Arkansas River Basin

John Martin Reservoir Wetlands and Nee Noshe Reservoir Bird Habitat

Nonconsumptive Needs Quantification Report

June 2011

CDM

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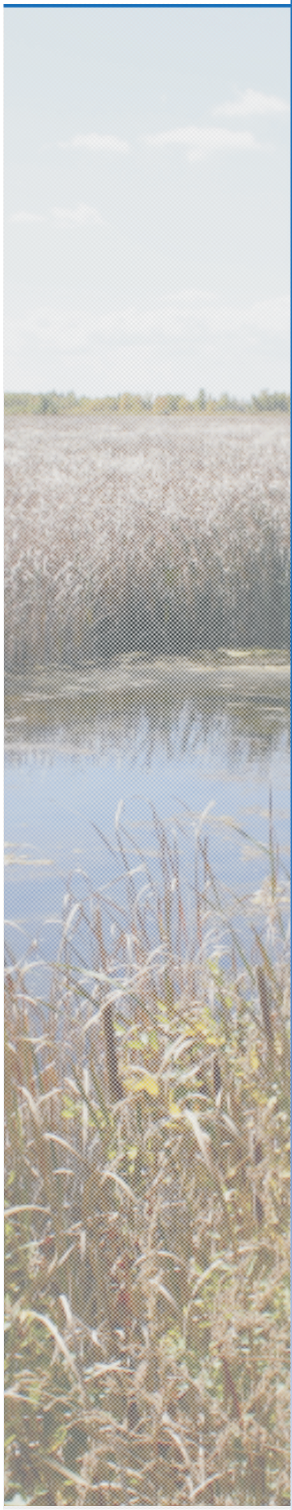

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Acronyms

AF	acre-feet
AFM	acre-feet per month
AFY	acre-feet per year
BLM	Bureau of Land Management
CDM	Camp Dresser & McKee Inc.
CDOW	Colorado Division of Wildlife
CGS	Colorado Geological Survey
DNR	Department of Natural Resources
DWR	Division of Water Resources
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration
GIS	geographic information system
gpm	gallons per minute
GPS	Geographic Positioning System
H-I Model	Hydrologic Institute Model
NAIP	National Agricultural Imagery Program
NCDC	National Climatic Data Center
NCNA	Nonconsumptive Needs Assessment
NED	National Elevation Dataset
NRCS	National Resources Conservation Service
NWI	National Wetland Inventory
SEV	Secondary Evapotranspiration
SSURGO	Soil Survey Geographic Database
SWA	State Wildlife Area
SWAM	Simplified Water Allocation Model
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WWSP	Winter Water Storage Program

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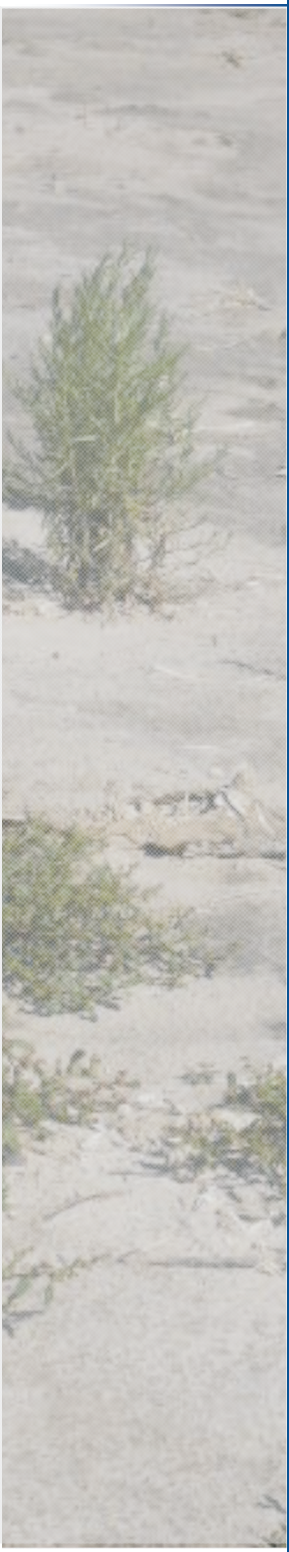
Executive Summary



Overview

The Arkansas Basin Nonconsumptive Needs Assessment (NCNA) committee has completed a study for the wetlands at John Martin Reservoir and bird habitat at Nee Noshe Reservoir in order to develop an understanding of the environmental and recreational resources that exist at both sites along with the water needs to support these resources. By characterizing the resources at both study sites, the NCNA committee has been able to estimate the quantities of water needed to maintain or enhance these resources and provide a foundation of knowledge that can be considered for future water management decisions.

Introduction

The lower Arkansas River Valley stretches across a six county area that is largely supported by agriculture and is rich in wildlife resources. The wetlands at John Martin Reservoir and the habitat at Nee Noshe Reservoir are both located in the lower Arkansas River Basin.

John Martin Reservoir Wetland Complex

John Martin Reservoir is a multipurpose reservoir and was constructed in the 1940s by the U.S. Army Corps of Engineers (USACE). A large wetlands complex exists upstream (west) of the reservoir, between Las Animas, Colorado and the reservoir's western shoreline. Wetlands provide numerous benefits for people, fish, and wildlife. Some of these functions include protecting and improving water quality, providing fish and wildlife habitats, storing floodwaters, and maintaining surface water flows during dry periods (U.S. Environmental Protection Agency [EPA] 2001). Wetlands also provide environmental benefits to the area because they prevent floods by temporarily storing water, allowing the water to evaporate, or percolate into the ground; improve water quality through natural pollution control such as plant nutrient uptake; filter sediment; and slow overland flow of water thereby reducing soil erosion (U.S. Department of Agriculture [USDA] 2011).

Nee Noshe Reservoir Bird Habitat

In Colorado, federally listed piping plover and least tern nest solely on the shorelines of large reservoirs in the southeast part of the state (Nelson 2009). Reservoirs in the southeast part of the state were last full in 1999 and since that time, available habitat for the birds has changed dramatically. The shoreline habitat has shrunk over the past decade due to unfavorable water levels and colonization of invasive plants. Both bird species have historically nested at the Great Plains Reservoirs.

The Great Plains Reservoir System is a system of four interconnected reservoirs (Queens or Nees Kah, Nee Gronda, Nee So Pah, and Nee Noshe). Nee Noshe Reservoir was selected for this study due to its location within the Great Plains Reservoir System. Nee Noshe Reservoir is located at the end of the system and if water was to become available for any of the Great Plains Reservoirs, it would be easiest to have access to it for downstream uses if it was stored in Nee Noshe Reservoir (Colorado Department of Wildlife [CDOW] 2011).

Approach

The general approach for both study sites began with the development of an understanding of the environmental and recreational resources at each location. Data available for the areas were used to identify the sources of water to, and the total acreage of, the wetlands complex at John Martin Reservoir. Available data were also used to estimate the existing shorebird habitat available at Nee Noshe Reservoir with relation to the reservoir levels at the site. Once the water sources and wetland area at John Martin Reservoir and the habitat/lake level relationship at Nee Noshe Reservoir were established, the information was used to support development of the overall water budgets or water balance at each location. A water budget is "the scientific method for measuring the amount of water entering, stored within, and leaving a watershed, and it is also called a hydrologic budget or a water balance (Giddings 2011)". A water budget was used to determine the interactions between the water inputs and outputs of both systems.

John Martin Reservoir Wetland Complex Water Budget

A water budget was constructed for the John Martin Reservoir wetlands to provide relative quantification of existing sources of supply to the wetlands. Historical aerial photographs showed that the wetlands were present in the area during reservoir construction and maintained a similar footprint regardless of reservoir levels. Because of this historical evidence, there were two major components of the analysis for the John Martin Reservoir wetlands: one focused on surface water dynamics and the other on subsurface dynamics. The water budgets were used to determine that the ultimate source of supply for these wetlands is shallow groundwater (subsurface) supported by agricultural return flows.

Nee Noshe Reservoir Water Budget

The Nee Noshe Reservoir is an off-channel reservoir that currently receives surface water diversions only sporadically during periods of high flow due to the junior priorities of the storage rights for the Great Plains Reservoirs. As a result of this condition, the water budget for the reservoir is mainly based on direct precipitation and evaporation. Since, on an annual basis, evaporative losses are higher than direct precipitation to the reservoir, the reservoir generally loses water.

Data Collection

Multiple sources of data were collected in order to characterize the wetlands northwest of John Martin Reservoir and the habitat areas for Nee Noshe Reservoir to provide information for the water needs quantification. Historical data were combined with knowledge gained through site visits to support the approach for the quantification of nonconsumptive needs at these sites. Historic hydrologic and hydraulic data were collected to provide input and output values for the water budgets and included the following data:

- Precipitation
- Pan evaporation
- Streamflow and canal diversion records
- Reservoir levels and storage
- ET rates
- Irrigation Return Flows and Ditch Losses
- Geology

John Martin Reservoir Wetland Data

Additional data specific to the wetlands at John Martin Reservoir were collected in order to estimate the full aerial extent of the complex. Aerial photography (including color infrared photography) was paired with National Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) information on the hydric soils of Bent County and the National Wetland Inventory (NWI) data for the region.

Nee Noshe Reservoir Threatened and Endangered Bird Habitat Data

Habitat information was gathered for both the least tern and the piping plover in order to establish the habitat needs of each species and characterize the available habitat at Nee Noshe Reservoir. The least tern is listed as "endangered" while piping plover are listed as "threatened" in the State of Colorado. The shorelines of southeast Colorado reservoirs provide breeding habitat for least terns and piping plover. Efforts are ongoing in Colorado to address fluctuating water levels, human disturbance, vegetation encroachment, and predation in these areas. Therefore, destruction or adverse modification of remaining habitats will cause continued reduction of the species' range and eventually a reduction in population numbers (Colorado 2009). Least tern have not nested at Nee Noshe Reservoir since 2004. Piping plovers have occurred at Nee Noshe Reservoir but have not nested at the site since 2003.

Field Data Collection

Two site visits to the John Martin Reservoir wetlands and Nee Noshe Reservoir were conducted in 2010. A tour of both sites was completed in July 2010 with Arkansas NCNA committee members and CDOW personnel to view the sites and photograph both the wetlands upstream of John Martin Reservoir and the bird habitat surrounding Nee Noshe Reservoir. A second site visit was completed in October 2010 with the goal of characterizing existing wetland habitats at specific John Martin Reservoir locations and least tern and piping plover breeding habitat at Nee Noshe Reservoir. Site visit data collected in the fall of 2010 were coupled with historical data to help characterize the environmental resources at both sites.

Results

John Martin Reservoir Wetlands

Data were used to estimate that the wetlands at John Martin Reservoir cover approximately 6,300 acres. The final wetlands water budget results (both annual and monthly) were then calculated using the available data. The water budget showed that the wetlands are maintained by approximately 32,000 acre-feet of water per year (AFY) which is supplied primarily by regional irrigation return flows to the sub-surface. Results also demonstrate that, on an annual basis, the Arkansas River gains flow through the study reach. On a monthly basis, this analysis shows significant fluctuations in inflows and outflows to the system, most likely as a result of changes in Arkansas River hydraulics. Results indicate large inflows to the sub-surface system in the spring and early summer, consisting primarily of river seepage and irrigation returns. During this period (May and June), the calculations indicate that the water table below the wetlands is. The results imply that the system changes in later summer and fall to a losing system, as river levels subside. During this period, a net loss of water was quantified from the sub-surface pool, primarily in the form of gains to the river. Based on this information, it is likely that the water table drops during this time.

Nee Noshe Reservoir Bird Habitat

Using historical data, the current habitat at Nee Noshe Reservoir and reservoir size were characterized. Nee Noshe Reservoir currently covers 300 acres and holds 3,500 acre-feet (AF) of water. There are approximately 80 acres of habitat available to the bird species at this reservoir size. Although habitat exists at the reservoir, least tern and piping plover have not been observed at the site since 2004. Because current conditions at Nee Noshe Reservoir do not support the bird populations, quantification of water needs were analyzed for three scenarios:

- Maintenance of current conditions;
- Maintenance of the dead pool capacity; and
- Maintenance of 2004 reservoir levels.

The additional scenarios were analyzed because if reservoir levels could be maintained at the dead pool capacity, it would provide the best opportunity for downstream use of any available water and least terns were last observed at Nee Noshe Reservoir in 2004.

Annual water budgets for both current and hypothetical scenarios were calculated using available data. A deficit of 1,000 acre-feet/year (AFY) was quantified for the current system based on the available historical data used to develop the water budget. Therefore, an average of 1,000 AFY of surface water is needed to maintain current levels of storage. Due to canal losses (approximately 45 percent), this is the equivalent of 1,800 AFY diverted at the canal headgate.

A seasonal investigation was also performed for the dead pool scenario and revealed high river diversion requirements, early in the water year, were needed to maintain targeted pool levels. These autumn and early winter diversions would provide the habitat inundation required to prevent vegetation encroachment. The sharp drop in diversion water in subsequent months (spring through summer) would allow for the desired drop in lake levels during the nesting and foraging seasons.

A previously established area-capacity curve was also used to estimate the capacity of Nee Noshe Reservoir in 2004 when least terns were last observed nesting on the shores. It is estimated that Nee Noshe Reservoir held 25,000 AF in 2004. For this scenario, a headgate diversion requirement of 12,300 AFY was calculated to maintain the 2004 reservoir level on an annual basis.

Conclusions and Recommendations

John Martin

The analysis performed for the wetlands at John Martin Reservoir identified subsurface water supplied primarily through agricultural return flows as the main source of water for the wetlands. Future water management practices should consider this established link when making decisions regarding the location and timing of future agricultural return flows.

Nee Noshe

The analysis performed for Nee Noshe Reservoir water levels showed that large quantities of water would be required to maintain the current conditions which have not supported the bird populations in recent years. Even greater quantities of water would be required to bring the reservoir level up to the dead pool which could then support downstream water uses when excess water was available. The 2004 reservoir levels, when least tern were last observed at Nee Noshe Reservoir, were higher than the dead pool which would require even greater amounts of water diversions. If it were possible to divert the volume of water required to maintain 2004 levels at Nee Noshe Reservoir, other management strategies for fisheries and invasive plants would likely need to be implemented to create an environment suitable for these shoreline species.

Section 1
Introduction

1.1 Background

The Arkansas Basin Nonconsumptive Needs Assessment (NCNA) committee has been meeting since 2006 to complete the Arkansas Basin's NCNA, which is required under House Bill 05-1177. The committee has focused on the following key efforts (see **Figure 1-1** for the mapping product associated with these efforts):

- Identifying environmental and recreational attributes in the Arkansas Basin;
- Prioritizing environmental and recreational needs in relation to water resources in the Arkansas Basin; and
- Identifying what areas in the basin require further analysis regarding quantification on environmental and recreational needs.

The NCNA mapping effort that is summarized in Figure 1-1 was used to identify and prioritize three areas in the basin that needed further study and quantification of environmental and recreational water needs. These areas include:

- Site-specific quantification for wetlands upstream of John Martin Reservoir that have environmental attributes such as bird habitat, waterfowl hunting, birding trails, and state wildlife areas.
- Site-specific quantification of lake levels for Nee Noshe Reservoir that have previously supported least tern and piping plover breeding habitats.
- Development of a river restoration plan for 44 miles of Fountain Creek. The Fountain Creek portion of the needs assessment has been addressed under a separate contract and therefore is not discussed further in this document.

The assessments for the John Martin Reservoir wetlands complex and the habitat areas surrounding Nee Noshe Reservoir are intended to provide information about the quantities of water needed for the following environmental and recreational attributes: habitat for birds that are of statewide conservation concern and/or federally listed as Threatened and Endangered; maintaining wetland and aquatic habitats that serve as waterfowl production areas that are needed to maintain and enhance waterfowl hunting and recreational opportunities; and maintaining and/or improving general wildlife and, specifically, bird watching recreational activities.

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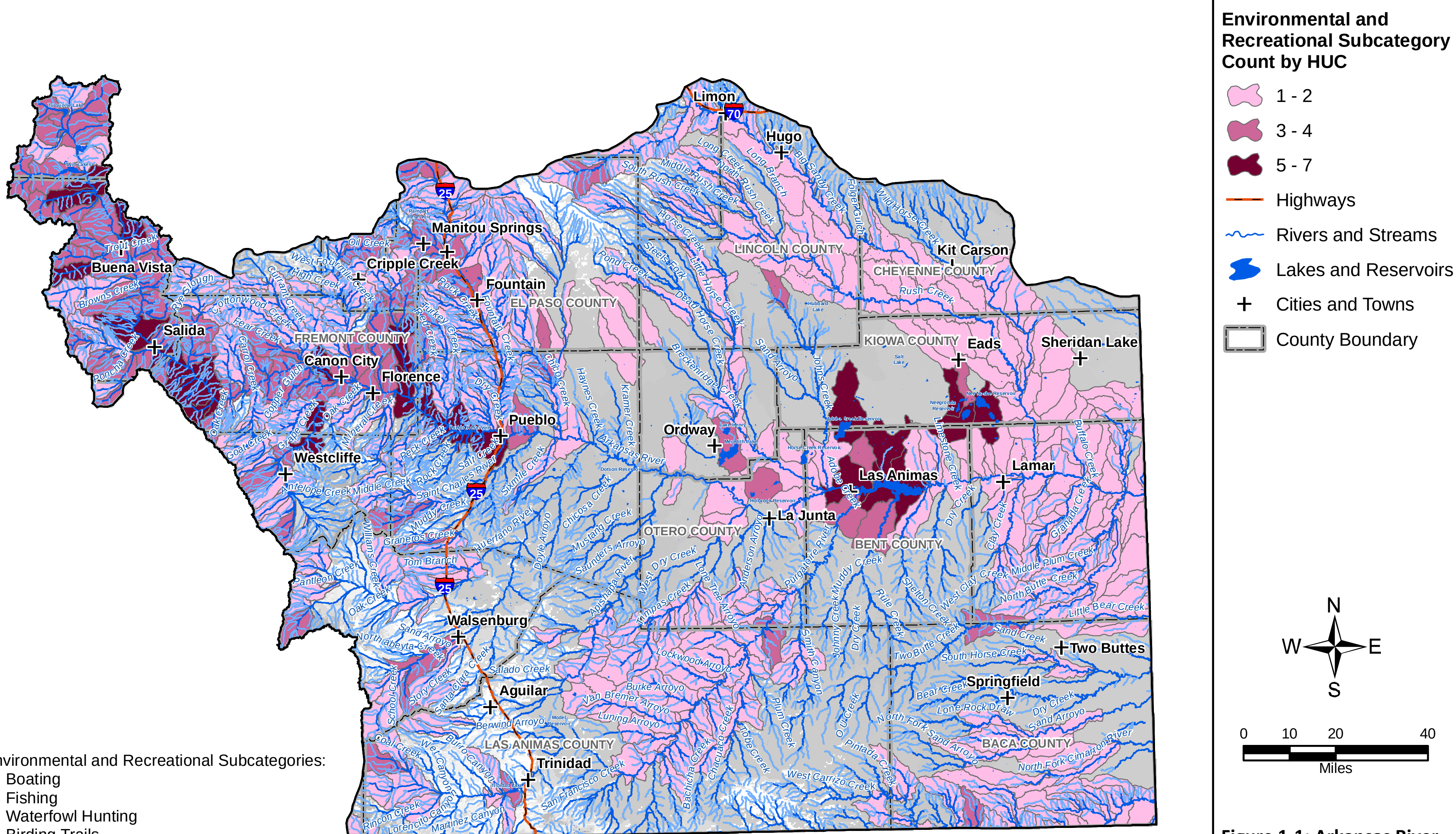

Environmental and Recreational Subcategories:

1. Boating
2. Fishing
3. Waterfowl Hunting
4. Birding Trails
5. Threatened and Endangered Species
6. Special Value Waters
7. Wetlands
8. Significant Riparian and Wetland Plant Communities
9. Audubon Important Bird Areas

Figure 1-1: Arkansas River Basin NCNA Environmental and Recreational Attributes

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1.2 Study Objectives

The objectives of the study are to:

- Develop an understanding of the environmental and recreational resources of the wetlands upstream of John Martin Reservoir and the habitat for threatened and endangered birds at Nee Noshe Reservoir;
- Identify the relationship between upstream water management, surface water levels and flows, groundwater levels, and the wetlands complex at John Martin Reservoir;
- Identify the relationship between lake levels and bird habitat at Nee Noshe Reservoir;
- Perform the study with consideration of existing flows within the basin and of existing water rights; and
- Identify multipurpose opportunities with planned projects within the Arkansas River Basin.

1.3 Study Area Overview

The lower Arkansas River Valley stretches across a six county area that includes Baca, Bent, Crowley, Kiowa, Otero, and Prowers Counties. The economy of the area is largely supported by agriculture. The valley has been irrigated for more than one hundred years through a complex network of irrigation canals, off-stream reservoirs, and laterals.

In addition to irrigation, the Lower Arkansas Valley is rich in wildlife resources. The area supports populations of species normally associated with short-grass prairie and riparian habitat. According to a 1993 study of the region, aquatic wildlife, mammals, and migratory and upland birds are all present. In addition, there are threatened and endangered species that have been sighted in the valley. Included in this category are the Arkansas darter, peregrine falcon, least tern, piping plover, lesser prairie chicken, and the black-footed ferret (Lower Arkansas River Commission 1993).

John Martin Reservoir and Nee Noshe Reservoir are located in the lower Arkansas River Basin (**Figure 1-2**). John Martin Reservoir is located on the Arkansas River in Bent County, downstream of Las Animas, Colorado. Nee Noshe Reservoir is one of four reservoirs within the Great Plains Reservoir System and is located in Kiowa County, northwest of Lamar, Colorado.

1.3.1 John Martin Reservoir Wetland Complex

John Martin Reservoir is a multipurpose reservoir and was constructed in the 1940s by the U.S. Army Corps of Engineers (USACE). It is used for flood control on the Arkansas River, recreation, irrigation, fish and wildlife, and began storage in 1948 to meet the requirements of the Arkansas River Compact. Total capacity of the reservoir at the top of the dam is approximately 800,000 acre-feet (AF) while maximum flood control storage is approximately 600,000 AF (U.S. Geological Survey [USGS] 2011). The reservoir is managed by USACE and operations of the reservoir are controlled by Colorado water administration policies and the Arkansas River Compact, which allocates water from John Martin Reservoir between Colorado and Kansas. Hydrologic descriptions of the Arkansas River in this area and reservoir storage data are provided in Section 3.2.1.

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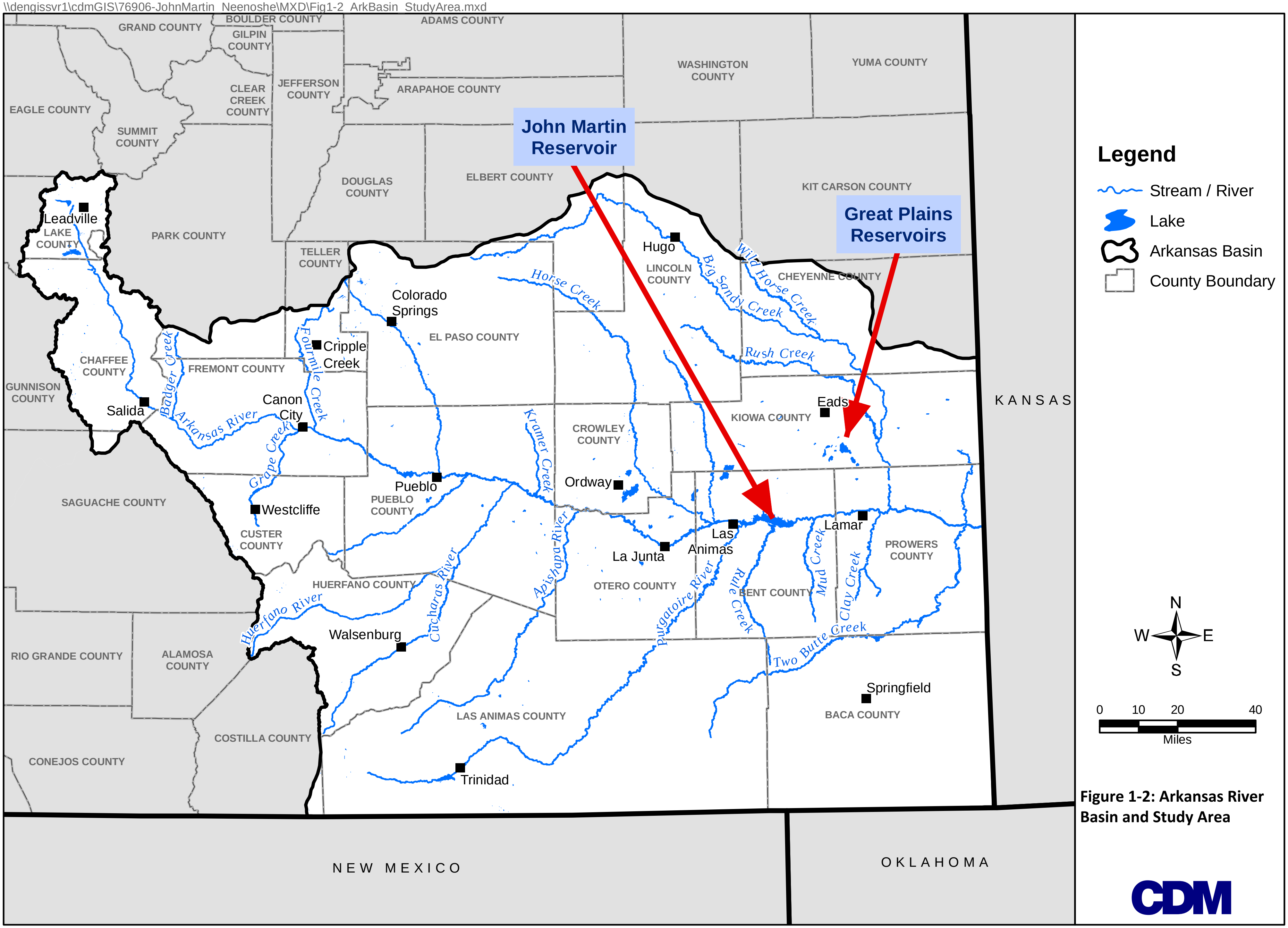

Figure 1-2: Arkansas River Basin and Study Area

John Martin Reservoir, and surrounding Bent County, is one of the premier birding locations in the interior United States, and is recognized nationally as an "Important Bird Area" (Colorado Department of Natural Resources [DNR] 2011). John Martin Reservoir is also part of a Colorado State Park that is managed by the DNR. As mentioned, the park is known for bird watching with over 400 species of bird having been identified in Bent County. A large wetlands complex exists upstream (west) of the reservoir, between Las Animas, Colorado and the reservoir's western shoreline. Wetlands provide numerous benefits for people, fish, and wildlife. Some of these functions include protecting and improving water quality, providing fish and wildlife habitats, storing floodwaters, and maintaining surface water flows during dry periods (U.S. Environmental Protection Agency [EPA] 2001). The large wetlands complex is located along the Arkansas River, north and east of the confluence with the Purgatoire River and south of agricultural lands irrigated from the Fort Lyon Canal (**Figure 1-3**). Much of the land surrounding the reservoir and the wetlands is also designated as a State Wildlife Area (SWA) by the Colorado Division of Wildlife (CDOW). SWAs in Colorado are a diverse array of recreational public lands that occupy the niche of providing wildlife-related recreation (CDOW 2011). The John Martin Reservoir SWA and the Fort Lyon SWA encompass the majority of the study area (**Figure 1-4**). Additionally, within the SWA, in the wetlands, CDOW constructed a set of level ditches and excavated a series of small pits in the 1970s within the flood pool area of the reservoir in order to provide fisheries habitat and open water surfaces for waterfowl to use for resting, nesting, and feeding. This area is shown on **Figure 1-5** for reference. Documentation on the CDOW waterfowl channel is provided in **Appendix A**.

