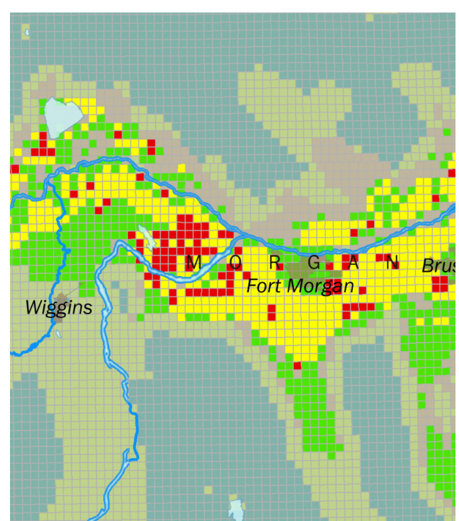
FINAL REPORT

Prepared for
Colorado Water Conservation Board

Development of Decision Support Model for Identifying and Ranking Waterfowl and Wildlife Related Recharge Projects along the South Platte River

September 30, 2013



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Ducks Unlimited

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Prepared for

Colorado Water Conservation Board, Denver, Colorado

September 30, 2013

Project No. CO-229-1

FINAL

Prepared By:

Ducks Unlimited, Inc., Brown and Caldwell, and Harvey Economics

Acknowledgements

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- Todd Doherty, formerly with CWCB
- Brent Schantz, DWR
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- Sean Cronin, St. Vrain and Left Hand Water Conservancy District
- Niki Kernohan, Colorado State University

The project team members included:

- Greg Kernohan, Ducks Unlimited
- Ed Harvey, Harvey Economics
- Matt Lindburg, P.E., Brown and Caldwell
- Zachary Wengrovius, P.E., Brown and Caldwell

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Executive Summary

Over the last few years, Ducks Unlimited (DU) has been working with the Colorado Water Conservation Board (CWCB) to construct multi-purpose, aquifer recharge wetlands that create or enhance wildlife habitat, provide bird watching and hunting opportunities, and supply recharge to the alluvial aquifer. The program has been successful and has been implemented where known partnership opportunities exist. However, there has not been a strategic or standardized approach for seeking new opportunities. The goal of this project, funded through a grant from the CWCB Water Supply Reserve Account (WSRA), was to develop a decision support model that can facilitate strategic targeting of specific areas within the South Platte River basin that could benefit from new or additional wildlife habitat and help meet local recharge demands. Additionally, the systematic approach developed through this project can be applied to other river basins in Colorado and for additional water resources applications.

Project Objectives

The overall objective for this project was to develop a decision support system model (DSS) or tool based on geospatial data that can be used to identify and rank potential sites for future recharge wetland projects in the South Platte River basin. The process for developing the DSS included identifying geographically variable factors important for determining locations for future wetlands, ranking the importance of those factors relative to each other, assigning a scoring system based on pre-determined criteria, and developing a process and tool using geographic information systems (GIS) data to translate the ranked factors to a spatially oriented grid.

The following factors represent a first tier of decision criteria that can be readily characterized using existing geographically-based data sets (hereinafter referenced as "Tier 1" data).

- Amount of existing waterfowl habitat near a project area
- Availability of water supply
- Alluvial aquifer properties
- Land ownership and the availability of public access
- Proximity to developed urban areas

Factors that do not easily lend themselves to spatial alignment, but are important in determining recharge wetland locations were considered in a second tier of decision criteria (hereinafter referenced as "Tier 2" data). These factors include:

- Funding partners
- Potential permitting issues
- Need for recreational opportunities
- Value of the water and land
- Comparative economic returns to water
- Suitability of the land

The DSS model will be used to highlight the favorable locations for wetlands based on the geospatial data (or first tier criteria) and then those sites will be evaluated with the second tier criteria to finalize the project site selection process.

Data Collection

The primary objective for the data collection phase was to identify spatial data that were representative of the important factors for selecting water recharge wetland sites. Several sources were used, with an emphasis placed on selecting free, publically available data that has received at least a minimum level of quality assurance and quality control (QA/QC) performed by the agencies that maintain the data catalogues. Additionally, spatial and tabular data generated through the development of the South Platte Decision Support System (SPDSS) was preferred over other sources. The project used only existing data sets, and where necessary, incomplete information was filled.

Data Limitations

Where possible, the most accurate spatial data were collected and utilized in the development of the DSS model. However, limitations to the accuracy, completeness, resolution, and timeliness of the various data exist. Minor discrepancies between layer alignments and layer detail caused by layer resolution or layer scale differences were not corrected. In general, the data used for the tool were representative of the various features within the layers at a regional scale, but they were not developed with the intent to represent features at specific locations.

GIS Analysis

After the types of data needed to complete the DSS model were identified, collected, and reviewed for accuracy and completeness, the individual GIS layers representing the Tier 1 factors were processed into uniform grid layers, assigned relative importance values or weights and scored based on predetermined criteria. A weighted score for each grid cell in each layer was calculated and then a final summation grid layer was created from the multiple grid layers. The cell-by-cell scores of the summation layer could then be used to highlight the areas that are more favorable for constructing new recharge wetland areas or expanding existing wetland areas.

Layer Selection and Processing

Carrying forward the work started during the data collection phase of selecting data to represent the Tier 1 factors, the selection process for layers to be used in the GIS tool analysis included input from stakeholders and a review of the overall appropriateness of the layers. The selection process was designed to be both collaborative and iterative. The final set of layers used in the GIS tool included:

- Mapping of the depth to groundwater in the alluvial aquifer
- Alluvial aquifer boundary mapping
- Mapping of ditch service areas and areas near water supplies
- Mapping of urban areas
- Existing wetlands mapping
- Land ownership mapping
- Mapping of existing recharge ponds
- Contours of lag times of return flows to the South Platte River

A comprehensive explanation of the layers included in the GIS tool is provided in Section 3.1 of this report.

After the selection process, the layers were assigned a range of scores which were typically based on attribute data characteristics, but for some layers, the scoring was based only on the areal extent of the layer (e.g., urban area mapping). The scores ranged from 0 to 5 for most layers, with 0 corresponding to the least favorable attributes or areas and 5 corresponding to the most favorable attributes. For a few layers, the minimum score was 1, but the maximum score was always 5. A full summary of the scoring for each layer is provided in Section 3.2 of this report.

In addition to the layer scores, each layer was given an independent importance value or weight. The GIS layers compiled for this project represent important criteria for selecting potential sites for constructing recharge wetlands, however, some layers represent factors that carry more weight and are more important to the decision making process. This concept was represented in the DSS model by assigning relative layer weights to each of the layers. The process for determining the layer weighting followed an approach called Marginal Rate of Attribute Substitution (MARS) (Rideout et al, 2007). A summary of the layer scores and weights is given in Table ES-1 below.

Table ES-1. Layering Weighting and Scoring Summary

Layers	Layer Weight	Minimum Score	Maximum Score
Depth To Groundwater	1.0	1	5
Ability to Recharge Alluvial Aquifer	0.9	0	5
Availability of Water Supply	0.8	1	5
Urban Area Mapping	0.7	0	5
Existing Wetlands	0.6	0	5
Land Ownership	0.4	1	5
Existing Recharge Ponds	0.2	0	5
Lag Time Characteristics	0.1	0	5

Grid Selection and Discretization

Many of the GIS layers representing the Tier 1 factors had different coverage extents, scales, and resolutions (for raster files) making them difficult to compare at any given location. To create a standardized layering system for comparing layer attributes and developing a scoring system, each layer was discretized onto a predetermined grid. Rules were established for converting the discrete elements of the individual layers into broader grid cells. Several grid characteristics were considered when selecting the base grid used for layer discretization and scoring, including grid cell size, alignment, and real-world reference. A grid based on quarter section boundaries from the Public Land Survey System (PLSS) was selected for this project.

A detailed description of the discretization process is provided in Section 3.5 of this report

Summation Grid

The final piece of the GIS tool was the development of a summation grid layer which incorporates the weighted scores from each grid layer into a final weighted score and maintains key attributes from the individual layers to provide context for the final score. The summation grid layout, cell size, and cell orientation was identical to that of the individual layers described in Table ES-1.

The final weighted score values for each cell were calculated using the following equation.

Restated, the final weighted score for each cell in the summation grid is equal to the sum of each individual layer's corresponding cell score multiplied by the layer weights.

GIS Tool Results

Given the layer weights and range of scores shown in Table ES-1 above, the final weighted score for any given grid cell in the summation grid layer could range from 2.2 to 23.5. The minimum and maximum weighted scores possible for each layer are shown in Table ES-2 below.

Table ES-2. Summary of Weighted Scores

Layers	Layer Weight	Minimum Layer Score	Maximum Layer Score	Minimum Weighted Score	Maximum Weighted Score
Depth To Groundwater	1.0	1	5	1	5
Ability to Recharge Alluvial Aquifer	0.9	0	5	0	4.5
Availability of Water Supply	0.8	1	5	0.8	4
Urban Area Mapping	0.7	0	5	0	3.5
Existing Wetlands	0.6	0	5	0	3
Land Ownership	0.4	1	5	00.4	2
Existing Recharge Ponds	0.2	0	5	0	1
Lag Time Characteristics	0.1	0	5	0	0.5
TOTAL				*2.2*	*23.5*

It was unlikely that any one grid cell would have the proper attributes and location to achieve the maximum score shown in Table ES-2, and results from the summation grid layer show that to be true. The maximum weighted score observed for individual cells in the summation grid layer was 22.5. The minimum observed weighted score did however match the minimum possible score of 2.2.

Given the range of possible and observed scores, scores were summarized or bracketed to categorize and analyze scores on a spatial basis. Table ES-3 shows the score bracketing and percentile ranks.

Table ES-3. Final Weighted Score Bracketing

Score Range	Percentile Range
0 – 4.50 [1)]	0-20%
4.50 – 9.00	20-40%
9.00 – 13.50	40-60%
13.5 - 15.75	60-70%
15.75 – 18.00	70–80%
18.00 – 20.25	80-90%
20.25 – 22.50	90-100%

Notes: 1) Minimum observed score was 2.2

The brackets with the higher percentiles ranks represent locations that are potentially favorable for constructing recharge wetlands.

Sensitivity

The GIS Tool and the DSS model as a whole are not designed in a way that lends itself to typical sensitivity analysis. However, an evaluation of some of the initial tool results revealed some patterns in the clustering of high favorability grid cells that highlighted the differences in spatial variability on local and regional scales between layers and indicated the need to potentially adjust layer weighting. Initial tool results indicated a heavy influence of layers with high variability on a local scale where they overlaid layers with low local variability. The patterns were observed even when the locally variable layer was given a low layer weight value.

Reducing the influence of locally variable layers with lower weights was taken into consideration when developing the individual layer weights for the layers included in the GIS tool and was a primary reason to implement the MARS approach. The MARS approach was not implemented to remove the influence of less important layers on the final summation grid results, but instead the purpose was to assign weights to layers that represented the priorities of DU and the stakeholders in the context of the other layers included in the GIS tool.

Economic Analysis

Harvey Economics (HE) was retained to identify and quantify, to the extent possible, the economic benefits that would accrue to various types of partners in a prospective recharge project. That is, as DU assembles or joins a consortium to develop and operate a recharge site, DU would like to better understand the economic benefits that the other parties might experience from this recharge project venture. With this information, DU will be in a better position to determine how the consortium of partners can be structured and the magnitude or proportion of contribution that respective partners might be able to bring to such a project. HE was not charged with estimating actual dollar figures that prospective partners could contribute, but rather economic guidance related to particular types of recharge project partners and any ranges of benefits that might be apparent.

At the outset of the HE research, DU indicated that the economic study would be most helpful if it were segregated into three geographic regions within the South Platte study area. The Lower South Platte region for this study is defined by the Sterling area, near the Colorado-Nebraska state line, moving upstream on the South Platte River to the area before Brush. The City of Brush, upstream to eastern Weld County in the Kersey area, would comprise the middle region of the South Platte River. The upper region of the South Platte is defined for this study as the area from Kersey upstream to Fort Lupton and Hudson, in Weld County. It became apparent that recharge projects in these three regions along the South Platte River would attract different types of partners with different economic circumstances.

Partners can include municipal water suppliers, the oil and gas industry, administrative organizations (i.e., Division of Wildlife), and other specific interests depending on the region. Each of these parties can bring assets to a recharge project consortium, either in the form of land, water, money, or services in-kind. The structure of the consortium, the relative contributions of the parties, and the value of the respective participation of the individual participants, in a recharge project along the South Platte River, is highly location and site specific. For this reason, HE determined that the most productive research approach for this inquiry would be a series of interviews with different prospective participants within the three regions of interest along the South Platte River.

Survey Approach and Results

The survey HE conducted for this task entailed a development of a list of discussion topics, the creation of a list of potential interviewees, and the completion of the interviews themselves. The interviews were conducted in June, 2013. The interview questions or discussion topics included a description of each organization and how that organization could benefit from a prospective recharge project. Further, the interview explored specific attributes of a recharge project which would work best for that participant, as well as how the recharge project could be tailored to the participant.

Key Findings

Based upon the interviews conducted, the key findings of this task are expressed in two ways: determinants of overall economic value and contribution, and regional differences among the three regions. As described earlier, the type of participant in each recharge project will vary according to region, and the economic value or contribution of that participant is location-specific and participant-specific.

Upper Region. The upper region, as defined previously, includes larger municipalities, such as Greeley and Fort Lupton, as well as oil and gas interests and some agricultural interests as well. Water availability and attractive sites in this region might be in short supply, but this region holds far more attractive economic valuation prospects compared to the middle or lower regions. Given this level of financial contribution, recharge projects in this area need not be optimal. In evaluating the relative prospects in the three regions, HE believes that, from an economic standpoint, this region would represent the priority for future DU recharge project development.

Middle Region. The middle region offers many attractive considerations from an economic standpoint. There is considerable need for additional water yield and development in this area and there are not many alternatives to recharge projects. For augmentation plans, agriculture needs recharge projects throughout this region. Municipal water providers in this area are very interested in recharge projects and pursuing those projects with DU. DU will face some competition from the agricultural sector in developing these recharge projects and securing the most favorable sites. Industry participants are possible in this area, but the likelihood of participation is more episodic than promising.

Lower Region. The lower region includes the City of Sterling, smaller municipal entities and irrigation districts, along with the South Platte Water-Related Activities Program. Like the other regions, there is interest in recharge, ponds, and DU's participation. However, the level of interest is less in this region than in the middle region, with fewer prospective project participants. Far from the Front Range and the influence of petroleum industry, the market from an economic value standpoint, is considerably less. There is an opportunity for DU participation, but, except for those entities interested in the Platte River Recovery Program or the Division of Wildlife, financial contributions are likely to be modest and less favorable than the other two regions.

Implementation Plan

DU will use the DSS model to identify hotspots where ecosystem services from recharge wetlands can be implemented to maximize water resources for wildlife, agriculture, and municipal and industrial needs. Our "thunderstorm" map clearly identified at least three focus areas where the top 10% of the highest ranked sites were clustered in all three regions outlined in the economic analysis; Gilcrest/Platteville, Golden Triangle – Fort Morgan (GTFM), and Julesburg. There are several other smaller sites or locations including the area around Hudson and Keenesburg that identified a large area that is mostly in the top 20% of sites.

The DSS shows the most significant grouping of top 10% sites for the entire river is in the GTFM area. DU will focus our ecosystem services program on this priority area. According to the economic analysis, the value of water in the reach is considerably more valuable than the lower river, but still highly reasonable for both agricultural and environmental interests to afford as opposed to the upper region. The area is positioned perfectly between rural water districts interested in both agriculture's continued vitality and rural municipal and industrial water needs and encroaching Front Range water interests creating opportunity for several diverse partnerships with the water community. Persistent desire to sustain an agricultural economy in the area presents opportunities to protect land and water rights for perpetual dedication to agriculture while exercising innovative alternative transfer methods (ATM)'s such as the FLEX Market, water cooperatives, and interruptible supply plans to meet Front Range municipal and industrial demands.

Demand to recharge the aquifer is high in both the upper and lower regions of the lower South Platte as well. The lower region supports a vibrant agricultural economy absent the pressures of Front Range growth. The lower region also boasts improved waterfowl populations closer to the central flyway funnel located in Nebraska. The lower region has enjoyed improved stream flows and water storage in the last ten years, but many augmentation plans and capacity to deliver water for the Platte River Recovery Implementation Program are short during specific months. DU will continue to work with traditional partners in the area to develop recharge facilities cooperatively.

A different strategy will be required in the upper region where myriad demands for consumptive water from several sectors are very high. Water and land in the area is a premium, pushing prices beyond the capability of most wildlife organizations. Strong partnerships with water providers will be developed to leverage wildlife investments and more effectively.

The DSS has already been implemented in developing proposals with both Great Outdoors Colorado (GOCO) and the State Land Board (SLB) with many more planned. GOCO recently completed a request for proposals to identify innovative water projects on open space and natural areas. DU used the tool to highlight the GTFM focus area as an opportunity for greater GOCO investment to protect agricultural water and land. The SLB owns 18,000 acres within the lower South Platte Focus River. DU developed proposal to use the tool and identify 10 of the top ranked SLB properties and conduct field investigations to identify the best 1 – 3 sites for recharge wetland development.

Discussion and Conclusions

The primary purpose of the GIS tool was to highlight potential sites for wetlands projects through an initial screening process. The final summation grid, as shown in Figure 4-1 of this report, was successful in identifying various potentially favorable sites throughout the South Platte River Basin.

The tool is not intended to provide definitive site selection results. In using this tool, DU can identify several areas important for agriculture, municipal and industrial water, and wildlife habitat to focus resources for the future. The results from the tool are intended to be used in conjunction with economic and administrative factors (Tier 2). On-site field investigations should be conducted prior to final site selection. Additionally, the various risks relating to construction of recharge wetlands in certain areas should be understood and properly considered during initial investigations, and decisions based on the risk assessments should be made independent of the results from the tool even if areas are potentially highly favorable.

Economic Analysis Summary

There is considerable interest in recharge projects in each of the three regions along the South Platte River. The needs of the participants in each region vary widely, and the values of each participant are highly variable. Given this variability, specific valuation figures would be misleading.

The economic value of the recharge projects are driven by the economic returns in the instance of agriculture or costs or other attributes of alternative water resource supplies in the case of municipalities and industrial or petroleum interests. Municipalities are particularly attracted to recharge projects, given the alternatives, but the project characteristics must fit their particular needs. The petroleum sector also would experience considerable value from a recharge project, especially if it is located close to the need.

The development prospects and the economic values to be gained from a recharge project are likely to be the highest in the upper region of the South Platte River as compared with the other two, with the middle region offering more opportunities, but less value. In the lower region, there is also an interest in additional recharge sites, but economic prospects are not as bright, and DU will face more competition for its service in this region.

Alternative Applications and Future Use

The GIS tool was built so that it can be easily adapted to fit the needs of projects other than site selection for wetlands. The underlying data in the tool is foundational for many potential applications and the processes used to generate the grid layers can be duplicated readily. Also, the layer weighting and scoring can be updated without having to reprocess individual grid layers to better match the priorities of other applications. Other easy modifications can be made to the GIS tool to suit the purposes of a new project including turning off certain layers (e.g. existing wetlands) and adding additional data. The addition of new data layers would require a re-evaluation of the layer weighting and processing of new grid layers. Examples of alternative applications include preliminary screen of sites for augmentation recharge facilities or investigations relating to installation of ASR facilities.

While the current GIS tool was developed for the South Platte basin, the tool could be adapted to other basins. To date, the South Platte basin is covered by a more comprehensive GIS database than other basins and some data relied on for the GIS tool are not as readily available for other basins. Part of the scope of work for developing DSS models in other basins would likely include in-depth data collection and data development to fill in any gaps in availability of data. The DSS model might also take on a different character depending on the needs and interests of stakeholders in the other basins.

Section 1

Introduction

With increasing demand for water from growing municipalities, the addition of wells to provide supplemental irrigation supplies, and the potential for reduced availability of surface water supplies, numerous groundwater recharge facilities have been constructed in the South Platte River basin. The primary purpose for many of these recharge ponds is to augment out-of-priority depletions of South Platte River flows associated with groundwater pumping. Over the last few years, Ducks Unlimited (DU) has been working with the Colorado Water Conservation Board (CWCB) to construct multi-purpose, aquifer recharge wetlands that create or enhance wildlife habitat, provide bird watching and hunting opportunities, and supply recharge to the alluvial aquifer.

Recharge wetlands are typically engineered facilities that are designed for multi-purpose uses that encompass various aspects of water conservation, wildlife habitat, and recreation. In the South Platte River Basin, recharge wetlands have been used to offset depletions caused by well pumping, but could also be used in the future to relieve exchange bottlenecks caused by low flow or calls at key points along the river, or be incorporated into plans for cooperative water sharing.

