Each variable was ranked for each potential reservoir site on an ordinal scale in which a larger number was considered more impacting or less desirable. The exception was residences. Each residence was counted and the number within the impounded area used as the impact score for this variable. A total "impact value" was calculated for each site. The total values for the 9 remaining sites were then averaged. Total scores above the average were considered to have more severe impacts with potential reservoir sites with scores below average were considered to have less impact.

Although it scored above average, Site 1 is rated better than most other sites for most variables. The impact of potentially extensive wetlands causes the low score. Further discussions with the Service and U.S. Army Corps of Engineers may be warranted to determine if, through site management, wetland impacts could be reduced or reasonably mitigated to improve the feasibility of this site.

Sites 17 and 18 also have higher than average scores due to their higher than average rating for a variety of factors considered. Sites 17a and 17b are eliminated due to high construction costs, a large number of residences requiring relocation, high potential for cultural resources, and the long distance to the Refuge. Site 18 is eliminated due to very high construction costs, being a long distance from the Refuge, and having significant environmental impacts.

Upon further discussion by the screening team, Sites 12 and 13 are also eliminated. A portion of Rattlesnake Creek below these sites is a losing stream which would result in significant conveyance losses. Site 8 is retained, although its score is roughly equal to the average score. At this time, this site provides a reasonable amount of storage and is one of the closest sites to the Refuge.

Five sites (1, 2, 3b, 6, and 8) were selected for a re-examination in the field. On September 10 and 11, 1997, these sites were revisited to verify conditions observed earlier and to look more critically at each site for potential engineering and environmental conditions and concerns. Nothing was observed in the field that could be used to further eliminate any of the sites. Subsequent to field evaluations, potential reservoir Site 8 was resized to optimize storage efficiency and site topography. The total area that would be

Table V-2
ALTERNATIVE RESERVOIR COMPARISON

Site Number	Construction Ranking Criteria				Environmental Ranking Criteria					Total Score
	Earth Work[1]	Outlet Works[2]	Spillway[3]	Pipeline Length (mi.)	Roads & Utilities (miles)	Residences (no.)	Wetlands Impact**	Cultural Resources Potential ***	Stream Distance to Refuge****	
1	**1.0**	**1.0**	**4.0**	**0.1**	**1.0**	**-**	**10.0**	**2.0**	**1.0**	**20.1**
2	**1.0**	**2.0**	**3.0**	**2.5**	**0.0**	**-**	**2.0**	**2.0**	**2.0**	**16.5**
3a	2.0	3.0	-	-	-	-	-	-	-	-
3b	**2.0**	**3.0**	**1.0**	**2.0**	**1.0**	**1**	**1.0**	**1.0**	**2.0**	**14.0**
4	4.0	-	-	-	-	-	-	-	-	-
5	3.0	1.0	-	-	-	-	-	-	1.0	-
6a	2.0	2.0	1.0	1.1	-	-	-	-	2.5	-
6b	2.0	1.0	1.0	1.2	-	-	-	-	2.5	-
6c	**2.0**	**4.0**	**1.0**	**1.0**	**2.0**	**-**	**2.0**	**1.0**	**2.5**	**16.5**
7	3.0	-	-	-	-	-	-	-	-	-
8a	5.0	-	-	-	-	-	-	-	-	-
8b	**2.0**	**3.0**	**4.0**	**0.4**	**1.0**	**3***	**2.0**	**2.5**	**1.5**	**18.5**
9	1.0	-	-	-	-	-	-	-	-	-
10	1.0	-	-	-	-	-	-	-	-	-
11	10.0	-	-	-	-	-	-	-	-	-
12	1.0	2.0	3.5	0.0	1.0	-	1.0	2.0	4.0	14.5
13	3.0	3.0	2.0	0.0	1.0	1	1.0	2.0	4.0	16.0
14	6.0	-	-	-	-	-	-	-	-	-
15	7.0	-	-	-	-	-	-	-	-	-
16	17.0	-	-	-	-	-	-	-	-	-
17a	2.0	4.0	4.0	1.5	2.0	-	2.0	2.5	2.0	-
17b	**2.0**	**5.0**	**4.0**	**1.5**	**2.0**	**7***	**2.0**	**2.5**	**2.0**	**26.0**
18	3.0	3.0	4.0	0.1	2.0	1	2.0	2.0	3.0	20.1
									AVERAGE	18.0

Note: Shaded sites are those proposed as final alternatives.

1 - Earthwork score based on Volume of Fill (cubic yards soil) / Storage Capacity (acre feet water) where a value of < 10 = 1, 10.1 - 20.0 = 2, 20.1 - 30.0 = 3, 30.1 - 40.0 = 4, etc.

2 - Outlet work score based on reservoir size storage capacity (acre feet). Storage capacity < 2000 = 1, 2000 - 4000 = 2, 4000 - 10,000 = 3, >10,000 = 4.

3 - Spillway work score based on size of drainage area (square miles) above damsite. Drainage area < 10 = 1, 10 - 30 = 2, 30 - 50 = 3, large = 4.

The following symbols denote that a score is accessed for that specific item:

* - One or more residences within 200' of inundation area.

** - Wetlands impact scores based on ranking the acreage of a sites wetlands inundated on an impact scale of 1 - 10, where 1 = few acres of wetlands lost, to 10 = many acres of wetlands lost.

*** - Cultural resource scores based on probability of cultural resources existing in proposed inundation area. 1 = low to moderate, 2 = moderate, 3 = moderate to high, 4 = high.

****- Stream distance scores based on four relative stream delivery distance categories to Quivira NWR. 1 = 0 - 5 miles; 2 = 15 - 30 miles; 3 = 55 - 60 miles; 4 = > 75 miles. .

inundated was significantly reduced as a result. Additional evaluation of these five sites was initiated, as discussed in subsequent sections of this report.

C. RESERVOIR STORAGE VOLUME

Reservoir Sites 1, 2, 3, 6, and 8, shown respectively in Figures V-2 through V-6, are selected for additional evaluation after the preliminary screening process. The contour lines are planimetered to estimate the area within each contour at each site. The prismoidal formula is used to estimate reservoir volume between contour lines. Estimated reservoir volumes for the five storage sites are listed in Table V-3.

Table V-3
ESTIMATED RESERVOIR VOLUMES

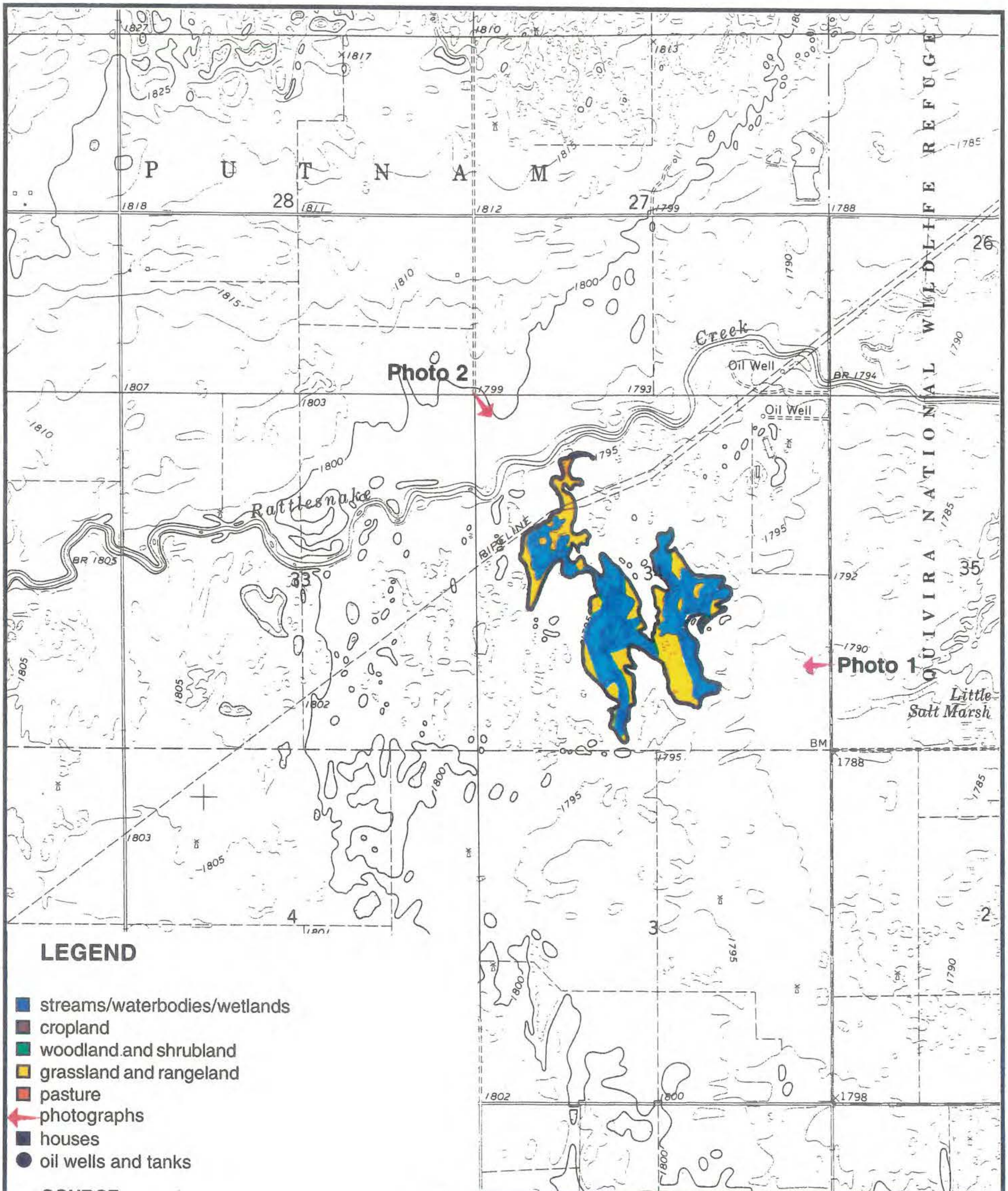
Site Number	Maximum Volume (acre-feet)	Maximum Area (acres)	Primary Watershed
1	161	80	--
2	3,383	550	Wild Horse Creek
3	4,318	550	Bear Creek
6	3,228	630	Spring Creek
8	656	160	--

1. Reservoir Yield Methodology

Monthly streamflow estimates for the period from 1955 to 1994, extracted from the SWATMOD model for the Rattlesnake Creek Basin, are used to estimate reservoir yield. A watershed map of Rattlesnake Creek with subbasins is shown in Figure I-1. The contributing subbasins to each specific reservoir are listed in Table V-4.

Table V-4
CONTRIBUTING SUBBASIN(S) TO RESERVOIR

Site Number	Primary Watershed	Additional Water Diverted
1	--	23
2	22	21
3	-	21 and 22
6	19	18
8	--	24



LEGEND

- streams/waterbodies/wetlands
- cropland
- woodland and shrubland
- grassland and rangeland
- pasture
- photographs
- houses
- oil wells and tanks

SOURCE:

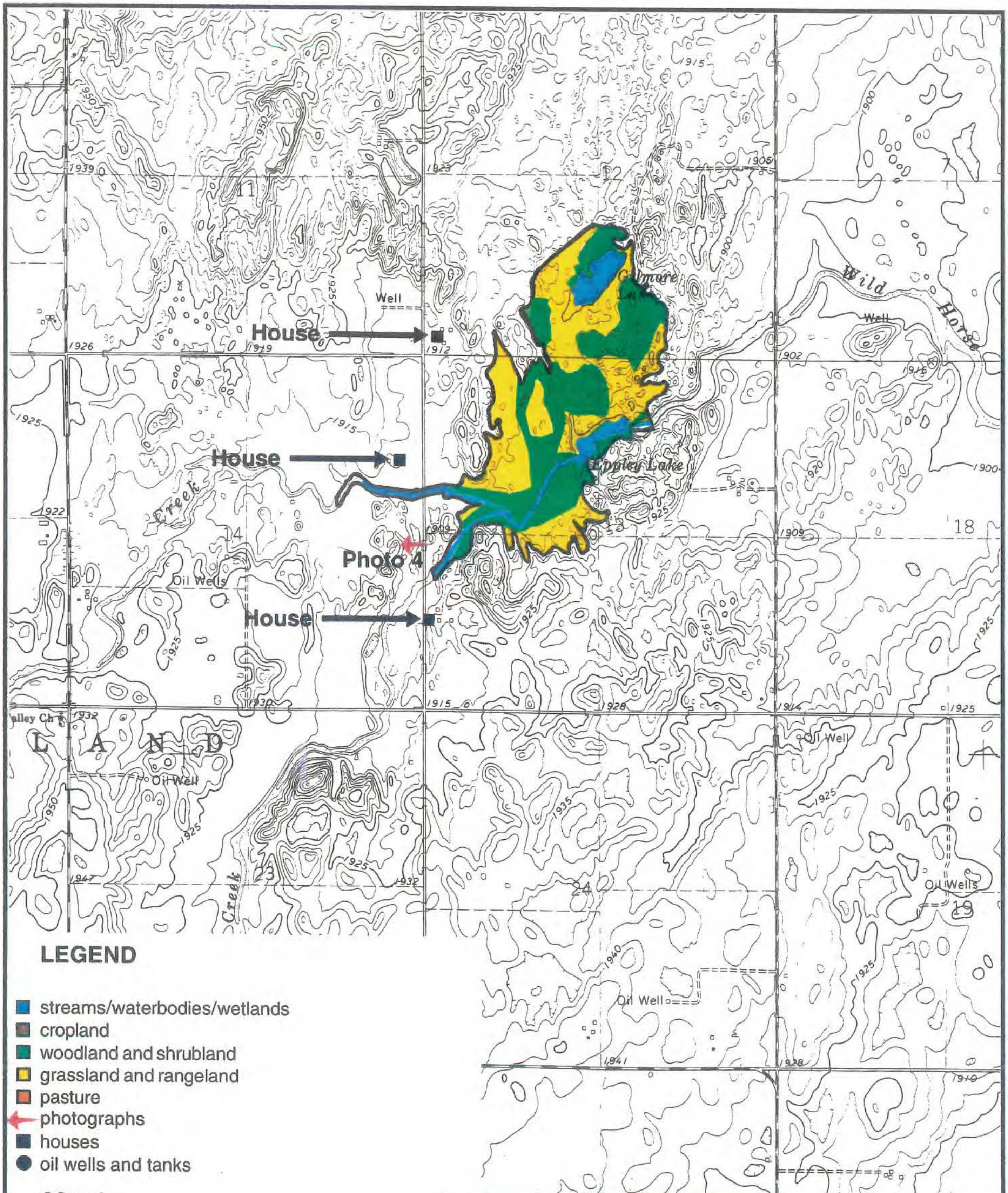
USGS Map - 7.5' (Topographic)
Hudson SE Quadrangle
Kansas - Stafford County

1000 0 1000 2000 3000 4000 FEET

N

Burns & McDonnell

Figure V-2
POTENTIAL RESERVOIR
SITE 1



LEGEND

- streams/waterbodies/wetlands
- cropland
- woodland and shrubland
- grassland and rangeland
- pasture
- photographs
- houses
- oil wells and tanks

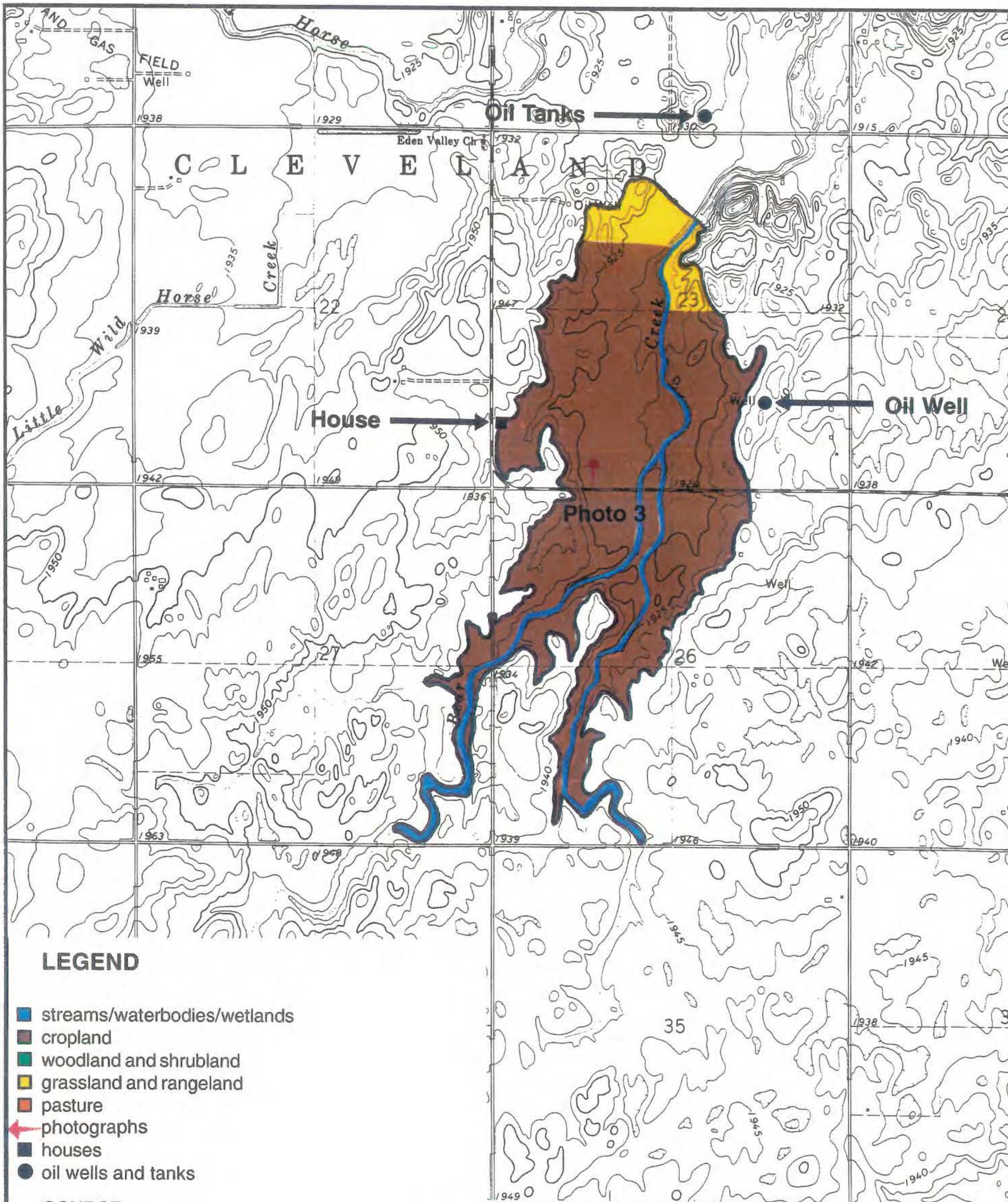
SOURCE:

USGS Map - 7.5' (Topographic)
Saint John North Quadrangle
Kansas - Stafford County

1000 0 1000 2000 3000 4000 FEET

Burns & McDonnell

Figure V-3
POTENTIAL RESERVOIR
SITE 2



LEGEND

- streams/waterbodies/wetlands
- cropland
- woodland and shrubland
- grassland and rangeland
- pasture
- photographs
- houses
- oil wells and tanks

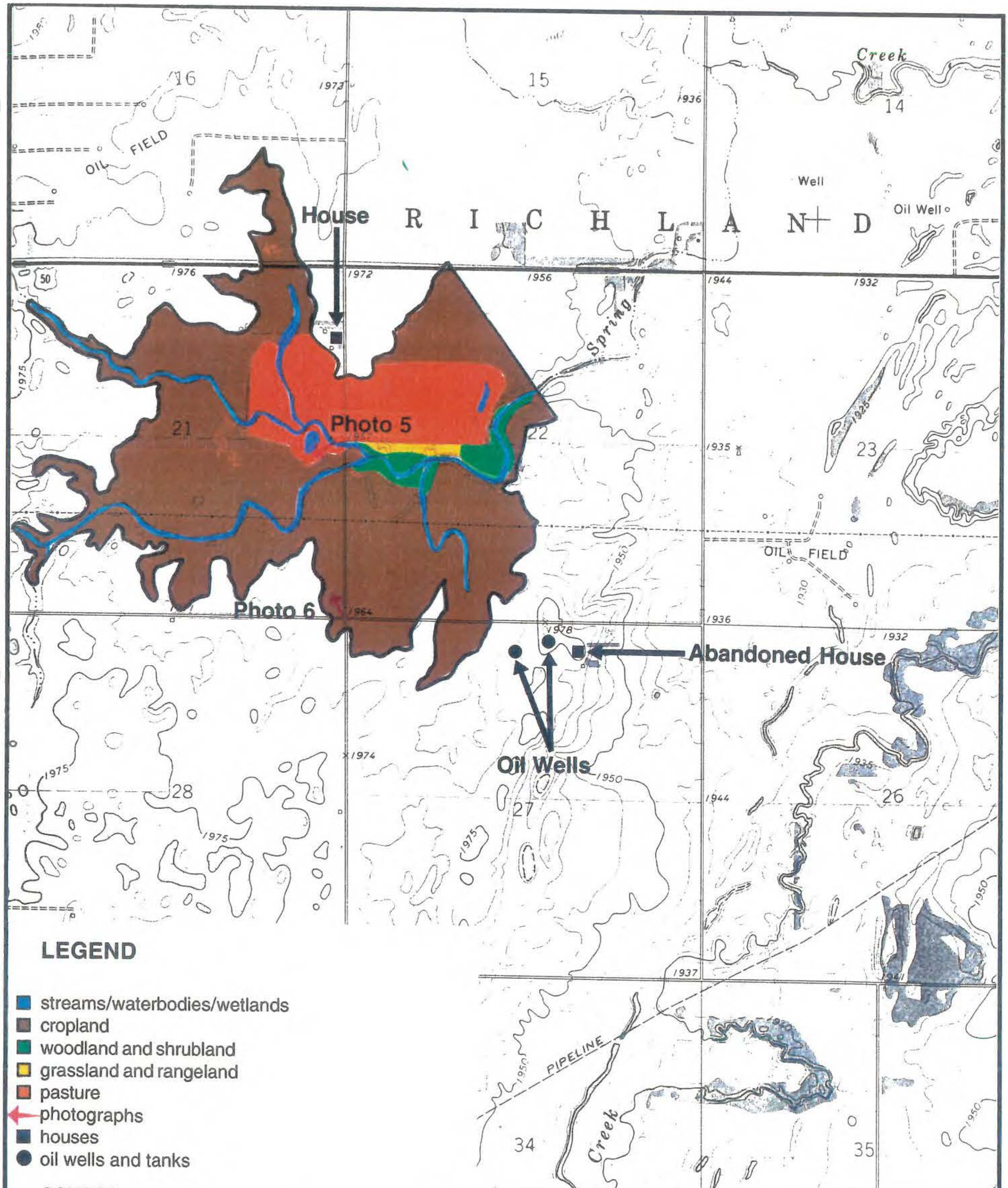
SOURCE:

USGS Map - 7.5' (Topographic)
Saint John North Quadrangle
Kansas - Stafford County

1000 0 1000 2000 3000 4000 FEET

Burns & McDonnell

Figure V-4
POTENTIAL RESERVOIR
SITE 3



LEGEND

- streams/waterbodies/wetlands
- cropland
- woodland and shrubland
- grassland and rangeland
- pasture
- photographs
- houses
- oil wells and tanks

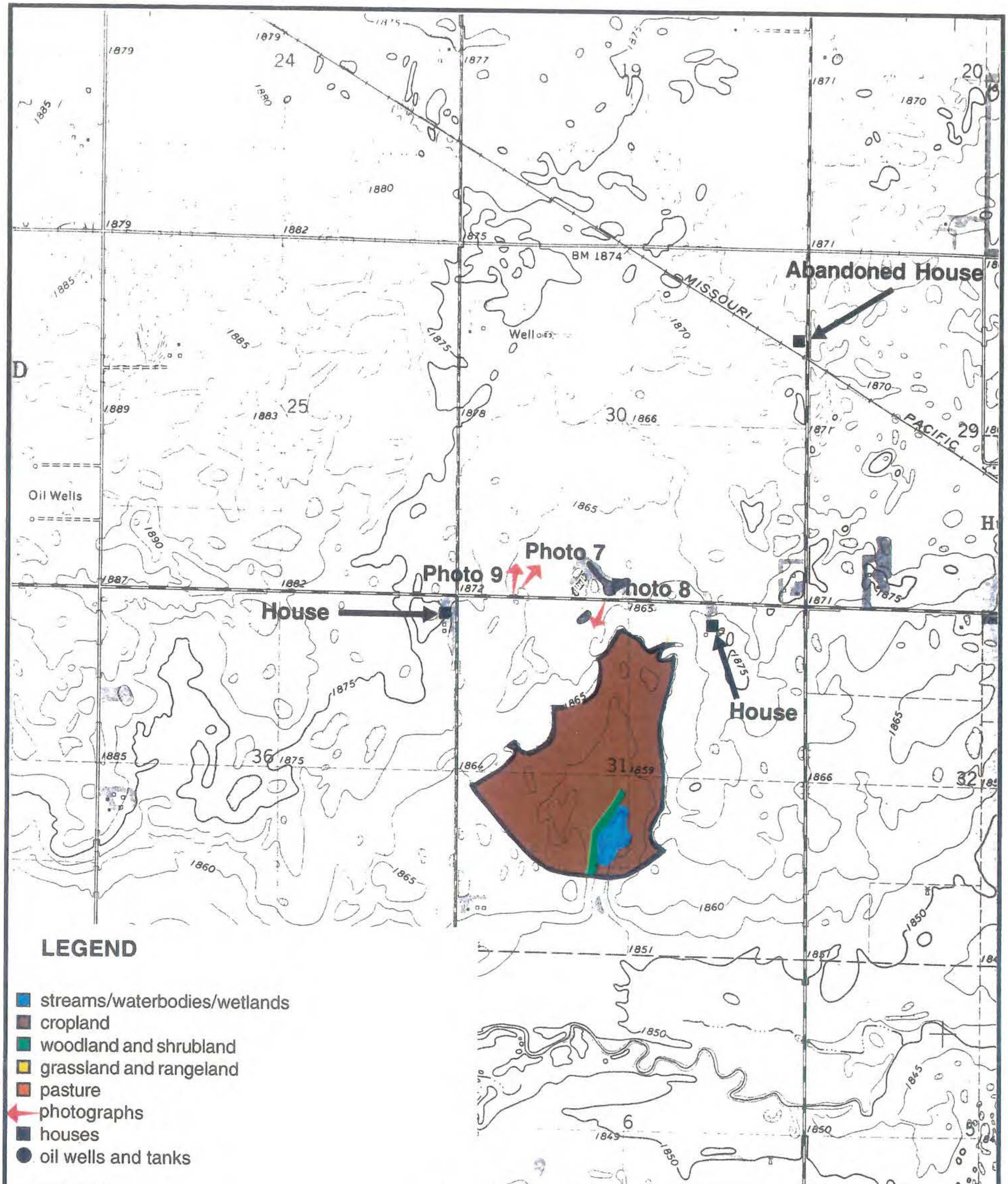
SOURCE:

USGS Map - 7.5' (Topographic)
Saint John South Quadrangle
Kansas - Stafford County

1000 0 1000 2000 3000 4000 FEET

Burns & McDonnell

Figure V-5
POTENTIAL RESERVOIR
SITE 6



LEGEND

- streams/waterbodies/wetlands
- cropland
- woodland and shrubland
- grassland and rangeland
- pasture
- photographs
- houses
- oil wells and tanks

SOURCE:

USGS Map - 7.5' (Topographic)

Hudson Quadrangle

Kansas - Stafford County

1000 0 1000 2000 3000 4000 FEET

N

Burns & McDonnell

Figure V-6
POTENTIAL RESERVOIR
SITE 8

For the initial reservoir yield estimates, the entire estimated flow at each subbasin outlet is assumed to be available for diversion to the potential reservoir. No allowance for maintenance of a minimum flow below the identified diversion point or points is included. Any minimum flow requirements, which may be imposed on this development, will reduce the corresponding yield estimates. The estimates of potential reservoir diversions do not take into account any existing senior water rights on Rattlesnake Creek, including those for the Refuge itself. Honoring these senior water rights will drastically reduce the quantities of water available for diversion and correspondingly the potential yields of these reservoirs. A schematic diagram of the reservoirs and diversions is shown on Figure V-7.

2. Reservoir Modeling

A spreadsheet model is used to estimate reservoir yields. The model operates on a monthly time step, consistent with the available streamflow estimates. The spreadsheet model assumes that inflow from the primary watershed, plus water diverted from Rattlesnake Creek, is available to fill the reservoir.

Evaporation estimates for the region are obtained from published sources. These values are in inches per month and are converted to evaporative loss volumes based on reservoir surface area. The net monthly inflow is the sum of basin inflow and diverted inflow, less evaporative losses and seepage losses. Seepage losses are based on estimates of seepage through the dam embankment only.

The reservoir yield model allows the input of a variable monthly water demand. Average monthly demands at the Refuge as a percentage of annual water demands are listed in Table V-5. The yield of each potential reservoir is defined as the maximum annual demand the reservoir can supply, without any shortages, during the study period.

3. Reservoir Environmental Characteristics

The environmental conditions within each reservoir inundation area are summarized in Table V-6 and described below. Impacts would result from the inundation of existing land use, land cover, and facilities below the conservation pool elevation of the reservoir.

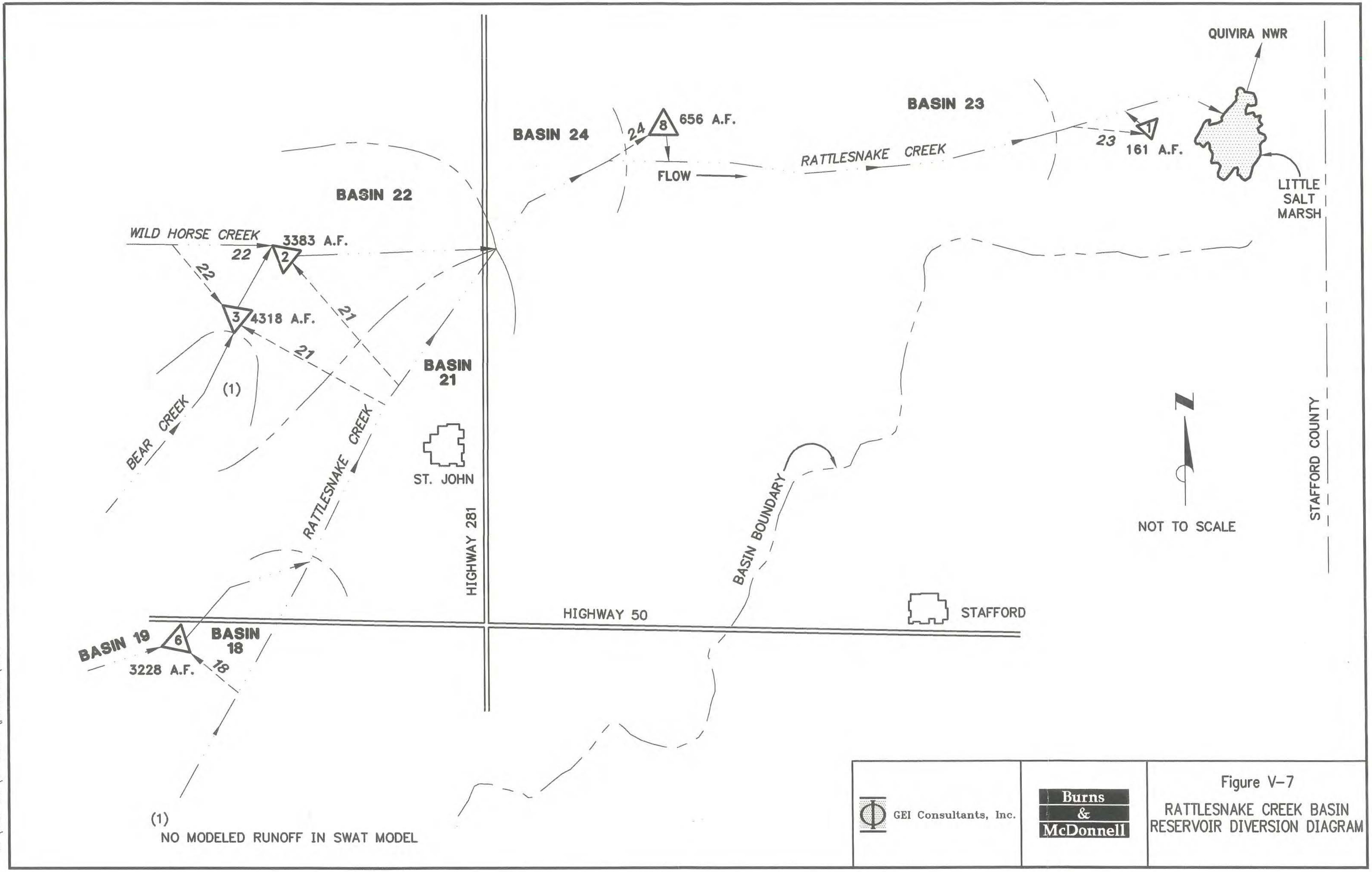


Figure V-7
RATTLESNAKE CREEK BASIN RESERVOIR DIVERSION DIAGRAM

J:\USP...\978064\procws\QUIVPLAN.DWG 02-03-1998 1... AAO

Table V-5
AVERAGE MONTHLY DEMANDS AT REFUGE
AS PERCENT OF TOTAL DEMAND

Month	Percent of Annual Demand	Month	Percent of Annual Demand
January	5	July	10
February	6	August	11
March	7	September	18
April	10	October	13
May	0	November	9
June	6	December	5

The five potential reservoir sites afford unique environmental features indicative of the presence of a wide range of cultural resources. To develop the predictive model for assessing potential cultural resource impacts used in this study, a review of previous cultural resource investigations, previously recorded site types, densities, distribution, and pertinent historical documents of the Rattlesnake Creek Basin was conducted. The results of the background research are used as the predictive model to assess each potential site. Although the significance of these potential cultural resources cannot be fully determined until additional archaeological investigations are conducted, any sites or cultural resource deposits that maintain a moderate to high degree of integrity would probably be considered potentially eligible for listing on the National Register of Historic Places. However, none of the proposed reservoir sites contain known archaeological sites or historic structures, and it is unlikely any significant structures would be impacted at any of the sites. A brief discussion of overall impacts associated with reservoir construction follows the discussion of existing site conditions for each potential reservoir.

a. Existing Environmental and Cultural Resource Conditions

Site 1

Site 1 is located approximately 0.5 mile west of the Refuge in Stafford County (T22S R11W Section 34), about 1.5 miles upstream of the confluence of Rattlesnake Creek and Little Salt Marsh (Figure V-2). As shown in Table V-6, about 80 acres of land would potentially be inundated. These lands consist of about

Table V-6
ENVIRONMENTAL CHARACTERISTICS OF FINAL RESERVOIR SITE ALTERNATIVES

Item	Reservoir Site Number				
	1	2	3b	6c	8b
Cropland (acres)	0	0	500	493	153
Grassland/Rangeland (acres)	13	260	40	10	0
Pasture (acres)	0	0	0	100	0
Woodland & Scrubland (acres)	0	235	5	20	3
Ponds & Lakes (acres)	0	35	0	2	0
Wetlands (acres)	67	20	5	5	4
Potential for Cultural Resources (See note below)	2	4	1	1	4
Prime Farmland (acres)	0	0	540	326	40
Length of Stream Indundated (miles)	0	1	4	5	0
Number of Occupied Residences	0	0	1	0	0
Number of Abandoned Residences	0	0	0	0	0
Roads & Utilities (miles)	0.05	0	2.3	1	0
Number of Oil Well Sites	0	0	0	0	0

Note: Scores based on probability of cultural resources existing within proposed inundation zone where 1 = low to moderate, 2 = moderate, 3 = moderate to high, 4 = high

13 acres of grassland/rangeland and 67 acres of emergent wetlands. Site 1 contains no prime farmland. There is no cropland, pasture, woodland/shrubland, ponds, lakes or streams in the proposed inundation area. Approximately 300 linear feet of natural gas pipeline are located within the inundation zone and would require relocation. There are no occupied or abandoned residences, roads or oil wells located within this site's proposed boundary.

Much of Site 1 is made up of low and flat areas, conditions that have a low probability for containing cultural resources. However, among these flats and natural ponds are several rises or sand dunes that have a high potential for containing cultural resources. Any sites that may be found are likely associated with the procurement of a variety of locally available resources. Such sites are generally small and have a low density of artifacts present. Another possible type of site in the project area is base camps. Base camps potentially contain numerous subsurface features and other cultural deposits. Based on field observations, Site 1 has an overall moderate probability rating for cultural resource activity. If this site is selected, additional archaeological investigations will be required for the rises, sand dunes, and other elevated portions.

Site 2

Site 2 is about 23 miles upstream from the confluence of Rattlesnake Creek and Little Salt Marsh (Figure V-3). It is located approximately 3 miles northwest of St. John, Kansas, in Stafford County (T23S R14W Sections 12, 13, and 14). Development of this site would inundate about 550 acres consisting of 260 acres of grassland or rangeland, 235 acres of woodland or shrubland, 35 acres of lakes (two lakes, 7 and 5 acres), 20 acres of wetlands, and one mile of stream would be lost. As with Site 1, Site 2 also contains no prime farmland. No lands within the potential reservoir are currently used for crop production or pasture. There are no occupied or abandoned residences, roads, utilities, or oil or gas facilities located with the proposed reservoir.

Site 2 is found in an environmental setting similar to Site 1. Both proposed project areas straddle or are adjacent to a stream and are dotted with playa lakes; however, for Site 2, the stream is a tributary of Rattlesnake Creek and the topographic relief is much more pronounced. Such a setting suggests a high potential for prehistoric and historic cultural resources. Sites potentially within this project area include

Photograph 1: Potential Reservoir Site 1 - Looking west from road on east side of site.

Photograph 2: Potential Reservoir Site 1 - Looking southeast, from southeast corner of Section 28.

base camps, campsites, kill sites, processing sites, and other limited activity sites. No historic habitations or structures are known in the area. Based on these observations, Site 2 is interpreted as having a high probability for containing cultural resources. If this project area is selected, additional archaeological investigations will be required.

Site 3

Site 3 is approximately 25 miles upstream from the confluence of Rattlesnake Creek and Little Salt Marsh (Figure V-4). It is located approximately 3 miles west/northwest of St. John, Kansas in Stafford County (T23S R14W Sections 23, 26, and 27). Two different sized alternatives, Sites 3a and 3b, are proposed. However, only the larger alternative, Site 3b, is considered a feasible alternative. The site would potentially inundate approximately 550 acres, including 500 acres of cropland, 40 acres of grassland/rangeland, 5 acres of woodland/shrubland, 5 acres of wetlands, and 4 miles of stream. Site 3b contains about 540 acres of prime farmland. Site 3b contains a low to moderate potential for cultural resources. There is one occupied residence and approximately one mile of road within the proposed inundation area that would require relocation. There are no pastureland, ponds, lakes, abandoned residences, or oil wells located within the proposed inundation area.

Bear Creek, a tributary of Rattlesnake Creek, passes through the middle of Site 3b, creating a low lying and gently sloping terrain. A few elevated areas are found within the site, which are considered to have high potential for containing prehistoric and historic campsites and limited activity sites. No historic structures or habitation sites are known within the project area. Overall, Site 3b is considered to have a low to moderate probability for cultural resources. If this site is selected, additional archaeological investigations will be needed for the elevated portions of the project area.

Site 6

Site 6 is approximately 30 miles upstream from the confluence of Rattlesnake Creek and Little Salt Marsh (Figure V-5). It is located approximately 4.5 miles southwest of St. John, Kansas in Stafford County (T24S R14W Sections 16, 21, 22, 27, and 28). Two different sized alternatives, Sites 6a and 6b are proposed for this site, however, only the larger of the alternatives, Site 6b, is considered a feasible alternative. The site would inundate approximately 630 acres, including about 493 acres of cropland, 10

Photograph 3: Potential Reservoir Site 3 - Looking north from county road between Sections 23 and 26.

Photograph 4: Potential Reservoir Sites 2 and 17 - Looking west from road between Sections 13 and 14.

Photograph 5: Potential Reservoir Site 6 - Looking west from county road between Sections 21 and 22.

Photograph 6: Potential Reservoir Site 6 - Looking north/northwest from southeast corner of Section 21.

acres of grassland/rangeland, 100 acres of pasture, 20 acres of woodland/shrubland, 2.0 acres of pond (two ponds, 0.7 and 0.8 acres), 5 acres of wetlands, and 5 miles of stream. Site 6b contains about 326 acres of prime farmland. Site 6b contains a low to moderate potential for cultural resources. Site 6b contains approximately 1.0 mile of road and 1.3 miles of electric transmission line that would require relocation. There are no occupied or abandoned residences or oil wells within the proposed inundation area.

Site 6 is on Spring Creek, a tributary of Rattlesnake Creek, and is characterized by flat to gently sloping floodplains. A few small rises and terrace remnants are indicated on the topographic quadrangle map. These areas are probable settings for prehistoric and historic campsites and limited activity sites. Although it is not apparent on the topographic quadrangle map, larger elevated areas maybe present in the site area. If these areas are found within the project area, they lend credence to the possibility that base camps exist within the project domain. No historic habitations or structures are recorded within this area. Based on the environmental features, Site 6 has a low probability for cultural resources across the floodplains and a moderate to high probability on the rises and other elevated areas. Overall, the probability rating for Site 6 ranges from low to moderately high.

Site 8

Site 8 is approximately 14 miles upstream of the confluence of Rattlesnake Creek and Little Salt Marsh (Figure V-6). It is located approximately 1 mile west of Hudson, Kansas in Stafford County (T22S R12W Sections 19, 30, and 31) and (T22S R13W Sections 25 and 36). Two different sized alternatives, Sites 8a and 8b, are proposed for this site, however, only the larger alternative, Site 8b, is considered a feasible alternative. The site would inundate approximately 160 acres, including approximately 153 acres of cropland, 3 acres of woodland/shrubland, and 4 acres of wetlands. Site 8 contains about 40 acres of prime farmland. It has a high potential for cultural resources. There are no grassland/rangeland, pasture, ponds, lakes, streams, residences, roads, or oil wells located within the proposed reservoir boundary.

Proposed reservoir Site 8 potentially would impact an area just north of Rattlesnake Creek. This project area is characterized by an intermittent drainage and a series of playa lakes. Similar settings across the

Photograph 7: Potential Reservoir Site 8 - Looking northeast from southwest corner of Section 30.

Photograph 8: Potential Reservoir Site 8 - Looking southwest from county highway, west of Hudson, Kansas.

Great Plains generally have high densities of cultural resources. Potentially, cultural resources within this project area would include prehistoric and historic campsites, base camps, kill sites, processing sites, and other limited activity sites. No known historic habitation sites or structures will be impacted by the project. Based on the characteristics of the proposed project area, reservoir Site 8 has a high probability for containing cultural resources.

b. Impacts

All lands within each potential reservoir inundation zone would be changed from various terrestrial habitats to aquatic habitats typical of a reservoir. Construction activities would temporarily disturb local area wildlife, perhaps forcing them to move to adjacent areas. Reservoir filling and operation would force wildlife within the inundation area to other adjacent areas. Less mobile species such as reptiles, amphibians, small mammals, and, depending on the season of the year, the nests and/or chicks of birds could be adversely effected, and perhaps lost. Stream species incapable of surviving in a reservoir environment would be displaced upstream or downstream of the reservoir to other sections of the stream or lost.

Reservoir filling would likely begin in the fall and continue throughout the winter and spring when higher stream flows are available. Water bodies comparable in size to the potential reservoirs are uncommon in the Rattlesnake Creek Basin. The topography of the potentially inundated lands would produce reservoirs that contain abundant shallow water habitat, ranging from only a few inches to 2 to 3 feet, as well as areas of deeper water. Any of these reservoir alternatives would provide suitable habitat for a variety of migrating waterfowl and shorebirds during the fall and spring migration periods.

Inflow during the summer months would typically be less than evaporative losses. As a result, water levels within the potential reservoirs would likely decrease during this time. Areas around the periphery of the reservoirs would become exposed, providing an opportunity for vegetation (including wetland and moist soil species) to become temporarily established. Wetlands may be established in the shallower areas of the reservoirs. As the reservoir water levels decrease in the summer and early fall, large areas of habitat for shorebirds and some species of waterfowl and wading birds would occur. As reservoir water levels increase during winter and spring, vegetated areas that developed the previous growing season around the periphery of the reservoir would be inundated, providing habitat for migrating waterfowl and shorebirds.

The reservoir may also provide habitat for some aquatic species. These would likely be primarily invertebrates capable of surviving dry periods as well as fish species capable of surviving in warm, highly turbid conditions. No dependable reservoir fishery would be expected to develop. Limited opportunities for bank fishing may occur if public access is provided.

Benefits to wildlife on the Refuge could occur for years following completion of reservoir construction. The additional water stored in the reservoir and available to the Refuge would enable Refuge personnel to provide habitat that is of more dependable quantity and quality. During normal or wet years, a variety of suitable habitat is widely available in the basin. In dry years, however, the more dependable Refuge habitat would likely provide an even more critical stopping, resting, staging, and recuperating area for species, including endangered whooping cranes, during their spring and fall migrations. More dependable wildlife habitat would not only help attract wildlife to the Refuge on a more consistent basis, but would provide more opportunities for public recreation on the Refuge and an increase in the number of tourists to the area.

4. Investigative Findings

Initial findings suggest that the average annual yield for each potential reservoir is meager compared to its evaporation. These potential reservoirs are very shallow. In order to provide any significant storage volume, each impoundment must cover a large area in proportion to its depth. As a result, evaporation losses are expected to be extremely high. Estimated reservoir yields are listed in Table V-7.

The firm yield estimates for each individual reservoir are listed on Table V-8. These yields range from a low of 150 acre-feet per year at Site 1 to a high of 1,120 acre-feet per year at Site 3. Although it is possible to develop two or more of these reservoirs, they would compete with one another for the available flow in Rattlesnake Creek; therefore, the combined firm yield of the reservoirs would likely be less than the sum of their individual yields. Also, as stated above, these yield estimates are optimistic since they do not account for senior water rights in the basin nor potential minimum release requirements.

Table V-7
MODEL RESULTS

Site	Cumulative Model Results, 1955-1994 (acre-feet) [1]			Average Annual Yield (acre-feet per year)
	Inflow	Evaporation	Gross Yield	
1	13,000	6,200	6,800	170
2	105,000	61,000	44,000	1,100
3	115,000	62,000	53,000	1,325
6	69,000	22,000	47,000	1,175
8	22,000	8,000	14,000	350

Note: 1. Values rounded to nearest thousand acre-feet.

Table V-8
ESTIMATED RESERVOIR YIELD

Site Number	Firm Yield [1] (acre-feet per year)
1	150
2	565
3	1,120
6	190
8	190

Note: 1. Highest annual demand the reservoir can support during operations simulation using work drought of record.

D. PRELIMINARY DAM CONCEPT DESIGN

Despite the relatively inefficient performance of surface storage reservoirs in developing additional supplies of water, reconnaissance-level development concepts and associated cost estimates are developed for each of the five surface storage options. The five storage sites will require dams that range in height from 8 to 31 feet, including freeboard above the maximum normal reservoir pool. The crest width of each dam is assumed to be 15 feet for equipment access.

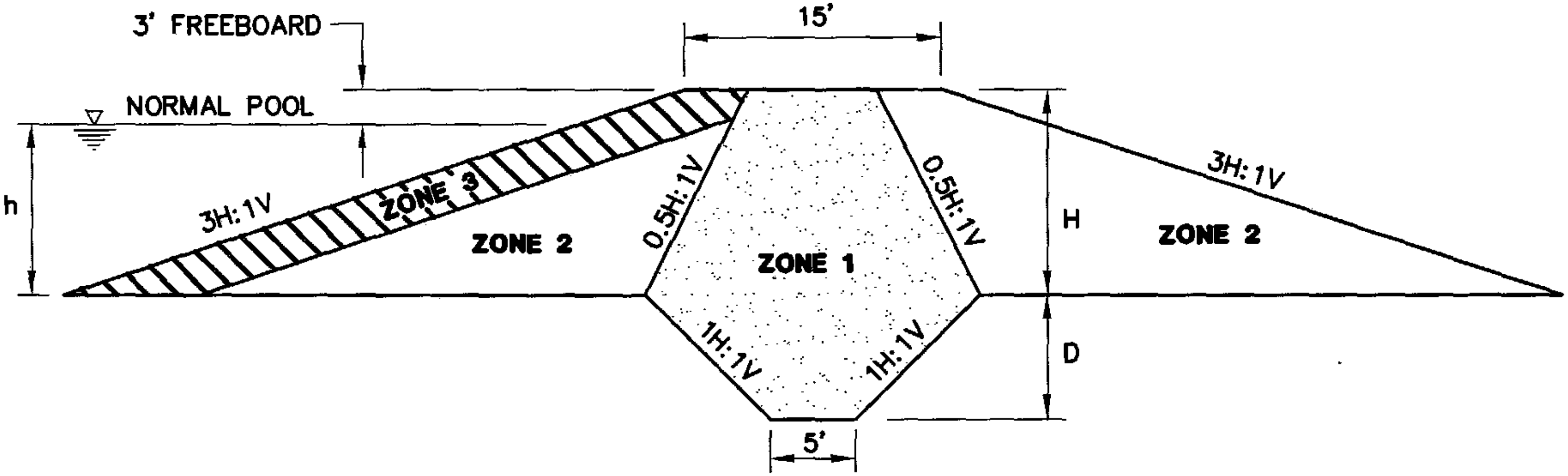
A typical dam cross section consists of a zoned embankment with an impervious central core and shells of more previous materials as shown in Figure V-8. The upstream slope of the dam is assumed to be protected by soil-cement. The outlet works are sized to accommodate the maximum monthly diversion for each reservoir or a 30-inch outlet pipe, whichever is found to be greater. The outlet works is assumed to consist of an inlet structure protected by a trashrack, a steel pipe in concrete encasement, valves, and outlet structure for energy dissipation. The spillway requirement for each dam depends on the findings of additional hydrologic studies beyond the scope of the current study; however, for embankment dams of this size, an excavated channel located in either abutment is recommended. Experience suggests that the spillway cost for low-head embankment dams can vary from 25 to 60 percent of the embankment cost; therefore, the spillway is estimated at a cost of 50 percent of the embankment material cost for each site.

As previously noted, storage sites passing the screening study are located off channel, providing regulation of flows from various Rattlesnake Creek tributaries, as well as regulation of flows diverted from Rattlesnake Creek by pumping. Diversion facilities are sized with pipelines and pumping stations to divert water into storage based on the capability to divert the reservoir volume over a 40-day period. This capacity is based on examination of daily flow records on Rattlesnake Creek. Diversion capacities and related information are listed in Table V-9.

Table V-9
RESERVOIR DIVERSION SUMMARY

Site Number	Diversion Capacity (cfs)	Pipeline Length (ft)	Pipeline Diameter (inches)	Pump Capacity [2] (Hp)
1	10	500	24	50
2	50	13,300	48	360
3 [1]	50	10,700	48	360
6	40	5,000	48	290
8	30	2,200	36	90

Notes:
1. Two points of diversion (Rattlesnake Creek and Wild Horse Creek) with diversion capacities of 50 cfs each.
2. Based on static elevation difference and friction loss of 2 feet per 1000 feet.



D = h, D_{min} = 3'
H = h + FREEBOARD
ZONE 1 = IMPERVIOUS FILL
ZONE 2 = GENERAL EARTHFILL
ZONE 3 = SOIL CEMENT (5' WIDE EXTEND FROM TOE TO CREST)

GEI Consultants, Inc.	Burns & McDonnell	Figure V-8 RATTLESNAKE CREEK BASIN TYPICAL CROSS SECTION OF DAM

E. OPERATIONS MODEL

The estimated firm yield of each potential reservoir is listed above in Table V-8. These firm yields however, can not be used directly to estimate the benefit these supplemental supplies may have on the Refuge. Therefore, separate operations models are constructed from the base model for each of the five remaining potential reservoirs. The required model modifications and other assumptions used to analyze these potential reservoirs are discussed below.

1. Reservoir Inflow

The conceptual design for each potential reservoir includes a diversion from Rattlesnake Creek. One of the reservoir sites, Site 3, also has a diversion from Wild Horse Creek to supply water to the reservoir. The assumed capacities of these diversion systems are listed above in Table V-9. Rattlesnake Creek has an established minimum desired streamflow (MDS) of 15 cfs. It is assumed that diversions from Rattlesnake Creek will be allowed only when the flow exceeds 15 cfs. Wild Horse Creek has no prescribed MDS value. For Wild Horse Creek, it is assumed that all available flow can be diverted.

The discharge in Rattlesnake and Wild Horse Creeks can change significantly from day to day. Therefore, the monthly flow data collected for the operations model can not be used directly to determine the water available for diversion. Daily discharge estimates are required to accurately estimate these data. The USGS maintains two stream gaging stations on Rattlesnake Creek that have historic daily discharge records. However, neither of these gages have records that cover the entire simulation period of the operations model, calendar years 1955 through 1994. The gage near Macksville (No. 07142300) began operation in October 1959 and the gage near Zenith (No. 07142575) began operation in May 1973. There are no daily streamflow records available for Wild Horse Creek.

Daily discharge data for the portion of the model simulation period not covered by the above gages (January 1955 through September 1959) are obtained from a USGS stream gaging station on the North Fork of the Ninnescah River (North Fork) near Cheney (No. 07144800). The North Fork basin is adjacent to that of Rattlesnake Creek, and this gage and the Zenith gage have similar drainage areas, 930 verses 1,047 square miles, respectively.

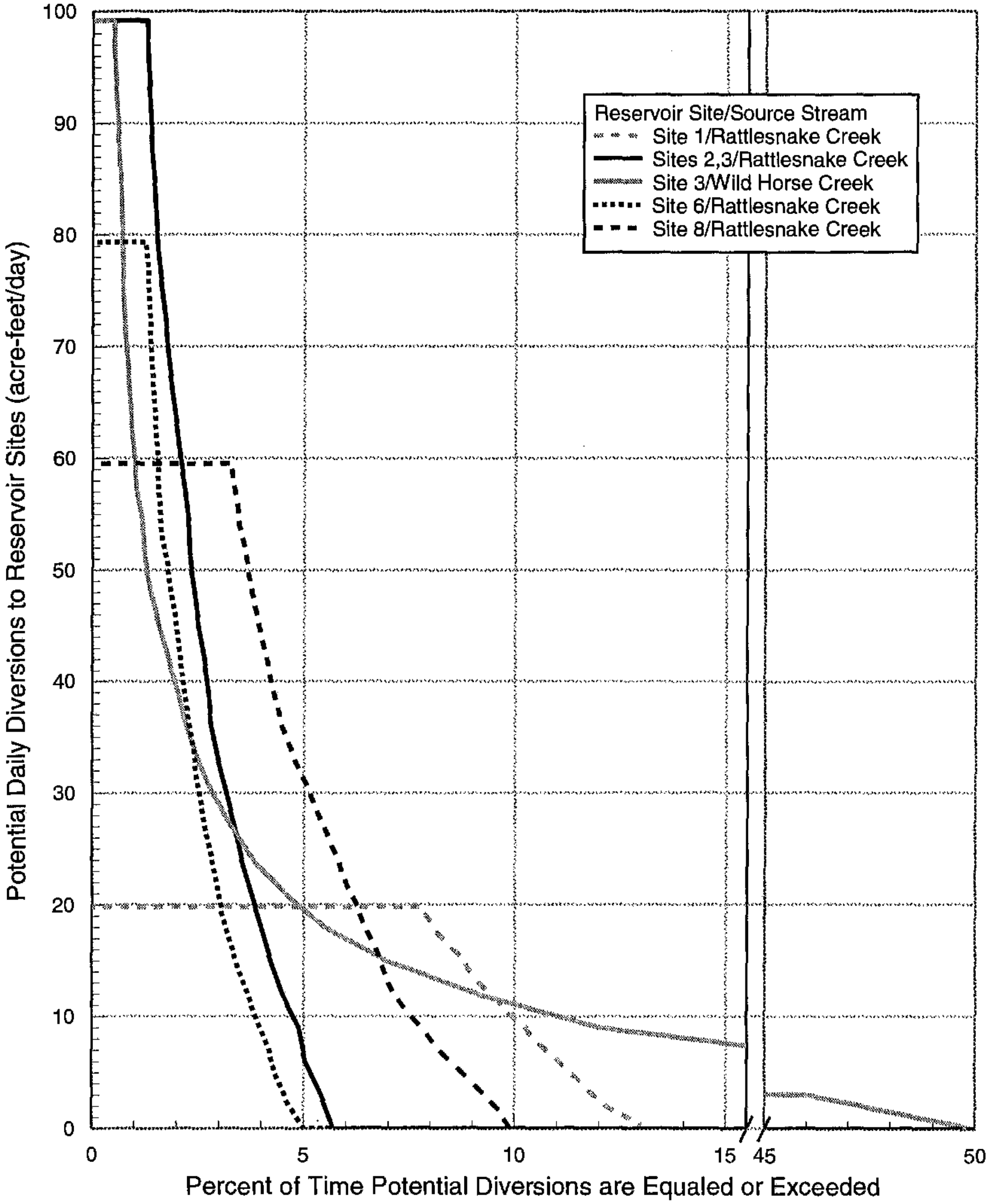
The daily discharge records available at these three gages are not used directly to estimate available diversion quantities. Instead, these data are used only as a means to distribute the monthly flow estimates, extracted from the SWATMOD model, across each month. This methodology has the additional advantage that it ensures the total monthly flow volumes used in the operations model and those used to estimate diversion quantities will match.

Using the flow distribution procedure discussed above, estimates of daily flow at the identified diversion points on Rattlesnake and Wild Horse Creeks are developed for the entire simulation period. These flow estimates are then used to estimate the amount of water that could be diverted, via induced infiltration or a surface water intake, each day. Once the MDS, if any, is satisfied, water can be withdrawn up to the limit of the assumed pumping capacity.

Figure V-9 is a graph that shows the durations for potential daily reservoir diversions. Review of this graph shows that the availability of water for diversion increases as one moves downstream on Rattlesnake Creek. For example, at the most upstream diversion point, which is for Site 6, water is available for diversion only about 5 percent of the time. This increases to about 13 percent near Site 1, which is located just upstream of the Refuge. Since Wild Horse Creek does not have a specified MDS, some water is available for diversion from this stream on a more frequent basis, approximately 50 percent of the time. The full capacity of the diversion system for Site 1 is utilized about 8 percent of the time. This percentage decreases as one moves higher in the basin and the maximum pumping rates increase.

Since the operations model uses a monthly time step, the daily potential diversion estimates were totaled by month for use in the model. Table V-10 presents a summary of these monthly data.

In addition to water supplied by the diversions discussed above, two of the reservoir sites (Sites 2 and 6) receive significant natural inflow from their respective watersheds. Site 2 is located across Wild Horse Creek (Subbasin 22) and Site 6 is located on Spring Creek (Subbasin 19). Streamflow estimates for these two subbasins are available from the SWATMOD model.



Notes:

1. Developed from monthly flow data from SWATMOD model and daily discharge data from USGS.
2. Period of record: 1/1/55--12/31/94
3. Diversions from Rattlesnake Creek are allowed only after minimum desirable streamflow (MDS) of 15 cfs is met. There is no MDS for Wild Horse Creek.
4. Maximum pumping rates: Site 1--10 cfs (19.8 AFD); Sites 2,3--50 cfs (99.2 AFD); Site 6--40 cfs (79.3 AFD); Site 8--30 cfs (59.5 AFD).

Burns & McDonnell

Figure V-9

DURATIONS OF POTENTIAL DAILY DIVERSIONS TO RESERVOIR SITES

Table V-10
SUMMARY OF POTENTIAL MONTHLY RESERVOIR DIVERSIONS

Site	Source Stream	Maximum Pumping Capacity (cfs)	Potential Monthly Diversion (acre-feet)		
			Minimum	Maximum	Average
1	Rattlesnake Creek	10	0.0	614.9	59.9
2	Rattlesnake Creek	50	0.0	2,767.2	77.7
3	Rattlesnake Creek	50	0.0	2,767.2	77.7
3	Wild Horse Creek	50	0.0	1,726.0	99.1
6	Rattlesnake Creek	40	0.0	1,870.0	55.7
8	Rattlesnake Creek	30	0.0	1,785.1	97.1

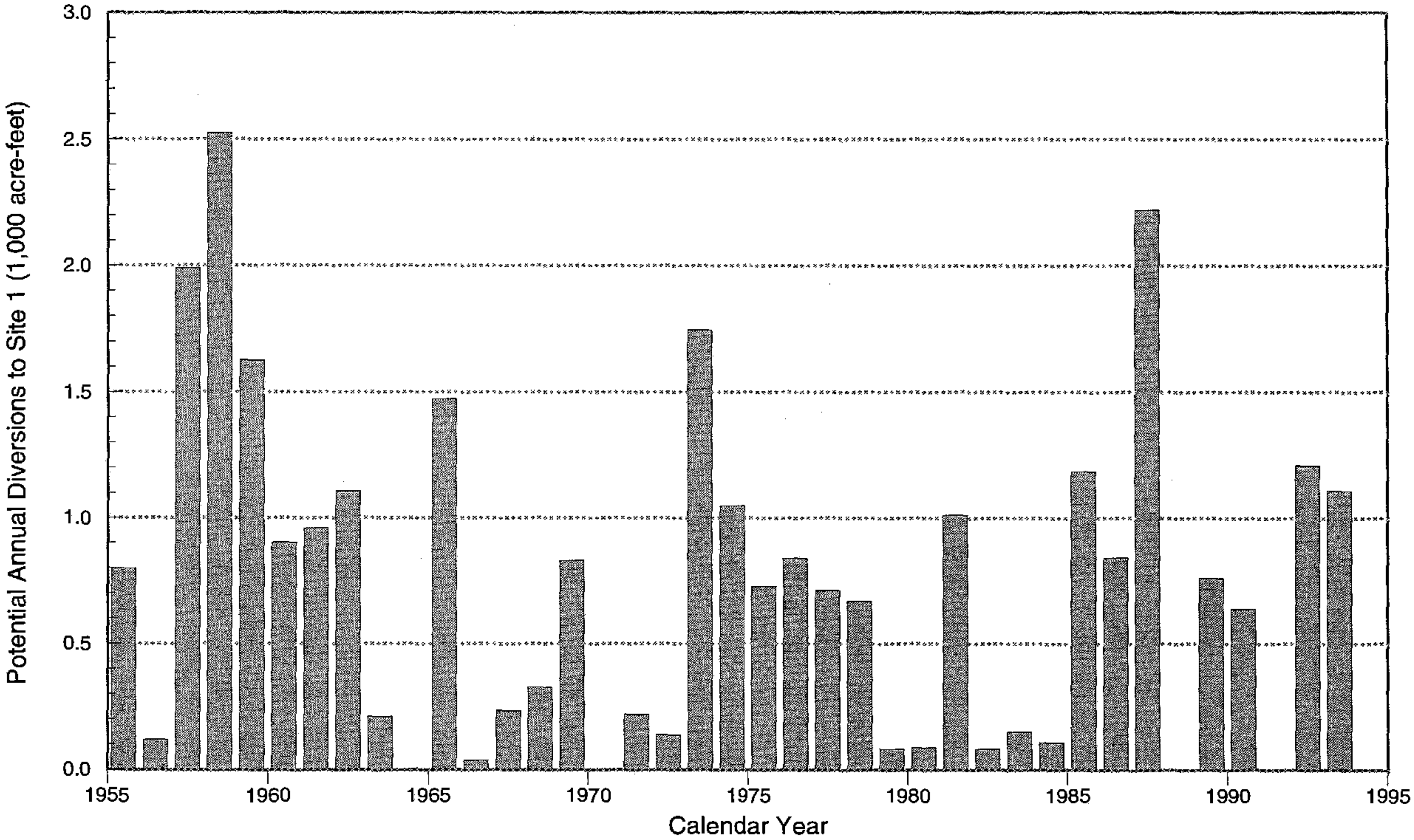
Figures V-10 through V-14 show the potential annual inflow to each reservoir site. For those sites that receive inflow from more than one source, these graphs also show the contributions from each source.

2. Model Revisions

Operation of the five reservoir alternatives are modeled by adding a single storage node to the base operations model. This storage node represents the potential reservoir in each model. Schematics that show the configurations of these revised operations models are included in the Models section of the Appendix. All of the revisions associated with these potential reservoirs are concentrated in the Rattlesnake Creek Basin above the Refuge. No changes to the model for the Refuge itself are necessary.

The unregulated "inflow" to the new storage nodes each month is set equal to the amount of the potential diversions. The incremental inflow used for the source node for each of these diversions is adjusted by netting out the potential diversion volumes so that the total volume of water available at these nodes remains unchanged each month. For Sites 2 and 6, which receive inflow from their respective watersheds, this reservoir inflow is represented in the model by a link from an upstream node.

The maximum storage for each potential reservoir is assigned as specified in Table V-3 above. For the purposes of the operations model, it is assumed there would be no losses from these reservoirs, other than evaporation, or from their respective diversion and conveyance systems. Due to the sandy nature of the

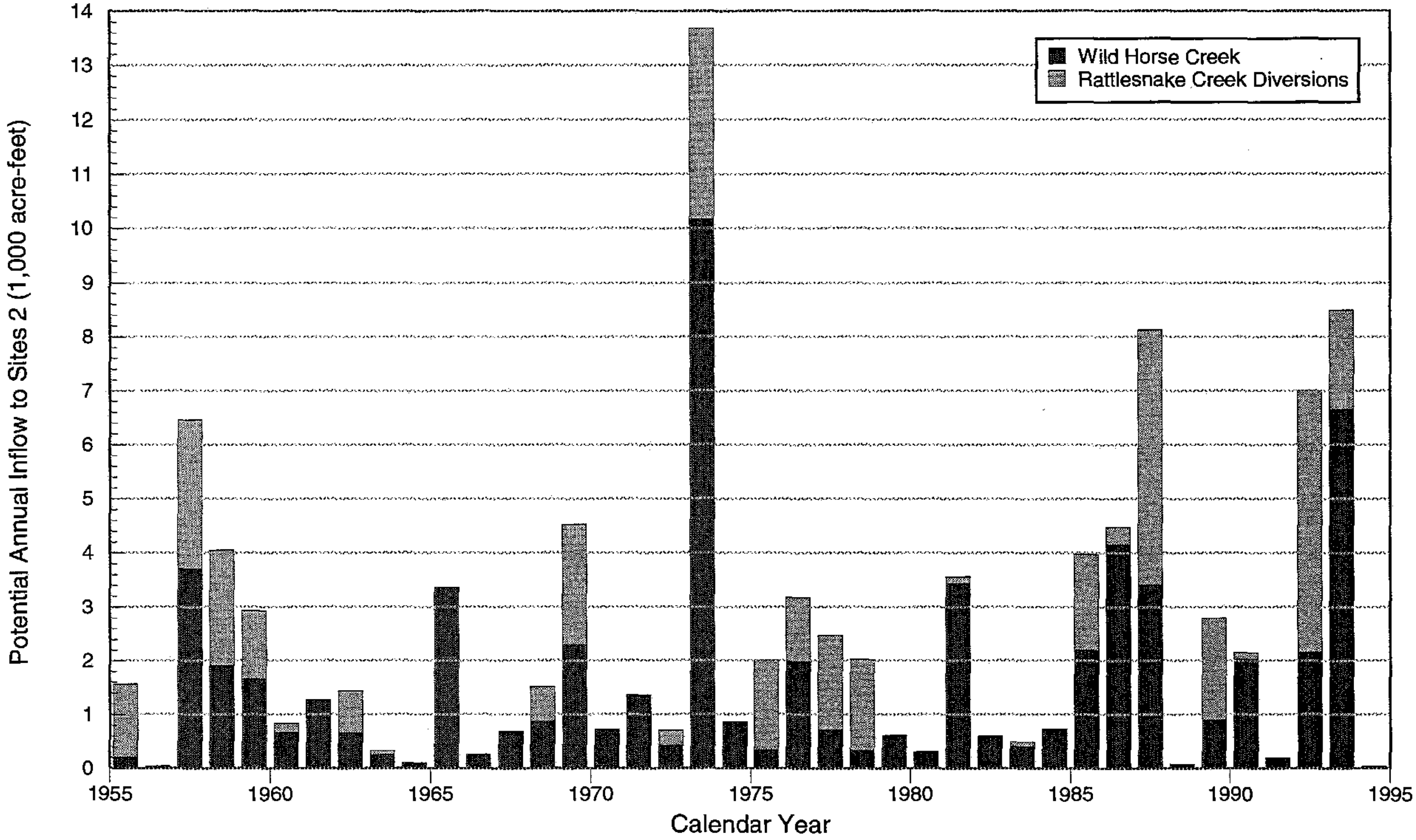


Notes
1. Based on MDS of 15 cfs for Rattlesnake Creek and maximum pumping rate of 10 cfs.
2. Demand for water at the Refuge would normally be given priority over diversions to Reservoir Site 1. Therefore, the amount of water actually diverted to this reservoir would be less than the quantities shown.

Burns & McDonnell

Figure V-10

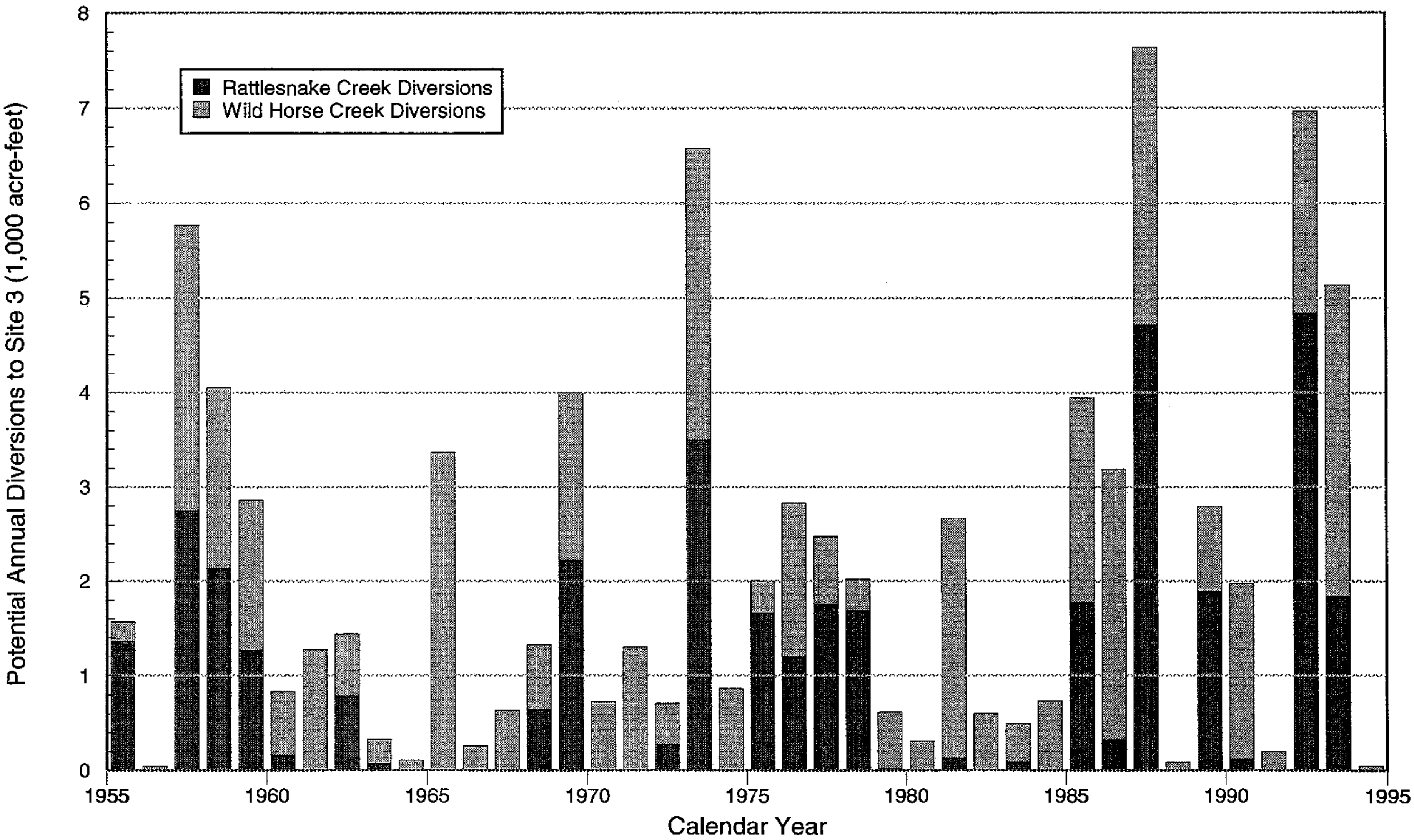
POTENTIAL ANNUAL DIVERSIONS TO RESERVOIR SITE 1



Notes
1. Based on MDS of 15 cfs for Rattlesnake Creek and maximum pumping rate of 50 cfs.
2. Demand for water at the Refuge would normally be given priority over diversions to reservoir. Therefore, the amount of water actually diverted to this reservoir would be less than the quantities shown.

Burns & McDonnell

Figure V-11
POTENTIAL ANNUAL INFLOW TO RESERVOIR SITE 2



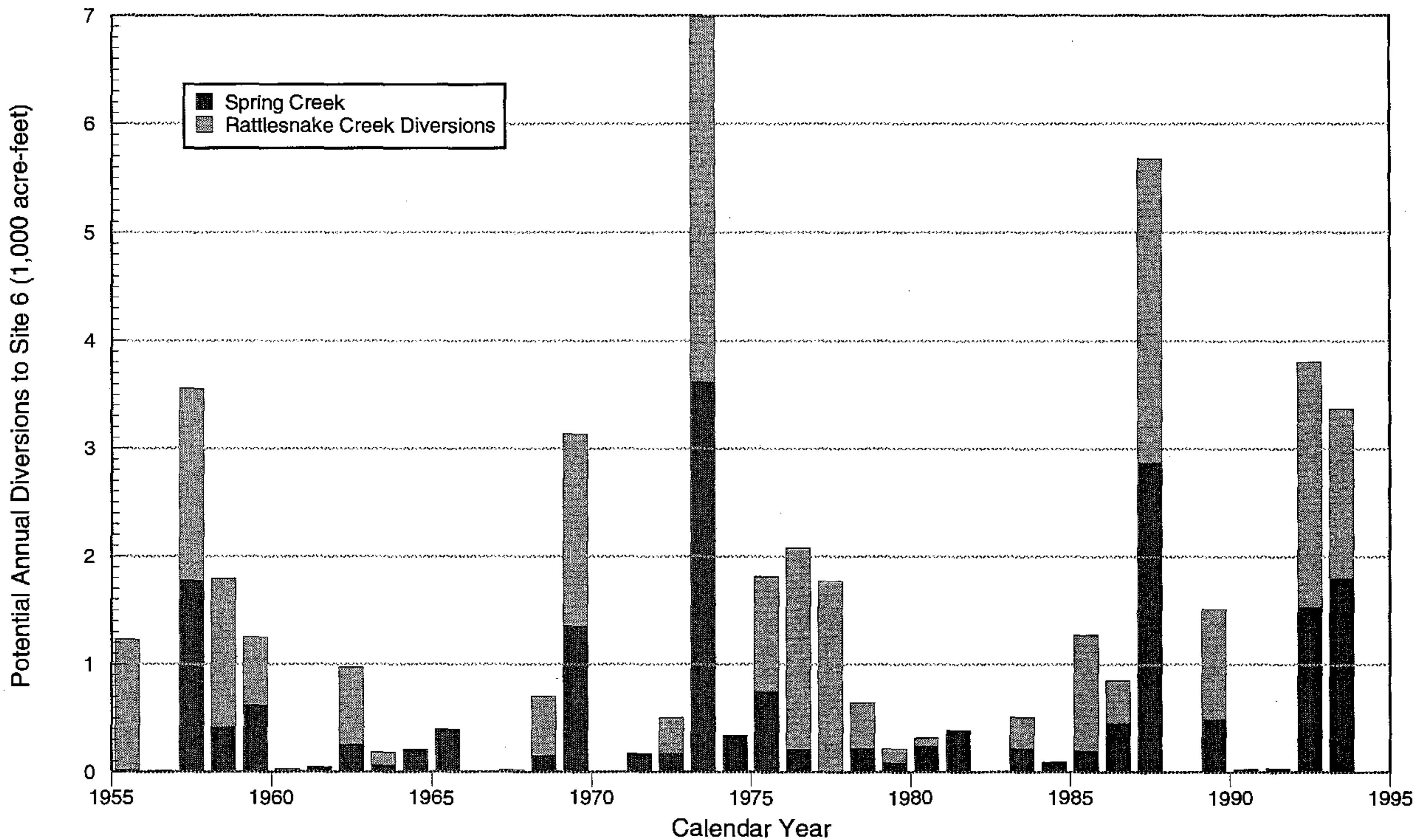
Notes

1. Based on MDS of 15 cfs for Rattlesnake Creek and 0 cfs for Wild Horse Creek. Maximum pumping rates from both sources is 50 cfs.
2. Demand for water at the Refuge would normally be given priority over diversions to reservoir. Therefore, the amount of water actually diverted to this reservoir would be less than the quantities shown.

Burns & McDonnell

Figure V-12

POTENTIAL ANNUAL DIVERSIONS TO RESERVOIR SITE 3

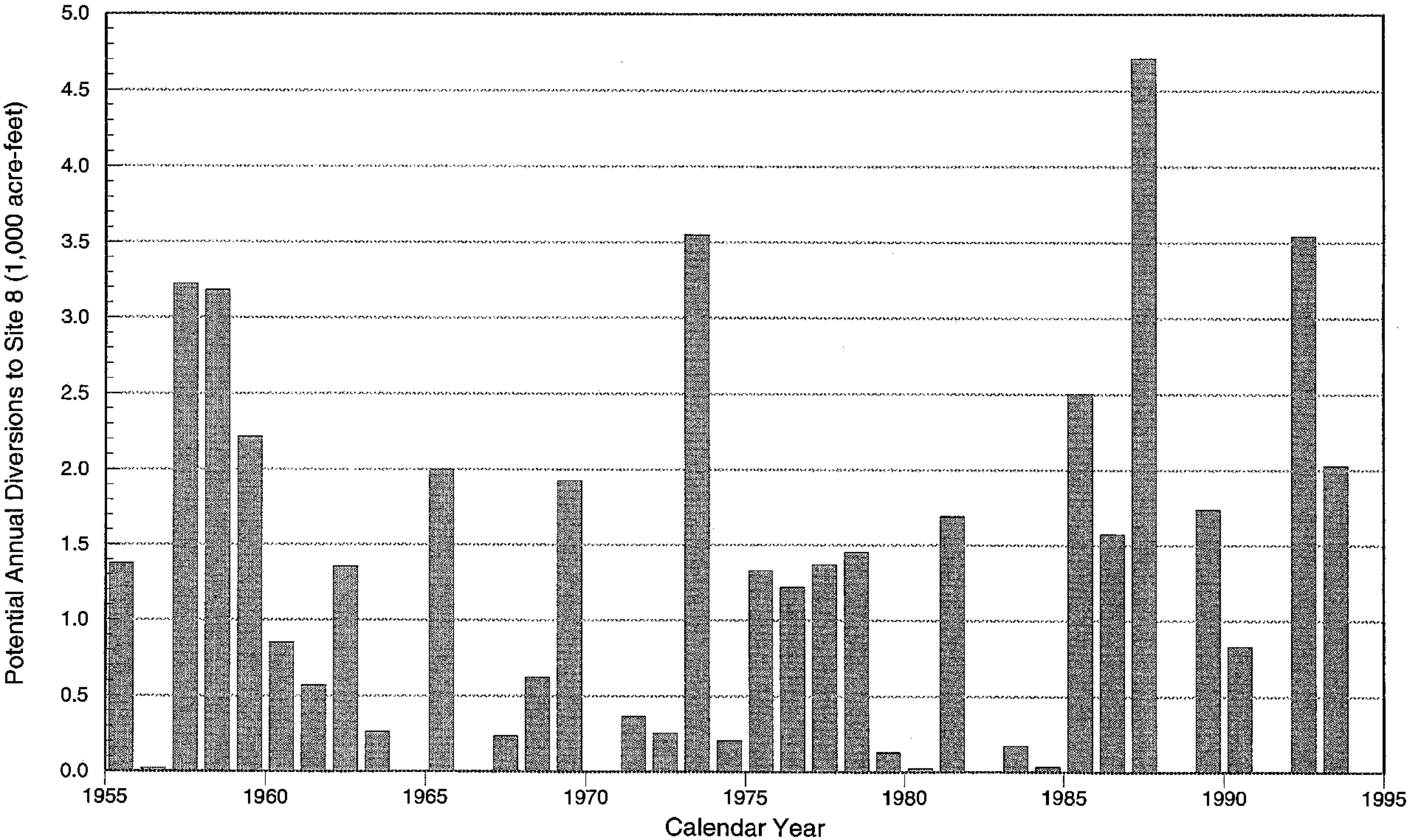


Notes
1. Based on MDS of 15 cfs for Rattlesnake Creek and maximum pumping rate of 40 cfs.
2. Demand for water at the Refuge would normally be given priority over diversions to Reservoir Site 6. Therefore, the amount of water actually diverted to this reservoir would be less than the quantities shown.

Burns & McDonnell

Figure V-13

POTENTIAL ANNUAL DIVERSIONS TO RESERVOIR SITE 6



Notes
1. Based on MDS of 15 cfs for Rattlesnake Creek and maximum pumping rate of 30 cfs.
2. Demand for water at the Refuge would normally be given priority over diversions to Reservoir Site 8. Therefore, the amount of water actually diverted to this reservoir would be less than the quantities shown.

Burns & McDonnell

Figure V-14

POTENTIAL ANNUAL DIVERSIONS TO RESERVOIR SITE 8

soils in the Rattlesnake Creek Basin, reservoir seepage losses could prove to be significant. Should development of these reservoirs appear attractive, allowances for reservoir seepage should be considered in subsequent analyses.

Water from these potential reservoirs would be released directly into the natural stream system and conveyed to the Refuge via Rattlesnake Creek. No additional stream losses, beyond those already represented in the baseline SWATMOD streamflow estimates, are accounted for in the operations model.

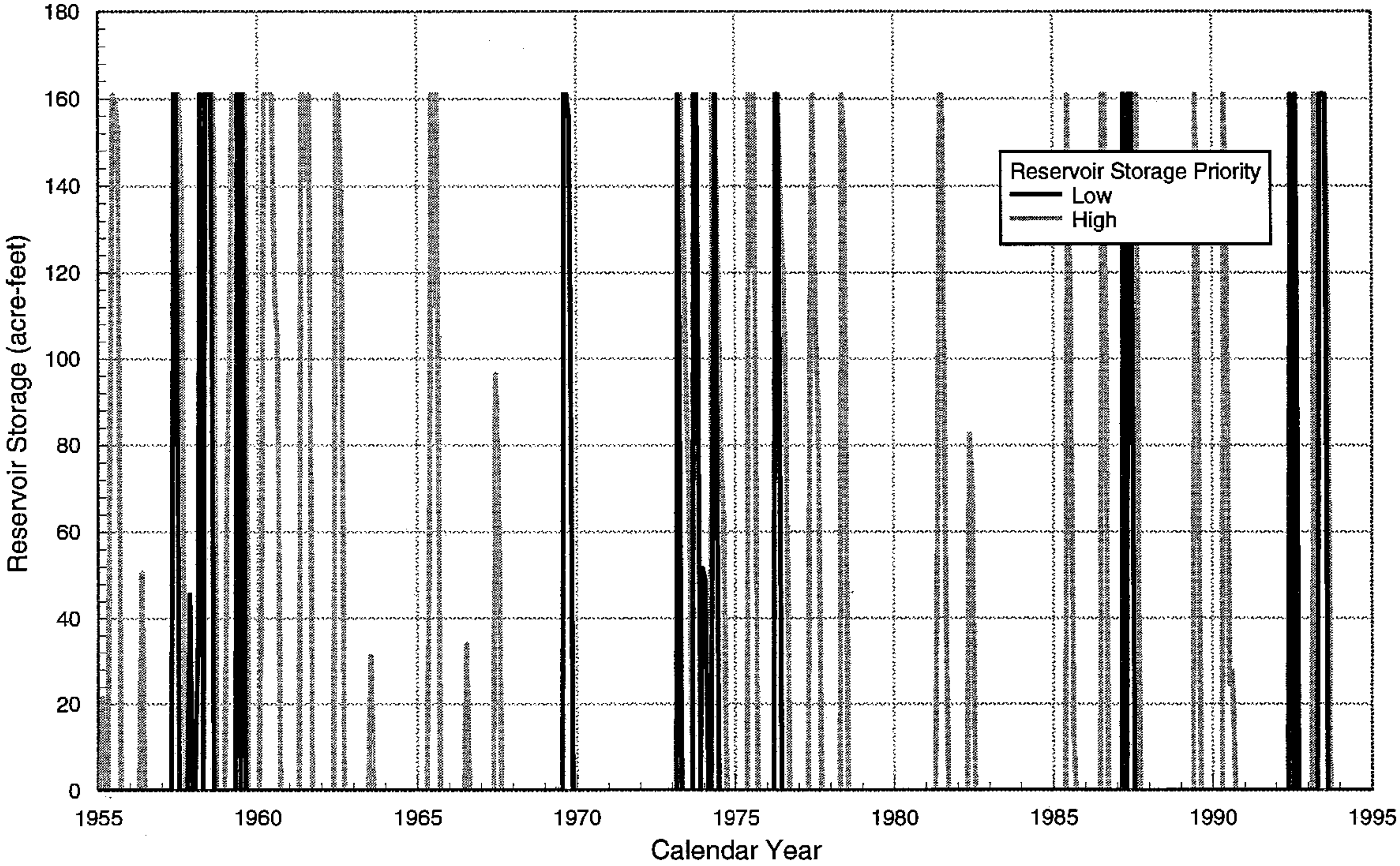
Two sets of storage priorities are used for each potential reservoir. The first set assumes that no water would be diverted to or stored in a reservoir until all Refuge management units were filled to their target levels. The second set of storage priorities gives a higher priority to the potential reservoirs during the first eight months of the year, January through August, in hopes of "saving" more water for use later in the year. For this model case, water is diverted to the reservoir during the months of January through August after the management units are filled only to the tops of their very low zones, as defined in Part III.

3. Modeling Results

For each of the five potential reservoir alternatives, the operations model was executed twice, once with each set of storage priorities. Table V-11 gives minimum, maximum and average end-of-month storage contents in the reservoirs for each case. Figures V-15 through V-19 are graphs of the simulated monthly storage in each reservoir.