1.3.2 Nee Noshe Reservoir

The Great Plains Reservoir System (**Figure 1-6**) is a system of four interconnected reservoirs (Queens or Nees Kah, Nee Gronda, Nee So Pah, and Nee Noshe) on Bureau of Land Management (BLM) land and owned and operated through a right-of-way by the Amity Mutual Irrigation Company. The reservoirs are located northeast of John Martin Reservoir and are filled by water diverted from the Arkansas River through the Fort Lyon Canal to the Kicking Bird Canal. Within the Great Plains Reservoir System, water can be transferred between reservoirs through the Lone Wolf Canal or the Santanta Canal. The reservoirs divert under a storage decree totaling over 265,000 AF (Boyle 1993). Nee Noshe Reservoir is located at the end of the system and water from Nee Noshe Reservoir can be delivered to the Amity Canal through the Comanche Canal. The total capacity of Nee Noshe Reservoir is approximately 95,000 AF with an available capacity of approximately 73,000 AF and a dead pool storage of approximately 21,000 AF (Boyle 1993). The term dead pool refers to the water level in a reservoir that cannot be drained by gravity through a dam's outlet works or spillway.

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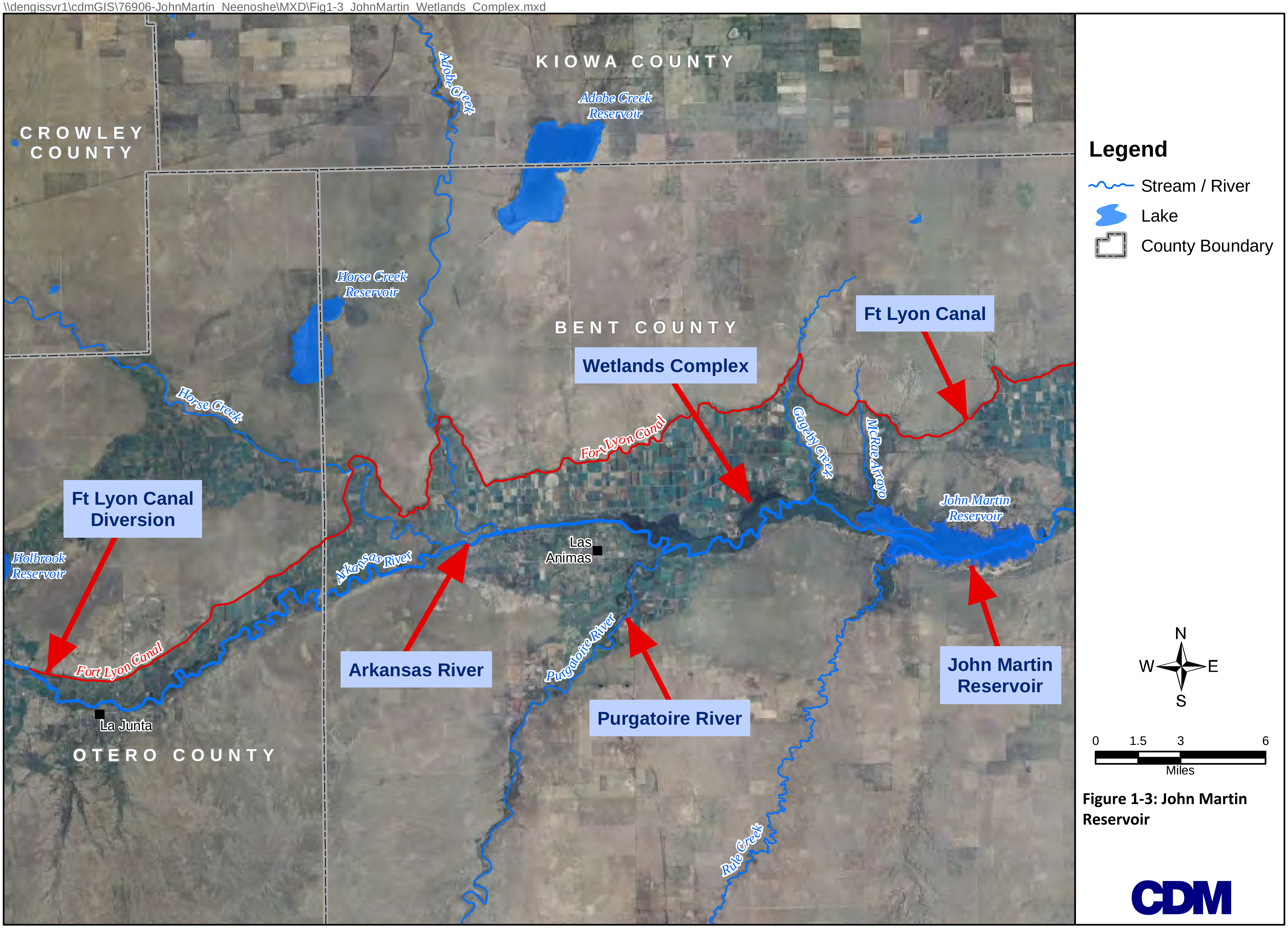

Figure 1-3: John Martin Reservoir

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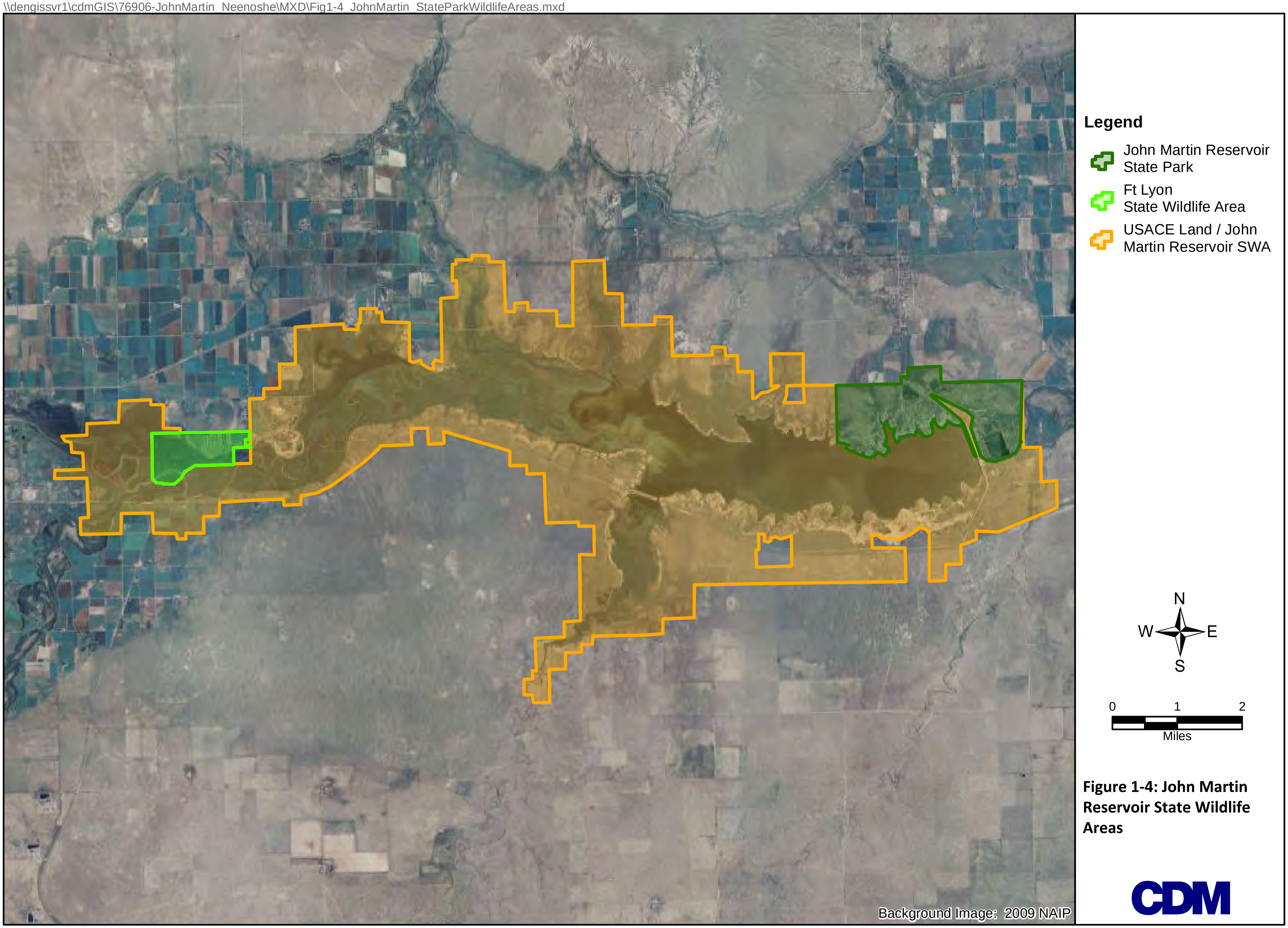

Figure 1-4: John Martin Reservoir State Wildlife Areas

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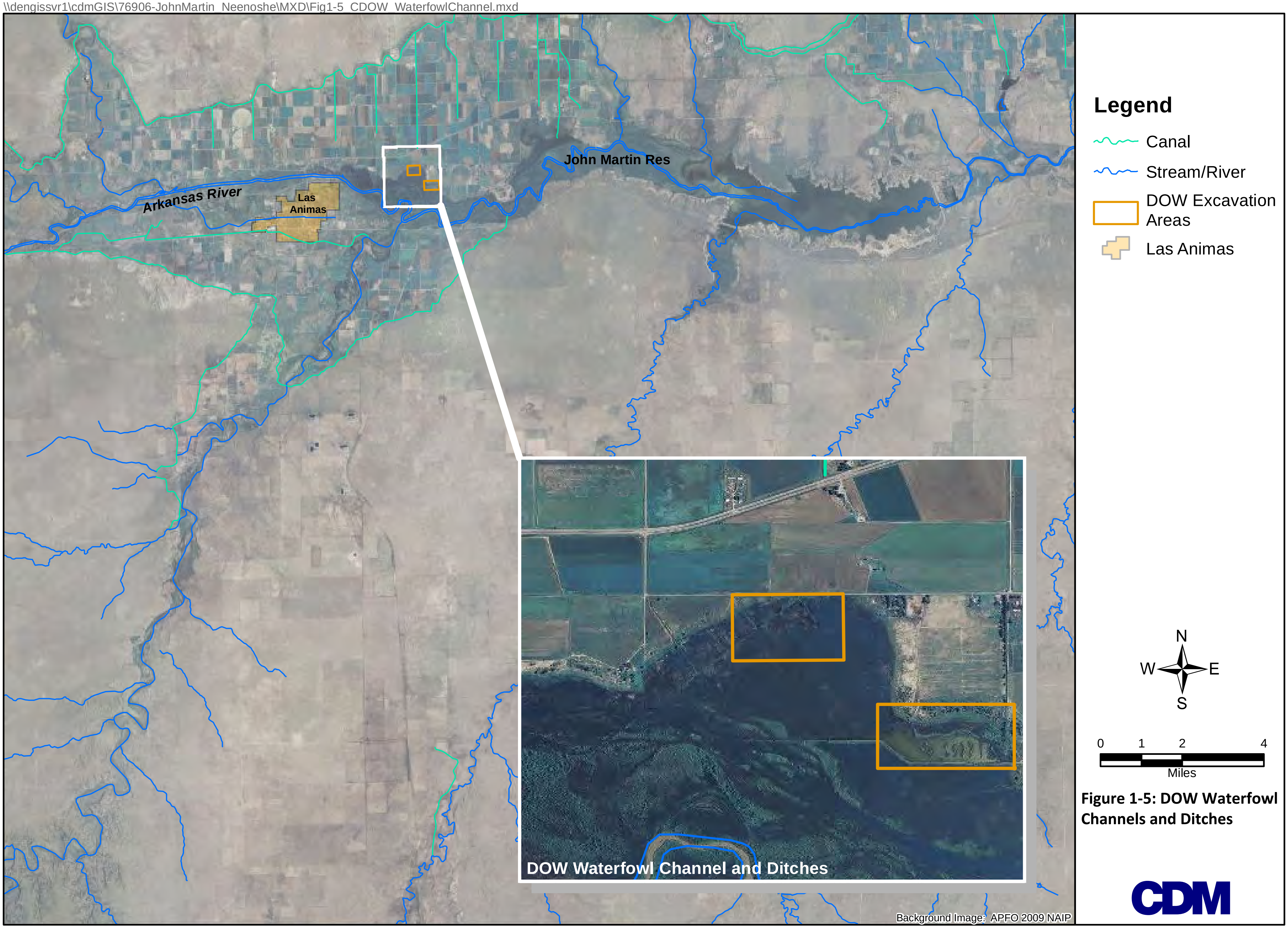

Figure 1-5: DOW Waterfowl Channels and Ditches

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Figure 1-6: Great Plains Reservoir System

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In 1976, the Amity Mutual Irrigation Company began storing up to 50,000 AF of its water allocated under the Great Plains decree in John Martin Reservoir under the Winter Water Storage Program (WWSP). Additionally, a transfer decree from 1984 allows up to 50,000 AF under the Great Plains decree to be stored in John Martin Reservoir (Boyle 1993). Under current practice, water only reaches Nee Noshe through the Lone Wolf Canal during extremely wet years and its content has been declining since the late 1990s.

The Great Plains Reservoir System is also designated as an "Important Bird Area." The system has hosted almost every species ever recorded in Colorado and Nee Noshe Reservoir is unique in the interior U.S. for hosting seven species of terns: Least, Black, Forsters, Common, Arctic, Caspian, and Royal (Audubon 2011). The Great Plains Reservoir System was considered for State Park status in the early 1990s. A study was completed by the Lower Arkansas River Commission (as established by Executive Order of then Governor Romer) that developed an "Implementation Plan for Water Resources and State Park Development in Southeastern Colorado." The study was intended to balance the demands for recreation, wildlife, and agricultural water on the Lower Arkansas River and included the goal of providing water for a state park, fishery, and wildlife at the Great Plains Reservoirs. The state park was not developed due to lack of funds to acquire water rights to maintain the lake at a constant level.

The last time water was delivered to Nee Noshe Reservoir was in 2008 when CDOW purchased approximately 10,500 AF of water from Aurora to raise water levels. Before the purchase, Nee Noshe was at an elevation of approximately 4,000 feet and the surface was approximately 450 acres. CDOW was able to deliver approximately 10,000 AF to the Fort Lyon Canal headgate. Out of the 10,500 AF of water purchased, CDOW also delivered approximately 600 AF to the Colorado Canal Company on behalf of Fort Lyon Canal Company as partial payment for running the water through their system. At the end of the delivery with a canal loss of 45 percent, Nee Noshe Reservoir saw an approximate increase in storage of 5,300 AF increasing the lake elevation by 7 feet, and creating a surface area of 1,000 acres (CDOW 2011). Since that time, precipitation has been the only water source and reservoir levels have decreased due to evaporation.

1.4 Report Overview

The remaining sections of this report contain:

- **Section 2 Approach** provides an overview of the approach taken and the water budgets developed for both sites
- **Section 3 Data Collection** discusses historic information and field data collected to assess each site
- **Section 4 Results** presents the quantifications of water needs for the wetlands complex upstream of John Martin Reservoir and for habitat areas around Nee Noshe Reservoir
- **Section 5 Conclusions and Recommendations** frames the quantification results with existing conditions and provides recommendations for potential future scenarios
- **Section 6 References** summarizes the reports and other information that were reviewed as part of the study.

1.5 Acknowledgements

Table 1-1 lists the members of the Arkansas Basin NCNA committee:

Table 1-1: Arkansas River Basin NCNA Committee Members

Name	Organization
SeEtta Moss	Arkansas Basin Roundtable Environmental Representative
Reed Dils	Arkansas Basin Roundtable Recreation Representative
John Tonko	CDOW
Misty DeSalvo	U.S. Forest Service
Pat Wells	Colorado Springs Utilities
Rob White	Colorado State Parks
John Smeins	Bureau of Land Management
Tom Simpson	Aurora Water

Throughout the course of this study, the NCNA committee members met regularly to review and discuss progress as well as refine the methodology. The NCNA group has also reported progress to the Arkansas River Basin Roundtable at their regular meetings. Meeting dates in 2011 include:

- **Conference Calls:** March 5, April 8, and May 6
- **Committee Meetings (in Canon City, Colorado):** February 9, March 31, and April 29
- **Roundtable Meetings (in Pueblo, Colorado):** March 9, April 13, and May 11

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Section 2
Approach

2.1 Approach Overview

The general approach for both study sites began with the development of an understanding of the environmental and recreational resources at each location. Data available for the areas were used to identify the sources of water to and the total acreage of the wetlands complex at John Martin Reservoir. Available data were also used to estimate the existing shorebird habitat available at Nee Noshe Reservoir with relation to the reservoir levels at the site. Once the water sources and wetland area at John Martin Reservoir and the habitat/lake level relationship at Nee Noshe Reservoir were established, the information was used to support development of the overall water budgets or water balance at each location. A water budget is "the scientific method for measuring the amount of water entering, stored within, and leaving a watershed, and it is also called a hydrologic budget or a water balance (Giddings 2011)". A water budget was used to determine the interactions between the water inputs and outputs of both systems.

A water budget is "the scientific method for measuring the amount of water entering, stored within, and leaving a watershed, and it is also called a hydrologic budget or a water balance (Giddings 2011)".

2.2 John Martin Reservoir Complex

As presented in Section 1, a large wetlands complex exists upstream of John Martin Reservoir. Wetlands are defined by the U.S. Division of Fish and Wildlife National Wetland Inventory (NWI) as: "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of the year." Hydric soils are those that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part of the soil layer (National Resources Conservation Service [NRCS] 2011). Wetlands provide environmental benefits to the area because they:

- Prevent floods by temporarily storing water, allowing the water to evaporate, or percolate into the ground;
- Improve water quality through natural pollution control such as plant nutrient uptake;
- Filter sediment; and
- Slow overland flow of water thereby reducing soil erosion (U.S. Department of Agriculture [USDA] 2011).

2.2.1 Wetlands Characterization

The existing conditions of the wetlands complex had not been previously established. The full aerial extent of the wetlands was approximated in order to form a foundation of understanding for water needs quantification efforts. In addition, a review of the surrounding hydrologic system provided a basis for developing the water budget.

A first step in the wetlands characterization efforts was to obtain historical and recent aerial photography to determine the current and historical reservoir levels and extent of the wetlands. **Figure 2-1** shows aerial photography from 1947, 1975, 2001, and 2009. Each photograph shows the reservoir at varying levels while also showing the presence of the wetlands at similar extents throughout this time period. This photographic evidence suggests that the wetlands were present before John Martin Reservoir was constructed and that they are not fully dependent on John Martin Reservoir levels.

Geological data were then reviewed to lend credibility to the theory that the wetlands are not dependent on John Martin Reservoir levels. The Geologic Map of Colorado (Tweto 1979) was reviewed in conjunction with soils data available through NRCS and elevation profiles around the site to explore the possibility that the wetlands are being sustained through subsurface water supplies. This effort (further discussed in Section 3) confirmed that the main source of water to the wetlands is through shallow groundwater from irrigation return flows in the area.

A final step for characterizing the wetlands was to determine the acreage that is currently present. The following data sources were reviewed in order to estimate the existing aerial extent of the complex:

- Recent aerial photography (including color infrared photography)
- NRCS hydric soils data
- NWI data
- Field data

Further descriptions and documentation of these data are provided in Section 3 and the results of the wetlands characterization is presented in Section 4.

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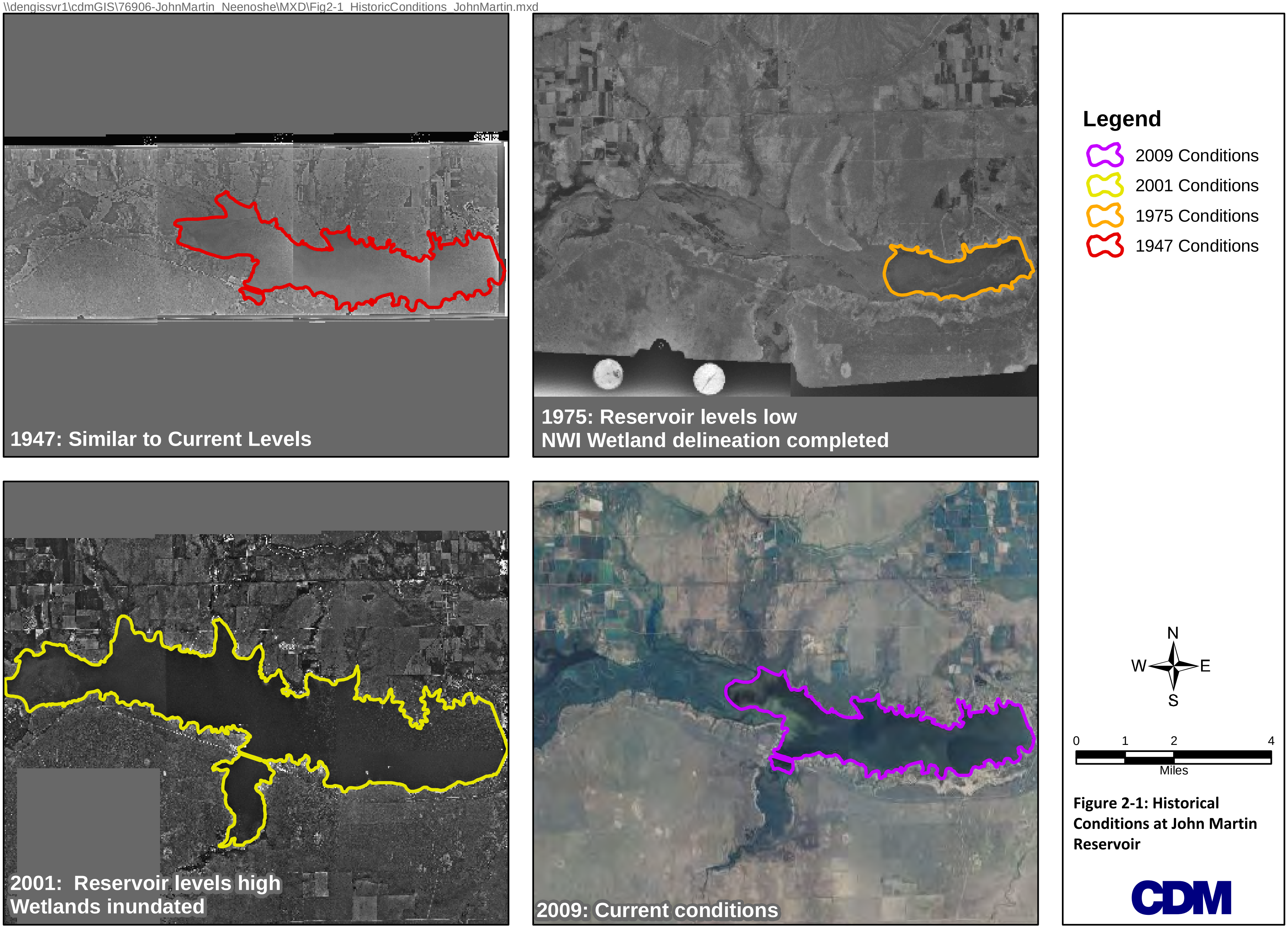

Figure 2-1: Historical Conditions at John Martin Reservoir

2.2.2 Water Budget

A water budget was constructed for the John Martin Reservoir wetlands (**Figure 2-2**) to provide relative quantification of existing sources of supply to the wetlands. Analyses were performed on both annual and monthly timescales, the latter to gain insight on system seasonal dynamics. The water "demands" of the wetlands were included in the water budget as mean evapotranspiration (ET) rates, based on literature review. There were two major components of the analysis: one focused on surface water dynamics and the other on subsurface dynamics. While the ultimate source of supply for these wetlands is recognized to be shallow groundwater (subsurface), the surface water analysis was required to quantify interactions between surface and subsurface hydrology – namely gains and/or losses from the Arkansas River to the alluvial aquifer in the vicinity of the wetlands. Each of these pieces of the analysis is detailed below.