The program has been successful and has been implemented where known partnership opportunities exist. However, there has not been a strategic or standardized approach for seeking new opportunities. The goal of this project, funded through a grant from the CWCB Water Supply Reserve Account (WSRA), was to develop a decision support model that can facilitate strategic targeting of specific areas within the South Platte River basin that could benefit from new or additional wildlife habitat and help meet local recharge demands. Additionally, the systematic approach developed through this project can be applied to other river basins in Colorado and for additional water resources applications.

1.1 Project Objectives

The overall objective for this project was to develop a decision support system model (DSS) or tool based on geospatial data that can be used to identify and rank potential sites for future recharge wetland projects in the South Platte River basin. The process for developing the DSS included identifying geographically variable factors important for determining locations for future wetlands, ranking the importance of those factors relative to each other, assigning a scoring system based on pre-determined criteria, and developing a process and tool using geographic information systems (GIS) data to translate the ranked factors to a spatially oriented grid.

The following factors represent a first tier of decision criteria that can be readily characterized using existing geographically-based data sets (hereinafter referenced as "Tier 1" data). Amount of existing waterfowl habitat near a project area

- Availability of water supply
- Alluvial aquifer properties
- Land ownership and the availability of public access
- Proximity to developed urban areas

Factors that do not easily lend themselves to spatial alignment, but are important in determining recharge wetland locations were considered in a second tier of decision criteria (hereinafter referenced as "Tier 2" data). These factors include:

- Funding partners
- Potential permitting issues
- Need for recreational opportunities
- Value of the water and land
- Comparative economic returns to water
- Suitability of the land

The DSS model will be used to highlight the favorable locations for wetlands based on the geospatial data (or first tier criteria) and then those sites will be evaluated with the second tier criteria to finalize the project site selection process.

1.2 Project Team

The WSRA grant application was completed by DU with the goal of continuing and enhancing the development of multi-purpose recharge wetlands through the development of the DSS model and standardized selection criteria. Assisting DU with the development of the DSS model and accompanying criteria were Harvey Economics and Brown and Caldwell. Brown and Caldwell took the lead in the geospatial data collection process, DSS model development, and project documentation. Harvey Economics provided analysis relating to the valuation of water rights, land, and the cost/benefit analysis of the projects. Throughout the development of the DSS model, Brown and Caldwell sought input from DU, CWCB, and potential stakeholders in the South Platte basin.

Section 2

Data Collection

The primary objective for the data collection phase was to identify spatial data that were representative of the important factors for selecting water recharge wetland sites. Several sources were used, with an emphasis placed on selecting free, publically available data that has received at least a minimum level of quality assurance and quality control (QA/QC) performed by the agencies that maintain the data catalogues. Additionally, spatial and tabular data generated through the development of the South Platte Decision Support System (SPDSS) was preferred over other sources. The project used only existing data sets, and where necessary, incomplete information was filled.

2.1 Data Selection

The first phase of the data collection process was identifying the characteristics and factors that are important for determining the suitability of locations for constructing recharge wetlands. These factors, discussed broadly in Section 1, were separated into tiers based primarily on the ease with which the factors can be represented in a spatial data set. The collection of the Tier 1 data, which includes hydrologic and hydrogeologic parameters and features, political and administrative boundaries, and land use designations, was the primary focus of the data collection task. The Tier 2 data, consisting of economic data and administrative factors, was also collected, but not incorporated into the GIS-based portion of DSS model.

2.1.1 Data Types and Sources

The types of Tier 1 data collected included ESRI Shapefiles (shapefiles), file geodatabases, raster datasets and Google Earth KML/KMZ files, with the majority of the data in the shapefile format. The spatial data were maintained in the format in which they were received, except for the KML files which were converted to shapefiles. Minor manipulation of the original data occurred for analysis purposes and generally included merging individual data sets, extracting or isolating data from a larger data set, creating buffers around particular features, or combining (dissolving) multiple but similar features into single features. The manipulations of the data were performed such that existing file attributes were preserved and the original source file remained unchanged. A more detailed description of data manipulation and analysis techniques is included in Section 3 of this report.

The scope of the project called for the use of existing data where possible. No new spatial data sets were created during the development of the DSS model other than various summation grid files used for calculation and spatial analysis purposes.

The SPDSS was the primary source of GIS data used in the DSS model. SPDSS, a component of the broader Colorado Decision Support System (CDSS), is a system of water-related modeling tools, data, and information developed by the CWCB and Colorado Division of Water Resources (DWR). As a part of the SPDSS development process, a comprehensive set of GIS data were created showing locations of hydrologic features, quantitative measurement locations, irrigation district boundaries, land use characteristics, alluvial aquifer characteristics and DWR administrative boundaries. Other important sources of spatial data were the DWR, Colorado Department of Transportation (CDOT), Colorado Natural Heritage Program (CNHP), United States Geological Survey (USGS), U.S. Bureau of Land Management (BLM), Colorado Division of Wildlife (DOW), the U.S. Census Bureau (Census), and the Denver Regional Council of Governments (DRCOG). All data from the agencies listed above are free, publically available, and have received some level of QA/QC. Links to the respective GIS Data catalogs are provided in the References section of this report.

2.1.2 Data Errors and Limitations

Where possible, the most accurate spatial data sets were collected and utilized in the development of the DSS model. However, limitations to the accuracy, completeness, resolution, and timeliness of the various data exist. Minor discrepancies between layer alignments and layer detail caused by layer resolution or layer scale differences were not corrected. In general, the data used for the tool were representative of the various features within the layers at a regional scale, but they were not developed with the intent to represent features at specific locations. The correction process would have been time consuming and would likely not have had a significant impact on the outcomes produced by the DSS model. Additionally, layers that covered only a limited portion of the analysis area and were not easily expanded to provide more complete coverage were not included in the tool. Examples of data limitations that were encountered during the analysis include:

- GIS layers only covering a small portion of the analysis area
- Raster data sets with varying cell sizes
- Layers created using out of date sources
- Data sets subject to change over time (e.g. depth to ground water, land ownership etc.)
- Layers with nonmatching coordinate systems
- Limited availability of certain data

An effort was made to minimize the impact of these limitations on the results of the tool, and none of the limitations were severe enough to exclude any of the layers from the tool. A detailed description of the input data will be provided in Section 3 of this report and will include a discussion of specific limitations of each input data layer.

Section 3

GIS Analysis

After the types of data needed to complete the DSS model were identified, collected, and reviewed for accuracy and completeness, the individual GIS layers representing the Tier 1 factors were processed into uniform grid layers, assigned relative importance values or weights and scored based on predetermined criteria. A weighted score for each grid cell in each layer was calculated and then a final summation grid layer was created from the multiple grid layers. The cell-by-cell scores of the summation layer could then be used to highlight the areas that are more favorable for constructing new recharge wetland areas or expanding existing wetland areas.

3.1 Layer Selection

The process for selecting layers that represented the hydrologic, hydrogeologic and administrative factors that are important for identifying favorable sites for building recharge wetlands grew from the criteria proposed in the grant application and highlighted in Section 1. Some additional layers were added and some removed based on input from DU and stakeholders, data availability or ease of integration into the GIS tool. Additionally, some layers initially included in the model were removed because their value was unclear or they did not provide meaningful differentiation between sites. For example, a soil mapping layer with soil drainage characteristics was considered but it was found to be redundant with depth to water and wetland location layers and was removed from the final list of layers. Decisions pertaining to which layers to include in the final version of the GIS tool were informed by an iterative process where both the feasibility of incorporating layers into the GIS tool and input from project sponsors and potential stakeholders was considered. The goal of this process was to decide on a set of layers that represent the important considerations for new wetland site selection and are consistent with a data-centered modeling approach.

3.1.1 Stakeholder Meetings

Input from project sponsors and stakeholders was sought at various stages throughout the development of the GIS tool. Three separate meetings were held to discuss layer selection and layer scoring and weighting. At the first meeting, an initial list of layers was compiled and the definitions of Tier 1 and Tier 2 datasets were refined. The two subsequent meetings were used to present preliminary summation grid results to stakeholders and solicit feedback on layer selection, layer scoring, and layer weighting. Stakeholders at these meetings included representatives from water conservancy districts, DWR, the Natural Resources Conservation Service, DU, and CWCB. The information provided in the stakeholder meetings had a significant impact on the final layer scoring and layer weighting and was a valuable component of the project.

3.1.2 Tier 1 Layers

The layers representing the final Tier 1 factors used in the GIS tool portion of the DSS model can be grouped into two general categories: layers that represent existing land use conditions and layers related to aquifer characteristics and water availability. The following text provides a detailed description of the layers used in the GIS tool including source information, layer attributes, and identification of important limitations to the data.

3.1.2.1 Urban Area Mapping

Early in the layer selection process DU indicated that developed urban areas were generally not desirable locations for constructing recharge wetlands. Urbanized areas were represented with a combination of mapping from the 2010 U.S. Census urban area mapping and municipal boundary mapping obtained from the CDOT spatial data library. The census data provides an accurate, up-to-date representation of areas that are developed and generally coincided with the CDOT municipal boundaries. In some areas, the CDOT municipal boundary layer extended beyond the census-designated urban areas. These areas were considered urban for the purposes of the tool and represent regions where future development is likely to take place. However, with growth and urban expansion, this layer will require updating in the future to maintain accuracy.

3.1.2.2 Existing Wetland Mapping

Knowing the locations of existing wetland areas and the type of wetlands was important for a few reasons. DU often looks to construct wetland ‘complexes’ by expanding existing wetland areas or building new wetlands directly adjacent to the existing wetlands. Favorable wetland types for creating complexes include freshwater emergent wetlands and fresh water emergent ponds. Other types of wetlands such as forested and riparian wetlands and large open water areas are not as favorable from a habitat enhancement and aquifer recharge standpoint either because the habitat type is abundant or the close proximity to the river greatly reduces value for aquifer recharge and stream flow augmentation. The existing wetland mapping data was provided by the CNHP and consisted of wetland mapping from the U.S. Fish and Wildlife Service National Wetland Inventory (NWI) and updates based on field investigations and analysis of aerial photography. Portions of the NWI data for the South Platte Basin were only available in hard copy format. In those areas, CNHP digitized the hard copy maps to create a comprehensive digital coverage of wetlands in Colorado. With the inclusion of the digitized data and updates, the wetland mapping provided by the CNHP provides the best coverage available. However, the mapping in most areas is based on work from the 1970s and 1980s and may not be representative of current conditions.

3.1.2.3 Land Ownership

Land ownership is an important factor for DU when considering wetland projects. DU builds wetland projects in partnership with state agencies or federal agencies such as the Division of Wildlife (DOW) and the State Land Board (SLB) and private landowners due to contract replication opportunities across a larger landscape and comparable mission characteristics for wildlife and recreation. Comprehensive land ownership data is maintained by CNHP as a part of the Colorado Ownership, Management, and Protection (COMaP) project. The COMaP database includes information on parcel ownership and management, status of protected areas, information on existing easements, and funding sources associated with the parcels.

3.1.2.4 Existing Recharge Ponds

The locations of existing recharge ponds can be indicative of favorable sites for constructing new recharge wetlands, as well as show areas where existing facilities can be expanded. Local areas with a high density of larger existing ponds were viewed as less favorable for construction of new recharge wetlands, because these areas already provide recharge and habitat benefits and the aquifer could already be at a locally high level in these areas. GIS mapping of the existing recharge ponds was provided by the DWR and included data such as the pond area, the augmentation plan associated with the pond, the surface water irrigation service area in which the pond was located, and the water district identification number (WDID) for the ponds. The recharge pond layer represents a snapshot of current conditions and would need to be updated as more ponds are added in the future.

3.1.2.5 Ability to Recharge Alluvial Aquifer

Part of the criteria established by DU for selecting sites for constructing recharge wetlands includes the suitability for multipurpose uses. In addition to habitat enhancement, the new wetlands could be used as sites for groundwater recharge relating to augmentation requirements or recharge projects aimed at relieving stream flow bottlenecks for the purpose of exchanging water upstream. This type of recharge is most useful when it accrues directly to the alluvial aquifer or in areas outside the mapped boundaries of the alluvial aquifer but are hydraulically connected to the aquifer. The extent of the alluvial aquifer in the South Platte basin (including tributary areas) was developed for the SPDSS project. Mapped alluvial areas that fell within the boundaries of designated groundwater basins were not considered to be hydraulically connected to the main aquifer for the purposes of the tool.

For the purposes of this project, areas outside of, but within 1 mile, of mapped alluvial boundaries were considered to be hydraulically connected to the alluvial aquifer. Favorable locations for recharge wetlands that fall within or adjacent to this 1-mile buffer should be further investigated to verify the hydraulic connection.

3.1.2.6 Lag Time Characteristics

Because of the multipurpose nature of the wetland projects, consideration was giving to the lagged return flow timing characteristics of potential recharge wetland sites. The lagged return timing refers to the length of time it takes for water recharged via a wetland or recharge site to affect the flow in an adjacent stream. Because of the properties of groundwater flow, the return flows accrue to the stream in a gradual manner, in many cases taking months or even years for all of the water to reach the stream. The Integrated Decision Support Group (IDS) at Colorado State University has developed a number or tools and datasets to aide in calculating the lagged return flow time for particular sites. The Alluvial Water Accounting System (AWAS) is an analytical model used to calculate return flow timing and is based on the Glover Equation. Model input parameters include the distance between the site and the stream, the overall width of the alluvial aquifer at the site, aquifer transmissivity, and specific yield. To streamline the collection of the AWAS input parameters, IDS generated a GIS-based grid of points within the mapped alluvial aquifer that include information describing distance to the stream, the aquifer width, the aquifer transmissivity, and the harmonic mean transmissivity for each point. The grid is available as a shapefile with a point spacing of 200 meters and was used as the basis for assigning return flow timing values in the GIS tool.

The raster layer representing return flow timing was first developed for a study of alternative agricultural water transfers in the South Platte River Basin. The study was funded by a CWCB Alternative Transfer Methods (ATM) grant and was also sponsored by DU along with the Colorado Corn Growers Association and the City of Aurora. The raster layer was produced by using the IDS grid input values and running the AWAS model for each of the gird points. The raster layers and custom scripts to run AWAS from the alternative transfer study were used again for this project. However, the original IDS grid and resulting raster layer were manually extended into the Cache la Poudre River and Beebe Draw areas to provide better coverage for the Tool.

The favorability and augmentation benefit of long or short return flow lag times can vary significantly depending on the overall goals of the recharge project and the end user of the augmentation credit. For example, an augmentation plan with wells far from the river may benefit the most from recharge facilities or recharge wetlands that are similarly located far from the river. For the purposes of this project, the favorability of lag times was considered in a more general sense and was based on input from DU and other stakeholders. In general, recharge facilities with extremely short and long lag times were thought to be less favorable when considering general recharge needs from augmentation plans along the South Platte and Cache la Poudre Rivers. Recharge facilities that produce significant augmentation supplies accruing to adjacent streams within 1 or 2 years were considered to be the most favorable. Again, the beneficial aspects of lags associated with recharge can be very specific to individual augmentation plans, and users of this tool may want to alter the relative scoring of lags based on their individual needs.

In general, most of the lag time curves generated by AWAS have long drawn out tails that suggest it may take multiple years for the last 5 or 10 percent of the recharged water to accrue to the river. Because of this, it is not necessarily useful or informative to base lag-time favorability on the time it takes for 100 percent of the recharge to reach the adjacent stream. To make the results more meaningful and reduce the influence of boundary condition effects, lag-time favorability was based on the time it takes for 50 percent of the recharge to reach the river. For example, areas defined as most favorable had lag time characteristics suggesting that 50% of the water recharged would emerge as stream flow in 1 to 2 years. The remaining amount of recharge in highly favorable areas would emerge over a longer period of time, perhaps over a 2 to 5 year period.

3.1.2.7 Depth to Groundwater

The depth of the local groundwater table is an important factor for determining the feasibility of constructing recharge wetlands at a particular site. Locations with deeper water tables were considered more favorable than sites with shallow groundwater. During the groundwater modeling phase of the SPDSS project, a raster file representing the elevation of groundwater in the alluvial system of the South Platte River was developed. The data were presented as absolute elevations above mean sea level, so it was necessary to retrieve ground surface elevation data and calculate the difference between the two layers. Ground surface data was acquired from the USGS. The extent of the groundwater elevation raster was limited to the mapped alluvial areas.

Groundwater levels fluctuate in response to wet and dry periods, groundwater pumping, groundwater recharge, etc. The groundwater level map used to develop this layer, however, is a static depiction of groundwater conditions in November 2006. The end user of this tool should consider potential groundwater fluctuations when evaluating favorable or unfavorable locations for recharge wetlands. Additionally, the depth to groundwater layer is representative of an estimate of regional groundwater conditions based on the best available, but limited data and is not intended to represent groundwater depths at specific locations.

3.1.2.8 Availability of Water Supply

Recharge wetlands can be supplied with water historically used for irrigation that has been changed to augmentation and replacement uses. This type of water is most readily available for conveyance to a recharge wetland within the service areas of existing irrigation ditches and laterals. Water supplies can also be obtained via new water rights or by working with entities that have junior recharge rights. New recharge wetlands that could use existing ditches and laterals to convey water to the site were considered to be favorable. In addition, areas adjacent to the South Platte and Cache la Poudre Rivers where water could be conveyed to a site via a pumping station and relatively short pipeline were considered somewhat favorable. Ditch service areas in which existing recharge facilities are located were considered to be most favorable, because they suggest that recharge water rights are present and the ditch company may be amenable to using their facilities to convey water to a new recharge wetland. Areas lying outside of ditch service areas or that are distant from the South Platte or Cache la Poudre Rivers were considered to be unfavorable for recharge wetlands with respect to availability of water supply. Mapping of ditch services areas was developed through the SPDSS project and obtained from DWR.

3.2 Layer Scoring

The layer scoring was typically based on attribute data characteristics, but for some layers, the scoring was based only on the extent of the coverage (e.g., urban area mapping). The layer scoring was independent of the layer weighting, which will be discussed in later sections of this report, and was applied after the individual layers were discretized into a uniform grid. The scores ranged from 0 to 5 for most layers, with 0 corresponding to the least favorable attributes or areas and 5 corresponding to the most favorable attributes. For a few layers, the minimum score was 1, but the maximum score was always 5. Table 3-1 below provides a summary of the layer scoring and the methodology used to assign the scores based on various attributes and layer coverage characteristics.

Table 3-1. Layer Scoring Summary

Layer	Discretization Criteria
Depth To Groundwater	With deeper depth to water values considered more favorable, areas where the water table was greater than 20 feet below ground surface were scored with a 5. When the water table was between 10 and 20 feet below ground surface, a score of 3 was assigned. Areas where the water table was shallower than 10 feet below ground surface and areas outside of the extent of the depth to groundwater layer (generally outside of the mapped alluvium) were given a score of 1.
Ability to Recharge Alluvial Aquifer	The areal extent of the mapped alluvium was used to determine the scoring for this layer. Areas within the mapped alluvium were given a score of 5. Recognizing that regions outside the mapped alluvium can also be hydraulically connected to the aquifer, areas within 1 mile of the mapped alluvium were given a score of 3. All regions outside of the mapped alluvium and the 1-mile buffer were assumed to not be in hydraulic connection with the aquifer and given a score of 0.
Availability of Water Supply	The areas located within the designated ditch service areas that also have existing recharge ponds were given a score of 5. If recharge ponds were not present in a ditch service area, those regions were given a score of 3. Additionally, regions outside of the ditch service areas but within 2 miles of a river were given a score of 3. All other areas were given a score of 1.
Urban Area Mapping	The scoring for the combined urban area layer was based on the extent of the designated urban areas. The portions of the layer within either of the urban areas as designated by the U.S. Census data or the municipal boundary were given a score of 0, and all other areas (non-urban) were given a score of 5.
Existing Wetlands	The categorization of the existing wetlands was used to develop the layer scoring. When 20 or more acres of freshwater emergent wetlands or fresh water ponds were present in a grid cell, those areas received a score of 5. Areas with existing forested or riparian wetlands received a score of 1, while large open water areas such as natural lakes or reservoirs received a score of 0. If no existing wetlands were present or if less than 20 acres of freshwater emergent wetlands or fresh water ponds were present, a score of 2 was given.
Land Ownership	The information relating to existing easements, access agreements, protection status, and funding sources is useful in the overall selection of sites for constructing recharge wetlands, the scoring for this layer was based only on the land ownership data. Land owned or managed by the SLB, DOW or U.S. Bureau of Reclamation (Reclamation) were given a score of 5. Private lands were scored with a 3, federal lands a 2, and non-SLB state lands, county or municipal lands were given a 1.
Existing Recharge Ponds	The grid cells with existing recharge ponds that have less than 10 acres of surface area were given a score of 5. If an area did not have an existing recharge pond, but was immediately adjacent to ponds of 10 acres or less, a score of 3 was given. If the existing recharge ponds in an area covered more than 10 acres or if no existing recharge ponds were present, a score of 0 was given.
Lag Time Characteristics	Areas where 50% of recharge accretions reach the river between 12 and 24 months were given a score of 5. Areas with lag times exceeding 24 months received a score of 3, and areas with lag times less than 12 months received as score of 0. The extent of the return flow timing coverage generally coincided with the extent of the mapped alluvium. The 1-mile buffer area outside of the mapped alluvium often did not have any return flow timing data associated with it; however, it was given a score of 3. All the remaining areas in the model were given a score of 0.

