NEBRASKA NATURAL RESOURCES COMMISSION

Water Sustainability Fund

Application for Funding

Section A.

ADMINISTRATIVE

PROJECT NAME: Columbus Area Recharge Project

PRIMARY CONTACT INFORMATION

Entity Name: Lower Loup Natural Resources District

Contact Name: Russ Callan

Address: 2620 Airport Drive, Ord, NE 68862

Phone: (308) 728-3221

Email: Rcallan@LLNRD.org

Partners / Co-sponsors, if any: Archer Daniels Midland Company (ADM), City of Columbus, Christopher's Cove Association (CCA).

1. **Dollar amounts requested**: (Grant)

   Grant amount requested. $ 1,224,000

   Loan amount requested. $ N/A

   If Loan, how many years repayment period? N/A

   If Loan, supply a complete year-by-year repayment schedule.
   N/A

2. Permits Needed - Attach copy for each obtained (N/A = not applicable)

Nebraska Game & Parks Commission (G&P) consultation on Threatened and Endangered Species and their Habitat N/A☐ Obtained: YES☐ NO☒

G&P coordination is not anticipated unless a new or modification to an existing water right is deemed necessary.

Surface Water Right N/A☐ Obtained: YES☐ NO☒

Preliminary analyses suggest that a surface water right may not be necessary for the project as conceived in the conceptual design; however, this will be finalized during consultation with the Nebraska Department of Natural Resources during the final design. If required, a new or modified water right would be pursued.

USACE (e.g., 404 Permit) N/A☐ Obtained: YES☐ NO☒

USACE coordination will be initiated at project inception. It is likely that a Section 404 permit(s) will be required for the water control structures and the associated ponded water in the Lost Creek channel. The cost associated with the effort to obtain the permit is included in the project total.

Cultural Resources Evaluation N/A☐ Obtained: YES☐ NO☒

A cultural resources evaluation may be required to support the USACE permits.

Other (provide explanation below) N/A☐ Obtained: YES☐ NO☒

An easement from Loup Power District will be required for the pump station near the canal, as well as any associated paperwork for the Federal Energy Regulatory Commission (FERC). In addition, an easement from UPRR will be required for the supply line to Christopher's Cove. The cost associated with the effort to obtain the permits is included in the project total.

If more than an acre is disturbed during construction, an NPDES SWPP will be required.

The Lost Creek portion of the project is located in a FEMA designated floodplain, so a floodplain development permit will be required. The cost associated with the effort to obtain the permits is included in the project total.

Nebraska Department of Environmental Quality Section 401 certification will be obtained, if applicable.

3. Are you applying for funding for a combined sewer over-flow project?

YES☐ NO☒

If yes, do you have a Long Term Control Plan that is currently approved by the Nebraska Department of Environmental Quality?

YES☐ NO☐

If yes attach a copy to your application. Click here to enter text.

If yes what is the population served by your project? Click here to enter text.

If yes provide a demonstration of need. Click here to enter text.

If yes and you were approved for funding in the most recent funding cycle, then resubmit the above information updated annually but you need not complete the remainder of the application.

4. If you are or are representing an NRD, do you have an Integrated Management Plan in place, or have you initiated one?

N/A☐ YES☒ NO☐

The Lower Loup NRD Integrated Management Plan (approved by NeDNR May 9, 2016) is included in Attachment A.

5. Has this application previously been submitted for funding assistance from the Water Sustainability Fund and not been funded?

YES☐ NO☒

If yes, have any changes been made to the application in comparison to the previously submitted application? N/A
If yes, describe the changes that have been made since the last application. N/A
No, I certify the application is a true and exact copy of the previously submitted and scored application. (Signature required) N/A

6. Complete the following if your project has or will commence prior to next July 1st.

As of the date of submittal of this application, what is the Total Net Local Share of Expenses incurred for which you are asking cost share assistance from this fund? Reimbursement is not being sought as part of this application.

Attach all substantiating documentation such as invoices, cancelled checks etc. along with an itemized statement for these expenses. N/A

Estimate the Total Net Local Share of Expenses and a description of each you will incur between the date of submittal of this application and next July 1st for which you are asking cost share assistance from this fund. The project will not commence until funding is secured. Without funding, the project will not move forward.

Section B.

DNR DIRECTOR'S FINDINGS

Does your project include physical construction (defined as moving dirt, directing water, physically constructing something, or installing equipment)?

YES☒ NO☐

1(a). If yes (structural), submit a feasibility report (to comply with Title 261, CH 2) including engineering and technical data and the following information:

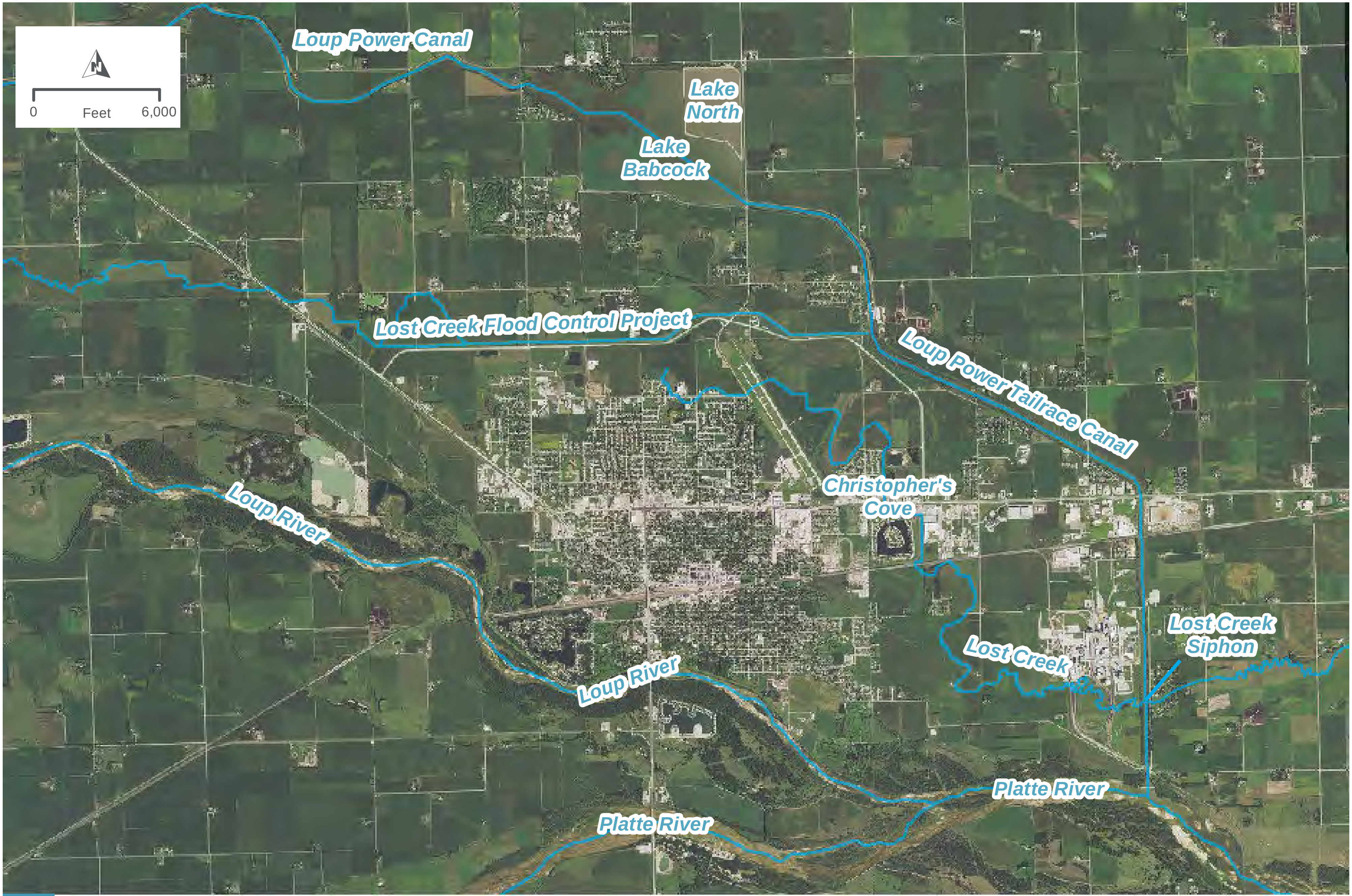
Refer to the following attachments, which are discussed in detail in this section:

- Attachment B: June 2016 Columbus Area Water Resources Assessment Report
- Attachment C: May 3, 2017 Final Report Addendum
- Attachment D: June 22, 2017 Alternative Analysis Summary

A discussion of the plan of development (004.01 A);

The community of Columbus has many demands placed on its water. Major water users in the vicinity of Columbus include the City, agricultural irrigation, and numerous industrial and commercial entities. The City distributes water for public potable supplies, as well as for three golf courses. In the vicinity of Columbus, many farms use groundwater to irrigate their crops. Large commercial and industrial water users that use groundwater for process water include the Archer Daniels Midland (ADM) ethanol plant and Becton, Dickinson and Company (BD). The community also has numerous man-made lakes that were created from gravel mining operations. Several of these lakes have become central water features for residential neighborhoods. As such, the Columbus area has both the largest municipal and commercial water uses within the entire Loup River Basin.

The Lower Loup Natural Resources District (Lower Loup NRD), in coordination with the City of Columbus, Nebraska (City), developed the Columbus Area Water Resources Assessment (CAWRA, or Study) with the goal of understanding the current water resources in the area and determining the feasibility of recharge projects to provide a sustainable water supply. The Study Area is shown in Figure 1.



COLUMBUS AREA RECHARGE PROJECT

STUDY AREA

FIGURE 1

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20170725\CAWRA_FIGURE1.MXD - USER: ASORENSE - DATE: 7/28/2017

The scope of the Study included:

1. Compilation of available hydrologic and geologic data;
2. Inventory of floodplain and stormwater data;
3. Development of an overall water budget;
4. Description of hydrogeology and development of a three-dimensional (3D) subsurface model;
5. Identification and ranking of recharge projects;
6. Research of water management strategies to supplement and stabilize water in Christopher's Cove;
7. Development of a local-scale groundwater model;
8. Identification of potential funding and technical resources.

The results of the Study are providing the Lower Loup NRD and City with information needed to make critical decisions regarding the future sustainability of surface water and groundwater, given the likely increased demands resulting from continued municipal, commercial, and industrial growth.

The hydrogeologic evaluation conducted for the Study indicates relatively steady state groundwater contours in the western and northern portion of the Study Area, with declining groundwater in the southeast portion of the Study Area. This declining groundwater trend began in approximately 2010. A groundwater model was developed and calibrated to assist in identifying the extent of the groundwater decline, as well as identifying potential water sources and recharge/water management projects to mitigate the decline and create a resilient and sustainable water supply for the community.

Several potential recharge locations were evaluated to determine if they were viable options to create a sustainable water resource. Two recharge locations possess the hydrogeologic characteristics, spatial location, and the associated capacity to supplement water to the aquifer and mitigate declining groundwater levels. These locations were evaluated and determined to be viable options to create a sustainable water resource. The two selected recharge locations are:

1. The Lost Creek channel south of Christopher's Cove; and
2. Christopher's Cove (a nearby former sandpit with direct connection to the groundwater).

Several water sources were evaluated for their potential to supply water to the selected recharge locations. The source water identified as the best alternative for groundwater recharge is the return water from ADM that is pumped for their production purposes, and is currently discharged into Loup Public Power District's (LPD) Tailrace Canal. This source water, or an equivalent volume, could be repurposed for aquifer recharge to provide a sustainable water supply. Currently, this return water is conveyed down the Tailrace Canal into the Platte River, and is lost from the system. The recharge project would re-use the return water by ponding the water in the two selected recharge locations, and allowing it to infiltrate into the areas most affected by declining groundwater trends, creating a sustainable approach to reduce groundwater declines.

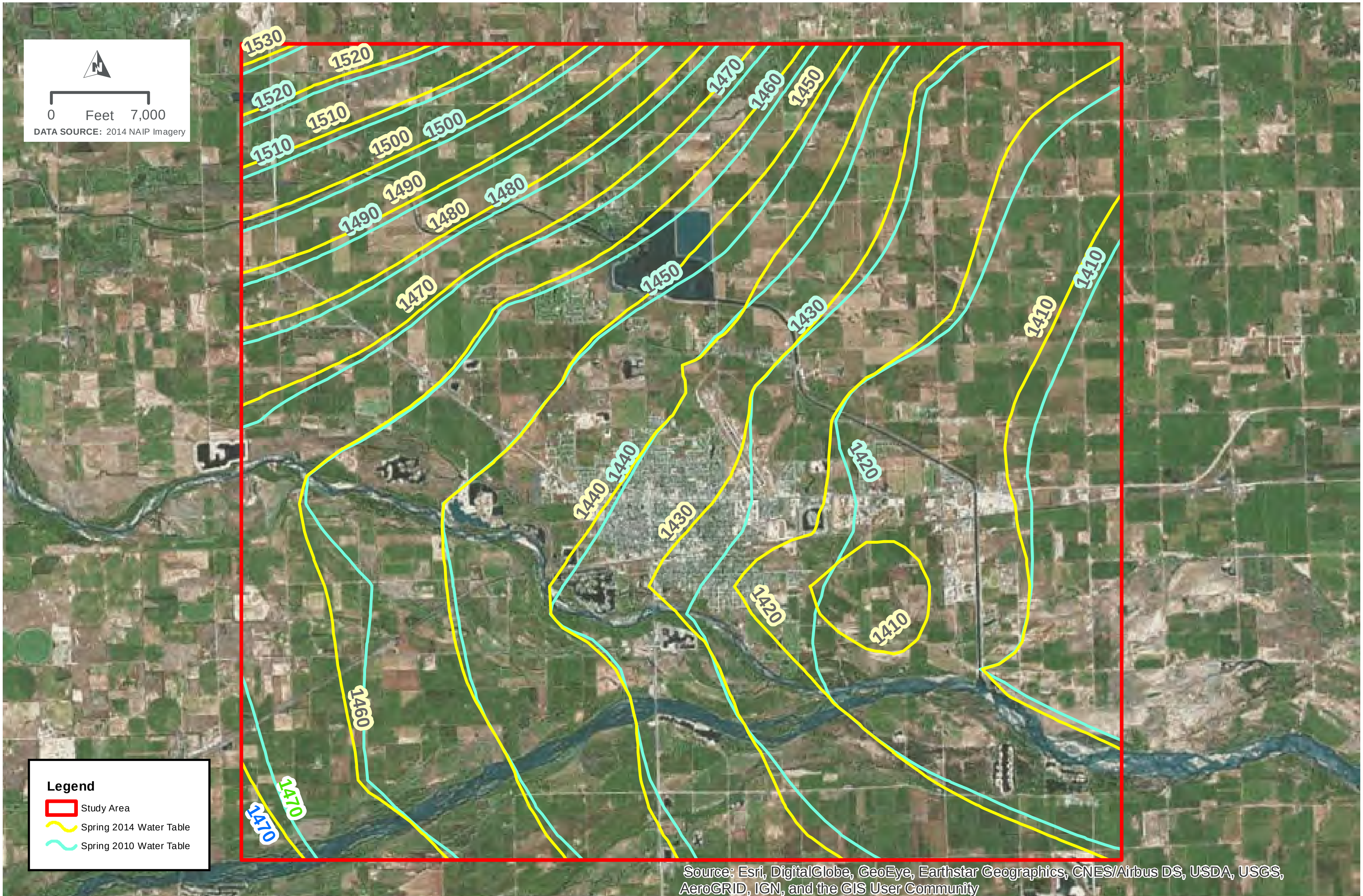
A description of all field investigations made to substantiate the feasibility report (004.01 B);

As part of the Study, a field reconnaissance was conducted that examined the potential recharge water sources and locations for recharging water to the aquifer. A windshield survey was conducted to determine preliminary routes that could move water to recharge areas. The old Lost Creek Channel and Christopher's Cove is located in the area most impacted by water level declines. Drone photographs and video were used to evaluate the size and condition of the old Lost Creek Channel and Christopher's Cove. Confirmation of anticipated locations for pumping equipment and discharge points for recharge water confirmed previously completed desktop analyses.

Maps, drawings, charts, tables, etc., used as a basis for the feasibility report (004.01 C);

The figures developed for the Study demonstrate the locations and magnitude of groundwater declines, recharge site suitability, and potential success of a recharge project.

- Figure 2 presents the water table difference between 2010 and 2014, indicating a groundwater decline in the southeast corner of the Study Area.
- Figure 3 presents the subsurface hydrogeology. The southeast corner of the Study Area contains the significant surface features of the old Lost Creek Channel and Christopher's Cove (a former sandpit mine) which are underlain with primarily gravels and sands, providing an excellent combination for a successful recharge project. The Study utilized groundwater modeling to confirm that the potential infiltration rate using Christopher's Cove and the Lost Creek channel as recharge locations is approximately 2,500 AF/year (2.25 million gallons/day).
- Figure 4 presents the conceptual supply line layout for the recharge locations, utilizing source water from ADM. The Study confirmed that sufficient water exists from ADM pump returns to support the infiltration amount of 2,500 AF/year.
- Figure 5 indicates a downward groundwater trend for the "without project" condition, and an increasing groundwater trend for the "with project" condition.
- Figure 6 shows the potential increase to groundwater levels based on groundwater modeling results. The groundwater contours represent the increase from existing conditions with the recharge project operating.



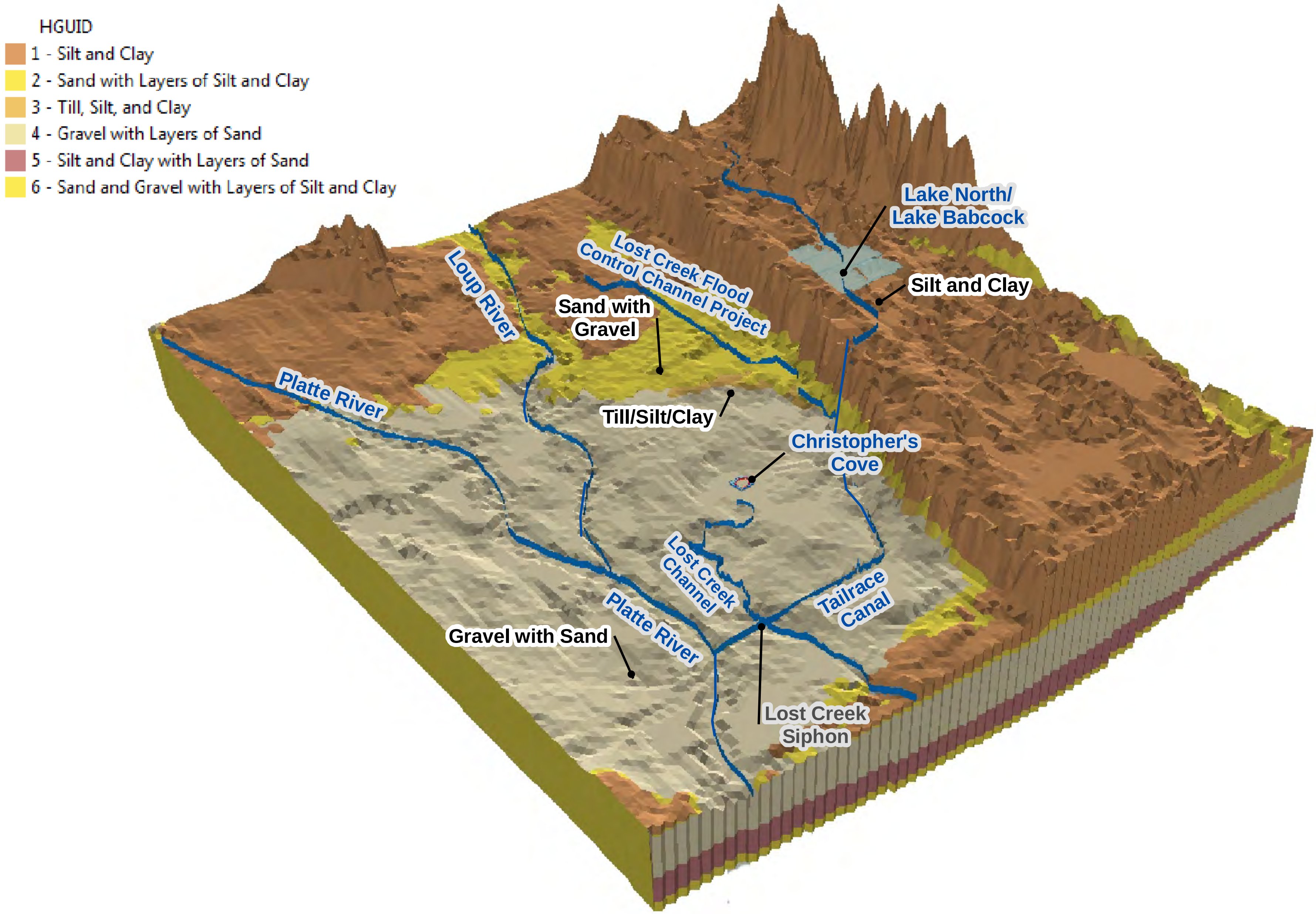
HDR THE FLATWATER GROUP INC. LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA RECHARGE PROJECT

2014 AND 2010 WATER TABLE COMPARISON

FIGURE 2

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20170725\CAWRA_FIGURE2.MXD - USER: ASORENSE - DATE: 7/27/2017



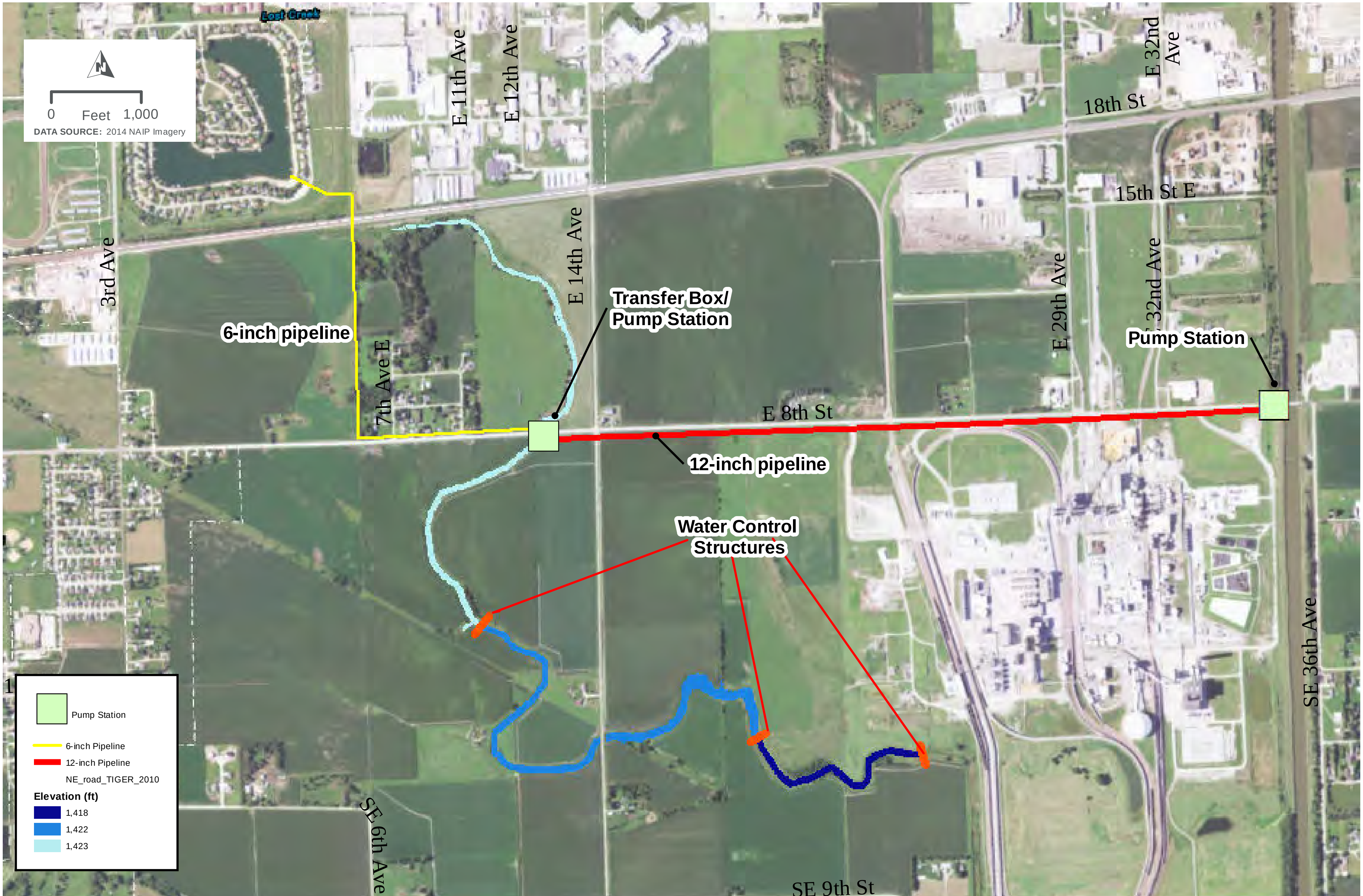
HDR THE FLATWATER GROUP INC. LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA RECHARGE PROJECT

SUBSURFACE CONDITIONS

FIGURE 3

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20170725\CAWRA_FIGURE3.MXD - USER: ASORENSE - DATE: 7/25/2017

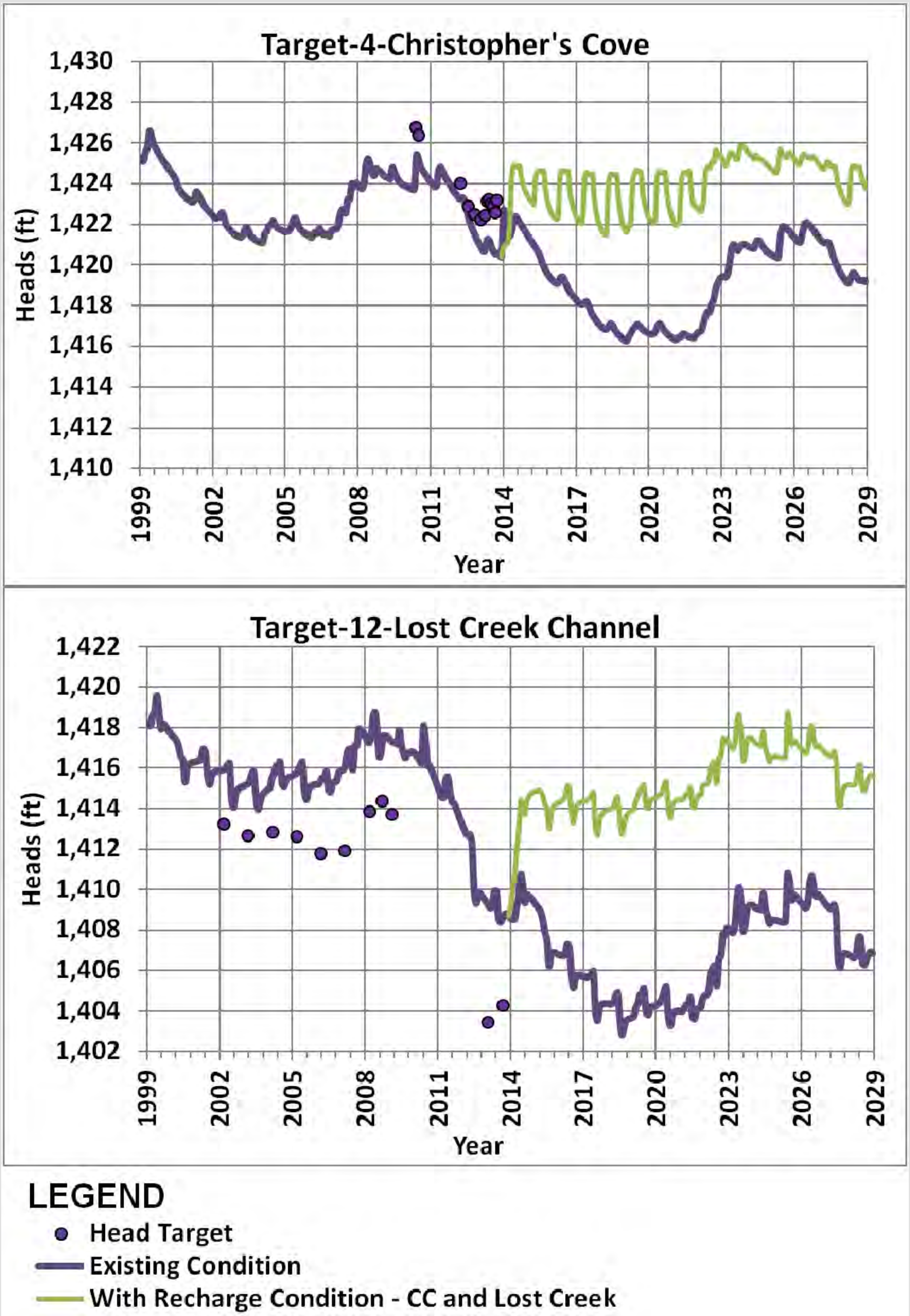


COLUMBUS AREA RECHARGE PROJECT

RECHARGE PROJECT CONCEPTUAL LAYOUT

FIGURE 4

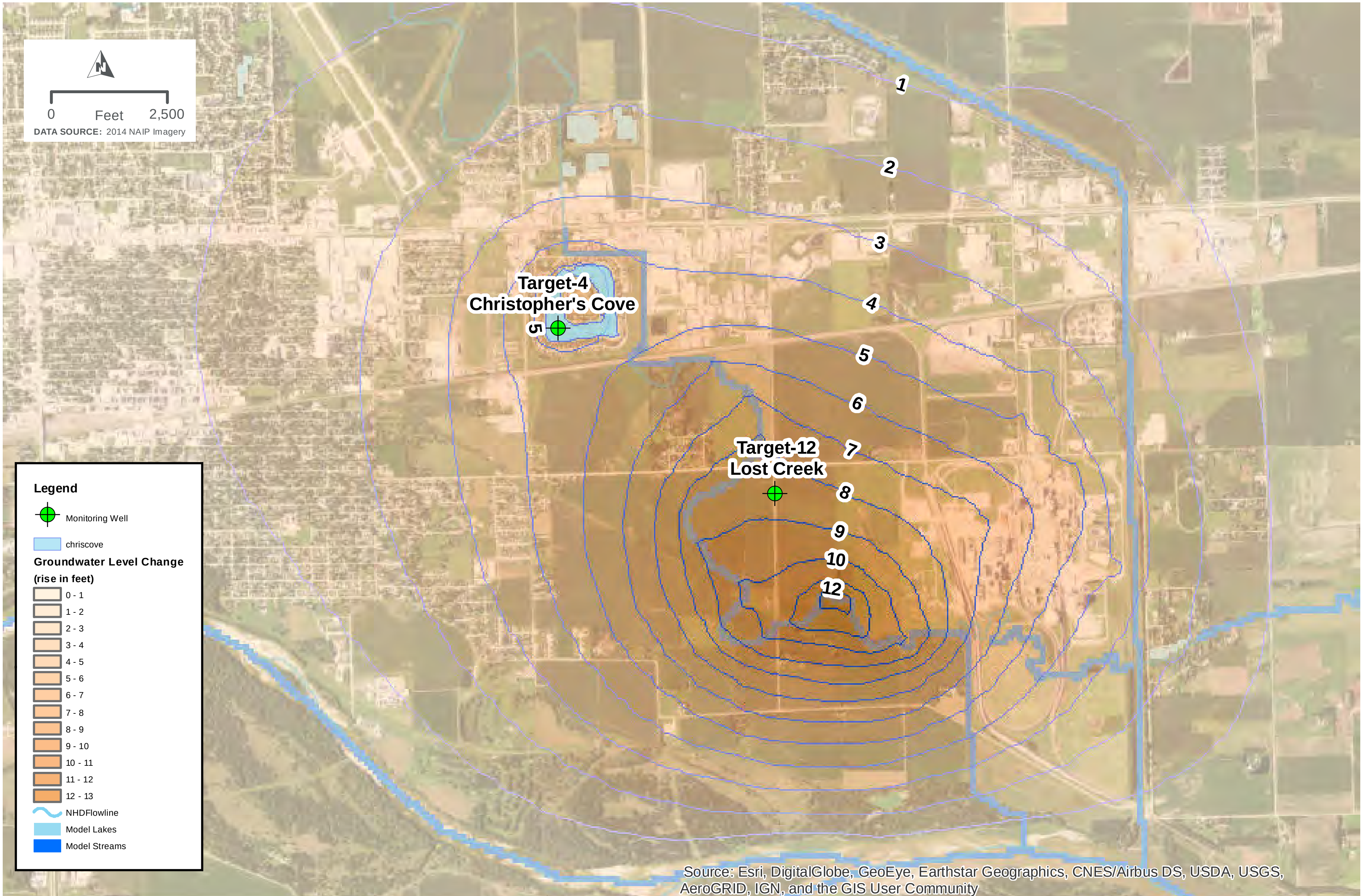
PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20170725\CAWRA_FIGURE4.MXD - USER: ASORENSE - DATE: 7/25/2017



COLUMBUS AREA RECHARGE PROJECT

EXISTING CONDITION VS. WITH RECHARGE CONDITION

FIGURE 5



COLUMBUS AREA RECHARGE PROJECT

GROUNDWATER LEVEL IMPACTS FOR CC & LOST CREEK RECHARGE, AUG 2028

CC HAS 1,000 FT^2/D CONDUCTANCE

FIGURE 6

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20170725\CAWRA_FIGURE6.MXD - USER: ASORENSE - DATE: 7/31/2017

A description of any necessary water and land rights and pertinent water supply and water quality information, if appropriate (004.01 D);

Groundwater data and analysis of the water budget information suggest that the decline in water levels would require a consistent source of water in both quantity and quality to mitigate groundwater deficits. The potential infiltration capacity of the recharge project locations, as determined in the Study is 2,500 AF/Yr, which is approximately 2.25 million gallons/day (MGD). Several water sources were identified in the Study as having a potential to supply water to the selected recharge locations (Attachment B - June 2016 Columbus Area Water Resources Assessment Report, Section 5.4):

1. BD plant wastewater effluent discharge data were obtained using NDEQ reported data. This information suggests about 0.2 MGD of effluent. This amount of water alone would fall short in satisfying the source water requirements. To modify the potential receiving stream location, NDEQ would need to be engaged, which would likely affect discharge standards in order to discharge to Lost Creek and/or Christopher's Cove.

2. The Columbus Wastewater Treatment Plant discharges a significant source of potential recharge water. Nearly 3.5 MGD, or 3,930 acre-feet/year, would be available. However, utilizing this effluent as source water could likely affect discharge standards in order to discharge to Lost Creek and/or Christopher's Cove, and would likely require NDEQ engagement.

3. The ADM plant uses water from the City system as well as groundwater wells near the plant boundary. While no records were available for those privately pumped amounts, it was determined that ADM returns a significant amount of its process water to the Loup Power Canal in the form of wastewater effluent. Records indicate more than 4 to 5.5 MGD (4,380 acre-ft/year to 6,020 acre-ft/year) is discharged. The effluent data and known process water requirements for corn milling would suggest that groundwater pumping could be 1.5 times effluent discharges or more (6 to 8.2 MGD). This information was estimated using discharge monitoring data reported to NDEQ and EPA. This water source is near potential recharge areas and is a viable source of water.

The source water evaluation from the Study indicates that sufficient water exists for recharge through repurposing wastewater effluent from the City and/or ADM. The available water from the City of Columbus or ADM (3.5 MGD to 5 MGD) far exceeds the potential requirements for a recharge project (2.25 MGD). Conceptually, using the ADM discharge would allow the groundwater that was withdrawn to return to its source area in the form of recharge. In addition, the return water for ADM meets NDEQ water quality standards for a receiving stream. Therefore, utilizing return water from ADM is considered the best alternative for source water. However, to avoid potential additional treatment of the ADM effluent for the purpose of ponding for recharge, withdrawal of water from the Loup Power Canal in a similar volume is recommended. The withdrawal of water may not be considered a new diversion because it is only repurposing an effluent discharge that would not otherwise be going into the canal if not for the groundwater pumping required by ADM operations. Coordination with NeDNR will be initiated at project inception to determine water permit requirements.

From a land rights perspective, the City of Columbus has utility easements along the road alignment where the pipes will be installed and a drainage easement for Lost Creek. The project would be constructed on ADM property and Christopher's Cove property, which are both private entities. They are both participating as partners/co-sponsors on this project, so easements should not be an issue. However, a Union Pacific Railroad easement will be required for the pipeline to the Christopher's Cove recharge location.

A discussion of each component of the final plan including, when applicable (004.01 E);

Required geologic investigation (004.01 E 1);
A three-dimensional (3D) subsurface model of the Study Area was developed utilizing existing boring and monitoring data (Attachment B - June 2016 Columbus Area Water Resources Assessment Report, Section 4.0). The 3D model was used to evaluate the hydrogeology within the Study Area (previously presented on Figures 3 and 4 in 004.01 C), support the development of the area water model, and to evaluate potential recharge projects/alternatives within the Study Area. In addition, the geologic units within the Study Area were characterized. Hydrogeologic data within and around the Study Area were compiled from various sources for use in development of the 3D model. The sources included:

1. The University of Nebraska Conservation Survey Division (UNL CSD) and United States Geological Survey (USGS) statewide groundwater level monitoring;
2. UNL CSD test-hole data base;
3. Nebraska Department of Natural Resources (NeDNR) registered groundwater wells data based;
4. City of Columbus;
5. Loup Power District Hydro-electric Project;

6. United States Army Corps of Engineers (USACE) Lost Creek Flood Control Project;
7. NeDNR topographic data; and
8. Soils information from the NRCS web soil survey data.

Geotechnical data will be collected as a component of the design process. Soil samples will be collected at several locations along the old Lost Creek channel to confirm recharge potential along the stream. Geotechnical data will also guide the specifications for pipeline construction, pumping plant facilities, and the design of channel check structure in Lost Creek.

Required hydrologic data (004.01 E 2);

The quantity of water required to mitigate the established groundwater declines and provide a sustainable water resource for the area was estimated in the Study. The hydrogeologic and groundwater modeling tools developed for the project were used to fine-tune the potential recharge amounts. The southeast corner of the Study Area consists primarily of gravels and sands, which is ideal for successful recharge. Two recharge locations were evaluated and selected as the best locations for a recharge project: Lost Creek Channel and Christopher's Cove (shown on Figures 3 and 4). Groundwater modeling performed for the Study indicated that the potential infiltration rate using Christopher's Cove and the Lost Creek channel as recharge locations is approximately 2,500 AF/year (2.25 million gallons/day) (Attachment D - June 22, 2017 Alternative Analysis Summary).

Sufficient water exists to support this infiltration amount (Attachment B: June 2016 Columbus Area Water Resources Assessment Report, Section 5.4). The ADM plant mostly uses water from groundwater wells for processing near the plant boundary. While no records were available for those privately pumped amounts, it was determined that ADM returns a significant amount of its process water to the Loup Power Canal in the form of wastewater effluent. As indicated in the Study, NDEQ records indicate more than 4 to 5.5 MGD (4,380 acre-ft/year to 6,020 acre-ft/year) is discharged. The available water from ADM (3.5 MGD to 5 MGD) far exceeds the potential requirements for a recharge project (2.25 MGD) and would even allow for additional recharge if final design data would indicate higher recharge potential then the conservative ranges used from existing soils information. Using the ADM discharge would allow for the return of groundwater that was withdrawn for processing purposes back to its source area in the form of recharge, and is therefore considered the most beneficial alternative for source water.

No additional data collection or analysis is anticipated in order to conduct a final design.

Design criteria for final design including, but not limited to, soil mechanics, hydraulic, hydrologic, structural, embankments and foundation criteria (004.01 E 3).
The final design for the recharge project will consist of a pump station at the source water, pipelines to convey the water to the recharge locations, energy dissipaters at the outlet of the delivery system, and water control structures to promote infiltration. The design process consists of:

1. Evaluating the utility alignment conflicts to determine the most effective route.
2. Designing the pump and pipeline hydraulics based on the required total dynamic head.
3. Coordinating with the power utility to get sufficient power to the pump station.
4. Evaluating the electrical system to allow for remote operation and monitoring.

A hydraulic analysis will be conducted to size water control structures and to set the elevations of these structures to maximize recharge conditions. The U.S. Army Corps of Engineering HEC-RAS two dimensional model will be used. This model will also be used in connection with geotechnical data to confirm slope and stream stability along the channel.

After construction, a land management plan will be developed to promote infiltration. This will include monitoring locations to minimize potential third party impacts, and identify land practices to maximize infiltration of recharge water.

1(b). If no (non-structural), submit data necessary to establish technical feasibility including, but not limited to the following (004.02):

A discussion of the plan of development (004.02 A);
N/A

A description of field or research investigations utilized to substantiate the project conception (004.02 B); N/A

A description of the necessary water and/or land rights, if applicable (004.02 C); N/A

A discussion of the anticipated effects, if any, of the project upon the development and/or operation of existing or envisioned structural

measures including a brief description of any such measure (004.02 D).
N/A

2. Provide evidence that there are no known means of accomplishing the same purpose or purposes more economically, by describing the next best alternative.
Several surface water recharge locations were evaluated, as described in more detail below. Injection wells using treated wastewater were also evaluated for their ability to mitigate declining groundwater levels; however, due to the likely significant maintenance costs and permitting obstacles, that option was quickly eliminated.

Eight water supply alignment alternatives were evaluated as documented in the Final Report, the Addendum to the Final Report, and the June 22, 2017 Alternative Analysis Summary (provided in Attachments B, C, and D). The alternatives built on the recharge locations detailed in the Study. The alternatives consist of delivering source water from either the Lost Creek Flood Control Channel or LPD's Tailrace Canal, and delivering to Christopher's Cove via a 6" pipeline or to the Lost Creek channel via a 12" pipeline. Considerations for the various alternatives included:

- Cost (capital and O&M);
- Route logistics;
- Source water;
- Discharge locations; and
- Third-party impacts.

Results indicate that costs vary considerably between the alternatives, based primarily on the withdrawal and discharge locations. Route considerations included:

- Piped length;
- Use of overland drainage routes;
- Major and minor road crossings (Highway 30; local streets, parking areas)
- Railroad crossings (Union Pacific Railroad, single track sidings); and
- Development along route.

Routes to Christopher's Cove assume that access would be through the corridor on the southeast corner of the cove.

The Lost Creek Flood Control Channel is used for source water for three of the alternatives. While this water has a lower sediment load than the Loup Power District Tailrace water, which may have an effect on channel sediment loading over time, it is not considered to be a reliable source of water due to flow variability. Two discharge locations were evaluated for four of the alternatives. The discharge locations were Lost Creek Channel north of 8th Street and west of East 14th Avenue, and Lost Creek Channel North of the Union Pacific Railroad.

The Lower Loup NRD Board selected Alternative 3 (See Figure 4) based on location to a reliable water source, closed conduit within City or co-sponsor right of way, and cost per acre-ft of recharged water. Alternative 3 consists of using both Christopher's Cove and the Lost Creek Channel for recharge. A 12" pipeline would deliver water to the Lost Creek channel, and a 6" pipeline would deliver water to the Christopher's Cove.

This recharge project would achieve a Lower Loup NRD IMP goal by working with local government (City of Columbus) to augment water supplies and maintain an efficient and economical balance between current users and future demands within the District. Without this recharge project, a sustainable water supply will not be achieved, thus negatively impacting project sponsors, and administration via regulation may need to be employed. While a regulatory option might achieve some relief, the cost and long-term effect on the community, businesses, and the Lower Loup NRD stakeholders would be mitigated using a sustainable water recharge approach to offsetting groundwater declines in the area.

3. Document all sources and report all costs and benefit data using current data, (commodity prices, recreation benefit prices, and wildlife prices as prescribed by the Director) using both dollar values and other units of measurement when appropriate (environmental, social, cultural, data improvement, etc.). The period of analysis for economic feasibility studies shall be fifty (50) years or with prior approval of the Director, up to one hundred (100) years [T261 CH 2 (005)].

- **Describe any relevant cost information including, but not limited to the engineering and inspection costs, capital construction costs, annual operation and maintenance costs, and replacement costs. Cost information shall also include the estimated construction period as well as the estimated project life (005.01).**

  Preliminary estimated project costs are based on engineering design and construction of a pump station and the delivery of water to the Lost Creek Channel and/or Christopher's Cove. Costs are presented in Attachment E. They include, but are not limited to:

  - General - Mobilization/demobilization, erosion and sediment control, site work/site prep;
  - Water Transfer Pipeline System - Excavation and pipe bedding, 12" PVC pressure pipe and fittings, Pump intake site work, 6000 GPM pump, electrical hookups;

- Water Control Structures – Excavation, embankments, sheet pile, riprap;
- Water Transfer System - Excavation and pipe bedding, 6” PVC pressure pipe and fittings, water transfer, pump intake, 1500 GPM pump, electrical hookups.
- O&M costs (20-yr) are also estimated to arrive at a total probable project cost. Finally, cost for repair, replacement, and rehabilitation of pump equipment are included every 20 years.

The project cost summary is shown in Table 1. It is noted that the funds being applied for in this application are for an assumed 20-year project life for a total cost minus O&M of $2,040,000, which is a reasonable project life for this type of project. However, the Water Sustainability Fund guidance requires a 50-year period of analysis on all proposed projects. To account for the full lifecycle costs of the recharge project, the initial O&M estimate, covering only the first 20 years of the 50 year project life, was converted to an average annual cost. Additionally, cost for repair, replacement, and rehabilitation of pump equipment, which have a useful life of 20 years, are added to the lifecycle costs at regular intervals and discounted to present value. The total present value cost of the project under a 50 year period of analysis is $2.8 million.

Table 1: Project Cost Summary

Cost Component	Project Costs
Implementation Costs	$2,040,000
Annual O&M	$25,659
Repair, Replacement, and Rehabilitation (RR&R) Costs*	$125,000
Present Value OMRR&R	$761,872
Total Discounted Costs	**$2,801,872**

- **Only primary tangible benefits may be counted in providing the monetary benefit information and shall be displayed by year for the project life. In a multi-purpose project, estimate benefits for each purpose, by year, for the life of the project. Describe any intangible or secondary benefits separately. In a case where there is no generally accepted method for calculation of primary tangible benefits describe how the project will increase water sustainability, such that the economic feasibility of the project can be approved by the Director and the Commission (005.02).**
A benefit cost analysis (BCA) was performed to evaluate the benefits of the recharge project. The analysis used guidelines for conducting economic analysis described in the March 2017 Water Sustainability Fund Guidance. All economic damages, benefits and costs use the

base year 2017 dollars. Benefits and costs have been discounted to present value, following a rate of 3 percent over a 50 year period of analysis.

The basic objective of the economic analysis is to determine whether benefits from the recharge project exceed project costs. The BCA compares benefits derived from a comparison of the alternative against a base condition. The alternative consists of the previously described project components.

The following assumptions were used for schedule of costs and benefits of the selected project:

- Construction would be begin in the first year of the period of analysis and would follow a one year construction phase.
- Project operations and maintenance would begin to accrue following the year of construction and continue for 49 years until the end of the period of analysis.
- Project benefits would accrue following the first year of construction and extend for 49 years until the end of the period of analysis.

Tangible benefits of the project include reduced pumping costs from groundwater wells and avoided emissions, specifically criteria air contaminants (CAC) and greenhouse gas (GHG) emissions associated with the production of electricity used to power groundwater well pumps.

Avoided ground water pumping costs were estimated for the City of Columbus downtown water supply wells, the ADM water supply well field, and for irrigation supply wells located in the vicinity of the project. Pumping costs were estimated for the City of Columbus using pumping rates for the downtown wells and power rates from the Loup Power District.

The resulting benefits are presented in Table 2, and the energy calculations for each entity were calculated as follows:

- The downtown City wellfield pumping water levels were reduced by 1 foot from 35 to 34 feet
- Irrigation pumping water levels were reduced by 10 feet from 65 feet to 55 feet
    - Assumes 3 wells pumping 1,000 gallons per minute, using electrical rates from Loup Public Power District
- ADM pumping water levels were also reduced by 10 feet from 65 feet to 55 feet
    - Assumes 7 wells pumping 1,000 gallons per minute, using electrical rates from Loup Public Power District

The recharge project could save up to 223,580 kilowatt hours per year for a total savings of $5.7 million over 50 years.

Table 2: Avoided Ground Water Pumping Costs

Beneficiary	Energy Savings (kwh/year) - Opening Year	First Year of Operation	50-year Present Value at 3% Discount Rate
City of Columbus	16,690	$16,690	$425,700
ADM	205,380	$205,360	$5,237,110
Irrigation Wells	1,510	$170	$4,320
Total	**223,580**	**$222,220**	**$5,667,130**

Reductions in CAC and GHG emissions were estimated for the recharge project. The analysis considers the recharge project results in less energy being used to power ground water wells in the area and therefore will reduce emissions associated with the generation of electricity from the power grid. The air quality impacts are related to power drawn from the electricity grid in the State of Nebraska. Impacts were estimated for criteria air contaminants {sulfur oxide (SOx), and nitrogen oxide (NOx)}, and green house gases {carbon dioxide (CO2), methane (CH4), and nitrous oxide (N20)}. Air quality impacts were estimated from the changes in energy demand by applying:

1. A electricity conversion factor (converts kilowatt hours to tons of pollution for each emission type); and
2. A cost of emission (monetizes the impact).

Data from the EPA eGrid inventories were used to derive a ton/kilowatt hour (KWh) for the Nebraska power grid, these rates are used to convert the electricity requirements for groundwater pumping into tons of emissions. The environmental sustainability benefits associated with reduced GHG and CAC emissions are shown in Table 3.

The recharge project would save up to 44.9 tons per year of emissions for a total savings of $714,000 in environmental damages over 50 years.

Table 3: Environmental Sustainability Benefits of Emission Savings

	Tons of Emissions Avoided - Opening Year	First Year of Operation	50-year Present Value at 3% Discount Rate
CAC Emissions			
SO2	0.0	$900	$43,000
NOx	0.1	$410	$19,440
Subtotal CAC	**0.1**	**$1,310**	**$62,450**
GHG Emissions			
CO2	39.5	$1,580	$75,180
CH4	4.5	$3,810	$181,400
N2O	0.7	$8,300	$394,730
Subtotal GHG	**44.8**	**$13,690**	**$651,320**
Total Emissions Savings	**44.9**	**$15,000**	**$713,770**

The summary of the estimated benefits for the recharge project are presented below in Table 4. The largest benefits are associated with reduced pumping costs to ADM groundwater wells. The total discounted benefits over the 50 year period of analysis are $6.4 million.

Table 4: Summary of Discounted Benefits from the Recharge Project

Long-Term Outcomes	Benefit Categories	50-year Present Value at 3% Discount Rate
Reduced Groundwater Pumping Costs	City of Columbus	$425,700
	ADM	$5,237,110
	Irrigation Wells	$4,320
Environmental Sustainability	Reduced Green House Gas Emissions	$651,320
	Criteria Air Contaminant Reductions	$62,450
Total Benefit Estimates		**$6,380,900**

Factoring in the investment costs of the recharge project, the alternative produces a favorable return of 2.3 dollars for every 1 dollar invested in the project as shown in Table 5. Finally, the recharge projects benefits will exceed the costs by nearly $3.6 million over the next 50 years.

Table 5: Benefit Cost Summary

Project Evaluation Metric	50-year Present Value at 3% Discount Rate
Total Discounted Benefits	$6,380,900
Total Discounted Costs	$2,801,872
Net Present Value	$3,579,000
Benefit / Cost Ratio	2.28

- **All benefit and cost data shall be presented in a table form to indicate the annual cash flow for the life of the proposal, not to exceed 100 years (005.03).**

  See Table 6.

Table 6: Annual Cost and Benefit Cash Flow ($ 000s)

Project Year	PV Factor	Construction Cost	OMRR&R	Total Costs	Reduced GW Pumping Costs	Criteria Air Contaminant Reductions	Reduced Green House Gas Emissions	Total Benefits
1	1.0	$2,040	$0	$2,040	$0	$0	$0	$0
2	1.0	$0	$25	$25	$216	$1	$13	$230
3	0.9	$0	$24	$24	$209	$1	$13	$224
4	0.9	$0	$23	$23	$203	$1	$13	$218
5	0.9	$0	$23	$23	$197	$1	$13	$212
6	0.9	$0	$22	$22	$192	$1	$13	$206
7	0.8	$0	$21	$21	$186	$1	$13	$201
8	0.8	$0	$21	$21	$181	$1	$13	$195
9	0.8	$0	$20	$20	$175	$1	$13	$190
10	0.8	$0	$20	$20	$170	$1	$13	$185
11	0.7	$0	$19	$19	$165	$1	$13	$180
12	0.7	$0	$19	$19	$161	$1	$13	$175
13	0.7	$0	$18	$18	$156	$1	$13	$170
14	0.7	$0	$17	$17	$151	$1	$13	$166
15	0.7	$0	$17	$17	$147	$1	$13	$161
16	0.6	$0	$16	$16	$143	$1	$13	$157
17	0.6	$0	$16	$16	$138	$1	$13	$153
18	0.6	$0	$16	$16	$134	$1	$13	$149
19	0.6	$0	$15	$15	$131	$1	$13	$145
20	0.6	$0	$15	$15	$127	$1	$13	$141
21	0.6	$0	$83	$83	$123	$1	$13	$138
22	0.5	$0	$14	$14	$119	$1	$13	$134
23	0.5	$0	$13	$13	$116	$1	$13	$131
24	0.5	$0	$13	$13	$113	$1	$13	$127
25	0.5	$0	$13	$13	$109	$1	$13	$124
26	0.5	$0	$12	$12	$106	$1	$13	$121
27	0.5	$0	$12	$12	$103	$1	$13	$118
28	0.5	$0	$12	$12	$100	$1	$13	$115
29	0.4	$0	$11	$11	$97	$1	$13	$112
30	0.4	$0	$11	$11	$94	$1	$13	$109
31	0.4	$0	$11	$11	$92	$1	$13	$106
32	0.4	$0	$10	$10	$89	$1	$13	$103
33	0.4	$0	$10	$10	$86	$1	$13	$101
34	0.4	$0	$10	$10	$84	$1	$13	$98
35	0.4	$0	$9	$9	$81	$1	$13	$96
36	0.4	$0	$9	$9	$79	$1	$13	$94
37	0.3	$0	$9	$9	$77	$1	$13	$91
38	0.3	$0	$9	$9	$74	$1	$13	$89
39	0.3	$0	$8	$8	$72	$1	$13	$87
40	0.3	$0	$8	$8	$70	$1	$13	$85
41	0.3	$0	$46	$46	$68	$1	$13	$83
42	0.3	$0	$8	$8	$66	$1	$13	$81
43	0.3	$0	$7	$7	$64	$1	$13	$79
44	0.3	$0	$7	$7	$62	$1	$13	$77
45	0.3	$0	$7	$7	$61	$1	$13	$75
46	0.3	$0	$7	$7	$59	$1	$13	$73
47	0.3	$0	$7	$7	$57	$1	$13	$72
48	0.2	$0	$6	$6	$55	$1	$13	$70
49	0.2	$0	$6	$6	$54	$1	$13	$68
50	0.2	$0	$6	$6	$52	$1	$13	$67
Total PV		**$2,040**	**$762**	**$2,802**	**$5,667**	**$62**	**$651**	**$6,381**

This recharge project will provide several intangible benefits starting with a local group working together to find a way to develop water sustainability and resolve a local concern. There is a broader benefit to the state as this type of project could act as an example for other NRDs and communities with similar water supply concerns. While not easily calculated in monetary terms, the project will help to promote a healthy and sustainable groundwater resource, develop a greenway space along the recharge zone, and avoid conflict among water users.

The project will include a monitoring component that will collect data on the results and efficiency of the recharge. This information will be used to evaluate any unforeseen or negative effects and allow for the adjustment of system operations. Data collected will be informative to others that may be evaluating the efficiency of the project for water sustainability.

This project is an innovative use of water sources and recharge that allows a local group to develop a sustainable water resource, all while achieving the Lower Loup NRD IMP goal of working with local government (City of Columbus) to augment water supplies and maintain an efficient and economical balance between current users and future demands within the District. Having a group come together and find solutions to water problems is the very thing Water Sustainability Fund was developed to help do.

- **In the case of projects for which there is no generally accepted method for calculation of primary tangible benefits and if the project will increase water sustainability, the economic feasibility of such proposal shall be demonstrated by such method as the Director and the Commission deem appropriate (005.04).**

N/A

4. **Provide evidence that sufficient funds are available to complete the proposal.**

The Lower Loup NRD has budgeted the funds necessary to support the Districts portion of the funding requirement. Additionally, Letters of Support from Archers Daniels Midland Company, City of Columbus, and Christopher's Cove Association are included with this application in Attachment F, providing the remainder of the funding required.

5. Provide evidence that sufficient annual revenue is available to repay the reimbursable costs and to cover OM&R (operate, maintain, and replace).

The commitment to participate at the current funding rate from the Lower Loup NRD and the other partners includes the O&M as figured in the project budget.

6. If a loan is involved, provide sufficient documentation to prove that the loan can be repaid during the repayment life of the proposal.

The application is for a grant, not a loan, therefore, no additional information is provided.

7. Describe how the plan of development minimizes impacts on the natural environment.

The goal of the recharge project is to offset the current groundwater decline. Water levels resulting from the recharge project are not anticipated to be higher than those observed prior to the deficit occurring, and thus are not expected to have an impact to the natural environmental or local residences and/or businesses.

To monitor potential impacts to the natural environment, local residences and/or businesses, a real time monitoring program will be implemented that consists of groundwater level wells and stream gages. Paired wells will provide observation of shallow and deeper water levels and provide an indicator of infiltration efficiency. On Lost Creek, a stream gage located at the downstream end of the project will be used to estimate the metered discharge water's efficiency in being recharged. Recharge rates and volumes will be adjusted using the data collected. Recharge source water will be controlled based on the monitoring indicators.

The recharge water will enhance the old Lost Creek channel. Currently, the channel does not achieve reliable streamflows, as a result of a former rerouting process. Through this recharge project, the natural environment will be enhanced as the project matures with anticipated improvements to the stream channel and associated biota. Water level control structures will allow flood events to pass and can be adjusted to accommodate wet and dry cycles that may affect recharge rates.

For example, in a wet cycle, system discharge might need to be curtailed if infiltration rates indicate the need for a temporary reduction. The elevation of the check structures within Lost Creek will be initially established at elevations that are not anticipated to cause localized impacts to homes. The check structure elevations could be adjusted as necessary based on the monitoring data. If there is a higher stage in the channel it would still flow through Lost Creek and to its confluence with the Platte River. Impact to the area around Christopher Cove is not anticipated as the water level would not be higher than those previously observed (prior to the deficit). Groundwater levels in and around the Christopher's Cove area historically did not have any known impacts, therefore it is not anticipated that using Christopher's Cove as a recharge zone would cause issues.

8. **Explain how you are qualified, responsible and legally capable of carrying out the project for which you are seeking funds.**

The Lower Loup NRD has the statutory responsibility to manage surface and groundwater. The existing Groundwater Management Plan and the Integrated Management Plan along with the Rules and Regulations supporting those plans, supply the legal capability and statutory requirements to allow the District to conduct and support this project. The Lower Loup NRD has contracted with HDR Inc. and its subconsultants the Flatwater Group and JEO Consulting Group to conduct the engineering and supply the expertise to design the project.

9. Explain how your project considers plans and programs of the state and resources development plans of the political subdivisions of the state.

This project has a direct correlation to the Integrated Management plans Goals and Objectives developed by the Lower Loup NRD and NeDNR to "Develop and implement water use policies and practices that prioritize and contribute to the protection of existing surface and groundwater uses while allowing for future water development". (see Attachment A, Lower Loup Natural Resources District Integrated Management Plan).In addition, the City of Columbus, a co-sponsor on this project, provided input on the project with respect to stormwater master planning and floodplain development.

10. Are land rights necessary to complete your project?

YES☐ NO☒

The City of Columbus has utility easements along the road alignment where the pipes will be installed and a drainage easement for Lost Creek. ADM and Christopher's Cove are private properties, and they are both participating as partners/co-sponsors on this project. An easement from UPRR and Loup Power District will be required. The City and ADM, as co-sponsors, have the easement information.

If yes, provide a complete listing of all lands involved in the project.
N/A

If yes, attach proof of ownership for each easements, rights-of-way and fee title currently held.

N/A

If yes, provide assurance that you can hold or can acquire title to all lands not currently held.
N/A

11. Identify how you possess all necessary authority to undertake or participate in the project.

The authority needed to conduct this project comes from the support of the project co-sponsors, the statutory authority of the NRD to manage Surface and Groundwater, the authorities granted to the City of Columbus through Zoning and existing easements.

12. Identify the probable environmental and ecological consequences that may result as the result of the project.

Creating a recharge project using the Lost Creek Channel will change the conditions of the channel from an intermittently flowing channel to a permanently inundated riparian corridor. Currently, Lost Creek Channel has flow during precipitation and subsequent runoff events. The project would create an impounded body of water within the channel banks. This will result in a change of habitat type and use. Existing habitat and correlating use is terrestrial species and, depending on the duration of flow, temporarily used by aquatic species. The project would provide a year-round water source, providing permanent aquatic resource habitat. This change in habitat type would not be detrimental to the ecosystem and would provide more aquatic habitat then currently exists.

Section C.

NRC SCORING

In the NRC's scoring process, points will be given to each project in ranking the projects, with the total number of points determining the final project ranking list.

The following 15 criteria constitute the items for which points will be assigned. Point assignments will be 0, 2, 4, or 6 for items 1 through 8; and 0, 1, 2, or 3 for items 9 through 15. Two additional points will be awarded to projects which address issues determined by the NRC to be the result of a federal mandate.

Notes:

- The responses to one criterion ***will not*** be considered in the scoring of other criteria. Repeat references as needed to support documentation in each criterion as appropriate. The 15 categories are specified by statute and will be used to create scoring matrixes which will ultimately determine which projects receive funding.

- There is a total of 69 possible points, plus two bonus points. The potential number of points awarded for each criteria are noted in parenthesis. Once points are assigned, they will be added to determine a final score. The scores will determine ranking.

- The Commission recommends providing the requested information and the requests are not intended to limit the information an applicant may provide. An applicant should include additional information that is believed will assist the Commission in understanding a proposal so that it can be awarded the points to which it is entitled.

Complete any of the following (15) criteria which apply to your project. Your response will be reviewed and scored by the NRC. Place an N/A (not applicable) in any that do not apply, an N/A will automatically be placed in any response fields left blank.

1. **Remediates or mitigates threats to drinking water;**
   - Describe the specific threats to drinking water the project will address.
   - Identify whose drinking water, how many people are affected, how will project remediate or mitigate.
   - Provide a history of issues and tried solutions.
   - Provide detail regarding long range impacts if issues are not resolved.

   The proposed recharge project will assist with mitigating potential threats to drinking water, as detailed below.

   - Describe the specific threats to drinking water the project will address.

Prior to 1993, the City of Columbus relied on the wellfield located in downtown Columbus. However, increased demand required development of an additional wellfield located north of town and south of Lake Babcock. While there are no specific threats to drinking water at this time, the proposed recharge project would increase the available water to the original Columbus well field, thus assisting in maintaining a sustainable water source.

- Identify whose drinking water, how many people are affected, how will project remediate or mitigate.

The downtown well field supports a substantial portion of the downtown and central part of Columbus. In addition, there are approximately two dozen private wells within the current groundwater decline area that are impacted by declining groundwater levels. Implementation of the proposed recharge project will provide a sustainable source of water for the entire community. Without the project, additional wellfield expansion may be required.

- Provide a history of issues and tried solutions.

The City was required to develop the north wellfield in 1993 to augment flows provided by the downtown wellfield.

- Provide detail regarding long range impacts if issues are not resolved.

Without this recharge project, a sustainable water supply may not be achieved without regulation from the Lower Loup NRD. Should this project not go forward and groundwater declines continue, the potential exists for the requirement of additional wellfield development. In addition, the private wells in the area may become inoperable, cost more to operate, or may need to be drilled deeper.

There could be increasing uncertainty as to the future of the municipal drinking water supply. Administration via regulation may need to be employed long-term if the project is not implemented. Although a regulatory option might achieve some relief, the community, businesses, and the Lower Loup NRD stakeholders will achieve a sustainable drinking water source to offset groundwater declines in the area by implementing this project.

2. Meets the goals and objectives of an approved integrated management plan or ground water management plan;

- Identify the specific plan that is being referenced including date, who issued it and whether it is an IMP or GW management plan.
- Provide the history of work completed to achieve the goals of this plan.
- List which goals and objectives of the management plan the project provides benefits for and how the project provides those benefits.

The proposed recharge project meets the goals and objectives of an approved integrated management plan, as detailed below.

- Identify the specific plan that is being referenced including date, who issued it and whether it is an IMP or GW management plan.

The Lower Loup NRD has an approved Integrated Management Plan (IMP). The Plan was developed by the Lower Loup NRD, NeDNR and a Stakeholders Advisory Committee and approved May 9, 2016. The purpose of the IMP is to achieve and sustain a balance between water uses and water supplies within the Lower Loup NRD for the long term. The Stakeholder Advisory Committee, working with the Lower Loup NRD and NeDNR, developed an appropriate set of goals, objectives, and action items for the IMP that facilitate sustainable water management in the NRD.

- Provide the history of work completed to achieve the goals of this plan.

The Lower Loup NRD Board of Directors had been operating under a new well moratorium since 2005 and a moratorium on the expansion of irrigated acres since 2008. However, the approval of the IMP with NeDNR in 2016 has established a limit on the expansion of groundwater-irrigated acres and surface water-irrigated acres. Because the IMP was only recently approved, this project will be one of the first to directly work towards achieving the goals of the plan.

- List which goals and objectives of the management plan the project provides benefits for and how the project provides those benefits.

The following IMP goals are addressed with this project:
Goal 2: Implement this water management plan to maintain an efficient and economical balance between current and future water supplies and demands. Objective 2.1: Collaborate with state and local governments to identify opportunities of augment water supplies within the district and, if necessary, identify opportunities to supplement with imported water from outside the District.

This project would achieve this goal through working with local government (City of Columbus) to augment water supplies and maintain and efficient and economical balance between current users and future demands within the Lower Loup NRD.

Goal 3: Develop and implement water use policies and practices that prioritize and contribute to the protection of existing surface and groundwater uses while allowing for future water development. Objective 3.1: Identify available water storage opportunities throughout the District.

This recharge project has identified a storage opportunity that would protect existing water uses while allowing for future development.

3. Contributes to water sustainability goals by increasing aquifer recharge, reducing aquifer depletion, or increasing streamflow;

List the following information that is applicable:

- The location, area and amount of recharge;
- The location, area and amount that aquifer depletion will be reduced;
- The reach, amount and timing of increased streamflow. Describe how the project will meet these objectives and what the source of the water is;
- Provide a detailed listing of cross basin benefits, if any.

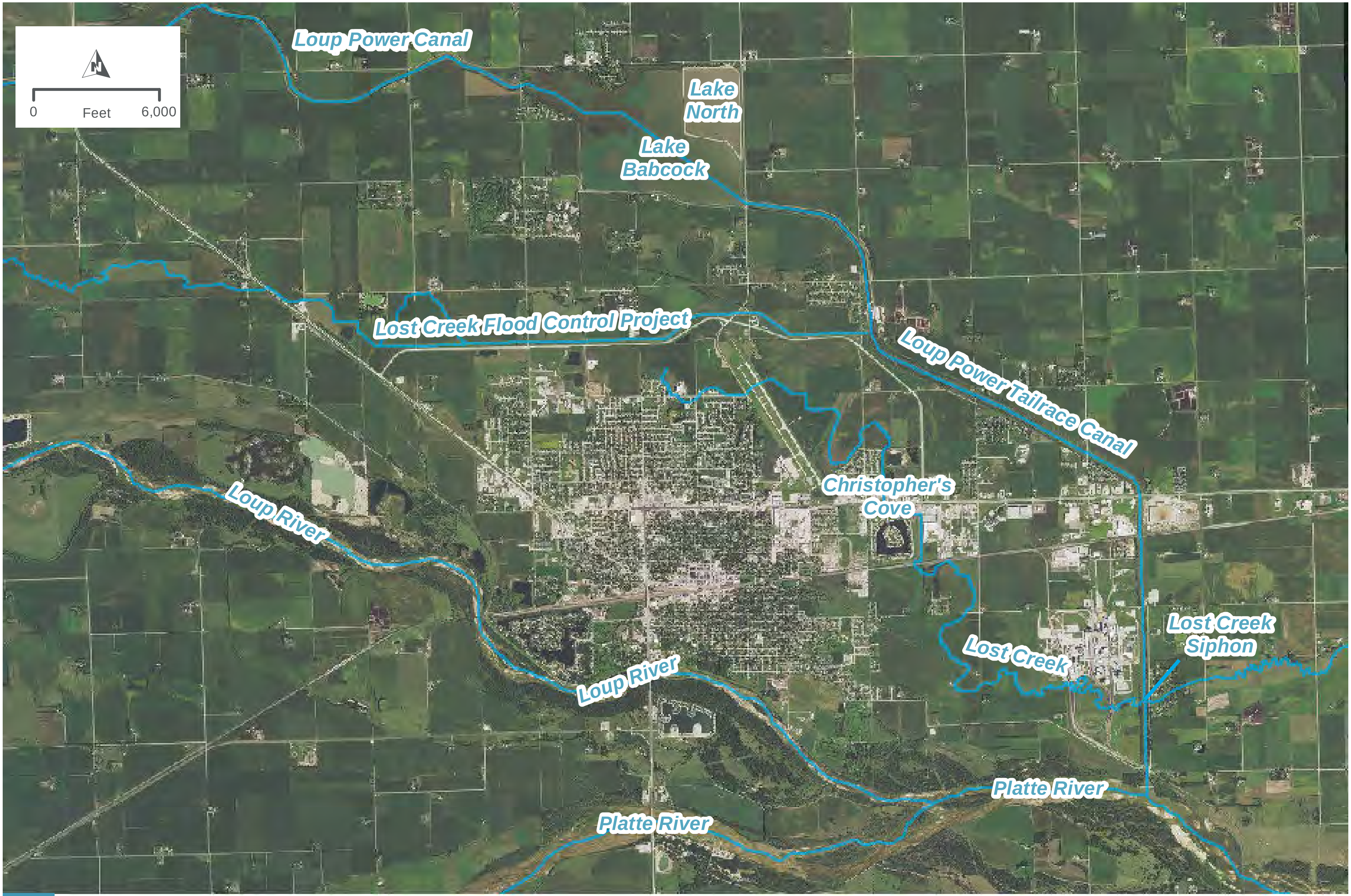
The recharge project contributes to sustainability by increasing aquifer recharge, reducing aquifer depletion or increasing streamflow, as discussed in detail below.

- The location, area and amount of recharge;
- The location, area and amount that aquifer depletion will be reduced;

The Columbus Area Water Resources Assessment (CAWRA, or Study) – Final Report (June 2016) presented in Attachment B, prepared for the Lower Loup NRD, presented the findings of an assessment of water resources available in the Columbus area (Figure 1). The Study concluded that there were significant water sources in the Study Area (Figure 1) (Attachment B: June 2016 Columbus Area Water Resources Assessment Report, Section 5.4). Evaluation of the hydrogeology within the Study Area indicates relatively steady state groundwater contours in the western and northern portion of the Study Area. However, a declining groundwater trend was identified in the southeast portion of the Study Area beginning in approximately 2010 (Figure 2) (Attachment B: June 2016 Columbus Area Water Resources Assessment Report, Section 4.2.1).

A groundwater model was developed and calibrated to assist in identifying the extent of the groundwater decline, as well as identifying potential water sources and recharge/water management projects to reduce the decline. Potential project alternatives were identified that have the hydrogeologic characteristics, spatial location, and the associated capacity to supplement water to the aquifer (recharge locations). Through evaluation in the Study, these alternatives were determined to be viable options for reducing the groundwater decline. The proposed recharge project will use the following recharge locations (Figure 3):

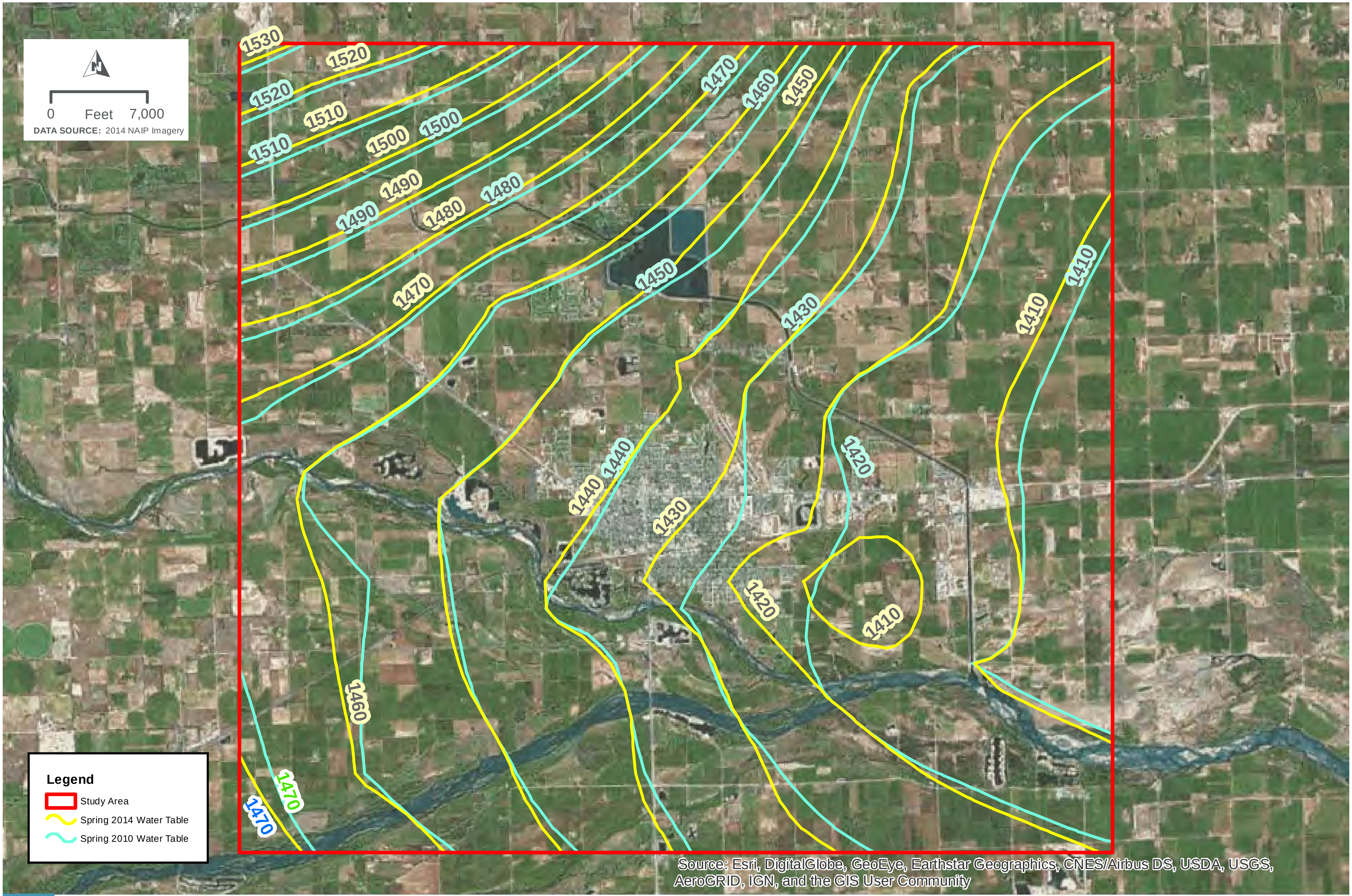
1. The Lost Creek channel south of Christopher's Cove; and
2. Christopher's Cove.



COLUMBUS AREA RECHARGE PROJECT

STUDY AREA

FIGURE 1



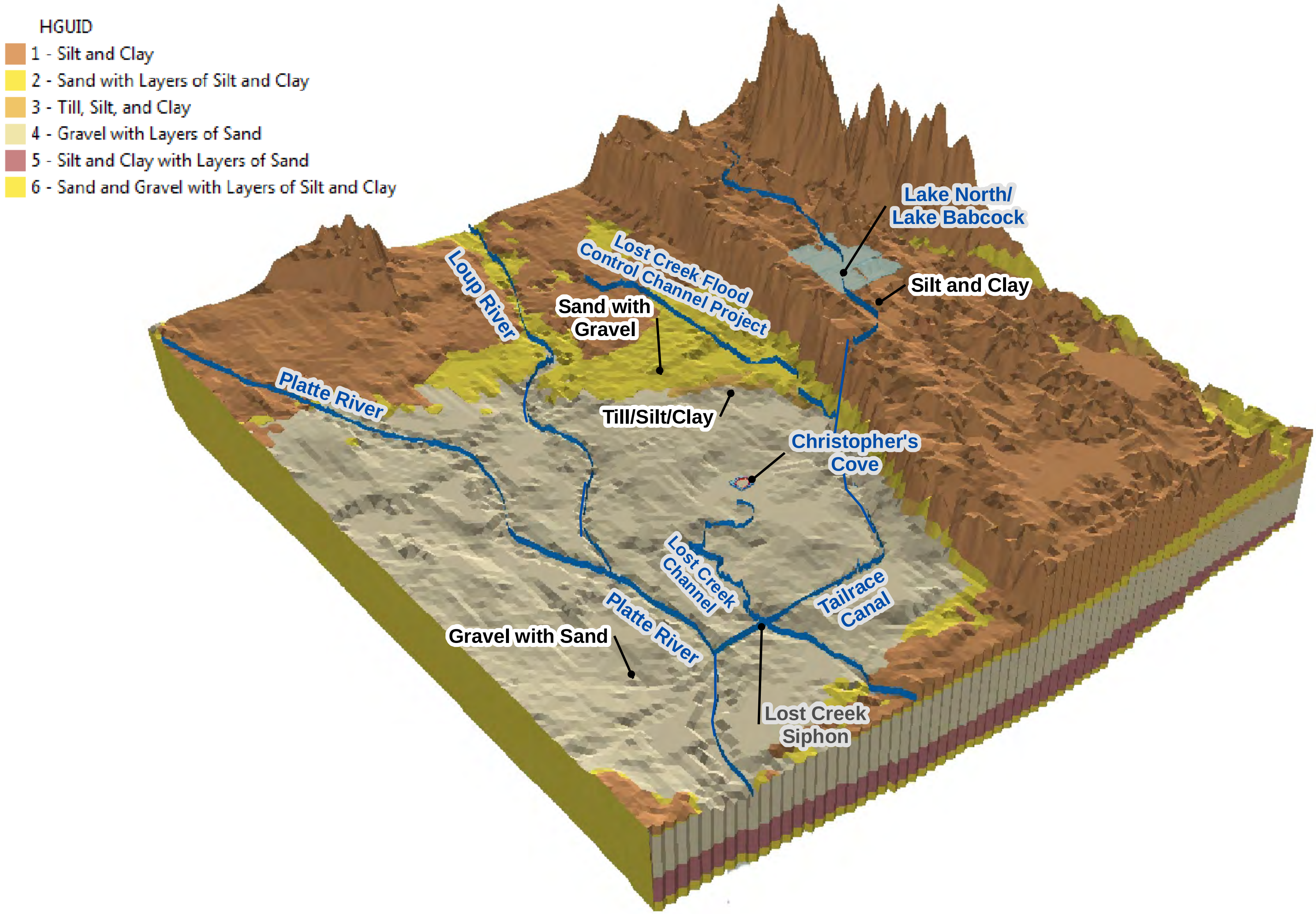
HDR THE FLATWATER GROUP INC. LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA RECHARGE PROJECT

2014 AND 2010 WATER TABLE COMPARISON

FIGURE 2

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20170725\CAWRA_FIGURE2.MXD - USER: ASORENSE - DATE: 7/27/2017



HDR | THE FLATWATER GROUP INC. | JEO | LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA RECHARGE PROJECT

SUBSURFACE CONDITIONS

FIGURE 3

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20170725\CAWRA_FIGURE3.MXD - USER: ASORENSE - DATE: 7/25/2017

A conceptual layout of the proposed recharge project is shown in Figure 4. The source water identified for groundwater recharge is the return water from ADM that is pumped from the local groundwater for their production purposes, and is discharged into Loup Public Power District's (LPD's) Tailrace Canal after their use. This source water, or an equivalent volume, will be repurposed for aquifer recharge. Currently, this return water is conveyed down the Tailrace Canal into the Platte River, and is lost from the system. The recharge project would re-use the return water by ponding the water within Lost Creek Channel and Christopher's Cove and allowing it to infiltrate into the water table, thus creating a sustainable approach to reduce groundwater declines. Based on the ground water model, the potential annual recharge due to this project is approximately 2,500 AF/Yr (Attachment D: June 22, 2017 Alternative Analysis Summary).

Figures 5 and 6 show the expected water level increases between the existing condition and with the project in place (Attachment B: June 2016 Columbus Area Water Resources Assessment Report, Section 6.7). The groundwater modeling shows:

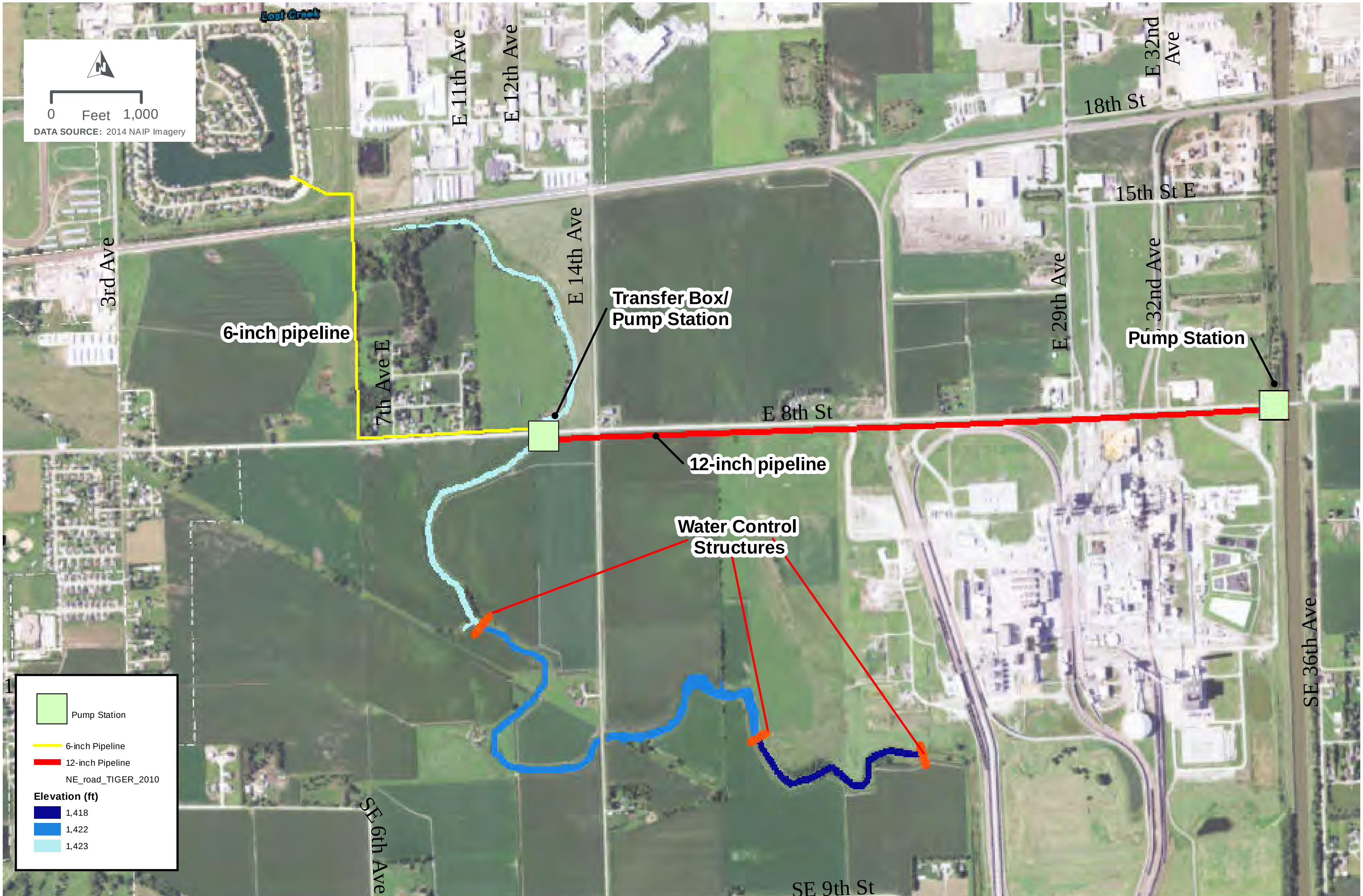
- Groundwater levels would rise approximately 10 ft to 12 ft in the vicinity of the Lost Creek, approximately 2 ft to 5 ft in Christopher's Cove, approximately 10 ft in the ADM well field and at decreasing amounts farther away from the creek;
- Under existing conditions, water is discharged into the aquifer from the Tailrace Canal. That discharge would decrease as much as 15 percent, which means more water will be conveyed into the lower Platte River; and
- A filling rate ranging from about 3.5 to 7.5 acft/d and averaging about 6.2 acft/d.

The hydrologic benefits of this project provide opportunities to use two recharge locations to reduce groundwater declines that currently exists and creating a sustainable and resilient water supply for the Columbus area.

- The reach, amount and timing of increased streamflow. Describe how the project will meet these objectives and what the source of the water is;
- Provide a detailed listing of cross basin benefits, if any.

The project will be returning a volume of water that is currently being withdrawn from the groundwater system directly back to the aquifer helping to create a more sustained groundwater resource. A water volume that is currently discharged to the canal tailrace as wastewater will now be recharged to the aquifer.

The project will create improved groundwater levels, reducing canal tailrace losses to the aquifer and likely increasing tailrace discharge to the Platte River.



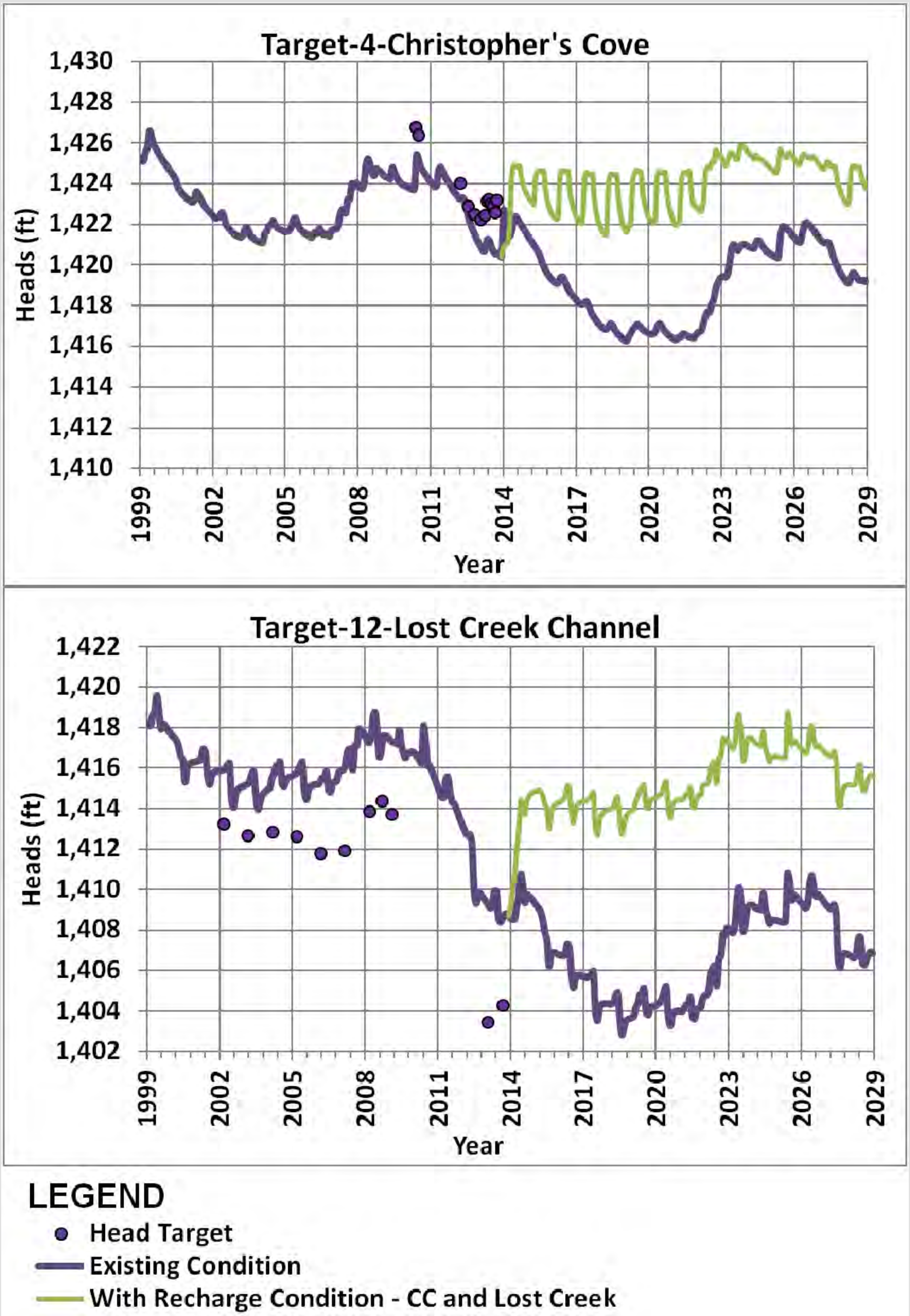
HDR | THE FLATWATER GROUP INC. | JEO | LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA RECHARGE PROJECT

RECHARGE PROJECT CONCEPTUAL LAYOUT

FIGURE 4

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20170725\CAWRA_FIGURE4.MXD - USER: ASORENSE - DATE: 7/25/2017

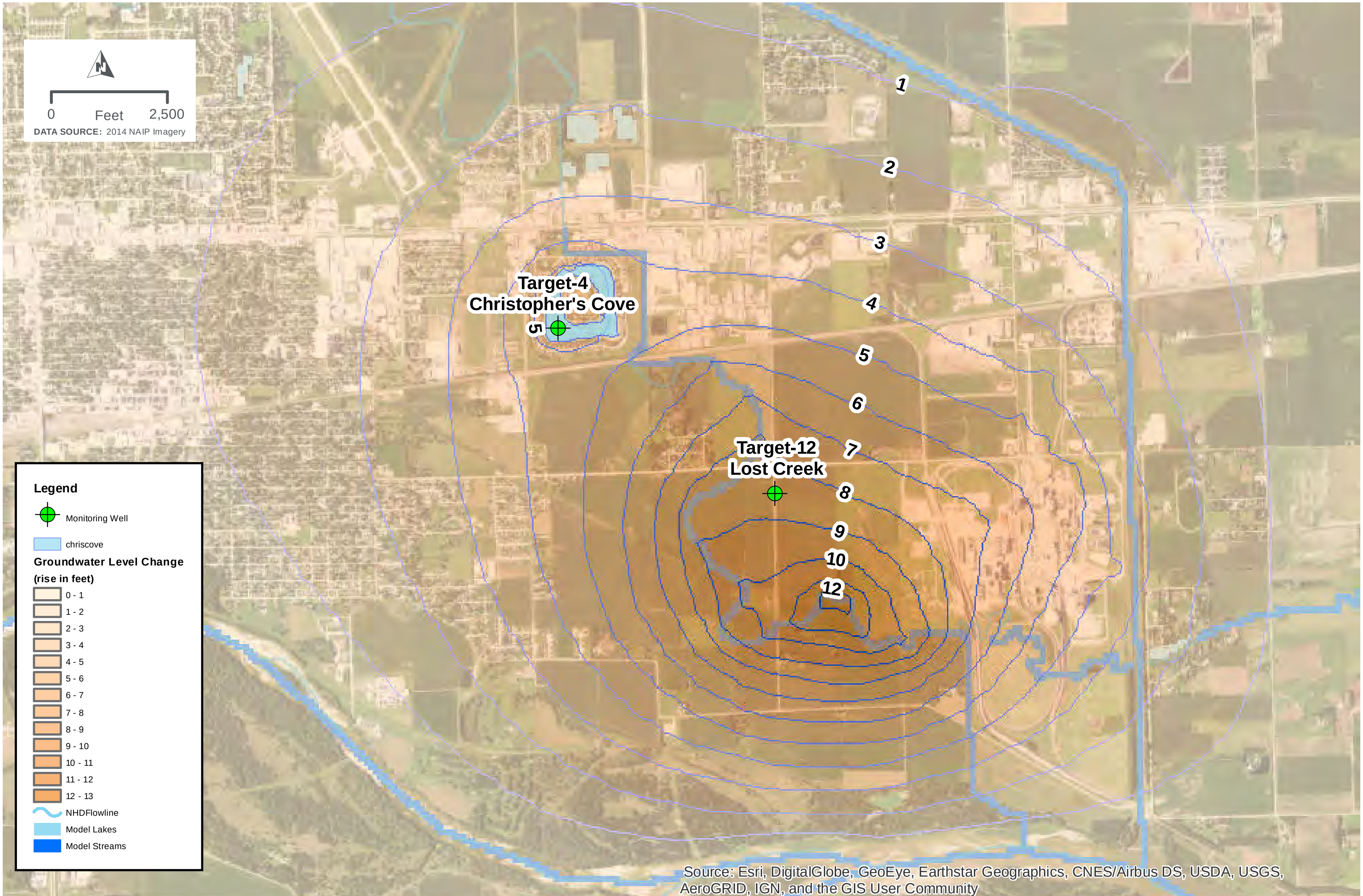


COLUMBUS AREA RECHARGE PROJECT

EXISTING CONDITION VS. WITH RECHARGE CONDITION

FIGURE 5

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20170725\CAWRA_FIGURE51.MXD - USER: ASORENSE - DATE: 7/25/2017



HDR | THE FLATWATER GROUP INC. | JEO | LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA RECHARGE PROJECT

GROUNDWATER LEVEL IMPACTS FOR CC & LOST CREEK RECHARGE, AUG 2028

CC HAS 1,000 FT^2/D CONDUCTANCE

FIGURE 6

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20170725\CAWRA_FIGURE6.MXD - USER: ASORENSE - DATE: 7/31/2017

4. Contributes to multiple water supply goals, including, but not limited to, flood control, agricultural use, municipal and industrial uses, recreational benefits, wildlife habitat, conservation of water resources, and preservation of water resources;

- List the goals the project provides benefits.
- Describe how the project will provide these benefits
- Provide a long range forecast of the expected benefits this project could have versus continuing on current path.

