MCCLUSKY CANAL IRRIGATION MASTER PLAN

For

Garrison Diversion Conservancy District

IRRIGATION MASTER PLAN REPORT

August 2016

AE2S Project #: *P00200-2013-009*

MCCLUSKY CANAL IRRIGATION MASTER PLAN REPORT

August 2016

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the laws of the State of North Dakota.

This document was originally issued and sealed by

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August 31, 2016 and the original documents are stored at the office of Advanced Engineering &

Environmental Services, Inc.

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Chapter 1.0 Irrigation Master Plan for the McClusky Canal

1.1 Project Background

The McClusky Canal is currently authorized for the development of up to 23,700 acres for irrigation. Presently, the 74-mile canal is underutilized for irrigation, and the State funding for the development of irrigation continues to go largely unused each biennium. As a result, the Garrison Diversion Conservancy District (GDCD) elected to engage Advanced Engineering and Environmental Services, Inc. (AE2S) to help plan for future irrigation growth through the development of a comprehensive irrigation master plan for the McClusky Canal area. The goal is to help the Garrison Diversion comprehensively plan for irrigation development from the canal by identifying and prioritizing potential irrigation projects and/or sub-projects and phasing, and to identify gaps or shortcomings that may preclude such orderly and practical irrigation development with respect to feasibility, logistics, and funding.

1.2 Irrigable Acreage Analysis

AE2S has provided an analysis of the irrigable acreage available along the McClusky Canal in the following sections. This was accomplished through an evaluation of land parcels within ten miles along either side of the canal, an analysis of available soil types, slope of available land, available parcels of land, and results presented in graphics/figures or maps to show the following:

1.2.1 Existing Irrigation Infrastructure along the McClusky Canal

Analyze and gather data for any existing irrigation infrastructure and summarize these findings in appropriate maps, figures, and tables. This also includes showing any active irrigation permits authorized through the North Dakota State Water Commission.

1.2.2 Summary of Irrigation Potential based on Prior Analyses

Research and gather data from stakeholder entities and agencies related to previous analyses of irrigation potential along the McClusky Canal, and analyze and summarize these findings.

1.2.3 Summary of Irrigation Potential based on New Analyses

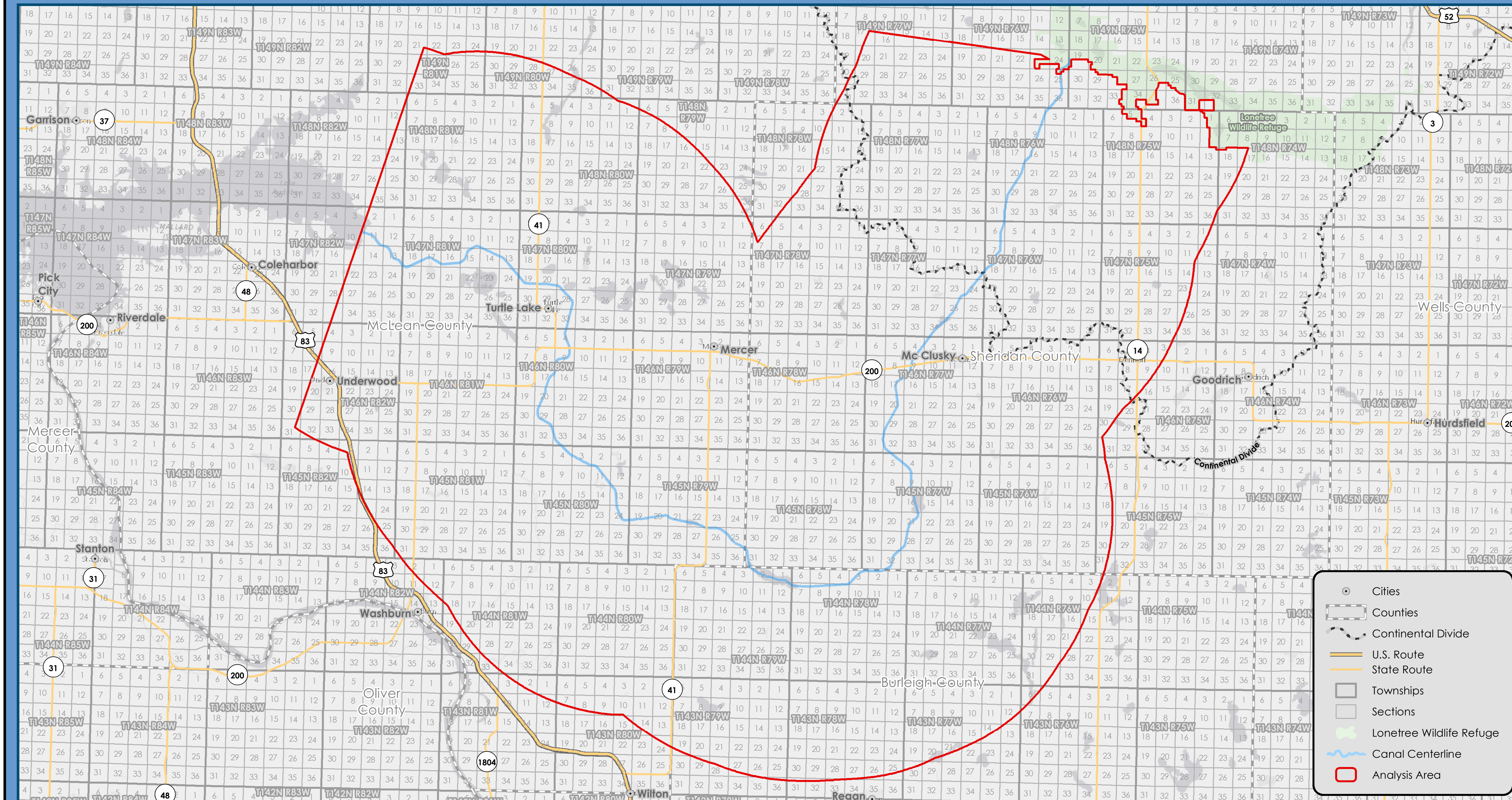
Research and gather current and existing data from stakeholder entities and agencies, and perform a new analysis showing irrigation potential along the McClusky Canal, and summarize these findings in any applicable maps, figures, and tables.

Chapter 2.0 **Irrigable Acreage Analysis**

2.1 Analysis Area

Land parcels were evaluated within 10 miles along either side of the canal. To the west, any land that was within the Lonetree Wildlife Refuge was excluded from this analysis. The analysis area is covers approximately 1300 square miles (832,342 acres) and falls within McLean, Sheridan, and Burleigh Counties in central North Dakota.

The area of analysis is mapped in *Figure 2.1*.



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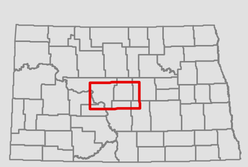
0 2.5 5 Miles

1 inch = 5 miles



Locator Map Not to Scale

Figure 2-1: Site Location Map

Irrigation Master Plan

Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

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C:\Data\Projects\RRVWSP\P00200-2013-009\100 Geomatic Services\Report Figure 2-01 Site Location Map.mxd | Edited by: DYL

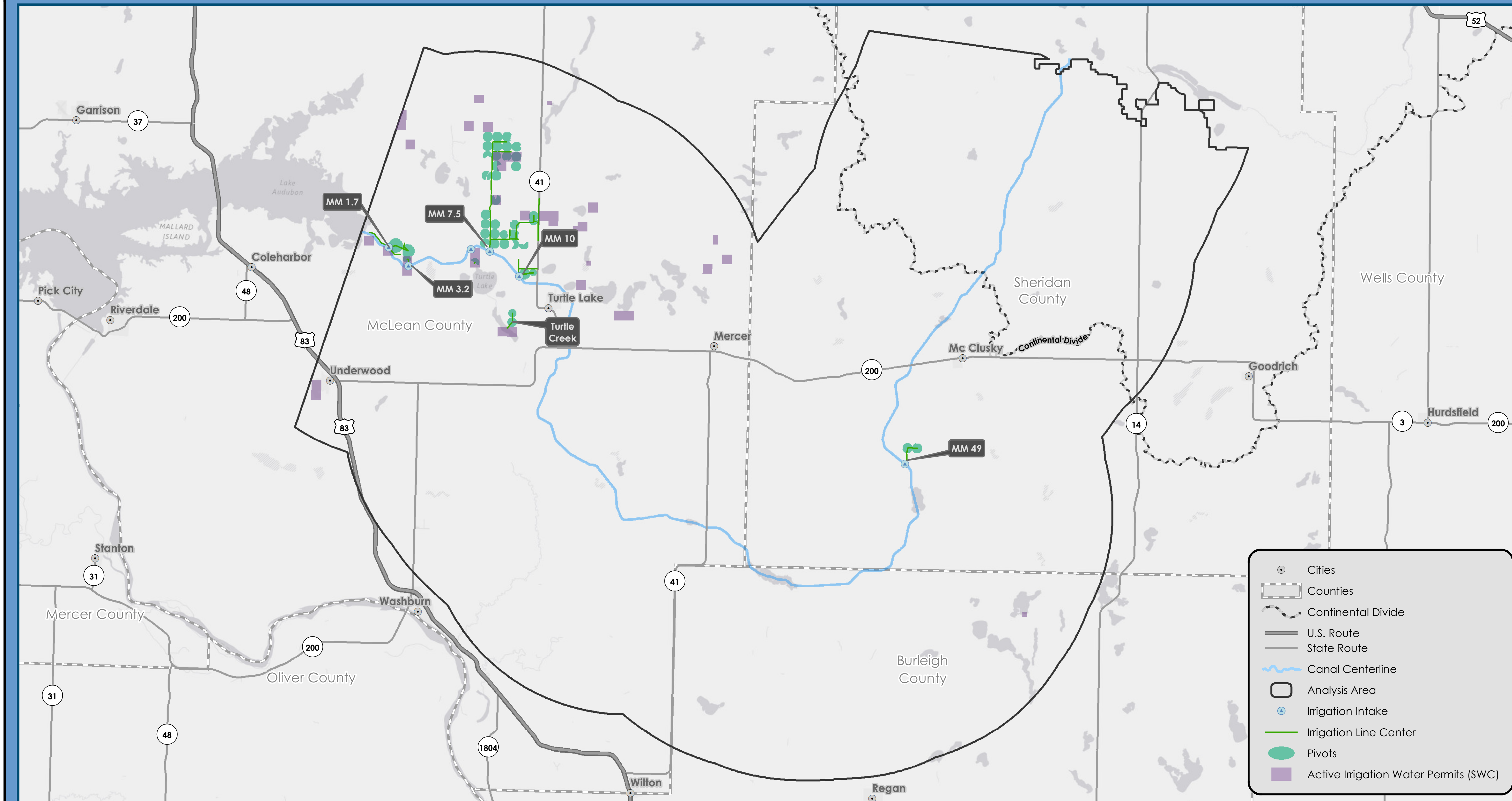
2.2 Existing Irrigation Infrastructure along McClusky Canal

Five major irrigation projects currently exist along the McClusky Canal. These are located at Mile Marker 1.7 (MM 1.7), Mile Marker 7.5 (MM 7.5), Mile Marker 10 (MM 10), Turtle Creek, and Mile Marker 49 (MM 49). A total of approximately 4,940 acres are currently irrigated through these five projects. Each site's irrigated area totals are shown in *Table 2.1*.

Table 2.1 Existing Irrigation Infrastructure Projects

Project	Irrigated Area (Acres)
MM 1.7	480
MM 7.5	3,696
MM 10	224
Turtle Creek	269
MM 49	269

In addition, the North Dakota State Water Commission (SWC) reports approximately 6,310 acres with active irrigation permits within the analysis area. Some of this acreage may be included as part of the existing irrigation infrastructure projects listed in *Table 2.1*. Current infrastructure and SWC permitted sites are mapped and shown in *Figure 2.2*.



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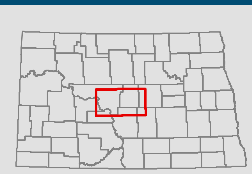

Locator Map Not to Scale

Figure 2-2: Existing Irrigation Infrastructure

Irrigation Master Plan
Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

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2.3 Summary of Irrigation Potential Based on Prior Analyses

The Garrison Diversion performed an in depth analysis of irrigation potential within 15 miles of the McClusky Canal, from the canal headworks located at Mile Marker 1 to the approximate location of Mile Marker 58 near Hoffer Lake.

The complete methodology is documented and shown in the Garrison Diversion's "Master Irrigation Plan Soils Evaluation" report included in *Appendix B*.

On a quarter-section basis, each site was evaluated in detail for the presence of limiting natural features (such as wetlands and waterbodies) or obstacles (such as transmission lines or roadways), and a mix of soil classifications deemed suitable for irrigation purposes.

The *Figure 2.3* flow chart describes the overall screening criteria.

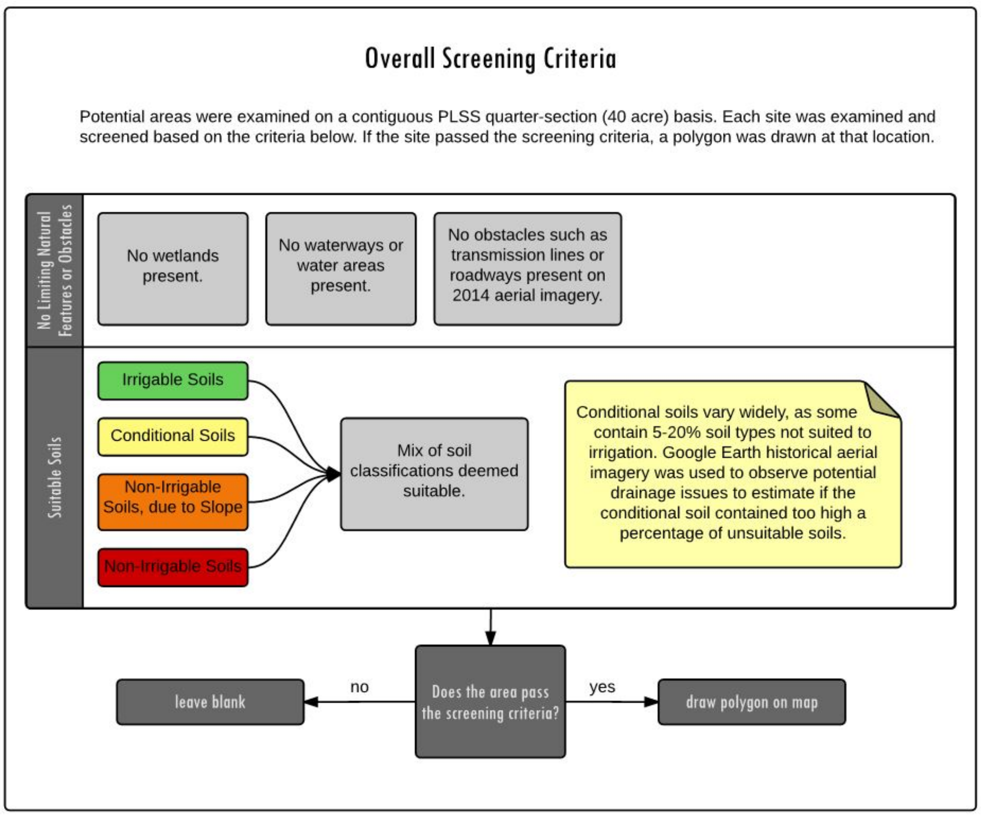

Figure 2.3 Overall Screening Criteria

Soils were classified according to a combination of their slope and erosion potential, and the criteria in NDSU Extension Service Publication AE-1637 as irrigable, conditional, non-irrigable due to slope, and non-irrigable. In addition, soils that were classified as conditional according to AE-1637 but in reality are known to have a high water holding capacity and poor drainage were classified as non-irrigable for the purposes of this analysis. As conditional soils vary widely, additional Google Earth historical aerial imagery was utilized to observe potential past drainage issues.

A flow chart describing these soils classification is shown in *Figure 2.4*.

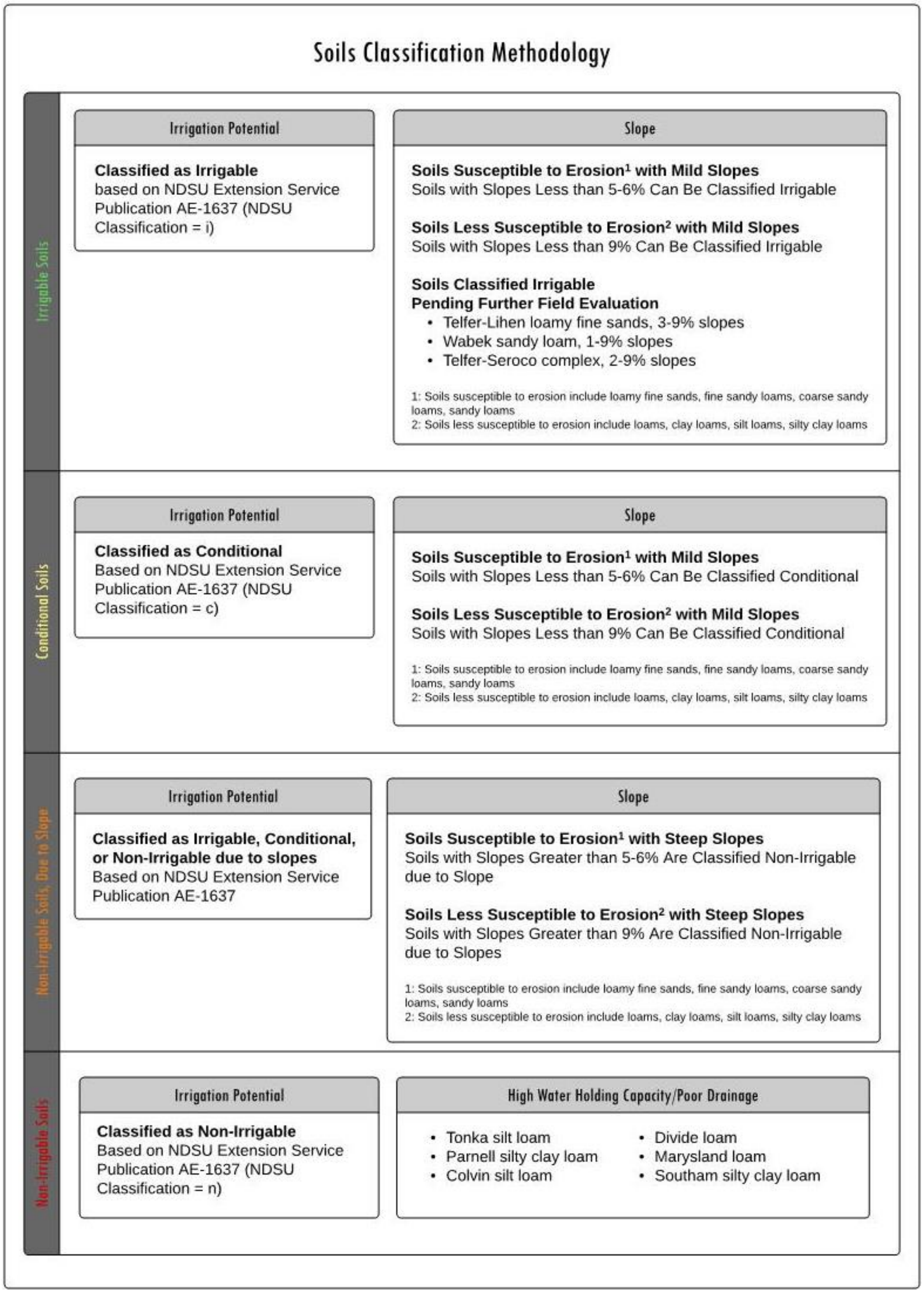

Figure 2.4 Soil Classification Methodology

After the Garrison Diversion's soils investigation was complete, but before Garrison Diversion engaged with AE2S, the Burleigh County soils were updated by the Natural Resources Conservation Service (NRCS). The updated soils data was obtained and appropriately categorized. Although there was a significant reclassification of soils, once these were classified, there were minimal changes to these soils resulting in no effect of the previous determination of irrigation potential. The most significant change was a reduction in conditional soils and an increase in non-irrigable soils within the area of interest.

The results of the soil classification are shown in *Figure 2.5*.

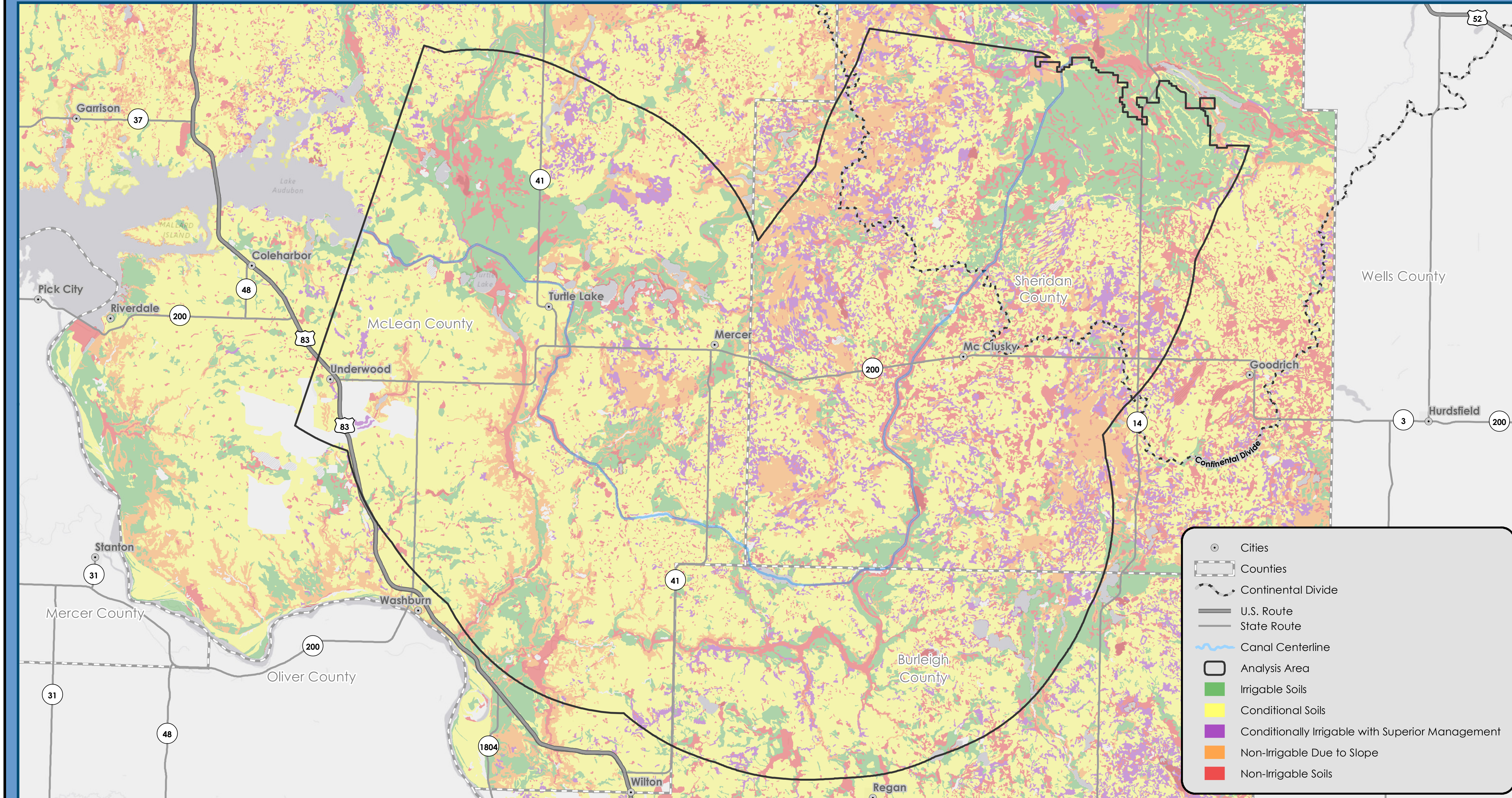

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Figure 2-5: Soils Classified by Irrigability

Irrigation Master Plan

Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

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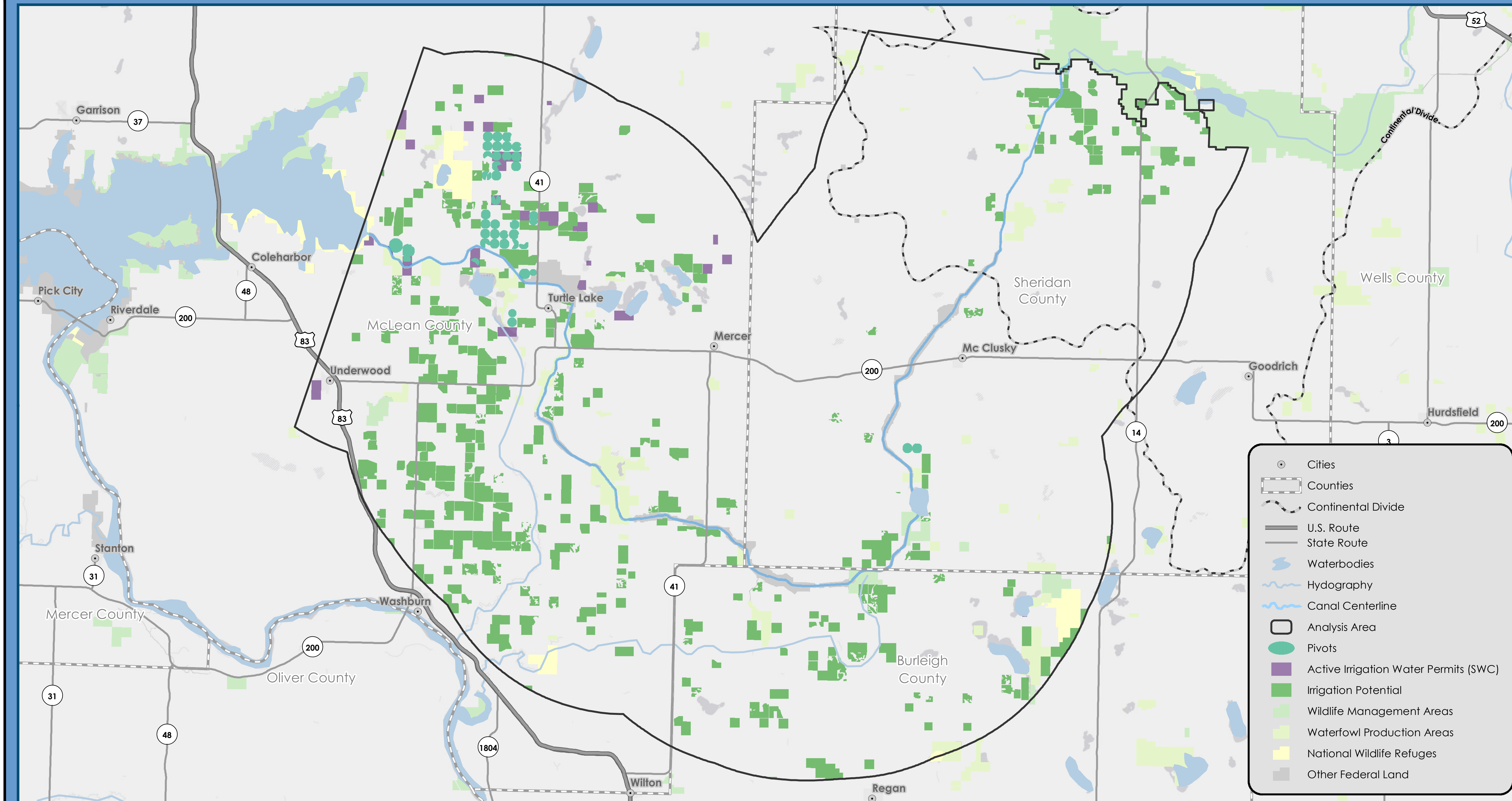
C:\Data\Projects\RRVWSP\P00200-2013-009\100 Geomatic Services\Report Figure 2-05 Soils Classified by Irrigability.mxd | Edited by: DYL

2.4 Summary of Irrigation Potential based on New Analyses

Further expanding the methodology used in the prior Garrison Diversion irrigation potential analysis, and performing a new analysis for the entire analysis area yielded a total of approximately 65,070 acres (102 square miles) of irrigation potential, or about 8% of the total land within the area of analysis.

These areas are shown in *Figure 2.6*.



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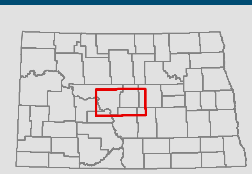

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Figure 2-6: Total Irrigation Potential

Irrigation Master Plan

Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

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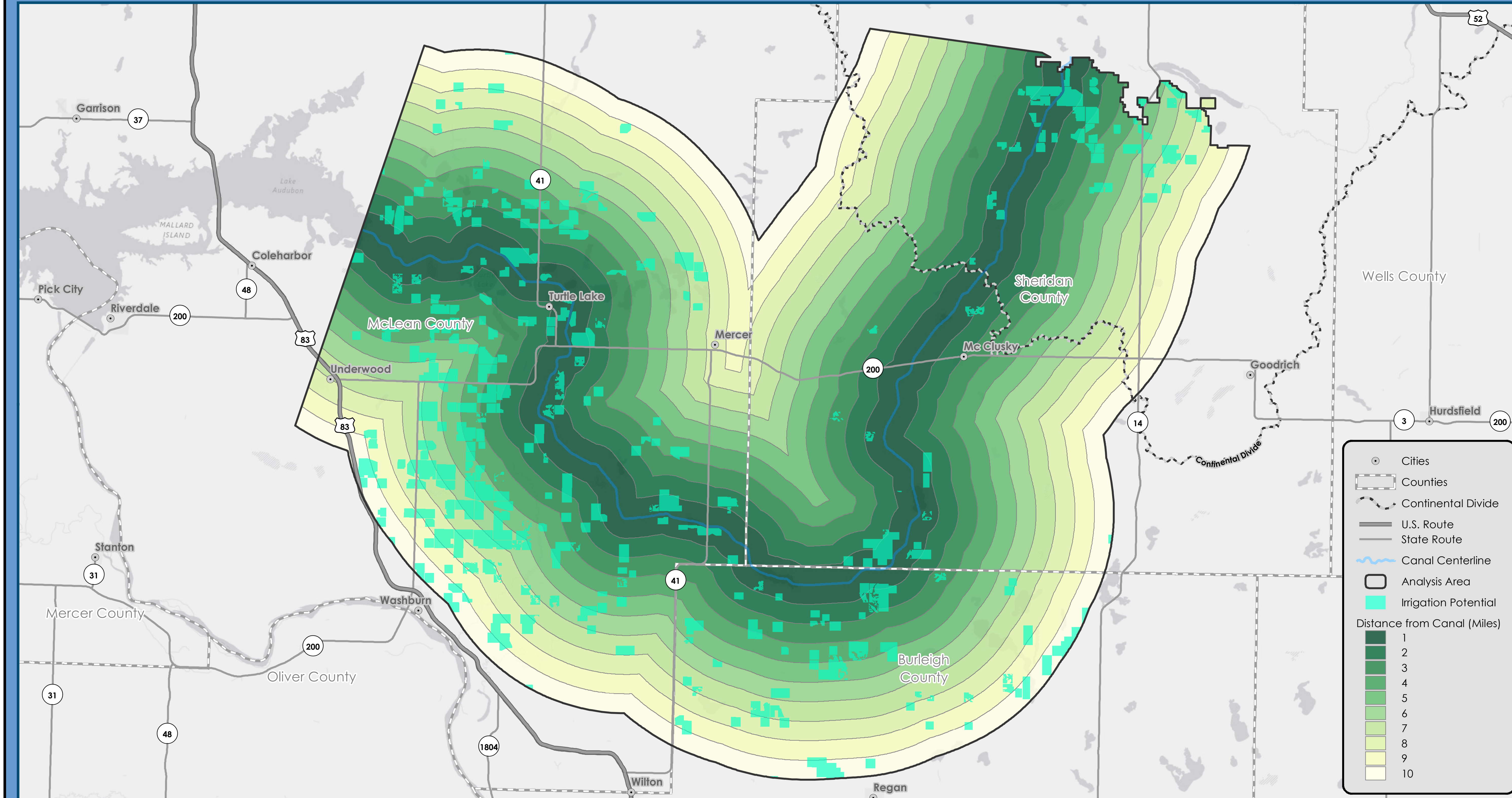
When looking at the distribution of the acres of irrigation potential, land can be classified according to *Table 2.2*. Fifty percent (50%) of the land that has irrigation potential is within 4 miles of the McClusky Canal.

Table 2.2 Distribution of Total Irrigation Potential

Distance from the Canal	Total Irrigation Potential (Acres)	Percent of Total Irrigation Potential
0-1 miles	10,140	16%
0-2 miles	17,695	27%
0-3 miles	24,538	38%
0-4 miles	32,345	50%
0-5 miles	39,620	61%
0-6 miles	46,221	71%
0-7 miles	52,574	81%
0-8 miles	57,114	88%
0-9 miles	60,429	93%
0-10 miles	65,070	100%

The distribution is also shown in *Figure 2.7*.



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N

0 2.5 5 Miles

1 inch = 5 miles

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Figure 2-7: Distribution of Total Irrigation Potential

Irrigation Master Plan

Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

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Chapter 3.0 **Irrigation Planning and Feasibility**

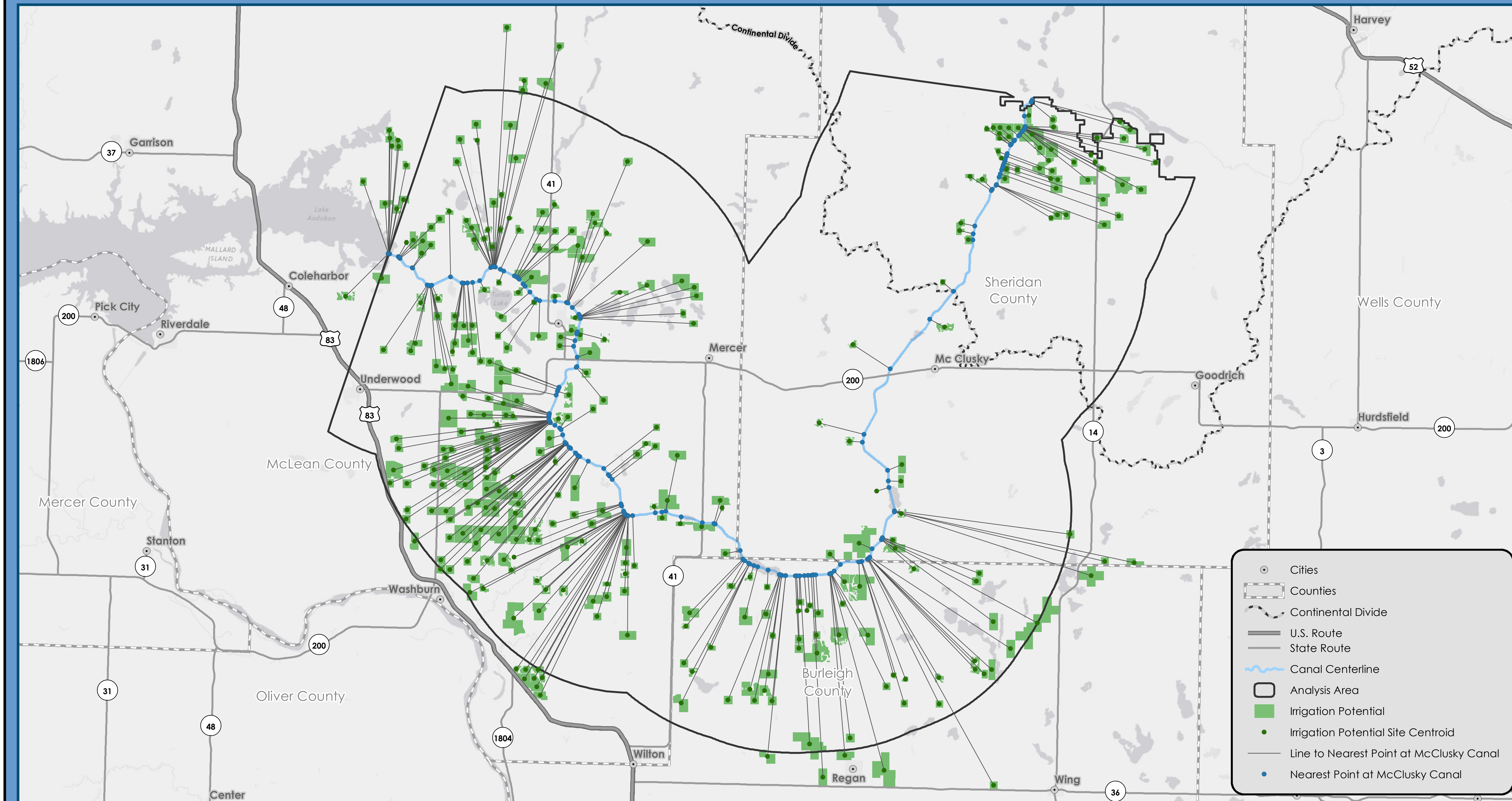
3.1 Irrigation Feasibility Analysis

The next step was to take the results of the Irrigable Acreage Analysis and prepare a feasibility analysis of the potential irrigable sites along the McClusky Canal by looking at factors like topography, elevation, overall distance from the canal, interested landowner participants, and the availability of electrical service and infrastructure. These factors were evaluated for each land tract with irrigation potential.