3.3 Layer Weighting

The GIS layers compiled for this project represent important criteria for selecting potential sites for constructing recharge wetlands, however, some layers represent factors that carry more weight and are more important to the decision making process. This concept was represented in the DSS model by assigning relative layer weights to each of the layers. The process for determining the layer weighting followed an approach called Marginal Rate of Attribute Substitution (MARS) that was originally developed to assist in planning and budgeting for wildfire management (Rideout, et al, 2007). The key to the MARS approach is that the importance of individual layers are ranked relative to each other with one layer representing a benchmark. The benchmark layer was assigned a weight of 1, and all other layers were assigned weights between 0.1 and 0.9. The MARS approach calls for layer weighting to be determined through consensus by a panel of 'experts' representing the spectrum of interests associated with project. For this project, participation in the expert's panel was limited to DU and Brown and Caldwell personnel, however prior input from the CWCB and South Platte Basin stakeholders was strongly considered.

Depth to groundwater was chosen as the benchmark layer and assigned a weight of 1.0. The decision to use depth to groundwater as the benchmark is reflective of the fact that if the groundwater table is too shallow, a recharge wetland for recharge purposes may not be feasible regardless of the favorability of other layers. No other individual factor was determined to be as important to the feasibility of a recharge wetland. The weighting of the remaining seven layers were determined relative to the depth to groundwater layer, and each layer was given a unique weight. Table 3-2 shows a summary of layer weights and scoring ranges for the Tier 1 layers.

Table 3-2. Layering Weighting and Scoring Summary

Layers	Layer Weight	Minimum Score	Maximum Score
Depth To Groundwater	1.0	1	5
Ability to Recharge Alluvial Aquifer	0.9	0	5
Availability of Water Supply	0.8	1	5
Urban Area Mapping	0.7	0	5
Existing Wetlands	0.6	0	5
Land Ownership	0.4	1	5
Existing Recharge Ponds	0.2	0	5
Lag Time Characteristics	0.1	0	5

The layer weighting results represent a consideration of physical attributes, (e.g. depth to groundwater) but also a consideration of the overall project goals for DU purposes. For example, the ability to recharge the alluvial aquifer isn't necessarily a physical constraint for building wetlands, however, if the wetlands are intended to serve multiple purposes, such as augmentation or replacement, the importance of the aquifer is amplified. Other end users of this tool may choose to assign different weights to the layers in Table 3-2.

3.4 Grid Development

Many of the GIS layers representing the Tier 1 factors had different coverage extents, scales, and resolutions (for raster files) making them difficult to compare at any given location. To create a standardized layering system for comparing layer attributes and developing a scoring system, each layer was discretized onto a predetermined grid. Rules were established for converting the discrete elements of the individual layers into broader grid cells.

Several grid characteristics were considered when selecting the base grid used for layer discretization and scoring, including grid cell size, alignment, and real-world reference. The smaller the grid cell size, the more specific the tool can be, however, it can increase the complexity of the layer processing and size output files. A grid cell size that is too large can result in the loss of meaningful detail in the underlying data and reduce the effectiveness of the tool. The alignment of the grid plays a role in determining the complexity of the discretization process of the layers. For the purposes of this project, a general north-south oriented grid was appropriate as there was no systematic preference for a different alignment in the underlying data. The ability to identify the locations of the individual grid cells in a meaningful way was important for selection the source of the grid used in the GIS tool. A grid based on quarter section boundaries from the Public Land Survey System (PLSS) was selected after consideration of the options discussed above. Basing the grid on quarter sections allowed for unique and specific identification of individual grid cells, provided a reasonable cell size at approximately ½ mile by ½ mile, and followed the north-south alignment.

A shapefile of state-wide quarter-section level PLSS data was obtained from the BLM geospatial data library. To reduce processing burdens and output file sizes, the grid was reduced to a smaller analysis area concentrating on the South Platte basin. Drainage areas to the east of Beaver Creek were excluded as well as areas to the north of the Cache la Poudre River and South Platte River beyond the mapped alluvium. The delineation of areas to be included or excluded generally followed drainage basin divides and significant topographical changes such as the Front Range foothills. Figure 3-1 shows the extent of the analysis area covered by the quarter-section grid.

3.5 Layer Discretization

The general process for discretizing the individual layers into the uniform grid was similar for each layer. The first step in the process was to combine the individual layer files with the quarter-section grid file. The combined layer and grid files were then simplified so that each grid cell represented a single attribute from the layer file. Figure 3-2 shows an example of the process for discretizing the urban area mapping onto the quarter-section grid. As shown, a number of grid cells were partially intersected by the urban boundaries but only some of those partially intersected cells were defined as urban areas in the final discretized grid layer.

Throughout the discretization process for the other layers, instances of partially intersected grid cells or multiple sections of the original layer present in one grid cell occurred frequently. The final discretized grid could only accommodate one set of attributes per cell, so it was necessary to establish criteria for assigning attributes to the grid cells for each layer. The attribute assignment criteria were standardized across each layer as much as possible, but adapted as necessary depending in the representation of the layer attributes and scoring criteria. Table 3-3 below provides a layer-by-layer summary of the criteria used for attribute assignment within the grid cells.

Table 3-3. Layer Discretization Criteria Summary

Layer	Discretization Criteria
Depth To Groundwater	Source layer was a raster data set with 100 m by 100 m cell spacing. Final grid attribute calculated as the average depth to water value of the raster cells intersecting the quarter-section grid cells.
Ability to Recharge Alluvial Aquifer	Layer based on mapping of the extent of alluvial aquifer. Grid cells overlapped by 50 or more acres of mapped alluvium were defined as alluvium. The same 50-acre threshold was used for defining grid cells within the 1-mile buffer area surrounding the mapped alluvium.
Availability of Water Supply	Base layer represented the service areas of ditches along the South Platte River. Grid cells with 50 or more overlapping acres of ditch service area were defined to be within the service area. When grid cells contained portions of multiple service areas, the attributes were assigned based on the service area with the most overlapping acres within the grid cell.
Urban Area Mapping	Final grid cells were defined as urban if 50 or more acres of the mapped urban areas overlapped the cell. All other areas were assigned non-urban status.
Existing Wetlands	All grid cells overlapped by existing wetlands were assigned the attributes corresponding to the wetland type category representing the greatest area of coverage within the grid cell. No minimum area threshold was established for defining grid cells containing existing wetlands.
Land Ownership	The land ownership source layer provided nearly continuous coverage of the analysis area. Grid cells were assigned ownership attributes corresponding to parcels with the greatest area of coverage within the cells. All grid cells were assigned land ownership attributes.
Existing Recharge Ponds	Any grid cell that overlapped all or part of an existing recharge pond was defined as containing recharge. The total areas of the ponds within the cells were tracked for scoring purposes.
Lag Time Characteristics	The lag timing source layer was a raster data set with cell spacing of 500 m by 500 m. Timing characteristics were assigned to the grid cells based on the average of the lag timing cells located within the grid cells.

The layer discretization criteria presented in Table 3-3 were developed such that the execution of the process could be automated using built-in functionality of ArcGIS and could be easily repeated by other users.

3.6 Summation Grid

The final piece of the GIS tool was the development of a summation grid layer which incorporates the weighted scores from each grid layer into a final weighted score and maintains key attributes from the individual layers to provide context for the final score. The final weighted score values were calculated using the following equation.

$$Final\ Weighted\ Score = \sum (Layer\ Score_i * Layer\ Weight_i)$$

Restated, the final weighted score for each cell in the summation grid is equal to the sum of each individual layer's corresponding cell score multiplied by the layer weights.

The summation grid layer was created by combining the individual grid layers based on the legal description using successive join operations. The weight, score and weighted score values from each layer were organized in the summation grid layer attribute table along with the relevant attributes. A field for the final weighted score was added and was calculated by summing the weighted scores previously calculated for each individual layer. Figure 3-3 shows a schematic of the process through which the summation grid layer is developed.

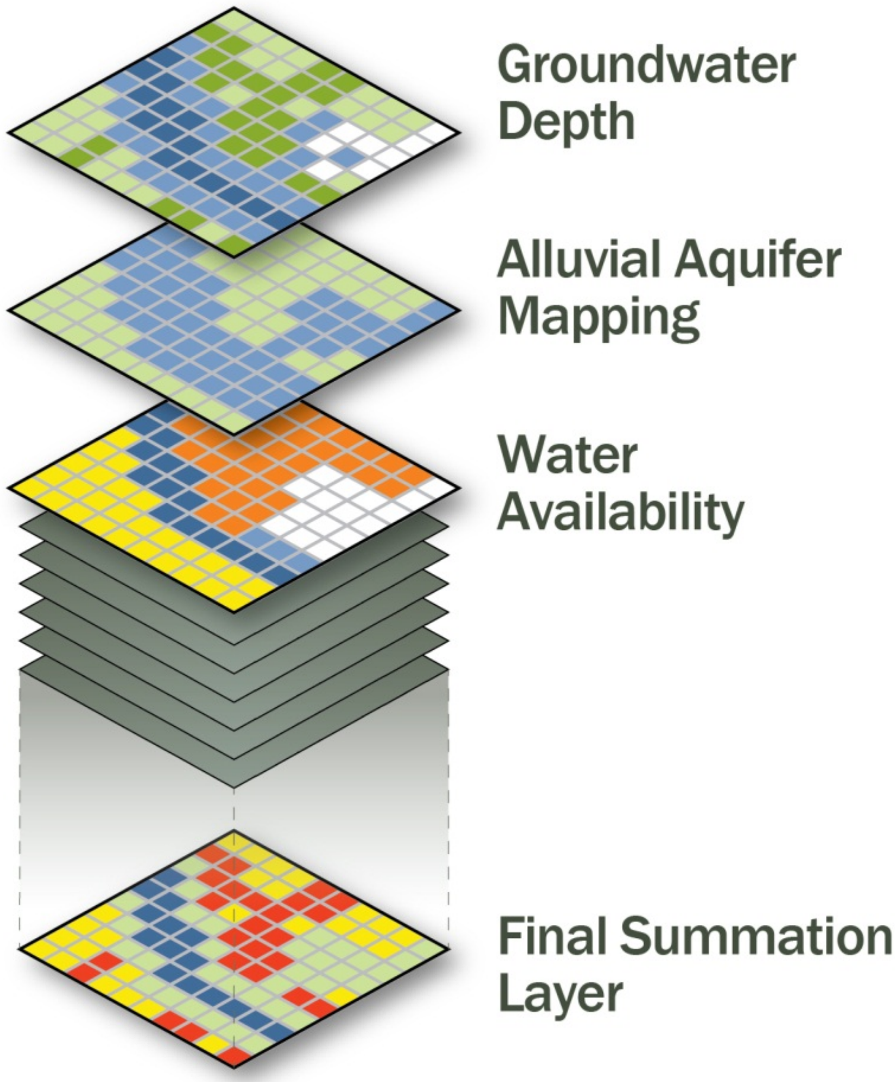

Figure 3-3. Summation Grid Formation Schematic

Section 4

GIS Tool Results

Once the summation grid layer was created using the process described in Section 3, the final weighted scores were mapped, categorized, and checked for reasonableness. To provide a meaningful presentation and summary of results, a method of categorizing and scaling the final weighted scores for each cell in the summation grid was developed. A standardized approach was used to display and categorize results so that future changes in layer weighting or scores could be easily comparable to previous results. In addition to processing the numerical scores from the summation grid, an analysis of the attributes of the high scoring locations was conducted to evaluate the influence and sensitivity of individual criteria to the final results.

4.1 Summation Grid Score Categorization

Given the layer weights and range of scores shown in Table 3-1 above, the final weighted score for any given grid cell in the summation grid layer could range from 2.2 to 23.5. The minimum and maximum weighted scores possible for each layer are shown in Table 4-1 below.

Table 4-1. Summary of Weighted Scores

Layers	Layer Weight	Minimum Layer Score	Maximum Layer Score	Minimum Weighted Score	Maximum Weighted Score
Depth To Groundwater	1.0	1	5	1	5
Ability to Recharge Alluvial Aquifer	0.9	0	5	0	4.5
Availability of Water Supply	0.8	1	5	0.8	4
Urban Area Mapping	0.7	0	5	0	3.5
Existing Wetlands	0.6	0	5	0	3
Land Ownership	0.4	1	5	00.4	2
Existing Recharge Ponds	0.2	0	5	0	1
Lag Time Characteristics	0.1	0	5	0	0.5
TOTAL				*2.2*	*23.5*

Weighted scores are calculated by multiplying layer weight by the layer scores in a particular cell. It was unlikely that any one grid cell would have the proper attributes and location to achieve the maximum score shown in Table 4-1, and results from the summation grid layer show that to be true. The maximum weighted score observed for individual cells in the summation grid layer was 22.5. The minimum observed weighted score did however match the minimum possible score of 2.2. Given the range of possible and observed scores, scores were summarized or bracketed to categorize and analyze scores on a spatial basis.

The selection of the bracketing criteria for identifying high scoring grid cells took into consideration the range of observed and possible score values, the exclusivity of the top category, and flexibility of the approach to easily adapt to future revisions in weighting and scoring of individual layers. Based on these considerations, the top bracket was set as the top 10 percent of scores. The next three brackets represented the scores between the top 40 percent and top 10 percent in increments of 10 percent. The next three brackets represented the bottom 60 percent of scores in 20 percent increments. Table 4-2 shows the score bracketing and percentile ranks.

Table 4-2. Final Weighted Score Bracketing

Score Range	Percentile Range
0 – 4.50 [1)]	0-20%
4.50 – 9.00	20-40%
9.00 – 13.50	40-60%
13.5 - 15.75	60-70%
15.75 – 18.00	70–80%
18.00 – 20.25	80-90%
20.25 – 22.50	90-100%

Notes: 1) Minimum observed score was 2.2

The bracketing distribution in Table 4-2 was applied to the summation grid to evaluate its ability to highlight the most favorable locations for recharge wetlands in a meaningful way. For example, if too few cells were included in the highest scoring brackets, very few favorable sites for new recharge wetlands would be identified. Conversely, if too many cells were included in the highest scoring brackets, the tool would not provide much assistance in identifying the best locations for constructing new recharge wetlands.

The weighted score bracketing shown in Table 4-2 provides a reasonable distribution of grid cells within each bracket, and the number of grid cells within top 10 percent bracket appears to be reasonable and shows high scoring cells across the extent of the South Platte Basin without over-saturating the grid. A full representation of the summation grid with color-coding based on the scoring brackets from Table 4-2 is shown in Figure 4-1.

4.2 Grid Attribute Analysis

Many of the grid cells representing the top 10 percent of final weighted scores shared similar attributes. Locations or cells receiving the 10 percent of scores were universally located within the alluvial aquifer and outside of urban zones; nearly all were located in ditch service areas with existing recharge; and all but a few cells had depth to groundwater values more than 20 feet below ground surface. This is not a surprising result in that those four layers received the highest weights. Most of the grid cells with scores in the top 10 percent were located on private land even though that was not the most favorable category of land ownership. The vast majority of area covered by the summation grid is under private ownership and the land ownership layer was given low importance, thus the contribution of land ownership to a cell's individual score is smaller and plays a less significant role in determining whether the final score of a cell is in the top 10 percent. The other layers such as existing wetlands, existing recharge ponds, and the lag time characteristics had a relatively small influence on the scores for the grid cells in the top 10 percent. Most likely, the low weight the layers received and the limited extent of the layers contributed to the small influence.

Even though the presence of existing wetlands did not account for a significant portion of the final score, the cells with the highest scores in the top 10 percent were located in areas of freshwater emergent wetlands or freshwater emergent ponds. Also, none of the grid cells in the top 10 percent were located in forested and riparian wetland zones or in large bodies of water. In a similar fashion, grid cells areas with unfavorable land ownership characteristics were also excluded from the top 10 percent bracket. This is further confirmation that brackets established for the scoring are appropriate.

The grid cells with weighted scores outside of the top 10 percent, but in the next two brackets, generally appear in consistent groupings covering large areas. These areas, represented in yellow and green on Figure 4-1, are almost always located within the mapped alluvium and are outside of urban zones. The grid cells with scores in the 80 to 90 percentile grouping (yellow) are predominantly associated with ditch service areas, especially those with recharge. The grid cells scores in the 70 to 80 percentile range generally occupy the non-urban areas within the alluvial aquifer that are not in the higher scoring brackets. Very few cells within the alluvial aquifer have scores lower than the 70th percentile. Those areas within the alluvial aquifer that have scores below the 70th percentile are typically in regions with an unfavorably high groundwater table and riparian wetland zone, and are concentrated in a narrow band along the rivers.

4.3 Grid Sensitivity

Typical sensitivity analyses for predictive models are conducted by changing individual input parameters and documenting the range of outcomes produced as a result of those changes. If a model is highly sensitive to a certain parameter, small changes in the values of that parameter can lead to large changes in the model outcome. The GIS Tool and the DSS model as a whole are not designed in a way that lends itself to typical sensitivity analysis. Each layer and the scoring in each layer are independent of the other layers. Changes to the layer scoring in one layer can only change the range of final scores by the difference in scores observed in the layer where the changes were made. Changes to the layer weighting will have a larger effect in general, but unless the entire weighting scheme is reconfigured, the overall outcomes will not be significantly different.

Given the above considerations, the sensitivity of the tool was evaluated in a general and qualitative manner. The evaluation revealed some patterns that can shape the results of the final weighted scores. The patterns were related to the extent of consistent values within a layer or group of layers when compared with local variability of the other layers. The layers representing the urban/non-urban areas, the alluvial aquifer extent, and ditch service areas tend to have lower “resolution” or spatial differences than other layers. For example, the alluvial extent covers a wide geographic area and cells within this wide area will have consistent scores relative to the ability to recharge the alluvial aquifer. The consistency of score values in wide areas tends to result in a baseline score for the region that has little to no changes from cell to cell. When layers that are locally variable such as existing recharge ponds and existing wetlands (i.e. layers with higher “resolution” characteristics or spatial differences) overlap with the regionally consistent layers, the higher scoring cells emerge in a pattern that resembles locally variable layer attributes. This can make the GIS tool appear to be more sensitive to those layers. These affects can be limited by the layer weighting process. Having high scoring summation grid cells appear to match a pattern of favorable attributes in a single layer is not necessarily an indication of an error in the model; however, if the effect is systematic, the layer may not be weighted appropriately. In other words, the end user of the tool may not want a single factor with a high level of local variability to have an undue influence on the results of the tool.

Reducing the influence of locally variable layers with lower weights was taken into consideration when developing the individual layer weights for the layers included in the GIS tool and was a primary reason to implement the MARS approach. Prior to implementing a MARS-like relative layer weighting scheme, clusters of high-scoring cells in the summation grid were appearing in patterns that resembled the patterns of layers with low weights. For example, one draft of the final summation grid showed a cluster of top 10 percent cells that closely followed the pattern of the return flow timing layer, the lowest weighted layer. By implementing the MARS weighting approach, the weight of the return flow timing layer was reduced such that it was 10 percent as important as the depth groundwater layer, which was the most important. Previously, the layer weights ranged from 1 to 3, providing less differentiation between the layers.

The MARS approach was not implemented to remove the influence of less important layers on the final summation grid results, but instead the purpose was to assign weights to layers that represented the priorities of DU and the stakeholders in the context of the other layers included in the GIS tool. Overall, the MARS approach was effective at removing the undue influence of less important layers and reducing the sensitivity of the tool to changes in those layers.

Section 5

Economic Analysis

Whereas the Brown and Caldwell process for identifying and prioritizing recharge sites focuses on hydrological, topographical and spatial attributes, Harvey Economics (HE) was retained to explore the economic aspects of recharge sites in order to assist in DU's recharge site selection. Specifically, HE was retained to identify and quantify, to the extent possible, the economic benefits that would accrue to various types of partners in a prospective recharge project. That is, as DU assembles or joins a consortium to develop and operate a recharge site, DU would like to better understand the economic benefits that the other parties might experience from this recharge project venture. With this information, DU will be in a better position to determine how the consortium of partners can be structured and the magnitude or proportion of contribution that respective partners might be able to bring to such a project. HE was not charged with estimating actual dollar figures that prospective partners could contribute, but rather economic guidance related to particular types of recharge project partners and any ranges of benefits that might be apparent.

At the outset of the HE research, DU indicated that the economic study would be most helpful if it were segregated into three geographic regions within the South Platte study area. The Lower South Platte region for this study is defined by the Sterling area, near the Colorado-Nebraska state line, moving upstream on the South Platte River to the area before Brush. The City of Brush, upstream to eastern Weld County in the Kersey area, would comprise the middle region of the South Platte River. The upper region of the South Platte is defined for this study as the area from Kersey upstream to Fort Lupton and Hudson, in Weld County. It became apparent that recharge projects in these three regions along the South Platte River would attract different types of partners with different economic circumstances; the research conducted by Harvey Economics verified the relevance of viewing partnerships and consortiums in these three regions as distinct.