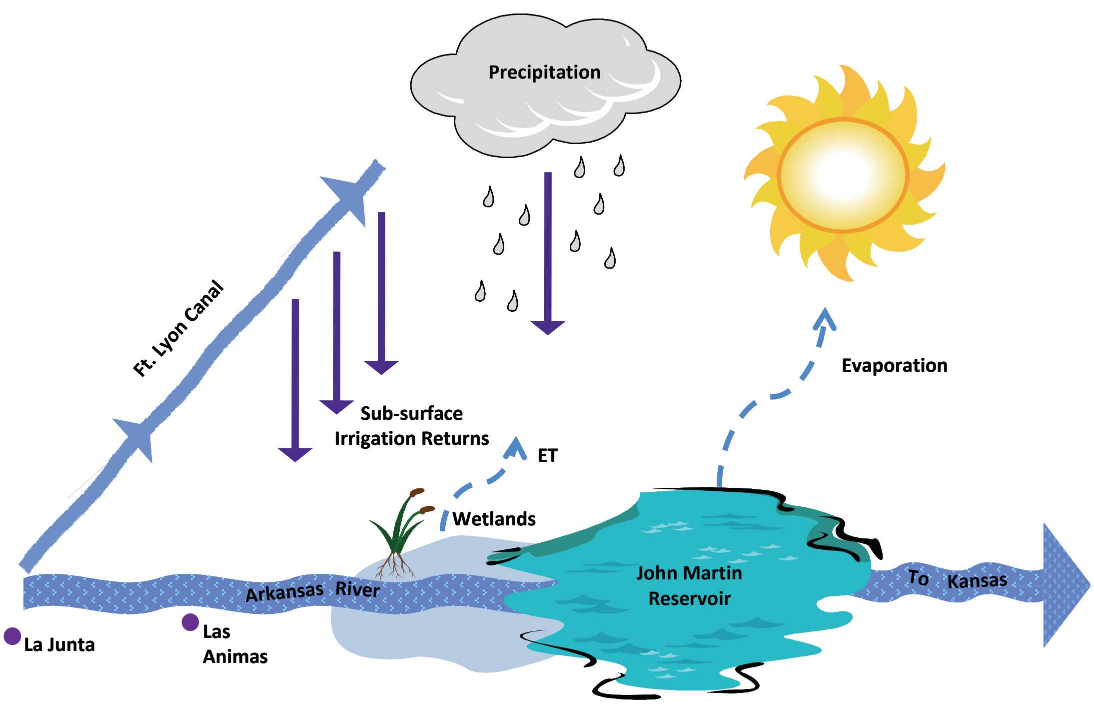

Figure 2-2: John Martin Reservoir Hydrology

The surface water budget for the wetlands starts with the reservoir itself. The reservoir is located essentially at the downstream end of the wetlands system and receives inflows from the Arkansas River (**Figure 2-3**). In this way, river inflows to the reservoir can be considered surface water outflows from the upstream wetlands reach.

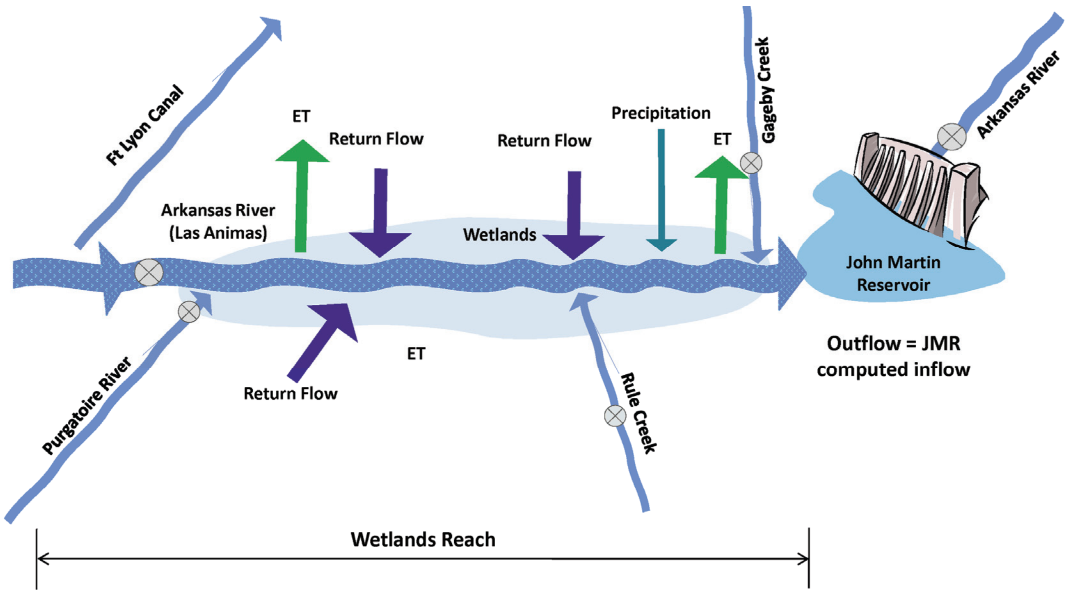

Figure 2-3: John Martin Reservoir Wetlands Surface Water Budget – Wetlands Reach

Monthly reservoir inflows ($Q_{res\ in}$) were calculated using simple storage water budget calculations, written as:

$$Q_{res\ in} = \frac{dS}{dt} - Q_{res\ out} - P + Evap$$

Where S = end-of-month reservoir storage, $Q_{res\ out}$ = reservoir outflow, P = direct precipitation to the reservoir, and Evap = reservoir evaporation. This equation was solved on a monthly timestep over an extended period of record (1978 – 2009). Mean monthly climate data (P and Evap) were combined with monthly gage data in this analysis, as summarized in **Table 2-1**.

Table 2-1: Sources of Data: Surface Water Budget

Reservoir	Source
Reservoir storage (S)	USGS gage 07130000, John Martin Reservoir at Caddoa (POR = 1978 - present)
Reservoir outflow (Q^{res}_{out})	USGS gage 07130500, Arkansas River below John Martin Reservoir (POR = 1938 - present)
Reservoir direct precipitation (P)	National Climatic Data Center (POR = 1941 - 2010)
Reservoir evaporation (Evap)	State of Colorado DWR calculated records for John Martin Reservoir (POR = 1979 - 2010)
Wetlands Reach	**Source**
Upstream Arkansas River flow (Q_{Animas})	USGS gage 07124000, Arkansas River at Las Animas (POR = 1939 - present)
Purgatoire River flow (Q_{Purg})	USGS gage 07128500, Purgatoire River near Las Animas (POR = 1922 - present)
Rule Creek flow (Q_{Rule})	USGS gage 07129500, Rule Creek near Caddoa (POR = 1942 - 1946)
Gageby Creek flow (Q_{Gageby})	State of Colorado DWR Hydrobase data for Gageby Creek below Fort Lyons canal (POR = 2006 - 2009)

Reservoir inflows calculated above were used to solve for Arkansas River gains and losses to the subsurface in the vicinity of the wetlands ("wetlands reach"). This reach extends from approximately the Las Animas gage of the Arkansas River to John Martin Reservoir. The water budget for this system can be written as:

$$Q_{gain}=Q_{res\ in}-Q_{Animas}-Q_{Purg}-Q_{Rule}-Q_{Gageby}$$

Where Q_{gain} = net gain to the Arkansas River along the wetlands reach, Q_{Animas} = upstream Arkansas River flow, Q_{Purg} = Purgatoire River flow at confluence with Arkansas River, Q_{Rule} = Rule Creek flow, Q_{Gageby} = Gageby Creek flow. This equation was solved for Q_{gain} on a monthly timestep over the same period as above (1978 – 2009). Monthly gage data were used for Arkansas and Purgatoire River flows, while mean gaged monthly values were used for Rule and Gageby Creek flows (Table 2-1).

The sub-surface water budget for the John Martin Reservoir wetlands (**Figure 2-4**) quantifies the hydrologic budget of the alluvial groundwater underlying the wetlands. It is this balance that maintains the water table levels needed for the wetlands. The key sources of supply to this local alluvium are irrigation return flows and precipitation. The main losses from the system are seepage to the Arkansas River and wetland plant ET.

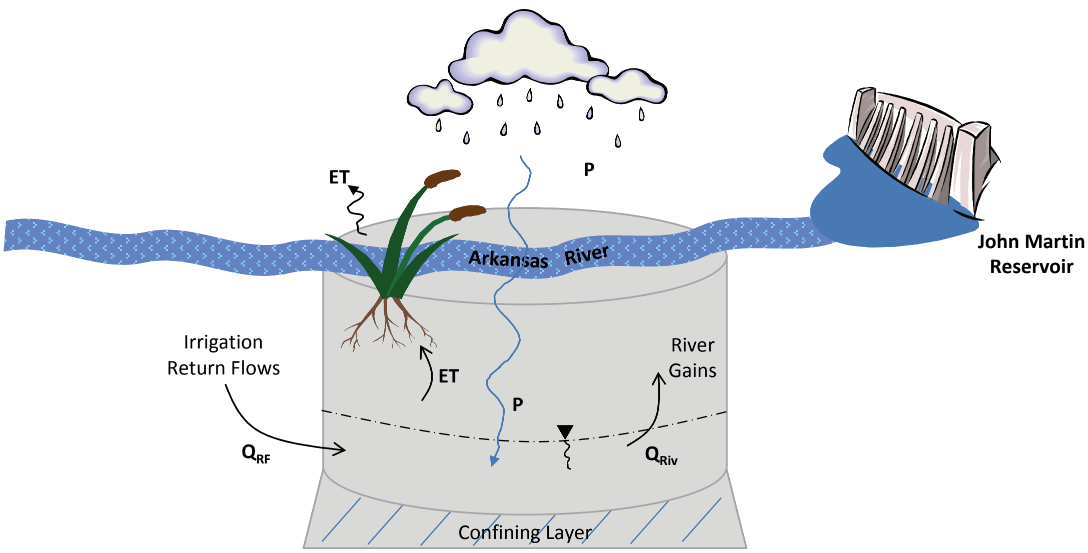

Figure 2-4: Subsurface Water Budget for John Martin Reservoir Wetlands

Water budgets were constructed on both an annual and mean monthly (seasonal) basis. Assuming a static water table, and neglecting lateral groundwater flows, the water budget can be written as:

$$Q_{RF}+P=Q_{Gain}+ET$$

Where Q_{RF} = irrigation return flows, P = local precipitation, Q_{Gain} = local gains to the Arkansas River, and ET = total wetlands evapotranspiration. The river gains term (Q_{Gain}) is quantified as part of the surface water budget described above. Sources of data for this analysis are provided in **Table 2-2**.

Table 2-2: Sources of Data: Subsurface Water Budget

Wetlands Reach	Source
Irrigation return flows (Q_{RF})	DWR Hydrologic Institution Model
Wetlands direct precipitation (P)	National Climatic Data Center (POR = 1941 - 2010)
Arkansas River gains (Q_{Gain})	Surface water budget
Wetlands ET	Literature: South et al. (1998); Jacobs et al. (2002); Wallace et al. (2005); Cooper et al. (2006)

2.3 Nee Noshe Reservoir

In Colorado, federally listed piping plover and least tern nest solely on the shorelines of large reservoirs in the southeast part of the state (Nelson 2009). Reservoirs in the southeast part of the state were last full in 1999 and since that time, available habitat for the birds has changed dramatically. The shoreline habitat has shrunk over the past decade due to unfavorable water levels and colonization of invasive plants such as saltcedar/tamarisk and invasive grasses. Both bird species have historically nested at the Great Plains Reservoirs; however, in recent years, nesting has been limited to Nee Granda Reservoir with only two pairs of piping plover and one pair of least tern in 2009.

Nee Noshe Reservoir was selected for this study due to its location within the Great Plains Reservoir System. Nee Noshe Reservoir is located at the end of the system (refer to Figure 1-6) and if water was to become available for any of the Great Plains Reservoirs, it would be easiest to have access to it for downstream uses if it was stored in Nee Noshe Reservoir (CDOW 2011).

2.3.1 Habitat Characterization

Both piping plover and least terns use sandy shoreline for nesting habitat. Nee Noshe Reservoir has supported both species in the past; least tern as recently as 2004, and piping plover as recently as 2003 (Nelson 2009). The process of characterizing the habitat at Nee Noshe Reservoir included defining the current conditions at the site as well as the historical conditions at the site when nesting has been observed. Historical and existing reservoir area and volumes were estimated through the following data sources:

- Recent and historical aerial photography
- Historical diversion records at the Kicking Bird Canal
- Historical area/capacity curve (Boyle 1993)
- Field data

Figure 2-5 shows aerial photographs from 1954, 1975, 1998, and 2009 for reference. The photographs show that the reservoir levels have varied through time and that levels were very high in the late 1990s and have significantly declined through 2009. Field data and aerial photography were also used to estimate the aerial extent of current shoreline habitat at the site. Further descriptions and documentation of these data are provided in Section 3 and the results of the wetlands characterization is presented in Section 4.

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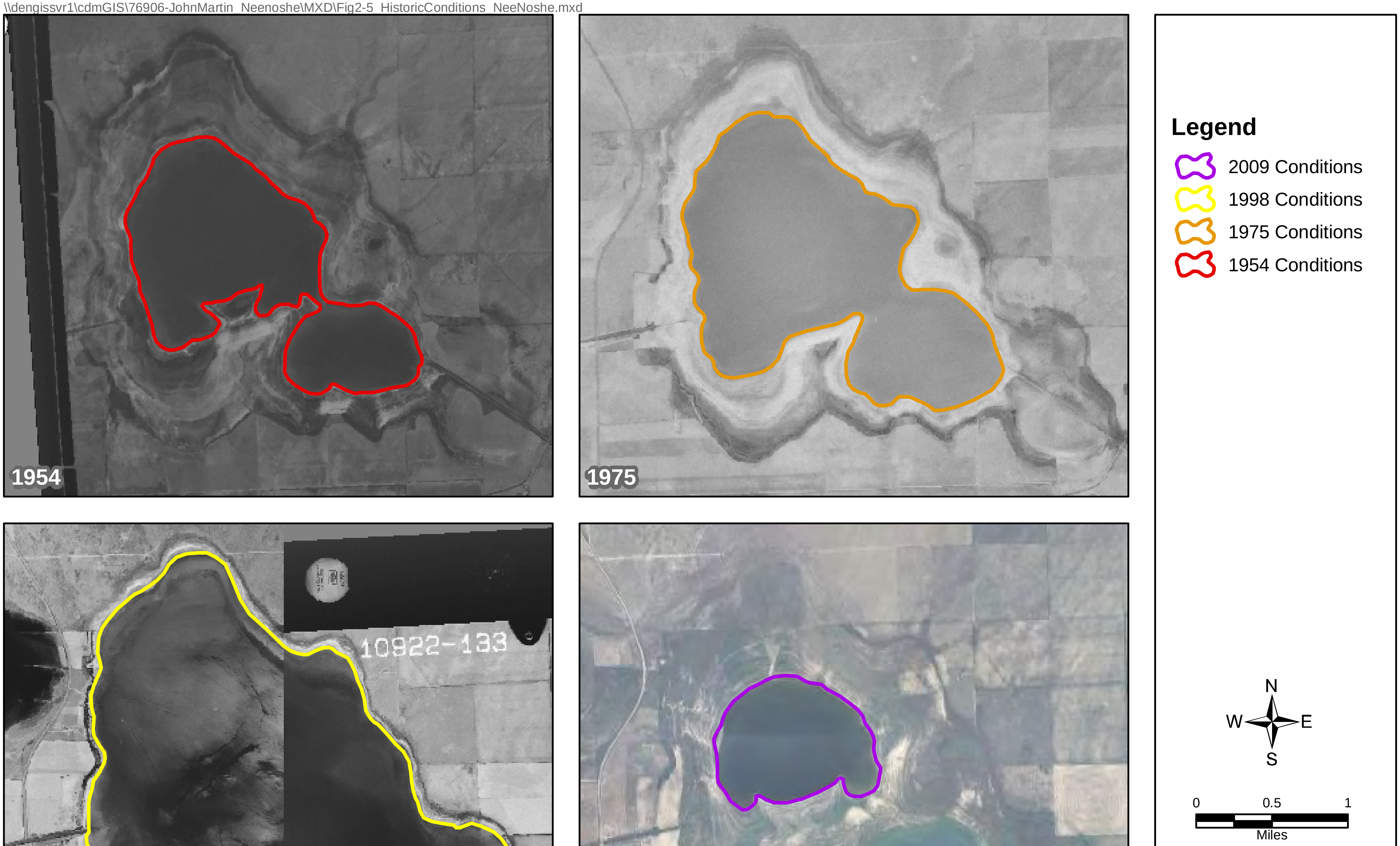


Figure 2-5: Historical Conditions at Nee Noshe Reservoir

2.3.2 Water Budget and Dynamic Reservoir Simulations

The Nee Noshe Reservoir is an off-channel reservoir that currently receives surface water diversions only sporadically during periods of high flow due to the junior priorities of the storage rights for the Great Plains Reservoirs. As a result of this condition, the water budget for the reservoir is mainly based on direct precipitation and evaporation (**Figure 2-6**). Since, on an annual basis, evaporative losses are higher than direct precipitation to the reservoir, the reservoir generally loses water. To quantify this budget, mean monthly precipitation values were assumed equal to those measured for the John Martin Reservoir (Table 2-2). Mean monthly evaporation rates were assumed equal to those measured for the John Martin Reservoir by USACE (Table 2-2). A pan factor of 0.7 (Bedient and Huber 1992) was applied in the water budget analysis. In the absence of site-specific data, and given the proximity of the two reservoirs, John Martin Reservoir measured climate data were deemed adequate for this analysis. Reservoir volumes were translated into reservoir surface areas via the reservoir's area-capacity curve (Boyle 1993). This enabled comparisons to delineated critical habitat areas in the margins of the reservoir.

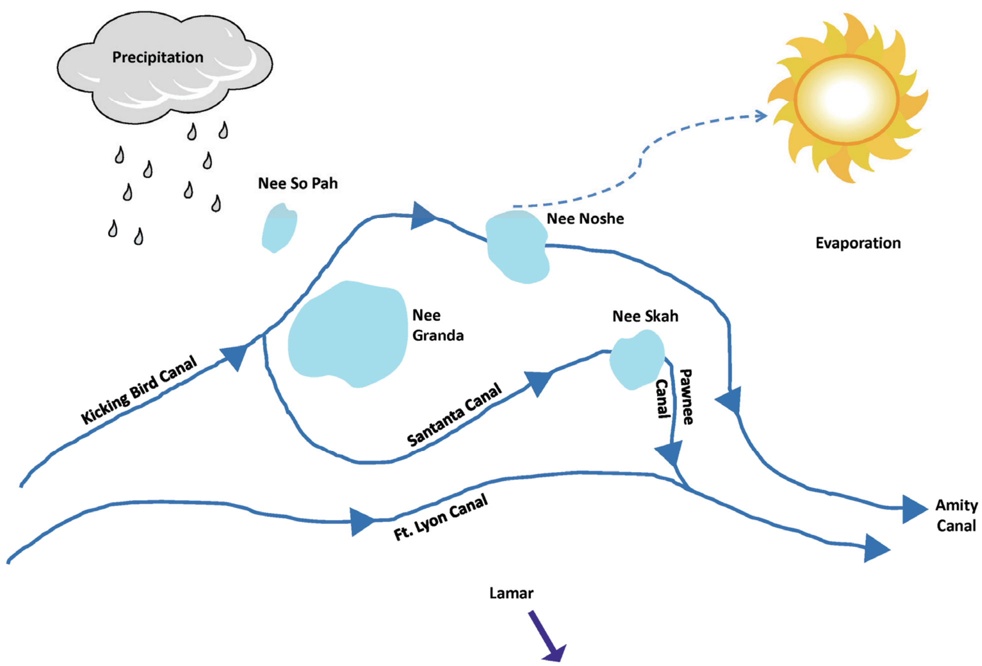


Figure 2-6: Nee Noshe Reservoir Water Budget

In addition to characterizing the current system, water budget calculations were performed to investigate two hypothetical conditions whereby storage pools of 21,000 and 25,000 AF were maintained annually in the reservoir. The former (21,000 AF) represents the reservoir dead pool level described in Section 1. The latter (25,000 AF) represents the estimated reservoir level for summer 2004, the time of the last reported sighting of least terns at the reservoir (Nelson 2009). The 2004 storage value was estimated as part of the historical model simulations described below. Total annual headgate diversions at Fort Lyons required to maintain these pools were quantified, assuming a 45 percent canal loss.

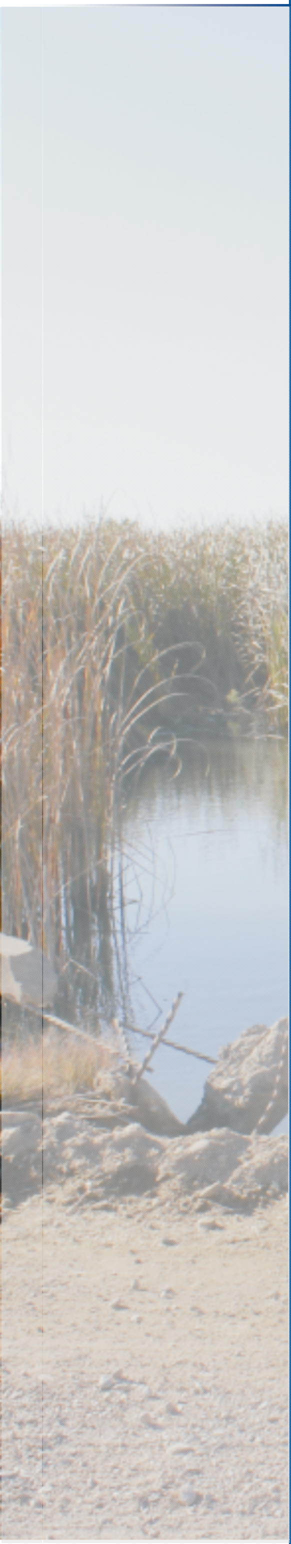
Seasonal dynamics associated with this system were investigated using Camp Dresser & McKee Inc.'s (CDM's) Simplified Water Allocation Model (SWAM). SWAM is a generalized monthly time-step water allocation tool that includes simple reservoir storage routing, nodal diversions and return flows, and water rights. For this analysis, a seasonal pattern of reservoir level fluctuations was conceptualized based on avian habitat requirements (described previously). These fluctuations generally followed:

- High reservoir levels that inundate habitat areas during the non-nesting season (winter) to prevent vegetation encroachment
- Low reservoir levels during the spring and summer months to allow for bird nesting and mudflats foraging

Given these hypothesized water level targets, SWAM was used to quantify seasonal diversion patterns at the Fort Lyon headgate (required to achieve the targets). Monthly net evaporation rates (Evap – P) and total canal losses were parameterized in the model as described above.

SWAM was also used to simulate historical fluctuations in Nee Noshe Reservoir levels since the end of the measured record (1995). The objective of this exercise was twofold: a) to provide confirmation of the system dynamics simulated in SWAM, and b) to provide a useful reference of estimated recent historical water level patterns in the reservoir. Monthly diversion records for the Fort Lyons headgate (1995 – 2009), provided by the state, were utilized for this analysis. Monthly mean net evaporation rates and a 45 percent canal loss were maintained as described above. No reservoir withdrawals or releases were assumed for this analysis. Simulated results were compared to two independently estimated data points: 1998 and 2009 reservoir storage levels calculated using geographic information system (GIS) and aerial photographs. For these two points, aerial photographs were digitized in GIS to allow for estimates of water surface areas. The reservoir area-capacity curve was then used to translate surface areas into storage values.

As a final exercise, SWAM was used to simulate a future scenario that includes periodic deliveries to the reservoir, via diversion at Fort Lyons headgate, to maintain current levels. For this exercise, the lumped diversions were set at 10,500 AF delivered in total in the spring (May). This value equates to the last recorded water purchase (2008) by CDOW described in Section 1. An iterative analysis was performed to determine the yearly frequency of this diversion required to maintain steady patterns of reservoir levels into the future, roughly equivalent to current levels. Monthly mean net evaporation rates and a 45 percent canal loss were assumed for this analysis, as explained above.



Section 3
Data Collection

3.1 Data Collection Overview

Multiple sources of data were collected in order to characterize the wetlands northwest of John Martin Reservoir and the habitat areas for Nee Noshe Reservoir to provide information for the water needs quantification. Historical data were combined with knowledge gained through site visits to support the approach for the quantification of nonconsumptive needs at these sites as described in Section 2. This section summarizes the historical data collected for each site as well as the field data collection.