3.2 Gathering Data Sources

3.2.1 Overall Distance to Canal Analysis

The distance from the McClusky canal was determined by locating the centroid of each land tract with irrigation potential and then connecting it to the nearest canal access point, as shown in *Figure 3.1*.



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N

0 2.75 5.5 Miles

1 inch = 5.5 miles

Locator Map Not to Scale

Figure 3-1: Distance to Canal Analysis Overview

Irrigation Master Plan

Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

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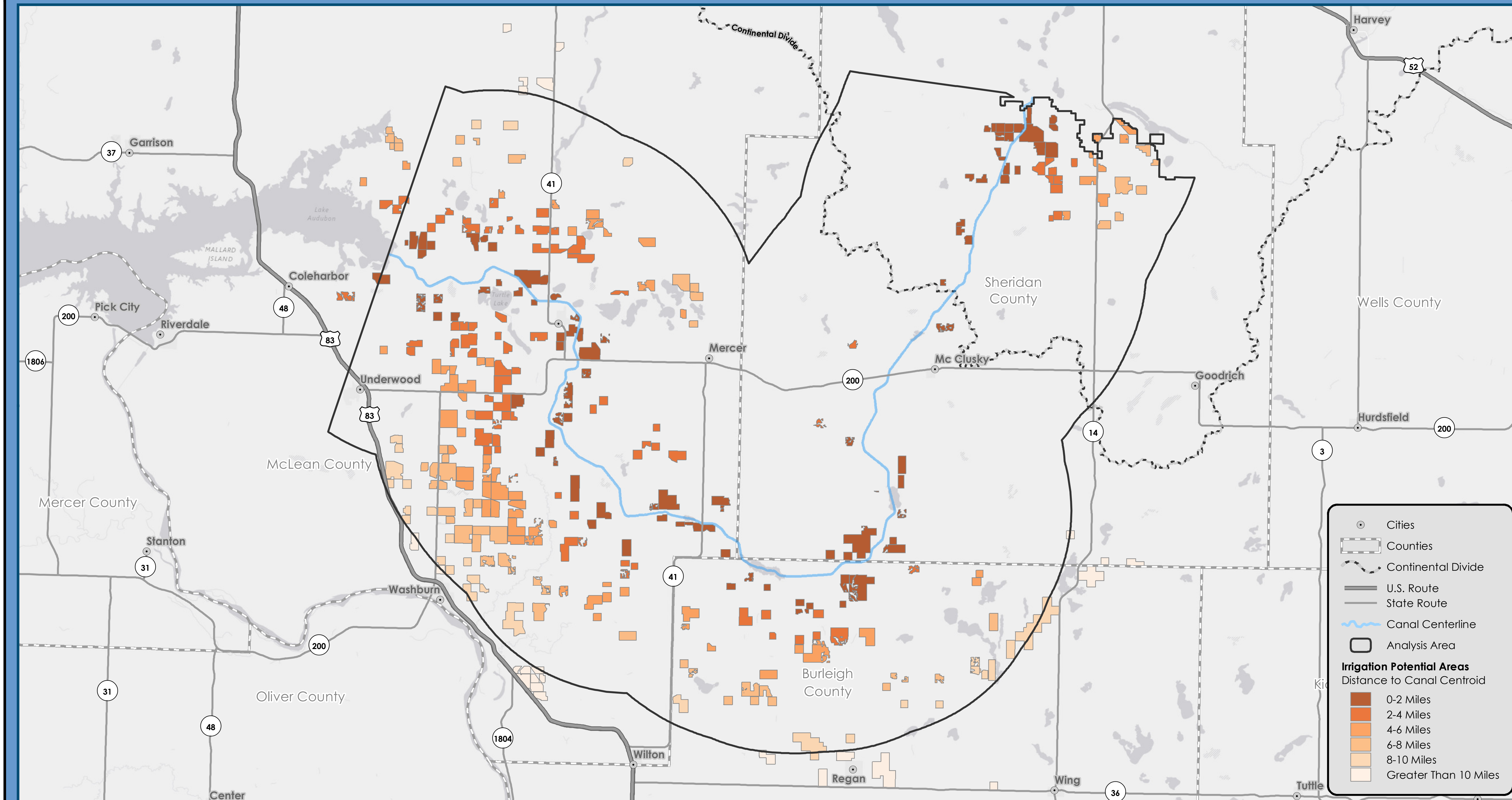
C:\Data\Projects\RRVWSP\P00200-2013-009\100 Geomatic Services\Report Figure 3-01 Distance to Canal Analysis Overview.mxd | Edited by: DYL

The distance from the land tract to the canal was assigned to each land tract with irrigation potential as shown in *Figure 3.2*.



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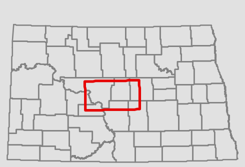

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Figure 3-2: Distance to Canal Analysis

Irrigation Master Plan

Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

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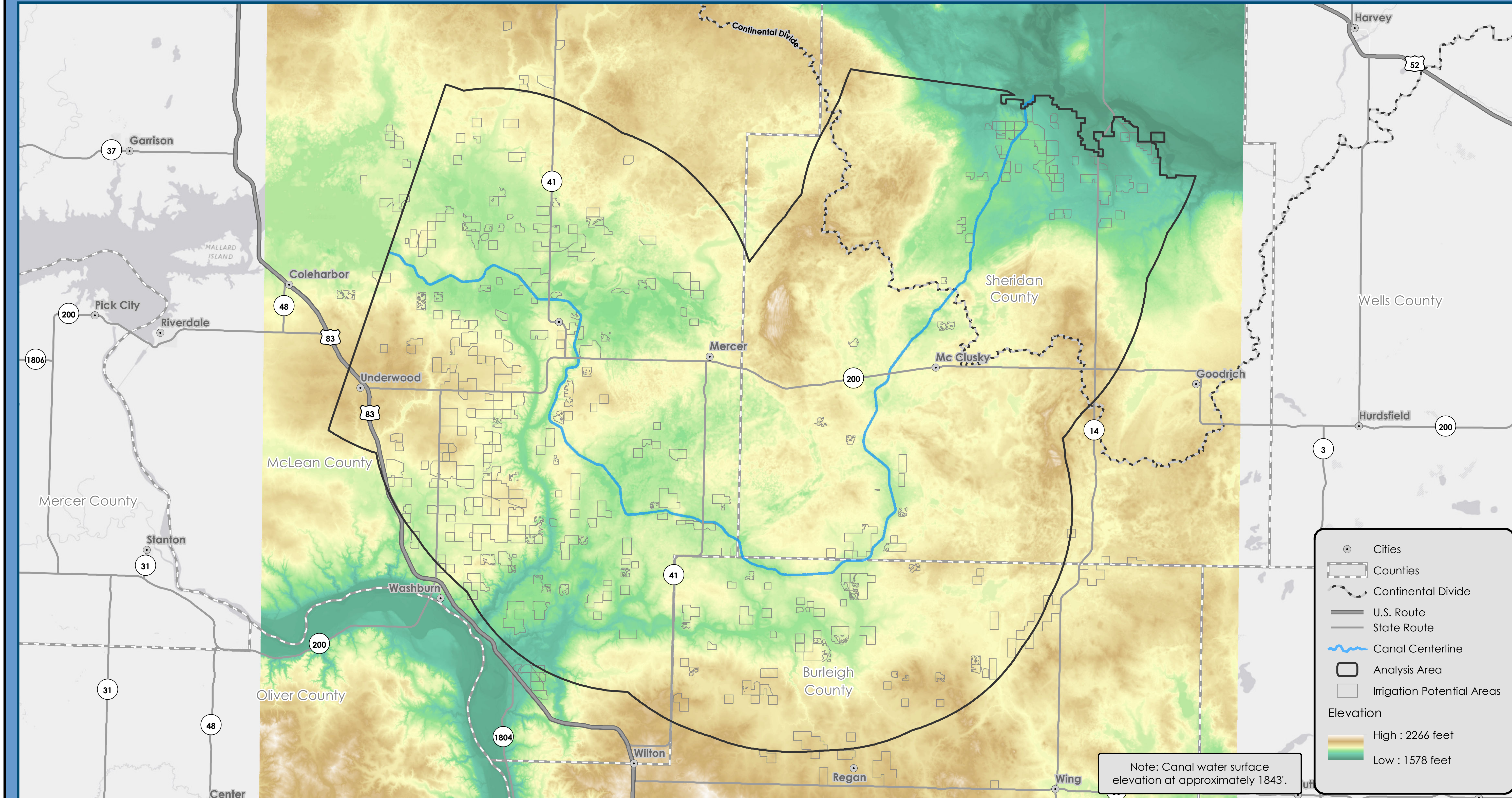
3.2.2 Overall Elevation and Topography Analysis

Topographic information was then obtained from the National Elevation Dataset as shown in *Figure 3.3*.



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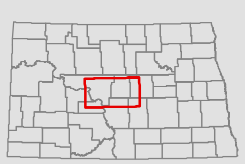

Locator Map Not to Scale

Figure 3-3: Elevation Analysis

Irrigation Master Plan

Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

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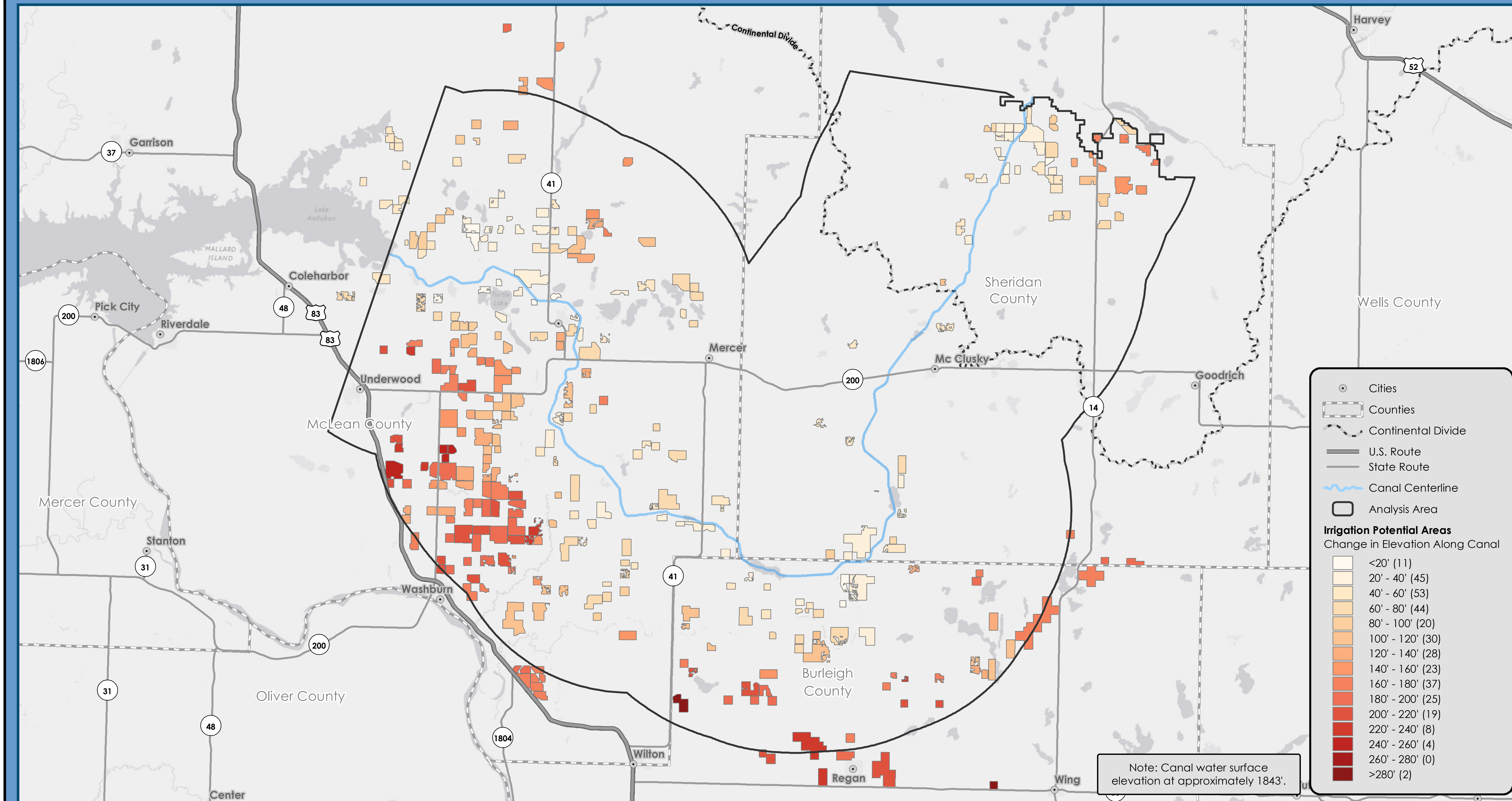
C:\Data\Projects\RRVWSP\P00200-2013-009\100 Geomatic Services\Report Figure 3-03 Elevation Analysis.mxd | Edited by: DYL

The change in elevation from the canal to each land tract is a crucial piece to the analysis as it directly relates to pumping calculations and pipeline distribution for potential projects. In order to approximate the change in elevation that any one land tract with irrigation potential might need to prepare for, it was assumed that each land tract would connect directly to the canal, as shown in *Figure 3.1.* An elevation profile along that connecting line was generated for each land tract, and statistics were calculated to determine the maximum and minimum elevations along this profile. Then, the minimum elevation was subtracted from the maximum elevation to determine the change in elevation for each land tract with irrigation potential, as shown in *Figure 3.4*.



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0 2.75 5.5 Miles

1 inch = 5.5 miles

Locator Map Not to Scale

Figure 3-4: Change in Elevation Along Distance to Canal Analysis

Irrigation Master Plan

Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

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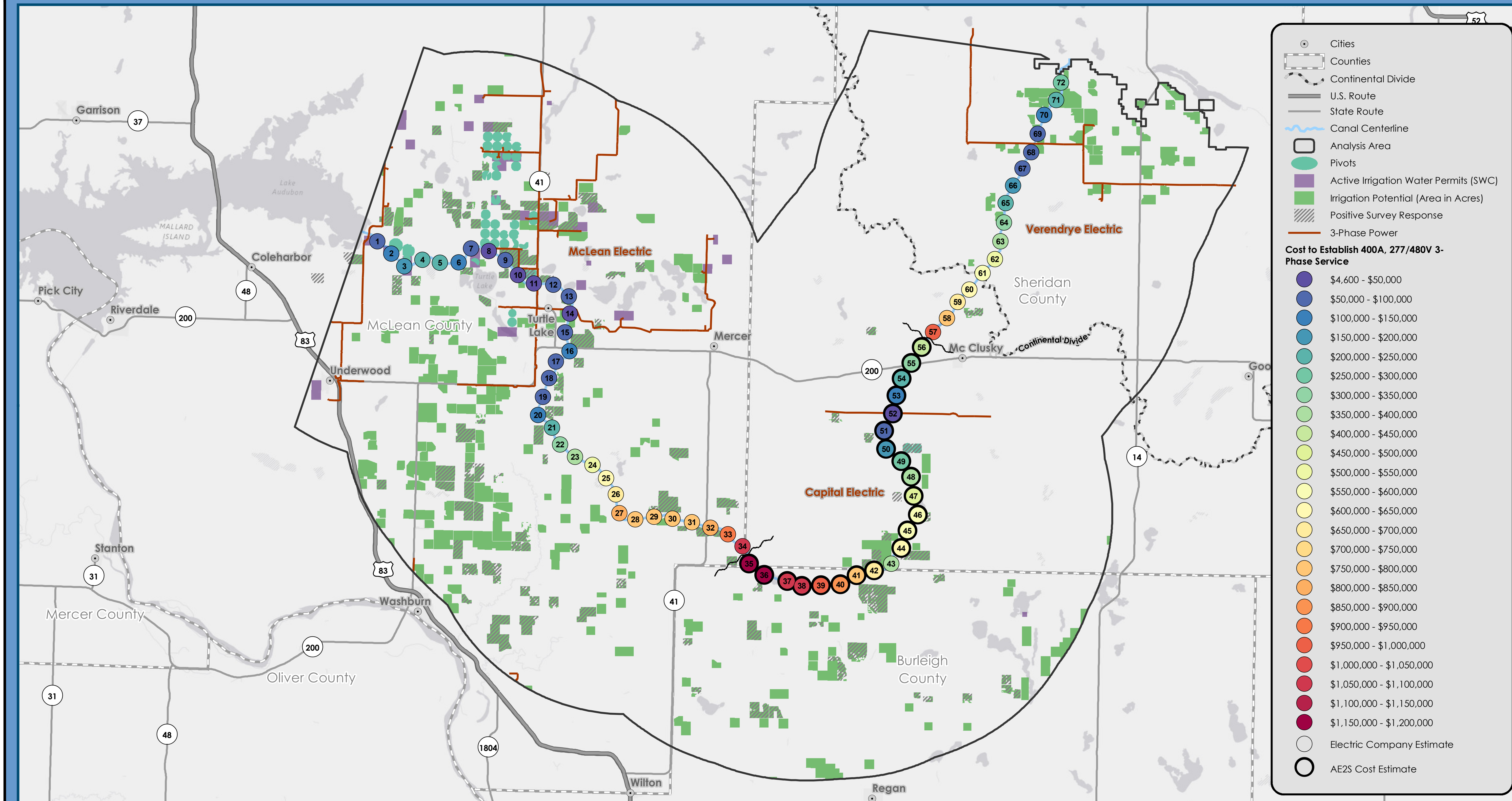
3.2.3 Interested Landowners

Garrison Diversion surveyed existing landowners for interest in irrigation from 2013-2015. These survey results were then matched to those landowners that also met the criteria for irrigation potential. This survey was likely a "snapshot in time," based on that landowner's current crop values, water, and individual experience, but provides a starting place for finding interested landowners with irrigable land potential.

3.2.4 Electrical Infrastructure and Availability Analysis

In order to evaluate the availability of electrical infrastructure for potential irrigation sites, AE2S reached out to Verendrye Electric Cooperative, Capital Electric Cooperative, and McLean Electric Cooperative in August 2015. AE2S received mapped infrastructure locations where available, as well as the cost of installing 3-phase electrical capacity to each mile marker point along the McClusky Canal. As electrical cost estimates were only provided for one mile marker from Capital Electric, AE2S estimated the cost by summing the x and y distance from the mile marker to existing electrical substations. Electrical cost estimate details are covered fully in *Chapter 4.0*. A map of the existing energy infrastructure and cost to bring 3-phase electrical service to each canal mile marker is shown below in *Figure 3.5*.



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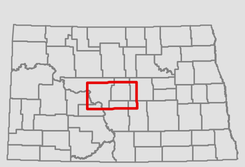

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Figure 3-5: Existing Energy Infrastructure and Cost Analysis

Irrigation Master Plan

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3.3 Irrigation Feasibility Analysis

Once the data related to irrigation feasibility was assembled, the next step was to find a lens through which to see the data and determine which sites would be most suited to selection. A weighted sum analysis was chosen because it allowed for all of the factors to be considered relative to their importance in the overall project feasibility.

For all identified land tracts that have irrigation potential, the following factors were considered:

- Change in Elevation from the Canal
- Distance from the Canal
- Belongs in a Cluster
- Electrical Cost at the Closest Mile Marker
- Land Owner Interest in Irrigation

The data related to each of these factors was classified so that a particular land tract was assigned one value per factor, on a scale from 0-3 (where 3 = best, 2 = good, 1 = OK, and 0 = poor). Then, the value for each factor was multiplied by the assigned weighting factor, and the resulting weighted values were summed to better identify more targeted parcels with irrigation potential.

A flow chart describing these factors, values, weights, and the weighted sum is shown in *Figure 3.6*.

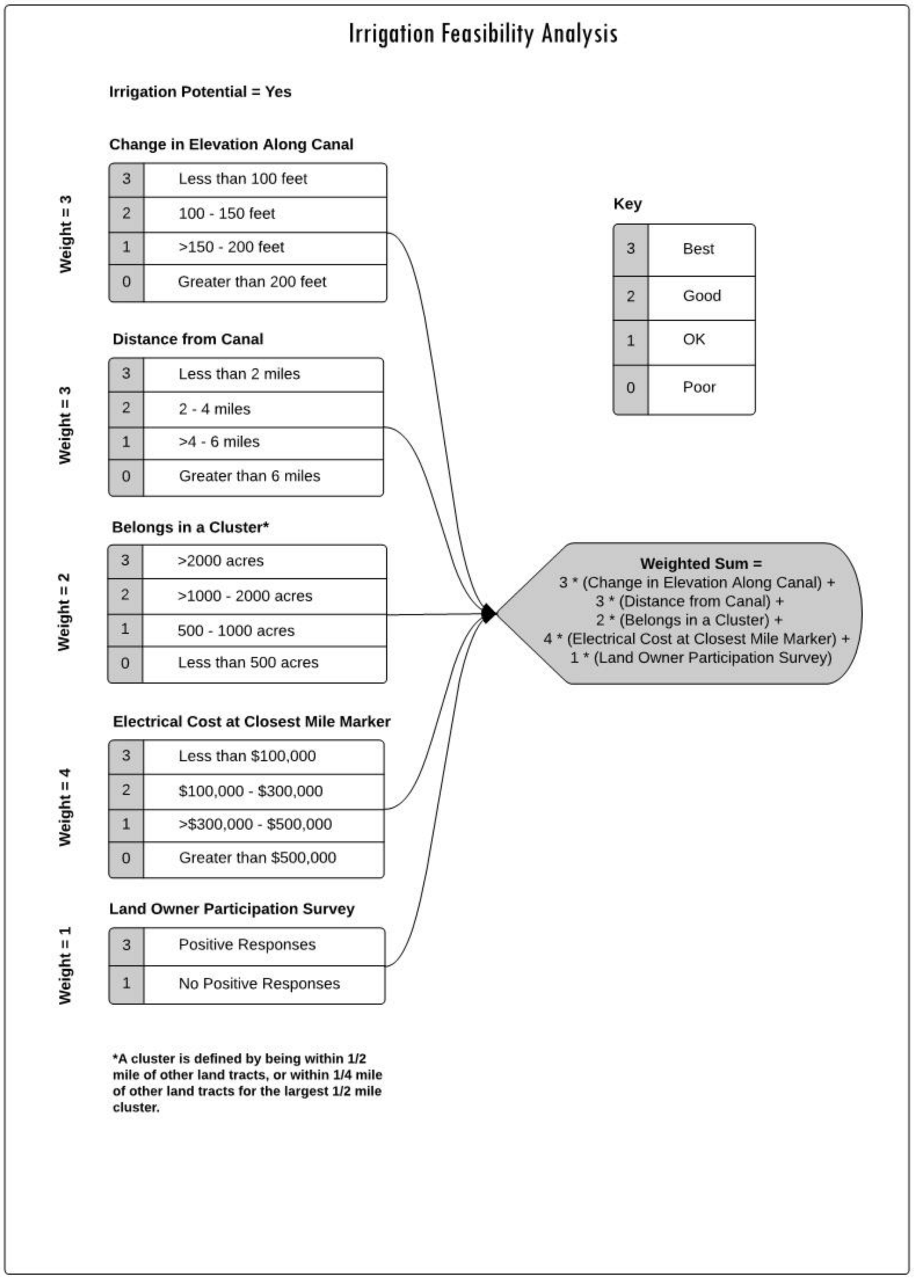


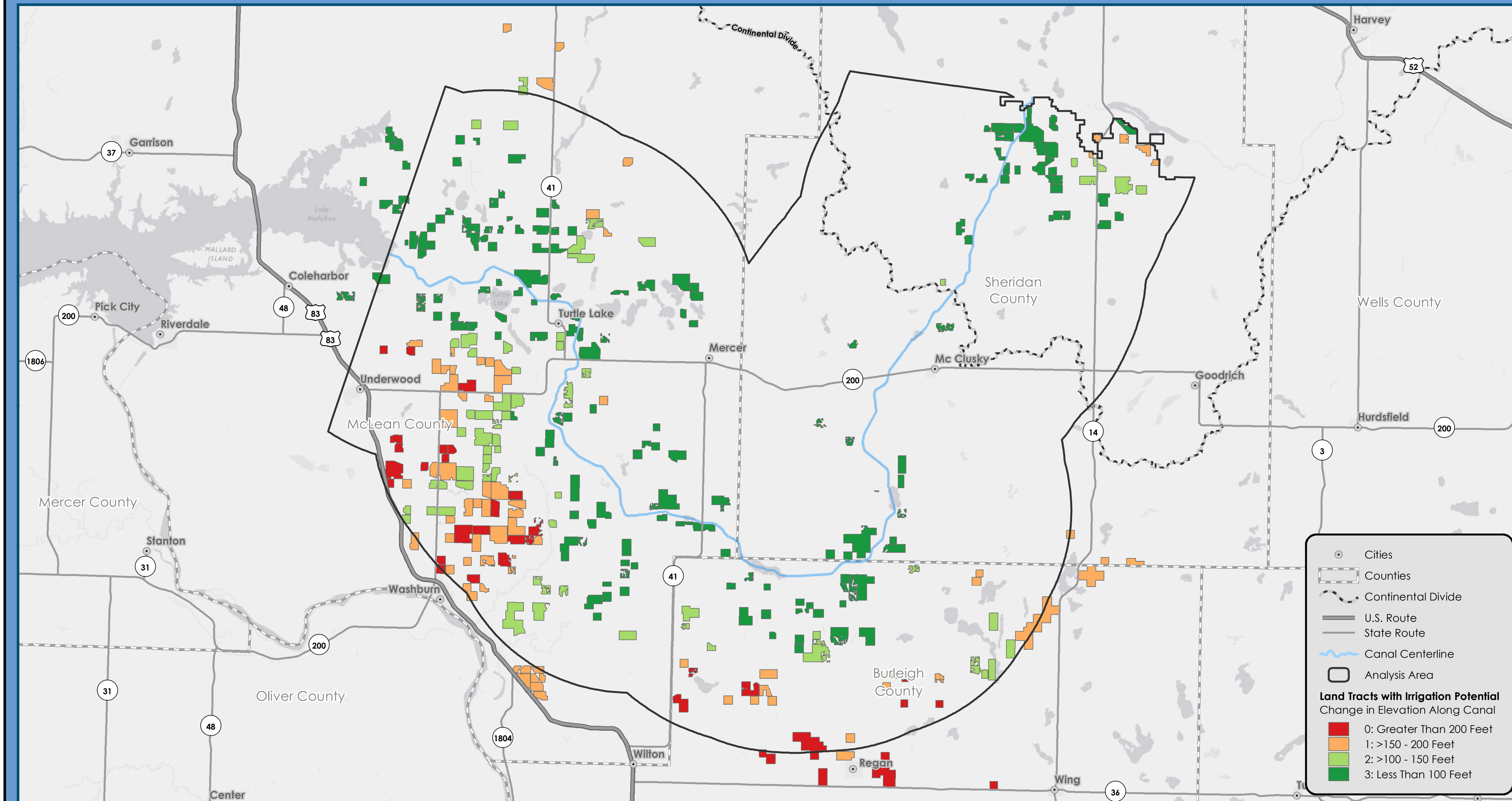
Figure 3.6 Irrigation Feasibility Analysis Flow Chart

3.3.2 *Change in Elevation Along Canal Analysis Factor*

Further utilizing the elevation data explained in *Section 3.2.2.*, the irrigable land tracts were taken and divided into four elevation classifications described as The Change In Elevation Along Canal Analysis Factor. These are shown in *Table 3.1* and *Figure 3.7*.

Table 3.1 Change in Elevation Along Canal Analysis Factor (Weight = 3)

Value	Description
3	Less than 100 feet
2	100 - 150 feet
1	>150 - 200 feet
0	Greater than 200 feet



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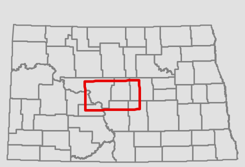
N

0 2.75 5.5 Miles

1 inch = 5.5 miles



Locator Map Not to Scale

Figure 3-7: Change In Elevation Along Canal Analysis Factor

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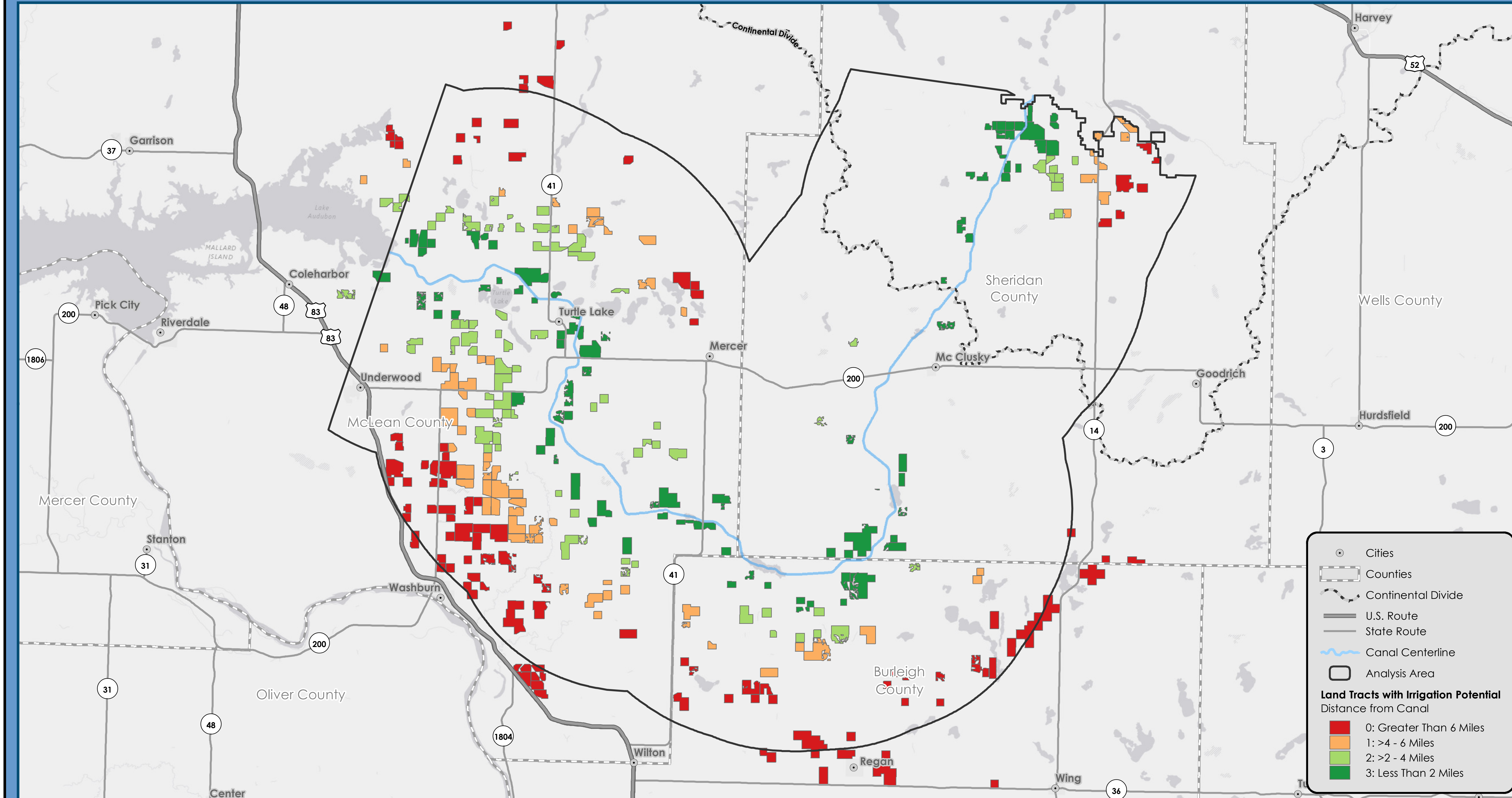
3.3.3 *Distance from Canal Analysis Factor*

The Distance from Canal Analysis Factor is shown in *Table 3.2* and *Figure 3.8*. This was derived from the data described in *Section 3.2.1* and separated into the shown distance classifications.