The proposed recharge project will contribute to multiple supply goals, as detailed below.

- List the goals the project provides benefits.

The primary goal of this project is to mitigate declining groundwater levels in the Study Area through a sustainable approach to water supply. As a result, the benefits provided to the entire community include the following, which are described below:

  - Municipal, agricultural, and industrial water supply certainty.
  - Increased flood control and improved water quality.
  - Additional recreational opportunities.
  - Increased wildlife habitat.
  - Conservation and preservation of the groundwater resource.
  - Reduced pumping costs and avoided emissions.
  - Collaboration among project partners to develop a sustainable source of supply that resolves a local concern.

- Describe how the project will provide these benefits

This project will seek to accomplish this goal, and the associated benefits shown below, through:

  - **Municipal, agricultural, and industrial water supply certainty.** Municipal, industrial, and agriculture will see direct benefits of an improved water supply by returning a portion that is lost from the system to the aquifer through the recharge project.
  - **Increased flood control and improved water quality.** The project will provide ancillary flood control and water quality within the old Lost Creek Channel. Flood control would be improved by providing a clear and well maintained channel that, while promoting infiltration, can also efficiently convey stormwater. During dry weather, the proposed water control structures will be designed to pond water, allowing for nutrients to settle out.

- **Additional recreational opportunities.** The corridor includes the potential for recreation by incorporating an adjacent trail in a "green" corridor that is currently zoned for industry and agriculture.
- **Increased wildlife habitat**. The recharge project will provide a "green" corridor within an area currently zoned primarily for industry and agriculture. This corridor will provide improved habitat. It addition, the project will increase the amount of permanent aquatic habitat available within the region.
- **Conservation and preservation of the groundwater resource.** This sustainable approach conserves and preserves the groundwater for generations through a sustainable solution.
- **Reduced pumping costs and avoided emissions, specifically, criteria air contaminants (CAC) and greenhouse gas (GHG) emissions.** Additional tangible benefits of the project include reduced pumping from groundwater wells resulting in lower power costs, avoided emissions, specifically criteria air contaminants (CAC) and greenhouse gas (GHG) emissions associated with the production of electricity used to power groundwater well pumps, as presented in Tables 7 and 8.

Table 7: Avoided Ground Water Pumping Costs

Beneficiary	Energy Savings (kwh/year) - Opening Year	First Year of Operation	Over the Project Lifecycle – 50 years
City of Columbus	16,690	$16,690	$425,700
ADM	205,380	$205,360	$5,237,110
Irrigation Wells	1,510	$170	$4,320
Total	**223,580**	**$222,220**	**$5,667,130**

Table 8: Environmental Sustainability Benefits of Emission Savings

	Tons of Emissions Avoided - Opening Year	First Year of Operation	Present Value Discounted at 3 Percent
CAC Emissions			
SO2	0.0	$900	$43,000
NOx	0.1	$410	$19,440
Subtotal CAC	**0.1**	**$1,310**	**$62,450**
GHG Emissions			
CO2	39.5	$1,580	$75,180
CH4	4.5	$3,810	$181,400
N2O	0.7	$8,300	$394,730
Subtotal GHG	**44.8**	**$13,690**	**$651,320**
Total Emissions Savings	**44.9**	**$15,000**	**$713,770**

- **Collaboration among project partners to develop a sustainable source of supply that resolves a local concern.** This project is an innovative use of water sources and recharge that allows a local group to develop a sustainable water resource, all while achieving the Lower Loup NRD IMP goal of working with local government (City of Columbus) and industry (ADM) to augment water supplies and maintain an efficient and economical balance between current users and future demands within the Lower Loup NRD. Having a group come together and find solutions to water problems is the very thing Water Sustainability Fund was developed to help do.

- Provide a long range forecast of the expected benefits this project could have versus continuing on current path.

While presenting a long range forecast of the expected benefits is difficult, given the uncertainties of hydrologic conditions, population growth, and other important factors, there are several identifiable benefits of implementing project actions versus following the status quo.

The long-term benefits of the project include a sustainable source of water for agricultural irrigation. Wildlife habitat will benefit by increasing the amount of permanent aquatic habitat available within the region. Pumped water will be conserved by recycling. Less water will be withdrawn from the canal due to increased available water volume (Attachment B: June 2016 Columbus Area Water Resources Assessment Report, Section 6.7.1.2).

If the project is not built, groundwater levels can be expected to remain degraded and likely continue a downward trend, as determined in the Study (Attachment B: June 2016 Columbus Area Water Resources Assessment Report, Section 6.4.1) and shown in Figure 5. The Lower Loup NRD IMP goal of working with local government (City of Columbus) to augment water supplies and maintain an efficient and economical balance between current users and future demands within the Lower Loup NRD will have to be met with ways that directly contradict the tenants of the Water Sustainably Fund.

The past 14 year hydrologic cycle was simulated for the “without project” condition, while maintaining current pumping. The current declining downward trend continued, taking the water table to unprecedented levels. The proposed recharge significantly reduces this decline. With the project, groundwater modeling shows an improvement in water table level of 8 ft to 12 ft, as presented in Figures 5 and 6 (Attachment D: June 22, 2017 Alternative Analysis Summary).

This project is an innovative use of water sources and recharge that allows a local group to develop a sustainable water resource, all while achieving the Lower Loup NRD IMP goal of working with local government (City of Columbus) and local industry (ADM) to augment water supplies and maintain an efficient and economical balance between current users and future demands within the Lower Loup NRD. Having a group come together and find solutions to water problems is the very thing Water Sustainability Fund was developed to help do.

5. Maximizes the beneficial use of Nebraska's water resources for the benefit of the state's residents;

- Describe how the project will maximize the increased beneficial use of Nebraska's water resources.
- Describe the beneficial uses that will be reduced, if any.
- Describe how the project provides a beneficial impact to the state's residents.

The proposed recharge project will maximize the beneficial use of Nebraska's water resources for the benefit of the state's residents, as detailed below.

- Describe how the project will maximize the increased beneficial use of Nebraska's water resources.

The proposed recharge project will maximize the increased beneficial use of the water resources in the Columbus area. A water volume that is now lost due to waste water discharge, will essentially be recycled back into the aquifer allowing for the highest and most beneficial uses including municipal/industrial and agriculture. This project is an innovative use of water sources and recharge that will allow groundwater levels to improve over the long-term. This in turn creates a more reliable and sustainable water resources for the citizens, industry, and agricultural in and around Columbus. Columbus is a thriving community that relies on a clean and abundant water supply. Columbus's industry and agricultural provides and economic boost to the region and the state as a whole.

- Describe the beneficial uses that will be reduced, if any.

No specific reductions in beneficial uses have been identified as part of this project.

- Describe how the project provides a beneficial impact to the state's residents.

The project would have clear beneficial impacts to the State's residents, due in part to the geographic location included under the project. The Lower Loup River Basin is home to thousands of businesses and industries, and recreation. This diverse group of water needs would likely all benefit from a sustainable solution to mitigate declining groundwater levels.

Additionally, this project will demonstrate a way for others in the state to bring together multiple interests to solve local water supply problems. Government and private interests are standing together in developing an innovative and long-term solution to an issue that cannot be left unattended.

Providing a reliable source to mitigate groundwater decline, and making the source sustainable, will allow for significant and sustained industrial and agricultural capital investment. Continued growth in Columbus provides increased tax revenues in Columbus that will benefit the entire state.

6. Is cost-effective;

- List the estimated construction costs, O/M costs, land and water acquisition costs, alternative options, value of benefits gained.
- Compare these costs to other methods of achieving the same benefits.
- List the costs of the project.
- Describe how it is a cost effective project or alternative.

The proposed recharge project will maximize the beneficial use of Nebraska's water resources for the benefit of the state's residents, as detailed below.

- List the estimated construction costs, O/M costs, land and water acquisition costs, alternative options, value of benefits gained.

Preliminary estimated project costs are based on engineering design and construction of a pump station and the delivery of water to the Lost Creek Channel and/or Christopher's Cove. Land and water acquisition costs are not anticipated. Costs are presented in Table 9.

Table 9: Conceptual Estimate of Probable Construction Cost

COLUMBUS AREA WATER RESOURCES ASSESSMENT					
WATER SUPPLY PROJECT					
Conceptual Estimate of Probable Construction Cost					
Alternative 3 (Combined Alts. 1 and 2)					
12" Pipe from Canal East of ADM plant along East 8th Street to Lost Creek (8,300 feet); 6" Pipe Continue to Christopher Cove (5,400 feet)					
ACTIVITY	**UNIT**	**UNIT COST**	**QUANTITY**	**COST**	
General					
Mobilization/Demobilization	LS	$24,011.27	1	$24,011.27	
Construction Survey	LS	$19,209.02	1	$19,209.02	
Site Security (construction fence, barricades, etc.)	LS	$4,802.25	1	$4,802.25	
Erosion and Sediment Control	LS	$19,209.02	1	$19,209.02	
General Site Work/Site Prep	LS	$19,209.02	1	$19,209.02	
Subtotal					**$86,400.00**
Water Transfer Pipeline System - 12"					
Excavation, Backfill and Removal of Spoil, Compaction	LF	$16.20	8,300	$134,460.00	
Pipe Bedding; Bank Sand	LF	$18.00	8,300	$149,400.00	
12" PVC Pressure Pipe Class 150, SDR 18, AWWA C900	LF	$30.50	8,300	$253,150.00	
12" PVC Pressure Pipe Fittings	LS	$12,657.50	1	$12,657.50	
Pump Intake Site Work (incl. pipe and screen)	LS	$6,000.00	1	$6,000.00	
6000 GPM Centrifigal Pump, Motor/Generator, Controls	EA	$100,000.00	1	$100,000.00	
Electrical Hookup (pole, transformer, hookup)	LS	$20,000.00	1	$20,000.00	
Outlet Site Work	LS	$2,500.00	1	$2,500.00	
Site Restoration	LS	$1,200.00	1	$1,200.00	
Subtotal					**$679,300.00**
Creek Stabilization/Check Structures (3)					
Excavation	CY	$9.64	300	$2,892.89	
Excavation Disposal	CY	$4.06	225	$913.50	
Embankments/Fills	CY	$4.06	75	$304.50	
Steel Sheet Piling	SF	$17.98	1,440	$25,888.90	
Type B Rip-Rap	TON	$55.00	504	$27,720.00	
Site Restoration (seeding and erosion protection)	EA	$5.00	750	$3,750.00	
Subtotal					**$61,400.00**
Water Transfer Pipeline System - 6"					
Excavation, Backfill and Removal of Spoil, Compaction	LF	$13.85	5,400	$74,790.00	
Pipe Bedding; Bank Sand	LF	$10.16	5,400	$54,864.00	
6" PVC Pressure Pipe Class 150, SDR 18, AWWA C900	LF	$12.85	5,400	$69,390.00	
6" PVC Pressure Pipe Fittings	LS	$3,469.50	1	$3,469.50	
Water Transfer from 12" to 6"	LS	$15,000.00	1	$15,000.00	
Pump Intake Site Work (incl. pipe and screen)	LS	$6,500.00	0	$0.00	
1500 GPM Centrifigal Pump, Motor/Generator, Controls	EA	$25,000.00	0	$0.00	
Electrical Hookup (pole, transformer, hookup)	LS	$15,000.00	0	$0.00	
Outlet Site Work	LS	$1,100.00	1	$1,100.00	
Site Restoration	LS	$1,000.00	1	$1,000.00	
Subtotal					**$219,600.00**
ESTIMATED CONSTRUCTION COST SUBTOTAL					**$1,046,700.00**
CONCEPT LEVEL CONTINGENCY 50%		50.00%			**$523,300.00**
TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION					**$1,570,000.00**
ENGINEERING DESIGN AND MANAGEMENT		25.00%			**$392,000.00**
ENVIRONMENTAL CLEARANCES/PERMITS		5.00%			**$78,000.00**
20 YEAR O&M COSTS (2.5% DISCOUNT RATE)					**$400,000.00**
TOTAL ESTIMATED PROBABLE PROJECT COST					**$2,440,000.00**

Costs include, but are not limited to:

- General - Mobilization/demobilization, erosion and sediment control, site work/site prep;
- Water Transfer Pipeline System - Excavation and pipe bedding, 12” PVC pressure pipe and fittings, Pump intake site work, 6000 GPM pump, electrical hookups;
- Water Control Structures – Excavation, embankments, sheet pile, riprap;
- Water Transfer System - Excavation and pipe bedding, 6” PVC pressure pipe and fittings, water transfer, pump intake, 1500 GPM pump, electrical hookups.
- O&M costs (20-yr) are also estimated to arrive at a total probable project cost. Finally, cost for repair, replacement, and rehabilitation of pump equipment are included every 20 years.

It is noted that the funds being applied for in this application are for an assumed 20-year project life for a total cost minus O&M of $2,040,000, which is a reasonable project life for this type of project. However, the Water Sustainability Fund guidance requires a 50-year period of analysis on all proposed projects, which was completed as part of Section B, DNR’s Directors Findings of this application.

The tangible benefits gained from project implementation include reduced pumping costs from groundwater wells and avoided emissions. The specific emissions are criteria air contaminants (CAC) and greenhouse gas (GHG) emissions associated with the production of electricity used to power groundwater well pumps. The pumping cost and avoided emissions benefits are summarized in Tables 7 and 8 presented earlier in Section C, Part 4. Details of the analysis are provided in Section B, DNR Director’s Findings, Part 3 (005.02).

- Compare these costs to other methods of achieving the same benefits.

The recharge locations closest in proximity to the project were selected. There were no other locations in the study are that had the direct impact that the Lost Creek channel or Christopher’s Cove recharge locations provided. Injection wells were only qualitatively evaluated, however, due to the likely significant maintenance costs, that option was quickly eliminated.

Eight water supply alignment alternatives were evaluated as documented in the Final Report, the Addendum to the Final Report, and the June 22, 2017 Alternative Analysis Summary. The alternatives built on the recharge locations detailed in the Study. The alternatives consist of delivering source water from either the Lost Creek Flood Control Channel or LPD’s Tailrace Canal, and delivering to Christopher’s Cove via a 6” pipeline or to the Lost Creek channel via a 12” pipeline. Considerations for the various alternatives included:

- Cost (capital and O&M);
- Route logistics;
- Source water;

- Discharge locations; and
- Third-party impacts.

Results indicate that costs vary considerably between the alternatives, based primarily on the withdrawal and discharge locations. Route considerations included:

- Piped length;
- Use of overland drainage routes;
- Major and minor road crossings (Highway 30; local streets, parking areas)
- Railroad crossings (Union Pacific Railroad, single track sidings); and
- Development along route.

Routes to Christopher's Cove assume that access would be through the corridor on the southeast corner of the cove.

The Lost Creek Flood Control Channel is used for source water for three of the alternatives. While this water has a lower sediment load than the Loup Power District Tailrace water, which may have an effect on channel sediment loading over time, it is not considered to be a reliable source of water due to flow variability. Two discharge locations were evaluated for four of the alternatives. The discharge locations were Lost Creek Channel north of 8th Street and west of East 14th Avenue, and Lost Creek Channel North of the Union Pacific Railroad.

Two of the alternatives resulted in slightly less cost per Acre/FT of recharge water, however, each alternative required the use of open channel flow over two miles through developed areas to convey water to the recharge location, which results in greater third party impacts.

The Lower Loup NRD Board selected Alternative 3 (See Figure 4) based on location to a reliable water source, closed conduit within City or co-sponsor right of way, and cost per acre-ft of recharged water. Alternative 3 consists of using both Christopher's Cove and the Lost Creek channel for recharge. A 12" pipeline would deliver water to the Lost Creek channel, and a 6" pipeline would deliver water to the Christopher's Cove.

- List the costs of the project.

The costs of the selected recharge project, Alternative 3, are identified in Table 9.

- Describe how it is a cost effective project or alternative.

The Lower Loup NRD Board selected Alternative 3 based on location to a reliable water source, maximizing potential recharge locations within the groundwater level decline area (Lost Creek Channel and Christopher's Cove), minimizing third party impacts by a closed conduit within City or co-sponsor right of way, and cost per acre-ft of recharged water. This recharge project would achieve a Lower Loup NRD IMP goal by working with local government (City of Columbus) to augment water supplies and maintain an efficient and economical balance between current users and future demands within the Lower Loup NRD. Without this recharge project, a sustainable water supply will not be achieved, thus negatively impacting project sponsors, and administration via regulation may need to be employed. While a regulatory option might achieve some relief, the cost and long-term effect on the community, businesses, and the Lower Loup NRD stakeholders would be mitigated using a sustainable water recharge approach to offsetting groundwater declines in the area.

7. Helps the state meet its obligations under interstate compacts, decrees, or other state contracts or agreements or federal law;

- Identify the interstate compact, decree, state contract or agreement or federal law.
- Describe how the project will help the state meet its obligations under compacts, decrees, state contracts or agreements or federal law.
- Describe current deficiencies and document how the project will reduce deficiencies.

The proposed recharge project helps the state meet its obligations under interstate compacts, decrees, and other state contracts or agreements, as detailed below.

- Identify the interstate compact, decree, state contract or agreement or federal law.

The State of Nebraska is not currently party to an interstate agreement for the Lower Platte River; however, the Central Platte River is subject to the Platte River Recovery and Implementation Program (PRRIP).

- Describe how the project will help the state meet its obligations under compacts, decrees, state contracts or agreements or federal law.

Groundwater modeling from the Study suggests that the project may result in increased Loup tailrace discharges as a result of improved groundwater levels, therefore reducing tailrace losses to the aquifer (Attachment B: June 2016 Columbus Area Water Resources Assessment Report, Section 6.7.1.2).

- Describe current deficiencies and document how the project will reduce deficiencies.

As previously stated, the State of Nebraska is not currently party to an interstate agreement for the Lower Platte River.

8. Reduces threats to property damage or protects critical infrastructure that consists of the physical assets, systems, and networks vital to the state or the Untied States such that their incapacitation would have a debilitating effect on public security or public health and safety;

- Identify the property that the project is intended to reduce threats to.
- Describe and quantify reductions in threats to critical infrastructure provided by the project and how the infrastructure is vital to Nebraska or the United States.
- Identify the potential value of cost savings resulting from completion of the project.
- Describe the benefits for public security, public health and safety.

The proposed recharge project helps reduce threats to property damage and protects critical infrastructure, as detailed below.

- Identify the property that the project is intended to reduce threats to.

This project will protect multiple properties from various effects. The in-stream weirs will provide stability to the streambed of Lost Creek, protecting adjacent properties, including nearby roads, bridges, railroad tracks, and utilities from erosion. Additionally, using Christopher's Cove as a recharge location will have a side benefit of maintaining Christopher's Cove water levels. This allows for existing infrastructure and property uses to be maintained so that the lake is deep enough for safe recreation. Ultimately, this helps to secure property values and maintains the functions of critical infrastructure.

Stream erosion, downcutting, and bank stability is a serious threat across the entire state, including in the project area. The erosion and migration of a stream places nearby infrastructure at risk, and can eventually destroy infrastructure. Protecting roads, bridges, utilities, railroads and other stream crossings prior to an emergency is not only cheaper, but it mitigates future losses. The cost for repairing and replacing bridges or other infrastructure is very high and the environmental permitting requirements associated with large streambank stabilization projects is very challenging.

This project will stabilize the streambed of Lost Creek, protecting two (2) road crossings, two (2) local streets, Union Pacific Railroad tracks, and nearby utilities, at a minimum.

The project will reduce the impact that groundwater pumping has on the local aquifer. By increasing water tables and arresting declining groundwater levels, the project will help maintain the function of existing infrastructure in the area. The project will protect critical infrastructure, such as the City of Columbus's public water supply wellfield, the replacement cost of which would be approximately $1,400,000. This will help to maintain the security of potable water for City residents, as well as public health and safety.

- Identify the potential value of cost savings resulting from completion of the project.

The project provides a potential cost savings to the county, the city, businesses, homeowners, and other landowners by mitigating future stream erosion, maintaining the existing lake levels, and protecting the groundwater aquifer which is used for domestic, industrial, and agricultural benefits. Increased water levels will directly reduce the cost to pump groundwater for municipal, industrial, and agricultural uses, as shown in Table 7 presented earlier in Section C, Part 4.

- Describe the benefits for public security, public health and safety.

The project provides a public safety benefit by mitigating future impact and losses to critical public and private infrastructure within the project area.

9. Improves water quality;

- Describe what quality issue(s) is/are to be improved.
- Describe and quantify how the project improves water quality, what is the target area, what is the population or acreage receiving benefits, what is the usage of the water: residential, industrial, agriculture or recreational.
- Describe other possible solutions to remedy this issue.
- Describe the history of the water quality issue including previous attempts to remedy the problem and the results obtained.

The primary purpose of the recharge project is to reverse groundwater declines and create a more reliable and sustainable resource. While not a specific issue, water quality Lost Creek Channel will improve as the modifications to Lost Creek will provide the City an opportunity to convey stormwater into the channel, which will improve the overall water quality of the drainage. Fringe wetlands will be supported and improve source water filtration, removing sediment from the water column and improving the overall water quality of any water that reaches the Platte River.

10. Has utilized all available funding resources of the local jurisdiction to support the program, project, or activity;

- Identify the local jurisdiction that supports the project.
- List current property tax levy, valuations, or other sources of revenue for the sponsoring entity.
- List other funding sources for the project.

The proposed recharge project has utilized available funding resources, as detailed below.

- Identify the local jurisdiction that supports the project.

The Lower Loup NRD will be the local sponsor for the proposed recharge project. This project includes a partnership with Archer Daniel Midlands Company, the City of Columbus and Christopher's Cove Association.

- List current property tax levy, valuations, or other sources of revenue for the sponsoring entity.

The Lower Loup NRD acting as the sponsor had a total valuation of $16,163,384,468 in FY2017. The Lower Loup NRD had a levy of .03399 dollars with a total Budget of $12,067,358 in FY2017.

- List other funding sources for the project.

The funding sources that would make up the matching portion (40%) of the proposed project would include $571,200 from Archer Daniels Midland Company, $163,200 from the Lower Loup NRD and $81,600 from the City of Columbus and Christopher's Cove Association.

In addition, each co-sponsor/partner has committed to providing O&M funding for the 20-year project life. ADM and Lower Loup NRD have committed $280,000 and $80,000, respectively, while the City and Christopher's Cove have committed $40,000. The combined total of the matching and O&M between the co-sponsors/partners is $1,216,000.

11. Has a local jurisdiction with plans in place that support sustainable water use;

- List the local jurisdiction and identify specific plans being referenced that are in place to support sustainable water use.
- Provide the history of work completed to achieve the goals of these plans.
- List which goals and objectives this project will provide benefits for and how this project supports or contributes to those plans.
- Describe and quantify how the project supports sustainable water use, what is the target area, what is the population or acreage receiving benefits, what is the usage of the water: residential, industrial, agriculture or recreational.
- List all stakeholders involved in project.
- Identify who benefits from this project.

The proposed recharge project has a local jurisdiction with plans in place that support sustainable water use, as detailed below.

- List the local jurisdiction and identify specific plans being referenced that are in place to support sustainable water use.

The Lower Loup NRD has a Groundwater Management Plan that has been in effect since 1985 (provided in Attachment A). The Plan includes the Goal of *"It Shall be the Goal of the Lower Loup Natural Resources District to maintain a perpetual source of groundwater for all uses – domestic, agricultural, and industrial."*

- Provide the history of work completed to achieve the goals of these plans.

To achieve this goal the Lower Loup NRD has implemented a static water level monitoring program, divided the Lower Loup NRD into 10 water quantity sub-areas, and developed groundwater models to support this goal. The Lower Loup NRD has also placed a self-imposed moratorium on new irrigation well development and new irrigated acres and additionally has required well meters within a water quality area. There is also a large water user rule that requires an industry (water user) that wants to pump over 500 ac ft./yr. or expand 250 ac ft./yr. over their current use, to do a Hydrogeologic impact study to determine the effects of the pumping on groundwater and surface water prior to obtaining a well permit.

The Lower Loup NRD has also adopted a Voluntary Integrated Management Plan with the Nebraska Department of Natural Resources to allow groundwater and surface water to be managed conjunctively. A goal of the plan is to "Develop and implement water use policies and practices that prioritize and contribute to the protection of existing surface and groundwater uses while allowing for future water development" with the objective to "Identify available water storage opportunities throughout the Lower Loup NRD" which includes groundwater recharge with aquifer storage. This project would allow aquifer recharge to protect current groundwater and surface water uses and could allow for additional development.

- Describe and quantify how the project supports sustainable water use, what is the target area, what is the population or acreage receiving benefits, what is the usage of the water: residential, industrial, agriculture or recreational.

The proposed recharge project supports sustainable water use by using discharge water from a local industry (ADM) and repurposing it for recharge water. The quantity of water required to mitigate the established groundwater declines and provide a sustainable water resource for the area was estimated in the Study. The hydrogeologic and groundwater modeling tools developed for the project were used to fine-tune the potential recharge amounts. The southeast corner of the Study Area consists primarily of gravels and sands, which is ideal for successful recharge. Two recharge locations were evaluated and selected as the best locations for a recharge project: Lost Creek Channel and Christopher's

Cove (as shown on Figures 3 and 4). Groundwater modeling performed for the Study indicated that the potential infiltration rate using Christopher's Cove and the Lost Creek channel as recharge locations is approximately 2,500 AF/year (2.25 million gallons/day) (Attachment D - June 22, 2017 Alternative Analysis Summary).

Sufficient water exists to support this infiltration amount (Attachment B - June 2016 Columbus Area Water Resources Assessment Report, Section 5.4). The ADM plant mostly uses water from groundwater wells for processing near the plant boundary. While no records were available for those privately pumped amounts, it was determined that ADM returns a significant amount of its process water to the Loup Power Canal in the form of wastewater effluent. As indicated in the Study, NDEQ records indicate more than 4 to 5.5 MGD (4,380 acre-ft/year to 6,020 acre-ft/year) is discharged. The available water from ADM (3.5 MGD to 5 MGD) far exceeds the potential requirements for a recharge project (2.25 MGD) and would even allow for additional recharge if final design data would indicate higher recharge potential then the conservative ranges used from existing soils information. Using the ADM discharge would allow for the return of groundwater that was withdrawn for processing purposes back to its source area in the form of recharge, and is therefore considered the most beneficial alternative for source water.

The target area is the southeast portion of the Columbus Area, where groundwater declines have occurred since approximately 2010. The recharge locations, the Lost Creek Channel and Christopher's Cover, are located within the area of noted groundwater decline.

Groundwater modeling performed for the Study indicates that the spatial extent of the groundwater increase occurs in the southeast portion of the Columbus area would be approximately 5,000 acres.

Water usage in the area, which would benefit from the recharge project is residential, industrial/commercial, and agricultural.

- List all stakeholders involved in project.

The stakeholders include the Lower Loup NRD, Archer Daniels Midland Company (ADM), City of Columbus, Christopher's Cove Association (CCA).

- Identify who benefits from this project.

The beneficiaries of the project are intended to be as diverse as the wide-ranging impacts experienced under declining groundwater conditions. Potential beneficiaries would include, but not be limited to, municipal drinking water users, irrigators, industrial and commercial water users, recreation interests, and environmental interests. This recharge project will provide several intangible benefits starting with a local group working together to find a way to develop water sustainability and resolve a local concern. There is a broader benefit to the state as this type of project could act as an example or surrogate for other NRDs and communities with similar water supply concerns. While not easily calculated in monetary terms, the project will help to promote a healthy and sustainable groundwater resource, develop a greenway space along the recharge zone, and avoid conflict among water users.

The project will include a monitoring component that will collect data on the results and efficiency of the recharge. This information will be used to evaluate any unforeseen or negative effects and allow for the adjustment of system operations. Data collected will be informative to others that may be evaluating the efficacy of project for water sustainability.

This project is an innovative use of water sources and recharge that allows a local group to develop a sustainable water resource, all while achieving the Lower Loup NRD IMP goal of working with local government (City of Columbus) to augment water supplies and maintain an efficient and economical balance between current users and future demands within the Lower Loup NRD. Having a group come together and find solutions to water problems is the very thing Water Sustainability Fund was developed to help do.

12. Addresses a statewide problem or issue;

- List the issues or problems addressed by the project and why they should be considered statewide.
- Describe how the project will address each issue and/or problem.
- Describe the total number of people and/or total number of acres that would receive benefits.
- Identify the benefit, to the state, this project would provide.

The proposed recharge project addresses a statewide problem or issue, as detailed below.

- List the issues or problems addressed by the project and why they should be considered statewide.

Groundwater declines have occurred across the state. Most declines are localized, but their impact can be felt throughout the state and region via reduced economic output and uncertainty in future economic strength. These struggles require strong local leadership. As a state, we charge local Natural Resource Districts with the responsibility of the management and preservation of our critical groundwater resources.

- Describe how the project will address each issue and/or problem.

The project will augment water supplies and maintain an efficient and economical balance between current users and future demands within the Lower Loup NRD. The Lower Loup NRD, City of Columbus, industry, and agriculture have come together to find an innovative solution to water supply problem that affects the majority of the residents in the southeast part of the City and region. The project is a perfect complement to the goals and objective of the Water Sustainability Fund and can be a model for other communities.

This project can be a model for other areas of the state that face similar water supply concerns. Providing a reliable source to mitigate groundwater decline, and making the source sustainable, will allow for significant and sustained industrial and agricultural capital investment. Continued growth in Columbus provides increased tax revenues in Columbus that will benefit the entire state.

13. **Contributes to the state's ability to leverage state dollars with local or federal government partners or other partners to maximize the use of its resources;**

- List other funding sources or other partners, and the amount each will contribute, in a funding matrix.
- Describe how each source of funding is made available if the project is funded.
- Provide a copy or evidence of each commitment, for each separate source, of match dollars and funding partners.
- Describe how you will proceed if other funding sources do not come through.

The proposed recharge project contributes to the state's ability to leverage state dollars with local or federal government partners to maximize the use of its resources, as detailed below.

- List other funding sources or other partners, and the amount each will contribute, in a funding matrix.

The project funding partners are shown in Table 10.

Table 10: Funding Matrix

Partner	Construction and Engineering Cost	20-year Operation and Maintenance Cost	Total
ADM	$571,200	$280,000	$851,200
Lower Loup NRD	$163,200	$80,000	$243,200
City/Christopher's Cove Association	$81,600	$40,000	$121,600
Total	**$816,000**	**$400,000**	**$1,216,000**

- Describe how each source of funding is made available if the project is funded.

Some form of interlocal agreement will be arranged to handle the financial aspects, as is commonly done with Natural Resource Districts.

- Provide a copy or evidence of each commitment, for each separate source, of match dollars and funding partners.

Letters of support from each partner are included in Attachment F.

- Describe how you will proceed if other funding sources do not come through.

The project will not commence until funding is secured. Without funding, the project will not move forward.

14. Contributes to watershed health and function;

- Describe how the project will contribute to watershed health and function in detail and list all of the watersheds affected.

The project is located within the Headwaters to the Lost Creek Watershed (HUC 12#: 102002010302). The headwaters of Lost Creek originate in the Columbus area, before flowing to the east, along the Platte River, through Schuyler, to where it discharges into the Platte River downstream of Schuyler. According to the most recent (2016) NDEQ Biannual Water Quality Integrated Report (IR), the creek is classified as a warm water stream and is not identified as having any water quality impairments. It is currently meeting its designated uses for aquatic life, aesthetics, and agricultural uses. Additionally, Christopher Cove is located within the watershed. Designated uses for the lake include primary contact recreation, aquatic life, agricultural and aesthetics. The lake was originally constructed as a sandpit lake, and is thus hydrologically connected to area groundwater.

Water for the recharge project is not expected to negatively impact water quality or watershed health. Any water which does not recharge into the aquifer will continue to flow downstream, contributing to additional stream health functions in the Lost Creek Watershed and the Platte River. The project is also designed to reduce in-stream erosion through the use of in-stream weirs or check structures. These will assist in stabilizing the streambed during project operations, as well as any time there is water flowing down the creek. This reduces sediments and nutrients such as phosphorus from impacting watershed health downstream.

15. Uses objectives described in the annual report and plan of work for the state water planning and review process issued by the department.

- Identify the date of the Annual Report utilized.

- List any and all objectives of the Annual Report intended to be met by the project
- Explain how the project meets each objective.

The proposed recharge project contributes to the state's ability to leverage state dollars with local or federal government partners to maximize the use of its resources, as detailed below.

- Identify the date of the Annual Report utilized.

The most recent (September 2016) *Annual Report and Plan of Work for the Nebraska State Water Planning and Review Process* was utilized in preparation of this application.

- List any and all objectives of the Annual Report intended to be met by the project

The following objectives will be met by this project:

  - Support locally developed water management plans for managing hydrologically connected water supplies.
  - Provide coordination of federal agencies, state agencies, local natural resources districts (NRDs), and other water interests for the development of water resources programs and projects.

- Explain how the project meets each objective.

The project meets these objectives through the following:

  - **Support locally developed water management plans for managing hydrologically connected water supplies.** The project combines water plans from the local level (City of Columbus), regional level (Lower Loup NRD), and state level (State of Nebraska); as well as involving private industry and local stakeholders.
  - **Provide coordination of federal agencies, state agencies, local natural resources districts (NRDs), and other water interests for the development of water resources programs and projects.** The project coordinates efforts from the local level (City of Columbus), regional level (Lower Loup NRD), state level (State of Nebraska), a national level (USEPA, US Army Corps of Engineers); as well as involving private industry and local stakeholders.

16. Federal Mandate Bonus. If you believe that your project is designed to meet the requirements of a federal mandate which furthers the goals of the WSF, then:

- Describe the federal mandate.

- Provide documentary evidence of the federal mandate.
- Describe how the project meets the requirements of the federal mandate.
- Describe the relationship between the federal mandate and how the project furthers the goals of water sustainability.

This project will help the State of Nebraska comply with the requirements of federal law, the Clean Water Act. **33 U.S.C. §1251 et seq. (1972).** The Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. The CWA also regulates nonpoint source pollution that generally results from land runoff, precipitation, drainage, seepage or hydrologic modification. This project will help to ensure the water quality in Lost Creek and Cristopher Cove Lake is maintained or improved. Additionally, the project has been designed to not contribute to water quality impairments, which would ultimately affect the Platte River.

Section D.

PROJECT DESCRIPTION

1. Overview

In 1,000 characters *__or less__*, provide a brief description of your project including the nature and purpose of the project and objectives of the project.

The southeast portion of Columbus is experiencing significant groundwater level declines. The Lower Loup NRD is charged with managing groundwater resources in the Columbus area. The proposed project utilizes available surface water coupled with a groundwater recharge system that will provide a sustainable water resource, all while achieving an IMP goal of working with local government to augment water supplies and maintain an efficient/economical balance between current users and future demands. The project will recycle an equivalent amount of ADM discharge water into Lost Creek Channel and Christopher's Cove. Check structures will regulate the water and pond it in the channel. Modeling suggests the project will increase groundwater levels more than 10 feet and local lakes will recover to their planned elevations. The NRD, City, homeowners, and ADM are all contributing financing and technically to the project to help find solutions to Nebraska's water challenges.

2. Project Tasks and Timeline

Identify what activities will be conducted by the project. For multiyear projects please list what activities are to be completed each year.

The proposed recharge project will be designed in 2018 and constructed in 2019. The following design activities will performed in 2018:

The design process consists of:

1. Evaluate the utility alignment conflicts to determine the most effective route.
2. Design the pump and pipeline hydraulics based on the required total dynamic head.
3. Coordinate with the power utility to get sufficient power to the pump station.
4. Evaluate the electrical system to allow for remote operation and monitoring.

Permitting will also be initiated upon receipt of grant funding. Coordination with NeDNR and USACE representatives to discuss and confirm permit requirements.

In addition, geotechnical data will be collected to assist with evaluation and design.

Typical operation, maintenance and monitoring will occur annually. Monitoring will include evaluating well levels in the area, and visually assessing water quality in the recharge locations.

3. Partnerships

Identify the roles and responsibilities of agencies and groups involved in the proposed project regardless of whether each is an additional funding source. List any other sources of funding that have been approached for project support and that have officially turned you down. Attach the rejection letter.

- ADM – funding source, providing right of way and recharge water
- Lower Loup NRD – funding source, project development, continued operation and maintenance;
- City of Columbus – funding source, providing right of way, continued operation and maintenance;
- Christopher's Cove Association – funding source, providing a recharge location and continued operation and maintenance.

No other entities have been approached about supporting the project.

4. Other Sources of Funding

Identify the costs of the entire project, what costs each other source of funding will be applied to, and whether each of these other sources of funding is confirmed. If not, please identify those entities and list the date when confirmation is expected. Explain how you will implement the project if these sources are not obtained.

The funding partners are shown in Table 11.

Table 11: Funding Partners

Partner	Construction and Engineering Cost	20-year Operation and Maintenance Cost	Total
ADM	$571,200	$280,000	$851,200
Lower Loup NRD	$163,200	$80,000	$243,200
City/Christopher's Cove Association	$81,600	$40,000	$121,600
Total	**$816,000**	**$400,000**	**$1,216,000**

Some form of interlocal agreement will be arranged to handle the financial aspects, as is commonly done with Natural Resource Districts.

Letters of support from each partner are included in Attachment F.

The project will not commence until funding is secured. Without funding, the project will not move forward.

5. Support/Opposition

Discuss both support and opposition to the project, including the group or interest each represents.

ADM, the Lower Loup NRD, City of Columbus and Christopher's Cove Association all support the project. There is no known opposition to the project at this time.

Attachment A: Lower Loup NRD Integrated Management Plan

LOWER LOUP NATURAL RESOURCES DISTRICT INTEGRATED MANAGEMENT PLAN

LOWERLOUP NATURAL RESOURCES DISTRICT

Nebraska Department of Natural Resources

Voluntary Integrated Management Plan

- Approved by the Lower Loup Natural Resources District Board of Directors March 24, 2016
- Order adopting the Lower Loup NRD Integrated Management Plan signed by DNR Director Gordon Fassett on May 9, 2016

TABLE OF CONTENTS

LIST OF APPENDICES

1.0 INTRODUCTION

The citizens of the Lower Loup Natural Resources District (Lower Loup NRD) depend on abundant, clean water in their homes for domestic use, on their farms for agricultural production, and for their industries to maintain economic viability. Wildlife that live and migrate through the Lower Loup NRD depend on clean water for sustenance and habitat. Furthermore, human inhabitants of the District use water in rivers and lakes for recreation including fishing, hunting, boating, and swimming.

The Lower Loup NRD is located in the southeastern half of the Loup Basin. The Loup Basin is approximately 14,200 square miles in area. The topography of the Loup Basin across the Lower Loup NRD predominately consists of gently rolling and dissected plains, with small areas of upland plains. Inhabitants of the Lower Loup NRD have relied on the abundant water resources of the area; over time, their water use has increased. In continuing with proactive management of natural resources, the Lower Loup NRD and citizen stakeholders within the area determined a water use plan needed to be developed to provide a framework for how to wisely manage water resources so they are available now and in the future.

South Loup River in Howard County

For these reasons, water management planning was voluntarily initiated by the Lower Loup NRD in collaboration with the Nebraska Department of Natural Resource (NDNR). Groundwater and surface water have been managed independently in the past. However, this plan, called an Integrated Management Plan (IMP), is a water planning document that provides a framework for how the Lower Loup NRD and the NDNR will work collaboratively to manage groundwater and surface water use across an area where the two are hydrologically connected. The IMP was initiated voluntarily by the Lower Loup NRD to ensure that water use is sustainable into the future.

Not only did the Lower Loup NRD volunteer to initiate an IMP, but numerous local stakeholders and other members of the public also volunteered to represent the wide array of water interests and provide invaluable input during the planning process. These stakeholders truly shared the insight and discussions necessary to not only develop a plan, but also to carry it forward into the future. The Lower Loup NRD and the NDNR are grateful for all their time and energy in helping put this plan together. A list of the stakeholder participants and the meeting schedule is included in Appendix B.

1.1 BACKGROUND AND PURPOSE

On April 15, 2004, Nebraska Legislative Bill (LB) 962 was approved, which set the stage for the NDNR and the NRDs to collaborate on the management of groundwater and surface water as a single, integrated resource. LB 962 requires the development of an IMP if a river basin, subbasin, or reach is determined to be fully appropriated by the NDNR. Each year, because of this legislation, NDNR produces a report called the "Annual Evaluation of Availability of Hydrologically Connected Water Supplies." This annual report provides the results of NDNR's evaluation of the expected long-term availability of hydrologically connected water supplies for both existing and new surface water uses and existing and new groundwater uses in each of the state's river basins.

On December 16, 2008, NDNR made a preliminary determination that the Lower Platte River Basin, which includes the Lower Loup NRD, was fully appropriated. A basin is considered fully appropriated when certain conditions for hydrologically connected surface water and groundwater are met under Neb. Rev. Stat. §46-713(3). The statute states that a basin is fully appropriated when current uses of hydrologically connected surface water and groundwater will, in the reasonably foreseeable future, cause:

- The surface water supply to be insufficient to sustain over the long term the beneficial or useful purposes for which existing natural-flow or storage appropriations were granted and the beneficial or useful purposes for which, at the time of approval, any existing instream appropriation was granted
- The streamflow to be insufficient to sustain over the long term the beneficial uses from wells constructed in aquifers dependent on recharge from the river or stream involved
- Reduction in the flow of a river or stream sufficient to cause noncompliance by Nebraska with an interstate compact or decree, other formal state contract or agreement, or applicable state or federal laws

The preliminarily determined area included nearly the entire Lower Loup, Upper Loup, and Upper Elkhorn NRDs, and portions of the Lower Platte North, Lower Platte South, Papio-Missouri River, and Lower Elkhorn NRDs. Prior to making a final determination, NDNR held a public hearing in early 2009. Through this hearing, new information was made available that resulted in NDNR reversing the preliminary determination during the Spring of 2009 (Neb. Rev. Stat. §46-714 (12)).

In 2010, Nebraska Legislative Bill (LB) 764 was passed allowing Natural Resource Districts and the Department to work together in a voluntary integrated management planning process. Then, in 2014, the Board of Directors of the Lower Loup NRD adopted a motion to inform NDNR that the

Lower Loup NRD intended to develop a voluntary IMP and requested the NDNR's participation. The NDNR approved the Lower Loup NRD's request and the development of this plan began.

This IMP was developed jointly by the Lower Loup NRD and NDNR with the express purpose of achieving and sustaining a balance between water uses and water supplies for the near and long term. The IMP provides the detailed goals, objectives, and action items, both regulatory and non-regulatory, that were developed with stakeholder involvement. This IMP was developed with the understanding that the Lower Loup NRD is not within a fully appropriated river basin; should that designation change, the IMP will be reevaluated. Additionally, the NRD is not subject to any interstate compact or decree or any other formal contract or agreement pertaining to surface water or groundwater use or supplies and so, there was no consideration of this in the IMP.

As this IMP is being entered into on a voluntary basis, the IMP area is not currently fully appropriated. The methodology utilized by NDNR to assess the available supplies and uses in the Annual Report will be used to track depletions and gains to streamflow from changes in availability and use. Current supplies are greater than the current level of use and therefore methods to identify water supplies to be used as offsets or for mitigation purposes or an identification de minimus effects are not included in this IMP. Additionally, the IMP area is not subject to any interstate compact or decree, or any other formal contract or agreement pertaining to surface water or groundwater use or supplies.

1.2 AUTHORITY

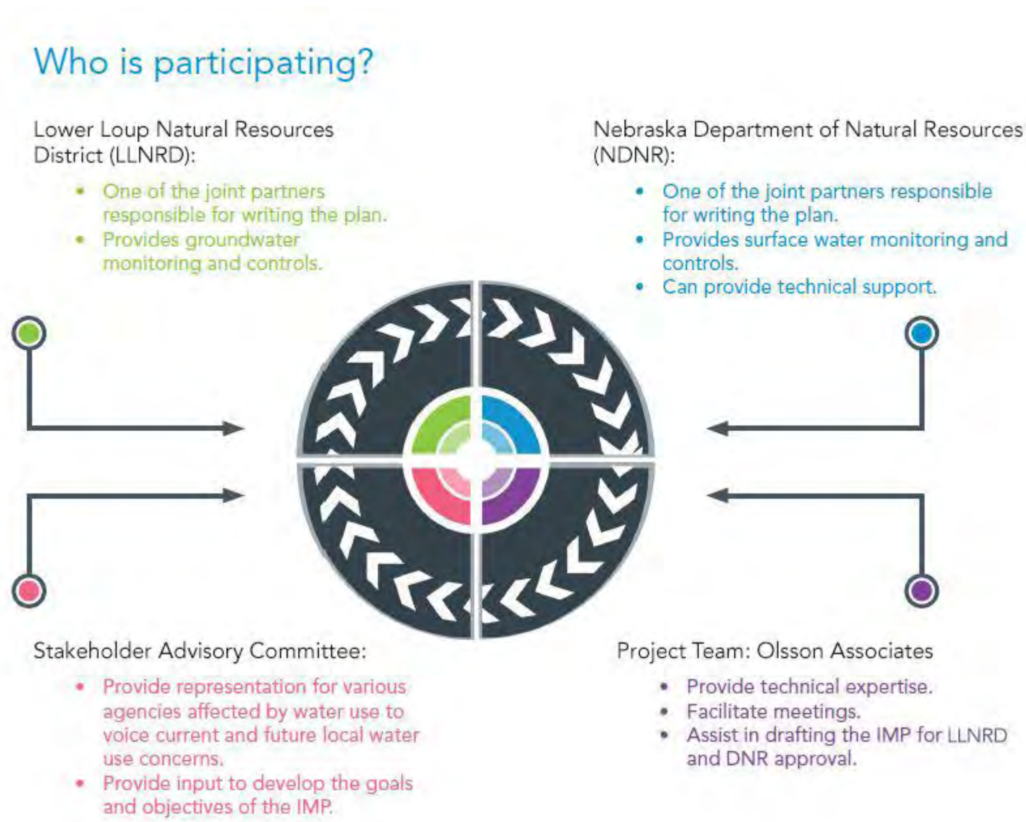
As authorized in Neb. Rev. Stat. § 46-715(1)(b), "a natural resources district encompassing a river basin, subbasin, or reach that has not been designated as overappropriated or has not been finally determined to be fully appropriated may, jointly with the department, develop an integrated management plan for such river basin, subbasin, or reach located within the district". As part of the requirements, the Lower Loup NRD notified the department of its intention to develop an IMP. A copy of the letters of intent are included in Appendix A. NDNR acknowledged the request, and this IMP was developed and adopted according to Neb. Rev. Stat. §46-715 to 46-717 and subsections (1) and (2) of section 46-718.

1.3 INTEGRATED MANAGEMENT PLANNING PROCESS

The IMP planning process is an adaptive approach to managing Nebraska's hydrologically connected groundwater and surface water. It allows for an integrated inventory of groundwater and surface water supplies and uses; increases collaboration between the entities that manage water resources; enhances public awareness of water resources issues; and increases opportunities to provide input on short- and long-term management of the water resources. An IMP works toward attaining or maintaining a balance between water users and water supplies. In accordance with Section 6.0 Monitoring Plan and Proposed Studies, this IMP may be altered as the affected area or subarea changes and/or more data becomes available to accommodate changing circumstances including hydrology, economics, water demands, and water supplies.

In accordance with Neb. Rev. Stat. §46-717(2), this IMP was developed collaboratively by the Lower Loup NRD and the NDNR, in consultation with the Lower Loup Stakeholder Advisory Committee. The Stakeholder Advisory Committee consisted of a variety of water users representing the following general interest groups: municipal water users, dry land farmers, agriculture industry, groundwater irrigators, surface water irrigators, water recreation, manufacturing/industrial water users, and wildlife conservation (see Appendix B for a complete list of participants). Technical advisory members for the Stakeholder Advisory Committee included representatives from the University of Nebraska-Lincoln and the Nebraska Department of Environmental Quality.

The Stakeholder Advisory Committee met three times throughout 2015 (Appendix B). These meetings helped create and develop the goals, objectives, and action items of this IMP. On February 29th, 2016, the Draft Voluntary IMP was made available to the public for review. On March 24th, 2016, a public hearing was held and public testimony on the IMP was taken. The NDNR and Lower Loup NRD reached joint agreement on the IMP on March 24th, 2016. The effective date of the IMP is June 1st, 2016.



Participants and IMP Development Roles and Responsibilities

2.0 MAP AND DESCRIPTION OF THE INTEGRATED MANAGEMENT PLAN AREA

As part of the process used to develop this IMP, multiple data sources were analyzed. These data sources were used to best report the land use, climate, groundwater, and surface water resources of the Lower Loup NRD. Two maps were generated to better illustrate these data sources, as shown in Appendix C (Figures).

2.1 MAP OF THE INTEGRATED MANAGEMENT PLAN AREA

The Lower Loup NRD is located in central Nebraska and includes all of or portions of Rock, Loup, Garfield, Wheeler, Boone, Platte, Custer, Valley, Greeley, Nance, Sherman, Howard, Butler, Hall, Merrick, and Buffalo counties (Figure 1). The LLNRD is bisected by multiple rivers including the Loup, Cedar, Calamus, North Loup, Middle Loup, Mud Creek, Beaver Creek, and South Loup rivers. The Lower Loup NRD is almost completely contained within the southeastern half of the Loup Basin.

Figure 1 illustrates the boundary of the area included in this IMP. Also illustrated in Figure 1 are the areas within the District where groundwater and surface water are hydrologically connected. As defined by NDNR, a hydrologically connected area is an area where a well pumped for 50 years will deplete the river or a base flow tributary by at least 10 percent of the amount pumped in the 50-year period (the 10/50 area). Hydrologically connected areas are published by the NDNR in the "Annual Evaluation of Availability of Hydrologically Connected Water Supplies" report.

2.2 LAND USE

The Lower Loup NRD covers approximately 5,088,565 acres. Current land uses in the NRD consist of range, pasture, and grasslands (67 percent), irrigated crops (19 percent), dryland crops (10 percent), forested areas (2 percent), urbanized areas and roads (1 percent), and open water and wetlands (1 percent). The most prominent irrigated crops are corn (12 percent of the land area in the NRD and 66 percent of all the irrigated crops in the NRD) and soybeans (5 percent of the land area in the NRD and 25 percent of all the irrigated crops in the NRD; 2005, CALMIT Land Use Data).

2.3 LOCAL HYDROLOGY

As a whole, the Lower Loup NRD receives approximately 22.8 inches of precipitation per year on average (based on 1988 through 2012 records). The amount of average annual precipitation varies across the NRD and increases from west to east. Local precipitation amounts can vary significantly within the growing season and from year to year. Seasonal dry periods and periodic droughts have led many agricultural producers to acquire surface water rights for irrigation or to drill irrigation wells.

The Loup, North Loup, Middle Loup, and South Loup rivers and their tributaries, Calamus and Cedar Rivers are present within the Lower Loup NRD. Most of the Loup River system are gaining streams, that is, most reaches of the stream gain water from the groundwater system. Because streamflow in the Loup River system is almost entirely from groundwater discharge, streamflow is nearly constant throughout the year (Peckenbaugh and Dugan, 1983). Popular recreation areas in the Lower Loup NRD include Davis Creek and Pibel Lake Recreation Areas. Davis Creek is primarily used as irrigation storage, and lake levels vary with the time of year. Davis Creek dam and reservoir and part of the North Loup Irrigation Project constructed in the 1980's. Pibel Lake Recreation Area is a 72-acre facility, including a 24-acre lake. Renovations on the lake have taken place in recent years. The Lower Loup NRD has also received a $240,000 grant from the Nebraska Environmental Trust for further renovations. Other important reservoirs in the Lower Loup NRD include the Calamus and Sherman reservoirs.

North Loup River near Saint Paul in Howard County

2.4 GROUNDWATER

The principal groundwater reservoir of the Lower Loup NRD consists of Quaternary sands, gravels, silts, and clays of fluvial origin and silts and clays of eolian origin (Peckenbaugh and Dugan, 1983). During the Quaternary, several periods of fluvial and eolian deposition were followed by periods of erosion. The Tertiary Ogallala Formation underlies the Quaternary sediments. The Ogallala is also fluvial is origin and consists of semi consolidated calcareous silt, sand, and sandstone

(Peckenbaugh and Dugan, 1983). The Upper Loup NRD GMP (1994) defined the base of the principal groundwater reservoir to be the base of the Ogallala and/or Arikaree Formation. Cretaceous bedrock units underlying the Ogallala consist primarily of shale and chalk and are not considered groundwater reservoirs in the area (Peckenbaugh and Dugan, 1983).

3.0 GOALS AND OBJECTIVES

The purpose of an IMP is to achieve and sustain a balance between water uses and water supplies within the Lower Loup NRD for the long term. The Stakeholder Advisory Committee, working with the Lower Loup NRD and NDNR, developed an appropriate set of goals, objectives, and action items for the IMP that will facilitate sustainable water management in the NRD. Before work began on developing goals and objectives, the Stakeholder Advisory Committee agreed upon the following definitions of goals, objectives, and action items:

- Goals are general statements of broad direction or intent with no time limit. Goals set the stage for meaningful objectives.
- Objectives define the measurable results that a group seeks to accomplish. Generally, an objective is a statement of what will be accomplished.
- Actions items are the specific tasks that the Lower Loup NRD and NDNR will undertake to achieve the goals and objectives.

Four goals and corresponding objectives were developed by the Lower Loup NRD and NDNR, in consultation with the Stakeholder Advisory Committee. Generally these goals and objectives strive to implement water policies that enable sustainable water management, develop a comprehensive water inventory of water supply and demand, and continue educational programs that promote conservation.

The four goals developed for the IMP are to be implemented simultaneously. As new information is gathered about the water supply and water demands in the NRD, the goals and objectives may be modified, as discussed in Section 8.0. The goals and objectives listed below are supported by detailed action items, as presented in Section 4.0. Action items will be implemented over several years as staff and financial resources are made available for implementation. More information on how progress made toward the goals are measured is provided in Section 7.0.

GOAL 1 – Promote and support a water supply and use inventory based on the best available data and analysis

Objectives

1.1. Develop and maintain a comprehensive inventory of the location and source of the District's current and future water supplies, water uses and outflows.
1.2. Monitor current and future water demands in the basin.
1.3. Use best available science and technology to monitor water supplies.

1.4. Utilize existing policies and authorities of the District and the Department to address water quantity issues.

GOAL 2 – Implement this water management plan to maintain an efficient and economical balance between current and future water supplies and demands

Objectives

2.1 Collaborate with state and local governments to identify opportunities to augment water supplies within the District and, if necessary, identify opportunities to supplement with imported water from outside the District.

2.2 Monitor the instream flow needs in the Lower Platte Basin to foster an understanding of any existing appropriation priorities and locations, and provide a basis for evaluating impacts of existing and future uses.

2.3 Evaluate options for water banking methodologies.

GOAL 3 – Develop and implement water use policies and practices that prioritize and contribute to the protection of existing surface and groundwater uses while allowing for future water development

Objectives

3.1. Identify available water storage opportunities throughout the District.

3.2. Evaluate, understand, and develop policies to address impacts on stream flows resulting from uses outside of management control.

GOAL 4 – Continue public education programs that encourage water conservation measures

Objectives

4.1. Investigate and promote water use efficiency.

4.2. Continue public education and cost share programs to encourage conservation and best management practices.

4.0 ACTION ITEMS

Action items were developed by the Lower Loup NRD and the NDNR with input from the Lower Loup NRD Stakeholder Advisory Committee. Action items provide a list of the direct tasks to be performed that are necessary to implement the plan. Action items help accomplish the objectives and move toward completion of the goals. Groundwater and surface water controls are action items which are considered regulatory. Action items listed by goal and objective, unless otherwise stated, are considered non-regulatory.

GROUNDWATER AND SURFACE WATER CONTROLS

There are two specific action items that were written in order to comply with Neb. Rev. Stat. § 46-715 (2) as the regulatory groundwater and surface water action items (or controls). These two action items are presented first with further description as to their applicability across the district. In accordance with the statute, the regulatory action items (or controls) shall:

- Be consistent with the goals and objectives of the plan
- Be sufficient to ensure that the state will remain in compliance with applicable state and federal laws and with any applicable interstate water compact or decree or other formal state contract or agreement pertaining to surface water or ground water use or supplies.

Groundwater Action Item (Control)

1. Establish a limit on the expansion of groundwater-irrigated acres.

Groundwater regulatory action items (or controls) implemented by the Lower Loup NRD are set forth in Neb. Rev. Stat. § 46-739 and apply to the groundwater control area as shown in Figure 2 and as listed in Appendix C. The groundwater regulatory action item will work in combination with Lower Loup NRD's Groundwater Management Plan and Rules and Regulations. The District's Rules and Regulations will contain procedural details for the control listed in this IMP. Persons desiring to apply for new groundwater irrigated acres or to increase existing groundwater irrigated acres should contact the Lower Loup NRD to ensure compliance with this IMP. The limit established on the expansion of groundwater irrigated acres is for agricultural production land irrigated from a new groundwater source, typically an irrigation well, and does not include testholes, replacement wells, water wells constructed to pump 50 gallons per minute or less, monitoring or observation wells, wells constructed for the purpose of contamination treatment, municipal, industrial, or commercial wells.

Surface Water Action Item (Control)

1. Establish a limit on the expansion of surface water-irrigated acres.

Surface water regulatory action items (or controls) implemented by the NDNR are set forth in Neb. Rev. Stat. § 46-716 and apply to the surface water control area as shown in Figure 2. NDNR will establish an annual limit on the expansion of surface water-irrigated acres. The limit on the expansion of surface water-irrigated acres shall be a maximum of one-third of the amount the Lower Loup NRD will allow for the expansion of groundwater-irrigated acres. NDNR will utilize the number of additional groundwater irrigated acres in place in the IMP area as of January 1 of each year for determining the number of additional acres for surface water irrigated on each calendar year. The limit established on the expansion of surface water irrigated acres is for agricultural production land irrigated from a new surface water appropriation and does not include other types of irrigation use, municipal use, or industrial use.

This limit will only apply to land within the Surface Water Control Area illustrated in Figure 2. Should Lower Loup NRD issue a moratorium on any increase in groundwater-irrigated acres, NDNR will issue a similar moratorium to limit development of additional acres for surface water irrigation. The NDNR is the State agency authorized by Nebraska statutes to regulate surface waters. All diversions of surface water require a State permit that is granted through the NDNR. To obtain a surface water permit, applicants apply through their local NDNR office.

ACTION ITEMS (BY GOAL AND OBJECTIVE)

4.1 ACTION ITEMS FOR GOAL 1

The Lower Loup NRD and NDNR will work together to ensure that they are using their authorities appropriately and collaboratively to manage the groundwater and surface water resources in the District. Throughout this section, either the Lower Loup NRD or NDNR are listed as the lead for completion of the action item as noted in parentheses at the end of the action item. Where they are working together, the lead is listed as "Both."

GOAL 1 – PROMOTE AND SUPPORT A WATER SUPPLY AND USE INVENTORY BASED ON THE BEST AVAILABLE DATA AND ANALYSIS

Goal 1 is designed to develop and implement water management policies and practices that could potentially provide for additional water resources development opportunities while protecting existing surface and groundwater uses.

OBJECTIVE 1.1 – Develop and maintain a comprehensive inventory of the location and source of the District's current and future water supplies, water uses and outflows.

Action Item 1.1.1 Collect and record relevant groundwater and surface water supply data in mutually agreeable units and format. (Both)

Action Item 1.1.2 Estimate groundwater inflow and outflow using the best available scientific methods. (Both)

Action Item 1.1.3 Maintain a database of surface water inflow and outflows and identify data gaps. (NDNR)

Action Item 1.1.4 Maintain and inventory of all registered wells and surface water appropriations. (Both)

OBJECTIVE 1.2 – Monitor current and future water demands in the Basin.

Action Item 1.2.1 Obtain short- and long-term water use projections from municipalities. (Lower Loup NRD)

Action Item 1.2.2 Identify water users. (Both)

Action Item 1.2.3 Identify downstream demands. (Both)

Action Item 1.2.4 Encourage voluntary water use reporting. (Both)

Action Item 1.2.5 Develop and require a notice for new demands. (Both)

Action Item 1.2.6 Develop estimates of water use from private, domestic, and other unmetered wells. (Lower Loup NRD)

Action Item 1.2.7 The NDNR will continue any existing stream gaging in the Lower Loup NRD and look for new opportunities to enhance the stream gage network. (NDNR)

Action Item 1.2.8 The NDNR will continue to administer surface water rights according to State law and monitor use of surface water to make sure that unauthorized irrigation is not occurring. (NDNR)

Action Item 1.2.9 The NDNR will continue to map and track surface water irrigated acres. The NDNR will also continue to require that project maps are submitted and approved prior to obtaining a surface water permit. (NDNR)

Action Item 1.2.10 The NDNR will implement a voluntary reporting program for surface water irrigation permit holders in the Lower Loup NRD aimed at identifying the quantity of water pumped, the acres irrigated, and the type of irrigation system used. (NDNR)

Action Item 1.2.11 The NDNR will continue to evaluate the necessity for mandatory installation of water flow meters on all surface water pumps for irrigation, industrial, and municipal uses. (NDNR)

Action Item 1.2.12 The NDNR will continue to enforce legislature (Neb. Rev. Stat. §§ 46-290 to 46-294.04) and NDNR rules pertaining to transfers of surface water rights. Should a moratorium be placed on new surface water appropriations in the Lower Loup NRD, the NDNR may grant a variance from the moratorium on a case-by-case basis, following the NDNR's rules and regulations. (NDNR)

South Loup River in Howard County

OBJECTIVE 1.3 – Use best available science and technology to monitor water supplies.

Action Item 1.3.1 Evaluate adequacy of existing groundwater monitoring and existing stream gaging. (Both)

Action Item 1.3.2 Consider the need for additional groundwater monitoring wells and additional stream gaging sites. (Both)

OBJECTIVE 1.4 – Utilize existing policies and authorities of the District and the Department to address water quantity issues.

Action Item 1.4.1 Review and evaluate the District's Groundwater Management Plan relative to the goals and objectives of the IMP. (Lower Loup NRD)

Action Item 1.4.2 Review and evaluate Department policies and practices relative to the goals and objectives of the IMP. (NDNR)

Action Item 1.4.3 Assess the need for additional study of aquifer properties, extents, and connectivity to surface water. (Both)

4.2 ACTION ITEMS FOR GOAL 2

GOAL 2 – IMPLEMENT THIS WATER MANAGEMENT PLAN TO MAINTAIN AN EFFICIENT AND ECONOMICAL BALANCE BETWEEN CURRENT AND FUTURE WATER SUPPLIES AND DEMANDS

Goal 2 is designed to provide valuable water use information to the Lower Loup NRD and NDNR. This information will be used to enhance the understanding of water demands within the District.

OBJECTIVE 2.1 – Collaborate with state and local governments to identify opportunities to augment water supplies within the District and, if necessary, identify opportunities to supplement with imported water outside the District.

Action Item 2.1.1 Evaluate the potential for conjunctive management programs or project opportunities. (Both)

OBJECTIVE 2.2 – Monitor the instream flow needs in the Lower Platte Basin to foster an understanding of any existing appropriation priorities and locations, and provide a basis for evaluation impacts of existing and future uses.

Action Item 2.2.1 Require an impact analysis on new large groundwater and surface water appropriations. (Both)

Action Item 2.2.2 Work with the appropriate agencies to identify streamflow necessary to protect and maintain public water supply, fish and wildlife, and public recreation. (Both)

Action Item 2.2.3 Review and assess the benefits from instream flow protection. (Both)

OBJECTIVE 2.3 – Evaluate options for water banking methodologies.

Action Item 2.3.1 Coordinate with other entities to identify, and study, opportunities for the development of water banking. (Both)

Action Item 2.3.2 Evaluate potential for additional groundwater and surface water storage within the District to bank future water supplies. (Both)

4.3 ACTION ITEMS FOR GOAL 3

GOAL 3 - DEVELOP AND IMPLEMENT WATER USE POLICIES AND PRACTICES THAT CONTRIBUTE TO THE PROTECTION OF EXISTING SURFACE AND GROUNDWATER USES WHILE ALLOWING FOR FUTURE WATER DEVELOPMENT

Goal 3 is designed to develop and implement water management policies that provide for additional water resources development opportunities while protecting existing surface and groundwater uses including instream flow rights that benefit recreation and wildlife in the Lower Loup NRD.

OBJECTIVE 3.1 – Identify available water storage opportunities throughout the District.

Action Item 3.1.1 Review and analyze existing studies of storage opportunities. (Both)

Action Item 3.1.2 Consider the potential for multi-agency studies of storage opportunities as necessary. (Both)

OBJECTIVE 3.2 – Evaluate, understand, and develop policies to address impacts on stream flows resulting from uses outside of management control.

Action Item 3.2.1 Identify users of streamflow that are outside of management control and their reason for streamflow use. (Both)

Action Item 3.2.2 Assess the impact of streamflow users outside of management control. (Both)

Action Item 3.2.3 Implement policies that protect streamflow while accommodating users that are outside of management control. (Both)

4.4 ACTION ITEMS FOR GOAL 4

GOAL 4 – CONTINUE PUBLIC EDUCATION PROGRAMS THAT ENCOURAGE WATER CONSERVATION MEASURES

Goal 4 is designed to increase the knowledge of water conservation and effective use within the Lower Loup NRD. The Lower Loup NRD currently has education and informational programs in place, therefore any new initiatives developed to achieve Goal 4 will be coordinated with the current programs.

OBJECTIVE 4.1 – Investigate and promote water use efficiency.

Action Item 4.1.1 Identify and quantify water usage efficiencies through technology, lower water use crops and improved management. (Both)

Action Item 4.1.2 Explore ways for the reuse of water such as the harvesting of rainwater, capture and reuse of storm water, reuse of municipal or industrial gray water, and reuse of irrigation water. (Both)

OBJECTIVE 4.2 – Continue public education and cost share programs to encourage conservation and best management practices.

Action Item 4.2.1 Continue to use existing and develop additional information and education programs that promote wise water use and quantify conservation. (Both)

Action Item 4.2.2 Identify existing and potential cost-share programs. (Lower Loup NRD)

Action Item 4.2.3 Pursue opportunities for public outreach efforts, such as news releases, in order to support water education or programs. (Lower Loup NRD)

5.0 INCENTIVE PROGRAMS

The Lower Loup NRD and NDNR will explore and evaluate cost-share incentive programs that promote water conservation practices. Incentive programs may include any program authorized by state law or federal programs. Water users or landowners may be required to enter into and perform such agreements or covenants concerning the use of land or water as are necessary to produce the benefits for which the incentive programs are established. The Lower Loup NRD will investigate grant opportunities to supplement the annual budgeting process for funding of water conservation practices.

6.0 FUNDING OPTIONS

In order to implement some of the action items listed in this IMP, the Lower Loup NRD and NDNR will need to secure additional funding sources. Some of the programs, projects, or activities (PPAs) identified in this IMP have multiple benefits. For example, incentive programs that encourage conversion from flood to center-pivot or drip irrigation have been shown to improve water quality. Specifically, the sprinkler and drip irrigation systems reduced nitrate loading on local aquifers. Incentive programs that encourage irrigation system conversions can reduce groundwater withdrawals and also directly impact rural landowners and small communities by preserving a viable source of drinking water. Ultimately, without these types of incentive programs, the communities may be required to construct costly treatment systems or look to distant systems of distribution for clean water. Thus, an incentive program such as irrigation system conversion may have both water quality and water quantity benefits, and funding opportunities to help achieve the goals may be accessed through different funding programs. This section provides information on a variety of funding options that may be used to by the Lower Loup NRD and/or NDNR.

The primary sources of funding for the IMP PPAs are the Natural Resources Conservation Service, Nebraska Department of Environmental Quality, Nebraska Environmental Trust, Nebraska Game and Parks Commission, NDNR, and non-profits. The general criteria and applicability of each of the funding sources are presented. It should be noted, however, that the funding sources presented here are not necessarily inclusive of all funding options available. Additionally, information presented here is subject to change as funding sources may change their terms and criteria.

South Loup River in Howard County

Federal Funding Opportunities

Natural Resource Conservation Service (NRCS). The 2014 Farm Bill offers conservation programs that benefit both agricultural producers and the environment.

- **Environmental Quality Incentives Program (EQIP).** Through EQIP, technical assistance, cost-share and incentive payments are available to agricultural producers to implement conservation practices that improve water quality, enhance grazing lands, and/or increase water conservation.

- **Conservation Stewardship Program (CSP).** The CSP is available in selected watersheds across the nation. The program is designed to reward farmers and ranchers who are implementing conservation on working lands and to encourage them to do more.
- **Agricultural Management Assistance Program (AMA).** AMA helps agricultural producers use conservation to manage risk and solve natural resource issues.
- **Agricultural Conservation Easement Program (ACEP).** Helps to conserve agricultural lands by preventing the conversions of these lands into non-agricultural lands. This program also acts to protect the restore wetlands.
- **Healthy Forests Reserve Program (HFRP).** The HFRP aids landowners in the restoration, protection, and enhancement of forestland resources on private lands. This program is designed to promote the recovery of endangered/threatened species, improve biodiversity, and enhance carbon sequestration.
- **Regional Conservation Partnership Program (RCPP).** The RCPP provides conservation assistance to producers and landowners by combining the authorities of four former conservation programs, the Agricultural Water Enhancement Program, the Chesapeake Bay Watershed Program, the Cooperative Conservation Partnership Initiative, and the Great Lakes Basin Program.

U.S. Department of the Interior – Bureau of Reclamation

- Water-Smart grants are provided to irrigation districts, water districts, and other organizations with water or power delivery to cost-share on projects that conserve and use water more efficiently. The projects should support water sustainability in the west.

State Funding Opportunities

The Nebraska Environmental Trust (NET). The Nebraska Environmental Trust was established in 1992 to conserve, enhance, and restore the natural environments of Nebraska. The Trust especially seeks projects that bring public and private partners together collaboratively to implement high-quality, cost-effective projects.

Nebraska Department of Environmental Quality (NDEQ)

- **Nonpoint Source Water Quality Grants (Section 319).** Under Section 319 of the federal Clean Water Act, the federal government awards funds to the Nebraska Department of Environmental Quality to provide financial assistance for the prevention and abatement of nonpoint source water pollution. This funding is passed through to units of government, educational institutions, and non-profit organizations for projects that facilitate implementation of the state Nonpoint Source Management Plan.

Nebraska Game and Parks Commission (NGPC)

- **Nebraska Wildlife Conservation Fund.** The purpose of this fund is to conserve nongame species and species determined to be endangered or threatened, for human enjoyment, for scientific purposes, and to ensure their continued existence as a part of our natural world.

Nebraska Department of Natural Resources (NDNR)

- **Water Well Decommissioning Fund.** The objective of the Water Well Decommissioning Fund is to encourage proper decommissioning of illegal water wells in the state. This is accomplished through providing financial incentives in the form of cost-share assistance.
- **Nebraska Soil and Water Conservation Fund.** This fund provides state financial assistance to Nebraska landowners for installation of approved soil and water conservation measures that improve water quality, conserve water, and help control erosion and sedimentation.
- **Small Watersheds Flood Control Fund.** The purpose of this fund is to assist local sponsors with the acquisition of land rights for flood control projects. Local sponsors use the fund to acquire easements or fee title to tracts that are needed to implement a project.
- **Natural Resources Water Quality Fund.** This fund was created to provide state funds to NRDs for their water quality programs.
- **Water Sustainability Fund.** The Water Sustainability Bill (LB 1098) was signed into law during the 2014 legislative session. This bill creates the Water Sustainability Fund, which will be used to address multiple water management and quality issues. This fund will act to improve water quality and usage, supply water management goals, provide flood control, and comply with existing interstate agreements and compacts.

Local Funding Opportunities

It is the intent of the Lower Loup NRD to utilize qualified projects described in Neb. Rev. Stat. § 2 3226.04 to provide river-flow enhancement in order to achieve the goals and objectives of the Lower Loup NRD and to achieve the goals and objectives of the NDNR under the Groundwater Management and Protection Act. The Lower Loup NRD may fund projects through one of two ways.

- **Levy Authority (Neb. Rev. Stat. § 2-3225(1) [c]).** This authority allows the Lower Loup NRD to levy an additional property tax of up to three cents per $100 of taxable value for purposes of administering and implementing groundwater management activities and integrated management activities under the Nebraska Groundwater Management and Protection Act. The Revenue Committee amendment to LB 1032 extended the sunset date to fiscal year 2016–17.
- **Occupation Tax (Neb. Rev. Stat. § 2-3226.05).** This authority allows the Lower Loup NRD to levy an occupation tax upon the activity of irrigation of agricultural lands on an annual basis. This tax is not to exceed ten dollars per irrigated acre.

Non-Profit Funding Opportunities

The Nature Conservancy (TNC)

- The Nature Conservancy is the leading conservation organization working around the world to protect ecologically important lands and waters for nature and people. The

Conservancy partners with indigenous communities, businesses, governments, multilateral institutions, and other non-profits to pursue non-confrontational, pragmatic solutions to conservation challenges.

- The Conservancy has protected over 107,000 acres in Nebraska through fee-title ownership, easements and deed restrictions, and assisting others with land transactions. TNC works in partnership with farmers and ranchers to promote good stewardship. TNC looks for ways to restore and protect grasslands and rivers.

Pheasants Forever (PF)

- Pheasants Forever is dedicated to the conservation of pheasants, quail and other wildlife through habitat improvements, public awareness, education and land management policies and programs.
- Nebraska has 60 Pheasants Forever (PF) chapters and 3 Quail Forever (QF) chapter with over 10,388 members. In 2012, Nebraska PF and QF chapters have spent over $4.9 million in the state on 5,456 habitat projects benefiting 148,597 acres.

Ducks Unlimited (DU)

- Ducks Unlimited (DU) is the world's leader in wetlands and waterfowl conservation. DU got its start in 1937 during the Dust Bowl when North America's drought-plagued waterfowl populations had plunged to unprecedented lows. Determined not to sit idly by as the continent's waterfowl dwindled beyond recovery, a small group of sportsmen joined together to form an organization that became known as Ducks Unlimited.
- Nebraska includes diverse wildlife habitats like the Sandhills and the Missouri River floodplain. While most waterfowl migrate to wintering habitats further south each fall, large numbers of mallards and Canada geese do remain in Nebraska during the winter, particularly along the Platte River. DU's highest priority in Nebraska is to protect and restore critical migration habitat in the Rainwater Basin and along the Platte River. It is important that waterfowl arrive in their northern breeding habitats in the Prairie Pothole region in good physical condition, ready to undergo the physically demanding reproductive period. This will be accomplished by providing high quality migration habitat in Nebraska's Rainwater Basin and along the Platte River corridor.

7.0 MONITORING PLAN AND PROPOSED STUDIES

The overall objective of the monitoring plan is to gather and evaluate data, information, and methodologies that could be used to accomplish the purpose of the IMP.

The Lower Loup NRD and the NDNR have agreed to accomplish the following actions set forth in the monitoring plans as required by Neb. Rev. Stat. § 46-715 (2)(e):

- Gather and evaluate data, information, and methodologies that could be used to accomplish the purpose of this IMP.
- Increase understanding of the surface water and hydrologically connected groundwater system.
- Test the validity of the conclusions and information upon which the IMP is based.

The NDNR will be responsible for collecting, tracking, evaluating, and reporting the following activities within the IMP Area on an annual basis:

- Department stream gage measurements on NDNR maintained gages
- Surface water permits issued, cancelled or denied
- Irrigation water use data collected
- Other data as agreed to

The Lower Loup NRD will be responsible for collecting, tracking, evaluating, and reporting the following activities within the IMP Area on an annual basis:

- Groundwater level measurements
- Stream gage measurements on NRD maintained gages
- Municipal, commercial and industrial water use
- Agricultural / irrigation water use
- Certified irrigated acres and any changes to certifications
- Well water construction permits approved, cancelled or denied
- Variances granted, cancelled or denied
- Water transfer permits granted, cancelled, or denied
- Water banking transactions (if a water banking system is established)

The Lower Loup NRD and the NDNR will jointly evaluate the data and information gathered for accuracy and flag data that may require closer inspection and reviews. In addition, the Lower Loup NRD and the NDNR will review annual water use data to historically reported water usage data to evaluate the impacts of new water users on existing water users within the IMP Area.

The Lower Loup NRD and NDNR will jointly, or separately, issue an annual report.

The NDNR has developed a methodology, in conjunction with several of the Loup River Basin NRDs, to quantitatively assess the hydrologically connected groundwater and surface water of the State for use in the Annual Evaluation of Hydrologically Connected Water Supplies. This methodology will be used to monitor the balance of water supplies within the IMP Area. This methodology will be updated with the best available data and analysis as provided by the Lower Loup NRD and the NDNR.

8.0 MODIFICATIONS TO THE INTEGRATED MANAGEMENT PLAN

Lower Loup NRD and NDNR will hold an annual review to evaluate the IMP. Action items undertaken by the Lower Loup NRD and NDNR will be reviewed to determine if these items are fulfilling the goals and objectives of the IMP. The NDNR and Lower Loup NRD will jointly determine if amendments to the IMP are necessary. Amendments to the IMP will require agreement by both parties. If amendments to the IMP are necessary, the Lower Loup NRD and NDNR will hold a joint hearing and issue the pertinent orders to formally adopt the revised IMP.

9.0 INFORMATION CONSIDERED IN DEVELOPMENT OF THIS PLAN

The following were sources of information used in the preparation of this IMP:

- Historic data on streamflows in the Lower Loup NRD and adjoining NRDs
- Past and present surface water use within and bordering the Lower Loup NRD
- Data on groundwater supplies and groundwater uses within and bordering the Lower Loup NRD
- Records on climate and precipitation trends within the Lower Loup NRD and adjoining NRDs
- Records on land use within the Lower Loup NRD and adjoining NRDs
- Stakeholder Involvement Plan for the Lower Loup NRD, 2015
- Rules and regulations for groundwater management within the Lower Loup NRD

10.0 GLOSSARY OF TERMS

Action Item – A specific task that the Lower Loup NRD or NDNR (or both) will undertake to achieve the goals and objectives of the Integrated Management Plan.

Aquifer - An underground geological formation of sand, soil, gravel, and rock able to store and yield water. Alluvial aquifers are comprised of unconsolidated materials such as sand and gravel. Bedrock aquifers are comprised of rock.

Appropriation – A permit to use water that has been perfected in accordance with terms stipulated by the NDNR.

Conjunctive management – An adaptive process that utilizes the connection between surface water and groundwater to maximize water use, while minimizing impacts to streamflow and groundwater levels.

Fully Appropriated – A determination made by the NDNR that a river basin, subbasin, or reach has reached a point where water uses are equal to water supplies.

Goal – A general statement of broad direction or intent with no time limit.

Groundwater – Water that occurs in or moves, seeps, filters, or percolates through ground under the surface of the land.

Groundwater Control Area - That portion of the Lower Loup NRD where groundwater is hydrologically connected to surface water (see Figure 2).

Groundwater management plan – The Lower Loup NRD's plan that identifies the water quantity and quality characteristics, supplies, uses, data collection methods, management objectives, and management areas of groundwater supplies within an NRD.

Hydrologically connected – An area where groundwater and surface water are interconnected, and withdrawals from one can affect the other. To determine if an area is hydrologically connected (as defined in Nebraska State Statute), one calculates if a well pumped for 50 years will deplete the river or a base flow tributary by at least 10 percent of the amount pumped in the 50-year period (the 10/50 area).

Integrated Management Plan – A document to manage a river basin, subbasin, or reach to achieve and sustain a balance between water uses and water supplies for the long term.

Lower Loup NRD – The Lower Loup Natural Resources District, a political subdivision of the state.

NDNR – The Nebraska Department of Natural Resources, a state agency.

NRD – Natural Resources District, a political subdivision of the state

Objective – A statement that defines the measurable results that a group seeks to accomplish.

River basin – The land area that is drained by a river and its tributaries.

Stakeholder Advisory Committee – Representatives from various interest groups and professional fields who provide consultation on aspects of the Integrated Management Plan.

Surface water – Water that is on the Earth's surface, such as a stream, river, lake, or reservoir.

Surface Water Control Area – That portion of the Lower Loup NRD that drains to the Platte River (see Figure 2).

Subbasin – A portion of a river basin that is drained by a waterway.

APPENDIX A
Letters Initiating the IMP Process

LOWERLOUP
NATURAL RESOURCES DISTRICT

2620 Airport Drive
Ord, Nebraska 68862-0210
PHONE (308) 728-3221
FAX (308) 728-5669
www.llnrd.org

February 25, 2014

Mr. Brian Dunnigan, P.E.
Director
Nebraska Department of Natural Resources
301 Centennial Mall South
Lincoln, Nebraska 68509-4676

Dear Director Dunnigan,

The Lower Loup Natural Resources District's Board of Directors, at their meeting on January 23, 2014, unanimously approved a motion to pursue an integrated management plan with the Department of Natural Resources. A copy of the item taken from the January, 2014, board minutes is enclosed with this letter.

This letter is the Lower Loup NRD's notification to the Department of Natural Resources of its intent to discuss options with DNR on the joint development of a voluntary integrated management plan in accordance with Sections 46-715 through 46-717 and Subsections (1) and (2) of Section 46-718. The Lower Loup NRD is committed to remaining proactive in its groundwater management activities, and the development of a comprehensive long-term integrated management plan seems a logical next step in this mission. The Lower Loup NRD has already compiled a significant amount of data and has initiated numerous rules, regulations and action items toward the protection of both surface water and groundwater resources. The Lower Loup NRD is hopeful a process can be initiated and a working plan developed with DNR in a suitable amount of time.

We look forward to meeting with DNR staff to initiate this process and explore the options available to us in the development of an IMP. Please advise us of a good time to meet and discuss this matter.

Thank you for your attention.

Sincerely,

Leon Koehlmoos
General Manager

Enclosure

Voluntary Integrated Management Plan

Callan said that an integrated management plan is required if a basin becomes fully-appropriated. Although the lower Platte River Basin is not fully-appropriated, Callan said the committee recommended looking into a voluntary plan, which would allow the Lower Loup NRD access to additional funding sources and is looked on favorably by members of the Legislature.

Callan said the plan has five requirements and would be a joint plan by the NRD and DNR that looks at groundwater/surface water interaction and the management of it.

There was discussion on groundwater restrictions, controls, and funding.

Callan said the NRD already has a lot of the information that is needed for the plan. Koehlmoos commented that the law says that if an integrated management process is started, the NRD would have three years, with the option of two more years, to complete the plan. He felt that it wouldn't take long to write up. He said there is oversight from the state which has a say in any rules and regulations that deal with integrated management plans.

Koehlmoos reminded the Board that this would be a 'voluntary' plan, and if the NRD gets partway through the plan and decides not to pursue it, the process can be discontinued. He said there is more leniency with a voluntary plan. Eventually, a plan will need to be written, whether it's voluntary or required.

There was discussion on banked acres, LB-517 task force, review of the plan, whether or not a plan would be beneficial, and staff time needed to complete the plan.

Thoene motioned, seconded by Adams, that the Lower Loup NRD pursue a voluntary integrated management plan. Motion carried by roll call vote, all present voting yes.

Dave Heineman
Governor

STATE OF NEBRASKA

DEPARTMENT OF NATURAL RESOURCES
Brian P. Dunnigan, P.E.
Director

March 5, 2013

IN REPLY TO:

12804

Gary Kruse, Chairman
Lower Loup Natural Resources District
2620 Airport Drive
PO Box 210
Ord, NE 68862-0210

Dear Mr. Kruse:

The Department is pleased to receive the Lower Loup Natural Resources District's February 25, 2014, letter stating the District's intent to develop a voluntary integrated management plan (IMP) per *Neb. Rev. Stat.* § 46-715(1)(b). The Department agrees with the District that developing an IMP is an appropriate step to continue proactive water planning.

Department staff will be contacting your District to discuss details and the next steps in the integrated management planning process. The Department looks forward to developing the IMP with the District, in addition to furthering the effective working relationship between the District and the Department.

Sincerely,

Brian P. Dunnigan

Brian P. Dunnigan, P.E.
Director

cc: Leon Koehlmoos, General Manager

APPENDIX B
Stakeholder Advisory Committee

Lower Loup Natural Resources District Voluntary Integrated Management Plan
Stakeholder Advisory Committee*

First Name	Last Name	Affiliation
Mike	Archer	Government, Water Recreation
Ryan	Chapman	Government
Shane	Cool	Municipal, Groundwater Irrigator, Dry Land Farmer
Miles	Danner	Groundwater Irrigator
Craig	Frenzen	Groundwater Irrigator, Dry Land Farmer, Surface Water Irrigator, Ag Industry
Clifford	Hanna	Groundwater Irrigator, Dry Land Farmer, Surface Water Irrigator
Dick	Harrington	Groundwater Irrigator, Dry Land Farmer, Surface Water Irrigator, Water Recreation
David	Haupt	Banking
Lex	Jeffres	Groundwater Irrigator, Dry Land Farmer, Surface Water Irrigator
Matt	Jeffres	Sand/Gravel Industry
Tim	Kayton	Groundwater Irrigator, Dry Land Farmer, Surface Water Irrigator, manufacturing/Industry, Ag Industry, Banking
Tom	Knutson	Municipal, Surface Water Irrigator, Ag Industry, Government
Jason	Kock	Ag Industry
Alphonse	Kowalski	Groundwater Irrigator, Dry Land Farmer, Surface Water Irrigator, Ag Industry, Wildlife, Water Recreation
John	Kriha	Groundwater Irrigator, Dry Land Farmer, Wildlife
John	Krohn	Groundwater Irrigator, Dry Land Farmer
Drew	Luebe	Manufacturing/Industry
Rex	Mahoney	Realtor
Mark	McGuire	Groundwater Irrigator, Dry Land Farmer
Joe	Novotny	Dry Land Farmer, Surface Water Irrigator
Corey	Schaaf	Groundwater Irrigator, Ag Industry
Gerry	Sheets	Surface Water Irrigator
Michael	Spotanski	Dry Land Farmer, Surface Water Irrigator
Brad	Stephens	Groundwater Irrigator, Dry Land Farmer, Ag Industry
Mark	Stock	Groundwater Irrigator, Realtor
Neal	Suess	Municipal, Government, Water Recreation
Allen	Volf	Dry Land Farmer
Mike	Wells	Surface Water Irrigator
Richard	Woollen	Groundwater Irrigator, Dry Land Farmer, Government

* This list only includes those who attended one or more meetings.

Appendix C
Figures

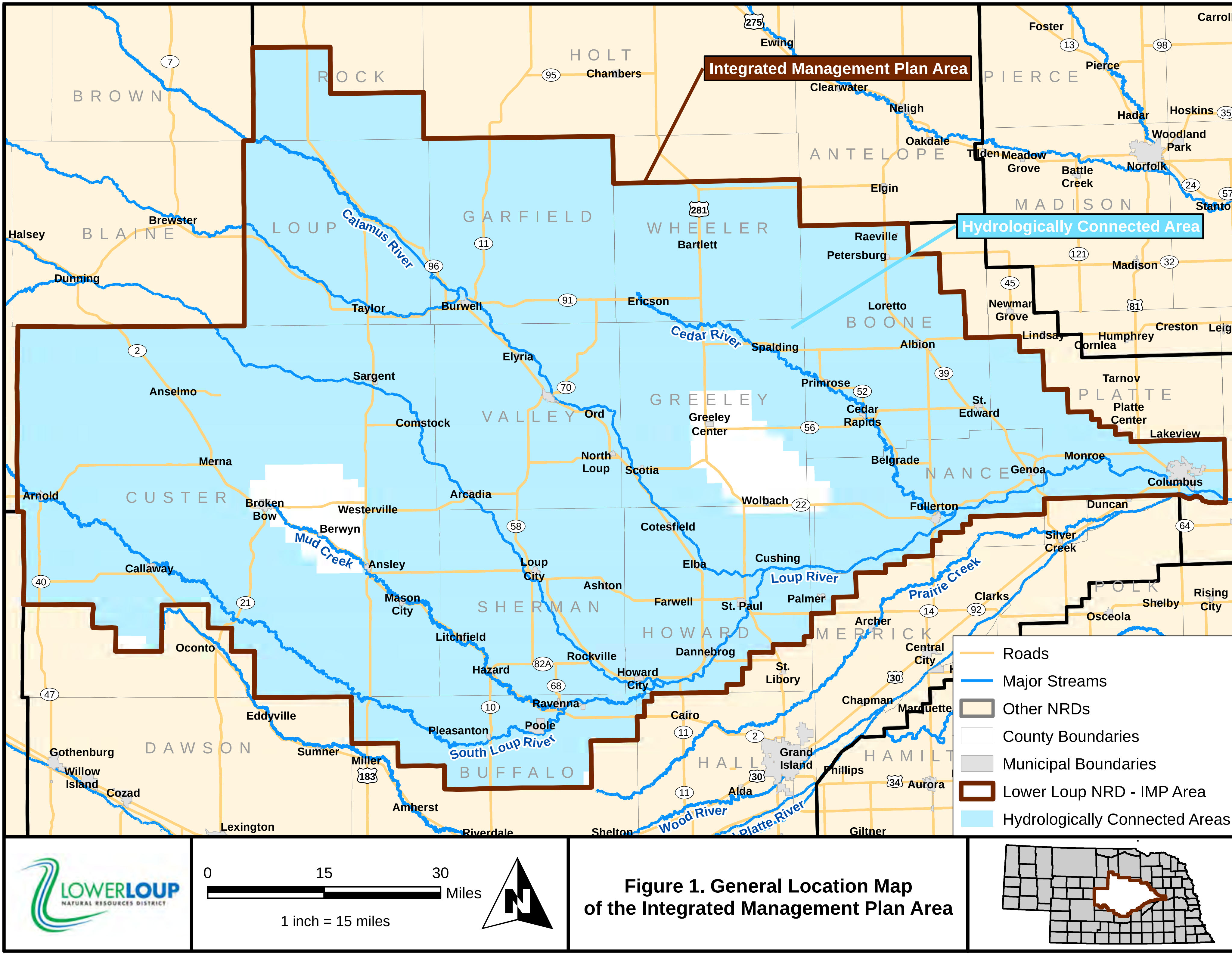


Figure 1. General Location Map of the Integrated Management Plan Area

Sources: NDNR - NRD Bound, Hydrologically Connected Areas; USGS - National Hydrography Dataset; U.S. Census Bureau - Roads, County Boundaries, Municipal Boundaries

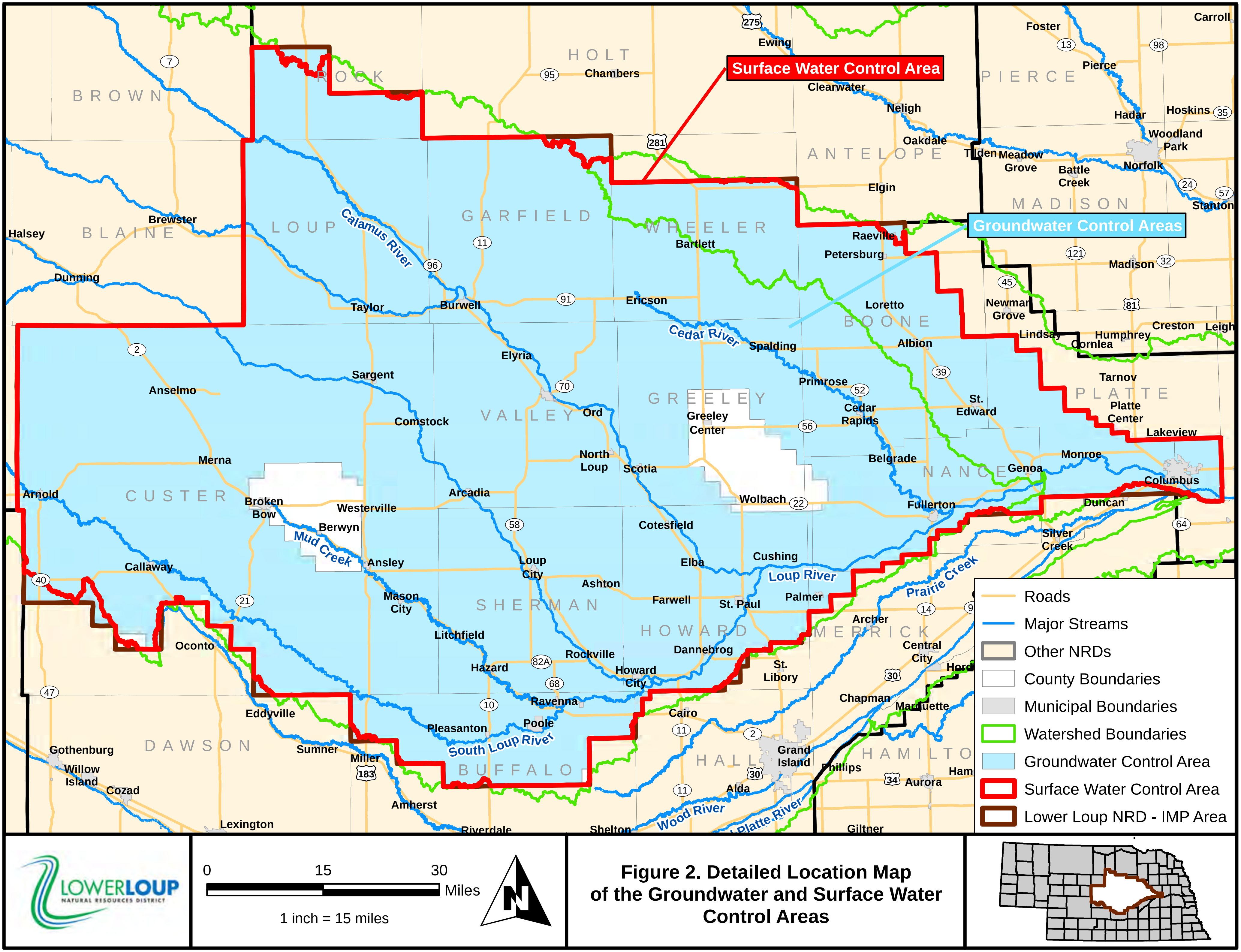
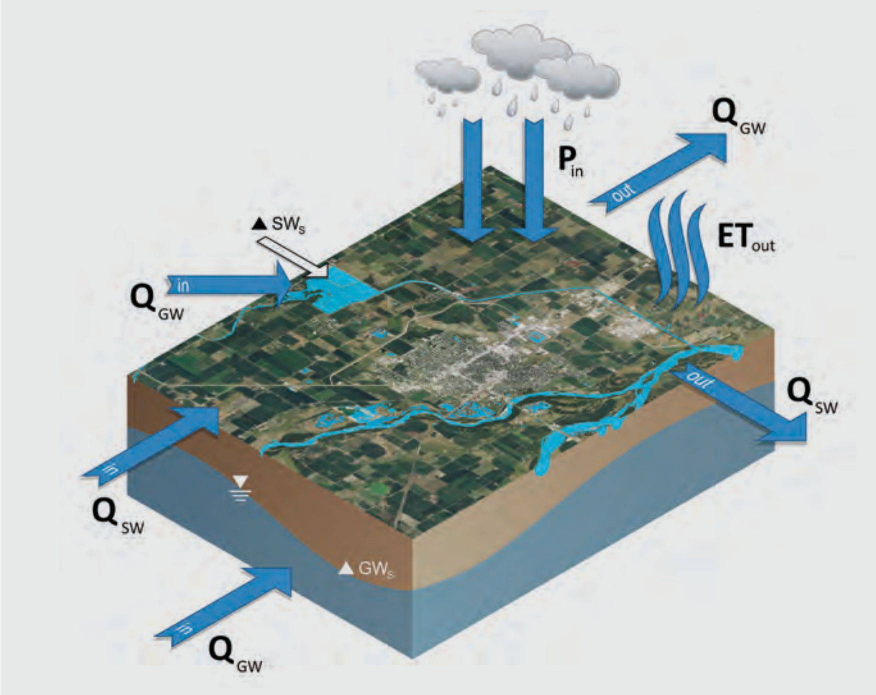


Figure 2. Detailed Location Map of the Groundwater and Surface Water Control Areas

Sources: NDNR - HUC04 Watersheds, NRD Bound, Hydrologically Connected Areas; USGS - National Hydrography Dataset; U.S. Census Bureau - Roads, County Boundaries, Municipal Boundaries

Attachment B: June 2016 Columbus Area Water Resources Assessment Report



LOWERLOUP
NATURAL RESOURCES DISTRICT

Final Report

Columbus Area Water Resources Assessment

Lower Loup Natural Resource District

June 2016

HDR THE FLATWATER GROUP INC. JEO CONSULTING GROUP INC

Contents

Tables

Executive Summary

An assessment was performed detailing the water resources in the Columbus area. The current floodplain information was cataloged, the stormwater system was evaluated, and potential stormwater system improvements were identified. A water budget of the major sources was developed and the annual contributions of each quantified, revealing that the Study Area has significant water sources. The hydrogeology within the study area was characterized showing relatively steady state groundwater contours in the western and northern portion of the study. However, a degradational trend in the southeast portion of the study area since approximately 2010 has occurred. A groundwater model was developed and calibrated to assist in identifying the extent of the groundwater decline as well as identify potential water sources and recharge/water management projects to offset the decline.