3.2 Historic Data

Historic hydrologic and hydraulic data were collected to provide input and output values for the water budgets described in Section 2. In addition, data were collected in order to fully characterize the wetlands at John Martin Reservoir and the available habitat at Nee Noshe Reservoir. A summary of these data are provided below.

3.2.1 Hydrologic/Hydraulic Historic Data Summary

In order to build the water budgets for both study areas as described in Section 2, hydrologic and hydraulic data were collected from the following sources:

- National Climatic Data Center (NCDC);
- Colorado Division of Water Resources (DWR);
- U.S. Geological Survey (USGS);
- Colorado Geological Survey (CGS)
- Hydrologic-Institutional Model (H-I Model); from DWR
- Previous studies and reports summarizing the hydrology and hydraulics of both sites; and
- Literature values for ET rates.

These data were used to build and confirm the water budget approach presented in Section 2 for both study sites. Information about the following hydrologic and hydraulic data is summarized in the remainder of this section:

- Precipitation
- Pan evaporation
- Streamflow and canal diversion records
- Reservoir levels and storage
- ET rates
- Irrigation Return Flows and Ditch Losses
- Geology

3.2.1.1 Precipitation

Precipitation records from the NCDC were collected for the John Martin Reservoir meteorological station for the period of record (1941 to 2010). Data from this station were applied to both water budgets (John Martin Reservoir wetlands and Nee Noshe Reservoir) as this station was the closest available to both sites and had the longest period of record. **Table 3-1** contains a summary of available precipitation data and shows that the area receives approximately 12 inches of precipitation annually. July is typically the wettest, hottest month while January is typically the driest, coldest month.

Table 3-1: Precipitation Records, John Martin Reservoir 1941-2010 (NCDC 2011)

Precipitation	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	45	51	58	69	78.4	89	94	92	84	72	57	46	69.7
Average Min. Temperature (F)	15	20	27	38	47.5	57	63	61	51	38	25	17	38.4
Average Total Precipitation (in.)	0.2	0.3	0.7	1	1.9	1.7	2.1	1.9	1	0.8	0.4	0.3	12.4

3.2.1.2 Pan Evaporation

The DWR maintains an evaporation pan at the John Martin Reservoir dam location. Monthly pan evaporation data were available from 1966 to 2009 and are summarized in **Table 3-2**. The pan evaporation station at John Martin Reservoir is the only station that collects this type of information in the area and was used for the water budget at Nee Noshe Reservoir. The John Martin Reservoir station has an annual pan evaporation loss of 84 inches with the highest losses recorded during July. Actual evaporation is typically less than pan evaporation, so the average annual pan evaporation was multiplied by pan factor of 0.7 (Bedient and Huber 1992).

Table 3-2: Pan Evaporation, John Martin Reservoir 1966-2009 (DWR 2011)

Month	Mean Pan Evaporation (in.)
January	2.5
February	3.7
March	6.4
April	7.8
May	9.1
June	11.6
July	12.8
August	10.5
September	8.5
October	5.6
November	2.7
December	2.5
Total	83.7

In addition to the pan evaporation values used for the water budget at Nee Noshe Reservoir, DWR also maintains daily accounting calculations for John Martin Reservoir. This was considered a better dataset for John Martin Reservoir as the data were available in units of flow. Because the data were in units of flow, they were not easily transferrable to another reservoir, and as such, the pan evaporation values (in units of depth) were applied to Nee Noshe Reservoir. **Table 3-3** contains the evaporation data used for the John Martin Reservoir surface water budget.

Table 3-3: Calculated Evaporation, John Martin Reservoir 1966-2009 (DWR 2011)

Month	Evaporation (AFM)
January	450
February	800
March	2,250
April	2,870
May	3,450
June	4,800
July	4,360
August	3,350
September	2,360
October	1,470
November	820
December	630
Total (AFY)	27,600

3.2.1.3 Streamflow and Canal Diversion Records

USGS and DWR gage data were also collected for streamflows into and out of the John Martin system. **Figure 3-1** shows the locations of the gages used for the John Martin Reservoir wetland analysis. **Table 3-4** contains monthly streamflows in AF per month (AFM) for each gage. Table 3-4 shows that Arkansas River is the largest contributor of surface water to the wetlands system while the Purgatoire River contributes significantly less water. Rule Creek and Gageby Creek provide minor surface water inputs to the wetlands. Flows in this area are highest into the system in early summer months and lowest during the fall and early winter. Releases from John Martin Reservoir are highest in midsummer and lowest in mid-winter.

Table 3-4: Mean Monthly Flow (AFM) (USGS & DWR 2011)

Gage Name	Rule Creek near Caddoa (2004-2009)	Arkansas River at Las Animas (1939-2011)	Arkansas River below John Martin (1938-2009)	Purgatoire River near Las Animas (1948-2011)	Gageby Creek (2007-2009)
January	40	8,300	1,800	1,600	100
February	40	7,200	1,700	1,500	90
March	60	5,800	3,300	2,200	370
April	140	8,300	28,000	4,200	100
May	390	28,000	36,000	8,600	140
June	60	42,000	40,000	9,700	270
July	400	26,000	43,000	8,500	240
August	10	17,000	33,000	10,000	290
September	20	5,600	20,000	3,300	520
October	30	7,000	12,000	1,700	580
November	30	6,500	2,700	1,700	300
December	40	6,800	1,700	1,500	110

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Figure 3-1: USGS and DWR Gages

Stream gage data are not available for the canals that supply water to the Great Plains Reservoir system. DWR provided diversion records for the Kickingbird Canal, which delivers water to Nee Noshe Reservoir. The values provided by DWR are for the Kickingbird Canal as measured at the Fort Lyon Canal headgate. The diversion values then need to be reduced by 45 percent to account for canal losses and estimate the amount of water that ultimately reaches the Great Plains system. **Figure 3-2** shows annual diversions for the Kickingbird Canal at the Fort Lyon Canal headgate for the period of record (1951-2010). The only water that has been diverted to Nee Noshe in the last decade occurred in 2008 and was approximately 10,500 AF at the Fort Lyon Canal headgate. These diversion values were used for confirmatory analysis of the Nee Noshe water budget.

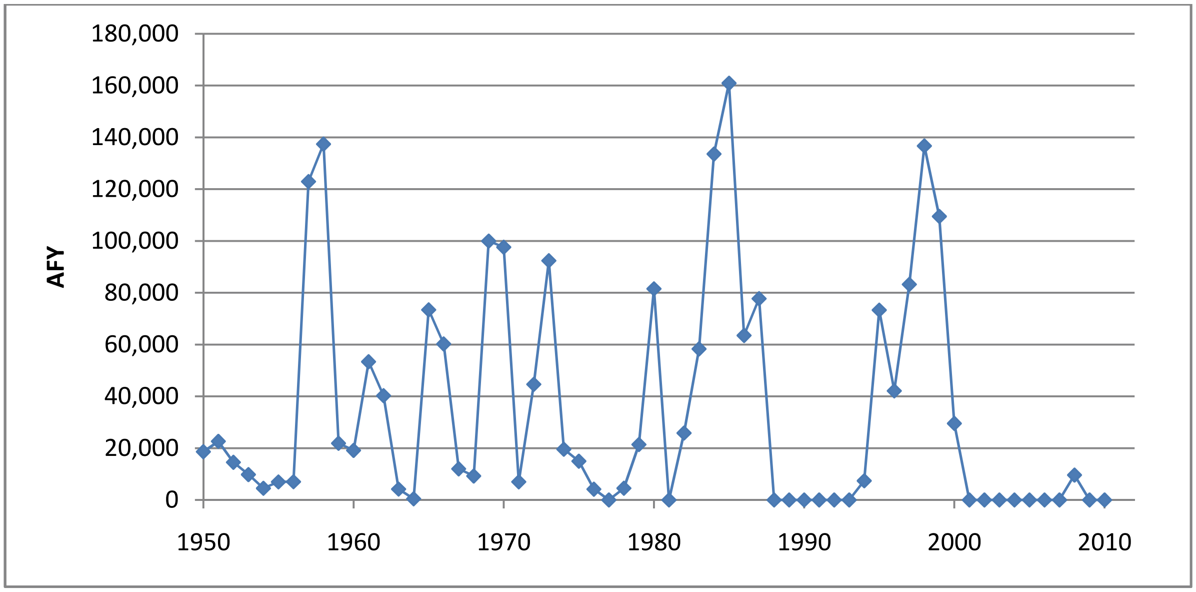

Figure 3-2: Annual Diversions to the Kicking Bird Canal at the Fort Lyon Canal Headgate (DWR 2011)

3.2.1.4 Reservoir Levels and Storage

Surface elevation and reservoir storage data for John Martin Reservoir are available through the USGS from the late 1970s to present. Aerial photographs were also available for a number of years to provide a frame of reference for storage levels. **Figure 3-3** contains a summary of historical data from USGS gage 07130000, John Martin Reservoir at Caddoa, Colorado. The figure shows maximum storage values recorded each year at the reservoir since 1978 and shows that reservoir levels have declined significantly since the late 1990s. Aerial photographs showed that although the reservoir levels are currently much less than they were in the late 1990s, the extent of the wetlands has remained constant. Storage data for John Martin Reservoir was also used in the John Martin Reservoir wetlands surface water budget.

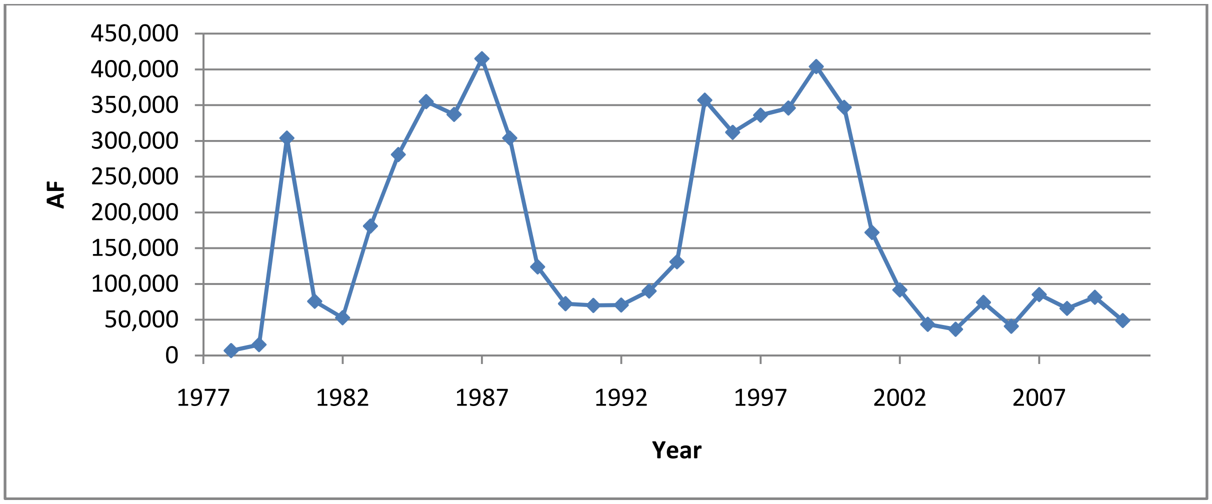

Figure 3-3: Annual Maximum Storage at John Martin Reservoir (USGS 2011)

Limited information is available for the Great Plains Reservoir systems. **Table 3-5** contains storage information for each of the reservoirs in the system (Boyle 1993). Nee Gronda Reservoir is the largest of the system and Queens Reservoir is the smallest of the system. Although Nee Noshe is not the largest in total capacity, it has a smaller dead pool than Nee Gronda, which provides a larger available capacity meaning it requires less water to fill its dead pool. Nee Noshe is also situated at the end of the system so any available capacity would be located closest to any downstream users.

Table 3-5: Great Plains Reservoir System Storage (Boyle 1993)

Reservoir	Unavailable Capacity (Dead Pool)	Available Capacity	Total Capacity
Nee So Pah	10,908	25,480	36,388
Nee Gronda	39,860	58,800	98,660
Nee Noshe	**21,485**	**73,362**	**94,847**
Queens	9,939	25,718	35,657
Total	82,192	183,360	265,552

In order to estimate capacities at Nee Noshe Reservoir, a previously established area-capacity curve was used (Boyle 1993). The area-capacity curve from the report is available in **Appendix B** for reference. Aerial photographs were downloaded into GIS and used to calculate surface areas. The area-capacity curve was then used to correlate these surface acres to capacity values and used to confirm water budget results calculated for the reservoir.

3.2.1.5 Evapotranspiration Rates

A literature review was performed to quantify a general range of wetland ET rates appropriate to the John Martin Reservoir wetland system. Colorado ET rates from Sanderson and Cooper, 2008 were supplemented with rates established for wetland plants across the country. Other than relatively minor air temperature differences and minor differences across species, the ET rates did not show large variability (i.e., order of magnitude) and confirmed that wetland plants have large ET rates regardless of location.

3.2.1.6 Irrigation Return Flows and Ditch Losses

Return flows accruing to the John Martin Reservoir wetlands complex from upstream and adjacent agricultural water use were calculated using input and output data from the H-I Model. This model was developed in conjunction with the Kansas v. Colorado litigation related to compliance with the Arkansas River Compact. DWR provided H-I Model documentation, input files, and spreadsheets of annual and monthly model output for the most recent (through 2009) Arkansas River Compact compliance simulations.

The H-I Model reach of interest for this study is Reach 10, which extends from the Arkansas River at Las Animas gage (USGS 071240000; DWR ID ARKLASCO) at the upstream end to the Arkansas River below John Martin Reservoir gage (USGS 07130500; DWR ID ARKJMRCO) at the downstream end. Irrigation ditches with losses that become return flows to Reach 10 include the Fort Lyon Canal on the north side of the Arkansas River and the Las Animas Consolidated Canal on the south side of the Arkansas River. Within the H-I Model, the Fort Lyon Canal is defined as "User 10," and the Las Animas Consolidated Canal is "User 13."

The H-I Model calculates multiple sources of water loss from each canal system, including (1) reservoir canal losses, i.e., seepage losses from canal delivering reservoir releases back to a main canal or lateral; (2) direct canal seepage losses; (3) off-farm lateral seepage losses; (4) on-farm lateral seepage losses; (5) tailwater, i.e., surface water returns via overland flow or drain canals; and (6) deep percolation, which includes both "initial" and "excess" deep percolation as calculated within the model. The return flows from the Fort Lyon Canal and Las Animas Consolidated Canal are distributed to more than one reach in the H-I Model. **Table 3-6** below summarizes the fraction of each system loss component that returns to Reach 10.

Table 3-6: H-I Model Reach 10 Return Fractions

Loss Component	Fort Lyon Canal		Las Animas Consolidated Canal	
	Reach 10 Return Fraction	Source H-I Model Input File	Reach 10 Return Fraction	Source H-I Model Input File
Reservoir Canal Loss	0.2310	CNRESP.DAT	0.4772	SWRESP.DAT
Direct Canal Loss	0.2310	CNRESP.DAT	0.4772	SWRESP.DAT
Off-Farm Lateral Loss	0.1250	SWRESP.DAT	0.4772	SWRESP.DAT
On-Farm Lateral Loss	0.1250	SWRESP.DAT	0.4772	SWRESP.DAT
Tailwater	0.1500	LAND.DAT	0.4000	LAND.DAT
Initial Deep Percolation	0.1250	SWRESP.DAT	0.4772	SWRESP.DAT
Excess Deep Percolation	0.1250	SWRESP.DAT	0.4772	SWRESP.DAT

The H-I Model documentation is contained within the January 2008 Proposed Judgment and Decree for Kansas v. Colorado (Fifth and Final Report, Volume III, Appendix C). This documentation provides descriptions of each of the H-I Model input files references in Table 1, as follows:

- CNRESP.DAT contains the canal seepage response functions for the Fort Lyon Canal (User 1) and the Amity Canal (User 17)
- SWRESP.DAT contains response functions for return flows from applied irrigation water
- LAND.DAT contains a seepage factor and the length of the canal for computing canal losses, a tailwater factor for each user, and a Secondary Evapotranspiration (SEV) factor defined as the percentage of canal and lateral losses and tailwater that is consumed by evaporation or non-crop evapotranspiration

In the CNRESP.DAT and SWRESP.DAT input files, the canal loss and irrigation loss return flows are set up as unit response functions. CNRESP.DAT lags Fort Lyon Canal return flows over a period of 240 months. Canal and irrigation return flows are lagged over 120 months by the unit response functions in SWRESP.DAT. However, for the purpose of this analysis, the system was assumed to be operating under steady-state conditions, and the values shown in Table 3-6 were applied to the model-calculated loss volumes in each month.

The SEV factor defined in the LAND.DAT description above was derived through the model calibration process. For upstream canals, including the Fort Lyon Canal and Las Animas Consolidated Canal, the annual average SEV is 24 percent. A monthly distribution of SEV is provided in **Table 3-7** below. Consistent with seasonal variability for ET, the SEV factors are lowest in the late fall and early winter months (0.078 in November and December, 0.084 in January) and highest at the peak of the growing season in mid-summer (0.435 in July).

Table 3-7: Monthly Distribution of SEV for Upstream Canals

Month	Upstream SEV Factor
January	0.084
February	0.121
March	0.204
April	0.279
May	0.334
June	0.403
July	0.435
August	0.372
September	0.282
October	0.193
November	0.078
December	0.078
Average	**0.240**

The H-I Model output data spreadsheets provided by DWR include monthly volumes for each of the seven loss terms for each user for calendar years 1950-2009. Each of these monthly volumes was multiplied by the appropriate factor in Table 1 to get the volume of each loss returning to Reach 10. Based on guidance from DWR, sub-total return flows accruing to Reach 10 from the Fort Lyon Canal and the Las Animas Consolidated Canal were calculated as follows:

Sub-Total Return Flows to Reach 10 from Canal = [(Reservoir Canal Loss + Direct Canal Loss + Off-Farm Lateral Loss + On-Farm Lateral Loss + Tailwater) x (1-SEV)] + Initial Deep Percolation + Excess Deep Percolation.

Total Reach 10 return flows were calculated by summing the Fort Lyon Canal and Las Animas Consolidated Canal sub-totals.

3.2.1.7 Geological Data

In order to confirm the theory that the wetlands are being primarily supplied with water from a shallow sub-surface aquifer, the geology of the area was reviewed. The following data sources were used for this exercise: the NRCS Soil Survey Geographic Database (SSURGO), the USGS National Elevation Dataset (NED), and the Geologic Map of Colorado (Tweto 1979). These data sources show that the wetlands occur on recent alluvial deposits of the Arkansas River. The confluence of the Purgatoire River and its associated alluvial deposits occur near the upper reach of the wetlands. Significant flood irrigation is conducted south of the wetlands in the alluvium of the Purgatoire River, and north of the wetlands on gently sloping areas underlain by terrace gravels and cretaceous bedrock units, including the Carlile Shale, Greenhorn Limestone, and Graneros Shale. The eastern limit of the wetlands is bounded on the north and south by outcrops of Dakota Sandstone. This outcrop area defined by the Dakota Sandstone is an area where the width of the alluvial deposits narrows significantly compared to upgradient areas.

Limited groundwater information is available adjacent to the wetlands area. Records of water wells show that several wells are completed in alluvial or terrace gravel deposits in the vicinity of the confluence of the Arkansas and Purgatoire River alluvial valleys that produce up to 1,000 gallons per minute (gpm) with gravel thicknesses of less than 50 feet. The total depth of the alluvial deposits in this area are not available from the data sources examined. Several sources of water potentially support the wetland vegetation that is present. The wetlands occupy lowlands adjacent to the Arkansas River in a band up to about a mile wide. Sources of supporting these wetlands include surface runoff from irrigated lands north of the wetlands, and shallow groundwater in the alluvium. The alluvium is likely receiving significant lateral inflows from infiltrating irrigation water in the area to the north. Infiltration and seepage losses from irrigation structures were calculated for this study using data from the H-I Model, as described in Section 3.2.2.6. This infiltrating water will move in the weathered bedrock interval in the direction of topography to points of surface discharge, or will move into the alluvial aquifer.

An additional factor affecting the shallow groundwater levels in the area is associated with the narrowing of the alluvial valley of the Arkansas, where it is constrained by outcrops of the Dakota Sandstone near the upper reaches of the John Martin Reservoir. This narrowing of the valley limits the amount of groundwater underflow, resulting in shallow groundwater levels as the groundwater emerges to the river channel.

3.2.2 John Martin Reservoir Wetlands Historic Data Summary

The approach for characterizing the wetlands at John Martin Reservoir was discussed in Section 2. Along with the hydrologic and hydraulic information presented above, additional data specific to the wetlands were collected in order to estimate the full aerial extent of the complex. Aerial photography (including color infrared photography) was paired with NRCS SSURGO information on the hydric soils of Bent County and the NWI data for the region.

3.2.2.1 Soils Data

NRCS SSURGO data are available through the NRCS website by county. The data were obtained for Bent County and imported into GIS and summarized geospatially by soil series. Hydric soils are those that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions (NRCS 2011) and are typically soils that support wetland vegetation. **Table 3-8** summarizes the hydric soils in Bent County while **Figure 3-4** shows the corresponding map units highlighted.

Table 3-8: Hydric Soils of Bent County (NRCS 2011)

Map Unit ID	Soil Series Name
Ac	Apishapa clay loam
Bd	Bankard soils
GbA	Glenberg sandy loam, 0 to 1 percent slopes
GbB	Glenberg sandy loam, 1 to 3 percent slopes
La	Las clay loam
Lm	Las Animas soils
NuB	Numa clay loam, et, 0 to 3 percent slopes

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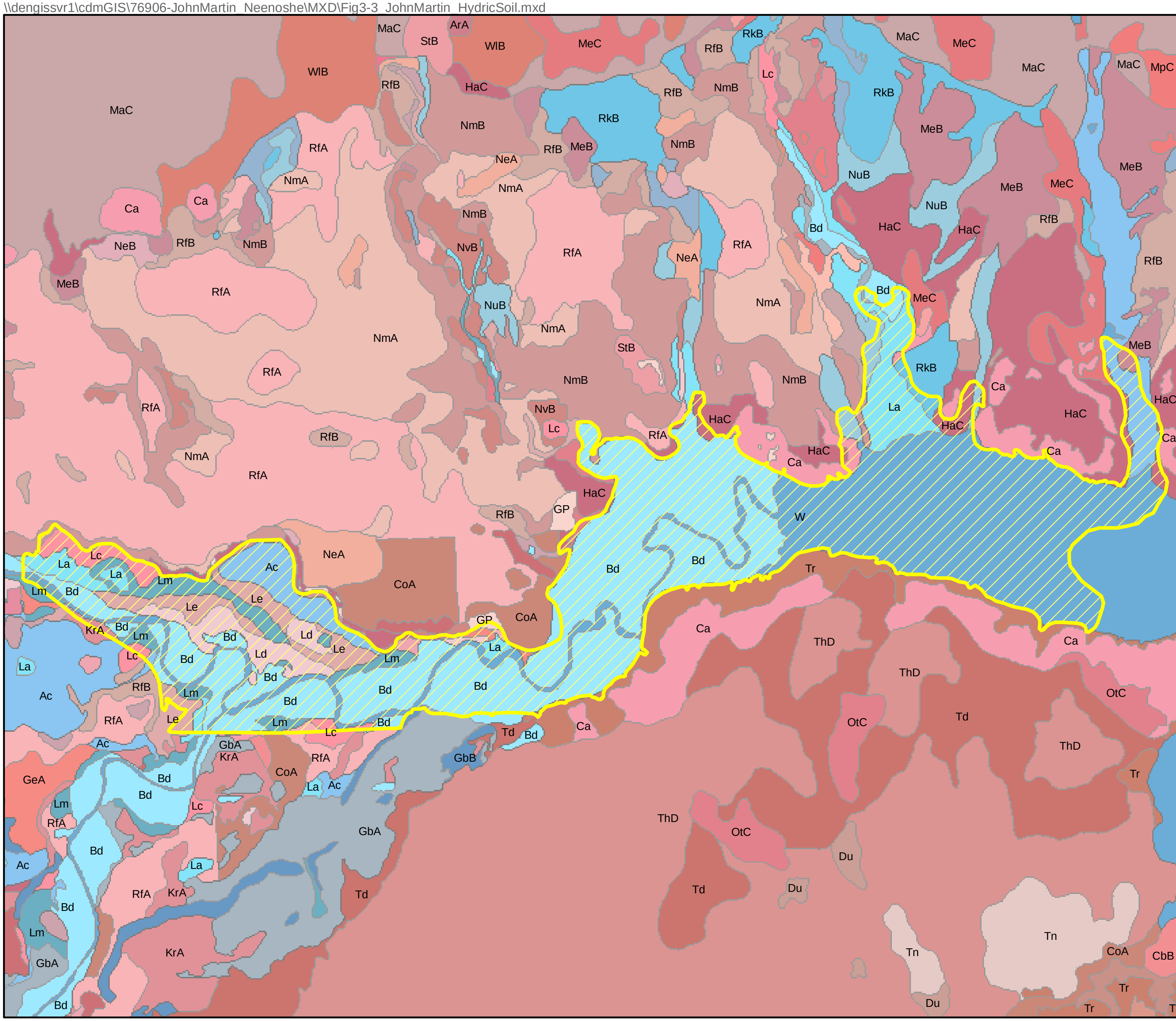

Legend

Wetland Boundary Estimate

Blue Shades: Hydric Soils

N
W E
S

0 0.5 1
Miles

Figure 3-4: Hydric Soils (NRCS 2011)

CDM

3.2.2.2 National Wetlands Inventory

The U.S. Fish and Wildlife Service (USFWS) maintains the NWI data that are available in digital format. NWI data for the southeast portion of Colorado has not been upgraded to the most recent version of the NWI database; however, data that were digitized in 1975 were available for the area. Wetlands are coded to adapt the national wetland classification system to map form. These alpha-numeric codes correspond to the classification nomenclature that best describes the habitat. The codes were developed through the Classification of Wetlands and Deepwater Habitats of the United States (17MB PDF), 1979, by Cowardin, Lewis M. et al. **Appendix C** provides information for the wetlands categories associated with the various mapping codes. **Figure 3-5** highlights the wetland area that was delineated in 1975 by the USFWS.