Table 3.2 Distance from Canal Analysis Factor (Weight = 3)

Value	Description
3	Less than 2 miles
2	2 - 4 miles
1	>4 - 6 miles
0	Greater than 6 miles



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N

0 2.75 5.5 Miles

1 inch = 5.5 miles

Locator Map Not to Scale

Figure 3-8: Distance from Canal Analysis Factor

Irrigation Master Plan

Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

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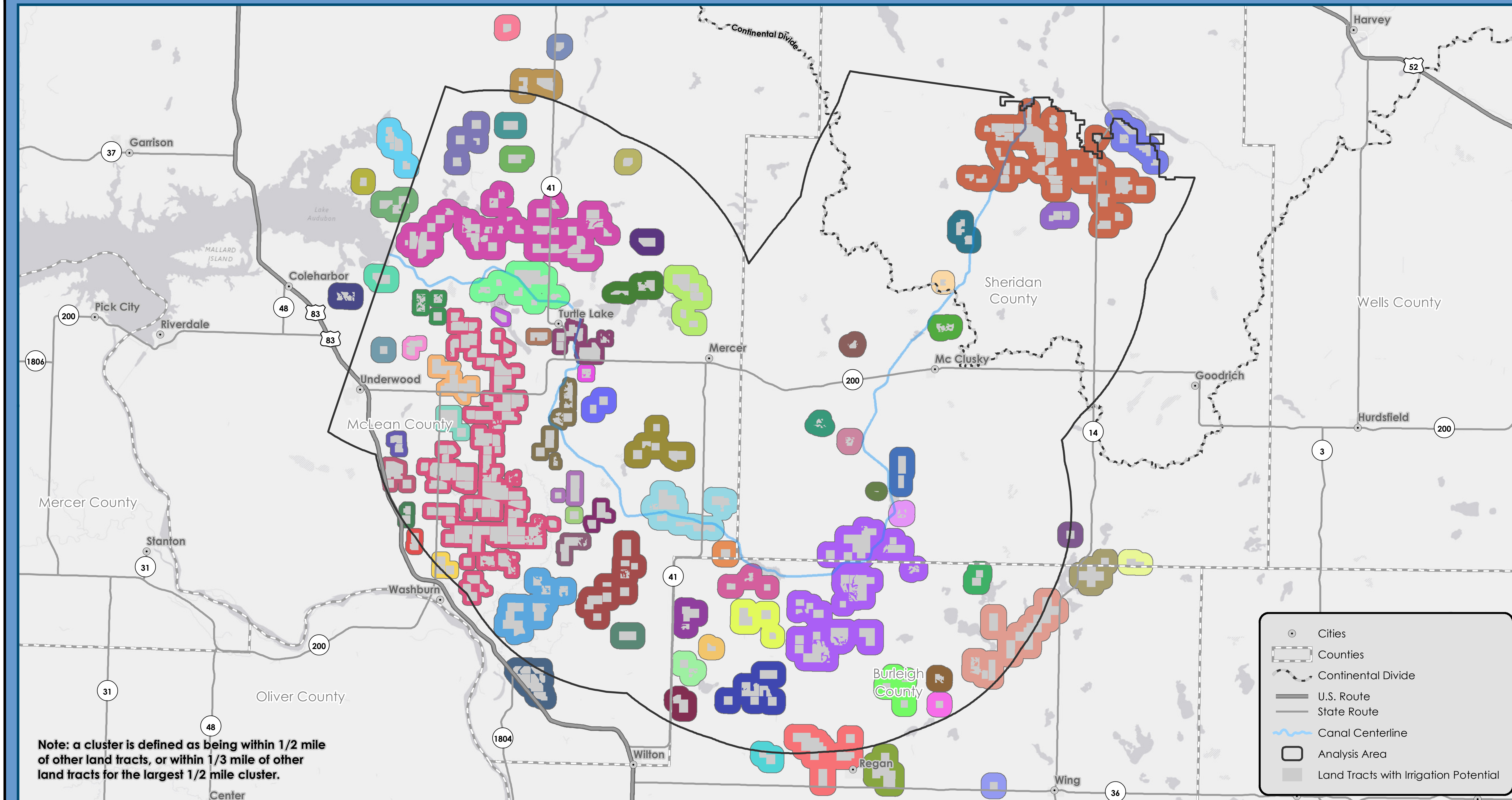
3.3.4 Belongs in a Cluster Analysis Factor

This analysis factor was created to capture the closeness of a potential site to other potential sites, as there is an advantage to placing a project where other projects could eventually be built out as well. A cluster was defined by being within a 1/2 mile of other land tracts, or within 1/4 mile of other land tracts for the largest 1/2-mile cluster.

A map of the layout of the clusters in shown in *Figure 3.9*.



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N

0 2.75 5.5 Miles

1 inch = 5.5 miles

Locator Map Not to Scale

Figure 3-9: Cluster Layout Analysis

Irrigation Master Plan

Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

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AE2S Advanced Engineering and Environmental Services, Inc.

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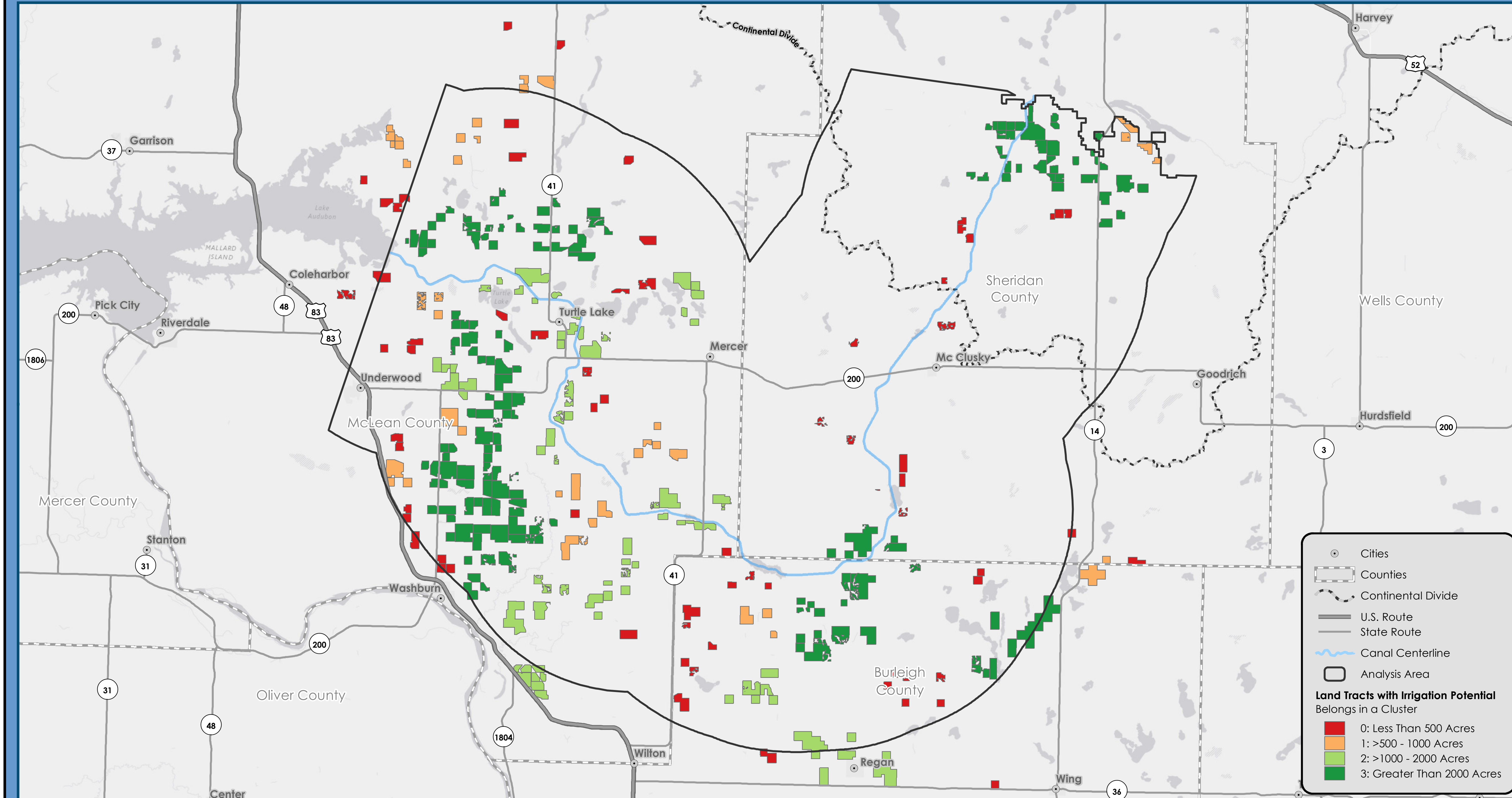
The project clusters were then sorted by their size in acres and classified in four different cluster sizes with a scoring emphasis being placed on larger acreages. The Belongs in a Cluster Analysis Factor is shown in *Table 3.3* and *Figure 3.10*.

Table 3.3 Belongs in a Cluster Analysis Factor (Weight = 2)

Value	Description
3	>2000 acres
2	>1000 - 2000 acres
1	500 - 1000 acres
0	Less than 500 acres



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N
0 2.75 5.5 Miles
1 inch = 5.5 miles

Locator Map Not to Scale

Figure 3-10: Belongs in a Cluster Analysis Factor (Cluster = Within 1/2 Mile of Other Land Tracts)

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Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

GARRISON DIVERSION

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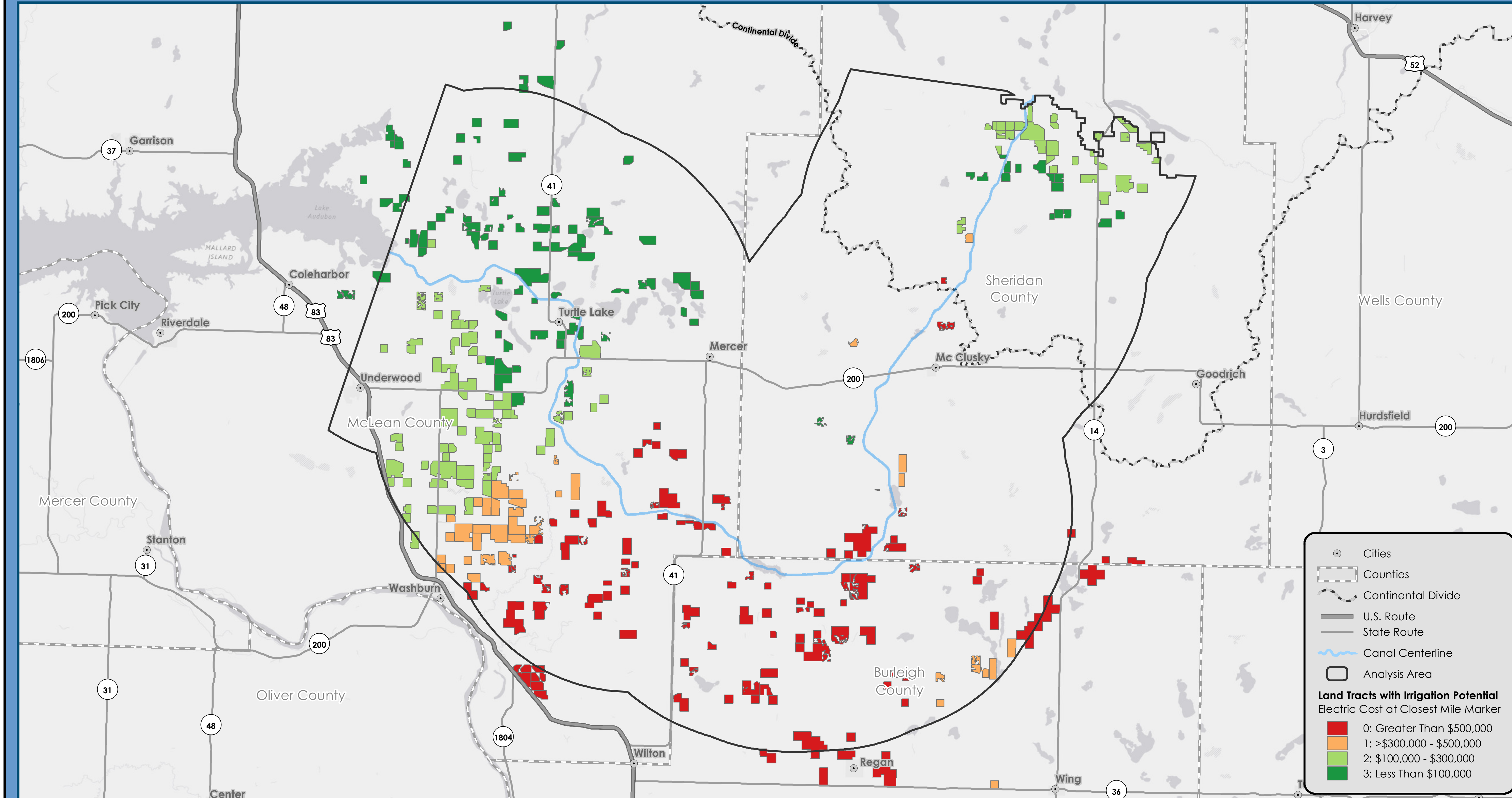
C:\Data\Projects\RRVWSP\P00200-2013-009\100 Geomatic Services\Report Figure 3-10 Belongs in a Cluster Analysis Factor.mxd | Edited by: DYL

3.3.5 *Electrical Cost at Closest Mile Marker Analysis Factor*

From the data and information described in *Section 3.2.4,* electrical costs along the canal were classified in four groups in the Electrical Cost at Closest Mile Marker Analysis Factor shown in *Table 3.4* and *Figure 3.11*. The highest rating weight of four was given for this analysis factor. This was based on the vast difference in 3-phase installation costs, and the overall effect these high costs have proven to be in the past in developing irrigation projects along the McClusky Canal.

Table 3.4 Electrical Cost at Closest Mile Marker Analysis Factor (Weight = 4)

Value	Description
3	Less than $100,000
2	$100,000 - $300,000
1	>$300,000 - $500,000
0	Greater than $500,000



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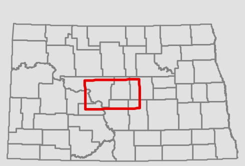
N

0 2.75 5.5 Miles

1 inch = 5.5 miles



Locator Map Not to Scale

Figure 3-11: Electric Cost at Closest Mile Marker Analysis Factor

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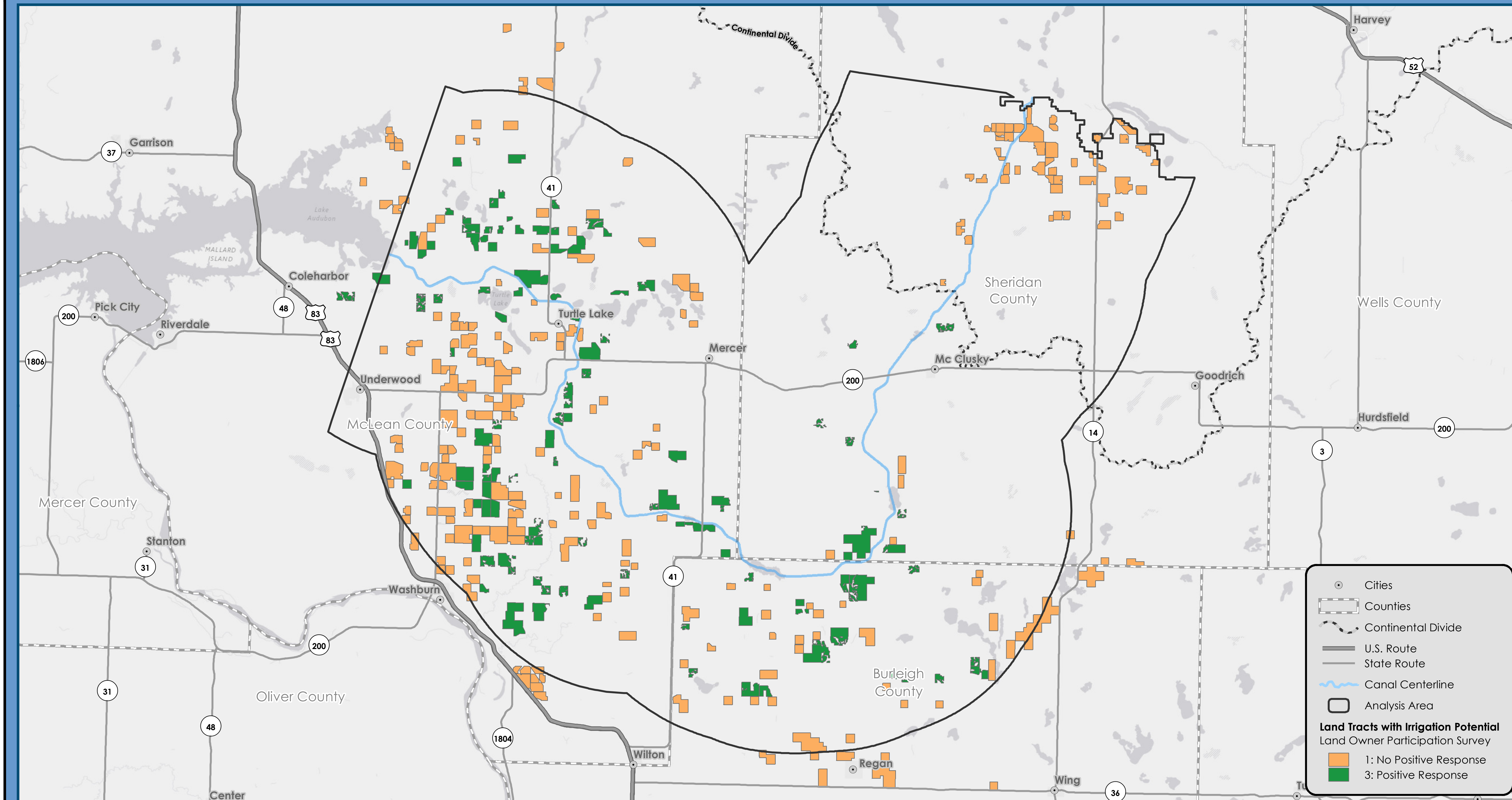
C:\Data\Projects\RRVWSP\P00200-2013-009\100 Geomatic Services\Report Figure 3-11- Electric Cost at Closest Mile Marker Analysis Factor.mxd | Edited by: DYL

3.3.6 *Land Owner Participation Survey Factor*

The Land Owner Participation Survey Factor is shown in *Table 3.5* and *Figure 3.12*, from the data described in *Section 3.2.3*.

Table 3.5 Land Owner Participation Factor (Weight = 1)

Value	Description
3	Positive Responses
1	No Positive Responses



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N

0 2.75 5.5 Miles

1 inch = 5.5 miles

Locator Map Not to Scale

Figure 3-12: Land Owner Participation Survey Factor

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3.3.7 Weighted Sum of All Factors Analysis

The weighted sum for each land tract for all of the previously described factors was found by multiplying the value for each factor by the weighting factor, and then summing those weighted values for an overall score. The land tracts identified with total weighted sums that are higher are considered more suited for irrigation projects than those land tracts with lower values.

Weighted Sum =

3 * (Change in Elevation Along Canal) +

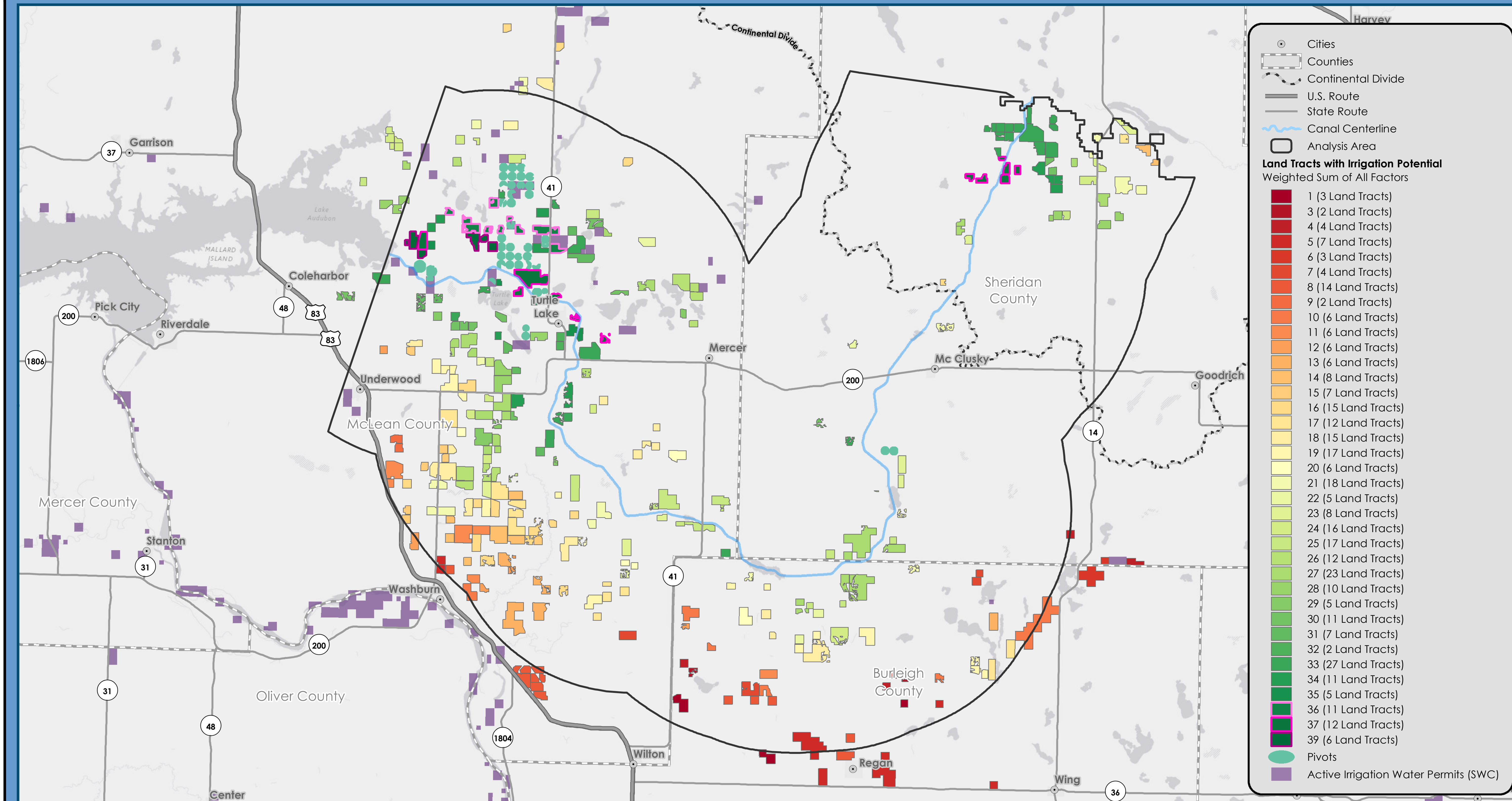
3 * (Distance from Canal) +

2 * (Belongs in a Cluster) +

4 * (Electrical Cost at Closest Mile Marker) +

1 * (Land Owner Participation Survey)

After this analysis, the overall result of these calculations are shown in the Weighted Sum of All Analysis Factors map in *Figure 3.13*.



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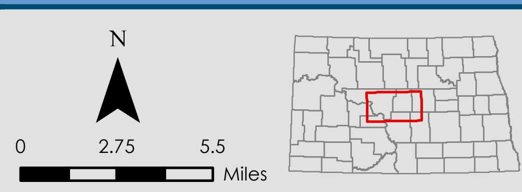

Figure 3-13: Weighted Sum of All Factors Analysis

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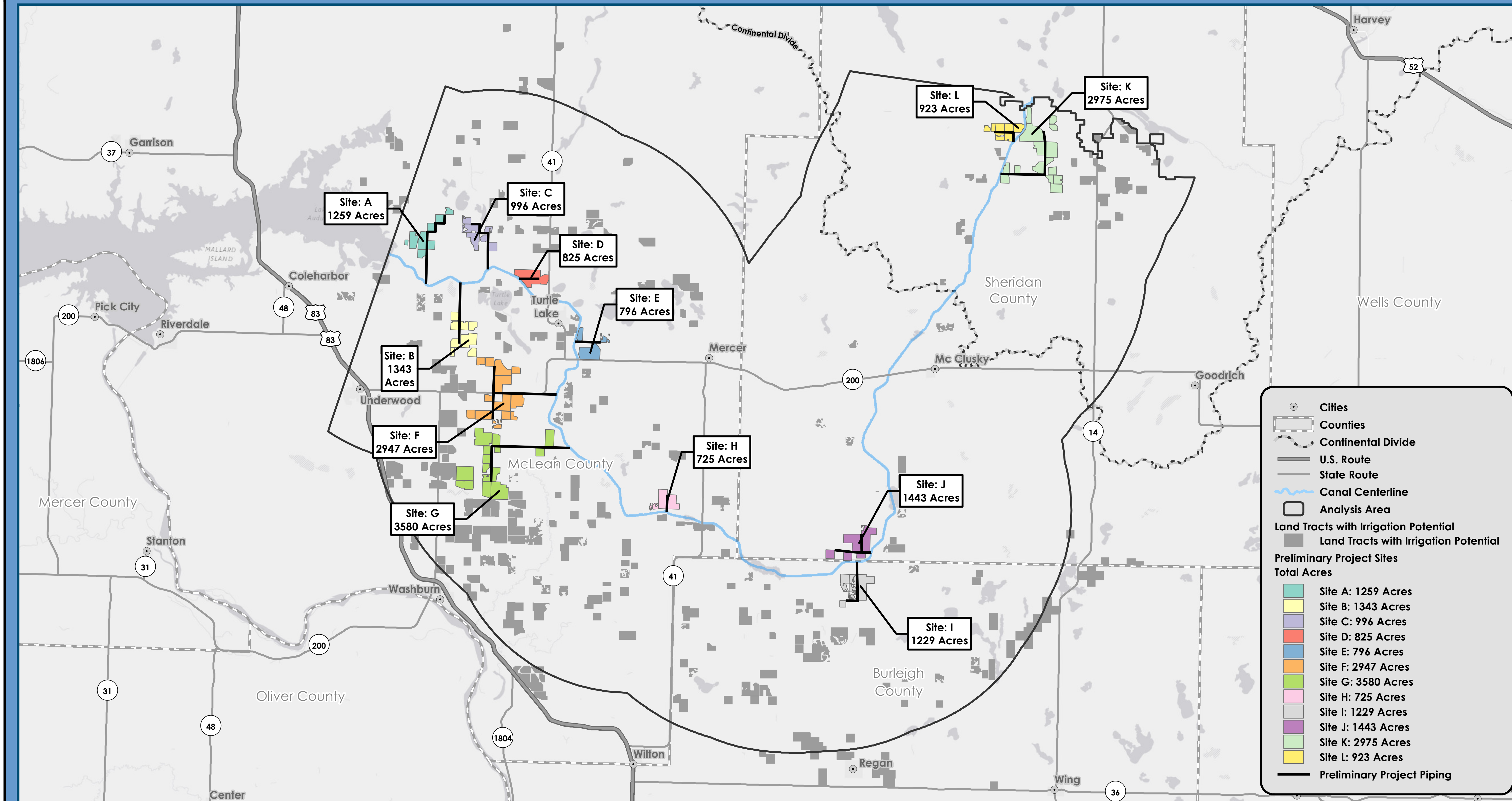
3.4 Preliminary Project Cost Estimates

Based on the results of the Irrigation Feasibility Analysis, 12 potential project sites were identified and hand selected from the weighted and grouped land tracts for a more detailed design and cost analysis. *Please note these preliminary project boundaries were not based upon any existing or potential landowner parcels or agreements. No potential or existing landowners were contacted in these efforts and these projects only represent potential projects based upon prior analyses in this report.*

The map of these 12 preliminary project sites is shown in *Figure 3.14*.



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N

0 2.75 5.5 Miles

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Locator Map Not to Scale

Figure 3-14: Preliminary Site Selection Overview

Irrigation Master Plan

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C:\Data\Projects\RRVWSP\P00200-2013-009\100 Geomatic Services\Report Figure 3-14 Preliminary Site Selection Overview.mxd | Edited by: DYL

Preliminary cost estimates were performed based on the following factors and design considerations:

- Total acres within each Project Site:
    - This area was used to calculate each project cost per overall *irrigable* project acre.
    - Total *irrigated* acreage for each project site were not estimated in these preliminary project sites and instead are calculated in future sections of this report when projects are more closely identified for design on a concept level.
- Total Dynamic Head (TDH) required:
    - This included the change in elevation along the preliminary pipeline corridor from the canal to each project site, the corresponding friction head loss in the pipeline, and estimated operating pressure required for the center-pivot irrigation systems.
- Required Flow Rate:
    - The overall required project flow was estimated at the rate of 6.5 gpm/acre for each project site, and then reduced to a flow rate able to irrigate 75% of the total project site at any given time. Similar flow rates have proven to be sufficient in previous Garrison Diversion irrigation projects, and are intended to encourage conservation and the use of water management practices.
- Horsepower (HP) required:
    - Water HP was calculated using an assumed pump efficiency of 75% and drive motor efficiency of 90%.
- Pipe Costs:
    - Pipes were sized based on the required flow rates for each project. Pipe lengths were measured along the estimated pipe corridor. Projects requiring parallel pipes were accounted for accordingly.
    - Unit prices for pipe were calculated based on previous Garrison Diversion projects, and current market conditions.
    - Fittings, valves, and drain costs were estimated on a per foot of pipe basis. The unit price was calculated based on previous Garrison Diversion projects.
    - Underground pipe borings for road and wetland crossings were estimated based on previous Garrison Diversion projects, and applied on a per foot of pipe basis.
- Electrical Costs:
    - Electrical costs were based on the cost to run 3-phase power to the respective canal turnouts, then along the pipe corridor to the project site.
    - The unit price of $15/foot was used to calculate electrical costs, based on input received from the electrical providers serving the area of each project site.

- Pump Costs:
  - Pump costs were based on a cost per horsepower calculated from previous Garrison Diversion projects, with a construction cost index inflation factor to 2015 dollars.
- Miscellaneous Costs:
  - Several miscellaneous costs including mobilization (6%), engineering and legal (15%), and a preliminary contingency (25%) were also included in the estimate.
- Comparable Metrics:
  - The completion of this preliminary cost estimate provided several comparable cost metrics including project cost per acre (off farm improvements only), and acres per horsepower providing a means to look at potential project operating costs over time.

The summary of these preliminary cost estimates are included below in *Table 3.6*. Each Project Site corresponds to the site labels in *Figure 3.14*. The comprehensive preliminary costs estimates are shown in the attached Preliminary Project Cost Estimate included in *Appendix C*.

Table 3.6 Preliminary Project Cost Estimate Summary Table

Project Site	Total Acres	Total Project Cost	Acres/HP	Project Cost/Acre
A	1,260	$2,560,000	2.6	$2,000
B	1,345	$2,530,000	1.9	$1,900
C	995	$1,550,000	3.6	$1,600
D	825	$680,000	5.5	$800
E	796	$980,000	3.4	$1,200
F	2,948	$4,830,000	1.8	$1,600
G	3,579	$8,310,000	1.7	$2,300
H	725	$1,670,000	3.5	$2,300
I	1,229	$2,900,000	4.3	$2,400
J	1,443	$2,650,000	2.9	$1,800
K	2,976	$4,610,000	2.4	$1,500
L	924	$970,000	3.3	$1,000

3.5 Preliminary Site Selection Analysis

Once the preliminary cost estimates were complete, another weighted sum analysis was utilized to compare each of the 12 preliminary project sites to determine those most likely to be developed into future irrigation projects. Three weighting factors were utilized to facilitate this analysis:

- **Project Cost Per Acre**
  - These costs were based on the derived Preliminary Project Cost Estimates (*Appendix C)* and are based on the overall project cost per *irrigable* acre.
  - A weighting factor of *two* was assigned for this analysis as project cost per acre to develop generally has a large impact in determining project feasibility.
- **Location of Project**
  - Each project was analyzed based upon the project location related to the location of the Continental Divide.
  - The highest weighting factor of three was assigned for this analysis based on current laws and regulations, and the fact than an act of congress would be required to enable Garrison Diversion irrigation project development on the east side of the Continental Divide.
- **Irrigable Project Acres Per Horsepower Required**
  - Each project was analyzed based upon the horsepower required to pump water to each *irrigable* project acre.
  - This factor provides value in evaluating the overall efficiency, as well as the operation and maintenance costs over the life of a potential irrigation project. A weighting factor of *one* was assigned for this portion of the analysis.

A flow chart describing the factors, values, weights, and the weighted sum is in *Figure 3.15*.

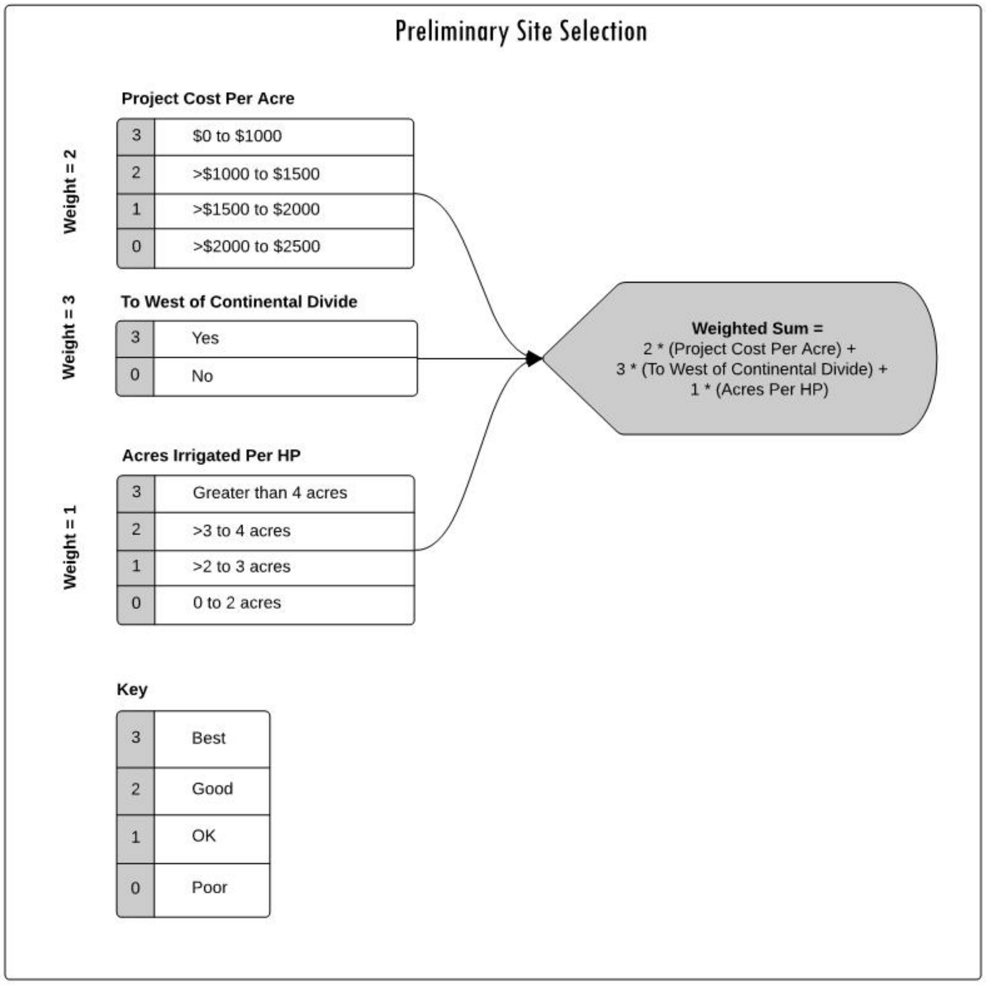


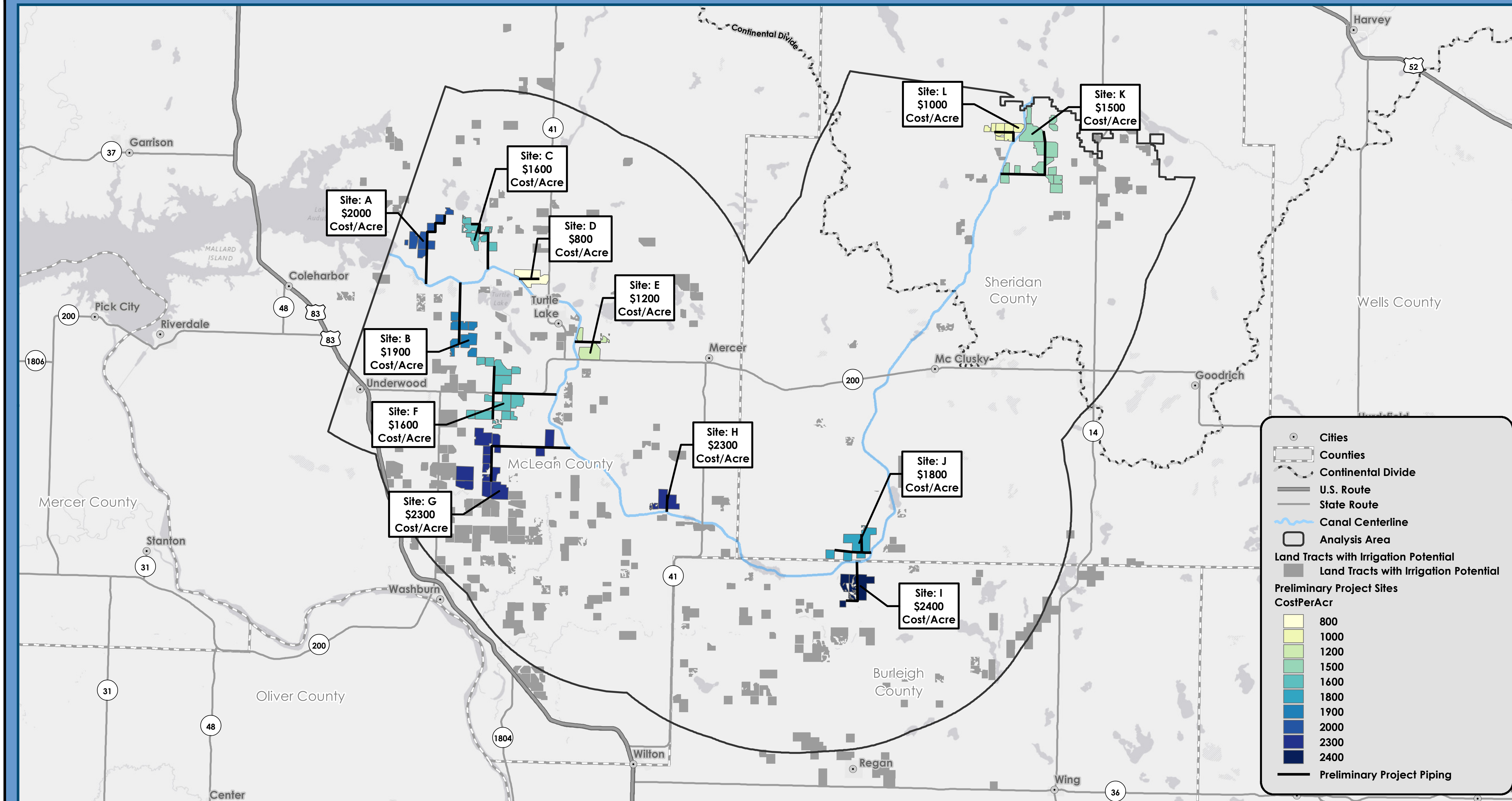
Figure 3.15 Preliminary Site Selection Analysis Flow Chart

3.5.2 Project Cost Per Acre Analysis Factor

The "Project Cost Per Acre" weighting factor is shown in *Table 3.7* and *Figure 3.16*.