Table V-11
RESERVOIR STORAGE SUMMARY

Site	End-of-Month Reservoir Storage (acre-feet)					
	Low Storage Priority			High Storage Priority (Jan-Aug)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
1	0	161	9	0	161	30
2	0	3,027	137	0	3,383	411
3	0	3,786	152	0	4,318	453
6	0	2,858	96	0	3,228	246
8	0	656	32	0	656	108

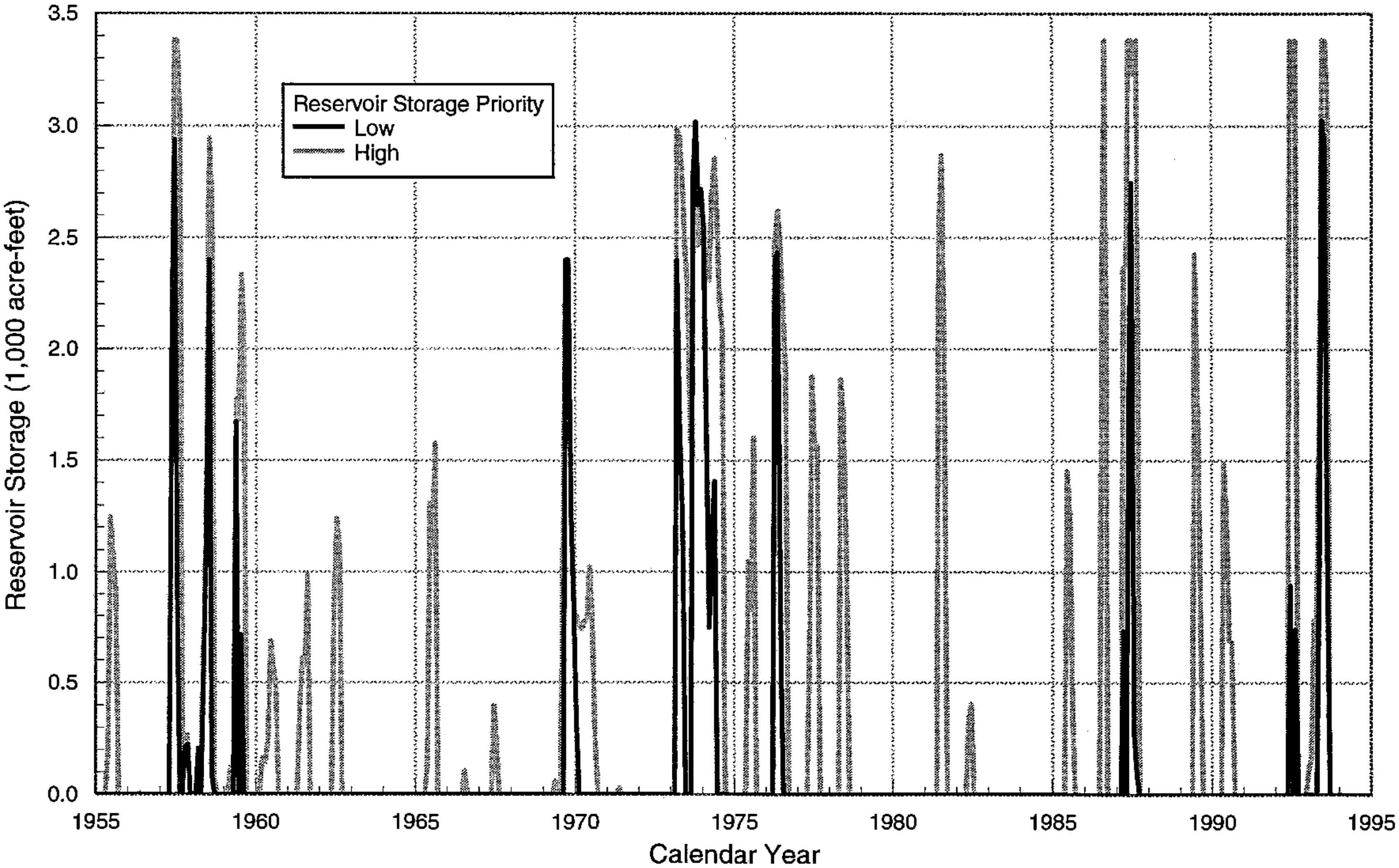


Notes
1. Monthly aquifer contents obtained from operations simulation for Reservoir Site 1 alternative.
2. Under low storage priority option, water needs at Refuge are always given priority over withdrawal of water for reservoir storage. The high storage priority option assumes a preference for reservoir storage during months of January through August.

Burns & McDonnell

Figure V-15

SIMULATED RESERVOIR STORAGE RESERVOIR SITE 1

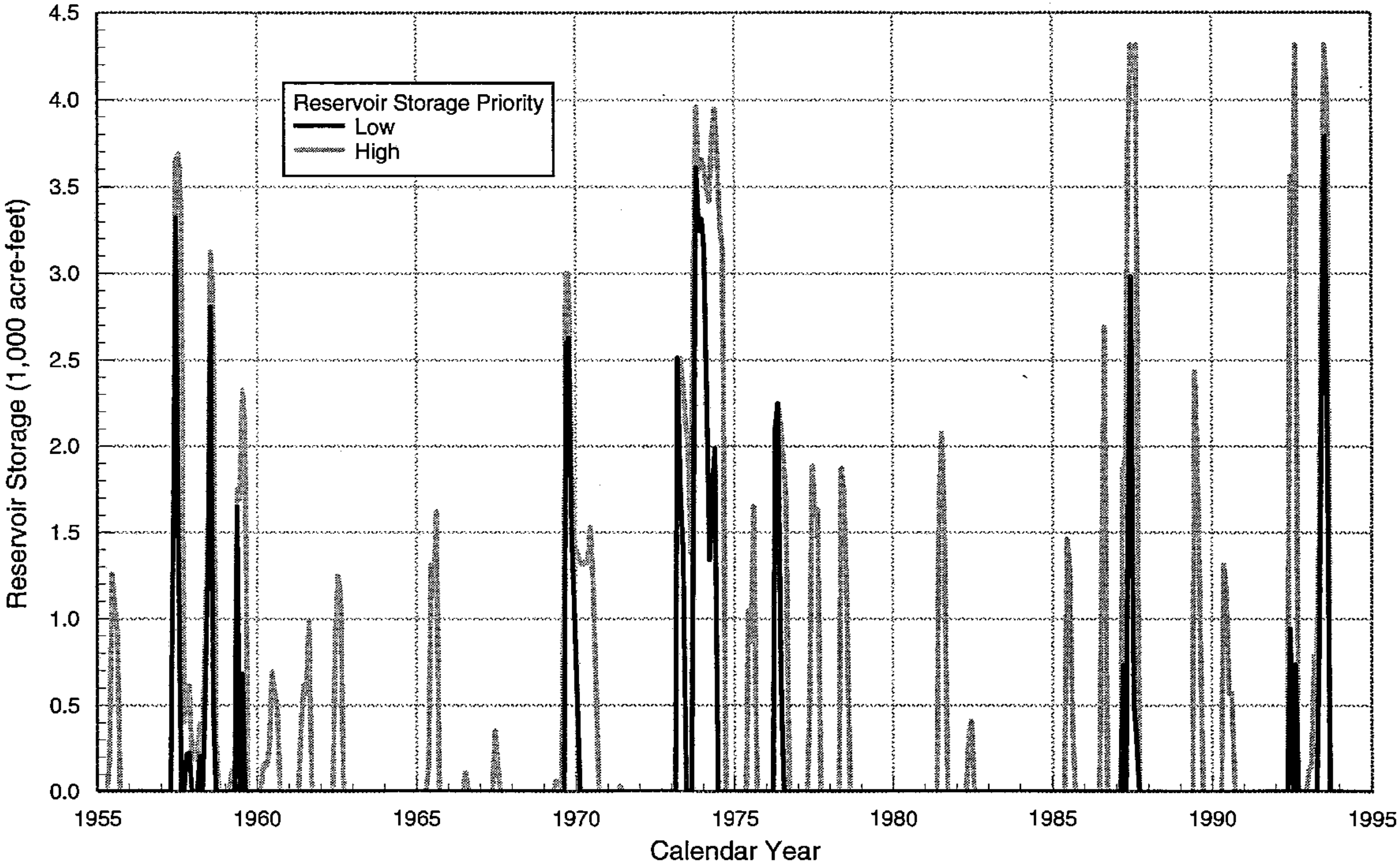


Notes
1. Monthly aquifer contents obtained from operations simulation for Reservoir Site 2 alternative.
2. Under low storage priority option, water needs at Refuge are always given priority over withdrawal of water for reservoir storage. The high storage priority option assumes a preference for reservoir storage during months of January through August.

Burns & McDonnell

Figure V-16

SIMULATED RESERVOIR STORAGE RESERVOIR SITE 2

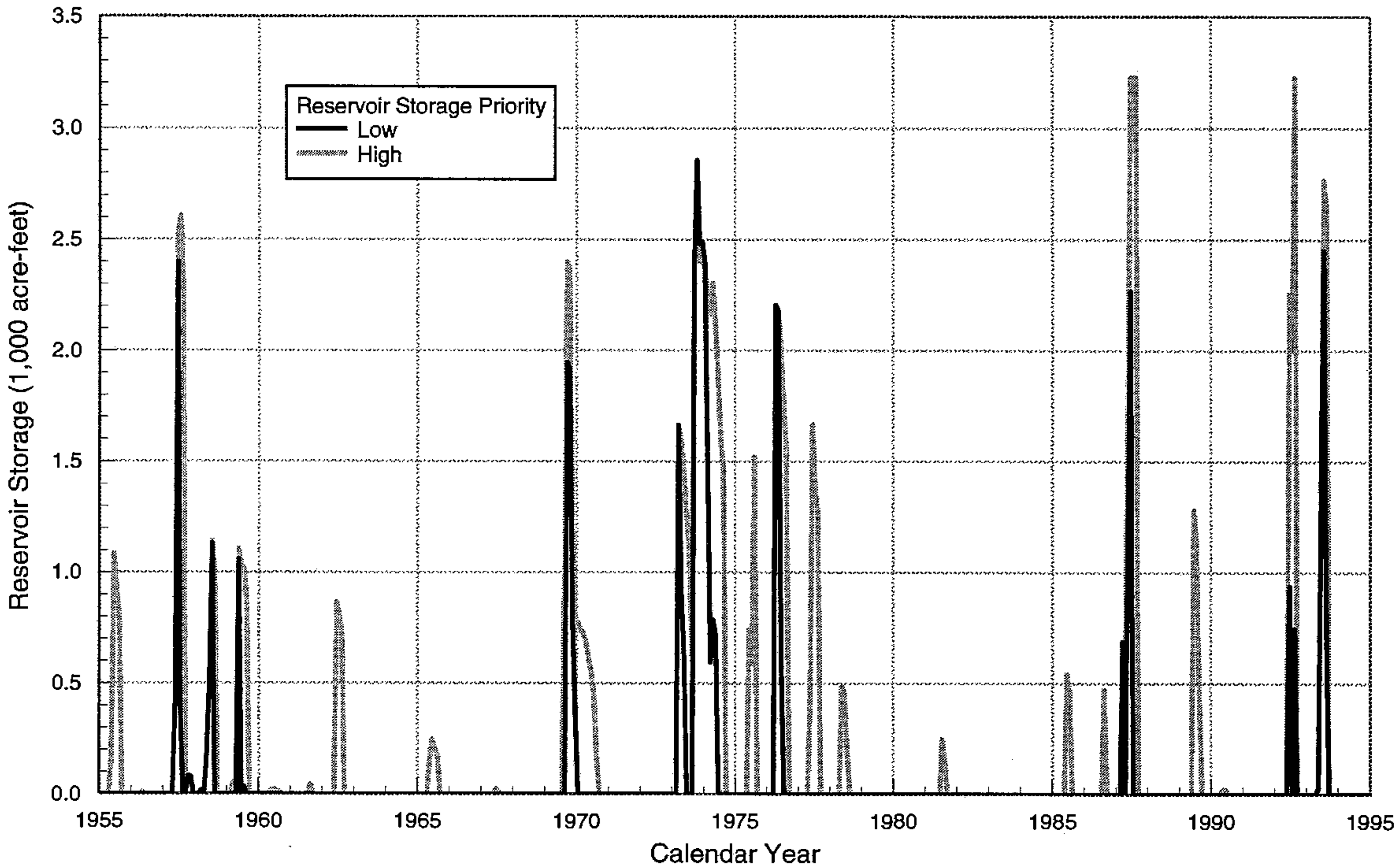


Notes
1. Monthly aquifer contents obtained from operations simulation for Reservoir Site 3 alternative.
2. Under low storage priority option, water needs at Refuge are always given priority over withdrawal of water for reservoir storage. The high storage priority option assumes a preference for reservoir storage during months of January through August.

Burns & McDonnell

Figure V-17

SIMULATED RESERVOIR STORAGE RESERVOIR SITE 3

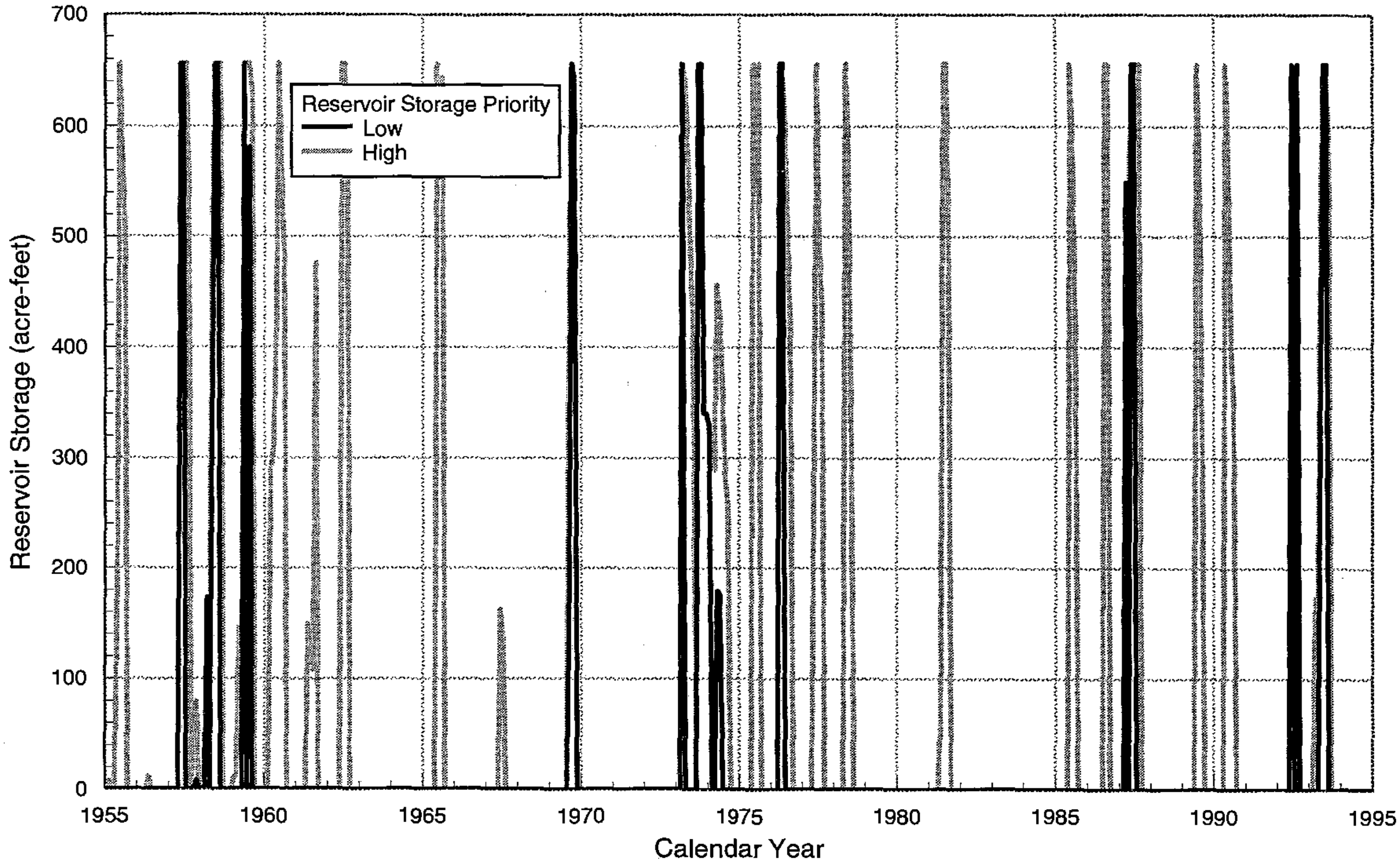


Notes
1. Monthly aquifer contents obtained from operations simulation for Reservoir Site 6 alternative.
2. Under low storage priority option, water needs at Refuge are always given priority over withdrawal of water for reservoir storage. The high storage priority option assumes a preference for reservoir storage during months of January through August.

Burns & McDonnell

Figure V-18

SIMULATED RESERVOIR STORAGE RESERVOIR SITE 6



Notes
1. Monthly aquifer contents obtained from operations simulation for Reservoir Site 8 alternative.
2. Under low storage priority option, water needs at Refuge are always given priority over withdrawal of water for reservoir storage. The high storage priority option assumes a preference for reservoir storage during months of January through August.

Burns & McDonnell

Figure V-19

SIMULATED RESERVOIR STORAGE RESERVOIR SITE 8

Review of Table V-11 and Figures V-15 through V-19 show that the five reservoir alternatives are only marginally successful. The goal of these alternatives is to store surplus flows that occur in the spring and summer for use during the fall. However, in drier years, all of the water available for diversion from Rattlesnake Creek must be used directly on the Refuge, leaving no water available for storage. The graphs of simulated reservoir storage show frequent periods for all alternatives when the reservoirs are empty for two or more consecutive years. It is only in wetter years, when supplemental water supplies are least valuable, when significant amounts of water can be captured for reservoir storage. Once captured, the water stored in the reservoirs can be released at a later date to supplement the supply to the Refuge; however, the capacity of these reservoirs is small in comparison to the annual water needs of the Refuge. For this reason, any water stored in the reservoirs is exhausted rapidly and provides supplemental supplies to the Refuge for only a few months into the next period with average or less streamflow.

Statistics on the availability of wetland habitat at the Refuge for the five potential reservoir alternatives with low and high storage priorities are presented in Table V-12. Peak habitat ranges up to approximately 700 acres for shorebirds and 1,000 acres for waterfowl. Average habitat values vary over only a small range for the various potential reservoir alternatives.

Table V-12
AVAILABLE WETLAND HABITAT FOR POTENTIAL RESERVOIR ALTERNATIVES [1]

Site	Storage Priority	Shorebird (1-4 in.)		Waterfowl (10-18 in.)		Total Wetland	
		Range	Average	Range	Average	Range	Average
1	Low	85-684	359	11-1,058	603	692-6,005	2,765
	High	85-684	358	11-1,055	601	692-6,005	2,760
2	Low	78-686	364	11-1,045	600	690-6,013	2,769
	High	85-694	366	11-1,052	611	699-6,005	2,835
3	Low	78-686	365	11-1,045	602	690-6,013	2,781
	High	85-703	369	11-1,052	616	696-6,005	2,863
6	Low	78-686	358	11-1,044	597	690-6,005	2,739
	High	78-691	360	11-1,054	602	690-6,005	2,774
8	Low	85-686	362	11-1,045	605	692-6,005	2,789
	High	85-686	361	11-1,055	608	699-6,005	2,797

Note: 1. All wetland habitat values in acres. Statistics include data for primary migration season, September through April, only.

The durations of available wetland habitat for Site 3 are shown in Figure V-20 as an example. Habitat duration curves for the other potential reservoirs are similar in shape. The 80th percentile habitat areas for the reservoir site and storage priority alternatives are shown in Table V-13, along with the change in these over baseline habitat areas.

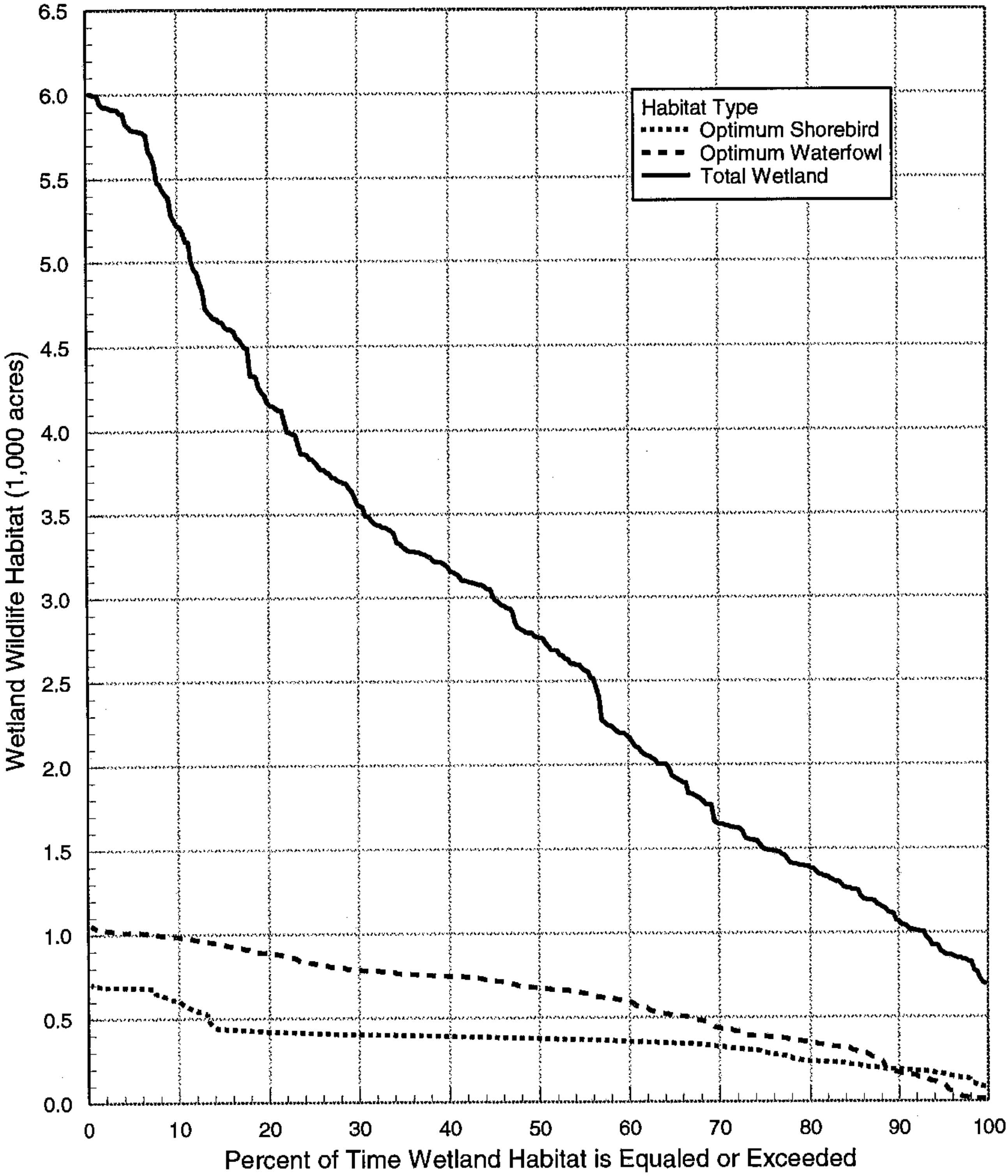
Table V-13
CHANGES IN AVAILABLE WETLAND HABITAT FOR POTENTIAL RESERVOIR ALTERNATIVES

Site	Storage Priority	Optimum Shorebird		Optimum Waterfowl		Total Wetland	
		80th Percentile	Change over Baseline	80th Percentile	Change over Baseline	80th Percentile	Change over Baseline
1	Low	237	-29	354	-10	1,416	0
	High	237	-29	354	-10	1,416	0
2	Low	236	-30	345	-19	1,381	-35
	High	237	-29	350	-14	1,394	-22
3	Low	237	-29	345	-19	1,381	-35
	High	237	-29	350	-14	1,394	-22
6	Low	236	-30	345	-19	1,381	-35
	High	237	-29	347	-17	1,383	-33
8	Low	237	-29	354	-10	1,416	0
	High	237	-29	358	-6	1,418	2

Review of Table V-13 shows that all of these potential reservoir alternatives either reduce habitat on the Refuge or leave it unchanged. This is not unexpected since the reservoirs are generally empty during dry years when they are needed most. When the reservoirs do have water in them, the evaporation from the reservoirs serves to deplete available water supplies in the basin.

F. PROJECT COST ESTIMATES AND ECONOMICS

Project costs, operation, maintenance, replacement and energy costs, present value and benefit-cost analysis are detailed below for various reservoir alternatives. These costs are used in Task E for the purpose of comparing and selecting the most economical alternative(s) for implementation.



Notes:
1. Developed from operations modeling for Quivira NWR for period 1/1955 through 12/1994 for ASR alternatives. Includes data for months of September through April only.
2. Optimum shorebird and waterfowl habitats defined as wetland areas 1-4 inches and 10-18 inches deep, respectively. Total wetland habitat is the sum of the surface areas of all ponded water in all management units, regardless of depth.
3. Habitat data reflect a high reservoir storage priority.

Burns & McDonnell

Figure V-20

WETLAND HABITAT DURATIONS RESERVOIR SITE 3

1. Project Costs

Project costs include construction costs and associated capital costs for the surface storage dams and reservoirs at Sites 1, 2, 3, 6, and 8. These costs are developed with current unit costs and estimated quantities and are respectively listed in Tables V-14 through V-18. Costs are included for land acquisition including the dam footprint and reservoir basin area. Allowances are added to the base construction estimate for contingencies of 30 percent at this reconnaissance level and other costs of 20 percent. Project costs range from a low of $1.4 million for Site 1 to a high of $18.0 million for Site 3. The average life cycle unit costs range from a low of $1,381 per MG for Site 1 to a high of $11,622 per MG for Site 6.

2. Operation, Maintenance, Replacement and Energy (OMR&E)

Operations costs for the dam and diversion facilities are estimated as the sum of the following for each site:

- Operation and maintenance of 1.0 percent of base construction cost, excluding energy .
- Pumping energy of $0.095 per kilowatt-hour.
- Annual inflation of 4.0 percent.

These costs are summarized below in Table V-19, and range from $9,000 per year for a small reservoir to $115,000 per year for a large reservoir.

3. Present Value Analysis

A present value analysis is used to estimate the cost of each reservoir alternative in present day dollars over a 20 year period of service as listed in Table V-19.

Table V-14
PROJECT COST ESTIMATE
RESERVOIR SITE NO. 1

Item	Quantity	Units	Unit Cost	Total Cost
Zone 1 Embankment	1,100	cy	$5	$5,500
Zone 2 Embankment	1,300	cy	$4	5,200
Zone 3 Embankment	300	cy	$40	12,000
Striping/Clearing/Grubbing	0	ac	$2,000	660
Land Acquisition	200	ac	$2,000	400,000
Foundation Excavation	550	cy	$7	3,850
Outlet Works	1	ls		18,000
Spillway	1	ls		11,350
Diversion Facilities	1	ls		285,000
Subtotal				742,000
Mobilization, Bonds and Ins. @ 6%				45,000
Subtotal				787,000
Contingency @ 30%				236,000
Subtotal				1,023,000
Other Costs @ 35%				358,000
Total Project Cost				**$1,381,000**

Table V-15
PROJECT COST ESTIMATE
RESERVOIR SITE NO. 2

Item	Quantity	Units	Unit Cost	Total Cost
Zone 1 Embankment	76,000	cy	$5	$380,000
Zone 2 Embankment	92,000	cy	$4	368,000
Zone 3 Embankment	10,000	cy	$40	400,000
Striping/Clearing/Grubbing	13	ac	$2,000	26,000
Land Acquisition	660	ac	$2,000	1,320,000
Foundation Excavation	38,000	cy	$7	266,000
Outlet Works	1	ls		146,000
Spillway	1	ls		574,000
Diversion Facilities	1	ls		3,578,000
Subtotal				7,058,000
Mobilization, Bonds and Ins. @ 6%				423,000
Subtotal				7,481,000
Contingency @ 30%				2,244,000
Subtotal				9,725,000
Other Costs @ 35%				3,404,000
Total Project Cost				**$13,129,000**

Table V-16
PROJECT COST ESTIMATE
RESERVOIR SITE NO. 3

Item	Quantity	Units	Unit Cost	Total Cost
Zone 1 Embankment	188,000	cy	$5	$940,000
Zone 2 Embankment	231,000	cy	$4	924,000
Zone 3 Embankment	15,200	cy	$40	608,000
Striping/Clearing/Grubbing	21	ac	$2,000	42,000
Land Acquisition	660	ac	$2,000	1,320,000
Foundation Excavation	94,000	cy	$7	658,000
Outlet Works	1	ls		167,000
Spillway	1	ls		1,236,000
Diversion Facilities	1	ls		3,766,000
Subtotal				9,661,000
Mobilization, Bonds and Ins. @ 6%				580,000
Subtotal				10,241,000
Contingency @ 30%				3,072,000
Subtotal				13,313,000
Other Costs @ 35%				4,660,000
Total Project Cost				**$17,973,000**

Table V-17
PROJECT COST ESTIMATE
RESERVOIR SITE NO. 6

Item	Quantity	Units	Unit Cost	Total Cost
Zone 1 Embankment	178,000	cy	$5	$890,000
Zone 2 Embankment	218,000	cy	$4	872,000
Zone 3 Embankment	16,400	cy	$40	656,000
Striping/Clearing/Grubbing	22	ac	$2,000	44,000
Land Acquisition	750	ac	$2,000	1,500,000
Foundation Excavation	88,800	cy	$7	621,600
Outlet Works	1	ls		158,000
Spillway	1	ls		1,209,000
Diversion Facilities	1	ls		1,545,000
Subtotal				7,496,000
Mobilization, Bonds and Ins. @ 6%				450,000
Subtotal				7,946,000
Contingency @ 30%				2,384,000
Subtotal				10,330,000
Other Costs @ 35%				3,616,000
Total Project Cost				**$13,946,000**

Table V-18
PROJECT COST ESTIMATE
RESERVOIR SITE NO. 8

Item	Quantity	Units	Unit Cost	Total Cost
Zone 1 Embankment	33,000	cy	$5	$165,000
Zone 2 Embankment	39,000	cy	$4	156,000
Zone 3 Embankment	5,900	cy	$40	236,000
Striping/Clearing/Grubbing	7	ac	$2,000	14,000
Land Acquisition	160	ac	$2,000	320,000
Foundation Excavation	16,100	cy	$7	112,700
Outlet Works	1	ls		127,000
Spillway	1	ls		278,500
Diversion Facilities	1	ls		639,000
Subtotal				2,048,000
Mobilization, Bonds and Ins. @ 6%				123,000
Subtotal				2,171,000
Contingency @ 30%				651,000
Subtotal				2,822,000
Other Costs @ 35%				988,000
Total Project Cost				**$3,810,000**

Table V-19
PRESENT VALUE SUMMARY

Site No.	Construction Cost ($)	Annual Operations Cost ($/yr) [1]	Present Value Costs ($)
1	1,380,000	9,000	1,420,000
2	13,130,000	83,600	13,400,000
3	17,970,000	115,500	18,360,000
6	13,950,000	88,200	14,230,000
8	3,810,000	24,700	3,900,000

Note: 1. Costs in year 2000 dollars.

The resulting present values for the reservoirs varies greatly. Site No. 1 has the lowest present value at $1.4 million. Site No. 3 has the highest present value at $18.4 million.

4. Benefit-Cost Analysis

The benefit-cost analysis shows the ratios of the project's benefits to the project's cost. This analysis is summarized in Table V-20. As shown in Table V-13, the estimated benefit of each of the potential reservoir alternatives is negative. This indicates development of upstream storage reservoirs is expected to decrease the availability of wetland habitat at the Refuge. Therefore, the benefit-cost ratios for these alternatives are also negative and indicate that none of the five alternatives should be pursued.

Table V-20
BENEFIT-COST SUMMARY

Site No.	Present Value of Cost ($) [1]	Present Value of Benefits ($) [1]	Benefit-Cost Ratio
1	1,420,000	0	0
2	13,400,000	- 197,000	- 0.01
3	18,360,000	- 197,000	- 0.01
6	14,230,000	- 299,000	- 0.02
8	3,900,000	20,000	0.01

Note: 1. Costs in year 1998 dollars.

PART VI

TASK B - AQUIFER RECHARGE

A. GENERAL

This section of the report addresses two approaches for aquifer recharge in the Rattlesnake Creek Basin and the Quivira National Wildlife Refuge (Refuge). These approaches include:

- Conventional aquifer storage and recovery (ASR) for specific Refuge use where water is captured from available sources (such as above-base flow) and stored in an aquifer for future use. The water is recovered when needed by wells and delivered to the Refuge for use.

- Enhancing natural recharge in the basin with the objective of raising groundwater levels that will, in the long-term, increase the base flow in Rattlesnake Creek. Increased base flow could result in additional water supply to the Refuge.

The feasibility for ASR and natural recharge options are discussed herein; however, detailed site specific investigations are required to confirm feasibility, receive state and federal agency approvals and permits, and prepare detailed design of possible projects. Management of existing water rights is not included in the scope of this study and is not evaluated.

B. INVESTIGATIVE APPROACH

1. Refuge Water Requirements

Based on net water needs as determined with the operations model, approximately 12,000 acre-feet of supplemental water is required at the Refuge on an average annual basis to meet operating goals and maintain water levels in management units (see Part IV). The maximum monthly supplemental need is approximately 3,400 acre-feet of water. These volumes are used as goals to site potential ASR facilities to provide supplemental water for the Refuge.

2. Aquifer Storage and Recovery

The feasibility of ASR requires several major components, including:

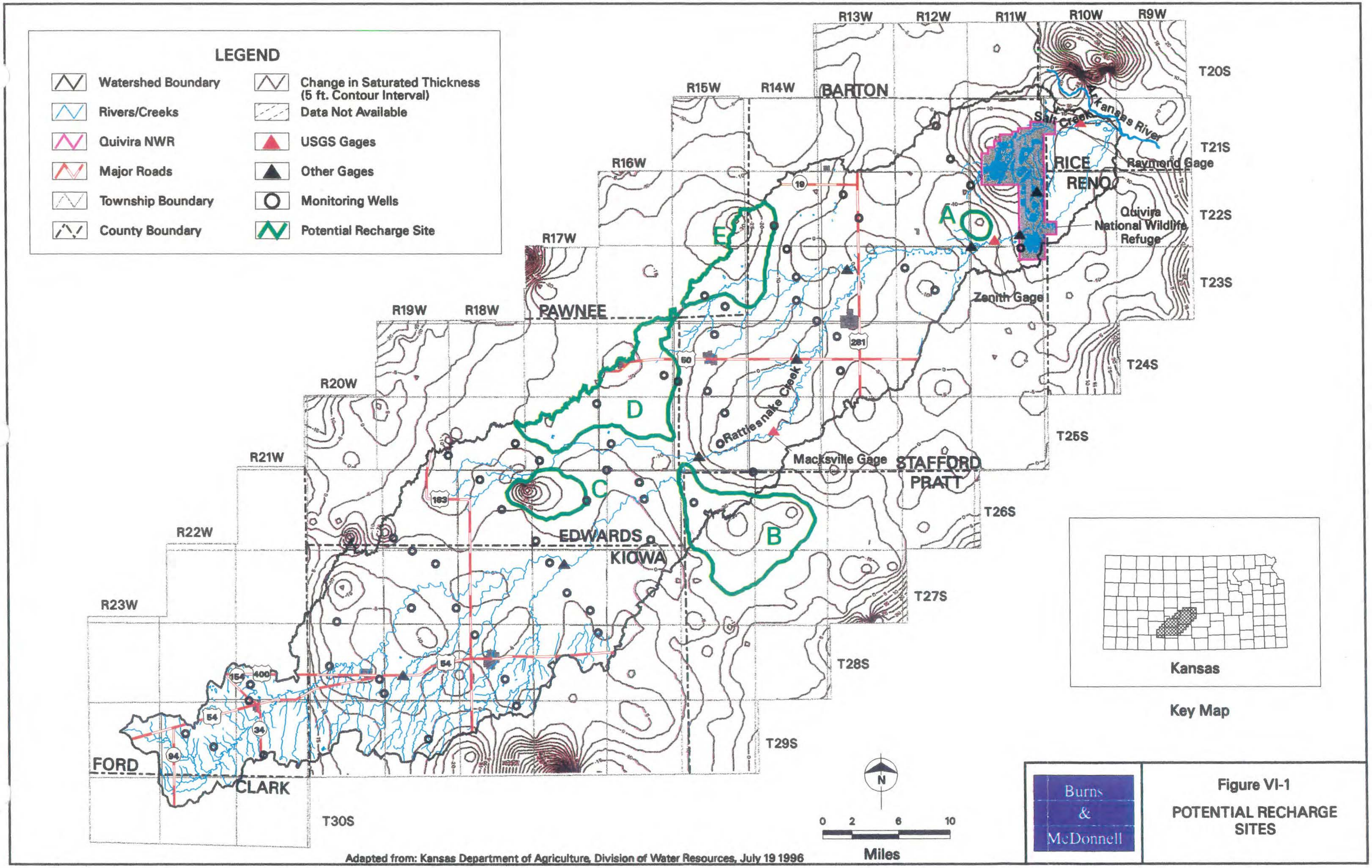
- A source of water with suitable quality and quantity.
- A suitable aquifer zone with both sufficient volume to store the recharged water for project needs and limited aquifer losses.
- Capture, conveyance, and recharge facilities. Treatment facilities may also be required.
- Recovery, conveyance, and delivery facilities.

a. Aquifer Storage Locations

Aquifer zones suitable for ASR development in this study are areas that have experienced large groundwater level drawdowns, leaving a large portion of the aquifer's storage capacity available for recharge. Potential locations for ASR are indicated by the change in saturated thickness of the aquifer in the Rattlesnake Creek Basin from pre-development to 1996 as shown in Figure VI-1. Areas with greater than 10 to 15 feet of lowered groundwater level are considered potential aquifer storage zones. Five areas are identified in Figure VI-1 and are labeled Recharge Areas A through E.

The surface area contained within each contour interval is used to estimate the total volume of available storage. The volume of water that can drain from an aquifer is known as specific yield. The specific yield typically ranges from 0.1 to 0.2 (10 to 20 percent of the total volume) for unconfined aquifers. Specific yield values used in the SWATMOD model for the Rattlesnake Creek Basin are 0.2 for the upper basin and 0.15 in the lower basin. The yield of the aquifer may be less than its specific yield. This may be due to the slow drainage of water from the aquifer materials and the presence of confining clay layers or silty areas that tend to retain water due to surface tension. For this analysis, the storage volume available in each area is estimated based on an effective specific yield of 0.15.

Estimated surface area and available storage volume, distance from stream and distance to Refuge for each of the five identified areas are shown below in Table VI-1. Review of Table VI-1 shows Recharge Area A has the shortest conveyance distance from Rattlesnake Creek of about 1 mile and the lowest available



Burns & McDonnell

Figure VI-1

POTENTIAL RECHARGE SITES

storage volume of 7,000 acre-feet. Recharge Area D has the greatest distance from Rattlesnake Creek of about 10 miles and the greatest available storage volume of 155,000 acre-feet.

Table VI-1
POTENTIAL ASR SITES
DATA SUMMARY

Recharge Area	Surface Area (Acres)	Available Storage Volume (Acre-feet)	Distance from Stream (miles)	Distance to Refuge (miles)
A	2,500	7,000	1	4
B	42,000	118,000	5	36
C	5,700	19,000	6	45
D	57,000	155,000	10	36
E	45,000	143,000	6[1]	22

Note: 1. Distance from a tributary to Rattlesnake Creek.

Several of the larger capacity recharge areas, B, D and E, could store the required volume of water; however, because of their location in the basin, significant transmission losses would occur when the recovered supplemental water is conveyed from the supply point to the Refuge by open flow in Rattlesnake Creek. Figure I-8 shows the areas of gaining and losing reaches along Rattlesnake Creek. Subbasins 9 and 34, as defined for the SWATMOD model, are generally losing reaches and are in areas of significant groundwater drawdown. Changes in river flow in Subbasin 9 vary from losses of about 165 acre-feet/mile/month to a gain of 30 acre-feet/mile/month depending on weather and well pumping activities and has an average loss of 10 acre-feet/mile/month. During wet weather and times of no irrigation pumpage, the creek is a gaining stream. During times when there is significant pumping, the creek is a losing stream. Other subbasins are either gaining or losing depending on weather and groundwater pumping conditions. The SWATMOD simulation shows that stream losses could potentially be as high as 4,000 acre-feet in a dry month for the entire reach of Rattlesnake Creek below South Branch. The greatest stream losses correspond to the time when the Refuge has the greatest demand for additional water supply. Note that Recharge Areas B, C and D are located upstream of the losing stream portion of Rattlesnake Creek.

In addition to conveyance losses due to stream bed seepage, recovered water released to the stream becomes part of the stream flow and is subject to diversion by downstream surface water users up to the limit of their water right. Between the upper potential aquifer recharge areas and the Refuge, there is one vested surface water right holder who is allowed to divert up to 75 acre-feet of surface water per year.

Based on information developed by the operations model, approximately 12,000 acre-feet of supplement water supply is required annually on average at the Refuge, excluding transmission losses and losses due to intermediate surface water diversion. In a worst case month, the Refuge can experience a total water need of 3,400 acre-feet.

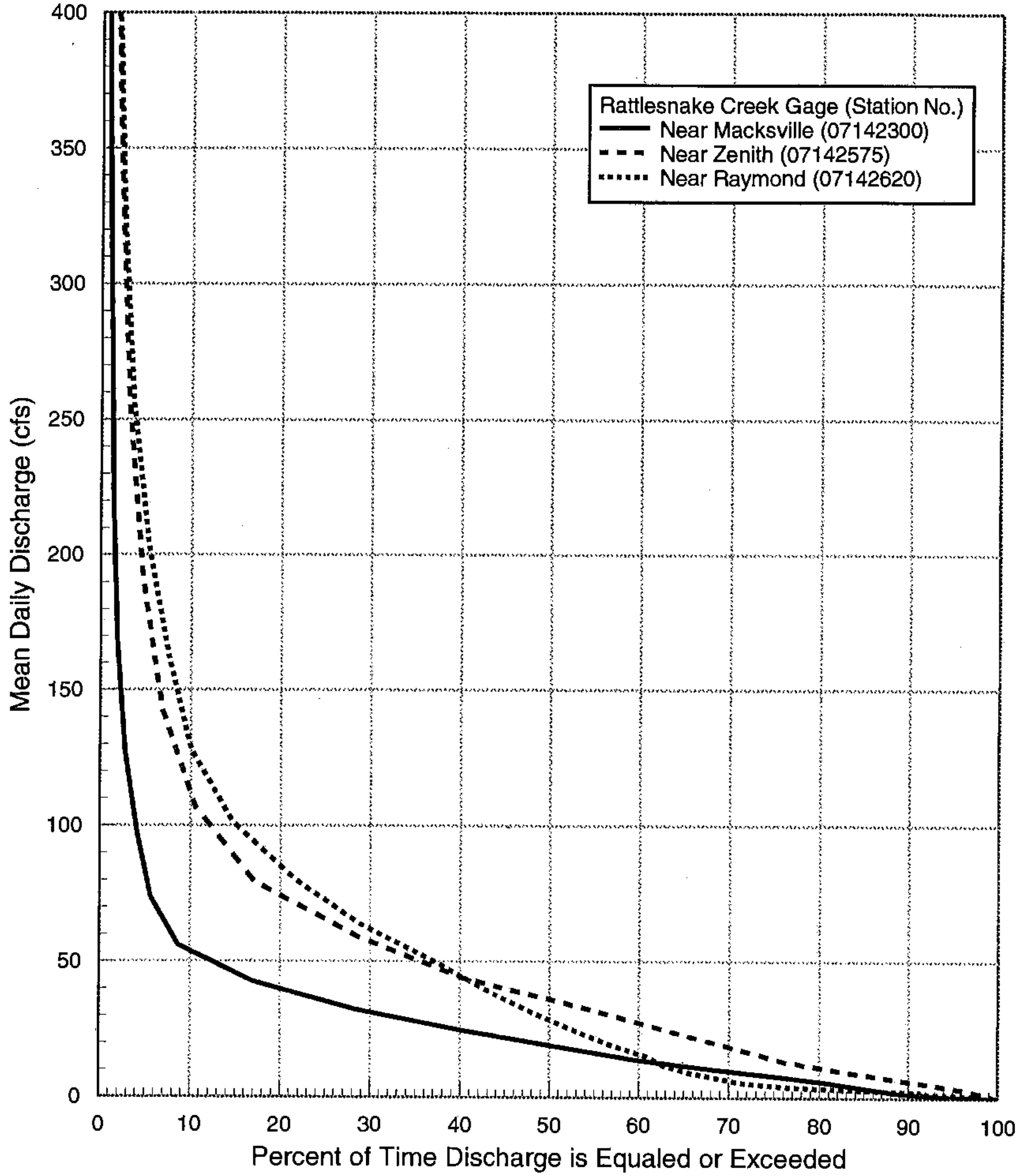
Recharge Area A is the only area selected for additional analysis due to the location, required diversion pipeline lengths, and potential losses in delivery. Although Recharge Area A can only store 7,000 acre-feet, which is less than the average need, this area has the best potential to supplement the water needs of the Refuge.

b. Water Source

Two possible sources of water are available for aquifer recharge, storage and recovery in the Rattlesnake Creek Basin. These sources are water from Rattlesnake Creek and the Arkansas River. The largest potential recharge sites are located at the upper end of the basin. The distance from the Arkansas River to most potential recharge sites is approximately 15 to 30 miles, making the conveyance from this source to the recharge area considerably more expensive than use of water from Rattlesnake Creek. Based on the potential cost difference, only above-base flow from the Rattlesnake Creek is evaluated for the aquifer recharge analysis.

The United States Geological Survey (USGS) maintains three streamflow gaging stations on Rattlesnake Creek as shown in Figure I-1. Basic hydrologic data for these gages are listed in Table VI-2.

Discharge duration curves, based on analysis of the historic record for each of these gages on Rattlesnake Creek, are presented in Figure VI-2. According to the USGS, nearly half of the basin is noncontributing. Basic flow characteristics at the gages are summarized below in Table VI-3.



Notes:
1. Developed from recorded discharge available from USGS for Rattlesnake Creek.
2. Periods of record
   Macksville: 10/1/59-9/30/96
   Zenith: 5/1/60-9/30/96
   Raymond: 5/30/73-9/30/96

Burns & McDonnell

Figure VI-2

DISCHARGE DURATIONS RATTLESNAKE CREEK

Table VI-2
USGS GAGE STATION DATA

Gage	Miles Above Mouth	Period of Record	Drainage Area (square miles)	
			Total	Noncontributing
Macksville	87.5	1960-1997	748	428
Zenith	22.1	1973-1997	1,047	519
Raymond	5.4	1960-1997	1,167	569

Table VI-3
RATTLESNAKE CREEK
FLOW DATA

Gage	Mean Flow (cfs)	Annual Runoff (acre-feet)	Flow Exceedance (cfs) Percent of time		
			10	30	50
Macksville	25.8	18,710	40	31	20
Zenith	49.8	36,110	82	58	38
Raymond	48.1	34,860	102	62	30

The potential source of water for recharge in this analysis is above-base flow in Rattlesnake Creek which occurs during periods of runoff. Above-base flows are defined as flows that exceed the streams calculated base flow and accommodate downstream surface water rights. The minimum desired streamflow (MDS) is defined by the state of Kansas based on water quality and environmental concerns. The MDS is generally somewhat less than base flow. A maximum of 15 cubic feet per second (cfs) has been established at the Zenith gage. One vested surface water right holder has a diversion right for 75 acre-feet per year located on Rattlesnake Creek approximately 10 miles upstream from the Refuge. An analysis of the flow data at the three gages shows that flows above the MDS are available over 50 percent of the time.

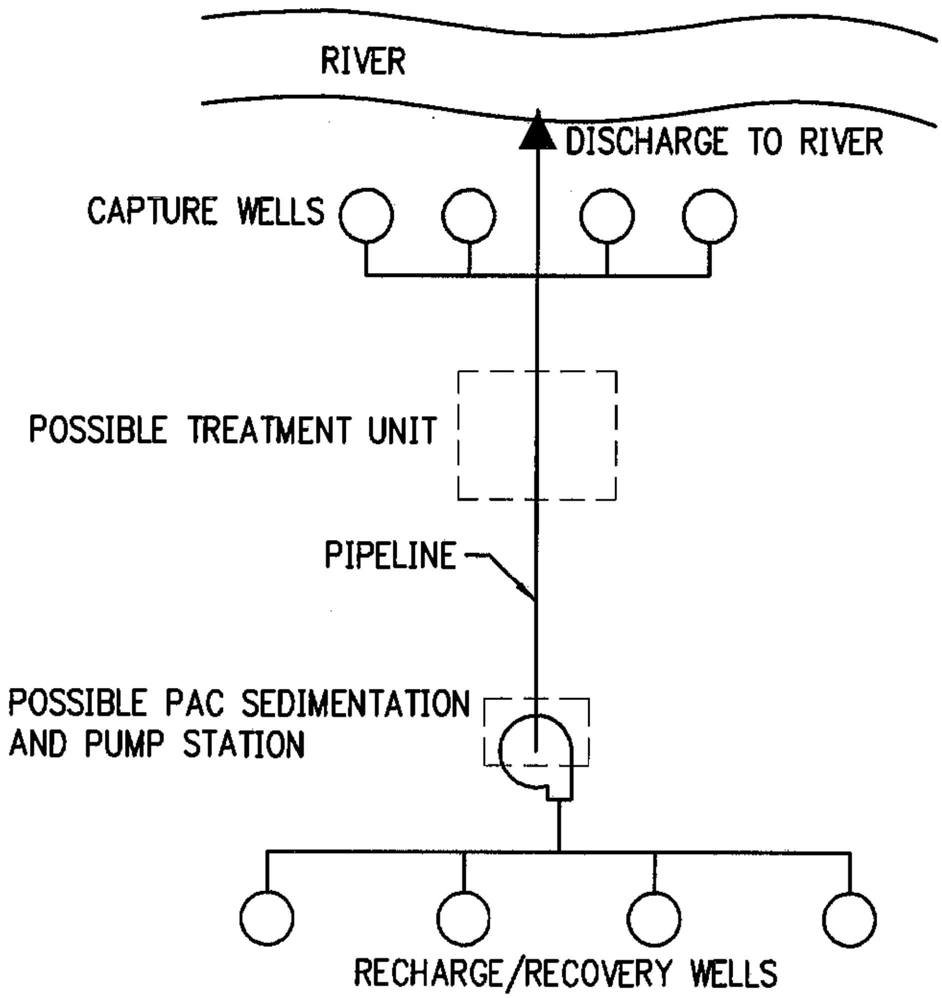
Because high volume flow events are generally short duration, large capacity diversion, treatment and storage facilities are required to capture the flow when it is available in order to replenish aquifer storage for later use. The further upstream the point of diversion is located, the less water will be available because of the smaller amount of contributing watershed.

c. Capture Facilities

Capture of the above-base flow from the stream can be accomplished by two different methods. If the river bed is permeable, with good stream-aquifer interaction, diversion wells installed adjacent to the creek are feasible. If there is not good communication with the aquifer, a surface water diversion will be required. Two recharge capture, storage and recovery conceptual layouts are shown in Figures VI-3 and VI-4, respectively, for induced infiltration wells and surface water intake layouts.

If the riverbed is permeable, allowing good percolation of stream flow, capture of the water by induced infiltration is the preferred method of diverting the above-base stream flow. Infiltration is induced by pumping wells located adjacent to a river to lower groundwater levels causing a reversal of the natural groundwater gradient toward the river. With lowered groundwater levels, water from the river percolates through the river bed and is captured by the well. The major advantage of using induced infiltration to capture river water is the natural filtration of sediment by the river bed. This produces clean water that is generally suitable for recharge with no additional treatment using a recharge (injection) well or basin; however, if the stream-aquifer interaction is good, dissolved contaminants, like obtrusion, may also be captured with the water. Water treatment will be required if obtrusion or other contaminants are present in sufficient quantities compared to the ambient quality of the groundwater in the recharge area.

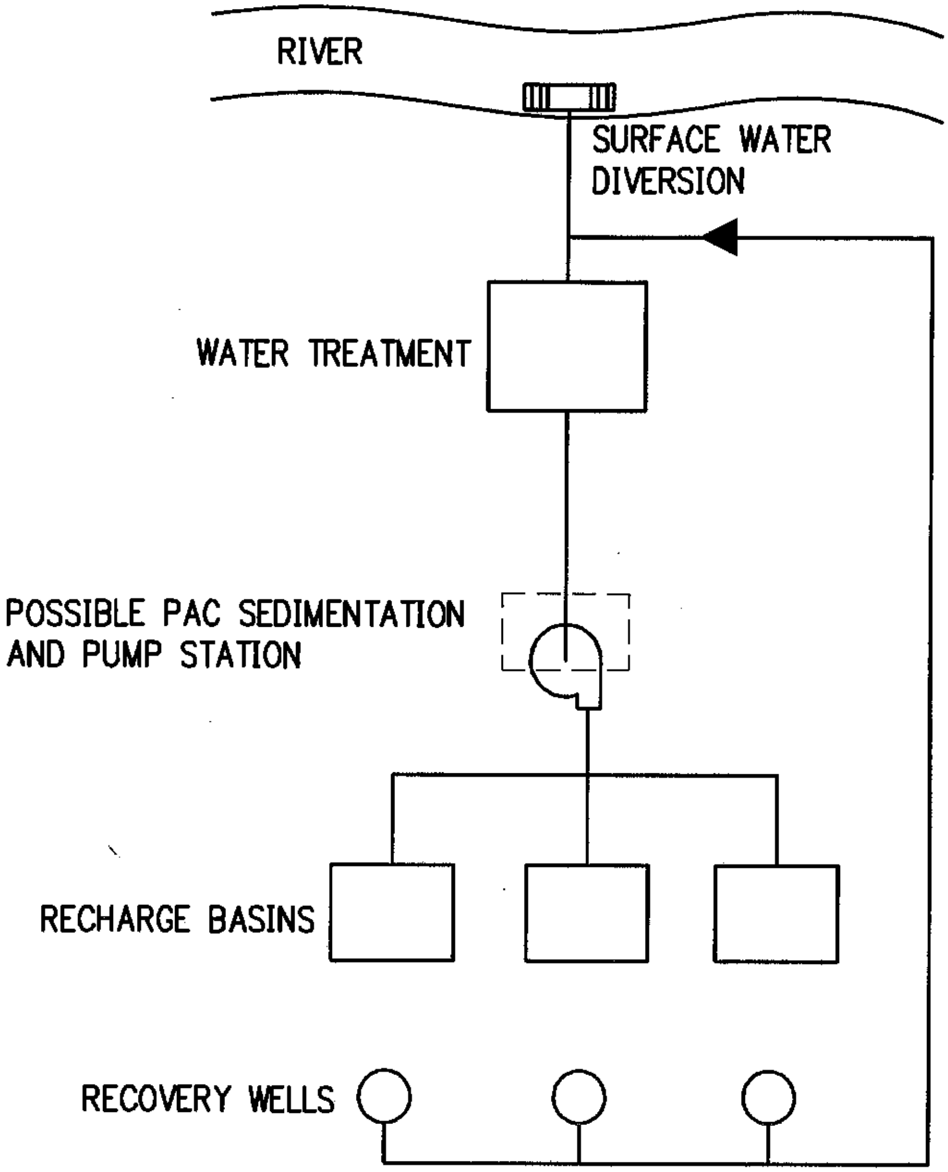
A second method of capture is by use of a surface water diversion structure, which typically includes an intake screen in the river and an adjacent pump station. The major advantages of this method is that generally larger volumes of water can be recovered than by using a well. Disadvantages of the surface diversion include the need for treatment to remove sediment and possible contaminants such as pesticides that may be contained in the captured surface water. If pesticides are contained in the surface water, they will generally be much higher than levels in water captured by induced infiltration. Generally, if a surface water diversion is used to capture water, percolation basins are used for recharge. Recharge basins typically require more land and have slower recharge rates. Higher turbidities associated with surface water tend to clog screens of recharge wells, making their maintenance very intensive. Recharge wells can be used with surface water if the captured water is treated to or near drinking water standards.



Burns & McDonnell

Figure VI-3
INDUCED INFILTRATION
AQUIFER RECHARGE, STORAGE
AND RECOVERY CONCEPT

J:\USF\978064\procws\ConceptA.DWG 02-04-1998 08:00 MJC



Burns & McDonnell

Figure VI-4

SURFACE WATER AQUIFER RECHARGE, STORAGE AND RECOVERY CONCEPT

J:\USFWS\978064\procws\ConceptB.DWG 02-04-1998 08:39 MJC

Captured surface water will need to be treated to reduce sediment loading and prevent plugging of the infiltration basins. Settling ponds or sedimentation basins are typically required as a minimum and chemical treatment may also be required depending on the settling characteristics of the sediment in the water.

The determination of the actual type of capture and recharge system recommended for use is based on site specific investigations. In this analysis, it is assumed that capture wells with a pipeline to recharge wells will be used.

Assuming that the storage facility will have to be re-filled each year for use during the latter part of the season, a large number of wells will be required to capture the water when it is available. For example, if Recharge Area A, which has a storage capacity of about 7,000 acre-feet, is to be filled with above-base flow that is available 20 percent of the time near the Zenith gage, 21-1,000 gallons per minute (gpm) wells would be required to divert the flow in the time period (at a rate of 95 acre-feet per day). Sixteen 1,000 gpm wells (one standby) would be required to fill Recharge Area A with flow that is available 30 percent of the time (at a maximum rate of 64 acre-feet per day). Partial system pumping can begin before the river flow reaches the 30 percent exceedance rate; however, the full capacity of the system could not be used until flow is greater than 70 acre-feet per day (about 32 cfs) plus the minimum desired stream flow (15 cfs at Zenith) and the maximum diversion rate of downstream surface water right holders.

d. Delivery and Recharge Facilities

Water will be delivered to the recharge area by pipeline or a series of pipelines from the diversion facilities. The pipeline will be designed to carry water at the maximum delivery or recovery rate needed by the Refuge, whichever is greater. The estimated storage and recovery rates are as follows:

- Maximum storage rate is 64 acre-feet/day (15-1,000 gpm wells)
- Maximum recovery rate is 67 acre-feet/day (15-1,000 gpm wells)

Infiltration basins may be used to recharge shallow aquifers if geologic conditions allow. Recharge rates vary with the subsoil conditions such as the grain size and the presence of silt or clay in the soil or clay layers in the aquifer. Typically overburden clays are removed to expose an underlaying sand layer to increase recharge rates. Recharge water should be relatively sediment free and may require treatment to remove sediments if the water is captured surface water.

Based on experience in south central Kansas, recharge rates in sandy materials may range from 1 to 5 feet per day. Under typical recharge conditions, the bottom of the infiltration basin will plug with biological growth and the accumulation of sediment. Periodic basin cleaning is required to maintain desired recharge rates. The frequency of cleaning depends on the amount of sediment in the recharge water, the amount of nutrients present, and length of time the water stands in the basins. Typically, an additional 50 percent of recharge basin capacity is needed to maintain maximum recharge capacity since some basins are drying or being maintained during recharge events. Approximately 70 acres of basins would be needed to meet the desired recharge rate for Recharge Site A.

e. Recovery Facilities

Recharged water is assumed to be recovered by conventional wells. If the preferred recharge method is through wells, wells can be developed for use as combination recharge/recovery wells. If the preferred recharge method is though infiltration basins, single purpose recovery wells must be installed to recover and deliver the stored water when needed.

For this analysis, a typical maximum rate of recovery of 2,000 acre-feet per month is assumed. This water is recovered by wells with a pumping capacity at a nominal 1,000 gpm or (4.4 acre-feet/day). For a 30-day pumping period, 15 wells would be required without backup.

f. Pilot Program

Prior to the implementation of an aquifer storage and recovery program, detailed investigations are required to obtain regulatory approval and develop the preferred final design for the full-scale project. A detailed investigation will include evaluation of water quality, site specific geologic and hydrogeologic characteristics, and operation of a small scale (pilot) program to prove the concept for local conditions prior to commitment of funds for the full-scale project and issuance of a construction permit by the State of Kansas.

3. Enhancing Natural Recharge

Several areas exist within the Rattlesnake Creek Basin where streams have ceased flowing or are losing streams during periods of significant groundwater pumpage. Wild Horse Creek, sections of Rattlesnake Creek, and other small tributaries have permeable stream beds that allow for rapid infiltration of surface water. Wild Horse Creek had been reported to have reduced flows within the last several years. The stream beds in these losing stream reaches could have the potential for recharging significant quantities of alluvial water if the flow can be retained; however, natural streamflows to the Refuge could be reduced during run-off events.

Low head flow-restriction structures would be constructed at several locations in the streams. These structures will slow the movement of surface water, except for high flow events, and allow more time for infiltration into the alluvial aquifer. Potential recharge rates may be as high as 0.5 to 1 acre-feet of water per acre flooded per day based on other investigations in Kansas. Other locations use similar techniques to enhance their water supply including Los Angeles County and Orange County, California (Todd, 1980; Bouwer, 1989; Markus, et al, 1994). Enhanced natural recharge could help improve the long-term condition of the aquifer and increase the stream base flow in the future; however, enhanced natural recharge will not supply large amounts of supplemental water to the Refuge during times of need.

Enhancing natural recharge has basin-wide benefits for all water users. Detailed estimates of costs and benefits would require site specific investigations to determine the number and height of retention structures, the amount of recharge that can be expected at specific sites, geological conditions that may impact design and the long-term environmental impact of the structures. Because enhanced natural recharge offers potential benefits for the entire basin, it is suggested that further investigations be undertaken by the Partnership.

C. AQUIFER IMPACTS

Degradation of water quality is the most significant potential impact to the aquifer. Water quality of Rattlesnake Creek, the recharge water source, varies widely, containing from 85 to 1,970 mg/L chlorides. The chloride content of the aquifer in the vicinity of Recharge Area A is about 100 to 250 mg/L in the upper part of the unconsolidated aquifer and 1,000 to 5,000 mg/L in the lower part (Whitimore, 1992).

Based on these data, recharge water from Rattlesnake Creek could degrade ambient groundwater quality and water treatment may be required. Site specific studies are required to determine actual aquifer water quality and potential impacts due to chlorides.

Captured water will have to be monitored for the presence of pesticides and other potential contaminants. Detection of contaminants will require treatment of the recharge water to prevent degradation of the aquifer water quality.

Water levels in the aquifer will have to be monitored during times of pumping to prevent drawdown impacts to other water users. Higher groundwater levels are beneficial to other users through the reduction of pumping costs. While higher groundwater levels may benefit some water users, no additional water rights or additional pumping should be allowed in the groundwater recharge areas.

D. WATER QUALITY

The State of Kansas has an anti-degradation policy for groundwater recharge. This policy requires all recharge projects to use recharge water that will not degrade the ambient aquifer water quality or prevent continuation of current water uses. Extensive water quality testing and a pilot recharge project are typically required by the State of Kansas to show that degradation to aquifer water quality will not occur before permitting a full-scale aquifer recharge, storage and recovery project.

Water quality in Rattlesnake Creek is highly variable. Water in the Rattlesnake Creek upstream of St. Johns, Kansas, appears to be fresh, while water quality downstream of St. Johns appears to be high in salinity. Surface water quality data from EPA's STORET database are used in this study to approximate the impacts of Rattlesnake Creek surface water on groundwater recharge. Chlorides, sodium, and pesticides (triazine herbicides like obtrusion) appear to be the primary water quality concerns. Irrigation water with excessive concentrations of chlorides and sodium can cause soil damage and is not tolerated by most crops. Recent 1990's pesticide data are not available at these sampling sites on Rattlesnake Creek.

Groundwater quality in the upper portion of Rattlesnake Creek Basin, upstream of St. John, is considered to be of high quality. In the lower portion of the basin, groundwater quality is impacted by upwelling saline water from Permian bedrock formations. East of St. John, the Cedar Hills sandstone subcrops along a north-south line. This unit is the source of the majority of the saline water entering the aquifer (Fader and Stoilken, 1978).

As described in Section C, chloride levels in the upper part of the unconsolidated aquifer are lower than levels at the base of the aquifer due to the saltwater intrusion from the bedrock. Additionally, seepage of poorer quality surface water degrades water quality in the upper unconsolidated aquifer in areas close to Rattlesnake Creek or near surface water impoundments in the Refuge.

Limited water quality data are available from STORET for the Rattlesnake Creek upstream of St. Johns. Limited sampling conducted during the winter of 1971 and 1972 shows flow ranged from 1 to 3 cfs and chlorides ranged from 16 to 58 mg/L with a mean of 33 mg/L. Based on data from 1962 through 1969 at another sampling site in the same general area, flow ranged from 10 to 33 cfs with a mean of 21 cfs, chlorides ranged from 7 to 23 mg/L with a mean of 17 mg/L, and sodium ranged from 6 to 28 mg/L with a mean of 22 mg/L.

Downstream or east of St. Johns, water quality on Rattlesnake Creek degrades. Based on limited data from 1992 through 1996, chlorides ranged from 85 to 1,970 mg/L with a mean of 1,382 mg/L and sodium ranged from 53 to 1,325 mg/L with a mean of 730 mg/L. This sampling site also showed high, above the EPA secondary maximum contaminant level or health advisory level, concentrations of the metals boron and iron. No flow data appears to have been collected with these samples. Limited data from 1971 to 1988 for another sampling site in the same general area showed flow ranging from 3 to 29 cfs with a mean of 16.5 cfs, chlorides ranged from 400 to 2,600 mg/L with a mean of 1,045 mg/L, and sodium ranged from 260 to 1,400 mg/L with a mean of 540 mg/L. Fecal and total coliforms counts were high at all sites where coliforms were tested.

Based on comparison of ambient groundwater quality to surface water quality data in STORET, groundwater recharge with surface water downstream of St. Johns will degrade the upper aquifer unless the recharge water is treated to reduce chlorides and sodium. The use of membrane technology to treat the recharge water and dispose of the brine waste has a construction cost of about $1.5 to 2.5 million per million gallon per day (MGD) of capacity and makes the use of this water infeasible at this time. As a result, membrane treatment of the recharge water is not considered feasible.

Surface water quality upstream of St. Johns appears to be adequate for aquifer recharge, storage and recovery using minimal treatment. Development of this alternative will require extensive water quality testing of the surface water near the points of diversion and the ambient groundwater.

E. ENVIRONMENTAL AND CULTURAL RESOURCE IMPACT

The groundwater recharge alternative would have minimal environmental impacts. The impacts of this alternative would primarily relate to the conversion of cropland to the non-agricultural uses associated with construction and operation of the facilities necessary for groundwater recharge. These facilities could include some or all of the following: wells, pipelines, recharge wells and recharge basins. Because of the limited size required in any one place for these facilities and the flexibility permitted by the need to locate them only in a general area, facilities could be located to minimize impacts to most, if not all, environmental parameters.

In order to minimize impacts to environmentally sensitive areas, recharge facilities would likely be constructed on land currently used for agriculture. While pasture and hayfields are present throughout the basin, it is likely recharge facilities would be located in cropland. Cropland is the predominant land use in the basin and most of the cropland is classified as prime farmland. Recharge facilities would occupy only a small area of land and would likely be distributed over several miles, minimizing the impact in any one area. Recharge basins could be an exception to this since these basins may require an estimated 70 acres or more in a recharge area. Construction of the proposed facilities would not result in a significant loss of prime farmland given the large amount of this resource present within the basin. Additionally, agricultural activities could continue around these recharge facilities and result in the removal of small portions of land from production. The presence of recharge facilities could be somewhat inconvenient but not detrimental to adjacent farming operations.

Pipelines needed for the groundwater recharge project would generally be located along existing roadways. In general, roadways in the Rattlesnake Creek Basin are bordered by cropland, pasture, shelter belts, hedgerows, stream crossings, and other habitats. Pipeline construction would therefore affect primarily these habitats. Pipelines would be routed to avoid wooded areas and stream crossings to the extent possible. Following construction, disturbed areas would either be revegetated or returned to agricultural production.

Recharge wells, basins, and pipelines would be located to avoid cultural resources and sensitive areas such as impacts to wetlands, important fish and wildlife habitat, or habitat for threatened or endangered species. Pipelines could impact wetlands if such areas are found adjacent to roadways. Additionally, minor impacts to wetlands could occur if such areas occur at any necessary stream crossing. No significant impacts to cultural resources are expected as recharge facilities could be located to avoid such resources.

Locations for groundwater recharge facilities will avoid any important fish and wildlife habitat. The location of recharge facilities adjacent to roadways generally limits the amount of habitat which could potentially be impacted. Additionally, no habitat for threatened or endangered species is known to occur in these areas. Location of pipelines adjacent to existing roadways also reduces the potential for disturbance to fish, wildlife, or threatened and endangered species resources. Prior to construction, more detailed evaluation of existing environmental resources located on and near potential construction sites for recharge facilities and pipelines would be undertaken.

Construction and operation of the groundwater recharge alternative would have little if any socioeconomic impact on the basin. Some minimal temporary disturbance to rural activities such as farming and recreation may occur. Construction equipment on and adjacent to roadways could cause minor traffic delays or accelerated deterioration of area roads. However, such impacts would be minimal. It is possible that some loss of agricultural production could occur if construction activities prevent seeding or disturb existing crops. This impact would be temporary, impacting only one growing season, and would involve only a small amount of land along the edge of a few fields.

Construction of low head flow-restriction structures in Rattlesnake Creek or other streams, either separately or in conjunction with other recharge facilities, would have little impact on the total environment within the basin. Structures would not increase flow or water levels so as to affect land areas adjacent to the stream channel. They would impound water within the stream channel, creating long shallow pools. The typical braided channels containing complexes of riffles, runs, and pools would be eliminated within these portions of the streams. Species inhabiting these habitats would be redistributed seeking desired habitats elsewhere in the stream; however, additional habitat would be created for pool species. Wetlands within the stream course could be impacted if water levels upstream of the structures are sufficiently altered. With such alterations to stream hydrology occurring, additional wetlands could expect to develop in other portions of the stream.

Retention of water in pools could result in surface water being more available than with existing surface flows. Water may be retained in the stream during periods when it would typically have been dry. More dependable habitat could occur for some aquatic species in the stream, and a more dependable water supply for area wildlife could result. Over time, the groundwater recharge could increase stream base flow, providing additional improved stream habitat.

Implementation of the enhanced natural recharge alternative could be an overall benefit to vegetation, wetlands, and wildlife resources of the Rattlesnake Creek Basin. A more dependable water supply would allow Refuge personnel to better manage and distribute water resources on the Refuge. The increased flexibility would enable Refuge personnel to provide more dependable amounts of fish and wildlife habitat in dry years, and a higher total quality of habitat during normal and wet years. Increased base flows would likely enhance existing wetlands in the basin, and could create additional wetland habitats.

Additional benefits to wildlife would occur following implementation of the enhanced natural recharge alternative. The more dependable water potentially provided by this alternative would enable Refuge personnel to provide a more dependable quantity and quality of habitat on the Refuge. The occurrence of this more dependable habitat is not as important in normal or wet years since these habitats would be widely available in the basin. However, in dry years, the more dependable habitat would provide more critical stopping, resting, staging, and recuperating area for species, including endangered whooping cranes, during spring and fall migrations. By providing more dependable wildlife habitat, this alternative would help attract wildlife to the Refuge on a more consistent basis, attracting more tourists to the area and providing more opportunities for public recreation on the Refuge.

F. PRELIMINARY AQUIFER STORAGE RECOVERY CONCEPT DESIGN

1. General

The preliminary conceptual design for an ASR project capable of meeting most of the Refuge's annual supplemental water need is described below. In order to design and permit a project of this magnitude, extensive additional site specific investigations and pilot studies would be required.

2. Preliminary Investigations and Pilot Study

Preliminary investigations include the following major components:

- Preliminary project siting based on existing data.
- Geological drilling to determine subsurface conditions, depth to bedrock, groundwater quality, grain size of the aquifer materials, thickness of overburden clay layers, depth of groundwater, and the existence of any clay lenses or restricting layers.
- Installation of monitoring wells to obtain current data on groundwater levels and water quality in the recharge area.
- Additional evaluation of surface hydrology.
- An aquifer pumping test to determine stream-aquifer interaction at the selected capture well site.
- Preparation of an engineering report to support permitting and any required NEPA documentation required.

A pilot study is highly recommended prior to the commitment of funds for a full-scale project. The pilot study would involve the construction and operation of a full size capture and recharge well for a two-year period. Its purpose would be to obtain operation experience with site specific conditions, and to collect water quality and quantity information to support permit acquisition from appropriate state and federal agencies. The basic elements of the investigation and pilot study are listed in Section H, Project Cost Estimates and Economics.

3. Preliminary Conceptual Design of the Recharge Facilities

a. Aquifer Recharge Area

As discussed above, Recharge Area A is selected for this analysis because it's location is close to the Refuge and it has the potential for capturing sufficient water to recharge the available storage. The recharge area is limited to approximately 7,000 acre-feet which does not completely meet the ultimate water needs of the Refuge.

b. Capture and Recharge Facilities

Wells are selected for preliminary design of the capture facilities assuming that adequate aquifer-stream interaction exists to induce infiltration. Although capture wells are more expensive than a surface water intake, a water treatment facility is assumed to not be required. A surface water diversion would require water treatment and other recharge facilities, resulting in increased project cost.

The ASR concept includes the following components in four identical systems as shown schematically in Figure VI-3:

- 4 capture wells.
- 12-inch diameter PVC collection and distribution pipelines.
- 16-inch diameter PVC transmission pipelines.
- 4 recharge/recovery wells.
- Electrical power supply.
- Gravel access road.
- Discharge at river.
- Other miscellaneous items.

For the induced infiltration capture system, water is recharged via recharge (injection) wells. Design of recharge wells is similar to the design of standard water supply wells with the following exceptions:

- The recharge water must be delivered by "full pipe flow" to below the water table to prevent aeration and precipitation of minerals within the well. Flow can be delivered through the pump or through special recharge tubes sized to maintain a positive pressure at the wellhead.

- Recharge wells require frequent redevelopment to remove any sediment that may accumulate on the well screen. Typically, the redevelopment rate should be greater than recharge rates causing higher water velocities to move through the well screen.
- Recharge wells require a Class V injection well permit from the Kansas Department of Health and Environment.

As described in Section B.2.c above, 16 recharge wells with a rated capacity of 1,000 gpm would be needed to store the desired amount of water. Maintenance of these wells include redevelopment about once per week and disinfection about once per month to prevent biofouling.

The conceptual plan assumes that water treatment will not be required. In the event pesticides are detected in the captured water, water treatment facilities consisting of powered activated carbon (PAC) addition and sedimentation basins would be required.

c. Operation and Maintenance

The conceptual design assumes that the capture and recovery wells will be operated 110 days per year (about 30 percent of the time). Labor for operation, monitoring, sample collection and general maintenance are estimated at approximately 550 man-hours per year which is included in the cost estimate.

Energy costs are based on 110 days per year of full operation of all wells. Periodic maintenance includes annual pumping tests to evaluate well efficiency, annual well disinfection and cleaning. The cost estimate also assumes pump replacement every 10 years.

G. OPERATION MODELING

In order to test the feasibility of ASR as a supplemental water source for the Refuge, the base operations model was modified to include an ASR facility at Recharge Site A. The model modifications and other assumptions used to analyze the ASR concept are discussed below.

1. Water Available for Aquifer Recbarge

As stated in the Section B.2, withdrawals from Rattlesnake Creek for aquifer recharge can occur only after the MDS is satisfied. The MDS for Rattlesnake Creek is 15 cfs. For any flow above 15 cfs, withdrawals can be made for aquifer recharge, up to the capacity of the recharge wells (16,000 gpm).

The discharge in Rattlesnake Creek can change significantly from day to day; therefore, the monthly flow data collected for the operations model can not be used directly to determine the water available for aquifer recharge. Daily discharge estimates are required to accurately estimate these data. Recharge Site A is located very close to an existing USGS stream gaging station near Zenith (No. 07142575), which has historic daily discharge records; however, the data available for this gage goes back only to June 1973. Therefore, additional streamflow data are required to estimate available recharge water for the period from January 1955 through May 1973.

There are two other USGS stream gaging stations on Rattlesnake Creek. These are located upstream near Macksville (No. 07142300) and downstream of the Refuge near Raymond (No. 07142620). Discharge at the Raymond gage is impacted by Refuge operations so it is not considered to be representative of natural flow in Rattlesnake Creek. Therefore, only data at the Macksville gage are used. The period of record for the Macksville gage begins in October 1959, almost five years after the start of the model simulation period.

Daily discharge data for the remaining portion of the model simulation period (January 1955 through September 1959) are obtained from a USGS stream gaging station on the North Fork of the Ninnescah River (North Fork) near Cheney (No. 07144800). The North Fork Basin is adjacent to that of Rattlesnake Creek, and this gage and the Zenith gage have similar drainage areas, 930 verses 1,047 square miles, respectively.

Correlation and regression analysis are conducted on the overlapping periods of record for the three stream gaging stations used in the analysis. Unfortunately, these did not yield satisfactory results. The resultant regression equations could not be used to reliably estimate daily flows in Rattlesnake Creek near Zenith from the records available at the other two gages. For this reason, an alternate procedure was used.

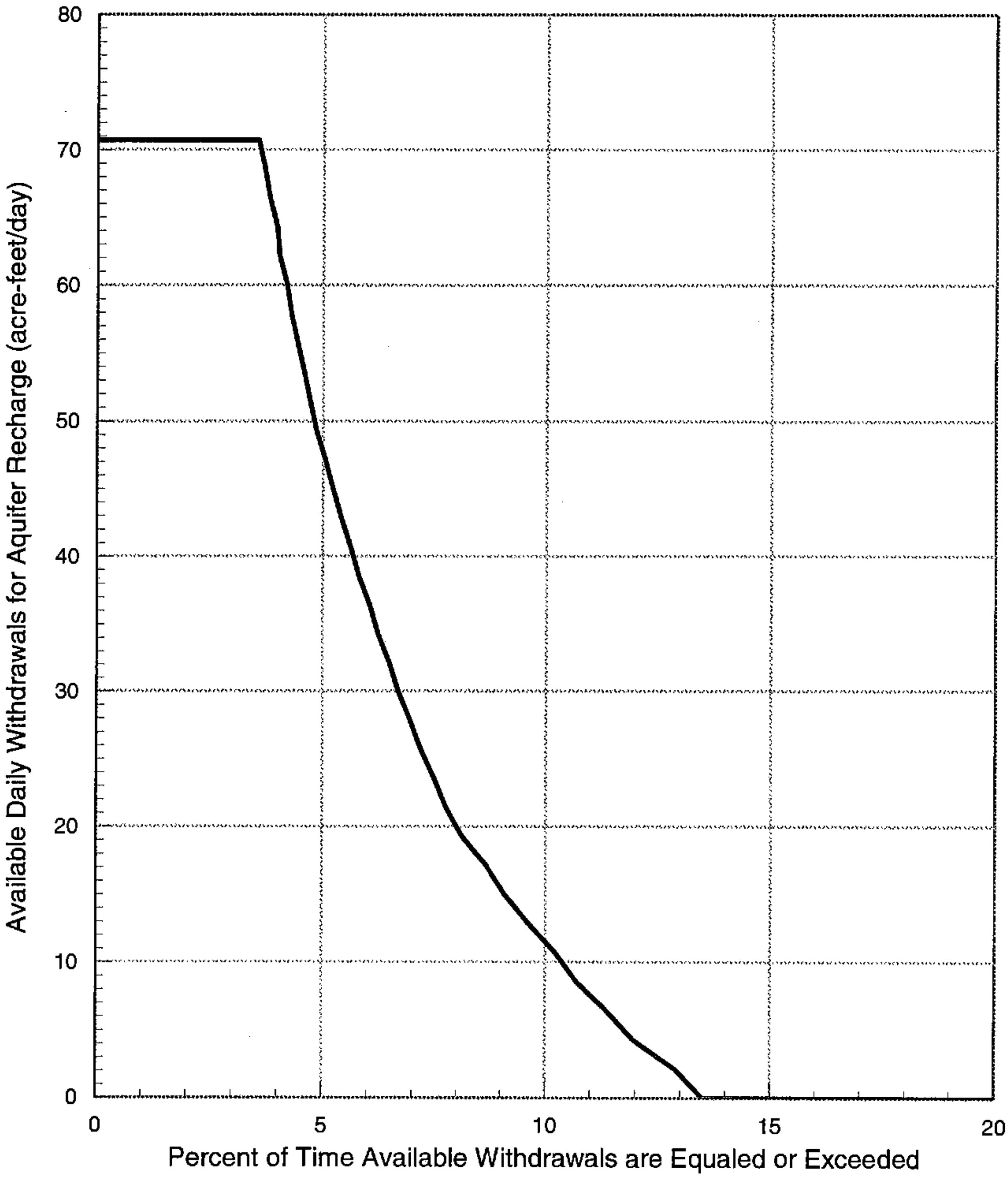
Instead of using the daily discharge records at the three gages directly to estimate discharge near Zenith, these records are used only as a means to distribute the monthly flow estimates, extracted from the SWATMOD model, across each month. This methodology has the additional advantage that it ensures the total monthly flow volumes used in the operations model and those used to estimate withdrawals for aquifer recharge match.

Using the flow distribution procedure discussed above, estimates of daily flow in Rattlesnake Creek near Zenith are developed for the entire simulation period, calendar years 1955 through 1994. These flow estimates are then used to estimate the amount of water that could be withdrawn, via induced infiltration or a surface water intake, for aquifer recharge each day. As stated previously, no water can be withdrawn unless flow in the creek exceeds 15 cfs. At this point, water can be withdrawn up to the limit of the assumed pumping capacity, 16,000 gpm or about 70.7 acre-feet per day. Figure VI-5 shows the durations for available withdraws for aquifer recharge. Review of this graph shows that some water is available for withdrawal about 13 percent of the time, or about 50 days per year on average. The full capacity of the recharge wells is utilized only about 4 percent of the time, or about 13 days per year on average.

Since the operations model uses a monthly time step, the daily aquifer recharge water estimates are totaled by month for use in the model. Table VI-4 presents a summary of these monthly data. The annual variability of the available recharge water is shown in Figure VI-6. As shown in Table VI-4 and in Figure VI-6, there are years when no recharge water is available. Even in the best year (1987), the available recharge water totals only about 6,000 acre-feet, which is 1,000 acre-feet less than the assumed capacity of the storage aquifer.

2. Model Revisions

Operation of the ASR alternative is modeled by adding a single storage node to the base operations model. This node, No. 105, represents the aquifer that is to be recharged. This node is located just upstream of Node 110. The link between Nodes 105 and 110 represents the aquifer recovery system that will pump water from the aquifer and return it to Rattlesnake Creek. No other changes to the base operations model schematic are necessary.

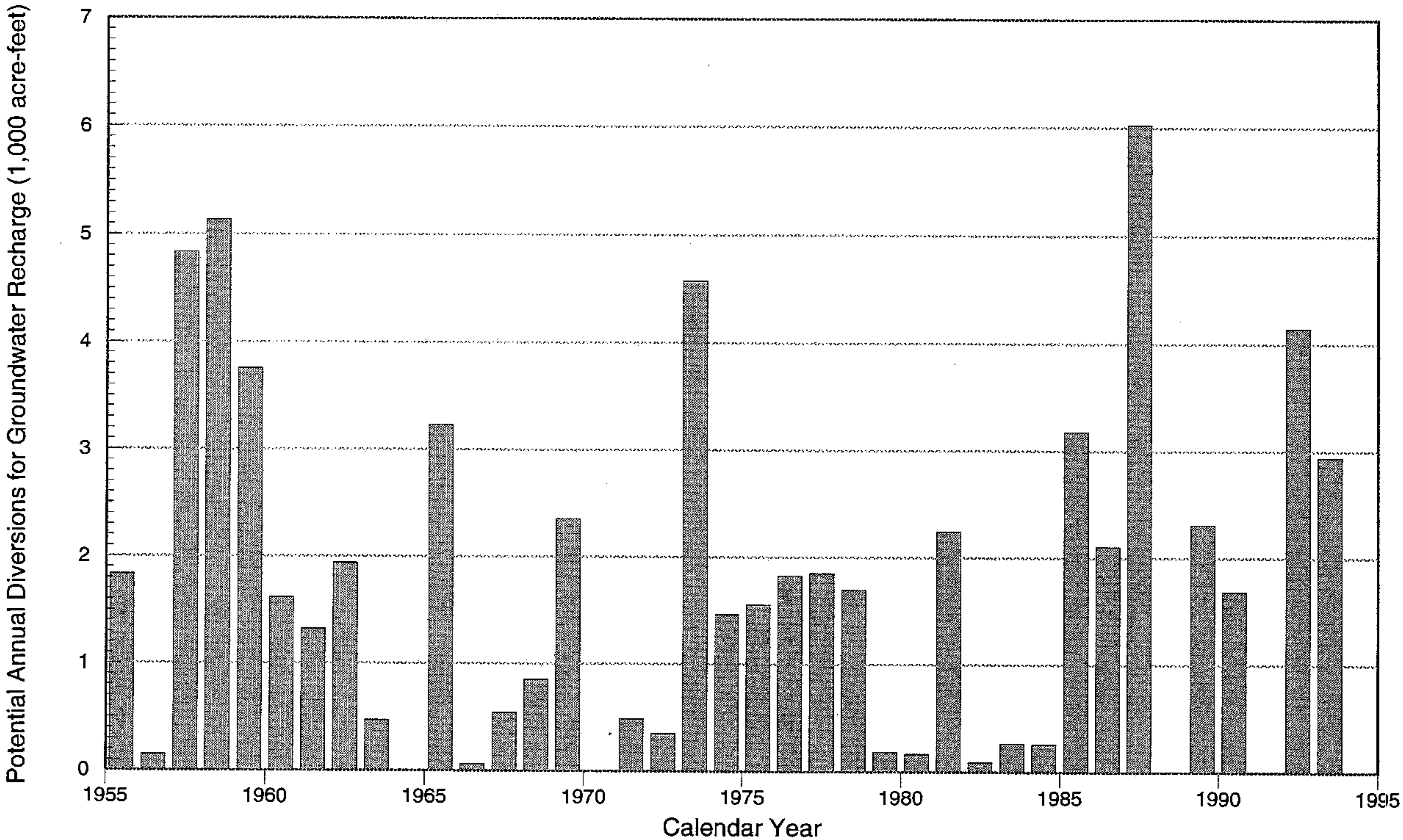


Notes:
1. Developed from monthly flow data from SWATMOD model near Zenith and daily discharge data from USGS.
2. Period of record: 1/1/55--12/31/94
3. Withdrawals for groundwater recharge are allowed only after minimum desirable streamflow of 15 cfs is met.
4. Maximum pumping rate is 16,000 gpm or about 70.7 acre-feet/day.

Burns & McDonnell

Figure VI-5

PUMPING DURATIONS FOR AQUIFER RECHARGE RATTLESNAKE CREEK



Notes

1. Based on MDS of 15 cfs for Rattlesnake Creek and maximum pumping rate of 16,000 gpm.
2. Demand for water at the Refuge would normally be given priority over diversions for groundwater recharge. Therefore, the amount of water actually diverted to the storage aquifer would be less than the quantities shown.

Burns & McDonnell

Figure VI-6
POTENTIAL ANNUAL DIVERSIONS FOR GROUNDWATER RECHARGE

Table VI-4
SUMMARY OF WATER AVAILABLE FOR AQUIFER RECHARGE

Month	Available Aquifer Recharge (acre-feet)		
	Minimum	Maximum	Average
Jan	0.0	71.4	1.8
Feb	0.0	52.8	3.6
Mar	0.0	1,521.8	101.8
Apr	0.0	1,253.0	69.7
May	0.0	1,889.1	309.3
Jun	0.0	2,121.2	508.5
Jul	0.0	1,489.6	171.1
Aug	0.0	2,023.2	182.4
Sep	0.0	1,750.3	184.8
Oct	0.0	1,680.5	136.7
Nov	0.0	278.8	11.0
Dec	0.0	250.2	8.7
Annual	0.0	6,028.3	1,689.5

Inflow to Node 105 each month is equal to the amount of water available for aquifer recharge that is estimated as discussed above. The incremental inflow used in the base operations model for Node 110 is adjusted by netting out the available aquifer recharge water so that the total volume of water available at Node 110 remains unchanged each month.

The storage aquifer is assigned a usable volume of 7,000 acre-feet. It is assumed there will be no losses from the aquifer, such as from leakage, evapotranspiration or additional well pumpage, or gains due to natural recharge for this preliminary analysis.