3.2.2.3 Digital Aerial Photographs

Digital aerial photographs for the area were available as recently as 2009. Historic photographs were downloaded from the USGS. Both regular spectrum photographs as well as infrared imagery for 2009 were downloaded from the National Agricultural Imagery Program (NAIP). The wetlands complex can easily be seen on the images. The 2009 aerial photograph was paired with the 1975 NWI data for comparison. **Figure 3-6** shows that the current wetland area is very similar to what was present in 1975, further suggesting that the wetlands are sustained through a shallow sub-surface aquifer. The infrared image (**Figure 3-7**) shows areas of the wetland that have dense vegetation (darker red areas) and further defines areas of transition.

3.2.3 Nee Noshe Reservoir Habitat Information

Habitat information was gathered for both the least tern and the piping plover in order to establish the habitat needs of each species and characterize the available habitat at Nee Noshe Reservoir.

3.2.3.1 Least Tern

The interior population of the least tern (*Sterna antillarum athalassos*) was listed as federally endangered on June 27, 1985 (50 Federal Register 21,784-21,792) (Sidle and Harrison 1990). The least tern is also listed as endangered in the State of Colorado. During the 1800s, the eastern coastal population of least terns was significantly reduced as the result of killing birds for their wings and feathers for the millinery trade. The population rebounded after receiving protection. Now, the population is declining again because of disturbance during the nesting season. Human recreational activity along beaches will cause least terns to abandon nesting activities, even after eggs have been laid. Another cause of nesting disruption is extreme water fluctuations during the nesting season in manmade lakes (CDOW 2009).

The least tern is the smallest of the North American terns. These terns breed along the California coast, along rivers in the Mississippi Valley, and along the coast from Maine to Florida. It winters from Baja California south to southern Mexico and also along the coast of South America. In Colorado, the least tern has bred in the southeastern portion of the state, generally in the area of La Junta and Lamar (CDOW 2009).

Interior least terns feed exclusively on a variety of small fish (Sidle and Harrison 1990). They are primarily a fish-eater, feeding in shallow waters of rivers, streams, and lakes. The birds are opportunistic and tend to select any small fish within a certain size range. Feeding behavior involves hovering and diving for small fish and aquatic crustaceans, and occasionally skimming the water surface for insects (Sidle and Harrison 1990, TWDW 2011). When hunting, the least tern dives from as high as 20 feet into the water to capture their prey (CDOW 2009). Terns nesting at sand and gravel pits and other artificial habitats may fly up to 3.2 kilometers (km) to fish (Sidle and Harrison 1990).

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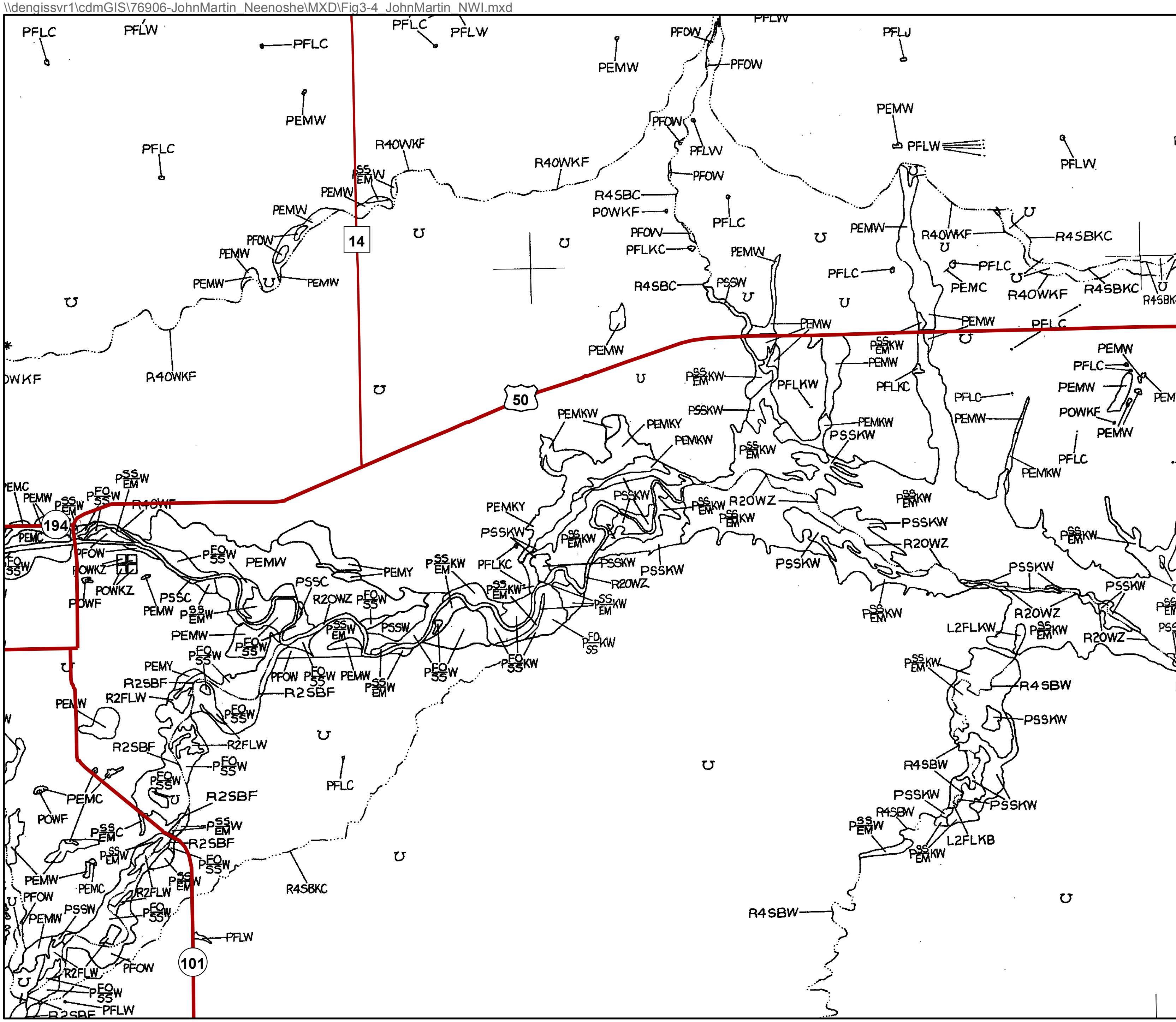

Legend

National Wetlands Inventory (1975)

N
W E
S

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Miles

Figure 3-5: NWI Wetland Delineation at John Martin Reservoir (NWI, 1975)

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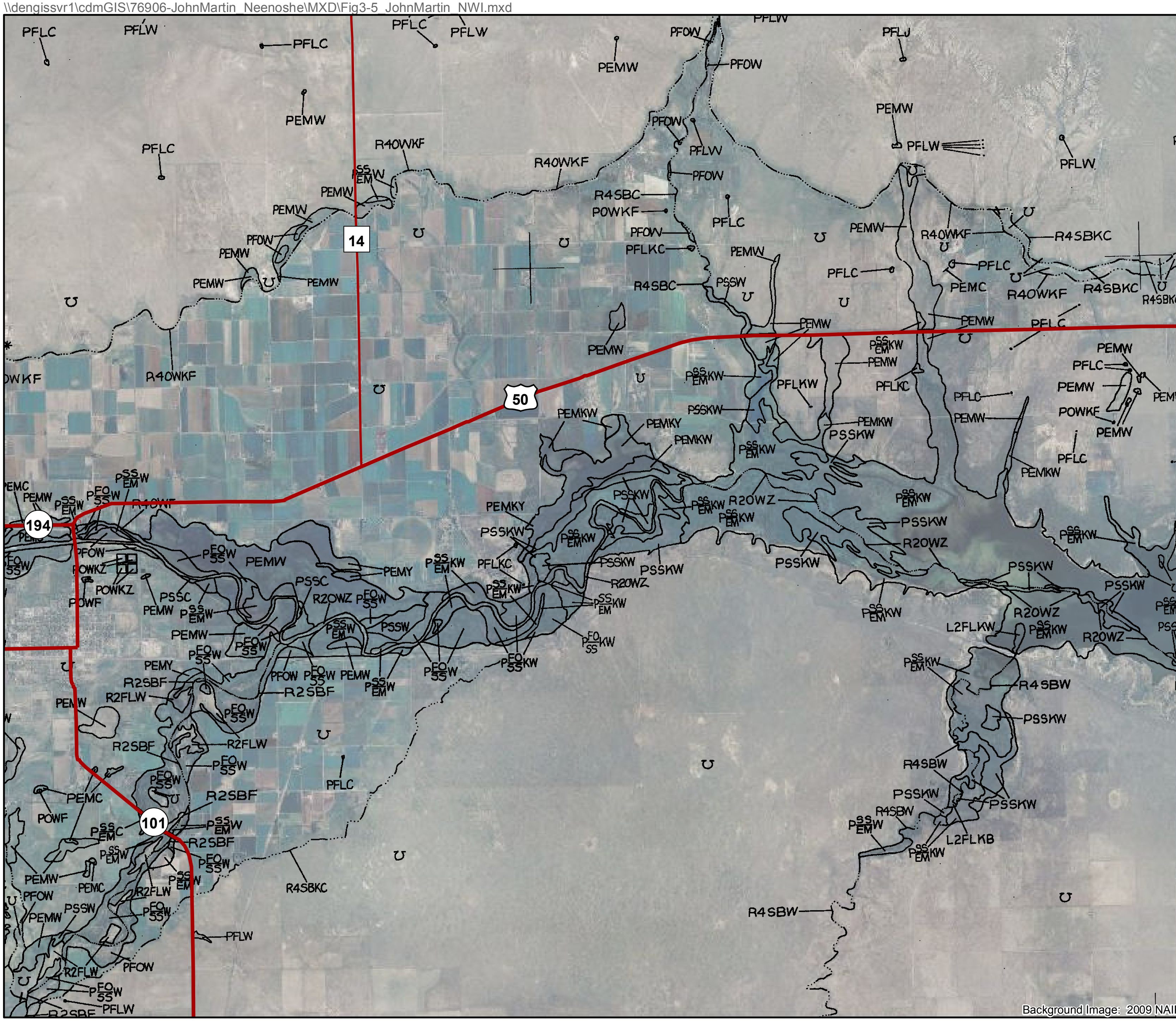

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National Wetlands Inventory (NWI)

N
W E
S

0 0.5 1 2
Miles

Figure 3-6: Comparison of 2009 Aerial Photograph to 1975 NWI Data

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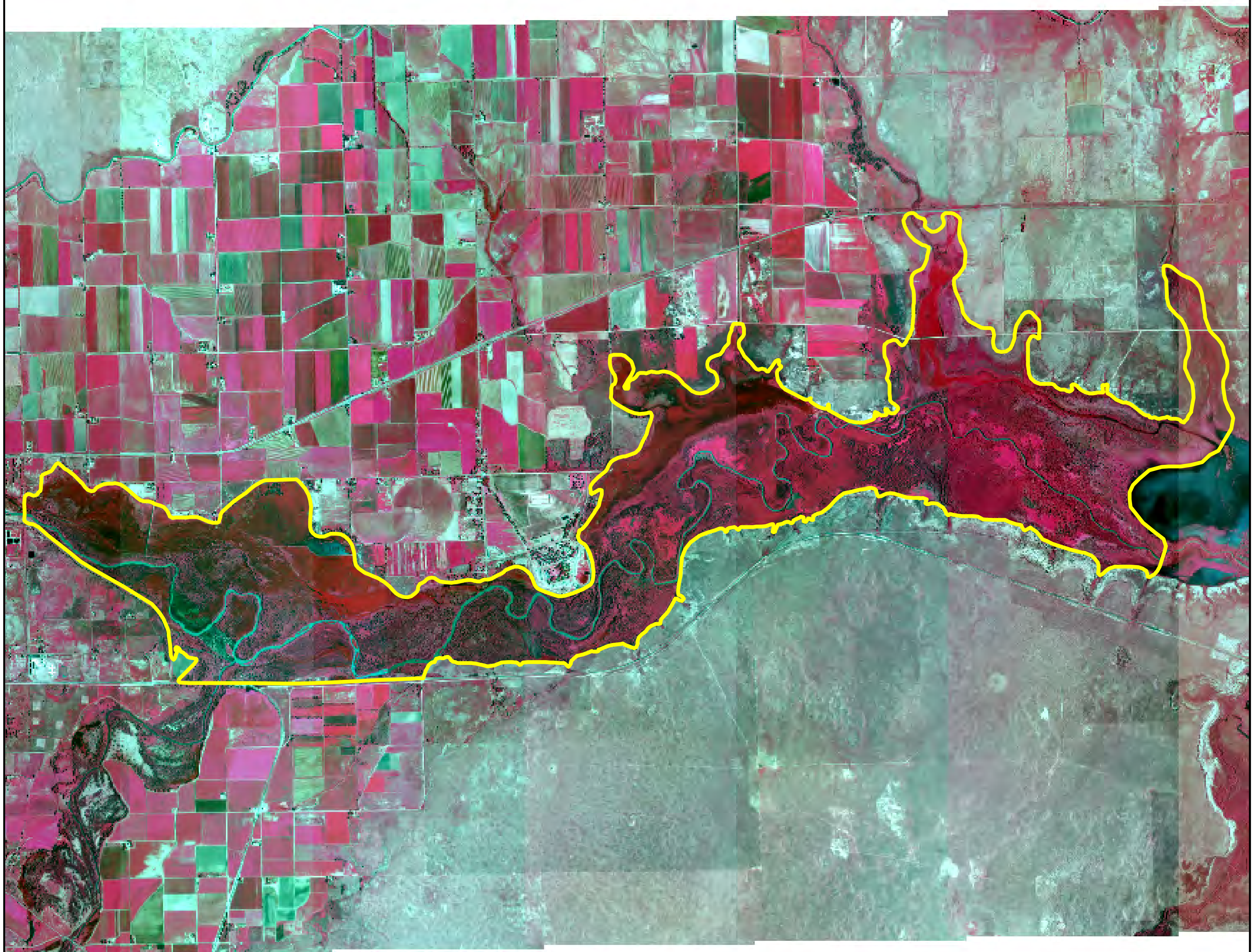

Legend

Wetland Boundary Estimate

N W E S

0 0.5 1
Miles

Figure 3-7: Infrared Imaging of Wetlands at John Martin Reservoir

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Background Image: NAIP 2009

Least terns arrive to breeding grounds starting in mid-May. Females typically lay two to three eggs, deposited in shallow "scrape" nests. Both sexes share incubation, which takes about 19 to 25 days. The nest is shallow depression and not easily seen. The preferred nesting habitat is on sandy or pebbly beaches, well above the water line, around lakes and reservoirs or on sandy soil sandbars in river channels (CDOW 2009). Nests can be found in open, sandy area, gravelly patch, or exposed flat areas. Small stones, twigs, pieces of wood, and debris usually lie near or around the nest (Sidle and Harrison 1990).

In Colorado, the least tern is known to breed at Adobe Creek Reservoir and has been observed at Nee Noshe Reservoir. The shorelines of the Adobe Creek Reservoir and Nee Noshe Reservoir provide breeding habitat for interior least terns (i.e., nesting areas on the shorelines along with a nearby supply of small fish for foraging). Efforts are ongoing in Colorado to address fluctuating water levels, human disturbance, vegetation encroachment, and predation of least terns of these areas. Therefore, destruction or adverse modification of remaining habitats will cause continued reduction of the species range and eventually a reduction in population numbers (Colorado 2009). The 1990 recovery plan cites "Manage reservoir and river water levels to the benefit of the species" as one of the necessary action items for the species (USFWS 1990). Least Tern have not nested at Nee Noshe Reservoir since 2004.

3.2.3.2 Piping Plover

The piping plover (*Charadrius melodus*) is listed as threatened in Colorado and federally. The Northern Great Plains population of piping plovers use suitable breeding habitat along prairie rivers and on alkali wetlands from Alberta to Manitoba, and south to Nebraska (Haig et al. 1988, USFWS 2003). Human recreational activities at reservoirs, such as beach camping and off-road vehicle use, can impact piping plovers by disrupting nesting and brood rearing activities. By temporarily closing nesting areas to these uses, piping plovers are given some protection during this critical portion of their life cycle (CDOW 2010).

When in its breeding plumage, the plumage most likely to be seen in Colorado, piping plovers have bright orange legs, a black breastband that may or may not go completely across the breast, a black bar across the forehead from eye to eye and a bill that is bright orange at the base with a black tip. In Colorado, piping plovers occur as migrants, arriving around the first of April. They can be found in the eastern part of the state with the Arkansas and South Platte River drainages being the best areas to find these birds (CDOW 2010).

Piping plovers feed on a variety of beach-dwelling invertebrates, including insects, small crustaceans and mollusks, and marine worms. Because of their relatively short beaks, they rely mainly on surface-dwelling organisms, or those that live just below the sand surface, for food (CDOW 2010).

Adult piping plovers arrive at their breeding grounds in April. Males make the nests, which are simply scrapes in the ground lined with pebbles and twigs. Females typically lay four eggs and both sexes share the duty of incubation. Incubation generally lasts 26 days. Nesting habitat in Colorado is on sandy lakeshore beaches, sandbars within riverbeds, or even sandy wetland pastures. An important aspect of this habitat is that of sparse vegetation. The plover depends on its coloration for camouflage and protection (CDOW 2010). Piping plover eggs many times blend in perfectly with the pebbles and small stones surrounding the nest.

In Colorado, the piping plover occurs along the Arkansas and South Platte River Drainages (CDOW 2010, USFWS 2003). Piping plovers have occurred at Nee Noshe Reservoir but have not nested at the site since 2003.

3.2.3.3 Piping Plover and Least Tern Interactions

In portions of the range, shorebirds such as the piping and snowy (*Charadrius alexandrius*) plover often nest in close proximity to least terns (TPWD 2011). Interior least terns breed with the piping plover in the Missouri River system and the snowy plover in the Arkansas River system. Nesting piping plovers usually can be found within or near nesting interior least terns at sand and gravel pits and on riverine sandbars (Sible and Harrison 1990).

3.3 Field Data Collection

Two site visits to the John Martin Reservoir wetlands complex and Nee Noshe Reservoir were conducted in 2010. A tour of both sites was completed in July 2010 with Arkansas NCNA committee members and CDOW personnel to view the sites and photograph both the wetlands upstream of John Martin Reservoir and the bird habitat surrounding Nee Noshe Reservoir (**Figures 3-8** and **3-9**, respectively). Additional photographs from this site visit are contained in **Appendix D**. During this site visit, DOW provided information on their historical involvement at Nee Noshe and the agency's past attempts to designate the reservoir as a Colorado State Park (see discussion in Section 2). Numerous stops were made in and around Nee Noshe Reservoir in order to photograph and discuss the site, including the concrete boat ramp, inlet canal, and islands that were previously constructed for bird nesting habitat but are now far from the reservoir pool. At the time, the Lone Wolf Canal and the inlet to Nee Noshe Reservoir were observed to be dry and contained significant amounts of tumbleweed. Several additional stops were made along the north and west sides of John Martin Reservoir to observe and discuss the reservoir's wetlands complex. Locations visited included Gageby Creek, wetlands near the former Fort Lyon Veterans Hospital, and two sites in the wetlands complex west of the current reservoir pool in which CDOW has constructed open water features for bird habitat (see discussion in Section 2).

Figure 3-8: John Martin Reservoir Wetlands Complex (July 2010)

Figure 3-9: Bird Habitat at Nee Noshe Reservoir (July 2010)

A second site visit was completed in October 2010 with the goal of characterizing existing wetland habitats at specific John Martin Reservoir locations and least tern and piping plover breeding habitat at Nee Noshe Reservoir. The effort at the John Martin Wetland Complex was intended to include surveys of wetland habitat, particularly in the Fort Lyon area, using a Geographic Positioning System (GPS) and conforming to the USACE Wetlands Delineation Manual (1987). While in the field, it was determined that the extent of wetlands in the Fort Lyon area would preclude a full delineation per the USACE Manual. Therefore, field data collection methods were altered to capture necessary field data that could then be paired with existing GIS data to map wetland habitat extents. Specifically collected data included:

- GPS data for the limits of each identified wetland,
- GPS data for any other pertinent information; and,
- Photo documentation for each delineated habitat.

While at the site, GPS points were taken based upon wetland vegetation characteristics and surface hydrology characteristics. Field work started at the eastern edge of the study area. For each area, wetland points were taken at the outer boundaries, and labeled for John Martin (JM), Wetland Number (1, 2, 3, etc.), and then cardinal direction (N, S, E, W, etc. – typically based on which side of the road the point was taken). **Figure 3-10** shows the GPS points taken during this site visit. In most locations, access was restricted to County Road JJ, which required GPS points being taken from the roadside. Where walk-in access was possible (such as GPS point JMW2), a northern point was taken. All wetlands extended into the Arkansas River or John Martin Reservoir so a southern point was not taken. Occasionally, additional information was recorded along with the GPS point, such as cattail, cottonwood, and tamarisk boundaries (e.g., JMW3CottonwoodCattail Boundary) so that different wetland classifications could be delineated. Finally, where open water existed, a data point was taken (e.g., JMW3GagebyCreek).

A similar survey was also performed at Nee Noshe Reservoir to identify wetlands and other habitats critical to least tern and piping plover nesting, primarily sand bars, mudflats, and open water. Again, as with the John Martin Reservoir wetlands, the extent of these habitats at Nee Noshe precluded a full delineation per the USACE Manual. Therefore, field data collection methods were altered to capture necessary field data that could then be paired with existing GIS data to map habitat extents. Specifically collected data included:

- GPS data for the limits of each identified habitat,
- GPS data for any other pertinent information; and,
- Photodocumentation for each delineated habitat.

GPS points were taken at the water's edge (NW#), where sand/mudflats gave way to vegetation (NV#), and where vegetation became dense/tall enough to preclude nesting (NTV#). **Figure 3-11** shows the GPS points that were taken at Nee Noshe Reservoir.

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Figure 3-10: GPS Points taken at John Martin Reservoir Wetlands, Fall 2010

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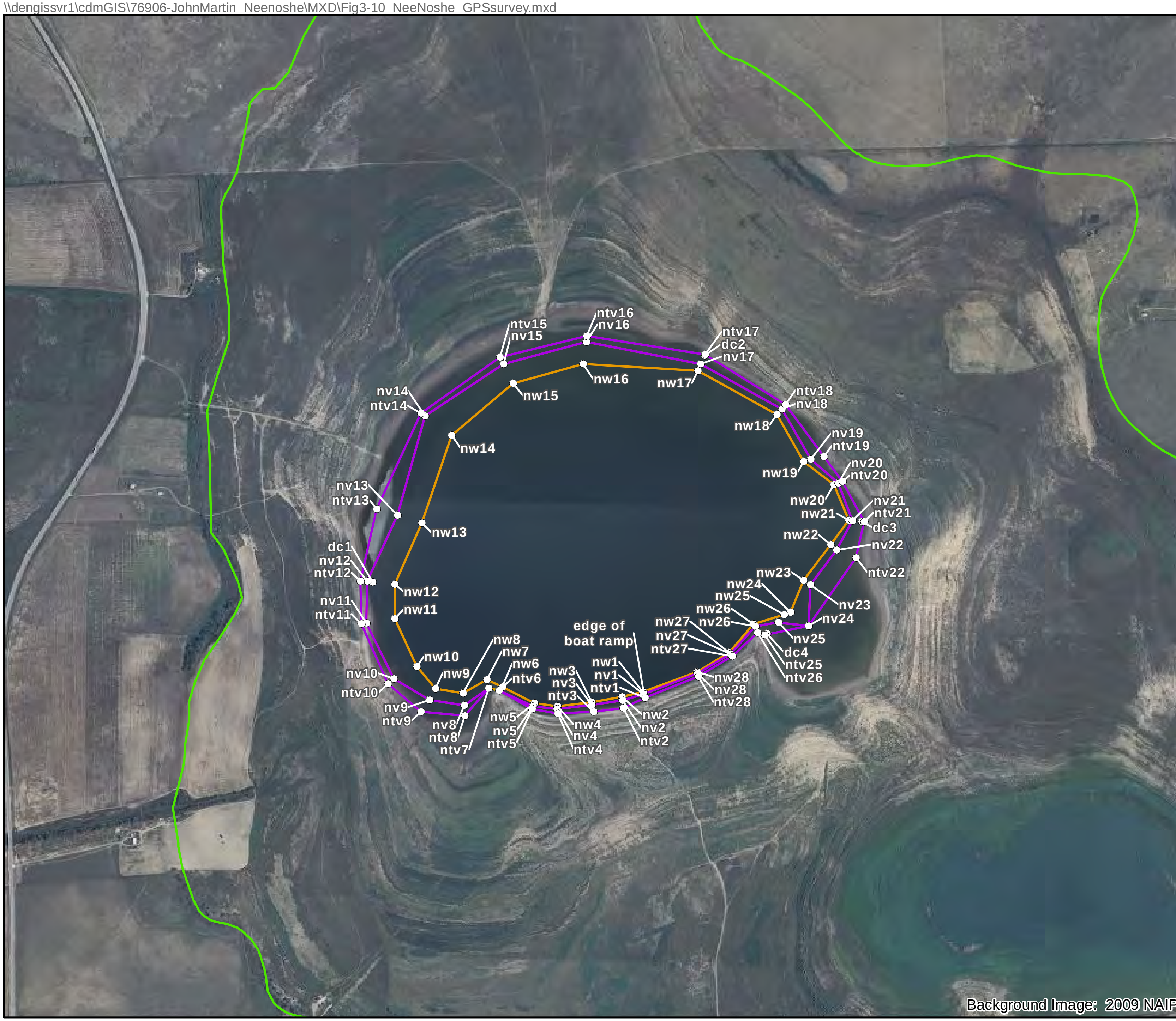

Legend

- Survey Points
- Stream / River
- Historic Reservoir Bed
- Vegetation Suitable for Nesting
- Sandbar/Mudflat

N
W E
S

0 500 1,000 2,000

Feet

Figure 3-11: GPS Points taken at Nee Noshe Reservoir, Fall 2010

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Section 4
Study Results

4.1 Study Results Overview

The Arkansas Basin NCNA committee used their NCNA mapping effort to identify and prioritize areas in the basin that needed further investigation and quantification of environmental and recreational water needs. For this study, the committee has focused attention on the development of site-specific quantification of water needs for the wetlands upstream of John Martin Reservoir and the habitat associated with reservoir levels at Nee Noshe Reservoir due to the combination of the environmentally and recreationally rich locations and the potential changes to the water management practices of the area. In order to quantify the water needs at both sites, it was necessary to develop an understanding of the environmental and recreational resources of the wetlands upstream of John Martin Reservoir and the habitat for threatened and endangered birds at Nee Noshe Reservoir. The data collected and presented in Section 3 were used to determine the aerial extent of the wetlands complex at John Martin Reservoir as well as the types of wetland plants that make up the complex. Data were also used to identify the habitat needs of least tern and piping plover in order to characterize the available habitat at Nee Noshe Reservoir. Results of these characterizations are presented in this section.