Table 3.7 Project Cost Per Acre Analysis Factor (Weight = 2)

Value	Description
3	$0 to $1000
2	>$1000 to $1500
1	>$1500 to $2000
0	>$2000 to $2500



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N

0 2.75 5.5 Miles

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Locator Map Not to Scale

Figure 3-16: Project Cost Per Acre Analysis Factor

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3.5.3 *Location of Project Weighting Factor*

Currently, only projects to the west of the Continental Divide have been authorized for irrigation development. It would take an act of congress to open up areas to the east of the Continental Divide for irrigation purposes. The “Location of Project” weighting factor is shown in *Table 3.8.*

Table 3.8 Location of Project Weighting Factor (Weight = 3)

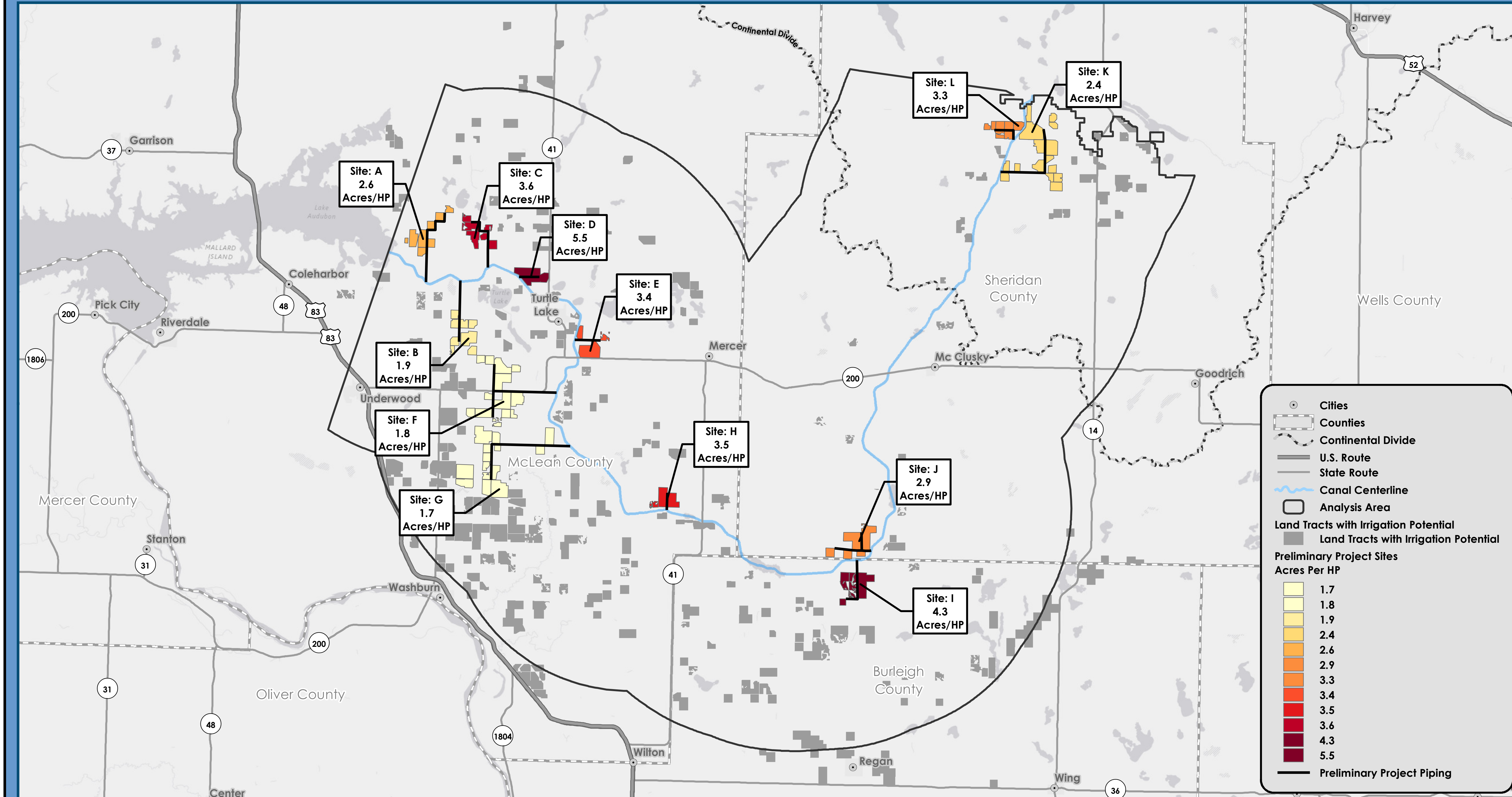
Value	Description
3	West of Continental Divide
0	East of Continental Divide

3.5.4 *Irrigable Project Acres Per Horsepower Weighting Factor*

The “Irrigable Project Acres Per Horsepower” weighting factor is shown in *Table 3.9* and *Figure 3.17*.

Table 3.9 Irrigable Project Acres Per Horsepower Factor (Weight = 1)

Value	Description
3	Greater than 4 Acres
2	>3 to 4 Acres
1	>2 to 3Acres
0	0 to 2 Acres



N
0 2.75 5.5 Miles
1 inch = 5.5 miles
Locator Map Not to Scale

Figure 3-17: Irrigable Project Acres Per Horsepower Analysis Factor

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3.5.5 Combined Analysis of All Weighted Factors

The weighted sum analysis for each site was found by multiplying the value for each factor by the weighting factor, and then summing those weighted values. Weighted sums that are higher are more suited irrigation projects than those with lower values.

Weighted Sum =

2 * (Project Cost Per Acre) +

3 * (To West of Continental Divide) +

1 * (Irrigable Acres Per HP)

The Combined Sum of All Weighted Factors map is shown in *Figure 3.18*.

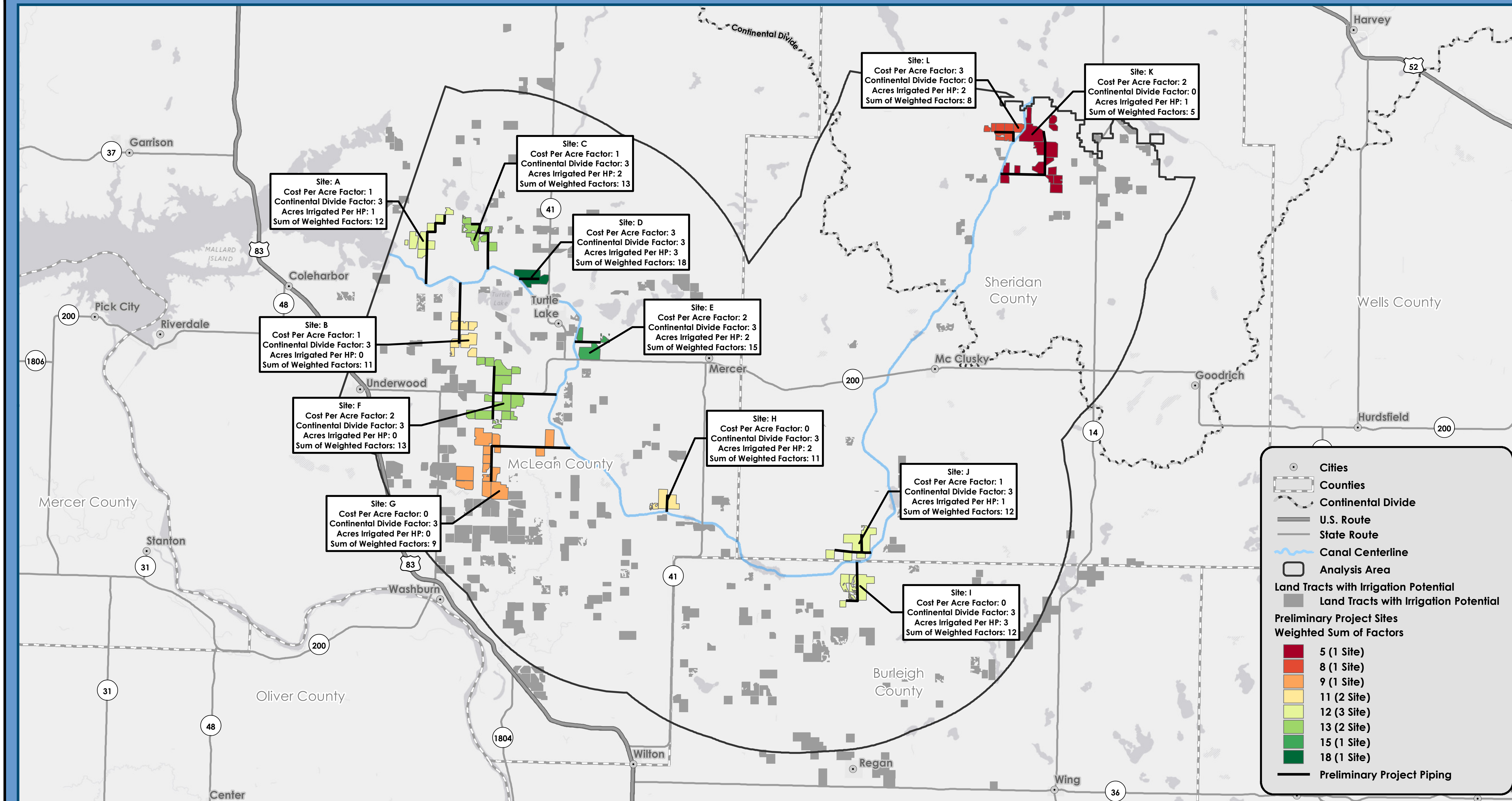

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Figure 3-18: Combined Sum of All Weighted Factors

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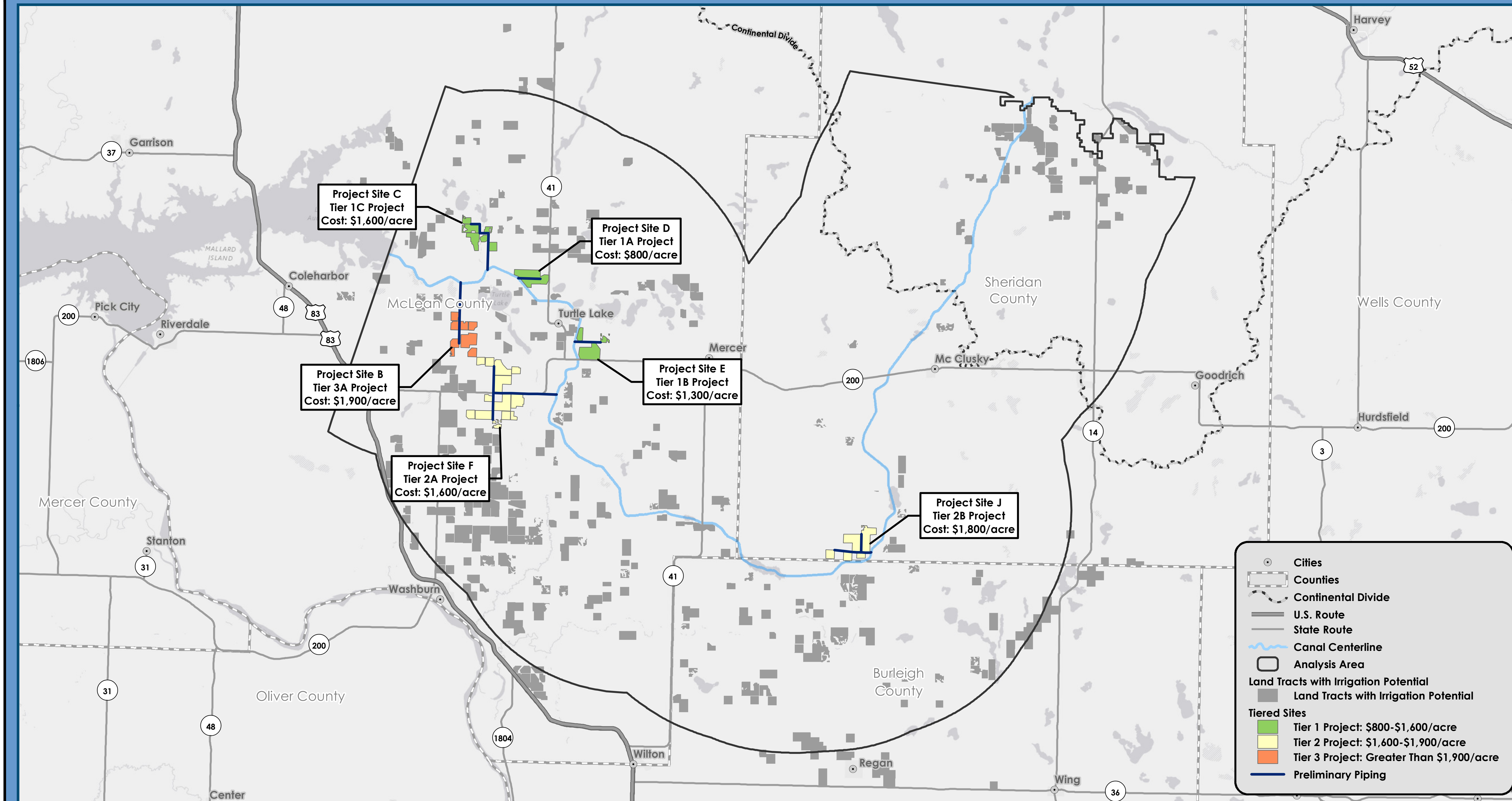
3.6 Targeted Project Areas

From the results of the Preliminary Site Selection Analysis, the *six* highest ranking sites were selected as targeted project areas for further analysis. Project site comparisons were reviewed and the six sites were separated into three project tiers based on the following parameters:

- **Tier 1 Project**
  - $800 - $1600 per acre cost to develop
  - Three Tier 1 Projects were selected:
    - Project Site D - $800 cost per acre
    - Project Site E - $1300 cost per acre
    - Project Site C - $1600 cost per acre
- **Tier 2 Project**
  - $1600 - $1900 per acre cost to develop
  - Two Tier 2 Projects were selected:
    - Project Site F - $1800 cost per acre
    - Project Site J - $1800 cost per acre
- **Tier 3 Project**
  - Greater than $1900 per acre cost to develop
  - One Tier 3 Project was selected:
    - Project Site B - $1900 cost per acre

The Tier 1, 2, and 3 Project Sites are shown in the following *Figure 3.19*.



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N

0 2.75 5.5 Miles

1 inch = 5.5 miles

Locator Map Not to Scale

Figure 3-19: Tier 1, 2, and 3 Project Sites

Irrigation Master Plan

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3.7 Target Project Concept Plans

A concept plan was prepared for each of the three Tier 1 projects, both Tier 2 projects, and the Tier 3 project. The concept plan for each location includes:

- Conceptual project layout including pipeline routing and center pivot irrigation layout
- Total irrigated acreage
- Design flow requirements
- Pumping requirements
- Electrical availability

A cost analysis demonstrating the financial feasibility of each of these six projects was developed and is provided in the following sections. Each cost analysis was separated into "Off Farm Costs", and "On Farm Costs", to differentiate between project costs eligible for current State cost share funding, and project costs that will be the responsibility of the producer wishing to irrigate through the use of the McClusky Canal.

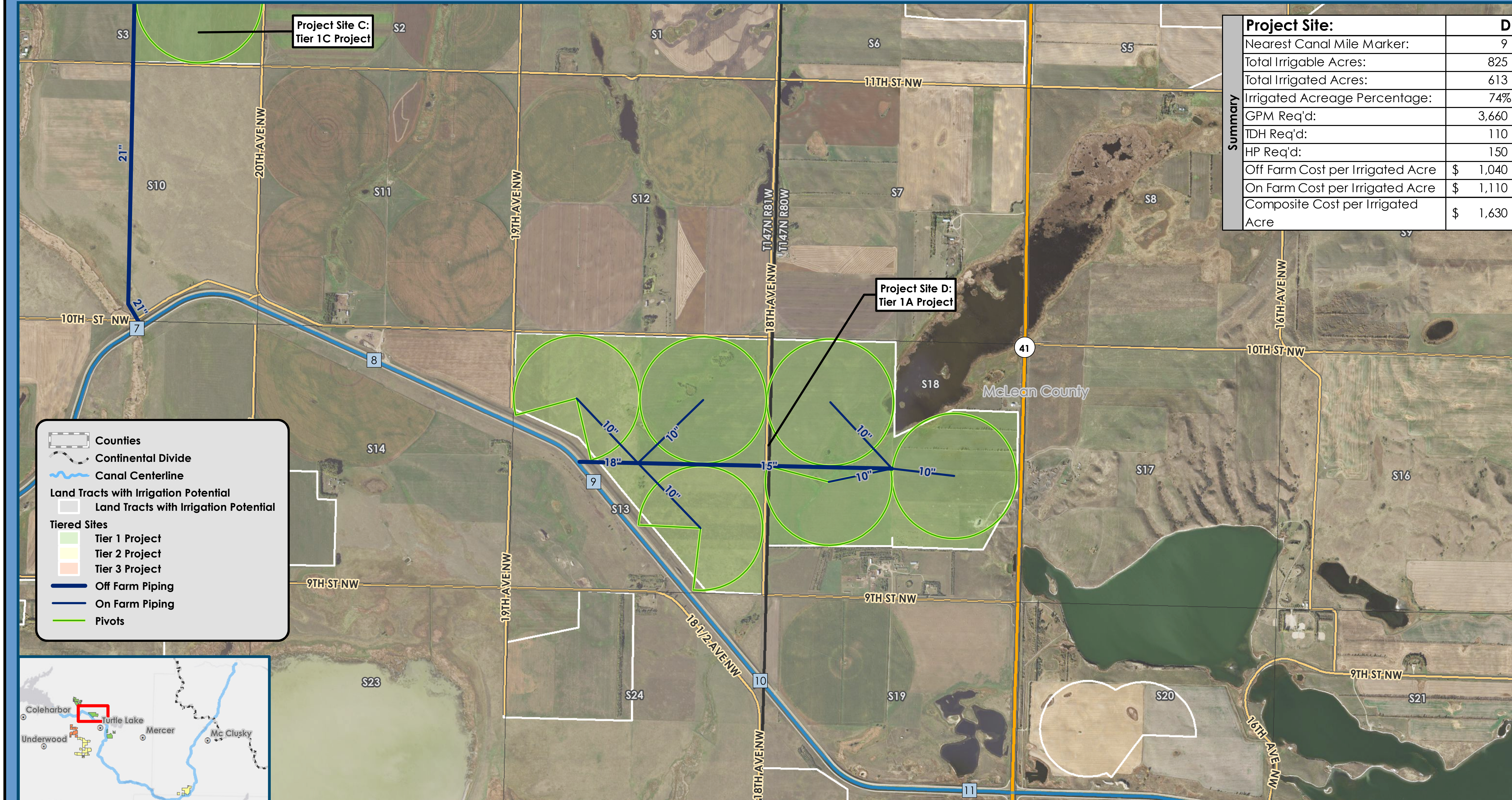
The cost estimating approach was similar to what was done for the preliminary cost estimates described previously in *Section 3.4*. In this concept plan stage, a closer look was taken at each site to determine probable center pivot layout, pipeline routing, and pipe sizing. This allowed the irrigated acreage and costs to be refined, and the level of uncertainty to be decreased.

Any project shortcomings, limitations with electrical availability, or any other item preventing the development of each project was identified and reflected in each of the cost estimates.

The cost estimates and accompanying site layouts for each of the Tier 1, 2, and 3 project sites are included in the following sections.

3.7.1 Tier 1 Project Site D – Concept Design and Cost Estimate

Project Site D is located in McLean County and consists of 613 irrigated acres. The conceptual project layout is shown in *Figure 3.20*. *Please note these concept project boundaries were not based upon any existing or potential landowner parcels and/or agreements. No potential or existing landowners were contacted in these efforts and the project shown only represents a potential concept project based upon the analyses in this report.*



Summary	Project Site:	D
	Nearest Canal Mile Marker:	9
	Total Irrigable Acres:	825
	Total Irrigated Acres:	613
	Irrigated Acreage Percentage:	74%
	GPM Req'd:	3,660
	TDH Req'd:	110
	HP Req'd:	150
	Off Farm Cost per Irrigated Acre	$ 1,040
	On Farm Cost per Irrigated Acre	$ 1,110
	Composite Cost per Irrigated Acre	$ 1,630

N

0 1,000 2,000 Feet

1 inch = 2,000 feet

Locator Map Not to Scale

Figure 3-20: Project Site D- Concept Design

Irrigation Master Plan

Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

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A cost analysis based on the conceptual project layout, as well as information such as total irrigated acreage, anticipated pipeline sizing, project design flow and horsepower pumping requirements, and location to existing electrical availability is included and reflected in the project estimate shown in *Table 3.10.* Once the cost estimate was complete, for comparison the project cost per ***irrigated*** acre was separated into the following three categories:

- Off Farm Cost Per Irrigated Acre
- On Farm Cost Per Irrigated Acre
- Composite Cost Per Irrigated Acre: cost includes 100% On Farm costs and 50% Off Farm costs consistent with current North Dakota State Water Commission irrigation cost share policy.

Table 3.10 Project Site D – Cost Estimate

Summary		
	Project Site:	**D**
	Nearest Canal Mile Marker:	9
	Total Irrigable Acres:	825
	Total Irrigated Acres:	613
	Irrigated Acreage Percentage:	74%
	GPM Req'd:	3,660
	TDH Req'd:	110
	HP Req'd:	150
	Off Farm Cost per Irrigated Acre	$ 1,040
	On Farm Cost per Irrigated Acre	$ 1,110
	Composite Cost per Irrigated Acre (50% Off Farm Cost Share Included)	$ 1,630

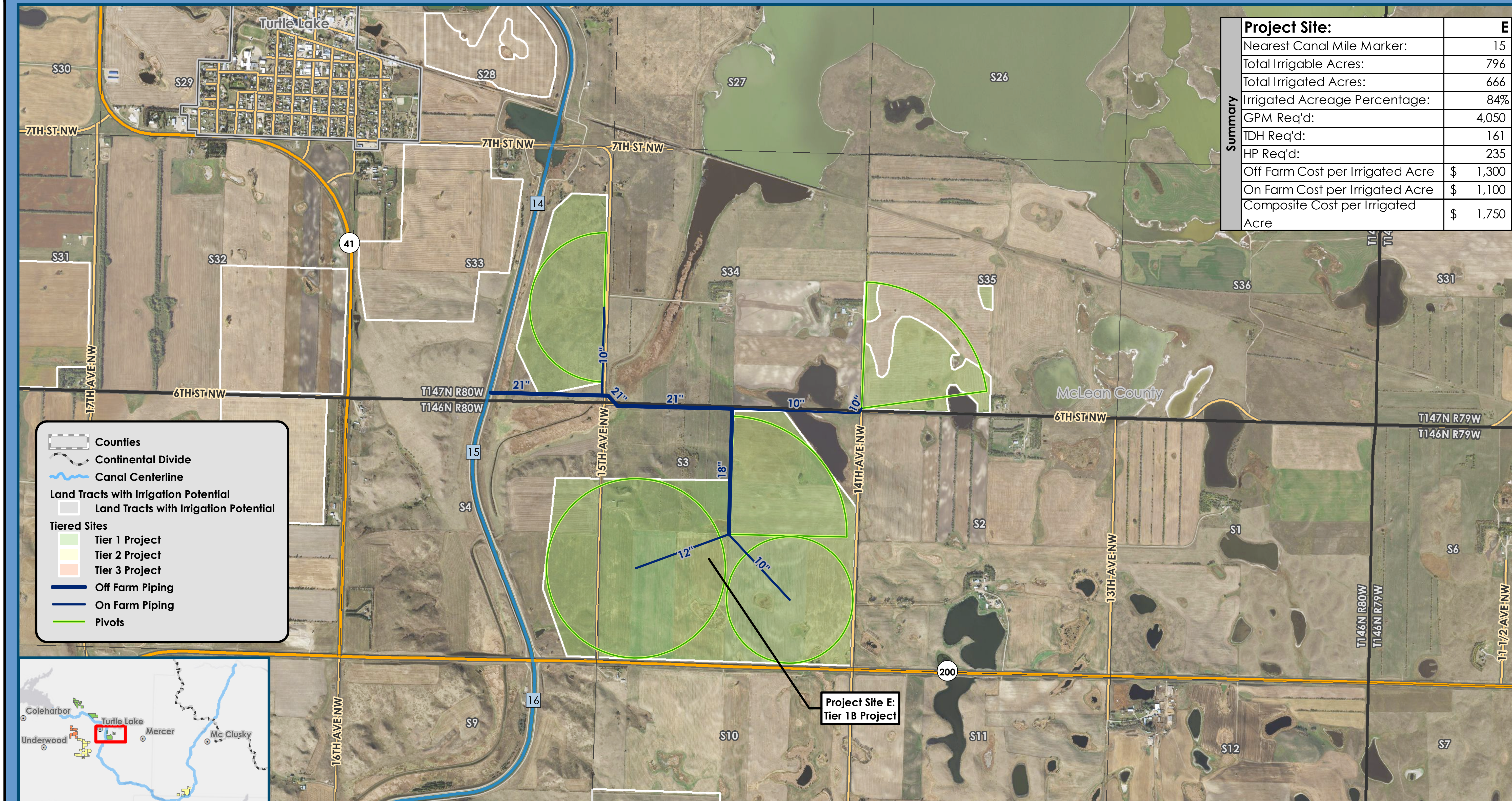
Off Farm Costs	Item	Qty	Unit	Unit Price	Total
	18" PVC Installed (80 psi)	1203	LF	$ 23	$ 28,000
	15" PVC Installed (80 psi)	5223	LF	$ 17	$ 91,000
	Fittings, Valves, Etc.	1	LS	$ 7,000	$ 7,000
	Pump Station	1	LS	$ 62,000	$ 62,000
	Pump Station Intake	1	LS	$ 61,000	$ 61,000
	3Phase Electrical to Pump Station	1	LS	$ 79,000	$ 79,000
	3Phase Along Main Pipeline	6426	LF	$ 13	$ 85,209
	Road Crossings (Boring)	1	LS	$ 36,000	$ 36,000
	Bonding (5%)	1	LS	$ 23,000	$ 23,000
	Mobilization (6%)	1	LS	$ 27,000	$ 27,000
	Engineering & Legal (15%)	1	LS	$ 68,000	$ 68,000
	Contingency (15%)	1	LS	$ 68,000	$ 68,000
				Off Farm Subtotal	$ 635,209

On Farm Costs	Item	Qty	Unit	Unit Price	Total
	10" PVC Installed (80 psi)	10030	LF	$ 9	$ 91,000
	Center Pivot Base Installation (Includes Fittings and Concrete Pivot Pads)	6	EA	$ 20,000	$ 120,000
	Center Pivot Installation and Freight	7752	LF	$ 47	$ 364,344
	Electrical Service to Pivot	10030	LF	$ 4	$ 42,000
	Contingency (10%)	1	LS	$ 62,000	$ 62,000
				On Farm Subtotal	$ 679,344

Total	**$ 1,314,553**

3.7.2 Tier 1 Project Site E – Concept Design and Cost Estimate

Project Site E is located in McLean County and consists of 666 irrigated acres. The conceptual project layout is shown in *Figure 3.21*. *Please note these concept project boundaries were not based upon any existing or potential landowner parcels and/or agreements. No potential or existing landowners were contacted in these efforts and the project shown only represents a potential concept project based upon the analyses in this report.*



Summary

Project Site:	E
Nearest Canal Mile Marker:	15
Total Irrigable Acres:	796
Total Irrigated Acres:	666
Irrigated Acreage Percentage:	84%
GPM Req'd:	4,050
TDH Req'd:	161
HP Req'd:	235
Off Farm Cost per Irrigated Acre	$ 1,300
On Farm Cost per Irrigated Acre	$ 1,100
Composite Cost per Irrigated Acre	$ 1,750

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N

0 1,000 2,000 Feet

1 inch = 2,000 feet

Locator Map Not to Scale

Figure 3-21: Project Site E- Concept Design

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A cost analysis based on the conceptual project layout, as well as information such as total irrigated acreage, anticipated pipeline sizing, project design flow and horsepower pumping requirements, and location to existing electrical availability is included and reflected in the project estimate shown in *Table 3.11*. Once the cost estimate was complete, for comparison the project cost per ***irrigated*** acre was separated into the following three categories:

- Off Farm Cost Per Irrigated Acre
- On Farm Cost Per Irrigated Acre
- Composite Cost Per Irrigated Acre: cost includes 100% On Farm costs and 50% Off Farm costs consistent with current North Dakota State Water Commission irrigation cost share policy.

Table 3.11 Project Site E – Cost Estimate

	Project Site:	E
Summary	Nearest Canal Mile Marker:	15
	Total Irrigable Acres:	796
	Total Irrigated Acres:	666
	Irrigated Acreage Percentage:	84%
	GPM Req'd:	4,050
	TDH Req'd:	161
	HP Req'd:	235
	Off Farm Cost per Irrigated Acre	$ 1,300
	On Farm Cost per Irrigated Acre	$ 1,100
	Composite Cost per Irrigated Acre (50% Off Farm Cost Share Included)	$ 1,750

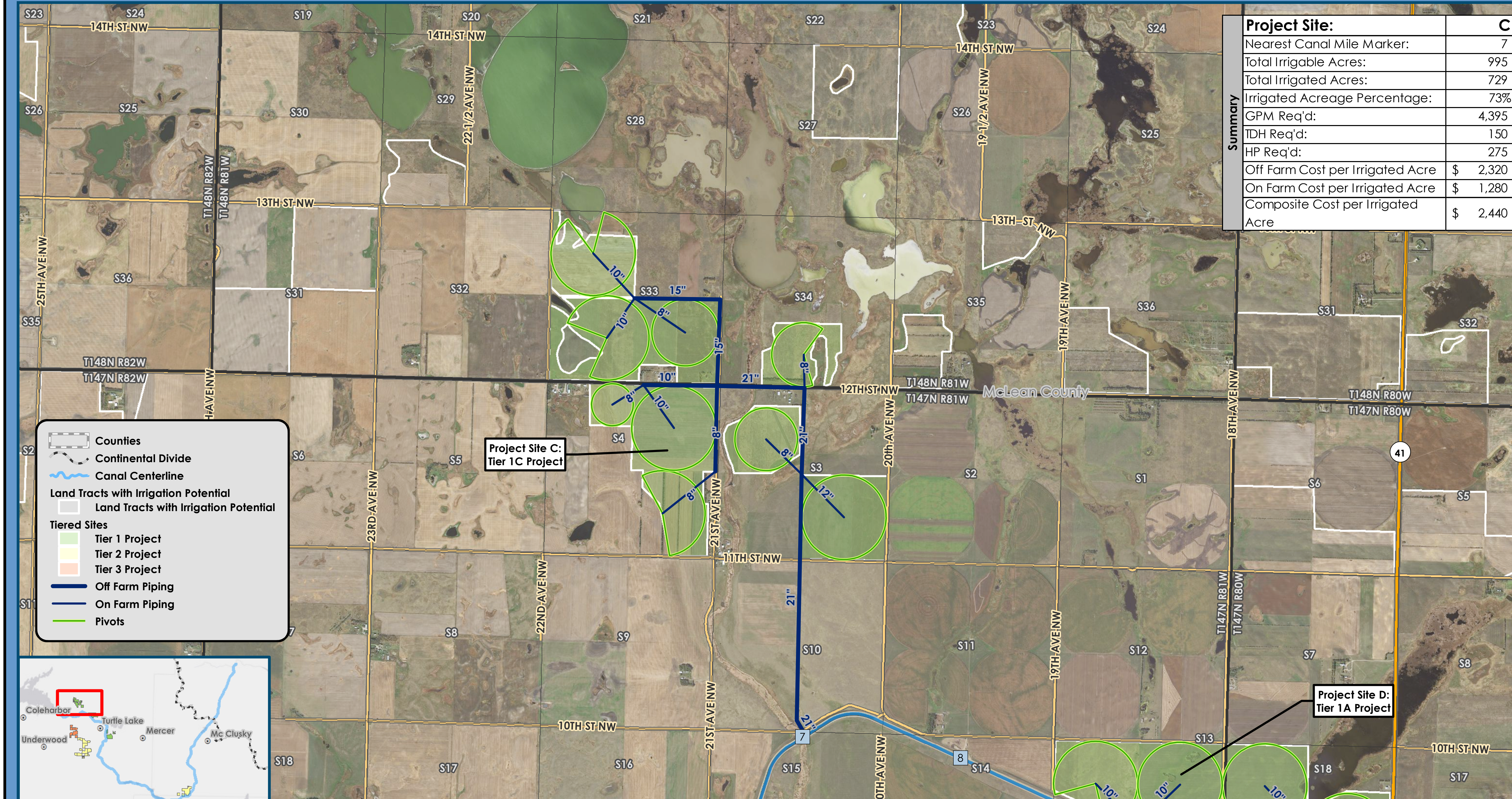
	Item	Qty	Unit	Unit Price	Total
Off Farm Costs	21" PVC Installed (100 psi)	2000	LF	$ 33	$ 66,000
	21" PVC Installed (80 psi)	3062	LF	$ 29	$ 91,000
	18" PVC Installed (80 psi)	2583	LF	$ 23	$ 60,000
	Fittings, Valves, Etc.	1	LS	$ 8,000	$ 8,000
	Pump Station	1	LS	$ 97,000	$ 97,000
	Pump Station Intake	1	LS	$ 67,000	$ 67,000
	3Phase Electrical to Pump Station	1	LS	$ 86,000	$ 86,000
	3Phase Along Main Pipeline	7645	LF	$ 13	$ 101,373
	Road Crossings (Boring)	1	LS	$ 36,000	$ 36,000
	Bonding (5%)	1	LS	$ 31,000	$ 31,000
	Mobilization (6%)	1	LS	$ 37,000	$ 37,000
	Engineering & Legal (15%)	1	LS	$ 92,000	$ 92,000
	Contingency (15%)	1	LS	$ 92,000	$ 92,000
				Off Farm Subtotal	$ 864,373

	Item	Qty	Unit	Unit Price	Total
On Farm Costs	12" PVC Installed (80 psi)	2035	LF	$ 11	$ 22,000
	10" PVC Installed (80 psi)	6377	LF	$ 9	$ 58,000
	Center Pivot Base Installation (Includes Fittings and Concrete Pivot Pads)	5	EA	$ 20,000	$ 100,000
	Center Pivot Installation and Freight	9580	LF	$ 47	$ 450,260
	Electrical Service to Pivot	8412	LF	$ 4	$ 35,000
	Contingency (10%)	1	LS	$ 67,000	$ 67,000
				On Farm Subtotal	$ 732,260

Total	**$ 1,596,633**

3.7.3 Tier 1 Project Site C – Concept Design and Cost Estimate

Project Site C is located in McLean County and consists of 729 irrigated acres. The conceptual project layout is shown in *Figure 3.22*. *Please note these concept project boundaries were not based upon any existing or potential landowner parcels and/or agreements. No potential or existing landowners were contacted in these efforts and the project shown only represents a potential concept project based upon the analyses in this report.*



Project Site:	C
Nearest Canal Mile Marker:	7
Total Irrigable Acres:	995
Total Irrigated Acres:	729
Irrigated Acreage Percentage:	73%
GPM Req'd:	4,395
TDH Req'd:	150
HP Req'd:	275
Off Farm Cost per Irrigated Acre	$ 2,320
On Farm Cost per Irrigated Acre	$ 1,280
Composite Cost per Irrigated Acre	$ 2,440

Summary

Any reliance upon this map is at user's own risk. AE2S does not warrant the map or its features are either spatially or temporally accurate or fit for a particular use.