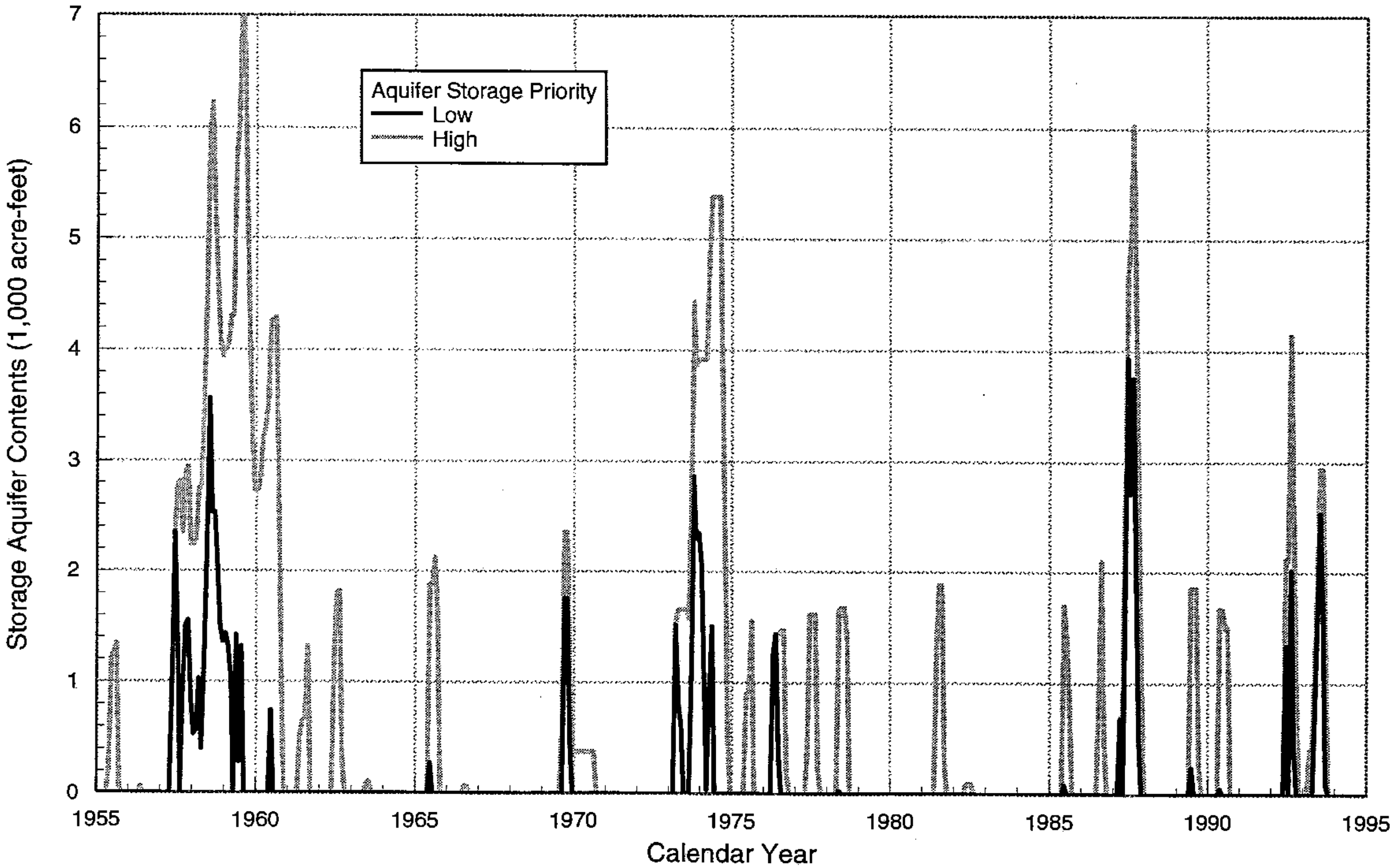
Two sets of storage priorities are used for the storage aquifer. The first set assumes that no water is diverted to the storage aquifer unless all management units at the Refuge are filled to their target levels. The second set storage priorities gives a higher priority to the storage aquifer during the first eight months of the year, January through August, in hopes of "saving" more water for use later in the year. For this model case, water is diverted to the storage aquifer during the month of January through August after the management units are filled only to the tops of their very low zones, as defined in Part III.

3. Modeling Results

For the ASR alternative, the operations model is executed twice, once with each set of storage priorities for the storage aquifer. Table VI-5 gives minimum, maximum and average end-of-month storage contents in the aquifer by month for each case. Monthly storage volumes in the aquifer are shown on Figure VI-7.

Review of Table VI-5 and Figure VI-7 shows that the aquifer storage and recovery scheme is only marginally successful. The goal of this alternative is to store surplus flows that occur in the spring and summer for use during the fall; however, in drier years, all of the available water in Rattlesnake Creek must be used directly on the Refuge, leaving no water available for storage. It is only in wetter years, when supplemental water supplies are least valuable, when significant amounts of water can be captured for aquifer recharge. Once captured, the water stored in the storage aquifer can be withdrawn at a later date to supplement the supply to the Refuge; however, the capacity of the storage aquifer is less than half of the potential annual water needs at the Refuge. For this reason, any water stored in the aquifer is exhausted rapidly and provides supplemental supplies to the Refuge for only a few months into the next period with average or less streamflow.

The recharge alternative provides a small volume of supplemental supply, volumes in excess of baseline conditions, to the Refuge. The low storage priority option provides an average annual supplemental supply of 568 acre-feet per year and the high storage priority option provides an average annual supplemental supply of 610 acre-feet per year. The higher volume of 610 acre-feet per year in the high storage priority scenario is used for project economic comparisons.



Notes
1. Monthly aquifer contents obtained from operations simulation for ASR alternative.
2. Under low storage priority option, water needs at Refuge are always given priority over withdrawal of water for aquifer storage. The high storage priority options assumes a preference for aquifer storage during months of January through August.

Burns & McDonnell

Figure VI-7

SIMULATED STORAGE AQUIFER CONTENTS ASR ALTERNATIVE

Table VI-5
SUMMARY OF STORAGE AQUIFER VOLUME

Month	End-of-Month Storage Aquifer Volume (acre-feet)					
	Low Storage Priority			High Storage Priority (Jan-Aug)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Jan	0	2,094	101	0	4,014	332
Feb	0	1,313	72	0	4,052	335
Mar	0	1,522	108	0	4,294	429
Apr	0	1,253	84	0	4,783	490
May	0	1,889	247	0	5,733	776
Jun	0	3,934	333	0	5,989	1,265
Jul	0	3,566	291	0	7,000	1,413
Aug	0	3,761	251	0	7,000	1,559
Sep	0	2,535	227	0	5,399	905
Oct	0	2,865	218	0	4,664	639
Nov	0	2,301	145	0	4,091	423
Dec	0	2,352	114	0	3,943	330

Monthly statistics on the availability of wetland habitat at the Refuge for the ASR alternative with low and high storage priorities are presented respectively in Tables VI-6 and VI-7. Peak habitat ranges up to approximately 700 acres for shorebirds and 1,000 acres for waterfowl. For the low storage priority alternative, average habitat areas are 372, 631, and 3,030 acres for shorebirds, waterfowl, and total wetlands, respectively. These same average values are only slightly higher for the high storage priority alternative at 382, 652, and 3,160 acres.

Table VI-6
AVAILABLE WETLAND HABITAT—ASR WITH LOW STORAGE PRIORITY [1]

Month	Shorebird (1–4 inches)		Waterfowl (10–18 inches)		Total Wetland	
	Range	Average	Range	Average	Range	Average
Jan	187-686	391	136-1,035	648	987-6,001	3,100
Feb	141-700	385	139-1,015	640	961-5,973	3,060
Mar	140-695	388	141-1,018	639	988-5,944	3,078
Apr	129-696	377	134-1,031	657	925-5,942	3,087
Sep	89-638	330	23-1,008	594	788-5,318	2,889
Oct	109-698	353	25-1,032	613	784-6,017	2,986
Nov	160-690	370	70-1,026	619	883-6,008	3,016
Dec	203-685	383	107-1,017	637	939-6,004	3,025
Sep–Apr	90-700	372	23-1,035	631	784-6,016	3,030

Note: 1. All wetland habitat values in acres. Statistics include data for primary migration season, September through April only.

Table VI-7
AVAILABLE WETLAND HABITAT—ASR WITH HIGH STORAGE PRIORITY [1]

Month	Shorebird (1–4 inches)		Waterfowl (10–18 inches)		Total Wetland	
	Range	Average	Range	Average	Range	Average
Jan	187-670	410	137-1,035	672	990-5,957	3,300
Feb	141-697	404	140-1,028	663	963-5,917	3,227
Mar	144-700	385	142-1,042	657	990-5,930	3,199
Apr	124-691	372	135-1,045	673	935-5,801	3,155
Sep	90-624	331	37-1,022	604	788-5,318	2,851
Oct	110-698	365	38-1,038	637	795-6,006	3,109
Nov	159-691	390	74-1,026	644	887-6,001	3,202
Dec	202-685	403	108-1,017	665	942-5,998	3,236
Sep–Apr	90-700	382	37-1,045	652	788-6,006	3,160

Note: 1. All wetland habitat values in acres. Statistics include data for primary migration season, September through April only.

The durations of available wildlife habitat for both the low and high storage priorities are shown in Figure VI-8. The 80th percentile habitat areas for both of these model runs and the change in these values over baseline conditions are 14 acres for low storage priority and 40 acres for high storage priority as listed in Table VI-8. As shown in this table, neither of the ASR alternatives are successful in providing significant additional habitat.

Table VI-8
CHANGES IN AVAILABLE WETLAND HABITAT

Habitat Type	ASR with Low Storage Priorities		ASR with High Storage Priorities	
	80th Percentile	Change over Baseline	80th Percentile	Change over Baseline
Optimum Shorebird	276	39	281	44
Optimum Waterfowl	368	14	374	20
Total Wetland	1,510	94	1,536	120

H. PROJECT COST ESTIMATES AND ECONOMICS

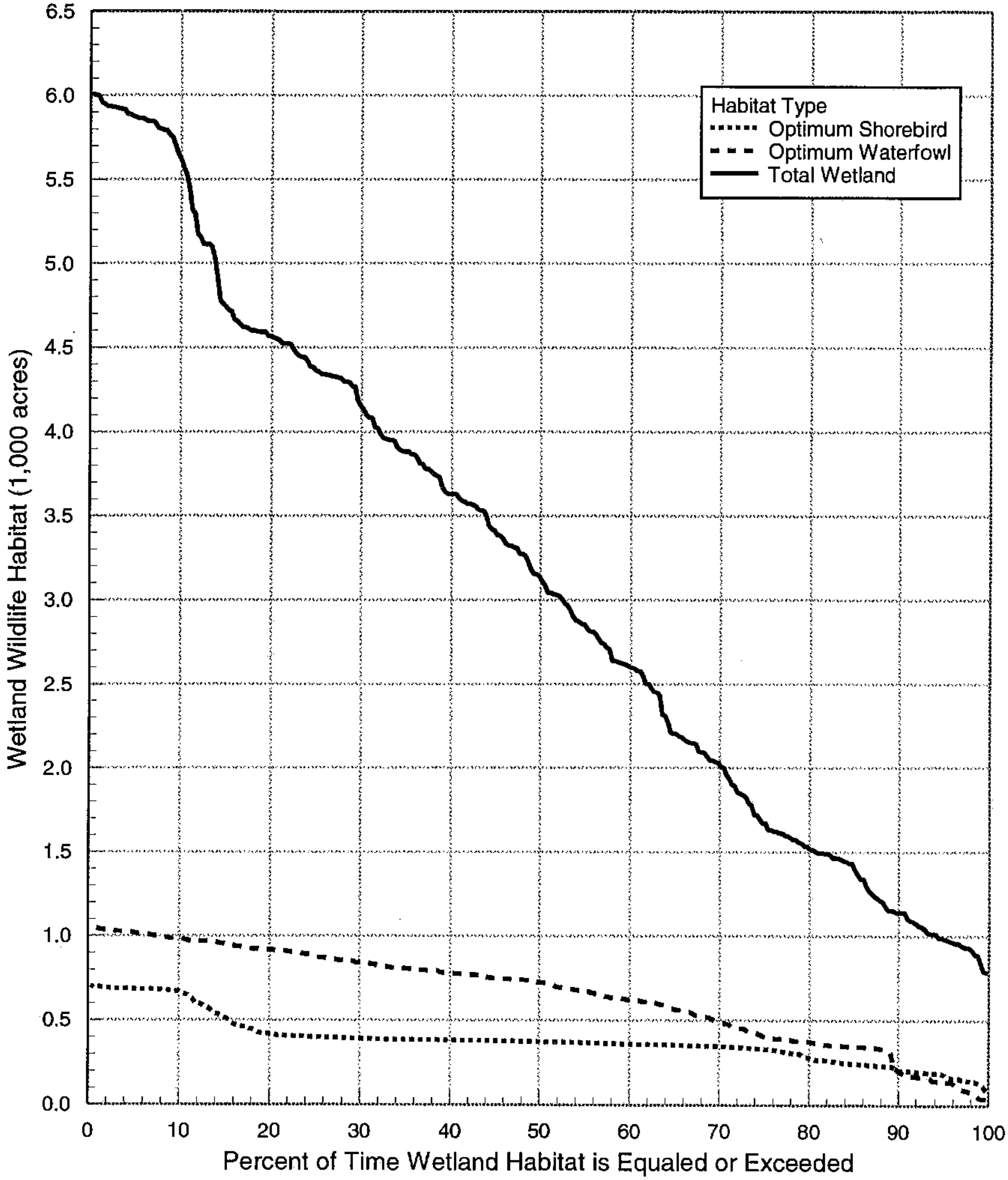
Project costs, operation, maintenance replacement and energy costs, present value and benefit cost analysis are detailed below for the recharge alternative. These costs are used in Task E for the purpose of comparing and selecting the best alternative(s) for implementation.

1. Project Cost

Project costs include construction costs and associated capital costs for the recharge alternative. The estimated project cost for this alternative is $17.0 million as listed in Table VI-9. The average life cycle unit cost of water is $4,275 per MG based on project costs.

2. Operation Maintenance, Replacement and Energy (OMR&E)

The operation and maintenance for this alternative requires one additional staff person, well cleaning, water quality testing and general operating and maintenance functions, replacement of mechanical equipment every 10 years, and energy costs as listed in Table VI-10. Costs for O&M are estimated to be $252,000 and energy is estimated to be $300,000 in the year 2000 for the aquifer recharge alternative.



Notes:
1. Developed from operations modeling for Quivira NWR for period 1/1955 through 12/1994 for ASR alternatives. Includes data for months of September through April only.
2. Optimum shorebird and waterfowl habitats defined as wetland areas 1-4 inches and 10-18 inches deep, respectively. Total wetland habitat is the sum of the surface areas of all ponded water in all management units, regardless of depth.
3. Habitat data reflect a high reservoir storage priority.

Burns & McDonnell

Figure VI-8

WETLAND HABITAT DURATIONS ASR ALTERNATIVE

Table VI-9
PROJECT COST ESTIMATE
AQUIFER RECHARGE, STORAGE & RECOVERY ALTERNATIVE - RECHARGE SITE A

Item	Subtotal Cost ($)	Total Cost ($)
PHASE I - INVESTIGATION & PILOT PROGRAM:		
Water Quality Sampling and Analysis (2 years)	1,000,000	
Test Drilling and Monitoring Well Siting (30 wells)	75,000	
Hydrologic and Environmental Studies	200,000	
Capture Well, Pump, Motor and Controls	80,000	
Pipeline (2 miles of 16")	264,000	
Recharge Well, Pump, Motor and Controls	110,000	
Piping, Valves, Fence and Access	15,000	
Land	14,000	
Access Road (2.5 miles)	277,000	
Electrical Power Supply (2 miles)	100,000	
Monitoring Wells (10)	25,000	
Data Collection/Instrucmentation (2 years)	120,000	
Environmental Documentation	100,000	
Operation Consul;ting	200,000	
SCADA System	50,000	
Phase 1 Subtotal	2,630,000	
Contingency at 20%	526,000	
Subtotal	3,156,000	
Other Costs at 5% (adjusted for services listed above)	158,000	
Phase I Project Cost		**3,314,000**

Table VI-9 (continued)
PROJECT COST ESTIMATE
AQUIFER RECHARGE, STORAGE & RECOVERY ALTERNATIVE - RECHARGE SITE A

Item	Subtotal Cost ($)	Total Cost ($)
PHASE II - DESIGN & CONSTRUCTION		
Test Drilling (64 holes)	96,000	
Capture Wells, Pump, Motor & Control (4 sets of 4 wells)	1,280,000	
Piping, Valves, Fence and Access	240,000	
Discharge Structure (4)	60,000	
Electrical Power Supply (5 miles)	600,000	
Collector Pipeline (2.5 miles of 12" PVC)	1,056,000	
Main Pipeline (2 miles of 16" PVC)	1,056,000	
Valves (air release, control, etc.)	200,000	
Recharge/Recovery Wells (4 sets of 4 wells)	1,600,000	
Piping, Valves, Fence and Access	240,000	
Electrical Power Supply (6 miles)	300,000	
Control Building and Monitoring Equipment (4 sets)	120,000	
Monitoring & Control (4 sets)	160,000	
Monitoring Wells (32)	80,000	
Land	191,000	
Access Road	2,661,000	
Concept and NEPA Document	200,000	
Use of Pilot Facilities	(640,000)	
Phase 1 Subtotal	9,500,000	
Contingency at 20%	1,900,000	
Subtotal	11,400,000	
Other Costs at 20%	2,280,000	
Phase II Project Cost		**13,680,000**
Total Project Cost		**16,994,000**
Average Annual Water Volume (MG)		**199**
Average Life Cycle Unit Cost of Water ($/MG)		**4,275**

Table VI-10
OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
AQUIFER RECHARGE, STORAGE & RECOVERY - RECHARGE SITE A

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	1.8	252,000		300,000	552,000
2001	1.8	262,000		312,000	574,000
2002	1.8	272,000		324,000	596,000
2003	1.8	283,000		337,000	620,000
2004	1.8	294,000		351,000	645,000
2005	1.8	306,000		365,000	671,000
2006	1.8	318,000		379,000	697,000
2007	1.8	331,000		395,000	726,000
2008	1.8	344,000		410,000	754,000
2009	1.8	358,000		427,000	785,000
2010	1.8	372,000	3,074,000	444,000	3,890,000
2011	1.8	387,000		462,000	849,000
2012	1.8	402,000		480,000	882,000
2013	1.8	418,000		499,000	917,000
2014	1.8	435,000		519,000	954,000
2015	1.8	452,000		540,000	992,000
2016	1.8	470,000		562,000	1,032,000
2017	1.8	489,000		584,000	1,073,000
2018	1.8	509,000		607,000	1,116,000
2019	1.8	529,000	4,375,000	632,000	5,536,000
Total	36.1	7,483,000	7,449,000	8,929,000	23,861,000

Notes:
1. Average pumping rate for 110 days per year.
2. O&M includes additional staff and materials, testing and operations.
3. Replacement of equipment every 10 years.
4. Energy costs are estimated at $.12/KWH.

3. Present Value Cost

A present value analysis is used to estimate the cost of the alternative in present day dollars over a service period of 20 years. The present value for the aquifer recharge alternative is $39.0 million in 1998 dollars as listed in Table VI-11. The average life cycle unit cost of water for this alternative is $9,807 per MG over 20 years of operation based on present value.

4. Benefit-Cost Analysis

The benefit-cost analysis shows the ratio of the project's benefits to the project's costs. A benefit of 120 acres of additional wetlands are estimated for the recharge alternative over a 20 year present value of $1,085,000. This results in a benefit cost-ratio of 0.0278.

Table VI-11
PRESENT VALUE ESTIMATE
AQUIFER RECHARGE, STORAGE & RECOVERY - RECHARGE SITE A

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0	1,657,000			1,657,000	1,657,000
1999	0	1,723,000			1,610,000	3,267,000
2000	1.8	14,796,000	552,000	15,348,000	26,329,000	29,596,000
2001	1.8		574,000	574,000	469,000	30,065,000
2002	1.8		596,000	596,000	455,000	30,520,000
2003	1.8		620,000	620,000	442,000	30,962,000
2004	1.8		645,000	645,000	430,000	31,392,000
2005	1.8		671,000	671,000	418,000	31,810,000
2006	1.8		697,000	697,000	406,000	32,216,000
2007	1.8		726,000	726,000	395,000	32,611,000
2008	1.8		754,000	754,000	383,000	32,994,000
2009	1.8		785,000	785,000	373,000	33,367,000
2010	1.8		3,890,000	3,890,000	1,727,000	35,094,000
2011	1.8		849,000	849,000	352,000	35,446,000
2012	1.8		882,000	882,000	342,000	35,788,000
2013	1.8		917,000	917,000	332,000	36,120,000
2014	1.8		954,000	954,000	323,000	36,443,000
2015	1.8		992,000	992,000	314,000	36,757,000
2016	1.8		1,032,000	1,032,000	305,000	37,062,000
2017	1.8		1,073,000	1,073,000	297,000	37,359,000
2018	1.8		1,116,000	1,116,000	288,000	37,647,000
2019	1.8		5,536,000	5,536,000	1,337,000	38,984,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						**9,807**

PART VII

TASK C - REFUGE ALTERNATIVES

This section of the report describes eight on-site and two off-site water management alternatives for the Refuge. Each of these ten alternatives are evaluated using engineering and environmental criteria. The ten alternatives investigated for Task C are listed below:

- Alternative 1—Raise dikes in Little Salt Marsh.
- Alternative 2—Construct cross dikes in Little Salt Marsh.
- Alternative 3—Develop additional water storage units.
- Alternative 4—Line conveyance canals.
- Alternative 5—Remove sediment from Little Salt Marsh.
- Alternative 6—Construct bypass canal around Little Salt Marsh.
- Alternative 7—Recontour additional areas to develop moist soil units.
- Alternative 8—Fill borrow areas.
- Alternative 9—Supplement with water supply from Arkansas River.
- Alternative 10—Supplement with water supply from groundwater.

Five of these alternatives, Alternatives 1, 2, 3, 5 and 6, would provide additional water storage or maintain existing storage on the Refuge. Alternatives 4 and 8 would conserve water for use in the management units. Two of these alternatives, Alternatives 9 and 10, would provide a supplemental water supply to the Refuge. One alternative, Alternative 7, would create additional management units on the Refuge. The investigations and evaluations completed for these ten alternatives are discussed in the remainder of this section.

A. ALTERNATIVE 1 - RAISE DIKES IN LITTLE SALT MARSH

1. General

This alternative evaluates raising the existing dikes in Little Salt Marsh (Unit 5) to increase water storage. Little Salt Marsh is the first point of diversion on the Refuge from Rattlesnake Creek and is the facility that provides the largest storage volume. Stored water is released from Little Salt Marsh for use in the other Refuge management units.

This alternative includes raising the existing surface water elevation of Little Salt Marsh from 1783 feet[1] to 1785 feet. This 2-foot increase enlarges the marsh's water surface area from 860 to 1,300 acres, and provides an additional 1,940 acre-feet of storage. The impacts of increasing storage in Little Salt Marsh are discussed below.

2. Little Salt Marsh

Elevation-area-capacity data for the enlarged Little Salt Marsh are listed in Table VII-1 . The data up to elevation 1,784 are based on equations provided by the U.S. Fish & Wildlife Service (Service). The data for elevation 1785 feet is based on planimetering U.S. Geological Survey (USGS) 7.5-minute topographic maps.

Table VII-1
ELEVATION-AREA-CAPACITY FOR THE ENLARGED LITTLE SALT MARSH

Elevation (feet)	Area (acres)	Storage (acre-feet)
1780	310	1
1781	530	420
1782	750	1,060
1783	860	1,870
1784	980	2,670
1785 [1]	1,300	3,810

Note: 1. Area for elevation 1785 feet was planimetered.

[1] All elevations cited in this document are heights above the National Geodetic Vertical Datum of 1929 and were estimated from available U.S. Geological Survey topographic maps.

Review of USGS topographic maps indicates that elevation 1785 feet is the maximum possible water surface elevation that Little Salt Marsh can be increased to and remain within existing Refuge boundaries. Additionally, this elevation also allows Rattlesnake Creek to remain within its channel on Refuge property.

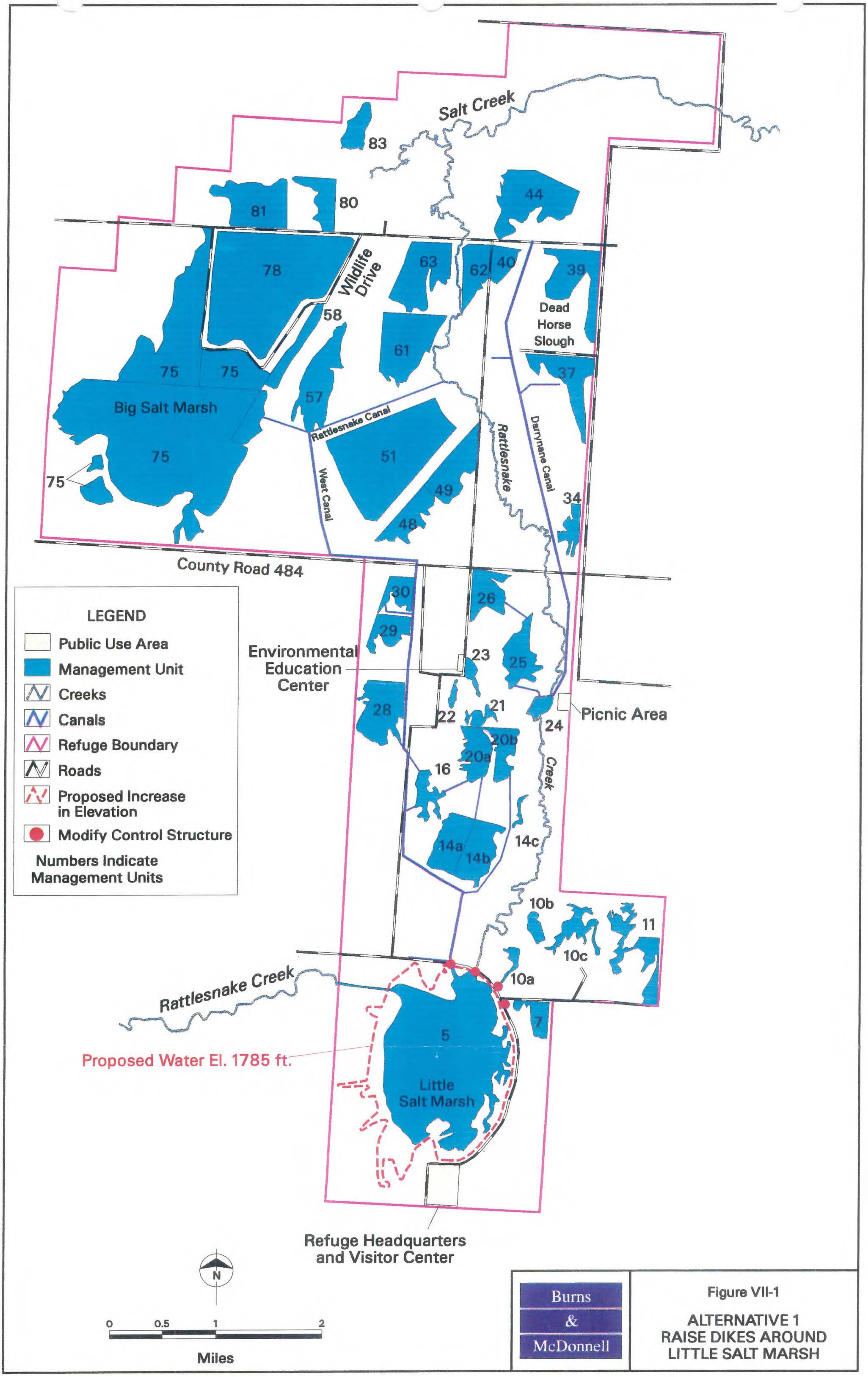
3. Preliminary Concept Design

The preliminary concept design for this alternative provides an additional two vertical feet of water storage and expands the water surface area in Little Salt Marsh (Unit 5) as shown in Figure VII-1. The concept design includes the following major components:

- Raise 6,900 linear feet of existing dikes.
- Construct 2,200 linear feet of new dikes.
- Construct 8,500 linear feet of gravel road on top of dike.
- Construct four new water control structures.
- Construct two new concrete spillways.

Little Salt Marsh provides critical water storage for downstream management units in the Refuge. Therefore, two important features of this alternative are to store as much water as possible for times of need and to minimize water losses due to leakage. To minimize leakage from Little Salt Marsh, an impervious clay barrier would be used in the construction of new or raised dikes. This should minimize leakage through dikes; however, water would be expected to continue to percolate through the bottom of the marsh.

Typical cross sections for the new and raised dikes are shown in Figure VII-2. For new dike sections, the impervious material is placed on the upstream side of the dike. A cutoff trench is keyed into existing surface soils at the toe of the dike to a depth of five feet. Five feet is the estimated depth to a silty-loam layer that acts as an impervious barrier to deter leakage from Little Salt Marsh. Actual soil conditions and design parameters should be determined in the final design to further refine the dike cross-section should this alternative be selected.

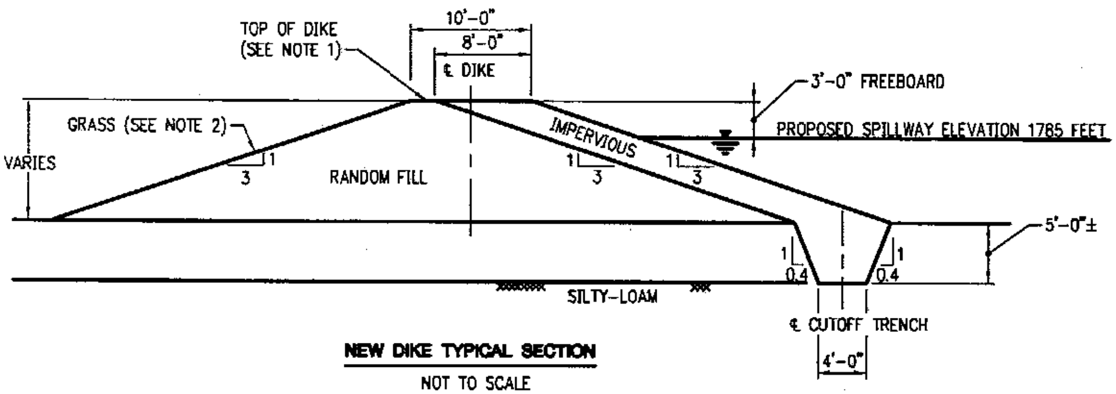


Burns & McDonnell

Figure VII-1

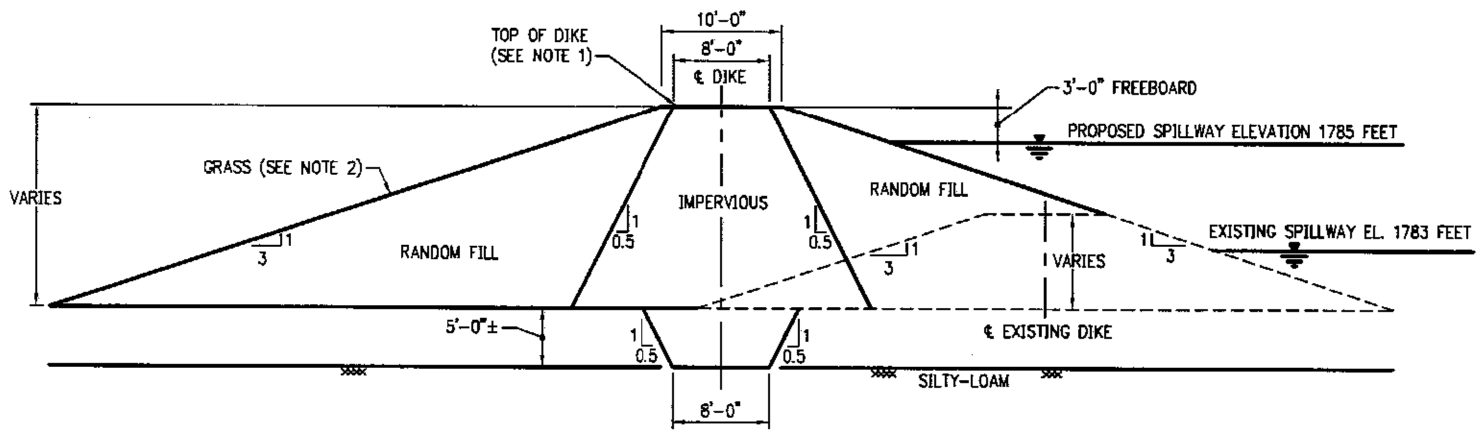
ALTERNATIVE 1
RAISE DIKES AROUND
LITTLE SALT MARSH

J:\U... WS\978064\procws\berm01.DWG 02-06-1998 14:05 AAO



NEW DIKE TYPICAL SECTION

NOT TO SCALE



RAISED DIKE TYPICAL SECTION

NOT TO SCALE

NOTES:

1. TOP OF DIKE INCLUDES 10 FEET WIDTH GRAVEL ROAD.
2. GRASS WILL BE PLANTED ON UPSTREAM FACE OF DIKE TO WATER SURFACE ELEVATION AND ENTIRE DOWNSTREAM FACE OF DIKE FOR EROSION CONTROL.

Burns & McDonnell

Figure VII-2

ALTERNATIVE 1
TYPICAL DIKE CROSS SECTIONS

For existing dike sections, a raised dike would be constructed on the downstream side of the existing dike, eliminating the need to drain Little Salt Marsh. The impervious core would be centrally located in the raised dike. A cutoff trench is keyed through the existing surface soil layer to the silty-loam layer mentioned above.

The proposed dikes are conceptually designed with 3:1 slopes based on field surveys of potential fill material. Random fill material would be obtained from borrow areas in the vicinity. For the impervious material, Carwile and Pratt soils can be obtained west and southeast of Little Salt Marsh within Refuge boundaries. An abundant supply of these impervious soils is also available north of the unit in the vicinity of Dead Horse Slough. These two soil types have a permeability that ranges from 0.06 to 2.0 inches/hour and a moderate to high, shrink-swell potential.

Gravel roads would need to be constructed on top of the new or raised dikes for access to control structures and maintenance. A warm season native grass seed mixture, made up of species found in the Refuge, would be planted on both the upstream (to water surface only) and downstream sides of the dike to control erosion. Additionally, two new concrete spillways each 300 feet wide would be constructed to replace the two existing spillways. The newly constructed concrete spillways will have crest elevations of 1,787 feet, one foot below the proposed top of dike elevation of 1788 feet.

To accommodate the raised dike, Control Structures C1, A1, A2 and A3 would be replaced with new structures similar to the existing structures. The invert elevation for C1, A1 and A2 is approximately 1778 feet. A total depth of water on the new structures would be seven feet, which includes the proposed two-foot increase. A total freeboard of three feet is assumed for this concept design. Control Structures C1 and A1 are gated with three bays 4.5 foot wide. Control Structure A2 is gated with three bays that are 10 feet wide. Control Structure A3 is a stoplog structure six feet high.

4. Operations Model

The potential benefits due to increased storage in Little Salt Marsh are estimated using the operations model for the Refuge and Rattlesnake Creek Basin. The development of the base operations model is described earlier in Part III. No changes to the schematic for the base operations model are necessary to investigate this alternative. The required change modifies the elevation–area–capacity data for Little Salt Marsh to reflect the increased spillway elevation and correspondingly larger storage potential. The storage priority data for Little Salt Marsh are also revised.

Execution of the operations model for this alternative shows that the additional storage volume in Little Salt Marsh increases the average water quantity available to the Refuge by about 7 percent. The average annual diversions to the Refuge would increase from a baseline value of 6,858 acre-feet to 7,359 acre-feet, an increase of 501 acre-feet per year.

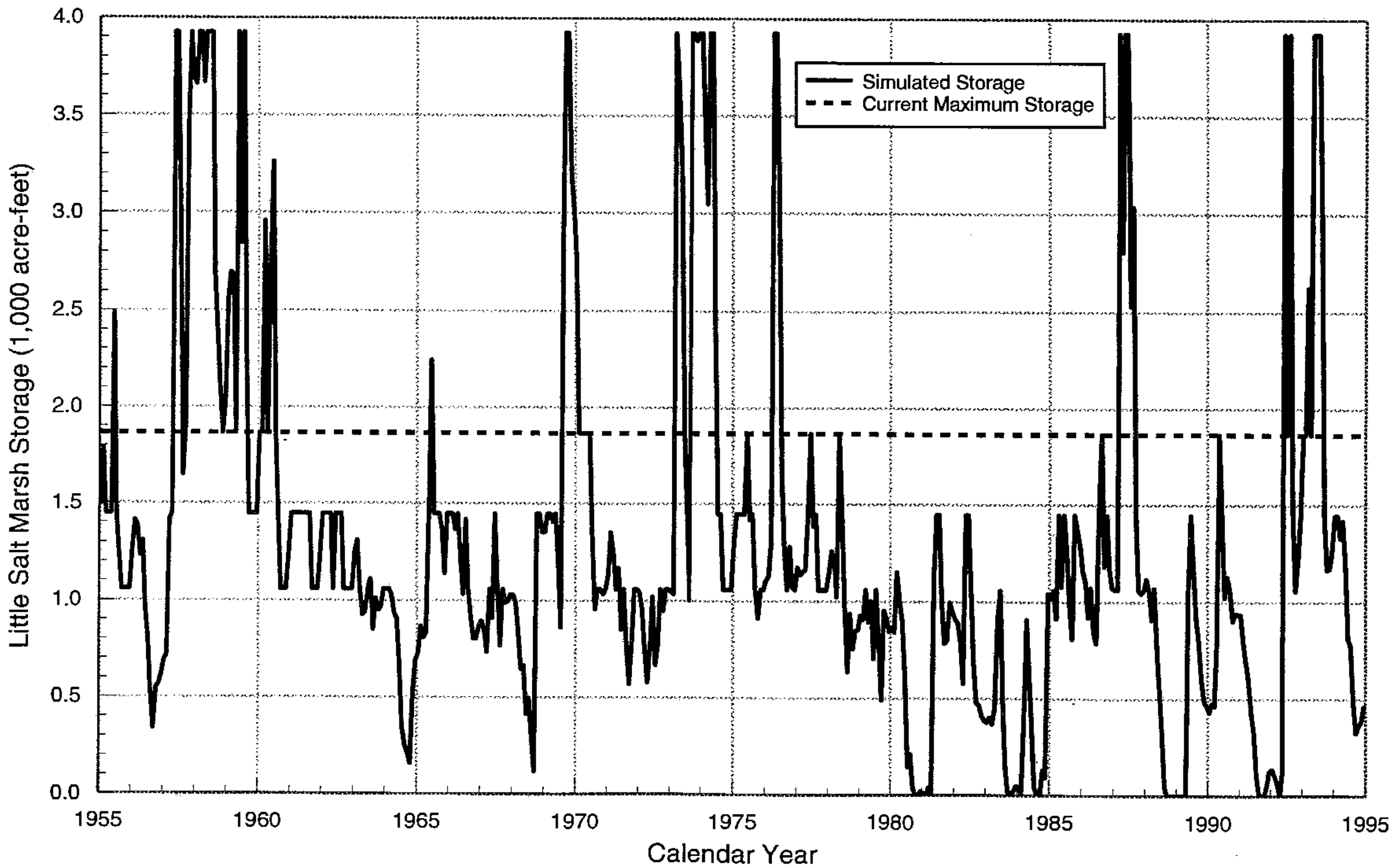
The simulated end-of-month storage contents in Little Salt Marsh are shown in Figure VII-3 . This graph shows a number of periods during the 40-year simulation period when the additional storage capacity of the marsh could be utilized; however, this additional storage is insufficient to provide carryover storage for dry periods. Figure VII-3 shows there are several periods during the 1980's and 1990's when the Little Salt Marsh could be expected to be completely dry.

Statistics on the availability of wetland habitat at the Refuge for this alternative are presented in Table VII-2. Also shown in this table are the corresponding baseline values. The increases in the optimum habitat for shorebirds and waterfowl are quite modest but the average amount of total wetland habitat increases by about 123 acres.

Table VII-2
AVAILABLE WETLAND HABITAT—ALTERNATIVE 1 [1]

Alternative	Shorebird (1–4 inches)		Waterfowl (10–18 inches)		Total Wetland	
	Range	Average	Range	Average	Range	Average
Baseline	85-684	358	11-1,055	602	692-6,000	2,757
C.1	85-736	371	11-1,017	607	692-6,442	2,880

Note: 1. All wetland habitat values in acres. Statistics include data for primary migration season, September through April only.



Notes
1. End-of-month unit storage obtained from operations simulation for Alternative 1.
2. This alternative assumes spillway crest elevation at Little Salt Marsh is raised 2 feet from current level of 1,783 feet to 1,785 feet.

Burns & McDonnell

Figure VII-3

SIMULATED STORAGE LITTLE SALT MARSH ALTERNATIVE 1

The 80th percentile habitat areas and the change in these values over baseline conditions are shown in Table VII-3. The durations of available wetland habitat for this alternative are shown on Figure VII-4, along with the habitat durations for baseline conditions. Review of this graph shows that the increased storage in Little Salt Marsh has no impact on the availability of habitat that now occurs more than about 60 percent of the time.

Table VII-3
CHANGES IN AVAILABLE WETLAND HABITAT—ALTERNATIVE 1

Habitat Type	Wetland Habitat (acres)	
	80th Percentile	Change over Baseline
Optimum Shorebird	237	0
Optimum Waterfowl	358	4
Total Wetland	1,415	0

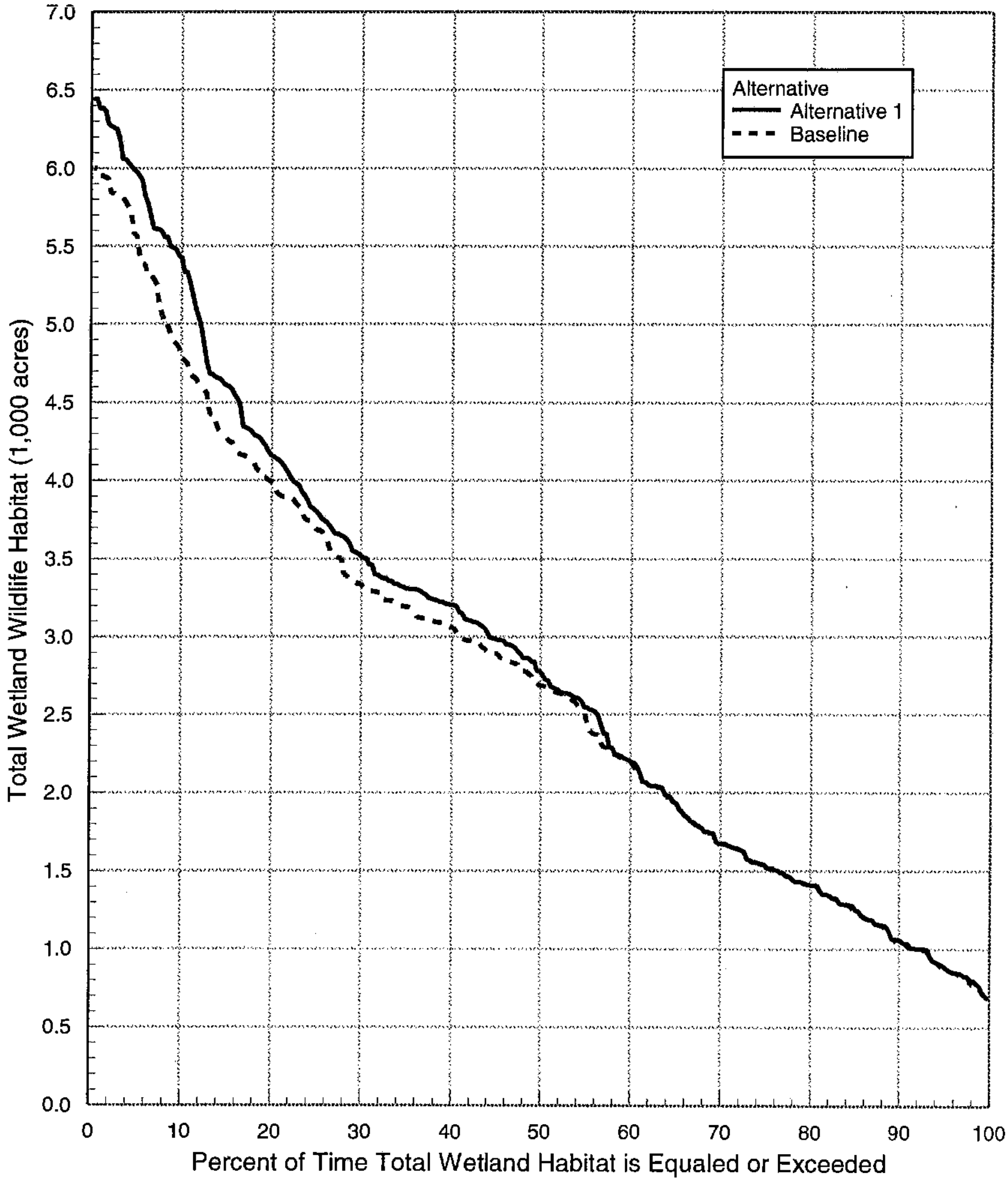
Table VII-3 shows that implementation of this alternative would have little impact on wetland habitat available at the Refuge 80 percent of the time. This results because the additional storage in Little Salt Marsh can extend the length of surplus periods but cannot provide multi-year carryover storage during droughts.

5. Water Quality

The source water for the additional storage in this alternative is Rattlesnake Creek, the Refuge's current water supply. Use of additional water from Rattlesnake Creek, when available, would not adversely impact the water quality in the Refuge.

6. Environmental and Cultural Resource Impacts

Currently, Little Salt Marsh (Unit 5) has a normal water surface elevation of approximately 1783 feet. At this surface elevation, water depths within the marsh average about two feet, ranging from only a few inches around the periphery up to four feet in the deeper portions. This range of depths provides abundant habitat for shorebirds, wading birds, and all types of ducks and geese that occur within the Central Flyway. The marsh also provides seasonal habitat for migrating sandhill cranes, federally endangered whooping cranes and peregrine falcons, and federally threatened bald eagles.



Notes:
1. Developed from operations modeling for Quivira NWR for period 1/1955 through 12/1994. Includes data for months of September through April only.
2. Total wetland habitat is the sum of the surface areas of all ponded water in all management units, regardless of depth.

Burns & McDonnell

Figure VII-4

WETLAND HABITAT DURATIONS ALTERNATIVE 1

Vegetation within the marsh is predominantly cattails. Various species of sedges, rushes and other wetland species occur in the shallower areas of the marsh and around the periphery. Cattails, however, occur throughout the marsh and have the potential to fill in existing open water areas. Currently, large areas throughout the marsh are heavily overgrown with cattails. While these areas provide cover for some wildlife species, they generally reduce the open water areas preferred by most species of waterfowl. Such growths of cattails are, therefore, generally less desirable. Open areas (without cattails) within the marsh are likely a result of deeper water levels that inhibit cattail growth and survival.

Vegetation around the periphery of the marsh is characteristic of very shallow water and moist soils. This is due to both the shallow nature of the water in these areas and the seasonal decrease in water levels during the hot, dry summer months. As these areas dry, excellent habitat for shorebirds results. During the late summer and early fall when wetland annuals have matured, water levels generally increase to flood these peripheral areas, providing excellent habitat for waterfowl.

With an average depth of approximately two feet and a maximum depth of approximately four feet, the majority of the marsh has the potential to be overgrown with cattails. Undoubtedly, much of this cattail growth occur in areas at or near the depth limits where they are able to survive. An increase in the water level would result in the replacement of these cattail communities with areas of open water. Increasing the depth of Little Salt Marsh would eliminate some of the existing cattail areas within the marsh, creating more open water having depths up to approximately six feet. Based on review of aerial photographs, it is estimated that about 20 acres of cattails currently existing within the deeper zones of Little Salt Marsh would be eliminated. Cattails currently found around the marsh periphery would be largely unaffected.

About 440 acres of new shallow water areas, outside the existing marsh pool, would be created by the inundation of peripheral lands. These new areas would be of suitable depth for colonization, establishment, and growth of cattails. An additional 420 acres of suitable cattail habitat would be developed; however, this new cattail habitat would be confined to the periphery of the marsh and have less potential for choking out open-water areas. These cattails would provide sufficient cover for wildlife species preferring this type of habitat while serving as a barrier ring around the marsh, helping to isolate wildlife from human activities on the Refuge and providing the security of large areas of open water. Habitat changes in acres to Little Salt Marsh resulting from this alternative are summarized as follows:

Habitat	Current	Created	Net Total	Net Change
Open water	650	20	670	20
Cattail marsh	210	440	630	420
Moist soil/grassland	440	0	0	-440

Other types of wetlands and moist soil vegetation would also develop around the periphery of the marsh. As with cattails, the inundation of adjacent areas surrounding Little Salt Marsh would result in more habitat for these wetland or moist soil species than is currently available. The existing vegetation of these areas, comprised mainly of grassland communities, would be lost. However, grassland communities are abundant throughout the basin as well as the Refuge.

Overall impacts to existing wildlife would be positive. Increased water levels in Little Salt Marsh would increase the acreages of open water available and preferred by most wildlife species, while maintaining or increasing the area of cattail areas and other wetland plants used for cover, nesting, and food. The primary impact to wildlife would be the temporary disturbance occurring during construction due to human activity and operation of heavy equipment. Construction activities would be scheduled during the drier summer months. During this time, wildlife use of the marsh is at its lowest point of the year, thus reducing the potential for disturbing and stressing significant numbers of individuals or species. Additionally, the wildlife present during the summer months would be primarily local species which are generally in better physical condition, adapted to local conditions, and less susceptible to stress than migrants. Wildlife that is present on Little Salt Marsh during construction could seek suitable refuge in more secluded areas of the marsh, away from construction activities.

Benefits to wildlife would occur for years to come following completion of dike construction. The additional water stored would enable Service personnel to provide a more dependable quantity and quality of wetland habitat on the Refuge. While not as important in normal or wet years due to habitat being widely available in the basin, the more dependable availability of habitat in dry years would provide even more critical stopping, resting, staging, and recuperating area during spring and fall migrations for migratory bird species, including endangered whooping cranes.

Upland wildlife using grasslands adjacent to the Little Salt Marsh would experience a reduction in habitat with the inundation of additional land areas and their conversion to marsh habitat. The benefits to wildlife, including threatened and endangered species, from the increase in marsh habitat and water availability, are considered to be more valuable than the loss of more common grassland habitat and the impacts it would have on upland wildlife within the basin and on the Refuge.

Prehistoric and historic peoples probably exploited the various resources of the Little Salt Marsh and the surrounding micro-environment. Campsites, food processing sites, and other limited activity areas associated with the retrieval of locally available resources would have been situated on the numerous rises in the area. This theory is based on other studies of natural lakes in the Plains and previously recorded archaeological sites in the Rattlesnake Creek Basin. Increasing the pool level of the marsh would likely affect sites found on the few rises in the marsh. Presumably, if Alternative 1 is selected, elevated portions or rises not previously inundated may require geomorphological and archaeological field investigations. It is likely that any sites discovered would be significant based on previous studies of similar type environments, the undisturbed nature of the sites, and the lack of known or recorded sites within the basin.

7. Project Cost Estimates

Project costs, operation and maintenance costs, present value and benefit-cost analysis for this alternative follow. Costs developed here are used in Task E to compare and select which alternative(s) should be included in a water supply plan for the Refuge and for implementation.

a. Project Costs

Project costs include construction costs and associated capital costs for Alternative 1. The estimated project cost for Alternative 1 is $1.4 million as listed in Table VII-4. The average life cycle unit cost of water for Alternative 1 is $430 per million gallons (MG) based on project costs.

Table VII-4
PROJECT COST ESTIMATE
ALTERNATIVE 1 - RAISE DIKES IN LITTLE SALT MARSH

Item	Cost ($)
Construct New and Raise Existing Dikes	368,000
Concrete Spillways	30,000
Erosion Control	10,000
Elevate Roads on Top of Dike	179,000
Water Control Structure for C1	100,000
Water Control Structure for A1	100,000
Water Control Structure for A2	180,000
Water Control Structure for A3	7,000
Subtotal	974,000
Contingency at 20%	195,000
Subtotal	1,169,000
Other Costs at 20%	234,000
Total Project Cost	**1,403,000**
Average Annual Water Volume (MG)	**163**
Average Life Cycle Unit Cost of Water ($/MG)	**430**

b. Operation and Maintenance (O&M) Costs

O&M costs presented here are those associated with the operation and maintenance of Alternative 1. The implementation of this alternative should not significantly change existing operation and maintenance costs for Little Salt Marsh. Additionally, this alternative does not include any mechanical equipment which would require replacement or energy. Therefore, there would be no additional O&M costs for this alternative.

c. Present Value Analysis

A present value analysis is used to estimate the cost of the alternative in present day dollars over a service period of 20 years. The present value for Alternative 1, in 1998 dollars, is $1.36 million. The average life cycle unit cost of water for Alternative 1 is $418 per MG over 20 years of operation based on present value.

d. Benefit-Cost Analysis

The benefit-cost analysis shows the ratio of the project's benefits to the project's costs. Development of this alternative would not increase the amount of wetland habitat that is available at the Refuge at least 80 percent of the time. Therefore, as discussed in Part IV, this alternative is considered to have no substantial benefits and a benefit-cost ratio of 0.0.

B. ALTERNATIVE 2 - CONSTRUCT CROSS DIKES IN LITTLE SALT MARSH

1. General

This alternative evaluates constructing a new circular ring dike within Little Salt Marsh to increase its storage. Two different scenarios are evaluated for this alternative.

Scenario 1 includes a 7-foot high ring dike that allows for the marsh's existing water surface elevation to be raised from 1783 to 1785 feet within the ring dike. Water would be delivered to the new impoundment area by gravity flow from Rattlesnake Creek. This scenario provides an additional 560 acre-feet of water storage capacity in Little Salt Marsh.

Scenario 2 includes a 17-foot high ring dike that allows for the existing water surface elevation to be raised from 1783 feet to 1795 feet within the ring dike. Water would be delivered to the new impoundment area by a pump station. This scenario provides an additional 3,360 acre-feet of water storage capacity in Little Salt Marsh.

2. Little Salt Marsh

The two development scenarios for Little Salt Marsh under this alternative are discussed below.

a. Scenario 1 - Gravity Flow

A ring dike, 4,000 feet in diameter, would be constructed within the existing area of Little Salt Marsh. This structure would allow the water surface elevation within the diked area to be raised to 1,785 feet, two feet above current conditions. Water would be delivered to this expanded storage area by gravity flow from Rattlesnake Creek. Whit this scenario, the existing storage potential of the marsh would increase by 560 acre-feet from 1,870 to 2,430 acre-feet. Elevation-area-capacity data for the marsh under proposed conditions are listed in Table VII-5. The construction of the ring dike allows for increased storage in Little Salt Marsh without disrupting existing shallow water habitat on the periphery of the marsh.

Table VII-5
ELEVATION-AREA-CAPACITY DATA FOR LITTLE SALT MARSH
SCENARIO 1

Elevation (feet)	Area (acres)	Capacity (acre-feet)
1780	310	1
1781	530	420
1782	750	1,060
1783	860	1,870
1784	1,140	2,140
1785	1,140	2,430

b. Scenario 2 - Pump Station

Scenario 2 is similar to Scenario 1 except that the ring dike would be ten feet higher. This would allow for storage of water within the diked area up to elevation 1,795 feet, an increase of 12 feet over current conditions. This scenario would increase the storage potential of the marsh by 3,360 acre-feet to a total of 5,230 acre-feet. Table VII-6 lists elevation-area-capacity data for the modified marsh.

Table VII-6
AREA-CAPACITY FOR LITTLE SALT MARSH
SCENARIO 2

Elevation (feet-USGS)	Area (acres)			Capacity (acre-feet)		
	Inside Ring	Outside Ring	Total	Inside Ring	Outside Ring	Total
1780	280	30	310	0	1	1
1781	280	250	530	0	420	420
1782	280	470	750	280	780	1,060
1783	280	580	860	560	1,310	1,870
1785	280	580	860	1,120	1,310	2,430
1795	280	580	860	3,920	1,310	5,230

3. Preliminary Concept Design

a. Scenario 1 - Gravity Flow

The preliminary concept design for this alternative provides an additional 2 vertical feet of storage as shown in Figure VII-5. To enable water to flow by gravity into this ring dike, levees must be constructed along the banks of Rattlesnake Creek to contain water to an elevation of 1785 feet. The concept includes the following major components:

- Construct 14,060 linear feet of new dikes.
- Construct 4,700 linear feet of berm along the banks of Rattlesnake Creek.
- Construct 13,760 linear feet of gravel road on top of the new ring dike.
- Construct one new water control structure in the ring dike for release of water into the remainder of Little Salt Marsh.
- Construct one concrete spillway on top of the ring dike.

Prior to dike construction, sheetpiling would be placed to divide Little Salt Marsh into a north and south section. Streamflow in Rattlesnake Creek would continue to fill the north section. Once the south section is drained of water, construction of the proposed ring dike would begin.

This ring dike structure would provide additional water supply storage on the Refuge for management of downstream units. Therefore, two important features of this scenario are to store as much water as possible for times of need and to minimize losses due to leakage. To minimize leakage from this ring dike structure, an impervious clay barrier is used in the construction of the new dikes as shown in Figure VII-6. This should minimize leakage through the dike, but water would continue to percolate through the bottom of the marsh.

The impervious core is centrally located in the new dike. A cutoff trench is keyed into the existing surface soil layer to a depth of five feet. This is the estimated depth of a silty-loam layer that serves as an impervious barrier to deter leakage through the dike from Little Salt Marsh. Actual soil conditions

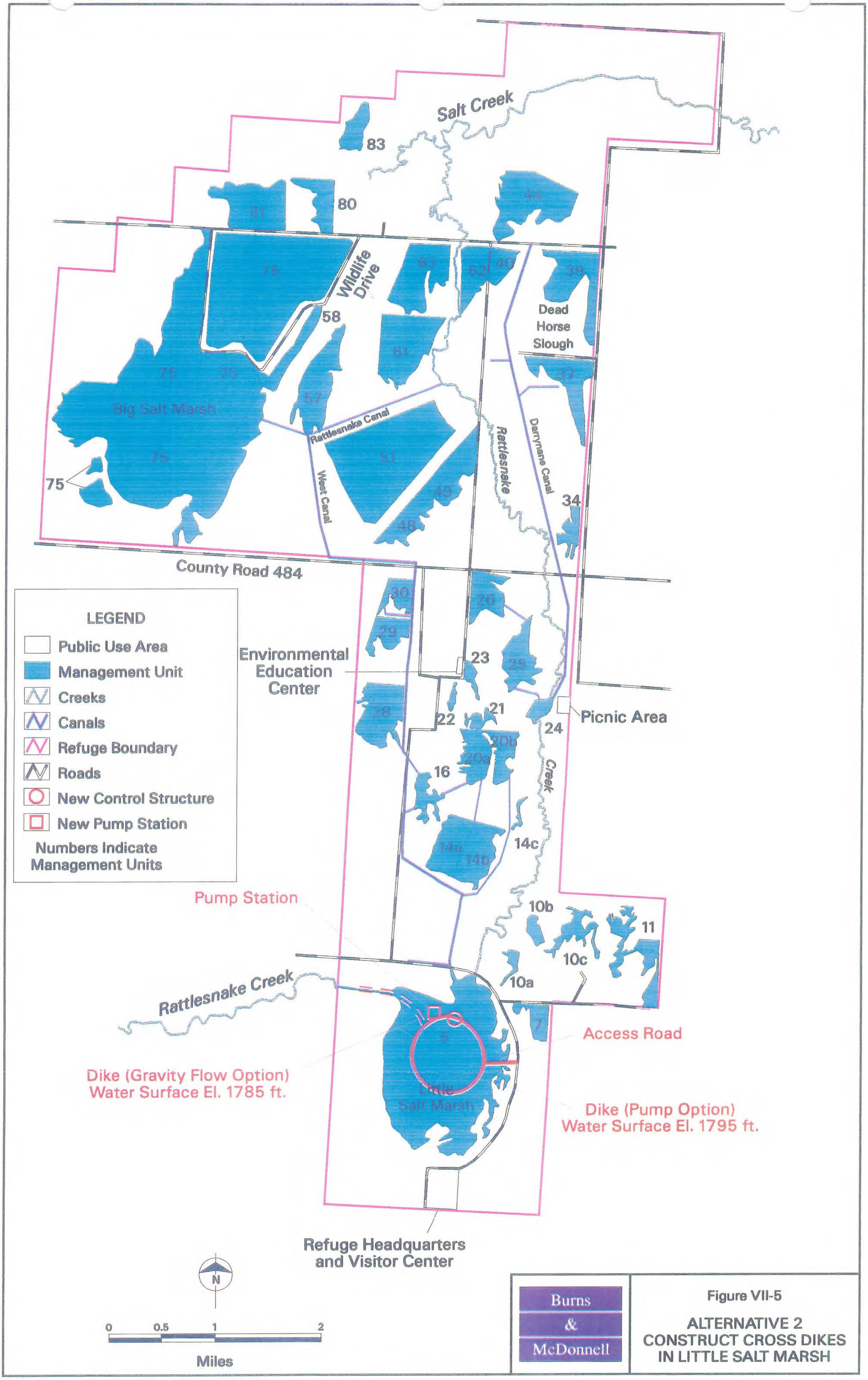
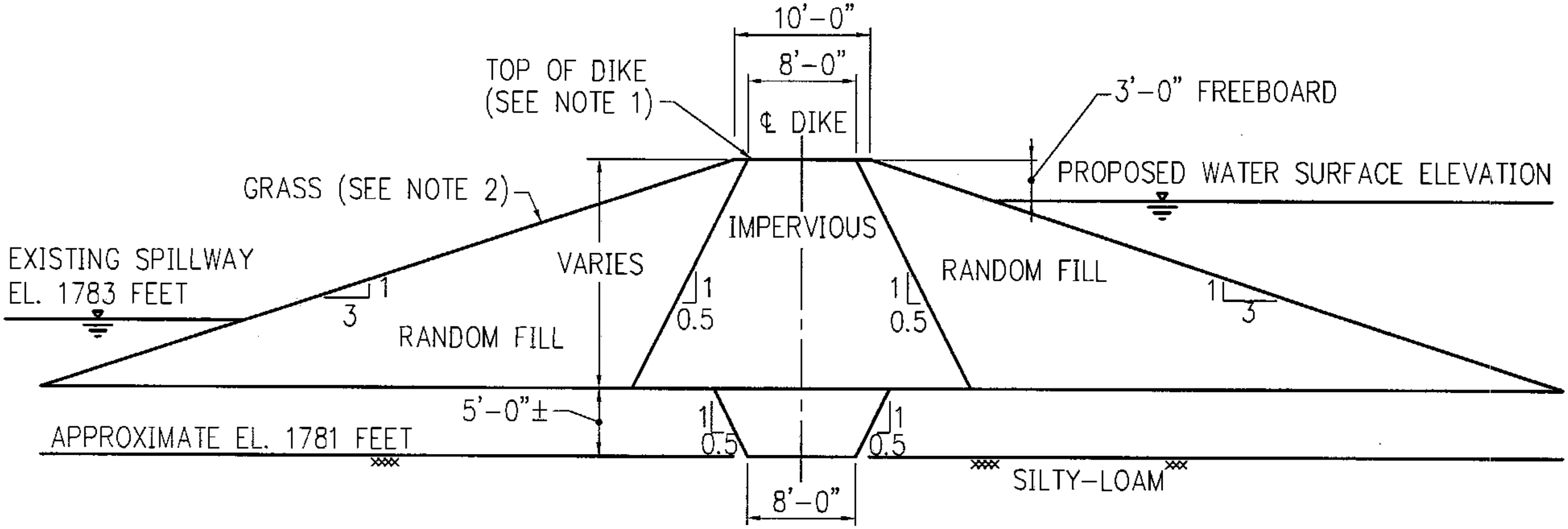


Figure VII-5

ALTERNATIVE 2
CONSTRUCT CROSS DIKES
IN LITTLE SALT MARSH



NEW DIKE TYPICAL SECTION

NOT TO SCALE

NOTES:

1. TOP OF DIKE INCLUDES 10 FEET WIDTH GRAVEL ROAD.
2. GRASS WILL BE PLANTED ON UPSTREAM FACE OF DIKE TO WATER SURFACE ELEVATION AND ENTIRE DOWNSTREAM FACE OF DIKE FOR EROSION CONTROL.

Burns & McDonnell

Figure VII-6

ALTERNATIVE 2
TYPICAL DIKE CROSS SECTIONS

and design parameters should be assessed in final design to further refine the dike cross-section should this alternative be selected.

The proposed dikes are conceptually designed with 3:1 slopes based on the field survey of potential fill material. Random fill material would be obtained from borrow areas in the vicinity. For the impervious material, Carwile and Pratt soils can be obtained from borrow areas west and southeast of Little Salt Marsh. An abundant supply of these impervious soils is available in the vicinity of Dead Horse Slough if needed for construction. Permeability for these two types of soils range from 0.06 to 2.0 inches/hour and have moderate to high, shrink-swell potential.

An access road to the ring dike would be located on the east side of the ring dike. This location is the shortest distance from an existing raised berm to the ring dike which would allow Refuge staff to gain access to the control structure. The access road would be constructed over a new 12-foot by 4-foot box culvert to allow maintenance of water levels around the periphery of the ring dike.

A gravel road would be constructed on top of the new dikes to allow access to the control structure and for maintenance of the dikes. A warm season native grass seed mixture containing species that occur within Refuge area would be planted on both the upstream side and the downstream side (to water surface area only) of the dike for erosion control. A concrete spillway 300 feet in width would be placed on the north side of the ring dike. The crest elevation for this new spillway will be one foot below the proposed top of dike elevation.

A new control structure would be placed on the north side of the ring dike at the approximate invert elevation of 1781 feet. This structure is gated with three 10-foot wide bays. The maximum water depth on the structure is 4 feet and freeboard is 3 feet.

b. Scenario 2 - Pump Station

The preliminary concept design for Scenario 2 of the ring dike alternative provides an additional 12 vertical feet and associated storage as shown in Figure VII-5. Two pump capacities are considered for filling the ring dike; 40 million gallons per day (MGD) and 80 MGD. A 40 MGD pump station is capable of filling the ring dike in four weeks and an 80 MGD pump station in two weeks based on continuous pumping and no losses. The concept includes the following major components:

- Construct 14,060 linear feet of new dikes.
- Construct 13,760 linear feet of gravel road on top of the ring dike.
- Construct one new water control structures for release of water into Little Salt Marsh.
- Construct one concrete spillway on top of dike.
- Option 1 - 40 MGD pump station.
- Option 2 - 80 MGD pump station.

The construction of the dike, access road and control structures for Scenario 2 are the same as described in Scenario 1. The concept design for the typical dike cross sections detailed previously also apply to Scenario 2. The primary difference between the two scenarios is that the dike height for gravity flow is 10 feet lower in Scenario 1 than for Scenario 2.

With Scenario 2, a new control structure would be placed on the north side of the ring dike at the approximate invert elevation of 1781 feet. This structure is gated with three 10-foot wide bays. The maximum water depth on the structure is 14 feet and freeboard is 3 feet.

The pumphouse would be constructed as part of the exterior of the ring dike as shown in Figure VII-5. Water would flow through a trash rack from the outer section of Little Salt Marsh into the pumphouse. Four submersible pumps would lift the water for discharge into the interior of the proposed ring dike.

4. Operations Modeling

In the operations model for Alternative 2, the inner and outer rings of Little Salt Marsh are modeled as two separate storage nodes. The inner ring is assigned a node number of 190, and the outer ring retains the current designation for Little Salt Marsh (Node No. 200). The storage priority assigned to the inner ring is less than that assigned to the target levels for all management units. Therefore, until all management units are filled to their desired levels, the model will not store water in the inner ring. The other changes to the schematic for the base operations model are discussed below.

a. Scenario 1 - Gravity Flow

Under Scenario 1, the inner ring of Little Salt Marsh has a maximum pool elevation of 1,785 feet, 2 feet higher than under current conditions. Via a system of levees, Rattlesnake Creek flows directly into the inner ring area and then water is released from there to the outer ring of Little Salt Marsh. The model links for Scenario 1 have been configured to reflect this arrangement. A schematic diagram of the model for Scenario 1 is included in the Appendix.

b. Scenario 2 - Pump Station

For Scenario 2, the inner ring of Little Salt Marsh is constructed to a much higher height, allowing the maximum pool level of this area to increase by 12 feet to elevation 1,795 feet. Under these conditions, water must be pumped from the outer ring to the inner ring. In the operations model for this option, Rattlesnake Creek is assumed to flow directly into the outer ring of Little Salt Marsh (Node No. 200) as it does in the baseline model. Two new model links, with opposite flow directions, are added to the model between Nodes 190 and 200 to represent the inner ring pump station and outlet structure. The maximum flow rate of the pump station link is set equal to the assumed pumping capacity. Two options are investigated with pumping capacities of 40 and 80 MGD. A schematic for the Scenario 2 model is also shown in the Appendix.

c. Model Results

Execution of the operations models for this alternative yields results similar to those for Alternative 1. The additional storage volumes in Little Salt Marsh do increase the average water quantity available to the Refuge. The average annual diversions to the Refuge increase by 85 acre-feet per year for Scenario 1 and 112 acre-feet per year for Scenario 2 (regardless of pumping capacity).

The doubling of the pumping capacity under Scenario 2 from 40 to 80 MGD has no impact on the modeling results. This results because, given the monthly time step of the operations model, surplus water supplies that are available for storage in the inner ring area never exceed 40 MGD, on average, in any given month. The highest modeled monthly diversion to the inner ring is 1,150 acre-feet, or an average of approximately 12.3 MGD. Although, the model indicates no difference between these two options, in actual operation there are likely to be short periods when the supply of water available for storage exceeds 40 MGD. Under these conditions, there would be some incidental benefit to having a larger pump station.

Statistics on the availability of wetland habitat at the Refuge for this alternative are presented in Table VII-7. Also shown in this table are the corresponding baseline values. The most significant changes in average habitat values are seen in the waterfowl category. Under Scenario 1, this value increases by 116 acres. A similar increase does not occur for Scenario 2 because the increased depth of water in the inner ring under this option exceeds the 18-inch maximum for optimum waterfowl habitat.

Table VII-7
AVAILABLE WETLAND HABITAT—ALTERNATIVE 2[1]

Alternative	Shorebird (1–4 inches)		Waterfowl (10–18 inches)		Total Wetland	
	Range	Average	Range	Average	Range	Average
Baseline	85-684	358	11-1,055	602	692-6,000	2,757
Scenario 1	139-697	368	11-1,298	718	805-6,000	2,824
Scenario 2[2]	138-696	378	12-1,216	605	695-6,002	2,838

Note: 1. All wetland habitat values in acres. Statistics include data for primary migration season, September through April only.
2. Same for 40 and 80 MGD pumping capacities.

The 80th percentile habitat areas and the changes in these values over baseline conditions are shown in Table VII-8. The durations of available wetland habitat for this alternative are shown on Figure VII-7, along the habitat durations for baseline conditions. Review of this graph shows that the increased storage in Little Salt Marsh has no appreciable impact on the availability of habitat.

Table VII-8 shows that implementation of this alternative will have only a modest impact on the amount of wetland habitat available at the Refuge 80 percent of the time. As with Alternative 1, the additional storage in Little Salt Marsh can extend the length of surplus periods but cannot provide multi-year carryover storage during droughts.

Table VII-8
CHANGES IN AVAILABLE WETLAND HABITAT—ALTERNATIVE 2

Habitat Type	Wetland Habitat (acres)			
	Scenario 1		Scenario 2	
	80th Percentile	Change over Baseline	80th Percentile	Change over Baseline
Optimum Shorebird	245	+8	249	+11
Optimum Waterfowl	342	-12	327	-27
Total Wetland	1,435	+19	1,464	+48

5. Water Quality

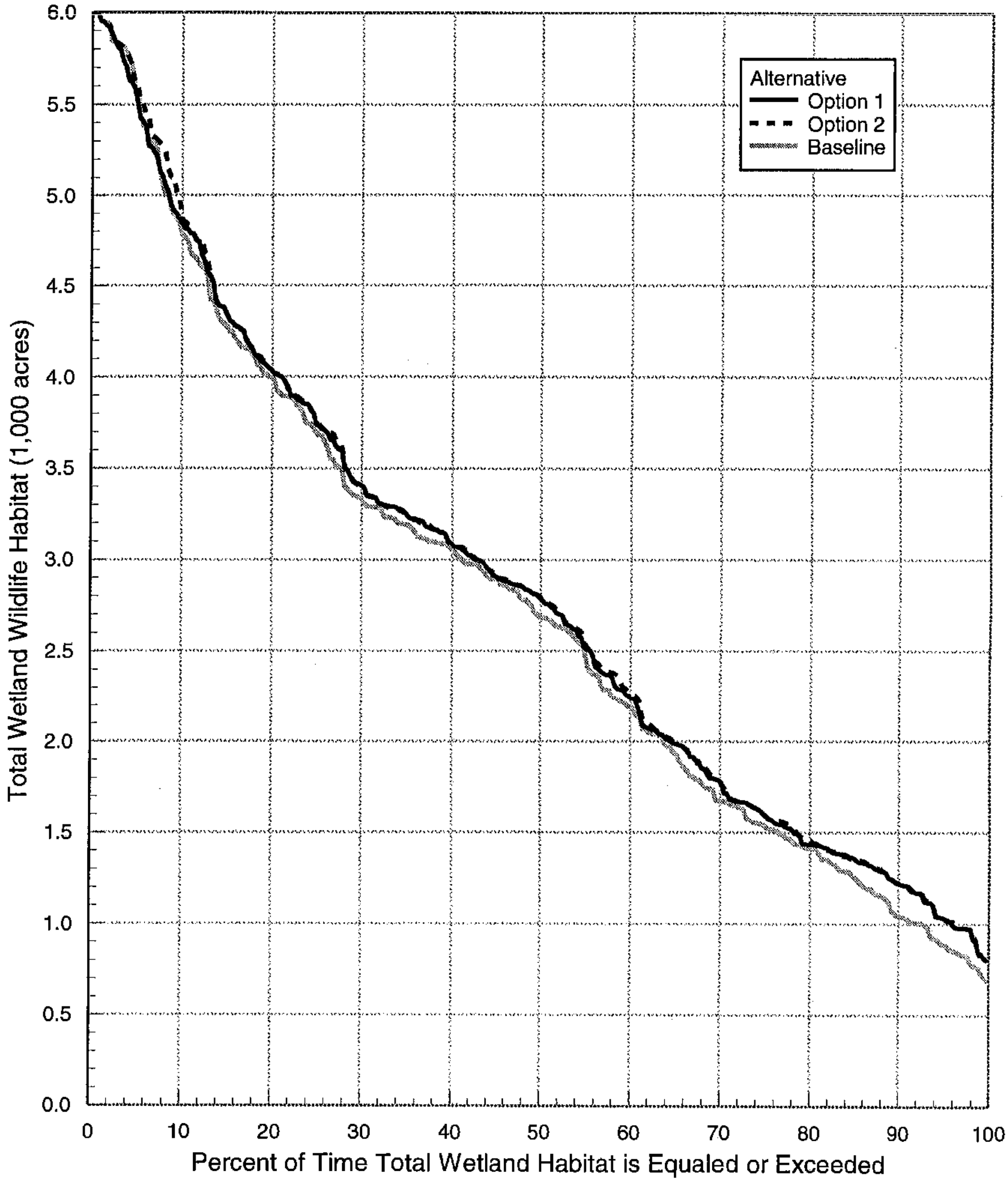
The source water for the additional storage in this alternative is Rattlesnake Creek, the Refuge's current water source. Use of additional water from Rattlesnake Creek, when available, would not impact the water quality in the Refuge.

6. Environmental and Cultural Resource Impacts

Little Salt Marsh is currently about 860 acres in size. The marsh contains a mix of open water and dense cattails respectively comprising 650 and 210 acres of the unit. Section A.6 provides a more detailed discussion of the marsh.

Construction of the circular ring dikes in Little Salt Marsh would enable the water depth of the central portion of the marsh to be increased from 2 feet to as much as 12 feet. This increase would only occur within the ring dike, which encloses approximately 290 acres. The periphery of the marsh would not change in depth or contour. Thus, areas outside the dikes would be unaffected by this alternative.

Within the diked area, any increases in water depth would likely create conditions unsuitable for cattail growth. Dense patches of cattails, currently totaling 10 to 20 acres, are present within the proposed dike area. These would be lost and open water areas would develop; however, the sloping sides on the dikes would provide some shallow water habitat. These areas would be colonized by cattails and other wetland species such as rushes and sedges; however, they would not replace the quantity of cattail habitat lost. Higher portions of the dike would support more upland species, including a variety of locally occurring



Notes:
1. Developed from operations modeling for Quivira NWR for period 1/1955 through 12/1994. Includes data for months of September through April only.
2. Total wetland habitat is the sum of the surface areas of all ponded water in all management units, regardless of depth.

Burns & McDonnell

Figure VII-7

WETLAND HABITAT DURATIONS ALTERNATIVE 2

grasses and weedy annuals. Periodic mowing of the dikes should help control shrubs and trees that could damage the dikes and provide a visual obstruction for wildlife. Such a visual obstruction could reduce wildlife species use of the area because of a small viewshed to watch for predators. Current habitat and modifications are summarized as follows:

Habitat	Current	Created	Net Total	Net Change
Open water	650	20	660 [1]	10
Cattail marsh	210	1	190	-20
Moist soil/grassland	0	1	1	1

Note: 1. Considers net loss of 10 acres of open water occupied by ring dike.

Impacts to vegetation and wildlife would result mainly during and shortly following construction. Construction of Alternative 2 would require the majority of Little Salt Marsh to be drained. A significant reduction in available habitat in the marsh would result, particularly for waterfowl and wading birds which prefer habitats with water depths of two or more feet. Shorebird habitat would likely be temporarily increased as water is drained and mudflats are created; however, even this habitat would soon be lost as construction activities continue and drained areas dry out. Construction equipment and activities occurring over a large portion of the marsh could cause significant disturbance to wildlife using the marsh, resulting in many relocating to other areas of the Refuge. Since construction would occur in the summer when wildlife numbers are reduced (as discussed in Section C), only a small number of species and individuals would be expected to be displaced. Additional habitats throughout the Refuge should be able to adequately absorb the temporary increase in use. However, if construction occurs during a dry year and less than normal habitat is available, the redistribution of wildlife could create an increase in wildlife densities, leading to increases in both inter- and intraspecific competition for space, nesting areas, forage, and the stresses such competition causes.

Construction would take approximately six months, beginning in late spring (April-May) and ending in early fall (September-October). Water stored in the marsh during the spring would be released and stored in other units to provide summer and fall habitat. After completion of construction, areas drained during construction would be allowed to refill. Excess streamflow in the fall and following spring would then be used to fill the ring dike to the desired depth. Termination of construction activities prior to peak migration periods would enable migrating birds to use the marsh undisturbed in the fall; however, some reduction in habitat quantity and quality would initially occur. Significant reduction in the habitat available on the marsh or the Refuge are not expected since the peripheral areas of the marsh will be relatively undisturbed. Over the following one to three years, habitat conditions would continually improve as disturbed areas are colonized and wetland vegetation becomes established. Within three years or less, high quality habitat would exist in areas once disturbed by construction.

The most significant negative impacts to wildlife would occur if construction were scheduled during a dry year. Water would not be available to fill Little Salt Marsh adequately following construction and peripheral areas of the marsh could dry up. Water drained from Little Salt Marsh and stored in other units could be depleted such that only limited habitat could be provided throughout the Refuge. Significant reductions in habitat for migrating waterfowl and shorebirds would result. If multiple dry years occur consecutively following construction, it could take several years for the Refuge to obtain enough water to provide normal quantity and quality habitat. While this would be a significant negative impact to migrating wildlife using the Refuge, it would not be unlike natural conditions that occasionally occur. Under the worst case, wildlife could experience several consecutive years of limited and poor quality habitat on the Refuge; however, once water is again available, it could be managed to provide optimum habitat during normal and wet years. The Refuge would be able to provide habitat of better quality and quantity during dry periods than possible now. Additional water storage would enable the Refuge to maintain a relatively good amount and quality of habitat during drier than normal periods until more normal water conditions return.

Dikes within the marsh would provide several types of wildlife habitat. A dry, vegetated area would provide additional nesting habitat, relatively inaccessible to predators. These areas would also serve as loafing, preening, and resting sites. Cover and foraging areas would be provided by the vegetation covering the dikes, particularly the wetland species around the berm fringes. During inclement weather, the elevated dikes would serve as windbreaks, providing sheltered areas on their leeward sides. Initially, wildlife, particularly waterfowl, may be hesitant to use the area due to the presence of the dikes. They may shy away from them due to hunting pressures experienced both on and off the Refuge; however, some individuals will undoubtedly begin to use the area and attract others. In this way, they will learn the area is safe and use should return to normal levels.

Benefits to wildlife would continue to occur for years following completion of construction and habitat development. The additional water stored would enable Refuge personnel to provide a more dependable quantity and quality of habitat on the Refuge. While not as important in normal or wet years since habitat is widely available in the basin, the more habitat that is available in dry years would likely provide an even more critical stopping, resting, staging, and recouperating area for species, including endangered whooping cranes, during their spring and fall migrations.

Essentially, Alternative 2 would include many of the same cultural resource considerations as Alternative 1, only on a smaller scale since much of the disturbance would be limited to areas of the marsh already covered by water. Any rises or elevated portions found within the proposed impact area could potentially contain archaeological sites. If these areas of higher elevation are to be leveled or otherwise affected, cultural resources may be impacted. Any mechanical alterations of the elevated terrain in and around the marsh, such as borrow areas, could potentially impact buried deposits. Many playa lakes or water sources that fluctuate through time and/or seasons often contain buried kill sites within the normal inundation area. Many archaeological investigations have been undertaken in similar settings that have produced evidence of humans killing and processing large mammals. Some of these kill sites date to the earliest confirmed human occupation of North America, the Paleoindian stage (10,000 B.C. to 6,000 B.C.). If any elevated areas within the marsh are to be leveled or impacted by construction, additional geomorphological and archaeological field investigations would likely be required. Any impact of subsurface deposits within the marsh may require exploratory backhoe trenching. Such trenches are commonly used by archaeologists and paleontologists to identify buried deposits of animal bones, which often contain evidence of human activities. It is likely that any sites discovered would be significant based on previous studies of similar type environments, the undisturbed nature of the sites, and the lack of known sites within the basin.

7. Project Cost Estimates

Project costs, operation, maintenance, replacement and energy costs, present value and benefit-cost analysis for this alternative are discussed below. These costs are used both here and in Task E to compare and select the best alternative(s) to include in a water supply plan for the Refuge.

a. Project Costs

Project costs include construction costs and associated capital costs for Alternative 2. The estimated project cost for Scenario 1 is $3.26 million as listed in Table VII-9. The average life cycle unit costs of water is $5,885 per MG based on project costs.

The estimated project costs for Scenario 2, Options 1 and 2 are respectively $7.78 million and $8.14 million as listed in Table VII-10. The average life cycle unit costs of water are $10,564 per MG and $11,147 per MG for Options 1 and 2 based on project costs.

b. Operation, Maintenance, Replacement and Energy (OMR&E) Costs

OMR&E costs include costs associated with the operation and maintenance, replacement of mechanical equipment every 10 years and energy for Alternative 2. Scenario 1 does not use any mechanical equipment; therefore, there are no replacement and energy costs. OMR&E costs for Scenario 2, Options 1 and 2 are $48,000 per year in the first year of operation and are inflated at 4 percent per year as listed in Tables VII-11 and VII-12. These costs are used in combination with the project costs to calculate the present value for the alternative.

c. Present Value Analysis

The present value analysis estimates the cost of the alternative in present day dollars over a service period of 20 years. The present value for Scenario 1 is $3.17 million. The average life cycle unit cost of water is $4,401 per MG over 20 years of operation based on present value. The present value for Alternative 1, Scenario 2, Options 1 and 2 in 1998 dollars are $8.62 and $9.12 million are listed in Tables VII-13 and VII-14. The average life cycle unit cost of water is $11,812 and $12,487 per MG over 20 years of operation based on present value.

d. Benefit-Cost Analysis

The benefit-cost analysis ratios the project's benefits to the project's costs. A benefit of 19, 48, and 48 acres of additional wetlands are estimated to result respectively for Scenario 1 and Scenario 2, Options 1 and 2 at a respective 20 year present value of $170,000, $430,000, and $430,000. The resulting benefit-cost ratio is 0.05 for Scenario 1, 0.05 for Scenario 2, Option 1, and 0.05 for Scenario 2, Option 2.

Table VII-9
PROJECT COST ESTIMATE
ALTERNATIVE 2 - CONSTRUCT CROSS DIKES
SCENARIO 1

Item	Cost ($)
Construct Cross Dikes	879,000
Sheet Pile	871,000
Concrete Spillway	15,000
Erosion Control	12,000
Elevate Roads on Top of Dike	289,000
Box Culvert	18,000
Water Control Structure	180,000
Subtotal	2,264,000
Contingency at 20%	453,000
Subtotal	2,717,000
Other Costs at 20%	543,000
Total Project Cost	**3,260,000**
Average Annual Water Volume (MG)	**28**
Average Life Cycle Unit Cost of Water ($/MG)	**5,885**

Table VII-10
PROJECT COST ESTIMATE
ALTERNATIVE 2 - CONSTRUCT CROSS DIKES
SCENARIO 2

Item	Option 1 Cost ($)	Option 2 Cost ($)
Pump Station		
40 MGD (62 cfs) capacity	1,000,000	
80 MGD (124 cfs) capacity		1,250,000
Construct Cross Dikes	2,866,000	2,866,000
Sheet Pile	990,000	990,000
Concrete Spillway	15,000	15,000
Erosion Control	23,000	23,000
Elevate Roads on Top of Dike	289,000	289,000
Box Culvert	18,000	18,000
Water Control Structure	200,000	200,000
Subtotal	5,401,000	5,651,000
Contingency at 20%	1,080,000	1,130,000
Subtotal	6,481,000	6,781,000
Other Costs at 20%	1,296,000	1,356,000
Total Project Cost	**7,777,000**	**8,137,000**
Average Annual Water Volume (MG)	**36**	**36**
Average Life Cycle Unit Cost of Water ($/MG)	**10,654**	**11,147**

Table VII-11
OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
ALTERNATIVE 2 - CONSTRUCT CROSS DIKES IN LITTLE SALT MARSH
SCENARIO 2, OPTION 1

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	1.0	0		48,000	48,000
2001	1.0	0		50,000	50,000
2002	1.0	0		52,000	52,000
2003	1.0	0		54,000	54,000
2004	1.0	0		56,000	56,000
2005	1.0	0		59,000	59,000
2006	1.0	0		61,000	61,000
2007	1.0	0		63,000	63,000
2008	1.0	0		66,000	66,000
2009	1.0	0		69,000	69,000
2010	1.0	0	520,000	71,000	591,000
2011	1.0	0		74,000	74,000
2012	1.0	0		77,000	77,000
2013	1.0	0		80,000	80,000
2014	1.0	0		83,000	83,000
2015	1.0	0		87,000	87,000
2016	1.0	0		90,000	90,000
2017	1.0	0		94,000	94,000
2018	1.0	0		98,000	98,000
2019	1.0	0	741,000	102,000	843,000
Total	19.8	0	1,261,000	1,434,000	2,695,000

Notes:
1. Average pumping rate is estimated at 90 percent of maximum.
2. No additional staff required and maintenance of pump station is minimal.
3. Replacement of equipment every 10 years.
4. Energy costs are estimated at $.095/KWH.

Table VII-12
OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
ALTERNATIVE 2 - CONSTRUCT CROSS DIKES
SCENARIO 2, OPTION 2

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	1.0	0		48,000	48,000
2001	1.0	0		50,000	50,000
2002	1.0	0		52,000	52,000
2003	1.0	0		54,000	54,000
2004	1.0	0		56,000	56,000
2005	1.0	0		59,000	59,000
2006	1.0	0		61,000	61,000
2007	1.0	0		63,000	63,000
2008	1.0	0		66,000	66,000
2009	1.0	0		69,000	69,000
2010	1.0	0	720,000	71,000	791,000
2011	1.0	0		74,000	74,000
2012	1.0	0		77,000	77,000
2013	1.0	0		80,000	80,000
2014	1.0	0		83,000	83,000
2015	1.0	0		87,000	87,000
2016	1.0	0		90,000	90,000
2017	1.0	0		94,000	94,000
2018	1.0	0		98,000	98,000
2019	1.0	0	968,000	102,000	1,070,000
Total	19.8	0	1,688,000	1,434,000	3,122,000

Notes:
1. Average pumping rate is estimated at 90 percent of maximum.
2. No additional staff required and maintenance of pump station is minimal.
3. Replacement of equipment every 10 years.
4. Energy costs are estimated at $.095/KWH.