Once the wetland area at John Martin Reservoir was established, the historical hydrologic and hydraulic data collected for the site were used to confirm the water budgets presented in Section 2. Although new data were not collected for this study, the use of historical data provided the level of detail needed to understand the overall water needs of both systems. The water budgets for the John Martin Reservoir wetlands (both surface and sub-surface water budgets) were used to quantify the water needed to maintain the wetlands at their current extent. The results of this effort are provided below in Section 4.2.2.

Using historical data, the current habitat at Nee Noshe Reservoir was characterized. Although habitat exists at the reservoir, least tern and piping plover have not been observed at the site since 2004. Because current conditions at Nee Noshe Reservoir do not support the bird populations, quantification of water needs were analyzed for three scenarios:

- Maintenance of current conditions;
- Maintenance of the dead pool capacity; and
- Maintenance of 2004 reservoir levels.

The third scenario was analyzed because if reservoir levels could be maintained at the dead pool capacity, it would provide the best opportunity for downstream use of any available water.

4.2 John Martin Reservoir Quantification Results

The following subsections present the results of the wetland characterization efforts and the water needs quantification for current conditions at the John Martin Reservoir site.

4.2.1 Wetlands Characterization

The wetlands at John Martin Reservoir were characterized using the methodology that was described in Section 2.2 and that data presented in Section 3.1.2. The following data (as described in Section 3) were compiled and reviewed in order to perform a best professional estimate of the aerial extent of the wetlands complex:

- NWI data;
- NRCS SSURGO data;
- Aerial photography; and
- Site visits (GPS points).

Using these data, it was estimated that the current size of the wetlands at John Martin Reservoir is approximately 6,300 acres. NWI data show that the complex is covered in a combination of emergent, scrub/shrub, and forested wetlands that are artificially flooded (refer to Figure 3-4). **Figure 4-1** shows the extent of the final area estimation.

4.2.2 Wetlands Water Needs Quantification

The final wetlands water budget results were calculated using the data inputs and the calculations presented in the preceding sections. These results, both annual and monthly, are summarized in **Tables 4-1** and **4-2**. Table 4-1 summarizes the water budget elements described in Section2 and presents the inflows and outflows into the wetland system on an annual basis. Annual budget results (Table 4-1) indicate that the wetlands ET demands are being met in this reach primarily by regional irrigation return flows to the sub-surface. Results also demonstrate that, on an annual basis, the Arkansas River gains flow through the study reach. The values in Table 4-1 were further analyzed into monthly values. Table 4-2 shows the monthly values further divided into system inputs and outputs. On a monthly basis (Table 4-2), this analysis shows significant fluctuations in inflows and outflows to the system, most likely as a result of changes in Arkansas River hydraulics. Results indicate large inflows to the sub-surface system in the spring and early summer, consisting primarily of river seepage and irrigation returns. During this period (May and June), the calculations indicate that the water table below the wetlands is rising (**Figure 4-2**). The results imply that the system changes in later summer and fall to a losing system, as river levels subside. During this period, a net loss of water was quantified from the sub-surface pool, primarily in the form of gains to the river. Based on this information, it is likely that the water table drops during this time (Figure 4-2).

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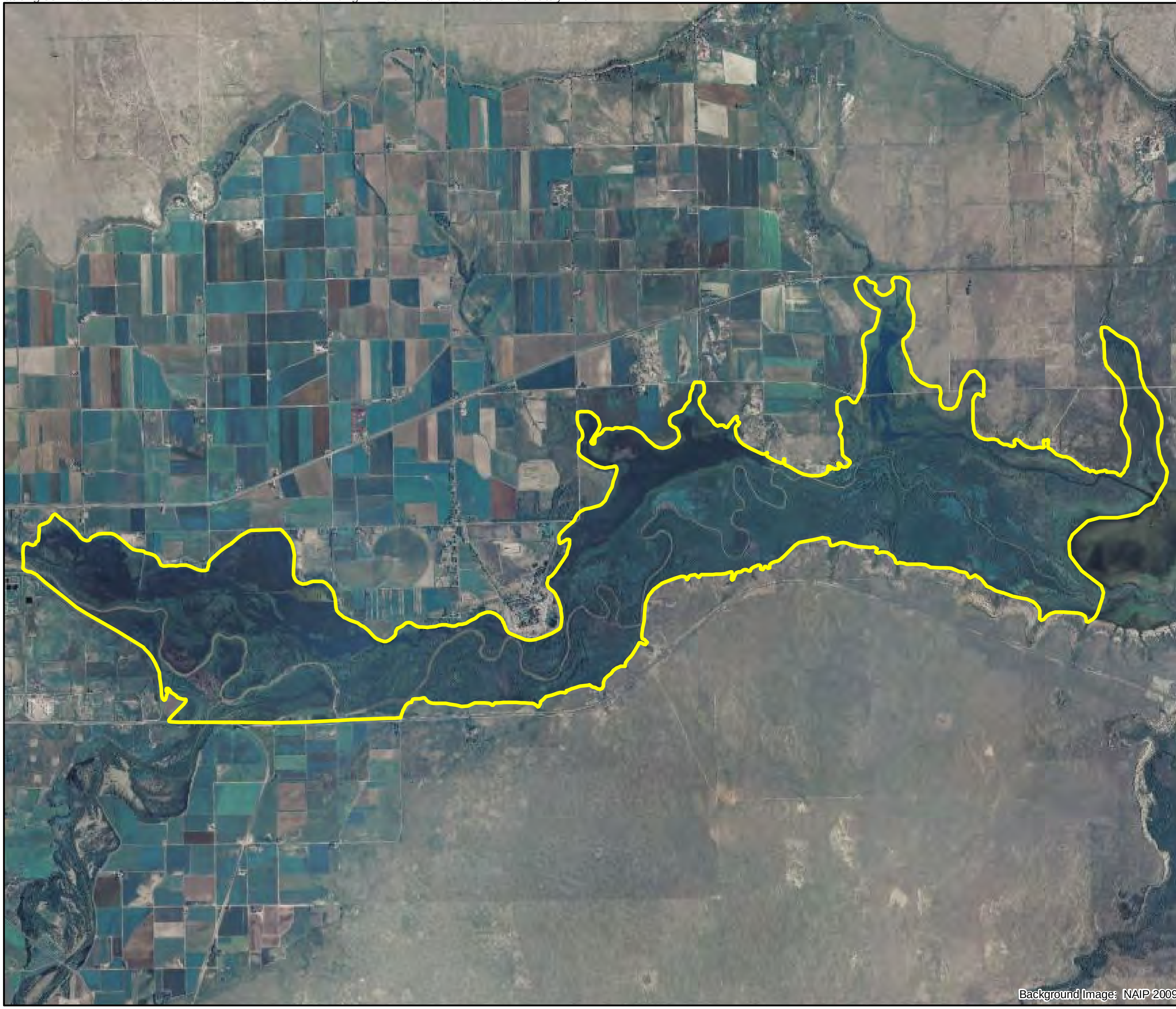

Legend

Wetland Boundary Estimate

Wetland Area: 6,300 Acres

N
W E
S

0 0.5 1
Miles

Figure 4-1: John Martin Reservoir Wetlands Estimation

CDM

Table 4-1: Estimated Annual Water Budget (AFY)
Subsurface Hydrology, John Martin Wetlands

Water Budget Elements	Inflow	Outflow
Irrigation Returns	26,000	
Precipitation	6,000	
Arkansas River Gains		7,000
Wetlands ET		25,000
Totals	**32,000**	**32,000**

Table 4-2: Estimated Monthly Water Budget (AFM)
Subsurface Hydrology, John Martin Wetlands

	Wetlands ET	River Gains	Ag Return Flows	Precipitation	Net Inflow
October	1,300	2,000	2,000	400	-900
November	0	2,000	2,000	200	200
December	0	2,000	700	200	-1,100
January	0	2,000	500	100	-1,400
February	0	2,000	600	100	-1,300
March	1,300	1,000	1,200	300	-1,200
April	1,300	1,000	2,400	500	600
May	4,300	-30,000	3,000	1,000	30,000
June	4,300	-10,000	4,000	900	11,000
July	4,300	15,000	3,600	1,100	-15,000
August	4,300	10,000	3,400	1,000	-10,000
September	4,300	10,000	2,200	500	-12,000

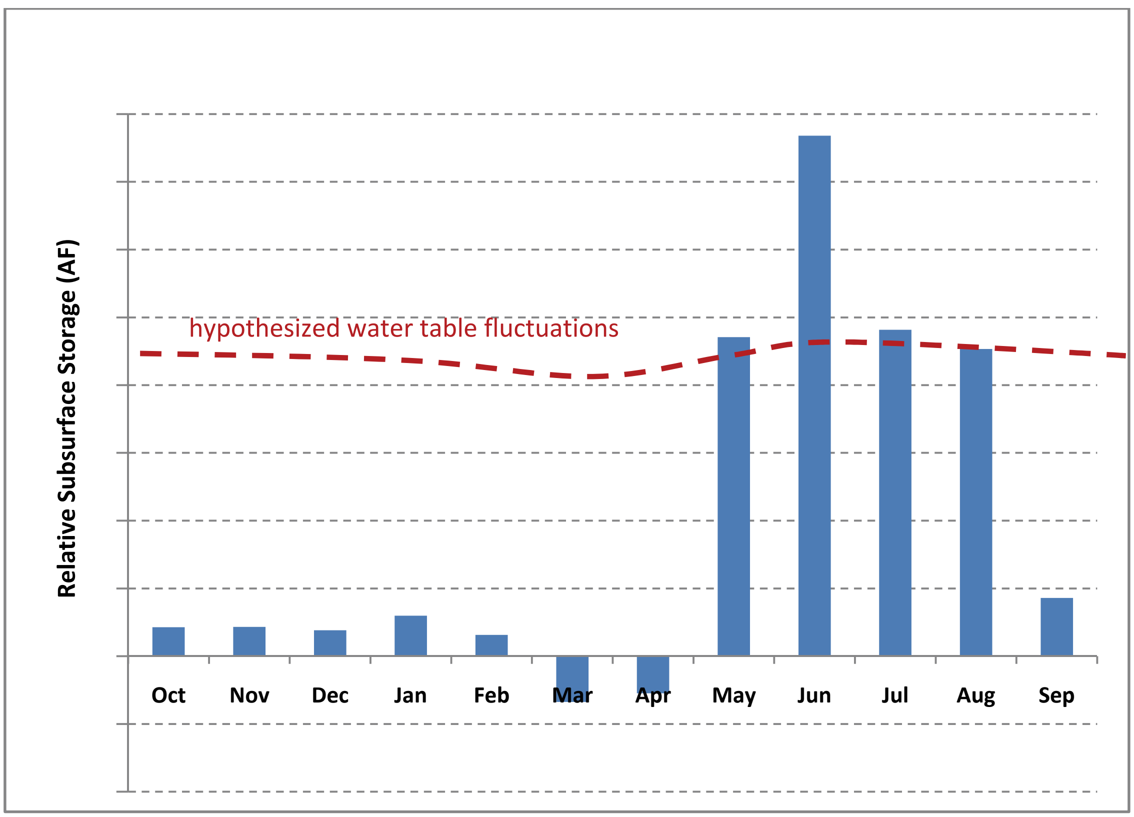

Figure 4-2: Subsurface Water Budget Seasonal Results: John Martin Reservoir Wetlands

4.3 Nee Noshe Reservoir

The following subsections present the results of the habitat characterization efforts and the water needs quantification for maintenance of current conditions, dead pool conditions, and 2004 conditions at Nee Noshe Reservoir.

4.3.1 Habitat Characterization

The habitat at Nee Noshe Reservoir was characterized using the methodology that was described in Section 2.2 and that data presented in Section 3.2.3. The following data (as described in Section 3) were compiled and reviewed in order to perform a best professional estimate of the aerial extent of the existing available habitat:

- Aerial photography;
- Piping plover and least tern Habitat information from literature; and
- Site visits (GPS points).

Using these data, it was estimated that the current size of the habitat at Nee Noshe Reservoir is approximately 80 acres. Using aerial photographs paired with the area-capacity curve, the current estimated surface area of the reservoir is approximately 300 acres and the capacity is approximately 3,500 AF. **Figure 4-3** shows the extent of these final estimations. Although this sandy shore area is currently available, it has not supported least tern since 2004 nor piping plover since 2003. This was considered during the quantification efforts as maintaining the current available habitat may not be adequate to support the bird populations at Nee Noshe Reservoir.

4.3.2 Nee Noshe Reservoir Quantification

Annual water budgets for both current and hypothetical scenarios are summarized in **Tables 4-3** through **4-5**. A deficit of 1,000 AFY was quantified for the current system based on the available historical data used to develop the water budget. Therefore, an average of 1,000 AFY of surface water is needed to maintain current levels of storage. Due to canal losses, this is the equivalent of 1,800 AFY diverted at the canal headgate.

Table 4-3: Estimated Annual Water Budget (AFY)
Nenoshee Reservoir, Current Conditions

	Inflow	Outflow
Precipitation	500	
Evaporation		1,500
Additional Surface Water	1,000	
Totals	**1,500**	**1,500**

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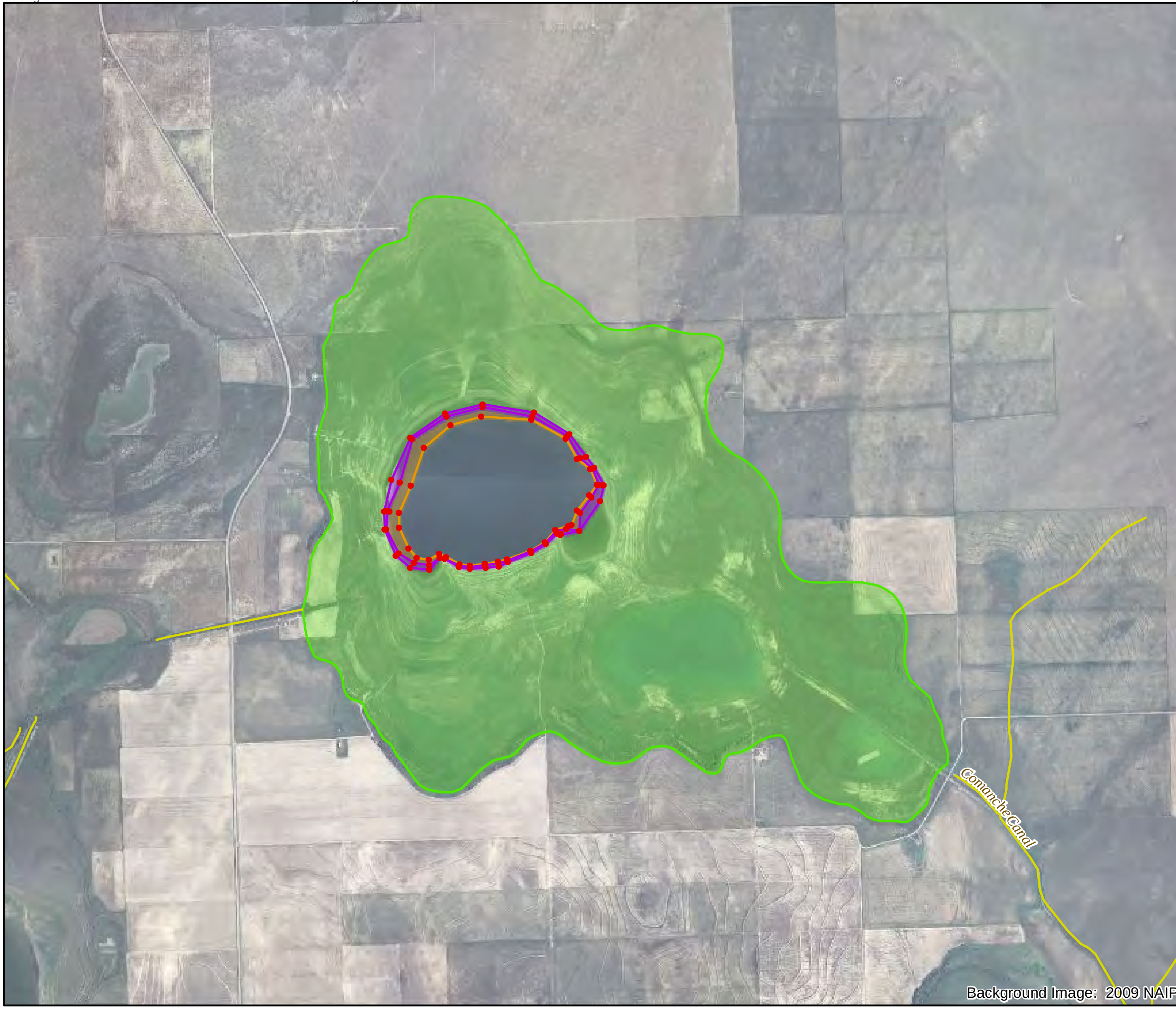

Legend

- Survey Points
- Canal
- Historic Reservoir Bed
- Sandbar/Mudflat
- Vegetation Suitable for Nesting

Current Reservoir Size:
~300 Acres / ~3,500AF

Current Habitat Size:
~80 Acres

N
W E
S

0 1,000 2,000 4,000
Feet

Figure 4-3: Existing Habitat at Nee Noshe Reservoir

CDM

The water budget for Nee Noshe Reservoir was then adjusted to estimate the diverted river water needs to maintain the dead pool of approximately 21,000 AF. **Table 4-4** shows that maintenance of the dead pool would require headgate diversions of 10,500 AFY.

Table 4-4: Estimated Annual Water Budget (AFY)
Nenoshee Reservoir, Future Conditions (dead pool = 21,000 AF)

	Inflow	Outflow
Precipitation	1,500	
Evaporation		7,300
Diverted River Water	*10,500*	
* Surface Water Delivered after Canal Losses	5,800	
Totals (Inflow = P + Surface Water Delivered)	**7,300**	**7,300**

A seasonal investigation, using SWAM (refer to Section 2.3.2), was also performed for the dead pool scenario and revealed high river diversion requirements, early in the water year, of approximately 2,000 AFM to maintain targeted pool levels, described in Section 2 (**Figure 4-4**). These autumn and early winter diversions would provide the habitat inundation required to prevent vegetation encroachment. CDOW biologists noted that due to the current extent of salt cedar/tamarisk at Nee Noshe Reservoir, additional vegetative management may be required to prevent vegetation encroachment. The sharp drop in diversion water in subsequent months (spring through summer) would allow for the desired drop in lake levels during the nesting and foraging seasons.

An additional investigation was performed using SWAM to determine if current levels could be maintained through periodic diversions as it is likely that water will not be available for regular annual diversions of the magnitude required to maintain the dead pool. The last diversion of water to Nee Noshe Reservoir occurred in 2008 when approximately 10,500 AF were purchased by DOW. Results of the periodic diversion analysis reveal that the assumed 10,500 AF Fort Lyons headgate diversion would need to occur at least once every 4 years to maintain current reservoir levels (**Figure 4 5**). As described previously (Table 4-3), an alternative scenario for approximately maintaining similar levels into the future would be to deliver 1,000 AF annually to the reservoir. Given the assumed canal losses, this equates to a Fort Lyons headgate diversion of approximately 1,800 AFY (see Table 4-3).

The annual water budget was paired with historical diversion records to simulate historical storage values at Nee Noshe Reservoir. Reservoir storage was estimated for 1998 using aerial photographs and the area-capacity curve for Nee Noshe Reservoir (Boyle 1993). Reservoir storage in 1998 was estimated to be approximately 70,000 AF, which was matched nearly exactly by the model. This exercise was repeated for current conditions. The 2009 analysis was slightly overestimated by the model, but still well within expected uncertainty for the analysis. The overestimation may be attributable to minor water losses or consumptive uses not included in the current model. These results also demonstrate and quantify the rapid drop in Nee Noshe Reservoir levels observed over the past decade. The results of the historical water level analysis (**Figure 4-6**) provide confirmation that the hydrologic dynamics of the system are being adequately captured in both the monthly SWAM simulations and the annual budget calculations.