Based on the availability of source water location, hydrogeology, and groundwater model, several sites were evaluated. Two project locations were identified which have the hydrogeologic characteristics and the associated capacity to supplement water to the aquifer, as well as the spatial location necessary to be viable options for offsetting the groundwater decline. In addition, the groundwater modeling results and the water budget indicate that sufficient source water is available in the vicinity of the potential recharge projects. The project locations are: 1) the Lost Creek channel south of the Union Pacific Railroad; and 2) Christopher's Cove. The source water would be from repurposed effluent discharge volumes and recharged to the aquifer. This is water that would otherwise have been lost from the system. The projects would return water to the aquifer creating a sustainable approach to help mitigate groundwater declines.

1.0 Introduction

The community of Columbus has many demands placed on its water. Major water users in the vicinity of Columbus include the public supplies, agricultural irrigation, and several industries. Water distributed by Columbus is for public potable supplies and three golf courses. In the vicinity of Columbus, many farms use groundwater to irrigate their crops. Large commercial and industrial water users include ADM's ethanol plant and Becton, Dickinson and Company (BD). Numerous man-made lakes that were created from gravel mining operations are in or near Columbus. Several of these lakes have become central water features for residential neighborhoods. As such, the Columbus area has both the largest municipal and commercial water uses within the entire Loup River Basin. In addition, Loup Power District diverts water from the Loup River west of Columbus, conveys water through a series of canals and water balancing reservoirs, and through two hydroelectric facilities before the water is discharged to the Platte River southeast of Columbus.

The Lower Loup Natural Resources District (LLNRD), in coordination with the City of Columbus, Nebraska (City), is developing the Columbus Area Water Resources Assessment (CAWRA or Study). The Study Area is shown in Figure 1. Through this study, the LLNRD and City will be better equipped to make critical decisions regarding future sustainability of surface water and groundwater, given the likely increased demands resulting from continued municipal, commercial, and industrial growth.

With this in mind, the LLNRD and Columbus have contracted with the HDR Team, which includes The Flatwater Group and JEO Consulting Group, to conduct a study that includes:

- Compilation of available hydrologic and geologic data (Sections 2.0 through 6.0)
- Inventory of floodplain and stormwater data (Section 2.0)
- Development of an overall water budget (Section 3.0)
- Description of hydrogeology and development of a three-dimensional (3D) subsurface model (Section 4.0)
- Identification and ranking of recharge projects (Section 5.0)
- Research of water management strategies to supplement and stabilize water in Christopher's Cove (Section 5.0)
- Development of a local-scale groundwater model (Section 6.0)
- Identification of potential funding and technical resources (Section 7.0)

2.0 Floodplain and Stormwater Data Inventory

Floodplain and stormwater data within the Study Area were compiled and categorized. An inventory and assessment of the data was developed to assist the LLNRD and the City with understanding runoff, flooding, and floodplain impacts within the Study Area. In addition, recommendations were provided for additional data and necessary procedures that would assist the LLNRD and the City with developing a comprehensive stormwater plan.

2.1 Floodplain Review

The City and Platte County, Nebraska, participate in the Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP). A Flood Insurance Study (FIS) was developed for Platte County and incorporated areas to establish flood risk data and promote sound floodplain management (FEMA 2010a). The Study Area contains floodplain designations within the incorporated jurisdiction of the City, as well as unincorporated areas of Platte County. The Study Area is located on the following Flood Insurance Rate Maps (FIRMs) for Platte County and incorporated areas:

- Map Number 31141C0310E, Effective Date April 19, 2010 (FEMA 2010b)
- Map Number 31141C0320E, Effective Date April 19, 2010 (FEMA 2010c)
- Map Number 31141C0330E, Effective Date April 19, 2010 (FEMA 2010d)
- Map Number 31141C0335E, Effective Date April 19, 2010 (FEMA 2010e)
- Map Number 31141C0340E, Effective Date April 19, 2010 (FEMA 2010f)
- Map Number 31141C0345E, Effective Date April 19, 2010 (FEMA 2010g)

The floodplain information has been compiled and is shown in Figure 2. The City is bounded on the southwest and south by the Loup River and on the southeast by the Platte River. The Loup and Platte Rivers within the Study Area are both designated as Zone AE floodways by FEMA. Zone AE is defined by FEMA as those areas subject to inundation by the 1-percent-annual-chance flood event determined by detailed methods (FEMA 2015). A "Regulatory Floodway" is defined by FEMA as the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than the minimum federal limit of 1 foot (FEMA 2010a).

The northern boundary of the Loup River floodway is the Loup River Flood Control Levee. As a result, a significant portion of the community shown on the effective maps is protected by the Loup River Flood

Control Levee, which is Provisionally Accredited. The City of Columbus has received Section 408 approval from the USACE for modifying the flood control project to improve the levee to current criteria (JEO 2015). Construction is anticipated to begin on or about May 2, 2016 and is anticipated to take one calendar year. Following the construction phase, the City will proceed with compiling an accreditation packet to be forwarded to FEMA documenting the levee condition and accrediting the levee for protection of the 1-percent-annual-chance flood event. At that time, the FIRMs will be re-issued with the Provisionally Accredited Levee designation removed and will show the levees as being fully accredited. If the levee modifications cannot be completed and the accreditation packet cannot be submitted, FEMA will begin the process of de-accrediting the levee system. This process would remove the flood control levee from the FEMA-issued FIRMs and would show a large portion of the City as included in the Special Flood Hazard Area (SFHA). This alteration of the FIRMs would have significant ramifications to the City; it would require flood insurance for a large number of properties and may have a negative impact on property values and potential development/redevelopment of the area. Figure 3 is a map prepared by FEMA and its contractor that approximately identifies the area of the City that would be included as floodplain if the levee were de-accredited.

Lost Creek flows into the western edge of the Study Area. As part of the USACE Lost Creek Flood Control Project, Lost Creek drainage is collected in the Lost Creek Flood Control Channel (USACE 1981). The Lost Creek Flood Control Channel is owned and maintained by the City. It begins east of U.S. Highway 81 and eventually drains into the Loup Power District's Tailrace Canal immediately downstream of the Loup Power District's Columbus Powerhouse. Lost Creek flows not captured in the Lost Creek Flood Control Channel are conveyed through a siphon (Lost Creek Siphon) along the Loup Power District's Tailrace Canal and continue east in Lost Creek to Schuyler, Nebraska, where the flows discharge into the Platte River. The portion of Lost Creek and its tributaries within the Study Area are designated as Zone AO by FEMA. Zone AO is defined as those areas subject to flood depths of 1 to 3 feet. The Lost Creek floodplain does encroach on the Columbus airport; it crosses the paved runway/taxiway at two locations and crosses what appears to be a grassed runway at one location. The existing buildings and other facilities at the airport are not included in the floodplain boundary.

Currently, there is not a floodplain mapped for the areas around Lake Babcock or the Loup Power Canal system on the north side of the City. On the extreme eastern end of the City, the Loup Power Canal is mapped south of the Union Pacific Railroad crossing as a backwater area from the Platte River.

The remainder of the City is designated as Zone X by FEMA. Zone X includes the areas outside the 0.2-percent-annual-chance floodplain, areas within the 0.2-percent-annual-chance floodplain, areas of 1-percent-annual-chance flooding where average depths are less than 1 foot, areas of 1-percent-annual-chance flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 1-percent-annual-chance flood by levees. No base flood elevations or base flood depths are shown within this zone.

Other than Lost Creek, which was already mapped, there are no other surface water flowages/channels within the City that appear to need evaluation for floodplain mapping purposes.

The City is currently considering a detailed study of the natural channel of Lost Creek and the Lost Creek Flood Control Project to more accurately define the floodplain. This area is included in future growth plans for the City, and having an updated and accurate map to reference in the planning of this growth would be valuable.

2.2 Storm Sewer System

The City does have an extensive storm sewer system. The existing storm sewer map provided by the City is shown in Figures 4-A through 4-D. The storm sewer map includes pipe size and type as well as the approximate location of inlets/manholes and outfalls. The City has also developed sub-basin information to approximately identify the watershed limits for each outfall. Several of the northernmost sub-basins discharge directly to the Lost Creek Flood Control Project, while some of the furthest east sub-basins discharge directly into Lost Creek. The majority of the system that serves the bulk of the developed area flows southerly and ultimately discharges into one of the sandpit lakes in the southwest corner of the City or to the Loup River through the flood control levee. An interior drainage assessment was developed to analyze the performance and characteristics of the interior drainage system as part of the levee modification project currently in the final stages of approval. The assessment is based on the joint probability of coincident flooding events on the Loup River and localized area. This evaluation identified areas of potential ponding during the 1% Joint Probability Event and also in the event of closure structure failure on the drainage outlets through the levee and into the Loup River. These ponding areas are shown in Figure 5, which was taken from the Levee Interior Drainage Evaluation as part of the Levee Improvements Preliminary Engineering Report (JEO 2015).

At this time, it does appear that the City has detailed information on the location, type, and size of the storm sewer system, but it does not appear that a comprehensive storm sewer evaluation has been completed to identify system deficiencies for typical storm sewer design criteria.

In addition to storm-sewer-related work the City has been completing locally, the City has been a key participant in the Nebraska H20 group. This cooperative group is made up of Nebraska communities all facing similar challenges in enforcement and management of the National Pollutant Discharge Elimination System (NPDES) and Municipal Separate Storm Sewer System (MS4) requirements from both the U.S. Environmental Protection Agency (EPA) and the Nebraska Department of Environmental Quality (NDEQ). In addition to Columbus, other communities include Grand Island, Beatrice, Fremont, Hastings, Kearney, Lexington, Norfolk, North Platte, and Scottsbluff. The goal of Nebraska H2O is to foster communication and cooperation among each of the communities.

The City has adopted construction stormwater standards developed by Nebraska H2O that address potential pollution during the construction process to comply with NPDES and MS4 criteria. These standards have been followed for all new development and re-construction, and are published in the City Municipal Code Chapters 53 and 54 (City of Columbus, 2015a). In addition, the City is currently reviewing post-construction stormwater standards developed by Nebraska H2O, a copy of which is included as Attachment 1 to this report. These proposed standards would promote water quality by requiring new development to include water quality treatment for the 80th percentile rain event (approximately 0.83”) and redevelopment to include water quality treatment for the 70th percentile rain event (approximately 0.62”). Water quality treatment measures could include infiltration trenches/basins, pervious pavements, extended detention, or other methods to promote infiltration and limit off site runoff. The City is currently considering implementing some of these standards on a regional basis to encompass several developments, not only to maximize the effectiveness of these sites but also to limit the operation and maintenance needs. Finally, the City has plans to review the existing storm sewer system to determine if opportunities exist for water quality features to be retrofit onto existing infrastructure in a cost-effective and efficient manner. In anticipation of this, the City is in the process of incorporating the existing system into a geographic information system (GIS) format.

2.3 Recommendations

Based on the floodplain and stormwater data inventory, the following items and associated milestone dates for completion are recommended:

- Develop a detailed flood insurance study and floodplain maps for Lost Creek and the Lost Creek Flood Control Project to guide future development (Fall 2017).
- Develop a long-term policy or criteria for management of stormwater, including adoption of post-construction stormwater standards developed by Nebraska H2O (Spring 2017). This may be adopted in 2017, but likely will not be mandatory until 2018 or 2019. Coordinate with future storm sewer modeling.
- Evaluate regional stormwater detention, including the following, as a means to mitigate proposed development (Spring 2017):
    - Impact on existing storm sewer infrastructure
    - Financing
    - Agreements with individual developments
    - Operation and maintenance responsibilities
- Develop a strategy, including the following tasks, to evaluate the storm sewer system on a citywide basis (Spring 2017):
    - Evaluate on a sub-basin level beginning with areas of known problems
    - Confirm sub-basin boundaries
    - Confirm storm sewer map through field visits
    - Develop a public participation strategy to inform the public of the project and to gather additional information on the flooding issues
    - Identify areas of deficiency not meeting current design standards
    - Develop conceptual improvements, including cost opinions
    - Evaluate storm sewer system modeling packages
- Complete the Lucity Community Maintenance Management System storm sewer database to incorporate as-built information, service/maintenance records, or any other pertinent data (Spring 2017 and continuing thereafter)
- Develop a strategy to re-populate/revise the storm sewer system as improvements or modifications are made so that the storm sewer database is consistently kept up-to-date (Summer 2017). This is in the form of Lucity, as noted above.
- Develop "Foreman's Maps" for City staff to use in the field for quick location/identification of storm sewer elements and to share with other City departments. This, too, is part of Lucity; it can be accessed in the field with tablets and will be updated as future development occurs.
- Develop Citywide storm sewer system model (Spring 2018). Coordination with the stormwater management and treatment policy will be required.
- Populate the City's Capital Improvement Plan (CIP) with storm sewer improvement projects, or coordinate with other utility or street work proposed in the area (Spring 2018).

3.0 Global Water Budget

A global water budget for the CAWRA Study Area was developed to catalogue the inflows to, and the outflows from, the Study Area primarily based on measured data. The global water budget is quantified by general water budget terms. Figure 6 illustrates the basic components of the water budget in the Study Area. Inflows to the Study Area include surface and subsurface inflows and precipitation. Outflows include surface and subsurface outflows. The difference between inflows and outflows in the global water budget is designated as the residual term. The residual is comprised of consumptive uses for example, pumping wells, evaporation, and evapotranspiration [ET], changes in surface and subsurface storage, and unmeasured inflows and outflows.

3.1 Surface Water Data

Gage data from the U.S. Geologic Survey (USGS) and the Nebraska Department of Natural Resources (NDNR) were used to develop surface water inflows and outflows. Table 1 lists the surface water gages used for this Study (USGS 2015; NDNR 2015a). In addition, Figure 7 shows the location of each gage.

Table 1. Surface Water Gages

Gage	Gage Number	Location	Period of Record[1]	Agency
Loup River near Genoa, Nebr	06793000	Approximate Loup River Mile 28.0	1929-04-01 to 1932-06-30; 1943-10-01 to 2014-10-21	USGS
Loup River Power Canal near Genoa, Nebr	06792500	Approximately 2 miles downstream of Diversion. Diversion is approximate Loup River Mile 34.2.	1937-01-01 to 2014-10-21	USGS
Loup River at Columbus, Nebr	06794500	Approximate Loup River Mile 2.95	1934-04-01 to 1978-10-10 (USGS); 2008-10-01 to 2013-09-30 (NDNR)	USGS/NDNR
Loup River Power Canal Return at Columbus, Nebr	00082100	Approximately 1.6 miles upstream of canal confluence with Platte River near Platte River Mile 101.5.	2002-10-1 to 2013-09-30	NDNR
Platte River near Duncan, Nebr	06774000	Approximately 1.5 miles south of Duncan, near Platte River Mile 113	1937-10-01 to 2014-10-01	USGS

[1]Period of record for approved data.

The global water budget was determined on a monthly time step beginning in October 1943 and ending in September 2013. The start date was selected because it provided a consistent start date for three of the four gages, the exception being the Loup River Power Canal Return at Columbus gage (00082100). Using the streamflow record extension technique, the record for that gage was extrapolated to 1943, as discussed below in Section 3.1.4, Surface Water Outflows. The end date was selected because it provided a consistent end date of records for three of the four gages, the exception being the Loup River at Columbus (06794500), which was interpolated between 1978 and 2008, as discussed below in Section 3.2, Surface Water Inflows.

3.2 Surface Water Inflows

Measured Study Area surface water inflows include the Loup and Platte Rivers, the Loup Power District's Loup Power Canal, and precipitation. Lost Creek inflows were estimated based on a basin yield approach. Loup River inflows were estimated at the Study Area boundary (see Figure 7) using the Loup River gages near Genoa and at Columbus, and using a drainage area relationship between the Loup River gage at Columbus and the Study Area boundary.

Loup Power District diverts water from the Loup River and conveys the flow through the Loup Power Canal to the Columbus Powerhouse. The flow at the Loup River near Genoa gage (06793000) is influenced by Loup Power District's diversion operations. The flow at the Loup River at Columbus gage (06794500) is also influenced by Loup Power District's operations, but to a lesser extent because there are several tributary inflows between gages. To adequately capture the hydrologic basin response of the system at the Study Area boundary and effectively normalize Loup Power District's operations, the Loup River diversion amount was included in the analysis. This was done by adding the Loup River diversion amount to both the Loup River gages near Genoa (06793000) and at Columbus (06794500).

The flow at the Study Area boundary, which includes the diverted amount, was then determined based on the drainage area ratio. The drainage area for the Loup River at Columbus (06794500) and the Study Area boundary is 6,230 square miles and 6,205 square miles, respectively. Finally, the diversion amount was subtracted from the calculated flow to get the resultant flow at the Study Area boundary. The following example is for May 27, 2008:

- Flow at the Loup River near Genoa gage (06793000) was 4,110 cubic feet per second (cfs).
- Flow at the Loup River Power Canal near Genoa gage (06792500) gage was 2,840 cfs.
- Flow at the Loup River at Columbus gage (06794500) was 4,660 cfs.
- Flow at the Loup River gages near Genoa (06793000) and at Columbus (06794500), including the diverted amount, is 6,950 cfs and 7,500 cfs, respectively.
- Applying the drainage area ratio, the discharge at the Study Area boundary including the diverted amount is 7,470 cfs.
- Subtracting the diverted amount results in a discharge at the Study Area boundary of 4,630 cfs.

The mean monthly Loup River volumes are listed in the Appendix, Table1. The average annual Loup River inflow volume to the Study Area is 671,700 acre-feet.

As shown in Figure 7, the Platte River is located along the south boundary of the Study Area. It was assumed that flows from the Platte River entering the Study Area would be approximately equivalent to the flows exiting the Study Area; therefore, the Platte River was not considered in the global water budget analysis.

The Loup Power Canal loses approximately 5 percent of the diverted amount between the diversion and the Columbus Powerhouse (Loup Power District 2008). This includes evaporation, ET, seepage, and irrigation withdrawals. The Loup Power Canal flows at the Study Area boundary were determined by interpolation based on canal river mile at the diversion, the Study Area boundary, and the Columbus Powerhouse. The mean monthly volumes for the Loup Power Canal are listed in the Appendix, Table 2. The average annual Loup Power Canal inflow volume to the Study Area is 1,168,230 acre-feet.

The Lost Creek flow at the Study Area boundary was estimated using a basin yield approach. The contributing Lost Creek drainage area upstream of the Study Area boundary is 9.0 square miles. A watershed model was used to determine runoff based on cover type, soil type, and precipitation (NDNR et al. 2013). The watershed model was built with response functions designed to simulate the effects of soil type, land use, and climate on the terms of the overland water budget. A response function is a mathematical expression of a cause and effect relationship. In this case, the functions may be thought of as a series of values or ratios that express a watershed's response to precipitation and applied irrigation water. Results from the soil-water balance model CROPSIM (Martin et al. 1984) are the foundation upon which the response functions are built. CROPSIM is a computer simulation model developed at the University of Nebraska-Lincoln (UNL) by Dr. Derrel Martin to aid in the prediction of field-scale ET, deep percolation, and runoff that occur from a range of cropped and naturally vegetated systems. CROPSIM uses daily precipitation and temperature information to generate several monthly unit values (that is, values having units of inches/acre), including runoff. The input data sets, which include land use, precipitation, and temperature, were obtained from the Lower Platte River – Missouri River Tributaries Groundwater Model Development project (NDNR 2015b). The consistent period of record for these data sources was from 1960 to 2013. Values prior to 1960 were set at the average value (by month) from 1960 to 2013. The mean monthly Lost Creek volumes are listed in the Appendix, Table 3. The average annual Lost Creek inflow volume to the Study Area is 950 acre-feet.

The National Oceanic and Atmospheric Administration (NOAA) Columbus 3 NE rain gage monthly data (GHCND: USC00251825) were used to estimate the precipitation contribution to Study Area for this analysis (NOAA 2015). The Study Area drainage area is 51,200 acres. The inflow from precipitation was determined by multiplying the Study Area by the monthly precipitation data from the NOAA Columbus 3 NE rain gage. The mean monthly volumes for precipitation are listed in the Appendix, Table 4. The average annual inflow volume to the Study Area from precipitation is 115,440 acre-feet.

3.3 Subsurface Inflows

Subsurface inflows, or groundwater inflows, were quantified based on results of past groundwater modeling efforts. The groundwater flow is calculated by the formula:

$$Q = kiA$$

where

- Q = flow (ft^3/day)
- k=hydraulic conductivity (ft/day)
- i= hydraulic gradient (ft/ft)
- A = cross-sectional area (ft^2)

The hydraulic conductivity values were derived from the Elkhorn-Loup River Basin Groundwater Model (USGS 2010) and the Central Nebraska Groundwater Flow Model (NDNR et al. 2014). The hydraulic gradient was calculated as the slope of the potentiometric surface or the change in hydraulic head over the change in distance in the vicinity of the Study Area boundaries. Water-level monitoring data managed by the UNL Conservation and Survey Division (CSD) (UNLCSD 2015a) was used to create the 2014 water table map. The wells are shown in Figure 8. These wells all had synoptic readings during the spring season and were therefore used to generate a water table surface during non-pumping season conditions.

Figure 9 shows the 2014 water table (potentiometric surface) for the Study Area. In addition, Figure 9 shows the general slope and direction of groundwater movement through the Study Area. The cross-sectional area was calculated as the width (perpendicular to flow) multiplied by the saturated thickness determined from 2014 water level data. The 2014 water table information was considered representative for purposes of the global water budget calculation because since 1950, there has been minimal change (± 2.5 feet) in the water table at the west and north boundaries of the Study Area. Figure 10 shows a hydrograph for the period of record for well G-018361; from the hydrograph, it is evident that there have been minimal impacts on the water table at the west boundary of the Study Area, and seasonal fluctuations in the water table are due to water use during different times of the year. Well G-018361 was used to represent the water level trend at the west boundary of the Study Area because it is the well nearest the west boundary with a significant period of record.

The average annual groundwater inflow volume from the west and north boundaries of the Study Area is 2,520 acre-feet and 3,620 acre-feet, respectively, for an average annual groundwater inflow total of 6,136 acre-feet. These annual data were divided into 12 equal parts to convert to monthly time steps for use in the global water budget analysis.

The area groundwater model, detailed in Section 6.0, will provide a more precise approximation of the aquifer water budget. However, this approximation is sufficient to identify the global water budget terms.

Table 2 and Figure 11 represent the average annual inflow volumes to the Study Area from calendar year (CY) 1943 to 2013.

Table 2. Average Annual Study Area Inflows

Source	Inflow (acre-ft/year)
Loup River	671,700
Loup Power District Canal	1,168,230
Lost Creek	950
Precipitation	115,440
Groundwater	6,140

3.4 Surface Water Outflows

Measured Study Area surface water outflows include the Loup River and the Loup Power Canal Tailrace Canal.

The Loup River discharges into the Platte River at the southern boundary of the Study Area. The Loup River at Columbus gage (06794500) is approximately 3 miles upstream of the Platte River confluence. Therefore, the Loup River at Columbus gage (06794500) was considered reasonable to approximate Loup River outflows. Mean daily data for the Loup River at Columbus gage (06794500) was not recorded from October 10, 1978, to October 1, 2008. The stream flow record extension technique, similar to the method used to determine the Loup River inflow at the Study Area boundary in Section 3.1.2, was used to extrapolate the record from 1978 to 2008. The mean daily flow for the Loup River at Columbus gage

(06794500) plus the Loup River diversion amount was plotted against the Loup River near Genoa gage (06793000) plus the Loup River diversion amount. Two linear relationships were established, as shown in Figures 12 and 13. Based on these relationships, the flow at the Loup River at Columbus gage (06794500), including the diversion amount, was approximated. The flow at the Loup River at Columbus gage (06794500) from 1978 to 2008 was then determined by subtracting the diversion amount. The mean monthly Loup River outflow volumes are listed in the Appendix, Table 5. The average annual Loup River outflow volume from the Study Area is 690,520 acre-feet.

The Loup River Power Canal Return at Columbus (00082100) gage is located at the 8th Street bridge, approximately 4 miles downstream of the Columbus Powerhouse and 1.6 miles upstream of the Platte River. This gage is the best available information to estimate Loup Power Canal Tailrace Canal outflows. The Lost Creek Flood Control Project discharges flow into the Loup Power Canal approximately 0.2 miles downstream of the Columbus Powerhouse, and several culverts along the canal allow for local drainage to enter the canal. These will both be taken into consideration when evaluating the residual term. Mean daily data for the Loup River Power Canal Return at Columbus gage (00082100) was available from October 2002 through September 2013 (NDNR 2015a). To extend the record back to 1943, the Loup River Power Canal Return at Columbus gage (00082100) was plotted against the Loup River Power Canal near Genoa gage (06792500). From this plot, a linear relationship was developed and used to extend the record, as shown in Figure 14. The mean daily discharges at the Loup River Power Canal Return at Columbus gage (00082100) were estimated using the relationship between 2002 through 2013 and the Loup River Power Canal near Genoa gage (06792500) from 1950 to 2002. The mean monthly Tailrace Canal volumes are listed in the Appendix, Table 6. The average annual Tailrace Canal outflow volume is 1,223,380 acre-feet.

3.5 Subsurface Outflows

Subsurface outflows, or groundwater outflows, were quantified using the same approach used to calculate groundwater inflows, with the exception that the water table has shown a significant decline over the past 50 years. UNLCSD well G-038241 has a period of record from 1972 to 2015 and is located in the eastern half of the Study Area. Figure 15 shows a hydrograph for well G-038241. Based on Figure 15, there is an overall decline in the water table. On average, the hydrograph is showing a declining trend of about 1 foot per decade. This well is considered to be an accurate representation of the decrease in water level because it is the only well near the east boundary of the Study Area with a significant period of record. Due to the lack of data, a water table surface could not be generated to compute the saturated thickness each year. Therefore, the trend shown in well G-038241 was applied to the entire east boundary of the Study Area.

Groundwater flow leaves the Study Area through east boundary (see Figure 9). Groundwater was assumed not to flow out the south boundary of the Study Area in a significant amount because the groundwater level contours do not indicate either a gaining or losing reach.

The total average groundwater outflow through the east boundary of the Study Area was estimated as 4,150 acre-feet/year. These values were divided into 12 equal parts to convert to monthly time steps for use in the global water budget analysis. The subsurface outflows are listed in the Appendix, Table 7.

The area groundwater model, detailed in Section 6.0, will provide a more precise approximation of the aquifer water budget. However, this approximation is sufficient to identify the global water budget terms.

Table 3 and Figure 16 represent the average annual outflow volumes to the Study Area from CY 1943 to 2013.

Table 3. Average Annual Study Area Outflows

Source	Outflow (acre-ft/year)
Loup River	690,520
Loup Power District Canal	1,223,380
Groundwater	4,150

3.6 Residual

The global water budget residual term is the difference between flows into the Study Area and flows out of the Study Area. It is comprised of consumptive uses (for example, pumping wells, evaporation, and ET), changes in surface and subsurface storage, and unmeasured surface inflows and outflows.

The global water budget residual is calculated according to the following mass balance equation (see Figure 6):

Residual = (Precipitation x Area) + QSW in + QGW in – QSW out – QGW out

The Loup Power Canal is the largest source of surface water inflows and outflows to the Study Area (see Tables 2 and 3). As previously stated, the Loup Power Canal inflows were approximated based on the amount of water diverted at the Loup River Power Canal near Genoa gage (06792500) and an approximation of the losses between the diversion and the Columbus Powerhouse (Loup Power District 2008). In addition, the Loup River Power Canal outflows were approximated by extending the Loup River Power Canal Return at Columbus gage (00082100) record based on the relationship between the amount of flow diverted at the Loup River Power Canal near Genoa gage (06792500) and the Loup River Power Canal Return at Columbus gage (00082100) from 2003 to 2012. The average annual Loup Power Canal inflow was determined to be 1,168,230 acre-feet/year. The average annual Loup Power Canal outflow was determined to be 1,223,380 acre-feet/year. This represents a net gain of approximately 55,154 acre-feet/year between the Columbus Powerhouse and the Loup River Power Canal Return at Columbus gage (00082100) at the 8th Street bridge. The Loup River Power Canal Return at Columbus gage (00082100) includes both the unmeasured Lost Creek Flood Control Project flows and local drainage returns, both of which are internal to the Study Area. Based on this and some uncertainty associated with the inflow and outflow data, as well as the relatively large magnitude of the Loup Power Canal volumes, the residual was calculated with and without the Loup Power Canal inflows and outflows.

The residual was calculated on a monthly time step for the calendar years (CYs) 1943 to 2013. The average annual Study Area inflows, outflows, and residuals are listed in Table 4. This information is also represented graphically in Figures 17 and 18.

Table 4. Average Annual Study Area Inflow, Outflow, and Residual, CY 1943 to 2013

Source	Inflow (acre-ft/year)	Outflow (acre-ft/year)	Residual (acre-ft/year)
Loup River	671,700	690,520	-
Loup Power Canal	1,168,230	1,223,380	-
Lost Creek	950	-	-
Precipitation	115,440	-	-
Groundwater	6,140	4,150	-
Total with Power Canal	1,962,450	1,918,050	44,400
Total without Power Canal	794,230	694,670	99,560

There is little measured data available to confirm the residual term. However, UNL published estimated average monthly ET values from 2000 to 2009 (Szilagyi et al. 2009, 2010, 2011a, 2011b). These results were compared to the computed residual, which includes ET, for the same time period. The average monthly residual values were converted from acre-feet to inches by dividing the monthly residual value by the area of the Study Area and multiplying by 12 to convert feet to inches. This served as a check for reasonableness of the computed residual for the global water budget. The average annual Study Area inflows, outflows, and residuals from calendar year (CY) 2000 to 2009 are listed in Table 5.

Table 5. Average Annual Study Area Inflow, Outflow, and Residual, CY 2000 to 2009

Source	Inflow (acre-ft/year)	Outflow (acre-ft/year)	Residual (acre-ft/year)
Loup River	662,120	705,500	-
Loup Power Canal	1,112,600	1,164,180	-
Lost Creek	940	-	-
Precipitation	114,340	-	-
Groundwater	6,140	4,030	-
Total with Power Canal	1,896,140	1,873,710	22,430
Total without Power Canal	783,540	709,530	74,010

The computed residual from CY 1943 to 2013 and CY 2000 to 2009 are compared to the UNL ET estimates in Figures 19 and 20 for the with- and without-power-canal values, respectively. The general shape of the monthly residual term matches the ET shape. The residual term is highest in May and June, which is likely due to Loup River spring runoff, while the ET term is highest in June, July, and August, which is consistent with the peak growing season. The average annual residual for CY 1943 to 2013 with and without the canal flows is 10.2 inches and 23.1 inches. The average annual residual for CY 1943 to 2013 with and without the canal flows is 5.0 inches and 17.1 inches. The average annual ET from the UNL study is 25.8 inches (or 110,080 acre-feet, if applied over the entire Study Area). The without canal residual more closely matches the UNL ET annual average value. This is reasonable given the large magnitudes of the Loup Power Canal water budget terms relative to the other water budget terms; uncertainties in the Loup Power Canal terms are therefore amplified and dwarf the other water budget terms. In addition, the Loup River Power Canal Return at Columbus gage (00082100) included a large gain internal to the Study Area. Therefore, the residual developed without the canal inflows and outflows are likely to provide a better estimate of the residual in the Study Area.

The computed residual, which includes ET, is less than the UNL ET value during the peak growing season. The difference between the ET value and residual is likely due to the underlying assumptions used in developing the water budget, neglecting changes in surface and subsurface storage and unmeasured inflows and outflows. It is noted that the computed residual for the period CY 1943 to 2013 is 98,560 acre-feet, which represents approximately 7 percent of the without canal inflows and outflows, and is within 12,000 acre-feet of the estimated annual average ET from the Study Area. The global water budget supports the estimated ET values developed by UNL.

A hydrologic classification of wet, dry, or normal was determined for each year from 1943 to 2013. The classification is based on an approach developed by Anderson and Rodney (2006). This approach ranks the mean annual discharge in descending order. The highest 33 percent of the mean annual flows recorded during the study period were classified as wet years. The lowest 25 percent of the mean annual flows recorded during the study period were classified as dry years. The remaining flows were classified as normal years. The classification for the Study Area was determined based on the mean annual discharge downstream of the Tailrace Canal. The mean annual discharge at the Tailrace Canal was determined by adding the mean annual discharge of the Loup River near Genoa gage (06793000), the Platte River near Duncan gage (06774000), and the Loup River Power Canal Return at Columbus gage (00082100). Table 6 lists the years by flow classification for the Platte River downstream of the Tailrace Canal.

Table 6. Hydrologic Classifications for Platte River Discharges Downstream of Tailrace Canal

Flow Classification	Water Year
Wet	1947, 1949, 1951, 1952, 1971, 1973, 1974, 1980, 1983, 1984, 1985, 1986, 1987, 1988, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2010, 2011
Normal	1944, 1945, 1948, 1950, 1953, 1958, 1960, 1962, 1965, 1966, 1967, 1968, 1969, 1970, 1972, 1977, 1978, 1979, 1982, 1989, 1990, 1991, 1992, 2001, 2007, 2008, 2009, 2012, 2014
Dry	1946, 1954, 1955, 1956, 1957, 1959, 1961, 1963, 1964, 1975, 1976, 1981, 2002, 2003, 2004, 2005, 2006, 2013

3.7 Summary

The global water budget provides insight into the types and relative magnitude of the inflows and outflows of the Study Area, as well as provides a framework to inform the more detailed Study Area water budget. The results of the global water budget can be used to define the residual term. These components include consumptive uses, unmeasured inflows and outflows, and changes in the surface and subsurface storage volumes. However, given the magnitude of available water within the Study Area, further characterizing these components and detailing supplies and uses internal to the Study Area will not be required to evaluate recharge potential.

4.0 Hydrogeology and 3D Model

Based on existing boring and monitoring data, a three-dimensional (3D) subsurface model of the Study Area was developed. The 3D model was used to evaluate the hydrogeology within the Study Area

(Figure 1), and to support the development of the area water model. In addition, the geologic units within the Study Area were characterized.

4.1 Data Sources

Hydrogeologic data within and around the Study Area were compiled from the information sources discussed below and incorporated in the Arc Hydro Groundwater (AHGW) 3.3.1 for ArcGIS 10.1 geodatabase (Aquaveo 2014) for use in development of the 3D model.

4.1.1 Statewide Groundwater-Level Monitoring Program

Beginning in 1930, UNLCSD and USGS developed, maintained, and operated an observation well network throughout Nebraska. UNLCSD and USGS still play a central role in the statewide groundwater-level monitoring program and continue to operate some of the original observation wells. However, other agencies have assumed the responsibilities of building and maintaining observation networks and measuring water levels. The majority of measurements are made by agencies such as the Natural Resources Districts (NRDs), U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and Public Power and Irrigation Districts (UNLCSD 2014).

Data from 829 statewide groundwater-level monitoring program wells in Platte, Butler, Polk, and Colfax Counties (UNLCSD 2015a), as shown in Figure 21, were obtained and incorporated into the Arc Hydro geodatabase. Of those 829 wells, 56 are located within the Study Area (Figure 21). In addition, Figure 21 indicates the number of readings since installation for each well. The data are typically recorded on an annual or semi-annual basis, and the record length varies from well to well. Water table contours and saturated thickness of the principal aquifer can be determined using the 3D model for a given year based on the available data for that year. It is noted that the accuracy of the contours and saturated thicknesses is dependent on the number of observation wells used in 3D model (i.e., more wells translates to increased accuracy). Well depth data were not available for monitoring wells. Therefore, the wells were given an arbitrary well depth elevation to allow for visualization in the 3D model.

4.1.2 UNLCSD Test-Hole Database

The Nebraska statewide test-hole database dates back to the 1930s and contains information for approximately 5,500 test holes drilled by UNLCSD, the UNL School of Natural Resources, and cooperating agencies. The database includes information such as test-hole locations, lithographic descriptions, stratigraphic interpretations, and geophysical log records (UNLCSD 2015b). The borehole logs from the test-hole database were incorporated into the Arc Hydro geodatabase and used to develop the stratigraphy of the Study Area using the 3D model.

The borehole log sheets were created by geologists describing cuttings or cores with the intent of incorporating the descriptions into the Nebraska statewide test-hole database. The borehole logs were prepared according to the guidelines in “Reference List for Describing Cuttings and Cores of Sediments and Sedimentary Rocks in Nebraska (EC-21)” (Korus 2011).

A total of 67 test holes were incorporated into the Arc Hydro geodatabase and used to develop the 3D model. These test holes are aligned along four cross sections spatially oriented in the north-south direction. Three cross sections span the western, central, and eastern portions of Platte County, respectively, while the fourth cross section spans the eastern side of Colfax County. Figure 22 shows the locations of the UNLCSD test holes used to develop the 3D model. UNLCSD and the UNL School of

Natural Resources do not warrant the accuracy of the data nor do they assume any responsibility or liability for use of the database by any party.

4.1.3 Nebraska Department of Natural Resources Registered Groundwater Wells Database

The NDNR registered groundwater wells database includes all registration documentation for water wells registered after January 1, 1969, except public water supply wells (NDNR 2015c). The database keeps records of both active and inactive wells. Wells identified as active were used to establish screen intervals in the 3D model. In the database, each well is given a use ID code. Only wells coded as C (commercial/industrial), D (domestic), and I (irrigation) were used in developing the 3D model. A total of 494 active wells with a C, D, or I designation are located within the Study Area, as shown in Figure 23. The data for those wells were downloaded from the NDNR database (NDNR 2015c) as an ArcMap shapefile, and the shapefile was imported into the 3D model.

Screen intervals based on the NDNR registered groundwater wells were incorporated into the 3D model. These data were downloaded by county. However, not all screen interval data are properly reported to NDNR. Wells without screen interval data were incorporated in the 3D model, but their screen intervals are not represented.

4.1.4 City of Columbus

Data were received for 13 City municipal wells, shown in Figure 24. Five wells (wells 14, 16, 17, 18, and 19) are located in the North Well Field just south of Lake Babcock. Seven wells (wells 1, 2, 4, 8, 11, 12, and 13) are located in the South Well Field in south central downtown. Well 15, located south of U.S. Highway 30 and west of the Tailrace Canal, was abandoned in 2003. The total well depth and screen interval depths were extracted from the NDNR well registration sheets (City of Columbus 1995) and included in the 3D model.

4.1.5 Loup Power District Hydroelectric Project and Lost Creek Flood Control Project Bathymetry

Bathymetry from the Loup Power District Hydroelectric Project's Loup Power Canal and regulating reservoirs (Lake North and Lake Babcock) was represented in the 3D model. The bathymetry was obtained from the 1934 design drawings for the Loup Power Canal (Loup Power District 1934). In addition, bathymetry from the Lost Creek Flood Control Project was incorporated into the 3D model. The data were obtained from the USACE Operation and Maintenance Manual for the Lost Creek Flood Control Project (USACE 1993). The elevations for both the Loup Power District Hydroelectric Project and the Lost Creek Flood Control Project were referenced to the 1929 National Geodetic Vertical Datum. The elevations were converted to the North American Vertical Datum (NAVD) 1988 using the USACE Corpscon conversion tool (USACE 2004). The locations of the Loup Power Canal and the Lost Creek Flood Control Project are shown in Figure 1.

4.1.6 Land Surface

The surface topography included in the 3D model was generated from various light detection and ranging (LiDAR) projects developed by NDNR (NDNR 2015d). The raw LiDAR grids were represented by 2-meter digital elevation models (DEMs), resulting in large files that limited the productivity in ArcScene. To facilitate ease of file use while maintaining the required topographic precision, the LiDAR data were resized to a single 10-meter DEM. The test hole and monitoring well datasets used to create the 3D model include the depth from land surface rather than an elevation. The DEM was used to establish test hole and well depth elevations in the 3D model.

4.2 3D Model

A 3D model of the Study Area was developed using the hydrogeologic data described above and AHGW (Aquaveo 2014). The AHGW software provides tools to take advantage of the ArcGIS platform to archive, manage, and visualize groundwater information. AHGW Subsurface Analyst provides the user tools within ArcMap and ArcScene to create and visualize 3D geologic models, starting with classifying and visualizing borehole logs, creating GeoRasters, and generating 3D GeoVolumes and GeoSections. The AHGW 3D Model is spatially referenced to the North American Datum (NAD) 1983 Nebraska State Plane Federal Information Processing Standard (FIPS) 2600 (US Feet); the elevations are referenced to NAVD 1988. The vertical exaggeration in the 3D model was set at 100 feet. For example, one unit horizontally represents 100 feet, and one unit vertically represents 1 foot.

4.2.1 Model Design and Development

AHGW Subsurface Analyst (Aquaveo 2014) was used to create and visualize a 3D model of the Study Area. The following were generated:

- 3D GeoVolumes – A feature class for storing 3D volumetric representations of hydrogeologic units.
- 3D GeoSections – A feature class for storing cross sections (i.e., fence diagrams) based on "section lines" drawn over the 3D model. These can be used to see if the interpolation options applied are reasonable before building features.

The 3D GeoVolumes and GeoSections were viewed using ArcScene. Based on the UNLCSD test-hole database, the hydrogeologic data were summarized into hydrogeologic units that represent the subsurface stratigraphy in the Study Area. Within AHGW, each hydrogeologic unit (HGU) was indexed by a hydrogeologic unit identifier (HGUID), and the properties of each were cataloged in a hydrogeologic unit table. In addition, each HGUID was indexed with a horizon ID. The term "horizon" refers to the top of each hydrogeologic unit that was represented in the subsurface portion of the 3D model. Horizons were numbered consecutively in the order that the strata were "deposited." To construct a continuous surface within AHGW, such as base of the aquifer, GeoRasters were created by interpolating the borehole data at points that were used to define continuous horizons. The GeoRasters were then used by AHGW to create the 3D GeoVolumes and GeoSections.

The 67 UNLCSD test holes used to create the subsurface for the 3D model span an area covering Platte County and the borders of the adjacent counties. This area is larger than the Study Area and was used to create a more accurate and uniform interpolation of the GeoRaster layers along the boundaries of the 3D model area. The layers created were then clipped to the boundaries of the Study Area. Each individual log was studied to establish how many horizons should be included and where each horizon began and ended. Based on evaluation of the test-hole data, as well as analysis of the geologic cross sections for Platte County (UNLCSD 2010), seven different unique simplified hydrogeologic units were identified. These units were represented in the 3D model.

Once the GeoRasters were created, GeoSection features were generated to represent the different HGUs in cross section or "fence diagrams" view. These 3D visuals were created by applying various AHGW Subsurface Analyst tools to the GeoRasters by establishing Section Lines. Section Lines are line type shapefiles drawn over the 3D model area to specify the locations of the GeoSections. In this model, AHGW Subsurface Analyst tools create GeoSections by applying various cut and fill options to the

GeoRasters by starting at the top of one horizon and filling down to the top of the next horizon. The top horizon is set to fill from the bottom of its horizon up to the land surface. In addition, the top horizon fills down to the next horizon. The bottom horizon (top of bedrock) is not used in the GeoSection or GeoVolume representation; it is simply used to define where the last principal aquifer horizon ends.

GeoVolumes were created in a similar fashion but represented in 3D for the entire model area. Section lines that were used to define the locations of the GeoSections were created along areas with and without borehole data to ensure that the GeoRaster interpolation from the borehole point data for each layer were reasonable. Figures 25 through 27 show 3D isometric views of the GeoVolumes and GeoSections that were created for the Study Area, as well as a geophysical description of each HGUID. Figure 26 shows the GeoSection features with a transparent aerial image for better spatial orientation; Figure 27 removes the aerial to better focus on the GeoSection features. The AHGW Groundwater Analyst was used to assist in importing monitoring well data into the model to generate water tables with respect to time and also to generate flow direction maps.

A 3D representation of how HGUs were assigned to test holes is provided in Figure 28. HGUID 7 (Horizon 4) cannot be seen in the 3D model because HGUID 7 represents the bedrock unit; the top of bedrock is represented by the bottom of HGUID 6. Units below HGUID 6 or below the top of bedrock were considered to be hydrogeologically insignificant for the purposes of this model.

The 2014 water table was created using wells with water level readings taken in March and April 2014. March and April were chosen to limit the seasonal irrigation impacts. This resulted in using 220 UNLCSD monitoring wells in and near the Study Area, with 16 of the wells being in the Study Area. These wells are shown in Figure 21. The Loup Power Canal and Lost Creek Flood Control Project water surface elevations (WSELs), as well as the Loup and Platte Rivers, were represented in the model based on the 2011 LiDAR data (NDNR 2015d). This was considered a good approximation of the normal WSEL based on the Loup Power Canal Tailrace Weir elevation and normal WSEL shown in the Loup Power District design drawings (Loup Power District 1934) and the Lost Creek Flood Control Channel invert shown in the USACE design drawings (USACE 1981). The Christopher's Cove WSEL was based on readings provided by the Christopher's Cover Homeowner's Association. The water table was created with GeoRasters to construct a water table surface from the monitoring wells. The following figures were created to represent the 2014 water table:

- Figure 29 – Plan view of 2014 water table with 10-foot contours
- Figure 30 – 3D isometric view of the 2014 water table, with GeoSections shown for spatial orientation
- Figure 31 –3D isometric view of the 2014 water table, with GeoSections and Land Surface shown for relative depth from land surface to 2014 water table

Water tables between years can also be compared. As an example, the 2010 water table was compared to the 2014 water table. The comparison was performed primarily using those monitoring wells that had consistent record between the two years. Between 2010 and 2014, 168 wells had coincident record. In addition, 27 wells that were within 1,500 feet of each other that had coincident record were also used. The 2010 groundwater contours were generated in the same manner in which the 2014 groundwater contours were generated. One well in close proximity did not have a measurement in 2010. Based on the relatively stable reading prior to 2009, the 2009 reading was used for 2010. The comparison between the 2010 water table and 2014 water table is shown in Figure 32. As evident in Figure 32, there has been a groundwater decline since 2014 in the southeast corner of the Study Area.

4.2.2 Model Results

Based on the 3D model, the following were generated:

- 3D GeoVolume of the Study Area displaying surface lithology
- Thickness maps for the various horizons in the 3D model
- A map that illustrates the bedrock geology and bedrock elevations within the Study Area
- A water table map of the unconsolidated/principal aquifer with flow direction vectors
- A map of the saturated thickness of the unconsolidated aquifers within the Study Area
- A qualitative representation of the Loup Power Canal, Lost Creek Flood Protection Project, and Christopher's Cove bathymetry

4.2.3 Discussion

4.2.3.1 *Geology*

Land surface lithology varies with different HGUs outcropping throughout the 3D model. Figure 33 shows a 3D GeoVolume portraying the variation of land surface lithology as well as descriptions of each HGU. Each HGU is spatially unique, and thickness varies for each throughout the model. The bottommost HGU (HGUID 7) is the bedrock unit, which is not visible in the 3D model. Horizon 4 represents the top of bedrock and was used only to determine the bottom of HGUID 6. The following is a description of each HGU within the Study Area:

- HGUID 1 is physically defined as a unit of silt and clay. HGUID 1 has a maximum thickness of 189 feet with an average thickness of 27 feet.
- HGUID 2 is physically defined as a unit of sand with layers of silt and clay. HGUID 2 has a maximum thickness of 83 feet with an average thickness of 19 feet.
- HGUID 3 is physically defined as a unit of till, silt, and clay. HGUID 3 has a maximum thickness of 100 feet with an average thickness of 9 feet.
- HGUID 4 is physically defined as a unit of gravel with layers of sand. HGUID 4 has a maximum thickness of 114 feet with an average thickness of 48 feet.
- HGUID 5 is physically defined as a unit silt and clay with layers of sand. HGUID 5 has a maximum thickness of 68 feet with an average thickness of 32 feet.
- HGUID 6 is physically defined as a unit of sand and gravel with layers of silt and clay. HGUID 6 has a maximum thickness of 38 feet with an average thickness of 9 feet.

4.2.3.2 *Hydrogeology*

The water table lies relatively close to the ground surface within the alluvial plain of the Loup and Platte Rivers, but tends to be much further below the ground surface outside of the alluvial plain, as shown in Figure 31. The water table elevations decrease from northwest to southeast. The hydraulic gradient is also higher in the northern part of the boundary and tends to decrease as the gradient moves into the alluvial plain. Near the Loup and Platte Rivers, the hydraulic gradient is dependent on the elevation of the water table relative to the stage of the river.

The saturated thickness of the principal aquifer varies throughout the Study Area and is largely dependent on the bedrock elevation. This is evident by comparing the saturated thickness map, shown in Figure 34, to the top of bedrock elevation map, shown in Figure 35.

4.2.3.3 *Alluvial Plain along Loup and Platte Rivers*

The stratigraphy of the Study Area within the alluvial plain of the Loup and Platte Rivers consists of gravel and sands as the top layer (HGUID 4), then underlain by a layer of silt and clay with patches of sand and gravel, and finally underlain by the bedrock. The Carlisle formation serves as the topmost bedrock unit in the area of the alluvial plain. Figure 35 shows the elevation range for the top of bedrock as well as the formation type over the Study Area.

4.2.3.4 *Loup Power Canal Downstream of Power Plant*

From the Loup Power Canal bathymetry, the portion of the canal downstream of the hydroelectric power plant has a flowline elevation that is lower than the water table. This portion of the canal is expected to be a gaining stream. Areas upstream of the hydroelectric power plant are perched above the water table. As a result, some level of seepage is expected to occur. Figure 36 shows a representation of the canal stream elevations with respect to the 2014 water table.

4.2.3.5 *Lost Creek Flood Control Project*

The Lost Creek Flood Control Project bathymetry indicates that the flowline lies beneath the water table. Therefore, base flow in the channel is expected throughout a majority of the year depending on precipitation and groundwater pumping.

4.2.3.6 *Lost Creek Channel*

This portion of Lost Creek Channel is the former channel from its confluence with the Platte River to the area adjacent to Christopher's Cove. The channel still carries some local storm runoff; however, the Lost Creek Flood Control Project diverts most runoff upstream from this segment of Lost Creek. This portion of Lost Creek has been modified over the years and is an open channel with a consistent channel shape and condition. Large concrete box culverts pass flows under the major roads in the area. The channel overlays or is adjacent to the area where groundwater declines have occurred. NRCS soil information indicates that the underlying soil structure is conducive to recharge. These factors suggest the Lost Creek Channel would be a good candidate for a significant recharge project.

4.2.3.7 *Christopher's Cove*

Christopher's Cove lies in an area where the soil consists primarily of sand and gravel. The lake level is dependent on the water table, and seasonal fluctuations as well as overall longer-term decreases in the water table have a significant impact on the lake level.

The hydrogeology of Christopher's Cove makes it a good candidate for potential recharge projects. Pumping into the lake would benefit the residents by keeping the water table from declining and the gravel and sands underlying the lake would allow for a steady infiltration rate into the subsurface.

The information from this and other previous sections was used to develop and analyze potential recharge projects/alternatives within the Study Area. From a water budget perspective, the extraction of groundwater from the southeast portion of the Study Area has an impact on surface water features and thus temporally and spatially will affect recharge area selection.

This information becomes important when examining potential recharge areas and source water alternatives for Christopher's Cove. Source water from initially identified locations such as BD wastewater streams and surface water runoff are dwarfed by large sources such as the return flow in the form of effluent from industrial groundwater withdrawals noted above or the Loup Power Canal return.

From a hydrogeologic perspective, there are sufficient locations where the potential recharge is likely to assist with offsetting the current declines. The primary goal of the recharge or water management projects is to offset the apparent losses in the Study Area identified through the water budget and hydrogeology analyses. These losses are impacting water resources. For example, water levels in Christopher Cove have dropped in recent years and data suggests that groundwater resources have also been affected. Projects identified will be targeted to help restore or otherwise counter the effect of these impacts.

5.0 Recharge Projects

An evaluation of possible groundwater recharge locations and source water that could be used for those sites was performed. Locations were identified using data and information provided by the project sponsors along with information obtained during site visits. Source water was analyzed to determine the potential for yielding a sufficient amount of water for project success. Possible groundwater recharge locations were initially screened based on their ability to meet stated goals and their relationship to source water. Evaluation criteria were then used to help screen and prioritize the best remaining recharge alternatives. The primary goal is to offset the apparent losses in the Study Area identified through the water budget and hydrogeology analyses.

5.1 Recharge Goal

The goal of identifying recharge locations within the Study Area is to identify projects that would be best suited to offset the current decline. Location preferences are those that help to mitigate identified groundwater deficiencies. Evaluation criteria presented in Section 5.7 will be used to rank locations that may provide the greatest recharge benefit to the Study Area. Figure 9 shows the locations where groundwater declines have occurred in recent years and have had an unfavorable effect on local water resources.

5.2 Potential Recharge Sites

Potential recharge sites within the Study Area were identified based on the water budget results, hydrogeology, and reconnaissance of the Study Area. Through coordination with LLNRD and the City, several potential sites were identified for initial evaluation. The sites are listed in Table 7 and are shown in Figure 37.

Table 7. Potential Recharge Sites

Site	Description
A	**Sand and gravel operation**: This location is an active sand and gravel operation. Available information suggests that the water level has been reasonably steady in recent years. This is supported by groundwater level information.
B	**Stormwater detention pond NW:** The City has identified the potential use of stormwater detention ponds as recharge zones. This site could serve multiple purposes: stormwater retention for flood control, recharge to groundwater, and water quality improvements.
C	**Stormwater detention pond NE:** The City has identified the potential use of stormwater detention ponds as recharge zones. This site could serve multiple purposes: stormwater retention for flood control, recharge to groundwater, and water quality improvements.
D	**Stormwater detention pond SE:** The City has identified the potential use of stormwater detention ponds as recharge zones. This location would likely be adjacent to the Lost Creek Channel. This site could serve multiple purposes: stormwater retention for flood control, recharge to groundwater, and water quality improvements.
E	**Christopher's Cove:** The cove is a former sand pit that has been adapted to a residential lake. Water levels have declined in recent years, indicating the impact from groundwater level reductions in the area. Given its connection with the groundwater system, the cove would provide good potential to recharge the groundwater.
F	**Agricultural Park Drainage Ditch:** This stormwater feature could be used to infiltrate source water into the ground and recharge local groundwater.
G	**Lost Creek Channel:** The Lost Creek Channel is a prominent local drainage feature in the southeast portion of the City. Upstream, the channel has been diverted around the City to provide stormwater control. The remnant channel sits very near the largest declines in groundwater levels and would be an excellent location to infiltrate source water back to the aquifer.
H	**BD Treatment Pond:** This is a small treatment pond that receives treated effluent from a portion of the BD plant's wastewater stream. It sits adjacent to Christopher's Cove and near Lost Creek.

5.3 Recharge Water Requirements

Using the water budget and hydrogeologic information, the potential quantity of source water needed to overcome or reduce deficits and/or to recharge the depleted groundwater system was examined. The recharge projects are envisioned to replace a portion of the water that is not consumptively used. To do that, the amount of water that might be required to arrest declines in Christopher's Cove and the amount of water that might be infiltrated in the Lost Creek area was estimated. These water needs are a good surrogate to evaluating the impact from groundwater withdrawals in that area.

At Christopher's Cove, the latest trend shows approximately 4 feet of elevation loss (from elevation 1427 down to elevation 1423). This change in elevation equates to about 138 acre-feet of water. At Christopher's Cove, there is about 34 acre-feet of storage capacity for every 1 foot of elevation change in the elevation range noted. This trend corresponds to increased groundwater pumping downgradient of Christopher's Cove. If the water levels were returned to elevation 1427, the increase in the head of water would assist in infiltrating that water back to the aquifer. Once filled, there would be a need to overcome continued losses (infiltration and evaporation) as water migrates to the aquifer based on current groundwater contours. The hydrogeologic and groundwater modeling tools developed for the project were used to fine tune the potential recharge amounts.

Lost Creek Channel has the potential to use 14,000 or more linear feet of recharge the aquifer along the channel length. LiDAR data suggest that 20 acres of infiltration footprint may be available. Soils in the channel area are generally Lawet silt loam. According to the U.S. Department of Agriculture Natural Resources Conservation Service soils report (NRCS 2016), Lawet silt loam has an infiltration rate ranging from 0.2 to 2 inches/hour. Conservatively using the low end of the range, 0.2 inch/hour equates to a potential of 8 acre-feet/day that could be infiltrated. Again, the groundwater modeling tool will assess the amount of potential infiltration (see Section 6.4).

Christopher's Cove would include a first fill of 140 acre-feet. Christopher's Cove losses would be on the order of 140 acre-feet/year or 0.4 acre-feet/day (losses to groundwater system and evaporation). Lost Creek Channel would be on the order of 8 acre-feet/day or 2,920 acre-feet/year.

For planning purposes, 8 acre-feet/day, which is equivalent to 4 cfs, or 1,800 gallons per minute (gpm), or 2.6 million gallons per day (MGD) was used as a start in developing alternatives. This amount of water is an estimate of the source water required for the two surrogate recharge areas, Christopher's Cove and the Lost Creek Channel, to infiltrate back into the aquifer.

5.4 Water Sources

Groundwater data and analysis of the water budget information suggest that the decline in water levels would require a consistent source of water in both quantity and quality to mitigate groundwater deficits. Sources identified include the following along with their potential quantity of water; information for water quantity was estimated using available data from the City, the Nebraska Department of Environmental Quality (NDEQ), EPA, and other sources:

1. BD plant wastewater effluent discharge data were obtained using NDEQ reported data (NDEQ, 2016). This information suggests about 0.2 MGD of effluent. This amount of water would fall short in satisfying the source water requirements. To modify the potential receiving stream location, NDEQ would need to be engaged. This change could likely affect discharge standards in order to discharge to Lost Creek and/or Christopher's Cove.

2. The Columbus Wastewater Treatment Plant discharges a significant source of potential recharge water. Nearly 3.5 MGD, or 3,928 acre-feet/year, would be available (City of Columbus, 2015c). Similar to the BD plant wastewater, this change could likely affect discharge standards in order to discharge to Lost Creek and/or Christopher's Cove, and would likely require NDEQ engagement.

3. The ADM plant uses water from the City system; however, much of the water comes from groundwater wells near the plant boundary. While no records were available for those privately pumped amounts, it was determined that ADM returns a significant amount of its process water to the Loup Power Canal in the form of wastewater effluent. Records indicate more than 4 to

5.5 MGD is discharged (NDEQ, 2016). The effluent data and known process water requirements for corn milling would suggest that groundwater pumping could be 1.5 times effluent discharges or more (6 to 8.2 MGD). This information was estimated using discharge monitoring data reported to NDEQ and EPA. ADM pumps much of this water near its plant, and this pumping is a major component of groundwater level declines in the area that are the focus of recharge. This water source is near potential recharge areas and is a viable source of water.

4. The Loup Power Tailrace Canal could be pumped to recharge areas. The available water far exceeds the potential requirements for a recharge project. Water from the canal could be pumped and piped to recharge areas from a number of potential locations. Diversion of the water would require coordination and permitting with NDNR and potentially other government agencies.

5. Stormwater recharge areas from detention would be dependent of runoff and would go only to mitigate the potential effects of groundwater withdrawals.

6. Groundwater wells could be used to transfer groundwater from areas where declines have not been as apparent. This amounts to a rebalancing of aquifer storage and will not be retained for additional consideration. If there are future areas where groundwater rises occur, this exchange from one area to another could be considered.

Sufficient water exists for recharge through repurposing wastewater effluent from the City and ADM. The Loup Power Canal also has water in excess of recharge needs. Conceptually, using the ADM discharge would allow for the return of groundwater that was withdrawn back to its source area in the form of recharge. To avoid potential additional treatment of the ADM effluent, seeking a permit to withdraw the water from the Loup Power Canal in a similar volume is recommended. The withdrawal of water should not be considered a new diversion because it is only repurposing an effluent discharge that would not otherwise be going into the canal if not for the groundwater pumping required by ADM operations.

5.5 Pre-Screening of Recharge Sites

The combination of water sources and water requirements was used to assess the potential viability of retaining a site for a more detailed feasibility evaluation. A number of sites have been eliminated because they do not have the best potential to meet the recharge goals. These sites include A, B, C, D, F, and H.

Site A is the location of an active sand and gravel operation. This site is located in an area that has not seen significant groundwater declines, and its resulting ability to effectively mitigate groundwater declines is limited. For these reasons, Site A will not be retained for further evaluation.

Sites B, C, and D were identified as potential stormwater detention areas. Converting these areas to water retention (through the regular addition of source water) may have some unintended consequences. These locations are also upgradient and some distance away from the area of groundwater declines. No notable groundwater level changes can be observed with available data (with the exception of Site D). The addition of source water to induce recharge in these areas could impact local groundwater conditions. Additionally, their distance from the best potential water sources would add cost and complexity to a potential project. If built for future stormwater detention, these sites would likely infiltrate a portion of water and could generally have a positive effect on improving conditions. Site D would be adjacent to the Lost Creek Channel and could provide a similar function as Christopher's Cove or the Lost Creek Channel itself. Given the cost of land acquisition for the site and having a similar effect as adjacent projects, Site D was not considered for further evaluation. If, however, feasibility studies or design analysis would indicate the need for additional infiltration, Site D could be reconsidered in the future. For these reasons, Sites B, C, and D will not be retained for further evaluation.

Site F is the Agricultural Park Drainage Ditch. It is located reasonably close to the area that requires recharge but does lack the size to effectively recharge significant amounts of water. It is also closer to both residential and industrial areas. Installation of piping and equipment for source water may have additional conflicts with existing utilities. Although Site F will not be retained for further evaluation, it could be evaluated as a future addition to a recharge complex in the area.

Site H is the BD Treatment Pond located just east of Christopher's Cove. Conceptually, this pond may have some ability to recharge the underlying aquifer. However, its scale is small compared to the amount of water required to effectively impact the system. It would also need to be evaluated for its ability to recharge water because the underlying soils were likely compacted during construction. For these reasons, Site H will not be retained for further evaluation.

Sites E and G remain for further evaluation and ranking. They have been assembled into potential alternatives and are presented in the next section.

5.6 Recharge Alternatives

Recharge alternatives were assembled for the most promising combinations of location and source water, as described below. For each alternative, the preliminary score (0 to 5) for each of the evaluation criteria was multiplied by the weighting factor to give a total criteria score. The total scores for the criteria was added together to provide an overall ranking or prioritization. As the alternatives were developed, it may become apparent that certain criteria may warrant a higher priority. The process that has been developed allows for this type of iterative modification. The comparison of alternatives using the evaluation criteria combined with the scoring and weighting factors is discussed below.

- Lost Creek Channel: The Lost Creek Channel would have check structures installed to be able to hold water levels in the channel and infiltrate that water. Similar structures are currently being used as part of a grade stabilization project along Rock Creek (NGPCa.2002), Antelope Creek in Lancaster County (City of Lincoln, 2006), Oak Creek, near the Lincoln Airport (NGPCb, 2009), and Shoemaker Wetland—Little Salt Creek (Lower Platte South NRD, 2006). For this concept-level analysis, it was assumed the water would be ponded upstream within the channel using three check or stoplog structures. The assumed depth at each structure was based on allowing approximately 1.5 to 2 ft of freeboard between the water surface and channel bank to avoid overbank flooding. These check structures would still pass storm flows and would not reduce the capacity of storm flows appreciably. The operational controls of each structure would likely be administered by the City, in cooperation with the LLNRD, through an interlocal agreement or other contractual measure. Linked with the check structures would be a pumping plant and pipeline from the Loup Power Tailrace Canal. This plant would have a capacity to pump up to 5,000 gpm at a variable rate. A 12-inch-diameter pipeline, approximately 8,300 ft in length, would deliver the water to Lost Creek. Power is readily available in the area. One potential pipeline route would be along 8th Street. A conceptual layout is shown in Figure 38, as well as the assumed water surface elevations behind each structure. Consideration of utilities, right-of-way, and other routing components would be evaluated during planning and design feasibility analysis. Because Lost Creek would have a semi-permanent footprint of water, FAA considerations regarding the potential for water features within the airspace envelope of the Columbus Airport may apply.

- Christopher's Cove: Recharge at Christopher's Cove would include several major elements: a pumping plant, pipeline, and discharge. Similar to Lost Creek, discussed above, the pumping plant would take water from the Loup Power Tailrace Canal and deliver it approximately 12,000 feet to Christopher's Cove. Route selection would be as discussed for Lost Creek. The pumping plant and pipeline would be smaller, with a pumping capacity of 1,500 gpm and corresponding 6-inch-diameter pressure pipeline. A conceptual layout is shown in Figure 38. Controls for maintaining a range of lake levels would be considered to automate the system.

The hydrogeologic and area groundwater models were used to evaluate the effectiveness of these projects in mitigating groundwater level declines in the area. Therefore, the evaluation and ranking of the alternatives is further discussed with the results of the model in Section 6.0. Recommendations on additional data collection are also discussed.

6.0 Area Groundwater Model

The Columbus groundwater model (CGWM) was developed and calibrated to evaluate the performance of two potential water management projects. The scope of the study is limited to an approximately 9.5-mile by 9.5-mile area that is centered on Columbus and uses existing, publically available data and reports.

6.1 Approach

The goal of the CGWM is to provide a tool that is suitable to aid in the development of water management plan(s) that is expected to include siting and evaluating candidate water management projects. The CGWM will be used to evaluate the effects of a candidate project on local groundwater levels, lake stages, baseflow in streams and canals, and mass water balances. In particular, the CGWM will be used to estimate the benefits of a project in comparison to a baseline or "no action" condition. For example, if a project scenario is to supplement water to Christopher's Cove during the summer to elevate the stage of the gravel pit, two CGWM simulations would be made. The first one is a baseline simulation that continues long-term average model boundaries and estimates recharge and pumping into the future. This simulation is called a baseline or "no action" alternative. The second one uses the same model parameters as the baseline simulation plus the project's water management scenario. The benefits of the project can be calculated by subtracting the baseline model results from the baseline plus project results. These calculations can provide: (1) groundwater level maps showing differences at specified times in the future, (2) hydrographs of differences in groundwater levels at specified locations, (3) hydrographs of differences in baseflow at specified locations, and (4) changes in water budgets. The baseline plus project results provide an estimate of hydrologic conditions in the future for selected assumptions. Although the model will be calibrated to historical conditions, there is enough uncertainty in the values of several parameters such as the aquifer's hydraulic properties, and recharge and pumping to have great confidence in the absolute values of the model results at specific locations. The importance of this uncertainty is minimized when one takes the difference of the two simulations. The timeframe for a project scenario commonly is either a repeat of historical pumping and recharge or uses of long-term averages that can either have an average for each month or long-term constant values.

6.2 Description of Study Area

The study area centers on Columbus and extends outward until no significant hydrologic effects would be expected from a water management project in or near Columbus. With this in mind, the northern boundary extends to just beyond Lake Babcock and the Loup Power Canal; the southern boundary extends to the Platte River; the western boundary is about 5 miles west of Columbus; and the eastern boundary is about 1 mile east of the Loup Power Tailrace Canal. The model boundary area is shown in Figure 39. The dimensions of the study area are about 9.5 miles by 9.5 miles. Topographic regions include the Rolling Hills and Valley-Side Slopes immediately north of the Lost Creek Flood Control Canal and Valleys and Plains in the central and southern part (UNLCSD and UNL Institute of Agriculture and Natural Resources 2001).

6.2.1 Surface Water

Major surface water features in the study area include:

- A short segment of the Platte River
- Lower reach of the Loup River
- Loup Power Canal
- Lake Babcock and Lake North
- Loup Power Tailrace Canal
- Lost Creek Flood Control Channel
- Lost Creek
- Numerous residential lakes and gravel pits, including Christopher's Cove

All of these surface water features are perennial except for the head waters of Lost Creek Flood Control Channel and Lost Creek which now originates in the urban area of Columbus. Historically, Lost Creek caused flooding and high water table problems in Columbus. Construction of the Lost Creek Flood Control Channel on the north side of the urban area intercept flood water from the headwaters area and substantially lowered groundwater levels in the central and northern parts of the Study Area.

Loup Power District operates a hydropower generation facility at Columbus. Water is diverted from the Loup River southwest of Genoa into the Loup Power Canal, enters two regulating reservoirs (Lake Babcock and Lake North) north of Columbus, conveys water through the Columbus Powerhouse, and discharges into the Loup Power Tailrace Canal which flows into the Platte River.

The Loup and Platte Rivers are not regulated by reservoirs in the vicinity of Columbus.

Numerous gravel pits exist in the study area. Several of the gravel pits have become major water features for residential neighborhoods, such as Christopher's Cove. Some of the gravel pits appear to be closed to mining operations and some, especially just north of the Loup River, appear to be active. Because of the shallow water table, the deep part of the pits is filled with water.

6.2.2 Groundwater

The principal aquifer in the study area is composed of Quaternary-age wind-deposited loess and fine-grained sand, and alluvial silt, sand, and gravel. These deposits form a relatively shallow aquifer that is largely unconfined. This shallow aquifer system is underlain by Cretaceous bedrock. A north-south interpretive cross-section just west of Columbus is presented in a map report for the Duncan 7.5 minute quadrangle (Hanson et al. 2009). As presented in the Hydrogeology and 3-D Model section, the aquifer materials are generally composed of clay, till, silt, sand and gravel. Various combinations of these materials form layers, such as “sand and gravel with layers of silt and clay.” The two dominate layers are “gravel with layers of sand and silt” and “clay with layers of sand.”

The water table was mapped for 2014 hydrologic conditions with water-level monitoring data compiled and managed by the UNL Conservation and Survey Division (CSD) (UNLCSD 2015a) (Figure 9). The 2014 spring measurements were used to generate a water-table representing recent and non-irrigation season conditions. This water table map, presented in the Global Water Budget section (Figure XX), indicates that groundwater inflow occurs mostly to the west and northwest of the study area and discharges to the Loup and Platte River valleys and to the east. Locally, all lakes function as open water bodies dug into the aquifer. An exception is the Loup Power Channel and Lake Babcock and Lake North which are on loess and are hydrologically perched above the principal aquifer.

Changes in groundwater levels since the early to mid-1970s suggest that: (1) the western side of the study area experienced no long-term trend and fluctuations of about 5 ft, and (2) the east-central part of the study area experienced a long-term declining trend of about 1 ft per decade in recent years. Recharge to the aquifer is primarily direct infiltration from precipitation, leakage in the headwater tributaries, deep percolation from excess irrigation, seepage from gravel pits, and underflow.

Discharge from the aquifer is primarily from wells, seepage into streams, canals and gravel pits, evapotranspiration from riparian vegetation, and evaporation from water bodies. Additional detail on the surface and subsurface geology is provided in the Hydrogeology and 3-D Model section. Additional detail on the water budget is provided in the Water Budget section.

6.3 Groundwater Model

This section describes the framework of a groundwater model that was developed to calculate hydrologic conditions in response to groundwater pumping and recharge within the principal aquifer, groundwater flow, and stream-aquifer interactions in the model domain for selected modeling scenarios.

6.3.1 Model Code and Processing Software

Groundwater models require large amounts of data to define aquifer properties and hydrologic conditions and stresses. These data were assembled as spatially referenced data layers within GIS and then assigned to the model. Aquifer conditions and stresses are defined at discrete intervals in space and time.

The model was constructed using MODFLOW 2005 (Harbaugh 2005), and utilizes numerous packages, including:

- Layer property flow (LPF) for aquifer properties,
- Preconditioned conjugate gradient (PCG) for numerical solver,
- Lakes for surface water features,
- General head boundary along most of the model perimeter,
- Stream to represent canals, creeks and rivers,
- Recharge for deep percolation, and
- Well to represent pumping from background, municipal and industrial wells.

The model was developed using Groundwater Vistas, Version 6.79, Build 7, 64 bit (Rumbaugh and Rumbaugh 2011). Groundwater Vistas is very useful for pre-processing and post-processing tasks.

6.3.2 Model Domain, Grid, Layering, and Coordinates

The model domain coincides with the study area, except for the area south of the Platte River (Figure 39). For purposes of this model, the Platte River is considered to effectively isolate the groundwater system on the north and south sides of the Platte. Thus, the area south of the Platte River has been coded to be inactive.

The gridding of the model is strongly influenced by the hydrologic importance of representing local surface water features to a local scale model. To represent and simulate their presences in the model, the model was gridded in the x and y directions with 100 ft by 100 ft model cells. This results in 425 model rows and 530 model columns. Figure 40 illustrates the grid detail in three local areas.

The model's vertical discretization is divided into two model layers. The top of layer 1 (land surface) was defined from various light detection and ranging (LiDAR) projects developed by the Nebraska Department of Natural Resources (NDNR 2015). The raw LiDAR grids were represented by 2-meter digital elevation models (DEMs), the model grid was projected over the DEM and each grid cell was assigned the mean elevation as the top of layer 1. The top layer is intended to be deep enough below the water table to keep the water features ponded in worst case scenarios and to keep the top model layer from going dry around pumping wells. The bottom layer is intended to represent the major water-bearing formation that is used by the majority of wells. A review of the subsurface stratigraphy did not indicate a consistent stratigraphic unit, such as a silt and clay layer, to provide a hydraulic marker for separation between the top and bottom layers. As an alternative, the bottom of the top layer was selected to be 40 ft below the 2014 water table; and, the top of the layer is land surface. The bottom layer is bound by the base of the top layer and the bottom of the aquifer. The bottom of layer 2 is defined as the base of the principal aquifer and was generated by using a combination UNLCSD test hole bore logs and base of principal aquifer 10 ft contours intervals also generated by UNLCSD and can be downloaded as an ArcMap shapefile from the UNLCSD website (UNLCSD 2015b/c). The bore logs and contours were used to generate a DEM in ArcMap and each model grid cell was assigned the mean base of principal aquifer elevation in a similar fashion as the top of layer 1.

The coordinate system used for the study is the Nebraska State Plane Coordinate System of 1983. It is based upon a network of geodetic control points referred to as the NAD 1983 State Plane Nebraska FIPS 2600 Feet. The vertical datum used for the study will be the North American Vertical Datum of 1988

(NAVD 88). The model coordinate system is False Easting at 1640416.67 and False Northing: 0.0 with no rotation.

6.3.3 Temporal Discretization

The selected temporal discretization is one-month intervals. This interval provides results for evaluation of projects where annual peaking and seasonality are important. The selected calibration period is from January 1999 to December 2013. The streamflow record for the Loup River gage at Genoa was reviewed to select a rather recent period of about 15 years where the hydrologic conditions have a relatively wide variation and the ending period utilizes the most recently available data (Figure 41). For purposes of this model, the selected calibration period begins during relatively wet conditions in 1999, transitions into relatively dry conditions in the early 2000s, returns to relatively wet conditions in 2010, and again returns to relatively dry conditions after 2010. Much of the data construct and calibrate the model ends in 2013.

6.3.4 Perimeter and Internal Boundaries

Model boundaries are shown in Figure 42. The perimeter model is represented with MODFLOW's General Head Boundary (GHB) package except along the Platte River where the Stream (STR) package is used. The GHB package provides a means for the model to provide a general accounting of aquifer properties and heads outside the model domain. The Spring 2014 water table was used to define the elevations in the GHB grid cells. The streams (Platte River, Loup River, Loup Power Tailrace Canal, Lost Creek Flood Control Canal, and Lost Creek) are represented with MODFLOW's Stream (STR) package. The STR package has an accounting of baseflow that limits losses to be no more than the flow in the stream. In the headwaters of a stream, the streamflow may be defined as being dry (no flow) as is done for the Lost Creek Flood Control Canal or a specified rate as is done for the Loup River. The STR package requires the stage to be defined for each stream. This was generated using the NDNR LiDAR elevations, and was considered a good approximation of the normal water surface elevation. The Lakes (LAK) package simulates a hydraulic connection between the lakes and adjacent model cells and accounts for water flowing into and out of the lakes.

Evapotranspiration is considered to be accounted for in the recharge estimates and minor lowering of the stream stages where riparian vegetation is a major feature.

6.3.5 Aquifer Properties

Aquifer properties that are needed to define the groundwater model include horizontal and vertical hydraulic conductivity, storage, and parameters for the General Head, Stream and Lake MODFLOW packages.

To aid calibration, up to ten (10) zones of fixed horizontal conductivity values were defined for layers 1 and 2. As calibration progressed and hydraulic conductivity was shown to have limited sensitivity the zones in layers 1 and 2 were combined. As a result, several of the zones were assigned the same hydraulic conductivity. The delineation of the zones was guided by the lithology of the subsurface materials, as presented in the Hydrogeology and 3-D Model section. The horizontal conductivity values are reasonably consistent with the CENEB and ELM studies.

The storage property (specific yield and specific storage) values are estimated to be uniform across the model.

Streambed conductance values are calculated from estimates of streambed width, vertical hydraulic conductivity of streambed sediments and thickness of the sediments. Because the values for these parameters are very poorly defined with data, the initial streambed conductance is based on similar models, professional judgment, and calibration. General Head Boundary parameters are consistent with estimates of initial aquifer properties in their location.

6.3.6 Groundwater Pumping and Recharge

Pumping in the model is subdivided into three categories, including background (agricultural irrigation, domestic and livestock), municipal and industrial. For purposes of this model, domestic and livestock pumping are assumed to be negligible in comparison to agriculture irrigation, municipal and industrial pumping. Estimates of agriculture pumping are from CROPSIM, for each model grid cell. The spatial distribution of the background pumping is an aggregate of the pumping within a quarter section and is assigned to a 100 by 100 ft model cell near the center of the quarter section. The distribution of the pumping is divided by zones and the magnitude of the pumping varies by year and month, but is averaged across each of the zones with an equal amount assigned to each of the wells in a quarter section. Pumping for municipal and industrial purposes is assigned on an individual well basis. Municipal pumping data were available from Columbus for their wells for most of the calibration period and estimated for missing periods (City of Columbus, 2015b). Local industrial pumping data were not available and were estimated from several data sources. Figure 43 shows the location of simulated background wells and individual municipal and industrial wells. Figure 44 shows monthly estimate of background, municipal and industrial pumping during the simulation period. The long-term average pumping in the model domain for the 15-year calibration period for background, municipal and industrial categories is about 11,300, 6,100, and 4,310, respectively.

Recharge is estimated on the basis CropSim and, for modeling purposes, is aggregated on a monthly basis into seven zones. Figure 45 shows these recharge zones, and Figure 46 shows the monthly and annual average recharge rates for all seven zones. As indicated in Figure 46, unusually wet conditions occurred for years 1999, 2007, 2008, and 2010 and unusually dry conditions occurred in years 2000, 2002, and 2012.

6.3.7 Model Calibration

6.3.7.1 *Approach*

The calibration approach begins with consideration of the parameters that are the most poorly defined and sensitive to computed heads, baseflows, and water budget. Sensitivity simulations were made for aquifer properties that are known to strongly influence model results. The calibration process continued by making numerous model runs with adjustments to aquifer properties and evaluating the model calculated heads to see if they reasonably matched the calibration targets.

6.3.7.2 *Targets*

The data set for model calibration included groundwater level measurements from wells. This data set usually includes spring and fall measurements. However, the data set has sparse coverage and extended periods without data. The locations of the head targets and model well IDs are shown on Figure 47.

6.3.7.3 *Calibrated Model Parameter Values*

Hydraulic Conductivity. Model sensitivity tests showed that modest variations made to hydraulic conductivity values, within reasonable ranges, had limited effects in areas outside of high pumping areas, such as municipal and industrial wells. With this finding, the initial hydraulic conductivity zones in layers 1 and 2 were redefined and set equal to each other. Figure 48 shows the hydraulic conductivity zones and calibrated values. The vertical hydraulic conductivity is set to one-tenth of the horizontal hydraulic conductivity.

Storage. The specific yield of the model was set to 0.15, and specific storage was set to 0.00001 per foot.

Streambed Conductivity. Sensitivity tests in the literature lists the degree of hydraulic connection between a model stream, river, drain and lake for a range of streambed materials. As one would expect, a poor hydraulic connection is simulated with a low streambed conductance, and visa versa. In this model, the conductance for the Loup and Platte Rivers was set equal to 50,000 ft^2/day and the conductance for canals and creeks was set equal to 500 ft^2/day. Adjustments to the conductance of the Tailrace canal were made during model calibration, with values of 1,000 ft^2/day and 100 ft^2/day evaluated, in addition to the calibrated value of 500 ft^2/day.

General Head Boundaries. The parameters for the General Head Boundaries were calculated from initial estimates of hydraulic conductivities and model cell parameters. The initial heads were set to estimated 2014 water levels and revised downward slightly in some areas to account for dry conditions during much of the simulation period.

6.3.7.4 *Calibration Results*

Evaluation of suitability of calibration is largely based on comparisons of measured and model water levels and statistics of the differences (residuals). Instead of just focusing on the statistics, emphasis was also placed on matching the spatial and temporal patterns or trends of water levels. The calibration approach avoided making local changes in aquifer properties, recharge, and pumping to accommodate individual wells. Instead, the approach was on finding a reasonable compromise within the constraints of the initial estimates of recharge and pumping and averages across zones. In several cases, local variations in the target groundwater conditions suggest irregularities in well construction or recent pumping.

Groundwater Levels. A common graphical measure of “goodness of fit” are comparison of water level hydrographs and a cross plot of calculated versus measured groundwater level elevations at the calibration targets. Figure 49 provides a comparison of the simulated and simulated water level hydrographs for 12 of the targets, which were selected on the basis of coverage and extent of data availability. For ease of comparison, the vertical scale on Figure 49 is 20 ft, with 2 ft intervals. Several of the hydrographs of measured data points show considerable differences in local areas. Examples include targets 7 and 9, and targets 6 and 10. Because the initial application of the model is to test water management projects in the vicinity of Christopher’s Cove and the industrial well field, emphasis was placed on matching the Christopher’s Cove target and target 12. Considerable difficulty was encountered in reasonably matching the 2013 water levels at target 12, which were about 10 ft lower than water levels measured prior to 2013. This relatively abrupt decline is believed to be attributed to a substantial increase in industrial pumping since the beginning of 2010.

A cross plot graphic (Figure 50) shows that there is little bias in the simulated results across the model domain. This plot shows that the model is reasonably well calibrated for its intended purpose. Calibration statistics are commonly reported as mean error (ME) and root mean square error (RMSE). ME is the mean of the differences between the measured and simulated water levels. RMSE is the square root of the average of the squared differences between the measured and simulated heads. A common calibration criterion is for RMSE to be equal to or less than 10 percent of the head range in the model domain. ME and RMSE values are -0.74 ft and 3.47 ft, respectively. The RMSE is about 6.1 percent of the 57 ft range in groundwater levels. These results suggest that the model is suitable for its intended purpose.

6.3.8 Simulation for Calibration Period

The model results for the calibration period include water levels and drawdown since the beginning of the simulation. For illustration purposes, the water levels at the end of the simulation (December 2013) were mapped and are shown in Figure 51. Interpretations from this map include:

- Underflow into the model domain is from the northwest north of the Loup River and from the west south of the Loup,
- Underflow out of the model is to the east,
- Three significant cones of depression are noted; the largest one is centered around the industrial wells,
- A groundwater mound underneath Lake Babcock and Lake North due to higher recharge rates is not evident. This may be attributed to high hydraulic conductivity of the aquifer and to relatively high pumping from a nearby Columbus well field,
- The lakes have a local and minor influence on the configuration of the contours,
- The Lost Creek Flood Control Canal gains a modest rate of water from the aquifer (baseflow) in the western half, and loses water to the aquifer in the eastern half,
- The Loup Tailrace Power Canal shows significant baseflow gains in the upper reach and losses in the lower reach,
- The Loup River appears to be a major groundwater discharge feature (high baseflows), and
- Lost Creek streambed, downstream of Christopher's Cove, appears to be above the water table.

Water Budget. The mass balance for the calibration period is presented in Table 8. Most of the inflow into the model domain is in the form of recharge from precipitation and groundwater underflow along the General Head Boundary to the west and north. Most of the outflow is to wells, discharging into streams and underflow out of the domain to the east. From Table 8, long-term average recharge is approximately 36 percent of the inflow, and pumping is approximately 32 percent of the outflow.

Table 8. Average of Water Balance Components for Calibration Period, Jan 1999–Dec 2013

Component	Inflow (acre-ft/year)	Outflow (acre-ft/year)	Balance (acre-ft/year)
Lake Leakage	5,940	5,770	170
Stream Leakage	3,540	10,470	-6,930
General Head Boundary	16,310	15,830	480
Recharge	24,470	-	24,470
Wells	-	22,090	-22,090
Change in Storage	17,370	14,470	2,900
Total	67,630	68,630	-1,000

6.4 Evaluation of Potential Recharge/Water Management Projects

Evaluation of future potential recharge/water management projects requires estimation of hydrologic conditions, especially pumping and recharge, during future project period. For pumping and recharge, there are three basic approaches, including: (1) repeat of historical conditions, (2) use of long-term averages, and (3) stochastics (using mathematical and statistical concepts) to create a statistically comparable data set to historical conditions. For purposes of these evaluations, a repeat of historical conditions in the calibration data set is selected because it captures a 15-year period with substantial wet and dry cycles and provides an opportunity for comparison to historical conditions.

Potential water management projects have been considered that are intended to contribute additional recharge to the aquifer and limit water-table decline and the associated negative impacts to lake level at Christopher's Cove in the future. The development and selection is discussed in the Recharge section. Two of these potential water management projects were simulated through time to provide estimates of changes to water levels, and the amount of supply water required. These changes provide an indication of the overall performance of the implementation of the two management projects.

The approach adopted for analysis was to simulate possible future conditions without any implementation of potential water management projects (the baseline), and then to compare the water management project simulations with the baseline. Therefore, three model simulations have been setup and executed. These two potential water management projects, and their performance, based on the three model simulations, are described.

6.4.1 Baseline (No Action)

The baseline model run is necessary to make comparisons between the performances of potential projects to be completed in the future. The future period baseline simulation has been setup with the following characteristics:

- Time Period
  Repeat of the calibration period; 15 years from January 1999 through December 2013. The future project period is defined as January 2014 through December 2028.
- Stress Periods
  Monthly stress periods are used (same as calibration period).
- Pumping and Recharge

  - Recharge and background pumping is repeated for 15 years without modification from the calibration period. Municipal pumping was revised such that the sequence of monthly averages from the last 5 years of the calibration period (2009–2013) was repeated three times over the 15-year future project period. Refer to Table 9 for annual average pumping and recharge rates for the future project period.
  - Industrial pumping from the ADM plant wells was revised to equal the last four (4) years in the calibration period; these values were held constant throughout the future project period (i.e., steady pumping rates).
- Initial Heads
  - Initial heads for the future project simulations were taken from the end of the calibration period simulation (December 2013).

Table 9. Average Annual Pumping and Recharge for the Future Project Period

.	Pumping (MGD) Background	Municipal	Industrial	Sum of All Pumping	Recharge Rate[1] (MGD)	Recharge Rate[2] (in/yr)
2014	6.47	5.19	10.96	19.92	40.11	10.96
2015	12.49	5.19	4.43	25.93	16.21	4.43
2016	12.79	5.19	6.75	26.23	24.68	6.75
2017	14.92	5.19	5.57	28.37	20.38	5.57
2018	14.35	5.19	6.26	27.80	22.89	6.26
2019	8.75	5.19	7.89	22.20	28.88	7.89
2020	12.39	5.19	6.93	25.84	25.34	6.93
2021	6.67	5.19	7.39	20.12	27.04	7.39
2022	4.69	5.19	13.68	18.14	50.05	13.68
2023	11.55	5.19	11.80	25.00	43.16	11.80
2024	8.15	5.19	7.42	21.60	27.14	7.42
2025	6.24	5.19	10.69	19.68	39.12	10.69
2026	4.57	5.19	8.64	18.02	31.61	8.64
2027	19.07	5.19	5.46	32.52	19.99	5.46
2028	8.17	5.19	7.61	21.62	27.85	7.61

[1]Volume is calculated by multiplying rate in L/T by active area of the model domain, 2.14206E+09 ft^2.
[2]Recharge rate is based on the average of all seven recharge zones, depicted on Figure 45.

6.4.1.1 *Groundwater Levels*

During the baseline model run, the water table responds to a repeat of drought conditions that occurred in the 2000s. This causes a widespread steep decline of aquifer heads in the future project period from about mid-2014 until mid-2023. This period is followed by a nearly complete rebound of water levels to 2014 levels by 2026, and then another 2-year period of declines in which water levels fall by an amount equaling approximately half the magnitude as they did during the extended drought. Selected hydrographs are plotted on Figure 52 through Figure 54, showing the simulated hydraulic heads at calibration target wells and other observation points, from Jan 1999 through Dec 2028 (30 years). In addition, Figures 52 through 54 show baseline hydraulic heads at the end of the future project period (Dec 2028).