Table VII-13
PRESENT VALUE ESTIMATE
ALTERNATIVE 2 - CONSTRUCT CROSS DIKES
SCENARIO 2, OPTION 1

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0				0	0
1999	0	8,088,080			7,559,000	7,559,000
2000	1.0		48,000	48,000	42,000	7,601,000
2001	1.0		50,000	50,000	41,000	7,642,000
2002	1.0		52,000	52,000	40,000	7,682,000
2003	1.0		54,000	54,000	39,000	7,721,000
2004	1.0		56,000	56,000	37,000	7,758,000
2005	1.0		59,000	59,000	37,000	7,795,000
2006	1.0		61,000	61,000	36,000	7,831,000
2007	1.0		63,000	63,000	34,000	7,865,000
2008	1.0		66,000	66,000	34,000	7,899,000
2009	1.0		69,000	69,000	33,000	7,932,000
2010	1.0		591,000	591,000	262,000	8,194,000
2011	1.0		74,000	74,000	31,000	8,225,000
2012	1.0		77,000	77,000	30,000	8,255,000
2013	1.0		80,000	80,000	29,000	8,284,000
2014	1.0		83,000	83,000	28,000	8,312,000
2015	1.0		87,000	87,000	28,000	8,340,000
2016	1.0		90,000	90,000	27,000	8,367,000
2017	1.0		94,000	94,000	26,000	8,393,000
2018	1.0		98,000	98,000	25,000	8,418,000
2019	1.0		843,000	843,000	204,000	8,622,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						**11,812**

Table VII-14
PRESENT VALUE ESTIMATE
ALTERNATIVE 2 - CONSTRUCT CROSS DIKES
SCENARIO 2, OPTION 2

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0				0	0
1999	0	8,462,480			7,909,000	7,909,000
2000	1.0		48,000	48,000	42,000	7,951,000
2001	1.0		50,000	50,000	41,000	7,992,000
2002	1.0		52,000	52,000	40,000	8,032,000
2003	1.0		54,000	54,000	39,000	8,071,000
2004	1.0		56,000	56,000	37,000	8,108,000
2005	1.0		59,000	59,000	37,000	8,145,000
2006	1.0		61,000	61,000	36,000	8,181,000
2007	1.0		63,000	63,000	34,000	8,215,000
2008	1.0		66,000	66,000	34,000	8,249,000
2009	1.0		69,000	69,000	33,000	8,282,000
2010	1.0		791,000	791,000	351,000	8,633,000
2011	1.0		74,000	74,000	31,000	8,664,000
2012	1.0		77,000	77,000	30,000	8,694,000
2013	1.0		80,000	80,000	29,000	8,723,000
2014	1.0		83,000	83,000	28,000	8,751,000
2015	1.0		87,000	87,000	28,000	8,779,000
2016	1.0		90,000	90,000	27,000	8,806,000
2017	1.0		94,000	94,000	26,000	8,832,000
2018	1.0		98,000	98,000	25,000	8,857,000
2019	1.0		1,070,000	1,070,000	258,000	9,115,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						**12,487**

C. ALTERNATIVE 3 – DEVELOP ADDITIONAL WATER STORAGE AND CONTROL UNITS

1. General

This alternative evaluates the modification of Units 14a, 14b, 28, 34 and 61 by raising the existing dikes or constructing new dikes to increase water storage capacity within each unit as shown in Figure VII-8. These units are capable of storing additional water which, in turn, can be released for use in the management of downstream units.

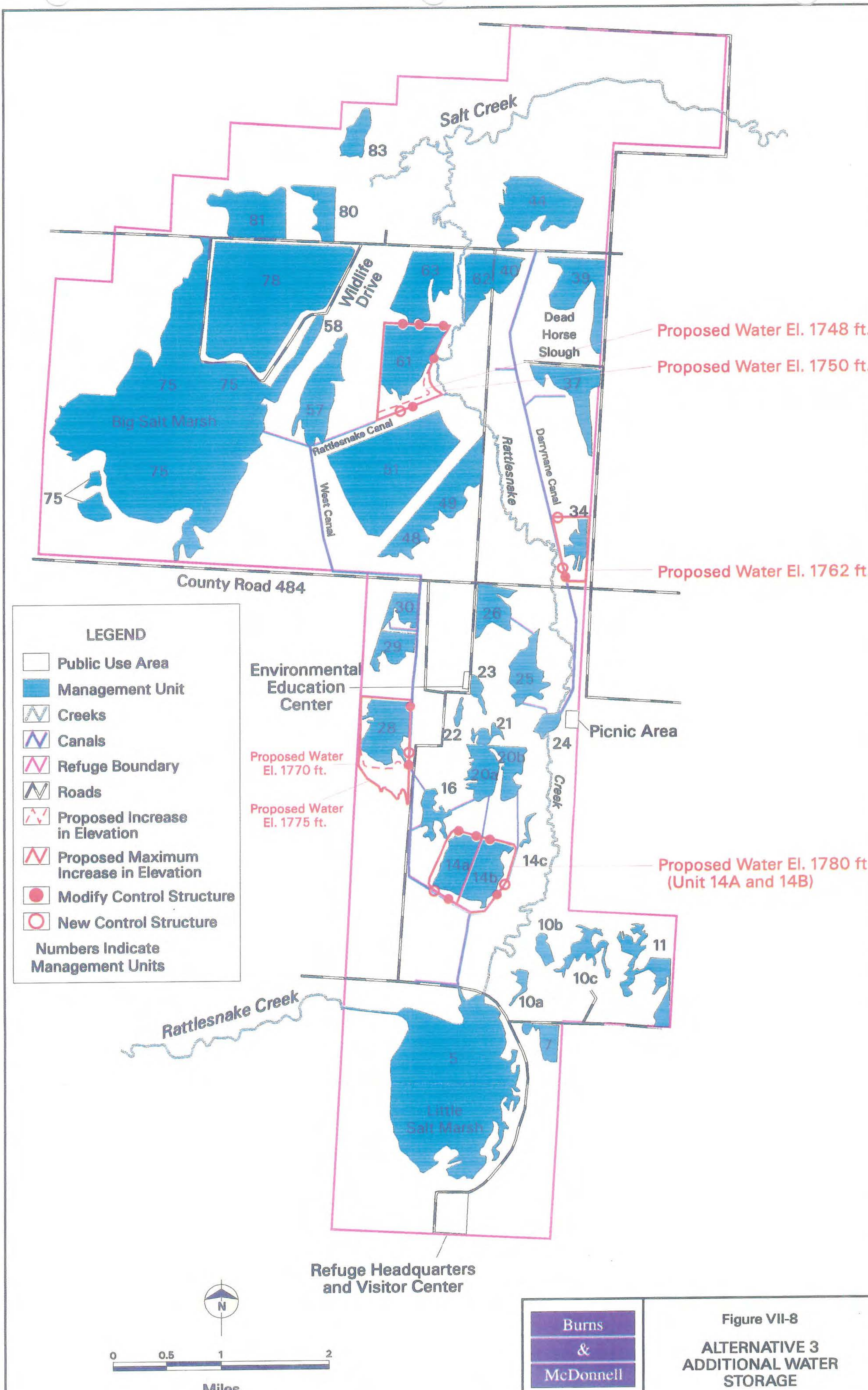
This alternative evaluates raising the existing water surface elevations of these units as follows:

- Unit 14a—2 feet.
- Unit 14b—3.3 feet.
- Unit 28—2 feet or 7 feet.
- Unit 34—New unit with 2-foot storage depth.
- Unit 61—2.5 feet or 4.5 feet.

These management units could be raised individually or in combination. Under this alternative, each is first evaluated individually on its own merits. To investigate the benefits of increasing the storage in multiple units, a combination alternative is also investigated. This combination alternative considers development of the maximum amount of additional storage possible from modification of all five of these units.

2. Additional Water Storage and Control Units

The existing management unit area-capacity data for Units 14a, 14b, 28, 34 and 61 are calculated with equations provided by the Service as listed in Table VII-15. The area-capacity data for proposed storage elevations are based on planimetering USGS 7.5-minute topographic maps.



Burns & McDonnell

Figure VII-8

ALTERNATIVE 3
ADDITIONAL WATER STORAGE

Table VII-15
AREA-CAPACITY DATA FOR
EXPANDED MANAGEMENT UNITS

Unit	Existing			Proposed		
	Elevation (feet)	Area (acres)	Storage (acre-feet)	Elevation (feet)	Surface Area (acres)	Storage (acre-feet)
14a	1778	90	200	1780	110	390
14b	1776.7	65	100	1780	100	390
28	1768	85	150	1770 1775	140 190	300 1,120
34	---	---	---	1762	80	170
61	1745.5	220	500	1748 1750	240 240	1,100 1,590

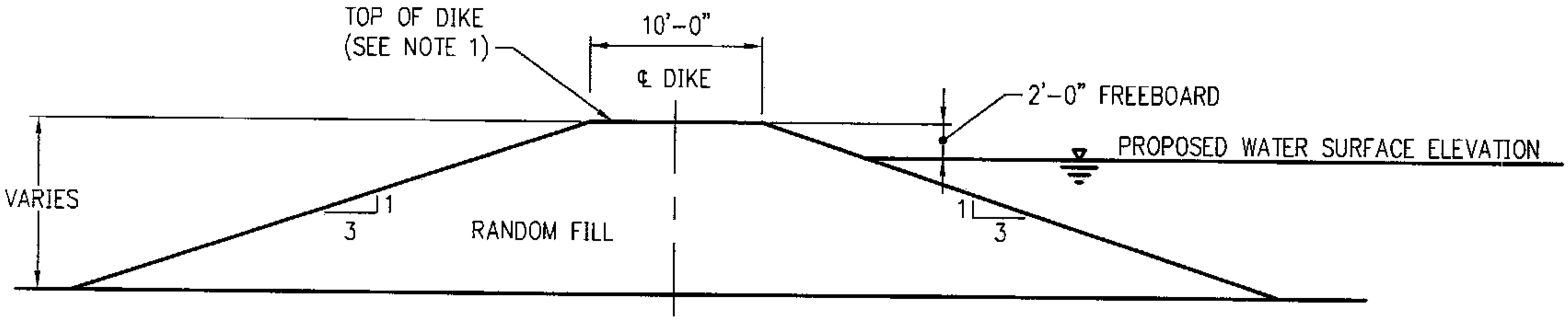
3. Preliminary Concept Design

The concept design for each unit, as shown in Figure VII-8, increases the units' surface area and provides additional water storage capacity for use in downstream management units on the Refuge. The proposed dikes are conceptually designed with 3:1 slopes based on the field survey of potential fill material. Random fill material would be obtained from borrow areas in the vicinity of the unit itself.

To minimize the cost for dike construction with this alternative, dikes are assumed to be constructed with random fill only as shown in Figure VII-9. An impervious core is unnecessary since any leakage will ultimately flow to downstream management units.

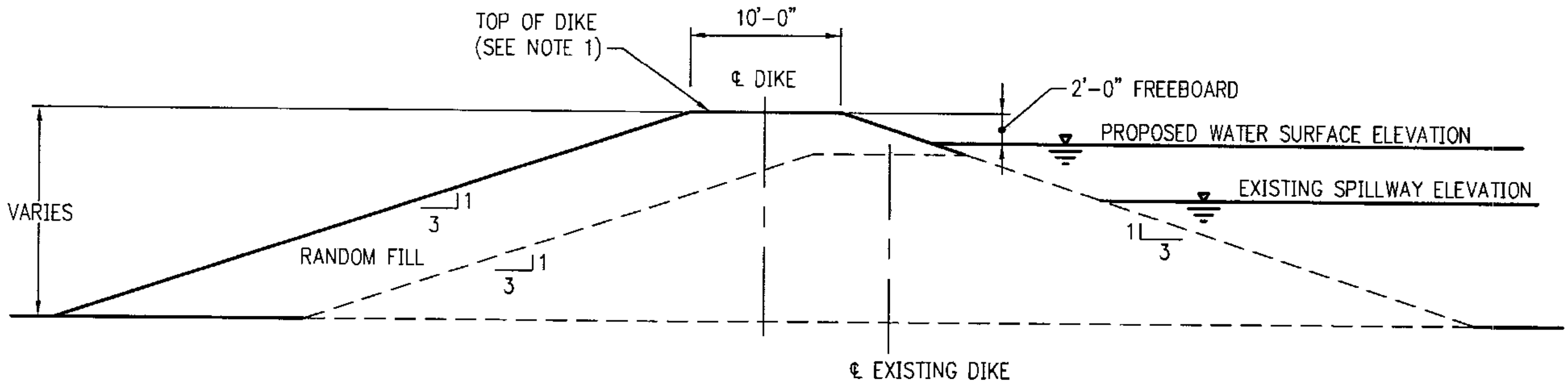
For existing dike sections, a raised dike would be constructed on the downstream side of the existing dike, eliminating the need to drain the unit. A two-foot freeboard is assumed for each unit. When possible, existing natural topography would be used to contain water in the unit. Native grasses would be planted on top, upstream (to water surface level only) and the downstream side of dikes for erosion control. The concept design for each unit is discussed below.

J: \USFWS\978064\procws\berm02.DWG 02-06-1998 14:12 AAO



NEW DIKE TYPICAL SECTION

NOT TO SCALE



RAISED DIKE TYPICAL SECTION

NOT TO SCALE

NOTE:

1. GRASS WILL BE PLANTED ON UPSTREAM FACE OF DIKE TO WATER SURFACE ELEVATION, TOP OF DIKE AND ENTIRE DOWNSTREAM FACE OF DIKE FOR EROSION CONTROL.

Burns & McDonnell

Figure VII-9

ALTERNATIVE 3
TYPICAL DIKE CROSS SECTIONS

Unit 14a

The existing maximum water surface elevation for Unit 14a is 1778 feet. A 2-foot increase to elevation 1780 feet increases storage capacity by 190 acre-feet. Unit 14a can be used to release water downstream to Units 16, 20a, 20b, 21, 22 and 23. Major components required to increase water storage in Unit 14a include:

- Construct 1,350 linear feet of new dikes.
- Raise 10,000 linear feet of existing dikes.
- Replace three existing water control structures.
- Construct new control structure in D-line Canal.

In order to raise the dike between Units 14a and 14b, Unit 14a would be drained, taking care not to disturb the operation of Unit 14b. To accommodate raising the dike, Control Structures 14a-1, 14a-2 and D1 would be replaced with new stoplog control structures. Construction of a new two-bay, 5-foot wide control structure in the D-line Canal is also needed to raise water levels in the canal to elevation 1780 so that Unit 14a can be fed by gravity flow from the canal. The banks of the D-line canal, adjacent to Unit 14a, must also be raised to accommodate these higher water levels without overtopping.

Unit 14b

The existing maximum water surface elevation for Unit 14b is 1776.7 feet. A 3.3 foot increase to elevation 1780 feet increases storage capacity of Unit 14b by 290 acre-feet. Unit 14b releases water downstream to Units 16, 20a, 20b, 21, 22 and 23. Major components required to increase storage capacity in Unit 14b include:

- Raise 11,350 linear feet of existing dikes.
- Replace two existing water control structures.
- Construct new control structure in F-line Canal.

In order to raise the dike between Units 14a and 14b, Unit 14b will need to be drained. To accommodate raising the dike, Control Structures 14B and F1 would be replaced with new stoplog control structures.

Construction of a two-bay, 5-foot wide control structure in the F-line Canal is required to raise water levels in the canal to elevation 1780 so that Unit 14b can be fed by gravity flow from the canal. The banks of the F-line Canal must also be raised to prevent overtopping.

Unit 28

The existing maximum water surface elevation for Unit 28 is 1768 feet. A 2-foot and 7-foot increase to elevation 1770 feet and 1775 feet respectively increases storage capacity by 150 and 970 acre-feet. Unit 28 releases water downstream to Units 29 and 30. Major components required to increase storage capacity include:

- Raise 4,600 linear feet of existing dikes and construct 1,400 linear feet of new dikes for a 2-foot level increase.
- Raise 4,600 linear feet of existing dikes and construct 7,700 linear feet of new dikes for the 7-foot water level increase.
- Replace two existing water control structures.
- Construct new control structure in West Canal.

Control Structures 28A and 28B would be replaced with new stoplog control structures. Construction of a two-bay, 5-foot wide control structure in the West Canal is required to raise water levels in the canal so that Unit 28 can be fed by gravity flow from the canal. The banks of the West Canal must also be raised to prevent overtopping.

Unit 34

Unit 34 was included in the Service's "Original Development Plan" for the Refuge, but was not constructed. This area includes a series of shallow depressions with Control Structure DCC used for flooding the unit from Darrynane Canal. By constructing a dike around this unit, 2 feet of water with a storage capacity of 170 acre-feet is created. Unit 34 releases water downstream to Units 37 and 39. Major components required to increase storage capacity include:

- Raise 7,000 linear feet of existing dikes.
- Construct 1,650 linear feet of new dikes.
- Replace existing Control Structure DCC.
- Construct two new control structures.

A new stoplog structure is needed at the north end of the unit to release water to downstream Units 37 and 39. Construction of a two-bay, 5-foot wide control structure in the Darrynane Canal is required to back water into Unit 34. The canal banks must also be raised to prevent overtopping.

Unit 61

The existing maximum water surface elevation for Unit 61 is 1745.5 feet. A 2.5 foot and 4.5 foot increase to elevations 1748 feet and 1750 feet, respectively, increases storage capacity by 600 and 1,090 acre-feet. Unit 61 releases water downstream to Units 57, 62 and 63. Major components required to increase storage capacity include:

- Raise 8,100 linear feet of existing dikes and construct 4,300 linear feet of new dikes for a 2.5-foot increase in water surface elevation.
- Raise 12,100 linear feet of existing dikes and construct 4,300 linear feet of new dikes for the 4.5-foot increase in water surface elevation.
- Replace six existing water control structures.
- Construct new control structure in Rattlesnake Canal.

Control Structures 61A, 61B, 61C, 61D, 61E and RCB would be replaced with new stoplog control structures. Construction of a two-bay, 5-foot wide control structure in Rattlesnake Canal is required to raise water levels in the canal so that Unit 61 can be fed by gravity flow. The canal banks must also be raised to prevent overtopping.

4. Operations Model

Analysis of the various options under Alternative 3 requires seven separate models plus the additional model for the combination option. The schematics for these models are all identical to that for the base operations model. The only changes required are to modify the elevation–area–storage data for the unit of units that are to be raised or created. The storage priorities for the increased storage volumes are set lower than those for the target level zone of each management unit. Therefore, until all management units are filled to their desired levels, the model will not store additional water in these expanded units.

Average Refuge diversions under each development option are summarized in Table VII-16. The option with the greatest impact on average diversions is to raise Unit 28 by 7 feet; however, even this increase represents a relative gain of only about 4 percent.

Table VII-16
AVERAGE ANNUAL REFUGE DIVERSIONS—ALTERNATIVE 3

Alternative	Average Annual Refuge Diversions (acre-feet per year)	
	This Alternative	Change over Baseline
Raise Unit 14a	6,924	+66
Raise Unit 14b	6,947	+89
Raise Unit 28 (2 feet)	6,950	+92
Raise Unit 28 (7 feet)	7,138	+281
Create Unit 34	6,943	+86
Raise Unit 61 (2.5 feet)	7,014	+157
Raise Unit 61 (4.5 feet)	7,089	+232
Combination [1]	7,526	+669

Note: 1. Combination includes Units 14a, 14b, 28 (7 feet), 34, 61 (4.5 feet).

Statistics on the availability of wetland habitat at the Refuge for this alternative are presented in Table VII-17. Also shown in this table are the corresponding baseline values. Review of this table shows that none of these options have a significant impact on the availability of wetland habitat.

The 80th percentile habitat areas and the changes in these values over baseline conditions are shown in Table VII-18.

Table VII-17
AVAILABLE WETLAND HABITAT—ALTERNATIVE 3 [1]

Unit Alternative	Shorebird (1-4 inches)		Waterfowl (10-18 inches)		Total Wetland	
	Range	Average	Range	Average	Range	Average
Baseline	85-684	358	11-1,055	602	692-6,000	2,757
14a	85-681	358	11-1,049	603	692-6,023	2,771
14b	85-687	359	11-1,059	605	692-6,046	2,777
28 (2 feet)	85-693	359	11-1,055	604	692-6,068	2,776
28 (7 feet)	85-703	362	11-1,044	606	692-6,118	2,818
34	85-677	359	11-1,044	607	686-6,052	2,778
61 (2.5 feet)	85-684	359	11-1,028	606	692-6,051	2,800
61 (4.5 feet)	85-682	358	11-1,022	604	692-6,051	2,819
Combination [2]	85-683	354	10-993	615	686-6,287	2,933

Note: 1. All wetland habitat values in acres. Statistics include data for primary migration season, September through April only.
2. Combination includes Units 14a, 14b, 28 (7 feet), 34, 61 (4.5 feet).

Table VII-18
CHANGES IN AVAILABLE WETLAND HABITAT—ALTERNATIVE 3

Unit Alternative	Shorebird (1-4 inches)		Waterfowl (10-18 inches)		Total Wetland	
	80th Percentile	Change	80th Percentile	Change	80th Percentile	Change
Baseline	237	---	354	---	1,416	---
14a	237	0	354	0	1,416	0
14b	237	0	354	0	1,416	0
28 (2 feet)	237	0	354	0	1,416	0
28 (7 feet)	237	0	354	0	1,416	0
34	238	1	354	0	1,412	-4
61 (2.5 feet)	237	0	358	4	1,416	0
61 (7.5 feet)	239	2	358	4	1,416	0
Combination [2]	240	3	358	4	1,411	-5

Note: 1. Combination includes Units 14a, 14b, 28 (7 feet), 34, 61 (4.5 feet).

Review of Table VII-18 shows that implementation of this alternative would have no impact on the amount of wetland habitat available at the Refuge 80 percent of the time. As with most of the other storage alternatives, the additional storage provided cannot provide multi-year carryover storage during droughts.

5. Water Quality

The primary source water for the additional storage for the units in this alternative is Rattlesnake Creek, the Refuge's current water source. Use of additional water from Rattlesnake Creek, when available, will not impact the water quality in the Refuge.

6. Environmeutal and Cultural Resource Impacts

Benefits to wildlife would occur in the years following completion of construction and implementation of Alternative 3. The actual benefits of Alternative 3 would depend upon the degree to which this alternative is implemented (i.e. modification to one, two, three, four, or all five units). The additional water storage capacity developed would enable Refuge personnel to ultimately provide a more dependable quantity and quality of habitat. In dry years, the more dependable available habitat would likely provide an even more critical stopping, resting, staging, and recouperating area during seasonal migrations for migrating bird species, including endangered whooping cranes. Opportunities for the public to use the Refuge for recreational activities would be increased (as discussed in Part I.5.).

The following discussion briefly describes the environmental impacts associated with development of each unit.

Unit 14a

Unit 14a has an average water depth of approximately two feet at its existing, desired management level. Approximately 90 surface acres of water are available when this level is attained. Approximately 45 acres of the unit has depths that range between four and six feet. The remaining 45 acres have depths that range from only a few inches to approximately 4 feet. Approximately half of the unit (45 acres) is open water that is too deep to support cattails; the remainder of the unit (45 acres) is heavily overgrown with cattails.

The proposed 2-foot increase in water depth would replace of some cattail communities with open water. Most of the shallow areas now have water levels less than two feet deep. Increasing water depth in these shallow areas to an average water level of less than four feet would convert 25 percent of the existing cattail communities (approximately 11 acres) to open water.

About 44 acres of new shallow water areas would be created. These areas would have a water depth between a few inches and 2 feet and would be suitable for colonization, growth, and establishment of new cattail communities. The net increase in suitable cattail habitat would be approximately 19 acres. Therefore, the enlarged Unit 14a would provide approximately 11 acres of additional deep, open water habitat and 30 acres of shallow, cattail habitat. The current and proposed composition of this unit includes:

Habitat	Current	Created	Net Total	Net Change
Open water	45	11	56	11
Cattail marsh	45	30	64	19
Moist soil/grassland	30	0	0	-30

Other types of wetland and moist soil vegetation, including sedges, rushes, and a variety of weedy annuals, would develop in the new, shallow water areas. The existing grassland vegetation of these areas would be lost; however, such areas are abundant throughout the Rattlesnake Creek Basin and in other areas of the Refuge.

Overall impacts to wildlife would be beneficial. Approximately 30 acres of habitat for upland species such as pheasants, quail, a variety of songbirds, and small mammals, would be lost. Open water areas would increase by 11 acres while 30 acres for growth of cattails and other wetland plants utilized for cover, nesting, and food by both wetland and upland wildlife would be provided.

The primary impacts to wildlife would be similar to those discussed in Section A.6. The size of Unit 14a would preclude its summer use by an extensive number of individuals, resulting in the displacement of only a small number of individuals. Additional habitats throughout the Refuge should be able to adequately absorb the temporary need for increased habitat; however, if construction occurs during a dry year and less than normal habitat is available, the redistribution of wildlife could create an increase in wildlife densities, leading to increases in both inter- and intraspecific competition for space, nesting areas, forage, and the stresses such competition causes. Following completion of construction, disturbance to wildlife would cease and wildlife would move back into the unit.

Unit 14a is positioned in a low lying area that has had some previous mechanical alterations. Based on the topographic characteristics and previous disturbances, this project area is considered to have low to moderate probability for containing prehistoric or historic sites. Although no known sites or historic structures have been recorded in the area, two slight rises in elevation have been observed on the western edge of the unit. These changes in elevation suggest a moderate potential for cultural resources. Additionally, the Comanche Site is located just west of the unit. There is a potential for the edges of this site or associated sites to extend into Unit 14a. If this alternative is selected, additional archaeological investigations will be required.

Unit 14b

Unlike Unit 14a, Unit 14b is largely overgrown with cattails. The water depth in this unit averages 1.5 feet and includes about 65 acres of marsh habitat. Only eight acres of the unit are open water, and include four acres of borrow areas adjacent to the dikes in the northwest corner of the unit and approximately four additional acres in small pools throughout the unit. The remaining 57 acres of the unit are heavily overgrown with cattails. Although Unit 14b appears to have a relatively uniform water depth, water levels appear to range from approximately two feet to only a few inches.

Implementation of Alternative 3 would result in water levels within Unit 14b being increased by two feet. This increase would inundate an additional 35 acres, enlarging the unit to a total size of 100 acres and increasing the average water depth to approximately 3.5 feet. Increasing the water level two feet would establish an average water depth of 3 feet or more over much of the unit. As much as 50 percent of the existing cattails could be eliminated or reduced to a marginal existence by this increase. At this rate, approximately 30 acres of cattails could be converted to open water; however, the increased water level would create an additional 35 acres of habitat two feet or less in depth. These areas would be quickly colonized by cattails and other wetland vegetation, resulting in a net increase in cattail habitat of approximately 9 to 10 acres. Overall, raising the water level in Unit 14b would increase both the open water and cattail habitat available in this unit. Habitat modifications to this unit would include:

Habitat	Current	Created	Net Total	Net Change
Open water	8	30	38	30
Cattail marsh	57	35	62	5
Moist soil/grassland	35	0	0	-35

As in Unit 14a, other types of wetland and moist soil vegetation, including sedges, rushes, and a variety of weedy annuals, would also develop in the new, shallow water areas. The existing grassland and scattered shrub/scrub vegetation of these areas, would be lost; however, such areas are abundant throughout the basin and in other areas of the Refuge.

Overall, impacts to wildlife would be beneficial. Approximately 35 acres of habitat for upland species such as pheasants, quail, a variety of songbirds, and small mammals, would be lost; however, the two-foot increase in water level would expand open water areas (38 versus 8 acres), converting them to more pond-shaped areas preferred by many wetland bird species. Additional areas (35 acres) for growth of cattails and other wetland plants used for cover, nesting, and food by both wetland and upland species would still occur. Additional impacts to wildlife would be similar to those described previously for Unit 14a.

Unit 14b is in a low lying area that is very similar to Unit 14a. Based on the topographic characteristics and previous disturbances, most of this project area is considered to have low probability for containing prehistoric or historic sites. A slight rise in elevation along the eastern boundary of the unit suggest a moderate potential for cultural resources. No known sites or historic structures have been recorded in the area. However, due to the proximity of the Comanche Site to this unit, it is possible that associated sites may be present within Unit 14b. If this unit is selected, additional archaeological investigations will be required.

Unit 28

Unit 28 has an average water depth of approximately 1.8 feet at the desired water management level. The unit contains a borrow area at the north end of the unit that is approximately six acres is size and about five feet deep. The entire unit is 85 acres in size and contains about 6 acres (borrow area) of deeper open water habitat and 79 acres of cattails and other emergent vegetation.

Two modifications to Unit 28 are proposed under Alternative 3-- increasing the water depth 2 feet and 7 feet. Increasing the water depth of Unit 28 by two feet would increase the average water depth of the unit to 1.8 feet, an increase of 0.3 feet due to the topography of the area. An additional 55 acres of shallow water habitat would be created. The average depth of 2.1 feet would not preclude growth of cattails. Few if any existing areas of cattails would be reduced or eliminated. Open water areas would remain nearly the same as the current conditions. Additionally, 55 more acres of suitable habitat for cattails and other emergent species would be created. The primary benefit to wildlife from this scenario would be the creation of 55 acres of shallow water habitat.

Raising the water level of Unit 28 by seven feet would increase the inundated area of the unit to 190 acres and would result in an increase in the average water depth to approximately 5.9 feet. As a result, about 30 percent of the unit would average about 5.9 feet deep, 30 percent would be deeper than 5.9 feet, and 30 percent would be shallower. Therefore, most of the unit would have water too deep for cattail growth. As much as 75 percent (approximately 64 acres) of the unit would be converted to open water. About 21 existing acres of cattails would remain; however, the increase in water depth would inundate an additional 105-acres, creating shallow water habitat. This area would be colonized by cattails and other emergent wetland vegetation.

Wildlife would benefit by the creation of approximately 58 additional acres of open water habitat and an additional 105 acres of shallow water habitats. A net total of approximately 64 acres of open water and 120 acres of shallow water would result. The following summarizes habitat changes, in acres, resulting from implementation of the two management modifications:

Habitat	Current	2-Foot Increase			7-Foot Increase		
		Created	Net Total	Net Change	Created	Net Total	Net Change
Open water	6	0	6	0	64	70	64
Cattail marsh	79	55	134	55	105	120	41
Moist soil/grassland	105	0	50	-55	0	0	-105

As stated above, modifications to Unit 28 would result in the loss of approximately 55 acres (2-foot increase) and 105 acres (7-foot increase) of existing upland habitat. This habitat consists mainly of grassland and scattered shrub/scrubland communities. These communities are readily available on the refuge and adjacent lands, and while they provide habitat for upland species and nesting waterfowl. The 7-foot increase would increase open water areas by 70 acres which are preferred by many wetland bird species. Additional areas for cattail growth and other wetland plants used for cover, nesting, and food by both wetland and upland species would be provided. Impacts to wildlife would be similar to those described previously for Unit 14a.

Although much of Unit 28 has been altered, additional mechanical stripping may impact buried kill site deposits in the pool area. The remainder of the proposed impact area is low and flat, suggesting a very low probability for campsites or other sites in the area. If any of the elevated areas around Unit 28 are used for borrow, additional archaeological and geomorphological investigations will be required.

Unit 34

Unit 34 is an undeveloped management unit that was proposed in the original Master Development Plan for the Refuge. A control structure is currently in-place to hold and release water; however, no berms or dikes have been constructed to confine water on the unit. The unit is currently managed as a moist soil area. Without dikes, water can only be retained on the unit for a short period before it runs off and/or soaks into the ground.

Development of Unit 34 for water storage would require construction of dikes around the unit. As currently envisioned, water up to two feet deep would be stored in the unit. Under these conditions, the unit would contain approximately 80 surface acres of water approximately 2 feet deep. These water depths would encourage the growth of more water tolerant species, such as cattails, sedges, and rushes. Over time, cattails would be expected to dominate the area and periodic maintenance would be required to control them. Sedges and rushes would be restricted to peripheral areas along dikes. The acres of habitat under current and potential management includes:

Habitat	Current	Created	Net Total	Net Change
Open water	0	0	0	0
Cattail marsh	0	80	80	80
Moist soil/grassland	80	0	0	-80

Moist soil areas, when inundated, are desirable habitat for waterfowl and may also be used by wading birds. When drained, the vegetation they contain provides habitat for a variety of upland species, especially ground nesting birds such as pheasant, bobwhite quail, and meadow larks. These moist soil habitats are less prevalent throughout the Refuge than cattails, and provide better quality foraging habitat and nesting habitat. Development of Unit 34 for storage would reduce the amount of the valuable moist soil habitat within the Refuge. The loss of this habitat would impact local upland species and nesting waterfowl less than those species using the area during migration. Upland habitats throughout the Refuge would absorb this loss.

Initially, the unit would provide excellent habitat for waterfowl during migration periods. Water levels would be ideal for dabbling ducks and abundant forage would be available from the residual seed base; however, once cattails begin to establish and dominate the unit, its value to wildlife would decrease. If the water stored in this unit were used to create additional moist soil areas, the impact of Unit 34 development would be reduced. Moist soil areas and wet meadow habitats are present throughout the Refuge, generally in conjunction with other management units. The loss of moist soil areas at Unit 34 is not expected to be a significant impact.

Wildlife would be impacted during construction. Human activities and the operation of heavy equipment would likely displace wildlife to other parts of the Refuge. Due to the location of the unit, it is unlikely it would be used by species other than upland species. These would be displaced to adjacent areas, possibly venturing back into the area during non-construction periods (evening and weekends). Following construction, most upland species would be permanently displaced from this unit. Additionally, some mortality of species including small mammals, reptiles, amphibians, and ground nesting birds (adults, nests, eggs, and chicks) could be expected, depending on the timing of construction. This mortality would be in common species found throughout the area and would not significantly affect the populations of these species on the Refuge.

Unit 34 is characterized by low lying areas or playa lakes with a ridge or terrace remnant running north-south through the center of the project area. Although some of the area has been modified by mechanical machinery, the playa lakes and the close proximity to Rattlesnake Creek indicate that this area has a high potential for containing cultural resources. These resources would predominately include prehistoric and historic campsites, kill sites, processing sites, and other limited activity sites. No evidence of historic habitations or structures have been recorded in the area. Based on the topographic characteristics, this project area is considered to have a high probability for containing prehistoric or historic sites. If this unit is selected, it is likely additional archaeological and possibly geomorphological investigations will be required.

Unit 61

At current full pool conditions, Unit 61 is about 220 acres in size and has an average water depth of about 2.5 feet. The desired water surface management depth is 1.5 to 2.0 feet. Unit 61 contains approximately 20 acres of linear, deeper open water areas created as a result of borrow areas adjacent to the dikes along the north and west sides of the unit, and approximately 200 acres of shallower areas dominated by dense growths of cattails. Enclosing Unit 61 with additional dikes would develop an area of about 240 acres in size.

Modification options evaluated for Unit 61 include raising the full pool water level 2.5 and 4.5 feet. A water level increase of 2.5 and 4.5 feet would result in the average depths increasing to approximately 4.5 and 6.5 feet, respectively. Under these conditions, the majority of the unit's existing cattail areas would be lost. Approximately 180 acres of cattails would be lost with a 2.5-foot increase and nearly all the 220 acres with a 4.5-foot increase. Some cattails and other species of wetland vegetation would still occur along the dikes, but the majority of the unit would be open water. Changes in habitat acres are summarized as:

Habitat	Current	2.5-Foot Increase			4.5-Foot Increase		
		Created	Net Total	Net Change	Created	Net Total	Net Change
Open water	20	180	200	180	220	240	220
Cattail marsh	220	20	60	-160	0	0	-220
Moist soil/grassland	20	0	0	-20	0	0	-20

Conversion of Unit 61 to open water would not have an impact on the availability of cattail habitat Refuge-wide. As previously discussed, dense growths of cattails are generally undesirable to migrating waterfowl, especially shorebirds, diving ducks and geese. They may be used to a limited extent by wading birds and dabbling ducks for nesting, brood rearing, and cover; however, during migration periods, dabbling ducks generally seek open water areas for roosting due to the viewshed. Initially, as existing cattails die-out and decay, they would provide an abundant food source for aquatic invertebrates, which in-turn would provide food for a variety of waterfowl and shorebird species. Following the initial bloom of productivity, invertebrate levels would stabilize, but should still provide a quality forage. Open water areas would increase the preferred areas for roosting and foraging on the Refuge and be more attractive to waterfowl by being more of a natural pond shape.

The primary impact to wildlife would be a temporary disturbance during the construction period from human activity and operation of heavy equipment. Other impacts would result from habitat reduction in the unit due to required water level draw-down. Construction impacts would be similar to those described in Section A.6. Wildlife present on Unit 61 could seek suitable refuge in the more secluded central area of the unit, away from construction activities in peripheral areas. No significant reduction in habitat due to draw-downs for construction would be expected.

Like many other units, Unit 61 is in a low lying area that has had some previous mechanical alterations. Based on the topographic characteristics and previous disturbances, this project area is considered to have low probability for containing prehistoric or historic cultural resources. No known archaeological sites or historic structures have been recorded in the area. If this unit is selected, it is unlikely additional archaeological investigations would be required.

7. Project Cost Estimates

Project costs, operation and maintenance costs, present value costs and cost-benefit analysis for this alternative are described below. These costs are used in Task E for the purpose of comparing and selecting the best alternative(s) for implementation.

a. Project Costs

The estimated project costs for the additional water storage and control units range from $145,000 for Unit 34 to $900,000 for Unit 61 (elevation 1750 feet) as summarized in Table VII-19. Detailed breakdowns of these cost estimates are provided in Tables VII-20 through VII-24. Also, included in Table VII-19 is the total project cost of $2,280,000 for all units combined to create the maximum water storage.

Table VII-19
COST SUMMARY FOR ALTERNATIVE 3
ADDITIONAL WATER STORAGE AND CONTROL UNITS

Unit	Total Project Cost ($)	Present Value in 1998 Dollars ($ M)	Avg. Life Cycle ($/MG)
14a	380,000	369,000	883
14b	238,000	231,000	410
28 (El. 1770)	221,000	215,000	369
28 (El. 1775)	617,000	600,000	337
34	145,000	141,000	259
61 (El. 1748)	545,000	530,000	533
61 (El. 1750)	900,000	875,000	595
Combination [1]	2,280,000	2,216,000	218

Note: 1. Combination includes Units 14a, 14b, 28 (7 feet), 34, 61 (4.5 feet).

b. Operation and Maintenance (O&M) Costs

The operation and maintenance of this alternative is not anticipated to require additional Refuge or contract personnel. Also, this alternative does not include any mechanical equipment that would require periodic replacement or consume energy. Therefore, there would be no additional O&M costs for this alternative.

c. Present Value Analysis

The present value costs for the proposed development under for Alternative 3 in 1998 dollars range from $141,000 for Unit 34 to $875,000 for Unit 61 (elevation 1750 feet) as listed in Table VII-19. The unit cost of water for 20 years of operation range from $259/MG for Unit 34 to $883/MG for Unit 14a as summarized in Table VII-19.

d. Benefit-Cost Analysis

None of the development options for this alternative are expected to significantly impact the amount of wetland habitat available at the Refuge 80 percent of the time or more. Therefore, none of these options including the combination of Units 14a, 14b, 28 (EL. 1775), 34 and 61 (EL. 1750) are considered to have any benefits, as discussed in Part IV, and have negative benefit cost ratios or 0.0.

D. ALTERNATIVE 4 - LINE CONVEYANCE CANALS

1. General

This alternative evaluates lining 13 miles of major conveyance canals in the Refuge to improve the efficiency of water delivery to the various management units. The primary canals considered for lining are the C-line, D-line, F-line, West, Rattlesnake and Darrynane Canals as shown in Figure VII-10. The smaller canals on the Refuge convey much smaller volumes of water, and have a reduced potential for losses. Therefore, the smaller canals on the Refuge are not included in the analysis.

Alternative 4 would be implemented by removing a one-foot layer of soil in the canals and replacing it with 6 inches of clay covered by 6 inches of random fill. By lining the canals, it is estimated that losses from infiltration would decrease from 10 percent to 1 percent. Operations modeling shows the net increase in water supply to the Refuge is about 112 acre-feet per year. Actual soil conditions and permeabilities should be tested prior to final design and construction to confirm potential water savings for this alternative.

2. Refuge Canals

The height, bottom width and top width dimensions for the primary Refuge canals are listed in Figure VII-11. These dimensions are developed from electronic survey data provided by the Service. The slope is calculated based upon several cross sections obtained from the Service's electronic survey. The lengths of each canal are estimated from the 7.5-minute USGS topographic maps.

3. Preliminary Concept Design

The concept design for this alternative provides for lining of the C-line, D-line, F-line, West, Rattlesnake and Darrynane Canals to improve water delivery efficiency. To minimize delivery losses from the canals, an impervious clay barrier is used as lining material. This alternative includes the following major components:

- Construct 3,900 linear feet of clay liner in C-line canal.
- Construct 4,150 linear feet of clay liner in D-line canal.

Table VII-20
PROJECT COST ESTIMATE
ADDITIONAL WATER STORAGE IN CONTROL UNITS
UNIT 14a

Item	Cost ($)
Construct New and Raise Existing Dikes	154,000
Erosion Control	13,000
Water Control Structure for D-1	7,000
New Water Control Structure for D-Line Canal	70,000
Water Control Structure for 14a-1	10,000
Water Control Structure for 14a-2	10,000
Subtotal	264,000
Contingency at 20%	53,000
Subtotal	317,000
Other Costs at 20%	63,000
Total Project Cost	**380,000**
Average Annual Water Volume (MG)	**22**
Average Life Cycle Unit Cost of Water ($/MG)	**883**

Table VII-21
PROJECT COST ESTIMATE
ADDITIONAL WATER STORAGE IN CONTROL UNITS
UNIT 14b

Item	Cost ($)
Raise Existing Dikes	124,000
Erosion Control	14,000
Water Control Structure for F-1	7,000
New Water Control Structure for F-Line Canal	10,000
Water Control Structure for 14b	10,000
Subtotal	165,000
Contingency at 20%	33,000
Subtotal	198,000
Other Costs at 20%	40,000
Total Project Cost	**238,000**
Average Annual Water Volume (MG)	**29**
Average Life Cycle Unit Cost of Water ($/MG)	**410**

Table VII-22
PROJECT COST ESTIMATE
ADDITIONAL WATER STORAGE IN CONTROL UNITS
UNIT 28

Item	Elevation 1770 Cost ($)	Elevation 1775 Cost ($)
Construct New and Raise Existing Dikes	60,000	319,000
Erosion Control	6,000	14,000
Water Control Structure for 28A	9,000	13,000
Water Control Structure for 28B	8,000	12,000
Water Control Structure for 28B (new)	70,000	70,000
Subtotal	153,000	428,000
Contingency at 20%	31,000	86,000
Subtotal	184,000	514,000
Other Costs at 20%	37,000	103,000
Total Project Cost	**221,000**	**617,000**
Average Annual Water Volume (MG)	**30**	**92**
Average Life Cycle Unit Cost of Water ($/MG)	**369**	**337**

Table VII-23
PROJECT COST ESTIMATE
ADDITIONAL WATER STORAGE IN CONTROL UNITS
UNIT 34

Item	Cost ($)
Construct New and Raise Existing Dikes	18,000
Erosion Control	1,000
Water Control Structure for DCC	6,000
New Water Control Structure for Darrynane Canal	70,000
New Water Control Structure 34A	6,000
Subtotal	101,000
Contingency at 20%	20,000
Subtotal	121,000
Other Costs at 20%	24,000
Total Project Cost	**145,000**
Average Annual Water Volume (MG)	**28**
Average Life Cycle Unit Cost of Water ($/MG)	**259**

Table VII-24
PROJECT COST ESTIMATE
ADDITIONAL WATER STORAGE IN CONTROL UNITS
UNIT 61

Item	Elevation 1748 Cost ($)	Elevation 1750 Cost ($)
Construct New and Raise Existing Dikes	224,000	451,000
Erosion Control	13,000	21,000
Water Control Structure for 61A	6,000	8,000
Water Control Structure for 61B	9,000	11,000
Water Control Structure for 61C	9,000	11,000
Water Control Structure for 61D	9,000	11,000
Water Control Structure for 61E	4,000	6,000
Water Control Structure for RCB	4,000	6,000
New Water Control Structure for Rattlesnake Creek	100,000	100,000
Subtotal	378,000	625,000
Contingency at 20%	76,000	125,000
Subtotal	454,000	750,000
Other Costs at 20%	91,000	150,000
Total Project Cost	**545,000**	**900,000**
Average Annual Water Volume (MG)	**51**	**76**
Average Life Cycle Unit Cost of Water ($/MG)	**533**	**595**

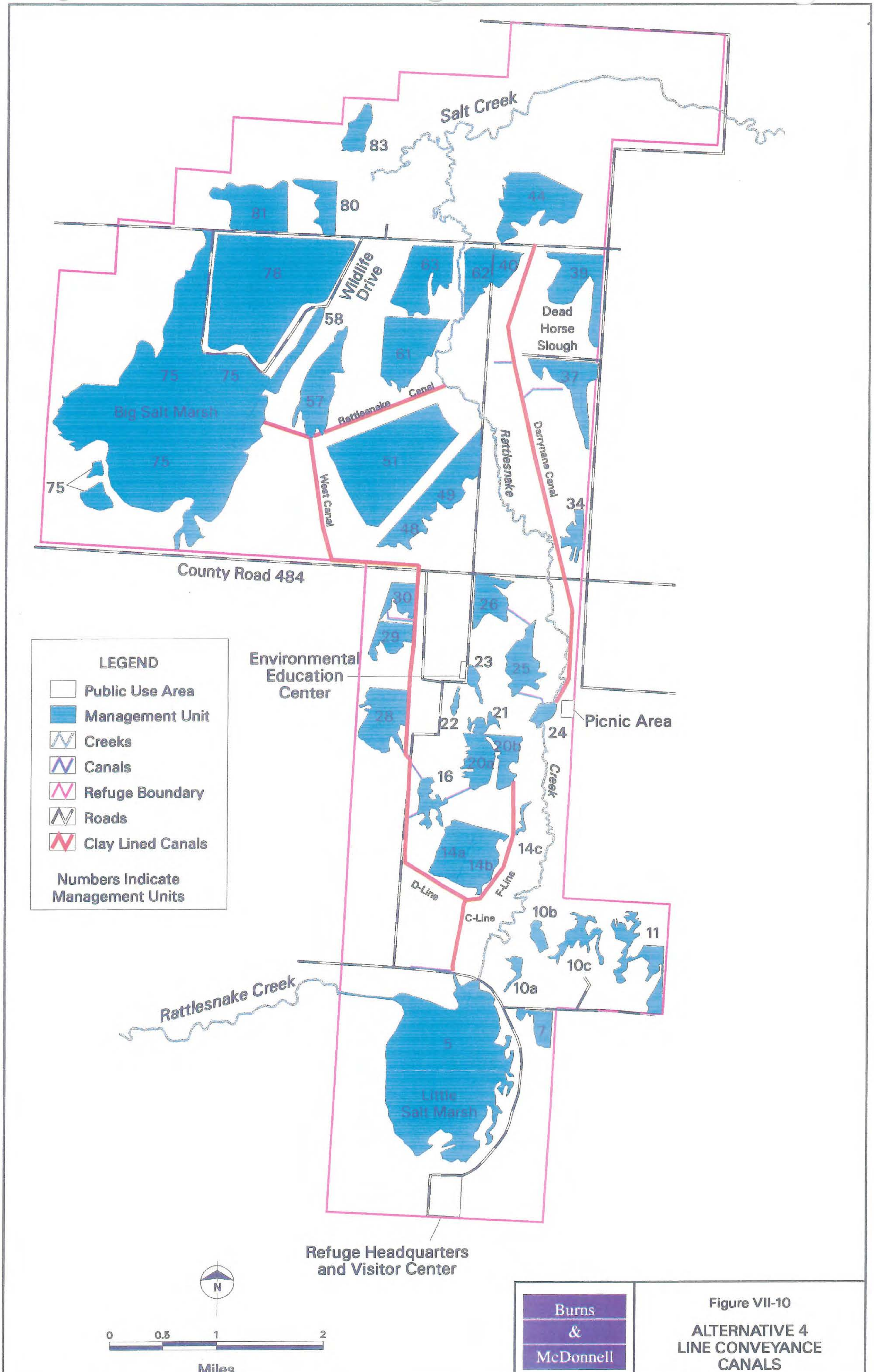
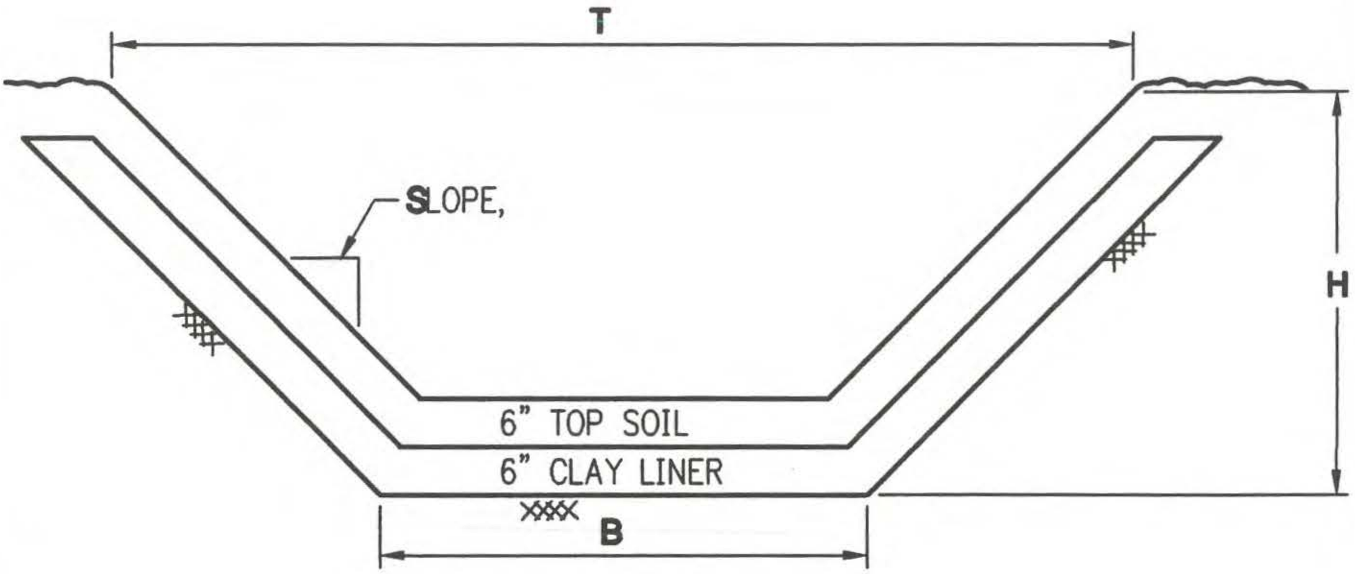


Figure VII-10

ALTERNATIVE 4
LINE CONVEYANCE
CANALS



CANAL TYPICAL SECTION

NOT TO SACLE

CANAL	SLOPE[2] S	HEIGHT[1] H (FEET)	BOTTOM WIDTH[1] B (FEET)	TOP WIDTH[1] T (FEET)	LENGTH[3] (FEET)
C-LINE	1:4	5	10	50	3,900
D-LINE	1:5	5	10	60	4,150
F-LINE	1:5	5	10	60	5,000
WEST	1:5	5	10	60	25,500
RATTLESNAKE	1:6.5	6	20	100	8,200
DARRYNANE	1:5	5	10	60	21,300

NOTES:

1. DIMENSIONS ARC AVERAGES OF CROSS SECTION FROM SERVICE'S ELECTRONIC SURVEY.
2. CALCULATED BASED ON DIMENSIONS OF CHANNEL.
3. MEASURED FROM 7.5 - MINUTE USGS TOPOGRAPHIC MAPS.
4. ALL ABOVE DIMENSIONS ARE APPROXIMATE.

Burns & McDonnell

FIGURE VII-11

ALTERNATIVE 4
TYPICAL CANAL LINING SECTION

J:\ WS\978064\procws\CANALS01.DWG 02-06-1998 14:33

- Construct 5,000 linear feet of clay liner in F-line canal.
- Construct 25,500 linear feet of clay liner in West canal.
- Construct 8,200 linear feet of clay liner in Rattlesnake canal.
- Construct 21,300 linear feet of clay liner in Darrynane canal.

Work to line the canals would begin with the removal of a one-foot layer of soil in each canal. Approximately 6 inches of clay would be placed and compacted on the entire excavated cross section of the canal. Another 6 inches of random fill would be placed over the clay layer. Excavated material would be used as random fill material in the canals if it is of suitable quality. Use of this layer of random fill will help the vegetation previously found in the canals become re-established. Excess excavated material from the canals can be placed and graded in the vicinity of the canal or used to fill nearby clay or random fill borrow areas.

Possible sources for impervious clay material include Carwile and Pratt soils that can be obtained from borrow areas west and southeast of Little Salt Marsh and in the vicinity of Dead Horse Slough. Permeability for these two soil types range from 0.06 to 2.0 inches/hour and exhibit a moderate to high, shrink-swell potential. This indicates good impervious material is located within the Refuge eliminating the need to import clay for lining.

4. Operations Model

The base operations model assumes 10 percent of the flow in the major canals is lost due to infiltration and evapotranspiration. The model for this alternative assumes these losses are reduced to 1 percent after these canals are lined. No other changes to the baseline model are necessary for this alternative.

Execution of the operations model for this alternative shows that lining these canals would reduce Refuge diversions slightly. The average annual diversions to the Refuge decrease from a baseline value of 6,849 acre-feet to 6,814 acre-feet, a slight decrease of 35 acre-feet per year. Diversions decrease slightly under this alternative since less water is lost from the canals and, therefore, less must be diverted to satisfy the net water needs of the Refuge.

Lining the major canals will reduce the canal losses. These losses are estimated to decrease from an average of 375 acre-feet per year under baseline conditions to about 228 acre-feet per year, a net decrease of 147 acre-feet per year. Therefore, the net increase in the water supply to the Refuge is about 112 acre-feet per year.

The operations model assumes that canal seepage losses are lost from the flow system entirely. In reality, some, if not most, of this "lost" water could reappear as inflow to downstream management units. Because of this, the base operations model probably overstates Refuge diversions to the extent that some of these canal losses are recaptured in lower management units. Under this assumption, the amount of water savings that can be achieved by lining the major conveyance canals is actually less than stated above. In any event, the magnitude of these canals losses, both under existing conditions and after lining, are relatively small and, therefore, the conclusions reached in this study are not impacted to a significant degree by this limitation of the operations model.

Statistics on the availability of wetland habitat at the Refuge for this alternative are presented in Table VII-25. Review of this table shows that lining the major canals increases the average amount of each type of habitat at the Refuge by a few acres.

Table VII-25
AVAILABLE WETLAND HABITAT—ALTERNATIVE 4 [1]

Alternative	Shorebird (1–4 inches)		Waterfowl (10–18 inches)		Total Wetland	
	Range	Average	Range	Average	Range	Average
Baseline	85-684	358	11-1,055	602	692-6,000	2,757
C.4	85-684	360	12-1,056	605	694-6,002	2,785

Note: 1. All wetland habitat values in acres. Statistics include data for primary migration season, September through April only.

The 80th percentile habitat areas and the change in these values over baseline conditions are shown in Table VII-26. The quantities of optimum shorebird and waterfowl habitat are virtually unchanged under this alternative. The amount of total wetland habitat does increase slightly.

Table VII-26
CHANGES IN AVAILABLE WETLAND HABITAT—ALTERNATIVE 4

Habitat Type	80th Percentile Wetland Habitat (acres)		
	Baseline	Alternative 4	Change over Baseline
Optimum Shorebird	237	237	0
Optimum Waterfowl	354	352	-2
Total Wetland	1,416	1,437	+21

Review of Table VII-26 shows that implementation of this alternative would be have only a slight impact on available wetland habitat at the Refuge. Although canal losses are assumed to be reduced by lining under this alternative, in the operations model these losses are low anyway during dry periods. The 80th percentile habitat values are indicative of the habitat available during these drier periods. The operations model estimates canal losses as a fixed percentage of the total flow in the canal each month. In actual fact, these losses are highly dependent on antecedent conditions. When a canal has been dry for an extended time, the initial canal losses will be significant and will gradually decrease to near zero as the soil and aquifer below the canal becomes saturated. More accurate estimation of canal losses is beyond the capabilities of the operation model. Increased canal losses during drier periods, as a percentage of total canal flow, will serve to reduce the amount of wetland habitat available at the Refuge during these critical times.

5. Water Quality

The source water does not change in this alternative; therefore, no impact to Refuge water quality is expected.

6. Environmental and Cultural Resource Impacts

Alternative 4 would involve modifications to approximately 13 miles of existing large water conveyance canals. These canals range in width from 50 to 100 feet and have soil bottoms and vegetated sides. Most canals contain some amount of emergent vegetation. Vegetative cover within the canals ranges from almost none to the canal being heavily overgrown. Many of the canals have become silted in over time, due to sediment deposition and to build-up of organic matter from vegetation. Some wildlife habitat is provided by the canals, especially for reptiles and amphibians. Wading birds use canal areas with little or no vegetation. While waterfowl have been observed in these canals (Hilley, 1998), they are generally too confining and do not offer waterfowl the security of open water areas. Habitat that is provided is generally of lesser quality than that provided by specific management units.

Lining the canals would involve cleaning the canals of vegetation and removing several inches of soil and silt. This would eliminate the existing vegetation within these canals, and would result in the loss of habitat. The habitat lost is not considered significant, given the amounts of similar and higher quality habitat available on the Refuge. Following placement of the clay liner, several inches of soil would be replaced in the canals to cover the liner. This material would provide substrate for vegetation reestablishment, and if excavated material is used as fill, would contain seeds, roots, and rhizomes of the wetland plants formerly growing in the canal. In one to two growing seasons, vegetation would again be actively growing in the canals. Within five years, the canals would be expected to have completely recovered from canal lining activities. As a result, only a minimal, short-term reduction of the habitat provided in the conveyance canals would occur.

Construction impacts for this alternative would be the same as discussed in Section C.6. Following completion of construction and the reestablishment of vegetation, disturbance to wildlife would cease and wildlife would move back into the canals.

No known cultural resources sites occur in the vicinity of any conveyance canals. No previously undisturbed areas would be impacted by canal lining. Any cultural resources discovered would have been previously disturbed or destroyed during canal construction, installation of control structures, or other construction activities associated with these canals. This alternative would have no impact on cultural resources. However, should any previously undisturbed areas need to be impacted by this alternative, they should be surveyed to determine if cultural materials are present, if they are significant, what project impacts would be, and what actions should be taken.

7. Project Cost Estimates

Project costs, operation and maintenance costs, present value and benefit-cost analysis for this alternative are included below and used in Task E to compare and select the best alternative(s) for implementation.

a. Project Costs

The estimated project cost for this alternative is $1.92 million as listed in Table VII-27. The average life cycle unit cost of water for Alternative 4 is $2,633 per MG based on project costs.

b. Operation and Maintenance (O&M) Costs

After lining, the operation and maintenance requirements of these canals will be no different than they currently are. Therefore, development of this alternative should have no net effect on O&M costs at the Refuge.

c. Present Value Analysis

The present value for Alternative 4 in 1998 dollars is $1.87 million. The average life cycle unit cost of water for Alternative 4 is $2,559 per MG over 20 years of operation based on present value.

d. Benefit-Cost Analysis

A benefit of 21 acres of additional wetlands are estimated at a respective 20 year present value of $190,000. This results in a benefit-cost ratio of 0.1.

Table VII-27
PROJECT COST ESTIMATE
ALTERNATIVE 4 - LINE CONVEYANCE CANALS

Item	Cost ($)	
C-Line Canal (3,900 linear feet)	64,000	16.4/ft
D-Line Canal (4,150 linear feet)	81,000	19.5/ft
F-Line Canal (5,000 linear feet)	97,000	19.4/ft
West Canal (25,500 linear feet)	497,000	19.5/ft
Rattlesnake Canal (8,200 linear feet)	229,000	27.9/ft
Darrynane Canal (21,300 linear feet)	367,000	16.9/ft
Subtotal	1,335,000	
Contingency at 20%	267,000	
Subtotal	1,602,000	
Other Costs at 20%	320,000	
Total Project Cost	**1,922,000**	
Average Annual Water Volume (MG)	**36**	
Average Life Cycle Unit Cost of Water ($/MG)	**2,633**	

E. ALTERNATIVE 5 - REMOVE SEDIMENT FROM LITTLE SALT MARSH

1. General

This alternative evaluates the removal of 100 acre-feet of sediment from Little Salt Marsh to restore the original storage potential of the marsh. Little Salt Marsh is the first point of diversion from Rattlesnake Creek and provides the greatest volume of water storage on the Refuge. Stored water is released from Little Salt Marsh for use in the management units. The removal of 100 acre-feet of sediment increases the existing storage capacity from 1,870 acre-feet to 1,970 acre-feet.

2. Little Salt Marsh

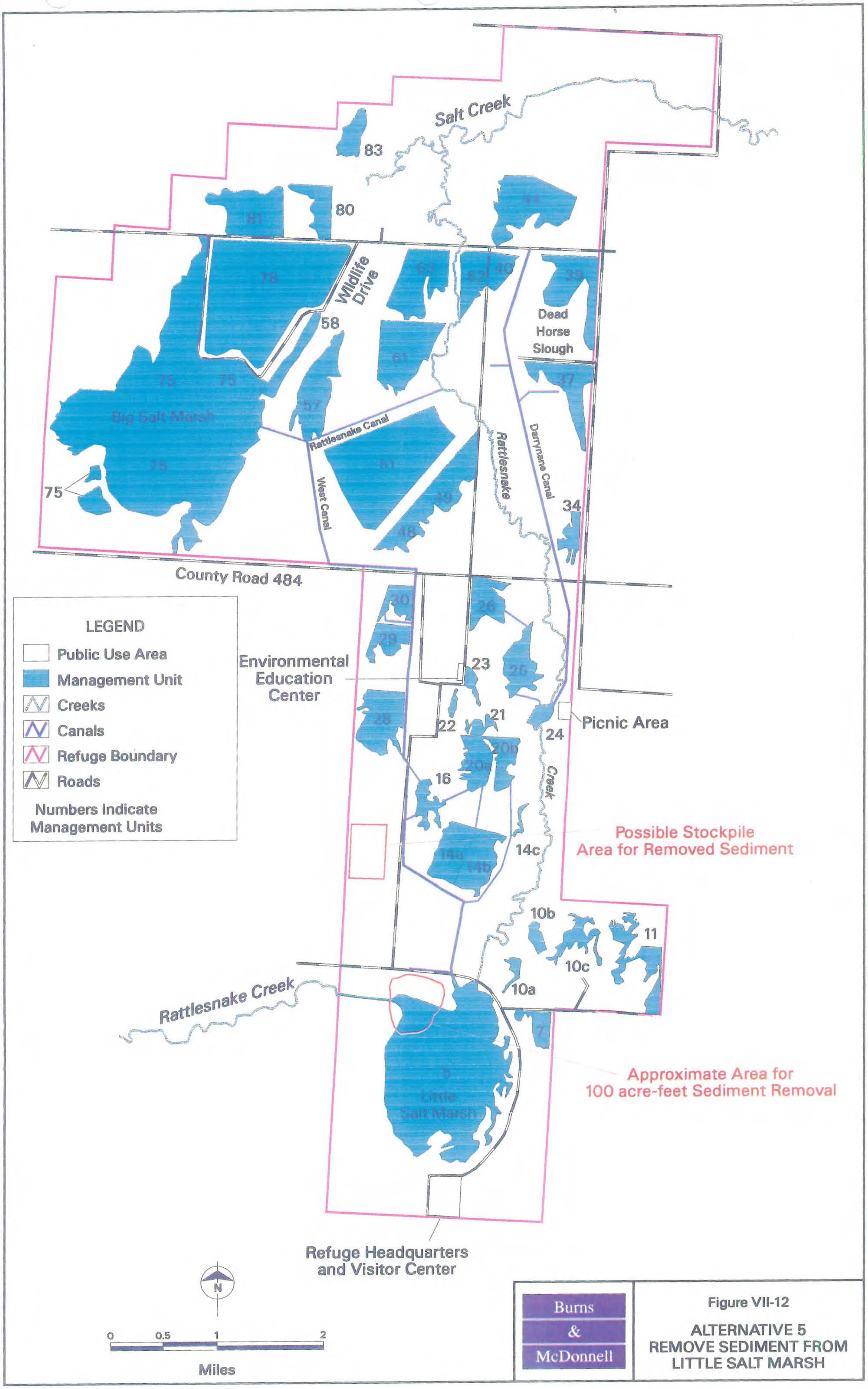
According to the Service, Rattlesnake Creek has deposited about 100 acre-feet of sediment in Little Salt Marsh over the last 3 to 4 decades. This natural occurrence is inevitable as sediments are held in suspension with higher flow velocities. As this sediment-laden water is discharged into Little Salt Marsh, the velocity decreases causing the sediment to be deposited, primarily near the mouth of the creek. Over time, deposited sediment accumulates and decreases the storage capacity of Little Salt Marsh.

3. Preliminary Concept Design

The concept design for this alternative provides an additional 100 acre-feet of storage capacity by removing sediment in Little Salt Marsh as shown in Figure VII-12. The design includes the following major components and a discussion of each component follows.

- Remove 100 acre-feet of sediment with heavy equipment.
- Stockpile removed sediment for possible reuse.

The removal of 100 acre-feet of sediment is assumed to take place when the water level in Little Salt Marsh is low. During that time, conditions for sediment removal are ideal since the area is assumed to be dry and no sheetpiling would be required. If sediment removal occurs when working conditions are wet, the cost is increased due to the time required for removal and hauling.



Burns & McDonnell

Figure VII-12

ALTERNATIVE 5
REMOVE SEDIMENT FROM LITTLE SALT MARSH

A 3-foot depth of sediment is removed from a 33.33 acre area using mechanical equipment such as dozers and scrapers, and is hauled about one mile to a proposed stockpile area northwest of Little Salt Marsh.

4. Sediment Deposition Rates

The removal of 100 acre-feet of accumulated sediment from Little Salt Marsh would not be a one time fix. Sediment will continue to accumulate with higher flows and with time in the marsh. To maintain the recovered storage in Little Salt Marsh, sediment will have to be removed periodically from the marsh. To estimate how often this may be required, an analysis was conducted to determine the rate of sediment deposition in the marsh. The findings from this analysis are discussed below.

The sediment load of Rattlesnake Creek can vary dramatically from day to day depending on a number of factors. These factors include:

- Flow rates in Rattlesnake Creek and its tributaries.
- Temporal and areal distribution of precipitation events within the watershed.
- Antecedent conditions of the watershed.
- Land use and soil conservation practices.
- Season of the year.

Although these and other factors will influence the sediment load of Rattlesnake Creek as it enters the Little Salt Marsh, the flow rate, or discharge, of Rattlesnake Creek is the only one of these factors that can be readily estimated. Therefore, a regression analysis is used to estimate suspended sediment concentrations in the creek as a function of its discharge. The USGS has collected discharge and suspended sediment concentration data from a number of locations on Rattlesnake Creek. These locations are listed in Table VII-28 along with the number of samples collected and collection period. The sampling data associated with these stations were obtained from EPA's STORET database.

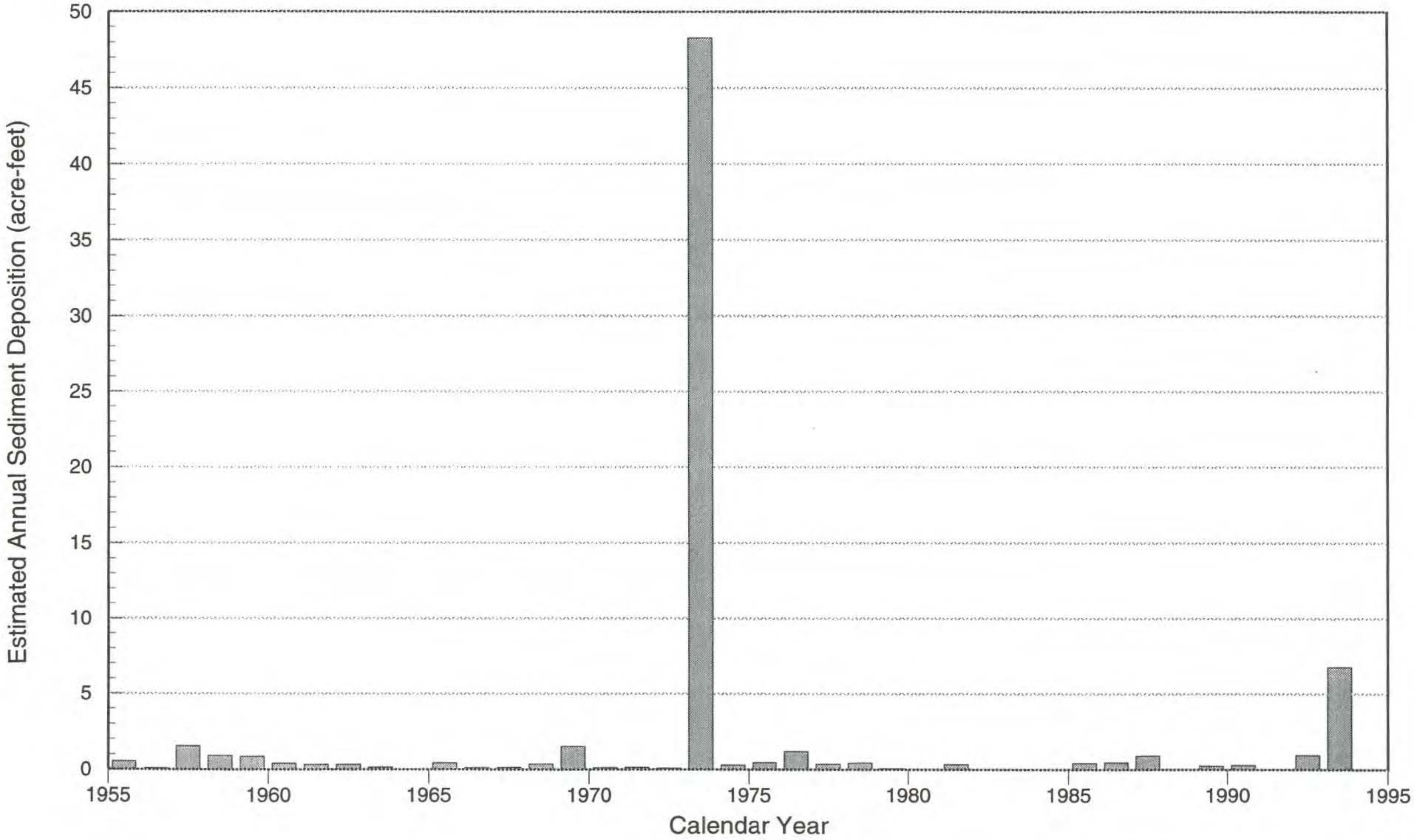
Table VII-28
SUSPENDED SEDIMENT DATA FOR RATTLESNAKE CREEK

Station No.	Station Name	No. of Samples	Period of Record
07142100	Rattlesnake Creek Tributary near Mullinville	1	5/73
07142300	Rattlesnake Creek near Macksville	68	10/73–03/87
07142575	Rattlesnake Creek near Zenith	4	05/85–03/87
07142620	Rattlesnake Creek near Raymond	21	03/60–10/75

Only two of the stations listed in Table VII-28 have a sufficient number of samples for use in regression analyses. These stations are located at the Macksville and Raymond gages. The Raymond gage is located downstream of the Refuge and the suspended sediment concentrations at this location are not expected to be representative of those which enter Little Salt Marsh. Therefore, only those data available at the Macksville gage were used in the regression analysis. The equation that results from this analysis is $C = 126.433 + 0.486\ Q$, where C is the suspended sediment concentration in milligram per liter (mg/l) and Q is the discharge in cfs. The coefficient of determination (R^2) for this regression equation is 0.354. This R^2 value indicates that the regression equation, or model, is able to account for 35.4 percent of the variations in the suspended sediment concentrations. The remainder of these variations are due to factors other than discharge. Although a higher R^2 value—ideally one substantially greater than 0.5—would strengthen the validity of this regression equation, it still represents the best means available to estimate sediment load.

The mean daily discharge in Rattlesnake Creek, as it enters Little Salt Marsh, is estimated using the flow distribution procedure discussed previously in Parts V and VI. These daily discharge estimates are used, along with the regression equation discussed above, to estimate daily sediment loads to Little Salt Marsh. To estimate sediment deposition, a trap efficiency of 50 percent is assumed. Sediment volumes are estimated using a unit weight of 100 pounds per cubic foot (pcf). The resulting estimated annual sediment deposition in Little Salt Marsh is shown on Figure VII-13. The total sediment deposition over the 40-year simulation period is estimated to be 71 acre-feet, or an annual average of 1.8 acre-feet per year.

As shown on Figure VII-13, most sediment accumulation occurs during flood events. The most significant such events at the Refuge occurred in 1973 and 1993. Since it is impossible to predict when future flood



Notes
1. Based on regression equation to predict suspended sediment concentrations as a function of discharge and daily discharge estimates for Rattlesnake Creek as it enters Little Salt Marsh.
2. Sediment trap efficiency of Little Salt Marsh assumed to be 50 percent.
3. Unit weight of deposited sediment assumed to be 100 pounds per cubic foot.

Burns & McDonnell

Figure VII-13

ESTIMATED SEDIMENT DEPOSITION LITTLE SALT MARSH

events will occur, future sediment accumulation should be estimated using the long-term average of 1.8 acre-feet per year. At this rate, the 100 acre-feet removed from the marsh would be redeposited in about 55 years. To retain the storage capacity of the Little Salt Marsh, it is recommended that sediment be removed from the marsh again once about 25 acre-feet of sediment has redeposited, or about every 14 years on average.

5. Operations Modeling

No changes to the schematic for the base operations model are necessary to investigate this alternative. The only required change is to modify the elevation–area–capacity data for Little Salt Marsh to reflect the removal of 100 acre-feet of sediment.

From review of the Service's data for Little Salt Marsh, it appears that deposited sediment is about three feet thick. Based on this depth, the 100 acre-feet removed from the marsh was assumed to be removed as a block of sediment 3 feet high by 33.3 acres in area. Although this assumption is sufficient for use in the operation model, the actual distribution of the sediment removed would likely vary from this.

Execution of the operations model for this alternative shows that the storage volume recovered in Little Salt Marsh does increase the water available to the Refuge. The average annual diversions to the Refuge increase from a baseline value of approximately 6,858 acre-feet to 6,887 acre-feet, an increase of 29 acre-feet per year.

Monthly statistics on the availability of wetland habitat at the Refuge for this alternative are presented in Table VII-29. Peak habitat ranges up to approximately 300 acres for shorebirds and 1,000 acres for waterfowl. The average habitat areas for shorebirds, waterfowl, and total wetlands are respectively 309, 526, and 2,463 acres.

Table VII-29
AVAILABLE WETLAND HABITAT—ALTERNATIVE 5 [1]

Month	Shorebird (1–4 inches)		Waterfowl (10–18 inches)		Total Wetland	
	Range	Average	Range	Average	Range	Average
Jan	177-684	376	110-1,020	625	972-6,033	2,884
Feb	173-682	374	144-1,029	623	1,023-5,857	2,890
Mar	170-683	376	145-1,017	631	1,028-5,974	2,945
Apr	133-681	368	117-1,055	672	937-5,869	2,968
Sep	78-626	309	11-1,019	526	723-5,338	2,463
Oct	97-684	334	12-1,021	561	759-6,028	2,586
Nov	130-681	354	42-1,054	561	859-5,982	2,676
Dec	145-682	370	81-1,035	600	921-5,984	2,746
Sep–Apr	78-684	358	11-1,055	600	723-6,034	2,770

Note: 1. All wetland habitat values in acres. Statistics include data for primary migration season, September through April only.

The 80th percentile habitat areas and the change in these values over baseline conditions are shown in Table VII-30. This table shows that implementation of this alternative would have little impact on available wetland habitat at the Refuge. This results because there is little benefit in having additional storage in Little Salt Marsh during drier years when flows are reduced. Also, for this analysis, it was assumed that sediment would be removed from the marsh in such a fashion that the pool surface area would increase. This increase in surface area would tend to increase evaporation losses, further reducing any benefits that may result from an increased storage capacity.

Table VII-30
CHANGES IN AVAILABLE WETLAND HABITAT—ALTERNATIVE 5

Habitat Type	Wetland Habitat (acres)	
	80th Percentile	Change over Baseline
Optimum Shorebird	237	0
Optimum Waterfowl	347	-7
Total Wetland	1,424	8

6. Water Quality

Since Rattlesnake Creek is the water source in this alternative, no impact to the Refuge water quality is anticipated.

7. Environmental and Cultural Resource Impacts

Sediment deposition has primarily occurred in the area where Rattlesnake Creek enters Little Salt Marsh. This deposition has reduced the water depth of the marsh in this area, creating shallower water suitable for cattail encroachment.

Based on a review of aerial photographs, most of the area of Little Salt Marsh around the mouth of Rattlesnake Creek is open water. However, the creek channel meanders through large areas of cattails. Approximately 20 acres of cattails are present where the creek enters the marsh. Additional cattail areas, totaling over 100 acres, ring this area of the marsh, apparently created by sedimentation and channel relocations of Rattlesnake Creek. Areas of wet meadow are present north of Rattlesnake Creek and may also be a product of sedimentation over the years. It is assumed most of the sedimentation has occurred within existing cattail areas around the northwest fringe of Little Salt Marsh.

Removal of silt should have little impact on the habitat, vegetation, and wildlife resources of Little Salt Marsh and the Refuge. The alternative would result in an increased depth of 3 feet over 33.3 acres of the marsh. Any vegetation currently present would be removed along with silt. However, a depth increase of three feet would not preclude reestablishment by the types of vegetation removed. Silt not removed would contain seeds, tubers, and rhizomes of previous vegetation that would quickly revegetate previously vegetated areas. This alternative would temporarily create 33.3 acres of additional open water habitat in Little Salt Marsh. However, following establishment of vegetation, no overall change in habitat types or availability would be expected.

The primary impact to wildlife would involve disturbance during construction due to human activity and operation of heavy equipment (see Section A.6). A large portion of the marsh would remain undisturbed, being a refuge for individuals disturbed by construction. Only a few individuals would be disturbed due to the small area involved and construction potentially occurring during a low wildlife use period. Overall, wildlife would benefit from the additional water storage capacity within the marsh as discussed in Section A.6.

Because only silt deposited in the marsh would be removed, no cultural resources would be disturbed by removal activities. Should previously undisturbed areas or material below that which has been deposited in the marsh require disturbance or removal, a cultural resources survey may be necessary. Such a survey would determine if cultural materials are present, if they are significant, what project impacts would be, and what actions should be taken.

8. Project Cost Estimates

These project costs are used in Task E for the purpose of comparing and selecting the best alternative (s) or plan for implementation.

a. Project Costs

The estimated project cost is $0.93 million as listed in Table VII-31. The average life cycle unit cost of water is $4,915 per million gallons (MG) based on project costs.

b. Operation and Maintenance (O&M) Costs

Maintenance cost for Alternative 5 includes the cost for 25 acre-feet of sediment removal every 14 years. The maintenance cost in year 2013 is $334,000 based on an inflation rate of 4 percent per year. This cost is used in combination with the project cost to calculate the present value for the alternative.

c. Present Value Analysis

The present value for Alternative 5 in 1998 dollars is $1.02 million. The average life cycle unit cost of water is $5,418 per MG over 20 years of operation based on present value.

d. Benefit-Cost Analysis

The addition of 8 acres of wetland habitat present value benefit of $73,000. This results in a benefit-cost ratio of 0.05 for this alternative.

Table VII-31
PROJECT COST ESTIMATE
ALTERNATIVE 5 - REMOVE SEDIMENT FROM LITTLE SALT MARSH

Item	Cost ($)
Sediment Removal	645,000
Subtotal	645,000
Contingency at 20%	129,000
Subtotal	774,000
Other Costs at 20%	155,000
Total Project Cost	**929,000**
Average Annual Water Volume (MG)	**9**
Average Life Cycle Unit Cost of Water ($/MG)	**4,915**

F. ALTERNATIVE 6 - CONSTRUCT BYPASS CANAL AROUND LITTLE SALT MARSH

1. General

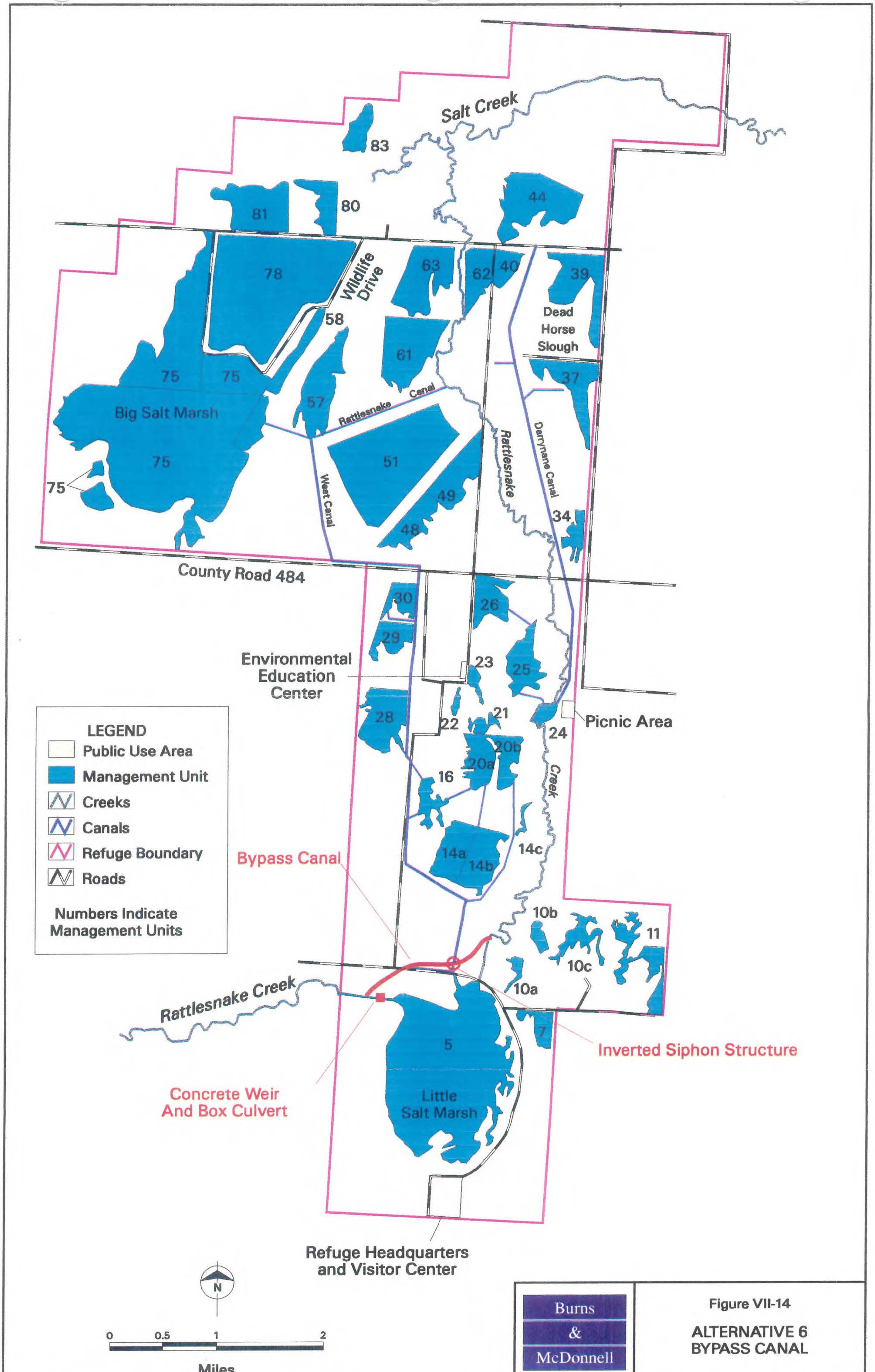
This alternative evaluates the construction of a bypass canal to minimize the amount of sediment being deposited in Little Salt Marsh during flood events as shown in Figure VII-14. Complete elimination of sediment deposition is not realistic, but the rate can be reduced by passing flood flows that generally carry large volumes of sediment.

This alternative includes the construction of a 1.4-mile long bypass canal, a concrete box culvert, and inverted siphon. Flows up to 300 cubic feet per second (cfs) in Rattlesnake Creek would pass through the concrete box culvert directly into Little Salt Marsh. At higher flows, the concrete box culvert would restrict inflow to Little Salt Marsh to a maximum of 550 cfs. All flow in excess of 550 cfs would discharge into the bypass canal over a 100-foot wide weir located upstream of the box culvert. The bypass canal flows back into Rattlesnake Creek downstream of Little Salt Marsh.

2. Bypass Canal

Rattlesnake Creek, immediately upstream of Little Salt Marsh, is incised in a channel with banks about six feet high. The bank-full discharge in the creek is estimated to be approximately 1,870 cfs. At flow depths up to about 8 feet, with a corresponding discharge of 2,400 cfs, the flow in Rattlesnake Creek stays confined to the immediate overbank areas along the creek. Above a discharge of 2,400 cfs, the flow in the creek spreads out dramatically, flooding much of the Refuge. Because of this limitation, it is considered impractical to control flood discharges much over 2,400 cfs. For this reason, the bypass canal and diversion structure are designed using a maximum discharge of 2,400 cfs and a design head of 8 feet.

The diversion structure for the bypass canal includes a concrete box culvert, 12 feet wide by 4 feet high. At a design head of 8 feet, the discharge through the box culvert into Little Salt Marsh will reach its maximum of 550 cfs. Under these design conditions, the remainder of the flow in Rattlesnake Creek, 1,850 cfs, will flow down the bypass canal. Therefore, the bypass canal is designed for a maximum discharge of 1,850 cfs.



Burns & McDonnell

Figure VII-14

ALTERNATIVE 6
BYPASS CANAL

3. Preliminary Concept Design

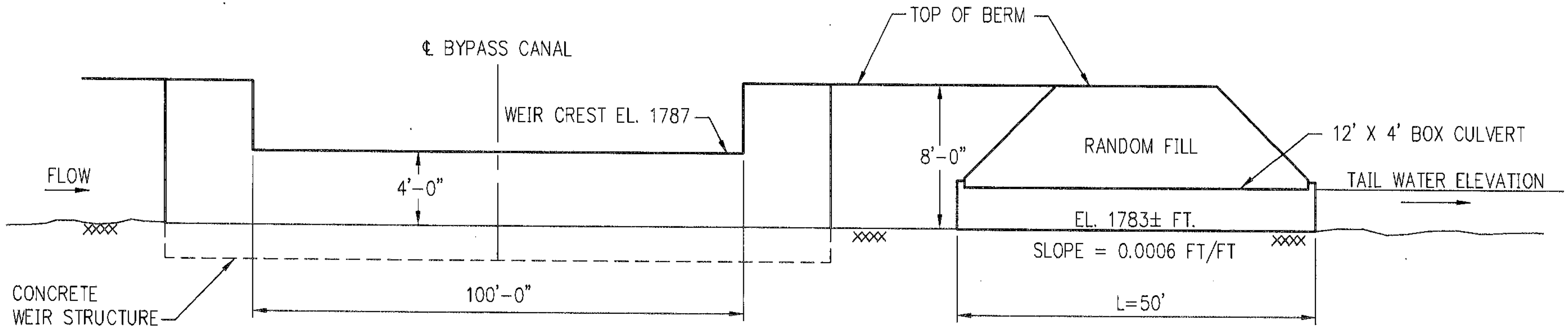
The preliminary concept design for this alternative provides for the construction of a concrete box culvert and a bypass canal as shown in Figure VII-15. The purpose of this alternative is to reduce the sediment deposited in Little Salt Marsh during flood events. This concept includes the following major components:

- Construct a 12-foot wide by 4-foot high concrete box culvert in Rattlesnake Creek.
- Construct 100-foot long concrete weir.
- Construct a bypass canal 7,550 feet in length, with a 100-foot bottom width and 2:5:1 side slopes.
- Construct an inverted siphon structure in C-line Canal.
- Construct 2,000 linear feet of berm, 2 feet high, to contain Rattlesnake Creek.