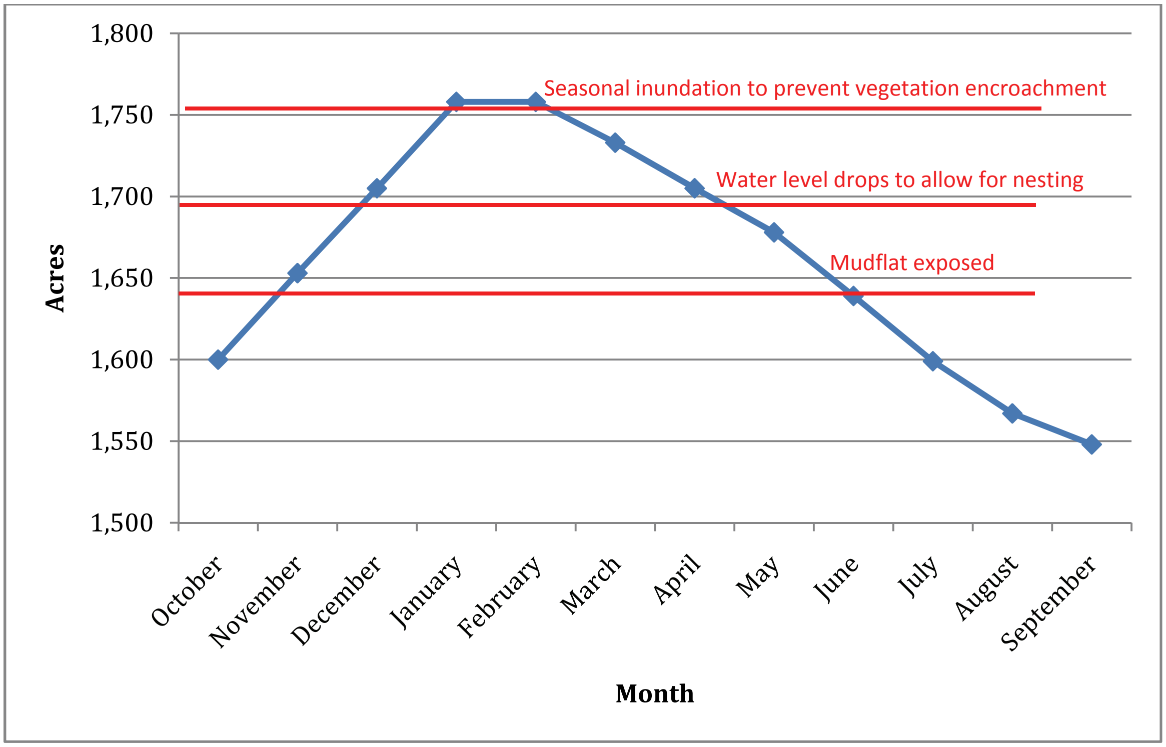

Figure 4-4a: Nee Noshe Seasonal Fluctuation Analysis – Hypothesized Target Pool Fluctuations

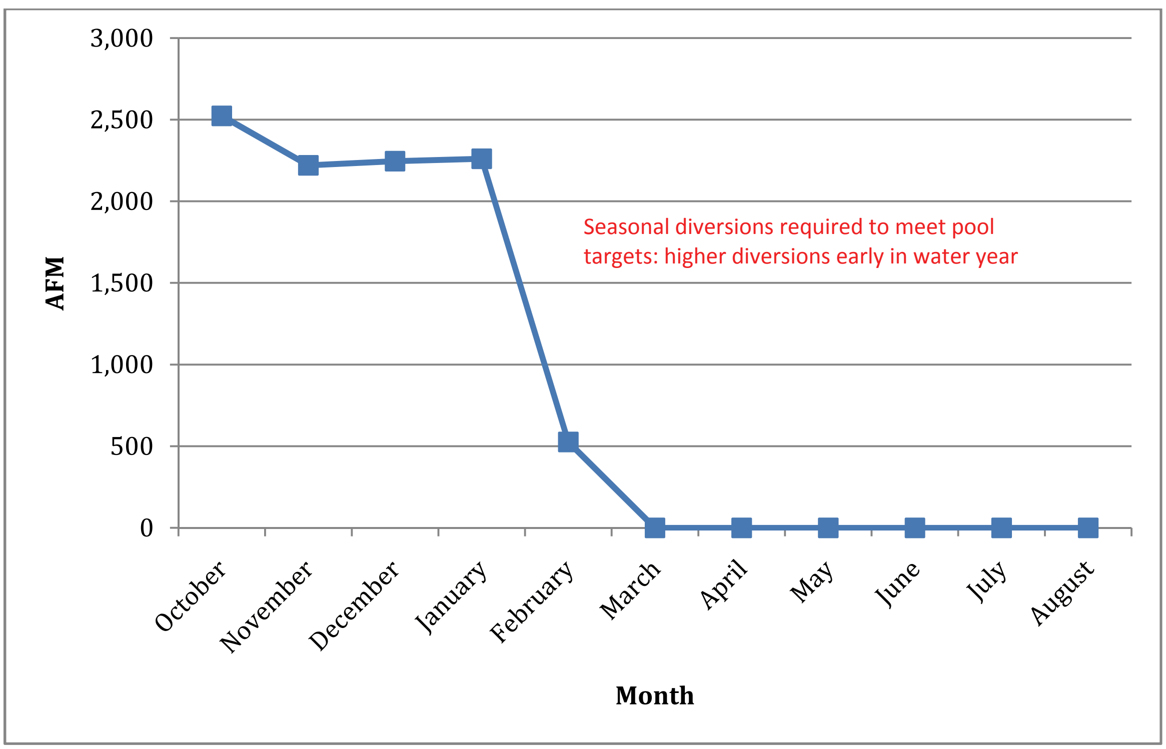

Figure 4-4b: Nee Noshe Seasonal Fluctuation Analysis – Calculated Headgate Diversion Requirements

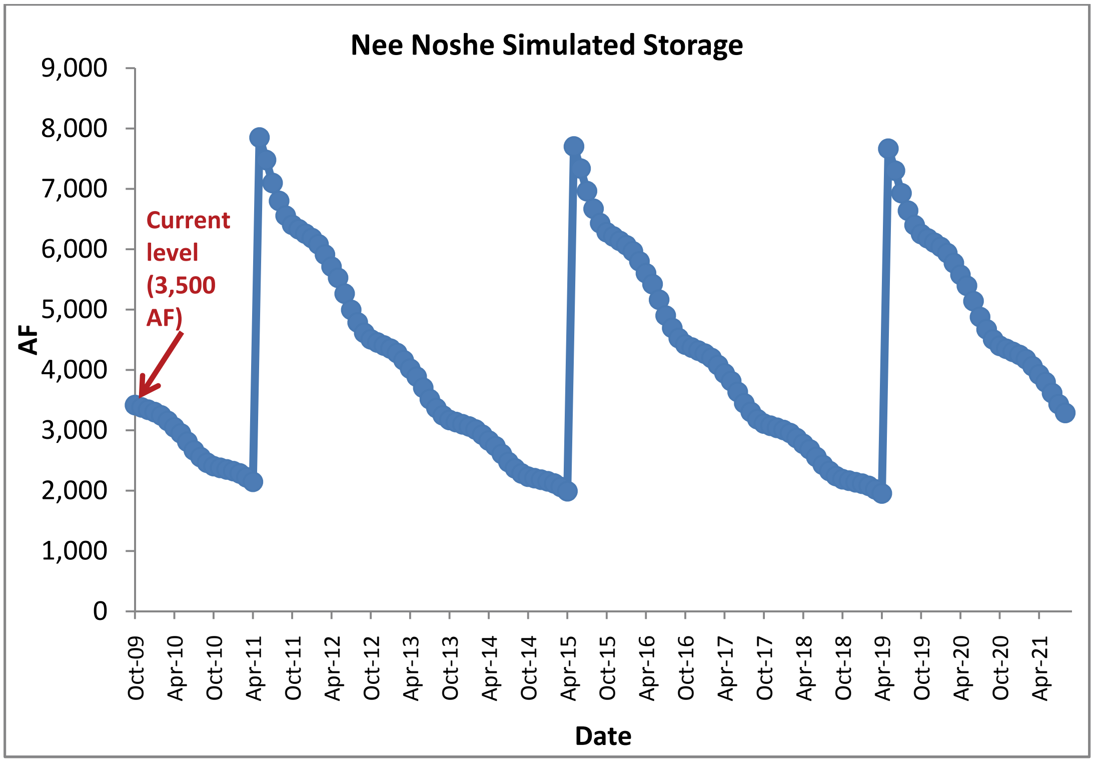

Figure 4-5: Future Nee Noshe Steady-State Given 10,500 AF Fort Lyons Diversion Every 4 Years

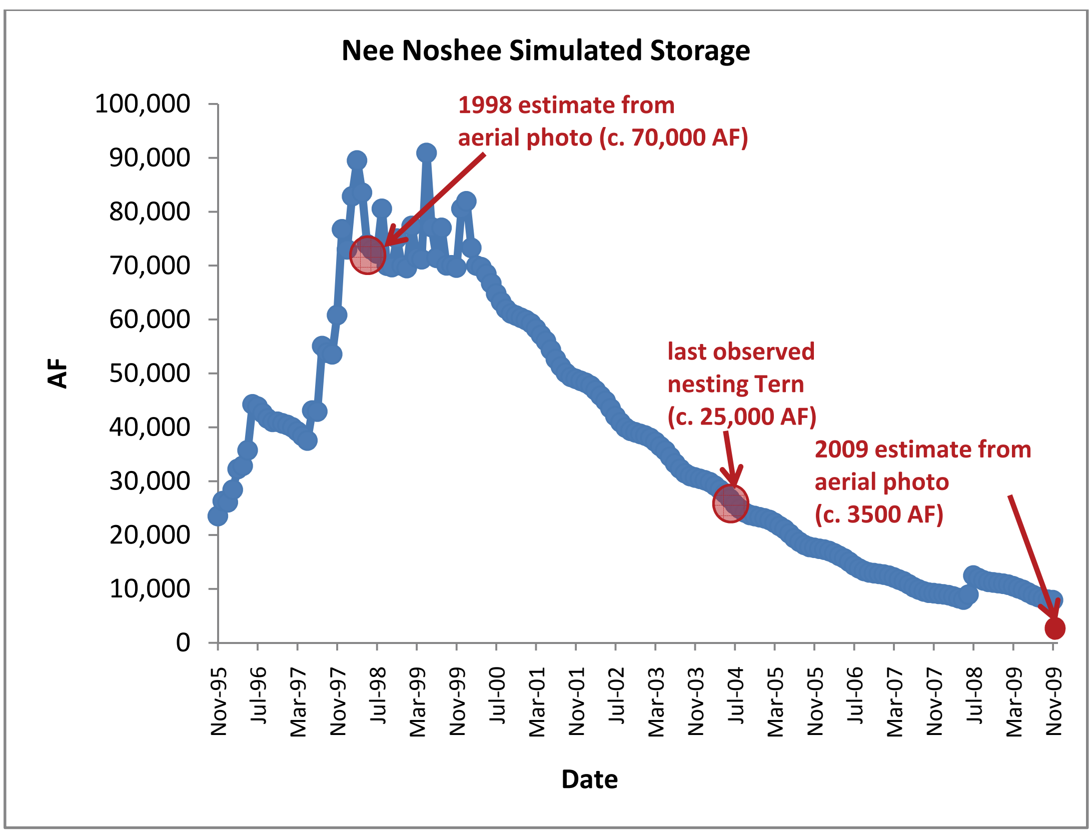

Figure 4-6: Simulation of Nee Noshe Recent Historical Storage Levels

This storage level exercise was also used to estimate the capacity of Nee Noshe Reservoir in 2004 when least terns were last observed nesting on the shores. It is estimated that Nee Noshe Reservoir held 25,000 AF in 2004. For this scenario, a headgate diversion requirement of 12,300 AFY was calculated to maintain the 2004 reservoir level on an annual basis (**Table 4-5**).

Table 4-5: Estimated Annual Water Budget (AFY)
Nenoshee Reservoir, 2004 Conditions (25,000 AF)

	Inflow	Outflow
Precipitation	1,500	
Evaporation		8,500
Diverted River Water	12,300	
* Surface Water Delivered after Canal Losses	7,000	
Totals (Inflow = P + Surface Water Delivered)	**8,500**	**8,500**

Section 5
Conclusions and Recommendations

5.1 Conclusions and Recommendations Overview

The mapping efforts completed by the Arkansas Basin NCNA Committee acknowledged the existence of important environmental and recreational attributes in the Lower Arkansas River Basin; specifically the wetlands at John Martin Reservoir and bird habitat at Nee Noshe Reservoir. Although previous studies have been completed in the area, there have been no recent efforts to characterize these resources and understand the water needed to maintain or enhance the benefits associated with these locations. The objectives of this study were to:

- Develop an understanding of the environmental and recreational resources of the wetlands upstream of John Martin Reservoir and the habitat for threatened and endangered birds at Nee Noshe Reservoir;
- Identify the relationship between upstream water management, surface water levels and flows, groundwater levels, and the wetlands complex at John Martin Reservoir;
- Identify the relationship between lake levels and bird habitat at Nee Noshe Reservoir;
- Perform the study with consideration of existing flows within the basin and of existing water rights; and
- Identify multipurpose opportunities with planned projects within the Arkansas River Basin.

5.2 John Martin Reservoir Wetlands

The extensive wetlands complex upstream of John Martin Reservoir is home to numerous wildlife species and provides environmental and ecological benefits to the surrounding area. The efforts described in previous sections of this report established the following conclusions about the wetlands upstream of John Martin Reservoir:

- The aerial extent of the wetlands is approximately 6,300 acres;
- The wetlands existed prior to John Martin Reservoir and are not dependent on reservoir levels;
- The wetlands are maintained by approximately 32,000 AFY from precipitation and return flows;
- Irrigation return flows and ET are the main inputs and outputs of the wetland system;

- The monthly water budget indicates seasonal fluctuations in Arkansas River gains and losses;
- Large river losses (recharging the water table) occur during spring high flow, but there is an overall net annual gain to the Arkansas River; and
- There are implied fluctuations in the subsurface water table with peak levels seen during wetlands growing season.

The analysis performed for the wetlands at John Martin Reservoir identified subsurface water supplied primarily through agricultural return flows as the main source of water for the wetlands. Future water management practices should consider this established link when making decisions regarding the location and timing of future agricultural return flows.

5.3 Nee Noshe Reservoir Bird Habitat

In Colorado, federally listed piping plover and least tern nest solely on the shorelines of large reservoirs in the southeast part of the state and have nested at Nee Noshe Reservoir as recently as 2003 (piping plover) and 2004 (least tern) (Nelson 2009). Due to water management changes and dry years at the Great Plains Reservoirs, water levels at Nee Noshe Reservoir have been declining since the late 1990s. Shoreline bird habitat has also decreased as invasive plants and grasses have encroached on the receding reservoir. In order to support piping plover and least tern at the reservoir, water must be managed in such a way as to inundate encroaching vegetation to open the shoreline area at the beginning of the water year and to recede water levels to expose the shoreline during nesting in late spring.

Nee Noshe Reservoir is located at the end of the Great Plains Reservoir system and was chosen for this study because water from Nee Noshe Reservoir can be delivered to the Amity Canal through the Comanche Canal for downstream water uses. The reservoir can store 95,000 AF with an available capacity of approximately 73,000 AF and dead pool storage of approximately 21,000 AF (Boyle 1993). The reservoir currently stores approximately 3,500 AF, which is significantly below the dead pool. The efforts described in previous sections established the following conclusions about water levels and bird habitat at Nee Noshe Reservoir:

- Seasonal diversions are required to satisfy habitat requirements with early water year inundation to prevent vegetation encroachment and water level decline in late spring to accommodate nesting;
- Higher diversions are needed early in the water year (September – January) to provide for this inundation;
- Current volumes (3,500 AF) can be maintained by diverting 1,800 AF annually to the Kicking Bird Canal or 10,500 AF every 4 years;
- Current levels do not support the bird species which have not nested at Nee Noshe since 2003 (piping plover) and 2004 (least tern);
- 10,500 AFY of diverted water is required to maintain dead pool conditions of 21,000; and
- 12,300 AFY of diverted water is required to maintain 2004 conditions which is the last year that least tern were observed nesting at Nee Noshe Reservoir.

The analysis performed for Nee Noshe Reservoir water levels showed that large quantities of water would be required to maintain the current conditions, which have not supported the bird populations in recent years. Even greater quantities of water would be required to bring the reservoir level up to the dead pool which could then support downstream water uses when excess water was available. The 2004 reservoir levels, when least tern were last observed at Nee Noshe Reservoir, were higher than the dead pool which would require even greater amounts of water diversions. The 2004 levels may not be adequate to sustain a nesting population of least terns at Nee Noshe Reservoir over the long term, although other management strategies might enhance the effectiveness of this water scenario. If it were possible to divert the volume of water required to maintain 2004 levels at Nee Noshe Reservoir, other management strategies for fisheries and invasive plants would likely need to be implemented to create an environment suitable for these shoreline species.

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Section 6
References

Audubon Society, 2011. Important Bird Areas, Colorado, Great Plains Reservoirs, Site Profile. http://iba.audubon.org/iba/viewSiteProfile.do?siteId=495&navSite=state

Bedient, P.B. and W.C. Huber 1992. Hydrology and Floodplain Analysis Second Edition. Addison-Wesley Publishing, New York.

Boyle Engineering Company. 1993. Engineering Hydrology Study of the Great Plains Reservoirs, CDOW.

CDOW (Colorado Division of Wildlife). 2011. http://wildlife.state.co.us/Landwater/statewildlifeareas/

CDOW. 2011. Personal communications with John Tonko.

CDOW. 2010. Natural Diversity Information Source species profile for the Piping Plover. Last Updated: 5/21/2010. http://wildlife.state.co.us/WildlifeSpecies/Profiles/Birds/PipingPlover.htm?Print=true

CDOW. 2009. Natural Diversity Information Source species profile for the Least Tern. Last Updated: 6/12/2009.

http://wildlife.state.co.us/WildlifeSpecies/Profiles/Birds/LeastTern.htm?Print=true

DNR (Colorado Department of Natural Resources). 2011. Checklist of John Martin Reservoir State Park and Bent County, Colorado.

DWR (Colorado Department of Water Resources). 2011. Calculated records for John Martin Reservoir (POR = 1979 - 2010).

DWR. 2011. Hydrobase data for Rule Creek and Gageby Creek.

DWR. 2011. Pan Evaporation Data for John Martin Reservoir.

DWR. 2011. Annual Diversions to the Kicking Bird Canal.

DWR. 2011. Personal communications with Dale Straw.

DWR. 2011. Documentation for the H-I Model.

Giddings, Todd. Ph. D, P.G. 2011. *What is a Water Budget?.* Penn State University.

Haig, S., W. Harrison, R. Lock, L. Pfannmuller, E. Pike, M. Ryan, and J. Sidle. 1988. Recovery plan for piping plovers (Charadrius melodus) of the Great Plains and Northern Great Plains. U.S. Fish and Wildlife Service. Washington, D.C.

Lower Arkansas River Commission. 1993. Implementation Plan for Water Resources and State Park Development in Southeastern Colorado.

NAIP (National Agricultural Imagery Program). 1998-2009. Aerial Photographs: July 3, 1998; February 28, 2001; Mosaic.

NCDC (National Climatic Data Center). 2011. Climate data for John Martin Reservoir.

NRCS (National Resources Conservation Service). 2011. http://soils.usda.gov/use/hydric/overview.html.

NRCS. 2011. SSURGO Data. http://soils.usda.gov/survey/geography/ssurgo/.

NRCS. 2011. Hydric Soils of Bent County.

Nelson, Duane. 2011. Technical Review.

Nelson, Duane. 2009. Piping Plover and Least Tern monitoring, Protection and Habitat Improvement at John Martin Reservoir and Southeast Colorado in 2009. US Army Corps of Engineers, Albuquerque District.

Sanderson, J. S. and D. J. Cooper. 2008. Ground water evapotranspiration from wetlands of an arid intermountain basin. Journal of Hydrology 351:344-359

Sidle, J.G., and W.F. Harrison. 1990. Recovery plan for the interior population of the least tern (Sterna antillarum). U.S. Fish and Wildlife Service. Washington, D.C.

Strom, Ken. National Audubon Society. 2011. Technical Review.

TPWD (Texas Parks and Wildlife Department). 2011. Wildlife Fact Sheet of the Interior Least Tern (Sterna antillarum athalassos). Wildlife Division, Diversity and Habitat Assessment Programs.

Tweto, Ogden. 1979. Geologic Map of Colorado. Geologic Survey of Colorado.

USACE (U.S. Army Corps of Engineers). 1987. Wetlands Delineation Manual. http://www.wetlands.com/regs/tlpge02e.htm.

USDA (U.S. Department of Agriculture). 2011. Wetlands Reserve Program Fact Sheet.

USEPA (U.S. Environmental Protection Agency). 2001. Functions and Values of Wetlands. Office of Wetlands, Oceans and Watershesds (4502T). EPA 843-F-01-002c.

USFWS (U.S. Fish and Wildlife Service). 2003. Recovery Plan for the Great Lakes Piping Plover (Charadrius melodus). Ft. Snelling, Minnesota. viii + 141 pp.

USFWS. 2011. National Wetlands Inventory Geospatial Wetlands Digital Data.

USGS (U.S. Geological Survey). Gage Data John Martin Reservoir at Caddoa; Arkansas River below John Martin Reservoir; Arkansas River at Las Animas; and Purgatoire River near Las Animas.

USGS. 2011. National Elevation Dataset (NED).

USGS. 1947-2001. Single frame Aerial Photography: July 19, 1947; September 18, 1954; June 11, 1975; and June 12, 1975 [multiple frames].

USGS. 2001. Digital Orthophoto Quadrangle (DOQ): February 28, 2001 [multiple frames].

Appendix A
Documentation of CDOW Waterfowl Channels and Ditches (CDOW 1978)

STATE OF COLORADO
Richard D. Lamm, Governor
DEPARTMENT OF NATURAL RESOURCES

DIVISION OF WILDLIFE

Jack R. Grieb, Director
6060 Broadway
Denver, Colorado 80216 (825-1192)
Southeast Region
2126 North Weber
Colorado Springs, CO 80907

March 3, 1978

Bruce DeBrine
Deputy State Engineer
Division of Water Resources
1313 Sherman Street - Room 818
Denver, CO 80203

Dear Mr. DeBrine:

Enclosed is a well application for a second set of level ditches in a swamp within the flood pool area of John Martin Reservoir. Like the previous set of ditches that we applied for, the Division of Wildlife has excavated a series of small pits in a cattail marsh. The pits have been constructed on Division of Wildlife property this time. As before, the purpose of these pits is to provide fisheries habitat and open water surfaces for waterfowl to use for resting, nesting, and feeding.

This application covers ditches that were dug in very close proximity, by two separate contractors. The combined surface area of these two construction jobs is approximately 7.5 surface acres of exposed water with an approximately equal amount of berm area adjacent to the ditches.

The Division of Wildlife feels that these ditches will not cause any damage to the Arkansas River system. For data substantiating this contention, please refer to my letter of January 19, 1978 that accompanied the first well permit application. This application covers the remainder of the already constructed ditches and will bring us up to date on our well permit applications. Any future applications will be made prior to construction of the ditches.

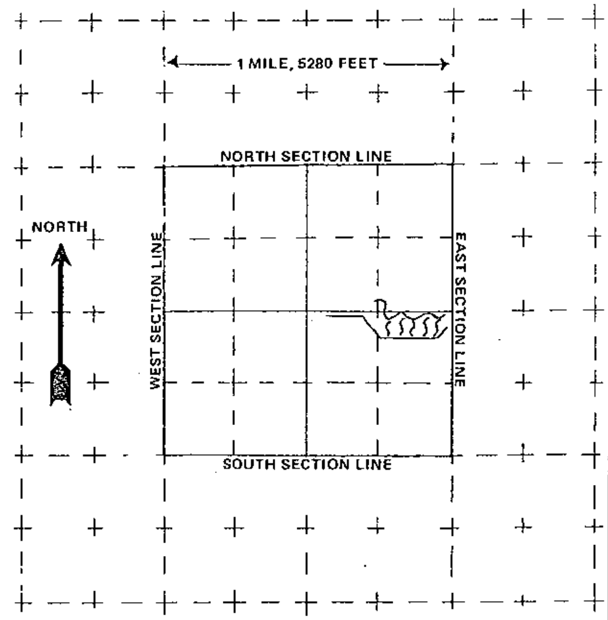
I hope that this letter is again helpful in your consideration of this application, and if you have any questions or comments feel free to contact me.

Sincerely,

Jack Vayhinger

Jack Vayhinger
Wildlife Biologist

THE LOCATION OF THE PROPOSED WELL and the area on which the water will be used must be indicated on the diagram below. Use the CENTER SECTION (1 section, 640 acres) for the well location.



The scale of the diagram is 2 inches = 1 mile
Each small square represents 40 acres.

WATER EQUIVALENTS TABLE (Rounded Figures)

An acre-foot covers 1 acre of land 1 foot deep
1 cubic foot per second (cfs) . . . 449 gallons per minute (gpm)
A family of 5 will require approximately 1 acre-foot of water per year.
1 acre-foot . . . 43,560 cubic feet . . . 325,900 gallons.
1,000 gpm pumped continuously for one day produces 4.42 acre-feet.

(6) THE WELL MUST BE LOCATED BELOW by distances from section lines.

2700 ft. from North (north or south) sec. line

200'-2700' ft. from East (east or west) sec. line

LOT ______ BLOCK ______ FILING # ______

SUBDIVISION ______

(7) TRACT ON WHICH WELL WILL BE LOCATED Owner: Colorado Division of Wildlife

No. of acres 520. Will this be the only well on this tract? Yes

(8) PROPOSED CASING PROGRAM

Plain Casing None

______ in. from ______ ft. to ______ ft.

______ in. from ______ ft. to ______ ft.

Perforated casing

______ in. from ______ ft. to ______ ft.

______ in. from ______ ft. to ______ ft.

(9) FOR REPLACEMENT WELLS give distance and direction from old well and plans for plugging it: N/A

(10) LAND ON WHICH GROUND WATER WILL BE USED:

Owner(s): Colorado Division of Wildlife No. of acres: 100

Legal description: N½ of the N½ of the SE¼ and a small portion of the SE¼ of the NE¼ Sec. 6, T23S., R.51W. 6th PM

(11) DETAILED DESCRIPTION of the use of ground water: Household use and domestic wells must indicate type of disposal system to be used.

This water provides open water in an otherwise completely overgrown cattail swamp for fisheries and waterfowl nesting, resting, and feeding.

(12) OTHER WATER RIGHTS used on this land, including wells. Give Registration and Water Court Case Numbers.