6.4.1.2 *Groundwater-Surface Water Exchange*

Exchanges of water between the aquifer and surface water features are an important consideration for the evaluation of management scenarios and their impacts on the aquifer and for quantifying the required amounts of water required to maintain desired stages and groundwater levels. Figure 55 shows the location of water accounting zones on surface water bodies of interest, considered for analysis of groundwater-surface water (GW-SW) exchange flows; these include: the Christopher's Cove, Lost Creek, and Tailrace Canal.

During the baseline simulation, each of these features, on average, lose water to the aquifer. The average recharge flow rates are as follows (in units of acre-feet per day; AF/day):

- Christopher's Cove – 0.048
- Lost Creek – 0.087
- Tailrace Canal – 4.489

6.4.2 Lost Creek

The project water will be delivered to Lost Creek where it will flow downgradient and pool behind three small check structures, which act to control the stage elevations of the water along the length of the stream. Recharge will occur via infiltration into the stream bed where project water is allowed to flow and pool along the stream length. This project was simulated by changing Lost Creek Stream package to the River package and specifying stages equal to the designed stage elevations associated with the check structures. Stream bed elevations were assigned from LiDAR survey data (mean within each grid cell) while the stream bed was dry. As noted in Section 5.6, water would be ponded behind each check structure such that 1.5 to 2 ft of freeboard would be available to avoid overbank flooding. The distance upgradient from the first check structure in which water was simulated to pond (stage greater than stream bed elevation) was approximately one mile. Figure 56 shows the designed water surface elevations behind each check structure for this scenario along Lost Creek.

The River package calculates exchange fluxes between the stream and aquifer based on the depth of water in the stream and the position of the water table in the grid cell containing the River cells. These exchange fluxes associated with the designed stages along Lost Creek, for the entire future project period, were then output from Groundwater VISTAS for external analysis.

Implementation of the Lost Creek recharge project as described above, with stages along the stream held fixed, results in increased groundwater levels adjacent to Lost Creek, relative to the future period baseline. Figure 57 through Figure 59 show the water-table response—groundwater level map at the end of the future project period (Dec 2028) and hydrographs at monitoring well locations throughout the entire 30-year simulation period (Jan 1999–Dec 2028), around the area of interest. Christopher's Cove shows a gradual increase in heads, relative to the baseline, over the first four years until reaching a maximum increase over baseline of approximately 3–3.5 ft that is sustained with the additional recharge water.

The difference in groundwater levels at the end of the future project period (Dec 2028), between the management project and baseline, is shown in map view on Figure 60. This figure indicates that groundwater levels nearest to the Lost Creek project are impacted the most and that the impacts decline with distance from Lost Creek. Additionally, this map provides the basis for understanding the changes to GW-SW exchanges along the water bodies of interest.

During the future project period simulation (Lost Creek), the water bodies of interest, on average continue to all lose water to the aquifer. Table 10 shows the simulated GW-SW exchange average flows over the future project period, and flows during the driest month (Aug 2018), for the baseline and project scenario, as well as the changes in these exchanges caused by the managed recharge. Although Lost Creek recharge rates increase relative to baseline, the increase of hydraulic heads near Christopher's Cove and along portions of the Tailrace Canal cause decreases in the amount of water lost to the aquifer from these two features. These results indicate the effects of recharging the aquifer with an additional 6.2 AF/day (on average) of water along Lost Creek associated with maintaining stages at 1423, 1422, and 1418 ft-msl.

Table 10. Groundwater-Surface Water Interactions for the Baseline and Lost Creek Project

Time Period	Water Body	Baseline (acre-ft/day)	Management Scenario (Lost Creek) (acre-ft/day)	Difference (change relative to baseline) (acre-ft/day)
Average over Prediction Period (2014-2028) GW-SW Exchange	Christopher's Cove	0.048	0.026	-0.022
	Lost Creek	0.087	6.274	6.187
	Tailrace Canal	4.489	3.700	-0.789
Driest Month (Aug 2018) GW-SW Exchange	Christopher's Cove	0.334	0.309	-0.025
	Lost Creek	0.190	7.435	7.245
	Tailrace Canal	7.434	6.846	-0.588

The GW-SW exchange rates are transient in nature; therefore, the results are best viewed as time-series plots. Figure 61 shows the results of the analysis over the future project period, including transient changes to hydraulic heads at Christopher's Cove in addition to the changes in the GW-SW exchanges caused by implementing the Lost Creek recharge project. During the driest month the change in the exchange rate (relative to baseline) increases from 6.2 AF/day to approximately 7.2 AF/day. Conversely, during wet periods, when the hydraulic heads rebound, the difference in the exchange rate of water from Lost Creek to the aquifer decreases to less than 4 AF/day.

Additional concerns about effects to property owners adjacent to Lost Creek can be evaluated in terms of the depth to water table (from land surface). If groundwater levels become too high due to the addition of water from managed recharge projects, this may result in the undesired effect of subsequent seepage of water into basements or water-logging of soils. As such, this resulting variable was evaluated based on the simulated hydraulic heads and the land surface elevations from LiDAR survey. Figures 62 and 63 show the depth to water table at the end of the project period (Dec 2028) for the baseline and project simulations, respectively. Figures 62 and 63 show the depth to water table decreases substantially in areas both upgradient and downgradient of the Lost Creek recharge project. Only minor areas become saturated with water from this project to the point where water levels rise to within 5 ft of the land surface. However, a much greater area is impacted by groundwater levels in the more immediate vicinity of Lost Creek, where water levels rise to within 5 to 7.5 ft of the land surface.

6.4.3 Christopher's Cove

The project water will be delivered directly to Christopher's Cove on an as needed basis to allow for a designed lake stage to be met and held constant over time. Recharge then occurs via infiltration through the lake bed. For demonstration purposes, an elevation of the lake was set at 1425 ft-msl, approximately 2 ft below Christopher's Cove "No Wake" zone, since this was the magnitude by which the model under-predicted lake stages at Christopher's Cove over the calibration period (Figure 49, Target 4). This project was simulated by changing Christopher's Cove to the Constant Head package and specifying lake stage to be equal to the designed stage elevation throughout the entire future project period. The Constant Head package calculates exchange fluxes between the Constant Head cells and aquifer based on the position of the water table in the grid cells adjacent to the Constant Head cells. When the aquifer heads fall below the design stage, the Constant Head cells supply water to the aquifer (recharge), and when aquifer heads rise above the design stage, the Constant Head cells remove water from the aquifer (discharge). These exchange fluxes between Christopher's Cove (Constant Head cells) and the aquifer associated with the designed lake stage, for the entire future project period, were then output from the modeling software for external analysis.

Implementation of the Christopher's Cove recharge project as described above, with stage of the lake held fixed, results in increased groundwater levels adjacent to the lake, relative to the future period baseline. Figures 64 through 66 show the water-table response—groundwater level map at the end of the future project period (Dec 2028) and hydrographs at monitoring well locations throughout the entire 30-year simulation period (Jan 1999–Dec 2028), around the area of interest. Fixing Christopher's Cove at an elevation of 1425 ft-msl, provides an increase in water stage, relative to baseline, by between approximately 2.5 and 8.5 ft over the future project period. On average over the future project period, the increase in water stage over baseline is approximately 5.8 ft.

The difference in groundwater levels at the end of the future project period (Dec 2028), between the management project and baseline, is shown in map view on Figure 67. This figure indicates that groundwater levels nearest to Christopher's Cove are impacted the most and that the impacts decline with distance from the lake. Additionally, this map provides the basis for understanding the changes to GW-SW exchanges along the water bodies of interest.

During the future project period simulation (Christopher's Cove), the water bodies of interest, on average continue to all lose water to the aquifer. Table 11 shows the simulated GW-SW exchange average flows over the future project period, and flows during the driest month (Aug 2018), for the baseline and project scenario, as well as the changes in these exchanges caused by the managed recharge. Although Christopher's Cove recharge rates increase relative to baseline, the increase of hydraulic heads near Lost Creek and along portions of the Tailrace Canal cause decreases in the amount of water lost to the aquifer from these two features. These results indicate the effects of recharging the aquifer with an additional 2.8 AF/day (on average) of water at Christopher's Cove, associated with maintaining lake stage at 1425 ft-msl.

Table 11. Groundwater-Surface Water Interactions for the Baseline and Christopher's Cove Project

Time Period	Water Body	Baseline (acre-ft/day)	Management Scenario (Christopher's Cove) (acre-ft/day)	Difference (change relative to baseline) (acre-ft/day)
Average over Prediction Period (2014-2028) GW-SW Exchange	Christopher's Cove	0.048	2.855	2.807
	Lost Creek	0.087	0.084	-0.004
	Tailrace Canal	4.489	3.765	-0.724
Driest Month (Aug 2018) GW-SW Exchange	Christopher's Cove	0.334	4.445	4.111
	Lost Creek	0.190	0.178	-0.011
	Tailrace Canal	7.434	6.714	-0.720

The GW-SW exchange rates are transient in nature; therefore, the results are best viewed as time-series plots. Figure 68 shows the results of the analysis over the future project period, including transient changes to hydraulic heads at Christopher's Cove in addition to the changes in the GW-SW exchanges caused by implementing the Christopher's Cove recharge project. During the driest month this change in exchange rate (relative to baseline) increases from 2.8 AF/day to approximately 4.1 AF/day. Conversely, during wet periods, when the hydraulic heads rebound, the difference in the exchange rate of water from Christopher's Cove to the aquifer decreases to less than 0.5 AF/day.

Based on the simulated hydraulic heads and the land surface elevations from LiDAR survey, the depth to water table was evaluated for this scenario. Figure 62 and Figure 69 show the depth to water table at the end of the project period (Dec 2028) for the baseline and project simulations, respectively. As Figures 62 and Figure 69 show, the depth to water table decreases in areas both upgradient and downgradient of Christopher's Cove. Only minor areas become saturated with water from this project to the point where water levels rise to within 5 ft, and 7.5 ft of the land surface.

6.5 Evaluation Criteria, Scoring, and Weighting

The original intent of developing evaluation criteria was to help screen and prioritize potential recharge sites. However, given the identification of source water requirements and location, a number of potential sites were screened from more detailed evaluation. Therefore, the recharge alternatives carried forward are discussed under each criterion below.

Cost and ability to mitigate the impacts on groundwater losses are two primary (i.e., highest weighted) criteria that will be used to evaluate alternatives. Third-Party impacts are also an important criteria. Additional criteria were used to narrow the selection of recharge locations and provide a finer prioritization. Depending on the final assembly of an alternative, some of the criteria may not be differentiators (i.e., all alternatives score approximately the same for the criteria) as they relate to the study goals.

For each alternative, the individual criteria were scored using a range of 0 to 5, with 0 being least favorable and 5 being the most favorable for a particular criterion. Weighting was used to identify a higher relative impact for those criteria that are deemed most important. A weighting range from 1 to 10 is used to normalize the criteria, with 1 being the least important and 10 being the most important.

The team met with the LLNRD to further refine a scoring and evaluation process. The resulting criteria and ranking were established in coordination with LLNRD.

A discussion for scoring the alternatives is provided in each of the following criteria.

6.5.1 Cost of Project to Deliver Water to Recharge Location

This criterion was used to evaluate the cost of a project to deliver water to a specific recharge location(s). Primary capital costs might include land acquisition, site preparation, plant and equipment, startup cost, engineering/design, and administrative/permitting. Every project will have ongoing annual costs; those that define the ongoing O&M associated with an alternative would include operational costs, monitoring, and maintenance. The total costs were divided by the volume of water delivered to the recharge site over a 20-year timeframe. Lower cost alternatives would rank higher. This provided an objective comparison for all alternatives when evaluated on an acre-foot basis and when coupled with the effect of mitigating losses. Primary components of each alternative were estimated at a conceptual level. At this level of analysis, it is prudent to use a larger contingency for unknowns. For this estimate a 50 percent contingency is included along with percentage estimates for Engineering Feasiblity/Design and Environmental Clearance/Permitting of 25 and 5 percent, respectively.

Lost Creek: Costs include construction of a pumping plant and associated piping system to deliver water to Lost Creek. The estimated Present Value Cost (which includes a 20-year O&M horizon) for the project is $1.75 million for the components listed in Section 5.6. The cost for the project, assuming an annual delivery of 2,275 acre-foot per year (6.2 acre-ft per day), would be on the order of $38/acre-foot.

Christopher's Cove: Costs include construction of a pumping plant and associated piping system to deliver water to Christopher's Cove. The estimated Present Value Cost (which includes a 20-year O&M horizon) for the project is $1.08 million for the components listed in Section 5.6. The cost for the project, assuming an annual delivery of 1,025 acre-foot per year (2.8 acre-ft per day), would be on the order of $52/acre-foot.

Similar construction procedures do not differentiate the cost of any one project appreciably. The primary differential is the size of a pumping plant and pipe size along with operational costs. These differences are however offset by the economy of scale to deliver a higher amount of water for recharge. For those reasons the Lost Creek project would score 4 while in comparison Christopher's Cove would be 2.

6.5.2 Effect on Mitigating Groundwater Declines

This analysis was used to gage the success in offsetting groundwater level impacts. Along with using our team's experience, the developed modeling tools were used to assess the effectiveness of water diverted to recharge projects. Certain applications (for example, initially overcoming deficits at Christopher's Cove) would have a need for more water initially before sequencing into a management mode of keeping up with losses. This analysis was unique to each recharge area and the source water for the project. An estimate of efficiency for both initial and ongoing offsets was used for this criterion.

Lost Creek: Using the modeling tools suggests that the Lost Creek project has the ability to recharge 2,275 acre-foot per year towards mitigating groundwater withdrawal impacts. Compared to Christopher's Cove project, it would have less influence in arresting Christopher's Cove water level declines, or maintaining a consistent water level.

Christopher's Cove: Using the modeling tools suggests that the Christopher's Cove project has the ability to recharge 1,025 acre-foot per year towards mitigating groundwater withdrawal impacts. In addition, the Cove's water levels could generally be maintained at a higher operating range, more fully mitigating the effect of their decline.

A comparable argument for scoring Lost Creek higher than Christopher' Cove can be made here as in the Cost Criteria. The Lost Creek alternative can deliver twice the amount of water back to the aquifer. For these reasons Lost Creek was scored at 4 and Christopher's Cove a 3. Section 6 discusses the results of modeling analysis in more detail.

6.5.3 Long-Term Viability

This criterion was used to evaluate how long a particular recharge alternative can be effectively used without significant modification. Some recharge locations may require ongoing or interval maintenance to keep the recharge location functioning as anticipated. For example, accumulated sediment that might impede recharge may need to be removed. Also, certain source water may have a requirement to revisit water quality components. Differing levels of monitoring and data collection would be anticipated depending on the recharge area. These various components could affect other criteria, including cost estimates. A range of time frames were used to score this criterion. A typical time range of uses might be less that 1 year (i.e., one-time use); 1 to 5 years; 6 to 10 years; 10 to 20 years; or more than 20 years. The longer the duration of the overall project, the more relevance this component would have.

Lost Creek: The channel of Lost Creek may require maintenance to address the potential of source water suspended solids affecting the efficiency of infiltration. For the analysis it was assumed that the channel would have an initial cleaning prior to pumping with similar maintenance conducted at 10-year intervals. Monitoring of infiltration efficiency would need to be conducted to fine tune maintenance activities. A system of two to three paired monitoring wells could be used for the monitoring along the creek.

Christopher's Cove: The Christopher's Cove may require maintenance of the outlet structure. Monitoring of infiltration efficiency would need to be conducted to maintain a desired water level.

Both alternatives present themselves well for long-term viability of the projects. While there may be some maintenance differences, there is a trade-off on the potential amount of water that could be infiltrated back to the aquifer. The source water is assumed to be viable for the long-term. For those reasons both projects were score at 4.

6.5.4 Permitting and Institutional Considerations

The relative ease of developing a recharge location coupled with construction and operational components was evaluated with this criterion. Factors might include ease of siting, land acquisition, route considerations, constructing or setting up equipment, start-up complexity, magnitude of O&M required, and ease of permitting. Permitting will likely include federal (Section 404 considerations) and state water quality permitting, and may include local permitting. In addition, a NDNR water rights application would likely be required. A potential consideration of the recharge projects are Federal Aviation Administration (FAA) rules and the restrictions of water bodies near the envelope of the Columbus Airports airspace. It is anticipated that only those projects that would have new footprints of water would be a concern.

Lost Creek: Securing a permit to withdraw water from the Loup Power Tailrace Canal will require interface with a number of regulatory authorities. Since the withdrawal would be in-kind from the ADM waste water discharge it would be the equivalent of placing the discharge directly into Lost Creek. There would need to be coordination with ADM to address any potential with their discharge permit and more importantly to determine their actual pumping volumes and discharge volumes of water. This project will require the acquisition of ROW for the pumping plant and piping. There also may be a ROW or easement requirement for the channel where check structures would be located. As noted in the criteria description, the FAA may need an evaluation for the potential of changing the creek to a once that is ephemeral to perennial. The project would likely need a 404 permit and a corresponding evaluation of potential wetland impacts, if any. There may be ongoing monitoring as a result of acquiring permits.

Christopher's Cove: With the exception of the FAA requirement, the permitting and institutional considerations would be similar to Lost Creek.

Both alternatives would have similar if not identical requirements. Permitting has become more complex and time dependent and will be an important consideration for further feasibility and design. For those reasons both projects were scored at 3.

6.5.5 Third-Party Impacts

It was expected that nearly every recharge project evaluated would need to consider the impact to or from third-party interactions. Whether it is the complexity of routing source water to a site or negotiating for land acquisition, the esoteric nature resulting with third parties to the project was an important consideration. Projects that would be perceived to have less conflict were scored higher than those that may have timing, higher cost, or other concerns (i.e. potential water in basements).

Lost Creek: Coordination with ADM will be a paramount consideration for the project. Understanding more specifically their current and projected pumping demands and wastewater effluent discharge expectations will be important. ROW access will also require coordination with the City and private land owners. A detailed analysis of any potential impact to the floodplain would need to be conducted.

Christopher's Cove: Third-Party impacts would be nearly the same for this alternative. Agreements for ROW and access to the Cove would be an additional consideration. An analysis of floodplain impacts and negation for ROW along Lost Creek would not be necessary.

These alternatives would have similar requirements; however, Christopher's Cove may have fewer overall considerations and for that reason it would score 4 as opposed to 3 for Lost Creek.

Table 12 presents the scoring for both the Lost Creek and Christopher's Cove alternatives. Primarily driven by the economy of scale to deliver more water and at a less expensive per unit cost, Lost Creek would appear to be the most favorable alternative. However, the differentiators are small and the additional of information such as recharge rates based on data could alter the apparent rankings.

Table 12. Alternative Scoring

Criteria Weighting Alternative	Cost Per AF of Water Delivered 5	Effect on Mitigating Groundwater Declines 7	Long-Term Viability 6	Permitting and Institutional Considerations 4	Third-Party Impacts 7	Total Scoring
Lost Creek Channel	20	28	24	12	21	**105**
Christopher's Cove	10	21	24	12	28	**95**

6.6 Limitations

6.6.1 Scenarios

For demonstration purposes, the future hydrologic conditions (recharge and background pumping) assume a repeat of the 1999-2013 hydrologic conditions. This period captures a period that starts out relatively wet, transitions to an extended drought, experiences another wet period and ends with the early stages of another drought. One may want to consider: (1) other future hydrologic conditions that are much longer, (2) long-term average recharge and background conditions, (3) some stochastic (random chance or probability) measure of pumping and recharge, or (4) changes or trends in pumping.

In the formulation of long-term scenarios, one should also review and revise the stream stages and aquifer heads in the boundaries.

6.6.2 Model Calibration

The model grid and layer is representative of a very detailed, local scale model. However, the aquifer properties recharge and background pumping values are considered to be relatively coarse. The recharge and background pumping was determined from a single iteration of CropSim. These values probably could have been refined if the calibration included: (1) interactive iterations between estimates of recharge, background pumping and values of aquifer properties, and (2) possibly the application of automated calibration procedures known as PEST. Also, minor improvements to the model calibration possibly could have been achieved if: (1) the aquifer heads for the model boundaries were varied over time to reflect drought and wet conditions, (2) if precipitation and evaporation were accounted for more directly from the lakes, and (3) if evapotranspiration were more explicitly accounted for from the shallow water table. Finally, the calibration is strongly constrained by a relatively sparse coverage of monitoring well data in time and space near the area of interest.

6.6.3 CGWM Conclusions

The Columbus Groundwater Model is considered to be sufficiently detailed and calibrated to provide a valuable tool for the assessment of potential water management projects. It has been calibrated to a 15-

year period that includes wet periods and droughts. Demonstrations for potential applications were made for two very different projects (recharge to Christopher's Cove and Lost Creek). It has the capability of providing a preliminary evaluation for a wide array of projects with variations in the delivery of water for recharge projects or adding new well fields. The project evaluation process formulates a baseline scenario and calculates the performance of a project by: (1) running the baseline (no action) scenario, (2) adding the project components to the baseline scenario and running it, (3) subtracting the baseline results from the baseline plus project results, and (4) comparing model temporal results (hydrographs of groundwater levels and baseflow) and model spatial results at a given time (water level maps) such as groundwater levels. Software is now available to develop animation of time series plots and maps.

6.7 Discussion

6.7.1 Water Management Projects

The selection of the Christopher's Cove and Lost Creek recharge projects was intended to provide two examples of "What if…" scenarios. These examples include:

- "What if a project is built to provide a sufficient supply of water to Christopher's Cove so that the cove's stage would be maintained at an elevation of 1,425 ft-msl? How much water would be required and what would be the aquifer's response in terms of changes in groundwater levels and surface water-groundwater interaction along the Tailrace Canal and Lost Creek?"
- "What if a project is built to maintain stages at constant levels behind three check dams on Lost Creek? How much water would be required and what would be the aquifer's response in terms of changes in groundwater levels and surface water-groundwater interaction along the Tailrace Canal and Lost Creek?"

6.7.1.1 *Christopher's Cove*

The groundwater modeling shows: (1) groundwater levels would rise substantially in the vicinity of the Cove and decreasing amounts farther away from the Cove, (2) leakage from the Tailrace Canal would decrease as much as 15 percent and has a delayed response of several years, and (3) a filling rate ranging from about 0.25 to 4.5 acft/d, averaging about 2.8 acft/d, and varying seasonally. The hydrologic benefits of this project optimize the stage in Christopher's Cove. It has moderate effects on local groundwater levels and reducing leakage from the Tailrace Canal. It shows very little rise in groundwater levels in the ADM's well field.

6.7.1.2 *Lost Creek*

The groundwater modeling shows: (1) groundwater levels would rise noticeably in the vicinity of the Lost Creek, approximately 2 ft in Christopher's Cove, approximately 10 ft in the ADM well field and at decreasing amounts farther away from the creek. The full effects or benefits of a higher stage in the cove are not realized for 4-5 years, (2) leakage from the Tailrace Canal would decrease as much as 15 percent and has a delayed response, and (3) a filling rate ranging from about 3.5 to 7.5 acft/d and averaging about 6.2 acft/d. The hydrologic benefits of this project provide a compromise to maintaining the stages in Christopher's Cove and reducing the groundwater cone of depression around the ADM well field.

6.7.1.3 *Other Projects*

Conceptualization of other projects is limited only by one's imagination. A few concepts include:

- A Christopher's Cove project where the diversion facilities are only utilized during certain seasons, or a percentage of the outfall from the ADM facility;
- A Lost Creek project where diversion facilities are only utilized during certain times of the year, or a percentage of the outfall from the ADM facility;
- Recharge projects in the vicinity of major municipal and industrial well fields;
- Recharge projects using water supplies other than from the Tailrace Canal; and
- Projects to increase natural leakage from Tailrace Canal and Lost Creek by removing bed sediments.

6.7.2 Potential Third Party Impacts

The goal of the recharge project is to offset the current deficit. Water levels resulting from the recharge project are not anticipated to be higher than those observed prior to the deficit occurring, and thus are not expected to have an impact to local residences. However, given the uncertainty associated with the recharge projects, potential impacts to local residences and/or businesses should be evaluated real time using a monitoring program consisting of groundwater level wells and stream gages. Paired wells will provide observation of shallow and deeper water levels and provide an indicator of infiltration efficiency. On Lost Creek, a stream a stream gage located at the downstream end of the project would be used to estimate the metered discharge water's efficiency in being recharged. Recharge rates and volumes would be adjusted using the data collected. Recharge source water would be controlled based on the monitoring indicators. For example, in a wet cycle, system discharge might be curtailed if infiltration rates indicate the need for a temporary reduction. The elevation of the check structures within Lost Creek will be initially established at elevations that are not anticipated to cause localized impacts to homes. The check structure elevations could be adjusted as necessary based on the monitoring data. If there is a higher stage in the channel it would still flow through Lost Creek and to its confluence with the Platte River.

Impact to the area around Christopher Cove is not anticipated as the water level would not be higher than those previously observed (prior to the deficit). Groundwater levels in and around the Cove area historically did not have any known impacts there or downgradient of the Cove area, there it is not anticipated that using the Cove as a recharge zone would cause future concerns.

6.8 OVERALL CONCLUSION AND/OR RECOMMENDATIONS

This Study considered a number of factors in evaluating the water resources of the Columbus area. Through an inventory of water resources, development of a global water budget, and the development of a flexible and dynamic set of hydrogeologic modeling tools, an analysis of projects to offset the water decline was conducted to evaluate their potential effectiveness in improving the overall conditions of Columbus important water resources. Two projects showed good potential as viable alternatives: a recharge project for the Lost Creek Channel in the southeast portion of the city or a recharge project involving the existing sandpit lake of Christopher's Cove. Both of these projects, or a combination of the two, offer promise and should be considered for a more detailed feasibility and engineering evaluation. Also, as noted above, the conceptualization of projects may be unlimited; however the Study suggests that the Lost Creek and Christopher's Cove projects would likely have some economy of scale in both mitigating groundwater impacts while providing a lower cost for each acre foot of water that is infiltrated back to the aquifer. Several recommendations for additional data collection and/or analysis for the next steps would include:

- An engineering study of the recharge potential of soils along the Lost Creek Channel. This would include geotechnical analysis via soil samples and borings, percolation tests, etc.
- Installation of additional groundwater monitoring wells, including paired wells to evaluate shallow recharge and groundwater levels within the aquifer.
- Research into the existing easement and or ROW associated with Lost Creek Channel.
- Alternative points of water diversion from the Loup Power Tailrace Canal.
- Groundwater pumping requirements at ADM, and effluent discharge volume confirmation.
- Formal discussion with the NDNR and NDEQ concerning the potential for withdrawing water from Loup Canal to be used as recharge water for the project(s).

7.0 Additional Financial and Technical Resources

LLNRD and the City of Columbus have many in-house financial and technical resources. However, fully implementing this study's recommendations may require the utilization of other external resources. All available monetary and technical resources should be explored and leveraged to achieve the project goals.

Opportunities for funding and technical assistance exist in many federal, state, and local agencies. The primary organizations (outside of LLNRD and the City) are identified below in Table 13. Additional information is available on each source below the table. These agencies or groups have been identified as being responsible for program oversight or fund allocation that may be useful in addressing water resource issues in the Columbus area. Participation will depend on the agency/organization's program capabilities and the project's objectives.

7.1 Alternative Funding Options

Successfully implementing these recommendations will require creative approaches to project funding and documentation of successful projects. Knowledge of a broader range of funding opportunities will enable the sponsor to keep as many options open as possible. Alternative funding opportunities can be developed at the regional or local level with private sector business, private foundations, and other non-governmental organizations. These programs should be continuously monitored as their status, priorities, and funding may change. The following identifies general kinds of alternative funding sources and techniques that have been employed in other communities, and could be considered further.

I. Local Options
    a. Capital Improvement Programs
    b. Permits and Fees
    c. In-Kind Services
    d. Developers/Property Owners
    e. Stormwater programs
II. Private and non-profit Foundations
III. Private Industry

Table 13. Summary of Financial & Technical Resources

Organization/Program	Acronym	Technical Assistance	Funding Assistance
Nebraska Environmental Trust (Trust) www.environmentaltrust.org/			
Nebraska Environmental Trust Fund	NETF		X
Federal Emergency Management Agency (FEMA) www.fema.gov/			
Hazard Mitigation Grant Program	HMGP		X
Pre-Disaster Mitigation	PDM		X
Flood Mitigation Assistance	FMA		X
Repetitive Flood Claims	RFC		X
Severe Repetitive Loss Program	SRL		X
US Army Corps of Engineers (USACE) www.usace.army.mil/			
Section 14 Emergency Streambank and Shoreline Protection	-	X	X
Section 206 Aquatic Ecosystem Restoration	-	X	X
US Department of Health and Human Services (DHSS) www.hhs.gov/			
Various Safe Water and Wastewater Treatment Programs	-	X	X
National Park Service (NPS) www.nps.gov/			
Various Recreational Facilities Programs	-	X	X
US Department of Agriculture (USDA) and Natural Resources Conservation Service (NRCS) http://www.nrcs.usda.gov/			
Environmental Quality Incentives Program	EQIP	X	X
Conservation Stewardship Program	CSP	X	X
Conservation Reserve Program	CRP	X	X
National Water Quality Initiative	NWQI	X	X
Agricultural Conservation Easement Program	ACEP	X	
Conservation Innovation Grants	CIG	X	X
Healthy Forests Reserve Program	HFRP	X	X
Regional Conservation Partnership Program	RCPP	X	X
Nebraska Department of Natural Resources (DNR) http://www.dnr.nebraska.gov/			
Small Watersheds Flood Control Fund	-		X
Natural Resources Water Quality Fund	NRWQF		X
Water Well Decommissioning Fund	-		X
Soil and Water Conservation Fund	-		X
Interrelated Water Management Plan Program Fund	IWMPP		X
Resources Development Fund	NRDF		X
Water Sustainability Fund	WSF		X

Organization/Program	Acronym	Technical Assistance	Funding Assistance
Nebraska Department of Environmental Quality (NDEQ) http://www.deq.state.ne.us/			
Nonpoint Source Pollution Management Program (Section 319)	CWA S 319	X	X
Wetlands Program Development Grants	WPDG		X
Linked Deposit Program through the Clean Water State Revolving Fund	-		X
Community Lakes Enhancement and Restoration Program	CLEAR	X	X
Underground Storage Tank Program	-	X	X
Nebraska Game and Parks Commission (NGPC) outdoornebraska.ne.gov/			
State Wildlife Grant Program	SWG		X
Land and Water Conservation Fund	LWCF		X
Recreational Trail Program	RTP		X
Nebraska Wildlife Conservation Fund	-		X
Aquatic Habitat Improvement Program	-	X	X
Open Fields and Waters Access Program	-	X	X
WILD Nebraska Program	-	X	X
Nebraska Natural Heritage Program	-	X	X
Nebraska Department of Agriculture www.nda.nebraska.gov/			
Nebraska State Buffer Strip Program	-		X
Groundwater Foundation www.groundwater.org/			
Education and Community-based action programs	-	X	
University of Nebraska Extension extension.unl.edu			
Information and Various Outreach Programs	-	X	
Pheasants Forever www.pheasantsforever.org/			
Corners for Wildlife Program	-		X
Platte County PF Chapter - Various conservation programs	-	X	X
Ducks Unlimited www.ducks.org/			
Various Conservation Programs	-	X	X

7.2 Water Sustainability Fund (WSF)

The WSF is a new source of funding for water management projects in Nebraska and is administered by the Natural Resources Commission (NRC) which oversees Fund operations including selecting successful applications, and NDNR which oversees administration.

The Fund is intended to build projects that control flooding, ensure long-term water availability, reduce aquifer depletion, increase stream flows, address water quality concerns, and keep Nebraska in compliance with interstate water compacts. Funding for the WSF is appropriated by the Nebraska Legislature each year, where 10% is designated to projects addressing combined storm and sewer water overflow, and 10% to projects requesting $250,000 or less. It is anticipated that the Fund will receive $11 million each year. WSF applications are due between July 16 and 31 each year. Based on our understanding of the requirements, and discussions with administrators, would suggest that this project is a good fit for the intention of the WSF. It is recommended that funding under this mechanism be pursued.

8.0 References

Aquaveo. 2014. Arc Hydro Groundwater 3.3.1 (for ArcGIS 10.1). Aquaveo. Build Date: May 7, 2014.

Anderson, Donald M., and Mark W. Rodney. 2006. Characterization of Hydrologic Conditions to Support Platte River Species Recovery Efforts. *Journal of the American Water Resources Association* 42(5):1391-1403.

City of Columbus. 1995.Columbus Public Works Office transmittal via e-mail, received November 9, 2015.

City of Columbus. 2015. Columbus, Nebraska City Code. July 6. http://library.amlegal.com/nxt/gateway.dll/Nebraska/columbus_ne/columbusnebraskacitycode?f=templates$fn=default.htm$3.0$vid=amlegal:columbus_ne.

City of Columbus. 2015b. Columbus Public Works Office Transmittal via e-mail, received November-December, 2015.

City of Columbus. 2015c. Columbus Public Works Office Transmittal via e-mail, received June, 2015.

City of Lincoln. 2006. Antelope Creek Restoration Project. Antelope Creek. Lincoln, Nebraska.

FEMA. 2010a. Flood Insurance Study, Platte County, Nebraska, and Incorporated Areas. Flood Insurance Study Number 31141CV000A. Effective April 19.

FEMA. 2010b. Flood Insurance Rate Map, Platte County, Nebraska, and Incorporated Areas. Map Number 31141C0310E. Effective April 19.

FEMA. 2010c. Flood Insurance Rate Map, Platte County, Nebraska, and Incorporated Areas. Map Number 31141C0320E. Effective April 19.

FEMA. 2010d. Flood Insurance Rate Map, Platte County, Nebraska, and Incorporated Areas. Map Number 31141C0330E. Effective April 19.

FEMA. 2010e. Flood Insurance Rate Map, Platte County, Nebraska, and Incorporated Areas. Map Number 31141C0335E. Effective April 19.

FEMA. 2010f. Flood Insurance Rate Map, Platte County, Nebraska, and Incorporated Areas. Map Number 31141C0340E. Effective April 19.

FEMA. 2010g. Flood Insurance Rate Map, Platte County, Nebraska, and Incorporated Areas. Map Number 31141C0345E. Effective April 19.

FEMA. 2015. "Zone AE and A1-30." Updated April 28. http://www.fema.gov/zone-ae-and-a1-30.

Hanson, P.R., A.R. Young, and L.M. Howard. 2009. Surficial Geology and Interpretive Cross Section of the Duncan 7.5 Minute Quadrangle, Nebraska. Conservation and Survey Division (Nebraska Geological Survey), School of Natural Resources, University of Nebraska-Lincoln. October. Available online at http://snr.unl.edu/csd-esic/download/geologysoils/digitalgeologicmaps/Duncan_Files/Duncan_Quad.pdf.

Harbaugh, Arlen W. 2005. MODFLOW-2005, The U.S. Geological Survey Modular Ground-Water Model—the Ground-Water Flow Process. U.S. Geological Survey Techniques and Methods 6-A16. Available online at http://pubs.usgs.gov/tm/2005/tm6A16/.

JEO Consulting Group, Inc. 2015. Levee Improvements Preliminary Engineering Report, Loup River Flood Protection Project. January.

Korus, Jesse. 2011. Reference List for Describing Cuttings and Cores of Sediments and Sedimentary Rocks in Nebraska (EC-21). 7 pp., size 8.5" x 11", laminated sheet with 6 additional pages.

Loup Power District. 1934. Loup Power Canal Plan and Profile. Loup River Public Power District.

Loup Power District. 2008. Pre-Application Document. Table 5-9. October 16. Available online at http://www.loup.com/relicense/html/documents.html.

Lower Platte South NRD. 2006. Shoemaker Wetland Restoration—Little Salt Creek. Lancaster County, Nebraska.

Martin, D. L., D. G. Watts, and J. R. Gilley. 1984. Model and Production Function for Irrigation Management. *Journal of Irrigation and Drainage Engineering* 110(2):149-164.

NDEQ. 2016. United States Environmental Protection Agency, Enforcement and Compliance History On-line. Accessed February 29, 2016. https://www.echo.epa.gov/

NDNR. 2015a. Current Stream Flow Conditions. Lincoln, Nebraska. Accessed July 10, 2015. http://data.dnr.nebraska.gov/RealTime/Gage/Index.

NDNR. 2015b. Lower Platte River – Missouri River Tributaries Groundwater Model Development (ongoing study).

NDNR. 2015c. Registered Groundwater Wells Data Retrieval. Nebraska Department of Natural Resources. Retrieved August 20, 2015. http://data.dnr.nebraska.gov/wells/Menu.aspx.

NDNR. 2015d. LIDAR 2 Meter 2009 - 2013. [Data used include 2010 Eastern Nebraska NIROC and NRCS shapefiles, and 2011 NRCS and USACE Nebraska shapefile.] Retrieved June 17, 2015. http://dnr.nebraska.gov/lidar-2-meter-2009-2012.

NDNR, Brown and Caldwell, and The Flatwater Group. 2014. Central Nebraska Groundwater Flow Model. Figure 5-2, Hydraulic Conductivity Distribution. Prepared by Brandi Flyr et al. (NDNR), Robert Wyckoff et al. (Brown and Caldwell), Marc Groff et al. (The Flatwater Group). August 5, 2013. Updated March 7, 2014.

NDNR, Central Platte Natural Resources District, HDR Engineering, Inc., The Flatwater Group, Inc., and Lee Wilson and Associates, Inc. 2013. COHYST 2010—A Total Water Budget Approach to

Integrated Water Management. Phase II Report: Documentation of Integrated Computer Models. July.

NGPCa. 2002. Jack Sinn Wetlands along Rock Creek. Saunders and Lancaster Counties.

NGPCb. 2009. Bowling Lake Restoration Project. Oak Creek. Lincoln, Nebraska.

NOAA. 2015. GHCND (Global Historical Climatology Network)-Monthly Summaries Database (for Columbus 3 NE rain gage monthly data [GHCND: USC00251825] and download documentation; accessed July 10, 2015). https://www.ncdc.noaa.gov/cdo-web/datasets/GHCNDMS/stations/GHCND:USC00251825/detail.

NRCS. 2016. Natural Resource Conservation Service, Web Soil Survey. Accessed March 7, 2016. http://www.websoilsurvey.nrcs.usda.gov/

Szilagyi, J., and J. Jozsa. 2009. Estimating spatially distributed monthly evapotranspiration rates by linear transformations of MODIS daytime land surface temperature data. *Hydrology and Earth System Sciences* 13(5):629-637.

Szilagyi, J., and A. Kovacs. 2010. Complementary-Relationship-Based Evapotranspiration Mapping (CREMAP) Technique for Hungary. *Periodica Polytechnica Civil Engineering* 54(2):95-100.

Szilagyi, J., and A. Kovacs. 2011a. A Calibration-Free Evapotranspiration Mapping Technique for Spatially-Distributed Regional-Scale Hydrologic Modeling. *Journal of Hydrology and Hydromechanics* 59(2):118-130.

Szilagyi, J., A. Kovacs, and J. Jozsa. 2011b. A Calibration-Free Evapotranspiration Mapping (CREMAP) Technique. In Evapotranspiration, ed. L. Labedzki, 257-274. Vienna, Austria: INTECH. Available online at http://www.intechopen.com/books/evapotranspiration.

UNLCSD. 2010. Compilation of Geologic Cross Sections of Eastern Nebraska. School of Natural Resources, University of Nebraska–Lincoln. Available online at http://nebraskamaps.unl.edu/productcart/pc/viewPrd.asp?idproduct=12114.

UNLCSD. 2014. Nebraska Statewide Groundwater-Level Monitoring Report 2014. Nebraska Water Survey Paper Number 82. Prepared by Aaron R. Young, Mark E. Burbach, and Leslie M. Howard. Conservation and Survey Division, School of Natural Resources, University of Nebraska–Lincoln. Available online at http://snr.unl.edu/csd-esic/GWMapArchives/GWReports/GW_Level_Report_2014.pdf.

UNLCSD. 2015a. Historic Nebraska Statewide Groundwater Level Program - Data Retrieval. School of Natural Resources, University of Nebraska–Lincoln. Retrieved June 17, 2015. http://snr.unl.edu/data/water/groundwater/NebGW_Levels.aspx.

UNLCSD. 2015b. Nebraska Statewide Test-Hole Database. School of Natural Resources, University of Nebraska–Lincoln. Retrieved May 21, 2015. http://snr.unl.edu/data/geologysoils/NebraskaTestHole/NebraskaTestHoleIntro.aspx.

UNLCSD and UNL Institute of Agriculture and Natural Resources. 2001. Topographic Regions Map of Nebraska. Publications from the Center for Applied Rural Innovation (CARI). Paper 62. Available online at http://digitalcommons.unl.edu/caripubs/62.

USACE. 1981. Detailed Project Report, Lost Creek At Columbus, Nebraska, Flood Protection Project. January. Omaha District.

USACE. 1993. Lost Creek Flood Protection Project, Columbus, Nebraska, Operation and Maintenance Manual . January. USACE Omaha District.

USACE. 2004. Corpscon Version 6.0.1. Topographic Engineering Center, Alexandria, Virginia.

USGS. 2010. Simulation of Groundwater Flow and Effects of Groundwater Irrigation on Stream Base Flow in the Elkhorn and Loup River Basins, Nebraska, 1895–2055—Phase Two. Prepared by Jennifer S. Stanton, Steven M. Peterson, and Michael N. Fienen. Scientific Investigations Report 2010–5149. Available online at http://pubs.usgs.gov/sir/2010/5149/.

USGS. 2015. USGS National Water Information System (NWIS). Washington, D.C. Accessed July 10. http://waterdata.usgs.gov/nwis/.

COLUMBUS AREA WATER RESOURCES ASSESSMENT

STUDY AREA

FIGURE 1

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE1.MXD - USER: TWIESE - DATE: 4/11/2016

COLUMBUS AREA WATER RESOURCES ASSESSMENT

FLOODPLAIN

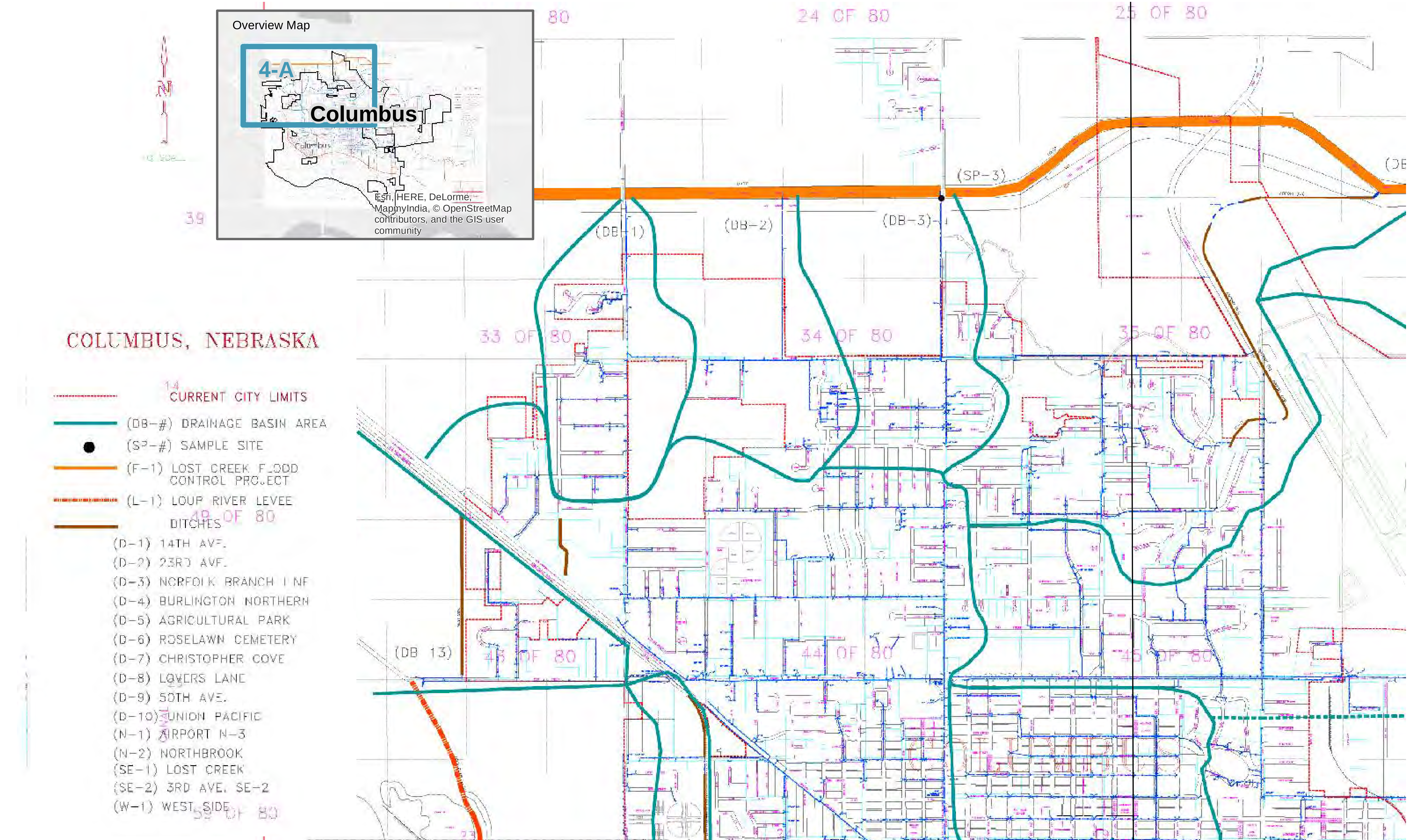
FIGURE 2

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE2.MXD - USER: TWIESE - DATE: 4/11/2016

HDR | THE FLATWATER GROUP INC. | JEO | LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT
SOUND REACH & FREEBOARD DEFICIENT OPTIONS
FIGURE 3

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE3.MXD - USER: TWIESE - DATE: 4/11/2016



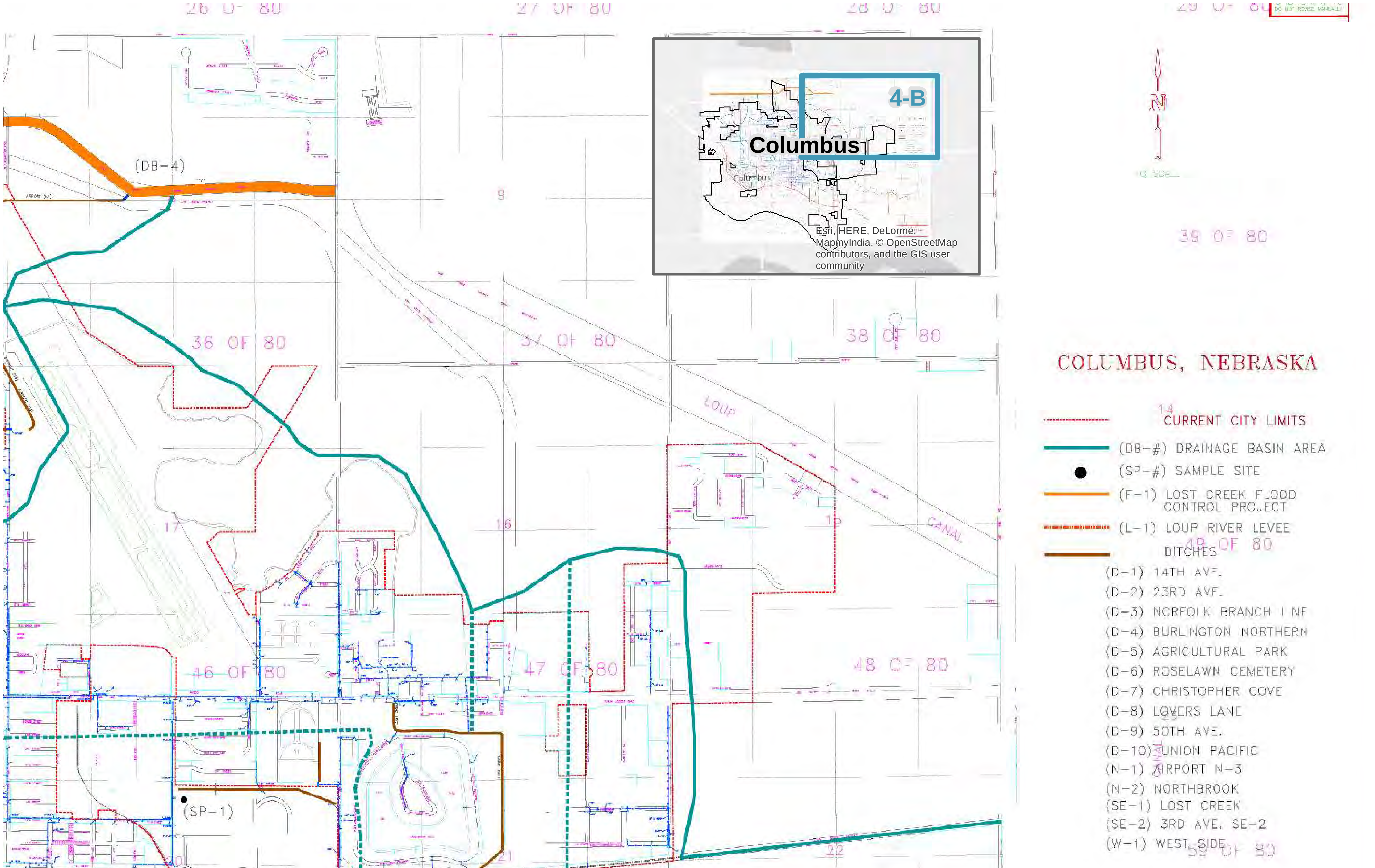
COLUMBUS AREA WATER RESOURCES ASSESSMENT

CITY STORM SEWER MAP

FIGURE 4-A

HDR · THE FLATWATER GROUP INC. · JEO · LOWER LOUP NATURAL RESOURCES DISTRICT

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\COLUMBUSAREA_CITYSTORMSEWER_3A.MXD - USER: TWIESE - DATE: 4/11/2016

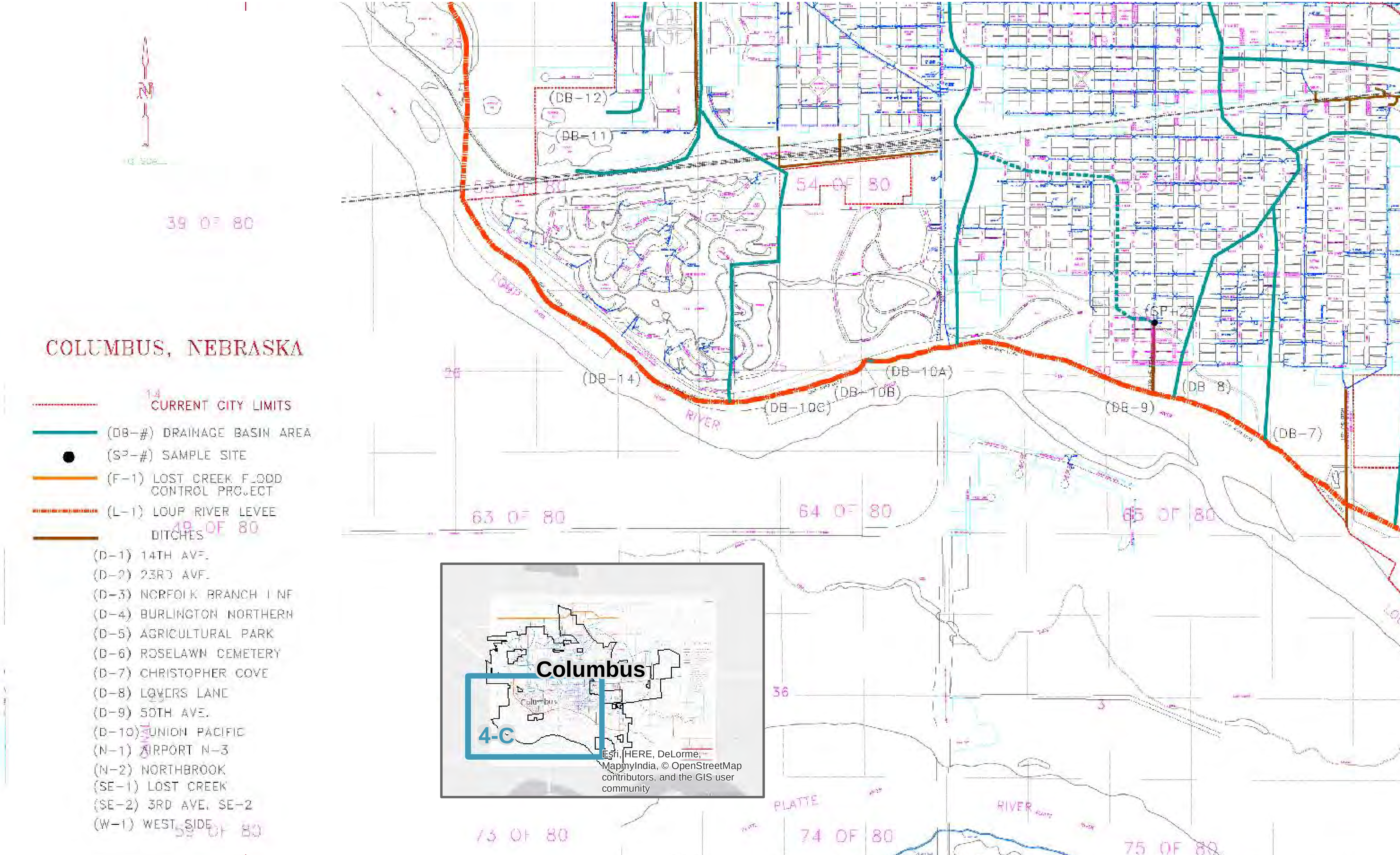


COLUMBUS AREA WATER RESOURCES ASSESSMENT

CITY STORM SEWER MAP

FIGURE 4-B

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE4B.MXD - USER: TWIESE - DATE: 4/11/2016



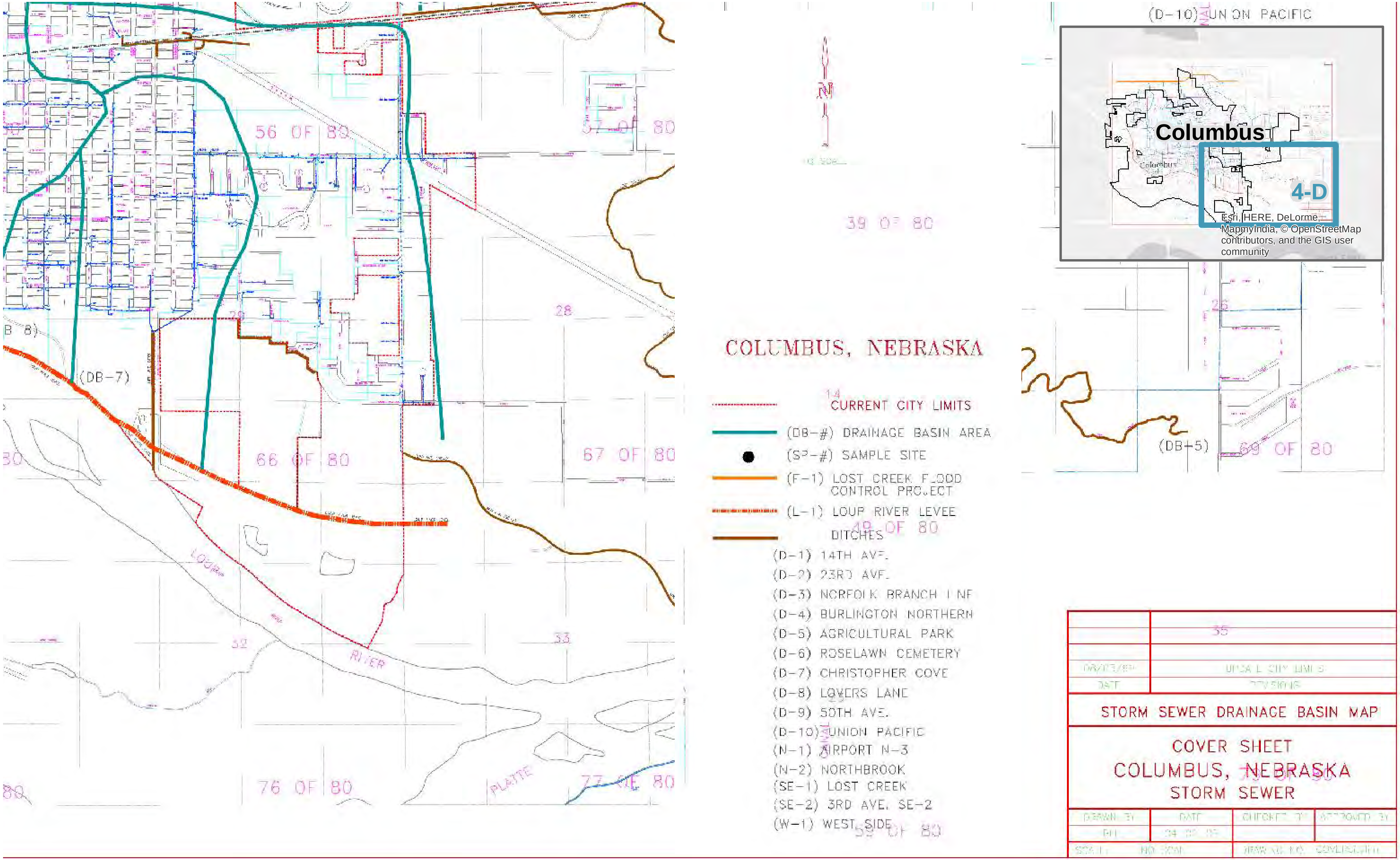
HDR | THE FLATWATER GROUP INC. | JEO | LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

CITY STORM SEWER MAP

FIGURE 4-C

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE4C.MXD - USER: TWIESE - DATE: 4/11/2016

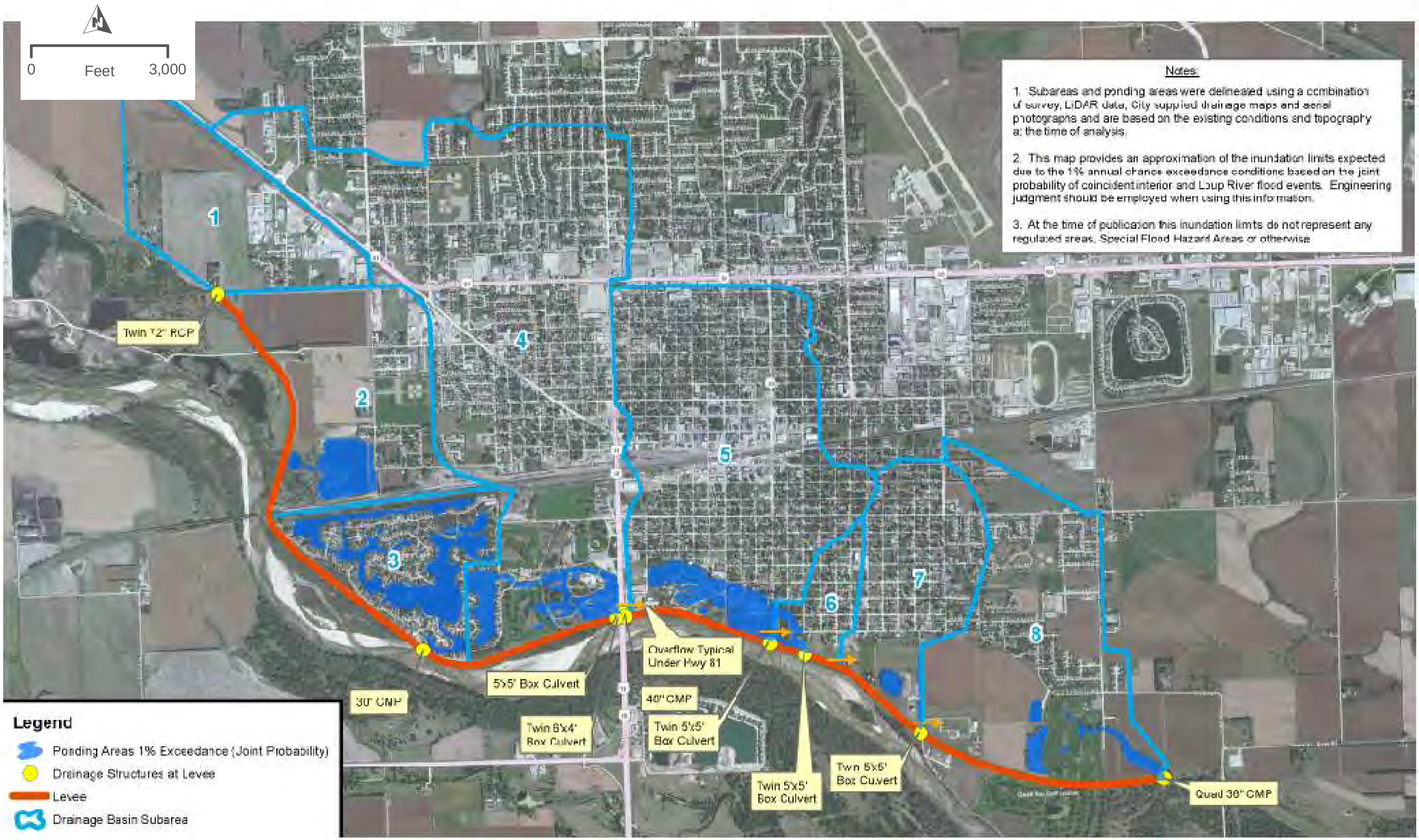


COLUMBUS AREA WATER RESOURCES ASSESSMENT

CITY STORM SEWER MAP

FIGURE 4-D

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE4D.MXD - USER: TWIESE - DATE: 4/11/2016



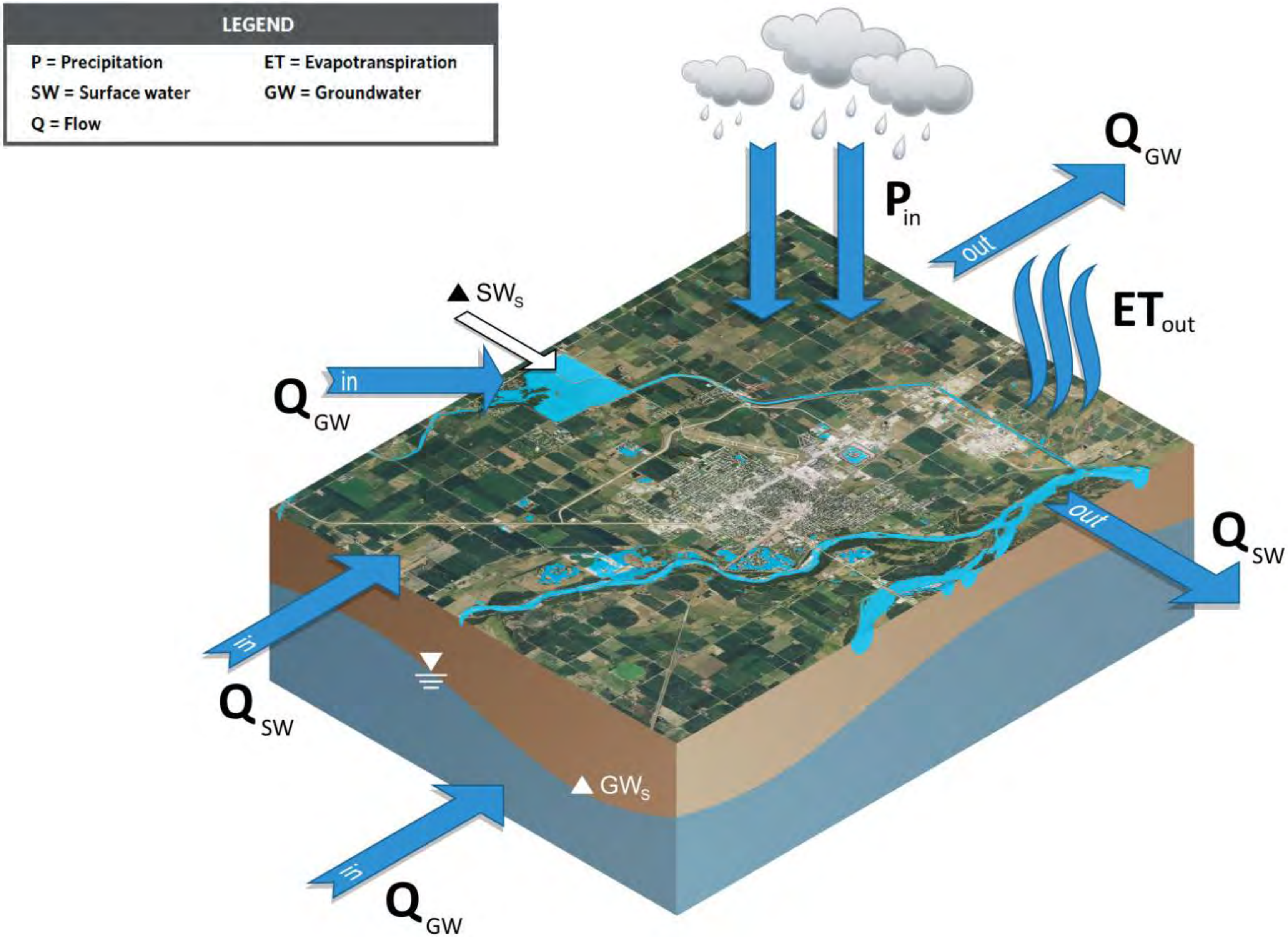
HDR THE FLATWATER GROUP INC. LOWERLOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

LEVEE INTERNAL DRAINAGE FINDINGS

FIGURE 5

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURES5.MXD - USER: TWIESE - DATE: 4/11/2016



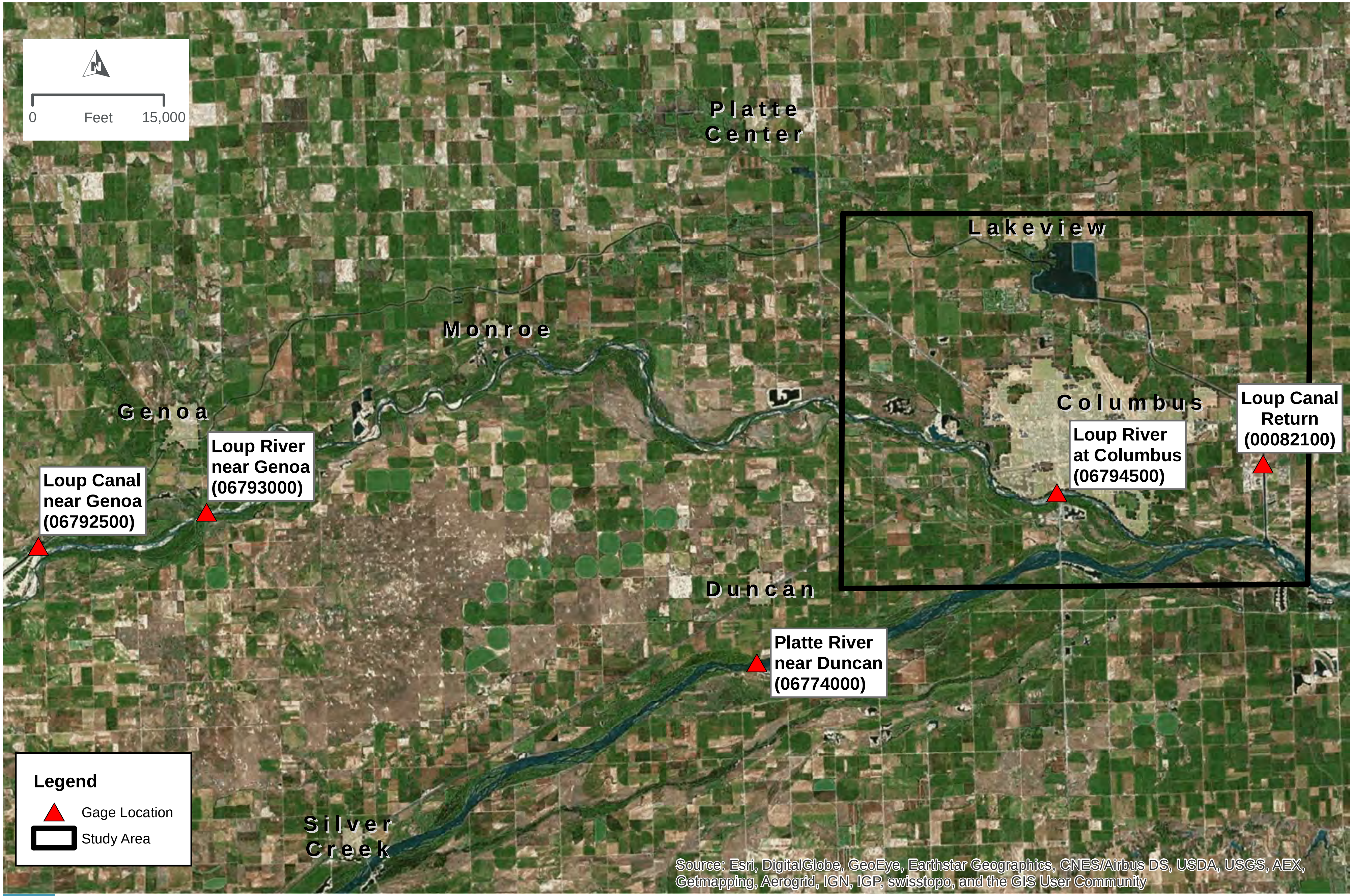
HDR | The Flatwater Group Inc. | JEO | Lower Loup Natural Resources District

COLUMBUS AREA WATER RESOURCES ASSESSMENT

GLOBAL WATER BUDGET TERMS

FIGURE 6

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE6.MXD - USER: TWIESE - DATE: 4/11/2016

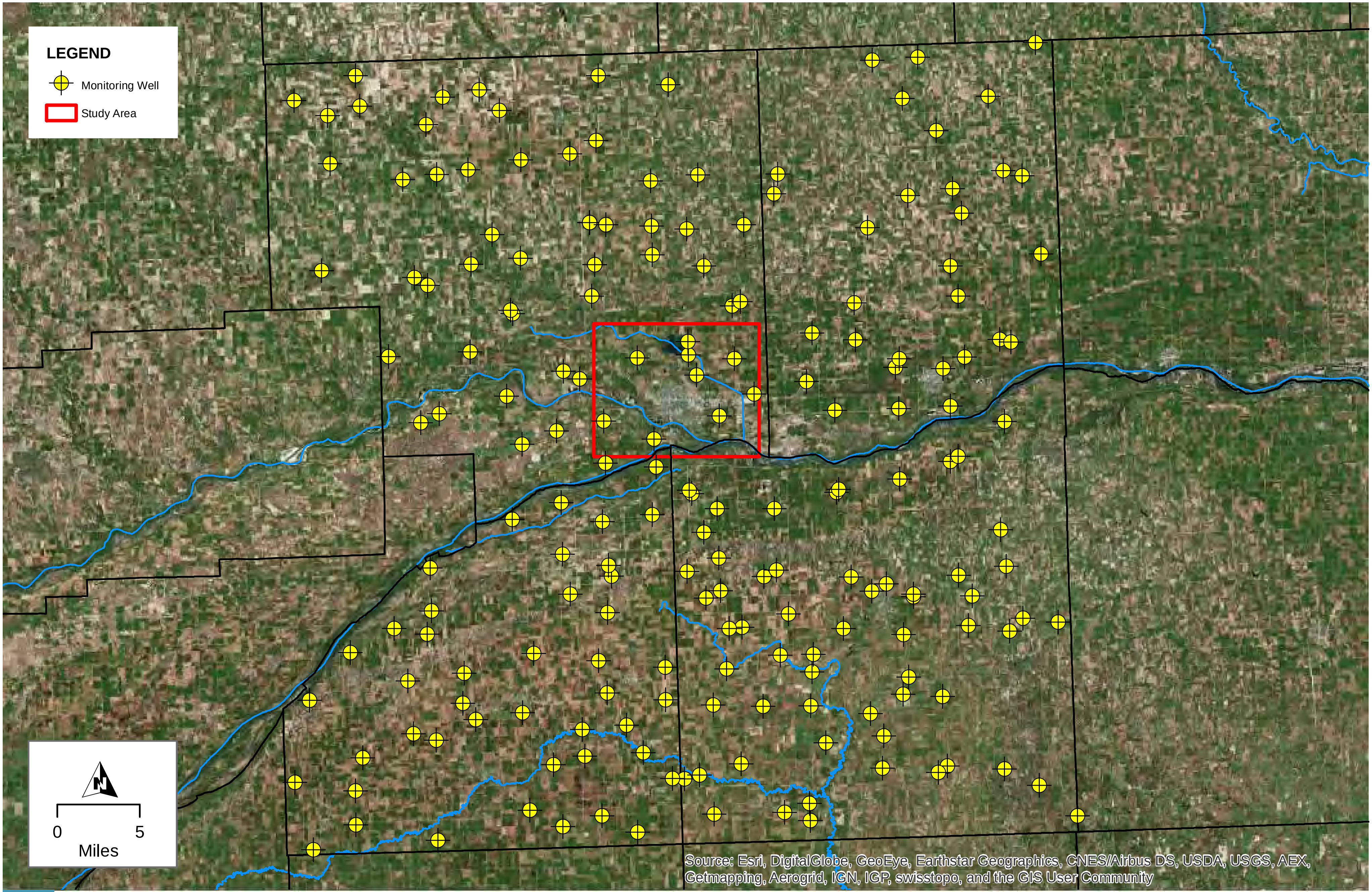


COLUMBUS AREA WATER RESOURCES ASSESSMENT

SURFACE WATER GAGES

FIGURE 7

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE7.MXD - USER: TWIESE - DATE: 4/11/2016

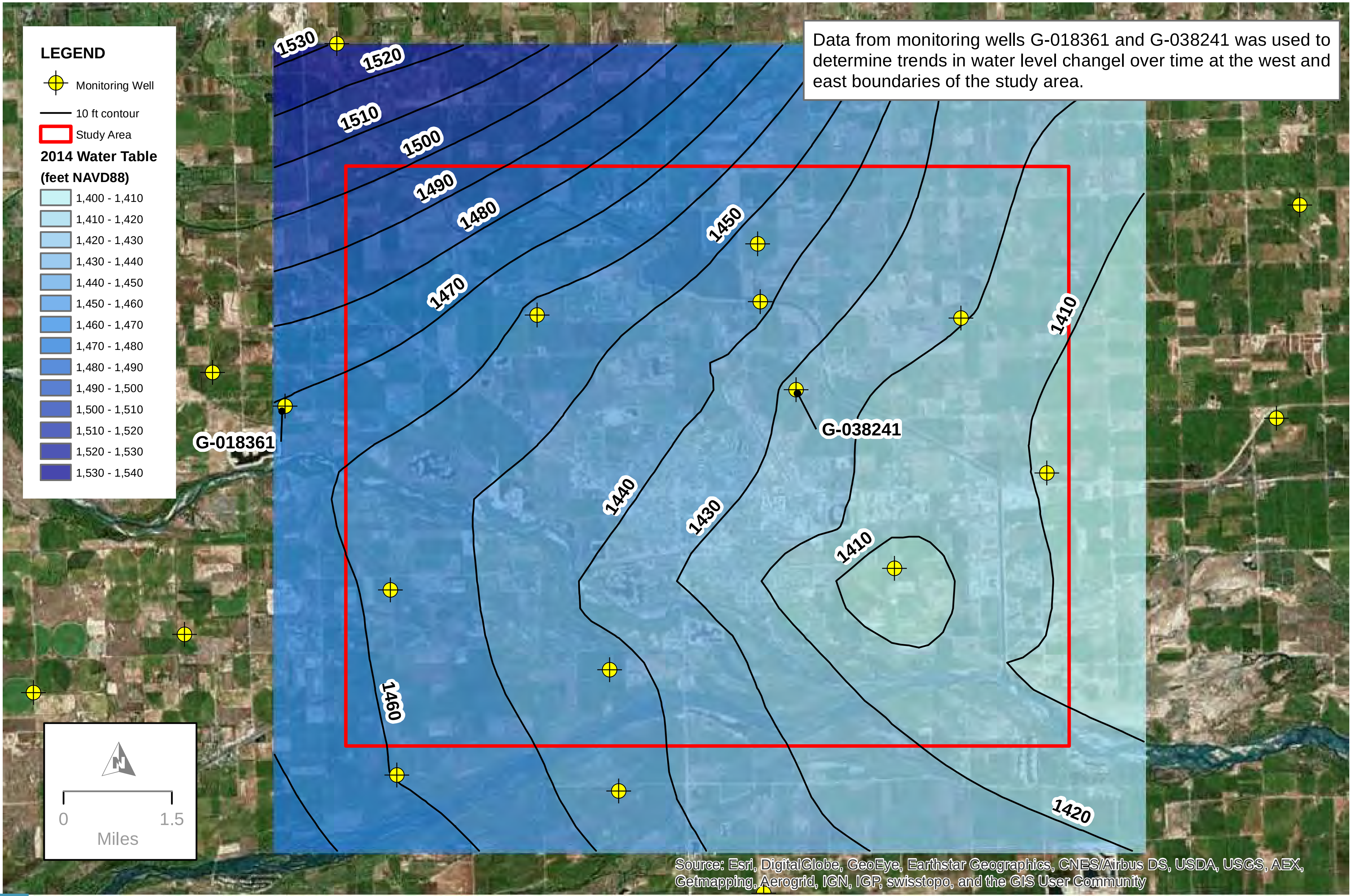


COLUMBUS AREA WATER RESOURCES ASSESSMENT

WELLS USED TO CREATE 2014 WATER TABLE

FIGURE 8

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\GLOBAL_WB_FIGURE8.MXD - USER: TWIESE - DATE: 4/11/2016



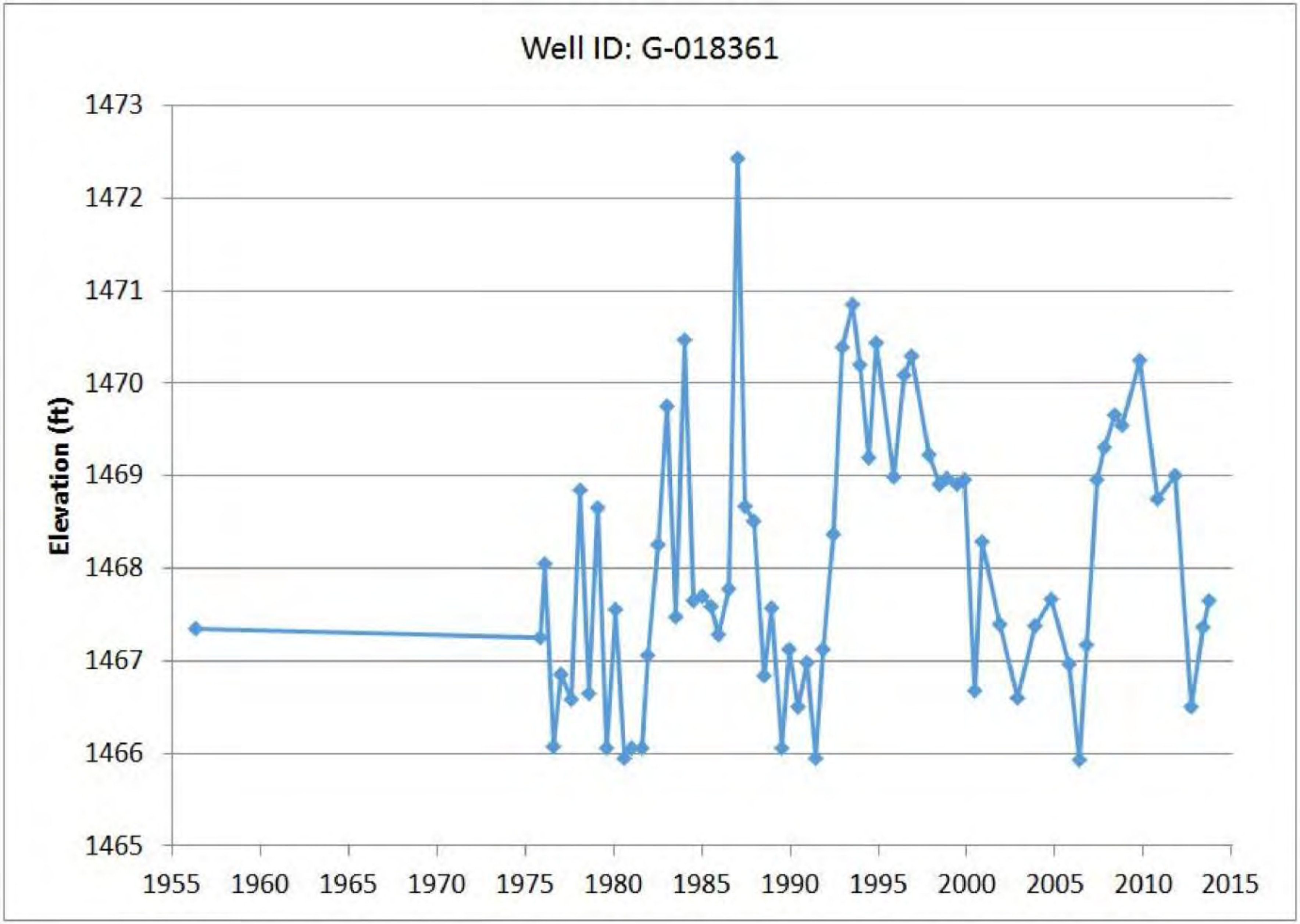
HDR | THE FLATWATER GROUP INC. | JEO | LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

SPRING 2014 WATER TABLE

FIGURE 9

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE9.MXD - USER: TWIESE - DATE: 4/11/2016

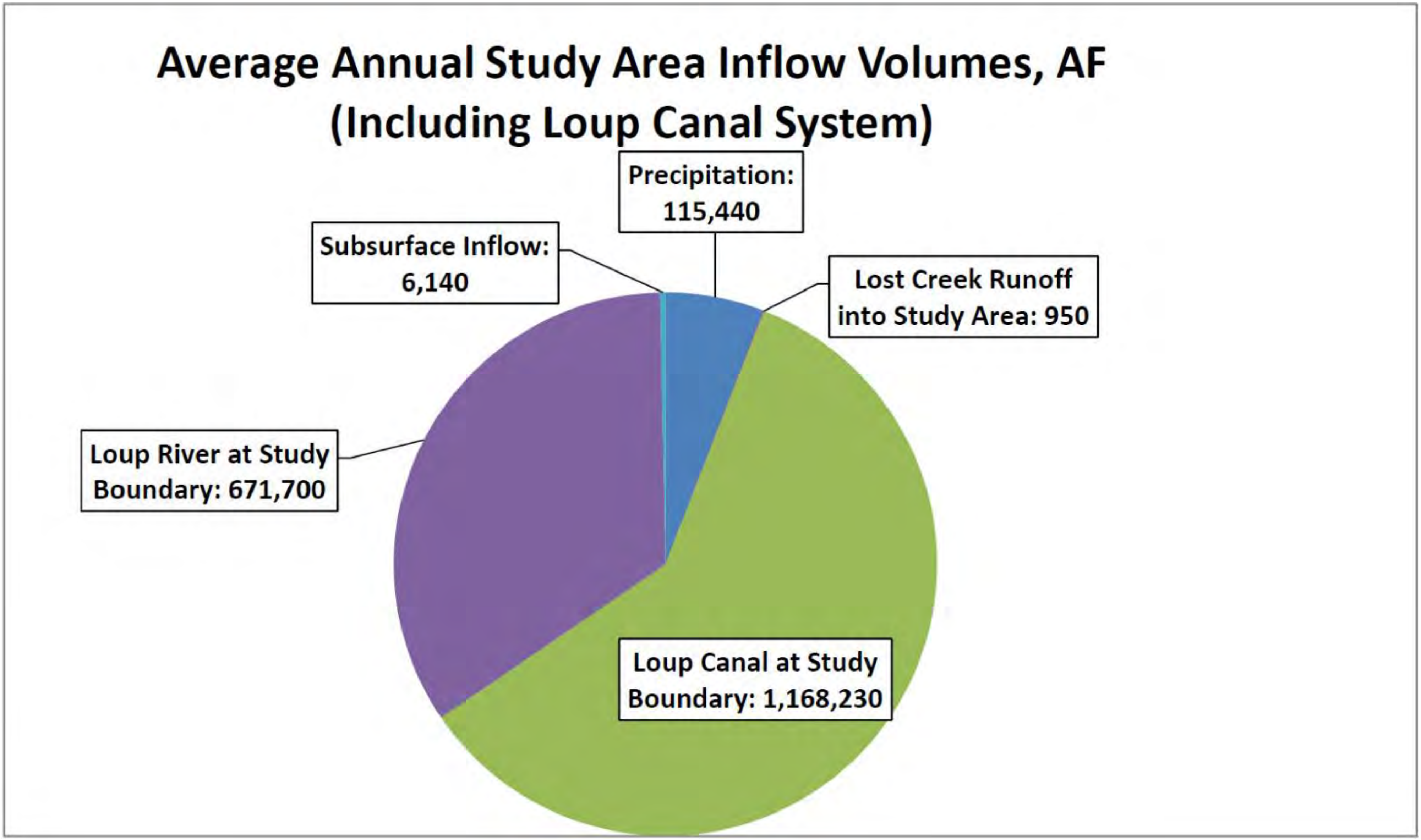


HDR | THE FLATWATER GROUP INC. | JEO | LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

HYDROGRAPH FOR MONITORING WELL G-018361

FIGURE 10



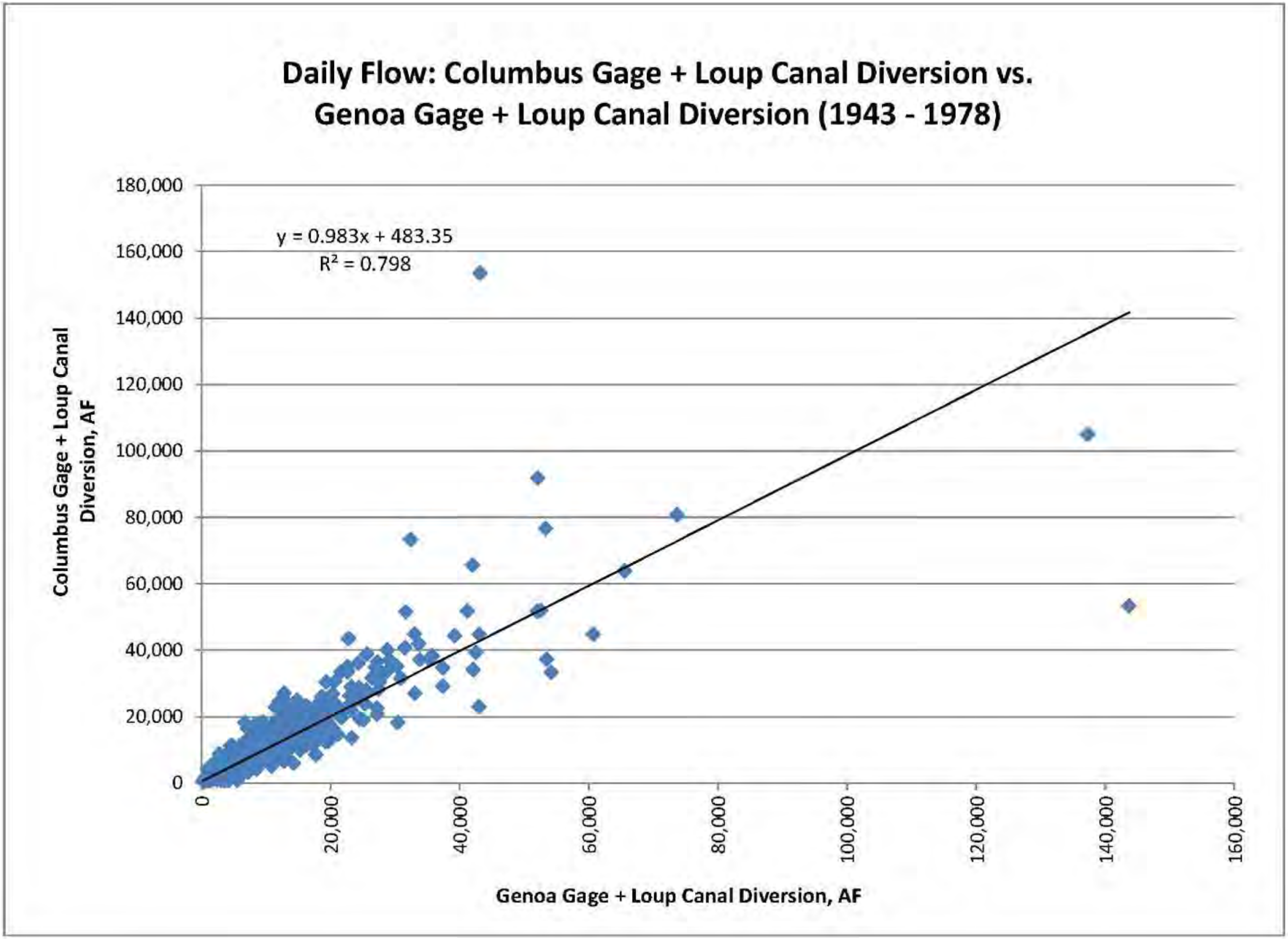
HDR | The Flatwater Group Inc. | JEO | Lower Loup Natural Resources District

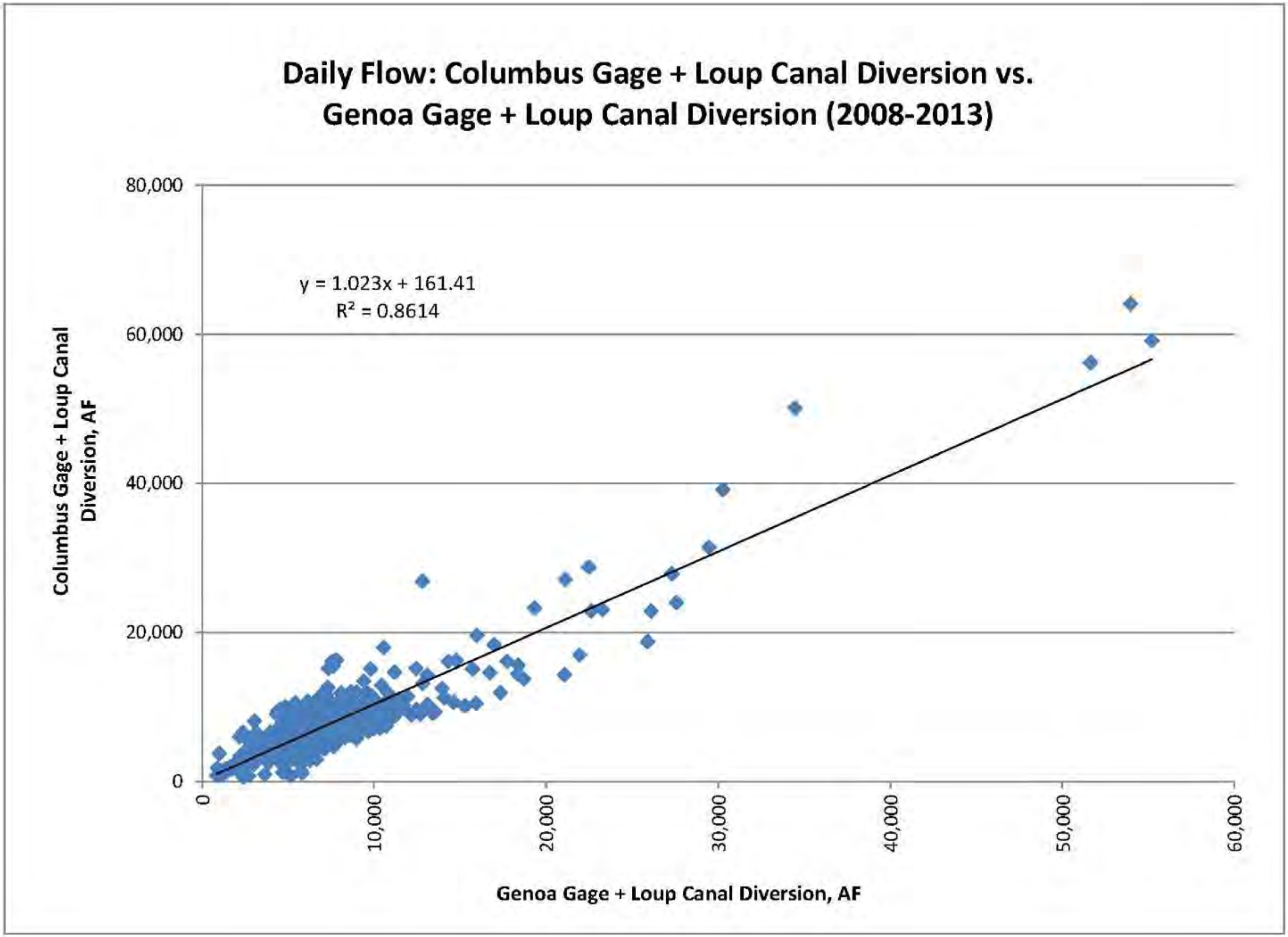
COLUMBUS AREA WATER RESOURCES ASSESSMENT

AVERAGE ANNUAL STUDY AREA INFLOW VOLUMES (INCLUDING LOUP CANAL)