N

0 1,500 3,000 Feet

1 inch = 3,000 feet

Locator Map Not to Scale

Figure 3-22: Project Site C- Concept Design

Irrigation Master Plan

Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

Advanced Engineering and Environmental Services, Inc.

Date: 7/15/2016 | Coordinate System: North Dakota State Plane South

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A cost analysis based on the conceptual project layout, as well as information such as total irrigated acreage, anticipated pipeline sizing, project design flow and horsepower pumping requirements, and location to existing electrical availability is included and reflected in the project estimate shown in *Table 3.12.* Once the cost estimate was complete, for comparison the project cost per ***irrigated*** acre was separated into the following three categories:

- Off Farm Cost Per Irrigated Acre
- On Farm Cost Per Irrigated Acre
- Composite Cost Per Irrigated Acre: cost includes 100% On Farm costs and 50% Off Farm costs consistent with current North Dakota State Water Commission irrigation cost share policy.

Table 3.12 Project Site C – Cost Estimate

Summary	**Project Site:**	**C**
	Nearest Canal Mile Marker:	7
	Total Irrigable Acres:	995
	Total Irrigated Acres:	729
	Irrigated Acreage Percentage:	73%
	GPM Req'd:	4,395
	TDH Req'd:	150
	HP Req'd:	275
	Off Farm Cost per Irrigated Acre	$ 2,320
	On Farm Cost per Irrigated Acre	$ 1,280
	Composite Cost per Irrigated Acre (50% Off Farm Cost Share Included)	$ 2,440

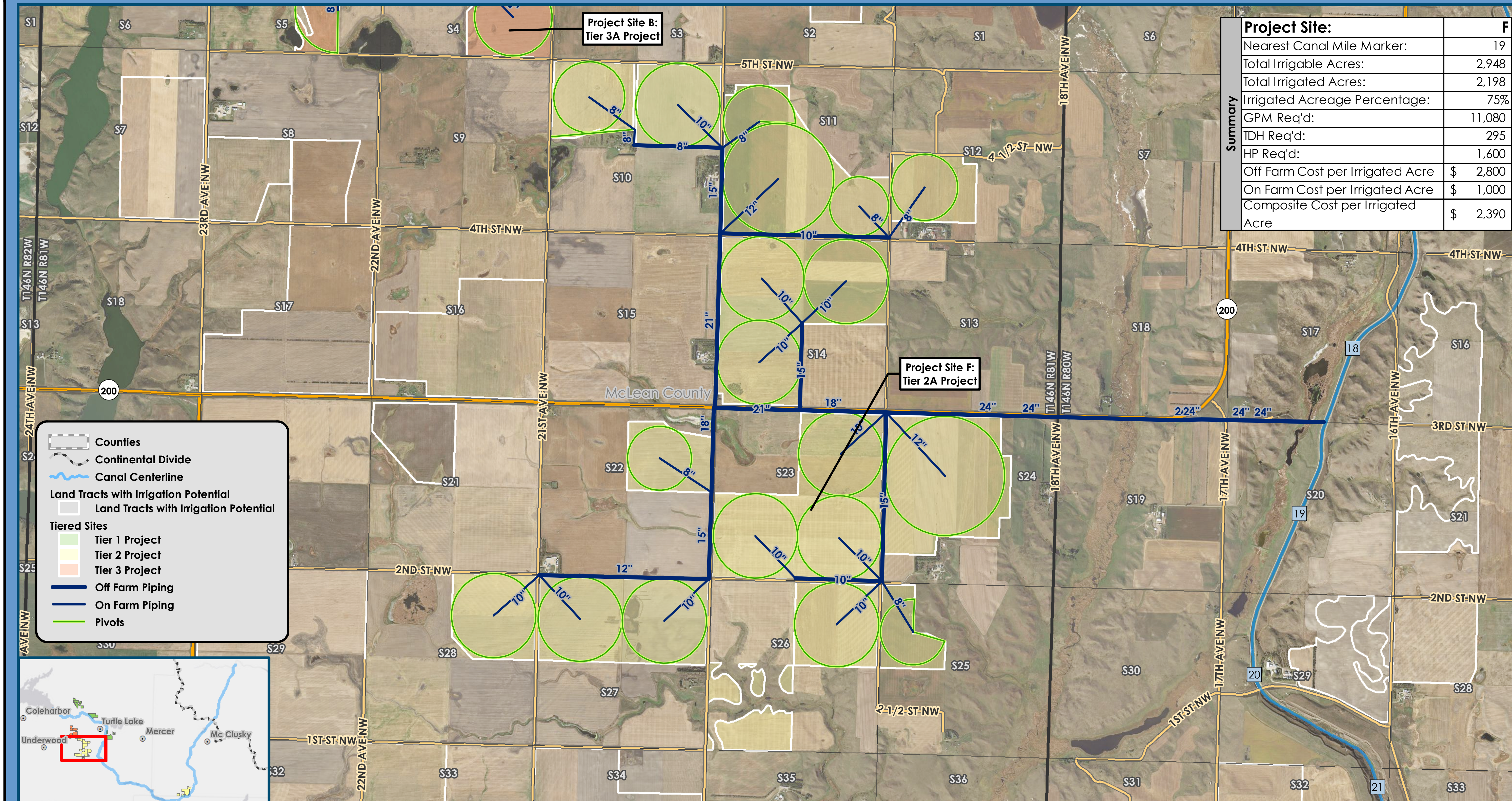
	Item	Qty	Unit	Unit Price	Total
Off Farm Costs	21" PVC Installed (100 psi)	1000	LF	$ 33	$ 33,000
	21" PVC Installed (80 psi)	12419	LF	$ 29	$ 366,000
	15" PVC Installed (80 psi)	5207	LF	$ 17	$ 91,000
	10" PVC Installed (80 psi)	2271	LF	$ 9	$ 21,000
	8" PVC Installed (80 psi)	2628	LF	$ 8	$ 22,000
	Fittings, Valves, Etc.	1	LS	$ 20,000	$ 20,000
	Pump Station	1	LS	$ 114,000	$ 114,000
	Pump Station Intake	1	LS	$ 73,000	$ 73,000
	3Phase Electrical to Pump Station	1	LS	$ 74,000	$ 74,000
	3Phase Along Main Pipeline	23525	LF	$ 13	$ 311,942
	Road Crossings (Boring)	2	LS	$ 36,000	$ 72,000
	Bonding (5%)	1	LS	$ 60,000	$ 60,000
	Mobilization (6%)	1	LS	$ 72,000	$ 72,000
	Engineering & Legal (15%)	1	LS	$ 180,000	$ 180,000
	Contingency (15%)	1	LS	$ 180,000	$ 180,000
				Off Farm Subtotal	$ 1,689,942

	Item	Qty	Unit	Unit Price	Total
On Farm Costs	12" PVC Installed (80 psi)	1856	LF	$ 11	$ 20,000
	10" PVC Installed (80 psi)	4999	LF	$ 9	$ 45,000
	8" PVC Installed (80 psi)	7654	LF	$ 8	$ 62,000
	Center Pivot Base Installation (Includes Fittings and Concrete Pivot Pads)	9	EA	$ 20,000	$ 180,000
	Center Pivot Installation and Freight	10136	LF	$ 47	$ 476,392
	Electrical Service to Pivot	14509	LF	$ 4	$ 60,000
	Contingency (10%)	1	LS	$ 85,000	$ 85,000
				On Farm Subtotal	$ 928,392

Total	**$ 2,618,334**

3.7.4 Tier 2 Project Site F – Concept Design and Cost Estimate

Project Site F is located in McLean County and consists of 2198 irrigated acres. The conceptual project layout is shown in *Figure 3.23*. *Please note these concept project boundaries were not based upon any existing or potential landowner parcels and/or agreements. No potential or existing landowners were contacted in these efforts and the project shown only represents a potential concept project based upon the analyses in this report.*



Summary	Project Site:	F
	Nearest Canal Mile Marker:	19
	Total Irrigable Acres:	2,948
	Total Irrigated Acres:	2,198
	Irrigated Acreage Percentage:	75%
	GPM Req'd:	11,080
	TDH Req'd:	295
	HP Req'd:	1,600
	Off Farm Cost per Irrigated Acre	$ 2,800
	On Farm Cost per Irrigated Acre	$ 1,000
	Composite Cost per Irrigated Acre	$ 2,390

N

0 1,500 3,000 Feet

1 inch = 3,000 feet

Locator Map Not to Scale

Figure 3-23: Project Site F- Concept Design

Irrigation Master Plan

Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

Advanced Engineering and Environmental Services, Inc.

Date: 7/15/2016 | Coordinate System: North Dakota State Plane South

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A cost analysis based on the conceptual project layout, as well as information such as total irrigated acreage, anticipated pipeline sizing, project design flow and horsepower pumping requirements, and location to existing electrical availability is included and reflected in the project estimate shown in *Table 3.13*. Once the cost estimate was complete, for comparison the project cost per ***irrigated*** acre was separated into the following three categories:

- Off Farm Cost Per Irrigated Acre
- On Farm Cost Per Irrigated Acre
- Composite Cost Per Irrigated Acre: cost includes 100% On Farm costs and 50% Off Farm costs consistent with current North Dakota State Water Commission irrigation cost share policy.

Table 3.13 Project Site F – Cost Estimate

Summary		
	Project Site:	**F**
	Nearest Canal Mile Marker:	19
	Total Irrigable Acres:	2,948
	Total Irrigated Acres:	2,198
	Irrigated Acreage Percentage:	75%
	GPM Req'd:	11,080
	TDH Req'd:	295
	HP Req'd:	1,600
	Off Farm Cost per Irrigated Acre	$ 2,800
	On Farm Cost per Irrigated Acre	$ 1,000
	Composite Cost per Irrigated Acre (50% Off Farm Cost Share Included)	$ 2,390

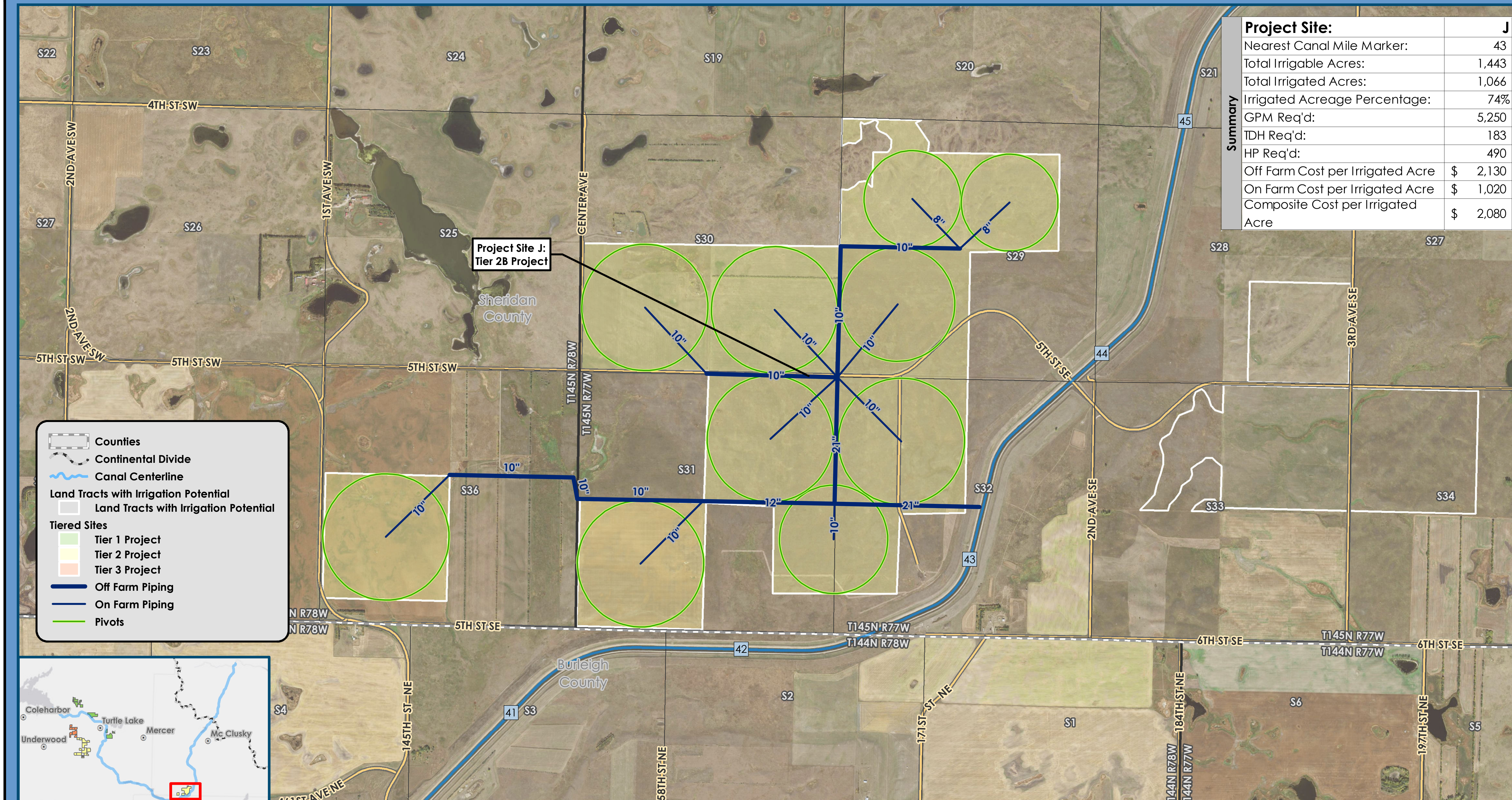
Off Farm Costs	Item	Qty	Unit	Unit Price	Total
	24" C900 DR 25 Installed (165 psi)	20000	LF	$ 52	$ 1,040,000
	24" PVC Installed (80 psi)	9699	LF	$ 36	$ 345,000
	21" PVC Installed (80 psi)	8001	LF	$ 29	$ 236,000
	18" PVC Installed (80 psi)	7921	LF	$ 23	$ 183,000
	15" PVC Installed (80 psi)	13200	LF	$ 17	$ 229,000
	12" PVC Installed (80 psi)	5240	LF	$ 11	$ 56,000
	10" PVC Installed (80 psi)	7872	LF	$ 9	$ 71,000
	8" PVC Installed (80 psi)	2722	LF	$ 8	$ 22,000
	Fittings, Valves, Etc.	1	LS	$ 78,000	$ 78,000
	Pump Station	1	LS	$ 658,000	$ 658,000
	Pump Station Intake	1	LS	$ 182,000	$ 182,000
	3Phase Electrical to Pump Station	1	LS	$ 45,000	$ 45,000
	3Phase Along Main Pipeline	74655	LF	$ 13	$ 989,925
	Road Crossings (Boring)	2	LS	$ 36,000	$ 72,000
	Wetland Crossings	1	LS	$ 150,000	$ 150,000
	Bonding (5%)	1	LS	$ 218,000	$ 218,000
	Mobilization (6%)	1	LS	$ 262,000	$ 262,000
	Engineering & Legal (15%)	1	LS	$ 654,000	$ 654,000
	Contingency (15%)	1	LS	$ 654,000	$ 654,000
				Off Farm Subtotal	$ 6,144,925

On Farm Costs	Item	Qty	Unit	Unit Price	Total
	12" PVC Installed (80 psi)	5114	LF	$ 11	$ 54,000
	10" PVC Installed (80 psi)	20525	LF	$ 9	$ 185,000
	8" PVC Installed (80 psi)	10590	LF	$ 8	$ 85,000
	Center Pivot Base Installation (Includes Fittings and Concrete Pivot Pads)	19	EA	$ 20,000	$ 380,000
	Center Pivot Installation and Freight	23989	LF	$ 47	$ 1,127,483
	Electrical Service to Pivot	36229	LF	$ 4	$ 149,000
	Contingency (10%)	1	LS	$ 199,000	$ 199,000
				On Farm Subtotal	$ 2,179,483

Total	**$ 8,324,408**

3.7.5 Tier 2 Project Site J – Concept Design and Cost Estimate

Project Site J is located in Burleigh County and consists of 1066 irrigated acres. The conceptual project layout is shown in *Figure 3.24*. *Please note these concept project boundaries were not based upon any existing or potential landowner parcels and/or agreements. No potential or existing landowners were contacted in these efforts and the project shown only represents a potential concept project based upon the analyses in this report.*



Project Site:	**J**
Nearest Canal Mile Marker:	43
Total Irrigable Acres:	1,443
Total Irrigated Acres:	1,066
Irrigated Acreage Percentage:	74%
GPM Req'd:	5,250
TDH Req'd:	183
HP Req'd:	490
Off Farm Cost per Irrigated Acre	$ 2,130
On Farm Cost per Irrigated Acre	$ 1,020
Composite Cost per Irrigated Acre	$ 2,080

Summary

N
0 1,000 2,000 Feet
1 inch = 2,000 feet

Locator Map Not to Scale

Figure 3-24: Project Site J- Concept Design

Irrigation Master Plan
Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

GARRISON DIVERSION

AE2S Advanced Engineering and Environmental Services, Inc.

A cost analysis based on the conceptual project layout, as well as information such as total irrigated acreage, anticipated pipeline sizing, project design flow and horsepower pumping requirements, and location to existing electrical availability is included and reflected in the project estimate shown in *Table 3.14.* Once the cost estimate was complete, for comparison the project cost per ***irrigated*** acre was separated into the following three categories:

- Off Farm Cost Per Irrigated Acre
- On Farm Cost Per Irrigated Acre
- Composite Cost Per Irrigated Acre: cost includes 100% On Farm costs and 50% Off Farm costs consistent with current North Dakota State Water Commission irrigation cost share policy.

Table 3.14 Project Site J – Cost Estimate

Summary		
	Project Site:	**J**
	Nearest Canal Mile Marker:	43
	Total Irrigable Acres:	1,443
	Total Irrigated Acres:	1,066
	Irrigated Acreage Percentage:	74%
	GPM Req'd:	5,250
	TDH Req'd:	183
	HP Req'd:	490
	Off Farm Cost per Irrigated Acre	$ 2,130
	On Farm Cost per Irrigated Acre	$ 1,020
	Composite Cost per Irrigated Acre (50% Off Farm Cost Share Included)	$ 2,080

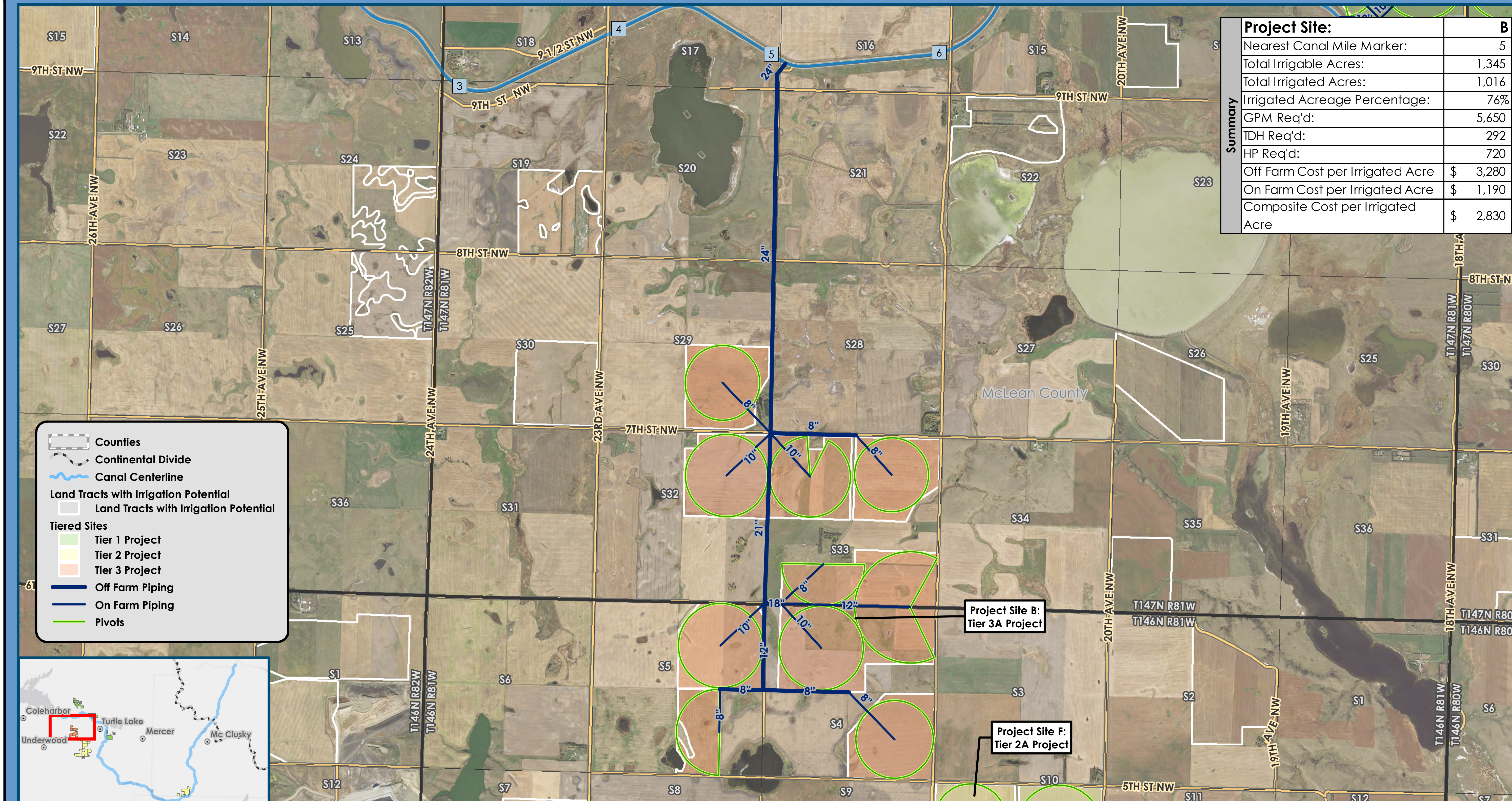
Off Farm Costs	Item	Qty	Unit	Unit Price	Total
	21" PVC Installed (100 psi)	4583	LF	$ 33	$ 152,000
	21" PVC Installed (80 psi)	1008	LF	$ 29	$ 30,000
	12" PVC Installed (100 psi)	1000	LF	$ 11	$ 12,000
	12" PVC Installed (80 psi)	1707	LF	$ 11	$ 18,000
	10" PVC Installed (80 psi)	13421	LF	$ 9	$ 121,000
	Fittings, Valves, Etc.	1	LS	$ 23,000	$ 23,000
	Pump Station	1	LS	$ 202,000	$ 202,000
	Pump Station Intake	1	LS	$ 87,000	$ 87,000
	3Phase Electrical to Pump Station	1	LS	$ 634,000	$ 634,000
	3Phase Along Main Pipeline	21719	LF	$ 13	$ 287,994
	Road Crossings (Boring)	1	LS	$ 36,000	$ 36,000
	Bonding (5%)	1	LS	$ 81,000	$ 81,000
	Mobilization (6%)	1	LS	$ 97,000	$ 97,000
	Engineering & Legal (15%)	1	LS	$ 241,000	$ 241,000
	Contingency (15%)	1	LS	$ 241,000	$ 241,000
				Off Farm Subtotal	$ 2,262,994

On Farm Costs	Item	Qty	Unit	Unit Price	Total
	12" PVC Installed (80 psi)	0	LF	$ 11	$ -
	10" PVC Installed (80 psi)	13095	LF	$ 9	$ 118,000
	10" PVC Installed (100 psi)	729	LF	$ 10	$ 8,000
	8" PVC Installed (80 psi)	2809	LF	$ 8	$ 23,000
	Center Pivot Base Installation (Includes Fittings and Concrete Pivot Pads)	10	EA	$ 20,000	$ 200,000
	Center Pivot Installation and Freight	12080	LF	$ 47	$ 567,760
	Electrical Service to Pivot	16633	LF	$ 4	$ 69,000
	Contingency (10%)	1	LS	$ 99,000	$ 99,000
				On Farm Subtotal	$ 1,084,760

Total	**$ 3,347,754**

3.7.6 Tier 3 Project Site B – Concept Design and Cost Estimate

Project Site B is located in McLean County and consists of 1016 irrigated acres. The conceptual project layout is shown in *Figure 3.25*. *Please note these concept project boundaries were not based upon any existing or potential landowner parcels and/or agreements. No potential or existing landowners were contacted in these efforts and the project shown only represents a potential concept project based upon the analyses in this report.*



Summary	Project Site:	B
	Nearest Canal Mile Marker:	5
	Total Irrigable Acres:	1,345
	Total Irrigated Acres:	1,016
	Irrigated Acreage Percentage:	76%
	GPM Req'd:	5,650
	TDH Req'd:	292
	HP Req'd:	720
	Off Farm Cost per Irrigated Acre	$ 3,280
	On Farm Cost per Irrigated Acre	$ 1,190
	Composite Cost per Irrigated Acre	$ 2,830

Any reliance upon this map is at user's own risk. AE2S does not warrant the map or its features are either spatially or temporally accurate or fit for a particular use.

N

0 1,500 3,000 Feet

1 inch = 3,000 feet

Locator Map Not to Scale

Figure 3-25: Project Site B- Concept Design

Irrigation Master Plan

Garrison Diversion Conservancy District | McLean, Burleigh, and Sheridan Counties, ND

GARRISON DIVERSION

AE2S Advanced Engineering and Environmental Services, Inc.

Date: 7/15/2016 | Coordinate System: North Dakota State Plane South

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A cost analysis based on the conceptual project layout, as well as information such as total irrigated acreage, anticipated pipeline sizing, project design flow and horsepower pumping requirements, and location to existing electrical availability is included and reflected in the project estimate shown in *Table 3.15*. Once the cost estimate was complete, for comparison the project cost per ***irrigated*** acre was separated into the following three categories:

- Off Farm Cost Per Irrigated Acre
- On Farm Cost Per Irrigated Acre
- Composite Cost Per Irrigated Acre: cost includes 100% On Farm costs and 50% Off Farm costs consistent with current North Dakota State Water Commission irrigation cost share policy.

Table 3.15 Project Site B – Cost Estimate

Summary		
	Project Site:	**B**
	Nearest Canal Mile Marker:	5
	Total Irrigable Acres:	1,345
	Total Irrigated Acres:	1,016
	Irrigated Acreage Percentage:	76%
	GPM Req'd:	5,650
	TDH Req'd:	292
	HP Req'd:	720
	Off Farm Cost per Irrigated Acre	$ 3,280
	On Farm Cost per Irrigated Acre	$ 1,190
	Composite Cost per Irrigated Acre (50% Off Farm Cost Share Included)	$ 2,830

Off Farm Costs	Item	Qty	Unit	Unit Price	Total
	24" C900 DR 25 Installed (165 psi)	11484	LF	$ 52	$ 598,000
	21" PVC Installed (80 psi)	5242	LF	$ 29	$ 155,000
	18" PVC Installed (80 psi)	498	LF	$ 23	$ 12,000
	12" PVC Installed (80 psi)	2678	LF	$ 11	$ 29,000
	10" PVC Installed (80 psi)	13421	LF	$ 9	$ 121,000
	8" PVC Installed (80 psi)	6617	LF	$ 8	$ 53,000
	Fittings, Valves, Etc.	1	LS	$ 42,000	$ 42,000
	Pump Station	1	LS	$ 297,000	$ 297,000
	Pump Station Intake	1	LS	$ 93,000	$ 93,000
	3Phase Electrical to Pump Station	1	LS	$ 254,000	$ 254,000
	3Phase Along Main Pipeline	39940	LF	$ 13	$ 529,604
	Road Crossings (Boring)	2	LS	$ 36,000	$ 72,000
	Wetland Crossings	2	LS	$ 50,000	$ 100,000
	Bonding (5%)	1	LS	$ 118,000	$ 118,000
	Mobilization (6%)	1	LS	$ 142,000	$ 142,000
	Engineering & Legal (15%)	1	LS	$ 354,000	$ 354,000
	Contingency (15%)	1	LS	$ 354,000	$ 354,000
				Off Farm Subtotal	$ 3,323,604

On Farm Costs	Item	Qty	Unit	Unit Price	Total
	12" PVC Installed (80 psi)	4002	LF	$ 11	$ 43,000
	10" PVC Installed (80 psi)	7438	LF	$ 9	$ 67,000
	8" PVC Installed (80 psi)	10650	LF	$ 8	$ 86,000
	Center Pivot Base Installation (Includes Fittings and Concrete Pivot Pads)	10	EA	$ 20,000	$ 200,000
	Center Pivot Installation and Freight	12926	LF	$ 47	$ 607,522
	Electrical Service to Pivot	22090	LF	$ 4	$ 91,000
	Contingency (10%)	1	LS	$ 110,000	$ 110,000
				On Farm Subtotal	$ 1,204,522

Total	**$ 4,528,126**

Chapter 4.0 Electrical Requirements for Irrigation Distribution

4.1 Electrical Requirements Summary

Analysis of the McClusky Canal electrical infrastructure was conducted to determine 3-phase power availability over the 72-mile span in this study, which extends through three separate electric utility jurisdictions; Capital Electric, McLean Electric and Verendrye Electric. Coordination with each of these companies provided cost estimations to bring 3-phase electrical service to each mile marker along the canal. This analysis was used to help narrow down potential irrigation sites into Tier 1, Tier 2 and Tier 3 Project levels based on cost of installation to each canal mile marker, and can be viewed in more detail in *Section 4.4* of this report.

In addition to the cost of installation to distribute power to each of the pump sites, further analysis was performed on Project Use Power in addition to local Electric Cooperative utility rates involved in each of the serving electric utility boundaries. Project Use Power is contracted through the Western Area Power Administration (WAPA) with additional charges billed through rural electric utility rates.

4.2 Project Use Power

Project Use Power is a part of Water Project Legislation that allows the Bureau of Reclamation to allocate power generated by the Garrison Dam to aid in offsetting the cost of providing irrigation water to irrigation users along the canal. This allocation is billed according to WAPA energy rates and is referred to as Project Use Power. WAPA also handles all metering of the irrigation pumping stations as described below.

Project Use Power is calculated by using a combination of irrigated acreage and the required horsepower to provide gravity feed pressure to the highest point of the irrigated area, or irrigable plane. Gravity feed pressure is defined as the pressure provided by ten feet of head above the highest point on the irrigable plane. After determining the gravity feed pressure required on the irrigable plane, the Bureau of Reclamation uses a worst-case scenario algorithm to calculate the kilowatt demand required to pump water from the canal to all turnouts or pivots in the irrigable plane it is feeding.

All Pump sites on the McClusky Canal, when managed by the GDCD, are given an allocated amount of Project Use Power based on calculations determined by the Bureau of Reclamation. Any energy requirement for pressurization over that of a gravity feed calculation, as described above, is provided by the rural electric utility that serves the project area and is billed according to the irrigation rates they have established separately if the Project Use Power allocation is surpassed.

The power usage at each project site is metered by WAPA, and the Project Use Power is separated out. Any kilowatt amounts remaining are then forwarded to the serving electric utility for billing based on their rates, less the percent value of power demand provided through WAPA. Thusly, two separate bills are sent to the GDCD at the end of each billing cycle. This cost separation may be viewed in further detail in *Section 4.4*.

4.3 Electric Utility Availability

In all cases analyzed, there is a need for local servicing utilities to install distribution to each of the project sites. Throughout the analyzed area of the McClusky Canal in this study, there are variances to the availability of 3-phase power. This section outlines the three serving rural electric utilities and their availability of existing infrastructure, and required extension costs for each mile along the McClusky Canal.

4.3.1 McLean Electric

McLean Electric is the serving electric utility for the first 34 miles of the McClusky Canal under review. Of the three utilities that provide electrical service along the canal, McLean Electric has the most available 3-phase infrastructure for expansion of irrigation lift stations. Underground 480V, 3-phase energy is approximately $70,000 per mile to install with some variations to cost based on the specific needs to install to any particular site.

Initial cost analyses were performed for each mile marker on the McClusky Canal to bring a 480V 3-phase service to each pump site. The cost breakdown for power delivery to each canal mile marker in McLean Electric's service area is shown in *Table 4.1*. A figure showing a visualization of these installation costs for each canal mile marker may be found in *Figure 3.5*.

Every 3-phase installation is evaluated by McLean Electric for additional benefits to their system, in which case they will implement cost sharing of installation of required lines for projects. This cost analysis is not performed until actual project installation is requested, and must be determined by the systems engineer at that time. *Table 4.1* does not include any cost sharing estimates and is based on the cost required to install a 400A, 480V, 3-phase service to each canal mile marker.

Table 4.1 McLean Electric Mile Marker Cost

McLean Electric		
Mile Marker	Proximity to 3-Phase Power (LF)	Cost to Establish 400A, 277/480V 3PH Service
1	3,300	$ 51,250
2	8,450	$ 124,975
3	11,250	$ 164,875
4	16,850	$ 242,575
5	16,950	$ 243,925
6	10,000	$ 143,800
7	4,150	$ 62,725
8	0	$ 4,600
9	4,600	$ 66,700
10	1,750	$ 28,225
11	1,200	$ 20,800
12	4,500	$ 67,450
13	4,400	$ 66,100
14	1,100	$ 19,450
15	6,450	$ 95,875
16	9,900	$ 142,450
17	6,700	$ 97,150
18	3,900	$ 57,250
19	5,000	$ 72,100
20	7,750	$ 113,425
21	15,850	$ 229,075
22	22,900	$ 328,450
23	28,400	$ 388,000
24	36,600	$ 517,600
25	42,200	$ 601,600
26	47,300	$ 674,650
27	56,500	$ 807,250
28	54,000	$ 773,500
29	53,500	$ 766,750
30	54,850	$ 784,975

4.3.2 Capital Electric

Capital Electric is the servicing utility responsible to provide electric service to canal mile markers 35 – 56. Each of the sites along the canal will be serviced from the McClusky Sub Station that is located southwest of McClusky, ND. Irrigation sites will be serviceable on the north side of the canal from this substation with limited capacities available. Underground 480V

3-phase service is $80,000 per mile to install. Cost estimates to provide electric service to each canal mile marker is provided in *Table 4.2*. A visual representation of cost to install utilities can also be viewed in *Figure 3.5*.