5.1 Overview of Recharge Consortium Structure

A recharge pond within the defined study area of the South Platte River must have certain characteristics to be beneficial to DU. First, the ponds must be about two feet deep to create duck forage. Second, there must be water in the ponds during the migratory periods, in late fall and early spring, each year. To be financially viable, the ponds should be at least 30 acres, although much larger ponds are possible. Besides these parameters, DU can be very flexible about other recharge pond characteristics to fit the other partners.

For a recharge pond of this size, typically about 1,200 acre-feet will be diverted off the main stem of the South Platte River or one of its tributaries. That water will percolate into the groundwater and migrate back to the stream course over time, relatively quickly or up to five years, depending on the distance from the river, geologic conditions, and other considerations. Roughly 10 to 15 percent will be lost to evaporation or otherwise not returned to the River (Kernohan, 2013).

The typical recharge project begins with a farmer or other landowner willing to provide property for the project. Many farmers along the South Platte look to these recharge projects to augment their groundwater pumping. Municipalities likewise have an interest in these recharge projects for augmentation purposes, but also for exchange and retiming of their own supplies. The oil and gas industry also has an interest in the exchange, storage, and retiming aspects of recharge projects to more effectively use more water supplies, similar to municipalities. An increasingly important water user, the petroleum industry, is very interested in recharge projects for the opportunity to obtain water supplies in locations convenient to their point of use in the lower region of the South Platte River. A special use is the South Platte Water-Related Activities Program, which is interested in recharge projects for the purpose of storing and retiming water releases to the State of Nebraska, in compliance with the Platte River Recovery Implementation Program. The Colorado Division of Wildlife is frequently a participant in these recharge projects as well.

Each of these parties can bring assets to a recharge project consortium, either in the form of land, water, money, or services in-kind. The structure of the consortium, the relative contributions of the parties, and the value of the respective participation of the individual participants, in a recharge project along the South Platte River, is highly location and site specific. For this reason, HE determined that the most productive research approach for this inquiry would be a series of interviews with different prospective participants within the three regions of interest along the South Platte River.

5.2 Survey Approach

The survey HE conducted for this task entailed a development of a list of discussion topics, the creation of a list of potential interviewees, and the completion of the interviews themselves. The interviews were conducted in June, 2013.

5.2.1 Interview Topics

HE developed a series of open-ended topics for discussion with each of the prospective interviewees. The questions or discussion topics included a description of each organization and how that organization could benefit from a prospective recharge project. HE discussed the attributes of recharge projects that could be beneficial and how those benefits would help achieve the goals of the organization or company. HE also discussed means of valuing those benefits and alternatives to the recharge project. Further, the interview explored specific attributes of a recharge project which would work best for that participant, as well as how the recharge project could be tailored to the participant.

5.2.2 List of Interviewees

The list of interviewees was initially provided by Greg Kernohan for each of the three regions of the South Platte River in this study. In addition, HE identified oil and gas companies active in the area, and the interviewees themselves suggested additional people to contact. In all, HE drew from a list of 18 individuals representing farmers and irrigation interests, municipalities, other water providers and the oil and gas industry. HE completed interviews with the following individuals:

Table 5-1. Survey Interviewees

Individual	Organization
Brad Stromberger	Lower Logan Well Users Association
Brent Nation	City of Fort Morgan
Don Chapman	Riverside Irrigation District
Joe Kiolbasa	City of Sterling
Kerry McCowen	Bonanza Energy
Larry Frame	Julesburg Irrigation District
Mark Kokes	Morgan County Quality Water District
Allan Berryman	Northern Water Conservancy District
Harvey Greenwood	Select Energy Services
Nancy Koch	City of Greeley
Joe Frank	Lower South Platte Water Conservancy District

The bulk of these interviews were conducted in person and they were completed during the month of June, 2013.

Since the survey discussion was open-ended, no tabulation of results is available. Interviewees were encouraged to speak frankly and therefore the results of these interviews were synthesized by region and type of user. The results of the interviews were combined with HE's background and knowledge of water markets and transactions in this region to develop research findings.

5.3 Key Findings

Based upon the interviews conducted, the key findings of this task are expressed in two ways: determinants of overall economic value and contribution, and regional differences among the three regions.

5.3.1 Overall Determinants of Economic Value and Contribution

As described earlier, the type of participant in each recharge project will vary according to region, and the economic value or contribution of that participant is location-specific and participant-specific. For example, agricultural participants' ability to contribute monies to a recharge project is limited by the net financial returns they will receive from growing various crops on land which they control. However, farmers can and will contribute water to a recharge project when that water is excess to their needs and they can benefit from the retiming of that water, perhaps sharing the cost with other consortium participants to achieve economies of scale. These straightforward value guidelines for farmers vary, of course, by region along the South Platte due to crop pattern differences and water availability.

Agricultural entities in the three regions along the South Platte have dealt with augmentation plans for a long time. Their cost limits generally suggest that they can contribute land or water to a recharge project, but not substantial monies in most instances. In fact, irrigation and ditch companies have created many recharge projects themselves, without the participation of DU, and may even see themselves in competition with DU or find their participation in the project unnecessary.

The economic interest of municipalities in a prospective recharge project is obviously more complicated than that of farmers. A municipality will gauge the maximum contribution that it can make to a recharge project by the alternatives that it may already be pursuing, such as a storage project or purchase of ditch company shares. These alternatives to recharge for each municipality will vary from place to place and over time. For instance, as of mid-2013, drought and other market influences have driven prices for water rights and ditch company shares higher than has existed in the historic recent past. Given the many difficulties in developing water supplies, including permitting to municipalities, most find recharge projects to be desirable, especially ones led by an environmental entity such as DU. Recharge projects will represent a special attraction to many municipalities, so that the financial contribution to a project need only equal, not beat, the alternatives available to municipalities. Tap fees and water rates of end-use customers among municipalities are likely not a consideration, since costs will be passed along, and if the water needs are there, they must be met. Further, municipalities represent a favorable partner for DU, since the timing of their needs is complementary to those of DU. Other important considerations relate to size of the recharge facility; the recharge project must be sufficiently large to achieve an economy of scale and a magnitude that will make the project worthwhile to a municipality.

Industrial water users will also value their participation in a recharge project in direct comparison to other alternatives available to them in that particular location. Industrial interests will not be price-averse to the same extent as municipalities, suggesting that they will evaluate alternative resources by different attributes, such as dependability, water quality, ease of transfer, etc. The value of an industrial entities' contribution to a recharge project may thus be less than other alternatives, simply because the other alternatives carry greater certainty and are easy to accomplish. Under these circumstances, aggressive leadership on a recharge project and confidence of yield delivery under all circumstances might be paramount. A greater level of engineering and planning may be worthwhile when industrial participants indicate interest. In some instances, the collaboration with an environmentally respected entity such as DU will carry additional value.

The petroleum industry is a special case along the South Platte River. A relatively recent entrant to this water market, the petroleum sector requires water for hydrologic fracturing (fracking) for exploration wells drilled in this area. Drilling is focused primarily in the upper region and to some extent the middle region, as previously identified. These petroleum exploration companies do not require large amounts of water in a given location, but do require water to be delivered or be available in some manner over a broad geographic area. The highest priority of the petroleum industry is obtaining the needed volume of water at a particular location, exactly when it is needed, with complete certainty. Based upon interviews, petroleum companies would be quite interested in participating in recharge projects with DU if the timing and location of the water can be assured. The value to the petroleum companies of such participation will be strictly determined based upon the cost of alternatives, such as trucking water in or creating a pipeline and pumping the water to particular locations. Since both of these alternatives are typically costly, the financial contribution to a project from the petroleum sector could be quite substantial. Interestingly, since the active petroleum companies in the region are not particularly large compared to other companies in the petroleum sector, their interest in the environmental cachet of DU might be only modest. The dollar cost and the assurance that the water will be available at the location when needed are vital to this type of prospective participant.

Throughout the three regions, the value of the recharge project to almost all types of participants is enhanced by a slower, rather than faster, return flow to the stream course. Most participants find a three to five-year return flow, or at least a "laddering" of return flows through a series of ponds to be more preferable than the immediate return of the water to the stream. Larger rather than smaller ponds are preferred and deeper ponds, or at least terraced bottoms, would be desirable.

Besides these general categories of participants, there will be unique types of prospective participants who deserve special attention in valuing interest. The Colorado Division of Wildlife and other environmental or recreational groups might also be willing to financially contribute to a DU recharge project. Their ability to contribute will be strictly limited to funding availability, and their interest in the viability of the project itself. Other specialized participants might be land or water investors in the upper region and participants in the

Platte River Recovery Program in the lower region. Value to these groups participating in DU recharge projects will be highly variable, as discussed in the regional differences section, which follows.

5.3.2 Upper Region

The upper region, as defined previously, includes larger municipalities, such as Greeley and Fort Lupton, as well as oil and gas interests and some agricultural interests as well. Water availability and attractive sites in this region might be in short supply, but this region holds far more attractive economic valuation prospects compared to the middle or lower regions. First, water values are higher in this region given the myriad of demands from municipal and industrial sources. Municipal entities will perceive narrow but valuable benefits, such as helping to meet return flow obligations or firming up other supplies and yields from existing water rights, where current costs are upwards of $15,000 per acre-foot in this area. Of particular importance is the marginal demand and effect on the market from the petroleum area. Whereas, some transactions have been more modest, in the neighborhood of $1,000 per acre-foot per year, it is believed that a recharge project in the right location could bring as much as $6,000 per acre-foot per year. Given this level of financial contribution, recharge projects in this area need not be optimal. In evaluating the relative prospects in the three regions, HE believes that, from an economic standpoint, this region would represent the priority for future DU recharge project development.

5.3.3 Middle Region

The middle region offers many attractive considerations from an economic standpoint. There is considerable need for additional water yield and development in this area and there are not many alternatives to recharge projects. For augmentation plans, agriculture needs recharge projects throughout this region. Farmers and ditch companies have and will continue to pursue those recharge project opportunities on their own or with DU. Agriculture will view the limit to value as the cost of pursuing recharge projects on its own, without DU. Municipal water providers in this area are very interested in recharge projects and pursuing those projects with DU. They will look at the cost of acquiring agricultural water or Colorado-Big Thompson shares as alternatives. Financial contributions to recharge projects in this area might range as high as $4,000 to $6,000 per acre-foot, under favorable project circumstances. DU will face some competition from the agricultural sector in developing these recharge projects and securing the most favorable sites. Industry participants are possible in this area, but the likelihood of participation is more episodic than promising.

5.3.4 Lower Region

The lower region includes the City of Sterling, smaller municipal entities and irrigation districts, along with the South Platte Water-Related Activities Program. Like the other regions, there is interest in recharge, ponds, and DU's participation. However, the level of interest is less in this region than in the middle region, with fewer prospective project participants. Far from the Front Range and the influence of petroleum industry, the market from an economic value standpoint is considerably less, as low as $40 per acre-foot, from the standpoint of agriculture. The focus in this area is on cost and efficiency, and the existing entities are pursuing recharge projects themselves. There is an opportunity for DU participation, but, except for those entities interested in the Platte River Recovery Program or the Division of Wildlife, financial contributions are likely to be modest and less favorable than the other two regions. The South Platte Water Related Activities Program appreciates effective management and expertise, such as DU can provide. The price sensitivity will be less than agriculture, certainly, and funding for well-conceived projects is possible. However, the need from this group is finite and will certainly drive any interest in future projects.

Section 6

Implementation Plan

Over the past several years, DU has organized diverse partnerships to develop alluvial aquifer recharge facilities through wetlands. Wetlands are dynamic ecological systems that can provide multiple benefits for wildlife, the environment, and people. Wetlands naturally recharge aquifers when present in the environment and can be designed specifically to provide aquifer recharge for improved water management. DU programs have leveraged millions of dollars to restore and create wetlands capable of meeting the needs of water demands in the 21st century in cooperation with many partners including the Lower South Platte Water Conservancy District, Northern Water Conservancy District, Sedgwick County Well Users, and South Platte Water Related Activities Program (SPWRAP), Lower Logan Well Users, and the City of Brush.

However, most projects have been discovered and developed opportunistically. The same statement can be applied to water transfers from the landscape as well. Statewide Water Supply Initiative projections provided by the CWCB indicate negative landscape impacts will be realized throughout the lower river as at least 180,000 acres of irrigated agriculture is lost to transfers for municipal and industrial needs through 2050. Strategies to mitigate potential impacts from transferring water have not been developed. Water transfers will continue to be haphazard; resulting in landscapes that are dry and have severe long-term economic impacts for rural municipalities.

Loss of consumptive use water on the landscape will impact non-consumptive benefits for the environment and recreation. Irrigated agricultural landscapes support waterfowl habitat in Colorado by providing forage for wildlife from residual crops and runoff and return flows that supply water for wetlands and river channel. Several thousand hunters and anglers travel to the area to pursue fish and game and several of the public sites are birding destinations. Loss of agricultural water could have exponential impacts on non-consumptive demands. Although an acre of irrigated ground is lost, return water infiltrates into the alluvial aquifer and spreads out to support a much larger area.

6.1 Areas of Focus

DU will use the DSS model to identify hotspots where ecosystem services from recharge wetlands can be implemented to maximize water resources for wildlife, agriculture, and municipal and industrial needs. The summation grid, or “thunderstorm” map, developed as part of this project clearly identified at least three focus areas where the top 10% of the highest ranked sites were clustered; Gilcrest/Platteville, Wiggins/Fort Morgan (Golden Triangle), and Julesburg. There are several other smaller sites or locations including the area around Hudson and Keenesburg that identified a large area that is mostly in the top 20% of sites. At this time, we will not focus on Hudson/Keenesburg unless it becomes a higher priority for our partners.

In an effort to conserve the agricultural and wildlife, DU will focus resources on these areas and employ strategies that deliver conservation programs throughout the Lower South Platte River. Varying degrees of success have been experienced with developing wetlands as part of water augmentation plans throughout the regions. DU will combine traditional program structure that shares and leverages resources with new alternative to agricultural transfer methods and asset investments to greatly influence water development in the focus areas. Engaging new partners will be part of the process starting with Great Outdoors Colorado (GOCO) and the State Land Board (SLB).

6.1.1 Golden Triangle & Fort Morgan

The Golden Triangle and Fort Morgan (GTFM) area has been a high priority conservation focus for DU since our program was established in 1987. Brush Prairie Ponds State Wildlife Area was our first project in Colorado and just happens to be a recharge facility for the City of Brush to augment their municipal wells. Several recharge wetland projects have been developed on private lands in the area including DT Ranch, Bridge Farm, and Drake Land Farms. The recharge location layer provided by the DWR indicates several concentrations of recharge facilities have already been developed in this area. Some projects include wetlands developed by Central Colorado Water Conservancy District, Riverside Irrigation District, Morgan County Quality Water District, and Bijou Irrigation District. Although this area experienced severe curtailment of irrigation in 2004 due to state orders that shut down wells without augmentation plans, a vibrant agricultural community and rural economy persists.

The DSS model shows the most significant grouping of top 10% sites in this area for the entire river indicating that many of the fundamentals for developing recharge are highly likely. DU has discussed the results and potential for additional development with several local partners mentioned above and is actively developing at least a single project with Morgan County Quality Water District at this time. Several other partners have indicated that the area is a high priority for developing more recharge. Additionally, both Central Colorado Water Conservancy District and United Water and Sanitation District confirmed that the area is a high priority for capturing and retiming river augmentation credits before they leave the district. Other Front Range municipalities have confirmed that land and water purchases in this focus area would be highly attractive as they look for senior water rights beyond 2035.

DU will focus our ecosystem services program on this priority area. According to the economic analysis, the value of water in the reach is considerably more valuable than the lower river, but still highly reasonable for both agriculture and environmental interests to afford with the potential for value growth as Front Range water interests consider investing in water assets further downstream. The area is positioned perfectly between rural water districts interested in both agriculture's continued vitality and rural municipal and industrial water needs and encroaching Front Range water interests creating opportunity for several diverse partnerships with the water community. Persistent desire to sustain an agricultural economy in the area presents opportunities to protect land and water rights for the perpetual use in agriculture assuring water is present to provide forage for wildlife and maintain return flows in a desirable manner that supports the landscape. Establishment of innovative alternative transfer methods (ATMs) such as the FLEX Water Market, water cooperatives, and interruptible supply plans will provide some water from existing water rights to lease, trade, or sell to Front Range municipalities.

DU has already used the DSS to develop a concept paper for GOCO's recent request for innovative water project proposals (Appendix C). The proposal more fully outlines the potential program development opportunities for the GTFM area. GOCO is seeking input from stakeholders for protecting water resources as part of developing their next strategic plan. Over the next two years, GOCO will develop programs that better address water needs using the concept papers as an opportunity to establish ideas worth pursuing.

6.1.2 Upper River (Brighton and Hudson to Greeley Area)

The area is host to several thousand ducks and geese associated with the river and tributaries. Geese utilize the area to loaf and stage for migration; using local parks and residential areas to forage on grass as well as residual crops. Waterfowl frequent locations associated with the river and agricultural lands throughout the area.

As identified in the economic analysis, potentially significant financial upside exists due to the myriad competing interests in water within the geographic area. As described in Section 5, recharge sites in this area do not have to be optimal. Discussions with Denver area municipalities and water districts have revealed that a significant amount of irrigation water has already been purchased for eventual municipal or industrial transfer. Agriculture still persists in the area, but it is unknown how much of the water rights are owned by municipalities and industries that are leasing water back to agricultural producers, a common practice. The amount could be significant.

However, DU projects and other wildlife conservation efforts have been highly limited in the area, mostly due to cost of land and water and the uncertainty that water could be available for long-term (30 years) conservation projects.

DU will use the DSS model to identify properties that match with Front Range municipal and industrial partner's water rights to optimize the location of new wetland recharge facilities. Program goals for this area will likely focus on providing state goals to fulfill the gap by assisting municipal and industrial water providers to change, retime, and exchange water rights to meet their needs through wetlands.

6.1.3 Lower River (Brush to the Nebraska Stateline)

The lower river has provided the most cooperative partnerships, most likely due to the lack of municipal and industrial pressure from the Front Range, a strong desire to develop strategies that firm agricultural water rights, and establishment of the Platte River Recovery Implementation Program (PRRIP). The area is a very important waterfowl habitat and waterfowl-hunting destination as bird numbers increase further east, closer to the central flyway "neck of the hourglass" in Nebraska. The area continues to support vibrant agriculture and thanks to substantial recharge facilities, storage, and reduced well pumping, water in some areas is prevalent enough in some plans to potentially increase agricultural production or facilitate water exchanges upstream.

However, some augmentation plans, including rural municipalities continue to suffer shortages during drought years and late summer irrigation. Additionally, SPWRAP must continue to build capacity toward meeting Colorado's water contribution to the PRRIP. Water for the PRRIP must be delivered during specific months, which are mostly outside irrigation seasons. Their burden is to prove that Colorado has the capacity to deliver 10,000 acre-feet annually to the central Platte River region.

Additional projects to retime free river water and river augmentation credits are required to better meet the various demands in the lower river. DU will work with our many partners in the lower river to further investigate the best sites identified by the DSS model and determine opportunities to further develop wetland recharge projects.

6.2 Project Partners

6.2.1 State Land Board

DU has used the DSS to identify SLB properties throughout the lower South Platte River located within the geographic boundary (Appendix D). The SLB owns more than 18,000 acres along the lower South Platte River within the study boundary and over 3 million acres throughout the state. Engaging the SLB in river augmentation through recharge wetlands will provide new revenue for the state, potentially improve capital asset value, and better steward lands. We hope the partnership will improve development opportunities on SLB properties throughout the state.

DU will use the weighted ranks to identify the top 10 scoring properties and perform field investigations to identify the top 3 properties that could be developed for wetland recharge. An attached scope of work outlines the details of this project (Appendix D).

6.2.2 Natural Resource Conservation Service

Part of the specified tasks was to meet with the Natural Resource Conservation Service (NRCS) to determine potential programs conducive to assisting landowners with implementing recharge projects. We met with Collin Lee, a private lands biologist with the NRCS and discussed the program and potential partnerships with NRCS. Collin expressed interest in collaborating and we hope to find some opportunities to leverage EQIP funds or develop other programs within NRCS to better involve them. Additionally, the Farm Bill that provides much of the funding for the NRCS has been struggling to be reauthorized by Congress. Continuing resolutions carried the Bill through this past year, but neither an extension nor a new bill has been approved.

6.2.3 Colorado Water Conservation Board

One of the stated objectives for developing the tool was to provide strategic foundation from which the CWCB can easily recognize the importance and suitability of a project. In the coming months, DU will work with CWCB staff to fully develop focus areas from the weighted rankings that could become “approved” priority projects for funding by the CWCB. Doing so, the CWCB will enjoy greater confidence that projects are contributing to the gap identified in the Statewide Water Supply Initiative in a strategic manner that encompasses the multiple demands for water. DU and our partners will realize some assurance that the CWCB will be a reliable funding partner throughout the life of approved focus area development.