FIGURE 11

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE11.MXD - USER: TWIESE - DATE: 4/11/2016


Daily Flow: Columbus Gage + Loup Canal Diversion vs. Genoa Gage + Loup Canal Diversion (1943 - 1978)
y = 0.983x + 483.35
R² = 0.798
Columbus Gage + Loup Canal Diversion, AF
Genoa Gage + Loup Canal Diversion, AF
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000

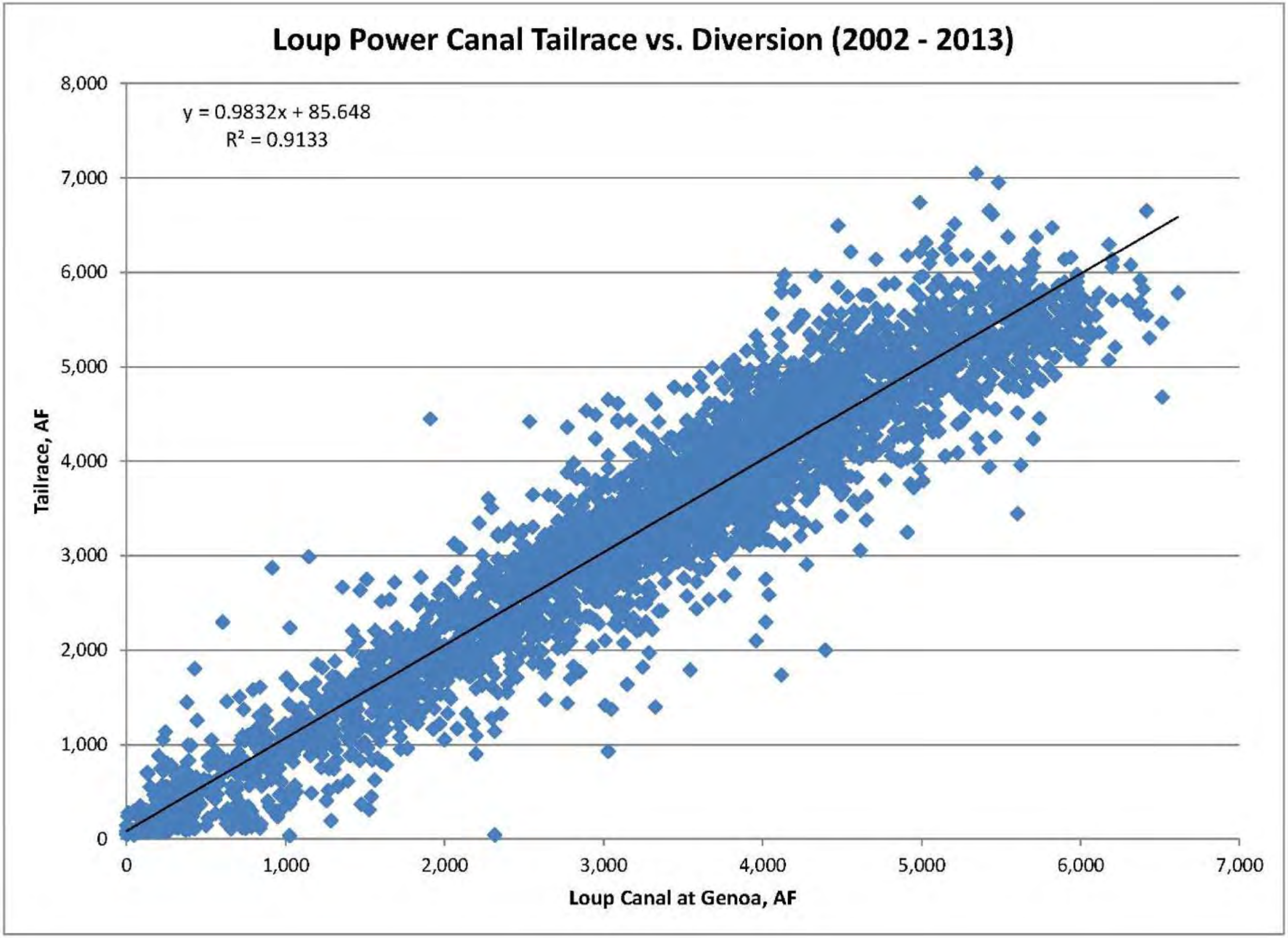


COLUMBUS AREA WATER RESOURCES ASSESSMENT

RELATIONSHIP BETWEEN LOUP AT GENOA AND LOUP AT COLUMBUS

FIGURE 13

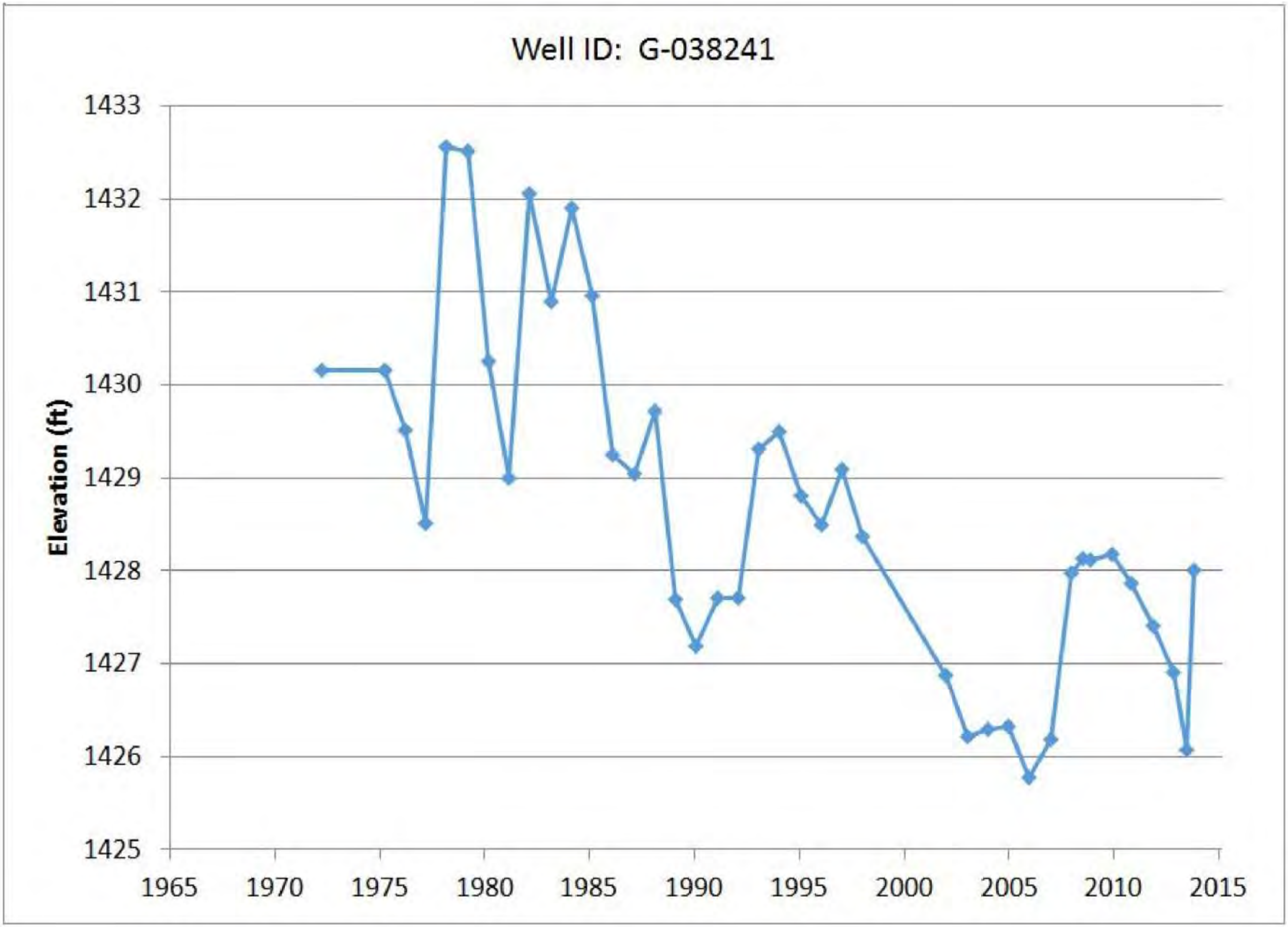
PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE13.MXD - USER: TWIESE - DATE: 4/11/2016



COLUMBUS AREA WATER RESOURCES ASSESSMENT

RELATIONSHIP BETWEEN LOUP CANAL AT GENOA VS. LOUP CANAL RETURN

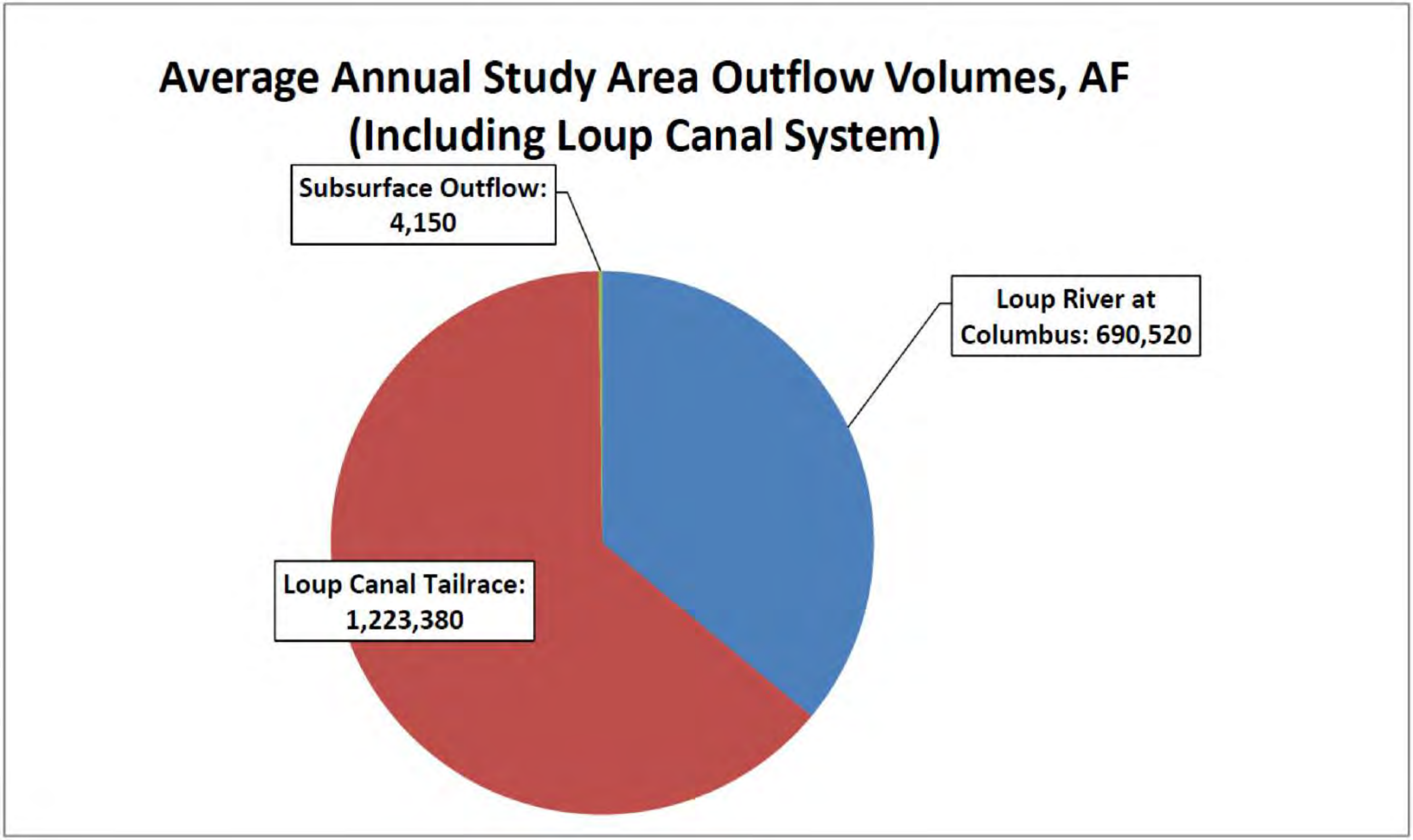
FIGURE 14

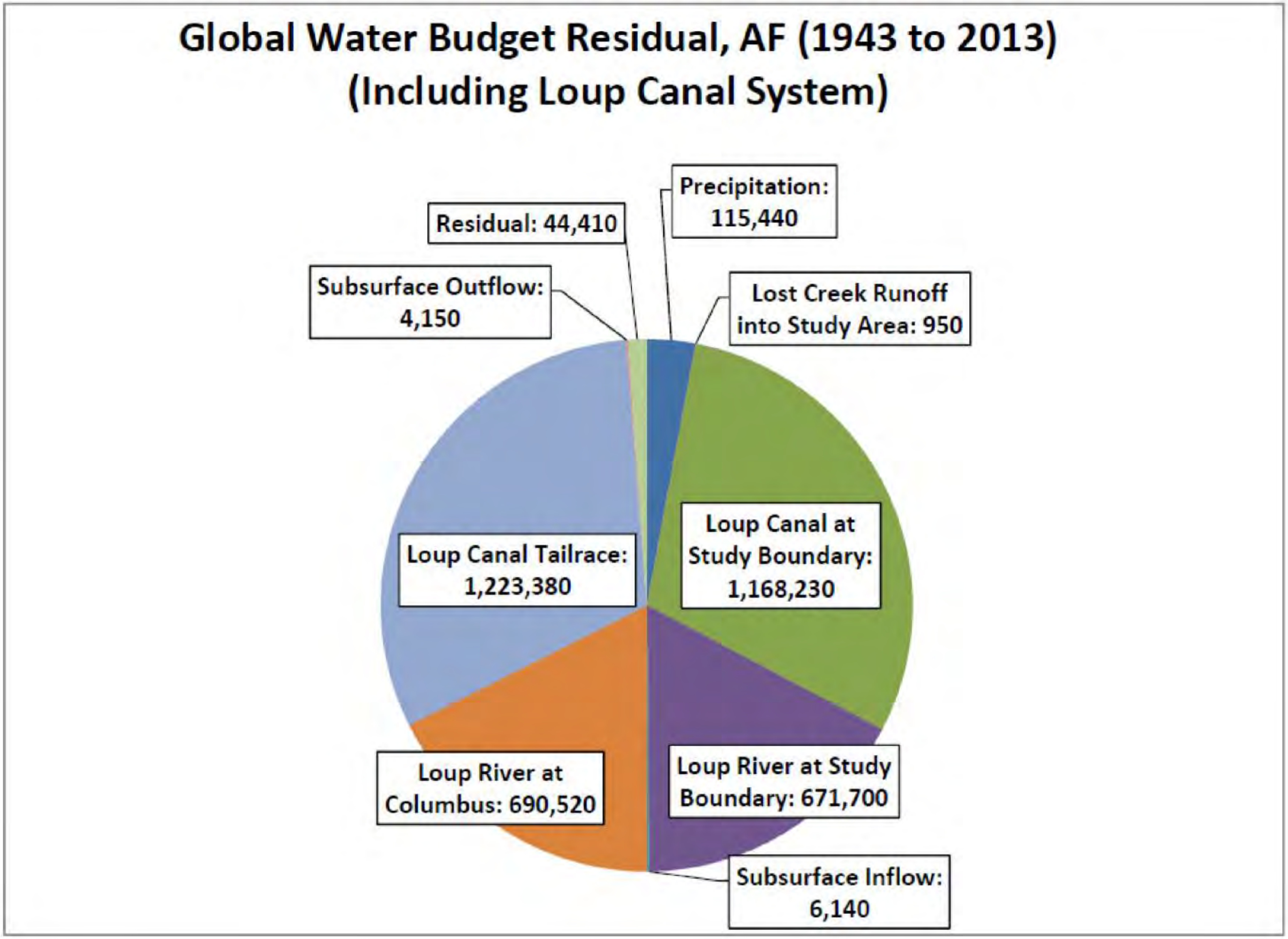


COLUMBUS AREA WATER RESOURCES ASSESSMENT

HYDROGRAPH FOR MONITORING WELL G-018361

FIGURE 15

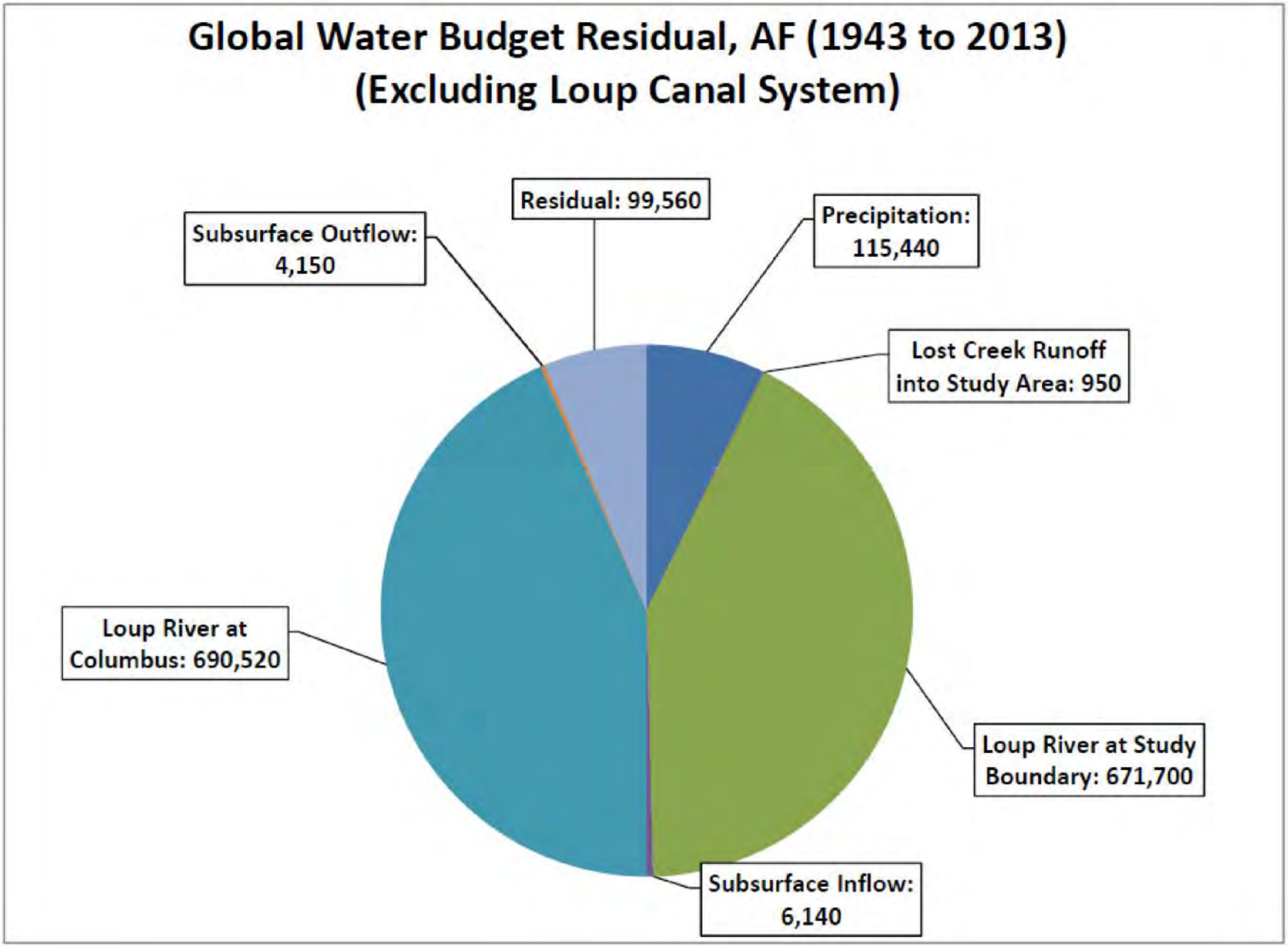

Average Annual Study Area Outflow Volumes, AF
(Including Loup Canal System)
Subsurface Outflow: 4,150
Loup River at Columbus: 690,520
Loup Canal Tailrace: 1,223,380



COLUMBUS AREA WATER RESOURCES ASSESSMENT

GLOBAL WATER BUDGET RESIDUAL (INCLUDING LOUP CANAL)

FIGURE 17

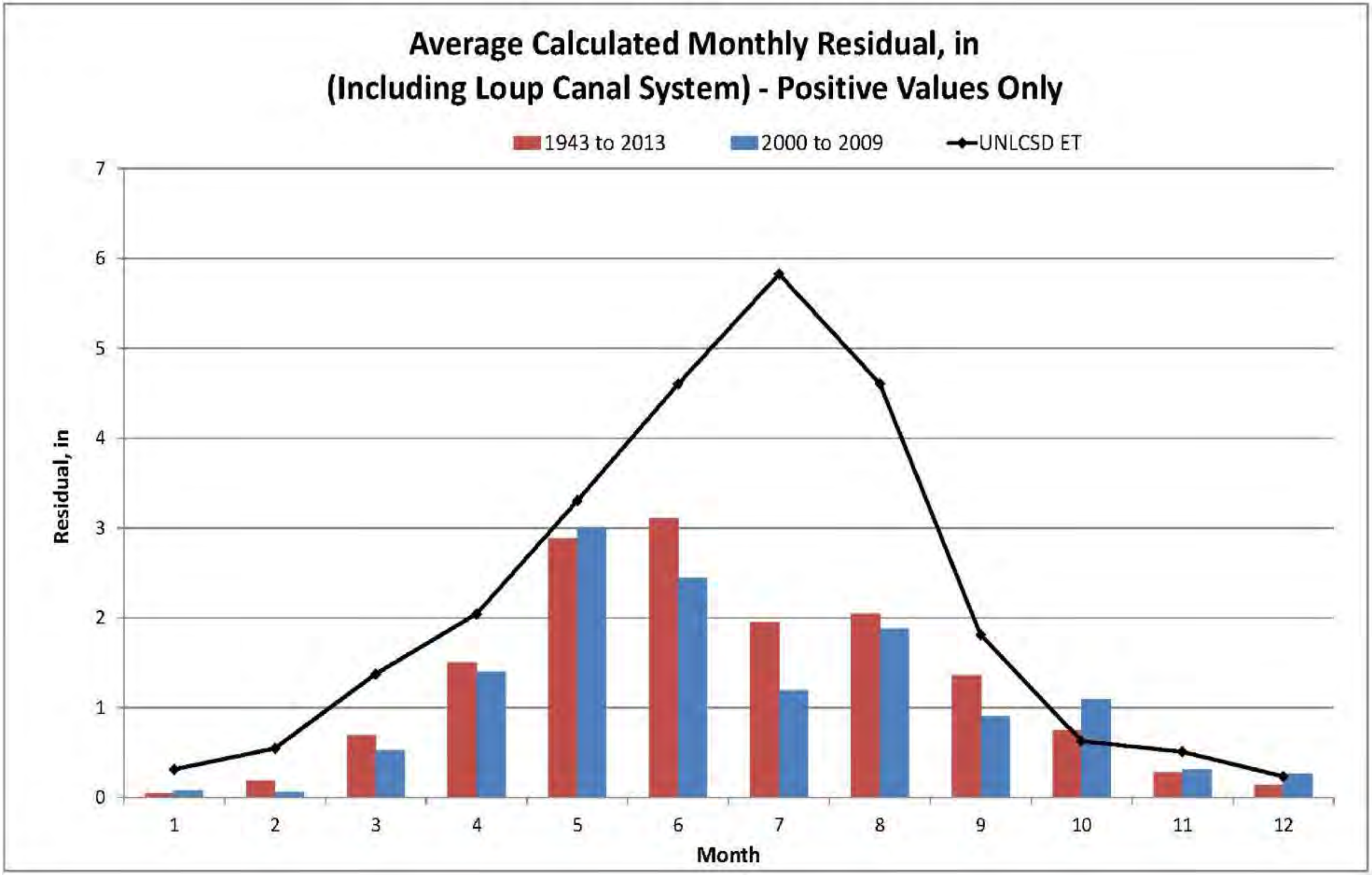


COLUMBUS AREA WATER RESOURCES ASSESSMENT

GLOBAL WATER BUDGET RESIDUAL (EXCLUDING LOUP CANAL)

FIGURE 18

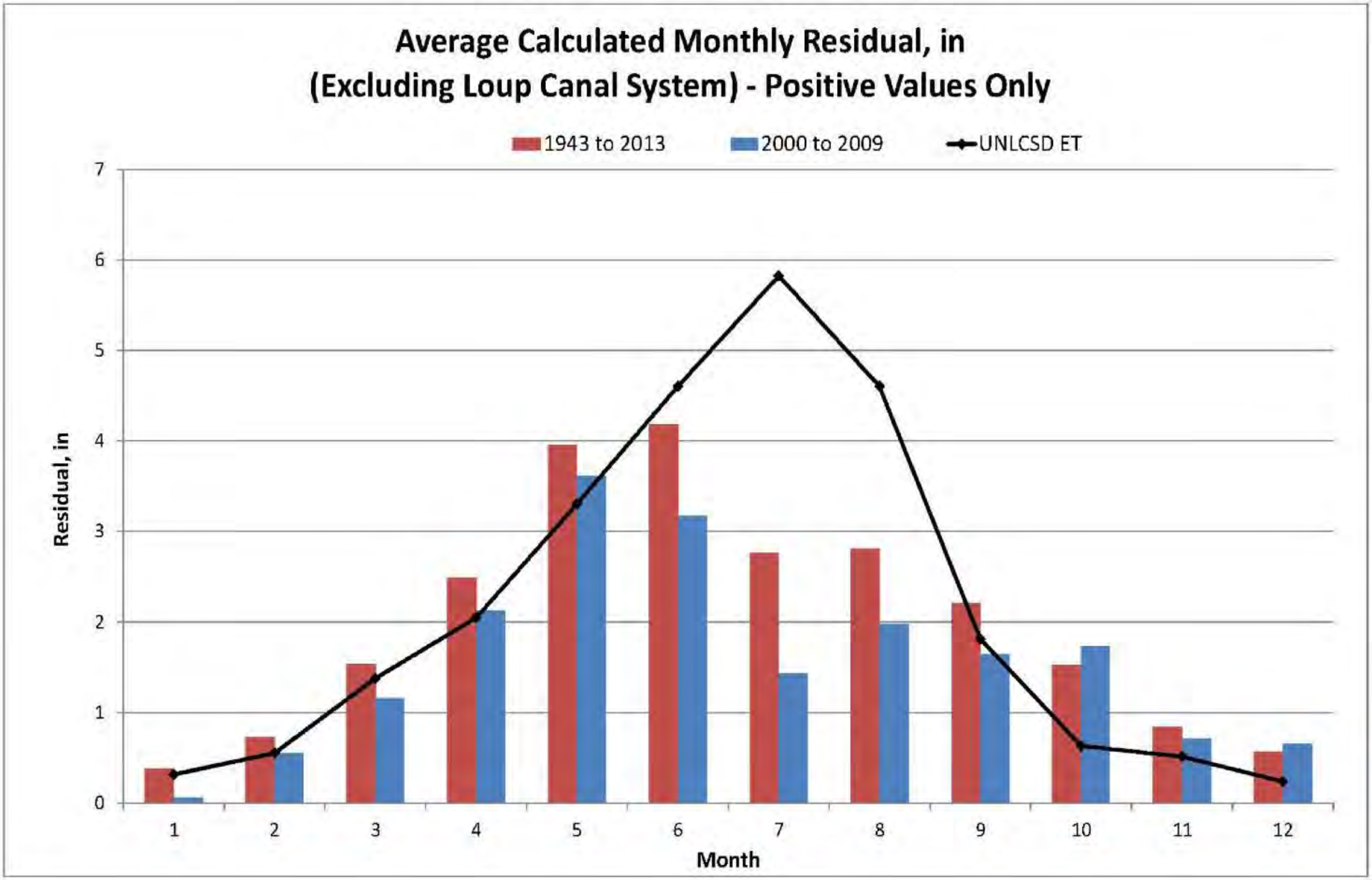
PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE18.MXD - USER: TWIESE - DATE: 4/11/2016



COLUMBUS AREA WATER RESOURCES ASSESSMENT

GLOBAL WATER BUDGET RESIDUAL (INCLUDING LOUP CANAL) - POSITIVE VALUES

FIGURE 19



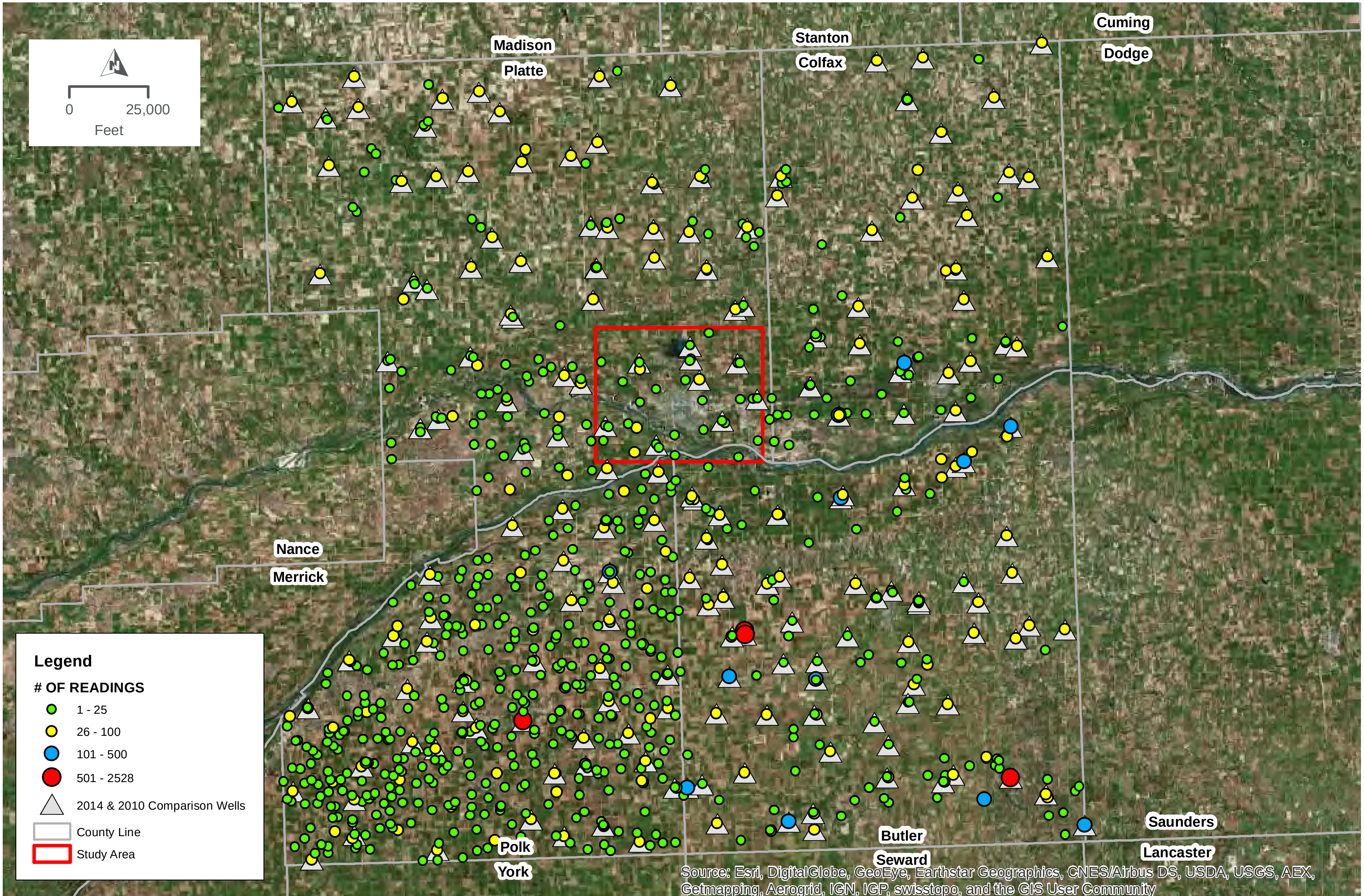
HDR | THE FLATWATER GROUP INC. | JEO | LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

GLOBAL WATER BUDGET RESIDUAL (EXCLUDING LOUP CANAL) - POSITIVE VALUES

FIGURE 20

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE20.MXD - USER: TWIESE - DATE: 4/11/2016



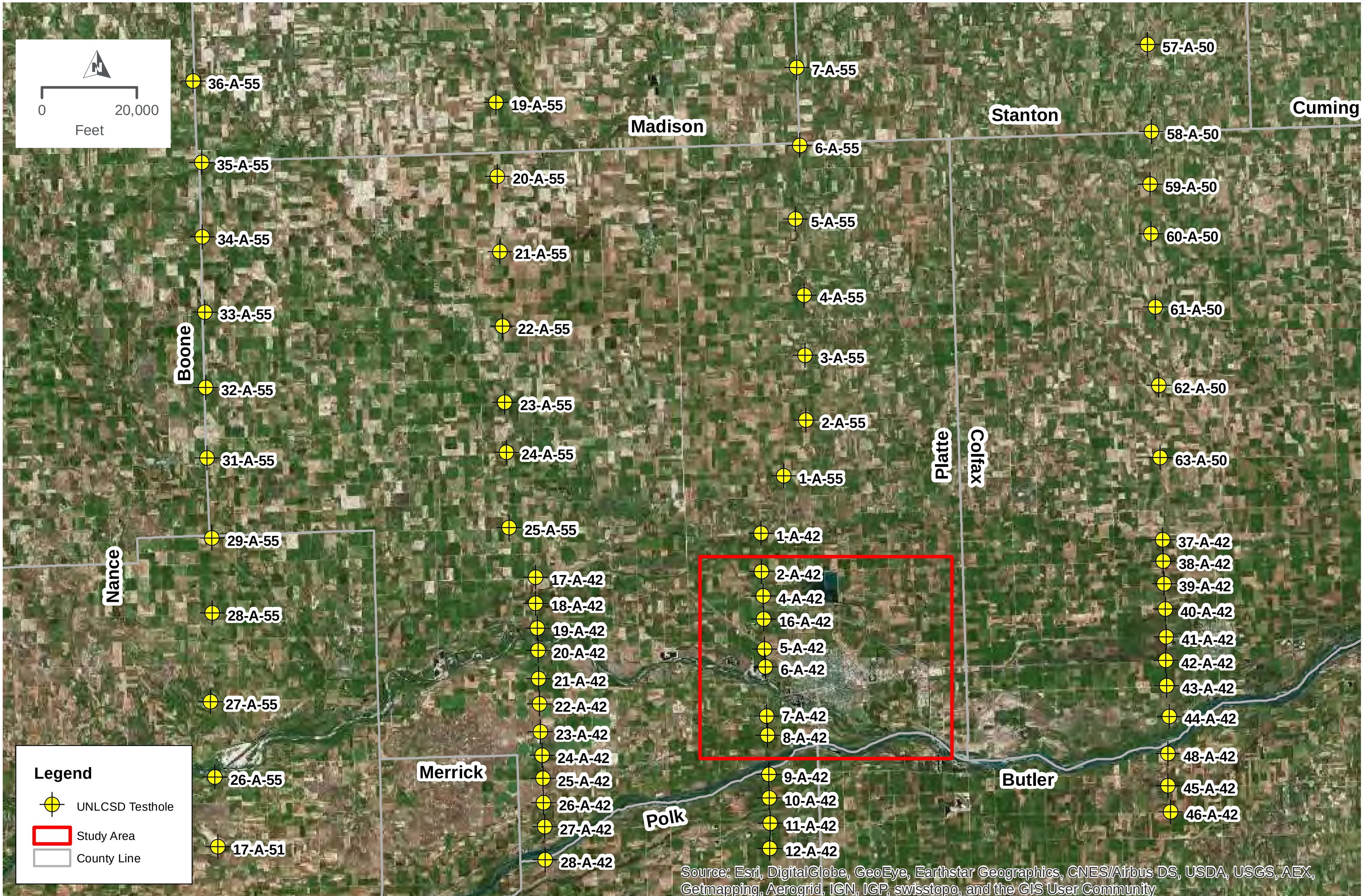
HDR THE FLATWATER GROUP INC. LOWERLOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

UNLCSD MONITORING WELL LOCATIONS

FIGURE 21

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE21.MXD - USER: TWIESE - DATE: 4/11/2016



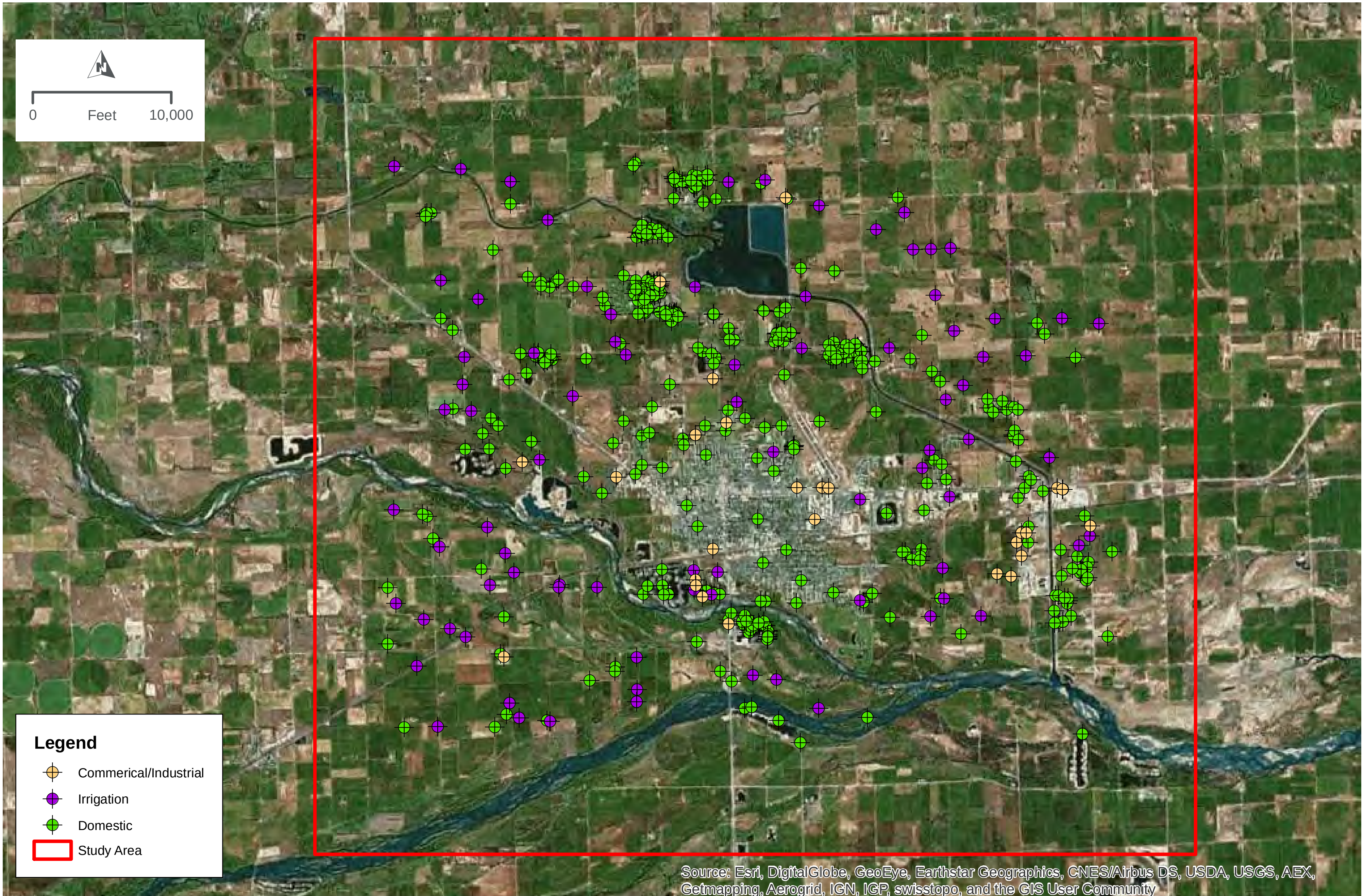
HDR THE FLATWATER GROUP INC. LOWERLOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

UNLCSD TESTHOLE DATA

FIGURE 22

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE22.MXD - USER: TWIESE - DATE: 4/11/2016



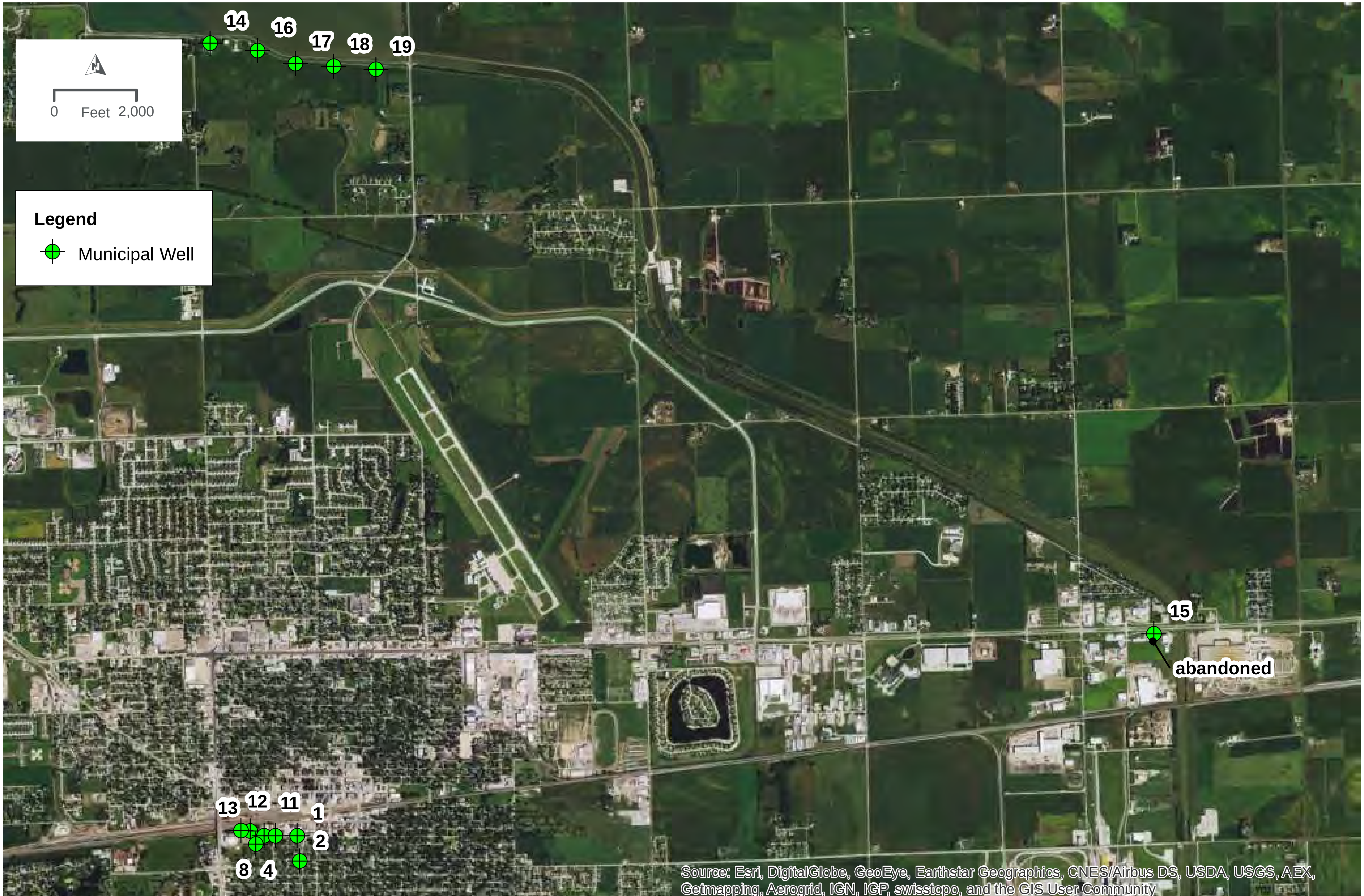
HDR THE FLATWATER GROUP INC. JEO LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

NDNR REGISTERED GROUNDWATER WELLS

FIGURE 23

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE23.MXD - USER: TWIESE - DATE: 4/11/2016

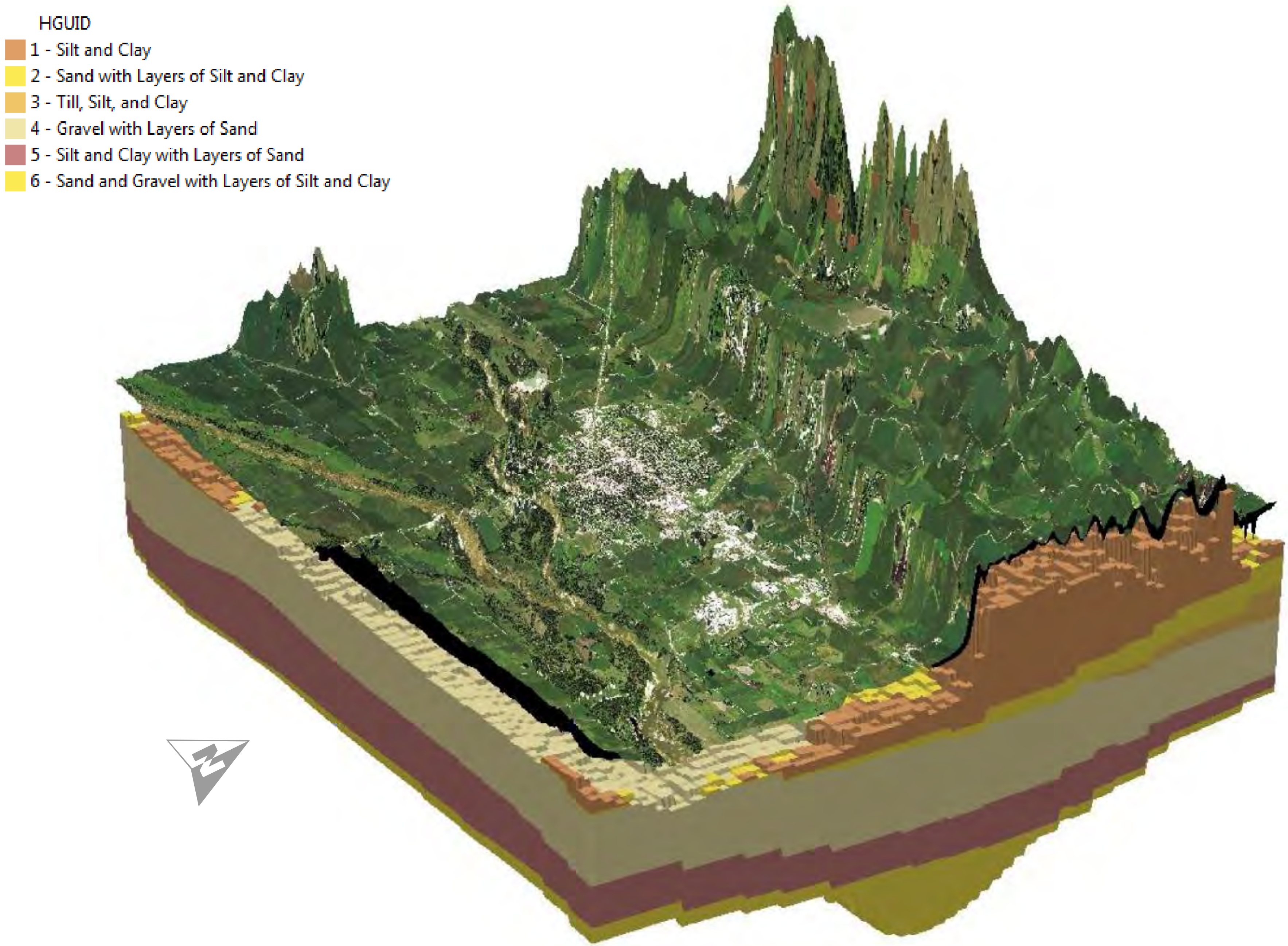


COLUMBUS AREA WATER RESOURCES ASSESSMENT

CITY OF COLUMBUS MUNICIPAL WELLS

FIGURE 24

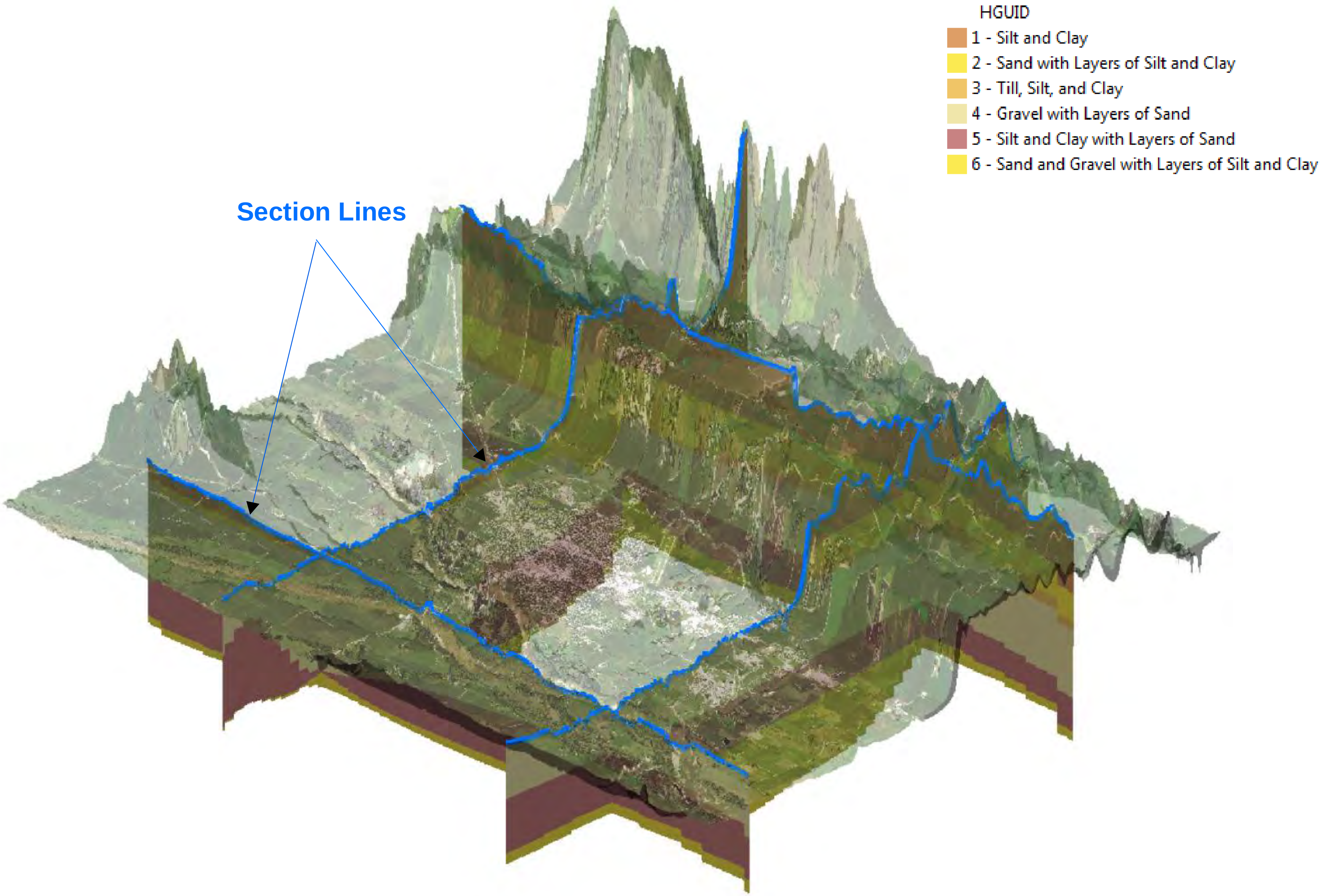
PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE24.MXD - USER: TWIESE - DATE: 4/11/2016



COLUMBUS AREA WATER RESOURCES ASSESSMENT

ISOMETRIC VIEW OF STUDY AREA GEOVOLUME WITH AERIAL

FIGURE 25

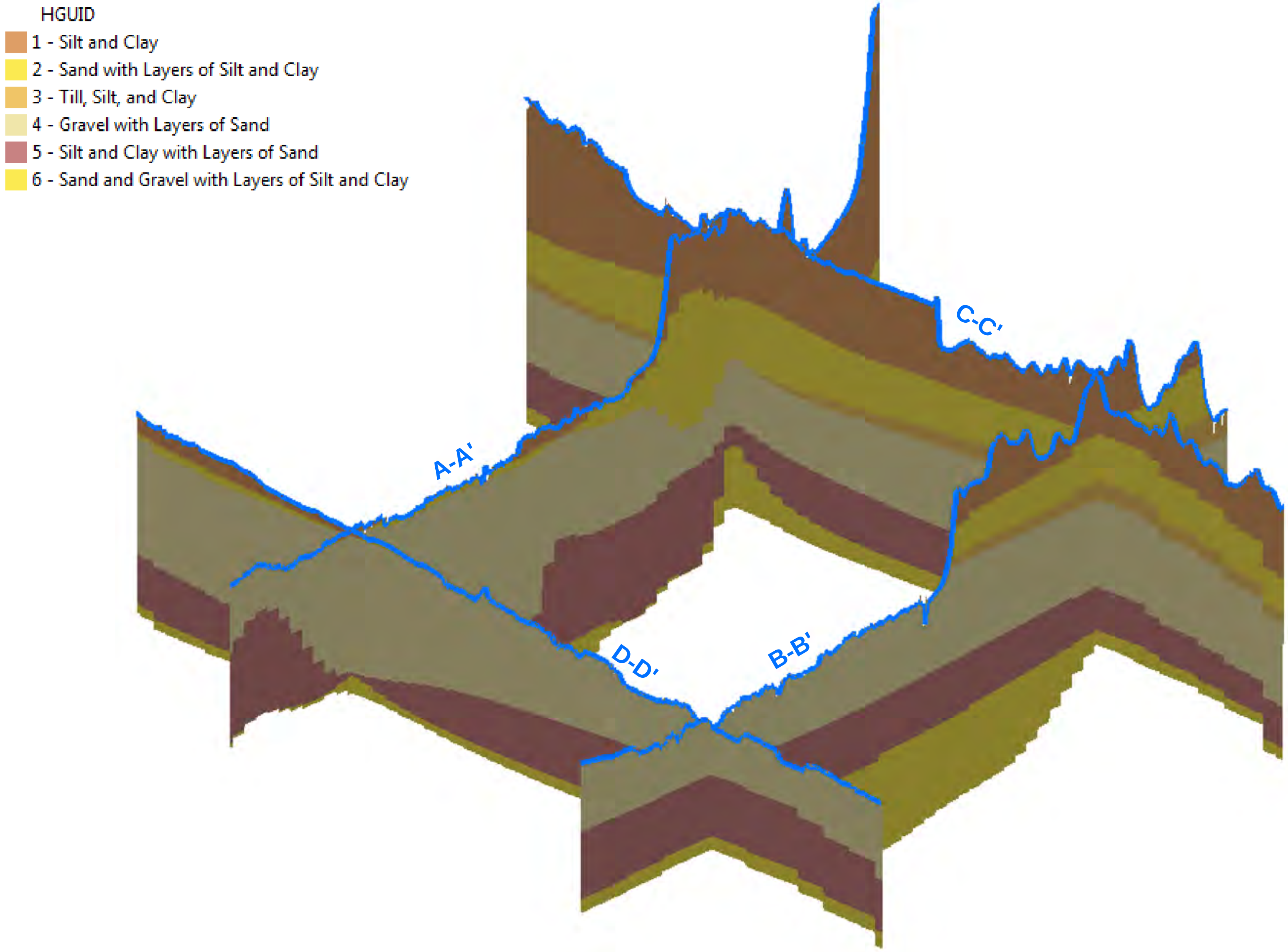


HDR | THE FLATWATER GROUP INC. | JEO | LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

ISOMETRIC VIEW OF STUDY AREA 3D GEOSECTIONS WITH AERIAL

FIGURE 26



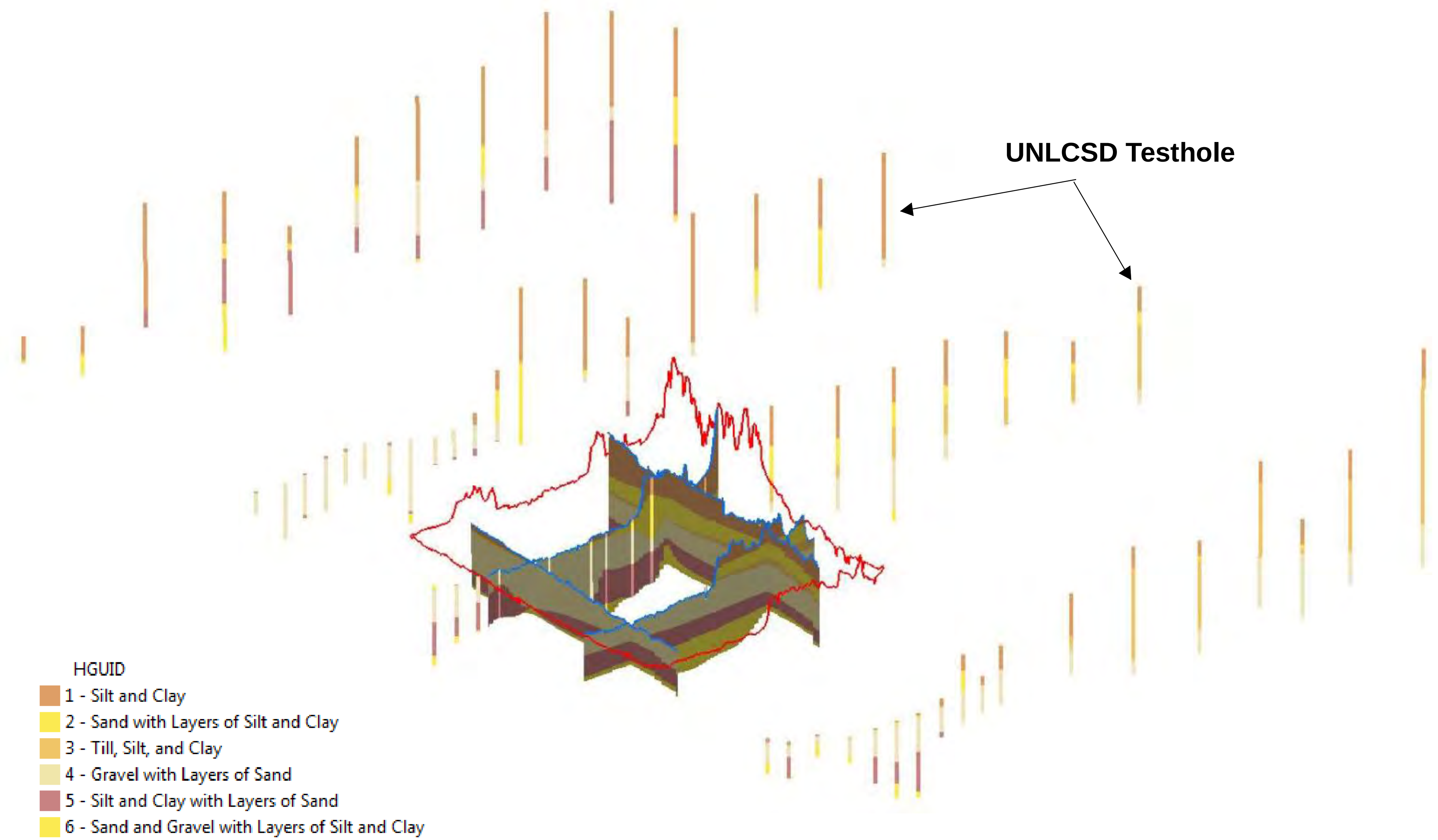
THE FLATWATER GROUP INC.
LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

ISOMETRIC VIEW OF STUDY AREA 3D GEOSECTIONS

FIGURE 27

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE27.MXD - USER: TWIESE - DATE: 4/11/2016



COLUMBUS AREA WATER RESOURCES ASSESSMENT

ISOMETRIC VIEW OF UNLCSD TESTHOLE LOCATIONS

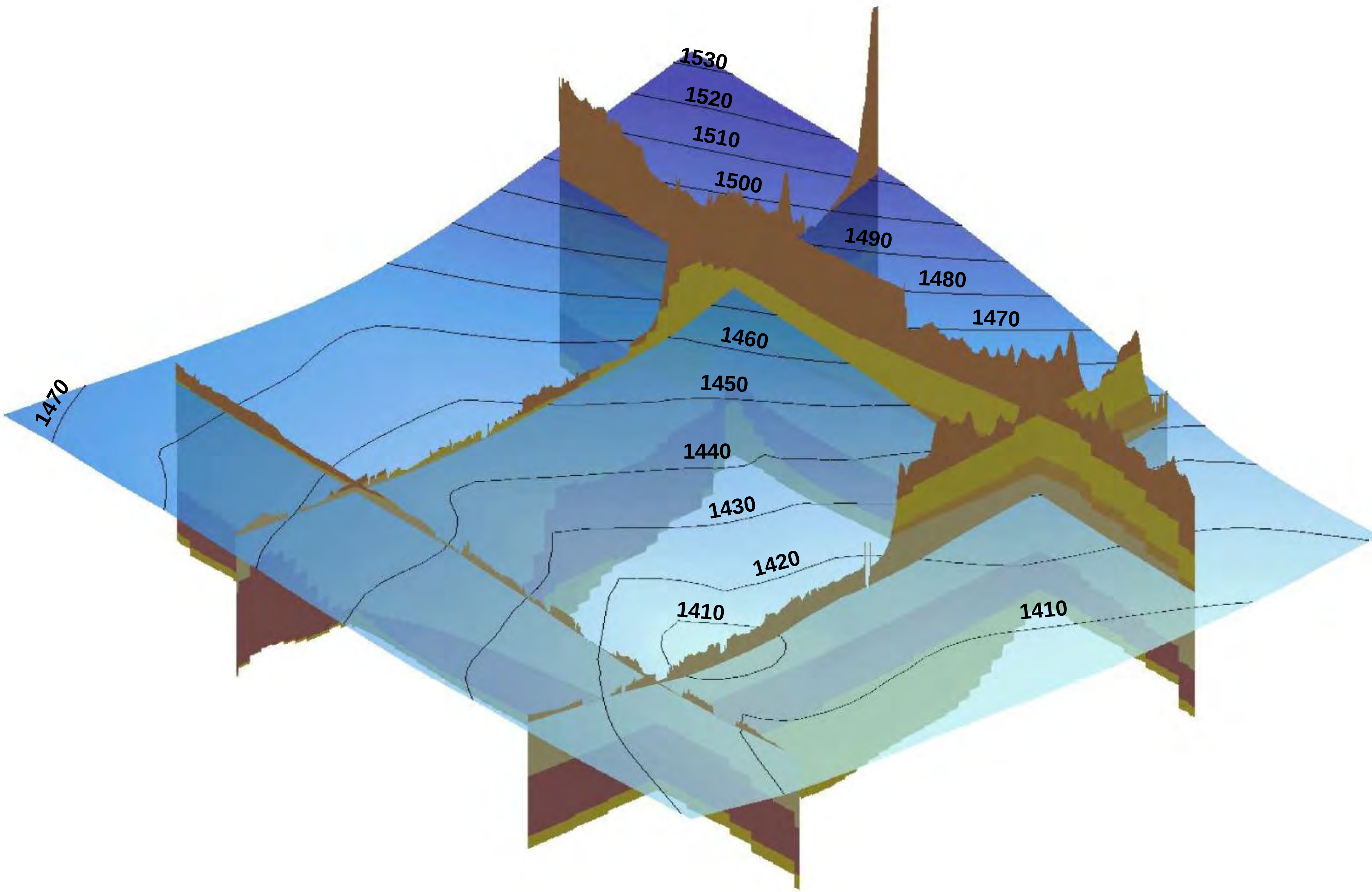
FIGURE 28

COLUMBUS AREA WATER RESOURCES ASSESSMENT

2014 WATER TABLE

FIGURE 29

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE29.MXD - USER: TWIESE - DATE: 4/11/2016



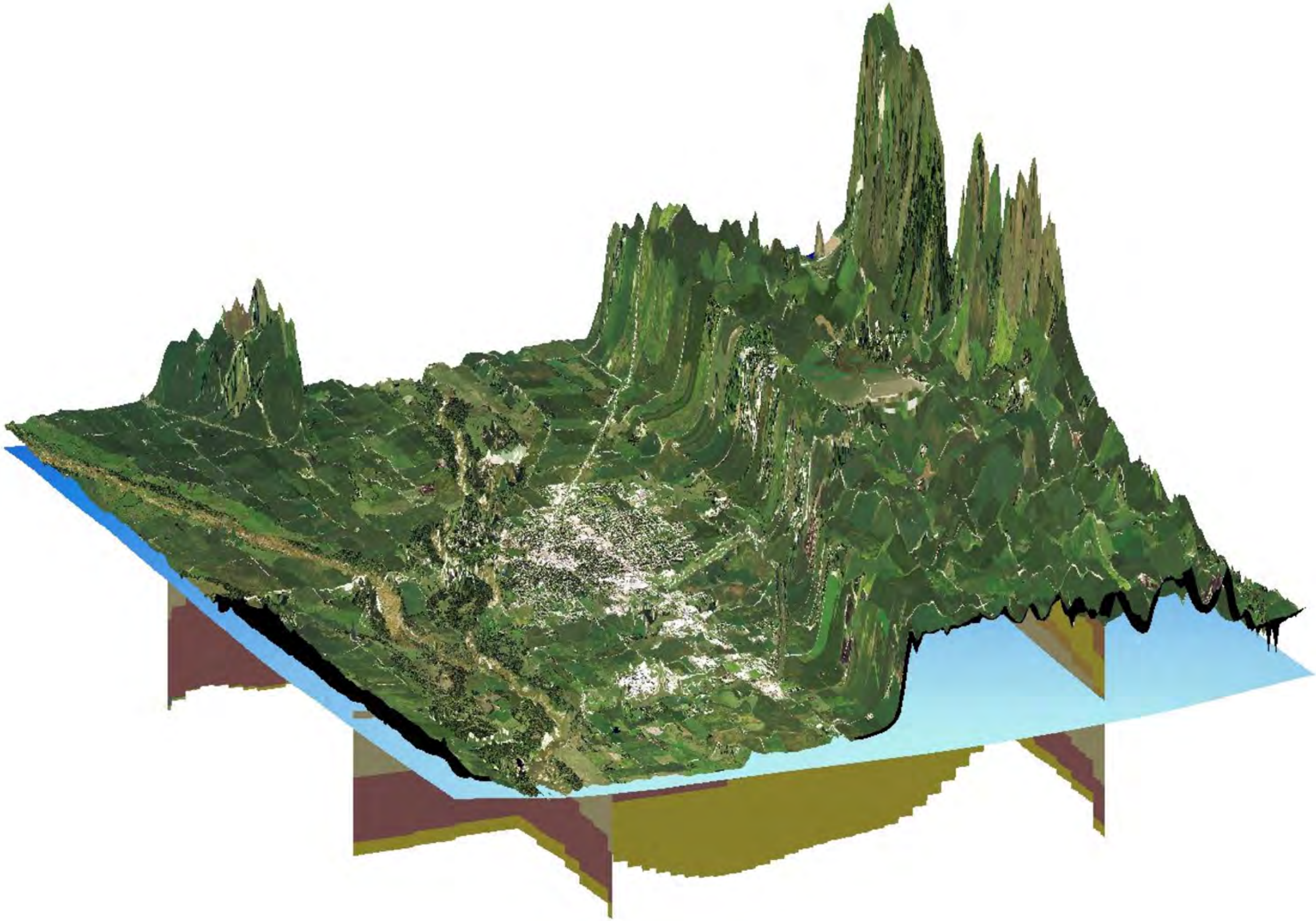
HDR | THE FLATWATER GROUP INC. | JEO | LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

2014 WATER TABLE WITH 3D GEOSECTIONS

FIGURE 30

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE30.MXD - USER: TWIESE - DATE: 4/11/2016

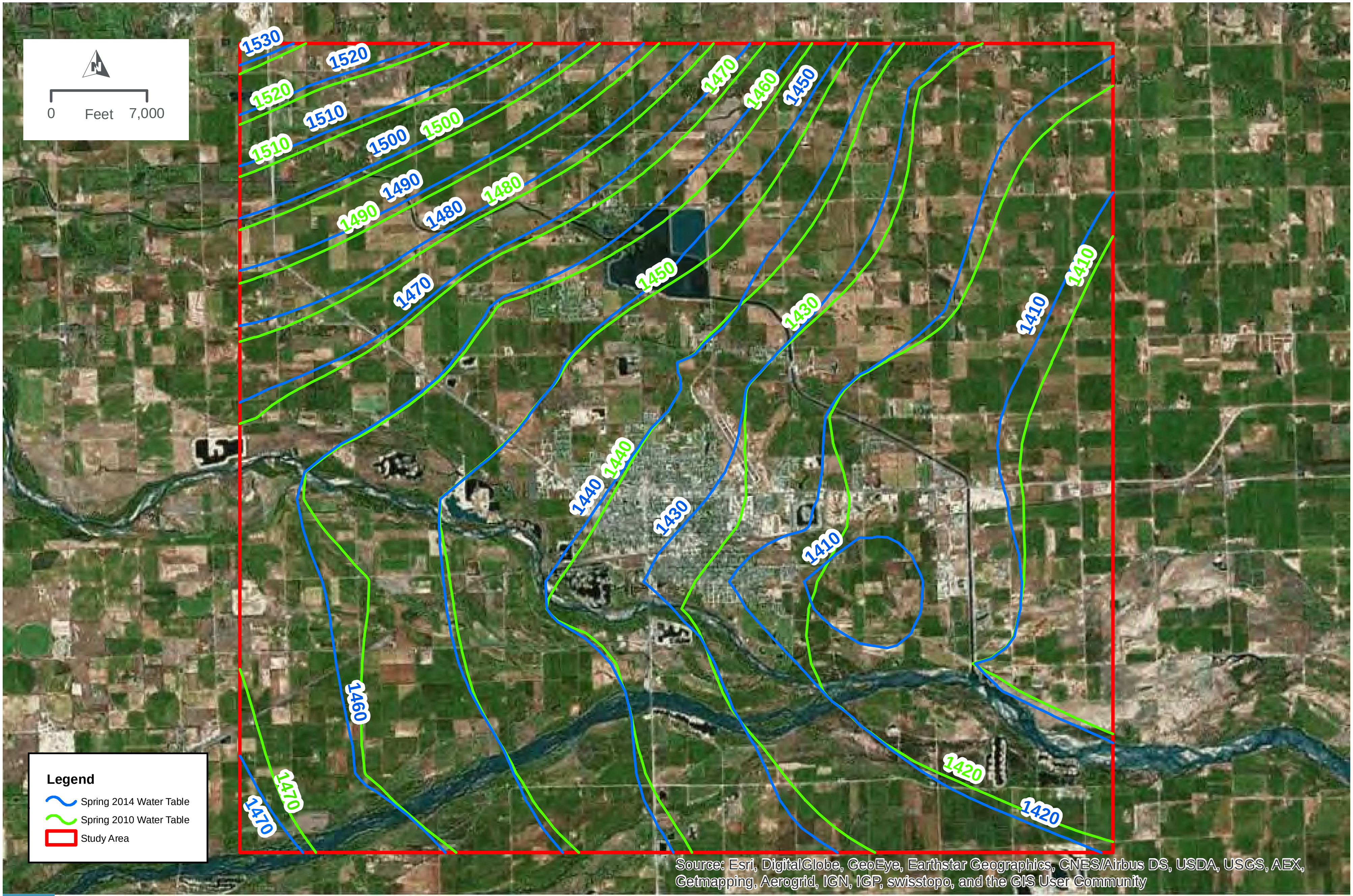


COLUMBUS AREA WATER RESOURCES ASSESSMENT

2014 WATER TABLE RELATIVE TO LAND SURFACE

FIGURE 31

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE31.MXD - USER: TWIESE - DATE: 4/11/2016



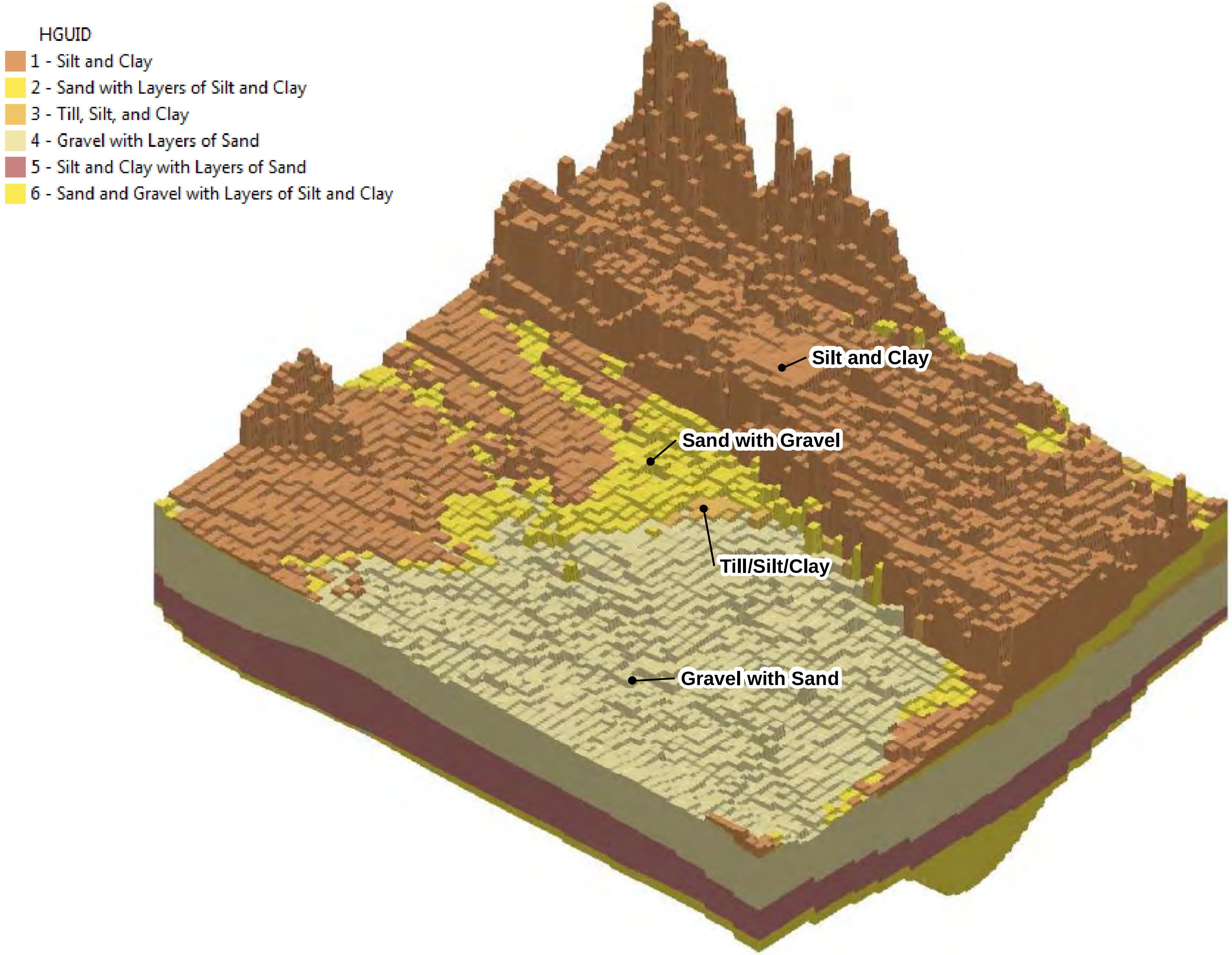
HDR THE FLATWATER GROUP INC. JE LOWERLOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

2014 AND 2010 WATER TABLE COMPARISON

FIGURE 32

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE32.MXD - USER: TWIESE - DATE: 4/11/2016

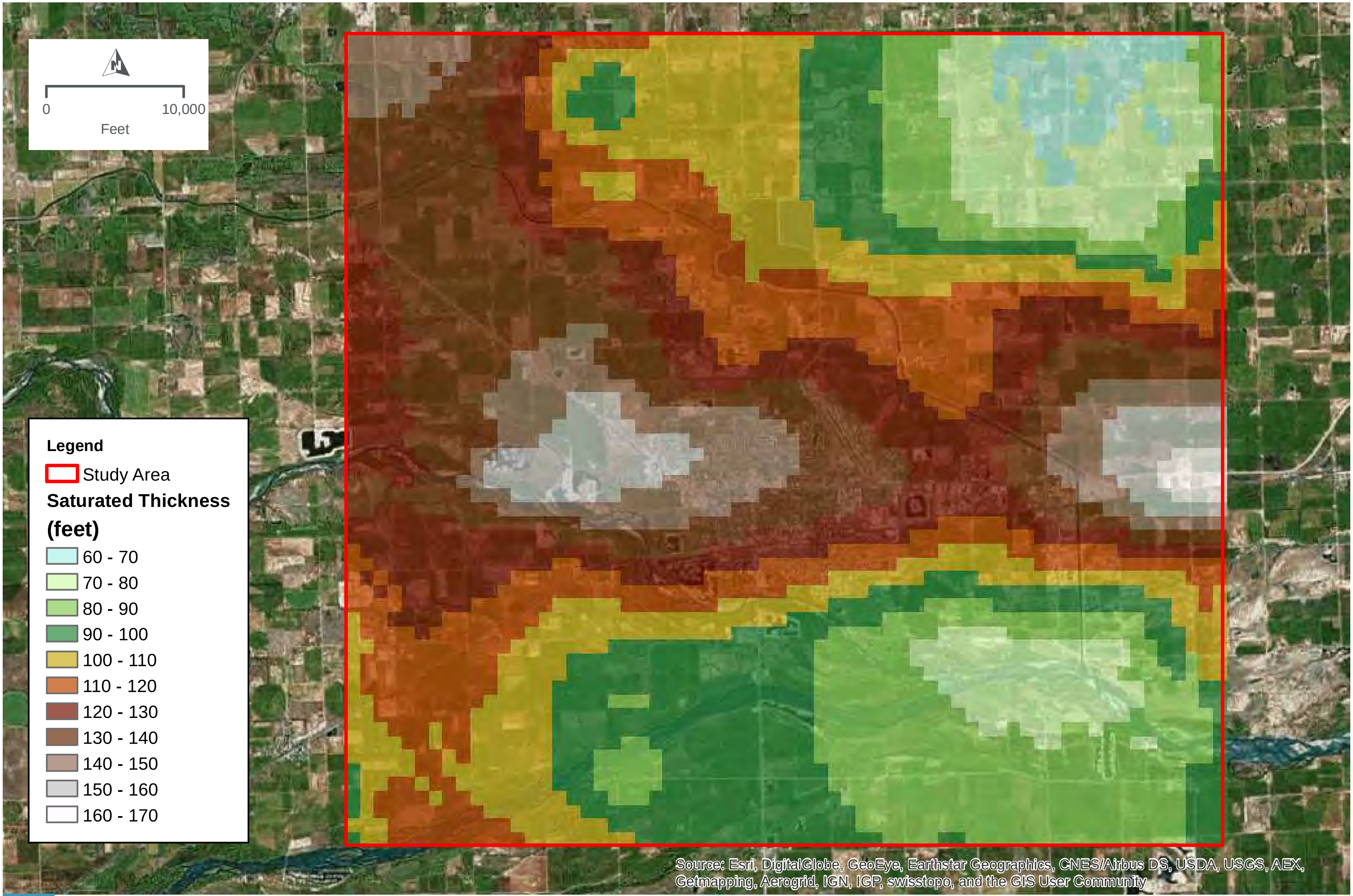


HDR THE FLATWATER GROUP INC. JEO LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

LAND SURFACE LITHOLOGY

FIGURE 33

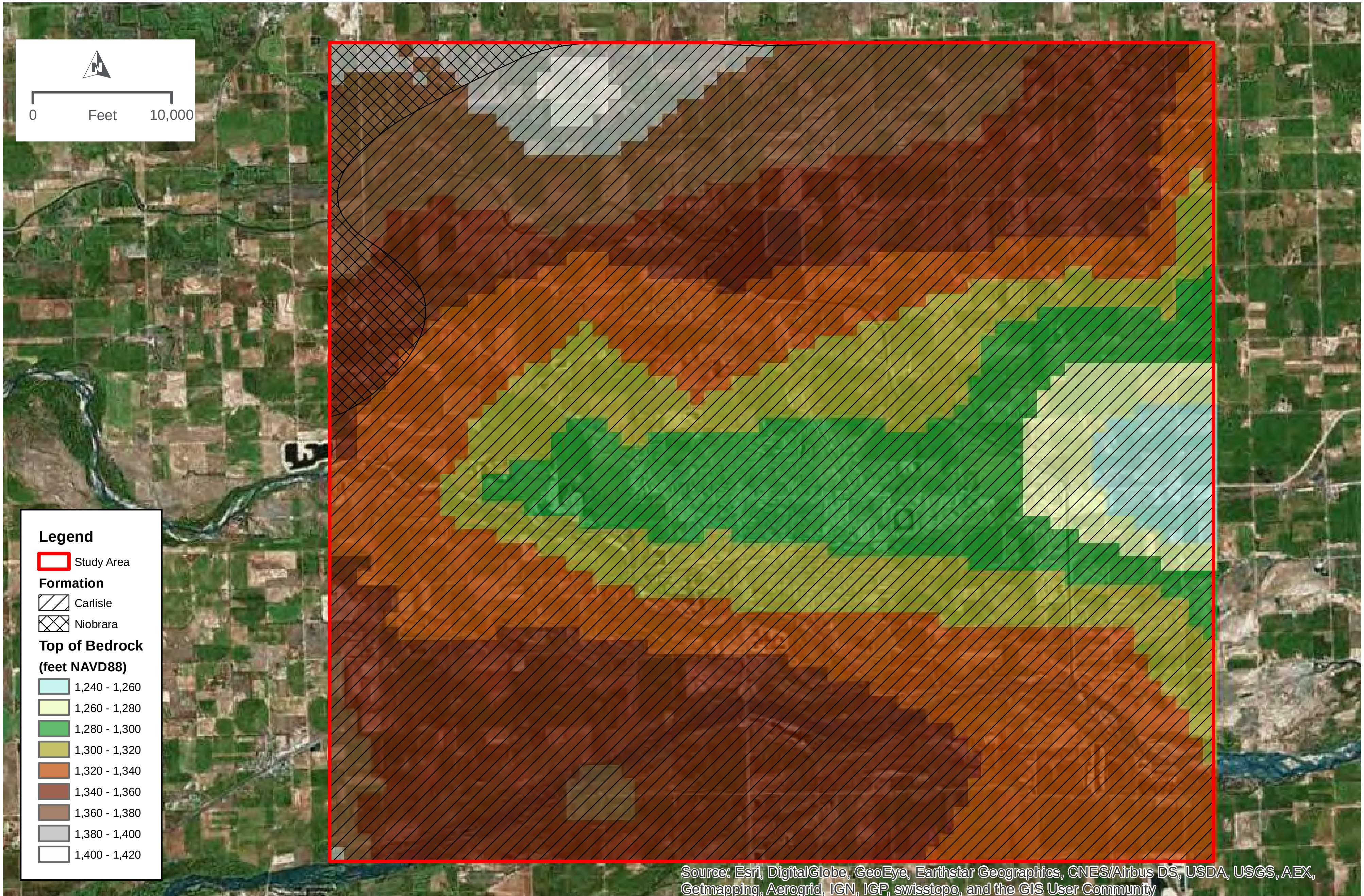


COLUMBUS AREA WATER RESOURCES ASSESSMENT

SPRING 2014 SATURATED THICKNESS

FIGURE 34

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE34.MXD - USER: TWIESE - DATE: 4/11/2016



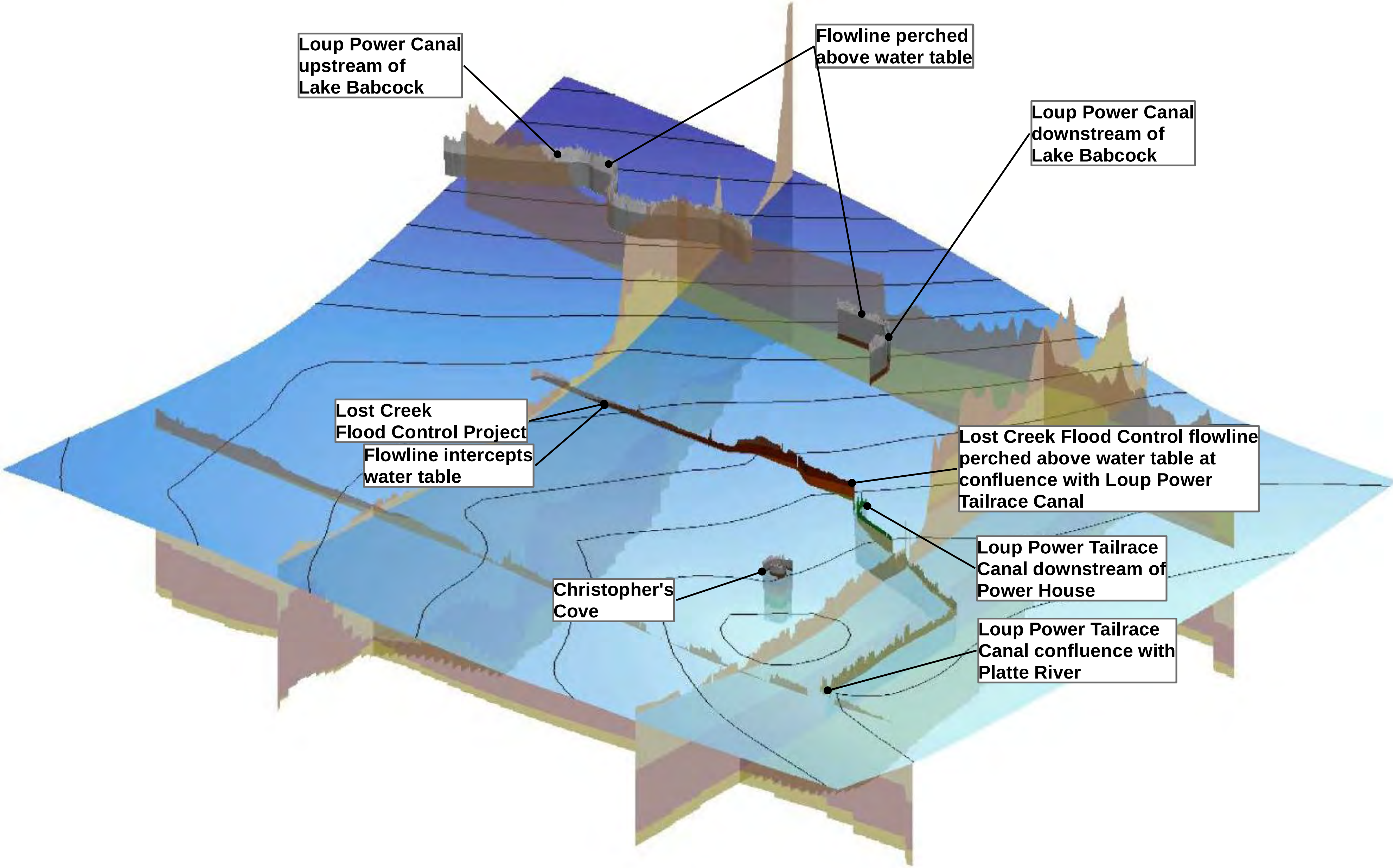
HDR THE FLATWATER GROUP INC. JEO LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

TOP OF BEDROCK

FIGURE 35

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE35.MXD - USER: TWIESE - DATE: 4/11/2016

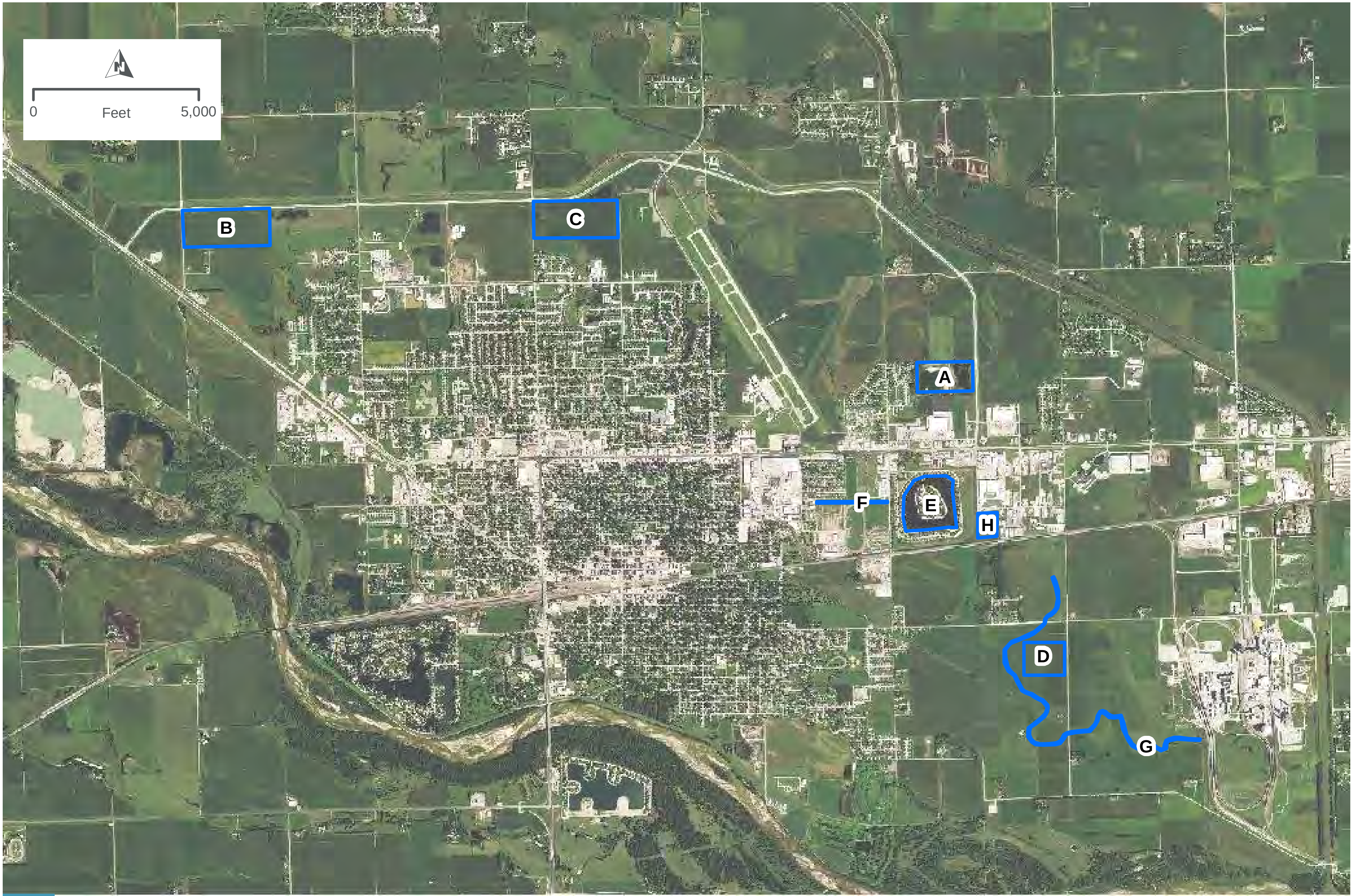


HDR THE FLATWATER GROUP INC. JEO LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