Collectively, this is the most expensive stretch of the McClusky Canal with regards to cost of installation of electrical infrastructure. This is due to the fact that Capital Electric's main customers are seasonal and require little demand. The addition of any 3-phase irrigation pump stations in this stretch will require upgrades to Capital Electric's only switchyard that is capable of feeding the required power to any of these sites.

Table 4.2 Capital Electric Mile Marker Cost

Capital Electric		
Mile Marker	Proximity to 3-Phase Power (Miles)	Cost to Establish 400A, 277/480V 3PH Service
35	14.6	$ 1,176,889
36	14.7	$ 1,161,130
37	14.5	$ 1,090,967
38	13.6	$ 1,051,413
39	13.1	$ 970,875
40	12.1	$ 886,356
41	11.1	$ 783,037
42	9.8	$ 691,475
43	8.6	$ 400,000
44	8.0	$ 625,940
45	7.8	$ 579,462
46	7.2	$ 556,955
47	7.0	$ 461,240
48	5.8	$ 372,522
49	4.7	$ 367,762
50	3.4	$ 155,615
51	1.9	$ 74,159
52	0.9	$ 37,294
53	0.5	$ 123,012
54	1.5	$ 212,841
55	4.0	$ 316,144
56	5.3	$ 424,709

4.3.3 Verendrye Electric

Verendrye Electric is the servicing electric utility for the remainder of the canal analysis area. Mile markers 57 – 72 is within the Verendrye Electric service boundaries and underground 3-phase service can be installed at $80,000 per mile. The longest distance to provide 3-phase service within this area is equal to twelve miles in length beginning at mile marker 57. Further details of each mile marker can be viewed in *Table 4.3* with visual representation shown in *Figure 3.5*.

At the start of the Capital Electric / Verendrye Electric service boundary, there is no availability of 3-phase power. This is the most expensive point to extend 3-phase service for potential irrigation projects. The cost of 3-phase installation goes down as you approach mile marker 69, and increases again to the end of the analysis area at mile marker 72.

Table 4.3 Verendrye Electric Mile Marker Cost

Verendrye Electric		
Mile Marker	Proximity to 3-Phase Power (Miles)	Cost to Establish 400A, 277/480V 3PH Service
57	12.0	$ 960,000
58	10.0	$ 800,000
59	8.5	$ 680,000
60	8.0	$ 640,000
61	7.0	$ 560,000
62	6.5	$ 520,000
63	5.0	$ 400,000
64	4.0	$ 320,000
65	3.0	$ 240,000
66	2.5	$ 200,000
67	1.0	$ 80,000
68	0.5	$ 60,000
69	0.5	$ 60,000
70	1.5	$ 120,000
71	2.8	$ 220,000
72	3.5	$ 280,000

4.3.4 Utility Rates

Table 4.4 Utility Rate Schedules

Classification	Utility	Irrigation Service	Off-Peak Irrigation Service
Annual Basic Service Charge	McLean Electric	-	-
	Capital Electric*	$250.00	$250.00
	Verendrye Electric	-	-
Monthly Service Charge	McLean Electric**	$12.00/HP	-
	Capital Electric	-	-
	Verendrye Electric	$43.00	$43.00 + $.067/kWh
Monthly Demand Charge	McLean Electric	$17.50/month	$0.00/month***
	Capital Electric	$14.00/kWh	$2.80/kWh
	Verendrye Electric	$11.25/kWh over 15kW	$20.00/kW*
Monthly Energy Charge	McLean Electric	$0.0719/kWh	
	Capital Electric	$0.0555/kWh	$0.0555/kWh
	Verendrye Electric	$0.094/kWh**	-

*Amounts shown are a minimum cost of service. Costs increase with demand and power usage with the minimum shown billed to the customer per month.

**Charges shown for monthly service charge are on a per horsepower rating or demand charge, whichever is greater.

***Off peak demand charges are zero up to a certain demand. See utility's rate schedules for details.

4.4 Targeted Project Areas

The areas determined as priority irrigation sites are outlined in *Chapter 3* and illustrated in *Figure 3.19*. The sites illustrated were determined to be target project sites and further information was requested from both McLean Electric and Capital Electric to provide a 3-phase service cost of installation to each site. Any cost estimates provided were based on the requested 400A service size and do not include any cost sharing amounts.

In addition to providing the 3-phase irrigation pump service from the McClusky Canal, an estimate of cost to extend underground electric utilities parallel to the irrigation pipeline was provided for each project site. The extension of 3-phase power along the pipeline route is intended to make power available to irrigation users along the pipeline within the irrigation project area. Line extensions in parallel to the pipeline provides 3-phase power to irrigation users who require 3-phase power to operate their center pivot irrigation systems. 3-phase service to the center pivots can be installed by the irrigator at the same time as their irrigation pipeline, and provides a cost saving passed on to the irrigator.

Also provided in this section are preliminary estimations of energy costs for required lift to provide irrigation to each of the Tier 1, 2, and 3 Project Sites. These estimations were completed using estimates provided by the Bureau of Reclamation. These were done by using their *First Lift* calculations to determine the amount of power anticipated to be provided through WAPA for each project site. These estimates provide a good base knowledge of what portion of power used will be billed on WAPA rates. A breakdown of cost is provided for each project site, and are shown in *Table 4.6*, *Table 4.7*, and *Table 4.8*. These estimations are based on the assumption that each project lift station is running at peak capacity. Also shown, are the estimated billing amounts from WAPA and the servicing Electric Utility, and the total estimated cost per season to power each project site.

4.4.1 Tier 1 Project Sites

As shown in *Chapter 3*, Project Sites C, D, and E were determined to be Tier 1 projects. All three of these sites are located in McLean Electric's service boundaries and are relatively close to existing utility distribution sites. The details of proximity to existing 3-phase service, and the cost of installation to each of the project lift station is listed in *Table 4.5*.

Along with 3-phase service installation to each of the project lift station sites, McLean Electric will install 3-phase service parallel with the proposed pipelines lines shown in *Figure 3.19* for $70,000 per mile. This cost will include cabinets every half mile for irrigation end users to obtain 3-phase power for center pivot operation, as well as service points for McLean Electric. On-Farm end users will be responsible for contacting McLean Electric for 3-phase service required to operate irrigation pivots.

Table 4.5 Tier 1, 2, and 3 Site Estimations

Project Tier	Project Site	Electrical Service Provider	Proximity to 3-Phase Power	Cost to Establish 400A, 277/480V 3PH Service
Tier 1	Site C	McLean Electric	5,075 LF	$73,113
	Site D	McLean Electric	5,300 LF	$78,850
	Site E	McLean Electric	5,800 LF	$85,600
Tier 2	Site F	McLean Electric	2,750 LF	$44,425
	Site J	Capital Electric	42,240 LF	$633,600
Tier 3	Site B	McLean Electric	17,200 LF	$253,700

Table 4.6 Energy Cost Estimations for Tier 1 Site Locations

Project Site C

Energy Share and Cost Analysis	
Total Power Required	195.7kW
Power Provided by WAPA	148.4kW
Power Provided by McLean	47.3kW
Total Demand Required	217.9kW
Total Run Time / Season	710
WAPA Cost / kWH	$0.016
Hours Billed @ WAPA Rates	$1,686.27
WAPA Demand / kW	-
Cost for Total Demand	-
McLean Cost / kWH	$0.075
Hours Billed @ McLean Rates	$2,519.09
McLean Demand / kW	$18.00
Demand Charges for 5 Months	$4,738.93
Total Cost for Season	$8,944.29

Project Site D

Energy Share and Cost Analysis	
Total Power Required	139.8kW
Power Provided by WAPA	78.5kW
Power Provided by McLean	61.3kW
Total Demand Required	155.6kW
Total Run Time / Season	710
WAPA Cost / kWH	$0.016
Hours Billed @ WAPA Rates	$892.01
WAPA Demand / kW	-
Cost for Total Demand	-
McLean Cost / kWH	$0.075
Hours Billed @ McLean Rates	$3,264.07
McLean Demand / kW	$18.00
Demand Charges for 5 Months	$6,140.39
Total Cost for Season	$10,296.46

Project Site E

Energy Share and Cost Analysis	
Total Power Required	195.7kW
Power Provided by WAPA	136.5kW
Power Provided by McLean	59.2kW
Total Demand Required	217.9kW
Total Run Time / Season	710
WAPA Cost / kWH	$0.016
Hours Billed @ WAPA Rates	$1,550.66
WAPA Demand / kW	-
Cost for Total Demand	-
McLean Cost / kWH	$0.075
Hours Billed @ McLean Rates	$3,154.77
McLean Demand / kW	$18.00
Demand Charges for 5 Months	$5,934.79
Total Cost for Season	$10,640.22

4.4.2 Tier 2 Project Sites

As listed in *Chapter 3*, Project Sites F and J were determined to be Tier 2 projects. Project Site F is located within McLean Electric's service boundaries with the cost to install 3-phase service to the project lift station listed in *Table 4.5*. 3-phase power installation at the cost of $70,000 per mile, parallel with the proposed irrigation pipelines, was planned to make 3-phase power available to On-Farm end users for center pivot operation.

Project Site J falls within the service Capital Electric service area, with the proximity and cost of installation for 3-phase electrical service to the project lift station shown in *Table 4.5*. Capital Electric will extend 3-phase power in parallel to the proposed irrigation pipeline at the cost of $80,000 per mile. This installation cost includes sectionalizing cabinets located every half mile for maintenance as well as points of extension to On-Farm end users for irrigation center pivot operation.

Table 4.7 Energy Cost Estimations for Tier 2 Site Locations

Project Site F

Energy Share and Cost Analysis	
Total Power Required	894.8kW
Power Provided by WAPA	651.5kW
Power Provided by McLean	243.3kW
Total Demand Required	996.0kW
Total Run Time / Month	710
WAPA Cost / kWH	$0.016
Hours Billed @ WAPA Rates	$7,401.37
WAPA Demand / kW	-
Cost for Total Demand	-
McLean Cost / kWH	$0.075
Hours Billed @ McLean Rates	$12,956.31
McLean Demand / kW	$18.00
Demand Charges for 5 Months	$24,373.52
Total Cost for Season	$44,731.19

Project Site J

Energy Share and Cost Analysis	
Total Power Required	274.0kW
Power Provided by WAPA	207.5kW
Power Provided by Capital	66.5kW
Total Demand Required	305.0kW
Total Run Time / Month	710
WAPA Cost / kWH	$0.016
Hours Billed @ WAPA Rates	$2,357.25
WAPA Demand / kW	-
Cost for Total Demand	-
Capital Electric Cost / kWH	$0.055
Hours Billed @ Capital Rates	$2,598.39
Capital Electric Demand / kW	$14.00
Demand Charges for 5 Months	$5,184.36
Total Cost for Season	$10,140.01

4.4.3 *Tier 3 Project sites*

As outlined in *Chapter 3*, Project Site B was determined to be the only Tier 3 project chosen for concept design purposes. Site B is also located within McLean Electric's service boundaries. Site B's proximity to existing 3-phase service and cost is listed in *Table 4.5*. As with the other sites located in McLean Electric's service boundaries, parallel service can be installed at the rate of $70,000 per mile. This cost per mile also includes installing sectionalizing cabinets located every half mile for maintenance purposes, as well as points of extension to potential On-Farm end users. The 3-phase power available would be utilized for center pivot operation, and the cost of installation would be the responsibility of the On-Farm end user.

Table 4.8 Energy Cost Estimations for Tier 3 Site Location

Project Site B

Energy Share and Cost Analysis	
Total Power Required	419.5kW
Power Provided by WAPA	362.4kW
Power Provided by McLean	57.0kW
Total Demand Required	466.9kW
Total Run Time / Season	710
WAPA Cost / kWH	$0.016
Hours Billed @ WAPA Rates	$4,117.07
WAPA Demand / kW	-
Cost for Total Demand	-
McLean Cost / kWH	$0.075
Hours Billed @ McLean Rates	$3,037.26
McLean Demand / kW	$18.00
Demand Charges for 5 Months	$5,713.72
Total Cost for Season	$12,868.05

Chapter 5.0 Financial Analysis

The Financial Analysis completed and summarized herein builds on previous studies performed by North Dakota State University (NDSU) and tailors it to provide a specific look at the benefit of irrigation for the six identified project sites. As a result, this analysis provides a detailed snapshot of the costs and benefit to an individual producer to switch to an irrigated method of crop production.

5.1 Previous Financial Analyses

NDSU has evaluated on a number of occasions the benefit of irrigation to farm-level returns. Most recently, NDSU conducted a study at the request of Garrison Diversion to evaluate the on-farm and off-farm economic benefit of irrigation (Ripplinger, et. al. 2014). This study found that to the individual producer, a net increase in return can be expected between $1,418 and $1,700 per acre over a 20-year period. The analysis at hand varies from these previous studies by looking at single year returns for specific project sites with detailed capital cost information.

5.2 Baseline Updates

As noted, Ripplinger, et. al. 2014 provides the baseline methodology for evaluating the benefit of irrigation service. Given the specifics of the project site-specific evaluations, a number of modifications were made to the NDSU methodology in order to make the results more relevant on a year-over-year cash basis of accounting. In addition, crop revenue and production cost data was updated using the most recent year (2016) crop budgets from NDSU (See *Appendix D* for Crop Budget Detail). Garrison Diversion is authorized to provide irrigation across two NDSU crop budget regions (North Central Region and South Central Region). The North Central Region includes the counties of Renville, Ward, McLean, Bottineau, McHenry, Rolette, Pierce, and Benson. The South Central Region includes the counties of Sheridan, Burleigh, Kidder, Logan, Emmons, and McIntosh. The crop budgets for these two regions are averaged to provide a composite for the baseline dry irrigation. The overall updates include:

- Incorporating 2016 crop budgets for the North Central Region and South Central Region;
- Modification of available irrigation crop budgets (2014) to reflect reductions in both input prices and commodity prices;
- Adding electricity capital costs to off-farm capital costs included under irrigation investment;
- Updating electricity costs for on-farm equipment based on lower electricity cost data from Western Area Power Administration and on-site electric providers;

- Replacing irrigation investment and depreciation costs with debt service to represent debt-financing capital infrastructure;
- Removing irrigation depreciation costs; and
- Updating electricity prices for pivot point pumping to include demand charges.

Keeping base capital costs steady, the changes to methodology outlined above result in an increased cost to irrigate of approximately $13.81 /acre. This increase is driven, in part, by the increase in Irrigated Power costs. The updated methodology below uses an average of the six sites identified. Actual site costs are calculated based on five months of maximum demand charges and 710 hours of runtime. *Table 5.1* compares the original 2014 NDSU Study to the Updated Methodology using the specific irrigation line items from NDSU's crop budgets.

Table 5.1 Irrigation Cost Methodology Comparison

	2014 NDSU Study	Updated Methodology
Irrigated Power	$9.86	$14.60
Irrigation Repairs	$13.03	$13.03
Irrigation Service	$18.00	$18.00
Irrigation Depreciation	$57.03	$0.00
Irrigation Investment	$34.22	$0.00
Irrigation Debt Service	$0.00	$100.32
Total	$132.14	$145.95

Table 5.2 Irrigation Cost Methodology Definitions

Irrigated Power	The electricity cost to run the pump, pivot, and associated machinery. Updated methodology includes demand charges as well as usage charges.
Irrigation Repairs	Costs associated with repair and maintenance of off-farm equipment.
Irrigation Service	Bureau of Reclamation charge for water.
Irrigation Depreciation	Depreciation of on-farm and off-farm irrigation capital equipment reflecting a 20 percent salvage value.
Irrigation Investment	The annualized investment in capital equipment based on NDSU methodology.
Irrigation Debt Service	The annual debt service payment for capital costs. This number replaces the Depreciation and Investment costs identified by NDSU.

5.3 Site-Specific Irrigation Analysis

The site-specific irrigation analysis uses the baseline methodology from Ripplinger et. al. with the modifications above. The result is a single-year snapshot comparing the return for that acreage based on the dryland rotation used in Ripplinger et. al. (Corn/Hard Red Spring Wheat (HRS)/ Dry Beans) to the primarily corn rotation used in the same analysis. *Table 5.3* provides the details of each area used to calculate the return.

Table 5.3 Site Specific Details

Site	D	E	C	F	J	B
Irrigable Acreage	825	796	995	2,948	1,443	1,345
Irrigated Acreage	613	666	729	2,198	1,066	1,016
On-Farm Cost	$679,344	$732,260	$928,392	$2,179,483	$1,084,760	$1,204,522
Off-Farm Cost	$635,209	$864,373	$1,689,942	$6,144,925	$2,262,994	$3,323,604
State Cost Share (50% Off-Farm)*	$317,604	$432,186	$844,971	$3,072,463	$1,131,497	$1,661,802
Composite Project Cost per Acre (50% Off Farm Cost Share Included)	$1,630	$1,750	$2,440	$2,390	$2,080	$2,830

*North Dakota offers cost-share on irrigation projects through the State Water Commission (SWC) as part of their Vision to ensure "Present and future generations of North Dakotans will enjoy an adequate supply of good quality water for people, agriculture, industry, and fish and wildlife". Cost-share is 35 percent of engineering design and 50 percent of construction related costs for off-farm infrastructure, simplified for this analysis to 50 percent of total off-farm costs.

5.3.2 *Non-Irrigated Return*

The non-irrigated return for each of these sites provides the baseline revenue expectation for each of the sites. This baseline revenue is compared against the irrigated returns to determine if at the current cost of irrigation, a producer would expect to see increased returns from the use of irrigation. Using the 2016 crop budgets and the selected dryland rotation, a producer can expect a return of roughly $(8.48)/acre. In the 2014 analysis, the selected dryland rotation resulted in a positive return. With decreasing commodity prices, the projected return for this rotation is negative in 2016. As a result, individual crop selections by producers will most likely vary from this baseline crop selection resulting in different producer-specific returns, but selected rotations will provide a consistent comparison to the original 2014 analysis. Due to a negative return for the dryland rotation, all sites would return a loss to the producer in 2016 based on the selected dryland rotation. *Table 5.4* shows the projected total dryland returns before irrigation based on the irrigated acreage for each site.

Table 5.4 2016 Non-Irrigated Return

Site	D	E	C	F	J	B
Irrigated Acreage	613	666	729	2,198	1,066	1,016
Total Return Before Irrigation	$ (5,199)	$(5,649)	$ (6,183)	$ (18,643)	$ (9,041)	$ (8,617)

*Primarily Corn Rotation

5.3.3 *Irrigated Return*

The irrigated return shows the return to labor and management for a producer after including the costs of irrigation and adjusting the yield and price for a selected crop. When compared to the return to labor and management in the dryland rotation, the net return shows whether the investment in irrigation services results in a higher return to labor and management in the test year (2016).

5.3.3.1 Irrigated Return Inputs

To calculate irrigated return and incorporate a varied crop budget based on the cost of providing service at varying locations from the canal, the primarily corn rotation was selected. The primarily corn rotation is used in this updated analysis to allow for easier comparison to the original NDSU analysis. Other rotations are identified in the original NDSU analysis. Depending on crop yields and prices in any given year, varying the rotation selected could result in greater return to management and labor. For the various sites, the returns and costs per acre remain constant except for the irrigation investment cost. Irrigation investment cost is determined by calculating a per acre loan payment for the total on-farm and off-farm irrigation cost to the producer. Consistent with the site-specific costs shown above, a 50 percent SWC cost-share is included in the analysis to offset the off-farm irrigation cost to the producer. Modeled loan terms are at 4 percent interest rate over 20 years. While various programs are available to offset additional costs to the producer, (for example, the Bank of North Dakota offers the Ag PACE program to reduce up to $20,000 in total interest reductions per project) they are not included in this calculation as the use of those programs will be producer specific. *Table 5.5* shows the revenues, costs, and return for the six sites.

Table 5.5 Irrigated Return

Site	D	E	C	F	J	B
Per Acre Revenue	$560.00	$560.00	$560.00	$560.00	$560.00	$560.00
Per Acre Direct Costs (Less Irrigation Power)	$309.24	$309.24	$309.24	$309.24	$309.24	$309.24
Per Acre Irrigation Power Costs	$16.80	$15.98	$12.26	$20.35	$9.51	$12.67
Per Acre Indirect (Fixed) Costs (Less Irrigation Investment)	$127.10	$127.10	$127.10	$127.10	$127.10	$127.10
Per Acre Irrigation Investment (Fixed Cost)	$119.67	$128.65	$178.99	$175.82	$152.98	$207.59
Total Return to Labor & Managemen t	$(12.81)	$(20.97)	$(67.60)	$(72.51)	$(38.83)	$(96.60)
Irrigated Acreage	613	666	729	2,198	1,066	1,016
Total Site Return After Irrigation	$(7,853)	$(13,968)	$(49,278)	$(159,375)	$(41,394)	$(98,145)

*Primarily Corn Rotation

Table 5.6 Irrigation Return Definitions

Per Acre Revenue	Projected based on yield and price per bushel. Shown on a per acre basis for corn.
Per Acre Direct Costs (Less Irrigation Power)	Includes costs such as seed, chemicals, fuels, irrigation repairs, drying, etc. Shown on a per acre basis for corn.
Per Acre Irrigation Power Costs	Annual per acre cost calculated based on five months of demand charges and 710 hours of operating time. Demand charges assume 100 percent of motors and pumps are started within 15 minutes of each other for maximum demand impact on system (consistent with design criteria)
Per Acre Indirect (Fixed) Costs (Less Irrigation Investment)	Includes irrigation service, machinery costs, overhead, and land charge. Does not include irrigation investment. Shown on a per acre basis for corn.
Per Acre Irrigation Investment (Fixed Cost)	Annual debt service payment on a per acre basis.
Total Return to Labor & Management	Calculated as the revenue less costs on a per acre basis.
Irrigated Acreage	Total number of acres served by the irrigation infrastructure.
Total Site Return After Irrigation	Total Return to Labor & Management over the irrigated acreage.

The negative returns shown are driven largely by the off-farm capital costs and irrigation power costs. For example, Site F's Off-Farm cost is approximately $6.1 M (before any cost-share). This cost is driven by two main factors, the gallon per minute pumping requirement to irrigate nearly 2,200 acres as well as the cost of 3-phase power to the site. The Off-Farm cost results in irrigation investment per acre of approximately $176. Site F's Irrigation Power cost is approximately $20 per acre driven largely by the demand charge associated with operating the equipment concurrently. These two items total over $196 driving the negative return of approximately $73.

While Off-Farm capital costs is one of the main causes of negative returns, the cause of large capital costs varies by site. For example, Sites E and C have very similar acreage, head requirements, and horsepower requirements for the pump stations, but due to pipe lengths, electric supply costs, and acreage served, Site C has nearly double the Off-Farm cost of Site E. Each potential site will need individual evaluations to determine the main cost-driver.

5.3.4 Return Summary

The overall increase or (decrease) in return is the difference between the before irrigation return and the after irrigation return, or net return after irrigation. The net return after irrigation is calculated by subtracting the return before irrigation from the return after irrigation. A positive net return after irrigation means that the benefit from irrigation is greater than the benefit from not irrigating. None of the sites evaluated resulted in an increased return, meaning that in the 2016 test year, irrigation would not result in higher returns for a producer.

Table 5.7 Summary of Returns

Site	D	E	C	F	J	B
Irrigated Acreage	613	666	729	2,198	1,066	1,016
Return Before Irrigation	$ (5,199)	$(5,649)	$ (6,183)	$ (18,643)	$ (9,041)	$ (8,617)
Return After Irrigation	$(7,853)	$(13,968)	$(49,278)	$(159,375)	$(41,394)	$(98,145)
Net Return After Irrigation	$(2,654)	$(8,319)	$(43,094)	$(140,732)	$(32,352)	$(89,527)

*Primarily Corn Rotation

5.4 Time-Sensitive Comparison

While the current analysis using 2016 data shows a negative return from irrigation, the 2014 NDSU analysis showed a positive return. The varying results are primarily driven by the fluctuating, and currently low, commodity prices throughout the region. In the 2014 analysis, estimated corn prices were $4.00 per bushel; by 2016, those prices had dropped to an estimated $3.50, resulting in lower returns for corn. Due to this varying nature of commodity prices, producers can expect that returns will vary from year to year. The 2014 NDSU analysis evaluated fluctuations in commodity prices by performing a stochastic analysis accounting for potential highs and lows over a 20-year timeframe. *Table 5.8* highlights the sensitivity of this analysis to various crop prices by overlaying using the commodity input costs and prices from the 2014 analysis onto the six evaluated sites.

Based on this, even a small ($0.50) move in commodity prices can result in changes in net return of nearly $90,000. As commodity prices fluctuate from year to year, producers will be able to expect a corresponding change in net returns from irrigation.

Table 5.8 Sensitivity Comparison

Site	D	E	C	F	J	B
2014 Return Before Irrigation	$13,936	$15,140	$16,573	$49,968	$24,234	$23,097
2014 Return After Irrigation	$31,104	$28,357	$(2,949)	$(1,907)	$23,421	$(6,259)
2014 Net Return After Irrigation	$17,169	$13,217	$(19,521)	$(51,875)	$(813)	$(29,356)
2016 Return Before Irrigation	$ (5,199)	$(5,649)	$ (6,183)	$ (18,643)	$ (9,041)	$ (8,617)
2016 Return After Irrigation	$(7,853)	$(13,968)	$(49,278)	$(159,375)	$(41,394)	$(98,145)
2016 Net Return After Irrigation	$(2,654)	$(8,319)	$(43,094)	$(140,732)	$(32,352)	$(89,527)
Change in Net Return After Irrigation from 2014 to 2016	$(19,822)	$(21,536)	$(23,573)	$(88,857)	$(31,539)	$(60,172)

*Primarily Corn Rotation

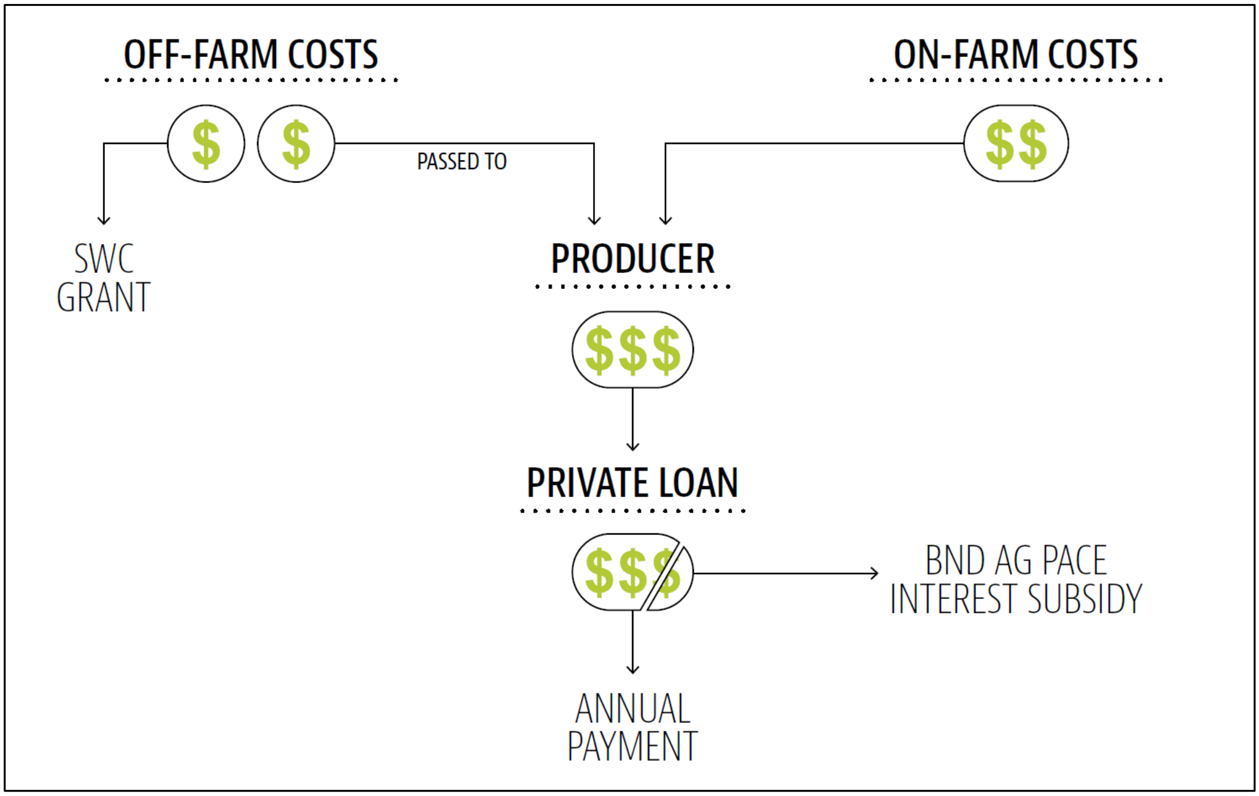
5.5 Existing Funding Framework

Existing funding options available for producers to implement irrigation include both grants, loans, and loan subsidies. For a typical project, costs will be realized both Off-Farm (pumps, piping, and related equipment) as well as On-Farm (pivot and related equipment). In general, these costs will be offset by grants and subsidized loan options when available. However, in the end, the producer is responsible for all remaining Off-Farm and On-Farm costs incurred to provide irrigation service.

Off-Farm costs generally represent the largest cost drivers for a project. These costs are first-offset by a cost-share program offered by the North Dakota SWC. The SWC's mission is "to strengthen the economy of North Dakota by managing water resources of the state for the benefit of its people". Recent reports from NDSU have shown the benefit of an increase of approximately $575/acre in gross business volume from irrigation along the McClusky Canal (summarized in *Appendix F* and *Appendix G*). The SWC's cost-share program has been modified in recent years from a flat 50 percent cost-share for Off-Farm costs to a tiered cost-share of 35 percent of engineering design and 50 percent of all other eligible costs. Eligible costs include "those associated with new central supply works, including water storage facilities, intake structures, wells, pumps, power units, primary water conveyance facilities, and electrical transmission and control facilities." The full cost-share policy is attached in *Appendix E*. As noted previously, the overall cost-share has been simplified to a flat 50 percent for this analysis. Additional stipulations apply to this program such as cost-share funding cannot fund most administrative costs as well as property acquisition costs. After applying the available State cost-share, Garrison Diversion then assesses Off-Farm costs to the producer for repayment.

This assessment becomes the ultimate responsibility of the producer to fund along with On-Farm costs. In order to fund these costs, a producer may use debt to spread the total costs over a period of time. If the producer does not use Garrison Diversion's special assessment authority to finance a project, they are responsible for identifying and securing this debt funding from local banks or credit services such as Farm Credit Service, AgCountry, or others. If a producer uses debt, the Bank of North Dakota offers Ag PACE to offset up to $20,000 in interest costs. Together, Off-Farm and On-Farm costs with these various programs applied will generally result in a debt-service payment for the producer. *Figure 5.1* outlines this process.

Figure 5.1 Project Funding Diagram



5.6 Funding Framework Alternatives

The existing funding framework assumes the best case-scenario for SWC cost-share funding (full 50 percent cost share of engineering and construction costs) and the producer being able to secure the remaining funding necessary for these projects. Applying this best-case existing funding framework all but one of the sites have increased returns over the non-irrigated alternatives at 2014 crop prices.

However, the existing funding framework does not guarantee implementation and the question on whether a producer will be able to secure debt funding for a project will be contingent upon the existing debt load of that producer and the value of assets. A producer will typically be able to obtain funding from a local bank for approximately 60 to 70 percent of the value of their assets. Using McLean County as an example, the 2015 County Rents and Values Report (ND Department of Trust Lands 2015: https://land.nd.gov/docs/surface/ctyrent15.pdf) returns an estimated value for (non-irrigated) land of $2,121. Assuming that acreage is collateral for any other loan, a producer could borrow approximately $1,500 (at 70 percent loan to value). The most economical site evaluated resulted in per acre irrigation costs of approximately $1,630. As a result, the producer would not be able to fund the full cost of irrigation at this site and would not be able to fund half the cost of irrigation service at the most expensive site. While the act of irrigation will increase the value of the land, there is no guarantee a producer will be able to fund this type of investment if he owns the land. If a producer rents, the logistics of securing funding becomes even more complicated with increasingly uncertain outcomes. While there is the potential to use Garrison Diversion's special assessment authority, the example of securing private financing is illustrative of the challenges a producer will face.

Due to these factors, an alternative funding framework would aid in promoting irrigation implementation across the state. The crux of an alternative funding framework would be to provide additional capital offsets where the cost of irrigation is higher to bring capital costs down to levels where producers may see more economically viable returns. This would be achieved by providing varied cost-share grant percentages above the 50 percent grant based on criteria such as irrigated acreage, overall head requirements, and other location-specific technical details.

As noted, even with reduced capital costs, a producer may run into issues securing financing for the project. As a result, the alternative funding framework should provide access to a State-sponsored loan program that provides financing for producers above certain collateralized levels. The rates and term on this program can remain flexible enough that the annualized cost per acre for irrigation is relatively consistent across any selected site and at a level that provides producers with the opportunity for increased returns. *Table 5.9* outlines the State cost-share necessary (above the current 50 percent) along with loan terms to provide positive returns for each site under 2014 commodity prices.

Table 5.9 Alternative Cost-Share Scenario 1

Site	D	E	C	F	J	B
State Cost-Share Percentage	50%	50%	66%	62%	51%	74%
Loan Interest Rate	4%	4%	4%	4%	4%	4%
Loan Term	20 years	20 years	20 years	20 years	20 years	20 years
Net Return	$17,169	$13,217	$375	$2,383	$852	$2,437

*Primarily Corn Rotation – 2014 Commodity Prices

A second funding framework alternative evaluated leaves the cost-share funding grant at 50 percent and varies the terms on the loan option. Recent loan funding programs from the State provide 30-year loans at no more than 2 percent interest. Using these example programs as the basis, *Table 5.10* provides Net Returns holding the cost-share at 50 percent and implementing a low-interest long-term loan program for each site under 2014 commodity prices.

Table 5.10 Alternative Cost-Share Scenario 2

Site	D	E	C	F	J	B
State Cost-Share Percentage	50%	50%	50%	50%	50%	50%
Loan Interest Rate	2%	2%	2%	2%	2%	2%
Loan Term	30 years	30 years	30 years	30 years	30 years	30 years
Net Return	$46,012	$46,906	$31,785	$100,073	$63,307	$26,671

*Primarily Corn Rotation – 2014 Commodity Prices

A third alternative cost-share scenario was created to identify the impact to the overall project return if the capital cost of providing 3-phase power service was not passed through to the producer. This approach helps to mitigate the overall cost impact to acreage that could greatly benefit from irrigation for the areas where it is costlier to supply the required 3-phase power. The other aspects of a cost-share program are consistent with the existing State policy, with the remaining 50 percent capital cost-share financed at 4 percent over 20 years. *Table 5.11* below outlines the net return after irrigation as compared to before irrigation for each site under 2014 commodity prices. Removing the burden of power costs from the producer results in potential profitability at three of the sites using 2014 commodity prices and the other assumptions outlined. This is one site more than the baseline analysis.