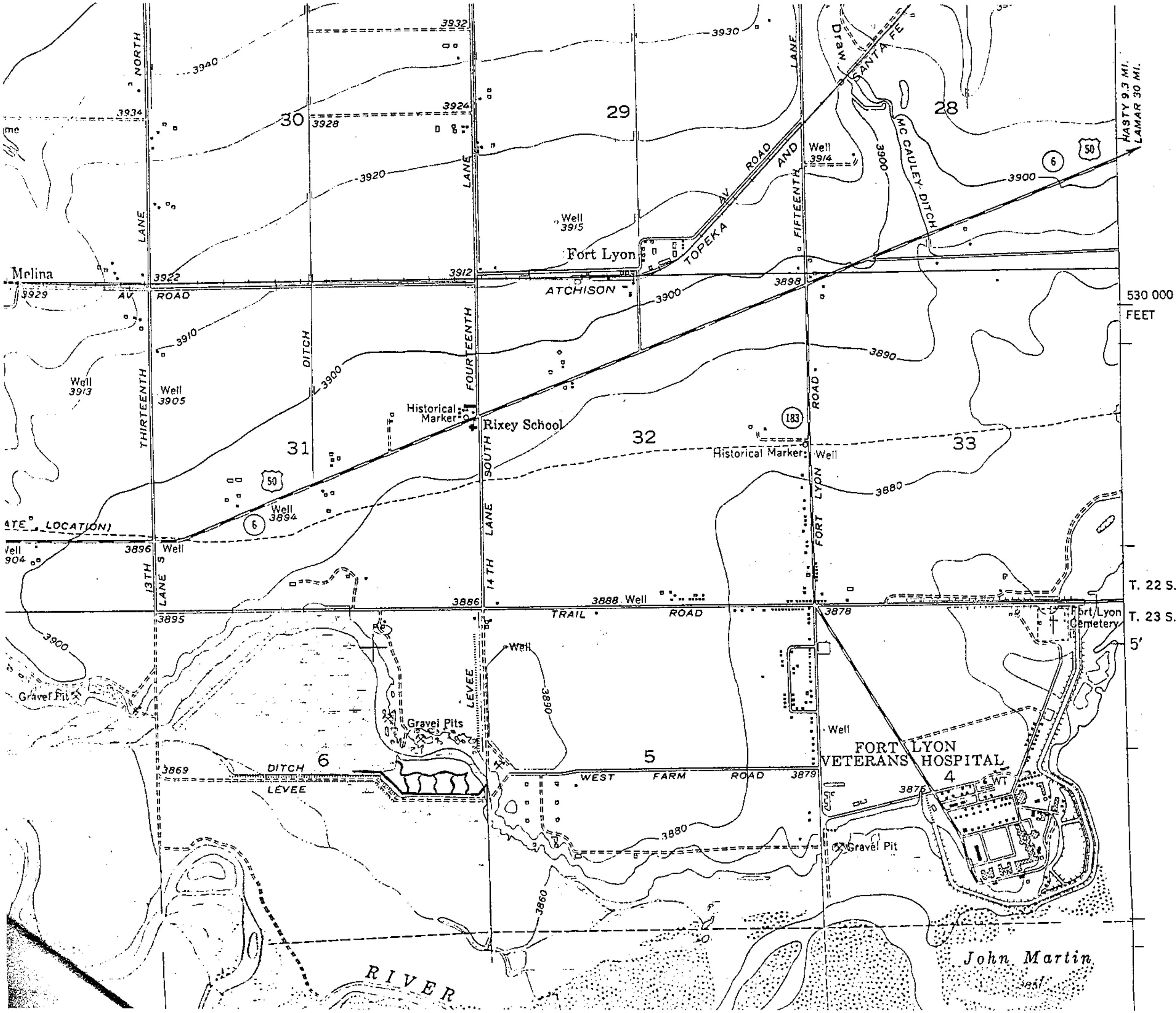
Type or right	Used for (purpose)	Description of land on which used
None		

(13) THE APPLICANT(S) STATE(S) THAT THE INFORMATION SET FORTH HEREON IS TRUE TO THE BEST OF HIS KNOWLEDGE.

Jack Grieb, Director

SIGNATURE OF APPLICANT(S)

Use additional sheets of paper if more space is required.



FORT LYON VETERANS HOSPITAL
Fort Lyon
Fort Lyon Cemetery
Melina
Rixey School
Historical Marker
John Martin
RIVER
HASTY 9.3 MI.
LAMAR 30 MI.
530 000 FEET
T. 22 S.
T. 23 S.
SANTA FE
TOPEKA AND AV ROAD
ATCHISON AV ROAD
MC CAULEY DITCH
Draw
FIFTEENTH LANE
FORT LYON ROAD
FOURTEENTH LANE
SOUTH 14TH LANE
THIRTEENTH LANE
NORTH LANE
13TH LANE S
TRAIL ROAD
WEST FARM ROAD
DITCH
LEVEE
Gravel Pits
Gravel Pit
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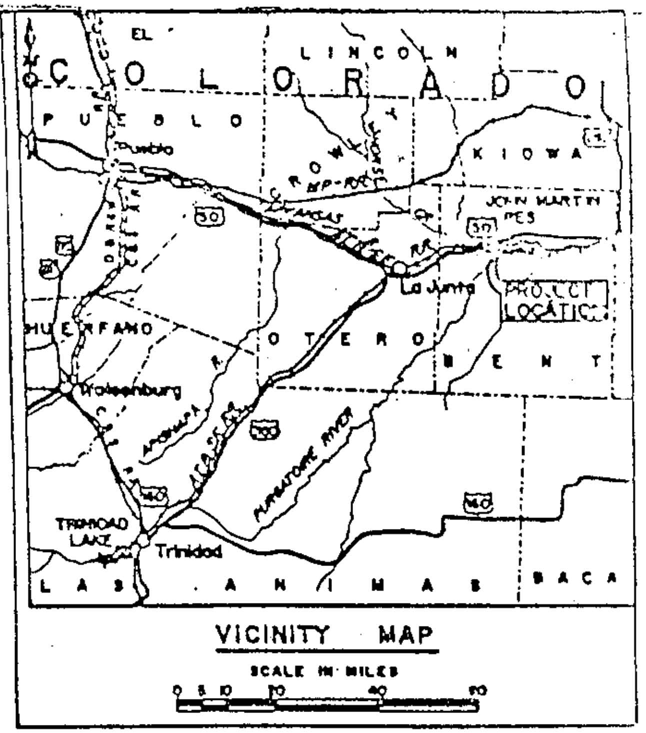
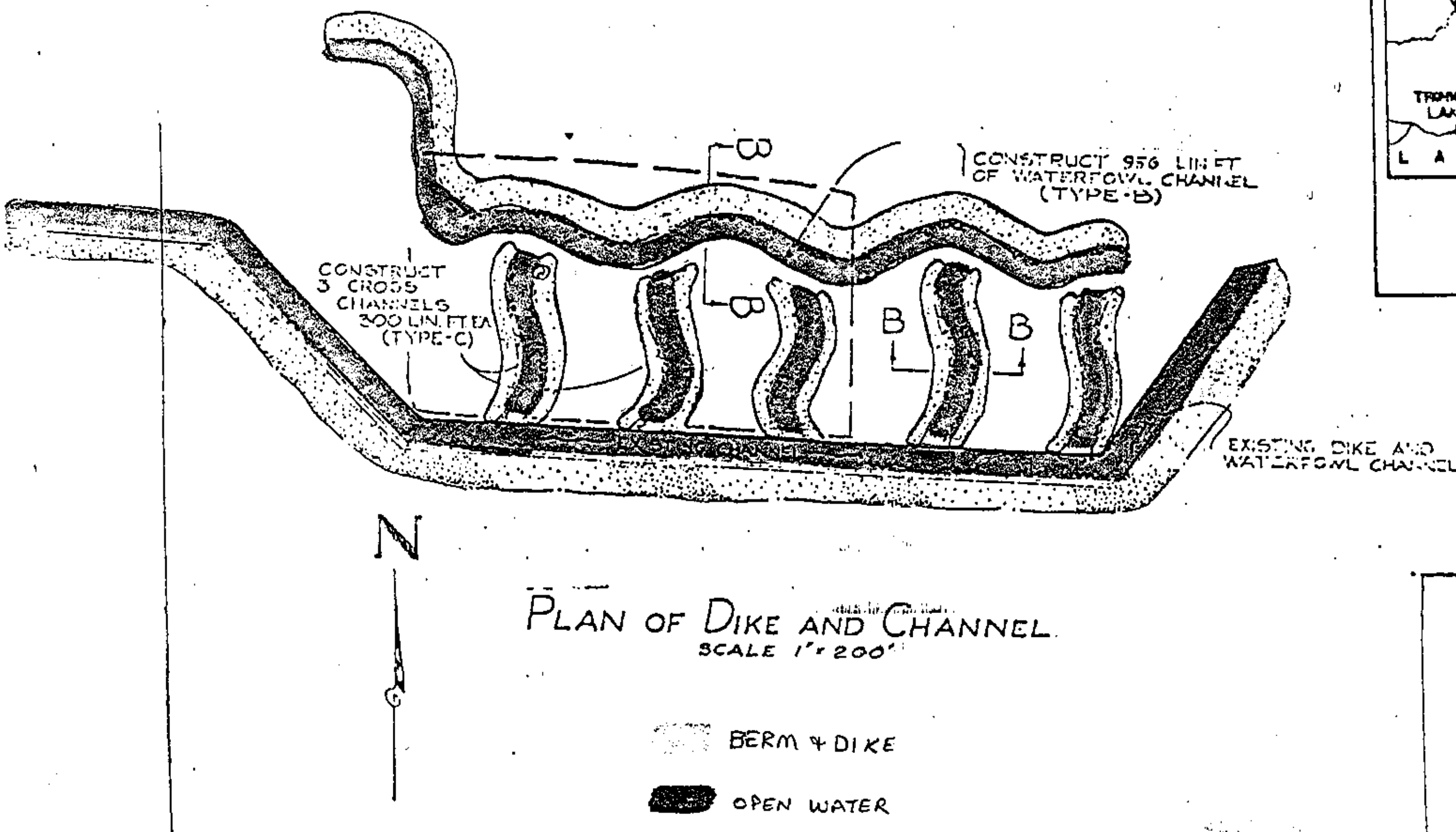
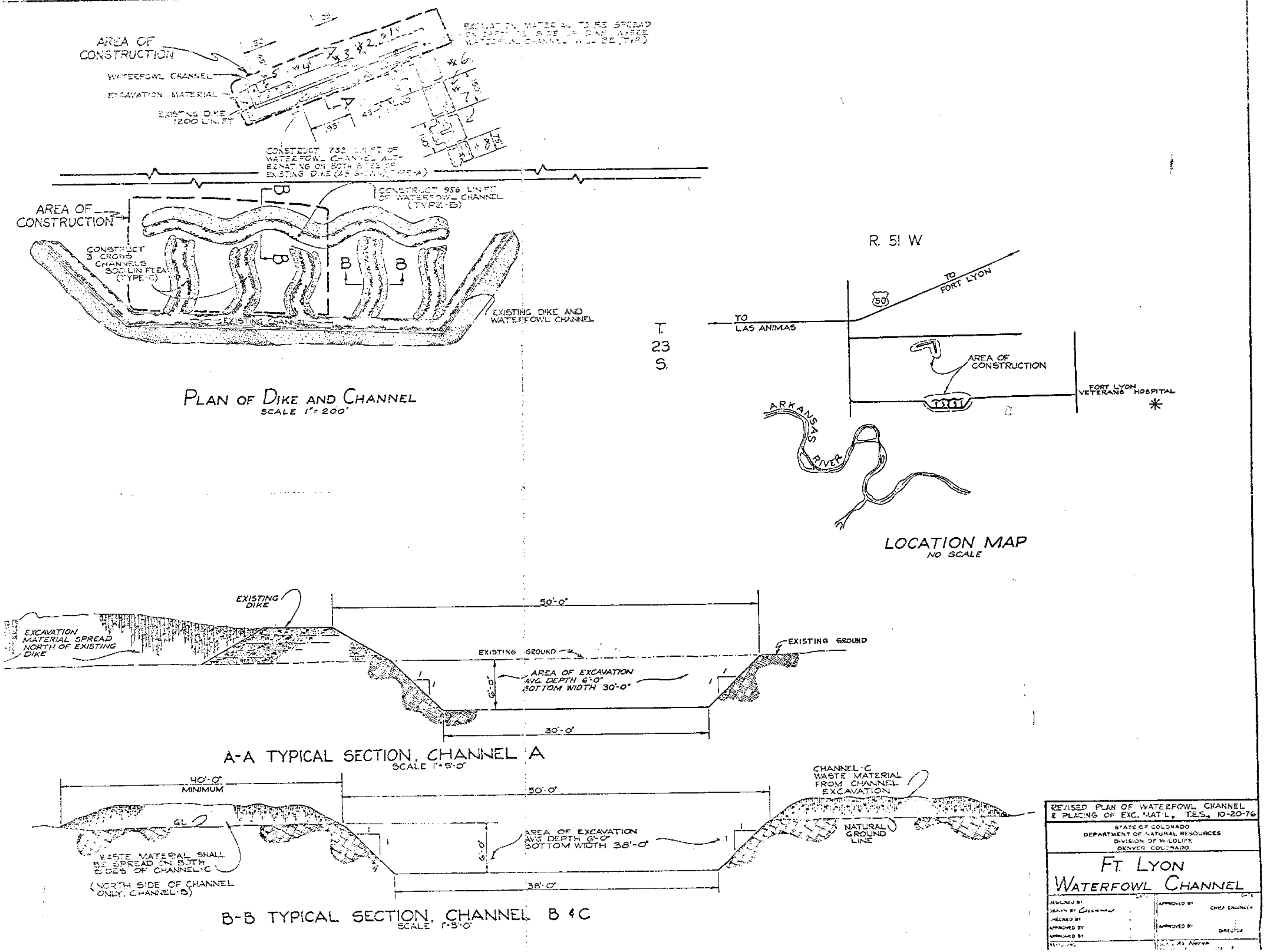




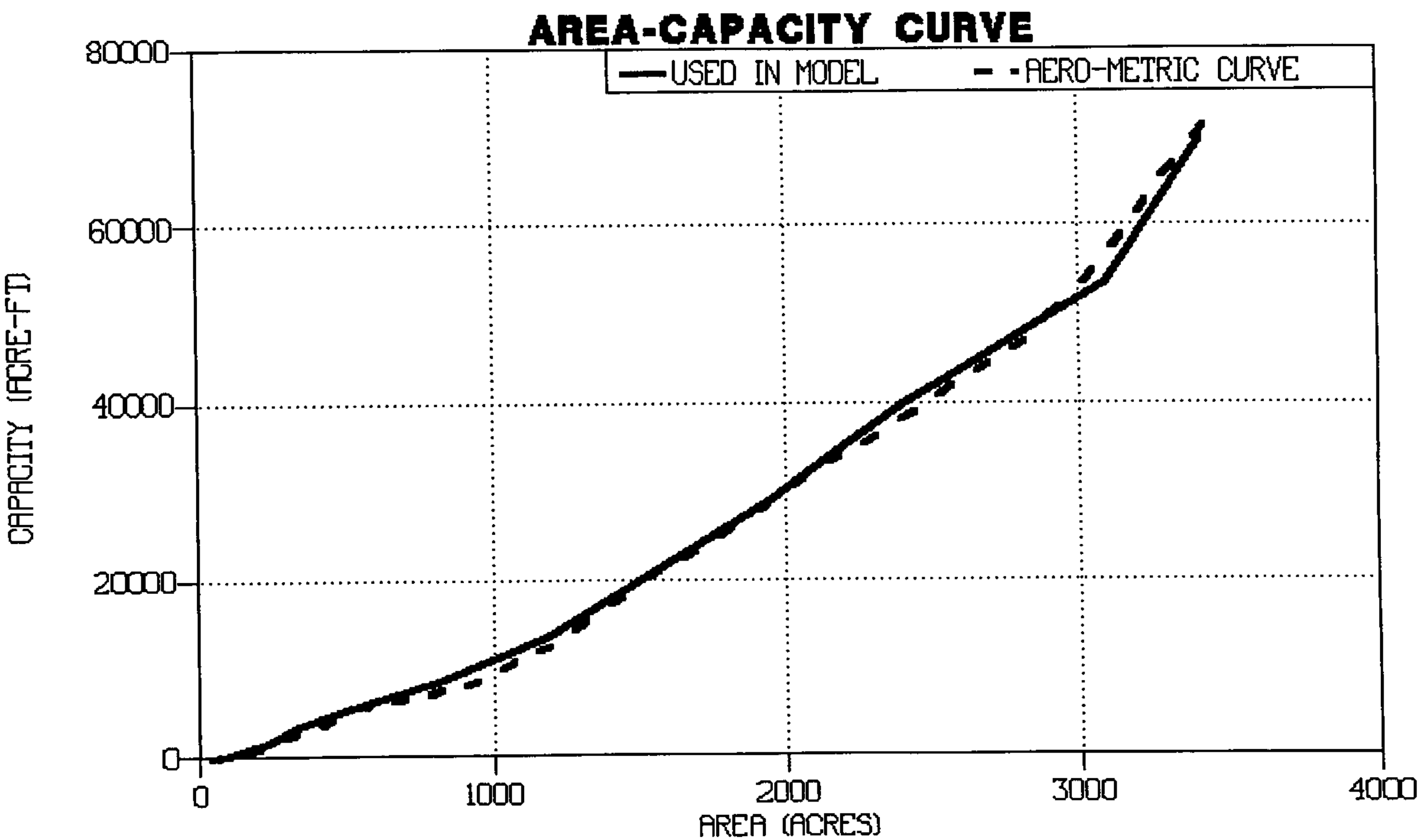
PROPOSED FT LYON WATERFOWL CHANNELS IN A WETLAND NEAR THE ARKANSAS RIVER
BENT COUNTY, CO

APPLICATION BY
COLORADO DIV OF WILDLIFE
SHEET 1 of 2 21 MAR 77


AREA OF CONSTRUCTION
WATERFOWL CHANNEL
EXCAVATION MATERIAL
EXISTING DIKE 1200 LIN. FT.
AREA OF CONSTRUCTION
CONSTRUCT 956 LIN. FT. OF WATERFOWL CHANNEL (TYPE-B)
CONSTRUCT 3 CROSS CHANNELS 300 LIN. FT. EA. (TYPE-C)
EXISTING CHANNEL
EXISTING DIKE AND WATERFOWL CHANNEL
PLAN OF DIKE AND CHANNEL
SCALE 1"=200'
R. 51 W
T. 23 S.
TO FORT LYON
50
TO LAS ANIMAS
AREA OF CONSTRUCTION
FORT LYON VETERANS HOSPITAL
ARKANSAS RIVER
LOCATION MAP
NO SCALE
EXISTING DIKE
EXCAVATION MATERIAL SPREAD NORTH OF EXISTING DIKE
50'-0"
EXISTING GROUND
EXISTING GROUND
AREA OF EXCAVATION AVG. DEPTH 6'-0" BOTTOM WIDTH 30'-0"
6'-0"
30'-0"
A-A TYPICAL SECTION, CHANNEL A
SCALE 1"=5'-0"
40'-0" MINIMUM
GL
WASTE MATERIAL SHALL BE SPREAD ON BOTH SIDES OF CHANNEL-C
(NORTH SIDE OF CHANNEL ONLY, CHANNEL-B)
50'-0"
AREA OF EXCAVATION AVG. DEPTH 6'-0" BOTTOM WIDTH 38'-0"
6'-0"
38'-0"
CHANNEL-C WASTE MATERIAL FROM CHANNEL EXCAVATION
NATURAL GROUND LINE
B-B TYPICAL SECTION, CHANNEL B & C
SCALE 1"=5'-0"
REVISED PLAN OF WATERFOWL CHANNEL & PLACING OF EXC. MAT'L, T.E.S., 10-20-76
STATE OF COLORADO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WILDLIFE
DENVER COLORADO
FT. LYON
WATERFOWL CHANNEL
DESIGNED BY
DRAWN BY
CHECKED BY
APPROVED BY
APPROVED BY
CHIEF ENGINEER
DIRECTOR

Appendix B
Area Capacity Curve for Nee Noshe Reservoir (Boyle 1993)

FIGURE B.2
NEE NO SHE RESERVOIR



Appendix C
Wetlands and Deepwater Habitats Classification Hierarchy
(Cowardin, Lewis M. et al. 1979)

WETLANDS AND DEEPWATER HABITATS CLASSIFICATION

System: M - Marine

Subsystem: 1 - Subtidal

Class	Subclass
RB – Rock Bottom	1 Bedrock 2 Rubble
UB – Unconsolidated Bottom	1 Cobble-Gravel 2 Sand 3 Mud
AB – Aquatic Bed	1 Algal 3 Rooted Vascular
RF – Reef	1 Coral 3 Worm

Subsystem: 2 - Intertidal

Class	Subclass
AB – Aquatic Bed	1 Algal 3 Rooted Vascular
RF – Reef	1 Coral 3 Worm
RS – Rocky Shore	1 Bedrock 2 Rubble
US – Unconsolidated Shore	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic

System: E - Estuarine

Subsystem: 1 - Subtidal

Class	Subclass
RB – Rock Bottom	1 Bedrock 2 Rubble
UB – Unconsolidated Bottom	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic
AB – Aquatic Bed	1 Algal 3 Rooted Vascular 4 Floating Vascular
RF – Reef	2 Mollusk 3 Worm

Subsystem: 2 - Intertidal

Class	Subclass
AB – Aquatic Bed	1 Algal 3 Rooted Vascular 4 Floating Vascular
RF – Reef	2 Mollusk 3 Worm
SB – Streambed	1 Bedrock 2 Rubble 3 Cobble-Gravel 4 Sand 5 Mud 6 Organic
RS – Rocky Shore	1 Bedrock 2 Rubble
US – Unconsolidated Shore	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic
EM – Emergent	1 Persistent 2 Non-persistent 5 *Phragmites australis*
SS – Scrub-Shrub	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 Deciduous 7 Evergreen
FO – Forested	1 Broad-Leaved Deciduous 2 Needle-Leaved Deciduous 3 Broad-Leaved Evergreen 4 Needle-Leaved Evergreen 5 Dead 6 Deciduous 7 Evergreen

System: R - Riverine

Subsystem: 1 - Tidal; 2 – Lower Perennial; 3 – Upper Perennial; 4* - Intermittent; 5* – Unknown Perennial

Class	Subclass
RB** – Rock Bottom	1 Bedrock 2 Rubble
UB – Unconsolidated Bottom	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic
SB** – Streambed	1 Bedrock 2 Rubble 3 Cobble-Gravel 4 Sand 5 Mud 6 Organic 7 Vegetated
AB – Aquatic Bed	1 Algal 2 Aquatic Moss 3 Rooted Vascular 4 Floating Vascular
RS – Rocky Shore	1 Bedrock 2 Rubble
US – Unconsolidated Shore	1 Cobble-Gravel 2 Sand 3 Mud 4 Organic 5 Vegetated
EM – Emergent	2 Nonpersistent

* **Intermittent** is limited to the **Streambed** Class;
Unknown Perennial is limited to **Unconsolidated Bottom** Class code **R5UB** only

** **Rock Bottom** is not permitted for the **Lower Perennial** Subsystem;
Streambed is limited to **Tidal** and **Intermittent** Subsystems

WETLANDS AND DEEPWATER HABITATS CLASSIFICATION

System: L - Lacustrine

- **Subsystem:** 1 - Limnetic
  - **Class:** RB – Rock Bottom
    - Subclass: 1 Bedrock; 2 Rubble
  - **Class:** UB – Unconsolidated Bottom
    - Subclass: 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic
  - **Class:** AB – Aquatic Bed
    - Subclass: 1 Algal; 2 Aquatic Moss; 3 Rooted Vascular; 4 Floating Vascular
- **Subsystem:** 2 - Littoral
  - **Class:** RB – Rock Bottom
    - Subclass: 1 Bedrock; 2 Rubble
  - **Class:** UB – Unconsolidated Bottom
    - Subclass: 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic
  - **Class:** AB – Aquatic Bed
    - Subclass: 1 Algal; 2 Aquatic Moss; 3 Rooted Vascular; 4 Floating Vascular
  - **Class:** RS – Rocky Shore
    - Subclass: 1 Bedrock; 2 Rubble
  - **Class:** US – Unconsolidated Shore
    - Subclass: 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic; 5 Vegetated
  - **Class:** EM – Emergent
    - Subclass: 2 Nonpersistent

System: P - Palustrine

- **Class:** RB – Rock Bottom
  - Subclass: 1 Bedrock; 2 Rubble
- **Class:** UB – Unconsolidated Bottom
  - Subclass: 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic
- **Class:** AB – Aquatic Bed
  - Subclass: 1 Algal; 2 Aquatic Moss; 3 Rooted Vascular; 4 Floating Vascular
- **Class:** US – Unconsolidated Shore
  - Subclass: 1 Cobble-Gravel; 2 Sand; 3 Mud; 4 Organic; 5 Vegetated
- **Class:** ML – Moss-Lichen
  - Subclass: 1 Moss; 2 Lichen
- **Class:** EM – Emergent
  - Subclass: 1 Persistent; 2 Nonpersistent; 5 *Phragmites australis*
- **Class:** SS – Scrub-Shrub
  - Subclass: 1 Broad-Leaved Deciduous; 2 Needle-Leaved Deciduous; 3 Broad-Leaved Evergreen; 4 Needle-Leaved Evergreen; 5 Dead; 6 Deciduous; 7 Evergreen
- **Class:** FO – Forested
  - Subclass: 1 Broad-Leaved Deciduous; 2 Needle-Leaved Deciduous; 3 Broad-Leaved Evergreen; 4 Needle-Leaved Evergreen; 5 Dead; 6 Deciduous; 7 Evergreen

MODIFIERS

In order to more adequately describe the wetland and deepwater habitats, one or more of the water regime, water chemistry, soil, or special modifiers may be applied at the class or lower level in the hierarchy. The farmed modifier may also be applied to the ecological system.

Water Regime			Special Modifiers	Water Chemistry			Soil
Nontidal	**Saltwater Tidal**	**Freshwater Tidal**		**Coastal Halinity**	**Inland Salinity**	**pH Modifiers for all Fresh Water**	
A Temporarily Flooded	L Subtidal	S Temporarily Flooded-Tidal	b Beaver	1 Hyperhaline	7 Hypersaline	a Acid	g Organic
B Saturated	M Irregularly Exposed	R Seasonally Flooded-Tidal	d Partly Drained/Ditched	2 Euhaline	8 Eusaline	t Circumneutral	n Mineral
C Seasonally Flooded	N Regularly Flooded	T Semipermanently Flooded-Tidal	f Farmed	3 Mixohaline (Brackish)	9 Mixosaline	i Alkaline	
E Seasonally Flooded/ Saturated	P Irregularly Flooded	V Permanently Flooded-Tidal	h Diked/Impounded	4 Polyhaline	0 Fresh		
F Semipermanently Flooded			r Artificial	5 Mesohaline			
G Intermittently Exposed			s Spoil	6 Oligohaline			
H Permanently Flooded			x Excavated	0 Fresh			
J Intermittently Flooded							
K Artificially Flooded							

Appendix D
Site Visit Photographs

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Site Visit Photographs

D.1 John Martin Reservoir Site Photos


2009/08/24


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D.2 Nee Noshe Wetlands Site Photos


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