CHRISTOPHER'S COVE, LOUP POWER CANAL, AND LOST CREEK FLOOD CONTROL COMPARED TO SPRING 2014 WATER TABLE

FIGURE 36

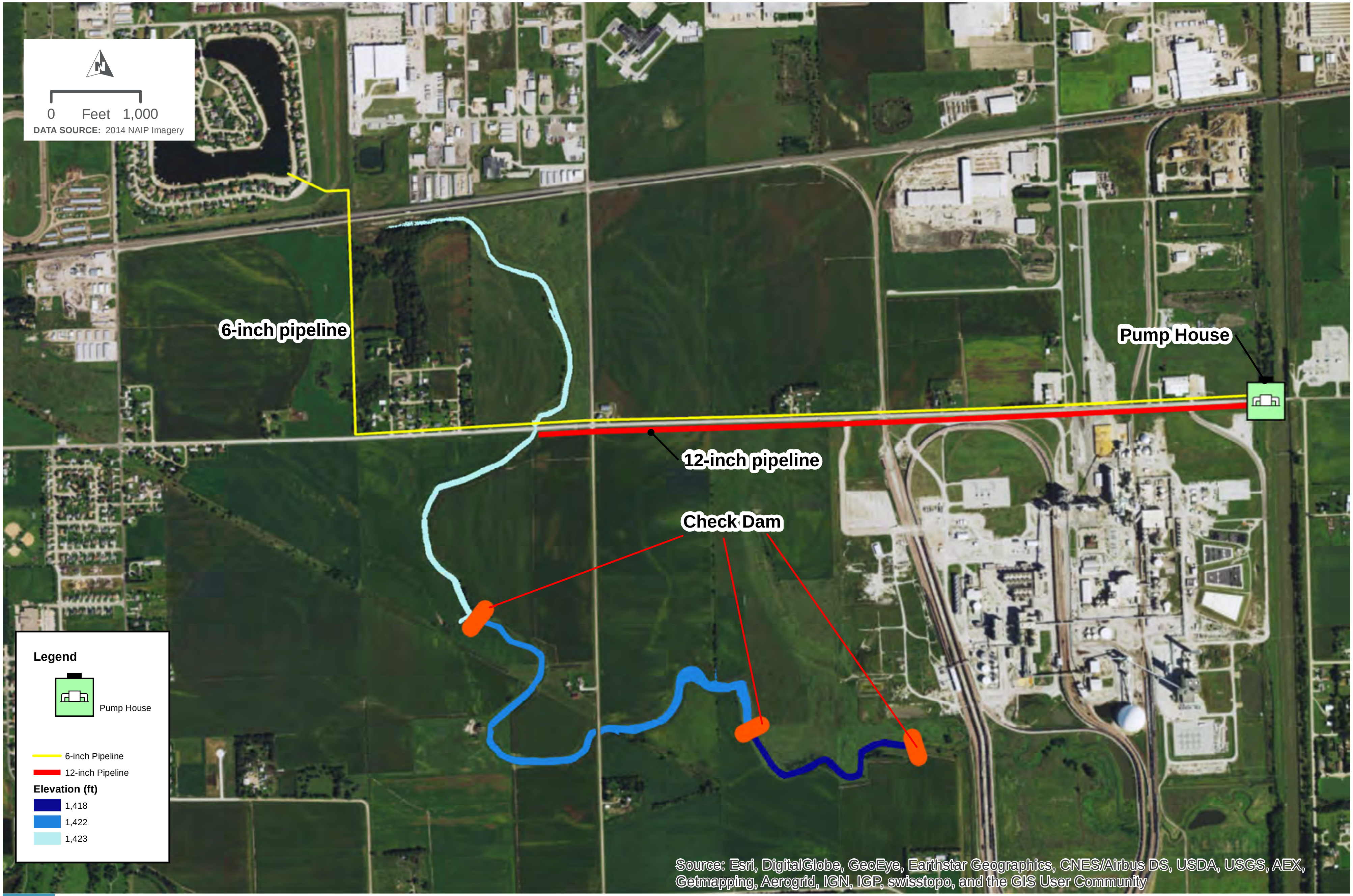


COLUMBUS AREA WATER RESOURCES ASSESSMENT

POTENTIAL RECHARGE SITES

FIGURE 37

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\RECHARGE_FIGURE1.MXD - USER: TWIESE - DATE: 4/11/2016

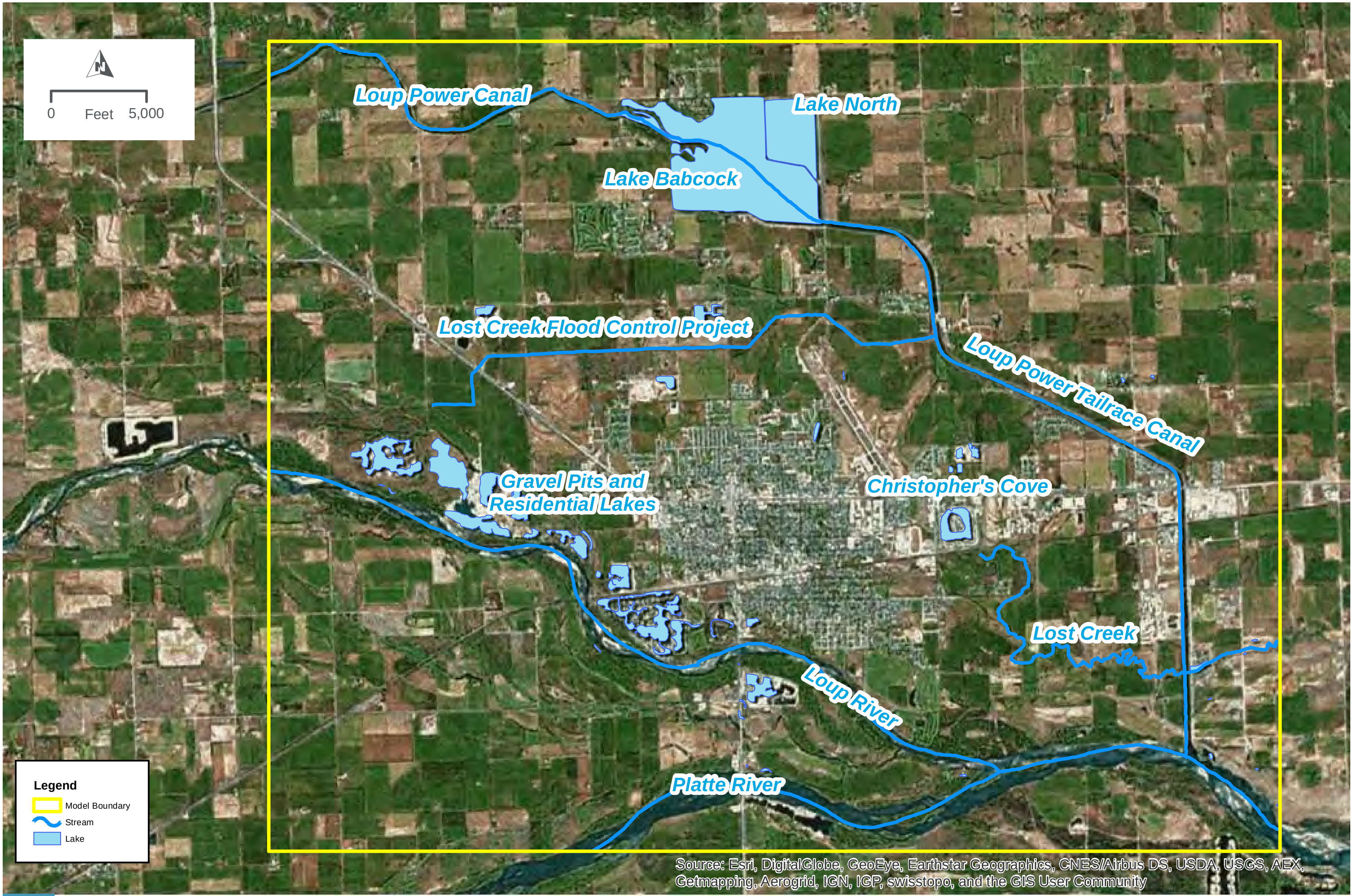


COLUMBUS AREA WATER RESOURCES ASSESSMENT

RECHARGE ALTERNATIVES CONCEPTUAL LAYOUT

FIGURE 38

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE38.MXD - USER: TWIESE - DATE: 6/1/2016



HDR THE FLATWATER GROUP INC. LOWERLOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

GROUNDWATER MODEL BOUNDARY

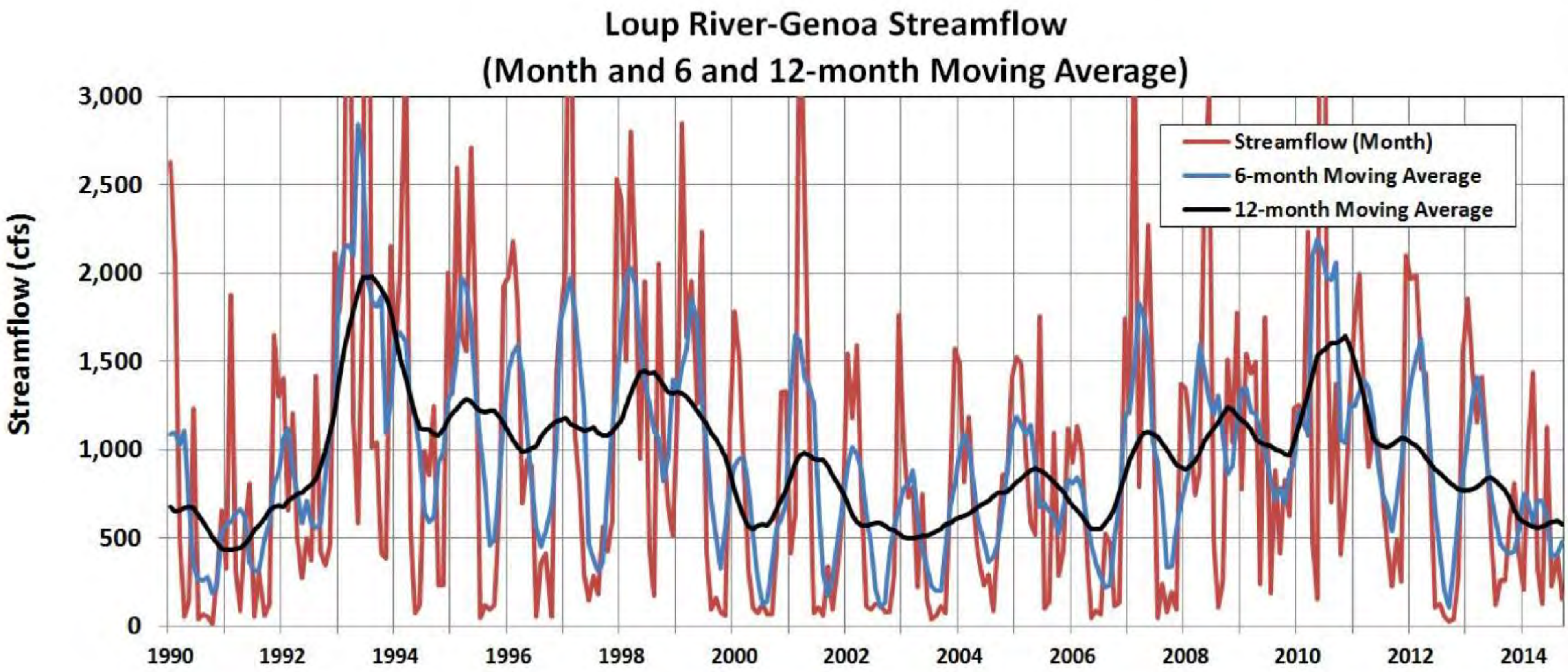
FIGURE 39

COLUMBUS AREA WATER RESOURCES ASSESSMENT

MODEL GRID EXAMPLES

FIGURE 40

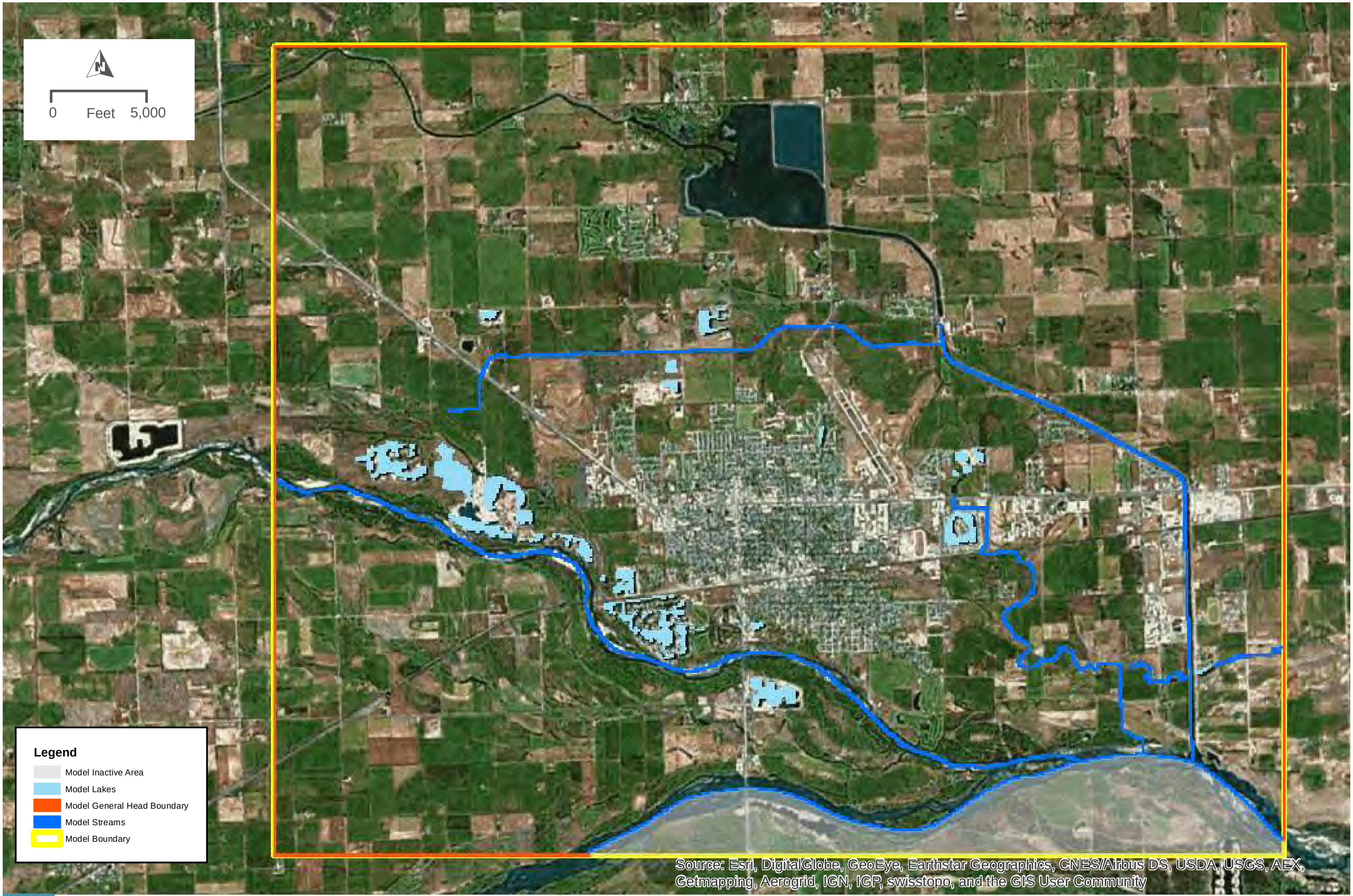
PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE40.MXD - USER: TWIESE - DATE: 4/11/2016



COLUMBUS AREA WATER RESOURCES ASSESSMENT

CALIBRATION PERIOD STREAMFLOW AT LOUP RIVER NEAR GENOA

FIGURE 41



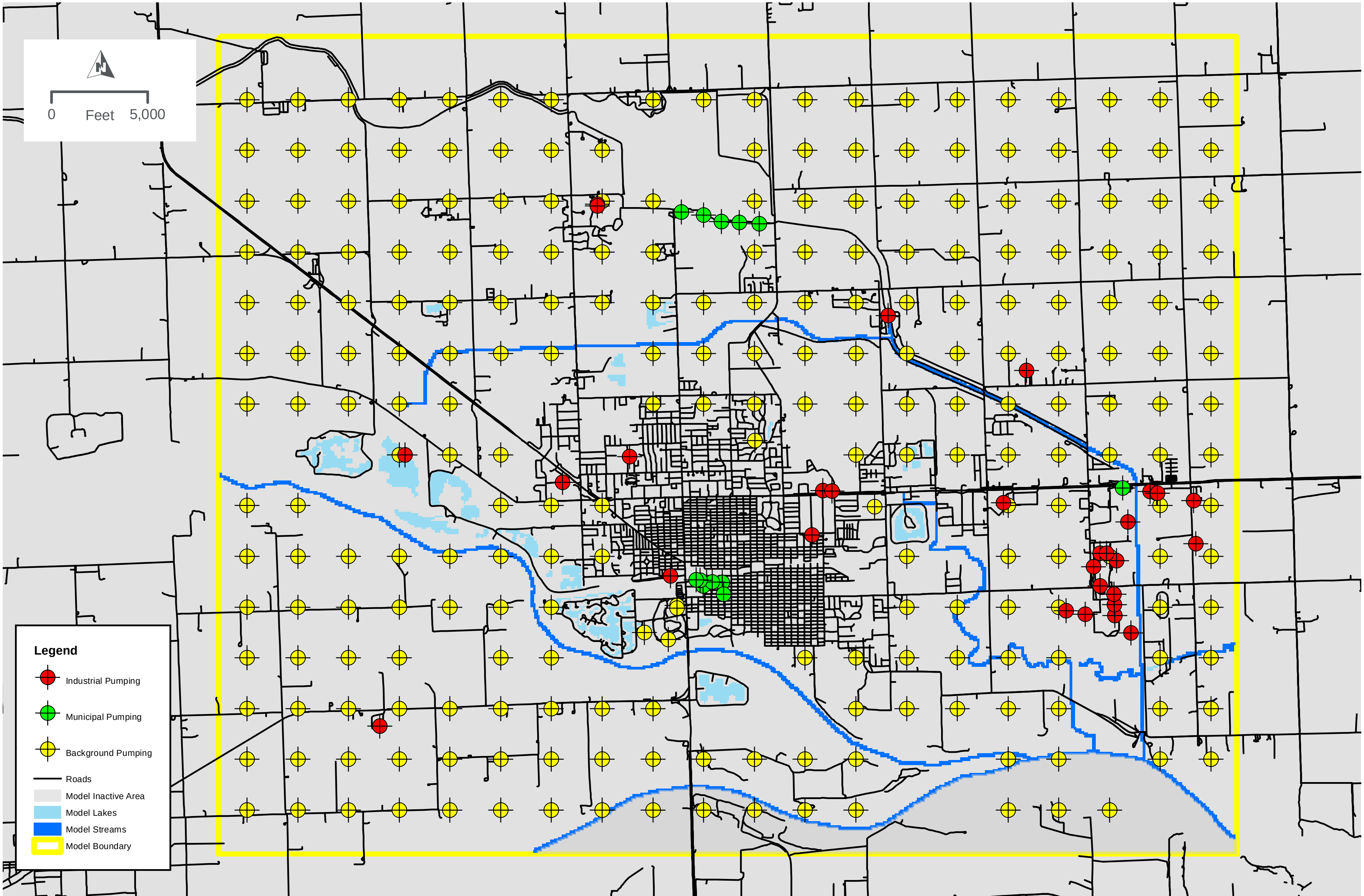
HDR THE FLATWATER GROUP INC. LOWERLOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

PERIMETER AND INTERNAL MODEL BOUNDARIES

FIGURE 42

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE42.MXD - USER: TWIESE - DATE: 4/11/2016

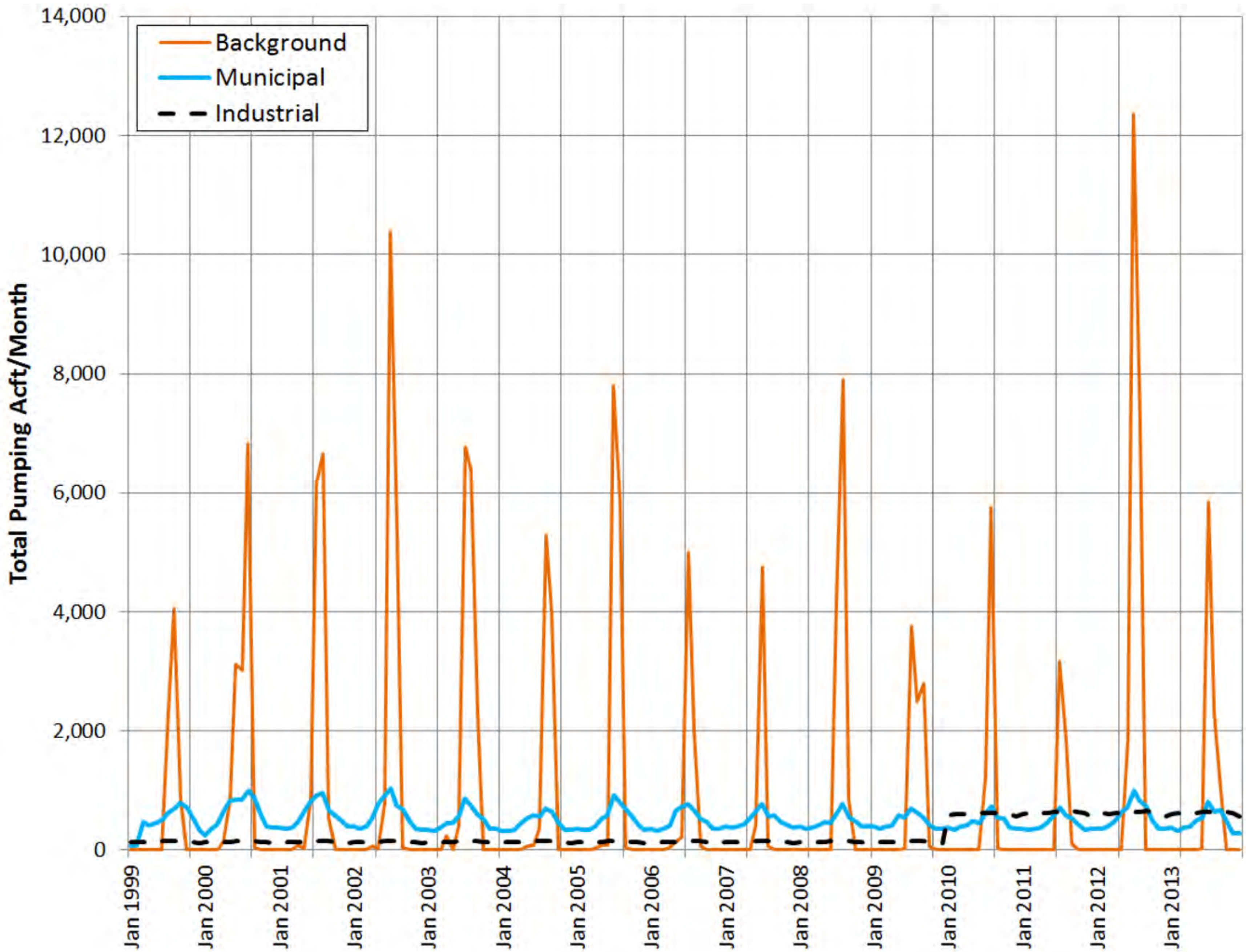


COLUMBUS AREA WATER RESOURCES ASSESSMENT

BACKGROUND, MUNICIPAL, AND INDUSTRIAL PUMPING

FIGURE 43

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE43.MXD - USER: TWIESE - DATE: 4/11/2016



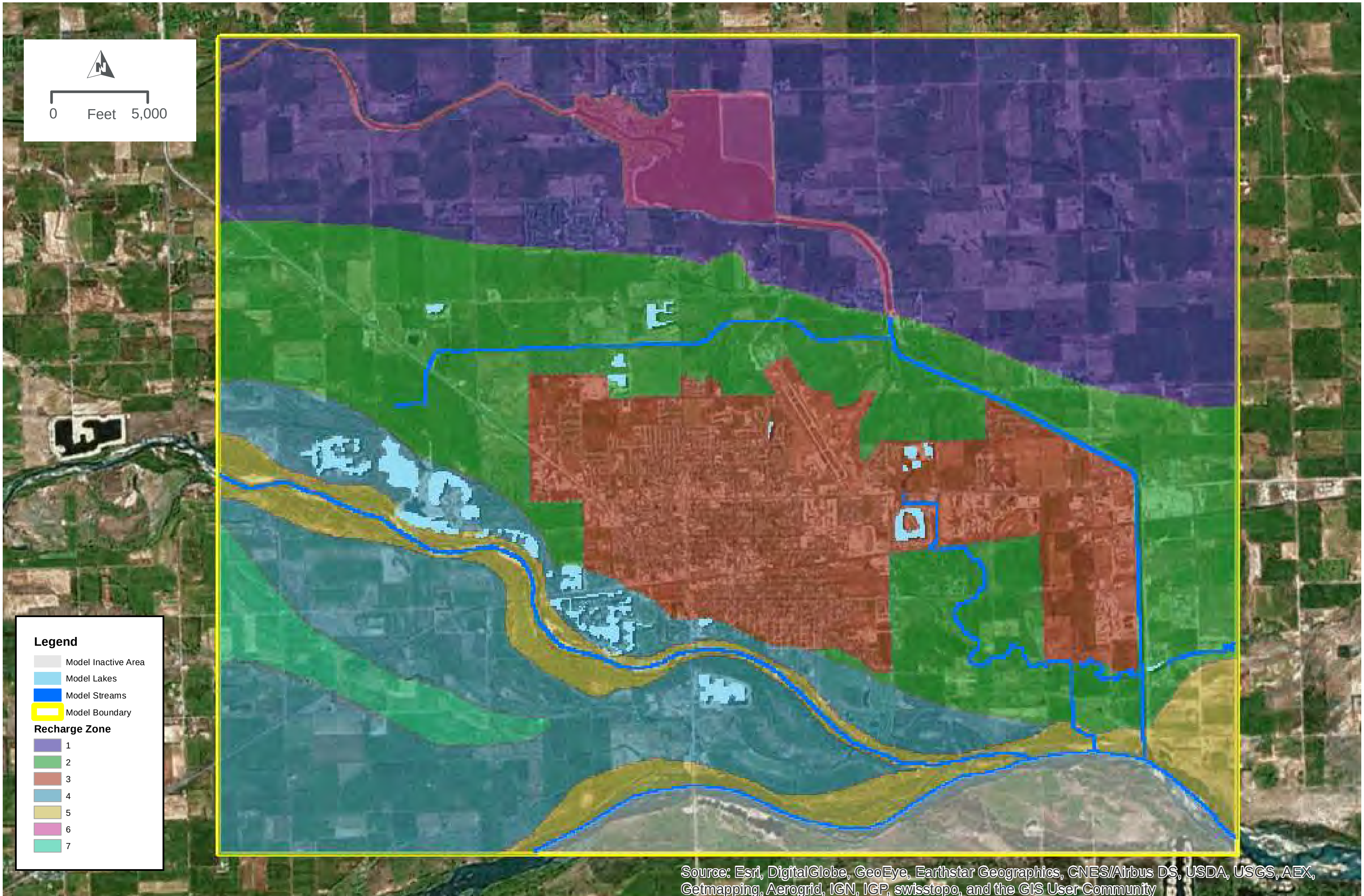
HDR THE FLATWATER GROUP INC. je LOWERLOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

MONTHLY ESTIMATES OF BACKGROUND, MUNICIPAL, AND INDUSTRIAL PUMPING

FIGURE 44

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE44.MXD - USER: TWIESE - DATE: 6/1/2016

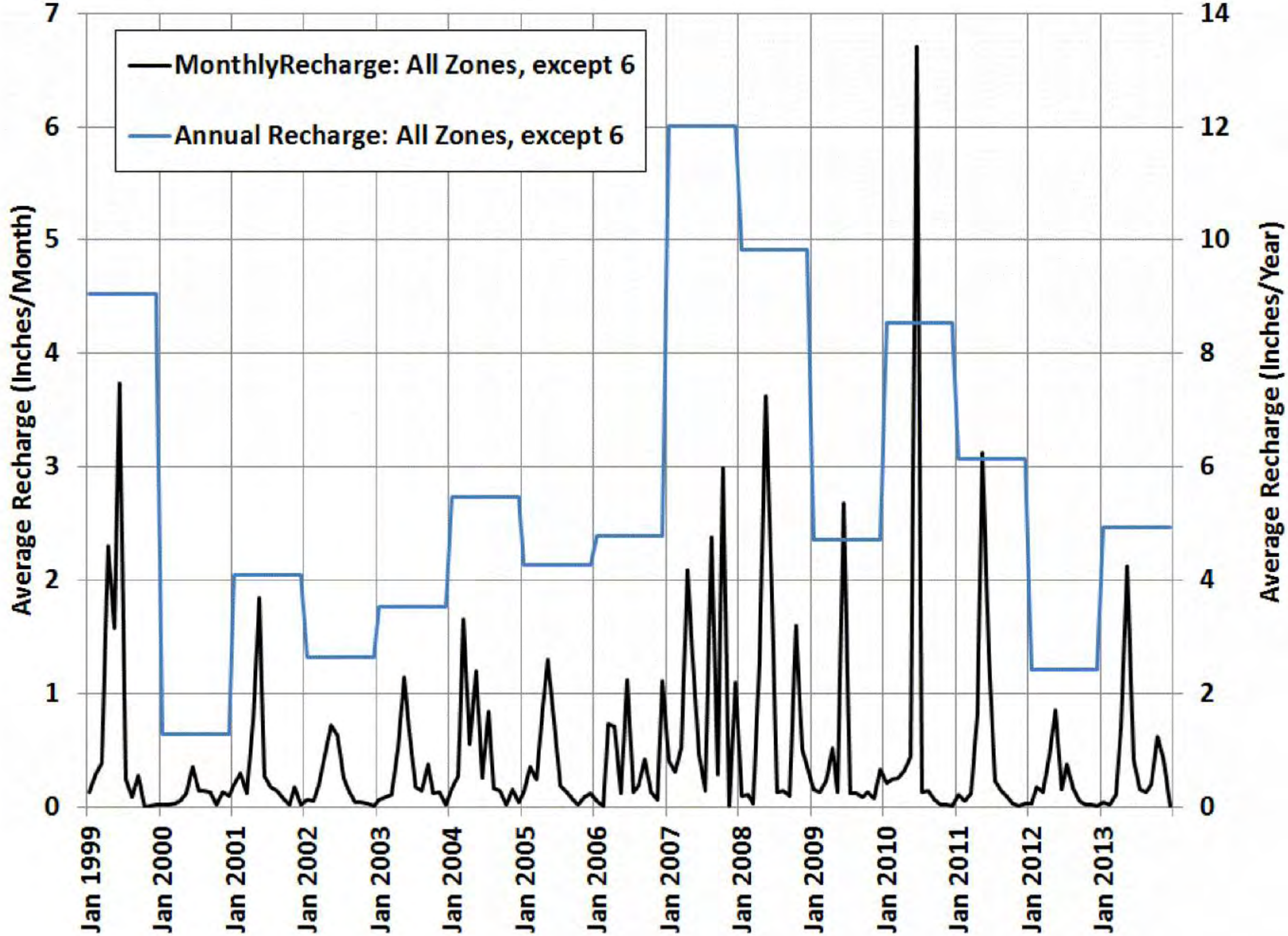


HDR THE FLATWATER GROUP INC. JEO LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

MODEL RECHARGE ZONES

FIGURE 45



COLUMBUS AREA WATER RESOURCES ASSESSMENT

MONTHLY AND ANNUAL ESTIMATES OF RECHARGE

FIGURE 46

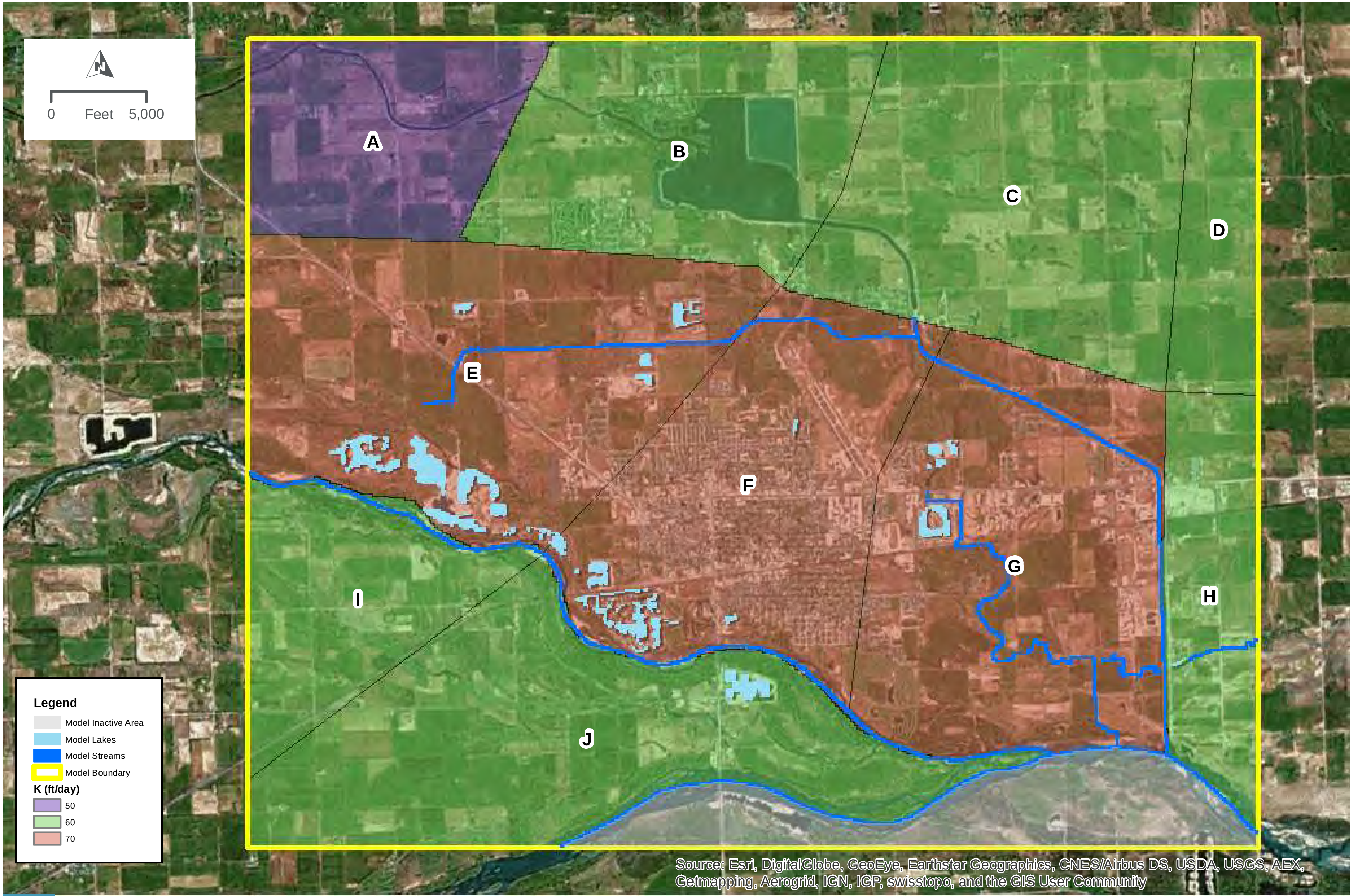
PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE46.MXD - USER: TWIESE - DATE: 4/11/2016

COLUMBUS AREA WATER RESOURCES ASSESSMENT

WELLS USED FOR GROUNDWATER TARGETS

FIGURE 47

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE47.MXD - USER: TWIESE - DATE: 4/11/2016

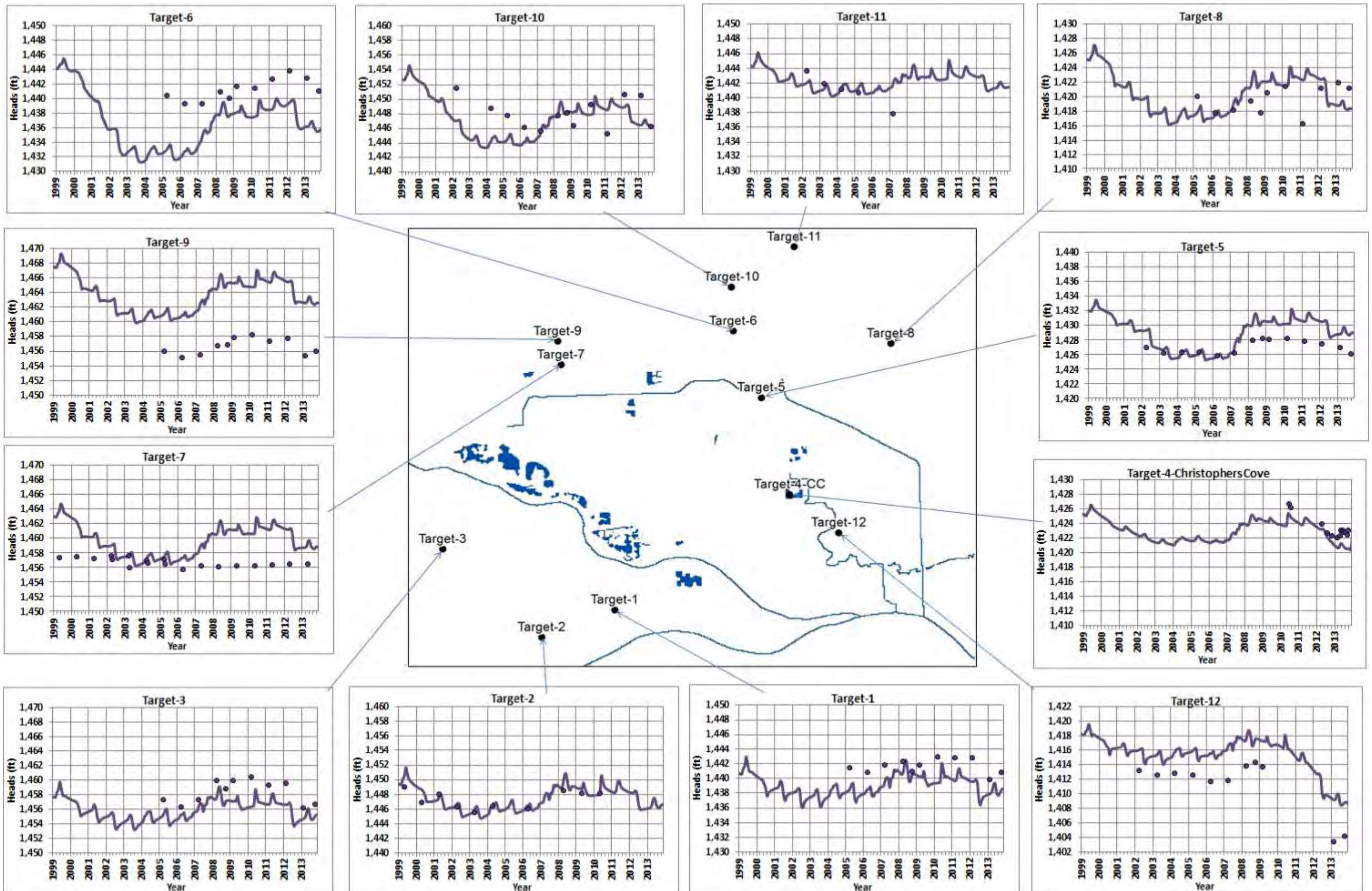


COLUMBUS AREA WATER RESOURCES ASSESSMENT

HORIZONTAL HYDRAULIC CONDUCTIVITY ZONES AND VALUES

FIGURE 48

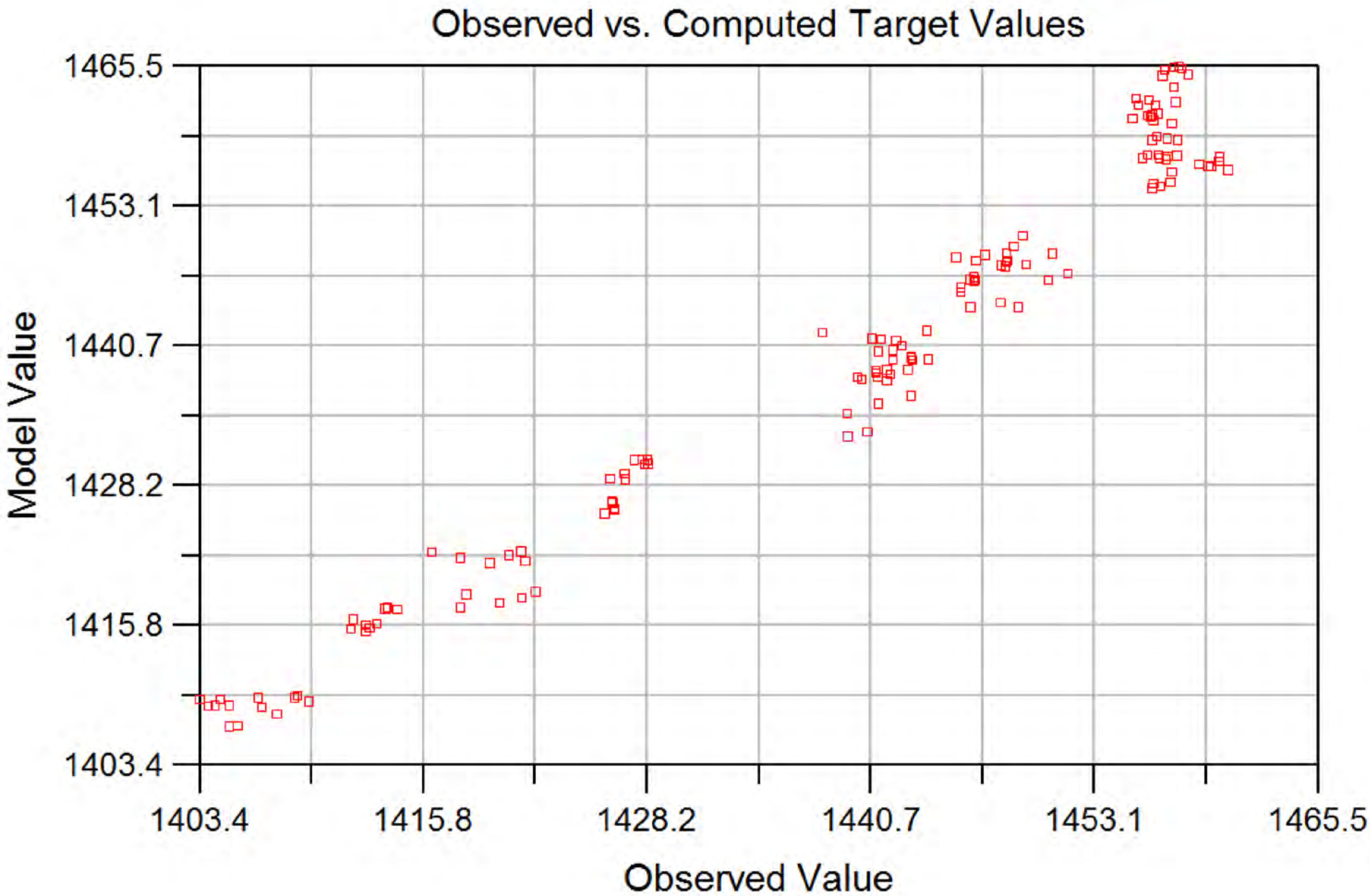
PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE48.MXD - USER: TWIESE - DATE: 4/11/2016



COLUMBUS AREA WATER RESOURCES ASSESSMENT

COMPARISON OF SELECTED MEASURED AND MODELED HYDROGRAPHS

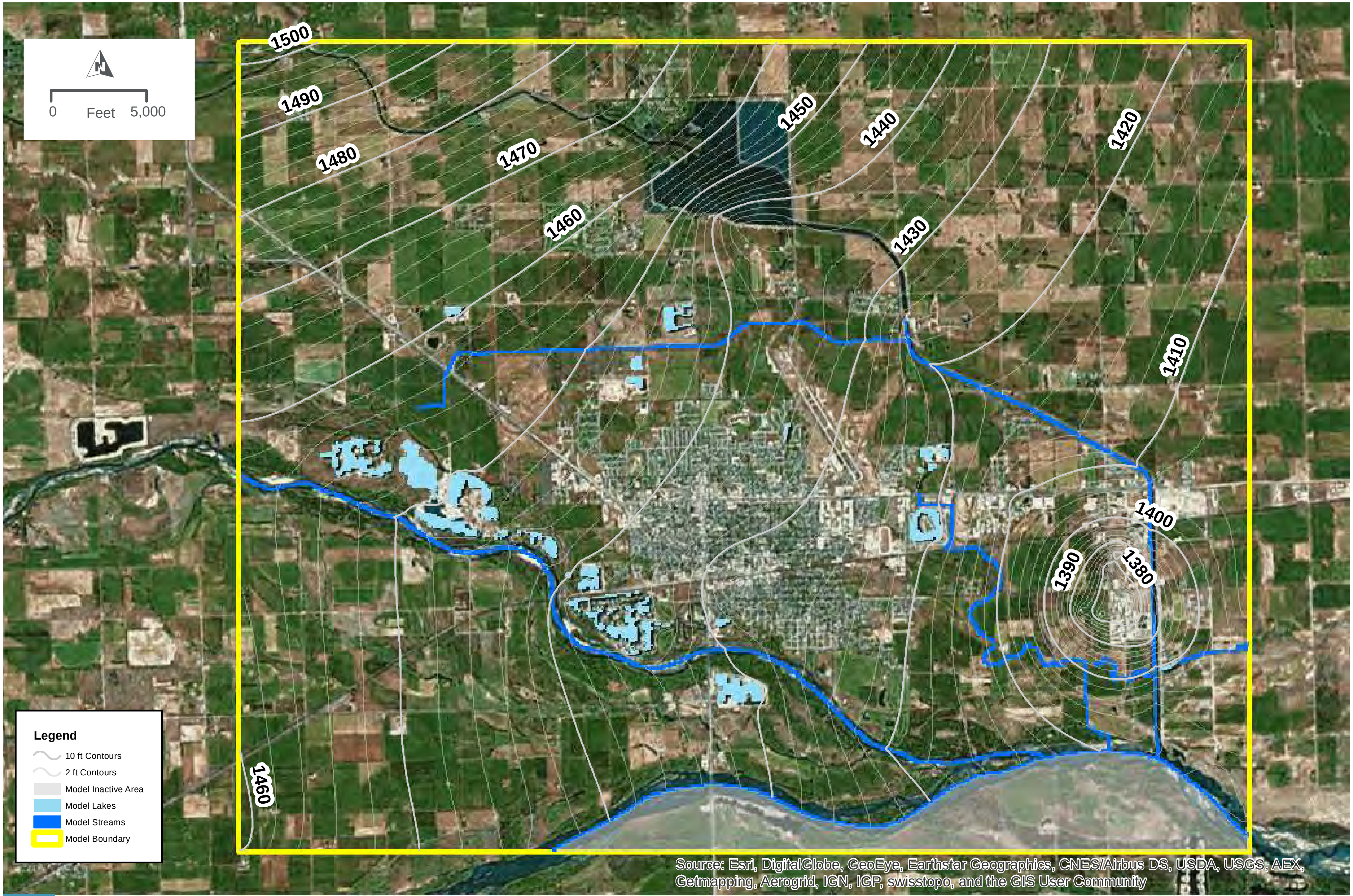
FIGURE 49



COLUMBUS AREA WATER RESOURCES ASSESSMENT

PLOTTED COMPARISON OF MEASURED AND MODELED WATER LEVELS

FIGURE 50

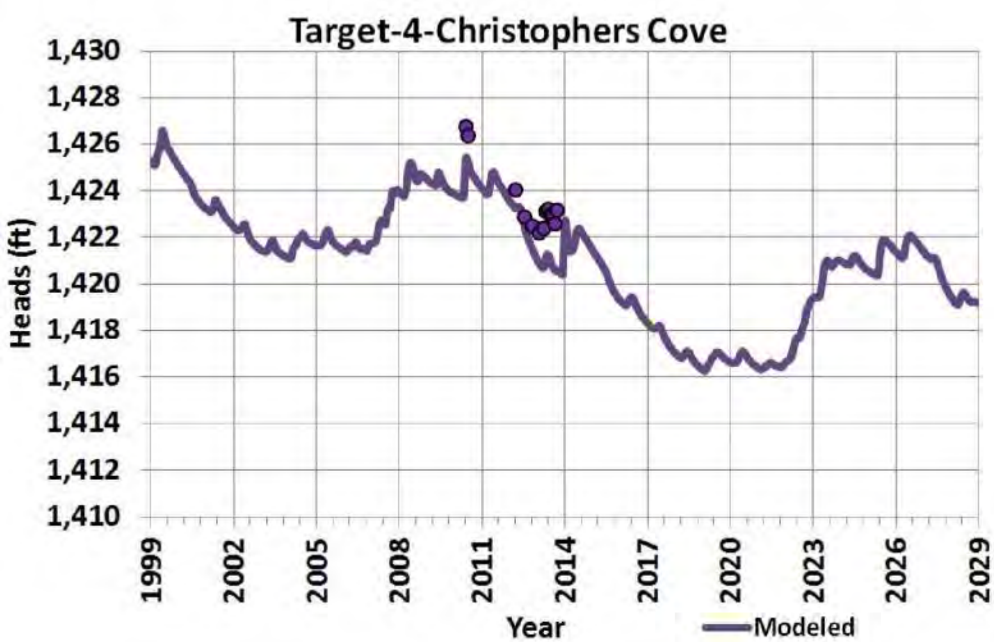


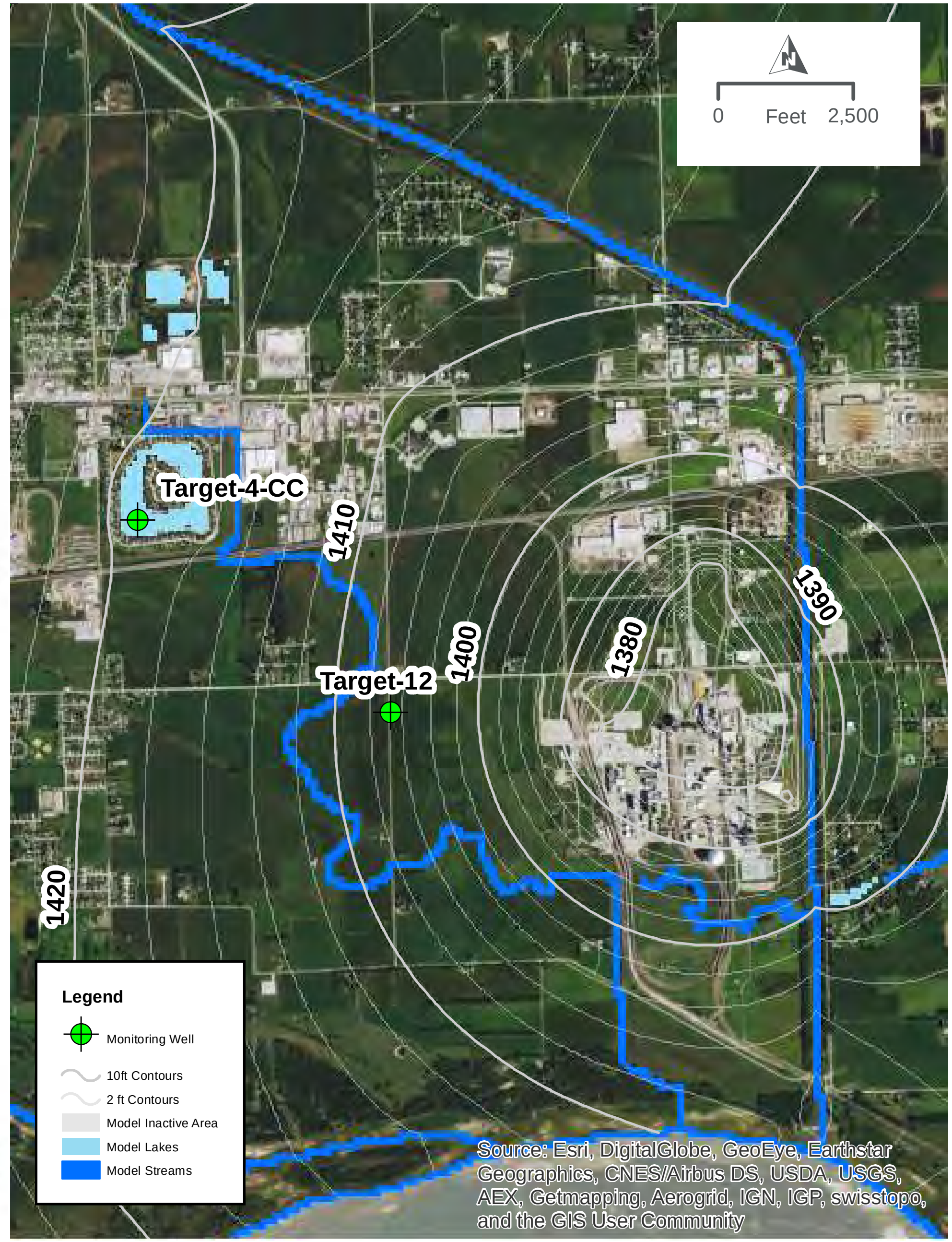
COLUMBUS AREA WATER RESOURCES ASSESSMENT

GROUNDWATER MAP AT END OF CALIBRATION, DEC 2013

FIGURE 51

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE51.MXD - USER: TWIESE - DATE: 4/11/2016



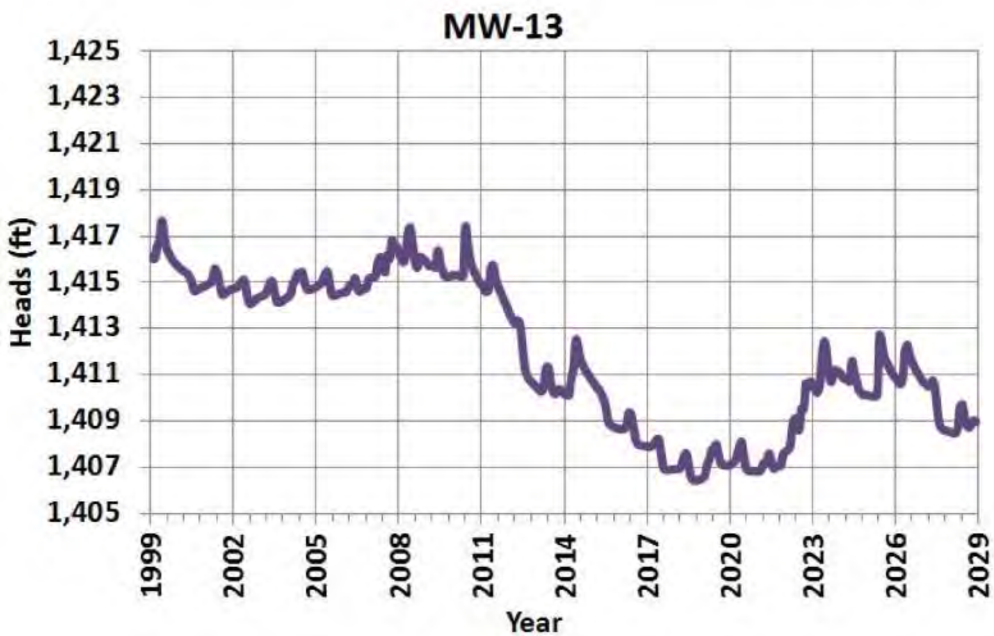


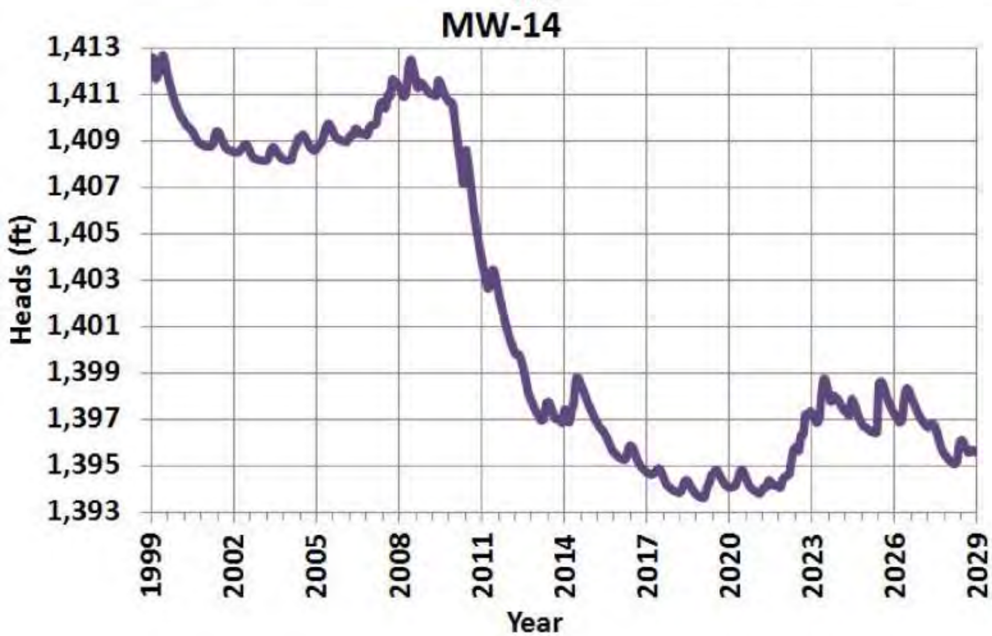
COLUMBUS AREA WATER RESOURCES ASSESSMENT

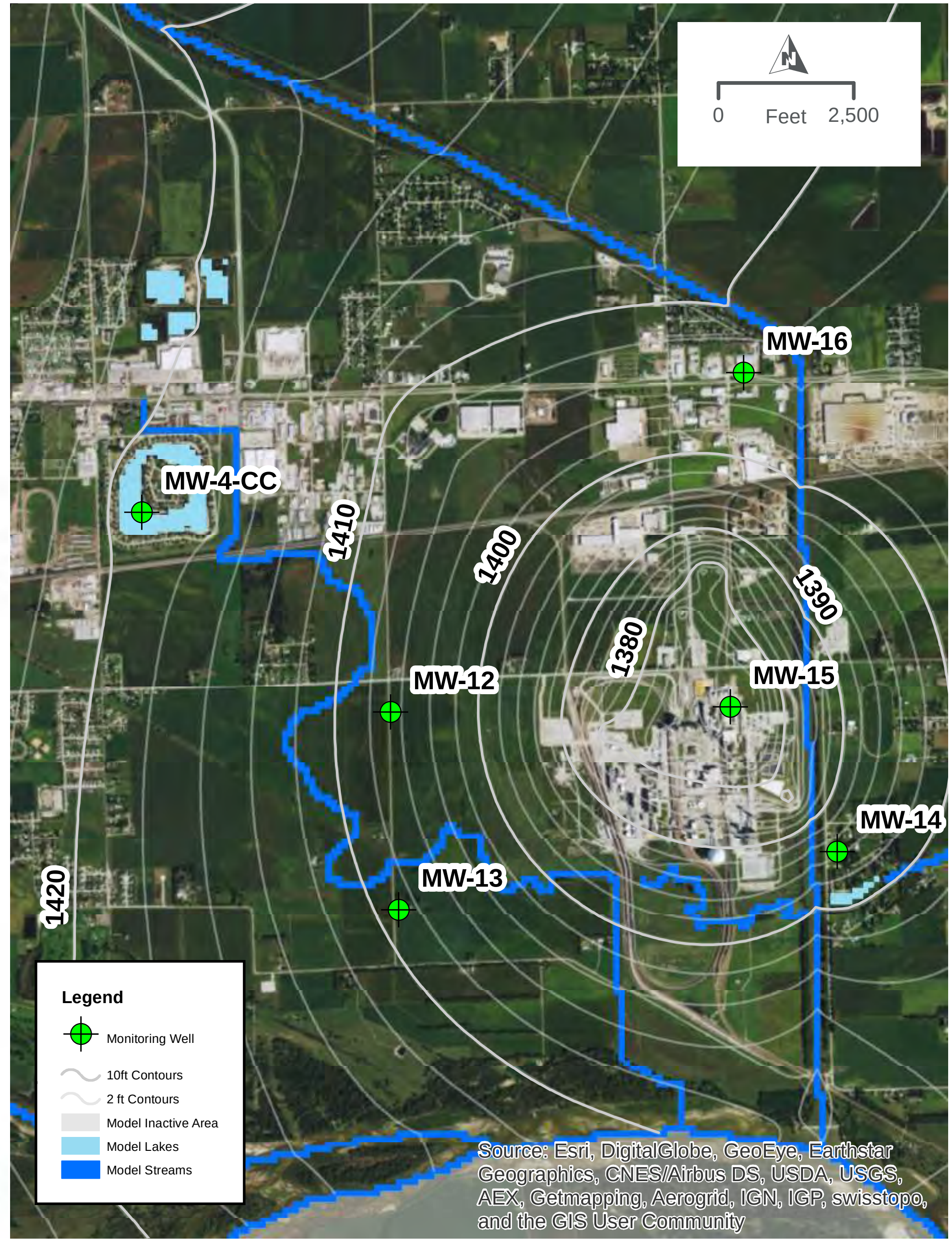
BASELINE GROUNDWATER LEVEL HYDROGRAPHS AND MAP, DEC 2028

FIGURE 52

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE52.MXD - USER: TWIESE - DATE: 4/11/2016





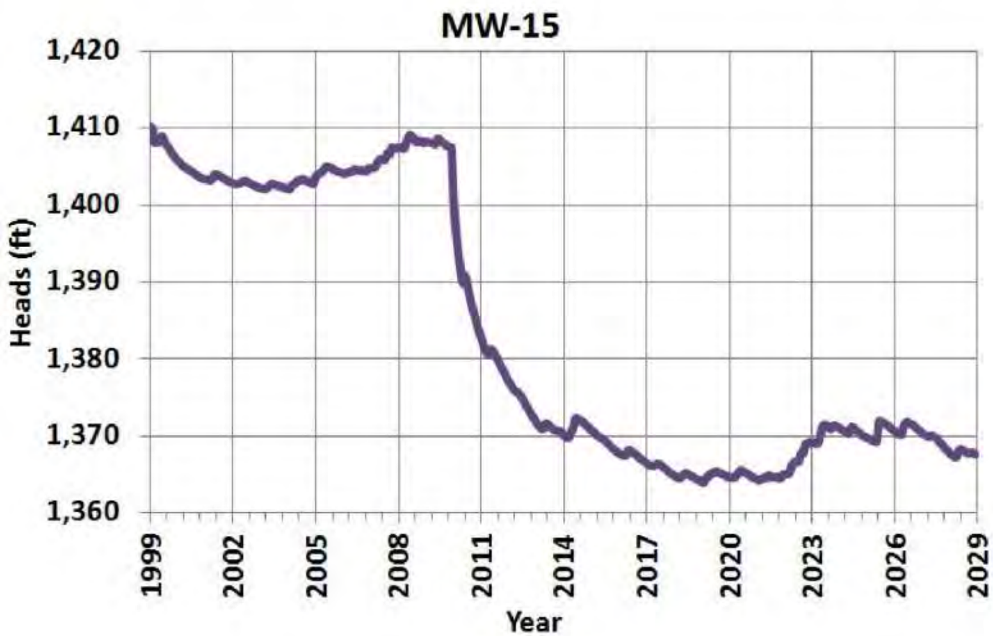


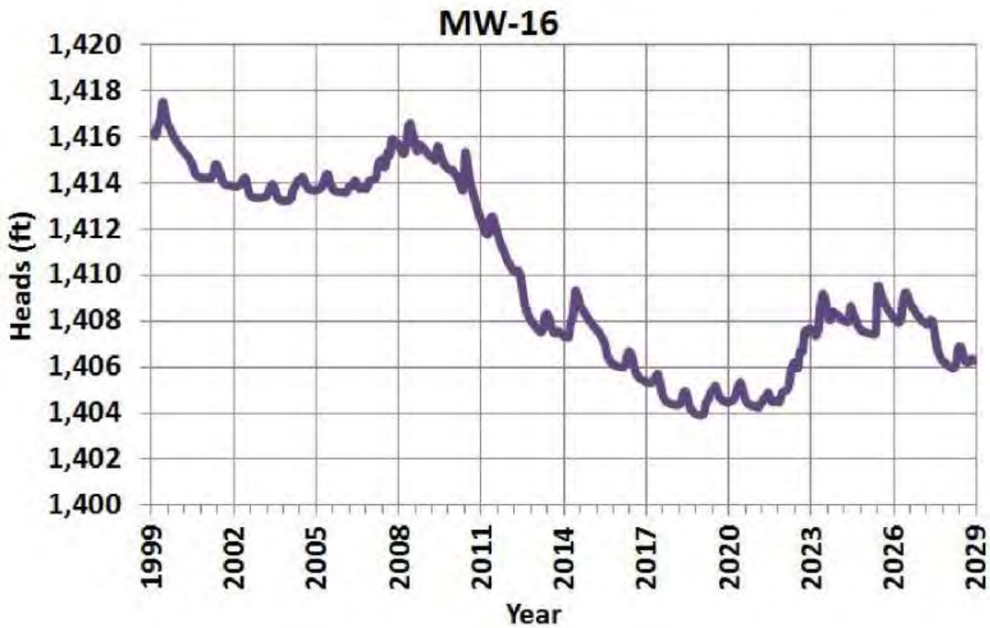
HDR | THE FLATWATER GROUP INC. | je | LOWER LOUP NATURAL RESOURCES DISTRICT

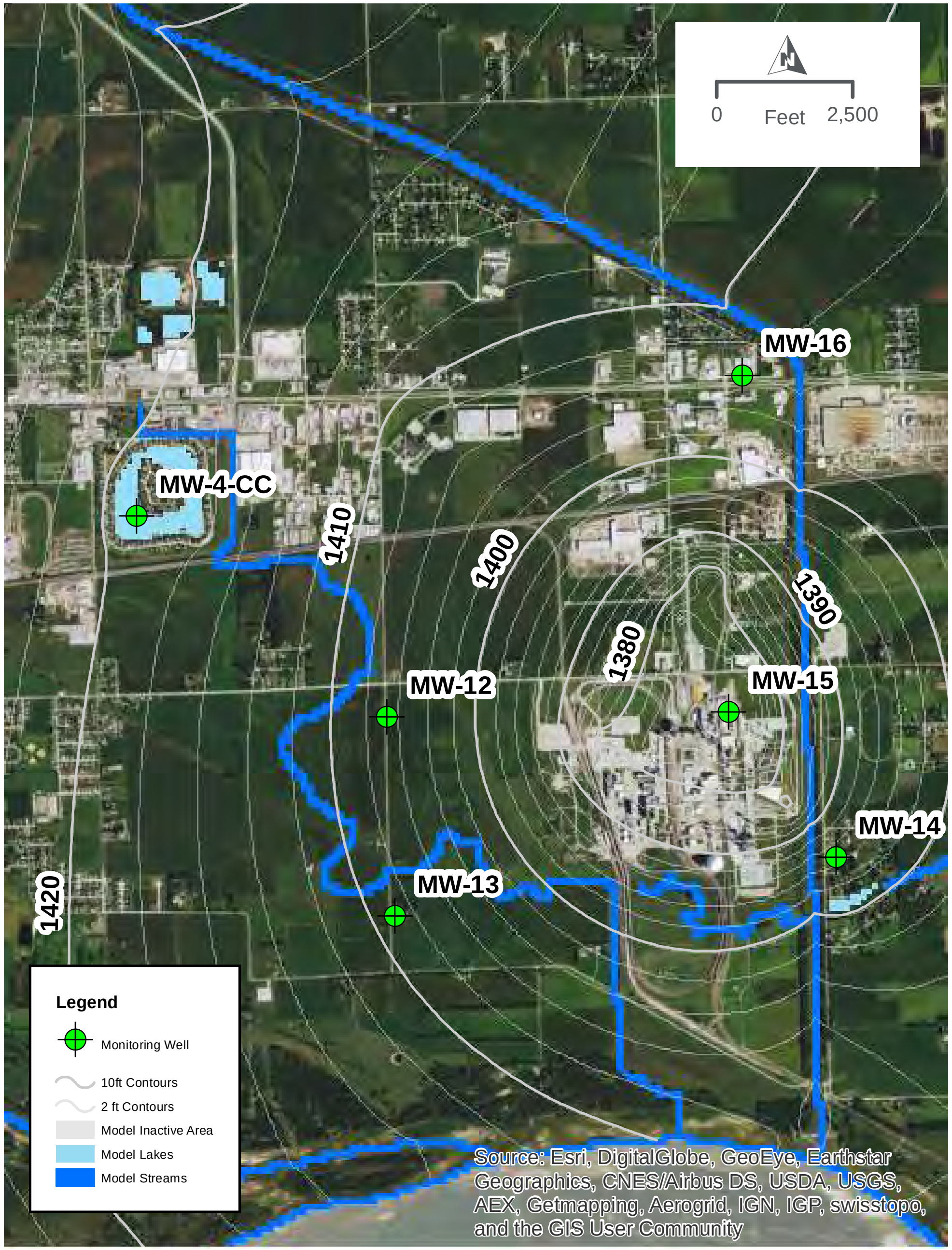
COLUMBUS AREA WATER RESOURCES ASSESSMENT

BASELINE GROUNDWATER LEVEL HYDROGRAPHS AND MAP, DEC 2028

FIGURE 53



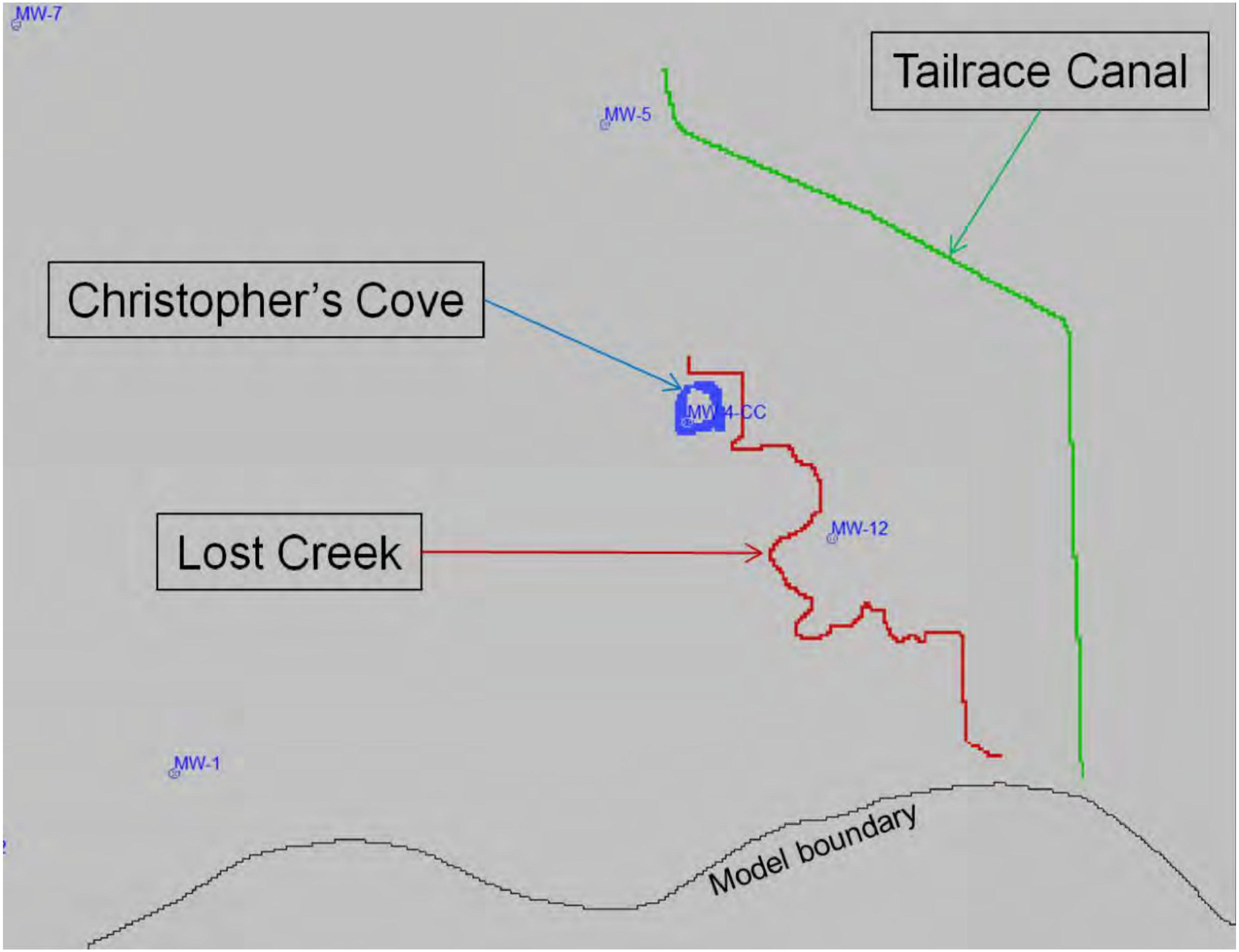




COLUMBUS AREA WATER RESOURCES ASSESSMENT

BASELINE GROUNDWATER LEVEL HYDROGRAPHS AND MAP, DEC 2028

FIGURE 54

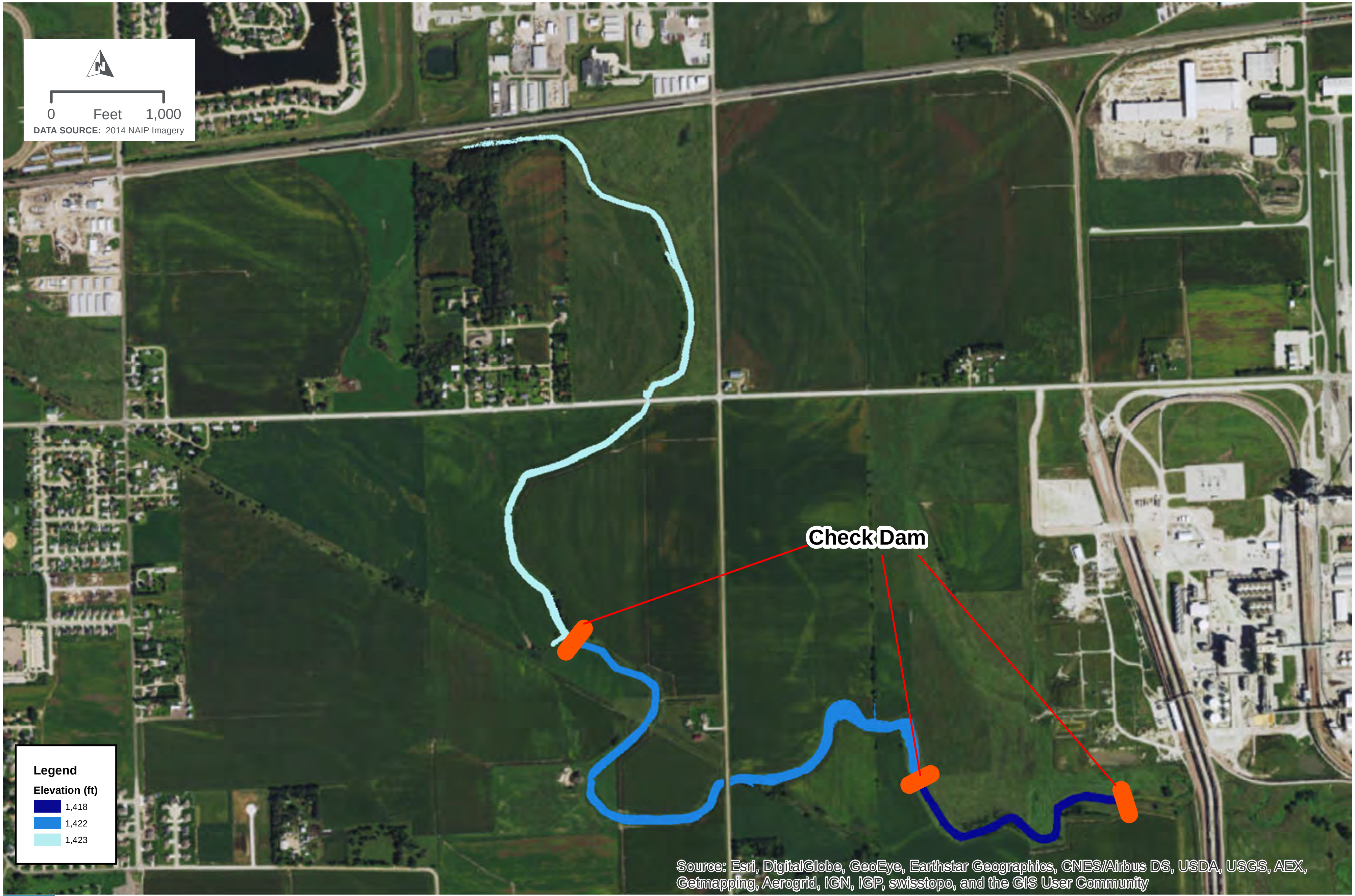


COLUMBUS AREA WATER RESOURCES ASSESSMENT

WATER ACCOUNTING ZONES ON SURFACE WATER BODIES OF INTEREST

FIGURE 55

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE55.MXD - USER: TWIESE - DATE: 4/11/2016

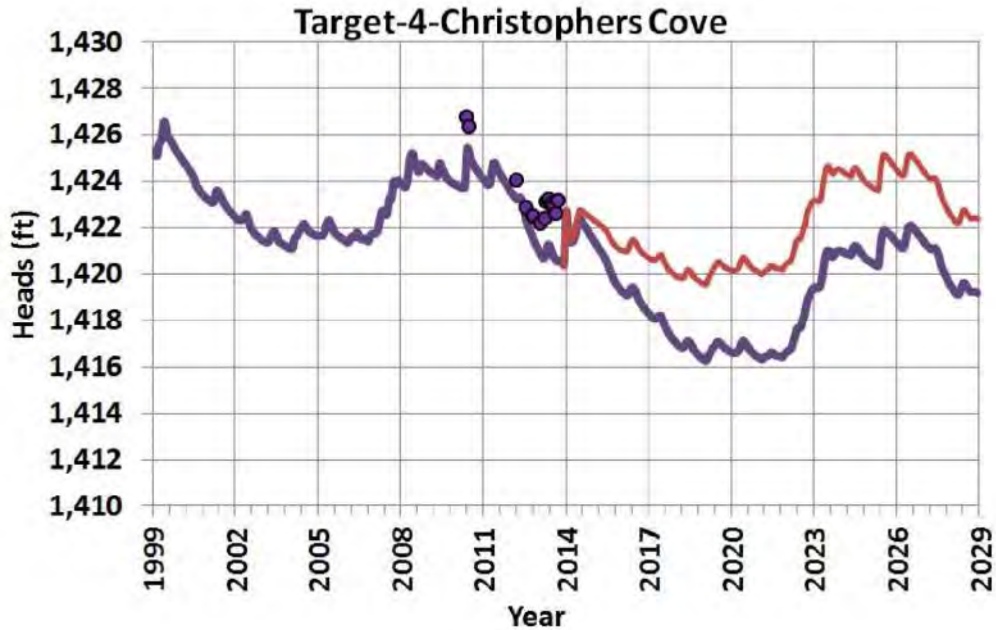


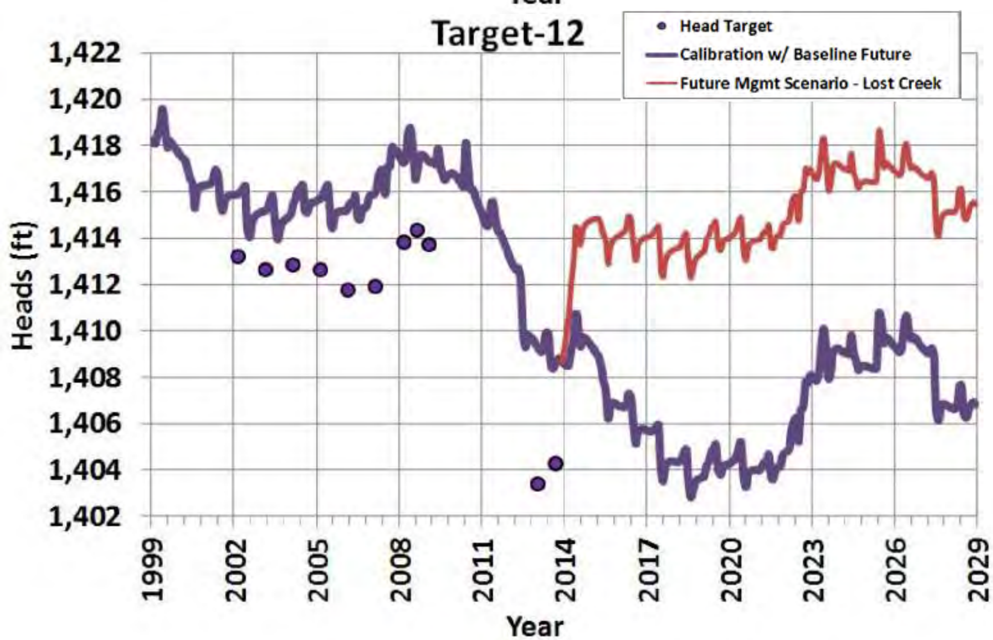
COLUMBUS AREA WATER RESOURCES ASSESSSMENT

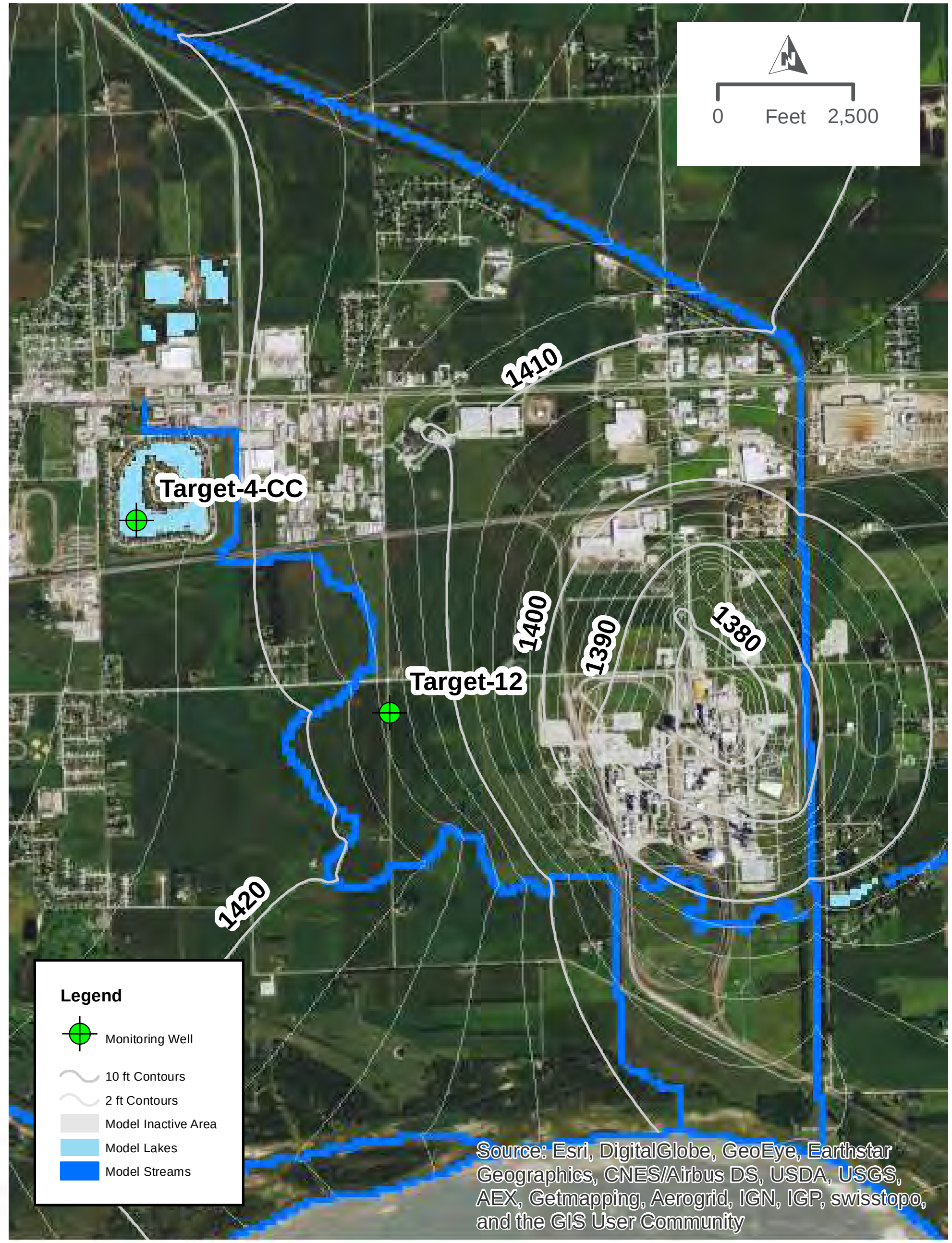
PROJECT LAYOUT FOR LOST CREEK RECHARGE

FIGURE 56

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE56.MXD - USER: TWIESE - DATE: 6/1/2016







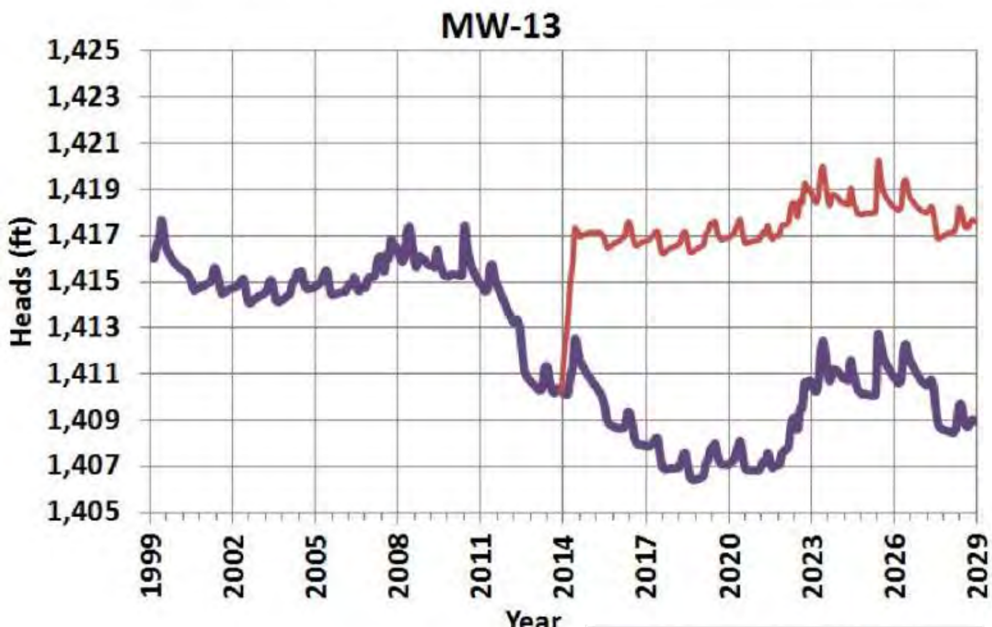
HDR THE FLATWATER GROUP INC. JEO LOWER LOUP NATURAL RESOURCES DISTRICT

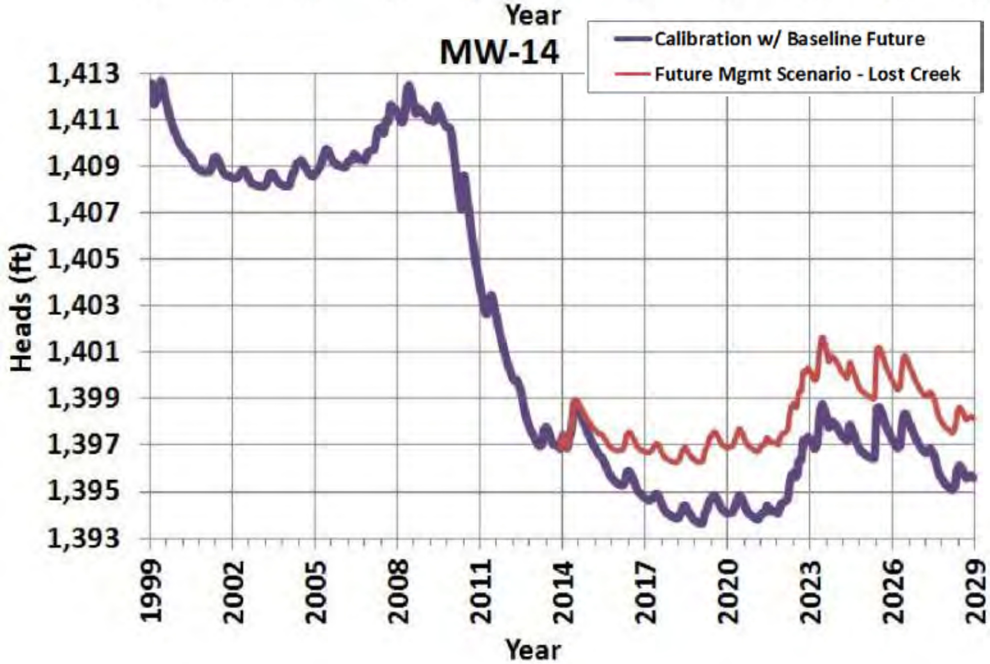
COLUMBUS AREA WATER RESOURCES ASSESSMENT

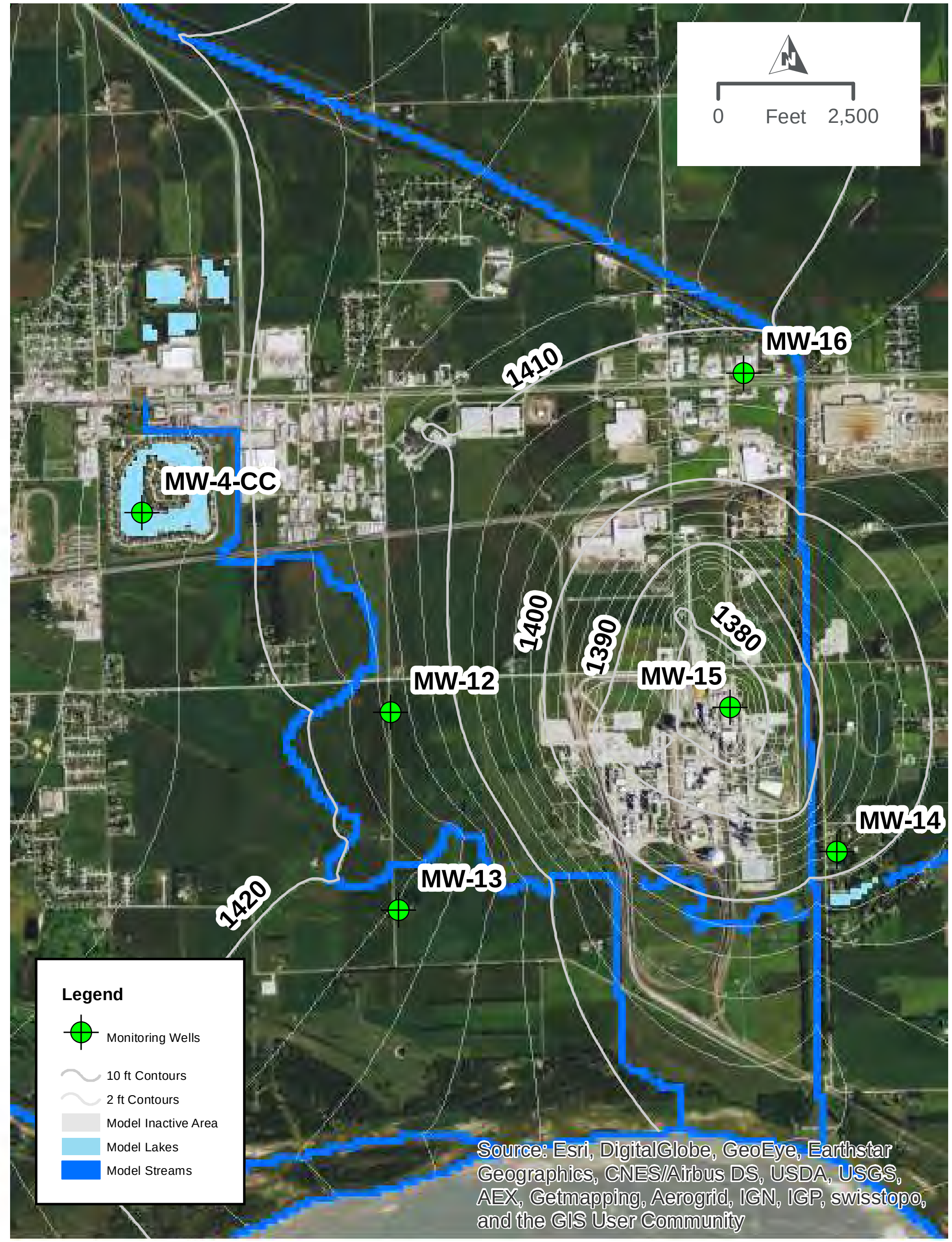
GROUNDWATER HYDROGRAPHS AND MAP WITH LOST CREEK PROJECT, DEC 2028

FIGURE 57

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE57.MXD - USER: TWIESE - DATE: 4/11/2016