Section 7

Discussion and Conclusions

The GIS tool portion of the DSS model was designed to streamline the initial screening process for selecting sites to construct recharge wetlands by highlighting areas where a combination of factors indicate favorable conditions. The tool is comprised of layers representing important factors relating to land use and water criteria that need to be considered when determining the feasibility of wetland projects. The output from the tool is a summation grid layer with a final weighted score representing the sum of the weighted scores from the individual layers corresponding to the important factors. As the results showed, the tool identified potential locations with highly favorable conditions for constructing recharge wetlands in areas throughout the South Platte River basin. Many highly favorable locations were located in areas that are already being used for wetlands projects or that were previously being considered for wetlands projects, which tends to validate the results of the tool.

7.1 Purpose and Limitations

The primary purpose of the GIS tool is to highlight potential sites for wetlands projects through an initial screening process. The tool is not intended to provide definitive site selection results. Using this tool, DU can identify several areas important for agriculture, municipal and industrial water users, and wildlife habitat to focus resources for the future. The results from the tool are intended to be used in conjunction with economic and administrative factors (Tier 2). On-site field investigations should be conducted prior to final site selection. Additionally, the various risks relating to construction of recharge wetlands in certain areas should be understood and properly considered during initial investigations, and decisions based on the risk assessments should be made independent of the results from the tool even if areas are potentially highly favorable.

Some general limitations of the tool include grid cell sizing, accuracy and completeness of source data, and the static nature of the source data. The grid cells are approximately ½ mile long on each side and cover about 160 acres. This is an appropriate grid size for a regional scale analysis, but may be inadequate for local applications. Major variations in conditions within the grid cells are possible; however, the tool is unable to fully account for those types of conditions. By relying on existing data, there is a risk of incorporating inaccuracies into the tool. Reasonable efforts were made to select accurate data that underwent a QA/QC process, but errors may still be present. Additionally, some data would benefit from being more dynamic, such as depth to water values and land ownership. All of these factors should be considered when using the GIS tool in a wetland site selection process.

7.2 Economic Evaluation Summary

There is considerable interest in recharge projects in each of the three regions along the South Platte River. The needs of the participants in each region vary widely, and the values of each participant are highly variable. Given this variability, specific valuation figures would be misleading.

The economic value of the recharge projects are driven by the economic returns in the instance of agriculture or costs or other attributes of alternative water resource supplies in the case of municipalities and industrial or petroleum interests. Municipalities are particularly attracted to recharge projects, given the alternatives, but the project characteristics must fit their particular needs. The petroleum sector also would experience considerable value from a recharge project, especially if it is located close to the need.

The development prospects and the economic values to be gained from a recharge project are likely to be the highest in the upper region of the South Platte River as compared with the other two, with the middle region offering more opportunities, but less value. In the lower region, there is also an interest in additional recharge sites, but economic prospects are not as bright, and DU will face more competition for its service in this region.

7.3 Implementation Plan Conclusions

The South Platte Recharge Location DSS model has provided one of the most productive tools to guide strategic development of alluvial recharge in Colorado since program inception. Identification of focus areas will support strategic development of water that meets the demands of stakeholders to incorporate environmental, social, and governance issues while meeting the substantial demands for consumptive water. As was hoped for the project, the tool has identified specific focus areas based off fundamental characteristics of successful recharge facilities within traditional waterfowl habitat priorities along the South Platte River. Over the coming months, the tool will be used to build support for water program development and strategic planning with several partners. Armed with this new information we can predict development of diverse ATM programs that include FLEX markets and water co-ops.

7.4 Alternative Applications

The GIS tool was built so that it can be easily adapted to fit the needs of projects other than site selection for wetlands. The underlying data in the tool is foundational for many potential applications and the processes used to generate the grid layers can be duplicated readily. Also, the layer weighting and scoring can be updated without having to reprocess individual grid layers to better match the priorities of other applications. Other easy modifications can be made to the GIS tool to suit the purposes of a new project including turning off certain layers (e.g. existing wetlands) and adding additional data. The addition of new data layers would require a re-evaluation of the layer weighting and processing of new grid layers.

Some examples of alternative applications for the GIS tool and DSS model are site selection for augmentation recharge facilities and selection of sites for installation aquifer storage and recovery (ASR) facilities. The augmentation recharge facilities selection would likely be very similar to the recharge wetland selection process, but more emphasis could be placed on return flow lag timing and availability of water supply while existing wetlands and land ownership could be ignored or be given a lower level of importance. Some additional layers may be helpful such as well locations. For ASR applications, more data relating to aquifer properties could be useful including saturated thickness, soil profile data, hydraulic conductivity, and locations of confined aquifers. Various scenarios could be run by implementing different weighting and scoring schemes tailored to the type of ASR technology being employed. Overall, the DSS model and GIS tool can be adapted to assist in site selection and administrative tasks for most projects where hydrologic, geologic, or administrative data are the basis for the decision making process.

7.5 Future Use and Development

While the current GIS tool was developed for the South Platte basin, using the existing data sets developed throughout the state as a part of the CDSS process, the tool could be adapted to other basins. To date, the South Platte basin is covered by a more comprehensive GIS database than other basins and some data relied on for the GIS tool are not as readily available for other basins. Part of the scope of work for developing DSS models in other basins would likely include in-depth data collection and data development to fill in any gaps in availability of data. The DSS model might also take on a different character depending on the needs and interests of stakeholders in the other basins.

7.5.1 Additional Tool Formats

The tool developed for this project requires GIS software and data processing knowledge to produce the summation grid and final weighted scores. While making updates to the tool for the purposes of running new scenarios for various applications is relatively straight forward, it is not a process that could be completed easily by independent users who are not versed in GIS. A possible future project could include an adaptation of the GIS tool into a web-based interface with user selectable weighting and scoring. Additionally, a number of predetermined scenarios could be run and the final summation grid could be accessed through a web-based interface. A web-based, user friendly version of the GIS tool could be an asset for stakeholders in the basin and basin administrators in addition to organizations such DU.

Section 8

Limitations

This document was prepared solely for Ducks Unlimited, Inc. to meet the tasks outlined in their grant award with the Colorado Water Conservation Board in accordance with professional standards at the time the services were performed and in accordance with the contract between Ducks Unlimited, Inc. and Brown and Caldwell dated 9/26/12. This document is governed by the specific scope of work authorized by Ducks Unlimited, Inc.; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by Ducks Unlimited, Inc. and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

Further, Brown and Caldwell makes no warranties, express or implied, with respect to this document, except for those, if any, contained in the agreement pursuant to which the document was prepared. All data, drawings, documents, or information contained this report have been prepared exclusively for the person or entity to whom it was addressed and may not be relied upon by any other person or entity without the prior written consent of Brown and Caldwell unless otherwise provided by the Agreement pursuant to which these services were provided.

Section 9

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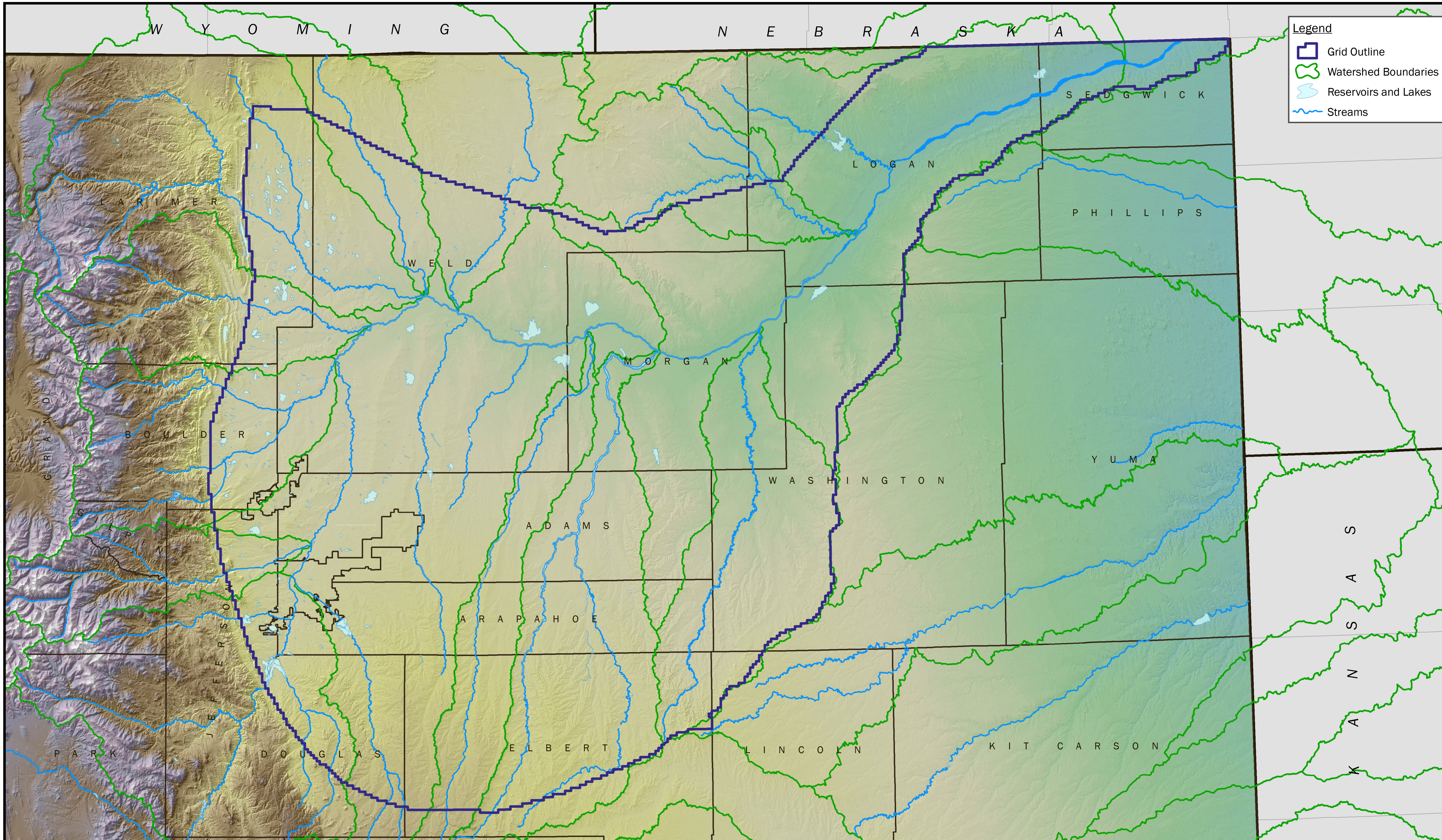
Spatial Data Catalog Links

BLM:	http://www.geocommunicator.gov/GeoComm/lsis_home/home/index.htm
CDOT:	http://dtdapps.coloradodot.info/Otis/catalog
CDSS/DWR:	http://cdss.state.co.us/GIS/Pages/Division1SouthPlatte.aspx
Census:	http://www.census.gov/geo/maps-data/data/cbf/cbf_ua.html
CNHP:	Wetlands: https://apps.cnhp.colostate.edu/webdav/Projects/Wetlands/Wetlands.zip
	COMaP: http://www.nrel.colostate.edu/projects/comap/
DOW:	http://www.arcgis.com/home/item.html?id=b1b27dc4bde744e490e0d1a9f9512032
DRCOG:	http://gis.drcog.org/datacatalog/
USGS:	http://nhd.usgs.gov/wbd.html



Brown AND Caldwell

Date: September 2013

Ducks Unlimited

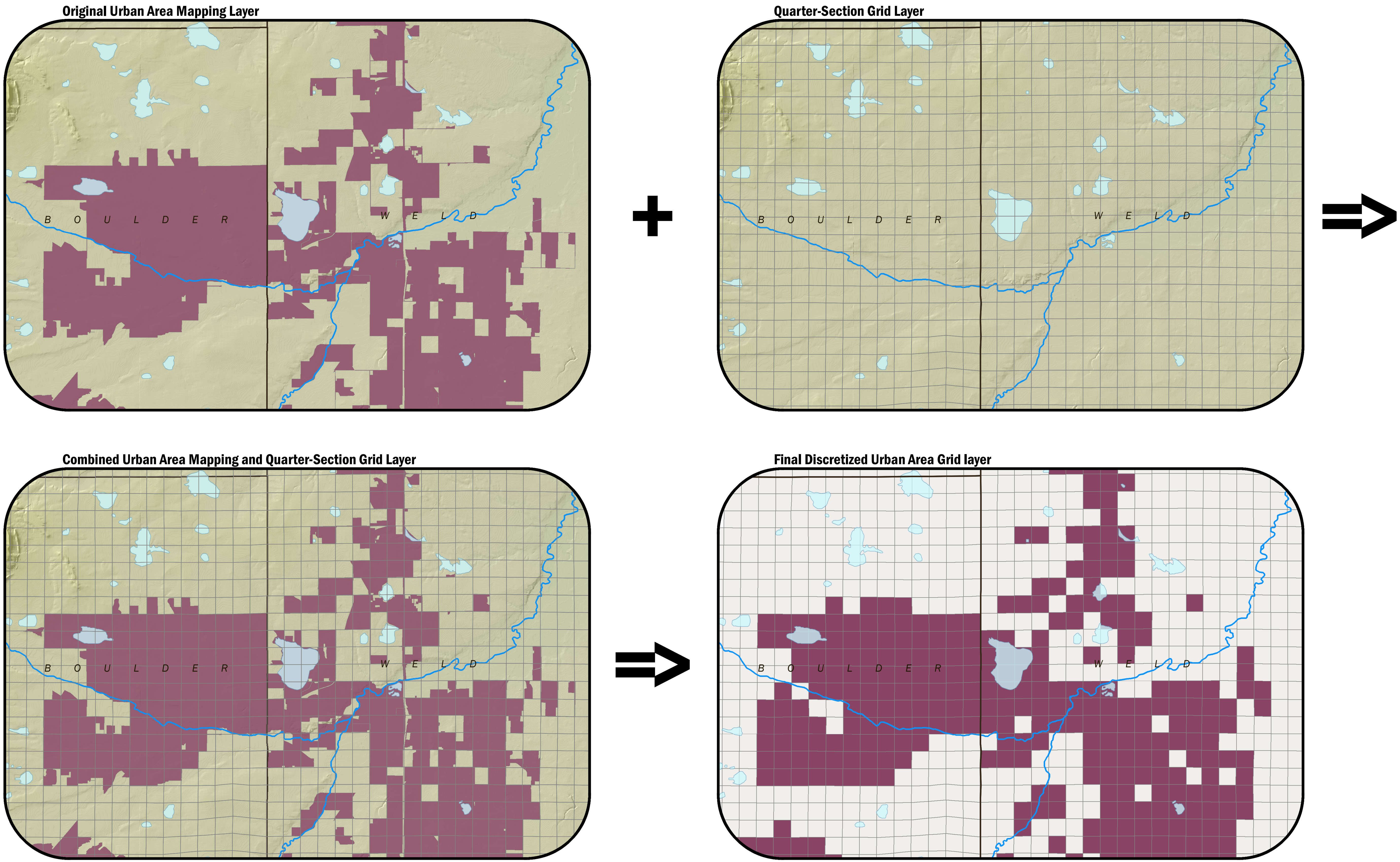
Project: 143429

Notes:
1. Projection: UTM Zone 13, 1983 North American Datum (Meters)

South Platte River Basin Colorado

Figure 3-1

Analysis Area Outline



Brown AND Caldwell

Date: September 2013

Ducks Unlimited

Project: 143429

0 15,000 30,000 Feet

N S W E

Legend

Streams

Reservoirs and Lakes

Analysis Grid

Mapped Urban Areas

Grid Discretization

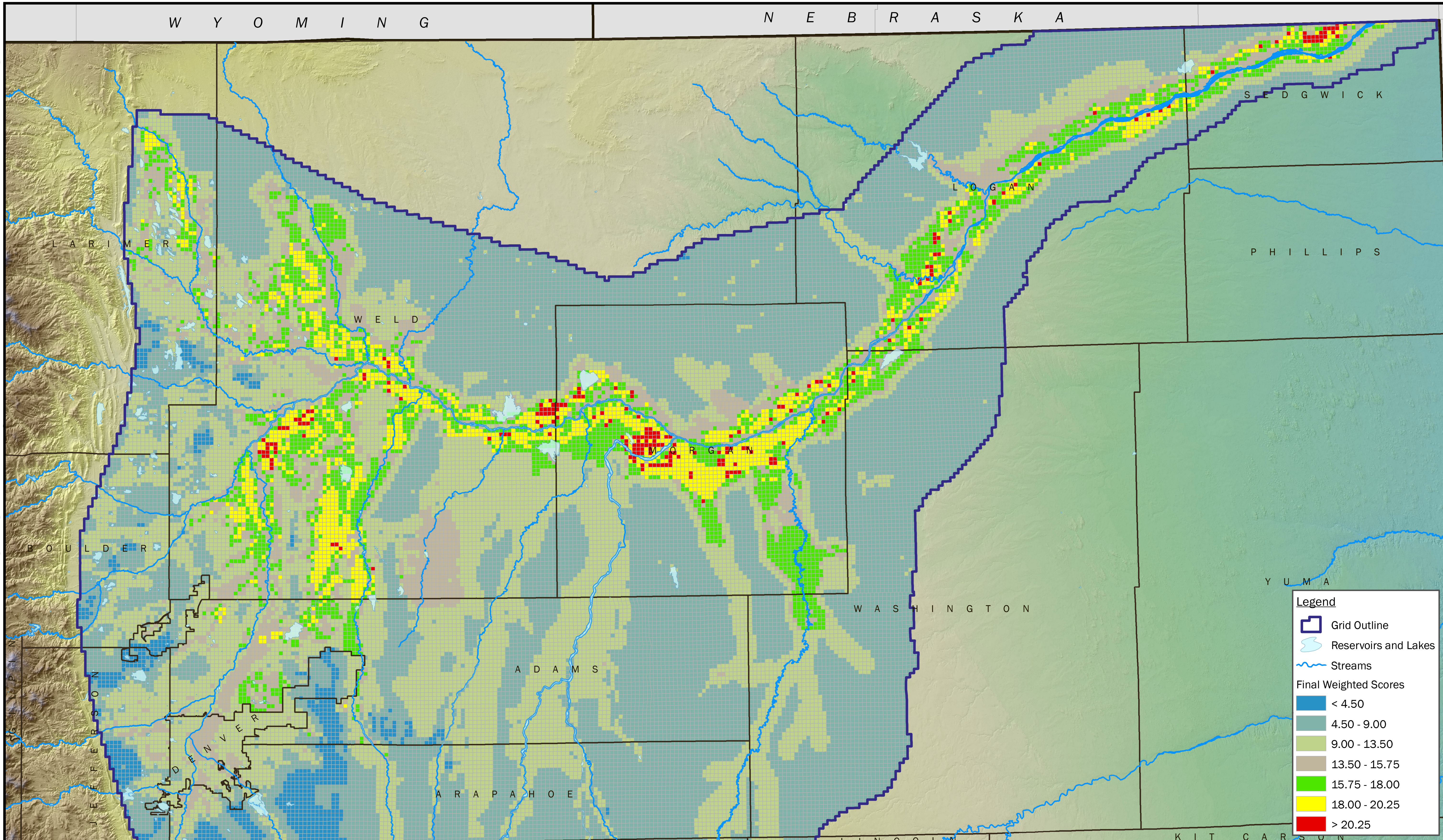
Non-Urban Area

Urban Area

South Platte River Basin Colorado

Figure 3-2

Urban Area Layer Discretization Example



[BCDEN02] P:\Data\GEN\Ducks Unlimited\Wetland DSS\GIS_MAPDOCS\Report Figures\Figure 4-1 - Summation Grid - Full Extent.mxd

Sep 19, 2013

zwengrovius

Brown AND Caldwell

Date: September 2013

Ducks Unlimited

Project: 143429

N W E S

0 60,000 120,000 Feet

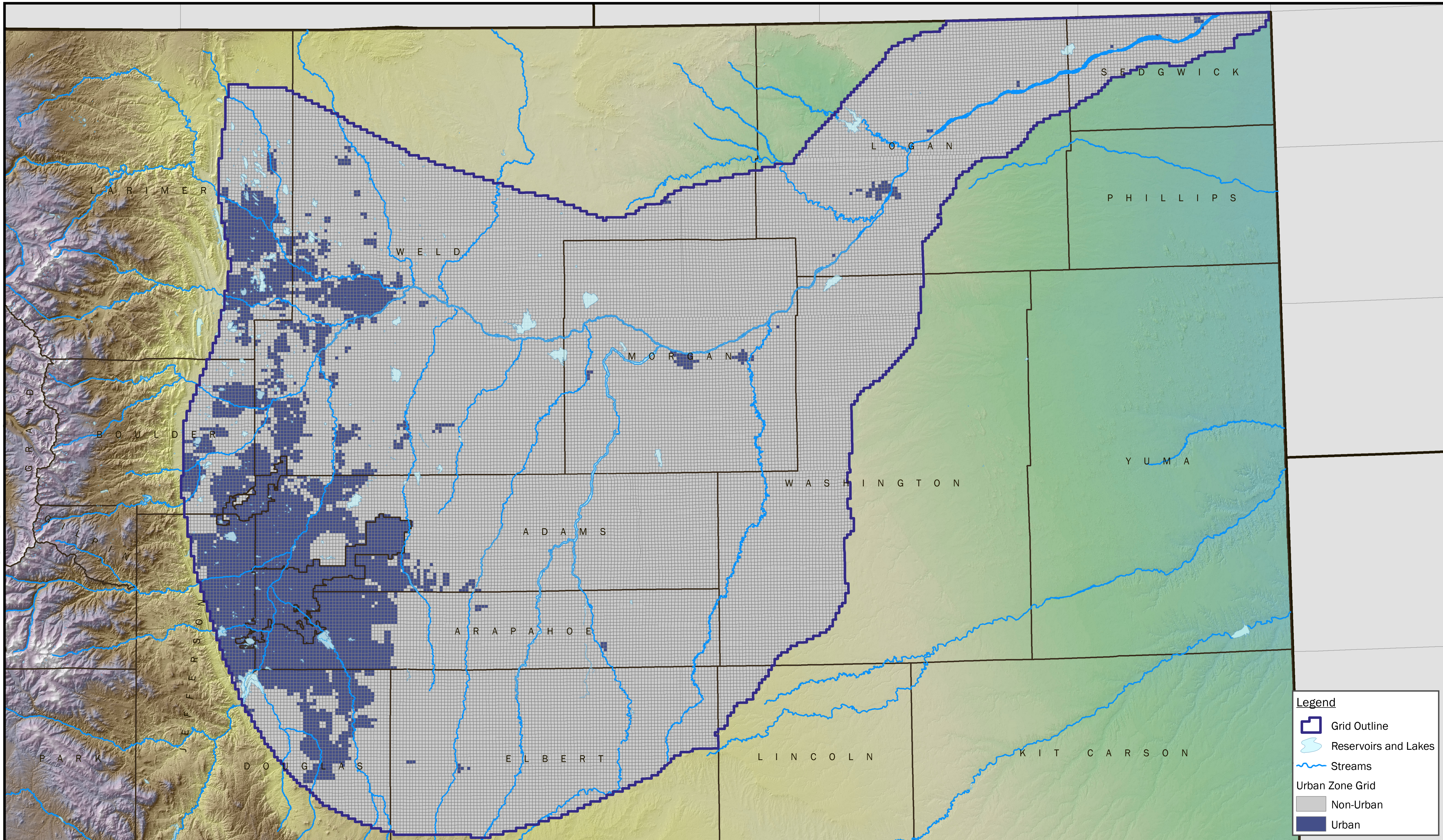
Notes:
1. Projection: UTM Zone 13, 1983 North American Datum (Meters)
2. Data Sources: Colorada Division of Water Resources, Colorado Department of Transportation, Natural Heritage Program - CSU, United States Geological Survey, Brown and Caldwell, Bureau of Land Managment, Colorado Division of Wildlife, and U.S. Census Bureau.