The proposed 12-foot wide and 4-foot high concrete box culvert is located downstream of the bypass canal in the existing Rattlesnake Creek channel. The culvert is assumed to be 50 feet in length and have a slope of 0.0006 feet per foot.

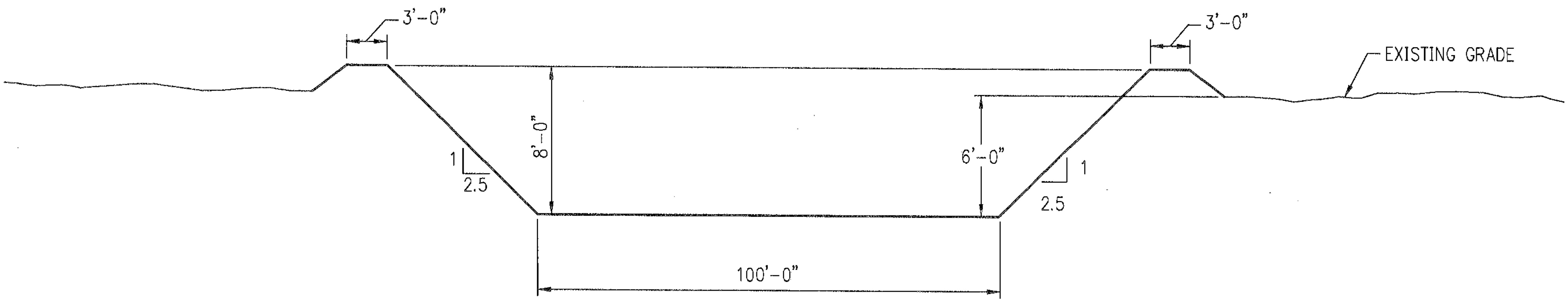
At depths greater than 4 feet in Rattlesnake Creek, excess flood flow will pass over the proposed concrete weir into the bypass canal. The bypass canal begins northwest of Little Salt Marsh and intersects Rattlesnake Creek 2,000 feet downstream of Little Salt Marsh. The proposed bypass canal generally follows the existing creek located northwest of Little Salt Marsh. The bypass canal has a bottom width of 100 feet, 2.5:1 side slopes and channel depth of 8 feet. The area in the vicinity of the concrete box culvert and weir, and the downstream reentry into Rattlesnake Creek will be ripraped to minimize erosion to the banks and dissipate energy during flood conditions. A warm season native grass seed mixture will be planted on the bypass canal berms for erosion protection.

An inverted siphon structure would be used to convey flow in the C-line Canal under the bypass canal. The inverted siphon is constructed below the bypass canal as shown in Figure VII-16. The inverted siphon includes an inlet and outlet control structure. Flow from the C-line Canal is diverted into a 24-inch reinforced concrete pipe with an average capacity of 13 cfs. Flows larger than 13 cfs flow over a 24-inch weir into the 48-inch reinforced concrete pipe which has a maximum capacity of 212 cfs. The total



CROSS SECTION ALONG RATTLESNAKE CREEK

NOT TO SCALE



TYPICAL BYPASS CANAL CROSS SECTION

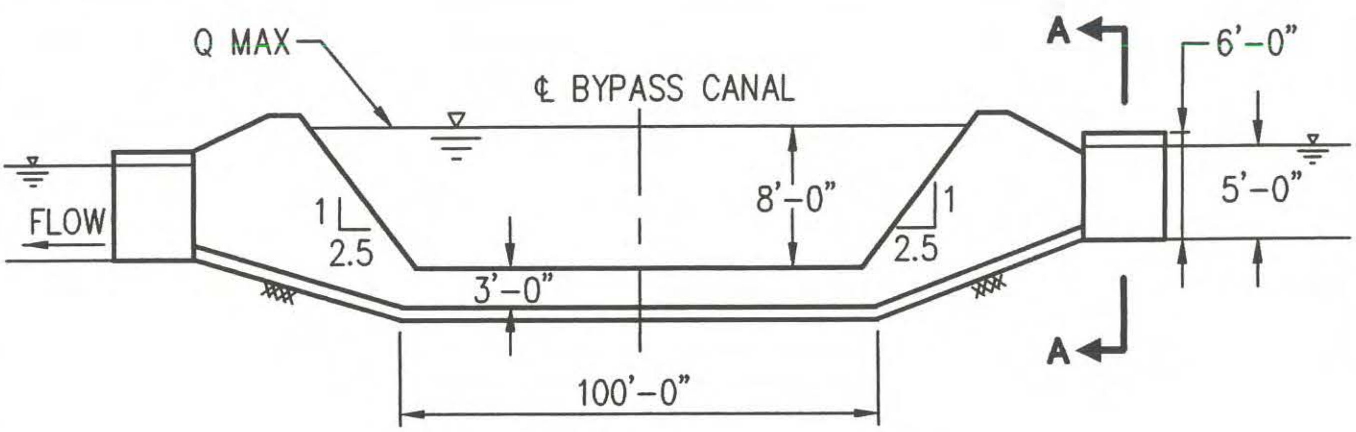
NOT TO SCALE

Burns & McDonnell

Figure VII-15

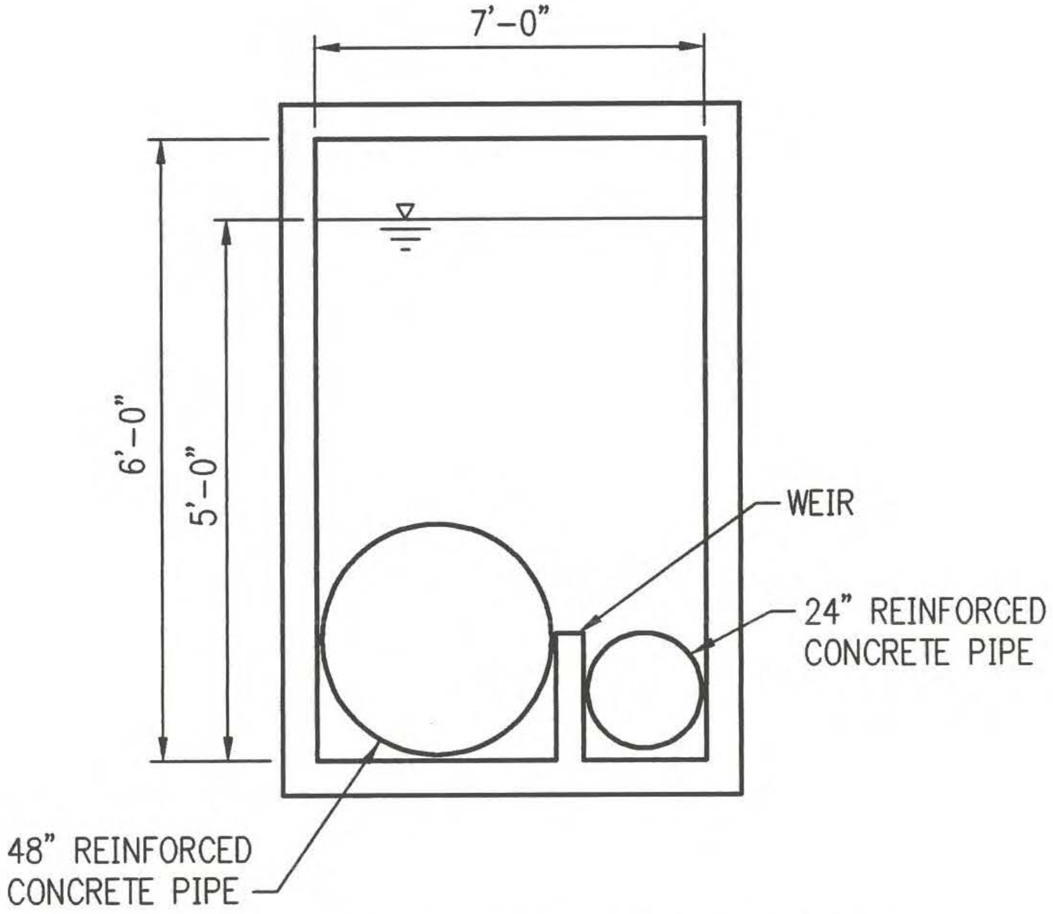
ALTERNATIVE 6
BYPASS CANAL AND
CULVERT DETAILS

J:\USFWS\978064\procws\ALT6-2.DWG 02-17-1998 13:02 AAO



INVERTED SIPHON CROSS SECTION

NOT TO SCALE



SECTION A-A INLET CONTROL STRUCTURE

NOT TO SCALE

Burns & McDonnell

Figure VII-16

ALTERNATIVE 6
INVERT SIPHON DETAILS

maximum combined capacity for both inverted siphons is 225 cfs, which is also the maximum capacity for C-line Canal.

4. Operations Model

Analysis of Alternative 6 requires the use of two separate operations models. These two models and their results are discussed in the following paragraphs.

a. Baseline Future Model

The purpose of the potential bypass channel is to divert flood flows around the Little Salt Marsh, and thereby, limit future sediment deposition in the marsh. Therefore, in order to evaluate this alternative, it must be compared against some future condition wherein sediment continues to deposit in the marsh. Under this "baseline future" condition, sediment will continue to accumulate, further reducing the storage capacity of the marsh. Since the planning horizon for the economic analysis is 20 years, the baseline future condition is defined as current conditions plus 20 years of additional sediment accumulation in Little Salt Marsh.

Sediment is assumed to deposit in Little Salt Marsh at the average annual rate of 1.8 acre-feet per year. This deposition rate is estimated as discussed under Alternative 5 above. Over 20 years, an additional 36 acre-feet of sediment is projected to accumulate in Little Salt Marsh. No changes to the schematic for the base operations model are necessary to investigate this alternative. The only required change is to modify the elevation–area–capacity data for Little Salt Marsh to reflect the addition of 36 acre-feet of sediment. This sediment is assumed to deposit in a 12-acre layer 3 feet thick.

b. Little Salt Marsh Bypass Model

Construction of the operations model for this alternative requires estimates of daily discharge in Rattlesnake Creek as it enters the Little Salt Marsh. These estimates are developed using the flow distribution procedure discussed in Parts V and VI. From these discharge estimates, the quantities of water entering and bypassing the marsh are estimated. All discharges of 300 cfs or less are assumed to enter the marsh without bypass. Above 300 cfs, the percentage of flow bypassed increases gradually until the inflow to Little Salt Marsh reaches it maximum of 550 cfs at a total flow of 2,400 cfs. All flow in Rattlesnake Creek above 2,400 cfs is assumed to bypass the marsh.

A single new junction node (No. 190) is added to the model for this alternative. This node is connected to Little Salt Marsh via a new link. The inflow to Node 190 is set equal to the estimated after-bypass inflow to Little Salt Marsh. The inflow to Node 110 is reduced by the amount of inflow to Little Salt Marsh and this link is redirected to Node 300. A schematic of this model is included in the Model section of the Appendix.

c. Modeling Results

Execution of the operations model for these two models shows that bypassing flood flows and reducing future sediment deposition in the Little Salt Marsh does increase the water available for diversion at the Refuge. The average annual diversions to the Refuge increase from a baseline value of approximately 6,849 acre-feet to 6,863 acre-feet, a small increase of about 14 acre-feet per year.

Statistics on the availability of wetland habitat at the Refuge for this alternative are presented in Table VII-32. Review of this table shows that the bypass channel reduces the average optimum shorebird habitat slightly but increases the average values for waterfowl and total wetlands.

Table VII-32
AVAILABLE WETLAND HABITAT—ALTERNATIVE 6 [1]

Model	Shorebird (1–4 inches)		Waterfowl (10–18 inches)		Total Wetland	
	Range	Average	Range	Average	Range	Average
Baseline Future	85-684	361	12-1,047	597	669-5,985	2,751
Alternative 6	85-684	358	12-1,055	599	693-5,999	2,758

Note: 1. All wetland habitat values in acres. Statistics include data for primary migration season, September through April only.

The 80th percentile habitat areas and the change in these values over baseline conditions are shown in Table VII-33.

Table VII-33
CHANGES IN AVAILABLE WETLAND HABITAT—ALTERNATIVE 6

Habitat Type	80th Percentile Wetland Habitat (acres)		
	Baseline Future	Alternative 6	Change over Baseline
Optimum Shorebird	245	240	-5
Optimum Waterfowl	351	351	0
Total Wetland	1,421	1,415	-6

Review of Table VII-33 shows that implementation of this alternative will have little impact on available wetland habitat at the Refuge. This results because there is little benefit in having additional storage in the Little Salt Marsh during drier years when flows are reduced. Also, for this analysis, it was assumed that sediment would be removed from the marsh in such a fashion that the pool surface area would increase. This increase in surface area would tend to increase evaporation losses, further reducing any benefits that may result from an increased storage capacity. The water bypassed around the Little Salt Marsh has little impact on the amount of available habitat. Bypasses occur during wetter periods when there is normally sufficient water available and the water bypassed is also available for diversion at Darrynane Lake and the Rattlesnake Canal.

5. Water Quality

The source water does not change in this alternative; therefore, no impact to Refuge water quality is anticipated.

6. Environmental and Cultural Resources Impacts

An unnamed, intermittent tributary currently connects Rattlesnake Creek west of Little Salt Marsh with the C-line Canal. This is a small, sand-bottomed meandering tributary with scattered wetland vegetation along its banks and within its channel. Alternative 6 proposes to channelize this tributary so that high flows can be bypassed around Little Salt Marsh, cross the C-line Canal, and reenter Rattlesnake Creek downstream of Little Salt Marsh. Bypassing high flows would reduce sedimentation in Little Salt Marsh.

The primary environmental impacts would occur in the bypass channel area and points downstream of the re-connection to Rattlesnake Creek. The intermittent tributary would be converted from a meandering small stream to a straight channel. Channelization would cut through meanders, creating numerous oxbows. As with normal geomorphic processes, these oxbows would fill with water during high flows that overtop the bypass channel. Backwater habitat for fish, shorebirds, and waterfowl would be provided. During low flow periods, they would likely dry up and provide substrate for certain wetland plant species. With time, oxbows would fill with sediment, becoming wetlands or wet meadow areas dominated by sedges and grasses. When flooded, they would provide moist soil habitats; in drier conditions, they would provide habitat for upland species.

Bypass of sediment laden high flows around Little Salt Marsh would introduce sediment-laden water into Rattlesnake Creek that now receives flows with lower sediment concentrations. Under existing conditions, water from Little Salt Marsh has been slowed and all but the finest sediment particles have settled. Bypass water would contain significant amounts of sediment that would be deposited on the inside bends of the channel, perhaps forming sandbars. Some sandbars may become semi-permanent, developing vegetation such as willows, rushes, cattails, and sedges. Others will continually be created and eroded away as part of the natural hydrologic regime of the creek.

Rattlesnake Creek flows through Darrynane Lake (Unit 24) below Little Salt Marsh. Using a bypass channel, water velocities would slow upon entering the unit and substantial sedimentation could occur. Unit 24 would effectively function as a sediment retention basin, and sediment trapped in this unit would not move downstream. Since Unit 24 is a major diversion point for water to downstream management units, increased sedimentation could impact and perhaps reduce the effectiveness of this water transfer function. Rattlesnake Creek would be expected to remain unaffected downstream of Unit 24.

Channelization following the existing stream channel will have no impact on intact deposits of cultural resources; however, the straightening and other cuts through terraces or other elevated landforms would likely impact cultural resources. Prehistoric and historic hunters and gatherers would have exploited this intermittent drainage for the locally available resources it would have provided. Because the stream is intermittent and no known historic habitations or structures are recorded here, it is anticipated that campsites and limited activity sites would occur on many of these elevated landform. Based on these observations, the canal alternative has both low and high probability areas for cultural resources. Those portions of the project that cut through the elevated land forms have a high probability, whereas those remaining in the stream cannel are low. If this alternative is selected, additional archaeological investigations will be required for any elevated landform that would be impacted.

7. Project Cost Estimates

Project costs, operation and maintenance costs, present value and benefit-cost analysis for this alternative are included below. These costs are used in Task E for the purpose of comparing and selecting the best water management alternative(s) for implementation.

a. Project Costs

The estimated project cost for this alternative is $3.61 million as listed in Table VII-34. The average life cycle unit cost of water for Alternative 6 is $38,964 per MG based on project costs.

b. Operation and Maintenance (O&M) Costs

The operation and maintenance of this alternative is not anticipated to require Service or contract personnel. Additionally, this alternative does not include any mechanical equipment which would require replacement or energy. Therefore, this alternative is not expected to increase O&M costs at the Refuge.

c. Present Value Analysis

The present value for Alternative 6, in 1998 dollars, is $3.5 million. The average life cycle unit cost of water for Alternative 6 is $37,872 per MG over 20 years of operation based on present value.

d. Benefit-Cost Analysis

Implementation of Alternative 6 is not expected to change the amount of wetland habitat available at the Refuge 80 percent of the time. Therefore, using the criteria discussed in Part II, this alternative is considered to have no benefits and a benefit-cost ratio of 0.0.

Table VII-34
PROJECT COST ESTIMATE
ALTERNATIVE 6 - CONSTRUCT BYPASS CANAL

Item	Cost ($)
Concrete Box Culvert (RS Creek)	18,000
Concrete Box Culvert (Bypass Canal)	45,000
Reinforced Concrete Weir	25,000
Inverted Siphon	320,000
Bypass Canal	671,000
Stock Pile Excavated Material	1,103,000
Gravel Road	8,000
Erosion Control	314,000
Subtotal	2,504,000
Contingency at 20%	501,000
Subtotal	3,005,000
Other Costs at 20%	601,000
Total Project Cost	**3,606,000**
Average Annual Water Volume (MG)	**5**
Average Life Cycle Unit Cost of Water ($/MG)	**38,964**

G. ALTERNATIVE 7 - RECONTOUR ADDITIONAL AREAS TO DEVELOP MOIST SOIL UNITS

1. General

This alternative evaluates the development of Moist Soil Areas A, B, C, D and E at the Refuge as shown in Figure VII-17. Moist soil areas are created by constructing one-foot high berms capable of storing 8 to 10 inches of water evenly over the entire area. The areas need to be filled in the spring to promote vegetation growth, allowed to dry during the summer, and filled again in the fall to provide habitat for waterfowl. The impacts of creating these moist soil areas are discussed below.

2. Additional Moist Soil Areas

The proposed moist soil Areas A, B, C, D and E were selected using 7.5-minute USGS topographic maps. The potential areas must be relatively flat to minimize earthwork during construction and capable of being filled with water by gravity. The area-capacity data for the potential moist soil areas, which are listed in Table VII-35, are based on planimetering 7.5-minute USGS topographic maps.

Table VII-35
AREA-CAPACITY FOR
ADDITIONAL MOIST SOIL AREAS

Moist Soil Area	Invert Elevation (feet - USGS)	Area [1] (acres)	Capacity (acre-feet)
A	1744	68	68
B	1752	64	64
C	1754	66	66
D	1755	42	42
E	1757	40	40

Note: 1. Proposed moist soil areas are planimetered.

The development of 280 acres of additional moist soil units will require an additional 560 acre-feet of water. The Service would either have to file for a new water right, or reduce the number of wetland acres elsewhere on the Refuge to ensure that consumptive use does not change.

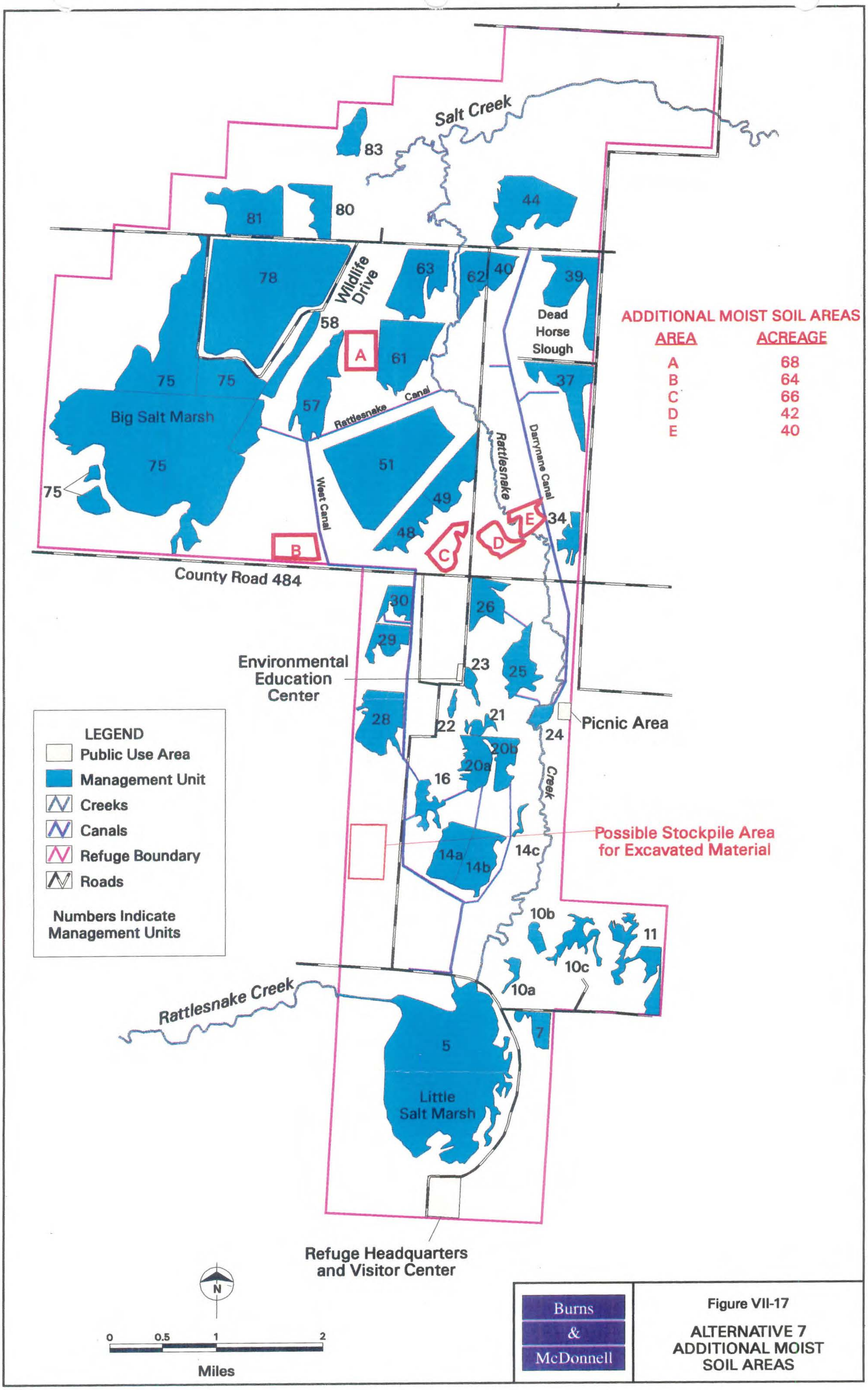


Figure VII-17

ALTERNATIVE 7 ADDITIONAL MOIST SOIL AREAS

3. Preliminary Concept Design

The proposed moist soil areas are designed with a one-foot high berm that has a three-foot top width with 1:1 side slopes as shown in Figure VII-18. The berms are capable of maintaining 8 to 10 inches of water evenly over the designated area. Random fill material needed for berm construction would be obtained from borrow areas in the vicinity of this unit or within the unit. When possible, natural topography would be used to contain water. To facilitate moist soil management, an area must be relatively level and capable of holding water. Areas proposed for development would require land leveling. Berms would be constructed to hold water to a certain depth before allowing it to spill out of the area. This water would be prevented from pooling in one area or at a depth which would prevent growth of the desired plant species. Concept design for each unit is discussed below.

a. Moist Soil Area A

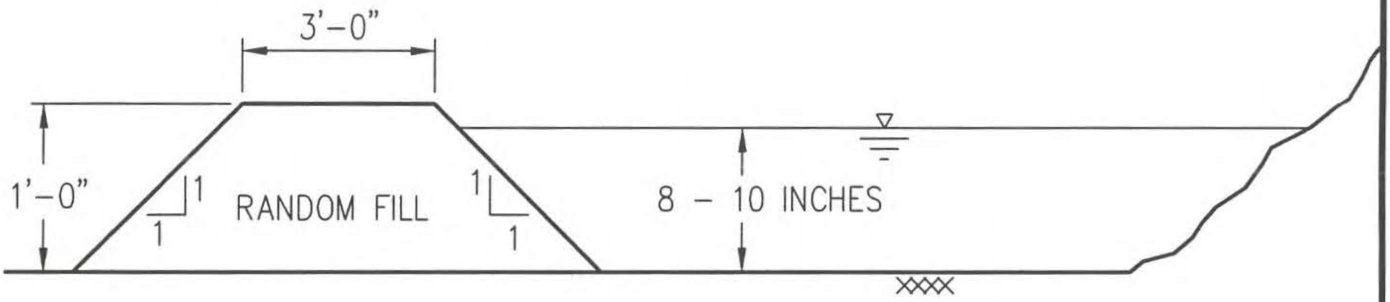
Moist Soil Area A is located west of Unit 61. The proposed invert elevation for this moist soil area is 1744 feet. Approximately 68 acres are available for development in this area. Major components required to develop this moist soil area are:

- Construct 1,500 linear feet of one-foot berm.
- Haul random fill from nearby borrow area

About 1,500 linear feet of one-foot berm would be constructed on the north side. Natural topography to the west and the road to the east eliminate the need for additional berm construction. Random fill will be hauled into the moist soil area to grade to elevation 1774 feet. Moist Soil Area A can be filled with water from Unit 61 using Control Structure E1.

b. Moist Soil Area B

Moist Soil Area B is located west of Unit 48 on the west side of West Canal. The proposed invert elevation for this moist soil unit is 1752 feet. Approximately 64 acres are available for development. Major components required for the development of this moist soil area are:



Burns & McDonnell

Figure VII-18

ALTERNATIVE 7
TYPICAL MOIST SOIL AREA
CROSS SECTION

- Construct 3,100 linear feet of one-foot berm.
- Cut and fill earthwork in the moist soil area.

About 3,100 linear feet of one-foot berm would be developed on the north and west side of the moist soil area. The West Canal and the road on the south side act as natural barriers. The cut on the south portion of the area would be used as fill on the north portion to grade to elevation 1752 feet. Moist Soil Area B can be filled with water from West Canal when water at least four feet deep occurs in the Canal. The area can also be filled by runoff, when available, from the area to the south.

c. Moist Soil Area C

Moist Soil Area C is located southeast of Unit 48. The proposed invert elevation for this moist soil area is 1754 feet. At this elevation, approximately 66 acres are available for development. Major components of this moist soil area include:

- Construct 3,500 linear feet of one-foot berm.
- Remove soil material and stockpile.

Approximately 3,500 linear feet of one-foot berm must be developed on the north and west side of this area. Moist Soil Area C is filled with water from the supply canal that fills Units 48 and 49.

d. Moist Soil Area D

Moist Soil Area D is located east of Unit 48 and southwest of Unit 49, on the west side of Rattlesnake Creek. The proposed invert elevation for this moist soil area is 1755 feet. Approximately 42 acres can be developed for this moist soil area. Major components needed for development include:

- Construct 3,700 linear feet of one-foot berm.
- Remove soil material and stockpile.

Moist Soil Area D will need 3,700 linear feet of one-foot berm to be developed on the north, east and west side. Intermittent streams on the east and west side serve as boundaries. The south end of this area is sufficiently elevated to contain the desired storage needed. Moist Soil Area D is filled with water from upstream management Unit 26.

e. Moist Soil Area E

Moist Soil Area E is located east of Unit 49, between Rattlesnake Creek and the Darrynane Canal. The proposed invert elevation for this moist soil area is 1757 feet. Approximately 40 acres are available for development. Major features needed for this moist soil area are:

- Construct 1,700 linear feet of one-foot berm.
- Cut and fill earthwork in the moist soil area.

About 1,700 linear feet of one-foot berm would need to be constructed on the north and south side. Rattlesnake Creek and the topography on the east side of this area act as natural barriers. The cut on the south portion of the proposed area would be used as fill on the north portion. Moist Soil Area E would be filled with water from Darrynane Canal.

4. Operations Model

The five potential new moist soil areas, A through E, are modeled as a group in a single run of the operations model. To set up this model, five new storage nodes are added to the base operations model, one for each new moist soil area. Some basic data on these new storage nodes and their associated model links are listed in Table VII-36. A schematic diagram of the operation model for this alternative is included in the Models section of the Appendix.

Table VII-36
NEW MODEL NODES FOR ALTERNATIVE 7

Moist Soil Area	Model Node No.	Water Source Link		Spill Link	
		Link No.	Origin Node	Link No.	Terminal Node
A	700	75	510	76	530
B	710	77	380	78	500
C	720	79	410	80	420
D	730	81	410	82	480
E	740	83	450	84	480

Each of these new moist soil areas are assumed to have a relatively flat bottom, which covers the areas listed above in Table VII-36. The maximum water depth in each area is assumed to be 12 inches with a target depth of 8-10 inches. The storage priorities for the new moist soil areas are set so they would be filled after all of the current management units are filled to the top of their low storage zones. The top of the low storage zone for each management unit is, generally, six inches below its target level. When there is sufficient water supply, the moist soil areas would be maintained at their target depths for the months of September through April. During the summer months, May through August, the moist soil areas would be allowed to dry up.

Execution of the operations model for this alternative shows that the new moist soil areas do increase the average water quantity diverted to the Refuge by about 0.7 percent. The average annual diversions to the Refuge increase from a baseline value of 6,858 acre-feet to 6,902 acre-feet, an increase of 44 acre-feet per year.

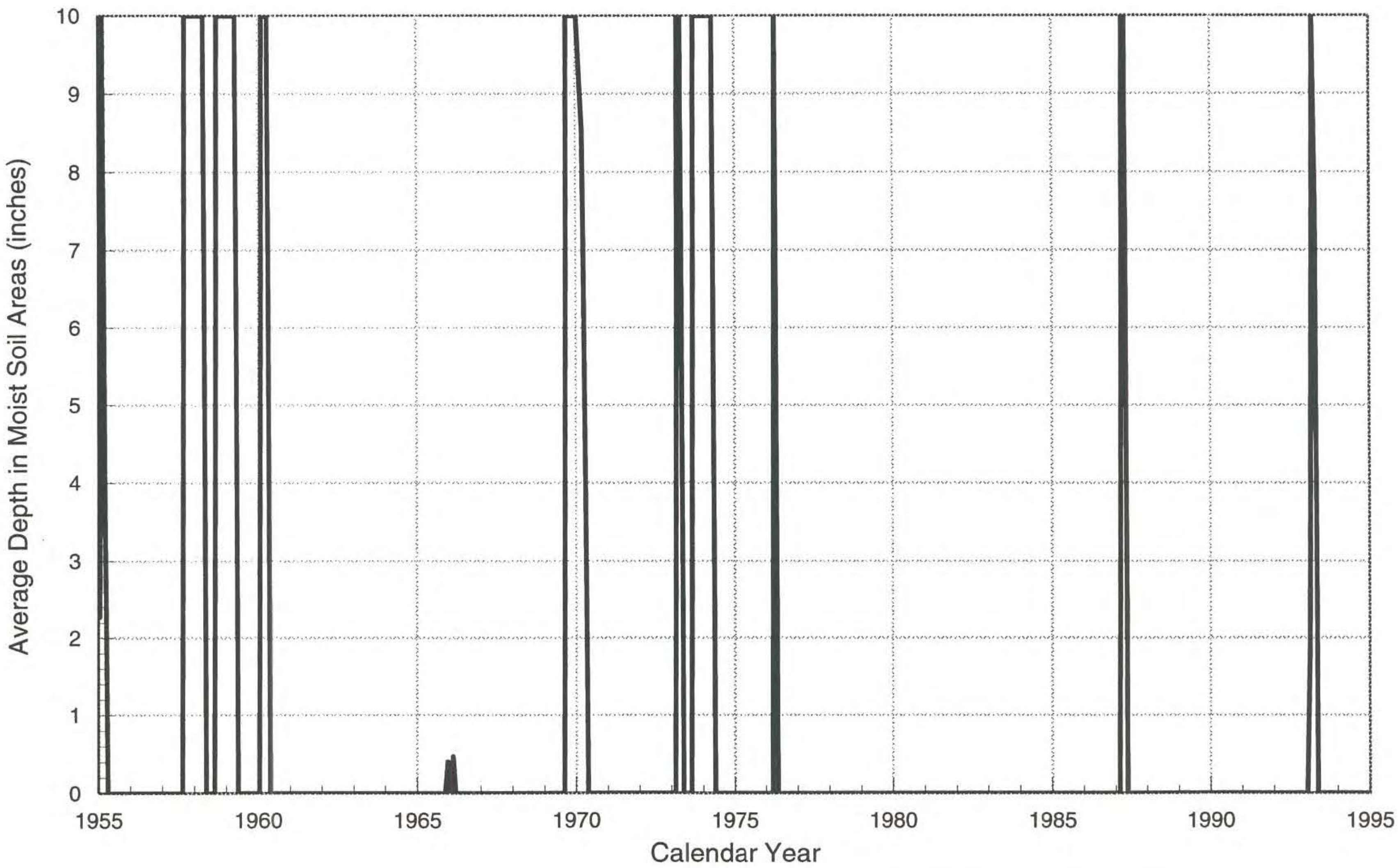
The simulated end-of-month average water depths in the five moist soil areas are shown in Figure VII-19. This graph shows there are only about 10 years during the 40-year simulation period when the new moist soil areas would receive any water. The interval between wet periods can be as long as ten years.

Statistics on the availability of wetland habitat at the Refuge for this alternative are presented in Table VII-37. Also shown in this table are the corresponding baseline values. Review of this table shows that this alternative does not have a significant impact on the availability of wetland habitat at the Refuge.

Table VII-37
AVAILABLE WETLAND HABITAT—ALTERNATIVE 7 [1]

Alternative	Shorebird (1–4 inches)		Waterfowl (10–18 inches)		Total Wetland	
	Range	Average	Range	Average	Range	Average
Baseline	85-684	358	11-1,055	602	692-6,000	2,757
7	85-684	356	11-1,122	607	692-6,279	2,762

Note: 1. All wetland habitat values in acres. Statistics include data for primary migration season, September through April only.



Note
End-of-month water depths obtained from operations simulation for Alternative 7.

Burns & McDonnell

Figure VII-19

SIMULATED WATER DEPTHS MOIST SOIL AREAS ALTERNATIVE 7

The 80th percentile habitat areas and the changes in these values over baseline conditions are shown in Table VII-38.

Table VII-38
CHANGES IN AVAILABLE WETLAND HABITAT—ALTERNATIVE 7

Alternative	Shorebird (1-4 inches)		Waterfowl (10-18 inches)		Total Wetland	
	80th Percentile	Change	80th Percentile	Change	80th Percentile	Change
Baseline	237	---	354	---	1,416	---
7	237	0	352	-2	1,414	-2

Review of Table VII-38 shows that implementation of this alternative will have no impact on the amount of wetland habitat available at the Refuge 80 percent of the time.

5. Water Quality

The source water for this alternative is Rattlesnake Creek; therefore, no impact to Refuge water quality is expected.

6. Environmental and Cultural Resource Impacts

Several undeveloped areas of the Refuge are proposed for development and management as moist soil areas. These moist soil areas would be flooded to a uniform depth of 8 to 10 inches during the early part of the growing season. As the season progresses, the water would gradually soak into the ground and evaporate. Growth of plant species more adapted to saturated soil conditions, such as smartweeds, knotweed, cutgrass, sedges, barnyard grass, millet, nettles, ragweeds, lambsquarters, pigweed, horseweed, goldenrods, and foxtail, would be encouraged.

By late spring or early summer, most standing water would be gone, although abundant soil moisture would still be present. The vegetation that has become established would grow and mature during the summer and early fall, when the area would again be flooded to a uniform depth of approximately 8 to 10 inches. During the fall, water would slowly soak in or run off but would be augmented by fall rains. Evaporative losses would be reduced. Throughout the fall until frozen over and again in the early spring after the thaw, the unit would provide excellent shallow water habitat with abundant, high quality food for waterfowl, particularly dabbling ducks.

Except for Area C, all of these proposed moist soil areas, are open grasslands. Area C contains about 30 acres of cropland and 33 acres of grassland. Impacts to these areas would be similar. Removal of cropland would have a minimal impact as the majority of the basin is agricultural. Additionally, Refuge personnel have expressed a desire to further reduce cropland on the Refuge (Hilley, 1997).

Vegetation and wildlife impacts for all proposed moist soil areas are similar; and therefore, are discussed together below. The potential impacts to cultural resources associated with each site are also presented below.

The proposed moist soil areas consist of upland grasses and forbs, with small shrubs scattered throughout. Development of these areas as moist soil habitat would eliminate a total of 280 acres of upland habitat. Water provided to these areas would encourage the growth of moist soil species, and result in converting these upland areas to communities characteristic of moist soil or wet meadow areas.

Conversion of uplands to moist soil areas would reduce available habitat for upland species. However, during the drier periods of the year or during years when water would not be available to flood these areas, good habitat would be provided for upland species. Habitat would include dense vegetation for cover and nesting and an abundant supply of food sources.

Construction would impact wildlife as discussed previously in Section C.6. However, following construction, most upland species would only be seasonally displaced from these areas due to inundation during the spring, winter, and fall.

Newly created and inundated moist soil areas are desirable habitat for waterfowl and wading birds. These areas would provide good habitat for waterfowl during migration periods. Water levels would be ideal for dabbling ducks, and when drained, the units would provide habitat for shorebirds until vegetation becomes established. Water contained in these areas in the spring would provide good habitat for amphibians, especially frogs and toads, and foraging areas for the avian and mammalian species that feed on them. In the summer, the vegetation formed provides habitat for a variety of upland species, especially ground nesting birds such as pheasant, bobwhite quail, and meadow larks.

The five different possible sites contain similar environmental features. Based on the similarities observed, concerns for cultural resources are virtually identical for most of the sites. Only one site, Site E, includes some degree of topographic relief and proximity to a water source or areas of critical resources. The remaining sites are adjacent to water sources, but lack the topographic relief generally associated with prehistoric cultural resource deposits in the area. In general, it is likely that any sites discovered at any of the proposed locations would be significant based on previous studies of similar type environments, the undisturbed nature of the sites, and the lack of known sites within the basin.

The proximity of Site A to the wetlands of the Refuge suggests the potential for campsites and limited activity sites associated with the procurement of locally available resources. Based on the limited topographic relief at this site, the potential for surface prehistoric cultural resources are very low; however, the wetland setting of the proposed site indicates a potential for buried prehistoric cultural deposits. Such sites will generally be limited to kill or processing sites. A review of historical atlases and other maps for Stafford County, on file at the Kansas State Historical Society, indicate that it is unlikely that historic homesteads or other historic structures will be found within the proposed site area. If this site is selected, additional archaeological and geomorphological studies may be required to determine impact on buried deposits.

Site B is proposed to straddle an intermittent tributary that feeds the southern portion of the Big Salt Marsh. Although the southeast portion of Site B does contain some topographic relief, the remainder of the site is characterized by flat to gentle sloping terrain. Based on the characteristics of the terrain and access to the numerous resources of the salt marsh, the probability for prehistoric cultural resources range from high in the very southeast corner to low throughout the remainder of Site B. A review of historical atlases and other maps for Stafford County, on file at the Kansas State Historical Society, indicate that it is unlikely historic homesteads or other historic structures will be found within the proposed site area. The extreme southeastern corner is the only portion of the project area likely to require further archaeological investigation.

In many aspects, including topography, Site C is very similar to Sites A and B. This site is not associated with a natural water source, such as those adjacent to the other proposed sites. As with the other sites, no historic structures are known within the area of Site C. Such characteristics make this site the least probable of all the sites in Alternative 7 to contain cultural resources. No additional investigation would likely be required if this site is selected.

Site D is a low, generally flat area between two intermittent tributaries of Rattlesnake Creek. This site has the same general characteristics as the previous three sites. The most notable exception to these similarities is the proximity of Site D to the main channel of Rattlesnake Creek. Rattlesnake Creek would have been a major resource for a number of subsistence-based items for both prehistoric and historic hunters in the area. Potentially, the area flanking the creek would include numerous campsites and limited activity sites associated with the procurement of a wide range of resources. These sites are typically found on elevated areas such as terraces, ridges, and knolls. Site D does not have any notable topographic relief that is readily identified on the topographic quadrangle maps. Based on the flat, low lying characteristics, Site D has a low probability of containing any cultural resources. A review of the historic plat maps on file at the Kansas State Historical Society indicate that no historic structures are within the project area.

Of all the proposed sites in Alternative 7, Site E has the highest potential for containing prehistoric cultural resources. The proximity to the main channel of Rattlesnake Creek and the distinct topographic relief, lend credence to this high probability ranking. No historic structures are noted within the project area, indicating that is unlikely that historic habitation sites will be found in this site. Even so, the potential for prehistoric or historic campsites and limited activity sites is very high for this area. If this site is chosen, it is likely that additional archaeological investigations will be needed for most, if not all, of the project area.

7. Project Cost Estimates

Project costs, operation and maintenance costs, present value costs and cost-benefit analysis for this alternative are described below. These costs are used in Task E for the purpose of comparing and selecting the best alternative(s) for implementation.

a. Project Costs

The estimated project cost for the additional moist soil units is $1.13 million as listed in Table VII-39. The average life cycle unit cost of water for Alternative 7 is $3,940 per million gallons (MG) based on project costs.

b. Operation and Maintenance (O&M) Costs

The operation and maintenance of this alternative is not anticipated to require additional personnel. This alternative does not include any mechanical equipment which would require replacement or energy. Therefore, no additional O&M costs are expected due to development of this alternative.

c. Present Value Analysis

The present value for Alternative 7 in 1998 dollars is $1.10 million. The average life cycle unit cost of water for Alternative 7 is $3,829 per MG over 20 years of operation based on present value.

d. Benefit-Cost Analysis

Development of this alternative is not expected to increase the amount of wetland habitat available at the Refuge 80 percent of the time. Therefore, this alternative is considered to have no benefits and a benefit-cost ratio of 0.0.

Table VII-39
PROJECT COST ESTIMATE
ALTERNATIVE 7 - ADDITIONAL MOIST SOIL UNITS

Item	Cost ($)
Moist Soil Area A	233,000
Moist Soil Area B	65,000
Moist Soil Area C	114,000
Moist Soil Area D	252,000
Moist Soil Area E	121,000
Subtotal	785,000
Contingency at 20%	157,000
Subtotal	942,000
Other Costs at 20%	188,000
Total Project Cost	**1,130,000**
Average Annual Water Volume (MG)	**14**
Average Life Cycle Unit Cost of Water ($/MG)	**3,940**

H. ALTERNATIVE 8 - FILL BORROW AREAS

1. General

This alternative evaluates filling borrow areas, in Units 26, 28, 29, 30, 40, 48, 49, and 63 in the Refuge as shown in Figure VII-20. Currently, when the units are basically dry, large volumes of water fill the old borrow areas before water spreads throughout each units' remaining area. By filling the borrow areas with random fill, less water is needed to develop various habitats in the unit. The impacts of filling the borrow areas with soil are discussed below.

2. Fill Borrow Areas

The soil material from the borrow areas of Units 26, 28, 29, 30, 40, 48, 49, and 63 was originally used for the construction of the dikes around each respective management unit. The depths of the borrow areas vary from 2 to 5 feet based on approximated depths from 7.5-minute USGS topographic maps and an electronic survey provided by the Service. Borrow area dimensions were determined from aerial photographs taken during a dry period. At that time, the management units were dry with the exception of the deeper borrow areas. The depths of and volumes required to fill the borrow areas for each unit are listed in Table VII-40.

**Table VII-40
DEPTHS AND VOLUMES FOR
MANAGEMENT UNIT BORROW AREAS**

Borrow Area	Depth [1] (feet - USGS)	Volume to Fill [2] (cubic yards)
Unit 26	2	25,000
Unit 28	3	30,000
Unit 29	2	25,000
Unit 30	3	12,000
Unit 40	4	28,000
Unit 48	2	10,000
Unit 49	4	40,000
Unit 63	5	58,000

Notes: 1. Depths approximated from 7.5-minute topographic maps and Service's electronic survey.
2. Approximate volume of soil needed to fill borrow area. Dimensions for borrow area obtained from aerial photographs.

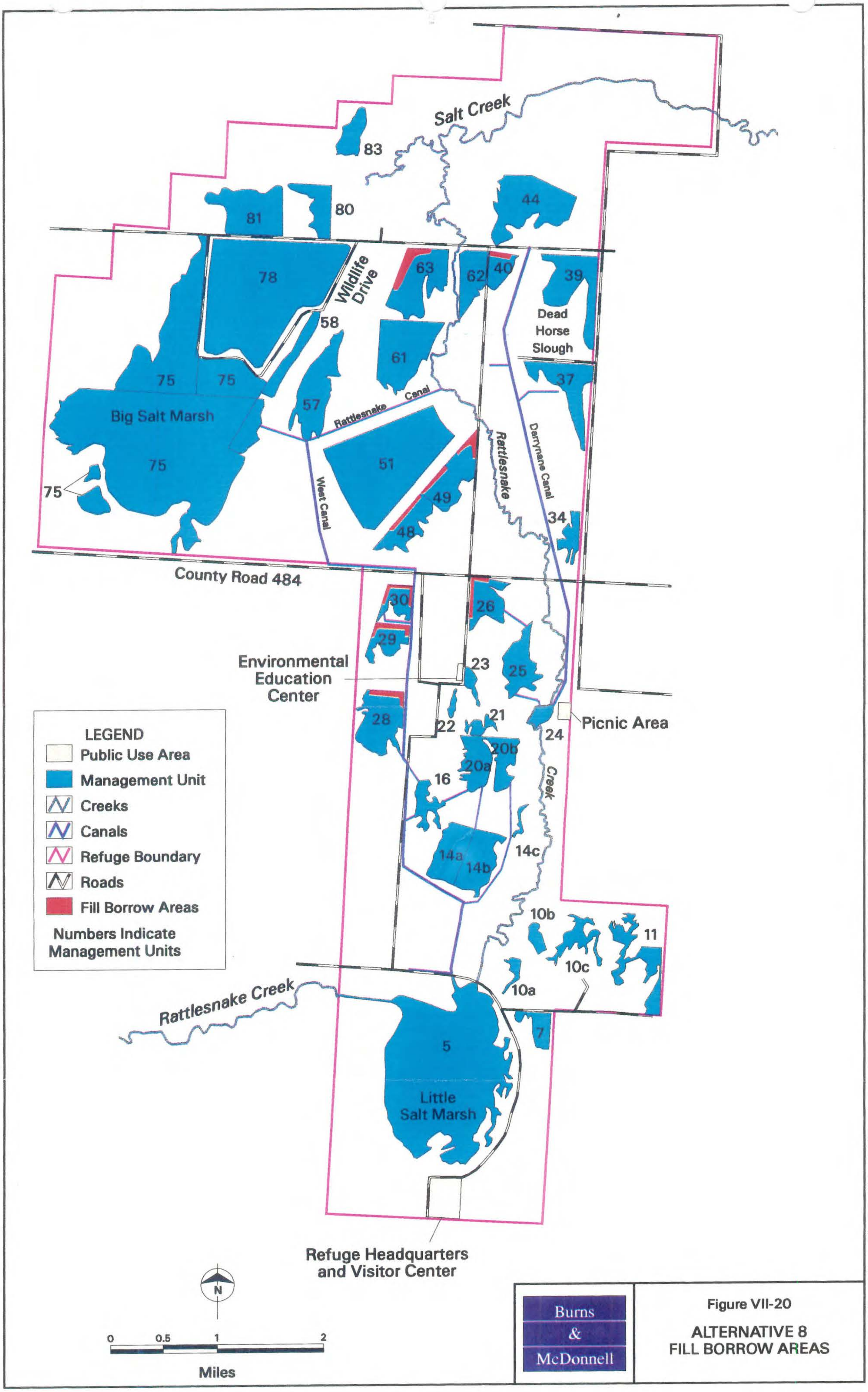


Figure VII-20
ALTERNATIVE 8
FILL BORROW AREAS

3. Preliminary Concept Design

The concept is to fill the borrow areas in Units 26, 28, 29, 30, 40, 48, 49, and 63 such that only a two foot depth of water occurs in the units (Figure VII-21). The ideal time for construction would be during a dry period when the unit would be mostly dry. If the borrow area contains water, it would be drained prior to filling. Material used to fill the borrow area within a management unit would be removed from the upslope portion of that unit. The areas adjacent to the control structures should be graded to allow for continued use of existing structures.

4. Operations Model

Filling the borrow areas will modify the elevation-area-capacity relationships in these management units; however, review of the existing elevation-area-capacity data for these units indicates that the borrow areas themselves are not reflected in these data. Therefore, it would be very difficult to accurately reflect an after-construction condition. For this reason, the operations model was not run for this alternative. The 80th percentile habitat areas within the Refuge are not likely to change as a result of these modifications.

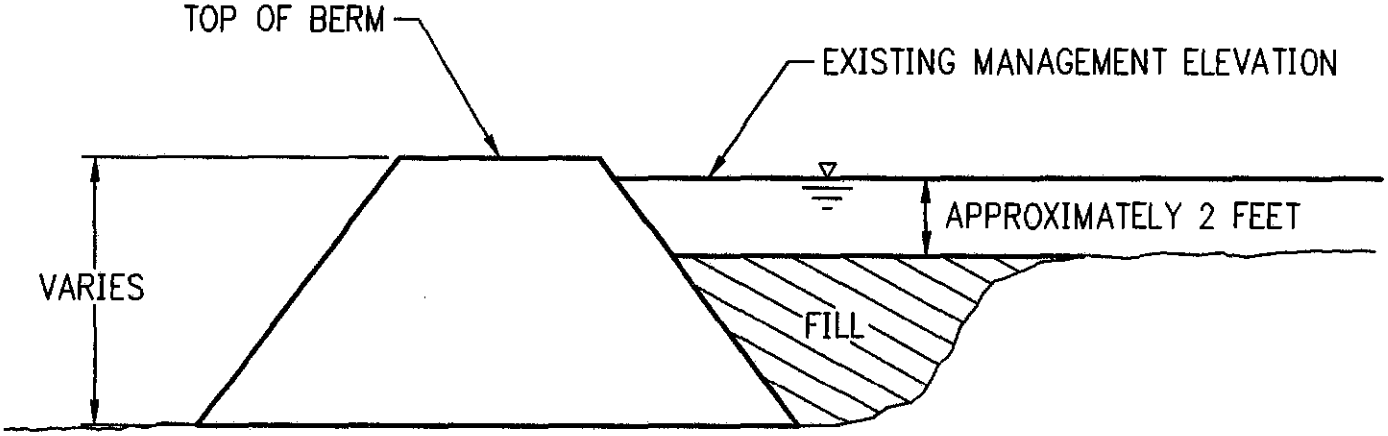
5. Water Quality

The source water remains Rattlesnake Creek for this alternative; therefore, no impact to Refuge water quality is expected.

6. Environmental and Cultural Resources Impacts

Numerous management units within the Refuge have borrow areas. Soil material from these borrow areas was excavated and mounded-up to create the dikes around the unit. Borrow areas are generally much deeper than the remainder of the unit and often contain the majority of the open water within the unit. The remaining portions of most units are not deep enough to prevent establishment of cattails and have become densely overgrown; however, muskrat activity has maintained some open water areas within the cattails.

Refuge personnel have stated a general desire to manage the majority of these management units as moist soil areas (Hilley, 1998). Moist soil management was previously discussed in Section I.4. Under this management system, cattails could be kept under control and the units would be managed to provide high



Burns & McDonnell

FIGURE VII-21

ALTERNATIVE 8
TYPICAL CROSS SECTION OF FILL FOR BORROW AREAS

quality habitat for waterfowl. Borrow areas in these units currently serve as sinks for water, are too deep to provide high quality habitat, and impede management of the units for high quality moist soil habitat.

Alternative 8 proposes to fill in the borrow areas of several units so that they can be managed more effectively and efficiently. The unit within which the borrow area occurs, the amount of open water, cattail marsh, and the total acres of each unit are presented below:

Unit	Open Water	Cattail Marsh	Total
Unit 26	5.9 acres	53.4 acres	59.3 acres
Unit 28	6.2 acres	79.1 acres	85.3 acres
Unit 29	6.9 acres	53.7 acres	60.6 acres
Unit 30	2.4 acres	75.6 acres	78.0 acres
Unit 40	4.4 acres	28.6 acres	33.0 acres
Unit 48	2.6 acres	86.7 acres	89.3 acres
Unit 49	6.3 acres	88.6 acres	94.9 acres
Unit 63	7.3 acres	147.0 acres	154.3 acres
Total:	**42.0 acres**	**612.7 acres**	**654.7 acres**

The borrow areas would be filled until it is level and covered by approximately two feet of water when the unit is at its desired water management level.

After filling borrow areas, shallow water habitat would be produced in each unit. These shallow areas would be suitable for invasion by cattails and other wetland species. Management units could be drained, providing an opportunity for controlling cattail growth by water level control or burning. Less water would be needed to provide the desired habitat within the unit. Units could be managed as moist soil areas, to exclude the establishment and spread of cattails, as well as rotated between moist soil and cattail marsh every few years.

Filling the borrow areas would result in the conversion of 42 acres of deeper, open water habitat to more shallow marsh. These areas could be allowed to develop into cattail marsh habitat. As previously discussed, dense growths of cattails provide little habitat for wildlife, especially large flocks of migrating waterfowl; however, they do provide cover and brood-rearing habitat for nesting waterfowl and cover, nesting, and foraging areas for some species of wading and song birds.

Another option would be to manage the units as moist soil areas instead of a cattail marsh. Cattail marsh is abundant on the Refuge and less desirable than moist soil areas. Water previously needed to fill borrow areas could be stored and used as necessary to facilitate the desired management. Conversion of all these units to moist soil areas would provide an additional 655 acres of this habitat on the Refuge. These areas would provide high quality waterfowl habitat in the fall and spring, as well as spring and summer nesting areas for both waterfowl and upland species. As a compromise, some units could be managed for each habitat, lessening the impact of converting the entire 613 acres of existing cattails to moist soil.

Wildlife would be impacted during construction activities associated with filling borrow areas. Human activities and the operation of heavy equipment used in the placement of fill would likely displace wildlife to other parts of the unit and Refuge. Construction activities would be restricted to the small borrow areas after the units had been drained. Habitat available for waterfowl, wading birds, and shorebirds would be reduced during construction. Individuals displaced to adjacent areas would possibly venture back into the areas during non-construction periods. Following construction, units would again be filled with water. Units to be managed as moist soil units would likely have cattail control measures implemented reducing the availability of this habitat. Units retained as cattail marsh would not be severely affected by construction, for following completion of construction and restoration of water levels, cattails would quickly establish in new shallow areas.

Unit 26 is a low lying, flat area that contains little topographic relief. The potential for historic and prehistoric habitations, campsites, or limited activity areas are generally very low. The one exception is the possibility for a buried kill site in the wetland area in the southeast corner of the project area. If this low area is disturbed by mechanical machinery, additional archaeological and geomorphological investigations may be required. No additional archaeological or other related studies will be required for the remainder of the project.

Although much of Unit 28 has been artificially altered, additional mechanical stripping may impact buried kill site deposits in the pool area. The remainder of the proposed impact area is low and flat, suggesting a very low probability for campsites or other sites in the area. If any of the elevated areas around Unit 28 are used for borrow, additional archaeological and geomorphological investigations will be required.

Unit 29 is very similar to Unit 28, with the exception of little to no topographic relief found adjacent to the project area. Based on the topography and the previous alterations to the landscape, Unit 29 has a low probability for containing campsites or similar cultural resource deposits. The only possibility for intact, significant cultural resources is the possibility of a buried kill site. Based on these observations, no additional archaeological investigations will be required in this area, unless the sediments of the pool are disturbed.

Unit 30 is very similar to Units 28 and 29, in that this low lying, flat pool area has been artificially produced and has a very low probability for containing cultural resources. The possibility for buried intact deposits, such as kill sites appear to be minimal for this project area. If this site is selected, no additional archaeological investigations will be required.

Much of Unit 40 is low and flat, very similar to Unit 63. A portion of the unit contains some topographic relief, suggesting that cultural resources may be present. Based on the proximity to Rattlesnake Creek, several intermittent streams, and seasonally inundated lowlands, the elevated portions of Unit 40 appear to be high probability areas for containing prehistoric and historic campsites and limited activity areas. After a review of the historic maps on file at the Kansas State Historical Society, it appears it is highly unlikely that historic habitation sites will be found in the project area. The sparse topographic relief in the surrounding area suggests that some of the more prominent or elevated areas may contain base camps. Such sites were occupied for extended periods and may contain several subsurface features. Based on these observations, Unit 40 will require additional archaeological investigations if it is selected.

Unit 48 is low lying and flat, virtually identical to Site 3 of Alternative 7. It is not associated with a natural water source, such as those adjacent to other proposed project areas. As with the other areas, no historic structures are known to be within Unit 48. Such characteristics suggest that this area has a low probability of containing cultural resources. No further archaeological investigations are likely if this site is selected.

Much of the low lying, flat area of Unit 49 has been artificial manipulated. Based on the landscape and previous disturbances, Unit 49 has a low probability of containing cultural resource deposits. If this unit is selected, no additional cultural resource investigations will be required.

Unit 63 is in a low lying area that has had some previous mechanical alterations. Based on the topographic characteristics and previous disturbances, this project area is considered to have low probability for containing prehistoric or historic sites. No known sites or historic structures have been recorded in the area. If this unit is selected, it is unlikely additional archaeological investigations will be required.

7. Project Cost Estimates

Project costs, operation and maintenance costs, present value costs and cost-benefit analysis for this alternative are presented below. These costs are used in Task E for the purpose of comparing and selecting the best alternative(s) for implementation.

a. Project Costs

The estimated project cost for filling borrow areas is $827,000 as listed in Table VII-41.

b. Operation and Maintenance (O&M) Costs

No additional O&M costs are anticipated as a result of implementation of this alternative.

c. Present Value Analysis

The present value for Alternative 8 in 1998 dollars is $804,000.

d. Benefit-Cost Analysis

This alternative has no additional wetlands and results in a benefit-cost ratio of 0.0. Although the operations model was not run for this alternative, it is expected that no net change in the availability of wetland habitat would occur.

Table VII-41
PROJECT COST ESTIMATE
ALTERNATIVE 8 - FILL BORROW AREAS

Item	Cost ($)
Unit 26	63,000
Unit 28	76,000
Unit 29	63,000
Unit 30	29,000
Unit 40	71,000
Unit 48	25,000
Unit 49	101,000
Unit 63	146,000
Subtotal	574,000
Contingency at 20%	115,000
Subtotal	689,000
Other Costs at 20%	138,000
Total Project Cost	**827,000**
Average Annual Water Volume (MG)	**0**
Average Life Cycle Unit Cost of Water ($/MG)	**NA**

I. ALTERNATIVE 9 - SUPPLEMENT WATER SUPPLY WITH ARKANSAS RIVER WATER

1. General

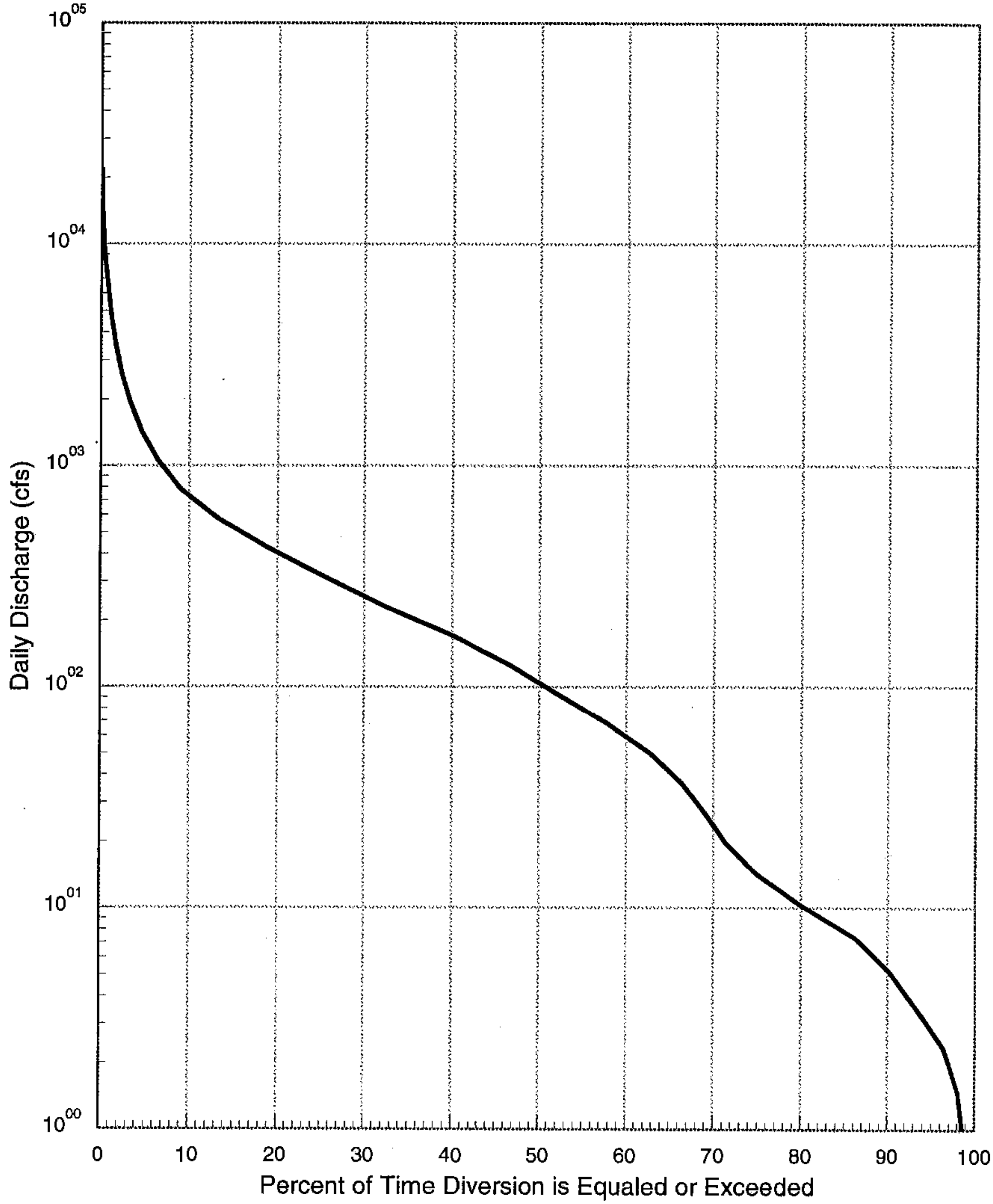
This alternative evaluates the development of a supplemental water supply to the Refuge from the Arkansas River. Water from the Arkansas River could be used on an as-available basis during and following runoff events.

2. Arkansas River

The durations of daily streamflow for the Arkansas River at the Great Bend gage are presented in Figure VII-22. Review of these data show the percent of the time specified flows are available from the river. These daily streamflow data are used in the operations model to determine when and how much water is pumped to the Refuge for a specified facility capacity.

The Arkansas River has a minimum desired streamflow (MDS) at Great Bend between 2 and 10 cubic feet per second (cfs) and at Hutchinson between 60 and 100 cfs as listed in Table VII-42. Based on review of these data, discussions were held with the Kansas Water Office (KWO) and the Kansas Board of Agriculture - Division of Water Resources (KDWR) to help determine a threshold value for use in the study. A total streamflow or threshold value of 62 cfs is selected for this study as the value above which the water from the Arkansas River could be pumped to the Refuge. This value consists of 60 cfs MDS plus downstream surface water rights between Salt Creek and Hutchinson of about 2 cfs. The value of 62 cfs serves as the "trigger" for pump activation in the operations model.

In the State of Kansas, Proceedings for the Water Transfer Act must be initiated for an entity to transfer more than 2,000 acre-feet per year of water over 35 miles. The Arkansas River supplemental supply alternative could transfer well over the 2,000 acre-feet per year of water a distance of 14 miles. Additionally, some of this water would eventually return to the Arkansas River. Based on conversations with the KWO, the Chief Engineer of Kansas could invoke Water Transfer Act Proceedings for this alternative due to the potentially large volume of water that could be transferred. The Proceedings could take a minimum of six months; to date, no entity has invoked the current Water Transfer Act. However, the Service should be able to obtain the necessary water rights for this alternative.



Notes:
1. Based on daily discharge recorded at USGS gaging station on Arkansas River at Great Bend, KS.
2. Period of record: 10/1/40-9/30/87; 10/1/88-9/30/96.

Burns & McDonnell

Figure VII-22

DISCHARGE DURATIONS ARKANSAS RIVER AT GREAT BEND, KS

Table VII-42
MINIMUM DESIRED STREAMFLOW FOR ARKANSAS RIVER

Month	Great Bend, Kansas (cfs)	Hutchinson, Kansas (cfs)
January	3	80
February	3	80
March	3	100
April	3	100
May	10	100
June	10	100
July	5	80
August	3	80
September	2	60
October	2	60
November	2	60
December	3	80

3. Preliminary Facility Concept

Facilities anticipated for the Arkansas River supplemental supply alternative include an intake and pump station adjacent to the river and 14 miles of pipeline from the river to the Little Salt Marsh as shown in Figure VII-23. A surface water intake is used in the concept to collect Arkansas River water for conveyance to the Refuge.

Four facility sizes are evaluated for this alternative as follows:

- 6 cfs (3.9 MGD) capacity intake and 16-inch diameter pipeline.
- 20 cfs (12.9 MGD) capacity intake and 24-inch diameter pipeline.
- 35 cfs (22.6 MGD) capacity intake and 30-inch diameter pipeline.
- 55 cfs (35.5 MGD) capacity intake and 36-inch diameter pipeline.

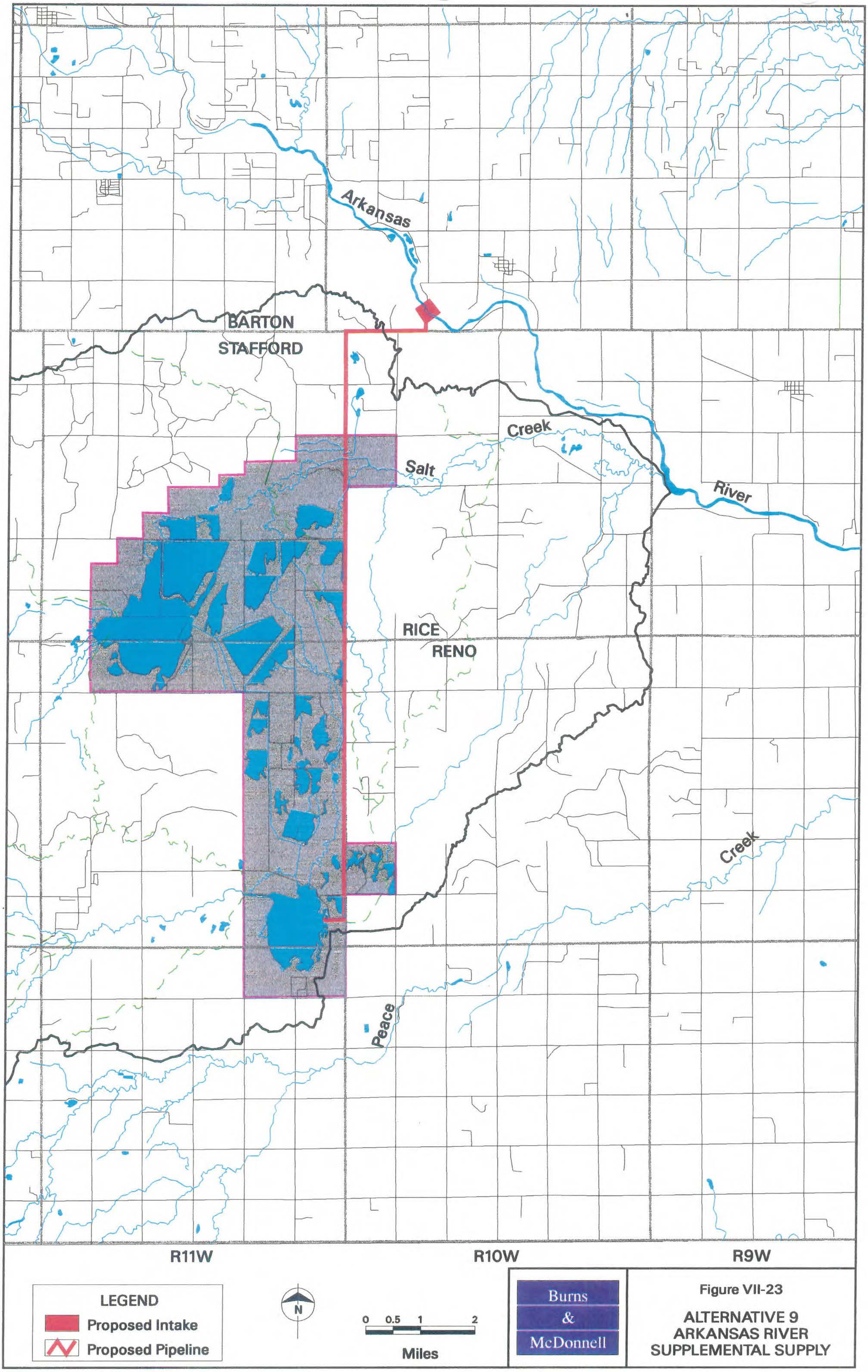


Figure VII-23

ALTERNATIVE 9
ARKANSAS RIVER
SUPPLEMENTAL SUPPLY

All piping is designed for a maximum rated operating pressure of 200 pounds per square inch. This allows the piping to convey a greater volume of water at reasonable velocity ranges.

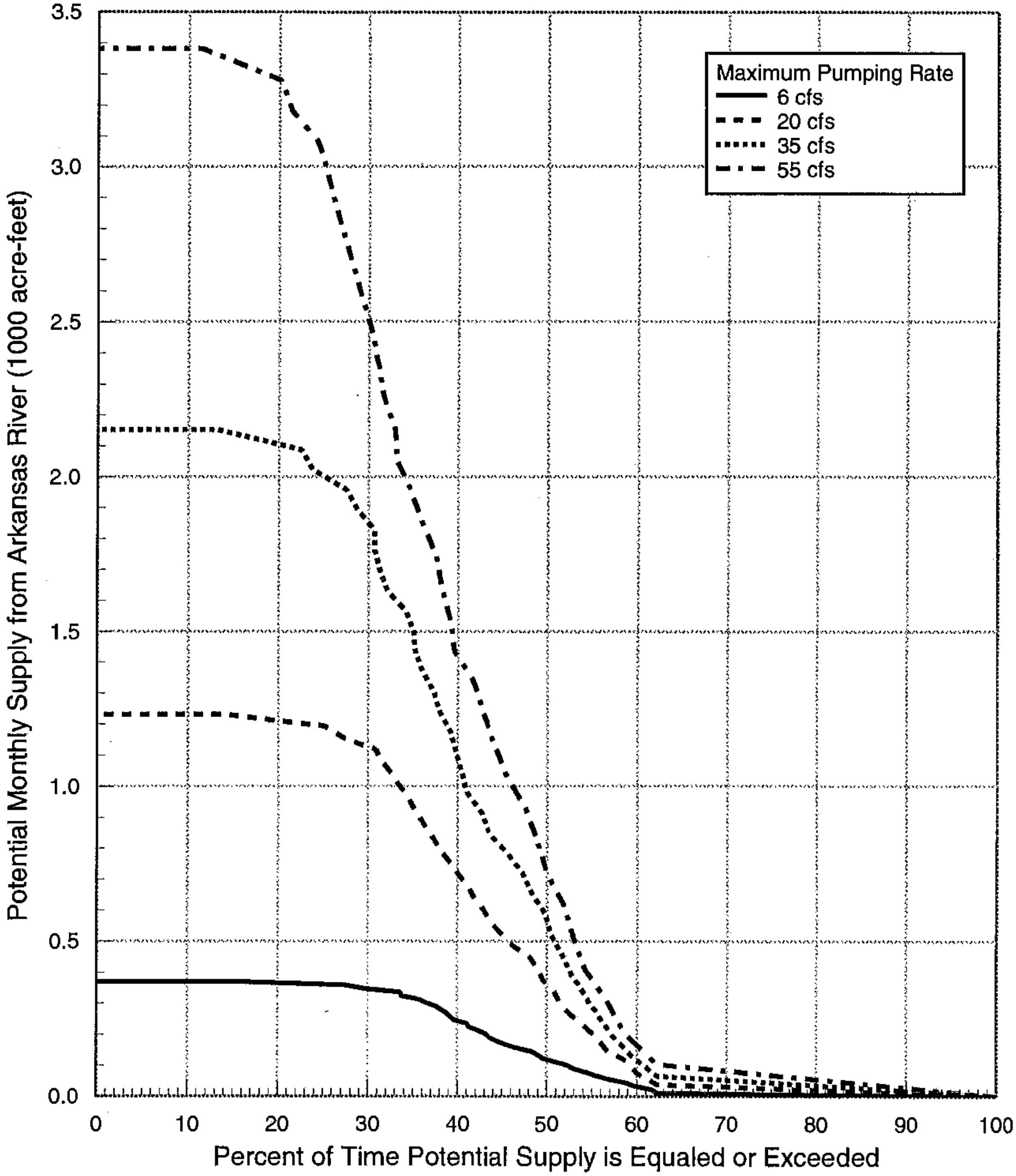
4. Operations Model

The base operations model is modified for this alternative by adding a single junction node. This node (No. 640) represents the potential Arkansas River pump station. From this new node, a single model link connects with the Little Salt Marsh. The model for this alternative assumes that all water available for diversion from the Arkansas River will be pumped to Little Salt Marsh. Any water not diverted at the Refuge flows back down Rattlesnake Creek and returns to the Arkansas River. In actual operation, the Arkansas River pump station would be operated only when water is available for diversion and when the Refuge is short of water.

As discussed above, it is assumed that water could be pumped from the Arkansas River only when the flow exceeds 62 cfs. The amount of water available for diversion from the river is estimated from daily streamflow data collected by the U.S. Geological Survey (USGS). The USGS maintains a stream gaging station on the Arkansas River at Great Bend (Station No. 07141300). The period of record for this gage covers the entire model simulation period except for water year 1988 (10/1/87–9/30/88). The missing data from water year 1988 are estimated using data at the downstream gage near Hutchinson (No. 07141330). The amount of water available for diversion each day is estimated using the daily discharge data for the river, the specified MDS value, and the rated capacity of the pump station. These daily diversion estimates are then summed by month to yield the inflow data for Node 640 that is used in the operations model. A separate inflow record is developed for each pumping capacity option.

Figure VII-24 shows the durations for potential Arkansas River diversions. About 40 percent of the time, the 60th percentile, little water is available for diversion. For the option with a 6 cfs pumping capacity, the pump station could be operated at maximum capacity about 33 percent of the time. This percentage decreases to about 10 percent of the time for the 55 cfs option. Potential annual diversions from the Arkansas River are shown in Figure VII-25.

The operations model is executed for each of the four alternative pumping capacities. The resulting annual average Refuge diversions are listed in Table VII-43.



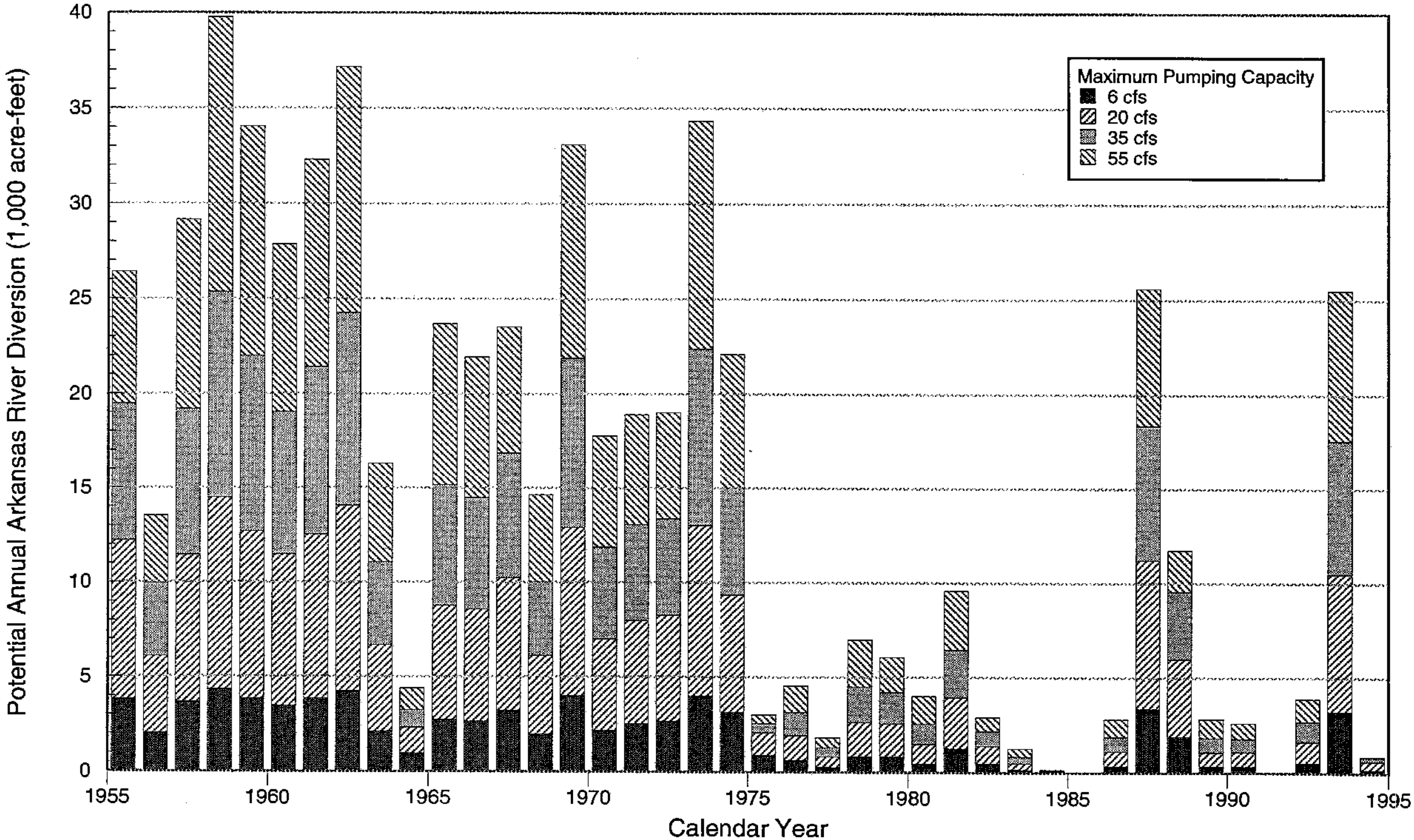
Note:

1. Developed from recorded discharge in Arkansas River at Great Bend, KS (USGS Station No. 0714130) for calendar years 1955-1994.
2. Intake pumps are assumed to operate only when Arkansas River discharge exceeds 62 cfs.

Burns & McDonnell

Figure VII-24

DURATIONS FOR POTENTIAL ARKANSAS RIVER SUPPLY



Notes
1. Estimated from daily discharge data for Arkansas River collected by USGS.
2. Based on MDS of 62 cfs for Arkansas River and specified maximum pumping rate.

Burns & McDonnell

Figure VII-25

POTENTIAL ANNUAL ARKANSAS RIVER DIVERSION

Table VII-43
AVERAGE ANNUAL REFUGE DIVERSIONS—ALTERNATIVE 9

Pumping Capacity (cfs)	Average Annual Diversions (acre-feet/year)	
	This Alternative	Change over Baseline
6	8,215	1,357
20	10,453	3,596
35	11,621	4,764
55	12,226	5,368

Statistics on the availability of wetland habitat at the Refuge for this alternative are presented in Table VII-44. Also shown in this table are the corresponding baseline values. Review of this table shows that these options could have a significant impact on the availability of wetland habitat.

Table VII-44
AVAILABLE WETLAND HABITAT—ALTERNATIVE 9 [1]

Alternative	Shorebird (1-4 inches)		Waterfowl (10-18 inches)		Total Wetland	
	Range	Average	Range	Average	Range	Average
Baseline	85-684	358	11-1,055	602	692-6,000	2,757
6 cfs	82-695	379	11-1,053	637	690-6,013	3,032
20 cfs	82-702	420	11-1,032	709	690-6,013	3,530
35 cfs	88-716	456	12-1,043	744	694-6,035	3,809
55 cfs	89-716	473	13-1,043	763	700-6,063	3,950

Note: 1. All wetland habitat values in acres. Statistics include data for primary migration season, September through April only.

The 80th percentile habitat areas and the changes in these values over baseline conditions are shown in Table VII-45. Wetland habitat durations for this alternative are shown in Figure VII-26.

Table VII-45
CHANGES IN AVAILABLE WETLAND HABITAT—ALTERNATIVE 9

Alternative	Shorebird (1-4 inches)		Waterfowl (10-18 inches)		Total Wetland	
	80th Percentile	Change	80th Percentile	Change	80th Percentile	Change
Baseline	237	---	354	---	1,416	---
6 cfs	309	72	397	43	1,607	191
20 cfs	329	92	491	137	1,947	531
35 cfs	340	103	558	204	2,165	749
55 cfs	346	109	568	214	2,265	849

Review of Table VII-45 shows that implementation of this alternative could have a significant impact on the amount of wetland habitat available at the Refuge 80 percent of the time.

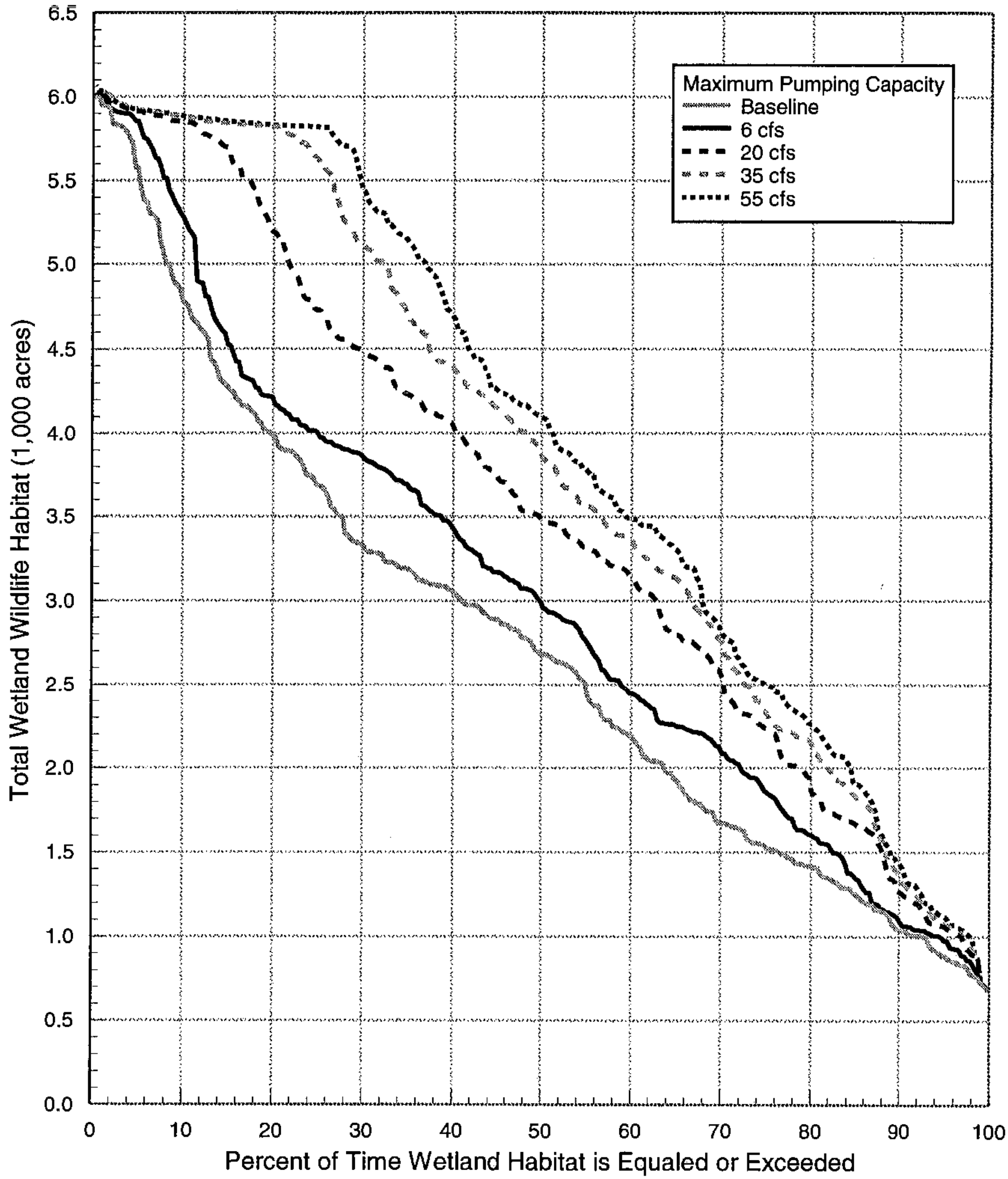
5. Water Quality

Water quality data for the Refuge and Arkansas River are listed respectively in Tables VII-46 and VII-47. Review of these tables shows the water quality in the Arkansas River upstream of Salt Creek has substantially lower salinity than the Refuge water and could be used at the Refuge as a supplemental supply. The increased salinity in the Arkansas River water at this point is due to flows from Salt Creek, which discharges water from the Refuge and Rattlesnake Creek.

6. Environmental and Cultural Resources

Environmental impacts of this alternative would occur from the conversion of cropland to the non-agricultural uses associated with construction and operation of an intake, pumps and pipeline facilities necessary to supply supplemental water. Because of the limited size required in any one place for these facilities and the flexibility available for their location, it is expected that most environmental impacts could be minimized.

The surface water diversion facilities would be developed adjacent to the Arkansas River. Impacts to existing cropland, pasture or hayfields would be minimal given the large areas of each existing in the Rattlesnake Creek Basin. Even though most of the cropland in the basin is classified as prime farmland,



Notes:
1. Developed from operations modeling for Quivira NWR for period 1/1955 through 12/1994 for Arkansas River supplemental supply alternative. Includes data for months of September through April only.
2. Total wetland habitat is the sum of the surface areas of all ponded water in all management units, regardless of depth.

Burns & McDonnell

Figure VII-26

TOTAL WETLAND HABITAT DURATIONS ALTERNATIVE 9

Table VII-46
WATER QUALITY DATA SUMMARY
QUIVIRA NWR

Parameter	Units	Little Salt Marsh					Big Salt Marsh				
		No. of Samples	Sample Dates	Mean	Maximum	Minimum	No. of Samples	Sample Dates	Mean	Maximum	Minimum
Conductance	uS/cm	6	7/88 - 6/94	6,362	7,430	5,130	6	7/88 - 6/94	10,295	18,980	1,080
pH	-	3	7/88 - 6/94	8.3	8.9	8.0	3	7/88 - 6/94	9.6	9.9	9.0
Total Hardness	mg/L	6	7/88 - 6/94	266	306	240	6	7/88 - 6/94	361	452	265
Sodium	mg/L	6	7/88 - 6/94	2,426	4,873	1,078	6	7/88 - 6/94	4,934	8,724	2,330
Chloride	mg/L	4	7/88 - 6/91	1,925	2,200	1,670	4	7/88 - 6/91	4,875	6,150	3,495
Iron	ug/L	4	6/91 - 6/94	1,260	1,990	553	4	6/91 - 6/94	683	1,330	114
Manganese	ug/L	4	6/91 - 6/94	150	185	110	4	6/91 - 6/94	81	130	36

Note: Water quality data from STORET.