Table 5.11 Alternative Cost-Share Scenario 3

Site	D	E	C	F	J	B
State Cost-Share Percentage	50%	50%	50%	50%	50%	50%
Loan Interest Rate	4%	4%	4%	4%	4%	4%
Loan Term	20 years	20 years	20 years	20 years	20 years	20 years
Net Return	$25,754	$22,971	$531	$9,654	$47,117	$(15,526)

*Primarily Corn Rotation – 2014 Commodity Prices

Based on these scenarios, under more favorable commodity cost prices a variation to the current cost-share approach can result in more favorable returns to the producer. Allowing for the potential in positive returns to the producer will spur interest in irrigation investment and a corresponding benefit to the State as a whole. However, determining the right mix of additional funding programs will depend on the specific goals and capabilities of State sponsors.

Appendix A: Data Sources

- Aerial Imagery for Burleigh, McLean, and Sheridan Counties: USDA-APFO National Agricultural Inventory Project (NAIP) 2014
- McClusky Canal Mile Markers, Garrison Diversion 2003
- McClusky Canal Centerline, Garrison Diversion 2003
- Water Courses, USGS 100K Resolution 2003
- Water Bodies, USGS 100K Resolution 2003
- Wetlands, National Wetland Inventory
- Soils: U.S. Department of Agriculture, Natural Resources Conservation Service, Soil Survey Geographic (SSURGO)
    - Burleigh County: Version 15 (September 23, 2014)
    - McLean County: Version 16 (April 28, 2009)
    - Sheridan County: Version 15 (April 24, 2008)
- National Elevation Dataset 1/3 Arc Second DEM (10-meter Resolution)
- Electrical Infrastructure Data obtained from Verendrye Electric Cooperative, Capital Electric Cooperative, McLean Electric Cooperative, August 2015
- Existing Irrigation Infrastructure and Sites, Garrison Diversion 2015
- Active Water Permits for Irrigation, State Water Commission, August 7, 2015
- Continental Divide: Delineated from the HUC-12 Watersheds in the National Hydrography Dataset, February 2, 2015: Version 9.3.1 220
- PLSS Townships, ND GIS Hub, February 2, 2015
- Transportation, ND GIS Hub, February 2, 2015
- County Boundaries, ND GIS Hub, February 2, 2015
- Cities and Municipal Boundaries, ND GIS Hub, February 2, 2015
- Ripplinger, David, Saxowsky, David, and Dean Bangsund. "Economic Feasibility of Irrigation Along the McClusky Canal in North Dakota: Farm-level Returns." North Dakota State University. 2014.

Appendix B: Garrison Diversion Master Irrigation Plan Soils Evaluation

Master Irrigation Plan
Potential Irrigation Areas

Through a series of efforts, Garrison Diversion has made a determination of soils with the potential to be irrigated in portions of McLean, Burleigh, Sheridan and Kidder counties. The total area examined encompassed approximately 1,195,000 acres. Documentation of the determination process and explanations of the resulting data follows.

Irrigation Potential Determination

NDSU Extension Service publication AE-1637, Compatibility of North Dakota Soils for Irrigation provided the basis for determination. All soils classified as "Irrigable Soils" and "Conditional Soils" were extracted from soil series shapefiles downloaded from the Natural Resources Conservation Service. Any areas with potentially suitable soils were examined in detail and a determination made of irrigation potential. Additional detail of the process is in Appendix A.

Irrigation Potential Datasets

Irrigation Potential Within 15 Miles

The data resulted from Garrison Diversion's initial effort to identify irrigation areas. Lands located up to 15 miles of the McClusky Canal, from the headworks to about mile marker 58 (Hoffer Lake) were examined. Polygons were created in areas with irrigation potential. Small tracts, generally less than 40 acres, were ignored unless there were larger suitable tracts in the immediate vicinity.

Final Irrigation Potential

Garrison Diversion surveyed landowners for interest in irrigation. The data is the intersection of the interest survey and the Irrigation Potential Within 15 Miles data.

Burleigh & Kidder Potential Irrigation

Recently, additional lands in Burleigh, Kidder, Sheridan and Wells counties were examined for irrigation potential. In order to estimate the acres of potential development, polygons representing center pivots were created. Note there is some overlap with the Irrigation Potential Within 15 miles data.

Kidder Potential Irrigation PLOTS

Several Kidder county locations with irrigation potential are enrolled in the ND Game & Fish Department PLOTS (private land open to sportsmen) program. Since the term of the contracts is not known, these lands were separated from the Kidder Potential Irrigation data.

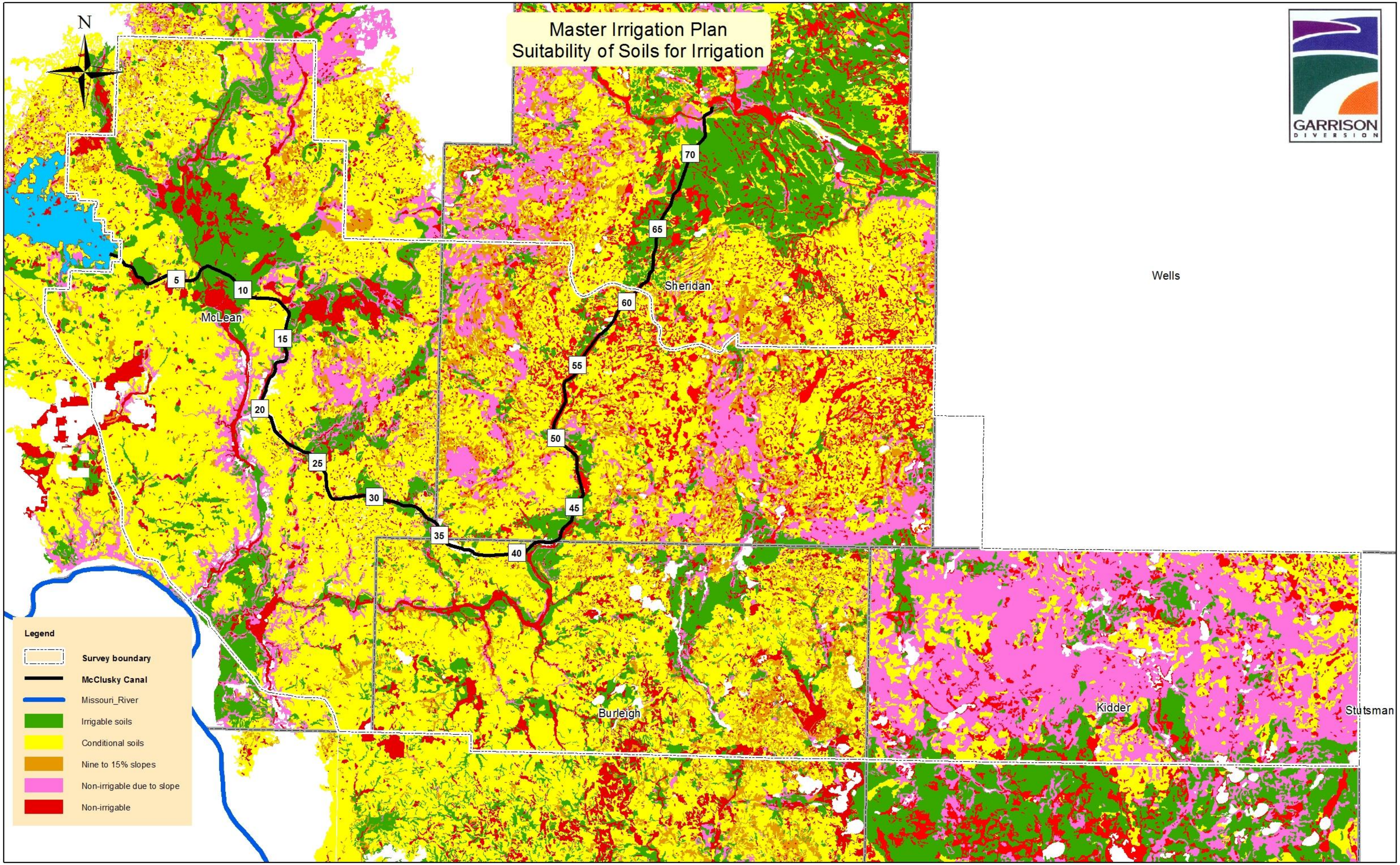
Appendix A
Soils Evaluation Process

Factors used in determining irrigation potential included coverage (contiguous acres) of suitable soils, slope, wetlands, wet areas, Google Earth historic imagery and obstacles (i.e. transmission lines). Results of this survey should be considered provisional.

Slope is an important factor in determining irrigation suitability. Within a soil series, NRCS subcategorizes based on slope. For soils highly susceptible to erosion, slopes of greater than 5-6% were eliminated. For soils less susceptible to erosion, soils of up to 9% slope were generally deemed as having potential for irrigation. Occasionally, small areas of unacceptable slope were included in order to maximize coverage of suitable soils.

Evaluating irrigation potential of conditional soils is a subjective process and the soils required greater scrutiny than those defined as irrigable. NDSU publication AE-1637 states "Soil conditions that contribute to conditional status instead of completely irrigable are the presence of salts, poor drainage properties, the presence of subsurface layering, and the need for supplemental surface and subsurface drainage." Another factor is the presence of other soil series, as some conditional soils contain from 5 to 20 percent of soils that are not suited to irrigation. Compared to the majority soils, the minority soils typically have higher water holding capacities and poorer drainage. Google Earth historic imagery was useful in observing potential drainage issues and estimating whether a conditional soil contained a significant percentage of unsuitable soils. If a parcel was deemed to contain too high a percentage of unsuitable soils and/or potential drainage issues, the parcel was eliminated.

Suitability based on irrigation water quality was not addressed during this survey. A majority of the conditional soils have a recommended maximum allowable EC (electrical conductivity) of 1.5 to 1.8 deci-Siemens per meter (dS/m).


Master Irrigation Plan
Suitability of Soils for Irrigation
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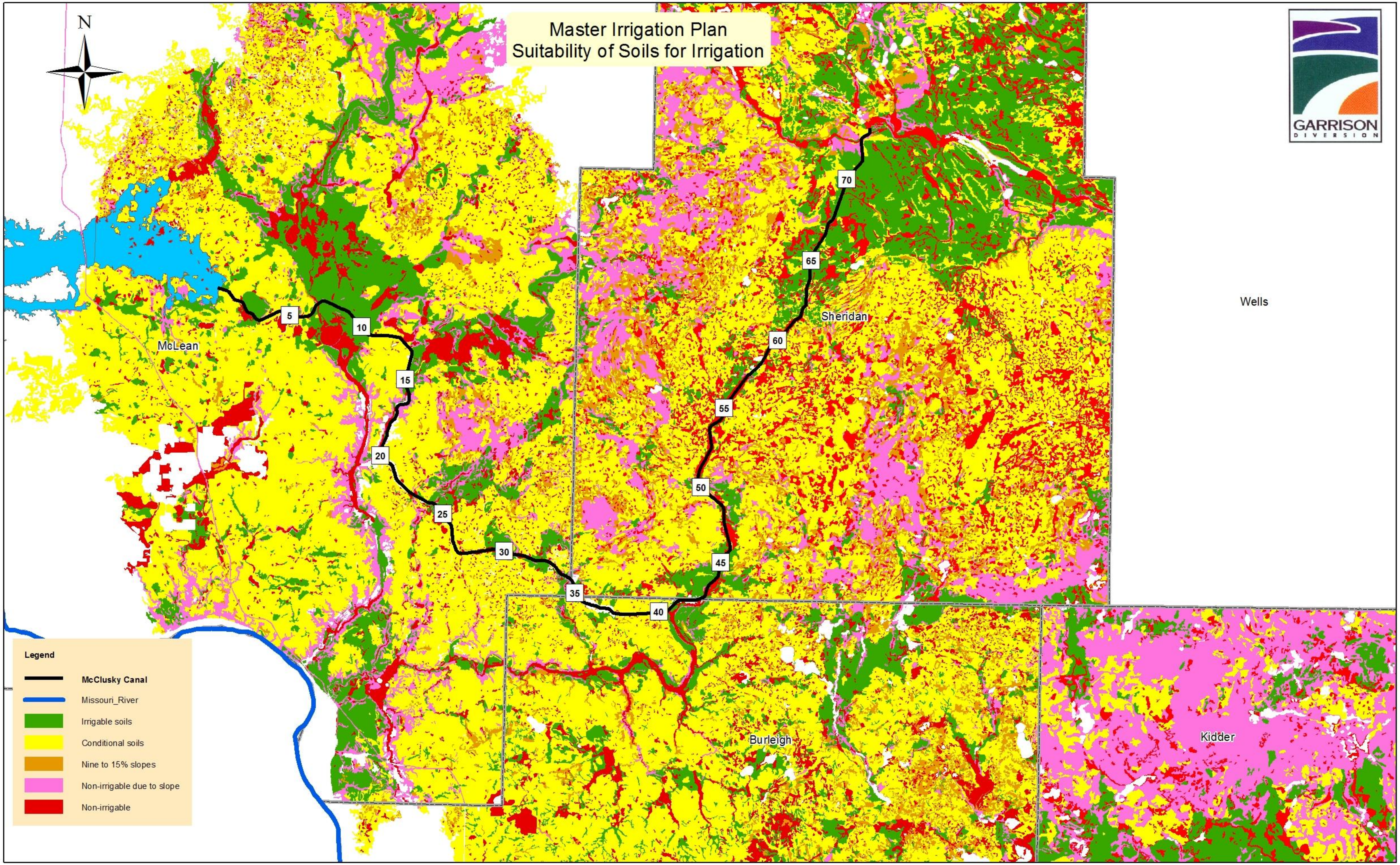
55
60
65
70
McLean
Sheridan
Wells
Burleigh
Kidder
Stutsman
Legend
Survey boundary
McClusky Canal
Missouri_River
Irrigable soils
Conditional soils
Nine to 15% slopes
Non-irrigable due to slope
Non-irrigable



Master Irrigation Plan
Suitability of Soils for Irrigation
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GARRISON
DIVERSION
McLean
Sheridan
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Legend
McClusky Canal
Missouri_River
Irrigable soils
Conditional soils
Nine to 15% slopes
Non-irrigable due to slope
Non-irrigable

AE-1637

Compatibility of North Dakota Soils for Irrigation

Dave Franzen
NDSU Extension Soils Specialist

Tom Scherer
NDSU Extension Agricultural Engineer, Irrigation/Water Quality

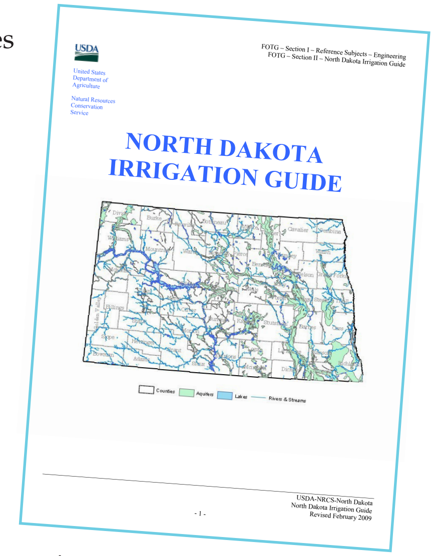
Steve Sieler
Natural Resources Conservation Service State Soil Liaison

Irrigation increases the productivity of soils, increases the effectiveness and consistency of certain soil-applied herbicides, and provides a stable supply of farm products to food product processors. However, irrigation can degrade the quality of soil and cause crop yields to decline even to the point of field abandonment when soil and irrigation water are not compatible. Examples of soil degradation and land abandonment due to improper irrigation can be found throughout history. When irrigation acreage expands to new areas, the determination of soil and water compatibility is critical to sustain yields at high levels.

NDSU EXTENSION SERVICE

February 2013

How to Use This Information



This publication is a condensed version of the “North Dakota Irrigation Guide,” which can be found on the Natural Resources Conservation Service (NRCS) website in section II of the “Electronic Field Office Technical Guide” (e-fotg). The e-fotg for North Dakota can be found in the left-hand menu at *www.nd.nrcs.usda.gov/*.

This publication is intended as a first step to help current and prospective irrigators understand the principles behind the irrigability of soils in North Dakota. This publication should be used in combination with soil survey information of the land to be irrigated. Soil surveys of every county in North Dakota have been completed and documented. Many counties have printed copies, but official, up-to-date soil survey information can be found only on the Internet at *http://websoilsurvey.nrcs.usda.gov/*. Your local NRCS or county Extension office can help you obtain soil survey information for the fields of interest.

Understanding the irrigability of the soil in a field begins with knowledge of the local soil series and the way they are represented on the soil survey map. When soil boundaries are drawn on soil maps, the soil mapping unit is not purely one soil. The other soils present are of minor extent and are called mapping unit inclusions. These inclusions need to be considered when making irrigation management decisions. Each soil description may have different phases of slope and other properties that modify its suitability for irrigation. Consultation with a qualified soil scientist is highly recommended before making the decision to irrigate.

The photo on the cover is of a lateral-move irrigation system (sometimes called a linear-move system) at the Nesson Valley Irrigation Research Site. It is about 30 miles east of Williston on the north side of Lake Sakakawea.

You can check out the research site at www.ag.ndsu.edu/willistonrec/nesson-valley-irrigation-project.

(Photo by Tyler Tjelde)

Classification of Soils for Irrigation Suitability

All soil series in North Dakota have been classified for irrigation suitability. A soil series is based on distinguishing characteristics, including the number of subsoil layers, or horizons; the depth of each horizon; and the texture, color, carbonate content, sodium content, structure, organic matter and other diagnostic characteristics of each horizon.

Soil series are grouped into three irrigation categories: nonirrigable (n), conditional (c) and irrigable (i). Nonirrigable soils should not be irrigated by any water source under any circumstances **(Table 1, pages 4-5)**. The decision to classify a soil as nonirrigable is based on the knowledge that irrigation will not benefit the irrigator in the short term economically and may decrease the productivity of the soil.

A conditional soil can be irrigated under a high degree of management that will vary according to the quality of water and soil properties. Specific recommendations for conditional soil management are important for sustaining irrigation and soil health for the future.

An irrigable soil generally can be irrigated from most water sources. A high level of management is advised to improve nutrient uptake and decrease collateral pollution due to excess water movement through the soil.

If most of the field falls into the irrigable category but significant areas are conditional and nonirrigable, management decisions will be strongly influenced by the soils in these categories. Required management may include annual soil testing for nitrates, sodium and salts; annual addition of calcium amendments; lower nitrogen fertilizer rates; installation of drain tile; use of no-till or reduced tillage; or other special activities. Special management methods will depend on the reason the soil was placed into conditional or nonirrigable classes.

The special requirements for irrigating small areas of conditional or nonirrigable soils should be part of the estimate of the total irrigation investment. As site-specific farming techniques are developed, more practical methods of managing soil inclusions will become available.

Commercial center pivot irrigation systems now have site-specific water application technology that will vary the amount of water applied to a particular area in the field. The improved water application technology, along with reduced or no-till technology, will make a big difference in how conditional soils will be irrigated.

Some fields will contain soils that fall into two or perhaps all three irrigation categories. The assistance of a qualified soil professional is advised for fields with conditional soils. An irrigation system should be designed to exclude irrigation on areas that fall into the nonirrigable category, but this may not be possible.

Irrigation Water Management

Irrigation water management is recommended for all irrigation systems. Applying additional water to the soil through an irrigation system is a management tool to prevent salinity and sodium buildup on some conditional soils. Irrigation scheduling is an important part of irrigation water management. Irrigation scheduling will minimize the use of water without loss of yield. It also is important for reducing nitrate leaching from overirrigation.

Three irrigation scheduling tools are available to irrigators in North Dakota. A manual method is outlined in Extension publication AE-792, "Irrigation Scheduling by the Checkbook Method." The other two are electronic methods. A site-specific Web-based application is available through the North Dakota Agricultural Weather Network (NDAWN) website, *http://ndawn.ndsu.nodak.edu*. A spreadsheet version of the checkbook and other irrigation scheduling methods, along with users manuals, can be found on the Web at *www.ag.ndsu.edu/irrigation/irrigation-scheduling*.

Table 1. Alphabetical list of soil series and associated irrigability group. Irrigability groups are from 1 to 29, and i is for irrigable, c is for conditionally irrigable and n is for not irrigable. Groups 1 to 7 are irrigable soils, 8 to 22 are conditional soils and 23 to 29 are nonirrigable. Irrigation group ratings listed do not address series phases such as saline, wet, flooded, drained, undrained, slope, etc.

Soil Series	Group	Soil Series	Group	Soil Series	Group	Soil Series	Group
AASTAD	8c	BRYANT	8c	EKALAKA	24n	GRAIL	10c
ABERDEEN	11c	BULLTOP	6i	ELMVILLE	17c	GRANO	22c
ABSHER	24n	BUSE	9c	EMBDEN	4i	GRASSNA	8c
ALKABO	11c	CABBA	26n	EMRICK	7i	GREAT BEND	8c
AMOR	12c	CABBART	26n	ENLOE	22c	GRIMSTAD	20c
ANTLER	15c	CASHEL	15c	ERAMOSH	27n	GWINNER	21c
APPAM	3i	CATHAY	11c	ESMOND	9c	HAMAR	18c
AQUENTS	27n	CAVOUR	24n	ESPELIE	20c	HAMERLY	15c
ARIKARA	23n	CEDAR PAN	26n	ETHRIDGE	10c	HAMLET	8c
ARNEGARD	7i	CHAMA	12c	EVRIDGE	24n	HANLY	2i
ARVESON	19c	CHANTA	6i	EXLINE	24n	HARRIET	24n
ARVILLA	3i	CHERRY	9c	FAIRDALE	9c	HATTIE	21c
AUGSBERG	15c	CHINOOK	4i	FALKIRK	8c	HAVRE	9c
AYLMER	2i	CLAIRE	2i	FALSEN	2i	HAVRELON	9c
BAAHISH	5i	CLONTARF	3i	FARFELD	26n	HECLA	3i
BAINVILLE	26n	COE	1i	FARGO	22c	HEDMAN	17c
BALATON	9c	COHAGEN	23n	FARLAND	8c	HEGNE	22c
BANKS	3i	COLVIN	15c	FARNUF	8c	HEIL	24n
BANTRY	18c	CORMANT	18c	FELOR	8c	HEIMDAL	7i
BARNES	8c	COZBERG	3i	FERNEY	24n	HIDATSA	5i
BEARDEN	15c	CRESBARD	11c	FLAMING	2i	HILAIRE	3i
BEARPAW	10c	CROKE	10c	FLASHER	23n	HOFFMANVILLE	21c
BECKTON	24n	DAGLUM	24n	FLAXTON	14c	HOVEN	24n
BEISIGL	13c	DARNEN	8c	FLEAK	26n	INKSTER	4i
BELFIELD	11c	DELAMERE	19c	FLOM	15c	JANESBURG	24n
BENZ	25n	DESART	24n	FOLDAHL	14c	KARLSRUHE	18c
BEOTIA	7i	DICKEY	14c	FORDVILLE	6i	KELVIN	10c
BIGSANDY	15c	DILTS	26n	FORMAN	8c	KENSAL	5i
BINFORD	3i	DIMMICK	27n	FOSSUM	18c	Kindred	15c
BLANCHARD	2i	DIVIDE	16c	FRAM	17c	KIRBY	1i
BOHNSACK	17c	DOGTOOTH	24n	FULDA	22c	KLOTEN	26n
BORUP	17c	DOOLEY	14c	GALCHUTT	15c	KORCHEA	9c
BOTTINEAU	10c	DORAN	15c	GALLATIN	19c	KORELL	8c
BOWBELLS	8c	DOVRAY	22c	GARBORG	18c	KRANZBURG	8c
BOWDLE	6i	DUNCOM	26n	GARDENA	7i	KRATKA	20c
BOXWELL	12c	DUPREE	26n	GERDA	24n	KREM	14c
BRANDENBURG	1i	EASBY	25n	GILBY	15c	KREMLIN	7i
BRANTFORD	5i	ECKMAN	7i	GLENDIVE	4i	LA PRAIRIE	8c
BREIEN	4i	EDGELEY	12c	GLYNDON	17c	LADELLE	8c
BRISBANE	6i	EGELAND	4i	GOLVA	8c	LADNER	24n

Soil Series	Group
LAKOA	8c
LAKOTA	24n
LALLIE	22c
LAMBERT	9c
LAMOURE	15c
LANGHEI	9c
LANKIN	8c
LANONA	14c
LARSON	24n
LAWTHER	21c
LEFOR	13c
LEHR	5i
LEMERT	24n
LETCHER	24n
LIHEN	3i
LINDAAS	22c
LINTON	7i
LISAM	26n
LISMORE	8c
LITTLEHORN	12c
LITTLEMO	6i
LIVONA	14c
LOHLER	21c
LOHNES	2i
LONNA	9c
LOWE	15c
LUDDEN	22c
MACHETAH	9c
MADDOCK	3i
MAGNUS	21c
MAKOTI	8c
MALTESE	24n
MANDAN	7i
MANFRED	24n
MANNING	3i
MANTADOR	19c
MARIAS	21c
MARKEY	27n
MARMARTH	12c
MARYSLAND	16c
MAUVAIS	25n
MAX	8c
MCDONALDSVILLE	22c
MCKEEN	27n
MCKENZIE	22c

Soil Series	Group
MEKINOCK	24n
METIGOSHE	3i
MIDWAY	26n
MINNEWAUKAN	18c
MIRANDA	24n
MONDAMIN	10c
MOREAU	12c
MORTON	12c
MOTT	4i
MUSTINKA	22c
NAHON	24n
NECHE	15c
NIOBELL	11c
NOONAN	24n
NUTLEY	21c
OBURN	24n
OJATA	25n
OLGA	21c
OMIO	12c
OSAKIS	3i
OVERLY	8c
PARNELL	22c
PARSHALL	4i
PATENT	9c
PEEVER	21c
PERELLA	15c
PETA	15c
PLAYMOOR	28n
POPPLETON	18c
PORTAL	24n
PROMISE	21c
RAUVILLE	27n
REEDER	12c
REGAN	15c
REGENT	12c
RENSHAW	5i
RHAME	13c
RHOADES	24n
RIDGELAWN	6i
RIFLE	27n
RINGLING	1i
ROCKWELL	20c
ROLETTE	21c
ROLISS	15c
ROLLA	21c

Soil Series	Group
RONDELL	9c
ROSEGLEN	7i
ROSEWOOD	18c
RUSKLYN	9c
RUSO	3i
RYAN	24n
SAKAKAWEA	9c
SANDBERG	2i
SAVAGE	10c
SCAIRT	24n
SCHALLER	3i
SCORIO	21c
SEARING	12c
SEELYEVILLE	27n
SEN	12c
SERDEN	2i
SEROCO	2i
SHAM	25n
SHAMBO	7i
SHIBAH	5i
SINAI	21c
SIOUX	1i
SISSETON	9c
SOUTHAM	22c
SPOTTSWOOD	6i
STADY	6i
STIRUM	24n
STRAW	7i
SUOMI	22c
SUTLEY	9c
SVEA	8c
SVERDRUP	3i
SWENODA	14c
SYRENE	15c
TALLY	4i
TANNA	10c
TANSEM	7i
TELFER	3i
TEMVIK	8c
THIEFRIVER	22c
TIFFANY	19c
TINSLEY	1i
TOLNA	19c
TONKA	22c
TOTTEN	24n

Soil Series	Group
TOWNER	14c
TREMBLES	4i
TUSLER	13c
ULEN	18c
URANDA	24n
VALENTINE	2i
VALLERS	15c
VANDA	25n
VANG	6i
VEBAR	13c
VELVA	4i
VENLO	18c
VERENDRYE	18c
VIDA	9c
VIKING	22c
VIRGELLE	14c
WABEK	1i
WAHPETON	21c
WALSH	8c
WALUM	3i
WAMDUSKA	1i
WANAGAN	5i
WARSING	5i
WATROUS	12c
WAUKON	10c
WAYDEN	26n
WERNER	23n
WHEATVILLE	15c
WHITEBIRD	24n
WIBAUX	1i
WILDROSE	21c
WILLIAMS	8c
WILTON	8c
WOLF POINT	21c
WYARD	15c
WYNDMERE	19c
WYRENE	18c
YAWDIM	26n
YEGEN	14c
YETULL	2i
ZAHL	9c
ZEELAND	10c
ZELL	9c
ZEONA	2i

Soil Texture Abbreviations

Soil texture (from coarse to fine) abbreviations used in this publication:

GR	Gravelly
S	Sand
CoS	Coarse sand
FS	Fine sand
LCoS	Loam coarse sand
LS	Loamy sand
LFS	Loamy fine sand
CoSL	Coarse sandy loam
SL	Sandy loam
FSL	Fine sandy loam
VFSL	Very fine sandy loam
L	Loam
SIL	Silt loam
CL	Clay loam
SCL	Sandy clay loam
SICL	Silty clay loam
SIC	Silty clay
C	Clay

Irrigability Groups

In the following text, < means "less than" and > means "greater than."

Irrigable Soils (i)

Irrigable soils generally require less management than conditional soils. Even though the soils are in an irrigable class, good irrigation management is essential. Attention to the allowable irrigation water quality is important. Use of lower-quality water than recommended can lower the productivity of the soils from salts and sodium. Different phases of each soil series may modify irrigation recommendations.

1i. Brandenburg, Coe, Kirby, Ringling, Sioux, Tinsley, Wabek, Wamduska, Wibaux

Drainage: excessively drained

Surface texture: L, SL

Substratum texture: sand and gravel

Surface intake rate for sprinkler irrigation: 0.5 to 0.7 in/hr

Limiting permeability within 40 inches: 0.6 to 2.0 in/hr in the upper part and > 6.0 in/hr in the lower part

Profile characteristics: shallow/very shallow (< 20 inches) to sand, gravel and porcellanite

Depth to lime: 0 to 10 inches

Surface pH: 6.6 to 8.4 inches

EC (maximum within 40 inches in dS/m): 0

SAR (maximum within 40 inches): 0

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	1.5 inches
2 feet	2.0 inches
3 feet	2.5 inches
4 feet	3.0 inches
5 feet	3.0 inches

Irrigation Water Quality
Maximum allowable EC < 3.0 deci-Siemens per meter (dS/m), Maximum allowable SAR < 12

Water Management Practices
Water management on these soils is critical because of low available water-holding capacity and nutrient leaching hazard.

2i. Aylmer, Banks, Blanchard, Claire, Falsen, Flaming, Lohnes, Sandberg, Serden, Seroco, Valentine, Yetull, Zeona

Drainage: moderately well to excessively drained

Surface texture: CoS, S, FS, LCoS, LS, LFS, CoSL, SL, FSL

Subsoil texture: FS, S, LCoS, CoS

Surface intake rate for sprinkler irrigation: 0.5 to > 1.0 in/hr

Limiting permeability within 40 inches: 6.0 to 20.0 in/hr

Profile characteristics: sandy and moderately coarse-textured material

Depth to lime: 10 to 30 inches

Surface pH: 6.1 to 7.3

EC (maximum within 40 inches in dS/m): 0

SAR (maximum within 40 inches): 0

Water-holding Capacity (rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	1.0 inches
2 feet	2.0 inches
3 feet	2.5 inches
4 feet	3.0 inches
5 feet	4.0 inches

Irrigation Water Quality
Maximum allowable EC < 3.0 deci-Siemens per meter (dS/m),
Maximum allowable SAR < 12

Water Management Practices
Water management on these soils is critical because of low available water-holding capacity and nutrient leaching hazard.

3i. Appam, Arvilla, Binford, Clontarf, Cozberg, Hanly, Hecla, Hilaire, Lihen, Maddock, Manning, Metigoshe, Osakis, Ruso, Schaller, Sverdrup, Telfer, Walum

Drainage: moderately well to somewhat excessively drained

Surface texture: FSL, SL, CoSL, LFS, LS

Subsoil and substratum texture: SL and L in the upper part and LS to sand and gravel in the lower part

Surface intake rate for sprinkler irrigation: 0.4 to 1.5 in/hr

Limiting permeability within 40 inches: 2.0 to 20.0 in/hr in the upper part and > 6.0 in/hr in the lower part.

Profile characteristics: moderately coarse and medium-textured material in the upper part and coarse-textured material in the lower part

Depth to lime: 10 to 30 inches

Surface pH: 6.1 to 7.8

EC (maximum within 40 inches in dS/m): 0

SAR (maximum within 40 inches): 0

Water-holding Capacity (rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	1.5 inches
2 feet	3.0 inches
3 feet	3.5 inches
4 feet	4.5 inches
5 feet	5.5 inches

Irrigation Water Quality
Maximum allowable EC < 3.0 deci-Siemens per meter (dS/m),
Maximum allowable SAR < 12

Water Management Practices
An irrigation scheduling system must be used.

4i. Breien, Chinook, Egland, Embden, Glendive, Inkster, Mott, Parshall, Tally, Trembles, Velva

Drainage: well and moderately well drained

Surface texture: SL, FSL, L

Subsoil texture: SL, FSL, L

Surface intake rate for sprinkler irrigation: .5 to 1.0 in/hr

Limiting permeability within 40 inches: .6 to 6.0 in/hr

Profile characteristics: moderately coarse and medium-textured material

Depth to lime: 10 to 20 inches

Surface pH: 6.1 to 8.4

EC (maximum within 40 inches in dS/m): 0 to 2

SAR (maximum within 40 inches): 0

Water-holding Capacity (rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	2.0 inches
2 feet	4.0 inches
3 feet	5.5 inches
4 feet	7.0 inches
5 feet	9.0 inches

Irrigation Water Quality
Maximum allowable EC < 3.0 deci-Siemens per meter (dS/m),
Maximum allowable SAR < 12

Water Management Practices
An irrigation scheduling system must be used.

5i. Baahish, Brantford, Hidatsa, Kensal, Lehr, Renshaw, Shibah, Wanagan, Warsing

Drainage: well and moderately well drained

Surface texture: SL, L

Substratum texture: 2C material is GrSL to sand and gravel

Surface intake rate for sprinkler irrigation: 0.5 to 0.7 in/hr

Permeability within 40 inches: 0.6 to 2.0 in/hr in the upper part and > 6.0 in/hr in the lower part

Profile characteristics: moderately coarse and medium-textured material over sand and gravel that is shallow to moderately deep (< 40 inches)

Depth to lime: 10 to 20 inches

Surface pH: 6.1 to 7.8

EC (maximum within 40 inches in dS/m): 0 to 1

SAR (maximum within 40 inches): 0

Water-holding Capacity (rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	2.0 inches
2 feet	3.0 inches
3 feet	3.5 inches
4 feet	4.0 inches
5 feet	4.5 inches

Irrigation Water Quality
Maximum allowable EC < 3.0 deci-Siemens per meter (dS/m), Maximum allowable SAR < 9

Water Management Practices
An irrigation scheduling system must be used.

6i. Bowdle, Brisbane, Bulltop, Chanta, Fordville, Littlemo, Ridgelawn, Spottswood, Stady, Vang

Drainage: moderately well and well drained

Surface texture: L, SIL, CL

Subsoil texture: L and CL in B horizons and GrL to GrS in the 2B or 2C horizons

Surface intake rate for sprinkler irrigation: 0.5 to 0.7 in/hr

Limiting permeability within 40 inches: 0.6 to 2.0 in/hr in the upper part and > 6.0 in/hr in the lower part

Profile characteristics: moderately fine textured material over moderately deep (20 to 40 inches) sand and gravel

Depth to lime: 15 to 30 inches

Surface pH: 6.1 to 7.3

EC (maximum within 40 inches in dS/m): 0 to 1

SAR (maximum within 40 inches): 0

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	5.5 inches
4 feet	6.0 inches
5 feet	6.5 inches

Irrigation Water Quality
Maximum allowable EC < 3.0 deci-Siemens per meter (dS/m), Maximum allowable SAR < 9

Water Management Practices
An irrigation scheduling system must be used.