South Platte River Basin Colorado

Figure 4-1

Summation Grid Final Weighted Scores

Appendix A: Grid Layer Figures



zwengrovius

Sep 25, 2013

[BCDEN02] P:\Data\GEN\Ducks Unlimited\Wetland DSS\GIS_MAPDOCS\Report Figures\Figure A-1 - Urban Area Grid.mxd

Brown AND Caldwell

Date: September 2013

Ducks Unlimited

Project: 143429

0 75,000 150,000 Feet

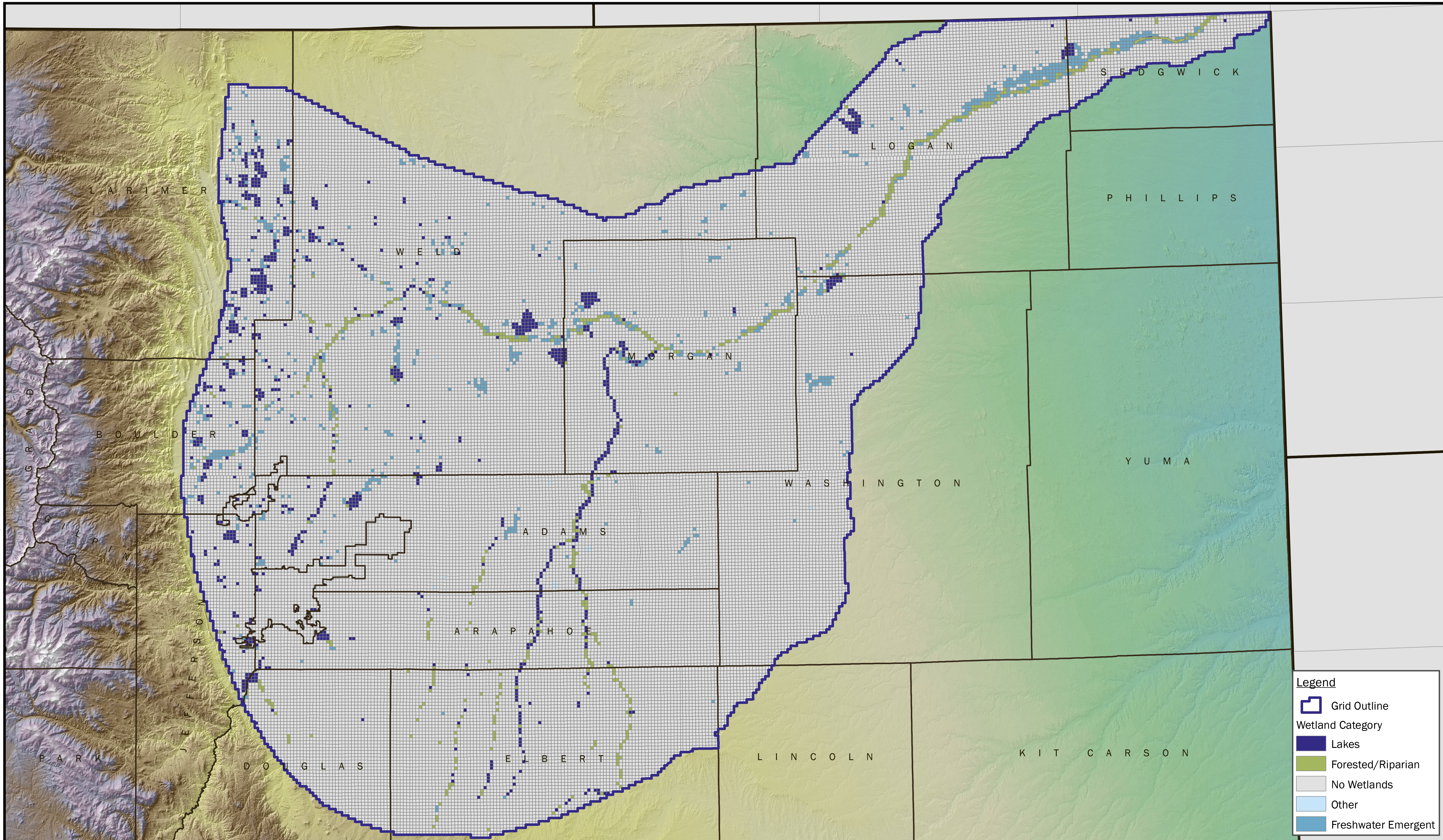
N W E S

Notes:
1. Projection: UTM Zone 13, 1983 North American Datum (Meters)
2. Data Sources: Colorada Division of Water Resources, Colorado Department of Transportation, Natural Heritage Program - CSU, United States Geological Survey, Brown and Caldwell, Bureau of Land Managment, Colorado Division of Wildlife, and U.S. Census Bureau.

South Platte River Basin Colorado

Figure A-1

Urban Zone Grid Layer



[BCDEN02] P:\Data\GEN\Ducks Unlimited\Wetland DSS\GIS_MAPDOCS\Report Figures\Figure A-2 - Existing Wetlands Grid.mxd Sep 12, 2013 zwengrovius

Brown AND Caldwell

Date: September 2013

Ducks Unlimited

Project: 143429

0 75,000 150,000 Feet

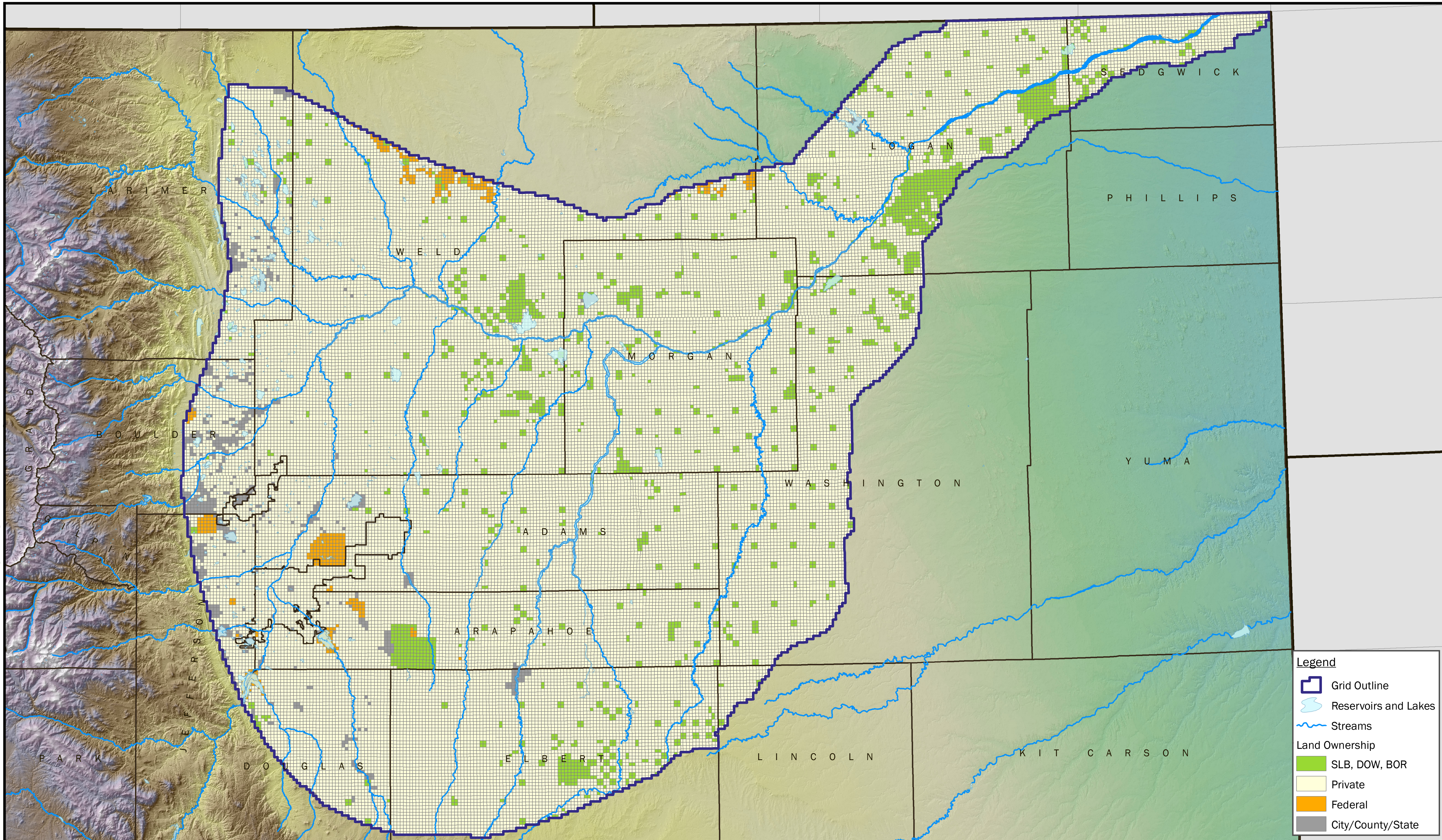
N S E W

Notes:
1. Projection: UTM Zone 13, 1983 North American Datum (Meters)
2. Data Sources: Colorada Division of Water Resources, Colorado Department of Transportation, Natural Heritage Program - CSU, United States Geological Survey, Brown and Caldwell, Bureau of Land Managment, Colorado Division of Wildlife, and U.S. Census Bureau.

South Platte River Basin Colorado

Figure A-2

Existing Wetlands Grid Layer



Brown AND Caldwell

Date: September 2013

Ducks Unlimited

Project: 143429

0 75,000 150,000 Feet

N S E W

Notes:
1. Projection: UTM Zone 13, 1983 North American Datum (Meters)
2. Data Sources: Colorada Division of Water Resources, Colorado Department of Transportation, Natural Heritage Program - CSU, United States Geological Survey, Brown and Caldwell, Bureau of Land Managment, Colorado Division of Wildlife, and U.S. Census Bureau.

South Platte River Basin Colorado

Figure A-3

Land Ownership Grid Layer

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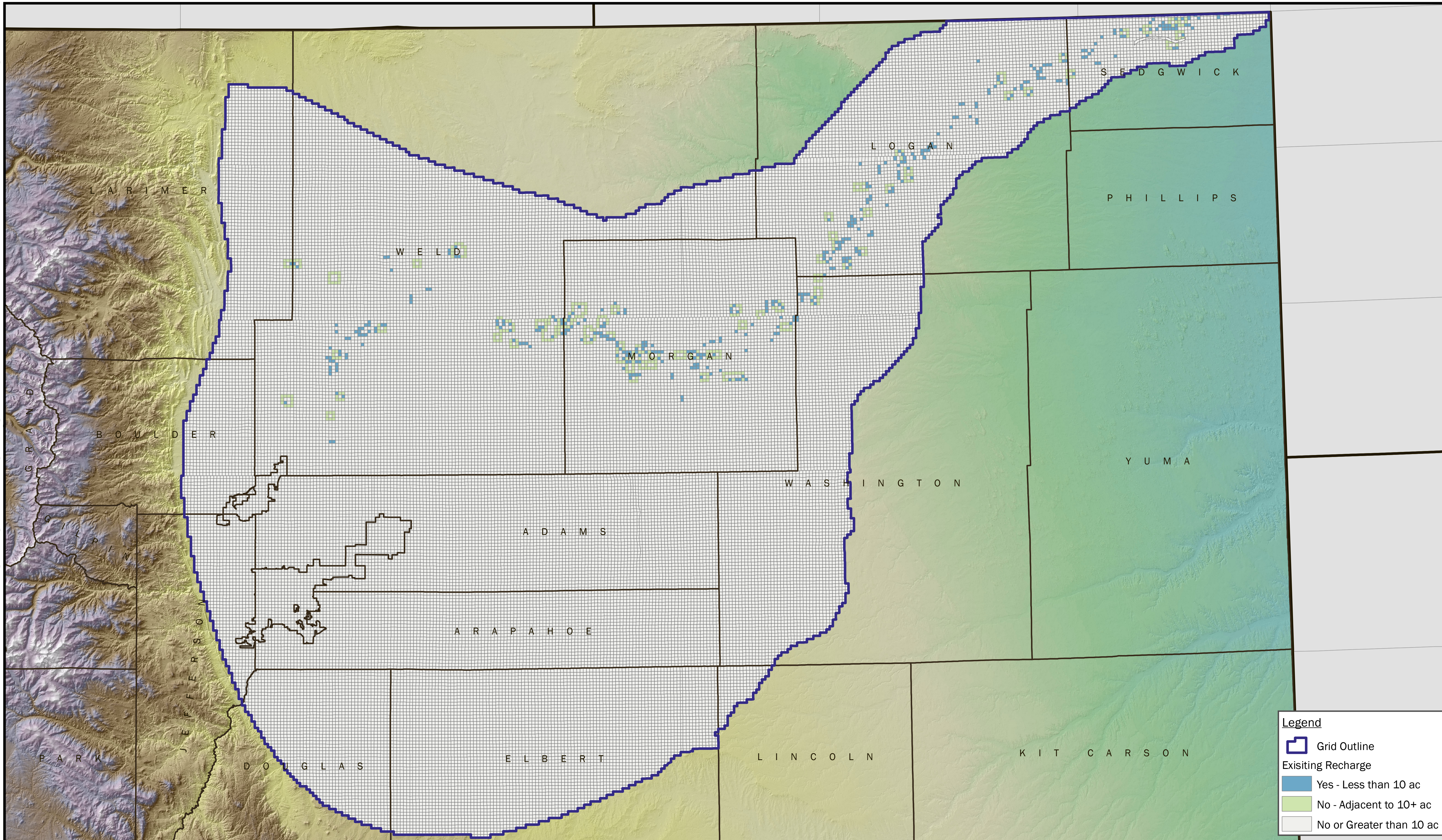
Sep 12, 2013

[BCDEN02] P:\Data\GEN\Ducks Unlimited\Wetland DSS\GIS_MAPDOCS\Report Figures\Figure A-4 - Existing Recharge Grid.mxd



Brown AND Caldwell

Date: September 2013

Ducks Unlimited

Project: 143429

0 75,000 150,000 Feet

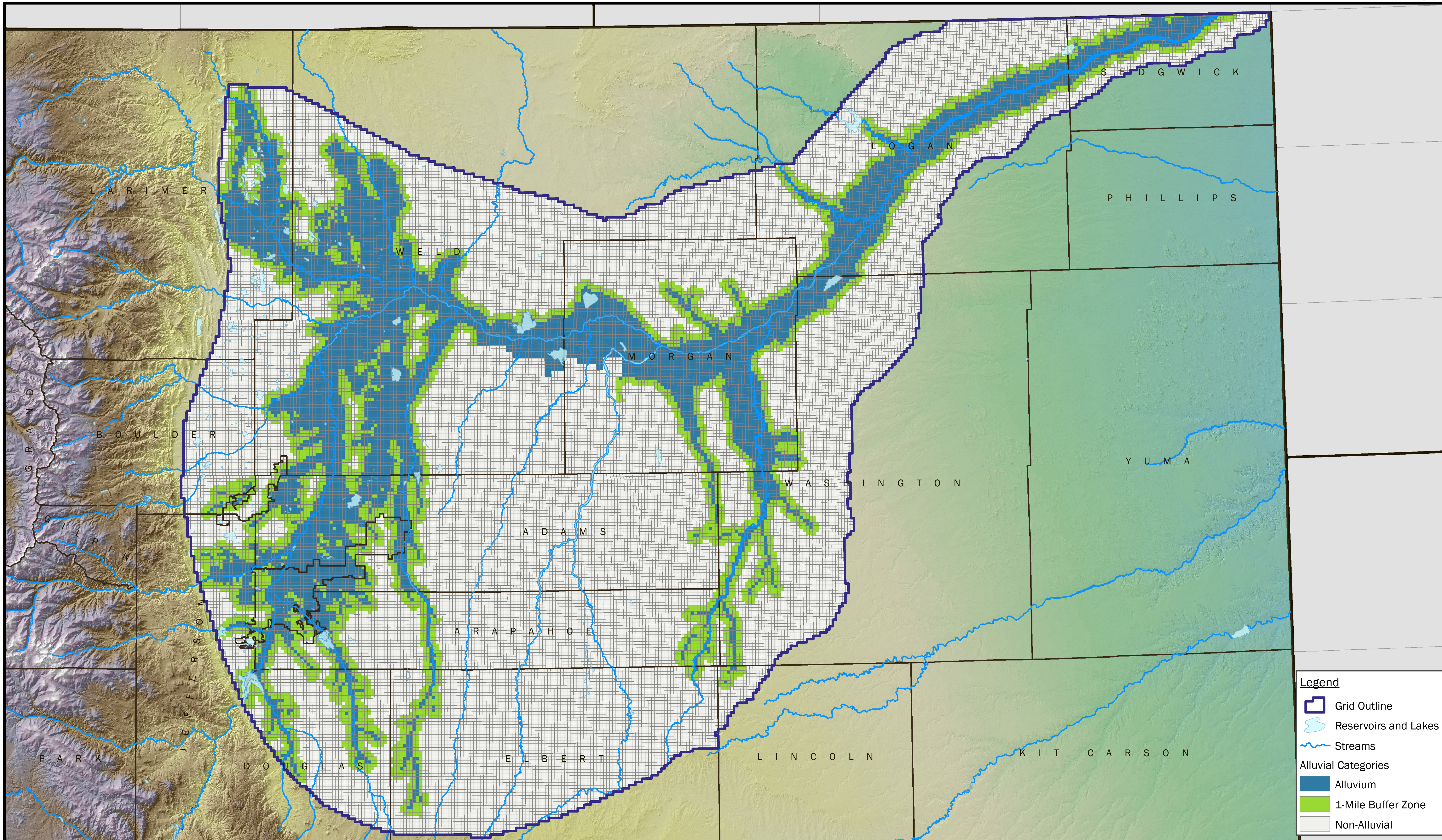
N W E S

Notes:
1. Projection: UTM Zone 13, 1983 North American Datum (Meters)
2. Data Sources: Colorada Division of Water Resources, Colorado Department of Transportation, Natural Heritage Program - CSU, United States Geological Survey, Brown and Caldwell, Bureau of Land Managment, Colorado Division of Wildlife, and U.S. Census Bureau.