Table VII-47
WATER QUALITY DATA SUMMARY
ARKANSAS RIVER

Parameter	Units	Great Bend Vicinity No. of Samples	Sample Dates	Mean	Maximum	Minimum	Hutchinson Vicinity No. of Samples	Sample Dates	Mean	Maximum	Minimum
Flow	cfs	287	3/44 - 5/75	1,166	27,400	2	249	9/59 -9/62	1066	15300	38
Flow - instanteous	cfs	223	7/57 - 8/95	446	950	0.05	-	-	-	-	-
Conductance	uS/cm	269	10/61 - 8/95	1,454	7,910	120	401	10/61 - 8/95	2,528	5,900	300
pH	-	253	10/61 - 8/95	7.9	12.0	6.7	343	10/61 - 8/95	7.8	9.1	6.9
Total Hardness	mg/L	168	10/61 - 9/75	551	1,110	84	178	10/61 - 9/75	404	805	-
Sodium	mg/L	168	10/61 - 9/75	153	350	5	177	10/61 - 9/75	371	1,110	23
Chloride	mg/L	168	10/61 - 9/75	68	130	0.7	255	10/61 - 4/92	564	1,700	27
Iron	ug/L	42	10/61 - 10/74	102	570	0	11	10/61 - 9/62	217	800	10
Manganese	ug/L	16	10/61 - 4/69	3.1	50	0	13	10/61 - 10/68	2	30	0
Flow	cfs	128	11/73 - 9/88	112	4,967	3	-	-	-	-	-
Conductance	uS/cm	213	11/73 - 12/96	1,298	3,100	200	40	5/90 - 11/96	2,398	3,600	742
pH	-	75	4/86 -12/96	7.8	8.7	-	41	3/90 - 11/96	8.3	8.7	7.4
Total Hardness	mg/L	213	11/73 - 12/96	375	1,111	65	40	3/90 - 11/96	328	583	117
Sodium	mg/L	212	11/73 - 12/96	133	330	4	40	3/90 - 11/96	321	506	64
Chloride	mg/L	202	11/73 - 12/94	129	565	4	28	5/90 - 11/94	524	762	160
Iron	ug/L	51	12/74 - 12/96	1,814	15,100	20	41	3/90 - 11/96	1,476	13,140	54
Manganese	ug/L	51	12/74 - 12/96	295	2,460	0	41	3/90 - 11/96	127	535	32
Flow	cfs	14	6/72 - 4/75	154	361	35					
Conductance	uS/cm	14	6/72 - 4/75	986	1,230	700					
Total Hardness	mg/L	14	6/72 - 4/75	372	456	268					
Chloride	mg/L	14	6/72 - 4/75	61	88	31					
Flow	cfs	21	4/71 - 6/77	208	1,080	14					
Total Hardness	mg/L	21	4/71 - 6/77	323	748	184					
Chloride	mg/L	21	4/71 - 6/77	75	160	22					

Note: Water quality data from STORET.

the development of an intake and other project facilities would not result in a significant loss of prime farmland within the basin. Additionally, agricultural activities could continue around these facilities.

Pipelines necessary to move the water from the surface water diversion to the Refuge would be located along existing roadways or fencelines. Some pipelines may need to be placed in agricultural land; however, after construction was completed, the agricultural use of the land would continue. Some mixing of soil profiles may occur, and could reduce crop yields; however, measures to place topsoil on the surface would minimize this impact. Pipelines would be routed to avoid wooded areas, wetlands, or other environmentally sensitive areas, thus minimizing or eliminating any impacts on these resources. Following construction, the rights-of-way for the facilities would either be revegetated or returned to agricultural production.

The intake and pipelines would also be located to avoid and minimize impacts to cultural resources, and any important fish, wildlife or threatened or endangered species habitat. Pipelines would temporarily impact streams where crossed. Likewise, no significant impacts to cultural resources are expected. The location of pipelines adjacent to existing roadways would reduce the potential for pipelines to cross significant, undisturbed cultural resource sites. Prior to construction, more detailed evaluation of environmental resources located in or adjacent to the potential diversion structure, and along potential pipeline right-of-way would be made to identify how to avoid or minimize impacts.

Some minimal disturbance to rural day-to-day activities such as farming and ranching may occur with construction. Construction equipment on and adjacent to roadways could temporarily cause minor traffic delays. Some impact to agricultural production could occur if construction activities occurred during the growing season and require the removal of crops. Most construction impacts would be temporary, occurring during only one growing season, and involving only a small amount of land along the edge of a field.

Direct removal of waters from the Arkansas River would have minimal impact on the river. Withdrawals would occur during periods of above-base flow, and would represent a small percentage of the total flow in the river. No modification to existing habitat along the river would be expected since diversions would be of short duration and occur late in the growing season or after growth had ceased. No changes in the hydrology of the river would be expected.

Alternative 9 would result in a more dependable supply of water to maintain existing Refuge habitat. Because water would be provided to the Refuge only as needed, no increase in the water depths of management units would occur. Short-term water depth increases could result from water being pumped into the storage units. Any increases would be temporary and only last until water could be released to other units. No change in the types or amount of habitat available on the Refuge would be expected.

Alternative 9 would provide supplemental water so that Refuge personnel could manage the Refuge and provide more dependable quantity and quality of habitat. In dry years, a more dependable habitat would likely provide an even more critical stopping, resting, staging, and recuperating area for migrating bird species, including endangered whooping cranes, during spring and fall migrations. A more dependable water supply in turn would increase the recreational opportunities available to the public on the Refuge.

7. Project Cost Estimates

Project costs, operating, maintenance, replacement and energy costs, present value and benefit-cost analysis for Alternative 9 are presented. These costs are used in Task E for the purpose of comparing and selecting the best alternative(s) for implementation.

a. Project Costs

The estimated project cost for Options 1, 2, 3, and 4 are respectively \$7.0, \$10.8, \$13.9, and \$16.9 million as listed in Table VII-48. The average life cycle unit cost of water for Options 1, 2, 3, and 4 are respectively \$453, \$216, \$189, and \$172 per MG based on project costs.

b. Operation, Maintenance, Replacement and Energy (OMR&E) Costs

OMR&E costs include costs associated with the operation and maintenance, replacement of mechanical equipment every 10 years and energy for Alternative 9. OMR&E costs for Options 1, 2, 3, and 4 are respectively \$189,000, \$479,000, \$673,000, and \$879,000 per year in the first year of operation and are inflated at 4 percent per year as listed in Table VII-49. These costs are used in combination with the project costs to calculate the present value for the alternative.

c. Present Value Analysis

The present value for Alternative 9 for Options 1, 2, 3, and 4 are respectively $9.5, $17.3, $23.0, and $28.9 million in 1998 dollars as listed in Table VII-50. The average life cycle unit cost of water for Options 1, 2, 3, and 4 are $615, $345, $313 and $295 per MG over 20 years of operation based on present value.

d. Benefit-Cost Analysis

A benefit of 91, 531, 749, and 849 acres per year of additional wetlands are estimated respectively for Options 1, 2, 3 and 4 at a respective 20 year present value of $0.82, $4.8, $6.8 and $7.7 million. This results in a benefit-cost ratio of 0.09 for Option 1, 0.28 for Option 2, 0.29 for Option 3, and 0.27 for Option 4.

J. ALTERNATIVE 10 - SUPPLEMENT WATER SUPPLY WITH GROUNDWATER WELLS

1. General

This alternative evaluates a supplemental water supply to the Refuge using a series of wells along Rattlesnake Creek west of Little Salt Marsh. These wells would pump groundwater directly into Rattlesnake Creek, on an as-needed basis, for downstream diversion and use in Refuge management units.

2. Preliminary Facility Concept

Facilities for the supplemental groundwater supply alternative include a series of groundwater wells on quarter-mile spacing adjacent to the Rattlesnake Creek. Pumped water would be discharged into the creek as shown in Figure VII-27. Each well is expected to pump about 800 gpm. The water would then flow by gravity to Little Salt Marsh. The first wells in this series are located on the west edge of the Refuge just upstream of Little Salt Marsh. Based on discussions with GMD5, the Service should be able to obtain water rights for this alternative.

Total diversion losses are expected to be minimized because:

- This section of the creek is not a losing stream.
- Static groundwater level is high.
- Diversion losses due to pumpage by other water right holders are not anticipated since water rights in this area are few.

Five supply options using a variable number of wells are considered as follows:

- 8 cfs or 500 acre-feet per month with 5 wells pumping for 6 months.
- 17 cfs or 1,000 acre-feet per month with 10 wells pumping for 6 months.
- 25 cfs or 1,500 acre-feet per month with 15 wells pumping for 6 months.
- 34 cfs or 2,000 acre-feet per month with 19 wells pumping for 6 months.
- 42 cfs or 2,500 acre-feet per month with 24 wells pumping for 6 months.

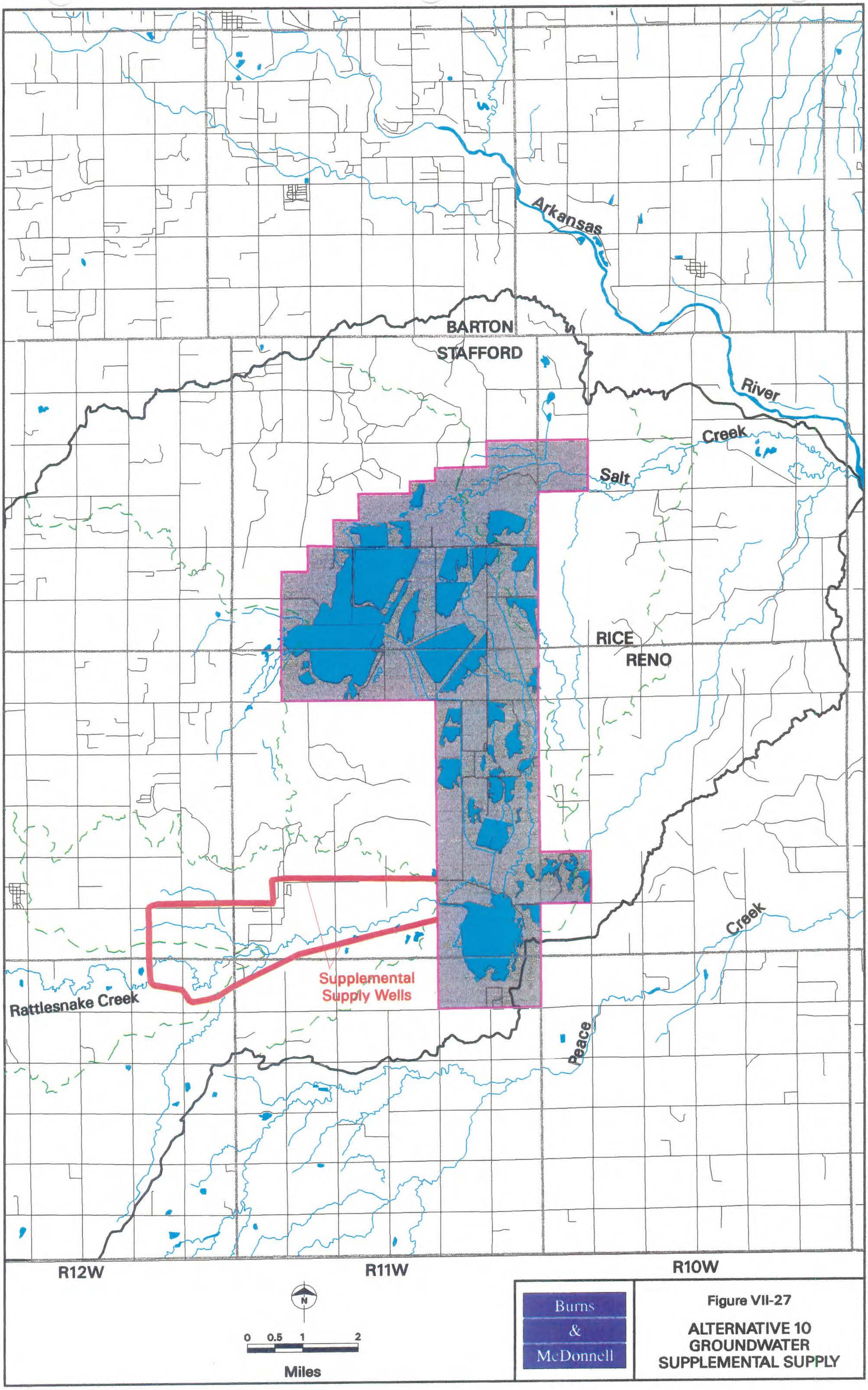


Figure VII-27

ALTERNATIVE 10
GROUNDWATER
SUPPLEMENTAL SUPPLY

3. Operations Model

Analysis for the various options under Alternative 10 requires five separate operations models, one model for each optional pumping capacity. The schematics for these models are all identical to that for the base operations model. The only change required in these models is to add an import to Little Salt Marsh. This import represents the additional water that is pumped into Rattlesnake Creek from the potential groundwater wells. In the operations model, these wells are assumed to operate continuously during the spring and fall months—February, March, April, September, October, and November—whether additional water is needed at the Refuge or not. Any water not required at the Refuge will continue down Rattlesnake Creek to the Arkansas River. In actual operation, these wells would be operated only when required. Due to the presence of confining layers, it is assumed that pumping these supplemental supply wells would not induce additional infiltration from Rattlesnake Creek to an appreciable degree.

Average Refuge diversions under each development option are summarized in Table VII-51. The three larger capacity options double or more than double the average amount of water that can be diverted to the Refuge.

Table VII-51
AVERAGE ANNUAL REFUGE DIVERSIONS—ALTERNATIVE 10

Number of Wells	Pumping Capacity (acre-feet/month)	Average Refuge Diversions (acre-feet/ year)	
		This Alternative	Change over Baseline
4	500	9,206	2,348
9	1,000	11,277	4,419
13	1,500	13,186	6,328
17	2,000	14,631	7,773
21	2,500	15,344	8,486

Statistics on the availability of wetland habitat at the Refuge for this alternative are presented in Table VII-52. Also shown in this table are the corresponding baseline values. Review of this table shows that implementation of this alterative could dramatically increase the availability of wetland habitat on the Refuge. The larger capacity options can increase the average shorebird and waterfowl habitat by about 50 percent, and nearly double the average total wetland habitat.

Table VII-52
AVAILABLE WETLAND HABITAT—ALTERNATIVE 10 [1]

Alternative	Shorebird (1–4 inches)		Waterfowl (10–18 inches)		Total Wetland	
	Range	Average	Range	Average	Range	Average
Baseline	85-684	358	11-1,055	602	692-6,000	2,757
4 Wells	141-694	390	14-1,052	708	885-6,006	3,341
9 Wells	142-698	418	231-1,040	797	1,053-6,006	3,869
13 Wells	225-713	459	379-1,040	858	1,425-6,006	4,335
17 Wells	322-715	508	482-1,043	898	2,014-6,017	4,740
21 Wells	329-715	551	582-1,043	923	2,290-6,017	5,010

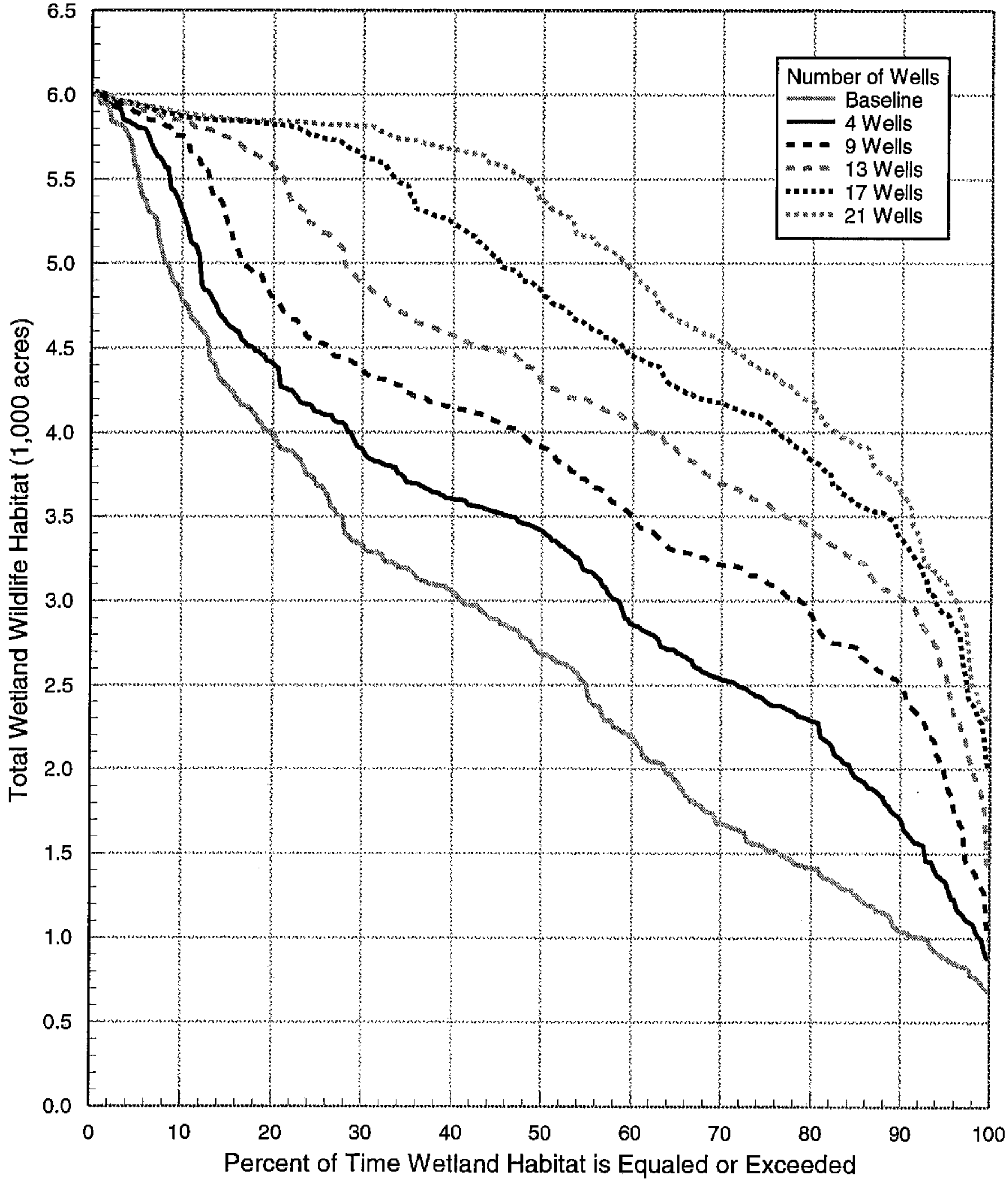
Note: 1. All wetland habitat values in acres. Statistics include data for primary migration season, September through April only.

The 80th percentile habitat areas and the changes in these values over baseline conditions are shown in Table VII-53. A comparison of the durations of total wetland habitat for the five optional pumping capacities and the baseline is shown in Figure VII-28.

Review of Table VII-53 shows that implementation of this alternative will have a dramatic impact on the amount of wetland habitat available at the Refuge 80 percent of the time. All options, except the four well option that has the lowest pumping capacity, will more than double the total wetland habitat at the Refuge, which is available in four out of five years.

Table VII-53
CHANGES IN AVAILABLE WETLAND HABITAT—ALTERNATIVE 10

Alternative	Shorebird (1-4 inches)		Waterfowl (10-18 inches)		Total Wetland	
	80th Percentile	Change	80th Percentile	Change	80th Percentile	Change
Baseline	237	---	354	---	1,416	---
4 Wells	335	98	525	171	2,290	874
9 Wells	355	118	703	349	2,923	1,507
13 Wells	363	126	754	400	3,449	2,033
17 Wells	366	129	804	450	3,841	2,425
21 Wells	369	132	841	487	4,189	2,773



Notes:
1. Developed from operations modeling for Quivira NWR for period 1/1955 through 12/1994 for supplemental groundwater supply alternative. Includes data for months of September through April only.
2. Total wetland habitat is the sum of the surface areas of all ponded water in all management units, regardless of depth.

Burns & McDonnell

Figure VII-28

TOTAL WETLAND HABITAT DURATIONS ALTERNATIVE 10

4. Water Quality

Water quality data for groundwater in the area are very limited. Review of Kansas Geological Survey Open File Report 93-2 shows ambient groundwater has chloride concentrations ranging from 100 to 500 mg/L in the upper unconsolidated aquifer and 1,000 to 10,000 mg/L at the base of the unconsolidated aquifer in the area of Rattlesnake Creek upstream of the Refuge. Chlorides in the upper aquifer are significantly less than the mean chloride concentration of 1,925 mg/L in Little Salt Marsh. Based on review of available data and discussions with GMD5 staff, supplemental wells on quarter mile spacing should be capable of pumping a minimum of 800 gpm from the shallow aquifer. Clay layers exist between the upper and lower sections of the aquifer and should minimize up-coning of high chloride water from the lower aquifer into the upper aquifer. This must be confirmed with a series of soil borings, pump tests and water quality sampling and analysis to determine the long-term pumping impacts on water quality of the supplemental wells.

5. Environmental and Cultural Resource Impacts

In Alternative 10, groundwater would only be pumped for use on the Refuge when needed. Environmental impacts associated with this alternative would include the conversion of small areas of cropland to the non-agricultural uses associated with operation of the proposed wells and the temporary disturbance associated with pipeline construction. It is expected that project facilities could be located to minimize environmental impacts.

Wells would be located on land currently used for pasture, hayfield, and/or cropland adjacent to Rattlesnake Creek. Most of the cropland in the basin is classified as prime farmland. Wells would be located if possible in areas not classified as prime farmland, and would be distributed to minimize the impact to any one field or landowner. Agricultural activities could continue around these facilities and could result in an inconvenience to current farming activities similar to that posed by existing irrigation wells.

Pipelines collecting water from wells and transporting it to Rattlesnake Creek would be short, extending only a small distance from the well to the creek. Pipelines could be located along roadways, largely avoiding important agricultural areas. Some collector lines may need to be placed across agricultural land. Any pipelines required to cross agricultural land would have a temporary impact on farming in the area.

Crop yields could be temporarily reduced, depending on the season construction occurs. Pipelines would be routed to avoid wooded areas to the extent possible. Following construction, the pipeline rights-of-way would either be revegetated or returned to agricultural production.

Wells and pipelines would be located to avoid and minimize impacts to wetlands, cultural resources, any important fish and wildlife habitat or habitat for threatened or endangered species. Pipelines could temporarily impact wetlands if such areas are found adjacent to roadways paralleled by pipelines or if they are present at any necessary stream crossing. Likewise, no significant impacts to cultural resources are expected as pipelines could be located to avoid such resources. Location of pipelines adjacent to existing roadways would reduce the potential for pipelines to cross significant, undisturbed cultural resource sites. Prior to construction, more detailed evaluation of environmental resources located in or adjacent to potential well sites and along potential pipeline rights-of-way would be made to identify how to avoid or minimize the impact on such resources.

Some minimal disturbance to rural day-to-day activities such as farming and ranching may occur with construction. Construction equipment on and adjacent to roadways could temporarily cause minor traffic delays . Some impact to agricultural production could occur if construction activities occur during the growing season and require the removal of crops. Most construction impacts would be temporary, occurring during only one growing season, and involving only a small amount of land along the edge of a field.

6. Project Cost Estimates

Project costs, operating, maintenance, replacement and energy costs, present value and benefit-cost analysis for Alternative 10 are presented. These costs are used in Task E for the purpose of comparing and selecting the best alternative(s) for implementation.

a. Project Costs

The estimated project cost for Options 1, 2, 3, 4 and 5 are respectively $1.4, $2.4, $3.5, $4.3 and $5.3 million as listed in Table VII-54. The average life cycle unit cost of water for Options 1, 2, 3, 4 and 5 are $92.5, $85.4, $85.8, $85.8 and $96.3 per MG based on project costs.

Table VII-54
PROJECT COST ESTIMATE
ALTERNATIVE 10 - SUPPLEMENTAL GROUNDWATER SUPPLY

Item	Option 1 Cost ($)	Option 2 Cost ($)	Option 3 Cost ($)	Option 4 Cost ($)	Option 5 Cost ($)
Testing Plan:					
Test Borings - 1 boring for every 2 wells	4,500	7,500	12,000	15,000	18,000
Pump Tests	120,000	120,000	180,000	180,000	180,000
Temporary Monitoring Wells - 10 per test	40,000	40,000	60,000	60,000	60,000
Water Quality Sampling and Analysis	40,000	40,000	60,000	60,000	60,000
Well, Pump and Controls:					
5 Wells with 8 cfs (5.2 MGD) capacity	375,000				
10 Wells with 17 cfs (11.0 MGD) capacity		750,000			
15 Wells with 25 cfs (16.0 MGD) capacity			1,125,000		
19 Wells with 34 cfs (22.0 MGD) capacity				1,425,000	
24 Wells with 42 cfs (27.0 MGD) capacity					1,800,000
Pipeline, Valves, Meter, Fence & Discharge	75,000	150,000	225,000	285,000	360,000
Test Drilling	10,000	23,000	33,000	43,000	53,000
Monitoring Wells	15,000	30,000	45,000	57,000	72,000
Electrical Power Supply	100,000	150,000	200,000	250,000	300,000
Access Road (10' wide gravel road)	139,000	277,000	416,000	527,000	665,000
Land and Right-of-way	15,000	31,000	46,000	59,000	74,000
Subtotal	933,500	1,618,500	2,402,000	2,961,000	3,642,000
Contingency at 20%	187,000	324,000	480,000	592,000	728,000
Subtotal	1,120,500	1,942,500	2,882,000	3,553,000	4,370,000
Testing Plan Other Costs	70,000	70,000	80,000	80,000	80,000
Other Costs at 20%	224,000	389,000	576,000	711,000	874,000
Total Project Cost	**1,415,000**	**2,402,000**	**3,538,000**	**4,344,000**	**5,324,000**
Average Annual Water Volume (MG)	**765**	**1,440**	**2,062**	**2,532**	**2,765**
Average Life Cycle Unit Cost of Water ($/MG)	**92.5**	**83.4**	**85.8**	**85.8**	**96.3**

b. Operation, Maintenance, Replacement and Energy (OMR&E) Costs

OMR&E costs include costs associated with the operation and maintenance, replacement of mechanical equipment every 10 years and energy for Alternative 10. OMR&E costs for Options 1, 2, 3, 4, and 5 are respectively $85,000, $120,000, $150,000, $177,000, and $195,000 per year in the first year of operation and are inflated at 4 percent per year as listed in Table VII-55. These costs are used in combination with the project costs to calculate the present value for the alternative.

c. Present Value Analysis

The present value for Alternative 10 for Options 1, 2, 3, 4, and 5 are $2.6, $4.1, $5.7, $6.9 and $8.2 million in 1998 dollars as listed in Table VII-56. The average life cycle unit cost of water for Options 1, 2, 3, 4, and 5 are $170, $143, $139, $137 and $162 per MG over 20 years of operation based on present value.

d. Benefit-Cost Analysis

A benefit of 874, 1507, 2033, 2425, and 2773 acres per year of additional wetlands are respectively estimated for Options 1,2, 3, 4 and 5 at a respective 20 year present value of $7.9, $13.6, $18.4, $21.9 and $25.0 million. This results in a benefit-cost ratio of 3.77 for Option 1, 3.89 for Option 2, 3.91 for Option 3, 3.78 for Option 4 and 3.63 for Option 5.

Table VII-55
OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
ALTERNATIVE 10 - SUPPLEMENTAL GROUNDWATER SUPPLY
OPTION 1

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	4.2	61,000		24,000	85,000
2001	4.2	63,000		25,000	88,000
2002	4.2	66,000		26,000	92,000
2003	4.2	69,000		27,000	96,000
2004	4.2	72,000		28,000	100,000
2005	4.2	75,000		29,000	104,000
2006	4.2	78,000		30,000	108,000
2007	4.2	81,000		31,000	112,000
2008	4.2	84,000		33,000	117,000
2009	4.2	87,000		34,000	121,000
2010	4.2	90,000	96,000	35,000	221,000
2011	4.2	94,000		37,000	131,000
2012	4.2	98,000		38,000	136,000
2013	4.2	102,000		40,000	142,000
2014	4.2	106,000		41,000	147,000
2015	4.2	110,000		43,000	153,000
2016	4.2	114,000		45,000	159,000
2017	4.2	119,000		46,000	165,000
2018	4.2	124,000		48,000	172,000
2019	4.2	129,000	137,000	50,000	316,000
Total	83.8	1,822,000	233,000	710,000	2,765,000

Notes:
1. Average pumping rate is assumed to be continuous.
2. O&M includes additional staff and materials, testing and operations.
3. Replacement of equipment every 10 years.
4. Energy costs are estimated at $.12/KWH.

Table VII-55 (continued)
OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
ALTERNATIVE 10 - SUPPLEMENTAL GROUNDWATER SUPPLY
OPTION 2

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	7.9	75,000		45,000	120,000
2001	7.9	78,000		47,000	125,000
2002	7.9	81,000		48,000	129,000
2003	7.9	84,000		50,000	134,000
2004	7.9	87,000		52,000	139,000
2005	7.9	90,000		54,000	144,000
2006	7.9	94,000		57,000	151,000
2007	7.9	98,000		59,000	157,000
2008	7.9	102,000		61,000	163,000
2009	7.9	106,000		64,000	170,000
2010	7.9	110,000	216,000	66,000	392,000
2011	7.9	114,000		69,000	183,000
2012	7.9	119,000		72,000	191,000
2013	7.9	124,000		75,000	199,000
2014	7.9	129,000		78,000	207,000
2015	7.9	134,000		81,000	215,000
2016	7.9	139,000		84,000	223,000
2017	7.9	145,000		87,000	232,000
2018	7.9	151,000		91,000	242,000
2019	7.9	157,000	308,000	94,000	559,000
Total	157.8	2,217,000	524,000	1,334,000	4,075,000

Notes:
1. Average pumping rate is assumed to be continuous.
2. O&M includes additional staff and materials, testing and operations.
3. Replacement of equipment every 10 years.
4. Energy costs are estimated at $.12/KWH.

Table VII-55 (continued)
OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
ALTERNATIVE 10 - SUPPLEMENTAL GROUNDWATER SUPPLY
OPTION 3

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	11.3	86,000		64,000	150,000
2001	11.3	89,000		67,000	156,000
2002	11.3	93,000		69,000	162,000
2003	11.3	97,000		72,000	169,000
2004	11.3	101,000		75,000	176,000
2005	11.3	105,000		78,000	183,000
2006	11.3	109,000		81,000	190,000
2007	11.3	113,000		84,000	197,000
2008	11.3	118,000		88,000	206,000
2009	11.3	123,000		91,000	214,000
2010	11.3	128,000	312,000	95,000	535,000
2011	11.3	133,000		99,000	232,000
2012	11.3	138,000		103,000	241,000
2013	11.3	144,000		107,000	251,000
2014	11.3	150,000		111,000	261,000
2015	11.3	156,000		115,000	271,000
2016	11.3	162,000		120,000	282,000
2017	11.3	168,000		125,000	293,000
2018	11.3	175,000		130,000	305,000
2019	11.3	182,000	444,000	135,000	761,000
Total	225.9	2,570,000	756,000	1,909,000	5,235,000

Notes:
1. Average pumping rate is assumed to be continuous.
2. O&M includes additional staff and materials, testing and operations.
3. Replacement of equipment every 10 years.
4. Energy costs are estimated at $.12/KWH.

Table VII-55 (continued)
OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
ALTERNATIVE 10 - SUPPLEMENTAL GROUNDWATER SUPPLY
OPTION 4

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	13.9	98,000		79,000	177,000
2001	13.9	102,000		82,000	184,000
2002	13.9	106,000		85,000	191,000
2003	13.9	110,000		89,000	199,000
2004	13.9	114,000		92,000	206,000
2005	13.9	119,000		96,000	215,000
2006	13.9	124,000		100,000	224,000
2007	13.9	129,000		104,000	233,000
2008	13.9	134,000		108,000	242,000
2009	13.9	139,000		112,000	251,000
2010	13.9	145,000	408,000	117,000	670,000
2011	13.9	151,000		121,000	272,000
2012	13.9	157,000		126,000	283,000
2013	13.9	163,000		131,000	294,000
2014	13.9	170,000		136,000	306,000
2015	13.9	177,000		142,000	319,000
2016	13.9	184,000		147,000	331,000
2017	13.9	191,000		153,000	344,000
2018	13.9	199,000		160,000	359,000
2019	13.9	207,000	581,000	166,000	954,000
Total	277.5	2,919,000	989,000	2,346,000	6,254,000

Notes:
1. Average pumping rate is assumed to be continuous.
2. O&M includes additional staff and materials, testing and operations.
3. Replacement of equipment every 10 years.
4. Energy costs are estimated at $.12/KWH.

Table VII-55 (continued)
OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
ALTERNATIVE 10 - SUPPLEMENTAL GROUNDWATER SUPPLY
OPTION 5

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	15.1	109,000		86,000	195,000
2001	15.1	113,000		89,000	202,000
2002	15.1	118,000		93,000	211,000
2003	15.1	123,000		97,000	220,000
2004	15.1	128,000		101,000	229,000
2005	15.1	133,000		105,000	238,000
2006	15.1	138,000		109,000	247,000
2007	15.1	144,000		113,000	257,000
2008	15.1	150,000		118,000	268,000
2009	15.1	156,000		122,000	278,000
2010	15.1	162,000	504,000	127,000	793,000
2011	15.1	168,000		132,000	300,000
2012	15.1	175,000		138,000	313,000
2013	15.1	182,000		143,000	325,000
2014	15.1	189,000		149,000	338,000
2015	15.1	197,000		155,000	352,000
2016	15.1	205,000		161,000	366,000
2017	15.1	213,000		167,000	380,000
2018	15.1	222,000		174,000	396,000
2019	15.1	231,000	718,000	181,000	1,130,000
Total	303.0	3,256,000	1,222,000	2,560,000	7,038,000

Notes:
1. Average pumping rate is assumed to be continuous.
2. O&M includes additional staff and materials, testing and operations.
3. Replacement of equipment every 10 years.
4. Energy costs are estimated at $.12/KWH.

Table VII-56
PRESENT VALUE ESTIMATE
ALTERNATIVE 10 - SUPPLEMENTAL GROUNDWATER SUPPLY
OPTION 1

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0				0	0
1999	0	1,472,000			1,376,000	1,376,000
2000	4.2		85,000	85,000	74,000	1,450,000
2001	4.2		88,000	88,000	72,000	1,522,000
2002	4.2		92,000	92,000	70,000	1,592,000
2003	4.2		96,000	96,000	68,000	1,660,000
2004	4.2		100,000	100,000	67,000	1,727,000
2005	4.2		104,000	104,000	65,000	1,792,000
2006	4.2		108,000	108,000	63,000	1,855,000
2007	4.2		112,000	112,000	61,000	1,916,000
2008	4.2		117,000	117,000	59,000	1,975,000
2009	4.2		121,000	121,000	57,000	2,032,000
2010	4.2		221,000	221,000	98,000	2,130,000
2011	4.2		131,000	131,000	54,000	2,184,000
2012	4.2		136,000	136,000	53,000	2,237,000
2013	4.2		142,000	142,000	51,000	2,288,000
2014	4.2		147,000	147,000	50,000	2,338,000
2015	4.2		153,000	153,000	48,000	2,386,000
2016	4.2		159,000	159,000	47,000	2,433,000
2017	4.2		165,000	165,000	46,000	2,479,000
2018	4.2		172,000	172,000	44,000	2,523,000
2019	4.2		316,000	316,000	76,000	2,599,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						**170**

Table VII-56 (continued)
PRESENT VALUE ESTIMATE
ALTERNATIVE 10 - SUPPLEMENTAL GROUNDWATER SUPPLY
OPTION 2

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0				0	0
1999	0	2,498,000			2,335,000	2,335,000
2000	7.9		120,000	120,000	105,000	2,440,000
2001	7.9		125,000	125,000	102,000	2,542,000
2002	7.9		129,000	129,000	98,000	2,640,000
2003	7.9		134,000	134,000	96,000	2,736,000
2004	7.9		139,000	139,000	93,000	2,829,000
2005	7.9		144,000	144,000	90,000	2,919,000
2006	7.9		151,000	151,000	88,000	3,007,000
2007	7.9		157,000	157,000	85,000	3,092,000
2008	7.9		163,000	163,000	83,000	3,175,000
2009	7.9		170,000	170,000	81,000	3,256,000
2010	7.9		392,000	392,000	174,000	3,430,000
2011	7.9		183,000	183,000	76,000	3,506,000
2012	7.9		191,000	191,000	74,000	3,580,000
2013	7.9		199,000	199,000	72,000	3,652,000
2014	7.9		207,000	207,000	70,000	3,722,000
2015	7.9		215,000	215,000	68,000	3,790,000
2016	7.9		223,000	223,000	66,000	3,856,000
2017	7.9		232,000	232,000	64,000	3,920,000
2018	7.9		242,000	242,000	63,000	3,983,000
2019	7.9		559,000	559,000	135,000	4,118,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						**143**

Table VII-56 (continued)
PRESENT VALUE ESTIMATE
ALTERNATIVE 10 - SUPPLEMENTAL GROUNDWATER SUPPLY
OPTION 3

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0				0	0
1999	0	3,680,000			3,439,000	3,439,000
2000	11.3		150,000	150,000	131,000	3,570,000
2001	11.3		156,000	156,000	127,000	3,697,000
2002	11.3		162,000	162,000	124,000	3,821,000
2003	11.3		169,000	169,000	120,000	3,941,000
2004	11.3		176,000	176,000	117,000	4,058,000
2005	11.3		183,000	183,000	114,000	4,172,000
2006	11.3		190,000	190,000	111,000	4,283,000
2007	11.3		197,000	197,000	107,000	4,390,000
2008	11.3		206,000	206,000	105,000	4,495,000
2009	11.3		214,000	214,000	102,000	4,597,000
2010	11.3		535,000	535,000	238,000	4,835,000
2011	11.3		232,000	232,000	96,000	4,931,000
2012	11.3		241,000	241,000	93,000	5,024,000
2013	11.3		251,000	251,000	91,000	5,115,000
2014	11.3		261,000	261,000	88,000	5,203,000
2015	11.3		271,000	271,000	86,000	5,289,000
2016	11.3		282,000	282,000	83,000	5,372,000
2017	11.3		293,000	293,000	81,000	5,453,000
2018	11.3		305,000	305,000	79,000	5,532,000
2019	11.3		761,000	761,000	184,000	5,716,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						**139**

Table VII-56 (continued)
PRESENT VALUE ESTIMATE
ALTERNATIVE 10 - SUPPLEMENTAL GROUNDWATER SUPPLY
OPTION 4

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0				0	0
1999	0	4,518,000			4,222,000	4,222,000
2000	13.9		177,000	177,000	155,000	4,377,000
2001	13.9		184,000	184,000	150,000	4,527,000
2002	13.9		191,000	191,000	146,000	4,673,000
2003	13.9		199,000	199,000	142,000	4,815,000
2004	13.9		206,000	206,000	137,000	4,952,000
2005	13.9		215,000	215,000	134,000	5,086,000
2006	13.9		224,000	224,000	130,000	5,216,000
2007	13.9		233,000	233,000	127,000	5,343,000
2008	13.9		242,000	242,000	123,000	5,466,000
2009	13.9		251,000	251,000	119,000	5,585,000
2010	13.9		670,000	670,000	297,000	5,882,000
2011	13.9		272,000	272,000	113,000	5,995,000
2012	13.9		283,000	283,000	110,000	6,105,000
2013	13.9		294,000	294,000	107,000	6,212,000
2014	13.9		306,000	306,000	104,000	6,316,000
2015	13.9		319,000	319,000	101,000	6,417,000
2016	13.9		331,000	331,000	98,000	6,515,000
2017	13.9		344,000	344,000	95,000	6,610,000
2018	13.9		359,000	359,000	93,000	6,703,000
2019	13.9		954,000	954,000	230,000	6,933,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						**137**

Table VII-56 (continued)
PRESENT VALUE ESTIMATE
ALTERNATIVE 10 - SUPPLEMENTAL GROUNDWATER SUPPLY
OPTION 5

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0.0				0	0
1999	0.0	5,537,000			5,175,000	5,175,000
2000	15.1		195,000	195,000	170,000	5,345,000
2001	15.1		202,000	202,000	165,000	5,510,000
2002	15.1		211,000	211,000	161,000	5,671,000
2003	15.1		220,000	220,000	157,000	5,828,000
2004	15.1		229,000	229,000	153,000	5,981,000
2005	15.1		238,000	238,000	148,000	6,129,000
2006	15.1		247,000	247,000	144,000	6,273,000
2007	15.1		257,000	257,000	140,000	6,413,000
2008	15.1		268,000	268,000	136,000	6,549,000
2009	15.1		278,000	278,000	132,000	6,681,000
2010	15.1		793,000	793,000	352,000	7,033,000
2011	15.1		300,000	300,000	124,000	7,157,000
2012	15.1		313,000	313,000	121,000	7,278,000
2013	15.1		325,000	325,000	118,000	7,396,000
2014	15.1		338,000	338,000	114,000	7,510,000
2015	15.1		352,000	352,000	111,000	7,621,000
2016	15.1		366,000	366,000	108,000	7,729,000
2017	15.1		380,000	380,000	105,000	7,834,000
2018	15.1		396,000	396,000	102,000	7,936,000
2019	15.1		1,130,000	1,130,000	273,000	8,209,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						**162**

Table VII-48
PROJECT COST ESTIMATE
ALTERNATIVE 9 - SUPPLEMENTAL SUPPLY WITH ARKANSAS RIVER

Item	Option 1 Cost ($)	Option 2 Cost ($)	Option 3 Cost ($)	Option 4 Cost ($)
Surface Water Intake & Pump Station				
6 cfs (3.9 MGD) capacity	500,000			
20 cfs (12.9 MGD) capacity		1,000,000		
35 cfs (22.6 MGD) capacity			1,500,000	
55 cfs (35.5 MGD) capacity				2,000,000
Pipeline (14.5 miles, 200 psi pressure class)				
16-inch diameter	4,287,000			
24-inch diameter		6,431,000		
30-inch diameter			8,039,000	
36-inch diameter				9,647,000
Electrical Power Supply (0 miles)	0	0	0	0
SCADA System	50,000	50,000	50,000	50,000
Land (5 acres) and Right-of-way (4 miles)	31,000	31,000	31,000	31,000
Subtotal	4,868,000	7,512,000	9,620,000	11,728,000
Contingency at 20%	974,000	1,502,000	1,924,000	2,346,000
Subtotal	5,842,000	9,014,000	11,544,000	14,074,000
Other Costs at 20%	1,168,000	1,803,000	2,309,000	2,815,000
Total Project Cost	**7,010,000**	**10,817,000**	**13,853,000**	**16,889,000**
Average Annual Water Volume (MG)	**774**	**2,509**	**3,674**	**4,908**
Average Life Cycle Unit Cost of Water ($/MG)	**453**	**216**	**189**	**172**

Table VII-49
OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
ALTERNATIVE 9 - SUPPLEMENTAL SUPPLY WITH ARKANSAS RIVER
OPTION 1

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	3.6	60,000		129,000	189,000
2001	3.6	62,000		134,000	196,000
2002	3.6	64,000		140,000	204,000
2003	3.6	67,000		145,000	212,000
2004	3.6	70,000		151,000	221,000
2005	3.6	73,000		157,000	230,000
2006	3.6	76,000		163,000	239,000
2007	3.6	79,000		170,000	249,000
2008	3.6	82,000		177,000	259,000
2009	3.6	85,000		184,000	269,000
2010	3.6	88,000	200,000	191,000	479,000
2011	3.6	92,000		199,000	291,000
2012	3.6	96,000		207,000	303,000
2013	3.6	100,000		215,000	315,000
2014	3.6	104,000		224,000	328,000
2015	3.6	108,000		233,000	341,000
2016	3.6	112,000		242,000	354,000
2017	3.6	116,000		252,000	368,000
2018	3.6	121,000		262,000	383,000
2019	3.6	126,000	285,000	272,000	683,000
Total	72.0	1,781,000	485,000	3,847,000	6,113,000

Notes:
1. Average pumping rate is estimated at 90 percent of maximum.
2. O&M includes additional staff and materials, testing and operations.
3. Replacement of equipment, 25 percent of intake cost, every 10 years.
4. Energy costs are estimated at $.070/KWH.

Table VII-49 (continued)
OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
ALTERNATIVE 9 - SUPPLEMENTAL SUPPLY WITH ARKANSAS RIVER
OPTION 2

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	11.7	60,000		419,000	479,000
2001	11.7	62,000		436,000	498,000
2002	11.7	64,000		453,000	517,000
2003	11.7	67,000		471,000	538,000
2004	11.7	70,000		490,000	560,000
2005	11.7	73,000		510,000	583,000
2006	11.7	76,000		530,000	606,000
2007	11.7	79,000		551,000	630,000
2008	11.7	82,000		573,000	655,000
2009	11.7	85,000		596,000	681,000
2010	11.7	88,000	400,000	620,000	1,108,000
2011	11.7	92,000		645,000	737,000
2012	11.7	96,000		670,000	766,000
2013	11.7	100,000		697,000	797,000
2014	11.7	104,000		725,000	829,000
2015	11.7	108,000		754,000	862,000
2016	11.7	112,000		784,000	896,000
2017	11.7	116,000		816,000	932,000
2018	11.7	121,000		848,000	969,000
2019	11.7	126,000	570,000	882,000	1,578,000
Total	233.4	1,781,000	970,000	12,470,000	15,221,000

Notes:
1. Average pumping rate is estimated at 90 percent of maximum.
2. O&M includes additional staff and materials, testing and operations.
3. Replacement of equipment, 25 percent of intake cost, every 10 years.
4. Energy costs are estimated at $.070/KWH.

Table VII-49 (continued)
OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
ALTERNATIVE 9 - SUPPLEMENTAL SUPPLY WITH ARKANSAS RIVER
OPTION 3

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	18.1	60,000		613,000	673,000
2001	18.1	62,000		638,000	700,000
2002	18.1	64,000		663,000	727,000
2003	18.1	67,000		690,000	757,000
2004	18.1	70,000		717,000	787,000
2005	18.1	73,000		746,000	819,000
2006	18.1	76,000		776,000	852,000
2007	18.1	79,000		807,000	886,000
2008	18.1	82,000		839,000	921,000
2009	18.1	85,000		873,000	958,000
2010	18.1	88,000	600,000	908,000	1,596,000
2011	18.1	92,000		944,000	1,036,000
2012	18.1	96,000		982,000	1,078,000
2013	18.1	100,000		1,021,000	1,121,000
2014	18.1	104,000		1,062,000	1,166,000
2015	18.1	108,000		1,104,000	1,212,000
2016	18.1	112,000		1,148,000	1,260,000
2017	18.1	116,000		1,194,000	1,310,000
2018	18.1	121,000		1,242,000	1,363,000
2019	18.1	126,000	855,000	1,292,000	2,273,000
Total	362.0	1,781,000	1,455,000	18,259,000	21,495,000

Notes:
1. Average pumping rate is estimated at 90 percent of maximum.
2. O&M includes additional staff and materials, testing and operations.
3. Replacement of equipment, 25 percent of intake cost, every 10 years.
4. Energy costs are estimated at $.070/KWH.

Table VII-49 (continued)
OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
ALTERNATIVE 9 - SUPPLEMENTAL SUPPLY WITH ARKANSAS RIVER
OPTION 4

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	24.9	60,000		819,000	879,000
2001	24.9	62,000		852,000	914,000
2002	24.9	64,000		886,000	950,000
2003	24.9	67,000		921,000	988,000
2004	24.9	70,000		958,000	1,028,000
2005	24.9	73,000		997,000	1,070,000
2006	24.9	76,000		1,036,000	1,112,000
2007	24.9	79,000		1,078,000	1,157,000
2008	24.9	82,000		1,121,000	1,203,000
2009	24.9	85,000		1,166,000	1,251,000
2010	24.9	88,000	801,000	1,212,000	2,101,000
2011	24.9	92,000		1,261,000	1,353,000
2012	24.9	96,000		1,311,000	1,407,000
2013	24.9	100,000		1,364,000	1,464,000
2014	24.9	104,000		1,418,000	1,522,000
2015	24.9	108,000		1,475,000	1,583,000
2016	24.9	112,000		1,534,000	1,646,000
2017	24.9	116,000		1,595,000	1,711,000
2018	24.9	121,000		1,659,000	1,780,000
2019	24.9	126,000	1,139,000	1,726,000	2,991,000
Total	498.3	1,781,000	1,940,000	24,389,000	28,110,000

Notes:
1. Average pumping rate is estimated at 90 percent of maximum.
2. O&M includes additional staff and materials, testing and operations.
3. Replacement of equipment, 25 percent of intake cost, every 10 years.
4. Energy costs are estimated at $.070/KWH.

Table VII-50
PRESENT VALUE ESTIMATE
ALTERNATIVE 9 - SUPPLEMENTAL SUPPLY WITH ARKANSAS RIVER
OPTION 1

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0				0	0
1999	0	7,290,000			6,813,000	6,813,000
2000	3.6		189,000	189,000	165,000	6,978,000
2001	3.6		196,000	196,000	160,000	7,138,000
2002	3.6		204,000	204,000	156,000	7,294,000
2003	3.6		212,000	212,000	151,000	7,445,000
2004	3.6		221,000	221,000	147,000	7,592,000
2005	3.6		230,000	230,000	143,000	7,735,000
2006	3.6		239,000	239,000	139,000	7,874,000
2007	3.6		249,000	249,000	135,000	8,009,000
2008	3.6		259,000	259,000	132,000	8,141,000
2009	3.6		269,000	269,000	128,000	8,269,000
2010	3.6		479,000	479,000	213,000	8,482,000
2011	3.6		291,000	291,000	121,000	8,603,000
2012	3.6		303,000	303,000	118,000	8,721,000
2013	3.6		315,000	315,000	114,000	8,835,000
2014	3.6		328,000	328,000	111,000	8,946,000
2015	3.6		341,000	341,000	108,000	9,054,000
2016	3.6		354,000	354,000	105,000	9,159,000
2017	3.6		368,000	368,000	102,000	9,261,000
2018	3.6		383,000	383,000	99,000	9,360,000
2019	3.6		683,000	683,000	165,000	9,525,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						**615**

Table VII-50 (continued)
PRESENT VALUE ESTIMATE
ALTERNATIVE 9 - SUPPLEMENTAL SUPPLY WITH ARKANSAS RIVER
OPTION 2

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0				0	0
1999	0	11,250,000			10,514,000	10,514,000
2000	11.7		479,000	479,000	418,000	10,932,000
2001	11.7		498,000	498,000	407,000	11,339,000
2002	11.7		517,000	517,000	394,000	11,733,000
2003	11.7		538,000	538,000	384,000	12,117,000
2004	11.7		560,000	560,000	373,000	12,490,000
2005	11.7		583,000	583,000	363,000	12,853,000
2006	11.7		606,000	606,000	353,000	13,206,000
2007	11.7		630,000	630,000	343,000	13,549,000
2008	11.7		655,000	655,000	333,000	13,882,000
2009	11.7		681,000	681,000	324,000	14,206,000
2010	11.7		1,108,000	1,108,000	492,000	14,698,000
2011	11.7		737,000	737,000	306,000	15,004,000
2012	11.7		766,000	766,000	297,000	15,301,000
2013	11.7		797,000	797,000	289,000	15,590,000
2014	11.7		829,000	829,000	281,000	15,871,000
2015	11.7		862,000	862,000	273,000	16,144,000
2016	11.7		896,000	896,000	265,000	16,409,000
2017	11.7		932,000	932,000	258,000	16,667,000
2018	11.7		969,000	969,000	250,000	16,917,000
2019	11.7		1,578,000	1,578,000	381,000	17,298,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						**345**

Table VII-50 (continued)
PRESENT VALUE ESTIMATE
ALTERNATIVE 9 - SUPPLEMENTAL SUPPLY WITH ARKANSAS RIVER
OPTION 3

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0				0	0
1999	0	14,407,000			13,464,000	13,464,000
2000	18.1		673,000	673,000	588,000	14,052,000
2001	18.1		700,000	700,000	571,000	14,623,000
2002	18.1		727,000	727,000	555,000	15,178,000
2003	18.1		757,000	757,000	540,000	15,718,000
2004	18.1		787,000	787,000	524,000	16,242,000
2005	18.1		819,000	819,000	510,000	16,752,000
2006	18.1		852,000	852,000	496,000	17,248,000
2007	18.1		886,000	886,000	482,000	17,730,000
2008	18.1		921,000	921,000	468,000	18,198,000
2009	18.1		958,000	958,000	455,000	18,653,000
2010	18.1		1,596,000	1,596,000	709,000	19,362,000
2011	18.1		1,036,000	1,036,000	430,000	19,792,000
2012	18.1		1,078,000	1,078,000	418,000	20,210,000
2013	18.1		1,121,000	1,121,000	406,000	20,616,000
2014	18.1		1,166,000	1,166,000	395,000	21,011,000
2015	18.1		1,212,000	1,212,000	384,000	21,395,000
2016	18.1		1,260,000	1,260,000	373,000	21,768,000
2017	18.1		1,310,000	1,310,000	362,000	22,130,000
2018	18.1		1,363,000	1,363,000	352,000	22,482,000
2019	18.1		2,273,000	2,273,000	549,000	23,031,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						**313**

Table VII-50 (continued)
PRESENT VALUE ESTIMATE
ALTERNATIVE 9 - SUPPLEMENTAL SUPPLY WITH ARKANSAS RIVER
OPTION 4

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0				0	0
1999	0	17,565,000			16,416,000	16,416,000
2000	24.9		879,000	879,000	768,000	17,184,000
2001	24.9		914,000	914,000	746,000	17,930,000
2002	24.9		950,000	950,000	725,000	18,655,000
2003	24.9		988,000	988,000	704,000	19,359,000
2004	24.9		1,028,000	1,028,000	685,000	20,044,000
2005	24.9		1,070,000	1,070,000	666,000	20,710,000
2006	24.9		1,112,000	1,112,000	647,000	21,357,000
2007	24.9		1,157,000	1,157,000	629,000	21,986,000
2008	24.9		1,203,000	1,203,000	612,000	22,598,000
2009	24.9		1,251,000	1,251,000	594,000	23,192,000
2010	24.9		2,101,000	2,101,000	933,000	24,125,000
2011	24.9		1,353,000	1,353,000	561,000	24,686,000
2012	24.9		1,407,000	1,407,000	546,000	25,232,000
2013	24.9		1,464,000	1,464,000	531,000	25,763,000
2014	24.9		1,522,000	1,522,000	516,000	26,279,000
2015	24.9		1,583,000	1,583,000	501,000	26,780,000
2016	24.9		1,646,000	1,646,000	487,000	27,267,000
2017	24.9		1,711,000	1,711,000	473,000	27,740,000
2018	24.9		1,780,000	1,780,000	460,000	28,200,000
2019	24.9		2,991,000	2,991,000	722,000	28,922,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						**295**

PART VIII

TASK D - REFUGE GROUNDWATER MODEL

A. GENERAL

This section of the report describes the development of a computer groundwater model to quantify the subsurface flow contribution to Big Salt Marsh on the north side of the Quivira National Wildlife Refuge (Refuge). The model will be used to quantify the area's water budget and to help evaluate alternatives for protecting the component of subsurface flow that helps maintain surface water in the Big Salt Marsh.

B. STUDY AREA

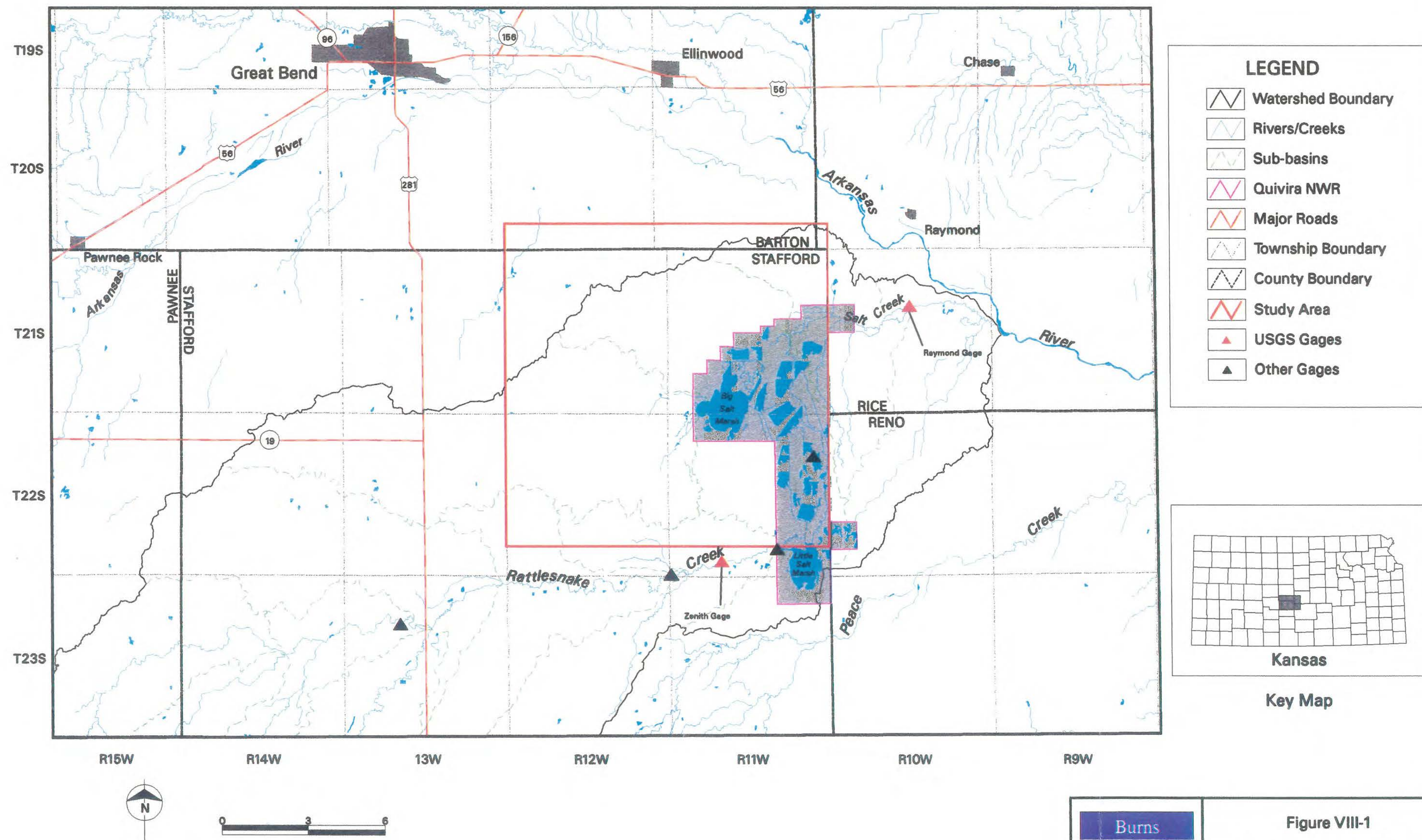
A subregional groundwater model of the study area for the Big Salt Marsh is developed to evaluate the area's water budget in greater detail than possible from previous regional models, while permitting consideration of regional influences. The study area included in the Big Salt Marsh model, as shown in Figure VIII-1, encompasses approximately 142 square miles and is located mainly in Stafford County with a small portion in Barton and Rice Counties. These boundaries are selected to include the sand hills within the Rattlesnake Creek watershed and focus on the Big Salt Marsh area. Big Salt Marsh occupies approximately 2.5 square miles.

C. PREVIOUS MODELS

Several two-dimensional models have been developed for this region. The earliest model included a simulation of the saltwater-freshwater interface (Sophocleous and Birdie, 1990). The effectiveness of this model was restricted by data deficiencies; therefore, this model was not reviewed further. The two most current and appropriate models for use here in this study are transient models and were developed by the Kansas Geological Survey (KGS) using the United States Geological Survey's (USGS) MODFLOW program (Sophocleous and Perkins, 1992, and Sophocleous, et al, 1997).

1. 1992 MODFLOW Model

The 1992 model (Sophocleous and Perkins, 1992) is a two-dimensional model of 560 square miles of the lower Rattlesnake Creek watershed. The study area is a rectangle that is 44 miles long and 23 miles wide. The study area is divided into 1,012 grid cells each representing one square mile (1 mile by 1 mile). The



Burns & McDonnell

Figure VIII-1

REFUGE GROUNDWATER MODEL STUDY AREA

model contains 562 active grid cells that lie inside the basin area and assumes unconfined conditions across the study area. This transient model represents the pre-development conditions of the aquifer and covers the 1995 to 1990 time period with 14 stress periods composed of one-year time steps.

2. 1997 SWATMOD Model

During the mid-90's, the KGS developed a model combining SWAT, which is a surface water model, with MODFLOW. The goal was to construct a more complete model of the surface and groundwater interaction in the Rattlesnake Creek watershed (Sophocleous, et al, 1997). The study area for this model covers the entire Rattlesnake Creek watershed which is 1,317 square miles in area. The rectangle outlining the study area in 90 miles long and 20 miles wide. The MODFLOW portion of this two-dimensional model is composed of 8930 grid cells that represent 0.25 square miles (½ mile by ½ mile). The model has 5,574 active grid cells within the watershed. Like the previous model, this model assumes unconfined conditions across the entire study area. The pre-development conditions of the basin provide the starting conditions for this model. The transient model represents the time period from 1955 to 1994. Forty annual stress periods are each divided into 12 time steps representing the months of the year.

3. Purpose and Use

The earlier models described above were constructed to evaluate groundwater conditions throughout either a larger portion of the watershed or the entire watershed and have a very large scale (node size). Additionally, these models were established as unconfined aquifers which was appropriate for a regional model; however, to more accurately simulate a smaller study area, a multi-layered model is needed to represent the various units of the hydrogeologic system that may be either confined or unconfined.

The groundwater in the vicinity of Big Salt Marsh is one component of the water supply that helps to maintain surface water levels in the marsh and other adjacent Refuge units. Prior discussions with the Service identified this water as artesian groundwater flow that discharges near the Refuge. This task requires an evaluation of the region around the Refuge, including the surrounding sand hills, the silt-clay bed that covers most of the study area, and the sands and gravels of the Mead Formation that form the primary aquifer of the region. This evaluation uses a quasi-three-dimensional model with a finer grid spacing than that of the previous models. The data utilized in the earlier models will provide a framework for the development of this subregional model. A quasi-three-dimensional model will provide a good representation of the impacts the silt-clay bed has on the groundwater flow in the study area.

D. BIG SALT MARSH CONCEPTUAL MODEL

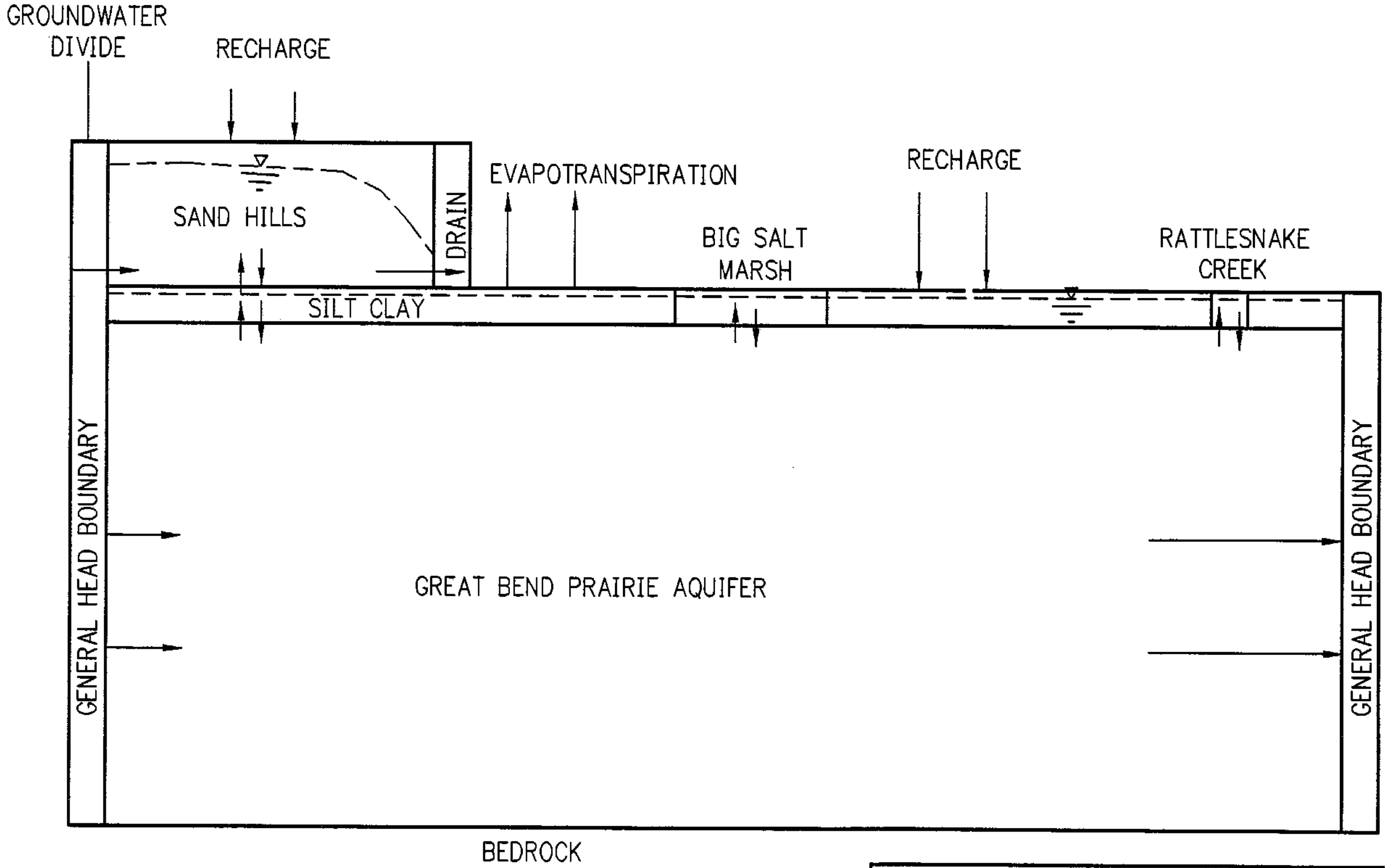
A conceptual model is a block diagram showing how geologic conditions are simplified for computer modeling simulations. The Big Salt Marsh study area has two important hydrogeologic units, the sand hills and the Great Bend Prairie Aquifer. This area receives recharge from precipitation, through overlying rivers, and as underflow from surrounding formations. The block diagram in Figure VIII-2 shows a simplified cross-section of the general aquifer configuration and is the basis for the Big Salt Marsh model construction using the USGS MODFLOW computer program.

1. Grid Spacing

In order to provide the necessary detail to simulate current conditions, a model with a fine grid spacing is needed for the Big Salt Marsh study area. A uniform grid spacing used across the model will provide good resolution of all parts of the study area. Node size is set at 500 feet (over 5 times finer resolution than the SWATMOD model) which should provide adequate resolution for this study. To meet the model objectives of evaluating the interaction of the groundwater with Big Salt Marsh, two layers are required to model the interaction between the sand hills and the Great Bend Prairie Aquifer. Model Layer 1 represents the sand hills. Model Layer 2 represents the Great Bend Prairie Aquifer. The silty clay layer between the two aquifer zones is represented by a low conductance value between the two model layers.

2. Boundary Conditions

The boundary conditions for a model are conditions surrounding the model (including the bottom and top of the aquifer) that can affect groundwater flow within the model area. Models are ideally constructed using natural flow boundaries as the boundaries for the model. Due to the resolution required for this study, the entire aquifer could not be included; however, the model utilizes natural boundaries where possible, including a groundwater divide on the northwest side of the model and bedrock as the lower boundary.



Burns & McDonnell

Figure VIII-2

CONCEPTUAL MODEL

J:\USFWS\978064\procws\CONMODEL.DWG 12-29-1997 11:16 MJC

The Great Bend Prairie Aquifer overlies the Cretaceous and Permian bedrock which have low permeabilities that limit groundwater flow from below the modeled aquifer. Although the bedrock contributes flow (and saltwater) to the system, there is not sufficient data to quantify this component of flow; therefore, the bedrock for this analysis is considered to be a no flow boundary. The minor bedrock contribution to the water budget is combined with the aquifer underflow.

In the areas where the natural aquifer extends beyond the model boundaries, general head cells are used to simulate the effects of distant parts of the aquifer on modeled groundwater responses. Data for the general head boundaries are based on information from the SWATMOD model and pre-development water levels contained in previous reports. General head boundaries allow water levels to change with differing pumping stresses which simulates changing water levels with time.

The portion of groundwater that exits the sand hills (Layer 1) and flows overland to the Big Salt Marsh is represented in MODFLOW and modeled as drains. The use of drains allows this flow component to be measured.

River cells are used to represent both stream and marsh areas for this model . These are active in Layer 2 of the model to simulate the interaction of the groundwater with the main aquifer and surface water bodies in the study area. Rattlesnake Creek, Salt Creek, and Big Salt Marsh are the major water bodies in this area.

3. Model Parameters

Many of the aquifer parameters used in this model are from previously calibrated groundwater models. Because of differences in model construction, additional parameters are estimated from published values based on the aquifer materials encountered in test hole and monitoring well drilling. These values may be adjusted during model calibration. Other properties, such as the bottom elevation and starting water levels in the sand hills layer, are estimated from information gathered from soil survey publications or interpretation of the probable depositional environment for the materials in the study area.

The initial water levels for the sand hills is based on information from the National Resource Conservation Services' (NRCS) Soil Survey of Stafford County, Kansas (USDA, 1978). The sand hills are composed mainly of Dillwyn Series soils which are poorly drained and are derived from the underlying eolian sands. The soil survey states:

"The water table fluctuates from a depth of about 1 foot in wet seasons to a depth of 5 feet in dry seasons."

Based on this information, the water levels are assumed to reflect the surface topography, particularly during the wet seasons in the sand hill layer. Previously established pre-development water levels (Sophocleous, et al, 1990) are used for the initial heads for Layer 2.

Aquifer properties for the models include hydraulic conductivity, storage coefficient and leakance. Hydraulic conductivity in the study area ranges from 20 to 100 feet per day (Sophocleous, et al, 1997). The storage coefficient used for both layers is 0.01.

Recharge occurs across the study area. The rate of recharge was determined on a monthly basis and summarized yearly by the SWATMOD model. The values passed from SWAT to MODFLOW in the SWATMOD model are effective net recharge which considers percolation, pond seepage, evapotranspiration, transmission losses, and subsurface lateral flow for the sub-watersheds within the Rattlesnake Creek Basin. Mean annual recharge values for subbasins in the Big Salt Marsh study area range from 1.8 to 4.5 inches for the pre-development time period (Sophocleous, et al, 1997). Recharge values in the SWATMOD model are reduced because of the greater depths to groundwater in some parts of the basin; however, no SWATMOD modifications for depth are made to recharge values in the Big Salt Marsh model area.

Evapotranspiration is the main source of water loss from the basin. In the Big Salt Marsh model, evapotranspiration is considered in the net effective recharge based on SWATMOD data. Evapotranspiration is included in the SWAT portion of the SWATMOD model and is used to establish effective recharge for MODFLOW. The recharge values from the SWATMOD model allow for potential evapotranspiration (PET). The average PET for the entire Rattlesnake Creek Basin is 64 inches per year

(Sophocleous, et al, 1997). Phreatophytic consumption of the saturated zone is simulated separately with a MODFLOW package in the SWATMOD model; however, the current version of the evapotranspiration package reviewed by Burns & McDonnell has values set extremely low, essentially zero, and appears to be disengaged.

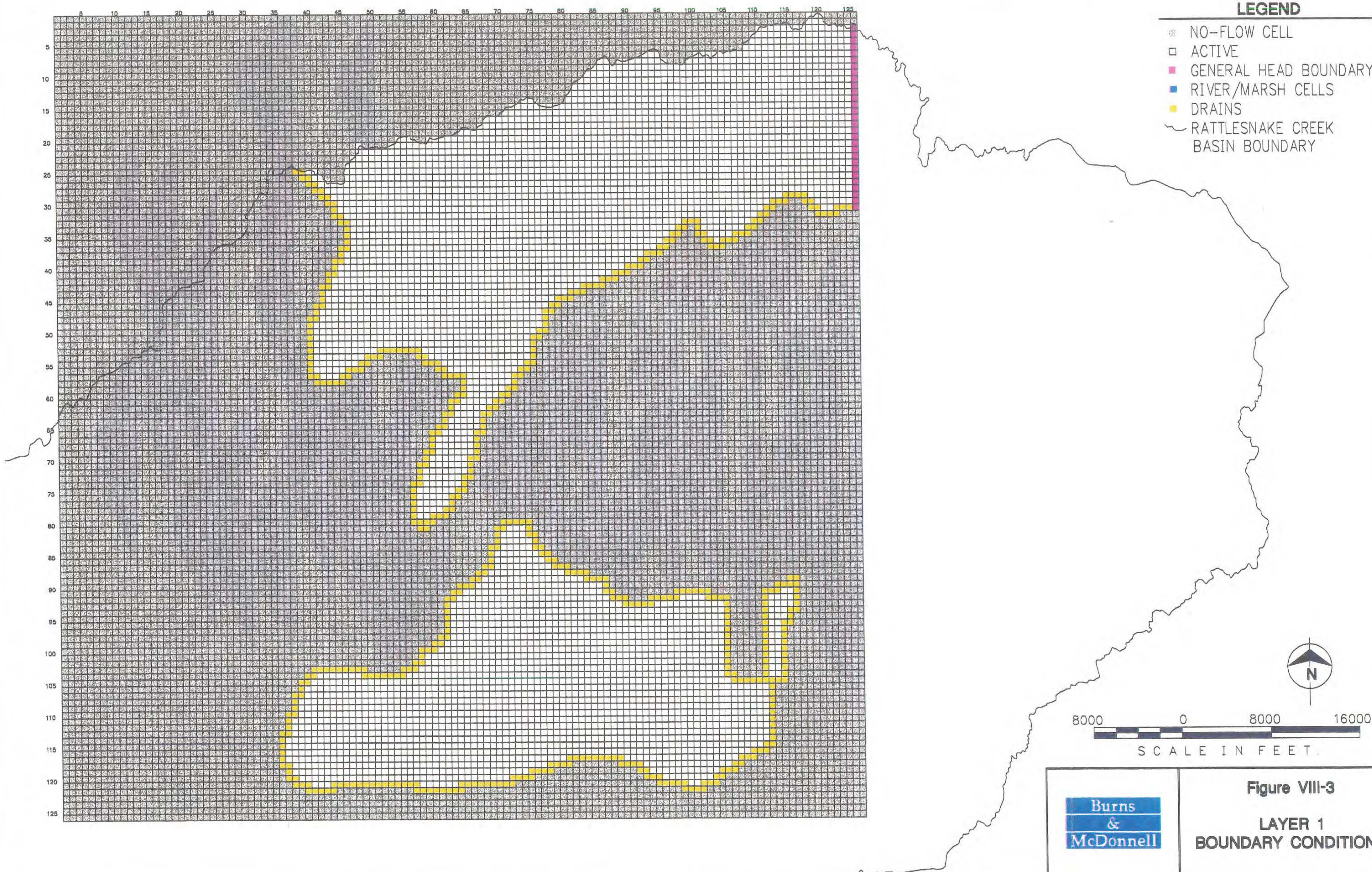
After initial calibration to pre-development conditions, the pumping rates and locations, for permitted wells as reported by the Kansas Division of Water Resources (KDWR) for 1995, are used to evaluate and compare the water budget components that affect the water in Big Salt Marsh.

E. MODEL DEVELOPMENT AND CALIBRATION

The modeling program selected for use with this study is MODFLOW, a USGS three-dimensional, finite-difference, groundwater flow model written by McDonald and Harbaugh (McDonald and Harbaugh, 1988). MODFLOW is a well documented model that is widely used and accepted by many regulatory agencies. This model uses a modular method of data entry to simulate specific aspects of the aquifer system such as wells, rivers, recharge, and evapotranspiration, along with aquifer properties. Additionally, it has been used with models previously constructed for the region. Data from these previously constructed models can be readily imported into a MODFLOW model that focuses on this area.

1. Grid Spacing

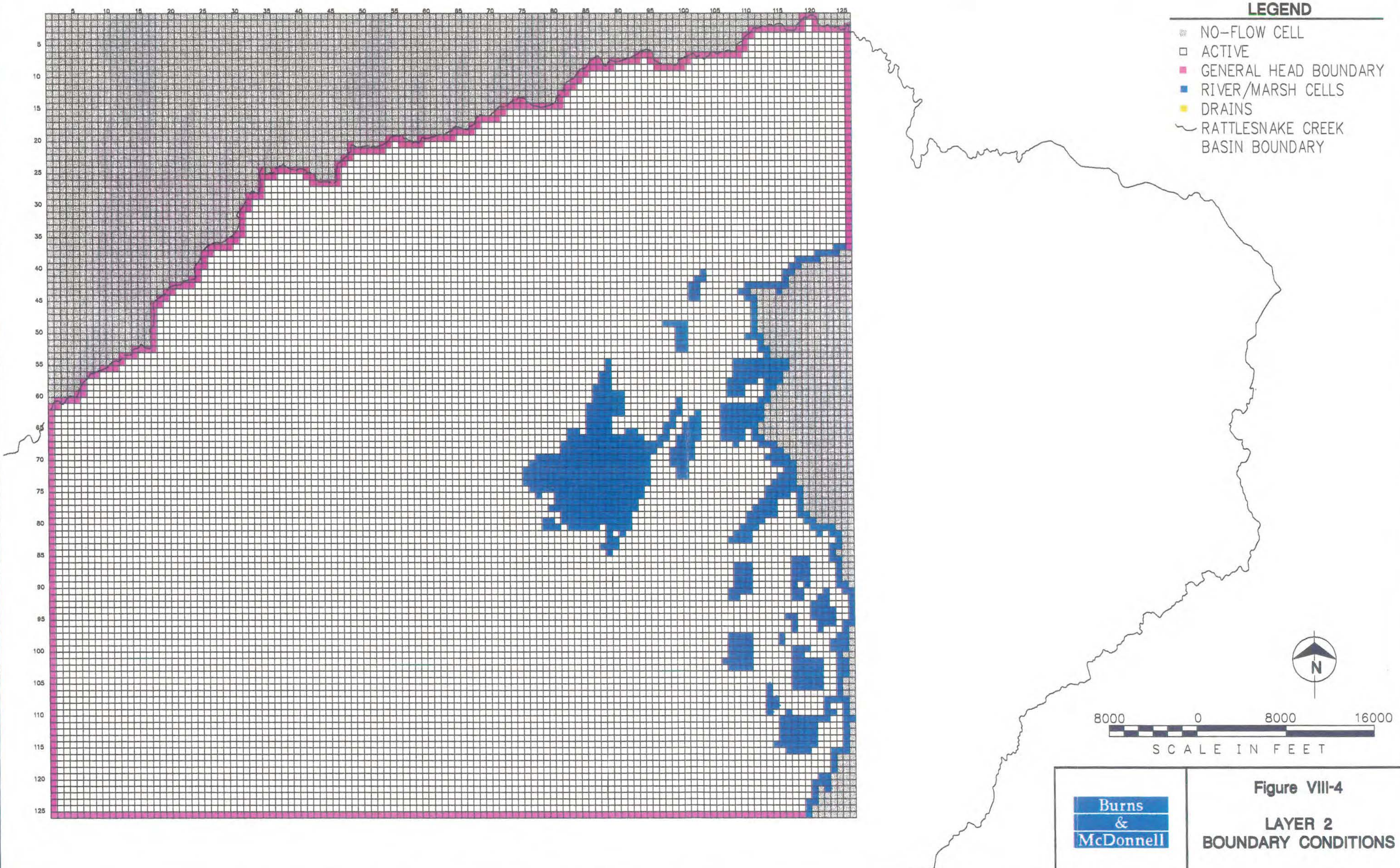
In order to provide the necessary detail, a model with a fine grid spacing is needed for the Big Salt Marsh study area. A uniform grid spacing of 500 feet used across the model will give good resolution of all parts of the study area. The model is constructed as a quasi-3D model with two layers to model the interaction between the sand hills and the Great Bend Prairie Aquifer. Model Layer 1, as shown in Figure VIII-3, represents the sand hills. A quasi-3D model uses a value of vertical leakance to control the movement of water between two model layers simulating a true 3-dimensional model. Layer 1 cells are inactive in areas outside the sand hills. Model Layer 2, as shown in Figure VIII-4, represents the main aquifer that underlies Rattlesnake Creek Basin. The inactive cells in Layer 2 represent areas outside of Rattlesnake Creek Basin. The silty clay layer between the two aquifer zones is represented by a low value of conductance between the two layers.



Burns & McDonnell

Figure VIII-3

LAYER 1 BOUNDARY CONDITIONS



Burns & McDonnell

Figure VIII-4

LAYER 2 BOUNDARY CONDITIONS

J:\USFWS 8064\GWMODELS\BIGSALT\layer2.DWG 01-22-199 6:10 MJC

2. Boundary Conditions

As previously discussed, the Big Salt Marsh model boundary conditions include zones of no flow, groundwater flow divides, and regional groundwater and surface water flow conditions. The bedrock surface defined the lower boundary of the model. Generally, the Cretaceous and Permian bedrock have low permeabilities that limit groundwater flow from below the aquifer. The Cedar Hills Sandstone is the source of the majority of groundwater flow from the bedrock. This unit subcrops along the western edge of the study area. A general head boundary condition was selected to represent the western edge of the model. This type of boundary condition represents flow from an external source or sources based on the difference between the head in the cell and the head assigned to the external source or sources which, in this case, are the aquifer outside of the model area and the underlying bedrock. The head assigned to the general head boundary cells is based on the pre-development water levels (Sophocleous, et al, 1990).

In the other areas where the natural aquifer extends beyond the model boundaries, general head cells are used to simulate the effects of distant parts of the aquifer on modeled groundwater responses. Data for the heads used in these general head boundaries are also from the pre-development water levels (Sophocleous, et al, 1990). The hydraulic conductivity for all of the general head boundary cells represents the hydraulic conductivity of the aquifer materials within the model area adjacent to the boundaries.

River cells are used to represent both stream and marsh areas for this model. These are active in Layer 2 of the model to simulate the interaction of the groundwater in the main aquifer with surface water bodies in the study area. The values for stage in Rattlesnake Creek is based on the values used in the SWATMOD model modified to reflect the greater resolution of the model. In the SWATMOD model, the conductance of the bed in the channel was set a 0.42 feet per day. The same conductance was used for the river bed in this model.

The water level set for the marshes is based on results from the surface operations model developed for this project. The pre-development number or conditions of the marshes in the Refuge area is not known; therefore, current conditions are used. The conductance for the bed of the marshes is set a 0.1 feet per day, which is a typical value for conductance in fine materials.

The boundary conditions in Layer 1 for the sand hills are represented by drains except for the area along the surface water divide and where the sand hills extend outside of the model area. The drains allow water to flow out of the layer to represent seepage from the hillsides. The hydraulic conductivity of the drain is estimated to be 0.12 feet per day based on published values for the materials and adjustments needed during model construction.

3. Model Parameters

There are three zones of hydraulic conductivity in this model. Layer 1 has one zone that represents the sand hills. According to the NRCS's Soil Survey of Stafford County, the soils on the sand hills have a conductivity of 12 to 40 feet per day. The lowest value of 12 feet per day is selected for the model. In Layer 2, there are two zones of hydraulic conductivity. These zones are based on the SWATMOD model. The majority of the area has a value of 100 feet per day. The aquifer material over the bedrock high located north of the Zenith Gaging Station is relatively thin. The hydraulic conductivity in this area is 20 feet per day, a value established during the calibration of the SWATMOD model. These values are adjusted during the calibration of the Big Salt Marsh model. Maps showing the zones of hydraulic conductivity after calibration are included in the Appendix.

Storage coefficient for the sand hills is the same as the aquifer. The storage coefficient is 0.01, the value used in SWATMOD, and is considered appropriate for the simulation under long-term pumping conditions. These parameters are unitless.

Leakance for the confining unit is based on typical published values of hydraulic conductivity for silty-clay of 0.000435 feet per day. Leakance is calculated by the model using the vertical hydraulic conductivity and thickness of the confining unit. Within the study area, the thickness ranges from 0 to 40 feet (Rosner, 1988) and an average value of 10 feet is used in this model.

Bottom elevations for the model are based on the elevations of the bedrock in this portion of the basin (KDWR, 1996). The bottom elevations reflect the locations of the buried channels that cross or are near the study area.

In the SWATMOD model, the effective net recharge is a function which considers percolation, pond seepage, evapotranspiration, transmission losses, and subsurface lateral flow for the sub-watersheds within the Rattlesnake Creek Basin. Recharge rates used in this model are the same rates used in the MODFLOW portion of the SWATMOD model.

4. Calibration and Sensitivity Analysis

Calibration of the model is used to determine the reasonableness of the fit of the simulated values with the measured data. Calibration adjusts parameters for which there is no measured or known data. During calibration, the input data for the model are modified to achieve a reasonable fit. There are two components in determining a reasonable fit. The quantitative component is based on statistics, and the qualitative component is an overall view of the fit of the simulated values accounting for the accuracy and/or limitations of the measured or known data.

Data points for the calibration targets are points that were used to construct the pre-development water level map (Sophocleous, et al, 1990). Thirteen points are selected; however, only twelve points are used. The following table lists the 13 data points that are selected for target values:

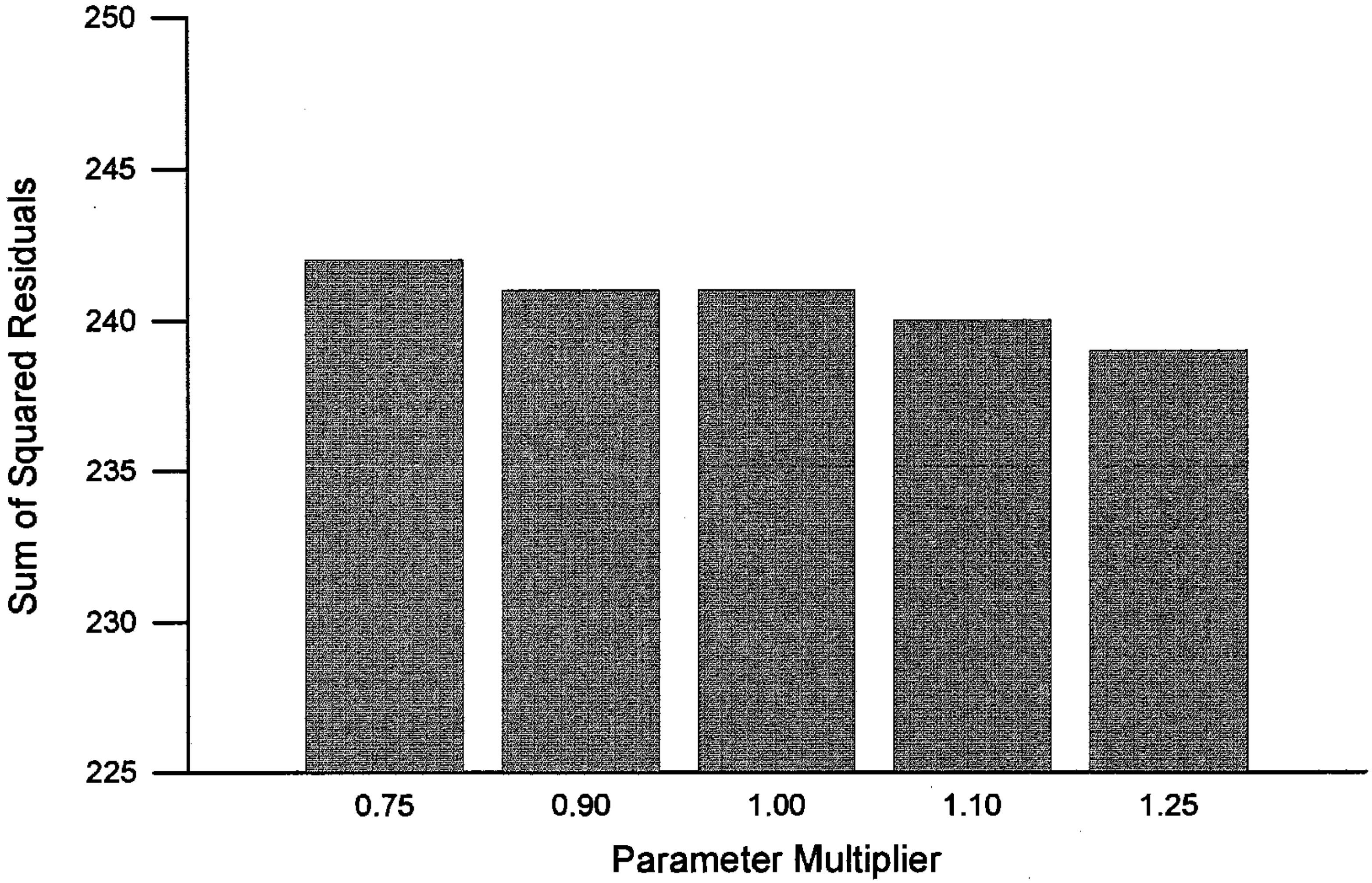
Legal Description	Groundwater Elevation, feet
NW ¼ NW ¼ Sec.3 T21S R11W	1755
NW ¼ SE ¼ Sec.9 T21S R11W	1756
SW ¼ SE ¼ Sec.20 T21S R11W	1751
SE ¼ SW ¼ Sec. 8 T21S R12W	1833
SW ¼ SE ¼ Sec 10 T21S R12W	1821
NW ¼ NW ¼ NW ¼ Sec. 25 T21S R12W	1805
SW ¼ NW ¼ Sec. 31 T21S R12W	1857
SE ¼ SE ¼ Sec. 19 T22S R11W	1818
NW ¼ SW ¼ Sec. 28 T22S R11W	1815
NW ¼ SE ¼ Sec. 1 T22S R12W	1802
NW ¼ SE ¼ Sec. 12 T22S R12W	1796*
NW ¼ NE ¼ Sec. 18 T22S R12W	1858
SW ¼ SW ¼ SW ¼ Sec. 23 T22S R12W	1848

This marked point (*) is reported to be a flowing artesian well and is located, in the model, under a cell representing a drain in Layer 1. Based on its location in the model, the value is excluded from the calibration.