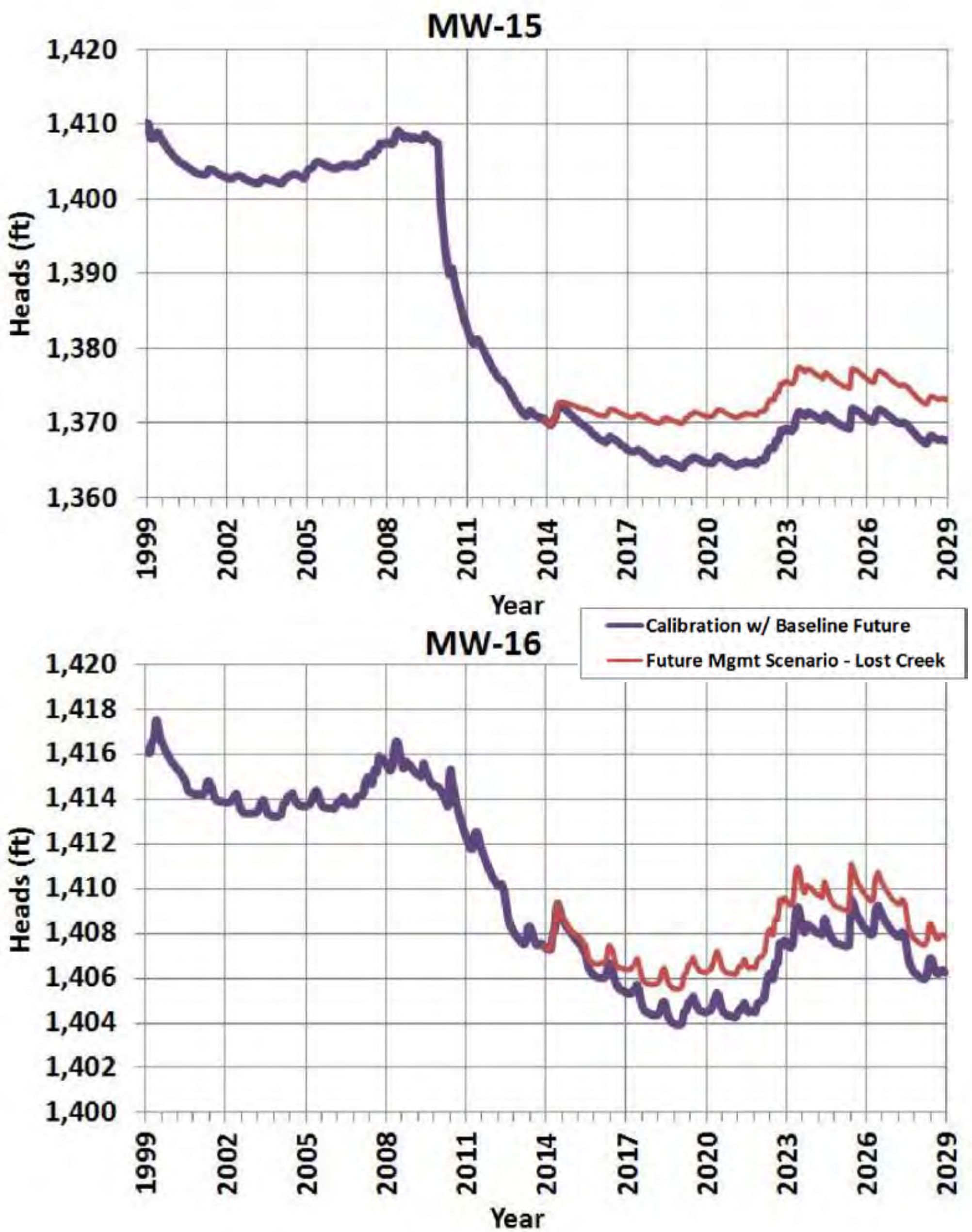


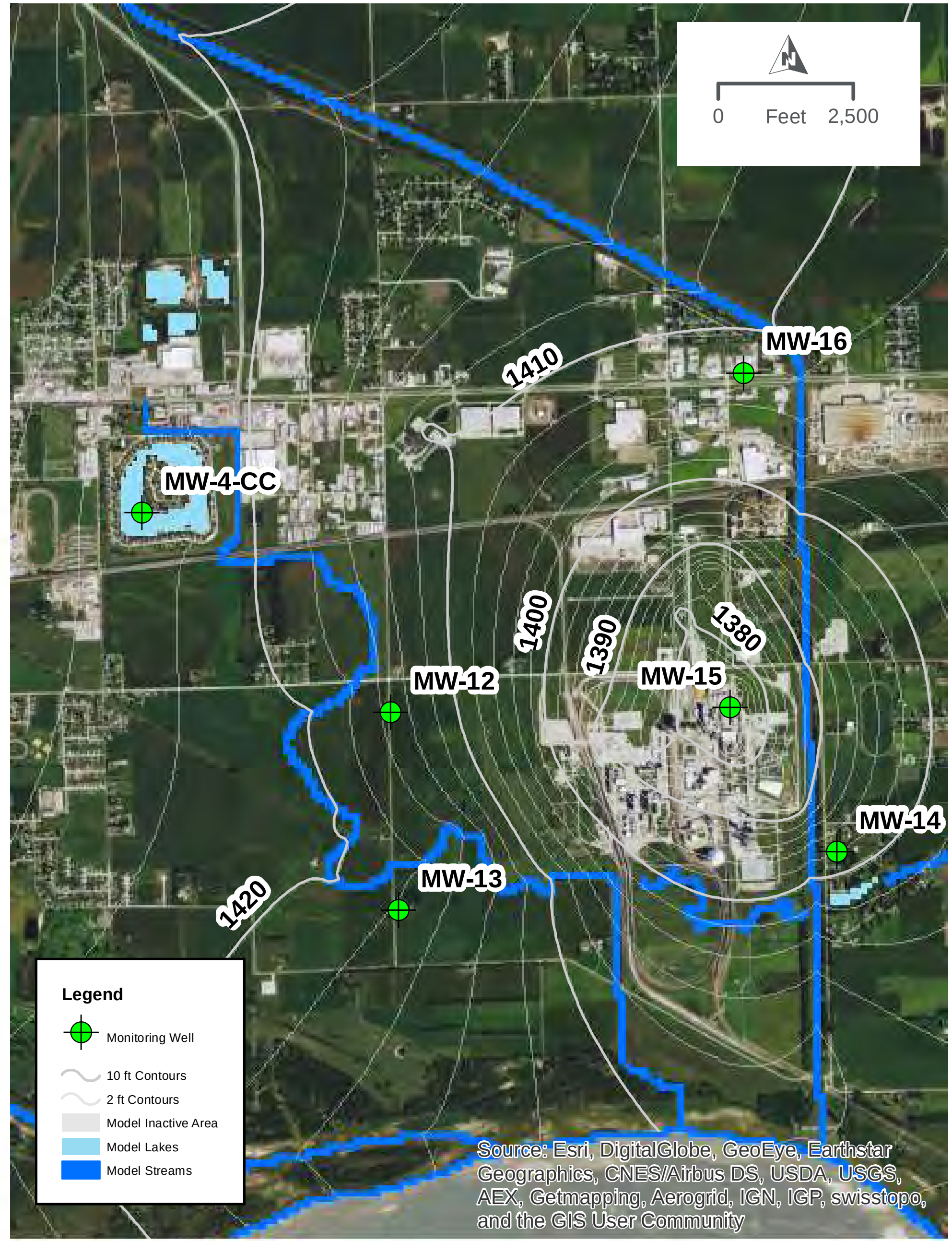
HDR THE FLATWATER GROUP INC. je LOWERLOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

GROUNDWATER HYDROGRAPHS AND MAP WITH LOST CREEK PROJECT, DEC 2028

FIGURE 58





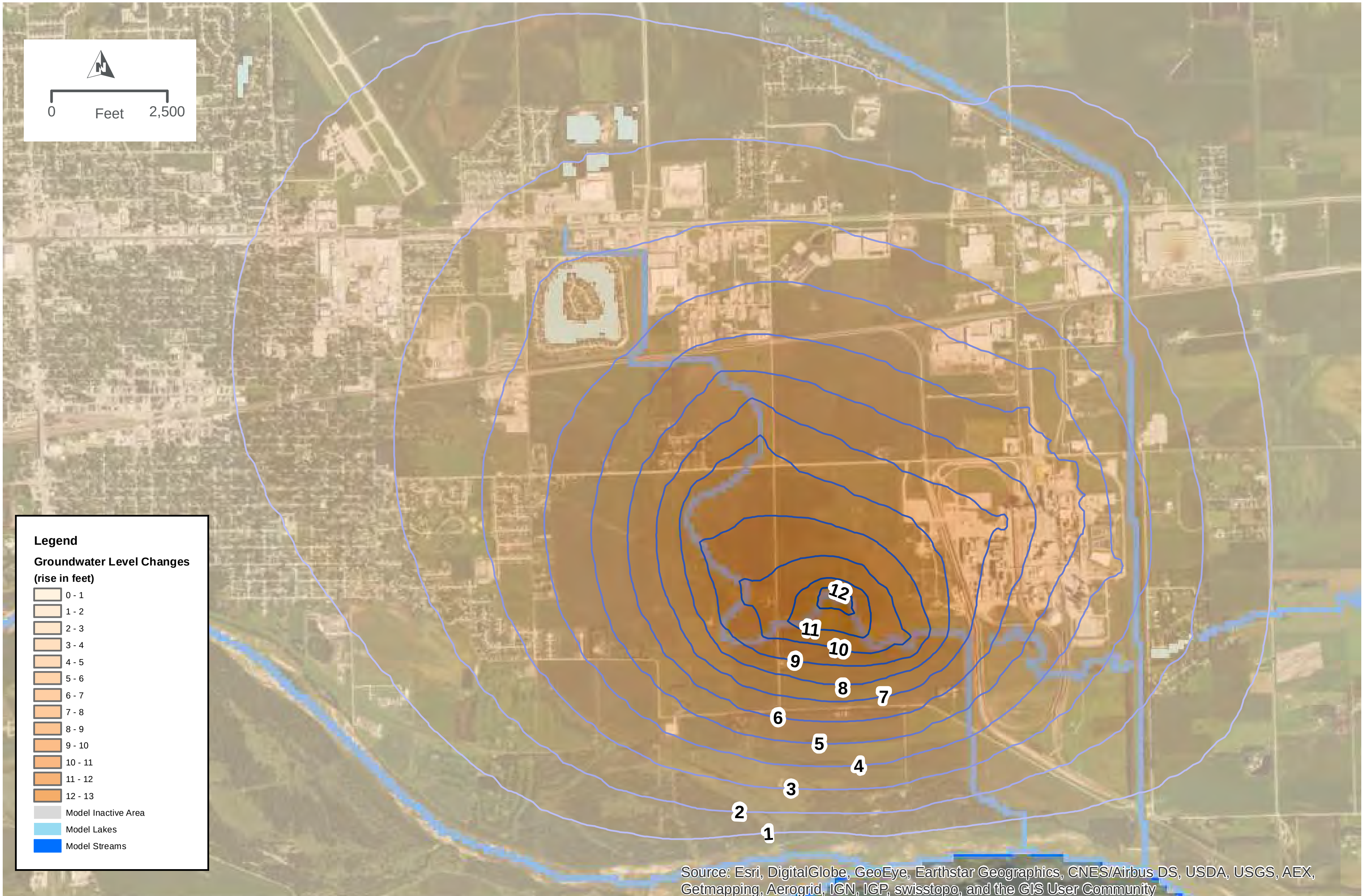
HDR THE FLATWATER GROUP INC. LOWERLOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

GROUNDWATER HYDROGRAPHS AND MAP WITH LOST CREEK PROJECT, DEC 2028

FIGURE 59

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE59.MXD - USER: TWIESE - DATE: 4/11/2016

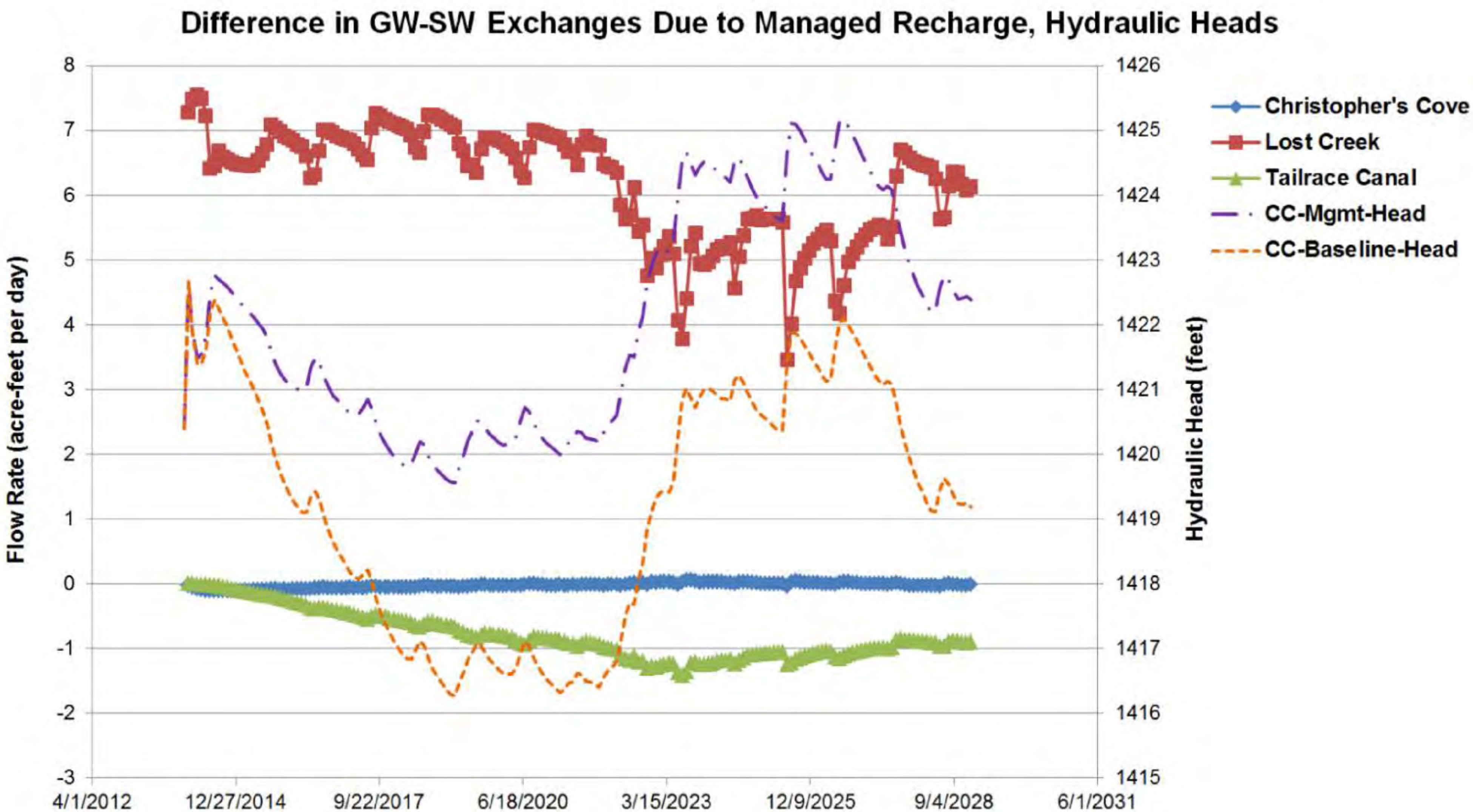


COLUMBUS AREA WATER RESOURCES ASSESSMENT

GROUNDWATER LEVEL IMPACTS FOR LOST CREEK RECHARGE PROJECT, DEC 2028

FIGURE 60

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE60.MXD - USER: TWIESE - DATE: 4/11/2016



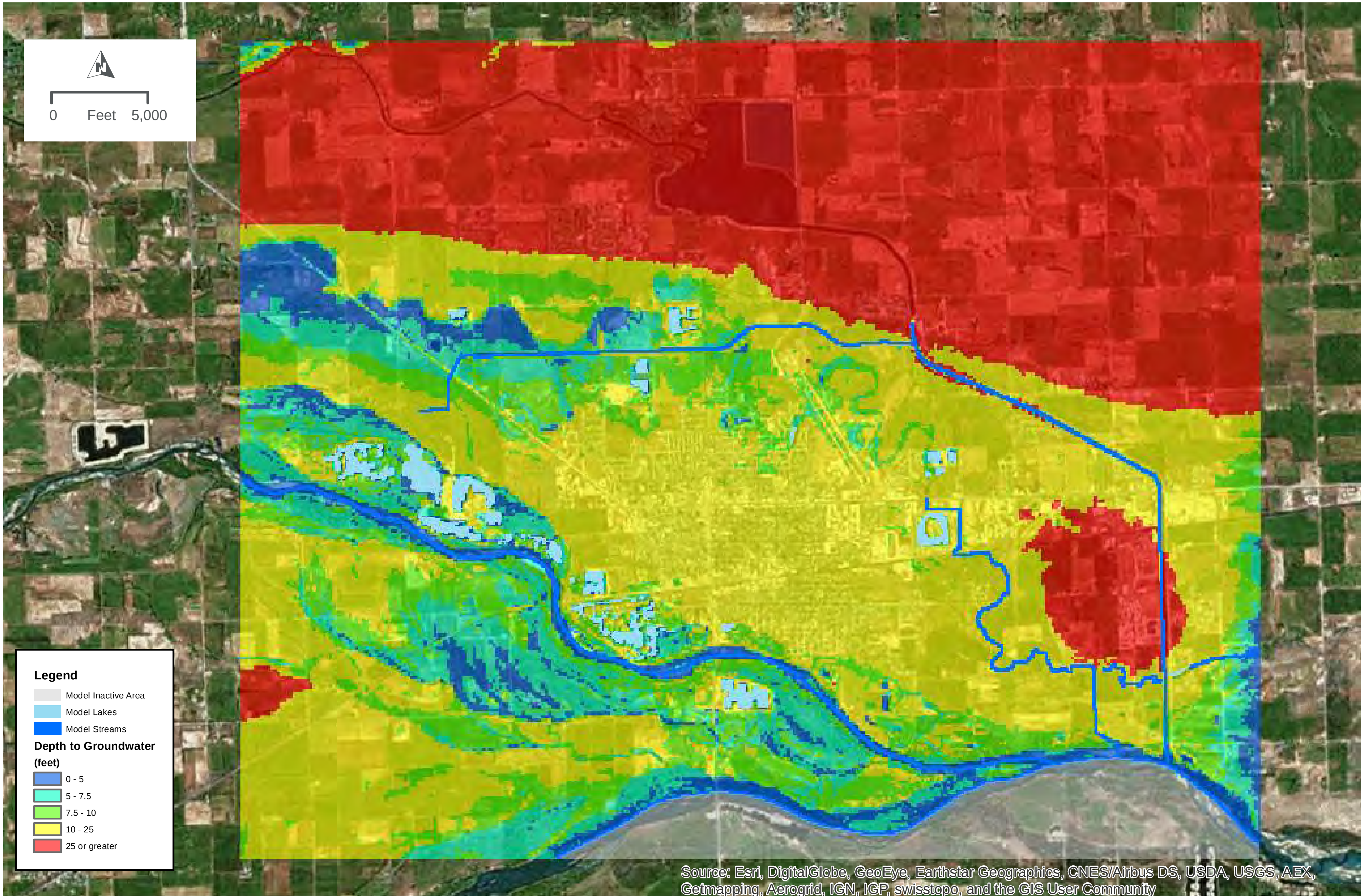
HDR | THE FLATWATER GROUP INC. | JEO | LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

CHANGES TO GW-SW EXCHANGES AND HEADS FOR LOST CREEK RECHARGE

FIGURE 61

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE61.MXD - USER: TWIESE - DATE: 4/11/2016



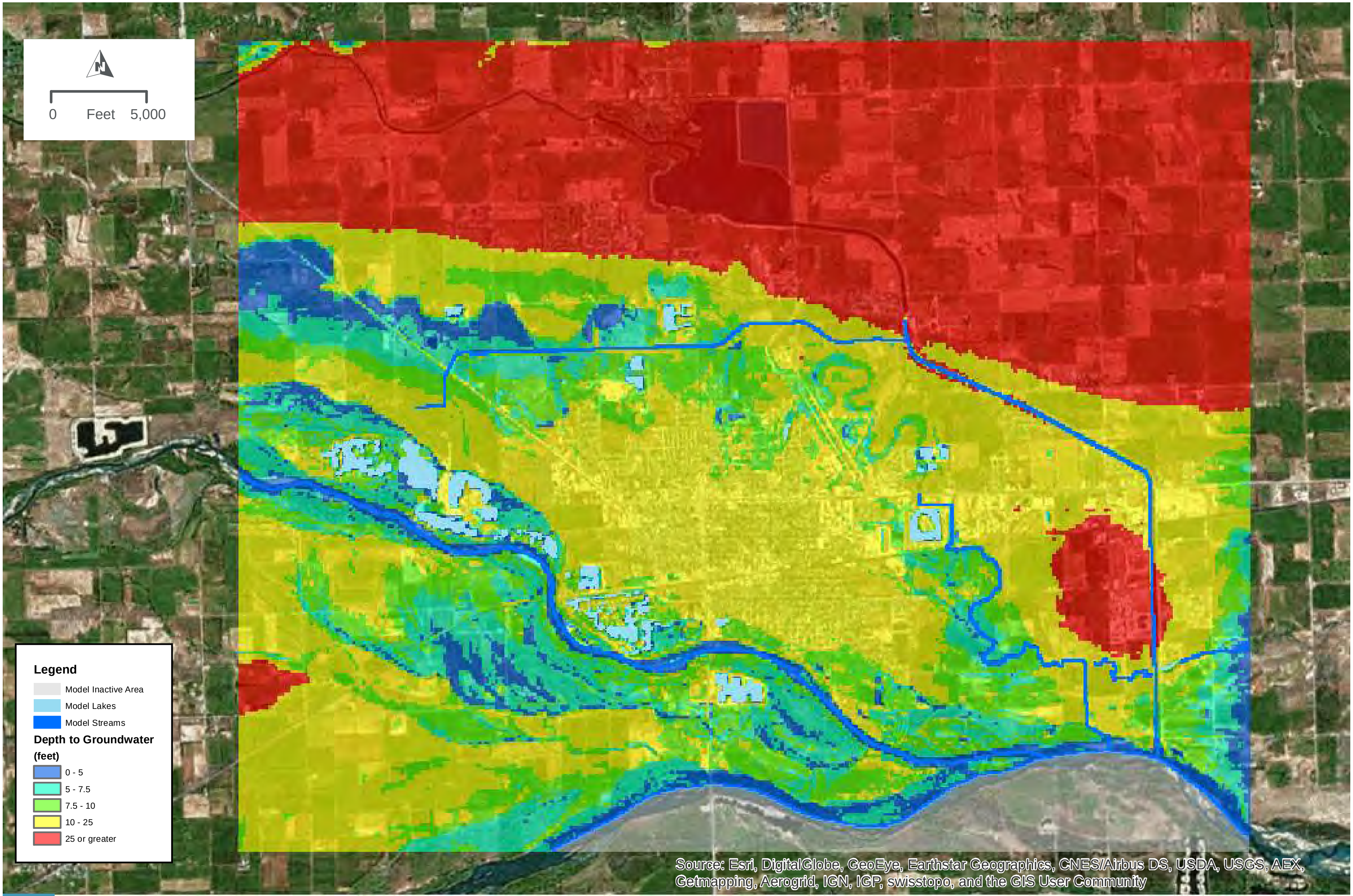
HDR THE FLATWATER GROUP INC. LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

DEPTH TO WATER TABLE FOR BASELINE, DEC 2028

FIGURE 62

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE62.MXD - USER: TWIESE - DATE: 4/11/2016



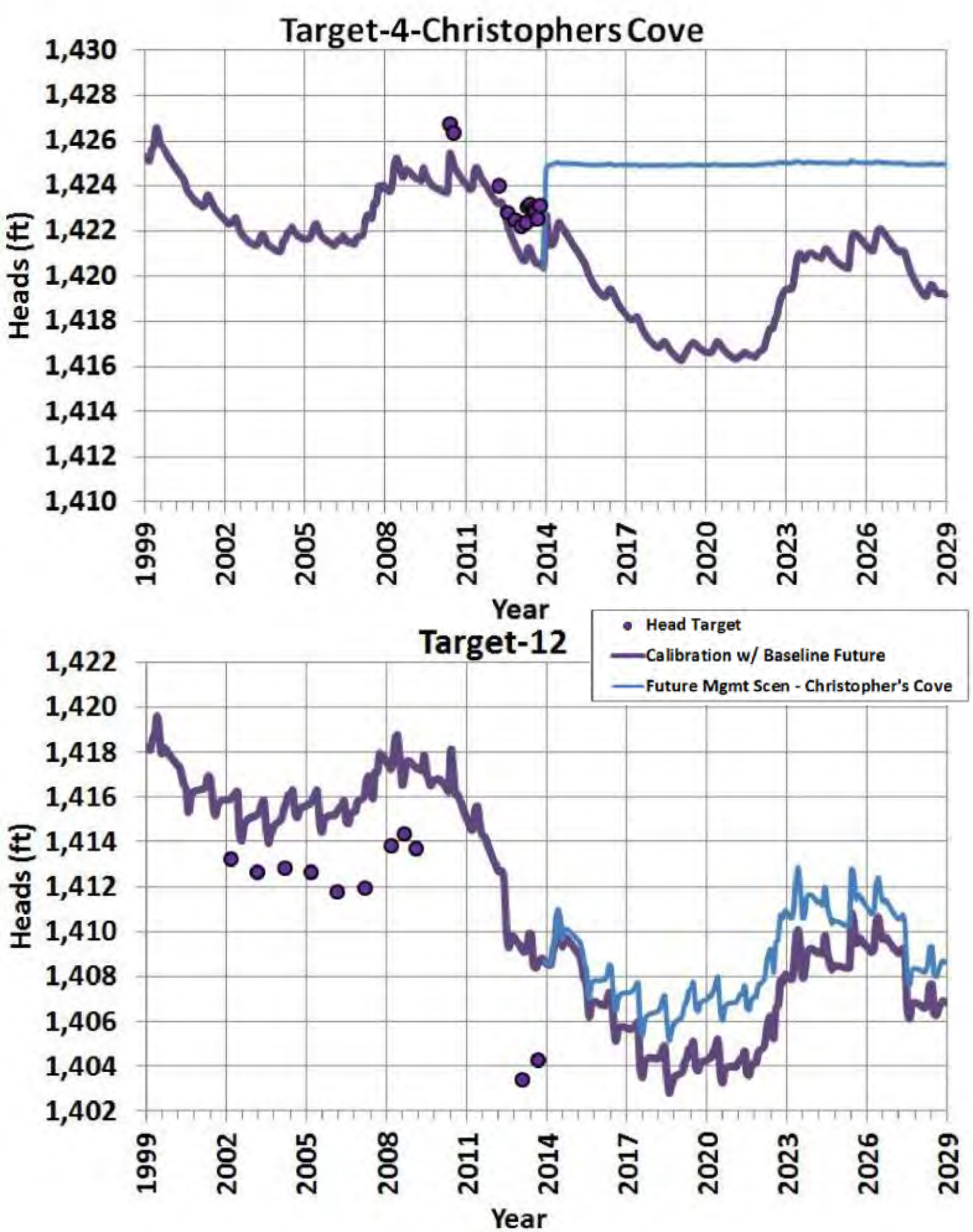
HDR THE FLATWATER GROUP INC. LOWER LOUP NATURAL RESOURCES DISTRICT

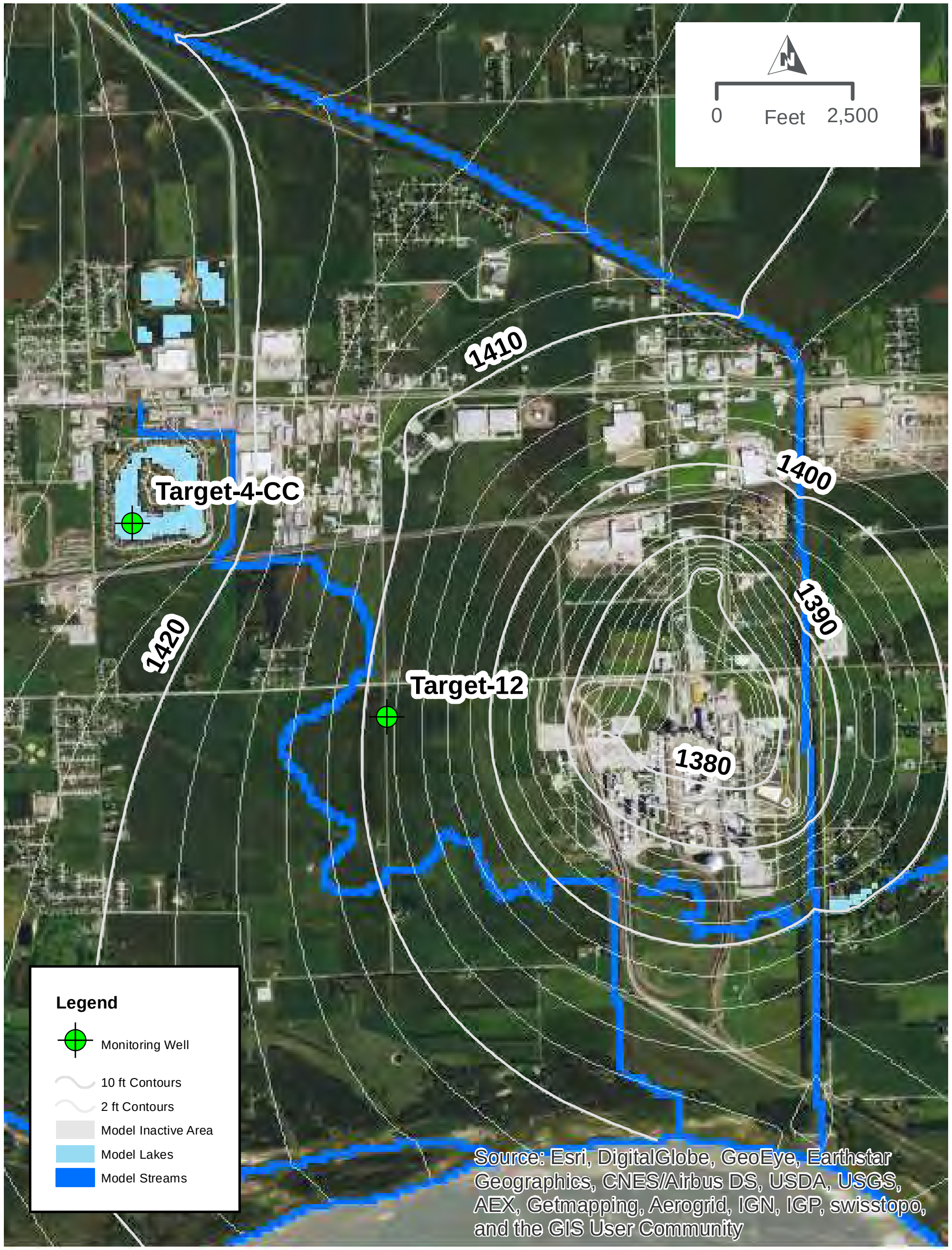
COLUMBUS AREA WATER RESOURCES ASSESSMENT

DEPTH TO WATER TABLE FOR LOST CREEK RECHARGE, DEC 2028

FIGURE 63

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE63.MXD - USER: TWIESE - DATE: 4/11/2016



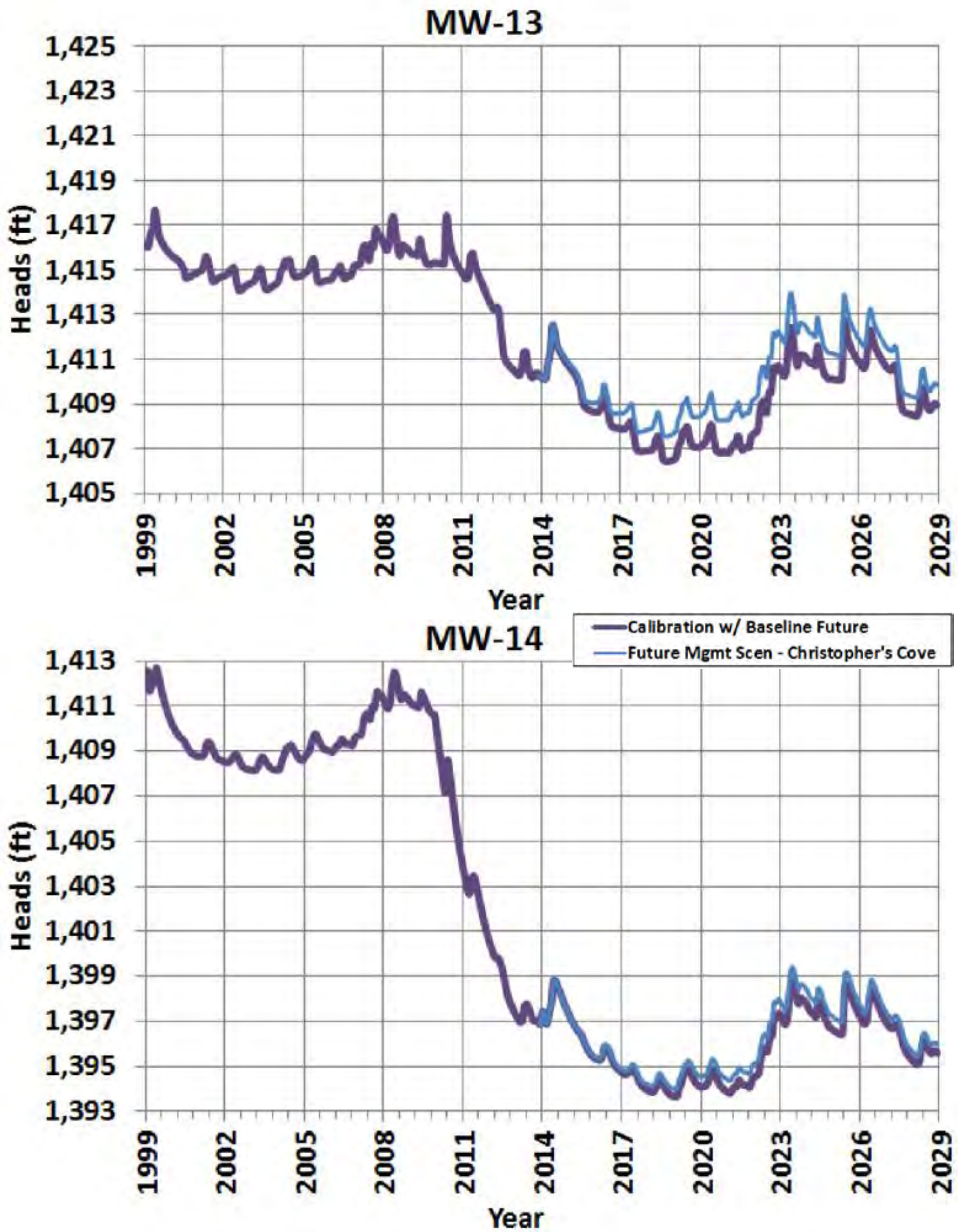


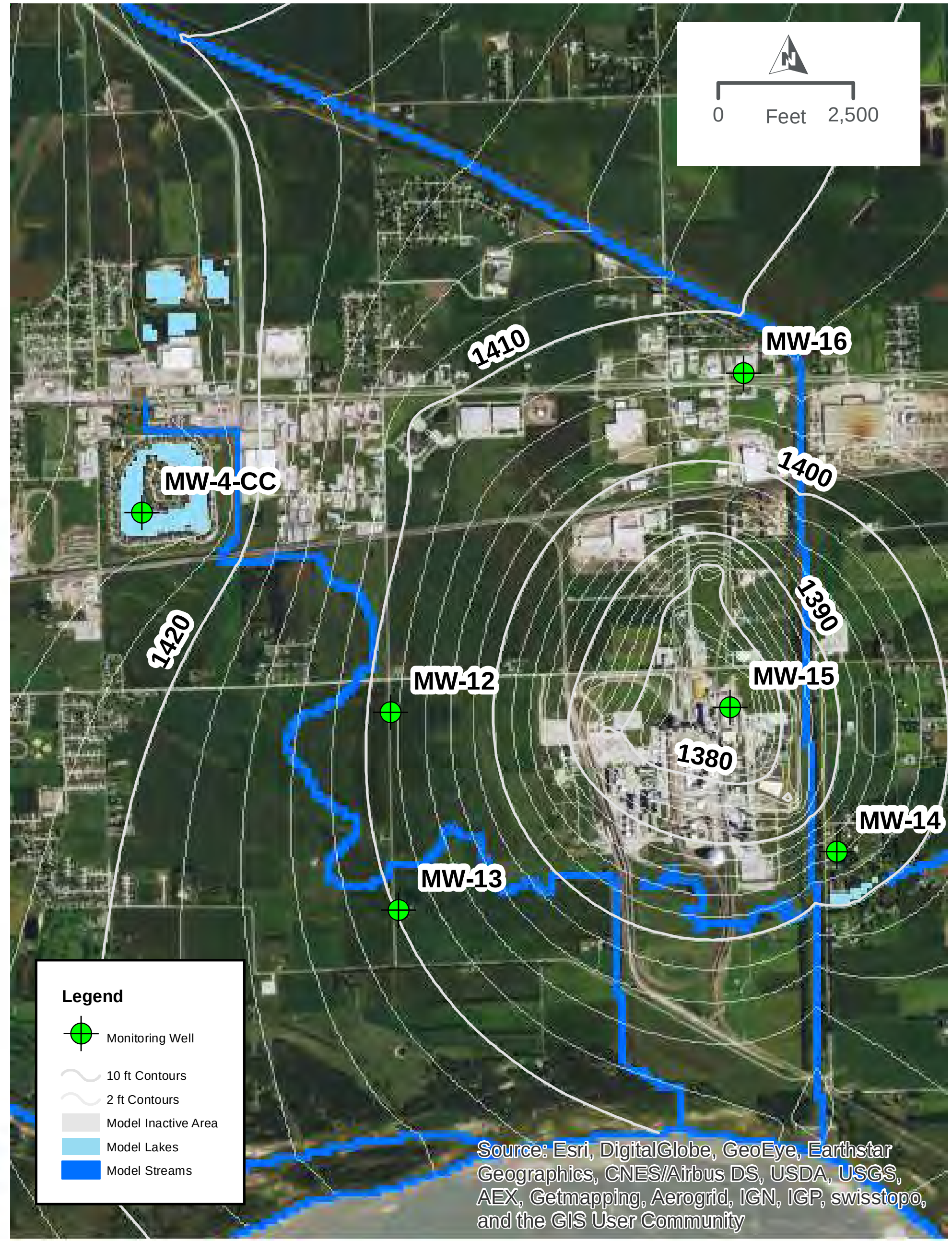
HDR | THE FLATWATER GROUP INC. | JEO | LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

GROUNDWATER HYDROGRAPHS AND MAP WITH CHRISTOPHER'S COVE PROJECT, DEC 2028

FIGURE 64



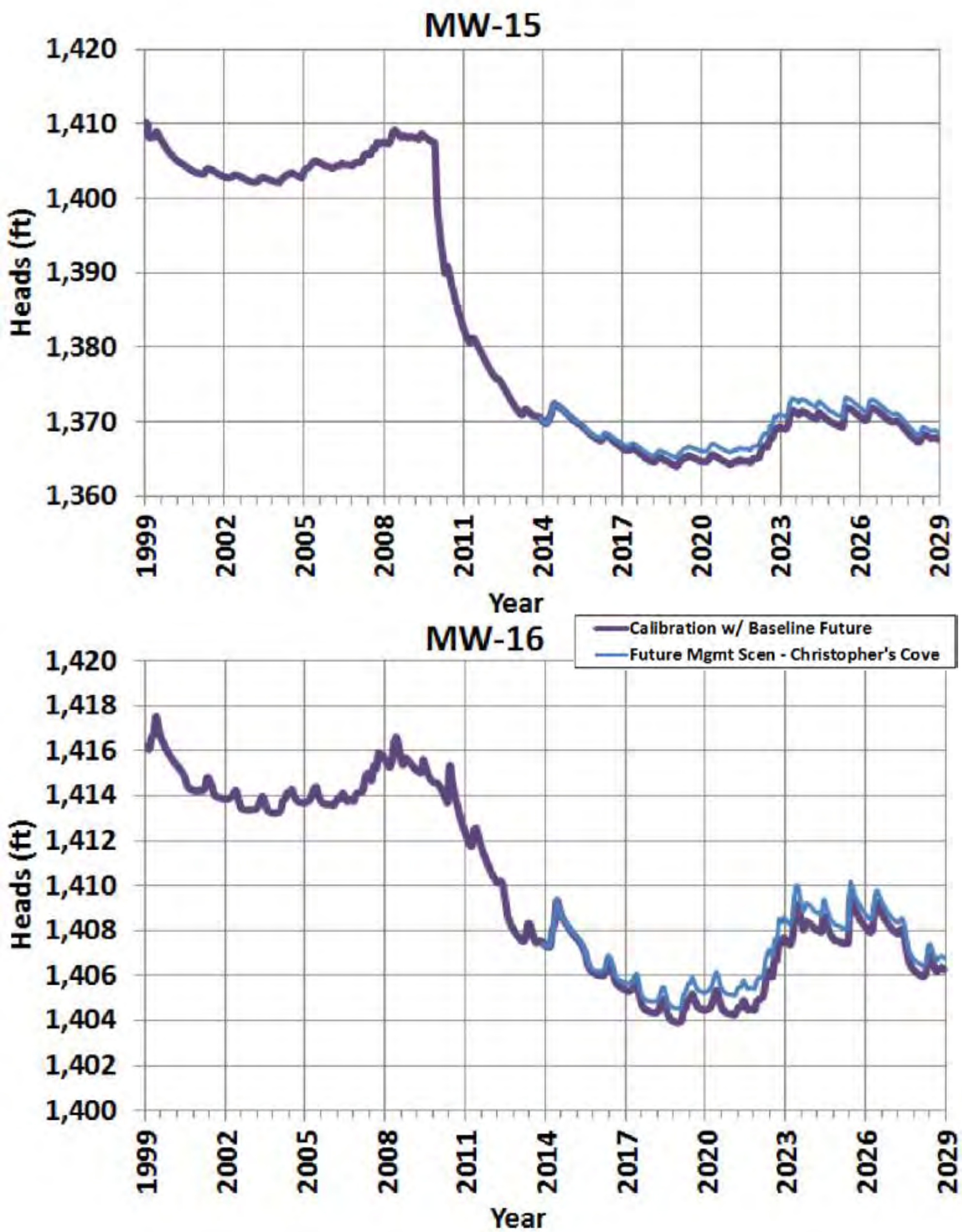


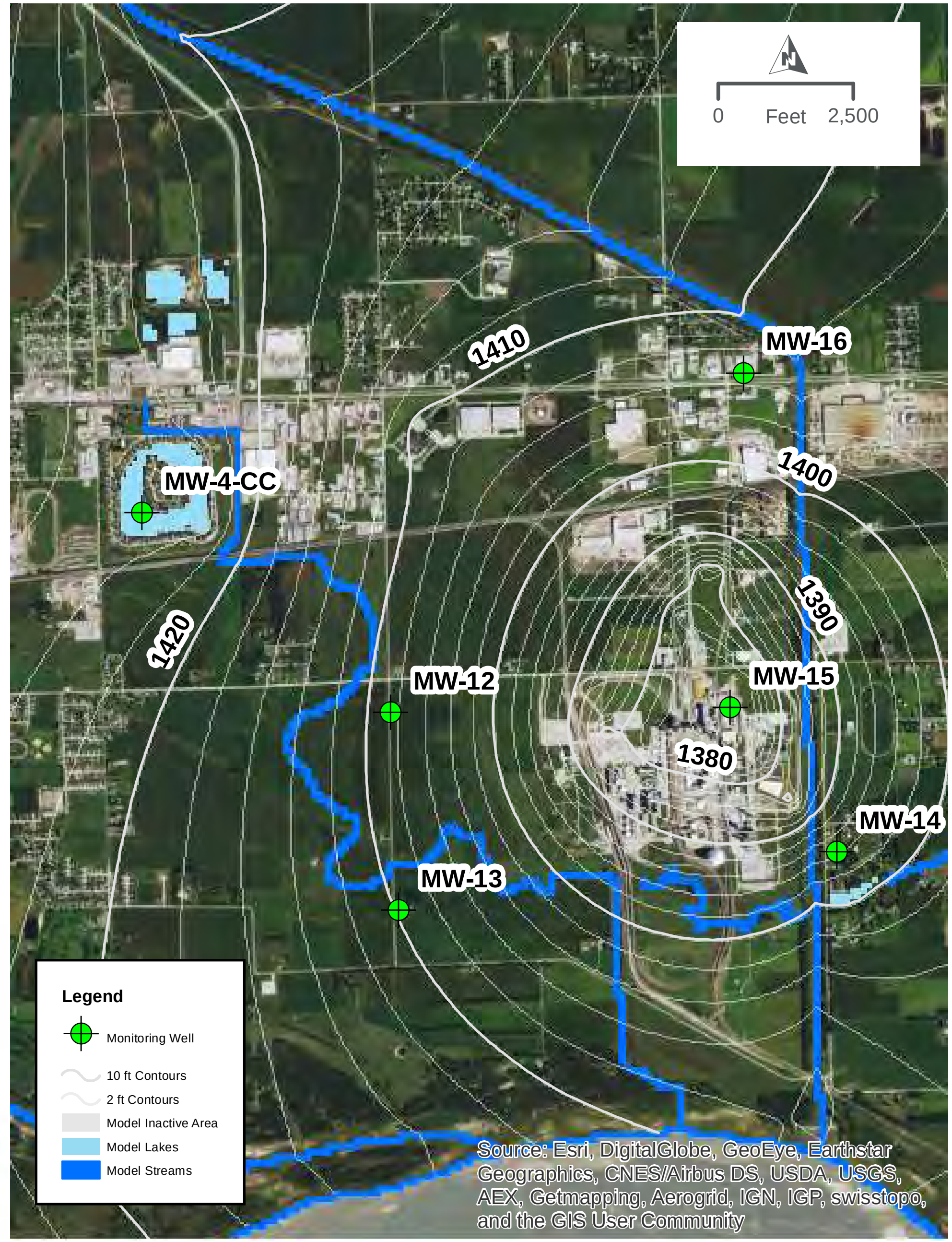
HDR | THE FLATWATER GROUP INC. | JEO | LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

GROUNDWATER HYDROGRAPHS AND MAP WITH CHRISTOPHER'S COVE PROJECT, DEC 2028

FIGURE 65



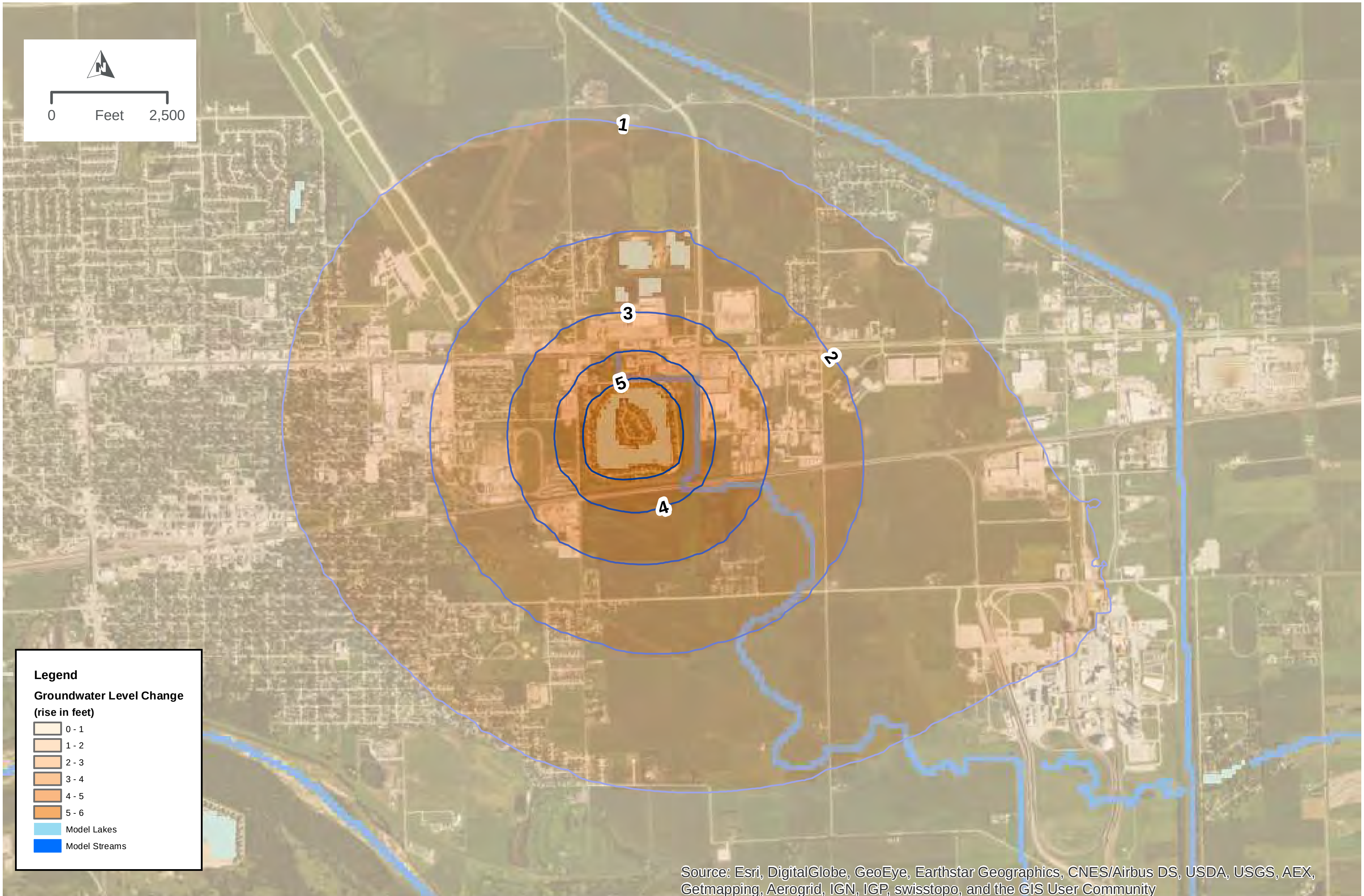


COLUMBUS AREA WATER RESOURCES ASSESSMENT

GROUNDWATER HYDROGRAPHS AND MAP WITH CHRISTOPHER'S COVE PROJECT, DEC 2028

FIGURE 66

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE66.MXD - USER: TWIESE - DATE: 4/11/2016



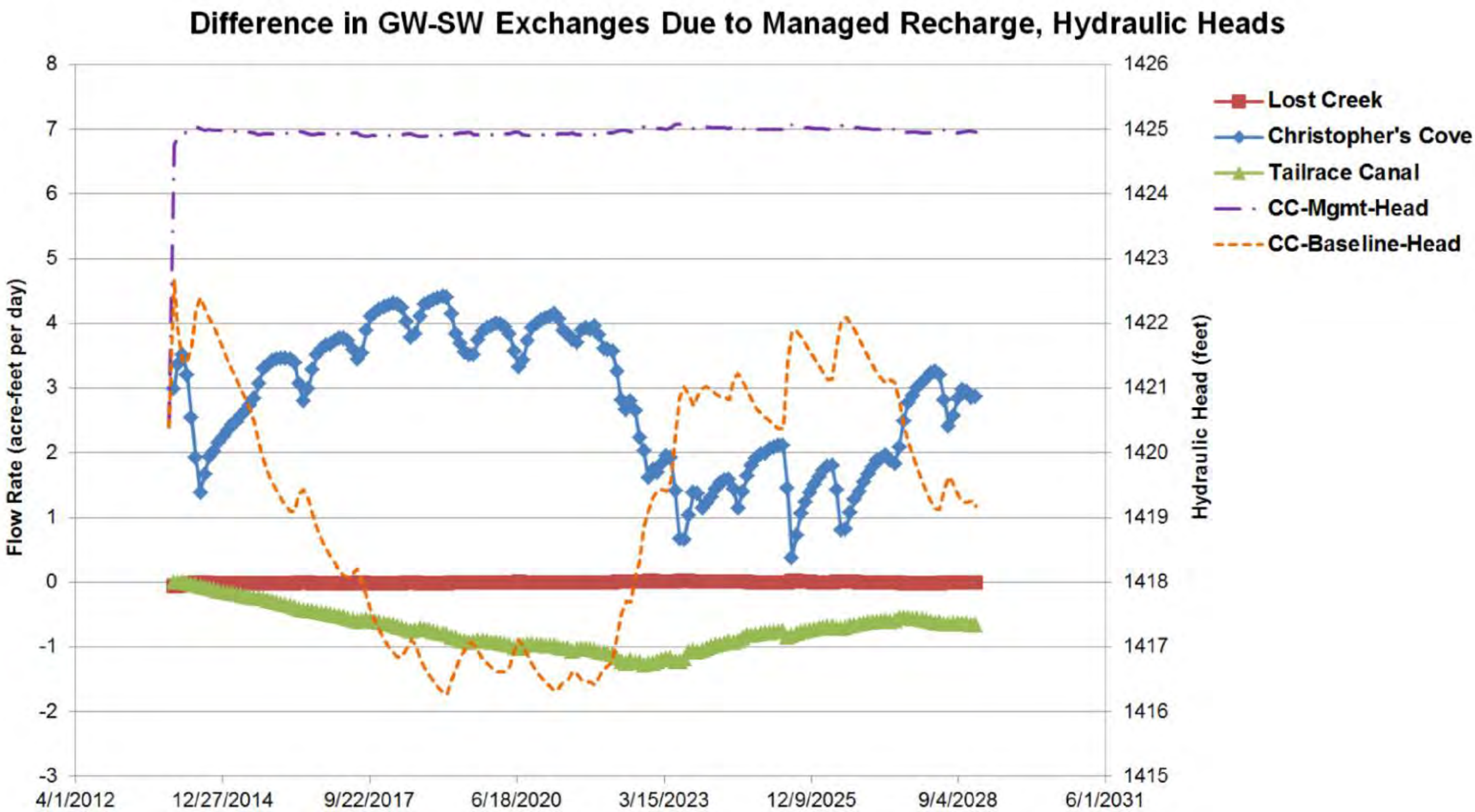
HDR | THE FLATWATER GROUP INC. | JEO | LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

GROUNDWATER LEVEL IMPACTS FOR CHRISTOPHER'S COVE RECHARGE PROJECT

FIGURE 67

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE67.MXD - USER: TWIESE - DATE: 4/11/2016

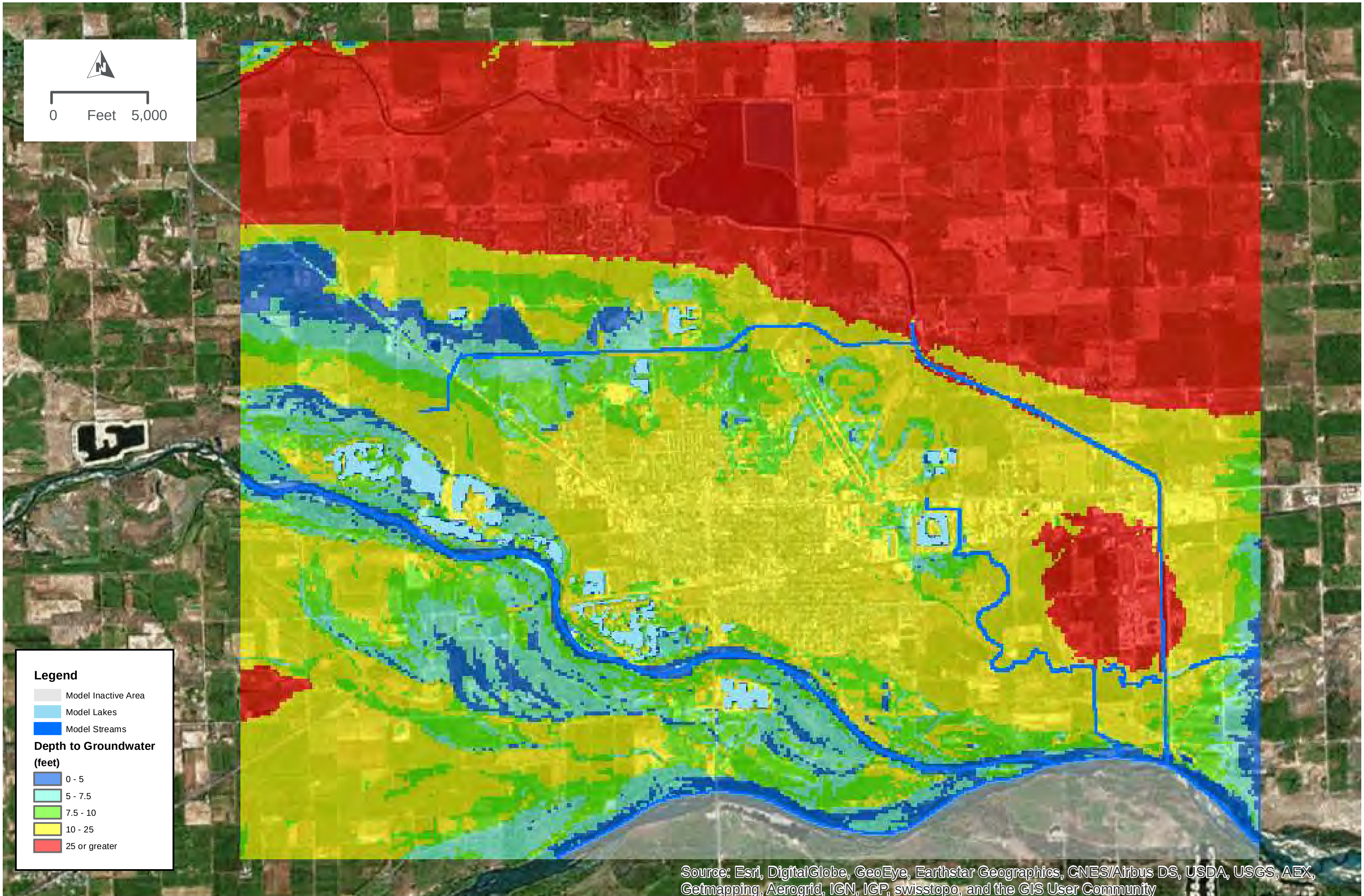


COLUMBUS AREA WATER RESOURCES ASSESSMENT

CHANGES TO GW-SW EXCHANGES AND HEADS FOR CHRISTOPHER'SCOVE RECHARGE

FIGURE 68

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE68.MXD - USER: TWIESE - DATE: 4/11/2016



COLUMBUS AREA WATER RESOURCES ASSESSMENT

DEPTH TO WATER TABLE FOR CHRISTOPHER'S COVE RECHARGE, DEC 2028

FIGURE 69

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\FINAL\FINAL_MXD_20160411\CAWRA_FIGURE69.MXD - USER: TWIESE - DATE: 4/11/2016

9.0 Appendix

Table 1

Loup River Inflow at Study Area Boundary, AF

Year	January	February	March	April	May	June	July	August	September	October	November	December
1943										6,593	11,994	29,715
1944	53,601	106,473	71,955	82,510	138,087	58,805	31,565	19,735	13,286	9,924	25,605	51,939
1945	52,516	77,404	56,691	27,225	62,564	140,085	59,013	14,165	10,975	9,569	23,274	29,617
1946	23,685	59,407	29,518	13,416	37,093	76,785	9,310	6,754	22,795	83,113	31,516	43,723
1947	25,450	59,084	77,753	50,391	29,540	485,467	42,382	12,852	10,405	10,085	25,256	54,587
1948	81,547	188,038	231,897	18,224	14,726	81,950	37,976	67,609	10,154	9,076	27,278	38,718
1949	15,560	27,353	204,347	87,763	37,606	102,134	13,990	13,057	23,091	11,393	11,793	53,982
1950	23,448	24,907	139,122	19,506	55,390	46,652	341,730	61,034	14,700	25,980	49,616	50,608
1951	23,324	76,714	138,085	62,308	103,651	97,535	50,357	62,450	40,380	16,569	79,362	44,429
1952	37,953	133,983	162,732	93,871	60,146	14,566	15,104	19,717	8,878	7,389	9,369	78,698
1953	92,102	86,641	82,220	32,232	115,262	53,690	21,673	10,568	6,857	7,056	15,704	54,406
1954	52,662	109,214	69,222	37,233	40,337	55,920	8,567	8,987	8,038	10,275	11,856	114,870
1955	68,534	9,555	139,164	23,864	12,255	22,837	10,399	2,124	2,649	5,449	60,742	22,223
1956	11,769	16,619	68,792	14,712	20,277	13,333	5,342	6,145	1,929	4,723	30,281	18,447
1957	21,216	41,579	23,257	13,402	73,677	118,540	16,179	5,325	18,033	11,253	21,862	38,142
1958	76,527	142,008	148,438	140,493	20,725	10,182	124,184	12,318	8,642	7,971	23,509	46,797
1959	21,508	26,404	85,036	25,049	30,693	16,942	14,899	6,423	5,889	8,456	53,372	51,970
1960	59,695	29,747	237,789	97,338	122,222	44,082	16,640	7,971	8,592	9,513	16,228	94,664
1961	51,635	82,299	40,471	19,451	31,786	41,869	4,133	7,638	5,244	8,626	13,540	16,009
1962	13,193	56,076	226,622	37,000	57,530	172,817	60,146	43,930	9,239	12,158	11,602	44,825
1963	23,813	80,481	67,281	14,854	12,249	10,176	3,635	6,173	15,293	8,868	8,967	12,783
1964	19,001	46,626	96,080	72,356	77,029	41,690	13,422	9,336	31,717	13,816	36,381	17,885
1965	19,287	42,331	162,559	51,601	124,006	66,051	14,806	9,843	44,711	31,443	27,491	72,488
1966	97,401	86,022	132,583	27,511	13,002	50,148	12,032	313,247	40,100	14,509	22,172	72,866
1967	23,290	27,313	47,156	12,688	11,805	373,271	18,064	12,294	10,848	15,132	37,669	91,654
1968	30,705	36,148	43,090	19,983	13,978	103,400	11,280	7,032	9,638	31,119	21,720	83,802
1969	32,027	31,257	307,270	67,796	18,104	76,162	17,295	11,243	11,357	19,835	41,258	106,697
1970	58,551	50,493	23,028	35,296	12,329	9,768	2,414	2,968	7,577	10,202	32,498	40,414
1971	44,332	148,360	154,043	33,310	34,979	36,941	16,433	4,130	5,646	9,148	15,146	90,641
1972	77,818	59,843	52,544	14,106	62,517	11,813	33,715	6,336	13,925	9,147	26,104	36,180
1973	112,389	93,299	113,337	42,175	46,531	34,715	20,928	8,395	23,852	28,084	29,784	49,669
1974	44,293	87,797	24,121	25,387	11,150	26,029	2,137	2,053	4,465	5,155	12,511	110,062
1975	58,314	17,818	54,593	26,947	10,724	72,423	10,726	3,656	5,672	4,001	23,207	98,367

Table 1

Loup River Inflow at Study Area Boundary, AF

Year	January	February	March	April	May	June	July	August	September	October	November	December
1976	41,355	93,877	31,693	19,644	35,176	24,568	5,559	841	3,077	3,761	26,615	71,192
1977	62,929	27,205	45,731	61,253	60,212	22,296	6,348	19,884	32,938	8,667	37,582	35,320
1978	18,222	8,884	391,971	104,812	19,981	17,812	7,938	17,623	6,238	7,163	36,374	75,832
1979	30,213	15,280	269,708	30,777	15,305	9,486	9,605	7,522	7,720	8,653	48,122	132,603
1980	118,603	80,656	79,980	38,699	8,589	7,920	5,579	6,578	7,698	10,020	14,936	88,530
1981	60,141	66,339	14,230	8,525	17,143	7,010	6,674	61,184	9,940	9,920	13,874	36,955
1982	11,443	122,954	89,462	23,657	88,457	60,163	14,230	10,561	9,428	18,021	68,298	87,804
1983	60,643	111,962	121,831	169,474	108,974	94,390	33,228	14,186	7,268	8,838	23,262	87,941
1984	89,593	204,975	146,888	233,969	304,277	326,868	63,433	12,303	8,083	22,703	34,489	126,337
1985	154,582	160,066	83,035	54,132	80,604	12,831	8,409	12,723	61,118	28,907	54,327	64,034
1986	107,466	139,163	61,045	70,985	31,938	13,152	14,050	20,262	88,176	42,707	69,762	163,531
1987	165,781	61,784	214,720	172,181	107,880	40,725	9,063	15,932	17,855	9,498	27,896	105,506
1988	121,443	232,657	140,524	23,616	46,064	7,985	11,408	11,035	19,759	57,187	18,860	85,135
1989	107,993	90,210	190,730	36,719	8,414	18,620	22,312	10,355	17,123	9,567	39,907	53,499
1990	170,787	123,257	40,234	10,952	17,588	82,961	9,397	11,066	9,689	8,854	24,871	47,804
1991	28,081	112,672	28,377	13,507	43,972	56,480	9,895	25,131	10,385	15,301	106,267	88,052
1992	95,264	45,919	83,738	37,200	24,489	37,927	30,958	96,628	32,893	29,642	35,633	137,650
1993	117,306	127,751	330,587	78,683	44,737	115,284	396,909	71,577	70,895	34,465	30,827	140,774
1994	103,108	119,388	214,455	41,587	12,535	14,247	70,279	60,561	82,046	22,950	22,233	131,416
1995	89,325	153,092	110,210	102,393	177,958	111,245	10,277	14,676	12,863	16,053	46,906	126,536
1996	129,583	133,900	121,453	49,928	67,065	63,434	10,690	30,719	32,759	11,659	93,680	115,469
1997	133,948	275,857	75,897	57,052	26,486	16,943	24,841	18,802	42,448	35,081	44,355	164,683
1998	156,505	91,965	181,714	127,724	66,692	126,431	35,143	19,284	129,905	74,849	50,056	39,378
1999	83,003	167,037	110,187	125,988	87,327	143,626	35,018	13,576	17,482	13,368	12,313	75,758
2000	117,198	95,237	63,551	27,065	13,924	11,625	14,996	10,940	11,463	33,759	86,828	89,739
2001	33,411	42,275	238,585	158,985	79,286	12,078	13,746	11,032	28,178	13,784	29,393	50,668
2002	102,330	72,468	106,273	51,491	14,429	12,133	13,529	14,434	11,976	12,550	25,282	116,444
2003	71,422	47,526	56,675	21,333	54,826	17,433	9,281	10,061	13,779	11,950	53,541	104,114
2004	98,596	54,223	82,048	47,482	32,391	21,435	25,634	11,980	36,628	60,398	59,966	94,348
2005	101,260	90,138	67,580	43,370	40,449	114,129	12,646	15,960	72,320	25,488	33,048	76,772
2006	65,474	70,175	68,895	35,667	9,911	11,401	10,235	39,150	36,071	14,799	15,444	114,987
2007	82,421	199,002	57,533	101,250	149,785	89,646	10,093	22,732	12,705	20,700	13,569	91,583
2008	90,110	71,386	54,419	60,955	161,620	190,752	38,834	13,761	22,372	111,921	47,951	84,393
2009	61,060	117,978	84,072	95,429	27,556	70,125	15,897	43,376	24,598	37,290	37,838	82,993
2010	80,319	71,316	202,844	47,008	21,861	441,760	70,821	29,982	38,008	23,385	30,670	159,054
2011	154,434	163,564	79,165	64,359	91,650	79,639	69,965	42,376	18,129	44,737	29,372	111,401
2012	158,693	154,059	117,792	115,919	71,478	9,892	6,449	3,846	2,820	6,459	20,938	102,187
2013	125,209	90,191	70,971	84,013	66,980	51,418	17,094	22,570	13,931			

Table 2

Loup Power Canal Inflow at Study Area Boundarè Σ !C

Year	January	February	March	April	May	June	July	August	September	October	November	December
1943										91,505	106,348	74,195
1944	80,100	72,006	90,875	150,416	120,836	125,795	90,482	55,622	84,544	104,912	98,881	37,157
1945	77,905	57,994	106,287	125,490	112,960	132,069	103,138	79,921	73,944	103,272	97,367	60,159
1946	101,918	82,446	135,521	99,381	100,771	91,051	72,183	46,809	104,607	144,142	132,832	81,465
1947	81,956	83,670	103,386	129,171	115,058	122,057	119,101	52,999	81,544	101,193	112,876	69,510
1948	30,789	38,412	84,925	112,502	93,602	113,818	100,045	124,956	68,863	97,627	94,701	75,374
1949	76,068	82,217	116,488	154,516	154,135	148,757	89,647	77,315	110,156	121,733	120,302	44,856
1950	68,783	99,209	88,487	140,060	153,239	108,059	117,823	118,472	113,227	127,492	80,806	73,455
1951	89,956	76,781	68,495	131,135	146,125	147,670	136,113	131,478	151,065	150,302	70,804	62,463
1952	94,136	73,040	67,820	112,178	138,077	83,926	69,065	72,384	73,520	108,287	103,258	39,895
1953	47,061	77,430	118,903	133,996	132,985	106,016	78,198	61,221	64,930	99,591	119,065	49,887
1954	34,699	67,211	94,884	112,655	134,034	109,680	45,434	94,375	79,471	119,158	116,736	37,430
1955	43,498	84,219	90,889	117,613	93,961	129,228	66,910	29,687	59,652	105,770	58,530	75,593
1956	102,547	101,269	102,410	126,768	113,399	109,107	62,793	60,676	63,985	94,937	92,725	94,974
1957	48,344	82,039	135,731	151,293	163,594	129,037	91,043	71,373	112,598	133,748	114,053	96,126
1958	48,550	23,399	83,361	99,591	130,677	117,423	151,179	90,517	87,271	108,879	103,529	79,238
1959	69,326	82,942	138,573	145,305	145,343	91,333	88,886	54,527	82,091	118,205	74,152	78,946
1960	44,354	108,955	117,899	146,583	160,066	138,611	95,645	63,046	74,829	109,489	105,387	34,235
1961	78,818	93,372	133,996	127,778	148,566	133,767	68,985	72,696	94,079	116,736	120,131	82,196
1962	94,995	78,774	64,948	128,961	134,434	168,439	159,990	111,510	106,724	136,227	129,113	66,395
1963	77,323	99,858	135,426	120,493	99,267	90,313	37,721	77,081	120,970	79,165	121,199	75,908
1964	116,221	100,125	123,083	142,368	99,768	104,820	88,573	75,145	108,726	96,025	70,404	84,875
1965	112,826	92,134	98,115	128,637	113,360	135,960	93,469	82,629	138,611	122,686	113,944	72,038
1966	11,153	53,650	86,384	119,520	104,568	99,495	49,136	38,038	92,870	104,645	97,136	29,888
1967	97,646	100,239	106,794	106,781	106,037	141,725	87,393	50,923	55,442	83,666	96,919	38,990
1968	88,076	105,989	129,933	127,645	117,785	82,543	69,113	64,734	86,927	106,457	116,866	29,765
1969	94,815	98,694	93,753	116,030	109,184	83,870	98,040	43,963	71,030	136,875	111,699	25,985
1970	64,332	102,223	139,050	138,325	96,215	84,805	30,550	37,784	63,643	121,885	95,836	72,231
1971	70,898	57,237	102,049	127,225	136,723	113,517	60,592	24,629	53,896	94,041	129,342	48,020
1972	49,029	93,965	116,404	112,979	134,415	80,062	80,363	59,020	74,548	99,400	123,468	80,413
1973	107,963	104,950	152,953	145,477	117,480	103,100	81,294	63,014	95,740	142,921	124,290	58,358
1974	93,583	101,056	146,125	133,157	104,206	105,284	20,433	53,854	62,396	90,093	115,121	9,171
1975	66,948	95,437	108,080	142,475	89,807	121,485	58,393	34,161	51,045	81,359	74,283	22,371

Table 2

Loup Power Canal Inflow at Study Area BoundaryΣ !C

Year	January	February	March	April	May	June	July	August	September	October	November	December
1976	78,197	112,159	128,066	141,853	113,704	79,137	49,094	33,878	59,959	94,613	72,578	28,344
1977	49,376	110,099	150,122	158,922	159,971	119,730	71,522	106,977	112,655	142,864	102,417	74,806
1978	87,492	106,361	121,380	151,045	136,265	113,017	66,056	78,309	68,625	107,067	79,123	43,930
1979	73,274	100,220	127,511	149,691	136,837	117,175	104,149	68,625	84,978	108,383	123,546	54,985
1980	24,746	110,999	132,331	143,074	107,982	102,354	18,267	40,914	54,556	108,497	120,665	45,722
1981	75,532	86,830	138,897	108,478	117,804	72,792	62,875	111,758	105,732	138,764	137,619	111,505
1982	93,946	96,215	117,981	128,904	143,245	147,346	87,465	73,078	95,147	152,609	96,799	43,019
1983	129,710	118,166	118,914	80,329	108,306	136,513	94,003	79,348	83,285	137,295	121,413	54,310
1984	91,524	95,922	98,569	105,598	22,323	45,682	53,934	76,762	82,108	153,620	150,130	22,392
1985	7,598	43,265	149,072	134,663	139,736	118,357	75,738	111,549	145,992	158,235	87,309	105,619
1986	103,342	60,138	154,345	109,699	142,387	130,925	96,515	107,551	126,482	161,401	110,791	36,335
1987	39,857	126,806	109,985	84,463	71,880	89,311	76,265	92,534	125,108	127,893	140,537	67,400
1988	60,777	77,380	111,316	134,835	138,725	82,865	85,386	65,177	106,912	122,391	127,725	63,985
1989	63,582	49,512	77,233	113,761	97,321	107,505	101,981	61,807	123,163	144,294	114,957	69,550
1990	49,633	56,457	158,026	124,689	140,518	141,510	72,313	76,841	68,859	125,814	132,972	66,014
1991	107,290	91,184	146,013	134,759	138,477	116,069	52,055	38,974	77,462	104,355	65,718	67,860
1992	91,262	120,058	131,822	110,080	99,782	116,374	105,694	117,823	120,951	126,024	115,611	22,018
1993	31,889	87,532	94,211	135,388	135,807	136,494	139,031	122,744	124,040	145,076	108,287	49,553
1994	33,753	54,876	123,545	124,269	117,079	89,197	122,610	77,983	72,920	131,783	144,428	50,947
1995	71,771	71,687	107,525	129,895	144,256	141,224	87,522	85,039	99,610	143,169	115,334	38,261
1996	28,954	73,000	80,508	122,210	137,181	150,569	97,684	140,842	128,789	143,264	92,578	46,254
1997	95,399	97,987	127,189	126,638	137,028	127,969	87,957	107,696	143,112	148,509	137,694	53,217
1998	38,835	104,168	53,482	123,621	95,109	132,470	132,966	136,094	30,074	88,270	160,848	106,598
1999	91,823	71,705	108,326	117,823	141,033	151,026	133,633	107,887	117,213	129,933	153,487	69,669
2000	22,256	60,376	125,738	114,009	103,100	89,281	91,308	72,544	96,406	114,657	64,894	62,888
2001	116,278	92,758	65,419	146,068	143,036	105,522	84,772	87,372	112,884	125,719	124,325	91,762
2002	29,887	58,225	78,813	105,465	93,221	68,844	27,465	54,149	86,413	102,757	110,481	42,787
2003	56,989	71,796	99,011	137,409	124,822	111,682	74,638	55,704	78,076	94,747	92,407	31,876
2004	21,347	76,877	110,347	77,209	96,806	103,691	96,108	63,008	63,964	77,605	101,712	49,710
2005	29,845	78,067	106,170	127,302	118,853	130,944	61,330	80,979	57,731	112,941	97,674	72,077
2006	101,757	62,768	105,318	123,335	74,846	50,543	40,018	59,068	115,611	117,137	105,705	47,192
2007	55,040	89,044	127,862	130,105	110,595	118,243	86,165	121,275	120,627	152,113	131,907	23,378
2008	41,166	83,437	118,414	136,952	128,293	127,645	105,446	83,552	97,703	157,244	148,490	41,198
2009	103,520	69,853	111,476	117,213	111,472	148,490	107,658	129,228	107,715	141,262	155,279	70,318
2010	112,521	105,999	137,047	152,991	135,903	163,766	152,590	117,461	106,247	129,285	111,379	62,798
2011	72,908	64,951	130,469	162,107	141,090	136,170	134,148	97,340	107,334	151,427	138,624	42,535
2012	43,832	64,274	107,277	90,818	100,563	65,419	26,915	32,421	55,551	93,431	110,498	49,465
2013	21,476	51,399	115,664	105,980	117,117	112,216	57,834	111,739	79,934			

Table 3

Lost Creek Inflow at Study Area Boundary, AF

Year	January	February	March	April	May	June	July	August	September	October	November	December
1943										37	21	15
1944	15	20	35	66	119	183	206	158	83	37	21	15
1945	15	20	35	66	119	183	206	158	83	37	21	15
1946	15	20	35	66	119	183	206	158	83	37	21	15
1947	15	20	35	66	119	183	206	158	83	37	21	15
1948	15	20	35	66	119	183	206	158	83	37	21	15
1949	15	20	35	66	119	183	206	158	83	37	21	15
1950	15	20	35	66	119	183	206	158	83	37	21	15
1951	15	20	35	66	119	183	206	158	83	37	21	15
1952	15	20	35	66	119	183	206	158	83	37	21	15
1953	15	20	35	66	119	183	206	158	83	37	21	15
1954	15	20	35	66	119	183	206	158	83	37	21	15
1955	15	20	35	66	119	183	206	158	83	37	21	15
1956	15	20	35	66	119	183	206	158	83	37	21	15
1957	15	20	35	66	119	183	206	158	83	37	21	15
1958	15	20	35	66	119	183	206	158	83	37	21	15
1959	15	20	35	66	119	183	206	158	83	37	21	15
1960	12	15	26	50	90	138	154	119	62	28	16	12
1961	6	7	13	25	45	68	77	59	31	14	8	6
1962	9	12	21	39	71	109	122	94	49	22	13	9
1963	9	11	20	39	70	107	120	92	48	22	12	9
1964	19	23	42	80	143	219	246	190	99	44	25	18
1965	19	24	43	82	146	225	253	195	102	45	26	19
1966	10	12	22	42	75	116	130	100	52	23	13	10
1967	20	26	46	87	156	240	269	207	108	48	28	20
1968	16	20	35	67	120	184	206	159	83	37	21	15
1969	8	10	18	34	61	94	106	82	43	19	11	8
1970	10	13	23	44	79	121	135	104	55	24	14	10
1971	12	15	26	50	90	139	156	120	63	28	16	12
1972	23	29	52	99	178	273	307	236	124	55	32	23
1973	15	19	34	66	118	181	203	157	82	36	21	15
1974	10	12	22	43	76	117	131	101	53	24	14	10
1975	14	17	31	58	105	161	181	139	73	32	19	13

Table 3

Lost Creek Inflow at Study Area Boundary, AF

Year	January	February	March	April	May	June	July	August	September	October	November	December
1976	10	13	22	43	77	118	132	102	53	24	14	10
1977	16	21	37	70	126	194	218	168	88	39	23	16
1978	11	14	25	47	84	129	145	112	58	26	15	11
1979	15	18	33	63	112	172	193	149	78	35	20	14
1980	9	11	20	38	68	105	118	91	48	21	12	9
1981	21	27	48	91	163	250	281	216	113	50	29	21
1982	29	37	65	125	223	343	385	297	155	69	40	29
1983	18	23	41	77	139	213	239	184	96	43	25	18
1984	21	27	48	91	164	251	282	217	114	51	29	21
1985	15	19	33	63	114	175	196	151	79	35	20	15
1986	17	21	37	71	127	196	220	169	89	39	23	16
1987	23	28	51	97	174	267	300	231	121	54	31	22
1988	10	12	21	41	73	113	126	97	51	23	13	9
1989	11	14	24	46	83	128	143	110	58	26	15	11
1990	22	28	50	95	171	262	294	227	119	53	30	22
1991	18	23	41	78	140	215	241	186	97	43	25	18
1992	16	20	36	69	124	191	215	165	86	39	22	16
1993	29	37	66	125	224	344	387	298	156	69	40	29
1994	11	14	25	48	86	131	148	114	59	26	15	11
1995	13	16	29	55	99	152	171	132	69	31	18	13
1996	20	25	45	86	155	238	267	206	108	48	28	20
1997	12	16	28	53	95	146	164	126	66	29	17	12
1998	18	22	40	77	137	211	237	182	95	42	24	18
1999	22	27	49	94	168	258	289	223	117	52	30	22
2000	9	11	21	39	70	108	121	93	49	22	12	9
2001	12	15	26	50	90	139	156	120	63	28	16	12
2002	10	13	24	45	80	123	139	107	56	25	14	10
2003	16	21	37	70	125	193	216	167	87	39	22	16
2004	15	19	34	65	117	179	201	155	81	36	21	15
2005	13	17	30	57	103	158	178	137	72	32	18	13
2006	14	17	30	58	104	160	179	138	72	32	19	13
2007	26	33	59	113	202	310	348	268	140	62	36	26
2008	25	31	56	107	192	295	332	256	134	59	34	25
2009	11	14	25	47	84	129	145	112	58	26	15	11
2010	17	21	38	72	130	200	224	173	90	40	23	17
2011	17	22	39	75	134	206	231	178	93	41	24	17
2012	10	13	23	44	80	123	138	106	55	25	14	10
2013	24	30	54	104	186	285	320	247	129			

Table 4

Mean Monthly Precipitation, AF (rainfall x drainage area)

Year	January	February	March	April	May	June	July	August	September	October	November	December
1943										12,279	1,663	-
1944	3,595	4,989	9,104	31,613	22,358	20,174	17,352	15,185	4,838	3,695	5,207	1,394
1945	2,049	3,880	3,695	13,539	31,278	19,586	35,007	7,055	16,562	50	168	7,575
1946	722	134	8,432	3,326	17,369	32,067	3,695	15,084	13,505	15,202	13,472	84
1947	4,132	722	2,570	14,748	18,662	40,399	2,435	6,417	8,180	9,658	6,064	5,106
1948	1,394	6,366	3,897	4,753	11,960	24,491	16,646	19,805	12,128	6,820	5,409	3,460
1949	9,104	991	9,995	6,702	16,714	23,550	11,103	18,511	17,873	7,223	-	1,108
1950	3,292	4,401	2,654	7,156	20,493	10,448	17,621	10,532	1,545	6,668	3,712	302
1951	3,074	7,542	11,120	14,967	27,112	17,571	14,312	22,845	11,439	9,676	2,939	4,015
1952	2,939	4,602	5,980	9,860	21,871	15,488	17,755	34,788	3,846	302	974	6,148
1953	4,267	4,854	3,527	19,368	7,844	15,286	12,598	13,774	3,712	1,831	6,786	5,157
1954	823	3,074	4,132	7,811	9,944	6,971	2,604	10,700	6,282	7,021	134	689
1955	957	2,654	2,318	4,434	11,910	20,073	9,474	6,836	9,339	2,267	436	3,376
1956	2,923	1,360	1,293	5,678	9,760	13,354	3,427	18,024	3,662	3,443	2,435	638
1957	974	856	13,405	11,238	15,185	33,175	24,273	13,052	11,002	12,934	7,206	168
1958	1,797	7,223	3,611	17,537	6,820	5,694	32,302	5,341	3,796	-	4,183	-
1959	1,360	2,486	14,160	13,102	25,516	19,452	6,484	24,290	8,214	7,206	4,737	1,865
1960	6,820	2,503	5,190	12,027	26,070	21,165	9,172	18,729	9,155	-	4,401	420
1961	470	588	2,738	5,090	13,539	6,719	14,244	-	1,528	4,854	6,114	5,022
1962	-	-	-	-	-	2,620	22,660	17,940	12,531	5,829	940	4,250
1963	4,115	420	5,761	3,679	7,861	33,579	5,190	20,846	12,733	504	1,108	1,293
1964	554	3,981	6,450	16,663	21,333	32,000	14,060	16,361	17,234	302	1,629	2,217
1965	1,948	5,946	4,955	7,593	34,469	21,837	17,352	9,978	43,036	2,100	420	1,999
1966	1,260	6,803	2,536	4,015	8,449	19,687	7,727	16,058	9,222	4,569	168	3,107
1967	773	218	2,083	7,727	13,472	53,283	14,681	10,834	7,206	7,928	352	4,267
1968	689	386	2,939	12,615	8,852	20,359	20,375	11,506	20,695	26,036	3,930	10,146
1969	2,083	8,819	924	3,191	6,954	18,494	10,902	20,695	6,064	16,848	-	5,207
1970	436	672	3,091	16,831	9,255	6,097	4,804	8,147	23,567	24,743	4,804	1,411
1971	1,495	9,591	2,604	3,225	24,541	16,344	16,361	3,376	4,938	9,843	6,854	2,721
1972	386	638	3,645	19,636	25,701	2,637	20,409	9,222	39,408	5,644	10,398	8,332
1973	5,845	2,284	16,865	6,568	17,067	9,356	19,066	5,073	27,632	15,118	7,038	4,535
1974	2,721	386	2,351	9,004	24,945	6,971	3,107	18,427	1,528	7,677	252	2,688
1975	4,216	2,772	3,208	20,208	10,667	28,623	15,235	7,979	4,132	268	13,304	1,797

Table 4

Mean Monthly Precipitation, AF (rainfall x drainage area)

Year	January	February	March	April	May	June	July	August	September	October	November	December
1976	1,108	3,074	12,061	10,095	14,614	2,772	6,786	4,653	8,886	1,612	-	940
1977	1,142	1,159	12,901	14,328	34,671	13,119	14,681	25,146	6,635	10,129	7,525	2,251
1978	890	5,022	3,191	32,067	11,355	8,785	10,364	12,413	6,719	3,208	3,930	3,091
1979	3,964	2,452	18,360	11,708	12,615	18,259	11,893	4,569	3,595	20,477	7,777	2,671
1980	1,747	2,267	4,687	5,442	7,525	16,730	6,013	29,279	823	7,424	806	773
1981	689	1,243	11,490	3,124	16,848	7,593	11,859	48,949	13,740	5,678	10,801	4,518
1982	3,124	2,939	9,339	7,424	32,521	25,516	17,553	24,474	11,338	14,144	8,584	9,104
1983	2,805	3,494	18,561	5,039	12,666	32,084	7,844	5,711	11,741	7,828	20,695	2,184
1984	302	7,861	8,718	31,177	27,800	17,537	8,416	6,904	2,200	22,828	5,929	5,946
1985	1,377	1,024	8,365	19,956	16,277	16,915	13,993	4,737	24,491	8,231	2,586	1,159
1986	-	4,468	13,623	16,966	15,672	25,146	16,680	16,058	21,333	16,025	4,418	2,469
1987	168	2,519	32,268	2,536	23,903	7,324	9,961	43,103	7,408	4,619	3,981	1,932
1988	1,797	940	101	11,573	11,926	10,583	19,838	5,123	17,419	436	5,594	4,015
1989	5,459	3,225	1,528	1,932	7,895	11,019	3,360	9,172	29,430	6,097	218	2,217
1990	856	1,024	10,347	1,360	22,391	41,961	22,324	3,914	3,091	6,349	5,594	3,914
1991	3,158	974	10,734	22,055	17,671	23,685	4,854	3,511	4,720	7,945	11,389	6,752
1992	3,292	7,256	11,741	4,787	19,452	14,715	34,351	17,856	7,945	15,269	6,383	3,779
1993	5,123	3,124	5,980	16,966	27,095	25,230	45,993	15,773	12,363	9,474	3,712	2,150
1994	3,023	3,023	-	8,012	5,157	22,711	30,287	6,232	17,806	6,013	9,020	4,636
1995	2,184	2,368	7,139	16,730	31,949	4,871	10,028	9,104	14,295	9,088	1,411	1,377
1996	3,813	504	1,831	5,291	37,845	20,023	26,708	28,405	8,231	739	16,311	1,344
1997	1,293	3,326	672	13,740	14,580	16,428	19,586	9,272	17,402	13,371	655	1,663
1998	2,855	1,881	12,346	15,235	10,851	30,874	14,563	14,194	4,787	11,439	11,002	1,058
1999	2,402	4,350	5,829	21,770	19,989	39,979	7,089	11,792	3,360	436	2,553	1,629
2000	739	4,771	4,099	4,938	9,440	20,561	13,371	5,257	3,343	9,440	10,415	3,611
2001	4,535	4,720	2,570	10,162	25,213	4,552	8,802	6,618	11,977	3,494	8,953	521
2002	2,772	252	5,140	11,053	16,210	11,523	3,981	8,231	4,771	12,850	1,260	168
2003	2,486	2,990	3,981	16,311	18,545	14,127	10,146	9,491	20,224	6,266	3,880	655
2004	4,065	6,417	14,077	8,130	21,988	10,263	28,153	2,956	8,987	3,645	11,406	1,142
2005	3,208	6,803	4,737	12,666	22,341	16,344	4,636	12,548	8,500	4,384	6,870	2,889
2006	1,277	386	14,748	11,759	2,604	23,013	13,102	20,661	19,569	4,485	1,663	11,943
2007	3,208	4,250	9,205	17,671	20,224	11,490	13,791	47,000	11,910	24,239	218	9,390
2008	840	1,545	2,469	12,564	36,502	22,022	8,046	4,250	19,149	26,843	5,090	4,586
2009	1,277	2,772	4,166	9,239	4,468	30,908	7,727	16,630	3,611	15,840	2,167	6,349
2010	2,721	3,276	3,964	7,206	10,162	52,460	13,136	8,247	14,580	3,141	2,435	1,360
2011	5,039	1,495	3,729	15,420	36,149	20,728	8,449	17,318	3,460	9,591	1,159	3,796
2012	336	4,048	2,637	9,961	20,224	5,207	134	6,400	1,108	6,501	2,016	4,687
2013	1,277	1,763	5,241	20,224	30,925	12,985	6,316	17,587	3,796			

Table 5

Loup River Outlfow at Study Area Boundary, AF

Source: USGS 06794500 - Loup River at Columbus, Nebr.

Shading denotes estimated value

Year	January	February	March	April	May	June	July	August	September	October	November	December
1943										6,619	12,042	29,835
1944	53,816	106,900	72,244	82,841	138,642	59,042	31,692	19,814	13,339	9,963	25,708	52,147
1945	52,727	77,715	56,919	27,334	62,816	140,647	59,250	14,222	11,019	9,607	23,368	29,736
1946	23,780	59,646	29,637	13,470	37,242	77,093	9,348	6,782	22,887	83,447	31,642	43,899
1947	25,552	59,321	78,065	50,593	29,658	487,417	42,552	12,904	10,446	10,126	25,358	54,806
1948	81,875	188,793	232,828	18,297	14,785	82,279	38,129	67,880	10,195	9,112	27,387	38,873
1949	15,622	27,463	205,168	88,116	37,757	102,544	14,046	13,110	23,184	11,438	11,840	54,199
1950	23,542	25,007	139,681	19,584	55,612	46,839	343,102	61,279	14,759	26,085	49,815	50,811
1951	23,417	77,022	138,640	62,558	104,067	97,927	50,559	62,701	40,542	16,636	79,681	44,607
1952	38,105	134,521	163,386	94,248	60,388	14,624	15,165	19,796	8,914	7,419	9,407	79,014
1953	92,472	86,989	82,550	32,361	115,725	53,906	21,760	10,611	6,884	7,084	15,767	54,624
1954	52,874	109,652	69,500	37,382	40,499	56,145	8,601	9,023	8,070	10,316	11,904	115,331
1955	68,809	9,593	139,723	23,960	12,304	22,928	10,441	2,132	2,659	5,471	60,986	22,313
1956	11,817	16,685	69,068	14,771	20,358	13,387	5,364	6,170	1,936	4,742	30,403	18,521
1957	21,301	41,746	23,350	13,456	73,973	119,016	16,244	5,346	18,105	11,298	21,950	38,295
1958	76,834	142,578	149,035	141,057	20,808	10,223	124,683	12,367	8,676	8,003	23,604	46,985
1959	21,594	26,510	85,378	25,150	30,817	17,010	14,959	6,449	5,912	8,490	53,587	52,179
1960	59,935	29,866	238,744	97,729	122,712	44,259	16,707	8,003	8,627	9,552	16,293	95,044
1961	51,842	82,629	40,634	19,529	31,914	42,037	4,150	7,669	5,265	8,661	13,595	16,074
1962	13,246	56,301	227,532	37,149	57,761	173,511	60,388	44,106	9,276	12,207	11,648	45,005
1963	23,909	80,804	67,552	14,913	12,298	10,217	3,649	6,197	15,355	8,904	9,003	12,834
1964	19,077	46,813	96,466	72,646	77,339	41,857	13,476	9,373	31,844	13,872	36,527	17,957
1965	19,364	42,501	163,211	51,809	124,504	66,316	14,866	9,882	44,891	31,569	27,601	72,779
1966	97,792	86,368	133,115	27,621	13,054	50,349	12,080	314,505	40,261	14,567	22,261	73,159
1967	23,384	27,423	47,346	12,739	11,852	374,770	18,137	12,343	10,892	15,193	37,820	92,022
1968	30,829	36,293	43,263	20,063	14,034	103,815	11,326	7,061	9,676	31,244	21,808	84,138
1969	32,155	31,383	308,504	68,068	18,176	76,468	17,365	11,288	11,403	19,915	41,424	107,126
1970	58,786	50,696	23,120	35,438	12,379	9,807	2,424	2,980	7,607	10,243	32,628	40,576
1971	44,510	148,955	154,662	33,444	35,119	37,089	16,499	4,146	5,669	9,185	15,206	91,005
1972	78,131	60,083	52,755	14,163	62,768	11,860	33,850	6,362	13,981	9,183	26,209	36,325
1973	112,840	93,674	113,793	42,344	46,718	34,854	21,012	8,429	23,948	28,197	29,904	49,868
1974	44,471	88,150	24,217	25,489	11,195	26,134	2,145	2,061	4,483	5,176	12,561	110,504

Table 5

Loup River Outlfow at Study Area Boundary, AF

Source: USGS 06794500 - Loup River at Columbus, Nebr.