South Platte River Basin Colorado

Figure A-4

Existing Recharge Grid Layer



Brown AND Caldwell

Date: September 2013

Ducks Unlimited

Project: 143429

0 75,000 150,000 Feet

N S W E

Notes:
1. Projection: UTM Zone 13, 1983 North American Datum (Meters)
2. Data Sources: Colorada Division of Water Resources, Colorado Department of Transportation, Natural Heritage Program - CSU, United States Geological Survey, Brown and Caldwell, Bureau of Land Managment, Colorado Division of Wildlife, and U.S. Census Bureau.

South Platte River Basin Colorado

Figure A-5

Alluvial Aquifer Boundary Grid Layer

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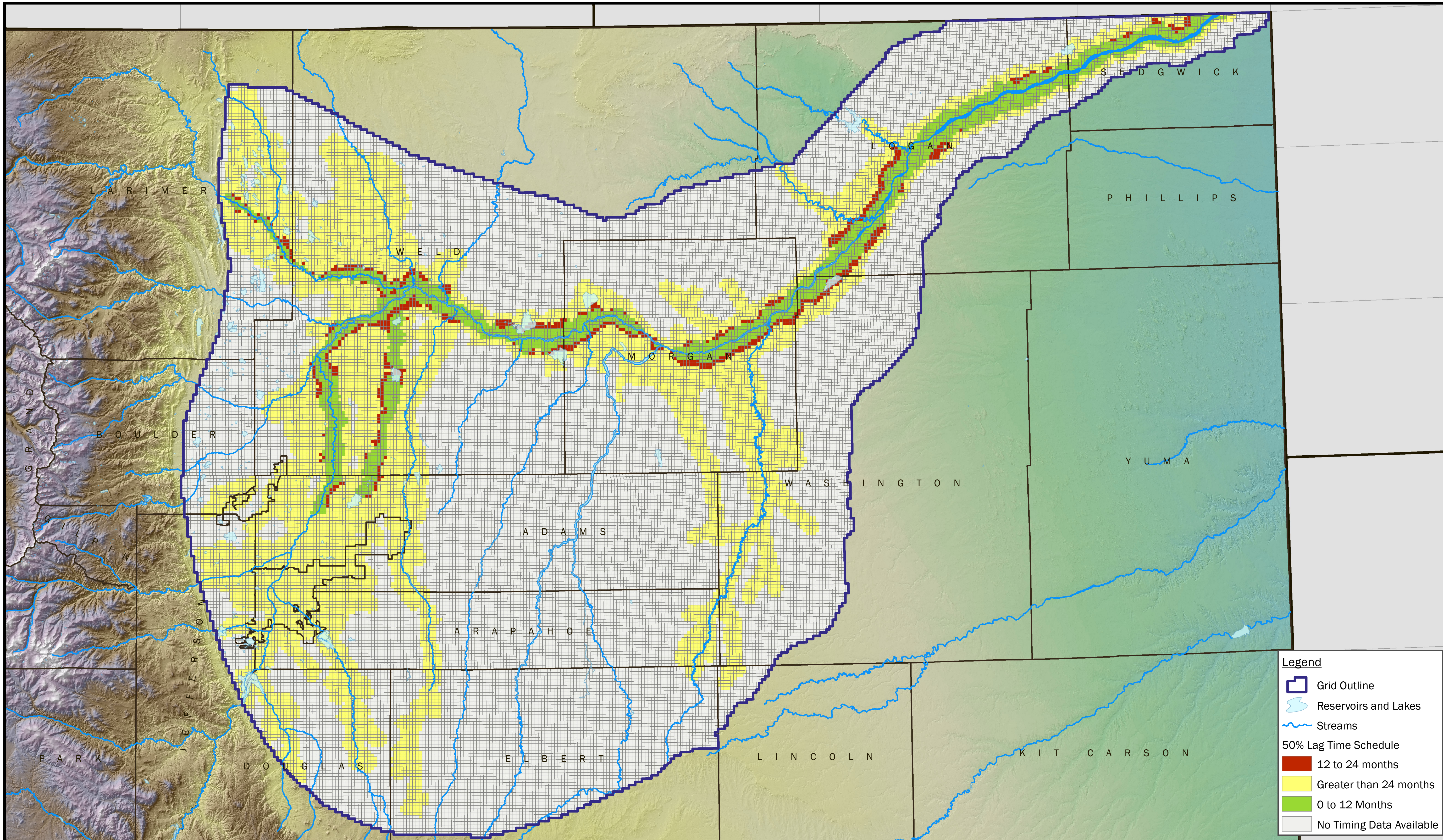

Brown AND Caldwell

Date: September 2013

Ducks Unlimited

Project: 143429

Notes:
1. Projection: UTM Zone 13, 1983 North American Datum (Meters)
2. Data Sources: Colorada Division of Water Resources, Colorado Department of Transportation, Natural Heritage Program - CSU, United States Geological Survey, Brown and Caldwell, Bureau of Land Managment, Colorado Division of Wildlife, and U.S. Census Bureau.

South Platte River Basin Colorado

Figure A-6

Return Flow Timing Grid Layer

[BCDEN02] P:\Data\GEN\Ducks Unlimited\Wetland DSS\GIS_MAPDOCS\Report Figures\Figure A-6 - Return Flow Timing Grid.mxd

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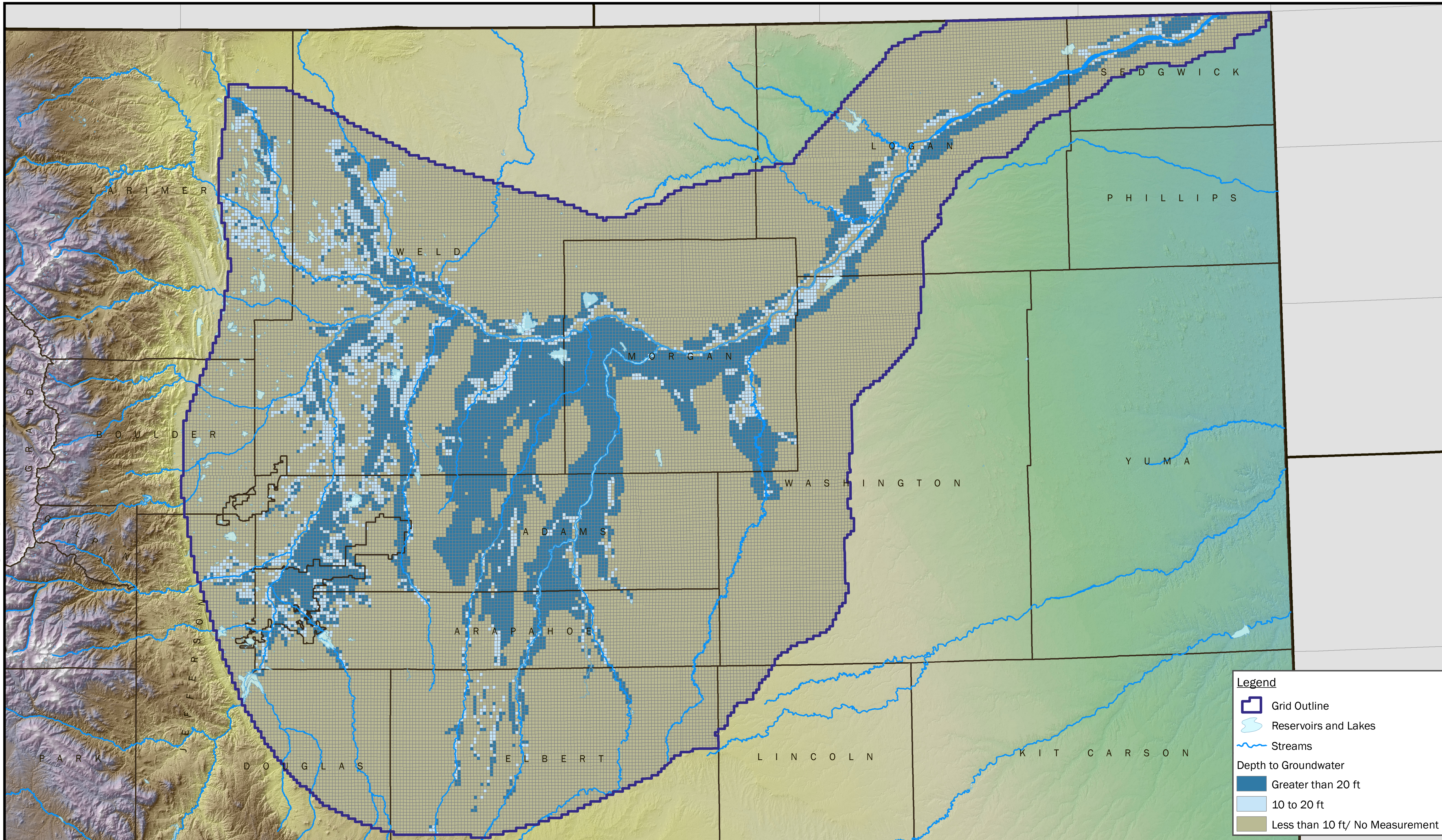


Brown AND Caldwell

Date: September 2013

Ducks Unlimited

Project: 143429

0 75,000 150,000 Feet

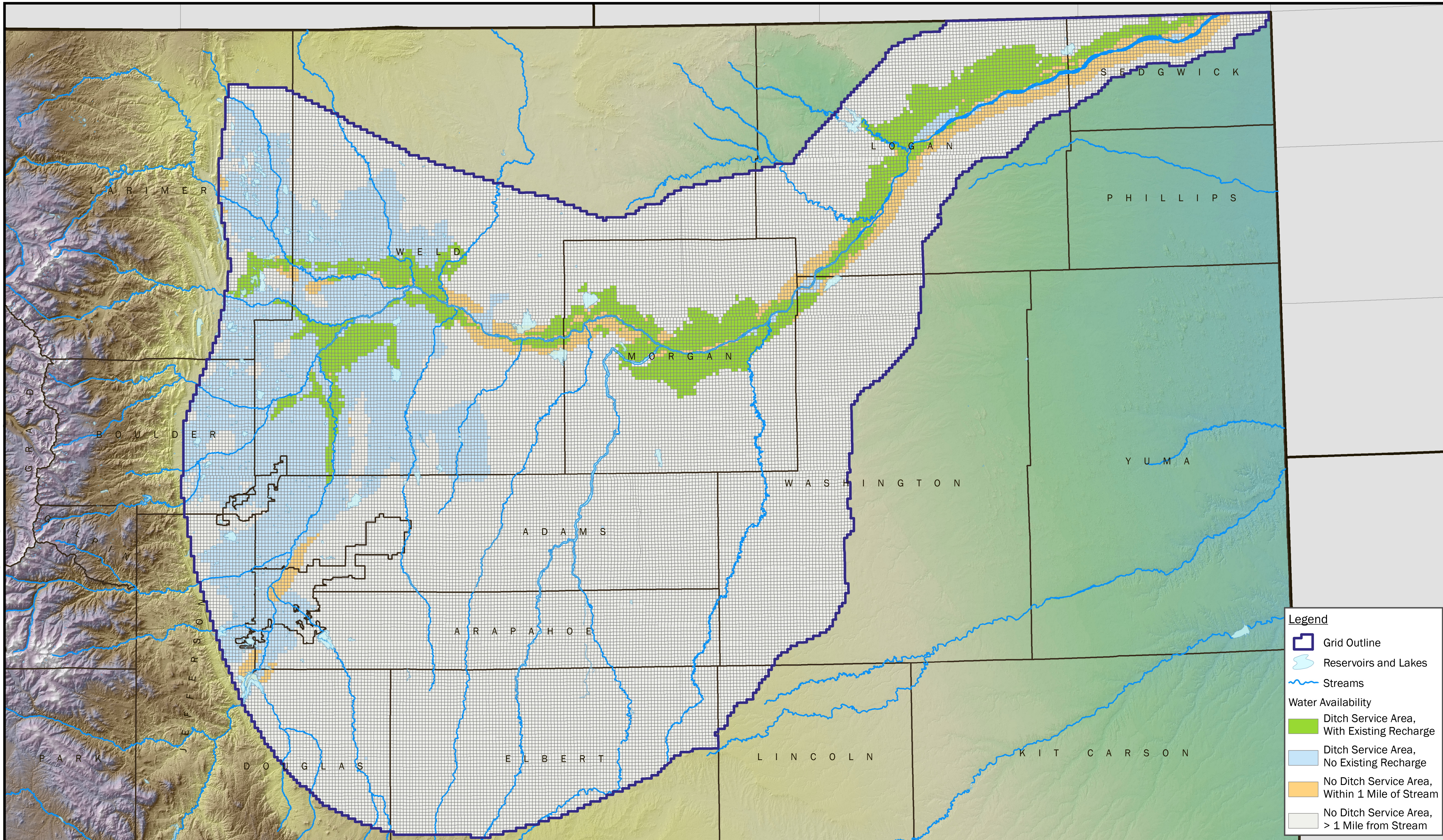
N W E S

Notes:
1. Projection: UTM Zone 13, 1983 North American Datum (Meters)
2. Data Sources: Colorada Division of Water Resources, Colorado Department of Transportation, Natural Heritage Program - CSU, United States Geological Survey, Brown and Caldwell, Bureau of Land Managment, Colorado Division of Wildlife, and U.S. Census Bureau.

South Platte River Basin Colorado

Figure A-7

Depth to Groundwater Grid Layer



Brown AND Caldwell

Date: September 2013

Ducks Unlimited

Project: 143429

Notes:
1. Projection: UTM Zone 13, 1983 North American Datum (Meters)
2. Data Sources: Colorada Division of Water Resources, Colorado Department of Transportation, Natural Heritage Program - CSU, United States Geological Survey, Brown and Caldwell, Bureau of Land Managment, Colorado Division of Wildlife, and U.S. Census Bureau.

South Platte River Basin Colorado

Figure A-8

Ditch Service Area Grid Layer

Appendix B: Layer Scoring Criteria Table

TABLE B-1

Tier 1 Criteria - Factors that are Important for Identifying Future Water Conservation Wetland Projects

Created in support of the Development of a Decision Support Model for Identifying and Ranking
Waterfowl and Wildlife Related Recharge Projects along the South Platte River

Category	Criteria	Layer Weight	Scoring Range Min	Scoring Range Max	Comments on Scoring	Data Used	Type	Sources	General Limitations
					(Note: High scores reflect favorable conditions and low score reflect unfavorable conditions. Scoring range is between 0 and 5.)				
Land Use									
	Urbanized/Non-Urbanized Areas	0.7	0	5	Urban areas are not desirable locations for water conservation wetlands. Urban areas or areas within mapped urban areas receive a 0 score; non-urban receive a 5.	Combination of US Census (2010) Urban Areas and municipal boundaries	ESRI Shapefile	U.S. Census via DRCOG, CDOT	No significant limitations, best available data
	Presence of Forested/Riparian Areas and Lakes; presence of fresh water emergent wetlands and freshwater ponds	0.6	0	5	This category will help target wetland projects where waterfowl habitat does not exist or where habitat could be enhanced. Grid cells with forested/riparian wetlands receive a score of 1. Large open water areas (e.g. lakes and reservoirs) receive a score of 0. Grid cells containing at least 20 acres of existing freshwater emergent wetlands and fresh water ponds receive a score of 5. Grid cells without existing wetlands receive a score of 2.	Updated National Wetland Inventory Mapping	File Geodatabase	Natural Heritage Program (CSU)	Relies mainly on 1970's era mapping, some areas me be out of date. best available data
	Land Ownership	0.4	1	5	Inclusion of this criteria would help identify lands that are already protected and that allow for public access. Potential locations on lands owned by the State Land Board and Colorado Division of Wildlife receive a score of 5, Bureau of Reclamation lands also receive a score of 5, private lands receive a score of 3, federal lands receive a score of 2, and other State, County or Municipally owned lands receive a score of 1.	COMap Land Ownership and Land Management geodatabase	File Geodatabase	COMaP (CSU),	Parcel ownership misidentified in some locations, best available data
	Existing Recharge Ponds	0.2	0	5	This category helps identify areas where recharge ponds have already been constructed, indicating favorable locations for new recharge and demand for recharge. Grid Cells containing existing recharge ponds less than 10 acres receive a score of 5, cells adjacent to existing recharge ponds greater than 10 acres in size receive a score of 3, and other cells with 10 or more acres of existing recharge receive a score of 0.	Existing Recharge Ponds for Division 1, District 2 recharge ponds	ESRI Shapefile, Google Earth KML	DWR	Best available data
Water Related Criteria									
	Ability to Recharge the Alluvial Aquifer	0.9	0	5	This category targets areas that are within the boundary of the alluvial aquifer and that are hydraulically connected to the South Platte River and its tributaries as well as areas within 1 mile of the alluvial boundary. Areas inside the mapped alluvium receive a score of 5, areas outside the mapped alluvium, but within the 1 mile buffer receive a score of 3, and areas outside of the 1 miles buffer receive a score of 0.	Alluvial Aquifer Boundary, 1-mile buffer (excluding designated basin areas)	ESRI Shapefile	DWR (SPDSS)	No significant limitations, best available data
	Lag time characteristics	0.1	0	5	This criteria will help identify areas where recharge can be recognized at the river over a desirable and reasonable length of time. Areas where it takes less than 12 months to get 50% of the water to the river receive a score of 1; areas where it takes more than 24 months to get 50% of the water to the river receive a score of 3; areas where it takes between 12 and 24 months to get 50% of the water to the river receive a score of 5. Areas outside of the mapped alluvium, but within a 1-mile buffer receive a score of 3 (no return time data available for these areas). Areas outside the mapped alluvium and the 1-mile buffer receive a score of 0.	AWAS timing grid for 50% of total return, IDS Group grid data, SPDSS Transmissivity Data	ESRI Grid	IDS Group (CSU), DWR (SPDSS), BC (from alternative transfer study)	Based on Herr-Schneider boundary and AWAS, some boundary conditions may lead to longer than expected return times
	Depth to Groundwater	1.0	1	5	Areas with shallow groundwater tables are less conducive to recharge than areas with deeper groundwater tables. Areas with shallow groundwater tables (0 to 10 feet depth-to-water) receive a score of 1; areas with moderately deep groundwater tables (between 10 and 20 feet depth-to-water) receive a score of 3; areas with deeper groundwater tables (greater than 20 feet depth-to-water) receive a score of 5.	National Elevation Dataset DEMs, SPDSS Groundwater Elevation Mapping	ESRI Grids	DWR (SPDSS), USGS	Static data. Does not reflect seasonal fluctuations in groundwater levels. Resolution of DEM and Water table layers not consistent
	Availability of Water Supply	0.8	1	5	Will help identify areas with reliable and local water supplies. Areas not within a ditch service area and more than 2 miles from the river receive a 1; areas not within a ditch service area and within 2 miles of the river receive a 3; areas within a ditch service area, but with no existing recharge receive a score of 4; and areas within a ditch service area with existing recharge receive a score of 5. Existing recharge based on presence of recharge decreed recharge ponds (recharge pond layer).	Division 1 Ditch Services Areas (2010), Mapped Recharge Ponds	ESRI Shapefile	DWR (SPDSS), DWR	No significant limitations, best available data

Appendix C: Great Outdoors Colorado Water Project Proposal

Lower South Platte River Water Resource Protection for the 21st Century

Colorado's water resources are under attack. The Colorado Water Conservation Board has projected that more than 538,000 to 813,000 acre-feet (acft) of water beyond currently available supplies will be needed to meet the state's more than 8 million people in 2050. The South Platte River, which includes both Metro Denver and surrounding municipalities as well as large urban centers and rural districts to the Nebraska state line will double adding over 2 million people to the basin. The next nearest growth basin is the Arkansas with less than 500,000 more people. Considering the South Platte and Metro basins account for 70% of all jobs and 60% of all revenue, it's an important economic driver for Colorado (CWCB, 2010).

Population in the South Platte basin will require approximately 350,000 to 400,000 acft more water by 2050 to address municipal, industrial, and agricultural (MIA) needs. This estimate does not address the demands placed on the river for environmental, wildlife, or recreational needs; termed non-consumptive needs. Even considering a realistic scenario of developing new storage facilities, passive conservation, and identified transfers of agricultural water to municipal and industrial, it is highly likely that a remaining gap of 280,000 acft will need to be satisfied (CDM, 2011).

One of the easiest procedures to meet the gap is to transfer water from agriculture to municipal and industrial benefits through a process known as "buy and dry". Agricultural producers currently own more than 85% of surface and groundwater rights in Colorado (CSU, 2008). Along the South Platte River more than 830,000 acres are currently irrigated representing 25% of all agriculture in the state. The current figure does not include the 100,000 acres lost in the previous 5 years due to the shut-down of wells in Weld County that failed to augment their needs. Future irrigated acres in Colorado may decrease by an additional 115,000 to 155,000 acres due to urbanization alone. Further decreases are expected due to municipal and industrial transfers predicted to be 100,000 to 176,000 acres. The combination is a 26% loss of irrigated agriculture in the lower South Platte by 2050 (CWCB, 2010).