During the development of the model, it appeared that leakance and hydraulic conductivity control the results of the model. A sensitivity analysis is conducted to determine how sensitive the model is to changes in these parameters. Adjustments to the leakance parameter for the silt-clay unit had little effect on the results of the model, therefore the initial value is not modified. Figure VIII-5 is a graph of the sum of squared residuals versus parameter multiplier for the analysis of the leakance parameter.

Initial adjustments to the two zones of hydraulic conductivity in Layer 2 indicated that a higher value for the zone that overlies the bedrock high would provide a better fit. The initial sensitivity analysis showed that the best statistical fit occurred when a parameter multiplier of 20 was used. Figure VIII-6 contains graphs of the sum of squared residuals for the adjustments made to the hydraulic conductivity in Layer 2. The best statistical fit is achieved when the sum of the squared residuals is lowest. A hydraulic conductivity of 400 feet per day provides a better fit both statistically and visually. Changing the hydraulic conductivity of this zone from 20 to 400 feet per day is a significant alteration from the previous models; however, the finer resolution of the Big Salt Marsh model allows for more detailed data to be considered (marshes, streams, bedrock, and sand hills) resulting in a more representative simulation.

Figure VIII-7 shows the simulated heads for the calibrated model compared with the pre-development water levels for the model area. The pattern of the groundwater surface is not matched exactly; however, an exact match cannot be expected due to the nature of the data used to create the pre-development water level map. The calibration data used were obtained during different seasons, years, and climatic conditions. This map represents a general trend for the pre-development water levels. The pre-development conditions can only be estimated as the exact climatic and hydrologic conditions are not known.

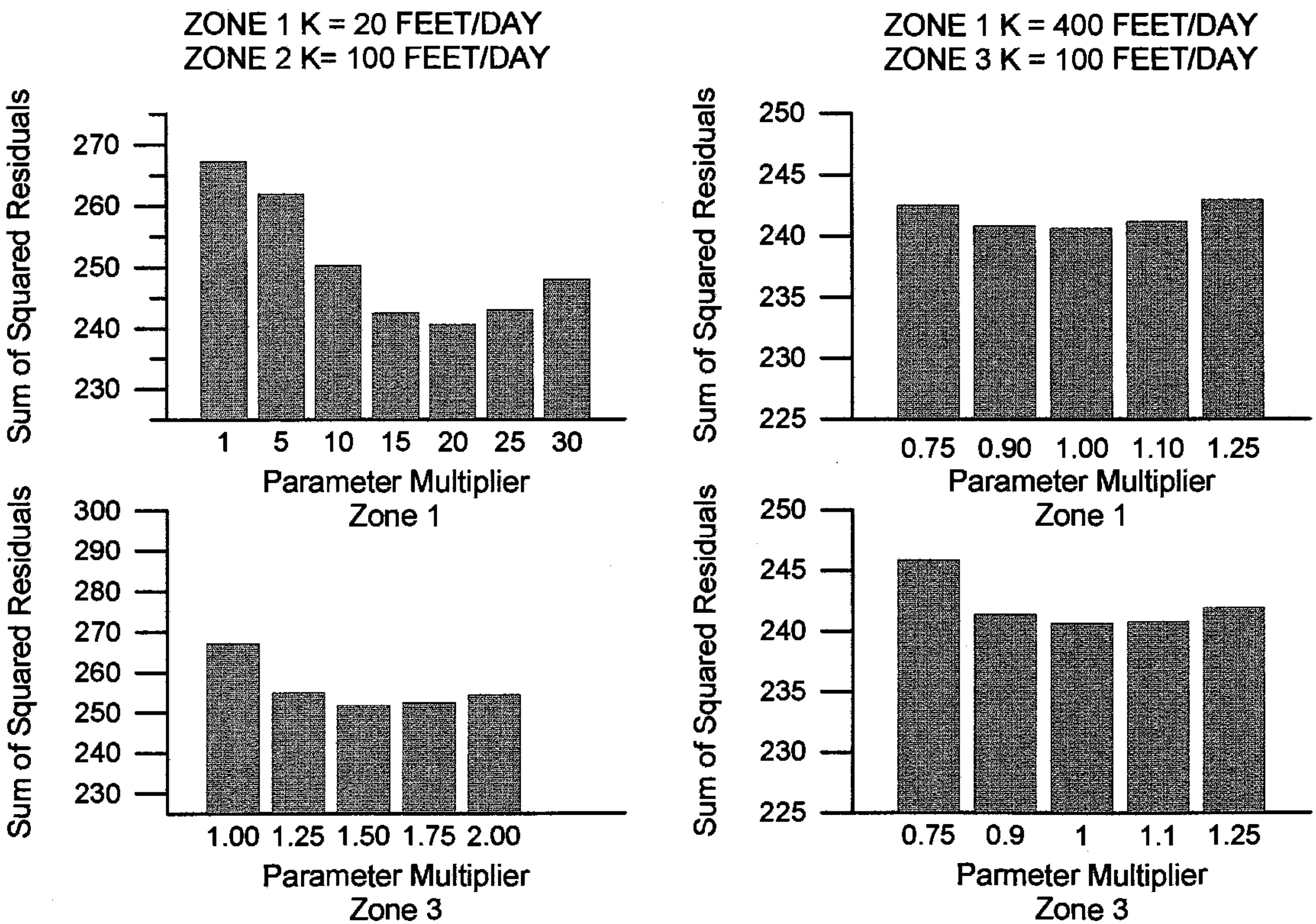


Burns & McDonnell

Figure VIII-5

SENSITIVITY ANALYSIS FOR LEAKANCE

J:\USFWS\978064\GWMODELS\SENS2.GRF

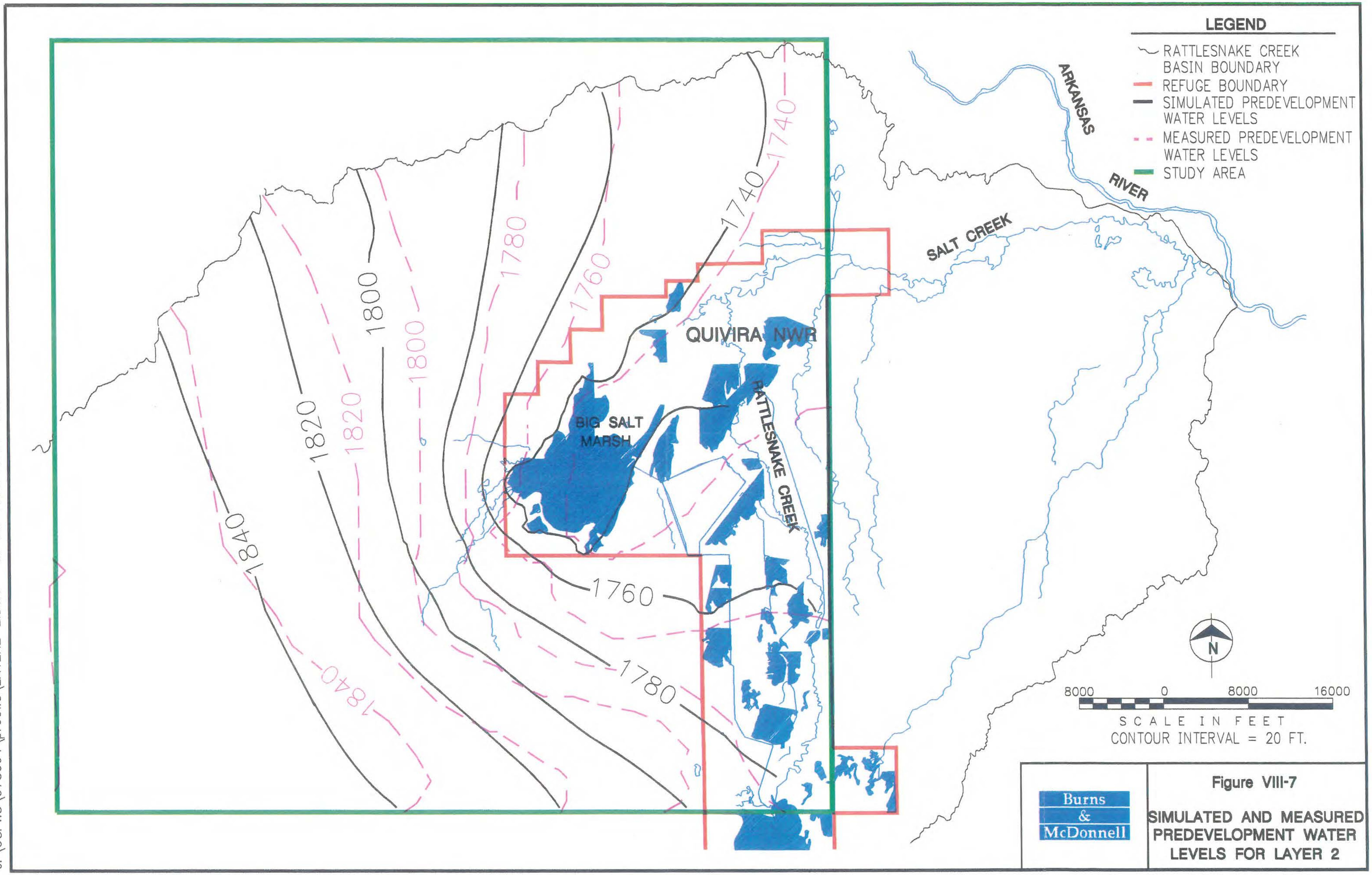


Burns & McDonnell

Figure VIII-6

SENSITIVITY ANALYSIS FOR HYDRAULIC CONDUCTIVITY

J:\USFWS\978064\GWMODELS\SENS1.GRF



Burns & McDonnell

Figure VIII-7

SIMULATED AND MEASURED PREDEVELOPMENT WATER LEVELS FOR LAYER 2

5. Model Accuracy

The model uses a water balance to determine relative computational accuracy that is presented as percent discrepancy. The predicted heads for the model are compared with the pre-development water levels (Sophocleous, et al, 1990) and are found to be similar. The water budget for the study's regional model has a volumetric water budget discrepancy of 0.7 percent. A volumetric water budget discrepancy of less than 1 percent is considered adequate for modeling studies.

F. MODEL LIMITATIONS

Many of the limitations of the Big Salt Marsh model are similar to the limitations discussed in the documentation for the SWATMOD model. The documentation discusses component limitations and overall model limitations include the following:

- The pre-development map of water levels may not be accurate. The pre-development water level map is developed from data acquired over several years and combined as a reasonable representation of steady state groundwater conditions. Actual water levels may vary with climate conditions. Additionally, elevation and measurement errors may affect the water level map and lead to calibration to slightly erroneous data.

- Model parameters are extrapolated from widely spaced data (i.e. pumping tests, etc.) and errors in the interpretation can lead to errors in the model construction. Calibration and sensitivity analysis will increase the confidence of the parameter selection.

- MODFLOW cannot account for the exact location of a well within a cell. All wells within a cell are summed and are assumed at the cell center. The water level in a single cell is the volumetric "average" of levels throughout the cell. Therefore, water levels from the model with relatively large cell size do not represent water levels within a single pumping well or the drawdown cone around a well. The well levels will represent regional trends and can show the effects of large scale pumping centers.

- Additional parameters are required for the Big Salt Marsh model that were not needed for the SWATMOD model. Many of these parameters are not readily available. These parameters are therefore estimated from other publications or from published values for the materials encountered. Some of these values are adjusted during calibration. Additional parameters required include:
  - Water levels in the sand hills.
  - Conductance between the Sand hills and the main aquifer.
  - Hydraulic conductivity and storativity of the Sand hills (Layer 1) materials.

- Some Refuge units, added after the "pre-development" time period, affect model accuracy. No records exist on which units were added and when they were added. This lack of information may impact the calibration to pre-development water levels. Because of the potential for this impact, greater emphasis will be placed on calibration targets away from Refuge units.

G. MODEL RESULTS

1. Model Water Budget

The Big Salt Marsh model is developed to simulate steady-state conditions which can be viewed as annual "average" conditions. Although seasonal variations affect groundwater levels and water budgets, the steady-state model provides a good net annual water budget.

A mass balance approach is used to evaluate the groundwater flow regime that influences Big Salt Marsh. Review of the pre-development flow patterns identified the portions of the sand hills that contribute seepage that flows overland to Big Salt Marsh. The seepage areas that contribute flow from the sand hills to Big Salt Marsh are shown in Figure VIII-8 and are simulated as drains in the groundwater model. Reach 102 simulates drainage from the northern stretch of sand hills that flows overland to the marsh, and Reach 105 simulates the seepage from the southern region of sand hills that flows to the marsh. The average daily seepage rate from these reaches of the drains is estimated from the model. Additionally, the groundwater flow regime under Big Salt Marsh is evaluated.

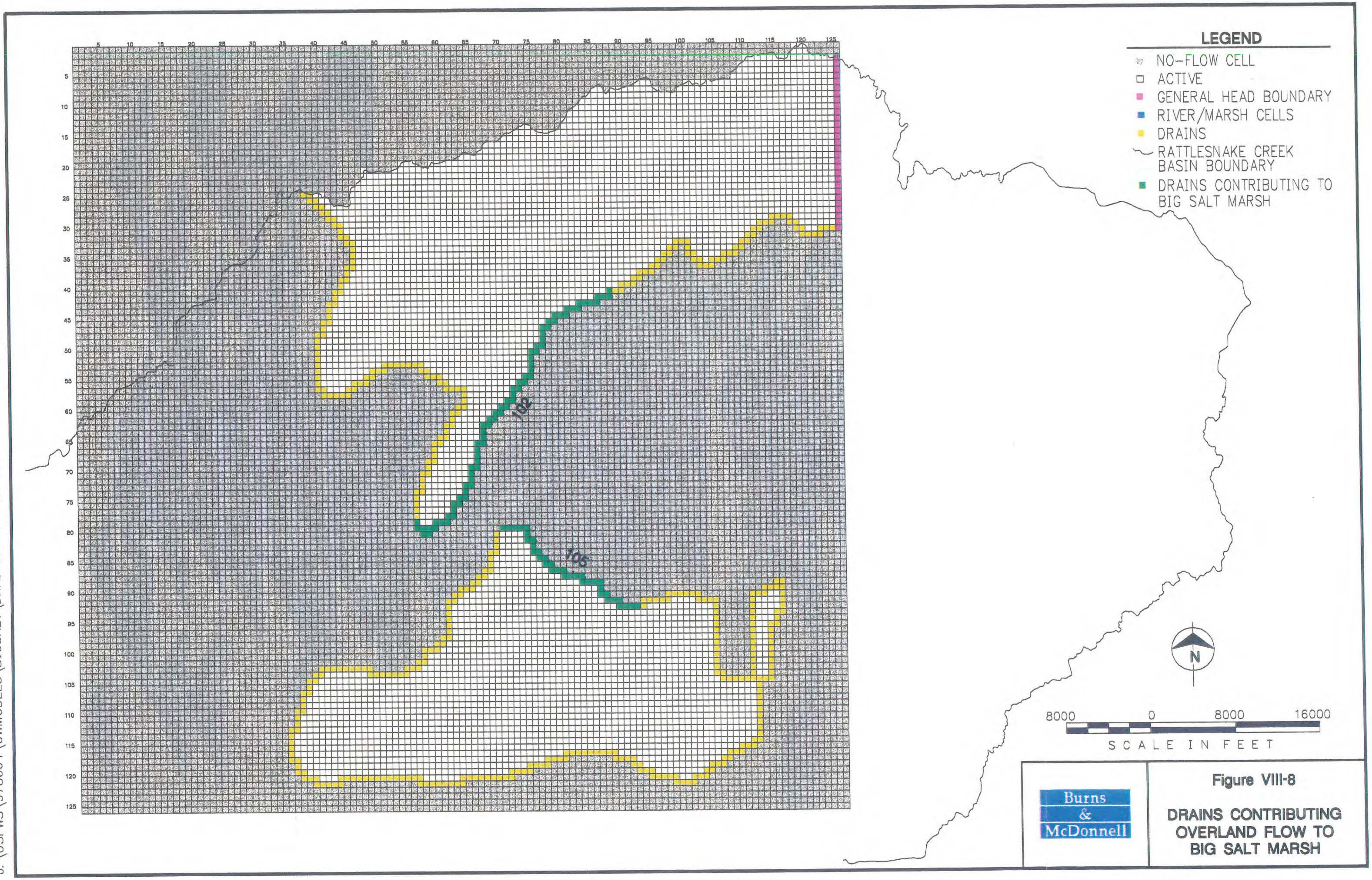


Figure VIII-8

DRAINS CONTRIBUTING OVERLAND FLOW TO BIG SALT MARSH

J:\USFWS\978064\GWMODELS\BIGSALT\DRAINS.DWG 01-22-1998 13:06 MJC

After the pre-development water budget is determined, pumping stresses based on reported 1995 KDWR annual water use data are applied to the model to determine their affect on the flows that interact with the marsh. The location of the wells within the model area are shown in Figure VIII-9. The initial simulation is run using 100 percent of the reported pumping rates.

The model, with pumping stresses added, is run as a steady-state simulation. The steady-state simulation assumes that pumping conditions have been constant for a sufficiently long period such that no further changes in water levels will occur. When a pump is first turned on, a significant part of the pump discharge is water that is in storage in the aquifer. As pumping time increases, less water is derived from aquifer storage and a greater percentage of the pumped water comes from recharge, induced infiltration, reduced outflow or additional underflow into the system. The steady-state model does not consider the volume of water that is removed from storage to reach steady-state conditions and therefore may be considered a "worst case" condition. The water budget results from pre-development conditions, simulated 1995 pumping conditions and the percent change in flows are presented in Table VIII-1.

Table VIII-1
BIG SALT MARSH MODEL
WATER BUDGET

Flow Component	Pre-development (acre-feet)		1995 Pumping Rate (acre-feet)		Change (Percent)
	Annual	Daily	Annual	Daily	
Net Recharge to Sand Hills	7,430	20.3	7,430	20.3	0
Seepage from Sand Hills to Aquifer	5,475	15	5,945	16.3	+8.6
Seepage from Sand Hills to overland flow	1,840	5	1,340	3.7	-27
Seepage from Aquifer to Sand Hills	17	<0.1	13	<0.1	-23
Leakance to Aquifer (rivers and recharge)	19,670	53.85	19,710	53.96	<-1
Leakance to Marsh (all river nodes)	35,900	98	33,450	91	-6.8
Total Underflow In	16,500	45	37,350	102	+126
Total Underflow Out	6,100	17	3,770	10.3	-38
Wells	--	--	26,125	71.5	--

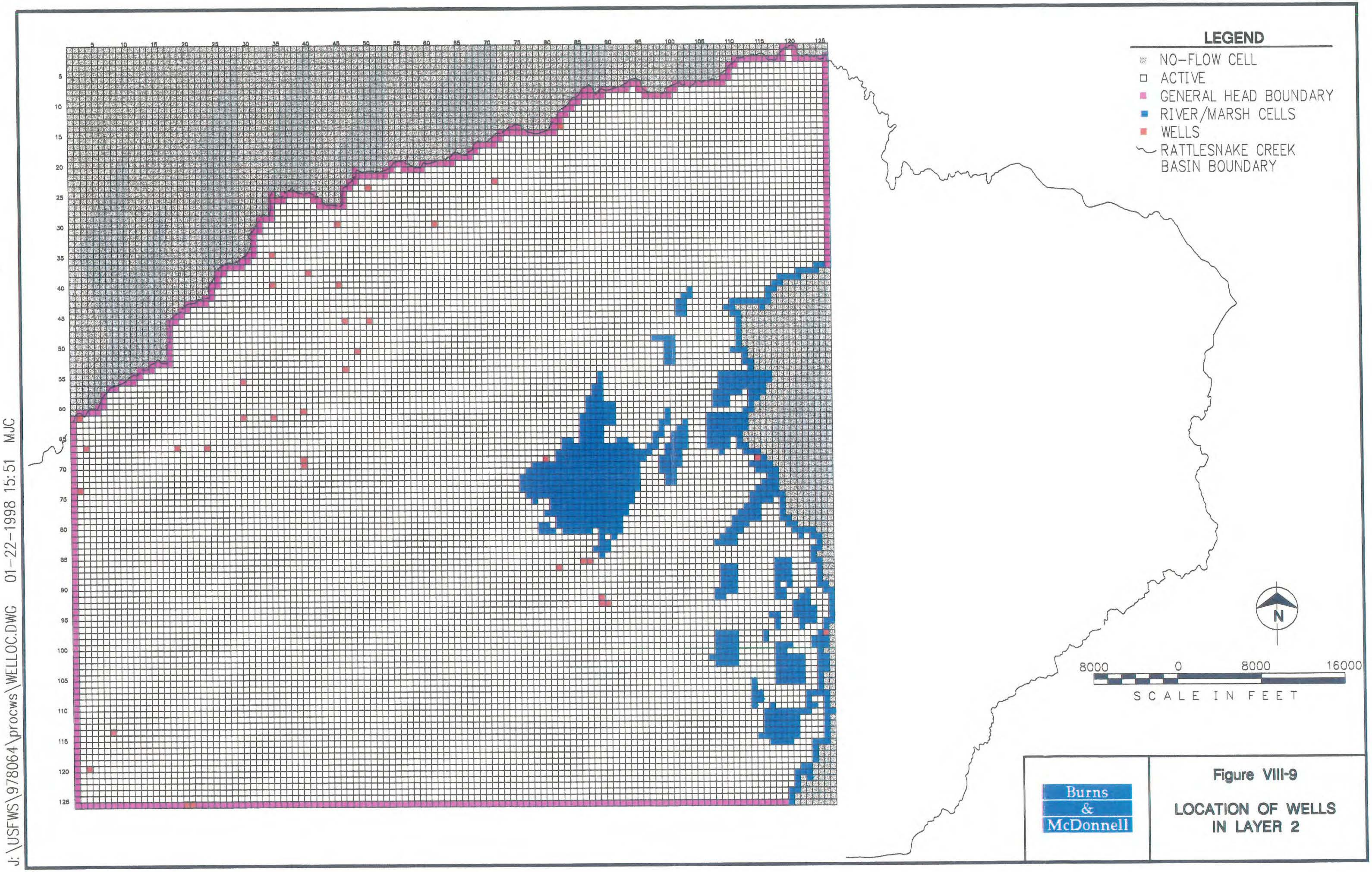


Figure VIII-9

LOCATION OF WELLS IN LAYER 2

2. Flow Contribution to Big Salt Marsh

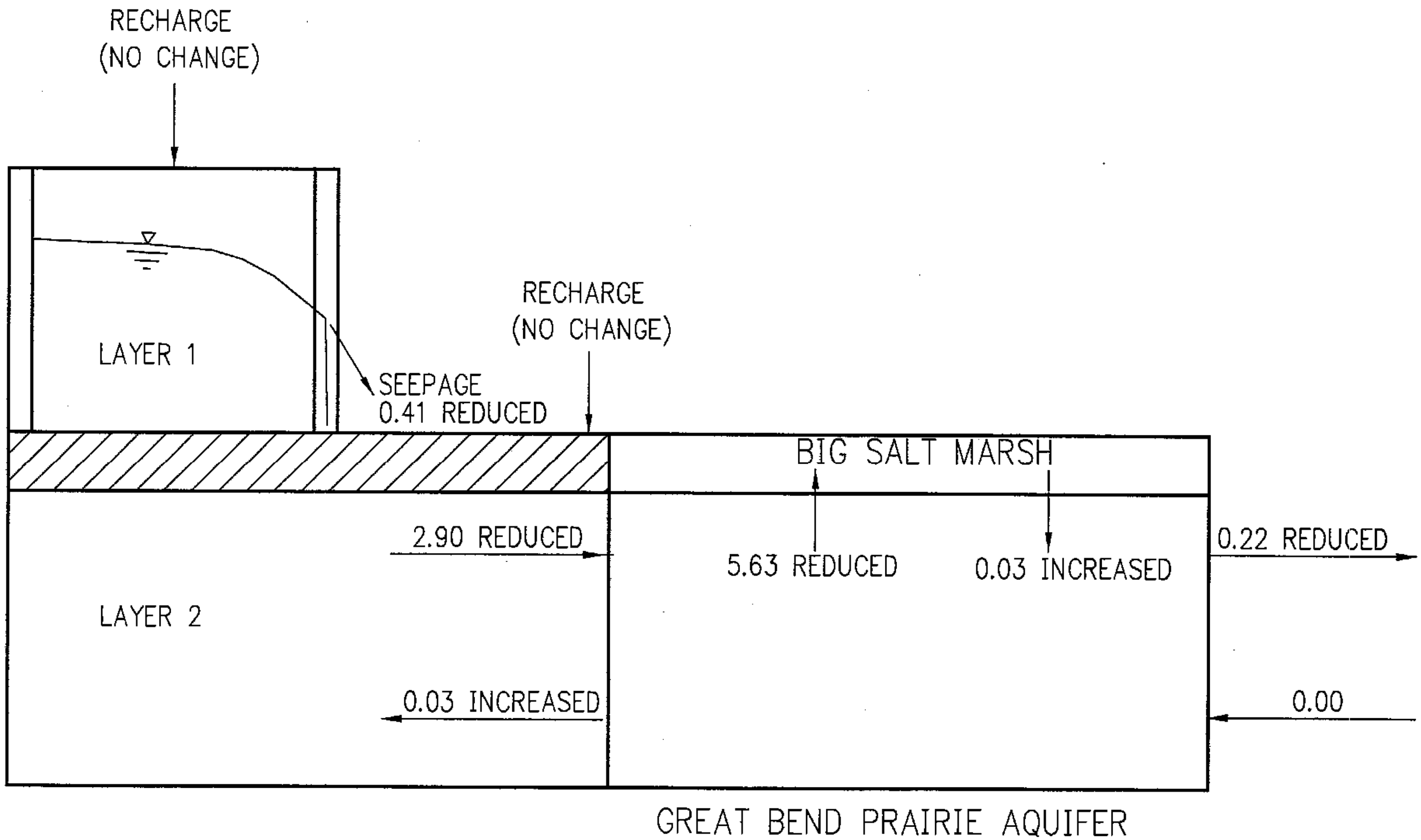
Groundwater flow to Big Salt Marsh includes two major components which are impacted by several mechanisms. The largest component is leakance from the aquifer upward into the marsh units and streams. The average pre-development flows are estimated to be approximately 98 acre-feet per day. The second component of flow is seepage from the sand hills that flows overland to the marsh. Estimated average flow from the reaches of sand hills that contribute to Big Salt Marsh is approximately 1 acre-feet per day. A more detailed evaluation of these flow components is performed to analyze the impacts on Big Salt Marsh by pumping or other factors. Additionally, to determine the sensitivity of the system to pumping stresses, additional runs are performed using pumping rates at 75 percent and 125 percent of the reported 1995 values.

a. Aquifer/Surface Water Interaction

A diagram of Big Salt Marsh and the underlying aquifer showing the groundwater flow components and the interaction of Big Salt Marsh with the aquifer is shown in Figure VIII-10. This diagram shows the change in the flow components caused by pumping stresses on the aquifer in the model area for the 1995 reported pumping rates. The two major parts of flow are underflow into and out of the aquifer under the marsh and leakance through the bed of the marsh. The change in the underflow and leakance for Big Salt Marsh and the underlying aquifer for 75, 100 and 125 percent of the reported 1995 pumping rates are listed in Table VIII-2. Review of Table VIII-2 shows that pumping stresses reduce the underflow to the aquifer under Big Salt Marsh. This reduction in underflow decreases the groundwater volume available for Big Salt Marsh.

Table VIII-2
CHANGE IN GROUNDWATER FLOW DUE TO PUMPING STRESSES APPLIED TO THE AQUIFER

	Change in Acre-Feet per Day for 1995 Reported Pumping Rates		
Flow Component	75%	100%	125%
Total Underflow In	-3.905	-5.338	-6.831
Total Underflow Out	-0.022	-0.030	-0.037
Leakance to Aquifer	0.019	0.026	0.033
Leakance to Marsh	-4.152	-5.630	-7.197



NOTES:

1. UNITS ARE ACRE-FEET PER DAY
2. 1995 REPORTED PUMPING RATES FOR STEADY – STATE MODEL

Burns & McDonnell

Figure VIII-10

CHANGE IN FLOW FOR BIG SALT MARSH DURING 1995 PUMPING STRESS

J:\USFWS\978064\procws\CHFLOW.DWG 01-22-1998 10:26 MJC

b. Seepage from the Sand Hills

Seepage from the sand hills is simulated as a drain in the MODFLOW model. The flows through the drain sections that contribute overland flow to Big Salt Marsh are evaluated along with the groundwater flows under Big Salt Marsh. The change in acre-feet per day of the seepage due to the pumping stresses applied to the model for 75, 100 and 125 percent of the reported 1995 pumping stresses is listed in Table VIII-3. Review of Table VIII-3 shows that pumping stresses in the aquifer reduce the volume of groundwater seepage from the sand hills by less than 0.5 acre-feet per day.

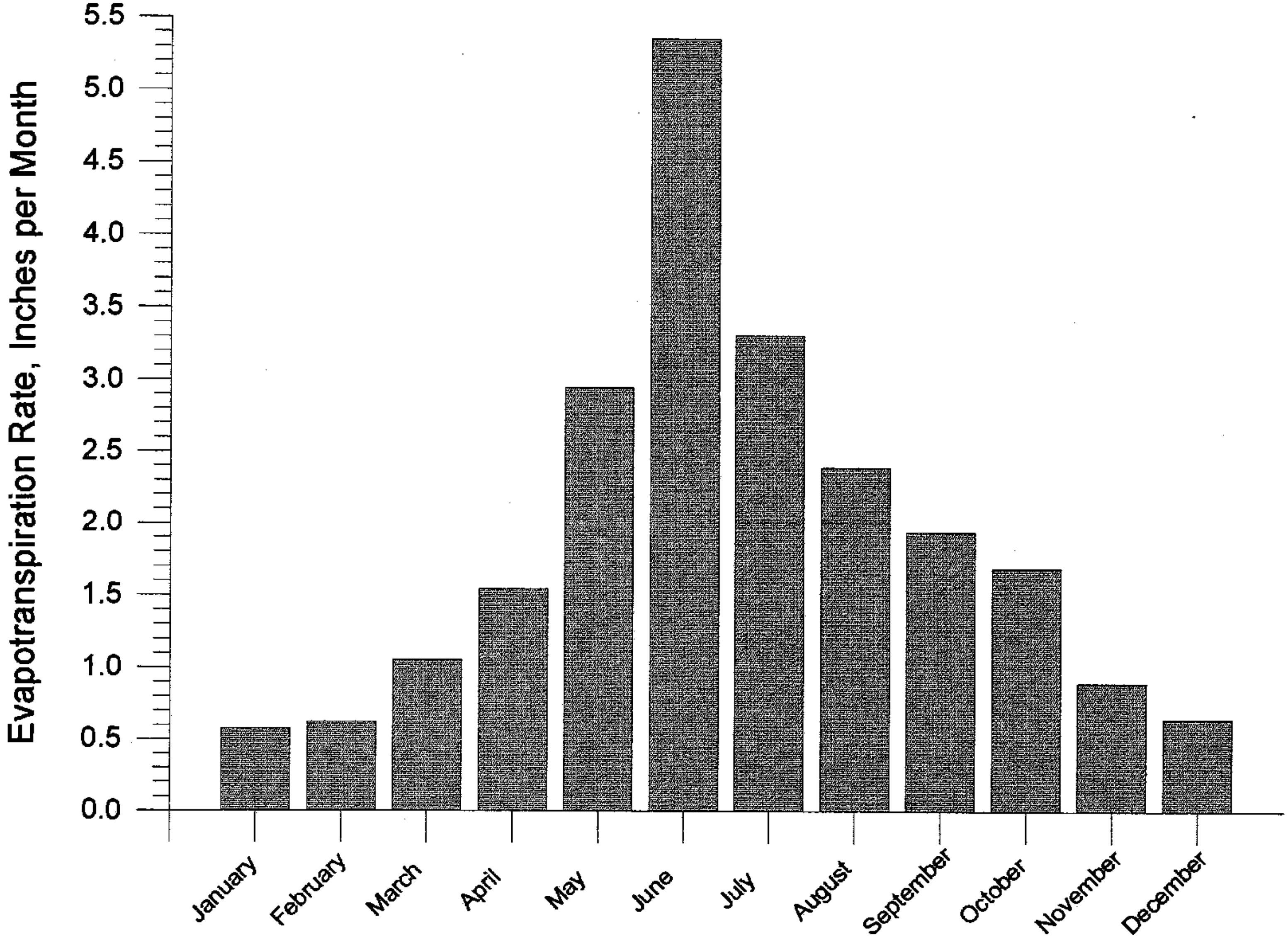
Table VIII-3
CHANGE IN SEEPAGE FROM THE SAND HILLS THAT CONTRIBUTES OVERLAND FLOW TO BIG SALT MARSH

Change in Acre-Feet per Day for 1995 Reported Pumping Rates			
Seepage Area	75%	100%	125%
Reach 102	-0.272	-0.359	-0.442
Reach 105	-0.035	-0.047	-0.058

3. Other Factors Contributing to Big Salt Marsh Water Budget

The Big Salt Marsh model input data are based on average annual conditions. Recharge data for this model are taken from the SWATMOD results and are representative of the average annual net recharge. The average annual net recharge accounts for annual average evapotranspiration; therefore, the model represents long-term "average" conditions, not considering seasonal variations. Besides pumping, which conservatively is assumed to be continuous, the other major influence on the water budget is evapotranspiration.

Average annual evapotranspiration is approximately 23 inches in this area of the Rattlesnake Creek Basin (Sophocleous, 1990). This value is factored into the net recharge in the Big Salt Marsh model. There are large seasonal variations in the monthly evapotranspiration. The average monthly evapotranspiration values from the SWATMOD data files in the vicinity of Big Salt Marsh are shown in Figure VIII-11. These average values range from a low of 0.57 inches per month to a high of 5.35 inches per month.



ADAPTED FROM: SOPHOCLEOUS, ET AL, 1997

Burns & McDonnell

Figure VIII-11

AVERAGE MONTHLY ET RATE FOR 1956 - 1994

J:\USFWS\978064\GWMODELS\ET.GRF

In the grassland area west of Big Salt Marsh shown in Figure VIII-12, evapotranspiration losses, adjusted to a volumetric rate, range from 4.4 acre-feet per day in the winter to about 43 acre-feet per day. The steady state model represents "average" outflow conditions from the drains through the grasslands to Big Salt Marsh. This "average" outflow is consumed during periods of high evapotranspiration.

4. Impacts to Big Salt Marsh and Surrounding Grasslands

The Big Salt Marsh model analyzes the subsurface flow conditions to determine impacts to the area due to regional pumpage resulting in lowered water level conditions. Additionally, evapotranspiration is evaluated to determine comparative impacts to the Big Salt Marsh area.

These results, summarized in Table VIII-4, show that evapotranspiration has a much greater impact than regional pumping at 1995 levels. About 6 acre-feet per day is lost from the water budget for an area around Big Salt Marsh due to pumping, and evapotranspiration losses are up to 43 acre-feet per day.

Table VIII-4
SUMMARY OF MODEL FLOW RESULTS
BIG SALT MARSH AREA

Condition	Flow (acre-feet per day)
Pre-development	
Seeps (drains)	1
Leakance to Marsh	98
Reduction due to Pumping	
Seeps	0.41
Net Leakance	5.66
Total	6.07
ET (grassland area only)	
January	4.4
June	43

H. REFUGE ALTERNATIVE

Possible alternatives to increase water supply to Big Salt Marsh include methods to reduce evapotranspiration consumption of seepage from the sand hills. However, the grassland habitat needs to be

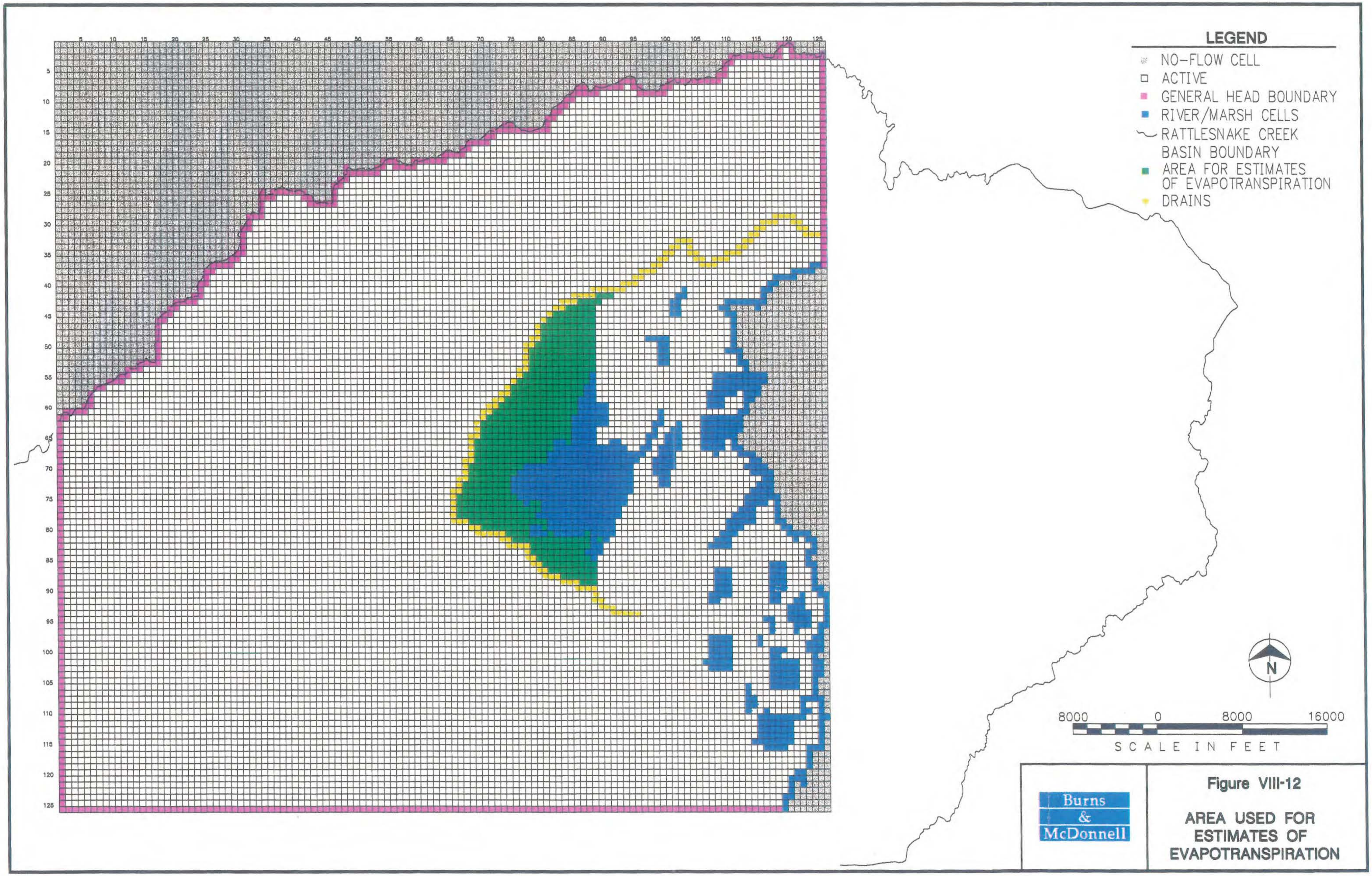


Figure VIII-12

AREA USED FOR ESTIMATES OF EVAPOTRANSPIRATION

:\USFWS\97 4\GWMODELS\BIGSALT\POLY-C.DWG 01-26-1998 .45 MJC preserved during certain times of the year. Additional ditches and control structures would provide the flexibility to better manage the seepage in the Big Salt Marsh area. Specific alternatives include:

- Clean and maintain approximately 5,000 linear feet of ditch along the south side of North Marsh Road west of Big Salt Marsh.

- Construct two stop-log control structures on above-referenced ditch along North Marsh road just west of big Salt Marsh. One structure will allow flow to the south into Big Salt Marsh, and the second structure will allow flow to the north into the North flats area.

Construction of the two stop-log structures is estimated at about $15,000. Cleaning 5,000 linear feet of drainage ditch is estimated at about $2,000.

The installation of two control structures and ditch cleaning should allow Refuge staff to improve control of flow in the Big Salt Marsh and North Flats area. Implementation of this alternative will not significantly impact water quality, since the same source of water is being used. Additionally, implementation will not significantly impact the available supply of water; therefore, the operations model is not used to evaluate habitat impacts.

I. ENVIRONMENTAL AND CULTURAL RESOURCE IMPACTS

Implementation of the Refuge groundwater alternative would have little if any impact on environmental constraints. Impacts would primarily involve the temporary disturbance to wildlife due to the increased human activity and presence of construction equipment during placement of water control structures and rehabilitation of road ditches. These activities would occur on and immediately adjacent to existing roads which currently carry light traffic. Disturbance would be limited to the construction period and, due to the limited area involved, would be anticipated to have only minor impacts to wildlife using adjacent areas of the Refuge. Additionally, construction activities would likely occur during the drier summer months. This is the period of lowest use of the Refuge by wildlife. Those individuals present would be engaged in brood-rearing activities and would generally select areas as far removed from human intrusion (such as along roads) as possible; therefore, impacts to wildlife would be reduced by the smaller wildlife populations and densities being in the area during the construction period.

Modifications to road ditches and placement of control structures would require removal of some or all vegetation within the ditches, some of which consists of wetland species. Wetland vegetation is likely present in these ditches due to the ditches primary function of draining roadways and adjacent areas; therefore, these ditches are not anticipated to be classified as jurisdiction wetlands by the U.S. Army Corps of Engineers. After ditches have been rehabilitated, it is anticipated they will revegetate over time with vegetation species similar or identical to those removed.

No impact to cultural resources would be expected. All construction activities would be limited to road rights-of-way where any such resources would have likely been previously disturbed or destroyed by road construction. Improvements to road ditches would be restricted to existing ditches and the minor amount of improvements required would be unlikely to affect any undiscovered and undisturbed cultural resources.

Implementation of this alternative would result in an overall positive benefit to vegetation, wetlands, and wildlife resources. Placement of control structures would allow water to be more efficiently directed to Big Salt Marsh and/or the North Flats area. Rehabilitation of road ditches currently draining water into Big Salt Marsh could reduce water losses to evapotranspiration. While not significantly increasing the water available at control structures, additional water quantities could be available for Refuge use.

The grassland west of Big Salt Marsh is prime habitat for several species, including the federally endangered whooping crane; therefore, disruption of overland flow could have serious environmental impacts. Refuge staff need the capacity to manage flow to the Big Salt Marsh and North Flats area seasonally. The drainage pattern of water into Big Salt Marsh would remain unchanged. Water could continue to be provided to the marsh at the existing location. Any increase in water draining overland into the marsh would not be significant enough to change existing vegetation patterns or species composition. Additionally, the quantity of additional water available for the marsh would not result in a significant change in marsh water levels or inundation area. This alternative, by providing a more efficient means of controlling this water source, would result in improved control of waters allocated to this area of the

Refuge. Such improved control could allow Refuge personnel to more effectively manage this area to provide improved conditions for the existing wetlands, vegetation, and wildlife in and around Big Salt Marsh.

This alternative would also allow Refuge personnel to better manage water on the North Flats to improve wetlands, vegetation, and wildlife habitat. Additional waters could be used to establish a new flow pattern over a portion of the southern end of the North Flats area. The presence of this water in areas not currently receiving it could result in a change in the vegetative and wetland communities in the new drainage pathways to more wetland-type species. Conversely, the absence of water from current drainage paths could result in conversion of these areas to more upland-type communities. No significant change in the amounts of various types of communities are anticipated, only a realignment of their locations. Any changes would likely be gradual because the amount of water being relocated is not large. Overall, the majority of the area would remain relatively unchanged. Better control of water should enable existing Refuge communities in the Big Salt Marsh and North Flat area to be more effectively and efficiently managed, resulting in an overall enhancement of the area.

Additional benefits to wildlife would occur for years to come following implementation of this alternative. The additional control of available water would enable Refuge personnel the flexibility to move water to areas where it would be most beneficial. While not as important in normal or wet years, due to habitat being widely available in the basin, the greater control of water in dry years would enable Refuge personnel to more effectively manage the habitats available, likely providing an even more critical stopping, resting, staging, and recuperating area for species, including endangered whooping cranes, during their spring and fall migrations. By enhancing Refuge staffs ability to better control water and thus habitat, this alternative would provide more opportunities for public recreation on the Refuge.

PART IX

TASK E - ALTERNATIVE COMPARISON

A. GENERAL

This section of the report compares and screens alternatives described in Tasks A through D (Parts V through VIII) in an alternative selection process. Based on this selection process and discussions with the U.S. Fish and Wildlife Service (Service), three water supply plans have been selected for final evaluation and comparison for the Quivira National Wildlife Refuge (Refuge). The three water supply plans are described below:

- Water Supply Plan 1 (WSP1)—the Service would operate the Refuge using a moist soil management approach while adding on-Refuge improvements; no supplemental water supply is included.
- Water Supply Plan 2 (WSP2)—the Service would use Rattlesnake Creek and supplemental groundwater diverted to Rattlesnake Creek to supply water and manage the Refuge using a moist soil approach; no on-Refuge improvements are included; water could be provided up to the Refuge's water right.
- Water Supply Plan 3 (WSP3)—using a moist soil management approach, the Service would use Rattlesnake Creek and supplemental groundwater diverted to Rattlesnake Creek to supply water to the Refuge; on-Refuge improvements are added, as justified; water could be provided up to the Refuge's water right.

Water supply plans (WSPs) are developed using viable alternatives from Tasks A, B, C and D as discussed in previous sections of this report. The plans are based on the alternative screening process and the Service's preferences for development of on-Refuge alternatives. The alternatives are evaluated in a three-phase screening and evaluation process. The three phases are as follows:

- Phase 1—Preliminary Alternative Screening: The 31 alternatives developed in Tasks A through D are evaluated using criteria on hydrology, engineering, environment, socioeconomics, and land use.

- Phase 2—Final Screening: The water supply alternatives that received the highest ranking in the Phase 1 screening are evaluated to identify the optimum supplemental water supply.
- Phase 3—Water Supply Plans: The three water supply plans described above are evaluated and optimized.

B. PHASE 1 - PRELIMINARY ALTERNATIVE SCREENING CRITERIA

Phase 1 includes an initial screening of the 17 water management and 14 water supply alternatives developed in Tasks A through D. An alternative screening process is used to evaluate and rank the alternatives. One of the first steps in this process is to identify criteria to be used in evaluating the alternatives.

Five general categories of screening criteria are applicable to a project of this nature and are used in the Phase 1 screening. These categories are not equivalent in their importance for this project; therefore, each is allocated a weight that is indicative of its relative importance in the preliminary screening process. The weights of these categories total 100 percent. The five general categories and their assigned weights are as follows:

Category	Assigned Weight
Hydrology	50
Engineering	15
Environmental	25
Socioeconomic	5
Land Use	5

Each general evaluation category is comprised of several more specific criteria that help define the important components of each general category. As with each of the five categories, the criteria within a given category are not equally important. Each criteria is allocated a weight indicating its relative importance in the category. Individual criteria weights add to the total category weight presented immediately above. The assigned weights are multipliers, which are applied to the individual scores for each criteria. Criteria are assigned a score between zero and ten based on how desirable the alternative is determined to be relative to that specific criteria. The larger the score, the less adverse impact or more positive benefit, and therefore, the more desirable the alternative is considering that specific criteria. Since the individual scores range between zero and ten, and the weights total to 100, the maximum possible score for each alternative is 1,000. The component criteria for each of the five evaluation categories and their assigned weights are summarized in Table IX-1.

Table IX-1
PHASE 1—PRELIMINARY SCREENING CRITERIA

Category/Criteria	Weight	Basis for Scoring
Hydrology		
Water Supply	35	Average annual Refuge diversions
Water Quality	3	Expected water quality impacts
Water Rights	5	Difficulty in obtaining water rights
Conveyance Loss	5	Magnitude of losses
Competing Use	2	Presence of competing water uses
Subtotal:	50	
Engineering		
Construction Cost	5	Estimated construction cost
OMR&E Cost	7	Estimated annual OMR&E cost
Constructability	1	Ease of construction
Land/Right-of-Way	2	Amount of new land/right-of-way
Subtotal:	15	
Environmental		
Wetlands Habitat	20	Estimated wetland habitat impacts
Terrestrial Wildlife Habitat	5	Estimated terrestrial wildlife habitat impacts
Subtotal:	25	
Socioeconomic		
Construction Impact	1	Noise, traffic, air quality impacts
Relocations (residential)	1	Number of relocations
Recreation	1	Relative recreation impacts
Cultural Resources	2	Probability of occurrence
Subtotal:	5	
Land Use		
Agricultural Activities	1	Type and acreage of agricultural land
Prime Farmland	2	Amount of prime farmland
Oil & Gas Facilities	1	Number of oil & gas facilities
Highways/Roads	1	Length and type of roads impacted
Subtotal:	5	
Total Weight	100	

The Quivira NWR was established and designed to provide habitat for those species dependent on wetland habitat. According to the Service (1998), the prioritized purposes of the Refuge are to:

- protect and enhance endangered species
- provide habitat for migratory birds (including ducks and other waterfowl)
- preserve and enhance natural diversity of other wildlife, and protect and enhance a healthy ecosystem
- provide public use, both interpretation and recreation

In the preliminary screening process, the environmental category was subdivided into two criteria - wetland habitat and terrestrial wildlife habitat. Wetland habitat was believed to be most important by the project team and was given 80 percent of the weight for the environmental category (20 out of 25 possible). Factors such as total wetland area, threatened or endangered species use of wetlands, fishery available, and habitat change were important considerations in assigning a score to the wetland habitat criteria for a given alternative. The terrestrial wildlife habitat criteria was given the remaining weight of five. Important considerations in the evaluation of this criteria included the amount of terrestrial wildlife habitat on the Refuge and on adjacent land areas, the particular species or group of terrestrial wildlife impacted by the change, and the potential temporary or permanent impact of the change on wildlife populations.

The selection of alternative screening criteria and the assignment of weights is a subjective process. The project team, composed of biologists, engineers, hydrologists, and geohydrologists, developed through team consensus the preliminary screening categories and criteria and assigned the weights applied to each. Following this determination, the project alternatives were preliminarily evaluated and scored. At this point, a sensitivity analysis was conducted to determine if minor changes in any one of the category or criteria weights or scores could significantly alter the preliminary ranking of the alternatives. Adjustments were made to the weights and scoring as necessary. Once the project team was satisfied with the preliminary screening process and results, a memorandum to obtain consensus and comments on the process was submitted to the Service.

The criteria selected for this screening analysis are discussed below along with the rationale used to assign individual scores for each alternative. Once again, for each criteria and alternative, a relative score between zero and ten is assigned with ten being the most beneficial value and zero the least beneficial.

1. Water Supply

An alternative that supplies additional water is crucial for Refuge management. The water supply criterion is assigned a weight of 35, the highest weight in the Phase 1 preliminary screening process. Water is needed to fill or flood units at certain times of the year to manage wetland and terrestrial wildlife habitat. Without an additional water supply, Refuge management becomes less flexible and more uncertain.

Table IX-2
RATING CRITERIA FOR WATER SUPPLY
(Weight: 35)

Score	Diversions (acre-feet/year)
10	> 6,750
9	6,000 - 6,750
8	5,250 - 6,000
7	4,500 - 5,250
6	3,750 - 4,500
5	3,000 - 3,750
4	2,250 - 3,000
3	1,500 - 2,250
2	750 - 1,500
1	0 - 750
0	0

The scores for water supply are based on the average annual net increase in diversions to the Refuge over baseline conditions. Baseline diversions are defined as the amount of water that can be diverted to the Refuge from Rattlesnake Creek, and put to beneficial use, each month during the simulation period for the operations model under current conditions. The criteria used to assign the scores for the Water Supply criterion are listed in Table IX-2. A score of zero is assigned to alternatives that provide no additional water supply.

2. Water Quality

The impact of chemical water quality on Refuge water use is not considered to be as important as some other subcriteria. For Phase 1 preliminary screening, the water quality criterion is assigned a weight of three. Water quality data for supplemental groundwater in the Rattlesnake Creek Basin are very limited. The quality of this supplemental groundwater could be similar to or better than current Refuge inflow from Rattlesnake Creek, but is conservatively assumed to be higher in chlorides with long-term pumping. This water quality is considered the least desirable from the array of potential alternatives and is given a score of zero. Water originating from Rattlesnake Creek is currently what is used on the Refuge and is given a median score of five. Water originating from the Arkansas River is considered to be the best quality of the three water sources and is given a score of ten.

3. Water Rights

The Rattlesnake Creek basin has been closed to new water rights since 1989. New groundwater rights within the GMD5 are allowed only if the District's "sustainable yield" criteria is met. New groundwater rights are potentially available in areas of elevated chloride content because there is little irrigation development in these areas. Additionally, exceptions are possible for "the public benefit." GMD5 has indicated in meetings that new rights for augmentation water for the Refuge are possible under this exception. These exceptions can be used to exclude the mineral intrusions policies in areas that currently have high chloride groundwater.

Excess flood water captured and stored off-site in either surface reservoirs or in the aquifer would probably require new ground or surface water rights because of the remote location of the new point of diversion. Stored water that is released for downstream delivery, recapture and use is subject to natural streamflow losses. Also, although there are few water rights in the Rattlesnake Creek Basin senior to those for the Refuge, the released water is subject to diversion by these senior appropriators. The only way to prevent potentially significant natural transmission losses is to transmit the stored water through a pipeline from the point of release to the point of use.

Another factor that could impact water rights and the implementation of a water supply plan is the development of additional moist soil units. The current water right for the Refuge is based on 6,138 acres of wetlands. If additional moist soil units are developed as part of a plan, the Service must file for a new water right or reduce the number of wetland acres elsewhere on the Refuge.

The ease or difficulty in obtaining water rights is also considered to be important in the alternative screening process; therefore, this criterion is assigned a weight of five. Obtaining water rights from the Arkansas River for the Refuge is considered to be the most difficult and is given a score of zero. Alternatives that require water rights for supplemental groundwater wells near the Refuge are considered to be less difficult to obtain and are assigned scores of five. Water rights for alternatives with supplies from Rattlesnake Creek adjacent to the Refuge are considered least difficult to obtain and are given a score of ten.

4. Conveyance Loss

Since the goal is to obtain and maintain a water supply for use on the Refuge, conveyance losses are considered to be as important as water rights in the preliminary screening process. The weight established for conveyance loss is five. For alternatives that may lose the least amount of water via conveyance, a score of ten is given. Examples of this situation are alternatives within the Refuge which only convey water short distances; therefore less water is lost. For alternatives that could lose a larger amount of water through conveyance, the score is zero. For example, Reservoir Site 2 is located furthest from the Refuge and would have the score of zero.

5. Competing Use

Competing water uses also have a direct impact on each alternative. The competing use criterion is considered less important in the screening process and is given a weight of two. An alternative that is located within the Refuge has little competition from other water users and is given a score of ten. Alternatives farthest from the Refuge will likely encounter the greatest competition for the use of the water supply and are given a score of zero.

6. Construction Cost

The estimated construction cost for an alternative is included in the preliminary alternative screening process. Construction cost is given a weight of five. As a governmental entity, the Service normally has to request construction funding several years in advance. Federal funds are obtainable provided the need can be shown and Congress provides the funds through

Table IX-3
RATING CRITERIA FOR CONSTRUCTION COST
(Weight: 5)

Score	Construction Cost ($ Million)
10	< 0.5
9	0.5 - 1.0
8	1.0 - 1.5
7	1.5 - 2.0
6	2.0 - 2.5
5	2.5 - 3.0
4	3.0 - 3.5
3	3.5 - 4.0
2	4.0 - 4.5
1	4.5 - 5.0
0	> 5.0

appropriations. In general, the lower the cost of construction, the more favorable the alternative. Scores are assigned based on the estimated construction cost of an alternative using the criteria listed in Table IX-3. For this analysis, the alternatives with construction costs greater than $5 million are considered excessive and given a score of zero. Those with construction costs less than $0.5 million are considered more acceptable and assigned a score of ten.

7. Operation, Maintenance, Replacement & Energy (OMR&E) Costs

OMR&E costs are recurring annual costs and are more difficult for government agencies to include in an operating budget than one-time construction costs. The Service does not have excess funds in the OMR&E budget for the Refuge; therefore, an alternative that will incur additional OMR&E costs is considered to be more difficult to implement by the Service. This criterion is weighted as a seven in the preliminary alternative screening process. The scoring criteria for OMR&E costs are listed in Table IX-4. Alternatives with no OMR&E costs are given a score of ten and alternatives with OMR&E costs greater than $450,000 per year are given a score of zero.

Table IX-4
RATING CRITERIA FOR OMR&E COSTS
(Weight: 7)

Score	OMR&E Cost ($ per year)
10	0
5	0 - 100,000
0	> 100,000

8. Constructability

Constructability is defined as the ease of constructing an alternative. None of the alternatives are considered to be difficult to construct. It is not considered to be significant in the preliminary screening analysis and is given a weight of one. An alternative constructed on the Refuge is scored a ten. Alternatives involving pump stations and groundwater wells are given a score of five. The constructability of a reservoir is considered to be the most difficult and is scored at zero.

9. Land/Right-of-Way

Obtaining land and right-of-way for an alternative is not considered to be difficult so this criterion is given a weight of two. Acquiring land or right-of-way required for alternatives on the Refuge is very simple and scored the highest or ten. Alternatives involving groundwater and the Arkansas River are given a middle score of five. Reservoir alternatives require the purchase of larger acreage of land for reservoir alternatives and rights-of-way for pipelines and are given the lowest score or zero.

10. Wetland Habitat

The availability of wetland habitat on the Refuge is critical for many wildlife species using the Refuge. The value of wetland habitat is reflected in the number and variety of terrestrial and aquatic wildlife species that use it. Wetland habitat affects all of the wildlife species that are found on the Refuge. Uses of wetlands include either singularly or in combination nesting, brood raising, foraging, cover, or resting. The habitat value of the Refuge is therefore directly tied to the amount of wetlands present.

Table IX-5
RATING CRITERIA FOR WETLAND HABITAT
(Weight: 20)

Score	Wetlands Available (acres)
10	> 3,750
9	3,750 - 3,500
8	3,500 - 3,250
7	3,250 - 3,000
6	3,000 - 2,750
5	2,750 - 2,500
4	2,500 - 2,250
3	2,250 - 2,000
2	2,000 - 1,750
1	1,750- 1,500
0	baseline (< 1,500)

All federal threatened or endangered species using the Refuge are dependent in some way on wetland habitat. Changes by either increasing or decreasing wetland habitat could alter threatened or endangered species use on the Refuge. Since the first Refuge purpose (Service 1998) is to protect and enhance endangered species, decreases in threatened or endangered species habitat are not acceptable. Any alternative that would decrease threatened or endangered species habitat on the Refuge would not be considered viable and not carried forward in the alternative screening process.

Many of the pools on the Refuge are intermittent and incapable of supporting a quality permanent fishery. As a result, the Refuge fishery consists primarily of non-game fish capable of surviving under poor water quality conditions in the more permanent wetland habitats; however, the fish that are present provide a forage base for a variety of wildlife species, including some T&E species.

Refuge objectives revolve around providing wetland habitat. Changes in the amount of wetland habitat affect use of the Refuge by threatened or endangered species, waterfowl, shorebirds, and other wildlife species, and the human visitors that are drawn to the Refuge for recreation and interpretative experiences. Increased wetland habitat directly correlates to increased use on the Refuge by both wildlife and humans (Hilley 1998).

As a result of all the above factors, wetland habitat is assigned the second highest weight of 20 in the preliminary alternative screening process. The score for each alternative is based on the amount of wetland habitat available 80 percent of the time above the baseline condition; therefore, the baseline of 1,500 acres of wetland habitat is set at zero. The score increases by one for each additional 250 acres of wetland habitat developed. The maximum score of ten is given for alternatives that provide more than 3,750 acres of wetland habitat 80 percent of the time above the baseline as listed in Table IX-5.

While different species require different types of wetland habitat and wetland habitat quality vary, these factors were not directly considered in the preliminary screening process. By increasing the amount of wetland habitat present, it is inherent that some of this wetland habitat would be suitable for all types of species including threatened or endangered species. Since different types of wetland habitat would be present, a range of wetland habitat quality would also exist.

11. Terrestrial Wildlife Habitat

The terrestrial wildlife habitat criterion is not considered to be as important as wetlands and has a weight of five in the preliminary screening process. Scoring is based on the anticipated amount of upland habitat lost or impacted by each alternative. If there is no loss of upland habitat, wildlife is not impacted and a score of ten is given. The score decreases by one for each 50 acres of lost upland habitat as shown in Table IX-6.

Table IX-6
RATING CRITERIA FOR TERRESTRIAL WILDLIFE HABITAT
(Weight: 5)

Score	Upland Habitat Lost (acres)
10	no change
9	1 - 50
8	50 - 100
7	100 - 150
6	150 - 200
5	200 - 250
4	250 - 300
3	300 - 350
2	350 - 400
1	> 400

12. Construction Impact

The construction of an alternative may have significant impacts to its surroundings. Impacts may be temporary or permanent and may include traffic, noise, air quality, and land use changes. Construction impacts are considered to be of minor importance in the Phase 1 screening process and are only given a weight of one. Alternatives with no construction impacts are given a score of ten. Alternatives with temporary moderate impacts or temporary large impacts are assigned scores as presented in Table IX-7. Alternatives that have permanent construction impacts are given a score of zero.

Table IX-7
RATING CRITERIA FOR CONSTRUCTION IMPACT
(Weight: 1)

Score	Probability
10	None
9 to 6	Low
5 to 1	Moderate
0	High

13. Relocations

Relocations for alternatives are limited to residences. This criterion is not considered to be very important in the preliminary screening process and is given a weight of one. Two alternatives would require one relocation each. Both alternatives are given a score of zero. All other alternatives do not involve a relocation and are scored a ten.

Table IX-8
RATING CRITERIA FOR RECREATION
(Weight: 1)

Score	Wetland Habitat (acres)
10	> 3,750
9	3,750 -3,500
8	3,500 - 3,250
7	3,250 - 3,000
6	3,000 - 2,750
5	2,750 - 2,500
4	2,500 - 2,250
3	2,250 - 2,000
2	2,000 - 1,750
1	1,750 - 1,500
0	baseline (< 1,500)

14. Recreation

The Refuge provides visitors a variety of recreational and interpretation opportunities including hunting, bird watching, fishing, and nature study. Recreational opportunities are a benefit that is associated with the wetland and wildlife habitat provided on the Refuge. In the Phase 1 screening process, recreation is given a weight of one. Recreation use of the Refuge is largely based on the amount of wetland habitat available on the refuge (Part II.H) (Hilley, 1998). Recreational impacts are based on the amount of wetland habitat available 80 percent of the time above the baseline condition. An alternative that provides wetland acreage at the baseline (1,500 acres) is scored at zero. Scores increase by one for each additional 250 acres as listed in Table IX-8. An alternative that provides wetland habitat well over the baseline (greater than 3,750 acres) is given the highest score of ten.

15. Cultural Resources

An alternative that requires temporary or permanent land use changes may impact cultural resources. This is not considered to be an important factor in the preliminary screening process and is given a score of two. The cultural resources criterion score is based on the probability of cultural resource occurrence. A summary of the scores assigned is listed in Table IX-9.

Table IX-9
RATING CRITERIA FOR CULTURAL RESOURCES
(Weight: 2)

Score	Probability
10	No probability
9	Low
5	Moderate
1	High
0	Definite impact

16. Agricultural Activities

The project area is dominated by agricultural activity. Agricultural activities includes cropland and pastureland. This screening criterion is given a score of one due to the prevalence of agricultural land in the basin. The basis for scoring depends on the type and acreage of agricultural land impacted. If no acreage is impacted, a score of ten is recorded. If greater than 450 acres of agriculture is affected, the alternative is given a score of zero. Alternatives that fall within these ranges are scored as listed in Table IX-10.

Table IX-10
RATING CRITERIA FOR AGRICULTURAL ACTIVITIES AND PRIME FARMLANDS
(Weight: 1 and 2)

Score	Agriculture Impacted (acres)
10	0
9	0 - 50
8	50 - 100
7	100 - 150
6	150 - 200
5	200 - 250
4	250 - 300
3	300 - 350
2	350 - 400
1	400 - 450
0	> 450

17. Prime Farmlands

The Natural Resource Conservation Service (NRCS) has designated many of the soils in the Rattlesnake Creek basin as prime farmlands; therefore, these lands have "the best combination of physical and chemical characteristics for producing food, feed, forage, fiber or oil seed crops." In the preliminary alternative screening process, prime farmland is given a weight of two. The basis for scoring this criterion depends on the acreage impacted and is similar to the Agricultural Activities criterion listed in Table IX-10.

18. Oil & Gas Facilities

Oil and gas facilities occur throughout the basin. Construction and operation of the various alternatives has the potential to impact these facilities. Impacts to these facilities are not considered very important in the preliminary alternative screening process and are only given a weight of one. Scores for this criterion are based on the degree of impact to oil and gas facilities as listed in Table IX-11.

Table IX-11
RATING CRITERIA FOR OIL & GAS FACILITIES
(Weight: 1)

Score	Degree of Impact
10	None
9	Low
5	Moderate
1	High
0	Definite

19. Highways and Roads

Impacts that occur to highways and roads in the project area include relocation, closing, construction, and traffic delays. This criterion is weighted a two. The basis for scoring the alternatives depends on the type of impact (flooding, pipeline crossing, etc.) and the length and type of road impacted. The degree of impact and scores are listed in Table IX-12.

Table IX-12
RATING CRITERIA FOR HIGHWAYS AND ROADS
(Weight: 1)

Score	Degree of Impact
10	None
9 to 7	Low
6 to 4	Moderate
1 to 3	High
0	Definite

C. PHASE 1 - PRELIMINARY ALTERNATIVE SCREENING

The Phase 1 - Preliminary Alternative Screening assesses each of the 31 alternatives developed in Tasks A through D using the categories and criteria described in Section B above. Each alternative is assigned a score for each criteria. The products of the scores and their respective weights are then summed to yield a total score for each alternative. The maximum possible total score is 1,000. The basis for the ratings and the evaluation summary for general categories are presented in the following sections.

1. Hydrology

The most important goal for this project is to develop and recommend a water supply alternative capable of providing additional water for use on the Refuge. The hydrology category is therefore allotted 50 percent of the total weight. The Hydrology category includes the following criteria: water supply, water quality, water rights, conveyance loss and competing use. The basis used in ranking each alternative is listed in Table IX-1. The hydrologic data used in ranking each alternative are summarized in Table IX-13.

2. Engineering

The Engineering category is weighted at 15 percent of the total and includes the following criteria: construction cost, OMR&E cost, constructability and land/right-of-way. The basis used to rank each alternative is listed in Table IX-1. The engineering data used to rank each water supply alternative are summarized in Table IX-14.

3. Environmental

The Environmental category is weighted at 25 percent and includes the following criteria: wetland habitat and terrestrial wildlife habitat. The basis used to rank each alternative is listed in Table IX-1. The environmental data used to rank each alternative are summarized in Table IX-15.

Table IX-13
HYDROLOGY SUMMARY

Alternative		Water Supply (1)	Water Quality (2)	Water Rights (3)	Conveyance Loss (4)	Competing Use (5)
Task A	Site No. 1	-17	RSC	RSC	Off-site	Off-site
Task A	Site No. 2	-157	RSC	RSC	Off-site	Off-site
Task A	Site No. 3	-68	RSC	RSC	Off-site	Off-site
Task A	Site No. 6	-146	RSC	RSC	Off-site	Off-site
Task A	Site No. 8	29	RSC	RSC	Off-site	Off-site
Task B	Aquifer Recharge	1,690	SGW	SGW	Off-site	Off-site
Task C	Alt 1 - Raise dikes 2'	501	RSC	RSC	On-site	On-site
Task C	Alt 2.1 - Cross dikes	85	RSC	RSC	On-site	On-site
Task C	Alt 2.2.1 - Pump 40 MGD	112	RSC	RSC	On-site	On-site
Task C	Alt 2.2.2 - Pump 80 MGD	112	RSC	RSC	On-site	On-site
Task C	Alt 3.14a - Raise 2'	66	RSC	RSC	On-site	On-site
Task C	Alt 3.14b - Raise 3.3'	89	RSC	RSC	On-site	On-site
Task C	Alt 3.28 - Raise 2'	91	RSC	RSC	On-site	On-site
Task C	Alt 3.28 - Raise 7'	281	RSC	RSC	On-site	On-site
Task C	Alt 3.34 - New 2' raise	86	RSC	RSC	On-site	On-site
Task C	Alt 3.61 - Raise 2.5'	157	RSC	RSC	On-site	On-site
Task C	Alt 3.61 - Raise 4.5'	232	RSC	RSC	On-site	On-site
Task C	Alt 4 - Line canals	112	RSC	RSC	On-site	On-site
Task C	Alt 5 - Remove sediment	29	RSC	RSC	On-site	On-site
Task C	Alt 6 - Bypass canal	14	RSC	RSC	On-site	On-site
Task C	Alt 7 - Moist soil units	44	RSC	RSC	On-site	On-site
Task C	Alt 8 - Fill Borrow area	--	RSC	RSC	On-site	On-site
Task C	Alt 9.1 - Arkansas River	1,357	ARK	ARK	Off-site	Off-site
Task C	Alt 9.2 - Arkansas River	3,596	ARK	ARK	Off-site	Off-site
Task C	Alt 9.3 - Arkansas River	4,764	ARK	ARK	Off-site	Off-site
Task C	Alt 9.4 - Arkansas River	5,368	ARK	ARK	Off-site	Off-site
Task C	Alt 10.1 - GW wells	2,348	SGW	SGW	Off-site	Off-site
Task C	Alt 10.2 - GW wells	4,419	SGW	SGW	Off-site	Off-site
Task C	Alt 10.3 - GW wells	6,328	SGW	SGW	Off-site	Off-site
Task C	Alt 10.4 - GW wells	7,773	SGW	SGW	Off-site	Off-site
Task C	Alt 10.5 - GW wells	8,486	SGW	SGW	Off-site	Off-site

Notes:
1. Based on average diversions available in acre-feet per year.
2. Based on water source (ARK - Arkansas River, RSC - Rattlesnake Creek, SGW - supplemental groundwater.
3. Based on difficulty in obtaining water rights
4. Based on distance for conveyance to Refuge. Refer to relevant sections for distances of off-site alternatives with respect to Refuge.
5. Based on presence of competing water uses. Refer to relevant section for distances of off-site alternatives with respect to Refuge.

Table IX-14
ENGINEERING SUMMARY

Alternative		Project Cost (1) ($million)	OMR&E Cost (2) ($1000 /yr)	Constructability (3)	Land / Right-of-way (4)
Task A	Site No. 1	1.4	9	High	High
Task A	Site No. 2	13.1	83.6	High	High
Task A	Site No. 3	18	115.5	High	High
Task A	Site No. 6	14	88.2	High	High
Task A	Site No. 8	3.8	24.7	High	High
Task B	Aquifer Recharge	17	1,193	Moderate	Moderate
Task C	Alt 1 - Raise dikes 2'	1.4	0	Low	Low
Task C	Alt 2.1 - Cross dikes	3.3	0	Low	Low
Task C	Alt 2.2.1-Pump 40 MGD	7.8	134.8	Low	Low
Task C	Alt 2.2.2-Pump 80 MGD	8.1	156.1	Low	Low
Task C	Alt 3.14a - Raise 2'	0.4	0	Low	Low
Task C	Alt 3.14b - Raise 3.3'	0.2	0	Low	Low
Task C	Alt 3.28 - Raise 2'	0.2	0	Low	Low
Task C	Alt 3.28 - Raise 7'	0.6	0	Low	Low
Task C	Alt 3.34 - New 2' raise	0.1	0	Low	Low
Task C	Alt 3.61 - Raise 2.5'	0.5	0	Low	Low
Task C	Alt 3.61 - Raise 4.5'	0.9	0	Low	Low
Task C	Alt 4 - Line canals	1.9	0	Low	Low
Task C	Alt 5- Remove sediment	0.9	29.4	Low	Low
Task C	Alt 6 - Bypass canal	3.6	0	Low	Low
Task C	Alt 7 - Moist soil units	1.1	0	Low	Low
Task C	Alt 8 - Fill Borrow area	0.8	0	Low	Low
Task C	Alt 9.1 - Arkansas River	7	189	Moderate	Moderate
Task C	Alt 9.2 - Arkansas River	10.8	479	Moderate	Moderate
Task C	Alt 9.3 - Arkansas River	13.9	673	Moderate	Moderate
Task C	Alt 9.4 - Arkansas River	16.9	879	Moderate	Moderate
Task C	Alt 10.1 - GW wells	0.9	85	Moderate	Moderate
Task C	Alt 10.2 - GW wells	1.8	120	Moderate	Moderate
Task C	Alt 10.3 - GW wells	2.5	150	Moderate	Moderate
Task C	Alt 10.4 - GW wells	3.2	177	Moderate	Moderate
Task C	Alt 10.5 - GW wells	3.9	195	Moderate	Moderate

Notes:
1. Includes construction and other associated costs.
2. Operation, maintenance, replacement and energy cost in year 2000.
3. Based on difficulty in construction.
4. Based on difficulty in obtaining land and right-of-way for an alternative.

Table IX-15
ENVIRONMENTAL SUMMARY

Alternative		Wetland Habitat (1)	Terrestrial Wildlife Habitat (2)
Task A	Site No. 1	1,416	80
Task A	Site No. 2	1,394	550
Task A	Site No. 3	1,394	550
Task A	Site No. 6	1,383	630
Task A	Site No. 8	1,418	160
Task B	Aquifer Recharge	1,536	50
Task C	Alt 1 - Raise dikes 2'	1,415	440
Task C	Alt 2.1 - Cross dikes	1,435	0
Task C	Alt 2.2.1 - Pump 40 MGD	1,464	0
Task C	Alt 2.2.2 - Pump 80 MGD	1,464	0
Task C	Alt 3.14a - Raise 2'	1,416	20
Task C	Alt 3.14b - Raise 3.3'	1,416	35
Task C	Alt 3.28 - Raise 2'	1,416	55
Task C	Alt 3.28 - Raise 7'	1,416	105
Task C	Alt 3.34 - New 2' raise	1,412	80
Task C	Alt 3.61 - Raise 2.5'	1,416	20
Task C	Alt 3.61 - Raise 4.5'	1,416	20
Task C	Alt 4 - Line canals	1,437	0
Task C	Alt 5 - Remove sediment	1,424	0
Task C	Alt 6 - Bypass canal	1,415	50
Task C	Alt 7 - Moist soil units	1,414	0
Task C	Alt 8 - Fill Borrow area	--	0
Task C	Alt 9.1 - Arkansas River	1,607	100
Task C	Alt 9.2 - Arkansas River	1,947	100
Task C	Alt 9.3 - Arkansas River	2,165	100
Task C	Alt 9.4 - Arkansas River	2,265	100
Task C	Alt 10.1 - GW wells	2,290	50
Task C	Alt 10.2 - GW wells	2,923	50
Task C	Alt 10.3 - GW wells	3,449	50
Task C	Alt 10.4 - GW wells	3,841	100
Task C	Alt 10.5 - GW wells	4,189	100

Notes:
1. Based on the quantity of wetland habitat available 80 percent of the time.
2. Based on the quantity of upland habitat (acres) lost or impacted which is dependant on the additional water surface area created. Arkansas River and groundwater alternatives are conservatively based on amount of land to be used for facilities.

4. Socioeconomic

The development of an alternative may negatively or positively impact the local community, project area, or visitors to the Refuge. For the Phase 1 alternative screening process, those alternatives with potentially high negative social impacts are penalized. The socioeconomic category used includes the following criteria: construction impact, residential relocations, recreation and cultural resources. The basis used in ranking each alternative is listed in Table IX-1. The socioeconomic data used to rank each alternative are summarized in Table IX-16.

5. Land Use

The Land Use category includes the following criteria: agricultural activities, prime farmland, oil and gas facilities and highway and roads. The basis used in ranking each alternatives is listed in Table IX-1. The land use data used to rank each alternative are summarized in Table IX-17.

The next step in evaluating the alternatives is to assign a score for each alternative based on the individual criteria discussed above. The individual criteria weight and the alternative score are multiplied and summed to yield a composite total score for each alternative as listed in Table IX-18. Task C, Alternative 10-4 has the highest score of 823; and Task A, Reservoir Site No. 6 has the lowest score of 136. The composite total scores for each alternative are listed in Table IX-19 and shown on Figure IX-1.

Review of Figure IX-1 shows Task C, Alternatives 10-4, 10-5 and 10-3 are the highest ranked alternatives. Each of these alternatives can provide supplemental water to the Refuge. These three water supply alternatives are evaluated further in Phase 2 - Final Alternative Screening. The alternative with the greatest number of benefits from the Phase 2 screening will be used in Water Supply Plans 2 and 3 as the preferred water supply alternative for the Refuge.

Table IX-16
SOCIOECONOMIC SUMMARY

Alternative		Construction Impact (1)	Residential Relocations (2)	Recreation (3)	Cultural Resources (4)
Task A	Site No. 1	Moderate	0	1,416	Moderate
Task A	Site No. 2	Moderate	0	1,394	High
Task A	Site No. 3	Moderate	1	1,394	Low
Task A	Site No. 6	Moderate	1	1,383	Low
Task A	Site No. 8	Moderate	0	1,418	High
Task B	Aquifer Recharge	Moderate	0	1,536	Low
Task C	Alt 1 - Raise dikes 2'	Low	0	1,415	Low
Task C	Alt 2.1 - Cross dikes	Low	0	1,435	Low
Task C	Alt 2.2.1 - Pump 40 MGD	Low	0	1,464	Low
Task C	Alt 2.2.2 - Pump 80 MGD	Moderate	0	1,464	Low
Task C	Alt 3.14a - Raise 2'	Low	0	1,416	Moderate
Task C	Alt 3.14b - Raise 3.3'	Low	0	1,416	Moderate
Task C	Alt 3.28 - Raise 2'	Low	0	1,416	Low
Task C	Alt 3.28 - Raise 7'	Low	0	1,416	Low
Task C	Alt 3.34 - New 2' raise	Low	0	1,412	High
Task C	Alt 3.61 - Raise 2.5'	Low	0	1,416	Low
Task C	Alt 3.61 - Raise 4.5'	Low	0	1,416	Low
Task C	Alt 4 - Line canals	Low	0	1,437	None
Task C	Alt 5 - Remove sediment	Low	0	1,424	None
Task C	Alt 6 - Bypass canal	Moderate	0	1,415	High
Task C	Alt 7 - Moist soil units	None	0	1,414	High
Task C	Alt 8 - Fill Borrow area	None	0	--	None
Task C	Alt 9.1 - Arkansas River	Low	0	1,607	Low
Task C	Alt 9.2 - Arkansas River	Low	0	1,947	Low
Task C	Alt 9.3 - Arkansas River	Low	0	2,165	Low
Task C	Alt 9.4 - Arkansas River	Low	0	2,265	Low
Task C	Alt 10.1 - GW wells	Low	0	2,290	Low
Task C	Alt 10.2 - GW wells	Low	0	2,923	Low
Task C	Alt 10.3 - GW wells	Low	0	3,449	Low
Task C	Alt 10.4 - GW wells	Low	0	3,841	Low
Task C	Alt 10.5 - GW wells	Low	0	4,189	Low

Notes:
1. None - no construction impact; low - insignificant temporary impact; moderate - significant temporary impact; high - significant and permanent impact.
2. Based on the number of dwellings that needs to be relocated.
3. Based on the quantity of wetland and wildlife habitat (acres) available 80 percent of the time.
4. Based on the probability of cultural resource occurrence.

Table IX-17
LAND USE SUMMARY

Alternative		Agricultural Activities (1)	Prime Farmlands (2)	Oil & Gas Facilities (3)	Highway / Roads (4)
Task A	Site No. 1	0	0	Moderate	None
Task A	Site No. 2	0	0	None	Low
Task A	Site No. 3	500	540	None	High
Task A	Site No. 6	593	326	None	Definite
Task A	Site No. 8	153	40	None	None
Task B	Aquifer Recharge	100	100	Low	Low
Task C	Alt 1 - Raise dikes 2'	0	0	None	Moderate
Task C	Alt 2.1 - Cross dikes	0	0	None	Moderate
Task C	Alt 2.2.1 - Pump 40 MGD	0	0	None	Low
Task C	Alt 2.2.2 - Pump 80 MGD	0	0	None	Low
Task C	Alt 3.14a - Raise 2'	0	0	None	None
Task C	Alt 3.14b - Raise 3.3'	0	0	None	None
Task C	Alt 3.28 - Raise 2'	0	0	None	None
Task C	Alt 3.28 - Raise 7'	0	0	None	None
Task C	Alt 3.34 - New 2' raise	0	0	None	None
Task C	Alt 3.61 - Raise 2.5'	0	0	None	None
Task C	Alt 3.61 - Raise 4.5'	0	0	None	None
Task C	Alt 4 - Line canals	0	0	None	Moderate
Task C	Alt 5 - Remove sediment	0	0	None	None
Task C	Alt 6 - Bypass canal	0	0	None	Low
Task C	Alt 7 - Moist soil units	30	30	None	None
Task C	Alt 8 - Fill Borrow area	0	0	None	None
Task C	Alt 9.1 - Arkansas River	50	50	None	Moderate
Task C	Alt 9.2 - Arkansas River	50	50	None	Moderate
Task C	Alt 9.3 - Arkansas River	50	50	None	Moderate
Task C	Alt 9.4 - Arkansas River	50	50	None	Moderate
Task C	Alt 10.1 - GW wells	50	50	None	Low
Task C	Alt 10.2 - GW wells	50	50	None	Low
Task C	Alt 10.3 - GW wells	50	50	None	Low
Task C	Alt 10.4 - GW wells	50	50	None	Low
Task C	Alt 10.5 - GW wells	50	50	None	Low

Notes:
1. Based on total acreage of cropland and pasture impacted.
2. Based on the acres of prime farmland impacted.
3. Based on the oil & gas facilities impacted.
4. Based on the highways and roads impacted.

Table IX - 18

PHASE 1 - PRELIMINARY SCREENING OF WATER RESOURCE ALTERNATIVES

Criterion	Weight (1)	Task A										Task B		Task C																	
		Site No. 1		Site No. 2		Site No. 3		Site No. 6		Site No. 8		Recharge Area		Alt 1		Alt 2-1		Alt 2-2.1		Alt 2-2.2		Alt 3-14a		Alt 3-14b		Alt 3-28 (2')		Alt 3-28 (7')		Alt 3-34	
		Score (2)	Value (3)	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value
Hydrology																															
Water Supply	35	0	0	0	0	0	0	0	0	1	35	3	105	1	35	1	35	1	35	1	35	1	35	1	35	1	35	1	35	1	35
Water Quality	3	5	15	5	15	5	15	5	15	5	15	5	15	5	15	5	15	5	15	5	15	5	15	5	15	5	15	5	15	5	15
Water Rights	5	5	25	5	25	5	25	5	25	5	25	5	25	10	50	10	50	10	50	10	50	10	50	10	50	10	50	10	50	10	50
Conveyance Loss	5	8	40	2	10	4	20	0	0	6	30	7	35	10	50	10	50	10	50	10	50	10	50	10	50	10	50	10	50	10	50
Competing Use	2	9	18	3	6	2	4	0	0	7	14	8	16	10	20	10	20	10	20	10	20	10	20	10	20	10	20	10	20	10	20
Subtotal:	50		98		56		64		40		119		196		170		170		170		170		170		170		170		170		170
Engineering																															
Construction Cost	5	8	40	0	0	0	0	0	0	3	15	0	0	4	20	0	0	0	0	0	0	10	50	10	50	10	50	9	45	10	50
OMR&E Cost	7	9	63	8	56	7	49	8	56	9	63	0	0	10	70	10	70	7	49	6	42	10	70	10	70	10	70	10	70	10	70
Constructability	1	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0	0	0	0	10	10	10	10	10	10	10	10	10	10
Land / Right-of-Way	2	0	0	0	0	0	0	0	0	0	0	5	10	10	20	10	20	10	20	10	20	10	20	10	20	10	20	10	20	10	20
Subtotal:	15		108		61		54		61		83		15		115		90		69		62		150		150		150		145		150
Environmental																															
Wetland Habitat	20	0	0	0	0	0	0	0	0	0	0	1	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Terrestrial Wildlife Habitat	5	8	40	0	0	0	0	0	0	6	30	9	45	2	10	10	50	10	50	10	50	9	45	9	45	8	40	7	35	8	40
Subtotal:	25		40		0		0		0		30		65		10		50		50		50		45		45		40		35		40
Socioeconomic																															
Construction Impact	1	3	3	2	2	1	1	1	1	3	3	5	5	7	7	6	6	6	6	5	5	8	8	8	8	8	8	8	8	8	8
Relocations (Residential)	1	10	10	10	10	0	0	0	0	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Recreation	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cultural Resources	2	5	10	1	2	9	18	9	18	1	2	9	18	9	18	9	18	9	18	9	18	5	10	5	10	9	18	9	18	1	2
Subtotal:	5		23		14		19		19		15		34		35		34		34		33		28		28		36		36		20
Land Use																															
Agriculture Activities	1	10	10	10	10	0	0	0	0	6	6	8	8	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Prime Farmlands	2	10	20	10	20	0	0	3	6	9	18	8	16	10	20	10	20	10	20	10	20	10	20	10	20	10	20	10	20	10	20
Oil & Gas Facilities	1	5	5	10	10	10	10	10	10	10	10	9	9	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Highway / Roads	1	10	10	8	8	1	1	0	0	10	10	9	9	5	5	5	5	9	9	9	9	10	10	10	10	10	10	10	10	10	10
Subtotal:	5		45		48		11		16		44		42		45		45		49		49		50		50		50		50		50
Total Value:			**314**		**179**		**148**		**136**		**291**		**352**		**375**		**389**		**372**		**364**		**443**		**443**		**446**		**436**		**430**

Notes:

(1) Total Weight is equal to 100.

(2) Basis for Scoring is outlined in Table IX-1.

(3) Value = Weight x Score.