Shading denotes estimated value

1975	58,549	17,889	54,812	27,055	10,767	72,714	10,769	3,671	5,694	4,017	23,301	98,762
1976	41,521	94,254	31,821	19,723	35,317	24,667	5,582	844	3,089	3,776	26,722	71,478
1977	63,182	27,314	45,914	61,499	60,453	22,386	6,374	19,964	33,070	8,702	37,733	35,462
1978	18,295	8,920	393,545	105,233	20,061	17,883	7,970	17,693	6,263	11,339	41,543	79,929
1979	36,150	20,534	261,308	34,666	20,629	15,273	15,976	14,805	14,327	14,981	51,649	133,342
1980	120,789	82,385	81,863	42,303	14,929	14,126	14,101	14,536	14,990	16,270	20,346	91,891
1981	64,388	69,098	19,567	14,560	22,794	13,930	14,134	64,559	15,959	15,496	18,961	41,663
1982	17,942	122,401	91,148	28,404	89,630	62,496	20,723	17,578	15,713	22,841	71,321	91,266
1983	63,644	111,518	121,723	167,326	109,809	95,091	38,533	20,864	13,938	14,506	28,199	91,142
1984	91,867	200,234	145,865	227,721	296,348	316,878	67,984	19,142	14,735	27,244	38,165	128,152
1985	155,183	158,671	84,374	57,080	82,286	18,408	15,484	18,756	63,428	33,005	58,329	67,391
1986	108,495	138,533	63,470	73,571	36,226	18,429	20,349	25,972	89,443	45,978	72,391	162,995
1987	165,043	63,894	209,725	169,792	109,593	45,427	16,091	22,218	23,005	15,341	32,149	107,450
1988	122,664	226,817	139,563	28,232	49,660	14,625	18,102	18,203	25,213	60,541	23,896	88,272
1989	109,887	92,500	187,786	41,091	15,004	24,124	28,036	17,637	22,357	15,038	44,077	58,243
1990	169,555	123,581	43,716	16,489	22,704	84,176	16,495	17,971	16,550	14,779	29,459	52,940
1991	33,369	112,795	32,778	18,678	47,689	59,718	17,422	32,116	17,015	21,356	107,910	90,942
1992	97,233	49,348	85,427	41,628	30,143	42,174	36,125	97,925	37,313	34,424	40,023	138,854
1993	119,403	127,130	319,601	80,271	48,472	114,841	381,283	74,136	73,163	38,554	35,644	141,188
1994	105,940	119,960	209,170	45,456	18,455	20,402	72,912	64,729	84,853	27,969	26,708	132,311
1995	92,057	151,440	110,995	102,805	174,206	110,917	16,985	21,199	18,860	21,194	50,684	127,984
1996	131,073	133,568	122,229	53,387	69,546	65,515	17,147	35,108	37,010	17,038	95,408	117,343
1997	133,705	266,889	78,119	60,021	31,194	22,078	30,742	24,590	45,846	39,060	47,771	163,705
1998	156,298	92,931	179,797	126,889	70,139	125,469	39,468	24,407	131,054	78,003	52,639	44,063
1999	85,631	164,620	110,955	125,379	88,611	141,304	39,334	19,645	22,830	18,953	17,128	79,281
2000	119,517	97,305	66,481	31,960	20,082	17,921	21,361	17,948	17,609	38,571	89,554	92,648
2001	38,205	46,218	233,285	155,934	80,966	17,984	20,326	17,702	33,038	19,441	33,928	55,068
2002	105,291	75,534	107,919	55,240	20,782	18,861	21,409	21,665	18,318	18,791	30,354	118,342
2003	75,467	51,653	60,583	26,016	58,255	22,908	16,333	17,496	20,210	18,404	57,471	106,933
2004	101,954	58,167	84,311	52,086	37,679	26,871	31,308	19,145	42,124	64,584	63,335	97,301
2005	104,281	91,790	70,730	47,073	44,800	113,875	19,813	22,504	76,001	30,791	37,982	80,185
2006	68,838	73,265	71,992	39,882	16,924	18,581	18,013	44,916	40,437	20,594	21,163	116,867
2007	85,907	194,445	60,745	101,720	148,333	91,018	16,842	27,999	18,238	25,385	18,800	95,280
2008	93,487	74,243	58,015	63,478	159,122	186,374	43,575	20,367	27,891	112,371	48,144	84,732
2009	61,305	118,452	84,409	95,812	27,667	70,407	15,961	43,550	24,697	37,440	37,990	83,326
2010	80,641	71,603	203,659	47,197	21,948	443,534	71,106	30,102	38,161	23,479	30,793	159,693
2011	155,054	164,221	79,483	64,617	92,019	79,958	70,246	42,546	18,202	44,916	29,490	111,848
2012	159,331	154,678	118,265	116,384	71,765	9,932	6,475	3,861	2,831	6,485	21,022	102,598

Table 6

Tailrace Return Outflows, AF

Source: NDNR 00082100 - Loup River Canal Tailrace at 8th St. Columbus, Nebr.

Shading denotes estimated value

Year	1	2	3	4	5	6	7	8	9	10	11	12
1943										96,059	111,125	78,391
1944	84,418	75,985	95,417	156,109	126,000	130,976	95,016	59,432	88,868	109,745	103,504	40,583
1945	82,177	61,596	111,149	130,665	117,960	137,381	107,935	84,235	78,048	108,071	101,958	64,063
1946	106,689	86,556	140,990	104,014	105,519	95,511	76,337	50,436	109,348	149,789	138,160	85,812
1947	86,312	87,805	108,188	134,422	120,102	127,161	124,229	56,755	85,806	105,949	117,789	73,608
1948	34,083	41,693	89,343	117,407	98,201	118,751	104,777	130,205	72,862	102,309	99,237	79,594
1949	80,303	86,322	121,562	160,294	159,990	154,415	94,163	81,576	115,013	126,915	125,370	48,442
1950	72,866	103,667	92,980	145,538	159,075	112,872	122,924	123,586	118,147	132,794	85,053	77,636
1951	94,479	80,774	72,572	136,427	151,814	153,305	141,594	136,863	156,770	156,077	74,844	66,415
1952	98,746	77,040	71,883	117,076	143,599	88,238	73,154	76,542	77,616	113,191	107,972	43,379
1953	50,693	81,436	124,026	139,347	138,401	110,787	82,477	65,147	68,848	104,314	124,106	53,578
1954	38,074	71,005	99,509	117,563	139,472	114,526	49,032	98,989	83,690	124,287	121,729	40,862
1955	47,056	88,366	95,431	122,625	98,567	134,480	70,954	32,958	63,459	110,621	62,315	79,818
1956	107,331	105,855	107,191	131,969	118,408	113,942	66,751	64,590	67,882	99,564	97,220	99,601
1957	52,003	86,141	141,204	157,004	169,646	134,286	95,588	75,510	117,505	139,180	118,990	100,776
1958	52,213	26,283	87,747	104,228	136,045	122,430	156,973	95,051	91,652	113,794	108,248	83,538
1959	73,421	87,062	144,105	150,891	151,016	95,799	93,387	58,314	86,365	123,314	78,260	83,240
1960	47,930	113,701	123,002	152,196	166,045	144,058	100,286	67,010	78,952	114,417	110,144	37,601
1961	83,110	97,708	139,433	133,001	154,306	139,114	73,072	76,861	98,602	121,815	125,194	86,557
1962	99,622	82,808	68,951	134,208	139,881	174,505	165,967	116,481	111,509	141,710	134,363	70,429
1963	81,584	104,329	140,893	125,564	103,983	94,757	41,160	81,336	126,051	83,464	126,285	80,139
1964	121,289	104,687	128,294	147,893	104,495	109,566	93,067	79,360	113,553	100,673	74,435	89,293
1965	117,824	96,445	102,807	133,877	118,369	141,352	98,065	86,999	144,058	127,889	118,879	76,189
1966	14,040	57,162	90,832	124,571	109,395	104,131	52,811	41,483	97,368	109,472	101,723	33,164
1967	102,328	104,719	111,666	111,567	110,894	147,237	91,862	54,635	59,163	88,058	101,501	42,454
1968	92,559	110,674	135,286	132,864	122,886	86,826	73,203	68,733	91,302	111,322	121,862	33,038
1969	99,439	103,142	98,355	121,009	114,106	88,181	102,731	47,531	75,074	142,372	116,588	29,179
1970	68,322	106,743	144,592	143,766	100,868	89,135	33,840	41,224	67,534	127,071	100,395	76,386
1971	75,025	60,824	106,823	132,436	142,217	118,443	64,505	27,795	57,584	98,649	134,597	51,672
1972	52,702	98,399	121,476	117,894	139,861	84,293	84,687	62,901	78,665	104,119	128,601	84,737
1973	112,860	109,527	158,783	151,066	122,574	107,810	85,637	66,977	100,298	148,543	129,440	62,225
1974	98,181	105,552	151,814	138,491	109,025	110,039	23,512	57,627	66,261	94,619	120,080	12,017

Table 6

Tailrace Return Outflows, AF

Source: NDNR 00082100 - Loup River Canal Tailrace at 8th St. Columbus, Nebr.

Shading denotes estimated value

1975	70,993	99,817	112,979	148,002	94,327	126,577	62,260	37,525	54,674	85,703	78,395	25,490
1976	82,475	116,971	133,380	147,368	118,719	83,349	52,768	37,237	63,773	99,233	76,654	31,587
1977	53,056	114,783	155,894	164,791	165,947	124,786	75,662	111,853	117,563	148,485	107,113	79,014
1978	91,964	110,968	126,555	156,751	141,749	117,933	70,082	82,590	72,619	111,945	83,336	47,497
1979	77,451	104,699	132,814	155,369	142,333	122,177	108,966	72,704	89,312	113,288	128,681	58,782
1980	27,915	115,788	137,733	148,614	112,879	107,049	21,301	44,418	58,258	113,405	125,739	49,326
1981	79,756	91,031	144,436	113,300	122,905	76,872	66,835	116,734	110,496	144,300	143,046	116,475
1982	98,551	100,611	123,086	134,149	148,874	152,974	91,936	77,250	99,692	158,433	101,378	46,568
1983	135,058	123,018	124,038	84,566	113,210	141,917	98,610	83,651	87,583	142,801	126,503	58,092
1984	96,079	100,397	103,270	110,360	25,442	49,200	57,709	81,011	86,382	159,465	155,816	25,512
1985	10,411	46,562	154,822	140,028	145,292	123,384	79,966	116,520	151,592	164,176	91,691	110,467
1986	108,143	63,785	160,204	114,546	147,998	136,213	101,174	112,439	131,677	167,407	115,661	39,744
1987	43,340	131,837	114,923	88,786	76,028	93,735	80,503	97,111	130,275	133,203	146,024	71,455
1988	64,694	81,471	116,282	140,204	144,261	87,155	89,814	69,185	111,702	127,587	132,946	67,968
1989	67,557	52,938	81,492	118,692	101,997	112,307	106,753	65,745	128,290	149,945	119,913	73,649
1990	53,319	60,027	163,962	129,847	146,091	147,017	76,469	81,091	72,858	131,081	138,302	70,039
1991	112,173	95,475	151,699	140,126	144,008	121,048	55,791	42,439	81,640	109,177	69,652	71,924
1992	95,812	125,035	137,213	114,935	104,508	121,359	110,543	122,924	126,031	131,295	120,581	25,130
1993	35,206	91,747	98,822	140,768	141,282	141,897	144,572	127,947	129,185	150,743	113,105	53,237
1994	37,108	58,414	128,765	129,419	122,165	93,618	127,811	82,257	77,003	137,175	149,996	54,660
1995	75,917	75,574	112,412	135,162	149,906	146,725	91,995	89,460	104,247	148,797	120,298	41,711
1996	32,210	76,999	84,835	127,316	142,684	156,264	102,367	146,422	134,033	148,894	97,070	49,869
1997	100,035	102,419	132,485	131,837	142,528	133,195	92,439	112,587	148,653	154,247	143,122	56,977
1998	42,296	108,729	57,247	128,757	99,739	137,790	138,382	141,574	33,268	92,758	166,757	111,466
1999	96,385	75,592	113,230	122,839	146,616	156,731	139,063	112,782	122,216	135,286	159,243	73,771
2000	25,373	64,114	131,003	118,945	107,896	93,704	95,859	76,705	100,977	119,693	68,811	66,849
2001	121,348	97,082	69,432	151,670	148,660	110,282	89,188	91,841	117,797	130,984	129,475	96,322
2002	33,162	61,832	83,104	110,224	97,812	72,843	30,690	57,929	90,776	119,321	125,756	43,784
2003	61,653	77,416	102,835	135,650	136,343	117,731	73,666	52,391	83,920	95,674	98,828	35,268
2004	18,822	85,467	112,662	81,016	95,210	109,771	103,899	66,950	65,704	82,097	100,679	56,866
2005	39,384	80,560	108,702	145,484	121,277	137,364	59,315	83,708	55,965	116,565	103,499	79,311
2006	104,069	63,386	110,258	120,917	79,046	53,292	41,016	62,390	133,777	132,339	113,082	50,831
2007	57,786	104,172	132,460	133,199	105,415	117,006	81,827	119,705	119,030	152,409	129,274	24,598
2008	49,706	95,685	119,539	144,324	133,022	134,741	106,760	83,079	100,736	159,667	157,846	46,160
2009	109,553	73,458	120,727	118,087	112,009	144,758	106,069	130,720	114,622	154,321	165,053	86,977
2010	137,155	107,771	146,243	153,866	136,679	160,222	151,312	126,443	108,326	133,709	117,151	65,013
2011	86,724	69,736	128,421	166,736	150,005	151,312	141,075	102,374	113,078	154,420	142,105	46,615
2012	46,629	69,357	117,810	88,556	102,346	69,443	25,651	34,315	62,200	101,930	114,076	51,141

Table 7

Mean Monthly Groundwater Outflow, AF

Decade	Annual	Monthly
2010s	3,978	331
2000s	4,029	336
1990s	4,080	340
1980s	4,131	344
1970s	4,182	349
1960s	4,233	353
1950s	4,233	353
1940s	4,233	353

Attachment 1

Final Nebraska H_20 Post-Construction Stormwater Program

Design Standards and Procedures Memorandum

FELSBURG HOLT & ULLEVIG
connecting and enhancing communities

FINAL Nebraska H_2O Post-Construction Stormwater Program Design Standards and Procedures Memorandum

To: Participating Nebraska H_2O Members

Project: NE H_2O Post Construction Stormwater Management Program Development – Phase 2 (FHU No. 12-221-XX)

From: Felsburg Holt & Ullevig

Date: August 26, 2015

1.0 Objective and Purpose

The Clean Water Act requires select communities in Nebraska to implement treatment practices to manage urban stormwater runoff in a manner that protects receiving water quality. These requirements are enforced through the National Pollutant Discharge Elimination System (NPDES) permit for each Municipal Separate Storm Sewer System (MS4). This programmatic permit is issued by the Nebraska Department of Environmental Quality (NDEQ).

Nebraska H_2O is a working group of Phase II communities in Nebraska that collaborate to develop solutions for common challenges in meeting MS4 permit requirements. Post-Construction Stormwater Management is one of six minimum control measures that each Nebraska H_2O community must satisfy. Each community is required to establish a Post-Construction Stormwater Management Program that meets Phase II MS4 permit general conditions as required by NDEQ.

The purpose of this memorandum is to provide the framework and guidance that each Nebraska H_2O community can use to satisfy part of their post-construction stormwater management program. Establishing this framework helps a community meet MS4 permit requirements and promotes sustainable watershed management policies. Whereas traditional storm sewer design and stormwater management focused on addressing water quantity and potential flood issues, the post-construction program also addresses water quality in each community. The framework includes establishment of minimum treatment and design standards, submittal and review process procedures, as well as maintenance, inspection and enforcement protocol.

2.0 Applicability

Post-construction stormwater program requirements shall be applicable to all construction activity and land developments requiring; including, but not limited to site plan applications, subdivision applications, building applications, and right-of-way applications from the City, unless exempt below. These provisions apply to all portions of any common plan of development or sale which would cause the disturbance of at least one acre of soil even though multiple, separate and distinct land development activities may take place at different times on different schedules.

The following activities are exempt from these requirements:

(1) Any emergency activity that is necessary for the immediate protection of life, property, or natural resources; and

(2) Construction activity that provides maintenance and repairs performed to maintain the original line and grade, hydraulic capacity, or original purpose of a facility.

3.0 Definitions

Definitions applicable to this memorandum are as follows:

70th Percentile Rain Event: A rainfall storm event equivalent to a depth of rainfall which is not exceeded in 70 percent of the historic runoff producing rainfall events. The depth of rainfall to be used shall be that which is identified in this memorandum or by a specific community using local precipitation data. The depth of rainfall is used in hydrologic calculations to determine the water quality volume or rate of discharge to be controlled for.

80th Percentile Rain Event: A rainfall storm event equivalent to a depth of rainfall which is not exceeded in 80 percent of the historic runoff producing rainfall events. The depth of rainfall to be used shall be that which is identified in this memorandum or by a specific community using local precipitation data. The depth of rainfall is used in hydrologic calculations to determine the water quality volume or rate of discharge to be controlled for.

Best Management Practices (BMPs): Schedules of activities, prohibitions of practices, general good housekeeping practices, pollution prevention and educational practices, maintenance procedures, and other management practices to prevent or reduce the discharge of pollutants directly or indirectly to storm water, receiving waters, or storm water conveyance systems.

To avoid confusion with temporary and permanent BMPs used during construction; best management practices associated with the post-construction stormwater management program shall be referred to as stormwater treatment facilities (STFs).

Builder: shall mean the general contractor responsible for permitting and constructing a structure and associated construction activity.

Common Plan of Development or Sale: A contiguous area where multiple separate and distinct land disturbing activities may be taking place at different times, on different schedules, but under one proposed plan which may include, but is not limited to, any announcement or piece of documentation (including a sign, public notice or hearing, sales pitch, advertisement, drawing, permit application, zoning request, computer design, etc.) or physical demarcation (including boundary signs, lot stakes, surveyor markings, etc.) indicating construction activities may occur on a specific plot.

Construction Activity: Such activities include but are not limited to clearing and grubbing, grading, excavating, demolition and other land disturbing actions.

Construction Site: Any location where construction activity occurs.

Contractor: Any person performing or managing construction work at a construction site, including, but not limited to, any construction manager, general contractor or subcontractor, and any person engaged in any one or more of the following: earthwork, pipe work, paving, building, plumbing, mechanical, electrical, landscaping or material supply.

Clearing: Any activity that removes the vegetative surface cover.

Drainage Design Guidance or Manual: Documentation that references design criteria and guidance by a community for stormwater management.

Disturbed Area: Area of the lands surface disturbed by any work or activity upon the property by means including, but not limited to, grading; excavating; stockpiling soil, fill, or other materials; clearing; vegetation removal; removal or deposit of any rock, soil, or other materials; or other activities which expose soil. Disturbed area does not include the tillage of land that is zoned for agricultural use.

Earthwork: The disturbance of soil on a site associated with construction activities.

Final Drainage Plan: A plan that indicates the characteristics of the complete project. The plan will also indicate the future conditions post-construction STFs will be maintained under.

Grading: Excavation or fill of material, including the resulting conditions thereof.

Municipal Separate Storm Sewer System (MS4): Publicly-owned facilities by which storm water is collected and/or conveyed, including, but not limited to, any roads with drainage systems, municipal streets, gutters, curbs, catch basins, inlets, piped storm drains, pumping facilities, retention and detention basins, natural and human-made or altered drainage ditches/channels, reservoirs, and other drainage structures.

Land Development: Any land change, including, but not limited to, clearing, digging, grubbing, stripping, removal of vegetation, dredging, grading, excavating, transporting and filling of land, construction, paving, and any other installation of impervious cover.

Maintenance Agreement: A binding document between an owner or developer and the community that outlines responsibilities of maintenance and inspection for STFs associated with land development along with recourse by the community upon default of said responsibilities.

MS4 Boundary: The boundary defined by each individual community that is subject to the requirements of their MS4 program. In no instance shall the MS4 boundary be less inclusive than the Urbanized Area map boundary prepared by the U.S. Census Bureau, the minimum boundary adopted by the EPA for Phase II communities as part of the MS4 program.

National Pollutant Discharge Elimination System (NPDES) Storm Water Discharge Permit: A permit issued by the EPA (or by a State under authority delegated pursuant to 33 USC § 1342(b) i.e. Nebraska Department of Environmental Quality) that authorizes the discharge of pollutants to waters of the State.

Owner: The person who owns a facility, development, part of a facility, or land.

Person: Means any individual, association, organization, partnership, firm, corporation, cooperative, limited liability company or other entity recognized by law.

Pollutant: Anything which causes or contributes to pollution. Pollutants may include, but are not limited to: paints, varnishes, and solvents; oil and other automotive fluids; non-hazardous liquid and solid wastes and yard wastes; refuse, rubbish, garbage, litter, or other discarded or abandoned objects, ordinances, and accumulations, so that same may cause or contribute to pollution; floatables; pesticides, herbicides, and fertilizers; hazardous substances and wastes; sewage, fecal coli form and pathogens; dissolved and particulate metals; animal wastes; wastes and residues that result from constructing a building or structure; wastes and residues that result from mobile washing operations; and noxious or offensive matter of any kind.

Pollution: The presence in waters of the State of any substances, contaminants, pollutants, or manmade or man-induced impairment of waters or alteration of the chemical, physical, biological, or radiological integrity of water in quantities or at levels which are or may be potentially harmful or injurious to human health or welfare, animal or plant life, or property or which unreasonably interfere with the enjoyment of life or property, including outdoor recreation unless authorized by applicable law.

Post-Construction Stormwater Management: The management of stormwater for a period of time in perpetuity from approval for final acceptance of the construction phase of any construction activity. The management of stormwater includes the use of STFs that meet minimum site performance standards in accordance with a community's MS4 permit. STFs are intended to provide stormwater treatment during this time period and are considered functional after vegetation has been established.

Post-Construction Stormwater Management Plan: Documentation supporting analysis, design, maintenance and inspection of STFs installed on a site in order to meet minimum site performance standards in accordance with a community's MS4 permit.

Receiving Water: Any water of the State of Nebraska, including any and all surface waters that are contained in or flow in or through the State of Nebraska, all watercourses, even if they are usually dry, irrigation ditches that receive municipal storm water, and storm sewer systems owned by other entities.

Sediment: Soil (or mud) that has been disturbed or eroded and transported naturally by water, wind or gravity, or mechanically by any person.

Site: The land or water area where any facility or activity is physically located or conducted, including adjacent land used in connection with the facility or activity.

Stormwater: Any surface flow, runoff, and drainage consisting entirely of water from any form of natural precipitation, and resulting from such precipitation.

Stormwater Treatment Facilities (STFs): Permanent best management practices put in place to provide control and treatment of stormwater runoff after construction activity for land development is complete. These facilities are physical in nature and sometimes referred to as “structural” BMPs.

Subdivision: Includes activities associated with the platting of any parcel of land into two or more lots and all construction activity taking place thereon.

Utilities: Infrastructure constructed to provide services that support land development such as water, sanitary sewer, storm sewer, electric, gas, telephone, television and communication services.

Waters of the State: Any and all surface and subsurface waters that are contained in or flow in or through the State of Nebraska. The definition includes all watercourses, even if they are usually dry.

4.0 Requirements

Each MS4 will implement a set of minimum programmatic requirements for new and redevelopment projects that disturb one acre of soil or more within their jurisdiction. This collection of requirements is generally referred to as the Permanent Stormwater Treatment for Post-Construction program. NDEQ has not dictated what minimum program requirements must be implemented, but five content areas must be satisfied according to Part IV.D.4 of the MS4 Permit. The five content areas include:

1. Minimum Site Performance Standards
2. Site Plan Review
3. Maintenance of Controls
4. Tracking Controls
5. Inspection and Enforcement

4.1 Minimum Site Peformance Standards

Each MS4 will require new and redevelopment projects to satisfy minimum site performance standards that address water quality. Minimum site performance standards vary in each of these instances however the methodology for calculating the minimum water quality control volume (WQCV) and water quality volume discharge rate (Q_{WQ}) remain the same. The methodology is based on average daily rainfall data gathered regionally and applied to three specific zones across the state. From that data, the runoff amount is calculated and applied to the treatment drainage area to get the WQCV or Q_{WQ}.

New Development

New development requirements apply to those areas which are being platted for development or have been platted but not built and are within the community's "MS4 boundary". The percentile rainfall event used as a minimum standard for new development is the 80^{th} percentile rainfall event.

> *Example 1) A parcel that had not been platted or zoned for development (i.e. agricultural land) is being platted as a subdivision for single family residential and is greater than 1 acre. The subdivision would be required to meet the minimum standard set forth herein for new development.*
>
> *Example 2) Several parcels are being replatted for development and the total area being replatted is greater than 1 acre. The replatted parcels would be required to follow new development standards.*
>
> *Example 3) An undeveloped parcel is being rezoned for another use and is greater than 1 acre. The rezoned parcel would be required to follow new development standards.*
>
> *Example 4) A warehouse has been proposed on an undeveloped parcel in an industrial area. Site disturbance is greater than 1 acre. The proposed development would be required to follow new development standards.*

Redevelopment

Redevelopment requirements apply to those areas which have been platted and built on within the community's "MS4 boundary". The percentile rainfall event used as a minimum standard for new development is the 70^{th} percentile rainfall event.

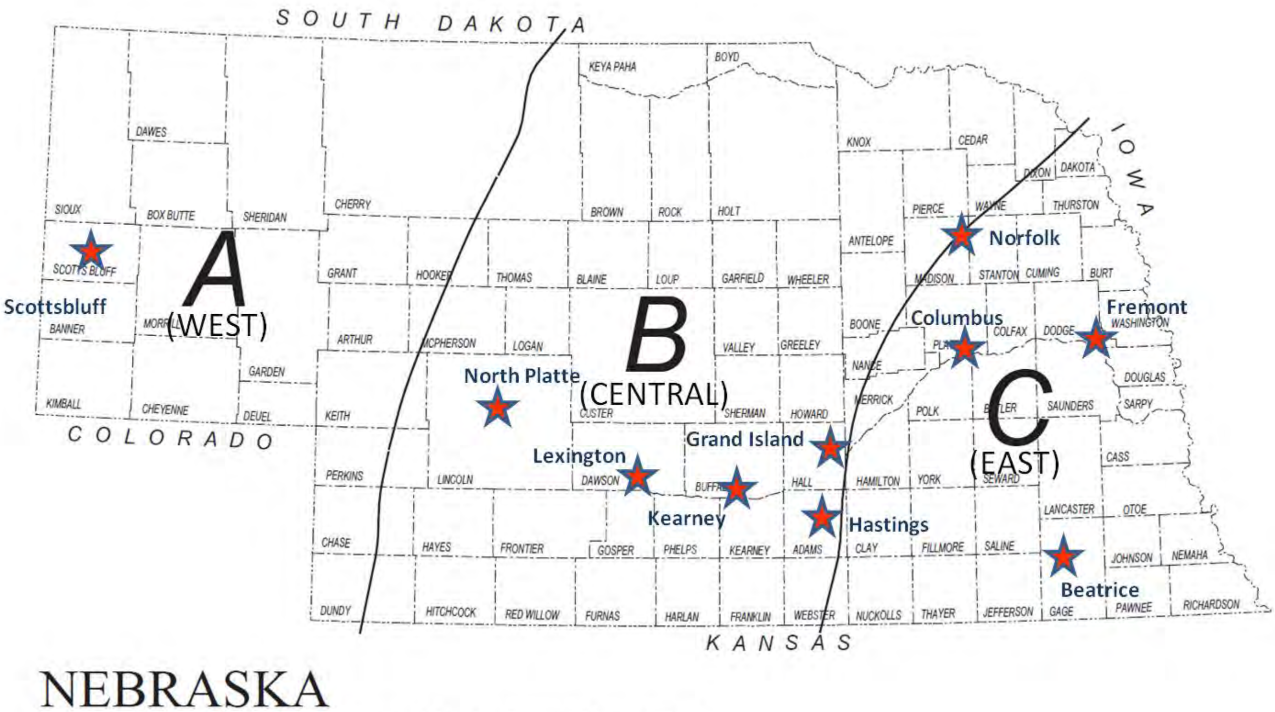
> *Example 1) A parcel that included a structure that was purchased and demolished by the City or other entity, and was sold or deeded over to a new property owner for constructing his or her own building. Site disturbance is greater than 1 acre. This site would be required to meet the minimum standard set forth herein for redevelopment.*
>
> *Example 2) A parcel with a building has been sold and is being converted into a new use with expanded parking. Site disturbance is greater than 1 acre. This parcel would be subject to requirements for redevelopment.*

Rainfall Zones

The percentile rainfall event varies across the state. Three regional rainfall zones have been established to support the calculation of WQCV or Q_{WQ} by any MS4 in Nebraska. These zones are displayed in Figure 1 and are the same as the zones portrayed in the Nebraska Department of Roads (NDOR), *"Drainage and Erosion Control Manual"*, Chapter One.

Rainfall values were interpolated between the depth of rainfall identified in Urban Drainage and Flood Control District's (UDFCD) *"Urban Storm Drainage Criteria Manual"* for the Denver, Colorado area for Region A (West Region) and the City of Lincoln's *"Drainage Criteria Manual"* for Region C (East Region).

Figure 1. Nebraska Regional Rainfall Zones



Adapted from NDOR Drainage and Erosion Control Manual Ch. 1

Rainfall amounts by region for new and redevelopment are provided in Table 1. These values will be used to calculate runoff and water quality control volume (WQCV).

Table 1. Rainfall Depth (P) By Region for Defined Percentile Rainfall Events

Applicable Region	Rainfall, P	
	80^{th} Percentile Event (New Development)	70^{th} Percentile Event (Redevelopment)
A (West)	0.61"	0.44"
B (Central)	0.72"	0.53"
C (East)	0.83"	0.62"

Minimum Design Criteria

STFs must be sized to handle the appropriate WQCV or equivalent water quality discharge rate to properly treat stormwater. Best Management Practices include retention-based stormwater treatment facilities that typically require or encourage using infiltration, evapotranspiration, or harvest practices to control a specified volume of stormwater within each development site.

The regulatory logic of controlling volume is that the stormwater pollutants contained in the volume of runoff captured are prevented from reaching the receiving water, and the remaining volume that does reach the receiving water is less polluted and erosive to the receiving waterbody.

The regulatory logic of controlling discharge rate is that the stormwater pollutants contained in stormwater runoff can be reasonably treated and that volume that does reach the receiving water is less polluted and erosive to the receiving waterbody.

<u>Water Quality Volume</u>

Design criteria to meet minimum site performance standards for new and redevelopment are expressed as the runoff from a specified percentile rainfall event applied across the treatment drainage area. The minimum WQCV for new and redevelopment can be calculated as follows:

WQCV = P x (0.05 + 0.009 x %Imp) x A x 1/12

Where, P = rainfall depth, in (from Table 1)

A = treatment drainage area, ac

%Imp = maximum percent imperviousness (expressed as a whole number not as a decimal) for proposed zoning type (varies by community)

The following example illustrates use of the WQCV equation:

Example 1) A 4.2 acre parcel in Kearney was purchased to construct a storage facility. The parcel is one of 4 in a new development that was zoned limited industrial district (M-1) . Light industrial zoning in Kearney has a maximum impervious percentage of 90%. On that parcel, 2.4 acres will be disturbed to construct the facility. An additional 0.4 acres, also zoned M-1, drain directly onto the site from adjacent property. The WQCV for the site Is calculated as follows:

WQCV = 0.72” x (0.05 + 0.009 x 90) x (2.4 ac + 0.4 ac) x 1/12 x 43,560 = 6,294 cubic feet

If there are multiple land uses within the treatment drainage area, the effective maximum percent imperviousness should be pro-rated based on the area of each zone as a percentage of the total area.

Stormwater runoff from all disturbed areas shall be treated before leaving the site. The treatment drainage area shall include all disturbed areas on the site and upstream drainage or “runon” unless the runon is diverted or bypasses the disturbed site (i.e. by pipe or swale) so that STFs are not overwhelmed. STFs may be distributed across the site to provide the required treatment.

Additional storage in the STF may be allowed, depending on the type of STF selected, to address stormwater detention requirements to control runoff from larger storm events such as the 2-, 10-, or 100-year event.

<u>Water Quality Volume Discharge Rate</u>

STFs that are sized based on a flow rate (i.e. swales, filter strips, manufactured systems, etc.) shall use the water quality volume discharge rate (Q_{WQ}). The Q_{WQ} is the peak runoff from the design water quality volume rainfall event. This peak runoff equivalent shall be calculated using the Natural Resources Conservation Service (NRCS) Curve Number (CN) procedure. The calculation is based on the 80th percentile rainfall event depth by region, a 24 hour duration storm event, and a time of concentration of 5 minutes. The area used is the <u>impervious surface only</u> within the treatment drainage area.

Table 2 has been prepared to provide the Q_{WQ} in each Region for sites with up to 6 acres of impervious area. These values shall be used to size STFs for the area of impervious surface within a given treatment drainage area. For sites greater than 6 acres, the designer shall use the methods and criteria specified above in a suitable model to calculate the discharge rate.

Table 2. Water Quality Discharge Rate (Q_{WQ}) for Selected Impervious Areas By Region

Impervious Area (Acres)	Q_{WQ} (cfs) West | Central | East	Impervious Area (Acres)	Q_{WQ} (cfs) West | Central | East	Impervious Area (Acres)	Q_{WQ} (cfs) West | Central | East
0.2	0.1 | 0.2 | 0.2	2.2	1.5 | 1.9 | 2.2	4.2	2.9 | 3.6 | 4.2
0.4	0.3 | 0.3 | 0.4	2.4	1.6 | 2.0 | 2.4	4.4	3.0 | 3.7 | 4.4
0.6	0.4 | 0.5 | 0.6	2.6	1.8 | 2.2 | 2.6	4.6	3.2 | 3.9 | 4.6
0.8	0.5 | 0.7 | 0.8	2.8	1.9 | 2.4 | 2.8	4.8	3.3 | 4.1 | 4.8
1.0	0.7 | 0.8 | 1.0	3.0	2.1 | 2.5 | 3.0	5.0	3.4 | 4.2 | 5.0
1.2	0.8 | 1.0 | 1.2	3.2	2.2 | 2.7 | 3.2	5.2	3.6 | 4.4 | 5.2
1.4	1.0 | 1.2 | 1.4	3.4	2.3 | 2.9 | 3.4	5.4	3.7 | 4.6 | 5.4
1.6	1.1 | 1.4 | 1.6	3.6	2.5 | 3.0 | 3.6	5.6	3.8 | 4.7 | 5.6
1.8	1.2 | 1.5 | 1.8	3.8	2.6 | 3.2 | 3.8	5.8	4.0 | 4.9 | 5.8
2.0	1.4 | 1.7 | 2.0	4.0	2.7 | 3.4 | 4.0	6.0	4.1 | 5.1 | 6.0

4.2 Platting and Site Plan Review

Land development that meets the land disturbance criteria of this memorandum must address storm water runoff quality through the use of STFs. STFs shall be provided for in the drainage plan for any subdivision plat, annexation plat, development agreement, subdivision agreement or other local development plan.

Implementation Schedule

Each Nebraska H2O partner will adopt a post-construction stormwater management program based on the guidance in this memorandum. Each community must consider local conditions, criteria, and procedures that are compatible or conflict with these recommendations and advance the final post-construction stormwater management program for local adoption. Each community will implement their program independently and under their own schedule; however, the implementation schedule for the post-construction stormwater program for Nebraska H2O partners should not exceed the following:

January 1, 2016: Local MS4 shall begin or continue a public involvement process with local leaders, engineers, the development community and the general public that will lead to adoption of the post construction stormwater management program no later than January 1, 2017.

January 1, 2017: For all developments that have not had a preliminary plat approved, the post-construction stormwater management plan MAY BE required to be satisfied. The MS4 MAY elect to require minimum stormwater treatment practices for replats that significantly increase the amount of impervious area in a preliminarily platted subdivision previously approved by this date. During this period, the municipality shall make known to the owners of all preliminarily platted subdivision that implementation of stormwater treatment controls SHALL BE required if a replat is January 1, 2019 or later The method of notification will be left up to the individual communities and make take the form of a Public Notice.

January 1, 2019: For all developments that have not had a preliminary plat approved, the post-construction stormwater management plan SHALL BE required to be satisfied. The MS4 SHALL require minimum stormwater treatment practices for all replats and modifications of preliminary platted subdivisions.

Procedures

Platting

For major subdivision applications drainage and post-construction shall be discussed at the pre-application conference. This would be followed by an initial review of the general design at the preliminary platting stage and detailed design carrying over into final design review.

The plat applicant shall identify, through the Subdivision Agreement or other City-approved means, whether post-construction stormwater management facilities will be (1) constructed by each lot owner on their own lot (Lot Level STFs); (2) constructed for the subdivision by the developer with reimbursement sought from individual lot builders (Neighborhood STFs); (3) mitigated off-site at regional facilities (Regional STFs), or (4) addressed by other means approved by the City. Any other conditions agreed to between the two parties, including inspections, maintenance, and funding of maintenance shall be included in that agreement.

Building Permits

When seeking a building permit, the City will need to investigate how drainage and post-construction stormwater management is being handled. If Lot Level STFs are required per the Subdivision Agreement or other agreement, then the lot builder will need to develop and have approved a drainage study, post-construction stormwater management plan, and maintenance agreement. A maintenance agreement for an individual lot shall include provisions for maintenance that shall be binding on all subsequent owners.

Submittals

Post Construction Stormwater Management Plan (PCSMP) Submittal

The PCSMP submittal will include the following components:

Plans

Plans showing topographic survey information along with proposed, grading, stormwater infrastructure (including STFs), pavement, and structures shall accompany any PCSMP submittal. Specifically, plans shall include the following information:

- Site topography including existing contours, property lines and easements, utilities, and site features such as existing water bodies, trees and shrubs, pavement and other structures
- Proposed contours
- Proposed inlets, storm sewer, culverts, and drainageways
- Proposed STFs and/or detention facilities
- Proposed roadways, parking, building footprints, and other structures

A table shall be provided in construction drawings that include, for each STF; (1) a location identifier, (2) the type of STF, (3) the location for each STF in latitude/longitude format, (4) the drainage area, and (5) the water quality volume/water quality volume discharge rate. The designer shall differentiate between the amount required by design and the amount that will be provided. Any discrepancies should be discussed with and approved by the City. The information shall be provided on drawings in a format that is consistent with the following:

STF Identification Number	STF Type	STF Location (Lat/Long)	Drainage Area (Acres)	Design WQCV (cf) or Q_{WQ} (cfs)	WQCV (cf) or Q_{WQ} (cfs) Provided

Preliminary submittals required by the City will include preliminary information. Final plans shall be representative of the intended construction bid package.

Calculations

All calculations for water quality volume and water quality volume discharge rate shall be submitted to the City as part of the site development drainage study. Calculations shall be completed as described herein for the appropriate STFs. Design criteria specific to the various STFs shall also be shown in the drainage study (i.e. calculations for drain down and infiltration).

When combining stormwater detention with STFs, the designer shall provide calculations that address both water quality volume and stormwater detention requirements using methodology approved by the community.

STFs shall be clearly shown on the drainage map along with other stormwater infrastructure and drainage basin boundaries.

Certification of Permanent STFs

Upon completion of a project the City shall be provided a written certification, by qualified personnel, stating that the completed project is in compliance with the approved Final Drainage Plan. Qualified personnel shall be a professional civil engineer licensed in the State of Nebraska or person(s) under the direct supervision of a professional engineer licensed in the State of Nebraska.

For commercial and industrial construction, certification will be required before a Certificate of Occupancy is granted (unless authorized by the community). All applicants shall submit “as built” plans certified by a professional engineer licensed in the State of Nebraska once final construction is completed. A final inspection by the City of all post-construction STFs shall be required before a Certificate of Occupancy will be issued or any public infrastructure is accepted.

Ongoing Inspection and Maintenance of STFs

A maintenance agreement will be required by the developer or builder for proposed STFs. The maintenance agreement shall include provisions that outline regular maintenance activity, and a schedule of periodic inspections by the Owner or Designees. Inspection frequency shall be consistent with the design criteria manual used and generally includes quarterly inspections during the first year of establishment following construction and annually thereafter.

The Owner or Designees providing routine inspections shall document all inspections and maintenance and repair needs to ensure compliance with the requirements of the agreement and the plan. The agreement shall allow access to City personnel for inspection and maintenance should the owner default in their responsibilities with the intent to invoice the owner for said work, if needed. Information about inspections and maintenance shall be provided by the owner to the City upon request.

<u>PCSMP Submittal Checklist</u>

A PCSMP checklist shall be submitted with design plans and be recorded by the City with the project record. The PCSMP checklist provided in Appendix A of this document may be used for reference by communities, developers, designers, and builders.

Off-Site Stormwater Mitigation

In some cases it may not be practicable to provide the required treatment within project limits due to various constraints such as site limitations, costs, or other obstacles. If shown by the owner that it is not practicable, off-site mitigation may be allowed at the discretion of the City.

Off site mitigation may be provided by a private land owner in a City-approved stormwater treatment facility or within a City-approved publicly owned stormwater treatment facility provided the proposed mitigation location meets the following minimum criteria;

- A drainage study confirms that the proposed mitigation location provides excess stormwater treatment that is not required to provide treatment for the drainage area.
- The excess treatment capacity in the proposed mitigation location is not already providing mitigation of required stormwater treatment for another development or redevelopment project.
- The owner of the proposed mitigation location maintains or enters into a maintenance agreement that shall be binding on all subsequent owners and includes all required inspection and maintenance requirements for stormwater treatment practices.

Off site mitigation should take place in accordance with the rules and conditions of each individual community. Each community will need to be able to provide the appropriate documentation for tracking all water quality debits and credits for such facilities in the event of an audit. Fees shall be established by the entity funding the stormwater treatment facility.

4.3 Maintenance of Controls

STFs located on private property shall be owned and operated by the owner(s) of the property on which the STF is located; unless the City agrees in writing that a person or entity other than the owner shall own or operate such STF. As a condition of approval of the STF, the owner shall also maintain the STF in perpetuity to its design capacity unless or until the City shall relieve the property owner of that responsibility in writing. The obligation to maintain the STF shall have been memorialized on a subdivision plat, annexation plat, development agreement, subdivision agreement or other form acceptable to the City and recorded by the City with the project records.

The City shall continue to maintain public storm sewer infrastructure including public STFs. Each homeowners association of a subdivision or individual lot owner shall maintain post-construction STFs. When public infrastructure improvements are constructed by the City, such as with the widening of a major arterial or other public improvement, the City shall take responsibility for maintenance of the STF unless otherwise specified in a maintenance agreement.

5.0 Design Guidance

STFs shall be designed using an approved design guidance manual that provides minimum design criteria and considerations. A selection of regional design guides are recommended for design within Nebraska H_2O communities. The most recent versions of the following design guides and manuals are approved for general use in the design of STFs:

- City of Omaha, *"Omaha Regional Stormwater Design Manual – Chapter 8: Stormwater Best Management Practices"*
- City of Lincoln, *"Drainage Criteria Manual - Chapter 8: Stormwater Best Management Practices"*
- NDOR, *"Drainage and Erosion Control Manual – Chapter 3: Stormwater Treatment within MS4 Communities"*
- Urban Drainage and Flood Control District (UDFCD), *"Urban Storm Drainage Criteria Manual, Volume 3: Best Management Practices"*

The designer is encouraged to adopt one design guide/manual for use on a project to the extent practicable. Other approved design guides and manuals may be used if design criteria for the desired STF are not provided in the primary design guide/manual. Any variances from these manuals will require approval of the City Engineer or their Designee. The community may evaluate the suitability of other types of STFs not referenced in the approved design guides and manuals on a case-by-case basis.

The designer shall discuss the use of the alternative design guidance manuals prior to starting design along with any variance in STF design. The designer shall also discuss other requirements for stormwater management within the community including the potential need for stormwater detention. Where one manual conflicts with another, the Engineer shall use sound, cost-effective design practices to resolve the issue. The following minimum design standards are provided to help resolve some conflicts identified.

Stormwater Treatment Facility Selection

Each design guidance manual includes a unique selection of STFs and what is included in one may not be included in another. Furthermore, two manuals may use different names for an STF with the same or similar function. The function, criteria and considerations of a specific STF is what shall be used to determine its use by a design engineer. Table 3 provides a general comparison of the types of STFs included in the approved design guidance manuals.

Table 3. STF Design Guidance for Various Regulatory Agencies

STF Type	Omaha	Lincoln	NDOR	UDFCD
Vegetated Filter Strip	X		X	X
Grass Swale	X		X	X
Infiltration Trench			X	
Infiltration Basin			X	
Bioretention Basin	X	X	X	X
Media Filter			X	
Sand Filter				X
Extended Dry Detention	X	X	X	X
Wet Detention Ponds	X	X	X	X
Stormwater Wetland	X	X	X	X
Underground Detention		X		X
Pervious Pavement	X	X	X	X
Proprietary Structural Treatment Controls	X		X	X
Green Roofs	X	X		X
Soil Conditioning	X			

All design guidance manuals include criteria and considerations for STF selection and should be used for this purpose. The design criteria within these guides shall be adhered to unless the design engineer demonstrates to the City why the criteria do not apply. Stormwater STF suitability will depend on number of factors including, but not limited to, the following:

- Available Space
- Property Access
- Site Topography
- Drainage Basin Size
- Infiltration Rates
- Depth to Groundwater/Bedrock
- Capital Costs/Maintenance

Community Preferences

Each community reserves the right to approve or reject certain STFs based on preferences and/or suitability for their community. Furthermore, certain communities may have regional STFs that they would prefer to use over on-site STFs. It is suggested that the designer discuss these preferences with the community during the pre-application phase of platting or at the beginning of design when considering building on an individual lot.

Collectively, Nebraska H_2O recommends the following preferences and exclusions from the approved manuals for consideration in your design:

Infiltration Rates

Minimum infiltration rate shall be 0.5 in/hr

Maximum infiltration rate shall be 12 in/hr

Infiltration Cells

Infiltration cells should incorporate conditioned soils to reduce the quantity of select material needed to provide treatment in a bioretention garden/basin. This method is described in the Omaha Regional Stormwater Design Manual and NDOR Drainage and Erosion Control Manual.

Drain Time and Control Valves

A design drain time of 24 hours will be used for all STFs that use a water quality control volume to provide treatment and control of runoff. Control valves shall be placed in underdrains to allow for adjustments to the drain time as needed.

Cleanouts

Cleanouts shall be provided on all underdrains to assist with providing needed maintenance.

Pretreatment

Measures shall be incorporated that prevent sediment from depositing in STFs during and after construction. Pretreatment of stormwater runoff through barriers, grass buffers or forebays is recommended on all STFs.

Landscaping

The following resources have been provided to assist in the design of landscaping for a project. It is strongly suggested that a landscape architect or designer assist with plant selection and landscape design.

- UNL Extension, "Stormwater Management: Plant Selection for Rain Gardens in Nebraska" http://www.ianrpubs.unl.edu/epublic/live/g1759/build/g1759.pdf
- UNL Extension, "Nebraska Bioretention and Rain Garden Plants Guide" http://marketplace.unl.edu/extension/ec1261.html
- NDOR, "Plan for the Roadside Environment" http://www.transportation.nebraska.gov/environment/docs/road-env-plan-total.pdf
- NDOR, "Roadside Flowers and Grasses" http://www.transportation.nebraska.gov/environment/flowers.html
- NDOR, "Roadside Vegetation Establishment and Maintenance" http://www.transportation.nebraska.gov/environment/docs/veg-manual_2014.pdf
- "The Seed", A Publication of the Nebraska Statewide Arboretum, Fall 2008 http://arboretum.unl.edu/documents/The%20Seed%20Water%20in%20Landscape.pdf

These links may contain other references to sources that may be helpful in plant selection and suitability for use with STFs. Keep in mind regional difference in your selection of plants along with differences in soil, light, and moisture within the stormwater STF itself.

APPENDIX A

POST-CONSTRUCTION STORMWATER MANAGEMENT PLAN (PCSMP)

SUBMITTAL CHECKLIST

Post-Construction Stormwater Management Plan (PCSMP) Submittal Checklist

Preliminary submittals required by the City will include preliminary information. Final submittals shall be representative of the intended construction bid package.

PROJECT NAME: ____

PLANS

- ☐ Site topography including existing contours, property lines and easements, utilities, and site features such as existing water bodies, trees and shrubs, pavement and other structures
- ☐ Proposed contours
- ☐ Proposed inlets, storm sewer, culverts, and drainageways
- ☐ Proposed STFs and/or detention facilities
- ☐ Proposed roadways, parking, building footprints, and other structures
- ☐ A table shall be provided in construction drawings that includes, for each Stormwater Treatment Facility (STF) The information shall be provided on drawings in a format that is consistent with the following:

STF Identification Number	STF Type	STF Location (Lat/Long)	Drainage Area (Acres)	Design WQCV (cf) or Q_{WQ} (cfs)	WQCV (cf) or Q_{WQ} (cfs) Provided

CALCULATIONS

- ☐ Water Quality Volume (WQCV) or Water Quality Volume Discharge Rate (Q_{WQ}) for each STF (To be included with a site design or subdivision drainage study)
- ☐ Drainage Study

AGREEMENTS

A maintenance agreement is required for neighborhood level and lot level STFs. If an agreement is made for mitigation off site or other agreements are made, make note and describe below

- ☐ Inspection and Maintenance Agreement
- ☐ Other Agreement

____

CERTIFICATION OF PERMANENT STFs

Unless otherwise indicated by the City, a Hold on the Certificate of Occupancy will be placed on the project until the STF has been certified. If applicable, check "Hold" until certification is received. If not applicable, check N/A.

- ☐ Hold on C.O.
- ☐ N/A

Submitted upon completion of a project; a statement by a professional engineer licensed in the State of Nebraska or person(s) under the direct supervision of a professional engineer licensed in the State of Nebraska attesting that the completed project is in compliance with the approved Final Plan.

- ☐ Certification of Permanent STFs
- ☐ Record Drawings (if required by City)

- ☐ Hold on C.O. Released (if applicable) Released By: ______________________________

Attachment C: May 3, 2017 Final Report Addendum

Final Report Addendum

Date:	Wednesday, May 03, 2017
Project:	Columbus Area Water Resources Assessment Phase II
To:	Russ Callan - LLNRD
From:	Pat Engelbert - HDR, Tom Riley - TFG
Subject:	Final Report Draft Addendum

The Columbus Area Water Resources Assessment (CAWRA) – Final Report (June 2016), prepared for the Lower Loup Natural Resources District (LLNRD), presented the findings of an assessment of water resources available in the Columbus area. The study concluded that there were significant water sources in the Study Area. Evaluation of the hydrogeology within the study area indicated relatively steady state groundwater contours in the western and northern portion of the Study Area. However, a declining groundwater trend was identified in the southeast portion of the study area beginning in approximately 2010. A groundwater model was developed and calibrated to assist in identifying the extent of the groundwater decline as well as identifying potential water sources and recharge/water management projects to reduce the decline.

Two potential project alternatives were identified that have the hydrogeologic characteristics, spatial location, and the associated capacity to supplement water to the aquifer (recharge locations). Through evaluation in the CAWRA, these alternatives were determined to be viable options for reducing the groundwater decline. The project alternatives are: 1) the Lost Creek channel south of Christopher's Cove; and 2) Christopher's Cove. The source water identified for groundwater recharge in the CAWRA was the return water from ADM that is pumped for their production purposes, and is discharged into Loup Public Power District's (LPD) Tailrace Canal. This source water, or an equivalent volume, could be repurposed for aquifer recharge. Currently, this return water is conveyed down the Tailrace Canal into the Platte River, and is lost from the system. The recharge projects would re-use the return water by ponding the water and allowing it to infiltrate into the water table, thus creating a sustainable approach to reduce groundwater declines.

This addendum presents the evaluation in support of the CAWRA and provides a description of some additional alternatives to deliver the source water to the recharge areas. Additional delivery options were evaluated, primarily from a cost and logistics standpoint using the recharge locations identified in the CAWRA. One variation on the source water is that some alternatives withdraw source water from the Lost Creek Flood Control Channel near its confluence with LPD's Tailrace Canal. The baseflow in the Lost Creek Flood Control Channel is primarily composed of intercepted groundwater.

Six additional alternatives were evaluated for this addendum. The six alternatives consist of delivering source water from either the Lost Creek Flood Control Channel or LPD's Tailrace Canal.

Considerations for the various alternatives included cost (capital and O&M), route logistics; source water, discharge locations, and third-party impacts. Preliminary estimated project costs are based on engineering design and construction of a pump station and the delivery of the water to the Lost Creek Channel and/or Christopher's Cove. Piping and overland flow via local drainages are evaluated in various alternatives. O&M costs (20-yr) are also estimated to arrive at a total probable project cost. Costs vary considerably between some of the alternatives, based primarily on the withdrawal and discharge locations.

Route considerations include piped length, use of overland drainage routes, major and minor road and railroad crossings (borings) along the route, and the amount of development along route. Major crossings would include Highway 30 and the Union Pacific Railroad. Minor crossing would be local streets, parking areas, and generally single track sidings. Routes to Christopher's Cove assume that access would be through the corridor on the southeast corner of the cove.

The primary difference in source water between the LPD Tailrace and the Lost Creek Flood Control channel is water turbidity (clarity). Alternatives 4, 5, and 6 use the Lost Creek Flood Control Channel for source water. This water has a significantly lower sediment load than the LPD Tailrace source water which may have an effect on channel sediment loading over time. Although none of the alternatives currently evaluated used the Lost Creek Flood Control Channel to supply Christopher's Cove, sources with lower sediment load may be beneficial for discharge into the cove.

Two discharge locations were evaluated for Alternatives 4, 5, 7, and 8. The discharge locations are Lost Creek Channel north of 8th Street and west of East 14th Avenue, and Lost Creek Channel North of the Union Pacific Railroad. The discharge location north of the Union Pacific Railroad results in shorter pipe distances, but may result in potential third party impacts because there is greater length of open channel conveyance.

All eight alternatives are summarized below and are shown in Figure 1. Table 1 provides a comparison of the alternatives.

<u>Alternative 1 – LPD Tailrace Canal to Lost Creek Channel near 8th Street</u>

This alternative includes withdrawal of source water from the LPD Tailrace Canal east of the ADM Plant via a 6000 gpm pumping plant and delivery via a 12" water line along 8th Street. Discharge is to Lost Creek west of East 14th Ave. The discharge location is just upstream of the first check dam in the Lost Creek recharge area.

Alternative 1 is the third lowest cost option in both capital and O&M costs and cost per AF. The cost of Alternative 1 is higher than in the CAWRA due to the addition of some O&M costs and an adjustment in the route.

The route length is approximately 8,300 feet, all piped. Development along the route is minimal; it crosses under the north portion of ADM Plant which is mostly driveways and railroad siding crossings. There are seven minor road/railroad crossings.

Alternative 2 – LPD Tailrace Canal to Christopher's Cove

This alternative includes withdrawal of source water from the LPD Tailrace Canal east of the ADM Plant via a 1500 gpm pumping plant and delivery via a 6" water line along 8th Street to East 6th Ave., then north to discharge in Christopher's Cove.

Alternative 2 is the second lowest cost option in capital and O&M costs but sixth in cost per AF because recharge supply volume is limited to 1,025 AF per year in Christopher's Cove vs. 2,275 AF in Lost Creek. The cost for Alternative 2 is also higher than in the CAWRA due to a route change.

The route length is approximately 13,500 ft, which is one of the longer routes. The entire length is piped. Development along the route is minimal and similar to Alternative 1. There are seven minor road/railroad crossings and the line crosses under the Union Pacific Railroad on the leg from Lost Creek north to Christopher's Cove.

Alternative 3 – LPD Tailrace Canal to Lost Creek and Christopher's Cove

Alternative 3 combines Alternatives 1 and 2. It includes withdrawal of source water from the LPD Canal east of the ADM Plant via a 6000 gpm pumping plant and delivery via a 12" water line along 8th Street with discharge into Lost Creek west of East 14th Ave. A separate 6" line will continue east and then north along East 6th Ave. to discharge in Christopher's Cove. Flow will be split off the 12" line with the assumption that no additional pumping capacity will be required since the system will be under pressure the entire length of the route.

Alternative 3 is the fourth lowest cost option in capital and O&M costs and second lowest in cost per AF. Using both Lost Creek and Christopher's Cove recharge sites means the combined recharge volume is 3,300 AF per year (2,275 AF plus 1,025 AF). The recharge volume offsets some of the capital costs.

The route length is approximately 13,700 ft; 8,300 feet of 12" pipe to Lost Creek, and 5,400 feet of 6" pipe to Christopher's Cove. Development along the route is minimal with the 12" line crossing under the north portion of the ADM Plant. There are eight minor road/railroad crossings plus the crossing under the Union Pacific main line.

Alternative 4 – Lost Creek Flood Control Channel to Lost Creek along 3rd Ave

This alternative includes withdrawal of recharge water from the Lost Creek Flood Control Channel near 3rd Ave. via a 6,000 gpm pumping plant and delivery via a 12" water line south along 3rd Ave. to 8th Street, then east to discharge into Lost Creek west of East 14th Ave. (4A discharges into Lost Creek north of the Union Pacific Railroad).

Alternative 4 is the most expensive cost option in both capital and O&M costs and cost per AF. This is primarily due to the added route distance coming from the LC Flood Control Channel to the north.

The length of this route is approximately 18,300 feet and is the longest route. The route runs through two major housing developments and some other minor developments. There are approximately 16 minor road/railroad crossings and the route crosses under both Highway 30 and the Union Pacific main line.

Alternative 5 – Lost Creek Flood Control Channel to Lost Creek along Lost Creek Parkway

Alternative 5 includes withdrawal of recharge water from the Lost Creek Flood Control Channel near 3rd Ave. via a 6,000 gpm pumping plant and delivery via a 12" water line along Lost Creek Parkway and 6th Ave. south to 8th Street then east to discharge into Lost Creek west of East 14th Ave. (5A discharges into Lost Creek north of the Union Pacific Railroad). This alternative is similar to Alternative 4 except for the route along Lost Creek Parkway and 6th Ave. from the north.

Alternative 5 is the second most expensive cost option in both capital and O&M costs and cost per AF for the same reasons as Alternative 4. The route along Lost Creek Parkway is slightly shorter than along 3rd Avenue (Alternative 4).

The route length of this alternative is approximately 16,800 feet, the second longest of the alternatives evaluated. The route crosses through a significantly less amount of developed areas, primarily on the south side of Hwy 30. There are five minor road/railroad crossings and two major crossings.

Alternative 6 – Lost Creek Flood Control Channel to Lost Creek (North)

This alternative includes withdrawal of recharge water from the Lost Creek Flood Control Channel near 3rd Ave. via a 6,000 gpm pumping plant and delivery via a 12" water line south along 3rd Ave. to Lost Creek north of 30th Street. This alternative has a significantly shorter piped length and uses the most open channel flow to deliver water to the recharge area at Lost Creek south of 8th Street.

Alternative 6 is the least expensive cost option in both capital and O&M costs and cost per AF due to the shortened piped distance. There would be some initial channel improvement needed under this alternative and the overland flow may have some additional third party impacts resulting from increased streamflow through developed areas. Some channel stabilization may be required due to the potential for low sediment laden water from the flood control channel to pick up sediment as it moves downstream.

The piped route length for this alternative is approximately 4,550 feet. The overland flow route is approximately 8,600 feet. There are no pipe crossings through major developments and only two minor road crossings.

Alternative 7 – LPD Tailrace Canal to Lost Creek

This alternative includes withdrawal of recharge water from the LPD Tailrace Canal north of 6th Ave. via a 6,000 gpm pumping plant and delivery via a 12" water line along 6th Ave south to 8th Street. Discharge is to Lost Creek west of East 14th Ave. (7A discharges into Lost Creek north of the Union Pacific Railroad).

Alternative 7 is the fourth highest cost option in capital and O&M costs and cost per AF. The supply route is piped from the tailrace to the north and is longer than from the tailrace to the east.

The route length is approximately 13,700 feet and crosses under minimal developed area primarily on south side of Hwy 30. There are five minor road/railroad crossings and two major crossings (Highway 30 and UP rail line).

<u>Alternative 8 – LPD Tailrace Canal to Lost Creek and Christopher's Cove</u>

Alternative 8 includes withdrawal of recharge water from the LPD Tailrace Canal north of 6th Ave. via a 6,000 gpm pumping plant delivery via a 12" water line along 6th Ave south to 8th Street. Discharge is to Lost Creek west of East 14th Ave. (8A discharges into Lost Creek north of the Union Pacific Railroad). This alternative includes a separate 6" water line diversion to Christopher's Cove. Flow would be diverted off the 12" water line using a 6" line and 1,500 gpm pumping plant to transfer water to Christopher's Cove. The additional pump would be required because as the pipeline continues south, the elevation decreases and flow in the pipeline may be gravity flow.

Alternative 8 is the third most expensive cost option in capital and O&M costs and fourth least expensive in cost per AF. The reduction in the AF cost is a result of adding the additional 1,025 AF/year in Christopher's Cove (total of 3,300 AF/year). The increased recharge volume offsets some of the capital costs including the additional pump system for Christopher's Cove.

The route length to Lost Creek is approximately 14,350 feet. The 6" pipe diversion to Christopher's Cove is approximately 650 feet to the southeast corner of the cove. Developed areas along the routes are similar to Alternative 7. There are six minor road/railroad crossings and two major road/railroad crossings.

Table 1. Alternative Summary											
	Withdrawal Location			Discharge Location		Recharge Location					
Alt. No.	LPD Tailrace Canal East	LPD Tailrace Canal North	LC Flood Control	LC at 8th St	LC at RR Tracks	Lost Creek	Christopher's Cove	AF/ Year	Pipe Length (ft)/Size	Estimated Cost w/ O&M (Million $)	Cost Per Acre Foot ($)
1	X			X		X		2275	8,300 (12")	1.94	42.65
2	X						X	1025	13,500 (6")	1.26	61.48
3	X			X		X	X	3300	8,300 (12") 5,400 (6")	2.44	37.02
4			X	X		X		2275	18,300 (12")	3.34	73.35
4A					X			2275	13,500 (12")	2.66	58.50
5			X	X		X		2275	16,800 (12")	3.14	68.95
5A					X			2275	12,350 (12")	2.51	55.18
6			X	LC-North		X		2275	4,550 (12")	0.96	21.20
7		X		X		X		2275	13,700 (12")	2.70	59.36
7A					X			2275	9,300 (12")	2.08	45.75
8		X		X		X	X	3300	13,700 (12") 650 (6")	2.91	44.09
8A					X			3300	9,300 (12") 650 (6")	2.29	34.70

Attachment D: June 22, 2017 Alternative Analysis Summary

Alternative Analysis Summary

Date:	Thursday, June 22, 2017
Project:	Columbus Area Water Resources Assessment Phase II
To:	Russ Callan - LLNRD
From:	Pat Engelbert - HDR, Tom Riley - TFG
Subject:	Alternative Analysis Summary

The Columbus Area Water Resources Assessment (CAWRA) – Final Report (June 2016), prepared for the Lower Loup Natural Resources District (LLNRD), presented the findings of an assessment of water resources available in the Columbus area. The study concluded that there were significant water sources in the Study Area. Evaluation of the hydrogeology within the study area indicated relatively steady state groundwater contours in the western and northern portion of the Study Area. However, a declining groundwater trend was identified in the southeast portion of the study area beginning in approximately 2010. A groundwater model was developed and calibrated to assist in identifying the extent of the groundwater decline as well as identifying potential water sources and recharge/water management projects to reduce the decline.

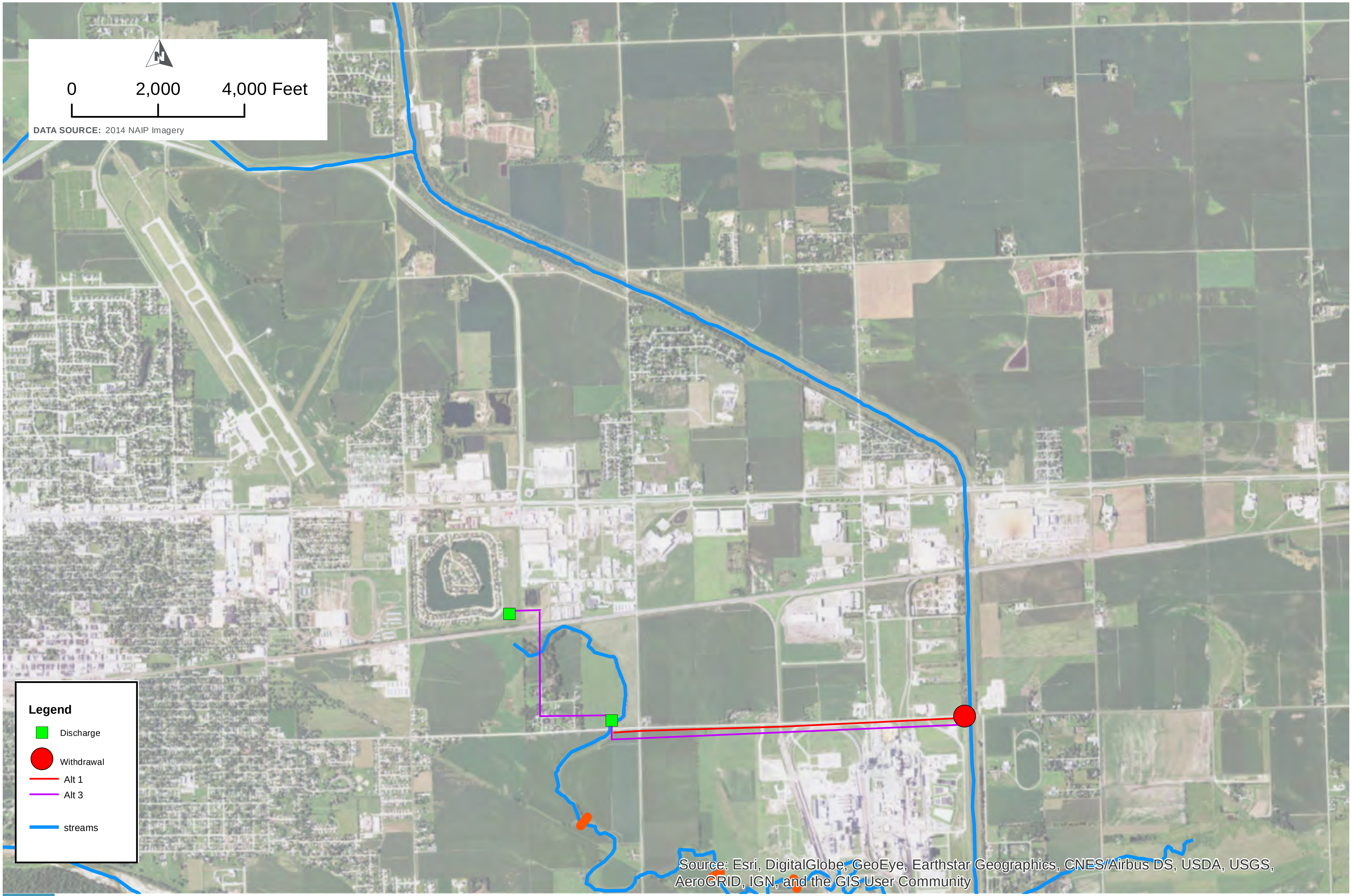
Potential project alternatives were identified that have the hydrogeologic characteristics, spatial location, and the associated capacity to supplement water to the aquifer (recharge locations). Through evaluation in the CAWRA, these alternatives were determined to be viable options for reducing the groundwater decline. The project alternatives include the following recharge locations: 1) the Lost Creek channel south of Christopher's Cove; and 2) Christopher's Cove. The source water identified for groundwater recharge was the return water from ADM that is pumped for their production purposes, and is discharged into Loup Public Power District's (LPD) Tailrace Canal. This source water, or an equivalent volume, could be repurposed for aquifer recharge. Currently, this return water is conveyed down the Tailrace Canal into the Platte River, and is lost from the system. The recharge projects would re-use the return water by ponding the water and allowing it to infiltrate into the water table, thus creating a sustainable approach to reduce groundwater declines.

Eight alternatives were evaluated, and are detailed in the Final Report Draft Addendum (May, 2017). Water source locations consisted of the Lost Creek Flood Control Channel or LPD's Tailrace Canal. Discharge locations included various locations along Lost Creek Channel and Christopher's Cove Lake. Cost considerations for the various alternatives included cost (capital and O&M), route logistics, source water, discharge locations, and third-party impacts. Preliminary estimated project costs were based on engineering design and construction of a pump station and the delivery of the water to the Lost Creek Channel and/or Christopher's Cove. Water delivery route considerations included piped length, use of overland drainage routes, major and minor road and railroad crossings (borings) along the route, and the amount of development along route. Major crossings would include Highway 30 and the Union Pacific Railroad. Minor crossings would be local streets, parking areas, and generally single track sidings.

Routes to Christopher's Cove assume that access would be through the corridor on the southeast corner of the cove. O&M costs (20-yr) were also estimated to arrive at a total probable project cost.

Based on discussion with LLNRD staff, two alternatives are being considered for implementation, Alternatives 1 and 3. A description of each alternative, as well as the pros, cons, and costs are provided in the table below. The cost assumes funding from the State of Nebraska Water Sustainability Fund (WSF), ADM, the LLNRD, the City, and Christopher's Cove Association (CCA). The WSF would fund 60% of the project. The cost split for the remaining 40% is assumed to be ADM (70%), LLNRD (20%), City and CCA (10%).

	Alternative 1	**Alternative 3**
Description	• Water Source – LPD Tailrace near 8th Street Bridge. • Discharge Location – Lost Creek Channel at 8th Street. • Annual Recharge Potential – 2,275 AF/Yr.	• Water Source – LPD Tailrace near 8th Street Bridge. • Discharge Location – Lost Creek Channel at 8th Street and Christopher's Cove. • Annual Recharge Potential – 2,500 AF/Yr.
Pros	• Recharge within area controlled by City through easement. • System control through likely agreement with the City. • Source water delivery route within industrial corridor. • Potential reduction in decline at Target 12 ~ 7' to 10'.	• Greater potential for recharge benefit. • Multiple participant benefits. • Increase in lake aesthetics, property value and tax revenues. • Source water delivery route within industrial corridor. • Potential reduction in decline at Target 12 ~ 8' to 12'. • Recharge from Christopher's Cove when operating during dry conditions ~ 1,000 AF/Yr.
Cons	• No opportunity for alternative recharge location. • Lowest potential for recharge benefit.	• Unknown operational control due to private use. • Water source turbid for addition to lake recharge location.
Cost/ Potential Breakdown	**Total $1,940,000** • WSF $1,164,000 • ADM $543,200 • LLNRD $155,200 • City & CCA $77,600 • Cost/AF = $42.70	**Total $2,440,000** • WSF $1,464,000 • ADM $683,200 • LLNRD $195,200 • City & CCA $97,600 • Cost/AF = $48.80



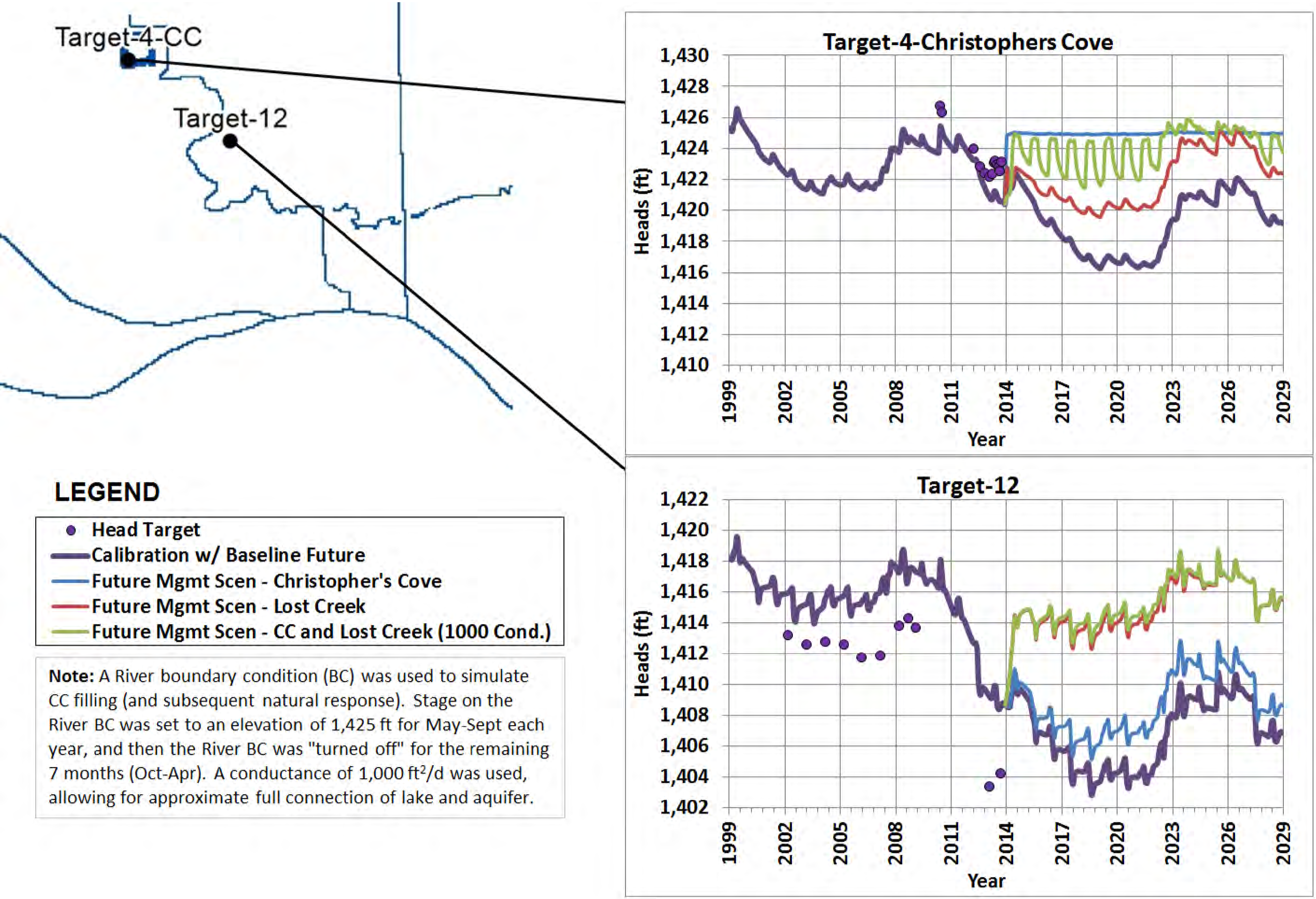
HDR THE FLATWATER GROUP INC. JE LOWER LOUP NATURAL RESOURCES DISTRICT

COLUMBUS AREA WATER RESOURCES ASSESSMENT

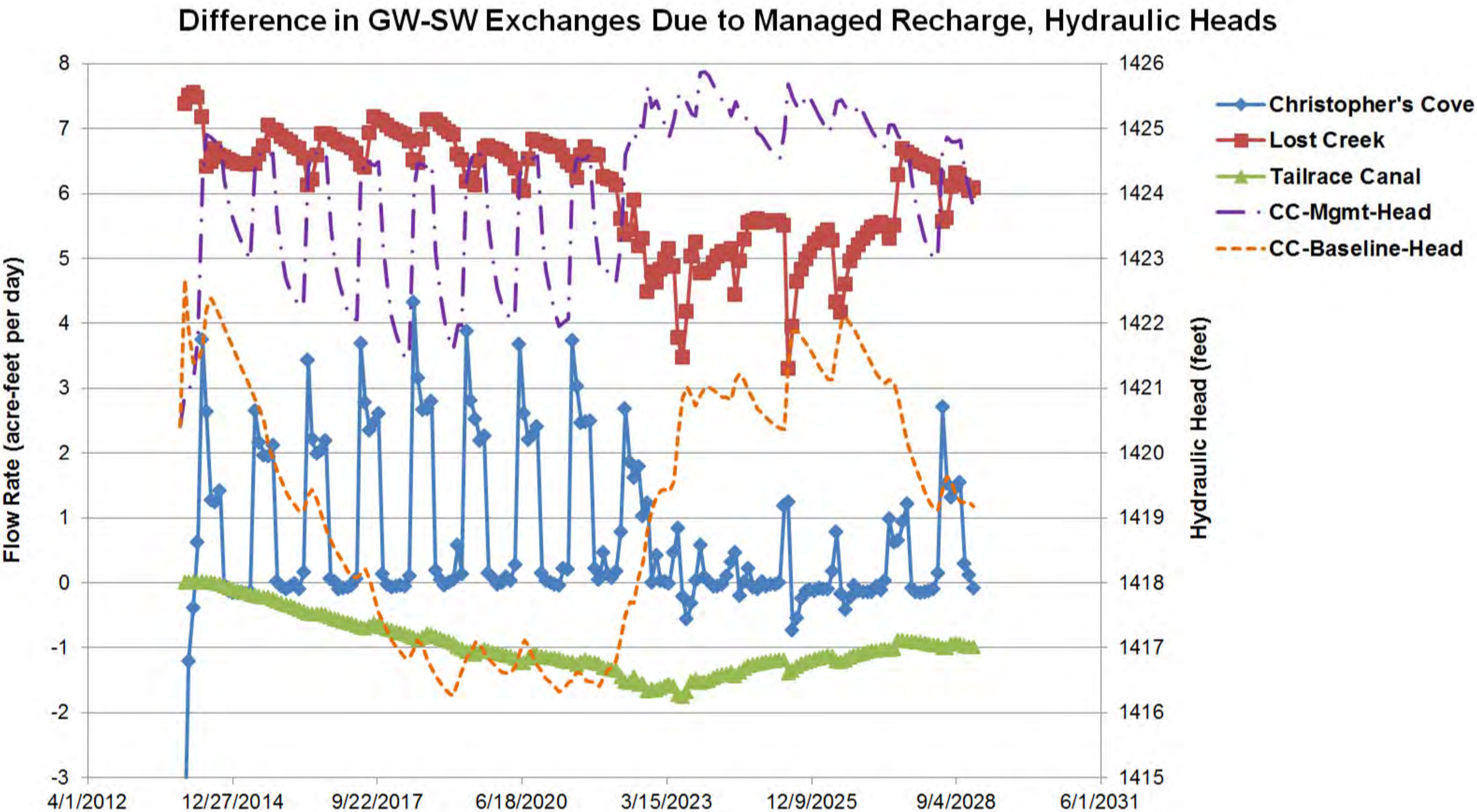
RECHARGE ALTERNATIVES CONCEPTUAL LAYOUT

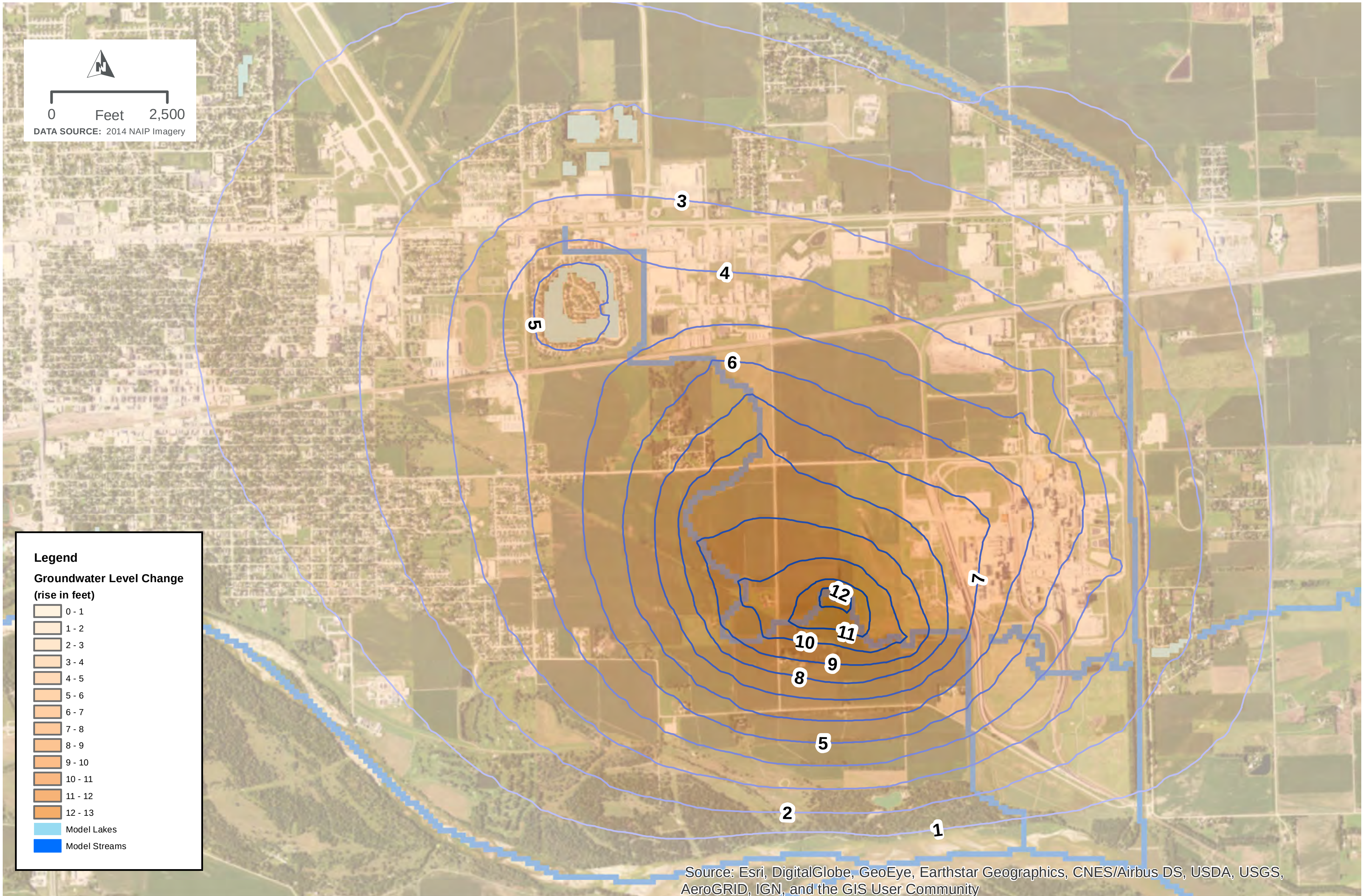
FIGURE 1

PATH: D:\TEMP\SROCK\COLUMBUS\CAWRA_WORKING.MXD - USER: SROCK - DATE: 6/14/2017



Note: A River boundary condition (BC) was used to simulate CC filling (and subsequent natural response). Stage on the River BC was set to an elevation of 1,425 ft for May-Sept each year, and then the River BC was "turned off" for the remaining 7 months (Oct-Apr). A conductance of 1,000 ft^2/d was used, allowing for approximate full connection of lake and aquifer.


Difference in GW-SW Exchanges Due to Managed Recharge, Hydraulic Heads
Flow Rate (acre-feet per day)
Hydraulic Head (feet)
Christopher's Cove
Lost Creek
Tailrace Canal
CC-Mgmt-Head
CC-Baseline-Head
8
7
6
5
4
3
2
1
0
-1
-2
-3
1426
1425
1424
1423
1422
1421
1420
1419
1418
1417
1416
1415
4/1/2012
12/27/2014
9/22/2017
6/18/2020
3/15/2023
12/9/2025
9/4/2028
6/1/2031



COLUMBUS AREA WATER RESOURCES ASSESSMENT

GROUNDWATER LEVEL IMPACTS FOR CC & LOST CREEK RECHARGE, AUG 2028

CC HAS 1,000 FT^2/D CONDUCTANCE

PATH: Z:\PROJECTS\LLNRD\256540_LLNRD_COLUMBUSWTRRESASSES\MAP_DOCS\DRAFT\CAWRA_CC-LSTCRK_MGDRECH_1K_GWLIMPACTS_AUG2028.MXD - USER: NROSSMAN - DATE: 6/21/2017

Attachment E: Project Budget

COLUMBUS AREA WATER RESOURCES ASSESSMENT					
WATER SUPPLY PROJECT					
Conceptual Estimate of Probable Construction Cost					
Alternative 3 (Combined Alts. 1 and 2)					
12" Pipe from Canal East of ADM plant along East 8th Street to Lost Creek (8,300 feet); 6" Pipe Continue to Christopher Cove (5,400 feet)					
ACTIVITY	**UNIT**	**UNIT COST**	**QUANTITY**	**COST**	
General					
Mobilization/Demobilization	LS	$24,011.27	1	$24,011.27	
Construction Survey	LS	$19,209.02	1	$19,209.02	
Site Security (construction fence, barricades, etc.)	LS	$4,802.25	1	$4,802.25	
Erosion and Sediment Control	LS	$19,209.02	1	$19,209.02	
General Site Work/Site Prep	LS	$19,209.02	1	$19,209.02	
Subtotal					**$86,400.00**
Water Transfer Pipeline System - 12"					
Excavation, Backfill and Removal of Spoil, Compaction	LF	$16.20	8,300	$134,460.00	
Pipe Bedding; Bank Sand	LF	$18.00	8,300	$149,400.00	
12" PVC Pressure Pipe Class 150, SDR 18, AWWA C900	LF	$30.50	8,300	$253,150.00	
12" PVC Pressure Pipe Fittings	LS	$12,657.50	1	$12,657.50	
Pump Intake Site Work (incl. pipe and screen)	LS	$6,000.00	1	$6,000.00	
6000 GPM Centrifigal Pump, Motor/Generator, Controls	EA	$100,000.00	1	$100,000.00	
Electrical Hookup (pole, transformer, hookup)	LS	$20,000.00	1	$20,000.00	
Outlet Site Work	LS	$2,500.00	1	$2,500.00	
Site Restoration	LS	$1,200.00	1	$1,200.00	
Subtotal					**$679,300.00**
Creek Stabilization/Check Structures (3)					
Excavation	CY	$9.64	300	$2,892.89	
Excavation Disposal	CY	$4.06	225	$913.50	
Embankments/Fills	CY	$4.06	75	$304.50	
Steel Sheet Piling	SF	$17.98	1,440	$25,888.90	
Type B Rip-Rap	TON	$55.00	504	$27,720.00	
Site Restoration (seeding and erosion protection)	EA	$5.00	750	$3,750.00	
Subtotal					**$61,400.00**
Water Transfer Pipeline System - 6"					
Excavation, Backfill and Removal of Spoil, Compaction	LF	$13.85	5,400	$74,790.00	
Pipe Bedding; Bank Sand	LF	$10.16	5,400	$54,864.00	
6" PVC Pressure Pipe Class 150, SDR 18, AWWA C900	LF	$12.85	5,400	$69,390.00	
6" PVC Pressure Pipe Fittings	LS	$3,469.50	1	$3,469.50	
Water Transfer from 12" to 6"	LS	$15,000.00	1	$15,000.00	
Pump Intake Site Work (incl. pipe and screen)	LS	$6,500.00	0	$0.00	
1500 GPM Centrifigal Pump, Motor/Generator, Controls	EA	$25,000.00	0	$0.00	
Electrical Hookup (pole, transformer, hookup)	LS	$15,000.00	0	$0.00	
Outlet Site Work	LS	$1,100.00	1	$1,100.00	
Site Restoration	LS	$1,000.00	1	$1,000.00	
Subtotal					**$219,600.00**
ESTIMATED CONSTRUCTION COST SUBTOTAL					**$1,046,700.00**
CONCEPT LEVEL CONTINGENCY 50%		50.00%			**$523,300.00**
TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION					**$1,570,000.00**
ENGINEERING DESIGN AND MANAGEMENT		25.00%			**$392,000.00**
ENVIRONMENTAL CLEARANCES/PERMITS		5.00%			**$78,000.00**
20 YEAR O&M COSTS (2.5% DISCOUNT RATE)					**$400,000.00**
TOTAL ESTIMATED PROBABLE PROJECT COST					**$2,440,000.00**

Attachment F: Letters of Support

LOWERLOUP
NATURAL RESOURCES DISTRICT

2620 Airport Drive
Ord, Nebraska
68862-1002
(308) 728-3221
(308) 728-5669 FAX
llnrd.org

July 27, 2017

Director Gordon W. Fassett, P.E.
Nebraska Department of Natural Resources
301 Centennial Mall South, 4th Floor
P.O. Box 94676
Lincoln, Nebraska 68509-4676

RE: Water Sustainability Fund Application for Columbus Area Recharge Project

Dear Director Fassett and Members of the Natural Resources Commission:

This letter is to document our support and financial commitment for the development of the Columbus Area Recharge Project. As a project partner, the Lower Loup Natural Resources District is submitting this Water Sustainability Fund Grant Application to develop a groundwater recharge project.

A declining groundwater trend has been identified in the southeast portion of Columbus, beginning in approximately 2010. A recently completed engineering study identified viable water sources and recharge/water management projects to reduce the decline. This proposed recharge project would utilize return water being discharged by ADM by allowing it to pond and infiltrate back into the water table, thus creating a sustainable approach to reduce groundwater declines.

As General Manager for the Lower Loup Natural Resources District, I am authorized to commit financial resources in support of this application. The Lower Loup Natural Resources District will commit $163,200.00 in local financial support for the proposal including the $80,000.00 O&M for a total of $243,200.00. These dollars, combined with the commitment from other project partners, will provide a total cost-share of $816,000.00 for the proposal (40%).

We urge the Nebraska Natural Resources Commission to recognize the importance and need for support and funding.

Sincerely,

LOWER LOUP NATURAL RESOURCES DISTRICT

Leon "Butch" Koehlmoos
General Manager

pc Russell Callan

Archer Daniels Midland Company
North American Headquarters
PO Box 1470
Decatur, Illinois 62525
t (217) 424 5200

ADM.COM

July 20, 2017

Mr. Russell Callan
Assistant General Manager
Lower Loup Natural Resources District
2620 Airport Drive, P.O. Box 210
Ord, NE 68862-0210

Dear Mr. Callan,

ADM is pleased to provide this letter of intent to provide funding up to the amount of $571,200 for the construction and engineering of the Columbus Area Water Resources Assessment Phase II project ("Alternative 3"). Additionally, over the next 20 years, ADM will provide 70% of the ongoing operation and maintenance cost, not to exceed $14,000 per year. This commitment to funding is based on our understanding we will enter into an agreement that:

1) The Lower Loup Natural Resources District will be responsible for project construction, ownership of the system, and ongoing operation and maintenance.
2) To support ADM's water tracking metrics, flow meter(s) will be installed to collect data on the volume of water pumped to the recharge basin(s), which will be provided at least monthly to ADM.
3) This project will not negatively affect water permits at ADM's facility.

Sincerely,

DJB

Chris Cuddy
Senior Vice President,
President Corn Processing Division
#90114.1

The City of **Columbus**

ENGINEERING DEPARTMENT

Phone: 402-562-4236 Richard J. Bogus, P.E. Fax: 402-562-4265

July 25, 2017

Director Gordon W. Fassett, PE
Nebraska Department of Natural Resources
301 Centennial Mall South, 4th Floor
PO Box 94676
Lincoln, NE 68509-4676

RE: Water Sustainability Fund Application for Columbus Area Recharge Project

Dear Director Fassett and Members of the Natural Resources Commission,

This letter is to document our support and financial commitment for the development of the Columbus Area Recharge Project. As a project partner, the City of Columbus (City) supports the Water Sustainability Fund Grant Application submitted by the Lower Loup Natural Resources District to develop a groundwater recharge project.

A declining groundwater trend has been identified in the southeast portion of Columbus, beginning in approximately 2010. A recently completed engineering feasibility study identified viable water sources and recharge/water management projects to reduce the decline. The selected recharge project would utilize return water being discharged by ADM by allowing it to pond and infiltrate back into the water table, thus creating a sustainable approach to reduce groundwater declines.

As Mayor of the City, I will commit my support of this application. Pending city council approval of the fiscal year 2017-2018 budget, and in coordination and commitments with the Christopher's Cove Association and Platte County, the partner's will commit a combined $121,600 in local financial support for the proposal submitted by the Lower Loup Natural Resources District. These construction and projected 20 year operations and maintenance dollars will provide the 40% cost share required.

The City fully supports the Lower Loup Natural Resources District's application and urges the Nebraska Natural Resources Commission to recognize the importance and need for support and funding.

Sincerely,

James B. Bulkley
Mayor
City of Columbus

Pc: Tara Vasicek, City Administrator
Rick Bogus, City Engineer

2424 14th Street • P. O. Box 1677 • Columbus, NE 68602-1677 Email: rick.bogus@columbusne.us

RECEIVED JUL 26 2017

July 19, 2017

Director Gordon W. Fassett, PE
Nebraska Department of Natural Resources
301 Centennial Mall South, 4th Floor
PO Box 94676
Lincoln, NE 68509-4676

RE: Water Sustainability Fund Application for Columbus Area Recharge Project

Dear Director Fassett and Members of the Natural Resources Commission,

This letter is to document our support and financial commitment for the development of the Columbus Area Recharge Project. As a project partner, Christopher's Cove Assocation supports the Water Sustainability Fund Grant Application submitted by the Lower Loup Natural Resources District (LLNRD) to develop a groundwater recharge project.

A declining groundwater trend has been identified in the southeast portion of Columbus, beginning in approximately 2010. A recently completed engineering study identified viable water sources and recharge/water management projects to reduce the decline. This proposed recharge project would utilize return water being discharged by ADM by allowing it to pond and infiltrate back into the water table, thus creating a sustainable approach to reduce groundwater declines.

The June 22, 2017, LLNRD Alternative Analysis Summary provides project alternatives to recharge the aquifer. Alternative 3 was selected as the preferred alternative by the LLNRD Board. The Christopher Cove Association [CCA] also strongly supports Alternative 3 as the best overall solution. Cost estimates for Alternative 3 appear reasonable, as well as the cost sharing with other project partners. CCA is committed to provide financial support for the project in coordination with the City.

We fully support the Lower Loup Natural Resources District's application and urge the Nebraska Natural Resources Commission to recognize the importance and need for support and funding.

Sincerely,

Gregg Melliger
President Christopher's Cove Association

cc: Roger Iwansky
Don Mroczek
John Bailey
David Hellbusch
Pat Sackett
Paul Louis