The governor's executive order (D2013-005), issued in May of this year, directs the Colorado Water Conservation Board to commence work on the Colorado Water Plan and identifies that "Coloradans find that the current rate of purchase and rate of transfer from irrigated agriculture… is unacceptable". Adding, "We have witnessed the economic and environmental impacts on rural communities when water is sold and removed from an agricultural area". The order directs development of a state water plan that supports a productive economy including viable agriculture and a strong environment that includes healthy watersheds, rivers and streams, and wildlife.

However, one of the most important elements of supporting viable agriculture in the South Platte basin where municipal and industrial demand will outpace the rest of the state will require new trans-mountain water supplies from the Colorado River. A white paper developed by the joint eastern basin roundtables specified, "The impact of not developing a new west slope water supply will have serious implications to the non-consumptive needs of the South Platte basin. If a new west-slope project is not undertaken immediately, the delay in implementation or do-nothing approach will result in the dry-up of eastern plains agriculture to the Front Range and in the loss of open space, wildlife habitat, and recreation". The document goes on to describe that non-consumptive needs in the South Platte basin are extremely important and should be accounted for when considering alternatives to meet future water supply shortages.

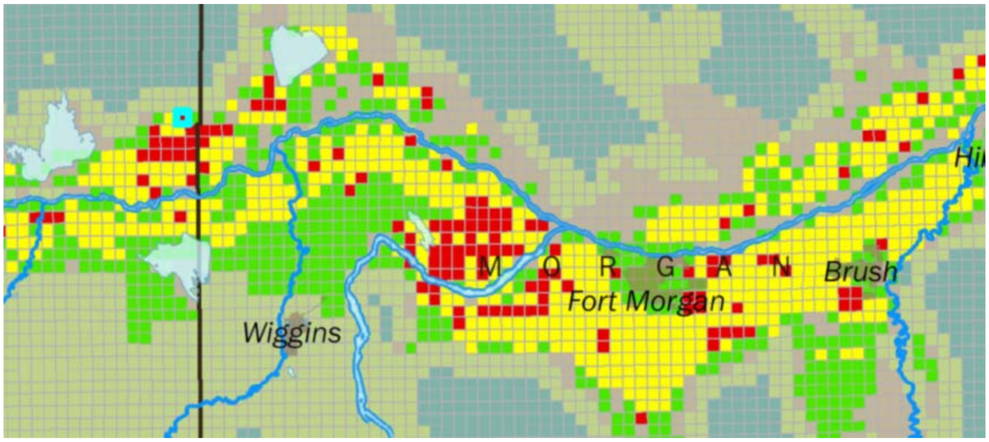
Roundtables consist mostly of municipal and county representatives concerned with MIA water needs. Less than 10% of members are directly tied to non-consumptive water needs. Considering the strong and potential opposed MIA representatives strong statement about non-consumptive needs, the white paper statement represents a very strong constituency of 150 members ready to support non-consumptive water needs.

Ducks Unlimited has successfully negotiated multi-lateral agreements between agricultural land and water owners, with municipalities and industries to accomplish their goals through wetlands that also provide habitat for waterfowl, wildlife and people. Our projects flood wetlands with water rights owned by agricultural or municipal water providers. Wetlands are located on agricultural land in a manner that retimes water through the alluvial aquifer and returns the water to the river during summer months when MIA demands are highest. The program is known a river augmentation through wetland recharge and has been incredibly successful. Projects require significant financial resources to construct infrastructure, restore or create wetlands, and protect the land and water rights for the contract term or in perpetuity. In fact, GOCO supported our flagship recharge project on South Platte River Ranch, near Ovid, Colorado.

Usually, the agricultural or municipal entity works through a water district to apply for new water rights or apply existing water rights to the project. DU works with a landowner to develop the agreements and easements needed to construct and manage the project over the long-term (30 – 50 years), and then protect the property in perpetuity. Water that augments the river through the wetland generates water credits when it returns to the river. The credits can be used to augment wells used by our MIA partners as decreed in water court. By retiming existing water supplies from a time of low or no demand to a time of high demand, we are able to keep agriculture on the landscape while stretching existing water supplies to assist in meeting the MIA water gap.

Ducks Unlimited recently completed a wetland recharge location study to identify the best areas for developing recharge projects that meet our goals, MIA goals, and assist the state in their water goals. Our spatial model weighed 9 criteria that included physical characteristics, socio-economic values, and the environment to develop a "thunderstorm" map (Figure 1). Based off that map we can see 3 to 4 high priority landscapes where the top 10% of identified sites are clustered. These include Gilcrest/Platteville, Fort Morgan, and Julesburg. Fort Morgan area is of particular interest due the relative size of the intact landscape that could provide sustainable agriculture at the nexus where rural municipal and agricultural water needs meet the terminus of Front Range municipal water interests. The area is also located at the heart of the "Golden Triangle", an important migratory bird area.

Figure 1: Recharge Location Study Highlighting the top 10% of potential high quality recharge sites in the Golden Triangle and Fort Morgan Area.



To be successful, we need to better engage GOCO much more fully in northeastern Colorado to support planning grants and provide open space funds to save the landscape. DU conservation easements are structured with water rights protection that is flexible enough to meet the diverse demands placed on water resources in the state. DU is dedicated to purchasing conservation easements, fee-title land holdings, and water rights in association with our partners to develop water projects for the benefit of state goals. Interviews with landowners in the area have indicated they would be more receptive to easements if a higher cash payment was provided. DU's programs have historically limited purchase price to 50% of easement value, but given the myriad positive outcomes from conserving the landscape and water rights in the area it may be substantially warranted to increase cash incentives.

Most of the work can be accomplished within existing GOCO program timelines, fiscal rules, and other requirements. Our experience with water projects indicates that fee-title purchases can be completed within a year and easements can be completed within 18- 24 months depending on internal budget year timing and grant application deadlines. Projects can take much longer if a change in water rights is required. We would protect properties and the water rights necessary to support conservation purposes of the property with GOCO funds and then use partner funds to complete the project and change a portion of the water rights when needed.

Through river augmentation projects, DU and our MIA partners are able to maintain water on the agricultural landscape while providing some water for municipal and industrial interests. We envision a landscape that supports viable agriculture while sharing water to meet municipal needs and benefitting the environment. As the state strives to balance diverse future water needs, an opportunity exists to extend our program beyond opportunistic protection to full-scale landscape protection in cooperation with MIA partners. We need GOCO's substantial resources to assist in our ambitious vision.

Appendix D: State Land Board Proposed Scope of Work

Exhibit A
Proposed Scope of Work
STATE LAND BOARD – WATER ECO-SERVICES
CO-248-1

Water Activity Name: Water Development Feasibility of Colorado State Land Board Property along the Lower South Platte River.

Project Contacts – Greg Kernohan
Ducks Unlimited, Inc.
2926 E. Mulberry Street
Fort Collins, CO 80524
970-481-7793

Mindy Gottsegen
State Land Board
1127 Sherman Street, Suite 300
Denver, CO 80203
303-866-3454 x3318

Funding Sources – Colorado State Land Board (SLB), Ducks Unlimited, Inc. (DU), Colorado Water Conservation Board (CWCB)

Introduction and Background – DU and the SLB will investigate several SLB properties along the lower South Platte River from Denver to the Nebraska state line to determine feasibility of developing 1-3 properties for river augmentation through wetland recharge. The project will include use of other CWCB tools such as the Wetland Recharge Location Model to identify the best potential sites based on the characteristics of that model. The very best sites from the model will be investigated in the field to determine the best 5 – 10 sites for rigorous field investigation. The top 1-3 properties will then be field tested to confirm model assumptions by coring potential recharge sites, conducting pump tests on potential recharge wells, performing AWAS analysis as required, etc. As many as 3 projects will be selected, if appropriate, and moved into design for construction and contracting with partners for water and funding.

The project is a revenue sharing partnership with the State Land Board. All expenses and eventual revenue from the project will be split between the parties. This contract composes the tasks and duties of Ducks Unlimited during the feasibility phase of the partnership.

Objectives – The overall goal of the project will be met through performing the following tasks:

Task 1 – Develop partnership and contract with SLB
Task 2 – Identify Several Top Tier SLB Properties Using the Wetland Recharge Location Model
Task 3 – Perform Field Investigations of the top 5 to 10 sites
Task 4 – Perform Detailed Investigations for Recharge Suitability
Task 5 – Provide Final Report and Accompanying Work Product

<u>Task 1</u> - Develop Partnership and Contract with State Land Board

Description of Task – Several months work were spent developing a partnership between DU and the

SLB. Activities included several meetings between staff, development and presentation of a fictional demonstration project, development of a proposal between the parties, and development and execution of a contract.

Method or Procedure – DU and SLB met on several occasions to discuss the potential to develop wetland recharge sites on SLB property. River augmentation was a new concept for the SLB. Despite having a couple recharge sites with Riverside Irrigation and with Central Colorado Water Conservancy District, the staff had not investigated the development techniques or business structure of river augmentation. DU also walked through our procedure for identifying potential sites and performed a desktop review for a single site owned by the SLB and provided that information as a demonstration of our procedures.

Deliverable – Executed Contract with SLB

Timing – November 2012 – September 2013

<u>Task 2</u> - Identify Several Top Tier SLB Properties Using the Wetland Recharge Location Model

Description of Task – This model was developed by DU under contract with the CWCB to identify potential recharge sites on a landscape level scale. We will use the model to identify the top 20% of sites in the model and which ones are owned by the SLB.

Procedure/Method - The model is currently being completed by our contractor, Brown and Caldwell, and is in such condition to require some GIS analysis skill to deliver specific property information. However, the model is mostly completed and will be submitted to the CWCB in September 2013. It is in such working condition that we can reliably identify quarter-section parcels we wish to further investigate.

1) We will have Brown Caldwell manage the model to identify the top 20% of sites in the model and then identify only SLB properties. The model already incorporates published SLB property boundaries so we should be able to identify the properties easily.
2) We will then use the weighted criteria to work through the properties from highest to lowest score to find the top 5 – 10 sites for further investigation.

Deliverable – Semi-annual report including map of top 5 - 10 property locations and accompanying report of the property characteristics as described by the model with weighted score for each property.

Schedule – August 2013

<u>Task 3</u> - Perform Investigations of the top 5 to 10 sites

Description of Task – Several criteria considered in the model need to be verified in the field. We will visit each site and determine as best we can the physical limitations and any obvious legal constraints that may hinder development of each property.

Procedure/Method – DU staff, SLB staff, and our contractor will travel to all selected sites and determine limiting characteristics such as topography, water availability, partnerships with water providers, access to the river, complications associated with access for construction of infrastructure and permitting. Some of these issues will be completed with the assistance of landowner boundary maps and discussions with known water providers in the area. It is expected that topography and location relative to the river will eliminate several sites.

1) Property Site Visit to confirm physical characteristic of each property.
2) Review of landowner maps to determine distance to river, water providers, other physical impediments and potential partners.
3) Review of potential access issues and other easements required to develop project.
4) Identify major permitting restrictions.

Deliverable – Semi- annual report discussing elimination of sites from the study due to preliminary investigations

Schedule – 180 days from Notice to Proceed (NTP)

<u>Task 4</u> - Perform Detailed Investigations for Recharge Suitability on remaining 1-3 sites

Description – Several different tasks will be pursued simultaneously during this task to determine the suitability of the best sites. We will perform detailed field tests of the remaining sites including soil coring of potential recharge facilities (wetlands), and test recharge well capacity (if needed). We will also be working on commitments from water providers as needed and developing easements from adjacent landowners as required.

Procedure/Method

1) Drill soil cores for potential recharge sites
2) Perform recharge well pump tests
    a. This will likely be performed from the closest local well.
3) Develop commitments with Water Providers
    a. MOU or Contracts
4) Develop access and pipeline easements as needed.

Deliverable – Provide information on all sites as part of the semi-annual report

Schedule – 275 days from NTP

<u>Task 5</u> - Develop Final Report

Description – The final report will be an add-on from the semi-annual reports required by the SLB. It will include the final agreements or commitments from water providers, identify all easements or potential easements required for the project and a conceptual design of the project.

Procedure/Method – Develop a written report for the SLB and roundtable. Turn over all work products and materials to the SLB.

Deliverable – Final report as required by the SLB.

Schedule – 365 days from NTP

Budget – Colorado State Land Board Eco-Services Contract

Task	Total	SLB	DU
1	$3,575	$0	$3,575
2	$1,181	$1,181	$0
3	$12,782	$6,391	$6,391
4	$33,664	$16,832	$16,832
5	$5,653	$4,023	$1,630
Total	$56,855	$28,427	$28,428

Task 1- Mostly complete due to DU’s time to develop the proposals and contract for State Land Board.

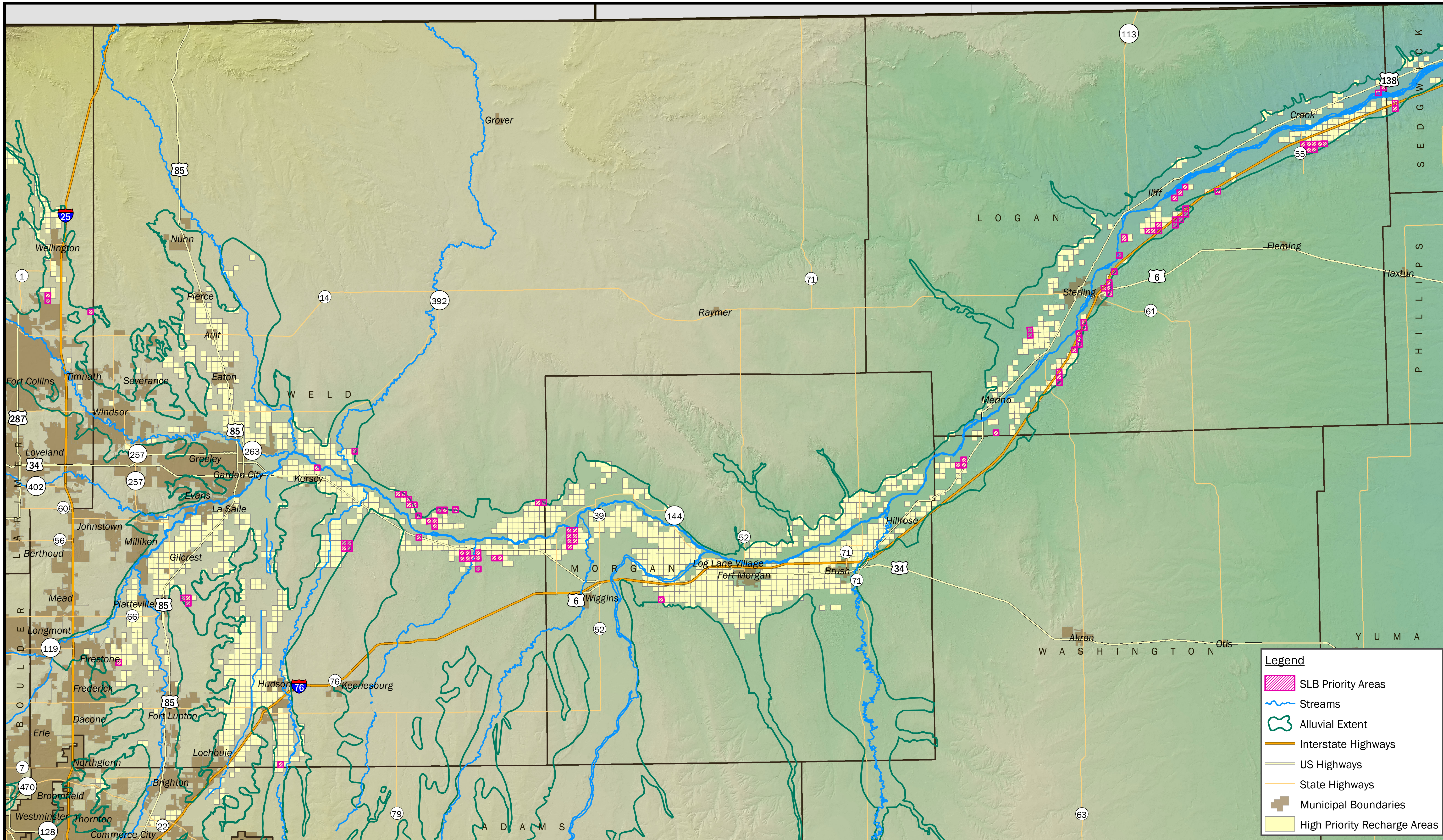
Task 2 – State Land Board will reimburse DU to time to complete Task 2

Task 3 – State Land Board and DU will split all costs. State Land Board to reimburse DU.

Task 4 – State Land Board and DU will split all costs. State Land Board to reimburse DU.

Task 5 – State Land Board to reimburse DU a disproportionate share to offset DU contribution in Task 1.

Total reimbursement from State Land Board for this contract is $28,427. Payment is due following delivery of each task as invoiced.



Date: August 2013

Ducks Unlimited

Project: WSRA Grant App.

0 45,000 90,000 Feet

Notes:
1. Projection: UTM Zone 13, 1983 North American Datum (Meters)
2. Total Area of SLB Lands in priority areas: 14,560 acres.

South Platte River Basin Colorado

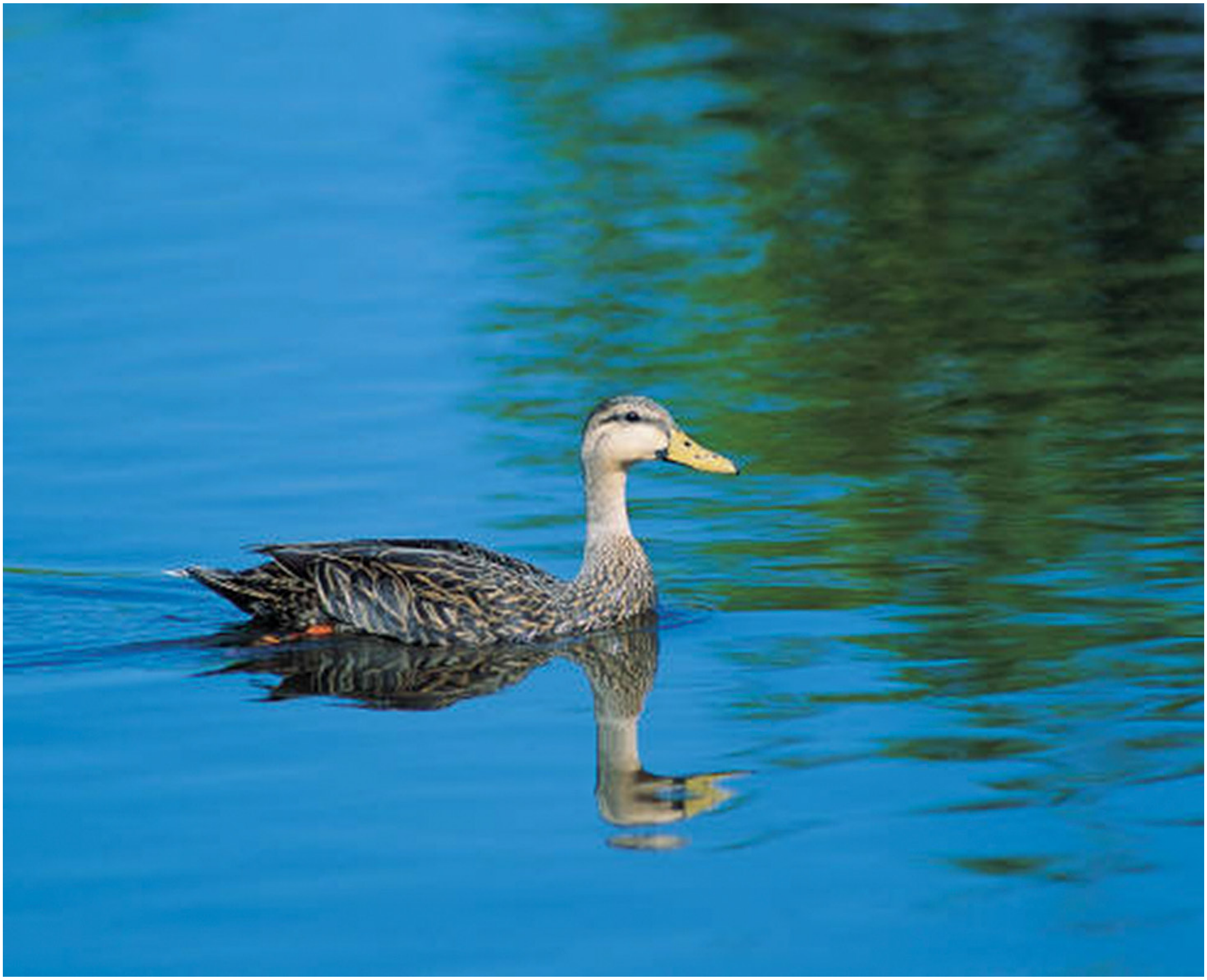
Figure 1

State Land Board Priority Areas

zwengrovius

Aug 13, 2013

[BCDEN02] P:\Data\GEN\Ducks Unlimited\Wetland DSS\GIS_MAPDOCS\WSRA Application Map.mxd



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