Table IX - 18 (continued)

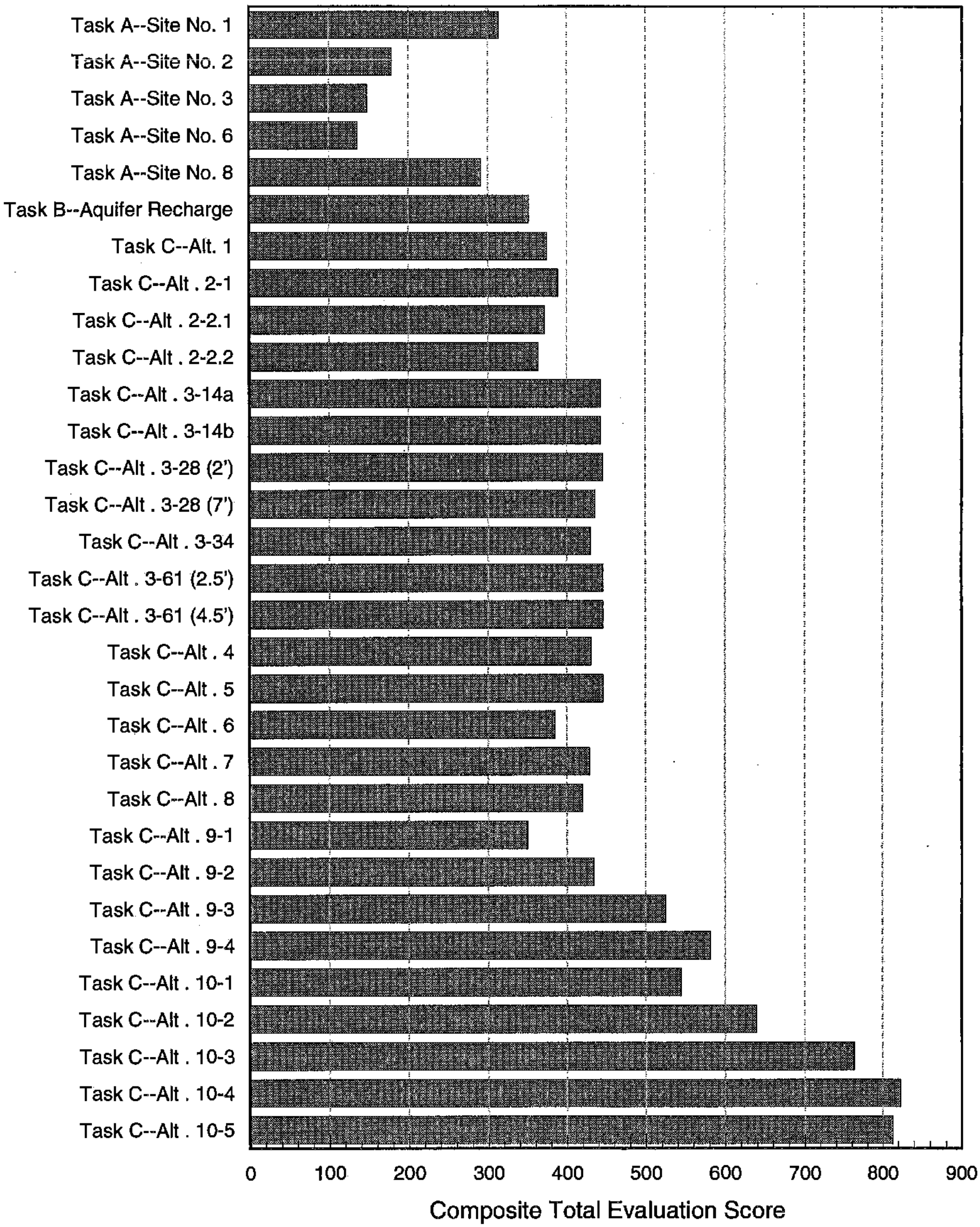
PHASE 1 - PRELIMINARY SCREENING OF WATER RESOURCE ALTERNATIVES

Criterion	Weight (1)	Task C (continued)																															
		Alt 3-61 (2.5')		Alt 3-61 (4.5')		Alt 4		Alt 5		Alt 6		Alt 7		Alt 8		Alt 9-1		Alt 9-2		Alt 9-3		Alt 9-4		Alt 10-1		Alt 10-2		Alt 10-3		Alt 10-4		Alt 10-5	
		Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value
Hydrology																																	
Water Supply	35	1	35	1	35	1	35	1	35	1	35	1	35	0	0	2	70	5	175	7	245	8	280	4	140	6	210	9	315	10	350	10	350
Water Quality	3	5	15	5	15	5	15	5	15	5	15	5	15	5	15	10	30	10	30	10	30	10	30	0	0	0	0	0	0	0	0	0	0
Water Rights	5	10	50	10	50	10	50	10	50	10	50	10	50	10	50	0	0	0	0	0	0	0	0	5	25	5	25	5	25	5	25	5	25
Conveyance Loss	5	10	50	10	50	10	50	10	50	10	50	10	50	10	50	9	45	9	45	9	45	9	45	8	40	8	40	7	35	7	35	7	35
Competing Use	2	10	20	10	20	10	20	10	20	10	20	10	20	10	20	5	10	5	10	5	10	5	10	9	18	9	18	8	16	8	16	8	16
Subtotal:	50		170		170		170		170		170		170		135		155		260		330		365		223		293		391		426		426
Engineering																																	
Construction Cost	5	9	45	9	45	7	35	9	45	3	15	8	40	9	45	0	0	0	0	0	0	0	0	8	40	6	30	3	15	2	10	0	0
OMR&E Cost	7	10	70	10	70	10	70	9	63	10	70	10	70	10	70	6	42	0	0	0	0	0	0	8	56	7	49	7	49	6	42	6	42
Constructability	1	10	10	10	10	5	5	10	10	2	2	10	10	10	10	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Land / Right-of-Way	2	10	20	10	20	10	20	10	20	10	20	10	20	10	20	5	10	5	10	5	10	5	10	5	10	5	10	5	10	5	10	5	10
Subtotal:	15		145		145		130		138		107		140		145		57		15		15		15		111		94		79		67		57
Environmental																																	
Wetland Habitat	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	20	2	40	3	60	4	80	4	80	6	120	8	160	10	200	10	200
Terrestrial Wildlife Habitat	5	9	45	9	45	10	50	10	50	9	45	10	50	10	50	8	40	8	40	8	40	8	40	9	45	9	45	9	45	8	40	8	40
Subtotal:	25		45		45		50		50		45		50		50		60		80		100		120		125		165		205		240		240
Socioeconomic																																	
Construction Impact	1	8	8	8	8	6	6	8	8	4	4	10	10	10	10	6	6	6	6	6	6	6	6	7	7	7	7	6	6	6	6	6	6
Relocations (Residential)	1	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Recreation	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	3	3	4	4	4	4	6	6	8	8	10	10	10	10
Cultural Resources	2	9	18	9	18	10	20	10	20	1	2	1	2	10	20	9	18	9	18	9	18	9	18	9	18	9	18	9	18	9	18	9	18
Subtotal:	5		36		36		36		38		16		22		40		35		36		37		38		39		41		42		44		44
Land Use																																	
Agriculture Activities	1	10	10	10	10	10	10	10	10	10	10	9	9	10	10	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Prime Farmlands	2	10	20	10	20	10	20	10	20	10	20	9	18	10	20	9	18	9	18	9	18	9	18	9	18	9	18	9	18	9	18	9	18
Oil & Gas Facilities	1	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Highway / Roads	1	10	10	10	10	5	5	10	10	7	7	10	10	10	10	6	6	6	6	6	6	6	6	9	9	9	9	9	9	9	9	9	9
Subtotal:	5		50		50		45		50		47		47		50		43		43		43		43		46		46		46		46		46
Total Value:			**446**		**446**		**431**		**446**		**385**		**429**		**420**		**350**		**434**		**528**		**581**		**544**		**639**		**763**		**823**		**813**

Table IX - 19

RANKING OF ALTERNATIVES FOR QUIVIRA NWR

Alternative		Total Value
Task C	Alt 10-4	823
Task C	Alt 10-5	813
Task C	Alt 10-3	763
Task C	Alt 10-2	639
Task C	Alt 9-4	581
Task C	Alt 10-1	544
Task C	Alt 9-3	525
Task C	Alt 3-28 (2')	446
Task C	Alt 3-61 (4.5')	446
Task C	Alt 3-61 (2.5')	446
Task C	Alt 5	446
Task C	Alt 3-14b	443
Task C	Alt 3-14a	443
Task C	Alt 3-28 (7')	436
Task C	Alt 9-2	434
Task C	Alt 4	431
Task C	Alt 3-34	430
Task C	Alt 7	429
Task C	Alt 8	420
Task C	Alt 2-1	389
Task C	Alt 6	385
Task C	Alt 1	375
Task C	Alt 2-2.1	372
Task C	Alt 2-2.2	364
Task B	Recharge Area	352
Task C	Alt 9-1	350
Task A	Site No. 1	314
Task A	Site No. 8	291
Task A	Site No. 2	179
Task A	Site No. 3	148
Task A	Site No. 6	136



Burns & McDonnell

Figure IX-1

PHASE I PRELIMINARY SCREENING SUMMARY

D. PHASE 2 - FINAL ALTERNATIVE SCREENING

The Phase 2 - Final Alternative Screening process focuses on the three highest ranked alternatives—Task C, Alternatives 10-3, 10-4 and 10-5. The analysis is designed to determine the alternative with the highest potential to effectively and efficiently increase the water supply to the Refuge.

Task C, Alternatives 10-3, 10-4 and 10-5 are evaluated in Phase 2 for their ability to meet the Services' desired moist soil management approach for the Refuge. Each alternative is evaluated with the operations model simulating the moist soil management approach for the following criteria:

- Quantity of supply above baseline.
- Cost per unit of water.
- Amount of wetland habitat available 80 percent of the time above the baseline.

The management objective of the Refuge, as described in Section IX.B, is to provide and enhance habitat for threatened or endangered species and waterfowl during their semi-annual migrations. Another objective is to provide and enhance natural diversity of other wildlife, protect the ecosystem and provide public recreational opportunities. To meet these objectives, the Refuge must provide flooded wetlands and marshes for threatened or endangered species, waterfowl and wildlife foraging, drinking, resting, and safety.

The Refuge is currently managed to provide the optimum habitat possible based on the limited water supply from Rattlesnake Creek. The availability of water for the Refuge can vary dramatically from year to year, averaging about 60 percent of their adjudicated water right. Refuge management currently involves diverting as much water as possible during stream flow events to insure water availability during the migratory seasons. Due to these less than desirable water supply conditions, the Refuge employs the following management practices:

- Filling management units during the August to April period below optimal levels, but up to levels that provide satisfactory threatened or endangered species and waterfowl habitat. This allows the available water to be used to provide satisfactory habitat on more units.

- Filling management units during the August to April period in a prioritized fashion to provide satisfactory habitat in the filled units in lieu of filling more units to unsatisfactory water levels.
- Filling and maintaining management units deeper than desired for threatened or endangered species or waterfowl habitat to store water for use in other units during high wildlife use periods.
- Storing water in management units longer than desired during the late spring and summer to increase the likelihood of having water in the units during the August to April period.
- Keeping water on units during the summer months to maintain soil moisture in the units and canals to reduce seepage losses during the August and September filling period.
- Filling smaller, deeper units during the late spring and/or summer to reduce evaporation losses.

By implementing these practices, Refuge personnel balance a variable water supply with the need to provide quality habitat for migrating species. These practices limit the ability of Refuge personnel to drain management units to promote the growth and development of moist soil plants that would provide higher quality habitat through the growth of abundant, high quality forage. The prolonged inundation of management units at shallow water levels increases the potential for encroachment by cattails and results in the need to continually implement control measures. As a result of the variable water supply, Refuge management units provide a lower quality habitat that requires more management efforts dedicated to the control of cattails.

Service personnel identified moist soil management as their preferred Refuge management approach. Moist soil management is designed to provide higher quality habitat and reduce the need for cattail control. This approach is used during the modeling and evaluation of the water supply plans to compare existing Refuge management and the desired Refuge management methods with the existing water supply and the proposed supplemental water supply.

Selected Refuge management units will not be managed as moist soil areas. Little Salt Marsh, Big Salt Marsh and Units 14a, 23, 26, 49, 58, 61, and 62 would be managed according to existing Refuge management methods. These units provide water storage for the Refuge as well as brood habitat for waterfowl and habitat for threatened or endangered species and diving ducks during seasonal migrations.

All remaining units would be managed as moist soil areas. Under these conditions, units would be drained or water would be allowed to evaporate or soak into the ground so the units would be dry by late spring or early summer (May to June). Abundant soil moisture would be present during the growing season to promote the growth of moist soil species such as smartweeds, knotweeds, cutgrasses, sedges, barnyard grass, millet, and numerous other species that would provide high quality forage. Because no additional water would normally be added to the units other than rainfall, the units would remain relatively dry throughout the summer, enabling growth and development of moist soil species while inhibiting cattail growth.

Moist soil units would be flooded beginning in early to mid-August, following the growth, development, and seed production of the vegetation within each unit. Units would be flooded to an average depth of 12 inches, providing a range of depth within any given unit of approximately 0 to 24 inches. All units would be filled by October 1. Water would be added to units throughout the fall, winter, and early spring (October through February) to maintain these water levels; however, the need to add water is expected to be minimal due to reduced evaporation rates and periodic ice cover during this period. After March 1, the need to maintain water levels would decline and no additional water would normally be added to the moist soil units. If necessary, units could be drained beginning in mid-March so the units would be dry by May 1. This process would be repeated each year for the moist soil units.

As previously stated, Little Salt Marsh, Big Salt Marsh, and Units 14a, 23, 26, 49, 58, 61, and 62 provide water storage and would continue as such in existing management practices. However, even these units would generally be allowed to naturally draw down during the growing season (April through July) to promote growth of moist soil species and inhibit cattail growth around the perimeter of the unit. Water would be provided as necessary to maintain some area of open water habitat within the units throughout the summer for brood rearing. Periodic cattail control measures would be required which could include rotating storage units out of service. Control measures involve draining the unit in February, burning the unit in March or April depending on weather conditions, and discing the unit up to three times during the summer and fall. In addition, the unit would be kept dry during the subsequent winter and would be refilled in February.

Units not scheduled for cattail control would have open water areas maintained throughout the summer for, as an example, puddle duck brood habitat. These units would be filled and the water levels raised during the fall, winter and early spring to provide deeper water habitat for diving ducks and roosting areas for a variety of species of ducks and geese.

The operations model for the various water management or development alternatives (described in Parts III through VII) is revised for use in Task E to reflect the Refuge's preferred moist soil management approach. This revision is accomplished by modifying the storage level and priority data in the operations model for the proposed moist soil units. The 26 units that are proposed for moist soil management are listed in Table IX-20.

As described above, the units included in the moist soil management approach will be drained during March and April. In the operations model, half of the moist soil units, those located in the southern portion of the Refuge, are drained during March. The remaining moist soil units are drained during April. These units are allowed to remain dry until the first of August. Any local inflow to or direct precipitation on these units is also drained off during the summer months. In August and September, the moist soil units are re-flooded. These units in the southern half of the Refuge are filled in August while those in the northern half of the Refuge are filled in September. The moist soil units are then maintained at their desired average water depth of 12 inches through the end of February when the cycle repeats.

There are times during the simulation period for the operations model when there may not be sufficient water available to maintain the desired average water depth of 12 inches. In the revised operations model, there are three operating regimes identified for each moist soil unit. The lowest regime extends from empty to the storage volume that achieves an average depth of 10 inches. The middle storage regime contains the incremental storage required to bring the average depth in each moist soil unit up to 12 inches. The top storage regime extends from the top of the middle regime up to the maximum storage level for each unit.

Table IX-20
PROPOSED MOIST SOIL MANAGEMENT UNITS

Moist Soil Management Units		
Unit 7	Unit 25	Unit 48
Units 10a & 10b	Unit 28	Unit 51–Rattlesnake Canal Berm
Units 10c & 11	Unit 29	Unit 57–East Lake
Unit 14b	Unit 30	Unit 63
Unit 14c	Unit 34	Unit 78
Unit 16	Unit 37–Dead Horse Slough	Unit 80
Units 20a & 20b	Unit 39–Dead Horse Slough	Unit 81
Unit 21	Unit 40	Unit 83–North Lake
Unit 22	Unit 44–Salt Flats	

In the operations model, the storage priorities for the moist soil units are specified so each is first filled up to the 10-inch average depth level, progressing from south to north on the Refuge. During times with limited water supplies, there may be insufficient water to re-flood the units at the north end of the Refuge. Once the 10-inch average depth is attained in all moist soil units, these units are brought up to their desired operating levels, which correspond to the top of the middle storage zone. Any water in the top storage zone is evacuated as soon as practical to maintain the desired average water depths.

Using the preferred moist soil management approach, the baseline and ultimate water need models for the Refuge described in Part IV are revised. The results of these model runs are summarized in Table IX-21.

Three of the supplemental groundwater supply alternatives are selected for additional evaluation in Phase 2. Alternatives C.10-3, C.10-4 and C.10-5 have the capacity to provide respectively 1,500, 2,000, and 2,500 acre-feet of water per month to the Refuge. The supplemental groundwater wells are assumed to be available for operation over a six-month period from August through January.

Table IX-21
BASELINE AND ULTIMATE WATER NEEDS
WITH PROPOSED MOIST SOIL MANAGEMENT

Data Type	Statistic	Baseline	Ultimate Usage	Difference
Annual Refuge Diversions (acre-feet)	Range	1,170 - 9,680	7,290 - 17,770	6,120 - 8,090
	Average	5,140	13,780	8,640
Shorebird Habitat (acres)	Range	67 - 730	620 - 730	553 - 0
	Average	330	690	360
	80th Percentile	210	670	460
Waterfowl Habitat (acres)	Range	20 - 1,040	870 - 1,060	850 - 20
	Average	510	960	450
	80th Percentile	330	950	620
Total Wetland Habitat (acres)	Range	680 - 5,060	3,720 - 5,060	3,040 - 0
	Average	2,400	4,770	2,370
	80th Percentile	1,500	4,800	3,300

Each of these three alternatives are evaluated using the modified operations model. Results from the evaluation included information on the increase in average diversion, the increase in wetland habitat available 80 percent of the time, and impacts on cost indicators and benefit-cost ratios for the Refuge. These results are shown in Table IX-22. Review of this table shows Alternative C.10-3, supplemental groundwater providing up to 1,500 acre-feet per month, provides an average annual diversion (with natural flow from Rattlesnake Creek) of 10,360 acre-feet per year, 3,530 acres of wetland habitat 80 percent of the time and has the highest benefit-cost ratio compared to Alternatives C.10-4 and C.10-5. The average annual diversion of 10,360 acre-feet per year is an increase of 5,220 acre-feet per year over the baseline diversion of 5,140 acre-feet per year. The wetland habitat available 80 percent of the time of 3,530 acres is an increase of 2,030 acres over the baseline of 1,500 acres. Based on the review of the diversion, wetlands acreage and cost parameters, Alternative C.10-3 provides the greatest benefit to the Refuge for the least amount of capital and operating funds and is therefore selected for use in WSPs 2 and 3.

Table IX-22
SUMMARY OF PHASE 2 ALTERNATIVES EVALUATION

Alternative	Average Diversion (ac-ft/yr)	Wetlands 80 % of Time (ac)	Project Cost ($million)	OMR&E ($1000/yr)	Project Cost Present Value ($million)	Wetlands Present Value ($million)	Avg. Life Cycle Present Value ($/MG)	B/C Ratio
C.10-3	10,360	3,530	3.5	117	5.2	18.4	78	3.54
C.10-4	10,810	3,750	4.3	132	6.3	20.3	90	3.22
C.10-5	11,130	3,920	5.3	145	7.5	21.9	104	2.92

Note: 1. Baseline for wetland acreage is 1,500 acres 80 percent of the time.

E. PHASE 3 - WATER SUPPLY PLANS

1. General

Based on the Phase 1 and 2 alternative screening process and comments received from the Service, three water supply plans are developed. To provide the best habitat for migrating bird populations, the Service would prefer to manage more units on the Refuge as moist soil areas. Each of the three water supply plans are developed using this moist soil management system. WSP1 also includes the optimized Alternatives 8, 3, 1 and 4 in that order of preference as stated by the Service. WSP1 utilizes on-site alternatives for the Refuge that improve the existing management of the Refuge. WSP2 is strictly an off-site alternative that provides supplemental water to the Refuge to manage existing units. WSP3 is a combination of WSP1 and WSP2. The operations model discussed above is used to optimize WSP1 and WSP3 to determine which alternatives provide the most benefit to the Refuge for the associated costs. Each water supply plan is discussed in the following sections.

WSP1 includes four on-site Refuge alternatives. Those on-site alternatives are 8, 3, 1 and 4 in that order of preference as stated by the Service. Alternative 8 fills the borrow areas in several units to their original grade to reduce water requirements and provide a variety of waterfowl habitats. Alternative 3 increases storage by 2,250 acre-feet by raising existing water surface elevations in Units 14a, 28 and 61. Alternative 3 originally included Units 14b and 34; however, Refuge personnel expressed a desire to manage Unit 14b in conjunction with 14a as a moist soil unit. Unit 34 was eliminated due to inadequate storage capabilities. Alternative 1 raises the existing water surface elevation in Little Salt Marsh two feet and adds 1,940 acre-feet of potential water supply storage. Alternative 4 includes the lining of 13 miles of major conveyance canals in the Refuge to conserve water. In this plan, the Refuge is managed using the moist soil management approach using existing water supplies that average about 9,000 acre-feet per year. No additional water is available for use on the Refuge in this plan.

WSP2 includes Alternative 10 which provides an off-Refuge groundwater supply from supplemental wells located along Rattlesnake Creek west of Little Salt Marsh. This alternative delivers additional water to the Refuge to support the moist soil management approach. Implementation of this plan requires consultation with the Kansas Department of Agriculture - Division of Water Resources (KDWR), and the Big Bend Groundwater Management District No. 5 (GMD5) concerning water rights, and the Kansas Department of Health and Environment (KDHE) and GMD5 for water quality and mineral intrusion concerns. Concerns for mineral intrusion involve the potential salt water migration into fresh water parts of the aquifer caused by pumping wells at excessively high rates.

WSP3 includes both on-Refuge and off-Refuge alternatives by combining WSPs 1 and 2. This water supply plan optimizes the two alternatives and shows the benefits of providing supplemental water wells for the Refuge's moist soil management approach. This plan also requires the approval of KDWR and GMD5 for water rights and KDHE and GMD5 for water quality and mineral intrusion concerns.

2. Water Supply Plan 1

a. Components of Plan

A schematic showing the selected components of WSP1 is shown in Figure IX-2. On-Refuge Alternatives 3 and 1 provide additional water storage and Alternatives 8 and 4 conserve water for use in the Refuge management units.

Alternative 8 involves filling in borrow areas in Units 26, 28, 29, 30, 40, 48, 49 and 63 such that only two feet of water exists in the units. By filling in the borrow areas, less water is needed to inundate various waterfowl and shorebird habitats in the unit. Water that is no longer needed to fill the borrow

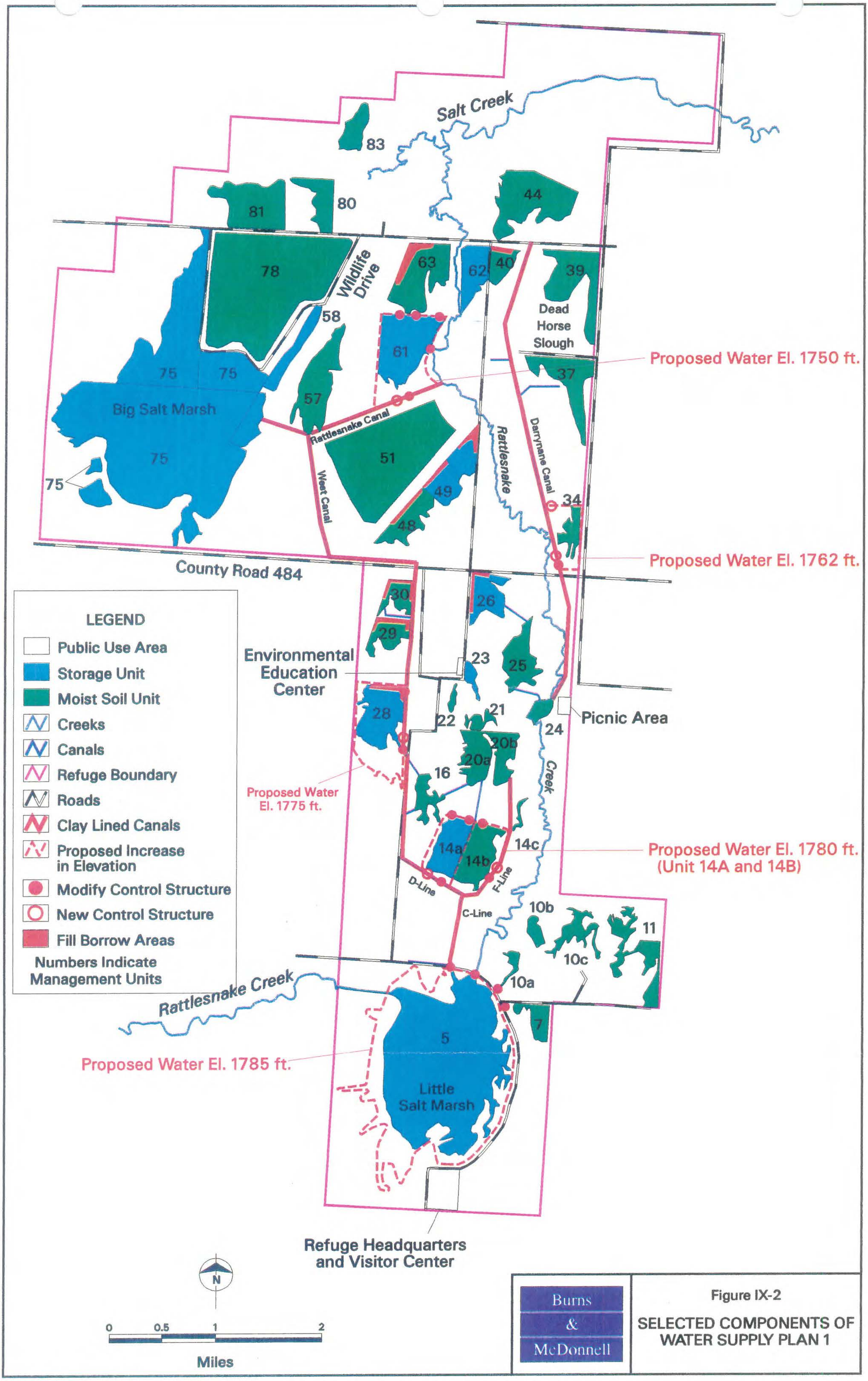


Figure IX-2

SELECTED COMPONENTS OF WATER SUPPLY PLAN 1 areas can be used in other units of the Refuge, thereby increasing the overall efficiency of the existing water supply.

Alternative 3 modifies Units 14a, 28 and 61 by raising the dikes respectively 2.0, 7.0 and 4.5 feet. By raising the existing dikes, the water storage capacity is increased in each of the units. This additional water can be used in the management of downstream units as desired. Units 14b and 34 are eliminated from this alternative since they are more appropriately used as moist soil management units, and not as a potential water supply. Alternative 3 adds the following major construction components to WSP1:

- Construct 13,350 linear feet of new dikes.
- Raise 26,700 linear feet of existing dikes.
- Replace 11 existing water control structures.
- Construct new control structures in D-line, West, and Rattlesnake Canal.

Alternative 1 raises the existing dikes in Little Salt Marsh (Unit 5) about 2 feet to increase water storage capacity. The major components of this alternative are:

- Raise 6,900 linear feet of existing dikes.
- Construct 2,200 linear feet of new dikes.
- Construct 8,500 linear feet of gravel road on top of dike.
- Construct four new water control structures.
- Construct two new concrete spillways.

Alternative 4 includes lining 13 miles of major conveyance canals in the Refuge to reduce the loss of water delivered to the various management units. An impervious clay barrier will be used as lining material in lieu of a geofabric. A geofabric would be more subject to damage and more difficult to repair than a clay barrier. This alternative includes the following major components.

- Construct 3,900 linear feet of clay liner in C-line canal.
- Construct 4,150 linear feet of clay liner in D-line canal.

- Construct 5,000 linear feet of clay liner in F-line canal.
- Construct 25,500 linear feet of clay liner in West canal.
- Construct 8,200 linear feet of clay liner in Rattlesnake canal.
- Construct 21,300 linear feet of clay liner in Darrynane canal.

b. Operations Modeling

Three options of WSP1 are evaluated with the operations model modified for the moist soil management to determine an optimized version of the plan. The three options evaluated are as follows:

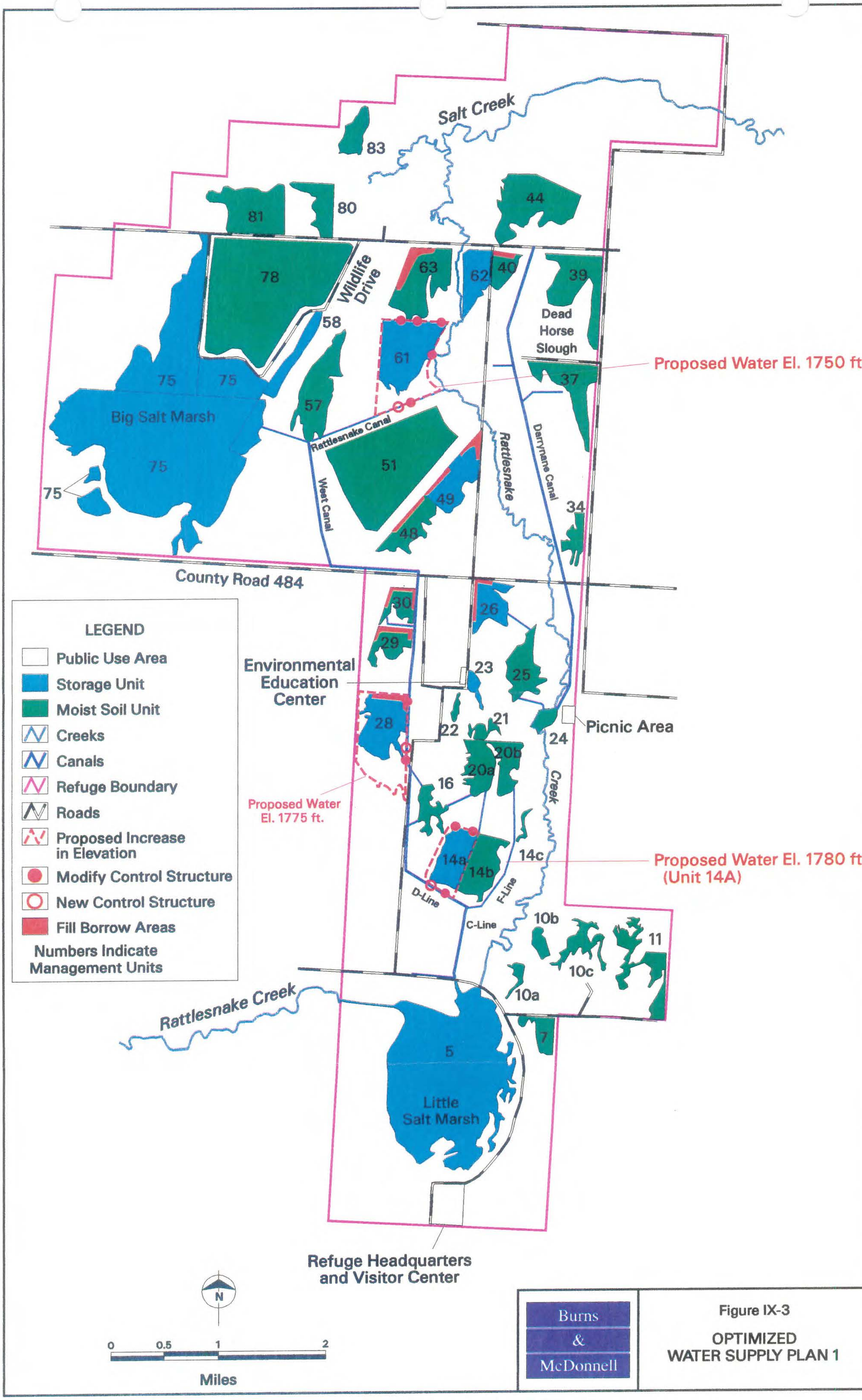
- WSP1a - Alternatives 8 and 3.
- WSP1b - Alternatives 8, 3 and 1.
- WSP1c - Alternatives 8, 3, 1 and 4.

WSP1a includes filling borrow areas and increasing water storage capacity on the Refuge. The plan allows average annual diversions of 6,350 acre-feet per year for the Refuge, an additional 1,210 acre-feet per year over baseline due to increased available storage. It also increases wetland habitat available 80 percent of the time to 1,630 acres, 130 acres over baseline.

WSP1b allows average annual diversions of 6,990 acre-feet per year for the Refuge, an additional 1,850 acre-feet per year over baseline due to increased available storage. The plan also increases wetland habitat available 80 percent of the time to 1,570 acres, 70 acres over baseline.

WSP1c allows average annual diversions of 6,850 acre-feet per year for the Refuge, an additional 1,710 acre-feet per year over baseline due to increased available storage. Diversions are less under WSP1c as compared to WSP1b because lining the major conveyance canals reduces canal losses and, therefore, less water must be diverted to satisfy Refuge needs. The plan also increases wetland habitat available 80 percent of the time to 1,610 acres, 110 acres over baseline.

WSP1a is the optimized version of WSP1 and is shown in Figure IX-3. WSP1a includes on-Refuge Alternatives 8 and 3.



Burns & McDonnell

Figure IX-3

OPTIMIZED WATER SUPPLY PLAN 1

c. Water Quality

The source of water for these alternatives is Rattlesnake Creek, the Refuge's current water source. Increasing the storage capacity or improving the water use efficiency on the Refuge would not adversely impact the water quality in the Refuge.

d. Environmental and Cultural Resource Impacts

Impacts to environmental and cultural resources in and around the Refuge are evaluated for WSP1. Potential impacts resulting from construction and operation of the individual on-Refuge Alternatives 8 and 3 are discussed in detail in Part VII (Task C) of this report.

Potential environmental and cultural resource impacts for WSP1 include temporary disturbance to wildlife during construction and semi-permanent to permanent changes in the amount and type of habitat available on the Refuge. The environmental impacts for WSP1 are summarized in Table IX-23 and the habitat provided is summarized in Table IX-21.

Construction and implementation of WSP1 provides approximately 1,600 acres of wetland habitat on the Refuge 80 percent of the time. This represents an increase of approximately 100 acres over the current baseline condition. WSP1 would convert 40 acres from deeper open water habitat to shallow water habitat, facilitating the management of up to 660 acres as moist soil area included as part of the revised operations plan. The increase in the amount of dependable wetland habitat (100 acres) also includes a much greater amount of moist soil area than currently available on the Refuge on a dependable basis.

TABLE IX-23
ENVIRONMENTAL CHARACTERISTICS OF WATER SUPPLY PLAN 1

Alternative		Impact		Habitat Provided
		Construction	Operation	
1		-temporary distrubance to wildlife -temporary displacement of wildlife -temporary inconvenience to visitors -potential to disturb significant cultural resource sites	-loss of 440 acres grassland/moist soil -creation 440 acres shallow water habitat -creation of 20 acres open water -provide 1,500 acres of wetland habitat 80% of the time	-670 acres open water -630 acres shallow water
3	14a	-temporary disturbance to wildlife -temporary displacement of wildlife -moderate potential for cultural resources	-loss of 30 acres grassland/moist soil -creation 30 acres shallow water habitat -creation of 11 acres open water -provide 1,500 acres of wetland habitat 80% of the time	-56 acres open water -64 acres shallow water
	28	-temporary disturbance to wildlife -temporary displacement of wildlife -low potential for cultural resources	-loss of 105 acres grassland/moist soil -creation 105 acres shallow water habitat -creation of 64 acres open water -provide 1,500 acres of wetland habitat 80% of the time	-70 acres open water -120 acres shallow water
	61	-temporary disturbance to wildlife -temporary displacement of wildlife -low potential for cultural resources	-loss of 20 acres grassland/moist soil -creation of 220 acres open water -provide 1,500 acres of wetland habitat 80% of the time	-240 acres open water
4		-temporary disturbance to wildlife -temporary displacement of wildlife -temporary removal of vegetated, shallow water habitat -temporary inconvenience to visitors -low potential for cultural resources	-provide 1,500 acres of wetland habitat 80% of the time	N/A
8		-temporary disturbance to wildlife -temporary displacement of wildlife	-loss of 42 acres of open water -creation 42 acres shallow water habitat -allow management of up to 655 acres as moist soil habitat -provide 1,500 acres of wetland habitat 80% of the time	-655 acres of shallow water, moist soil or combination of the two

WSP1 would allow Refuge managers to vary the location of wetland habitat and moist soil areas receiving water throughout the Refuge by providing additional areas for water storage while reducing the water needs of the Refuge through the filling of borrow areas. Available water could be rotated to create, enhance or maintain Refuge wetlands; however, the total number of wetlands receiving water on the Refuge would not change. This plan would increase wetland management flexibility as maintenance or vegetation control activities are needed on management units. Some management units, for example, could be kept dry for extended periods to control cattails while maintaining other areas for wetland habitat. However, the wetland habitat available at the 80th percentile (1,610 acres) is significantly below the maximum wetland capacity of the Refuge, 6,138 acres. This plan would improve the flexibility of Refuge operations but does not represent a significant improvement to Refuge wetland habitat availability.

WSP1 would maximize the use of the existing water supply from Rattlesnake Creek by increasing the flexibility of management for Refuge personnel and allowing for the increase in moist soil units. WSP1 would provide alternative areas for wetlands during maintenance of other units, provide an opportunity to rotate wetlands, allow some units to develop a more dense and diverse vegetative cover and seed base by rotating from dry to wet for several years, or increase the amount of habitat available on the Refuge when water is abundant.

e. Project Cost Estimates

Project costs, operation and maintenance costs, present value and benefit-cost analysis for WSP1 are included below and used to select the best water supply plan for implementation.

1) Project Costs

The estimated project cost for WSP1a, WSP1b and WSP1c are respectively \$2.7, \$4.1 and \$6.0 million as listed in Table IX-24.

2) Operation and Maintenance (O&M) Costs

The operation and maintenance requirements of WSP1 will not require additional personnel. In fact, this alternative does not include any mechanical equipment which would require replacement or energy. Therefore, the additional O&M for this alternative is \$0.

Table IX-24

PROJECT COST ESTIMATE
WATER SUPPLY PLAN 1

Item	Option a Cost ($)	Option b Cost ($)	Option c Cost ($)
Alternative C.8 - Fill Borrow Areas	580,000	580,000	580,000
Alternative C.3 - Raise Dikes on Storage Units	1,320,000	1,320,000	1,320,000
Alternative C.1 - Raise Little Salt Marsh		970,000	970,000
Alternative C.4 - Line Conveyance Canals			1,320,000
Subtotal	1,900,000	2,870,000	4,190,000
Contingency at 20%	380,000	574,000	838,000
Subtotal	2,280,000	3,444,000	5,028,000
Other Costs at 20%	456,000	689,000	1,006,000
Total Project Cost	**2,736,000**	**4,133,000**	**6,034,000**

3) Present Value Analysis

The present value for WSP1a, WSP1b and WSP1c in 1998 dollars are respectively $2.5, $3.8, and $5.6 million. The average life cycle unit cost of water for WSP1a, WSP1b and WSP1c are respectively $61, $84 and $126 per MG over 20 years of operation based on present value.

4) Benefit-Cost Analysis

The benefit of 130, 70 and 110 acres of wetlands are estimated respectively for WSP1a, WSP1b and WSP1c at a 20 year present value of $1.2, $0.6 and $1.0 million. This results in respective benefit-cost ratios for WSP1a, WSP1b and WSP1c of 0.48, 0.16 and 0.18.

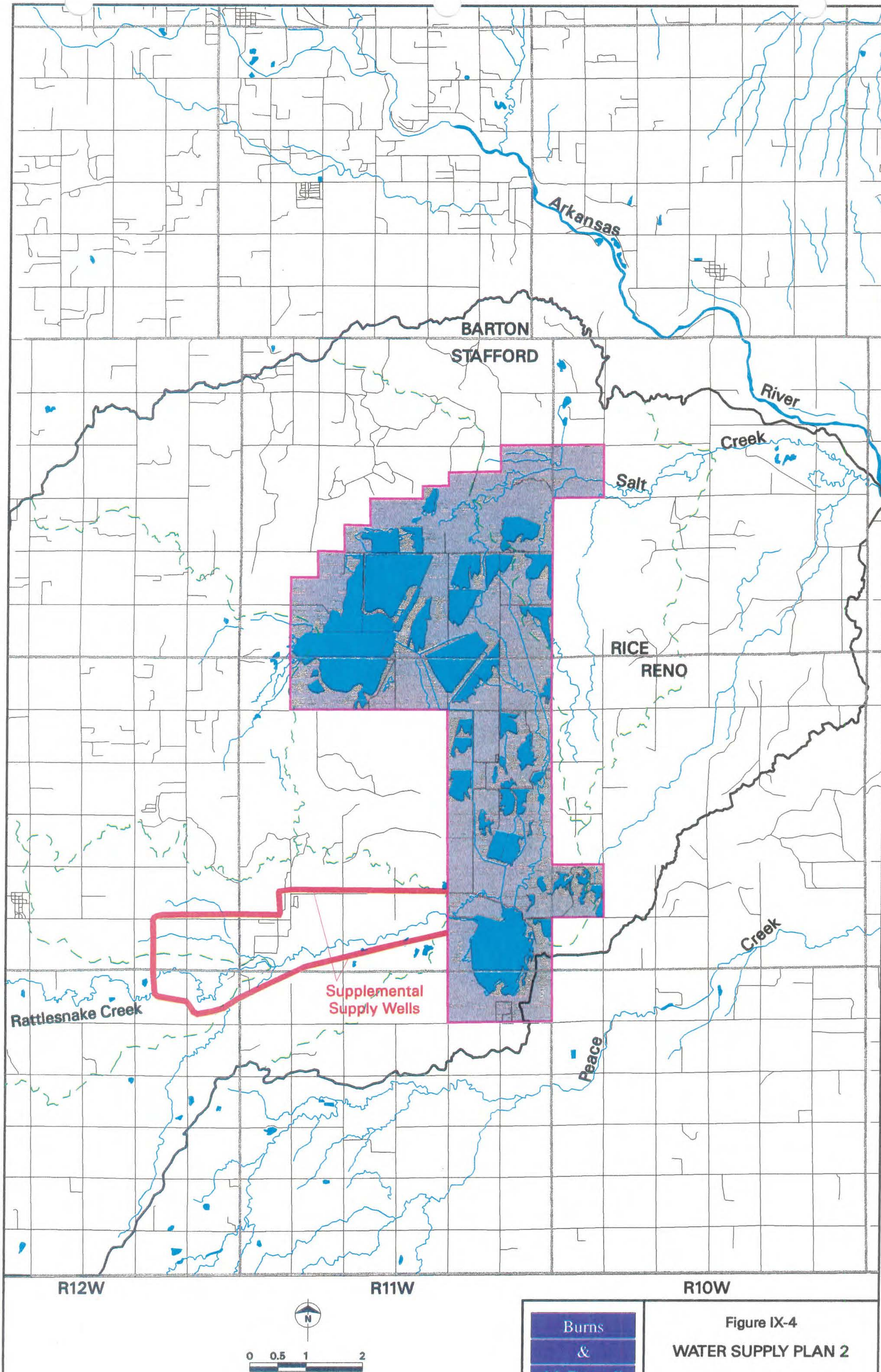
2. Water Supply Plan 2

a. Components of Plan

A schematic of WSP2 is shown in Figure IX-4. This plan includes a supplemental water supply to the Refuge using a series of 15 wells (14 pumping with 1 back-up) adjacent to Rattlesnake Creek and west of Little Salt Marsh. This plan utilizes off-Refuge wells spaced every quarter-mile, which pump would groundwater directly into Rattlesnake Creek on an as-needed basis. Each well would pump about 800 gallons per minute (gpm), providing an additional 1,500 acre-feet per month of flow into Little Salt Marsh or other units on the Refuge. To reduce the likelihood of mineral intrusion, the supplemental groundwater wells are assumed to operate a maximum of six months per year. Based on discussions with GMD5, the Service would have to deal with water right concerns under this plan.

b. Operations Modeling

The operations model is modified to evaluate WSP2 with Alternative C.10-3 supplying supplemental groundwater to the Refuge under the moist soil management scenario. WSP2 enables average annual diversions of 10,350 acre-feet per year to the Refuge, an additional 5,210 acre-feet per year over baseline. The plan also increases wetland available 80 percent of the time to 3,530 acres, 2,030 acres over baseline.



Burns & McDonnell

Figure IX-4

WATER SUPPLY PLAN 2

c. Water Quality

Water quality data for groundwater in the area are very limited. Review of KGS Open File Report 93-2 shows ambient groundwater has chloride concentrations ranging from 100 to 500 mg/L in the upper unconsolidated aquifer and 1,000 to 10,000 mg/L at the base of the unconsolidated aquifer in the area of Rattlesnake Creek upstream of the Refuge. Chlorides in the upper aquifer are significantly less than the mean chloride concentration of 1,925 mg/L in Little Salt Marsh. Based on review of available data and discussions with GMD5 staff, supplemental wells on quarter mile spacing should be capable of pumping a minimum of 800 gpm from the shallow aquifer. Clay layers exist between the upper and lower sections of the aquifer and should minimize up-coning of high chloride water from the lower aquifer into the upper aquifer. This must be confirmed with a series of soil borings, pump tests and water quality sampling and analysis to determine the long-term pumping impacts on water quality of the supplemental wells.

d. Environmental and Cultural Resource Impacts

The environmental and cultural resources impacts associated with construction and operation of WSP2 are discussed in detail for this alternative in Part VII, Task C. Table IX-25 summarizes the environmental characteristics of this water supply plan. The development and use of groundwater would have minimal environmental impact due to the ability to avoid environmental and cultural issues prior to construction. The primary impact would be the removal of a small amount of agricultural land to facilitate plan development.

TABLE IX-25
ENVIRONMENTAL CHARACTERISTICS OF WATER SUPPLY PLAN 2

Alternative	Impact		Habitat Provided
	Construction	Operation	
10-3	-conversion of cropland to well facilities -potential temporary interruption of agricultural activities -potential placement of pipelines and access road across agricultural lands -potential temporary disruption of traffic on local roadways	-provide 3,533 acres of wetland habitat 80% of the time under revised operations plan.	-418 acres shorebird habitat 835 acres waterfowl habitat

Operation of WSP2 would provide 3,532 acres of wetland habitat 80 percent of the time. This is 1,899 acres more than the maximum potentially provided under WSP1. However, it is only approximately one-half of the 6,138 acres of wetlands that are potentially available at the Refuge. The most significant difference between WSP1 and WSP2 would be an over 100 percent increase in the amount of additional wetlands or wetland habitat available 80 percent of the time over the baseline condition. The increased dependability provided by WSP2 would allow greater management flexibility, potentially enabling modifications to management units such as increased drawdown for cattail control and moist soil management. Units that normally would be used to store water could be drawn-down for maintenance or for moist soil management instead of restricting their use solely for storage.

e. Project Cost Estimates

Project costs, operation and maintenance costs, present value and benefit-cost analysis for WSP2 is included below and used to select the best water supply plan for implementation.

1) Project Costs

The estimated project cost for WSP2 is $3.5 million as listed in Table IX-26.

2) Operation and Maintenance (O&M) Costs

OMR&E costs include costs associated with the operation and maintenance, replacement of mechanical equipment every 10 years and energy for WSP2. OMR&E costs for WSP2 is $117,000 per year in the first year of operation and is inflated at 4 percent per year as listed in Table IX-27. These costs are used in combination with the project costs to calculate the present value for the alternative.

3) Present Value Analysis

The present value for WSP2 in 1998 dollars is $5.3 million as listed in Table IX-28. The average life cycle unit cost of water is $78 per MG over 20 years of operation based on present value.

4) Benefit-Cost Analysis

A benefit of 2,030 acres per year of additional wetlands is estimated at a respective 20 year present value of $18.3 million for WSP2. This results in a benefit-cost ratio of 3.45.

Table IX-26

PROJECT COST ESTIMATE
WATER SUPPLY PLAN 2

Item	Cost ($)
Testing Plan:	
Test Borings - 1 boring for every 2 wells	12,000
Pump Tests	180,000
Temporary Monitoring Wells - 10 per test	60,000
Water Quality Sampling and Analysis	60,000
Well, Pump and Controls:	
15 Wells with 25 cfs (16.0 MGD) capacity	1,125,000
Pipeline, Valves, Meter, Fence & Discharge	225,000
Test Drilling	33,000
Monitoring Wells	45,000
Electrical Power Supply	200,000
Access Road (10' wide gravel road)	416,000
Land and Right-of-way	46,000
Subtotal	2,402,000
Contingency at 20%	480,000
Subtotal	2,882,000
Testing Plan Other Costs	80,000
Other Costs at 20%	576,000
Total Project Cost	**3,538,000**

Table IX-27

OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
WATER SUPPLY PLAN 2

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	5.5	86,000		31,000	117,000
2001	5.5	89,000		32,000	121,000
2002	5.5	93,000		34,000	127,000
2003	5.5	97,000		35,000	132,000
2004	5.5	101,000		37,000	138,000
2005	5.5	105,000		38,000	143,000
2006	5.5	109,000		39,000	148,000
2007	5.5	113,000		41,000	154,000
2008	5.5	118,000		43,000	161,000
2009	5.5	123,000		44,000	167,000
2010	5.5	128,000	312,000	46,000	486,000
2011	5.5	133,000		48,000	181,000
2012	5.5	138,000		50,000	188,000
2013	5.5	144,000		52,000	196,000
2014	5.5	150,000		54,000	204,000
2015	5.5	156,000		56,000	212,000
2016	5.5	162,000		58,000	220,000
2017	5.5	168,000		61,000	229,000
2018	5.5	175,000		63,000	238,000
2019	5.5	182,000	444,000	66,000	692,000
Total	110.0	2,570,000	756,000	928,000	4,254,000

Notes:
(1) Average pumping rate is assumed to be continuous.
(2) O&M includes additional staff and materials, testing and operations.
(3) Replacement of equipment every 10 years.
(4) Energy costs are estimated at $.12/KWH.

Table IX-28

PRESENT VALUE ESTIMATE
WATER SUPPLY PLAN 2

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0				0	0
1999	0	3,680,000			3,439,000	3,439,000
2000	5.5		117,000	117,000	102,000	3,541,000
2001	5.5		121,000	121,000	99,000	3,640,000
2002	5.5		127,000	127,000	97,000	3,737,000
2003	5.5		132,000	132,000	94,000	3,831,000
2004	5.5		138,000	138,000	92,000	3,923,000
2005	5.5		143,000	143,000	89,000	4,012,000
2006	5.5		148,000	148,000	86,000	4,098,000
2007	5.5		154,000	154,000	84,000	4,182,000
2008	5.5		161,000	161,000	82,000	4,264,000
2009	5.5		167,000	167,000	79,000	4,343,000
2010	5.5		486,000	486,000	216,000	4,559,000
2011	5.5		181,000	181,000	75,000	4,634,000
2012	5.5		188,000	188,000	73,000	4,707,000
2013	5.5		196,000	196,000	71,000	4,778,000
2014	5.5		204,000	204,000	69,000	4,847,000
2015	5.5		212,000	212,000	67,000	4,914,000
2016	5.5		220,000	220,000	65,000	4,979,000
2017	5.5		229,000	229,000	63,000	5,042,000
2018	5.5		238,000	238,000	62,000	5,104,000
2019	5.5		692,000	692,000	167,000	5,271,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						**78**

3. Water Supply Plan 3

a. Components of Plan

A schematic showing the selected components of WSP3 is shown in Figure IX-5. This plan utilizes both the on-Refuge alternatives and an off-Refuge supplemental groundwater supply while maximizing the moist soil management strategy. The plan would provide supplemental water supply needed by the Refuge, to use its full annual water right, allow for increased water storage in several management units, and conserve water. Based on discussions with GMD5, the Service would have to deal with water right concerns for this plan.

b. Operations Modeling

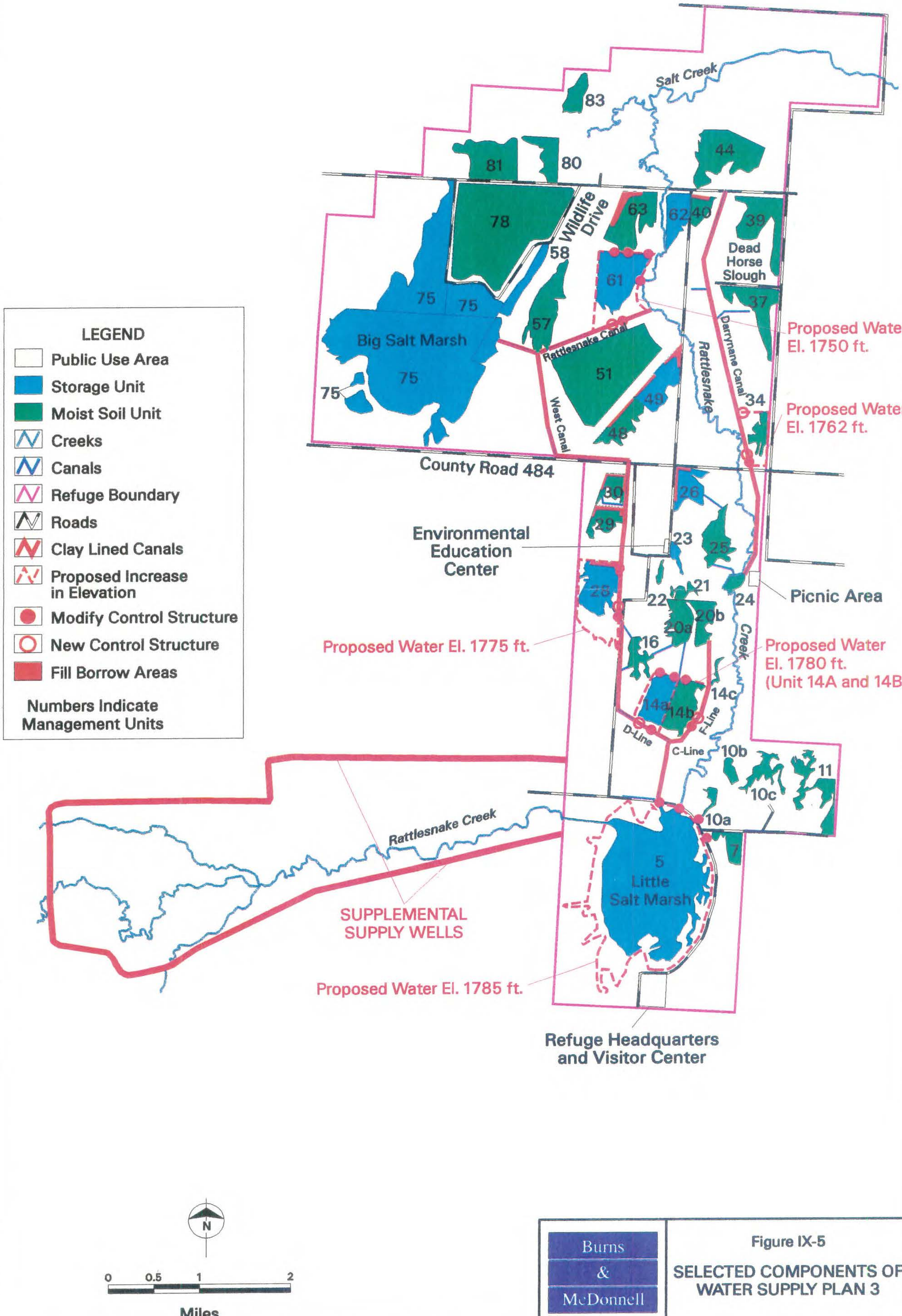
Three options of WSP3 are evaluated with the operations model modified for the moist soil management to determine an optimized version of the plan. The three options evaluated are as follows:

- WSP3a - Alternatives C10-3, 8 and 3.
- WSP3b - Alternatives C10-3, 8, 3 and 1.
- WSP3c - Alternatives C10-3, 8, 3, 1 and 4.

WSP3a enables average annual diversions of 12,160 acre-feet per year for the Refuge, an additional 7,020 acre-feet per year over baseline due to increased available storage and water availability. The plan also increases wetland habitat available 80 percent of the time to 3,860 acres, 2,360 acres over baseline.

WSP3b enables average annual diversions of 13,240 acre-feet per year for the Refuge, an additional 8,100 acre-feet per year over baseline due to increased available storage and water availability. The plan also increases wetland habitat available 80 percent of the time to 4,200 acres, 2,700 acres over baseline.

WSP3c enables average annual diversions of 12,600 acre-feet per year for the Refuge, an additional 7,460 acre-feet per year over baseline due to increased available storage and water availability. Diversions are less under WSP3c as compared to WSP3b because lining the major conveyance canals reduces canal losses and, therefore, less water must be diverted to satisfy Refuge needs. The plan also



Burns & McDonnell

Figure IX-5

SELECTED COMPONENTS OF WATER SUPPLY PLAN 3 increases wetlands and wetland habitat available 80 percent of the time to 4,340 acres, 2,840 acres over baseline.

WSP3a is the optimized version of WSP3 and is shown in Figure IX-6. WSP3a includes alternative C.10-3, 8 and 3.

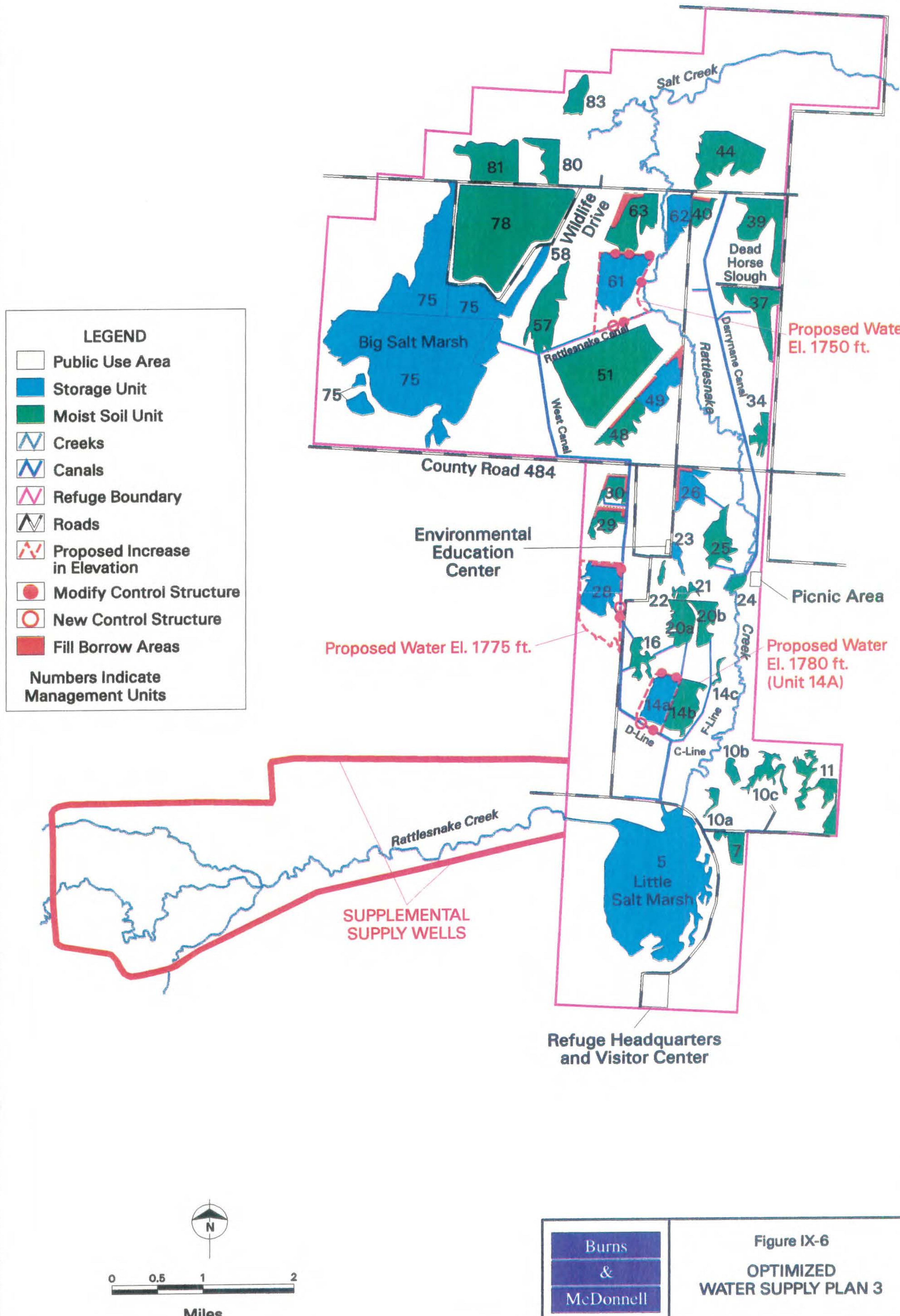
c. Water Quality

Water quality data for groundwater in the area are very limited. Review of KGS Open File Report 93-2 shows ambient groundwater has chloride concentrations ranging from 100 to 500 mg/L in the upper unconsolidated aquifer and 1,000 to 10,000 mg/L at the base of the unconsolidated aquifer in the area of Rattlesnake Creek upstream of the Refuge. Chlorides in the upper aquifer are significantly less than the mean chloride concentration of 1,925 mg/L in Little Salt Marsh. Based on review of available data and discussions with GMD5 staff, supplemental wells on quarter mile spacing should be capable of pumping a minimum of 800 gallons per minutes from the upper aquifer. Clay layers exist between the upper and lower sections of the aquifer and should minimize up-coning of high chloride water from the lower aquifer into the upper aquifer. This must be confirmed with a series of soil borings, pump tests and water quality sampling and analysis to determine the long-term pumping impacts on water quality of the supplemental wells.

d. Environmental and Cultural Resource Impacts

WSP3 is essentially a combination of WSP1 and WSP2. The potential environmental and cultural resource impacts for this water supply plan include the temporary disturbance to wildlife during construction, semi-permanent to permanent changes in the amount and type of habitat available on the Refuge, and conversion of agricultural lands to well field facilities. A more detailed discussion of the potential impacts associated with each of these alternatives is included in Part VII Task C and under WSP1 and WSP2. The environmental impacts of each alternative are summarized in Tables IX-23 and IX-25.

Construction and implementation of WSP3 provides the Refuge with the opportunity to increase wetland habitat on the Refuge 80 percent of the time to 4,340 acres. With the implementation of Alternative 8,



Burns & McDonnell

Figure IX-6

OPTIMIZED WATER SUPPLY PLAN 3

filling borrow areas, an additional 40 acres would be converted from deeper open water habitat to shallow water habitat, facilitating the management of up to 660 acres as moist soil area.

WSP3 would allow Refuge managers to vary the location of wetlands and moist soil areas receiving water throughout the Refuge by providing additional wetland areas for water storage while reducing the water needs of the Refuge through the filling of borrow areas. Available water could be rotated to create, enhance or maintain Refuge wetlands or wetlands habitat. However, the total wetland acres receiving water on the Refuge would not change. This plan would increase wetland habitat management flexibility as maintenance or vegetative control activities are needed on management units. Some management units, for example, could be kept dry for extended periods to control cattails while maintaining other areas for wetland habitat. The benefits WSP3 would provide to Refuge personnel would be a combination of those provided by WSP1 and WSP2. It would provide alternative areas for wetlands during maintenance of other units, provide the opportunity to rotate wetlands, allow some units to develop more diverse and denser vegetative cover and seed base by rotating from dry to wet for several years or increase the amount of habitat available on the Refuge during the uncommon times when water is abundant.

Additionally, combining WSP1 and WSP2 would provide the Refuge a supplemental water supply capable of providing the Refuge with sufficient water annually to maintain 3,530 acres of wetland habitat 80 percent of the time, along with the benefits of WSP1 discussed previously. The increased dependability provided by the supplemental water supply would allow greater management flexibility. This flexibility allows for management unit drawdown for cattail control and moist soil management while still enabling the Refuge to maintain the quantity of wetland habitat necessary to meet its management objectives. Units that normally would be used to store water could be drawn-down for maintenance or moist soil management instead of restricting their use solely for storage. Current storage units could continue to be managed for storage. The water stored could be used to provide for summer waterfowl brood habitat, flood irrigation of moist soil units, maintain a permanent fishery to benefit wading birds, or provide deeper, open water habitat for migrating waterfowl. WSP3 would provide additional water and increase the efficiency and effectiveness of water usage to increase the wetland habitat provided on the Refuge to more closely approach the acreage of Refuge wetlands allowable under its existing water right.

e. Project Cost Estimates

Project costs, operation and maintenance costs, present value and benefit-cost analysis for this alternative are included below and used to select the best water supply plan for implementation.

1) Project Costs

The estimated project cost for WSP3a, WSP3b and WSP3c are respectively $6.3, $8.5 and $11.4 million as listed in Table IX-29.

2) Operation and Maintenance (O&M) Costs

OMR&E costs include costs associated with the operation and maintenance, replacement of mechanical equipment every 10 years and energy for the supplemental groundwater supply only. OMR&E costs for WSP3a, WSP3b and WSP3c are respectively $122,000, $136,000 and $145,000 per year in the first year of operation and is inflated at 4 percent per year as listed in Tables IX-30, IX-31 and IX-32. These costs are used in combination with the project costs to calculate the present value for the alternative.

3) Present Value Analysis

The present value for WSP3a, WSP3b and WSP3c are respectively $8.0, $10.4 and $13.4 million as listed in Tables IX-33, IX-34 and IX-35. The average life cycle unit cost of water for WSP3a, WSP3b and WSP3c are respectively $118, $148 and $185 per MG over 20 years of operation based on present value.

4) Benefit-Cost Analysis

The benefit of 2,360, 2,700 and 2,840 acres of additional wetlands are estimated respectively for WSP3a, WSP3b, and WSP3c at a 20 year present value of $21.3, $24.4 and $25.7 million. This results in respective benefit-cost ratios for WSP3a, WSP3b and WSP3c of 2.66, 2.35 and 1.92.

F. RECOMMENDATIONS

Based on review of Table IX-36, the preferred water supply plan for the Refuge on the basis of hydrologic, hydrogeologic, environmental and engineering studies is WSP2. WSP2 includes the

Table IX-29

PROJECT COST ESTIMATE
WATER SUPPLY PLAN 3

Item	Option a Cost ($)	Option b Cost ($)	Option c Cost ($)
Testing Plan:			
Test Borings - 1 boring for every 2 wells	12,000	15,000	18,000
Pump Tests	180,000	180,000	180,000
Temporary Monitoring Wells - 10 per test	60,000	60,000	60,000
Water Quality Sampling and Analysis	60,000	60,000	60,000
Well, Pump and Controls:			
15 Wells with 25 cfs (16.0 MGD) capacity	1,125,000		
19 Wells with 34 cfs (22.0 MGD) capacity		1,425,000	
24 Wells with 42 cfs (27.0 MGD) capacity			1,800,000
Pipeline, Valves, Meter, Fence & Discharge	225,000	285,000	360,000
Test Drilling	33,000	43,000	53,000
Monitoring Wells	45,000	57,000	72,000
Electrical Power Supply	200,000	250,000	300,000
Access Road (10' wide gravel road)	416,000	527,000	665,000
Land and Right-of-way	46,000	59,000	74,000
Alternative C.8 - Fill Borrow Areas	580,000	580,000	580,000
Alternative C.3 - Raise Dikes on Storage Units	1,320,000	1,320,000	1,320,000
Alternative C.1 - Raise Little Salt Marsh		970,000	970,000
Alternative C.4 - Line Conveyance Canals			1,320,000
Subtotal	4,302,000	5,831,000	7,832,000
Contingency at 20%	860,000	1,166,000	1,566,000
Subtotal	5,162,000	6,997,000	9,398,000
Testing Plan Other Costs	80,000	80,000	80,000
Other Costs at 20%	1,032,000	1,399,000	1,880,000
Total Project Cost	**6,274,000**	**8,476,000**	**11,358,000**

Table IX-30

OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
WATER SUPPLY PLAN 3a

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	6.3	86,000		36,000	122,000
2001	6.3	89,000		37,000	126,000
2002	6.3	93,000		39,000	132,000
2003	6.3	97,000		40,000	137,000
2004	6.3	101,000		42,000	143,000
2005	6.3	105,000		43,000	148,000
2006	6.3	109,000		45,000	154,000
2007	6.3	113,000		47,000	160,000
2008	6.3	118,000		49,000	167,000
2009	6.3	123,000		51,000	174,000
2010	6.3	128,000	312,000	53,000	493,000
2011	6.3	133,000		55,000	188,000
2012	6.3	138,000		57,000	195,000
2013	6.3	144,000		60,000	204,000
2014	6.3	150,000		62,000	212,000
2015	6.3	156,000		64,000	220,000
2016	6.3	162,000		67,000	229,000
2017	6.3	168,000		70,000	238,000
2018	6.3	175,000		72,000	247,000
2019	6.3	182,000	444,000	75,000	701,000
Total	126.0	2,570,000	756,000	1,064,000	4,390,000

Notes:
(1) Average pumping rate is assumed to be continuous.
(2) O&M includes additional staff and materials, testing and operations.
(3) Replacement of equipment every 10 years.
(4) Energy costs are estimated at $.12/KWH.

Table IX-31

OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
WATER SUPPLY PLAN 3b

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	6.7	98,000		38,000	136,000
2001	6.7	102,000		40,000	142,000
2002	6.7	106,000		41,000	147,000
2003	6.7	110,000		43,000	153,000
2004	6.7	114,000		44,000	158,000
2005	6.7	119,000		46,000	165,000
2006	6.7	124,000		48,000	172,000
2007	6.7	129,000		50,000	179,000
2008	6.7	134,000		52,000	186,000
2009	6.7	139,000		54,000	193,000
2010	6.7	145,000	408,000	56,000	609,000
2011	6.7	151,000		59,000	210,000
2012	6.7	157,000		61,000	218,000
2013	6.7	163,000		63,000	226,000
2014	6.7	170,000		66,000	236,000
2015	6.7	177,000		68,000	245,000
2016	6.7	184,000		71,000	255,000
2017	6.7	191,000		74,000	265,000
2018	6.7	199,000		77,000	276,000
2019	6.7	207,000	581,000	80,000	868,000
Total	134.0	2,919,000	989,000	1,131,000	5,039,000

Notes:
(1) Average pumping rate is assumed to be continuous.
(2) O&M includes additional staff and materials, testing and operations.
(3) Replacement of equipment every 10 years.
(4) Energy costs are estimated at $.12/KWH.

Table IX-32

OPERATION, MAINTENANCE, REPLACEMENT AND ENERGY COST ESTIMATE
WATER SUPPLY PLAN 3c

Year	Average Pumping Rate (MGD)(1)	O&M (2)	Replacement (3)	Energy (4)	OMR&E Total
2000	6.4	109,000		36,000	145,000
2001	6.4	113,000		37,000	150,000
2002	6.4	118,000		39,000	157,000
2003	6.4	123,000		41,000	164,000
2004	6.4	128,000		42,000	170,000
2005	6.4	133,000		44,000	177,000
2006	6.4	138,000		46,000	184,000
2007	6.4	144,000		47,000	191,000
2008	6.4	150,000		49,000	199,000
2009	6.4	156,000		51,000	207,000
2010	6.4	162,000	504,000	53,000	719,000
2011	6.4	168,000		55,000	223,000
2012	6.4	175,000		58,000	233,000
2013	6.4	182,000		60,000	242,000
2014	6.4	189,000		62,000	251,000
2015	6.4	197,000		65,000	262,000
2016	6.4	205,000		67,000	272,000
2017	6.4	213,000		70,000	283,000
2018	6.4	222,000		73,000	295,000
2019	6.4	231,000	718,000	76,000	1,025,000
Total	127.0	3,256,000	1,222,000	1,071,000	5,549,000

Notes:
(1) Average pumping rate is assumed to be continuous.
(2) O&M includes additional staff and materials, testing and operations.
(3) Replacement of equipment every 10 years.
(4) Energy costs are estimated at $.12/KWH.

Table IX-33

PRESENT VALUE ESTIMATE
WATER SUPPLY PLAN 3a

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0				0	0
1999	0	6,525,000			6,098,000	6,098,000
2000	6.3		122,000	122,000	107,000	6,205,000
2001	6.3		126,000	126,000	103,000	6,308,000
2002	6.3		132,000	132,000	101,000	6,409,000
2003	6.3		137,000	137,000	98,000	6,507,000
2004	6.3		143,000	143,000	95,000	6,602,000
2005	6.3		148,000	148,000	92,000	6,694,000
2006	6.3		154,000	154,000	90,000	6,784,000
2007	6.3		160,000	160,000	87,000	6,871,000
2008	6.3		167,000	167,000	85,000	6,956,000
2009	6.3		174,000	174,000	83,000	7,039,000
2010	6.3		493,000	493,000	219,000	7,258,000
2011	6.3		188,000	188,000	78,000	7,336,000
2012	6.3		195,000	195,000	76,000	7,412,000
2013	6.3		204,000	204,000	74,000	7,486,000
2014	6.3		212,000	212,000	72,000	7,558,000
2015	6.3		220,000	220,000	70,000	7,628,000
2016	6.3		229,000	229,000	68,000	7,696,000
2017	6.3		238,000	238,000	66,000	7,762,000
2018	6.3		247,000	247,000	64,000	7,826,000
2019	6.3		701,000	701,000	169,000	7,995,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						118

Table IX-34

PRESENT VALUE ESTIMATE
WATER SUPPLY PLAN 3b

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0				0	0
1999	0	8,815,000			8,238,000	8,238,000
2000	6.7		136,000	136,000	119,000	8,357,000
2001	6.7		142,000	142,000	116,000	8,473,000
2002	6.7		147,000	147,000	112,000	8,585,000
2003	6.7		153,000	153,000	109,000	8,694,000
2004	6.7		158,000	158,000	105,000	8,799,000
2005	6.7		165,000	165,000	103,000	8,902,000
2006	6.7		172,000	172,000	100,000	9,002,000
2007	6.7		179,000	179,000	97,000	9,099,000
2008	6.7		186,000	186,000	95,000	9,194,000
2009	6.7		193,000	193,000	92,000	9,286,000
2010	6.7		609,000	609,000	270,000	9,556,000
2011	6.7		210,000	210,000	87,000	9,643,000
2012	6.7		218,000	218,000	85,000	9,728,000
2013	6.7		226,000	226,000	82,000	9,810,000
2014	6.7		236,000	236,000	80,000	9,890,000
2015	6.7		245,000	245,000	78,000	9,968,000
2016	6.7		255,000	255,000	75,000	10,043,000
2017	6.7		265,000	265,000	73,000	10,116,000
2018	6.7		276,000	276,000	71,000	10,187,000
2019	6.7		868,000	868,000	210,000	10,397,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						**148**

Table IX-35

PRESENT VALUE ESTIMATE
WATER SUPPLY PLAN 3c

Year	Average Pumping Rate (MGD)	Total Project Cost	Total OMR&E	Annual Total	Total Present Value	Summation Present Value
1998	0.0				0	0
1999	0.0	11,812,000			11,039,000	11,039,000
2000	6.4		145,000	145,000	127,000	11,166,000
2001	6.4		150,000	150,000	122,000	11,288,000
2002	6.4		157,000	157,000	120,000	11,408,000
2003	6.4		164,000	164,000	117,000	11,525,000
2004	6.4		170,000	170,000	113,000	11,638,000
2005	6.4		177,000	177,000	110,000	11,748,000
2006	6.4		184,000	184,000	107,000	11,855,000
2007	6.4		191,000	191,000	104,000	11,959,000
2008	6.4		199,000	199,000	101,000	12,060,000
2009	6.4		207,000	207,000	98,000	12,158,000
2010	6.4		719,000	719,000	319,000	12,477,000
2011	6.4		223,000	223,000	93,000	12,570,000
2012	6.4		233,000	233,000	90,000	12,660,000
2013	6.4		242,000	242,000	88,000	12,748,000
2014	6.4		251,000	251,000	85,000	12,833,000
2015	6.4		262,000	262,000	83,000	12,916,000
2016	6.4		272,000	272,000	80,000	12,996,000
2017	6.4		283,000	283,000	78,000	13,074,000
2018	6.4		295,000	295,000	76,000	13,150,000
2019	6.4		1,025,000	1,025,000	248,000	13,398,000
Average Life Cycle Unit Cost of Water ($/MG) (20 year present value)						185

supplemental supply of 1,500 acre-feet per month of groundwater from wells adjacent to the Refuge as shown in Figure IX-4. This plan utilizes fifteen 800 gpm wells on quarter mile spacing to supply water to the Refuge on an as needed basis. WSP2 is the least expensive plan that supplies additional water to the Refuge. Additionally, WSP2 could be expanded in the future with additional wells if the Service desired to increase potential diversions and wetland habitat acreage for the Refuge. This plan is recommended as the first choice for implementation by the Service.

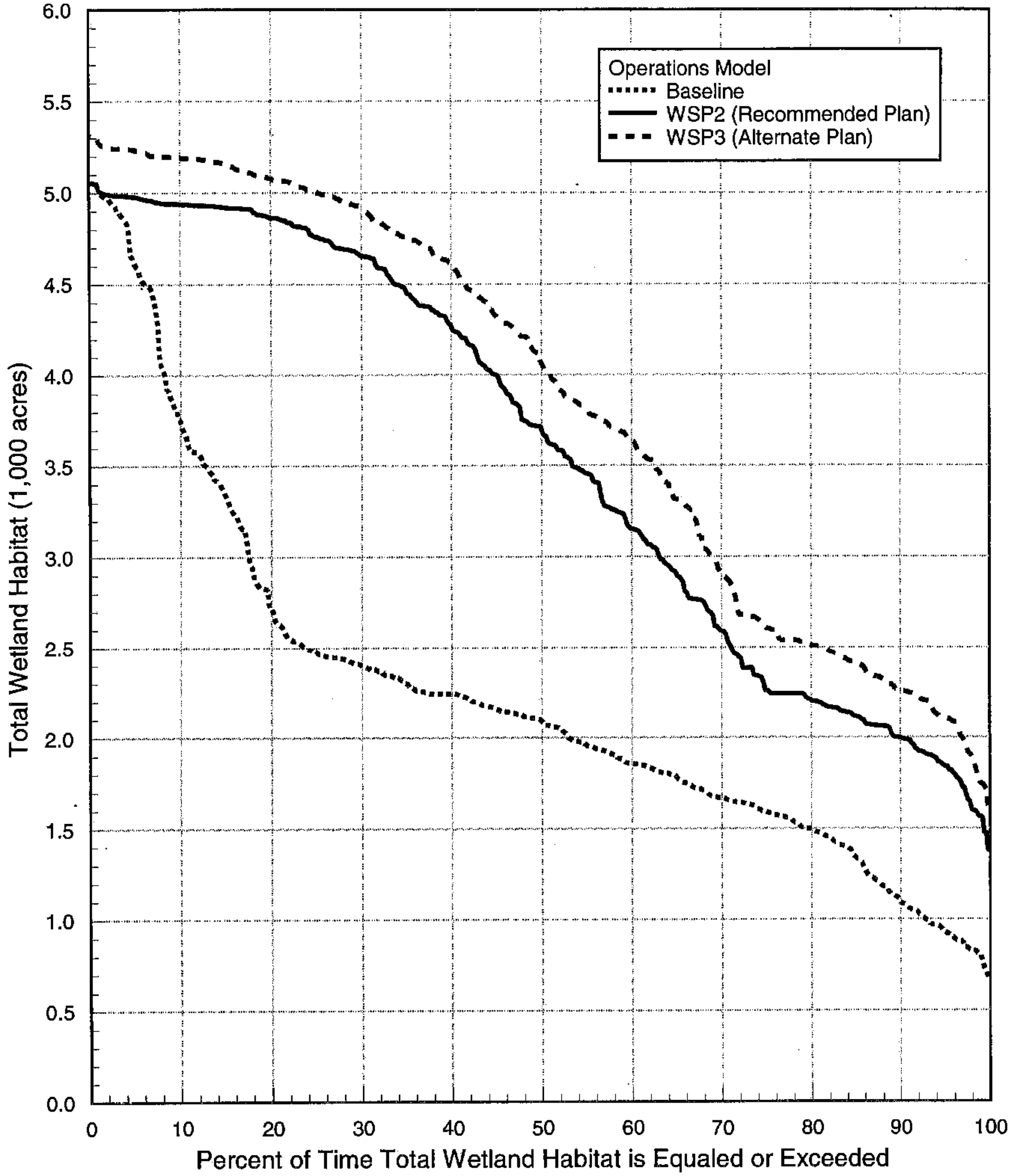
The second ranked plan is the optimized version of WSP3 and includes alternatives C.10-3, 8 and 3. This plan provides additional water to the Refuge on an as-needed basis and on-Refuge improvements including the filling of borrow areas and increasing storage in three units. This plan provides a greater supply of water and creates more wetland habitat than WSP2; however, the project cost is substantially greater than WSP2 resulting in the second best benefit-cost ratio.

Table IX-36
SUMMARY OF WATER SUPPLY PLANS

WSP	Average Diversion (ac-ft/yr)	Wetland Habitat 80 % of Time (ac)	Project Cost ($million)	OMR&E ($1000/yr)	Project Cost Present Value ($million)	Wetland Habitat Present Value ($million)	Avg. Life Cycle Present Value ($/MG)	B/C Ratio
1a	6,350	1,360	2.7	0	2.5	1.2	61	0.48
1b	6,986	1,570	4.1	0	3.8	0.6	84	0.16
1c	6,853	1,610	6.0	0	5.6	1.0	126	0.18
2	10,355	3,530	3.5	117	5.2	18.4	78	3.54
3a	12,161	3,860	6.3	122	8.0	21.3	118	2.66
3b	13,238	4,200	8.5	136	10.4	24.4	148	2.35
3c	12,602	4,340	11.4	145	13.4	25.6	185	1.91

Note: 1. Baseline for wetland habitat is 1,500 acres 80 percent of the time.

The benefits to the Refuge from implementation of the recommended or alternate water supply plans (WSP2 or WSP3, respectively) are illustrated in Figures IX-7 and IX-8. Figure IX-7 shows the durations of total wetland habitat on the Refuge. Review of this figure shows the dramatic increases in the availability of wetlands that are possible with a supplemental water supply. For example, implementing



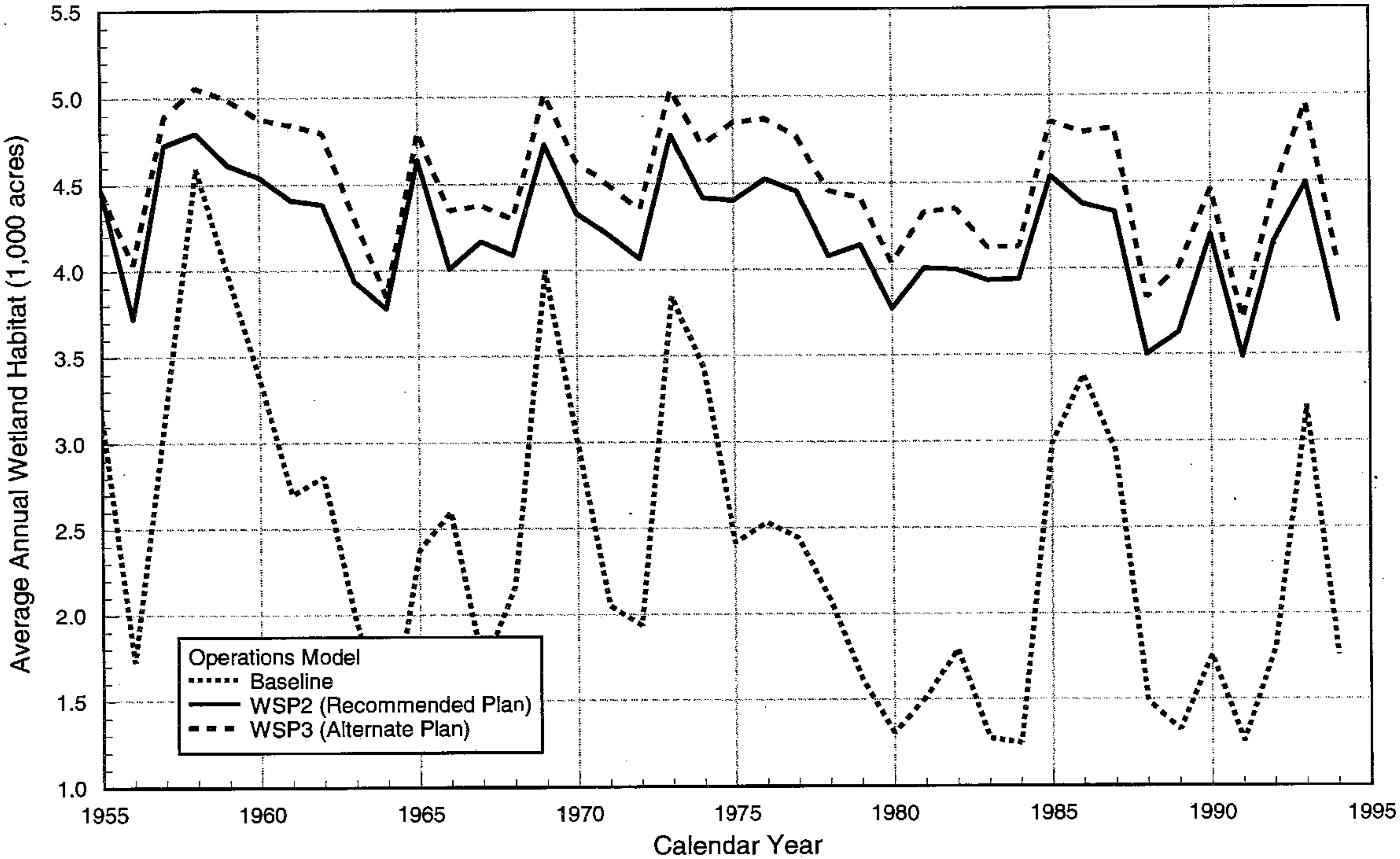
Notes:

1. Developed from operations modeling for Quivira NWR for period 1/1955 through 12/1994.
2. Operating results based on adoption of preferred management plan for the Refuge, which operates most management units as moist soil areas.
3. Data are for total wetland habitat, which is the sum of the surface areas of all ponded water in all management units, regardless of depth.

Burns & McDonnell

Figure IX-7

WETLAND HABITAT DURATIONS RECOMMENDED WATER SUPPLY PLANS



Notes
1. Based on monthly wetland habitat estimates obtained from operations simulation at Refuge using preferred management plan, which operates most management units as moist soil areas.
2. Annual averages are for total wetland habitat calculated using data for primary migration season (September-April) only.

Burns & McDonnell

Figure IX-8

SIMULATED TOTAL WETLAND HABITAT RECOMMENDED WATER SUPPLY PLANS

WSP2 nearly doubles the median (50th percentile) amount of wetland habitat on the Refuge. The additional improvements provided by implementing WSP3 are much more modest. Figure IX-8 shows how the average amount of wetlands are estimated to vary with time during the 40-year simulation period. Although some variability still remains, development of either water supply plan stabilizes the amount of wetland habitat. This is particularly evident during drought periods when the amount of wetlands available under current (baseline) conditions can decrease by two-thirds over peak amounts present during wetter years.

Implementation of the supplemental groundwater for WSP2 requires additional studies consisting of soil borings, test well installation and pumping, and water quality sampling and analysis to confirm plan feasibility. Soil borings are required to obtain additional geologic and hydrogeologic data on potential well sites. The area typically has a clay layer that separates the upper and lower portion of the aquifer. This clay layer would also act to minimize upconing of the high chloride water in the lower aquifer into the lower chloride water in the upper aquifer. Test wells would be installed and run for an extended period to confirm long-term safe yield, drawdown, area of influence and impacts on water quality.

These studies should be initiated immediately to insure adequate time for implementation of the initial phases of WSP2.

Other improvements that should be considered include the installation of the stop log structures on the northwest area as discussed in Task D. These structures are relatively inexpensive at a cost of $17,000, do not impact supply quantity but do provide increased operational control to Refuge staff for an important environmental area.

Public meetings should be conducted as part of an environmental assessment to implement WSP2 and gain consensus on a local level. The Partnership and the public should be advised of the project status, the results of this study and the Service's implementation plan.