7i. Arnegard, Beotia, Eckman, Emrick, Gardena, Heimdal, Kremlin, Linton, Mandan, Roseglen, Shambo, Straw, Tansem

Drainage: moderately well and well drained

Surface textures: VFSL, SIL, L

Subsoil texture: VFSL, SIL, L, SICL

Surface intake rate for sprinkler irrigation: 0.1 to 0.5 in/hr

Limiting permeability within 40 inches: 0.2 to 2.0 in/hr

Profile characteristics: medium and moderately fine-textured material

Depth to lime: 15 to 30 inches

Surface pH: 6.6 to 7.8

EC (maximum within 40 inches in dS/m): 0 to 2

SAR (maximum within 40 inches): 0

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	5.0 inches
3 feet	7.0 inches
4 feet	9.0 inches
5 feet	11.5 inches

Irrigation Water Quality
Maximum allowable EC < 2.25 deci-Siemens per meter (dS/m), Maximum allowable SAR < 6

Water Management Practices
An irrigation scheduling system must be used.

Conditional Soils (c)

Conditional soils can be irrigated under a high level of management. Soil conditions that contribute to conditional status instead of completely irrigable are the presence of salts, poor drainage properties, the presence of subsurface layering, and the need for supplemental surface and subsurface drainage. Irrigation without high levels of management may degrade the soil quality for future generations, but conditional soils can be irrigated successfully if recommendations are followed. Soil phases of each soil series may modify irrigation recommendations.

8c. Aastad, Barnes, Bowbells, Bryant, Falkirk, Farland, Farnuf, Felor, Forman, Golva, Grassna, Great Bend, Hamlet, Korell, Kranzburg, La Prairie, LaDelle, Lakoa, Lankin, Lismore, Makoti, Max, Overly, Svea, Temvik, Walsh, Williams, Wilton

Drainage: moderately well to well drained

Surface texture: L, SIL, SICL

Subsoil texture: L, CL, SICL

Surface intake rate for sprinkler irrigation: 0.1 to 0.7 in/hr

Limiting permeability within 40 inches: 0.2 to 2.0 in/hr

Profile characteristics: medium and moderately fine-textured material

Depth to lime: 10 to 20 inches

Surface pH: 6.1 to 7.8

EC (maximum within 40 inches in dS/m): 0 to 4

SAR (maximum within 40 inches): < 2

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	6.5 inches
4 feet	8.5 inches
5 feet	10.0 inches

Irrigation Water Quality
Maximum allowable EC < 1.5 deci-Siemens per meter (dS/m),
Maximum allowable SAR < 6

Water Management Practices
These soils are conditional for irrigation due to moderate and moderately slow permeability and a potential for salinity increase in the subsoil. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. Water, additional to that used for crop production, may be required for leaching. Leaching should be done in the fall or early spring when crop requirements for water are low. An irrigation scheduling system must be used.

9c. Balaton, Buse, Cherry, Esmond, Fairdale, Havre, Havrelon, Korchea, Lambert, Langhei, Lonna, Machetah, Patent, Rondell, Rusklyn, Sakakawea, Sisseton, Sutley, Vida, Zahl, Zell

Drainage: moderately well and well drained

Surface texture: VFSL, FSL, SL, L, SIL, CL, SICL 2/

Subsoil texture: L, SIL, CL, SICL

Surface intake rate for sprinkler irrigation: 0.5 to 0.7 in/hr

Limiting permeability within 40 inches: 0.6 to 2.0 in/hr

Profile characteristics: calcareous/medium and moderately fine-textured materials

Depth to lime: 0 to 10 inches

Surface pH: 6.6 to 8.4

EC (maximum within 40 inches in dS/m): < 4

SAR (maximum within 40 inches): < 2

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	6.5 inches
4 feet	8.5 inches
5 feet	10.0 inches

Irrigation Water Quality
Maximum allowable EC < 1.8 deci-Siemens per meter (dS/m),
Maximum allowable SAR < 6

Water Management Practices
These soils are conditional for irrigation due to moderate and moderately slow permeability and a potential for salinity increase in the subsoil. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. Water, additional to that used for crop production, may be required for leaching. Leaching should be done in the fall or early spring when crop requirements for water are low. An irrigation scheduling system must be used.

10c. Bearpaw, Bottineau, Croke, Ethridge, Grail, Kelvin, Mondamin, Savage, Tanna, Waukon, Zeeland

Drainage: moderately well and well drained

Surface texture: L, CL, SICL

Subsoil texture: CL, SICL, SIC, C (> 35% clay)

Surface intake rate for sprinkler irrigation: 0.1 to 0.5 in/hr

Limiting permeability within 40 inches: 0.06 to 0.6 in/hr

Profile characteristics: moderately fine to fine-textured material

Depth to lime: 15 to 40 inches

Surface pH: 6.1 to 7.8

EC (maximum within 40 inches in dS/m): < 4

SAR (maximum within 40 inches): < 4

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	6.5 inches
4 feet	8.5 inches
5 feet	10.5 inches

Irrigation Water Quality
Maximum allowable EC < 1.0 deci-Siemens per meter (dS/m),
Maximum allowable SAR < 6

Water Management Practices
These soils are conditional for irrigation due to moderately slow and slow permeability and a potential for salinity increase in the subsoil. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. Water, additional to that used for crop production, may be required for leaching. Leaching should be done in the fall or early spring when crop requirements for water are low. Subsurface drainage may be required for continued irrigation. An irrigation scheduling system must be used.

11c. Aberdeen, Alkabo, Belfield, Cathay, Cresbard, Niobell

Drainage: moderately well and well drained

Surface texture: L, SIL, SICL

Subsoil texture: CL, SICL (> 35% clay)

Surface intake rate for sprinkler irrigation: 0.1 to 0.7 in/hr

Limiting permeability within 40 inches: 0.06 to 0.2 in/hr

Profile characteristics: moderately fine and fine-textured materials that have a degraded natric horizon within 20 inches

Depth to lime: 20 to 30 inches

Surface pH: 5.6 to 7.3

EC (maximum within 40 inches in dS/m): 2 to 8

SAR (maximum within 40 inches): 5 to 15

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	6.0 inches
4 feet	8.0 inches
5 feet	10.0 inches

Irrigation Water Quality
Maximum allowable EC < 1.5 deci-Siemens per meter (dS/m), Maximum allowable SAR < 4

Water Management Practices
These soils are marginal for irrigation, and irrigation of extensive areas should be avoided. Continued irrigation could cause restricted water intake and permanent soil damage. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. Water, additional to that used for crop production, may be required for leaching. Leaching should be done in the fall or early spring when crop requirements for water are low. Subsurface drainage may be required for continued irrigation.

12c. Amor, Boxwell, Chama, Edgeley, Little Horn, Marmarth, Moreau, Morton, Omio, Reeder, Regent, Searing, Sen, Watrous

Drainage: well drained

Surface texture: L, SIL, SICL

Subsoil texture: L, SIL, SICL

Surface intake rate for sprinkler irrigation: 0.1 to 0.5 in/hr

Limiting permeability within 40 inches: 0.0 to 0.6 in/hr depending on texture of soft, weathered bedrock

Profile characteristics: medium and moderately fine-textured materials moderately deep (20 to40 inches) to soft, weathered bedrock

Depth to lime: 10 to 20 inches

Surface pH: 6.1 to 7.8

EC (maximum within 40 inches in dS/m): 2 to 8

SAR (maximum within 40 inches): 0 to 4

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	6.5 inches
4 feet	0.08 inches
5 feet	0.08 inches

Irrigation Water Quality
Maximum allowable EC < 1.8 deci-Siemens per meter (dS/m), Maximum allowable SAR < 6

Water Management Practices
These soils are marginal for irrigation due to moderately deep (20 to 40 inches) bedrock and the potential for lateral seepage. Avoid irrigating extensive areas or where stratification is evident and seeps are present. Salinity monitoring should be done on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

13c. Beisigl, Lefor, Rhame, Tusler, Vebar

Drainage: well to somewhat excessively drained

Surface texture: LS, LFS, SL, FSL

Subsoil texture: LS, LFS, SL, FSL

Surface intake rate for sprinkler irrigation: 0.5 to 1.5 in/hr

Limiting permeability within 40 inches: 0.0 to 0.6 in/hr

Profile characteristics: coarse and moderately coarse-textured material moderately deep (20 to 40 inches) to soft, weathered beds

Depth to lime: 10 to 20 inches

Surface pH: 6.1 to 7.8

EC (maximum within 40 inches in dS/m): 0

SAR (maximum within 40 inches): 0

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	1.5 inches
2 feet	3.0 inches
3 feet	3.5 inches
4 feet	0.08 inches
5 feet	0.08 inches

Irrigation Water Quality
Maximum allowable EC < 1.8 deci-Siemen per meter (dS/m), Maximum allowable SAR < 6

Water Management Practices
These soils are marginal for irrigation due to moderately deep (20 to 40 inches) bedrock and the potential for lateral seepage. Avoid irrigating extensive areas or where stratification is evident and seeps are present. Salinity monitoring should be done on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

14c. Dickey, Flaxton, Krem, Lanona, Livona, Swenoda, Towner, Virgelle, Yegen

Drainage: moderately well and well drained

Surface texture: LS, LFS, SL, FSL

Subsoil texture: L, CL, SICL

Surface intake rate for sprinkler irrigation: 0.5 to 1.5 in/hr

Limiting permeability within 40 inches: 0.2 to 0.6 in/hr

Profile characteristics: coarse textured material over medium and moderately fine-textured material

Depth to lime: > 15 inches

Surface pH: 6.1 to 7.3

EC (maximum within 40 inches in dS/m): 0 to 4

SAR (maximum within 40 inches): < 2

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	1.5 inches
2 feet	3.0 inches
3 feet	4.5 inches
4 feet	6.5 inches
5 feet	8.0 inches

Irrigation Water Quality
Maximum allowable EC < 1.8 deci-Siemen per meter (dS/m), Maximum allowable SAR < 9

Water Management Practices
These soils are conditional for irrigation due to the subsoil's moderately slow permeability and potential for increased salinity. Salinity in the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. Water, additional to that used for crop production, may be required for leaching. Leaching should be done in the fall or early spring when crop requirements for water are low. An irrigation scheduling system must be used.

15c. Antler, Augsberg, Bearden, Bigsandy, Cashel, Colvin, Doran, Flom, Galchutt, Gilby, Hamerly, LaMoure, Lowe, McKeen, Neche, Perella, Rauville, Regan, Roliss, Styrene, Vallers, Wheatville, Wyard

Drainage: somewhat poorly and poorly drained

Surface texture: L, SIL, SICL, SIC, C

Subsoil texture: L, SIL, SICL, SIC, C

Surface intake rate for sprinkler irrigation: 0.1 to 0.7 in/hr

Limiting permeability within 40 inches: 0.2 to 0.6 in/hr

Profile characteristics: medium to fine-textured materials

Depth to lime: 0 to 10 inches

Surface pH: 6.6 to 8.4

EC (maximum within 40 inches in dS/m): < 6

SAR (maximum within 40 inches): < 3

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	7.0 inches
4 feet	9.0 inches
5 feet	10.0 inches

Irrigation Water Quality
Maximum allowable EC < 1.5 deci-Siemen per meter (dS/m), Maximum allowable SAR < 6

Water Management Practices
Irrigate only if adequate surface and subsurface drainage has been provided. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

16c. Divide, Marysland

Drainage: somewhat poorly and poorly drained

Surface texture: L, CL, SIL

Subsoil texture: L, CL

Surface intake rate for sprinkler irrigation: 0.1 to 0.5 in/hr

Limiting permeability within 40 inches: 0.6 to 2.0 in/hr in the upper part and > 6.0 in/hr in the lower part

Profile characteristics: Aeric and Typic Calciaquolls, medium and moderately fine-textured material over sand and gravel

Depth to lime: 0 to 10 inches

Surface pH: 7.to 8.4

EC (maximum within 40 inches in dS/m): < 2

SAR (maximum within 40 inches): 0

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	5.0 inches
4 feet	5.5 inches
5 feet	6.0 inches

Irrigation Water Quality
Maximum allowable EC < 3.0 deci-Siemens per meter (dS/m), Maximum allowable SAR < 9

Water Management Practices
Irrigate only if adequate surface and subsurface drainage has been provided. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

17c. Bohnsack, Borup, Elmville, Fram, Glyndon

Drainage: somewhat poorly and poorly drained

Surface texture: FSL, SIL, L

Subsoil texture: FSL, SIL, L

Surface intake rate for sprinkler irrigation: 0.5 to 1.0 in/hr

Limiting permeability within 40 inches: 0.6 to 2.0 in/hr

Profile characteristics: Aeric and Typic Calciaquolls, moderately coarse and medium-textured material

Depth to lime: 0 to 10 inches

Surface pH: 7.4 to 8.4

EC (maximum within 40 inches in dS/m): < 6

SAR (maximum within 40 inches): 0 to 1

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	6.0 inches
4 feet	8.5 inches
5 feet	10.5 inches

Irrigation Water Quality
Maximum allowable EC < 2.25 deci-Siemens per meter (dS/m), Maximum allowable SAR < 6

Water Management Practices
Irrigate only if adequate surface and subsurface drainage has been provided. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

18c. Banks (variant), Bantry, Cormant, Fossum, Garborg, Hamar, Karlsruhe, Minnewaukan, Poppleton, Rosewood, Ulen, Venlo, Verendrye, Wyrene

Drainage: somewhat poorly and poorly drained

Surface texture: CoSL, LFS, LS, FS, S

Subsoil texture: LFS, LS, S, FS

Surface intake rate for sprinkler irrigation: 0.5 to 1.5 in/hr

Limiting permeability within 40 inches: 2.0 to 20.0 in/hr

Profile characteristics: coarse and moderately coarse-textured material

Depth to lime: 0 to 30 inches

Surface pH: 6.1 to 8.4

EC (maximum within 40 inches in dS/m): 0 to 2

SAR (maximum within 40 inches): 0 to 1

Water Holding Capacity (rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	1.5 inches
2 feet	2.5 inches
3 feet	3.0 inches
4 feet	4.0 inches
5 feet	5.0 inches

Irrigation Water Quality
Maximum allowable EC < 3.0 deci-Siemens per meter (dS/m), Maximum allowable SAR < 12

Water Management Practices
Irrigate only if adequate surface and subsurface drainage has been provided. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

19c. Arveson, Delamere, Fossum, Galatin, Mantador, Tiffany, Tolna, Wyndmere, Wyrene

Drainage: somewhat poorly and poorly drained

Surface texture: VFSL, FSL, SL

Subsoil texture: VFSL, FSL, SL

Surface intake rate for sprinkler irrigation: 0.5 to 1.25 in/hr

Limiting permeability within 40 inches: 2.0 to 6.0 in/hr

Profile characteristics: moderately coarse and medium-textured material

Depth to lime: Calciaquolls 0 to 10 inches, Aquolls > 20 inches

Surface pH: 6.1 to 8.4

EC (maximum within 40 inches in dS/m): 0 to 2

SAR (maximum within 40 inches): 0 to 1

Water-holding Capacity (rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	2.0 inches
2 feet	3.5 inches
3 feet	5.0 inches
4 feet	6.5 inches
5 feet	7.5 inches

Irrigation Water Quality
Maximum allowable EC < 3.0 deci-Siemens per meter (dS/m), Maximum allowable SAR < 12

Water Management Practices
Irrigate only if adequate surface and subsurface drainage has been provided. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

20c. Espelie, Grimstad, Kratka, Rockwell, Tiffany, Wyndmere

Drainage: somewhat poorly and poorly drained

Surface texture: L, FSL, SL, LFS, LS

Subsoil texture: SL, SIL, L, CL

Surface intake rate for sprinkler irrigation: 0.5 to 1.5 in/hr

Limiting permeability within 40 inches: 0.2 to 2.0 in/hr

Profile characteristics: coarse and moderately coarse-textured material over medium-textured material

Depth to lime: 0 to 10 Inches

Surface pH: 7.4 to 8.4

EC (maximum within 40 inches in dS/m): < 4

SAR (maximum within 40 inches): < 2

Water-holding Capacity (rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	1.5 inches
2 feet	3.0 inches
3 feet	4.5 inches
4 feet	6.5 inches
5 feet	8.0 inches

Irrigation Water Quality
Maximum allowable EC < 1.8 deci-Siemens per meter (dS/m), Maximum allowable SAR < 9

Water Management Practices
Irrigate only if adequate surface and subsurface drainage has been provided. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. An irrigation scheduling system must be used.

21c. Gwinner, Hattie, Hoffmanville, Lawther, Lohler, Magnus, Marias, Nutley, Olga, Peever, Promise, Rolette, Rolla, Scorio, Sinai, Wahpeton, Wildrose, Wolf Point

Drainage: moderately well and well drained

Surface texture: SIC, C

Subsoil texture: SIC, C

Surface intake rate for sprinkler irrigation: 0.1 to 0.2 in/hr

Limiting permeability within 40 inches: 0.06 to 0.2 in/hr

Profile characteristics: fine-textured material

Depth to lime: 0 to 20 inches

Surface pH: 7.3 to 8.4

EC (maximum within 40 inches in dS/m): 1 to 4

SAR (maximum within 40 inches): 0 to 1

Water-holding Capacity (rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	2.5 inches
2 feet	4.5 inches
3 feet	6.0 inches
4 feet	8.0 inches
5 feet	10.0 inches

Irrigation Water Quality
Maximum allowable EC < 1.0 deci-Siemens per meter (dS/m), Maximum allowable SAR < 6

Water Management Practices
These soils are conditional for irrigation due to moderately slow and slow permeability and a potential for salinity increase in the subsoil. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. Water, additional to that used for crop production, may be required for leaching. Leaching should be done in the fall or early spring when crop requirements for water are low. Subsurface drainage may be required for continued irrigation. An irrigation scheduling system must be used.

22c. Dimmick, Dovray, Enloe, Fargo, Fulda, Grano, Hegne, Lallie, Lindaas, Ludden, McDonaldsville, McKenzie, Parnell, Southam, Suomi, Thief River, Tonka, Viking

Drainage: poorly drained and drained phases of poorly and very poorly drained

Surface texture: L, SIL, SICL, SIC, C

Subsoil texture: SIC, C

Surface intake rate for sprinkler irrigation: 0.1 to 0.4 in/hr

Limiting permeability within 40 inches: .06 to 0.2 in/hr

Profile characteristics: medium to fine-textured material in the upper part and fine-textured material in lower part

Depth to lime: 0 to > 40 inches

Surface pH: 6.1 to 8.4

EC (maximum within 40 inches in dS/m): < 4

SAR (maximum within 40 inches): 0

Water-holding Capacity
(rounded to the nearest 0.5 inch; on-site values may vary):

Depth	Average Cumulative Available Water Capacity
1 foot	2.0 inches
2 feet	4.0 inches
3 feet	6.0 inches
4 feet	7.5 inches
5 feet	9.5 inches

Irrigation Water Quality
Maximum allowable EC < 1.0 deci-Siemens per meter (dS/m), Maximum allowable SAR < 6

Water Management Practices
These soils are conditional for irrigation due to slow permeability, wetness and a potential for salinity increase. Salinity of the root zone should be monitored on a three- to five-year basis or more frequently if plant growth is restricted. Water, additional to that used for crop production, may be required for leaching. Leaching should be done in the fall or early spring when crop requirements for water are low. Subsurface drainage may be required for continued irrigation. An irrigation scheduling system must be used.

Nonirrigable (n)

These are soils with very severe limitations to irrigation because of one or more of the following: slope, sodicity, salinity, excessively slow permeability, root-restrictive subsoil layering. Irrigation is strongly discouraged. Irrigation will cause soil quality to be degraded and reduce the productivity of the soils for future generations of farm producers. Different phases of each soil series will modify irrigation recommendations.

23n. Nonirrigable because of relief, depth or root-restrictive substrata

Arikara, Cohagen, Dumps, Dune Land, Flasher, Werner

24n. Non-rrigable because of relief, sodicity, salinity, slow or very slow permeability, or root-restrictive subsoil

Absher, Barkof, Beckton, Cavour, Daglum, Desart, Dogtooth, Ekalaka, Evridge, Exline, Ferney, Gerda, Harriet, Heil, Hoven, Janesburg, Ladner, Lakota, Larson, Lemert, Letcher, Maltese, Manfred, Mekinock, Miranda, Nahon, Noonan, Oburn, Portal, Rhoades, Ryan, Scairt, Stirum, Totten, Uranda, Whitebird

25n. Nonirrigable because of salinity

Classified in other groups but may have saline phases: Antler, Arnegard, Arveson, Bearden, Belfield, Benz, Borup, Colvin, Divide, Easby, Elmville, Ojata, Fargo, Fossum, Fram, Gilby, Glyndon, Grano, Grassna, Hamerly, Hegne, Ladelle, Lallie, LaMoure, Lohler, Ludden, Mandador, Moreau, Ojata, Overly, Parshall, Patent, Playmoor, Regan, Savage, Scorio, Sham, Vallers, Vanda, Velva, Wyndmere

26n. Nonirrigable due to shallow depth of root-restrictive substrata

Bainville, Cabba, Cabbart, Cedarpan, Dilts, Duncom, Dupree, Farfeld, Fleak, Kloten, Lisam, Midway, Wayden, Yawdim

27n. Nonirrigable because of slow or very slow permeability or ponding

Classified in other groups but may have very slow permeability: undrained Arveson, Borup, Colvin, Dimmick, Fargo, Fossum, Hegne, Lallie, Ludden, Marysland, McKeen, Neche, Parnell, Rauville, Regan, Roliss, Rosewood, Southam, Venlo. Peat and Muck soils: Eramosh, Markey, Rifle, Seelyeville

28n. Nonirrigable because of frequent flooding

Classified in other groups but may have flooded phases: Banks, Breien, Cashel, Colvin, Divide, Fairdale, Glendive, Hanly, Havre, Havrelon, Korchea, Korell, La Prairie, LaDelle, Lallie, LaMoure, Lohler, Ludden, Magnus, Marysland, Minnewaukan, Neche, Ojata, Patent, Playmoor, Rauville, Regan, Rhoades, Scorio, Straw, Svea and Trembles, Velva, Wolfpoint

29n. Non-rrigable due to numerous surface stones or boulders

Classified in other groups but may have extremely stony phases: Amor, Barnes, Beisigl, Boxwell, Buse, Cabba, Cabbart, Forman, Marmarth, Max, Morton, Reeder, Ringling, Sioux, Svea, Vallers, Vebar, Wabek, Wamduska, Williams, Zahl

Important Topographic and Soil Properties Affecting Irrigability

Soil Depth

Soil depth depends on the potential rooting depth of the plants to be grown and any restrictions in the soil that may hinder rooting depth. The rooting depth of potatoes may be only 18 to 24 inches, while for alfalfa, the rooting depth may be more than 4 feet. Discontinuities in the soil from layers of sand, gravel or bedrock may physically limit rooting depth.

Soil Texture

The percentage of sand-, silt- and clay-sized particles determines the texture. Texture influences other properties, such as, but not limited to, water-holding capacity, infiltration rate and internal drainage.

Soil Structure

Movement of water into and within soils is partially dependent on soil structure. Soil structure refers to how sand, silt and clay particles are arranged in the soil. Particles aggregate via organic matter and associated biological activity, roots, soil mineral composition, freeze-thaw cyles, wet-dry cycles and time. Outside forces can impact aggregation and soil structure, such as compaction. Soils containing aggregates are unstable under irrigation and may require special management.

Water-holding Capacity

Water-holding capacity is defined as the soil water retained between a suction of 0.1 to 0.5 bars (field capacity) and 15 bars (permanent wilting point). Water held between these two suction values is regarded as plant available water. A silt loam soil holds about 2.25 to 2.5 inches of water per foot of soil. A sandy loam can hold only about 1 inch of water per foot. Soil with high organic matter can hold more water than a soil with similar texture and lower organic matter.

Slope

Slope is important in determining the runoff potential of water from a field. Water and soil losses from runoff reduce short-term and long-term economic returns. Generally, more runoff will occur on fine-textured soils than coarser-textured soils on similar slopes.

Infiltration Rate

The infiltration rate is the relative rate that water penetrates and moves into the soil and is primarily dependent on soil texture and structure. A faster infiltration rate allows less runoff than soil with slower rates.

Internal Drainage

Internal drainage describes the degree and persistence of soil wetness and is influenced by slope, soil infiltration rate, soil texture (percent gravel, sand, silt and clay), depth to water table and depth to impermeable layers. Excessively drained soils often have crop production problems related to lack of water and nutrients due to rapid movement of water through the soil profile. On the other hand, soils with poor internal drainage that remain wet may increase disease potential to crops, cause denitrification losses of nitrogen fertilizer or cause the accumulation of salts. Soils with good internal drainage respond well to irrigation. Irrigation water is retained for use by crops while allowing sufficient movement of water within the soil to minimize saturation of pore space.

Salinity

High levels of soluable salts at or near the surface are usually the result of a high water table. High salt levels may reduce crop yields and increase plants' water requirements. Irrigation may decrease the depth to the water table through time in some soils, thus increasing the risk of salinization. Irrigation water containing high salt levels also may increase the risk of salinization. As salinity increases, crop productivity will decrease.

Salinity is a soil property that changes relatively quickly with time, compared with other properties such as texture. Soil testing for salts is necessary to not only follow possible increases through time in irrigated fields, but also determine if irrigation should be attempted in the first place.

Salts are detected by measuring the flow of electrical current through a sample of soil or water. The more salts in a sample, the less resistance to electrical current and greater the electrical conductivity (EC).

Sodicity (sodium buildup in soil)

Sodium (Na) affects the physical condition of the soil by dispersing soil aggregates. The soil becomes pasty when wet and develops a conditioin called "puddling," which is water remaining on the surface for an extended period. The soil becomes hard when dry and its permeability to water and air is reduced. If irrigation causes sodium salts to accumulate near the soil surface, yields may be reducted.

Sodium buildup usually occurs slowly and may not be easily detected from year to year. Excess sodium accumulation in the root zone is a major threat to good productivity on some soils. Regular soil testing by including the sodium absorption ratio (SAR) on your checklist every three to five years is recommended to determine long-term trends in sodium accumulation.

Quality of Irrigation Water

The quality of some water sources is not suitable for irrigating crops. Irrigation water must be compatible with the crops and soils to which it will be applied. The Soil and Water Environment Laboratory at NDSU provides soil water compatiblity analysis and recommendations for irrigation. An analysis of the water to be used for irrigation and a legal description of the land are needed to make a recommendation.

Salinity and Sodicity of Irrigation Water

The salt (or mineral) content of irrigation water is important for the long-term irrigability of many soils. Irrigation water with large concentrations of salts, when applied to the soil, increases the salt content in the soil because the water is taken up by the plant or evaporates while the salt remains.

The salt content in water is determined by measuring the flow of electrical current (EC) through a sample of the water. Distilled water has very high resistance, but when the salt content increases, the resistance decreases. The electrical conductivity, or EC, has units of deci-Siemens per meter (dS/m), millimhos per centimeterr (mmhos/cm) or micromhos per centimeter (umhos/cm). Here is how to convert from one to the others:

1 dS/m = 1 mmho/cm = 1,000 umhos/cm

The sodium level in the soil in relation to the calcium and magnesium, as well as sodium content in the irrigation water, are important to the long-term productivity and health of the soil. The use of high-sodium water for irrigation depends on the level of salinity (EC) and sodicity in the soil and water. The measure of the sodium impact is the sodium absorption ratio (SAR); its units are dimensionless. It is the ratio of sodium concentration to the concentration of calcium and magnesium in soil or water. Generally, soil and water with SARs less than 6 are acceptable.

Countering Sodium Buildup From the Use of High-SAR Irrigation Water

The laboratory-derived SAR may not be a clear indicator of the actual dispersion of clay particles due to increased sodium levels or decreased soluble calcium and magnesium in a soil. A quick field test of suspected problem areas may help direct the need for an amendment. Place ½ cup of surface soil in a clear glass quart jar, add 1 pint of water and shake well. Leave for an hour undisturbed. If the water has not cleared in that time, the clay has become dispersed and an amendment may be required to keep the surface soil productive.

Sodium accumulation and clay dispersion may be countered by the addition of soluble calcium compounds that replace more weakly held sodium on clay and organic matter surfaces and increase flocculation. Free sodium then can be leached from the soil surface to below the root zone, where it will not interfere with plant growth.

The sodicity buildup hazard for irrigation water is dependent on its SAR and salinity. As the salt content of the water increases, the sodicity hazard also increases. This means that lower SARs may cause significant sodium buildup in the soil. The reason for the increased sodicity hazard with greater salinity is simply the greater number of sodium ions to replace calcium and magnesium in the soil.

Calcium Amendments for Soil and Irrigation Water

Gypsum, which is the common name for calcium sulfate ($CaSO4$), has been used successfully as a reclamation amendment when the soil was not already saturated with gypsum. In areas with low soil salt content, gypsum is the preferred method of reclaiming high-sodium soils.

Gypsum dissolves in the soil and calcium ions replace sodium ions on clay and organic-matter surfaces. Water moving through the soil then leaches the sodium out of the root zone.

However, in many North Dakota soils, sodium and calcium levels are high together. The addition of gypsum in soils already high in gypsum will not result in a replacement of sodium because greater amounts of gypsum will not increase the number of free calcium ions in solution. Other amendments may be more useful.

For soils with high levels of calcium carbonate and low levels of gypsum, the application of elemental sulfur sometimes is used to produce gypsum. Sulfur is oxidized in soils by sulfur bacteria. The resulting sulfuric acid reacts with calcium carbonate to produce gypsum.

On a few soil series, subsurface gypsum layers can be incorporated into surface soils with high sodium levels through deep tillage. Mixing gypsum into high-sodium soils may be a practical way to reclaim some soils. Before tillage, soil sampling surface and deep layers forsodium and gypsum levels will be necessary. If excess gypsum is not present in the subsurface layers, deep tillage may not be helpful.

More soluble calcium amendments, such as calcium chloride, may be more useful in replacing sodium ions in sulfatic systems. Calcium chloride is more soluble in sulfatic systems than gypsum.

The economics of reclamation and effectiveness of amendments in reclaiming sodic soils or countering sodium accumulation should be evaluated before deciding to use soluble calcium and magnesium amendments.

NDSU Soil and Water Testing Laboratory

North Dakota State University
Soil and Water Environment Laboratory
NDSU Dept. 7680
P.O. Box 6050
Fargo, ND 58108-6050

(701) 231-7864

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Appendix C: Preliminary Project Cost Estimate

PRELIMINARY PROJECT COST ESTIMATE

Project Site	Total Acres [1]	TDH Class	ΔZ	GPM Req'd [2]	TDH Req'd	HP Req'd [3]	ϕ (in)	Length of Pipe [4]	Electrical Length [5]	Pump Cost [6]	Intake Cost [7]	Pipe Cost [8]	Nearest MM	Electrical Cost [9]	Fittings, Valves, Drains [10]	Road, Wetland, Crossings [11]	Mobilization (6%)	Engineering & Legal (15%)	Contingency (25%)	Total Project Cost	Ac/HP	Project Cost/Acre [12]
D	825	1	20	4,050	100	150	15	12,400	6,180	$ 71,000	$ 67,000	$ 152,000	10	$ 121,000	$ 13,000	$ 45,000	$ 28,000	$ 70,000	$ 117,000	$ 680,000	5.5	$ 800
L	924	2	75	4,500	164	280	21	8,500	8,500	$ 133,000	$ 74,000	$ 227,000	68	$ 188,000	$ 9,000	$ 31,000	$ 40,000	$ 99,000	$ 166,000	$ 970,000	3.3	$ 1,000
E	796	2	74	3,900	161	235	15	14,600	7,300	$ 112,000	$ 64,000	$ 179,000	16	$ 252,000	$ 15,000	$ 52,000	$ 40,000	$ 101,000	$ 169,000	$ 980,000	3.4	$ 1,200
K	2,976	2	96	14,500	232	1,260	24	52,200	26,100	$ 599,000	$ 238,000	$ 1,626,000	69	$ 452,000	$ 54,000	$ 187,000	$ 189,000	$ 473,000	$ 789,000	$ 4,610,000	2.4	$ 1,500
C	995	1	35	4,900	150	275	21	18,200	18,200	$ 131,000	$ 80,000	$ 486,000	8	$ 278,000	$ 19,000	$ 65,000	$ 64,000	$ 159,000	$ 265,000	$ 1,550,000	3.6	$ 1,600
F	2,948	3	161	14,500	295	1,600	24	51,700	25,900	$ 760,000	$ 238,000	$ 1,611,000	19	$ 461,000	$ 53,000	$ 186,000	$ 199,000	$ 496,000	$ 827,000	$ 4,830,000	1.8	$ 1,600
J	1,443	2	82	7,150	183	490	18	21,200	10,600	$ 233,000	$ 117,000	$ 425,000	41	$ 942,000	$ 22,000	$ 76,000	$ 109,000	$ 272,000	$ 454,000	$ 2,650,000	2.9	$ 1,800
B	1,345	3	161	6,600	292	720	18	35,400	17,700	$ 342,000	$ 108,000	$ 709,000	6	$ 409,000	$ 37,000	$ 127,000	$ 104,000	$ 260,000	$ 433,000	$ 2,530,000	1.9	$ 1,900
A	1,260	2	91	6,200	207	480	24	23,200	23,200	$ 228,000	$ 102,000	$ 723,000	4	$ 591,000	$ 24,000	$ 83,000	$ 105,000	$ 263,000	$ 438,000	$ 2,560,000	2.6	$ 2,000
H	725	2	66	3,600	152	205	18	5,100	5,100	$ 97,000	$ 59,000	$ 102,000	30	$ 861,000	$ 5,000	$ 18,000	$ 69,000	$ 171,000	$ 286,000	$ 1,670,000	3.5	$ 2,300
G	3,579	3	171	17,500	323	2,115	24	99,800	33,300	$ 1,005,000	$ 287,000	$ 3,109,000	22	$ 828,000	$ 103,000	$ 358,000	$ 341,000	$ 854,000	$ 1,423,000	$ 8,310,000	1.7	$ 2,300
I	1,229	1	24	6,025	126	285	18	30,100	15,000	$ 135,000	$ 99,000	$ 603,000	41	$ 1,008,000	$ 31,000	$ 108,000	$ 119,000	$ 298,000	$ 496,000	$ 2,900,000	4.3	$ 2,400

[1] Total irrigable acres within each project area.

[2] GPM required based on 6.5 gpm/acre delivering water to 75% of the total project at any given time.

[3] Water HP required calculated using an assumed pump efficiency of 75% and drive motor efficiency of 90%.

[4] Pipe length measured from the canal turnout to each project. Projects requiring parallel pipes will show a length two or three times the actual project length to account for the multiple pipes.

[5] Electrical length measured from the canal turnout to each project.

[6] Pump costs are based on a cost per HP calculated from previous GDCD projects, with an inflation factor to 2015 dollars.

[7] Intake costs are based on a cost per GPM calculated from previous GDCD projects, with an inflation factor to 2015 dollars.

[8] Pipe costs are based on a cost per foot calculated from previous GDCD projects, with an inflation factor to 2015 dollars.

[9] Electrical cost is based on the cost to run 3-phase power to the canal turnout, then along the pipe path to the project site ($15/ft)

[10] Fittings, valves, and drain costs were estimated on a per foot of pipe basis. (Unit price was calculated from the total cost of these items on previous GDCD projects, divided by the total pipe length.)

[11] Road and wetland crossing costs were estimated on a per foot of pipe basis. (Unit price was calculated from the total cost of these items on previous GDCD projects, divided by the total pipe length.)

[12] Project Cost per Acre values do not include any on farm improvements.

Appendix D: Crop Budgets

Dryland Crop Budget

	2016 Average of Regions									
	Barley	**Durum**	**HRS**	**Corn**	**Soybeans**	**Drybeans**	**Flax**	**Canola**	**Sunfower (Oil)**	**Sunflower (Confection)**
Yield	64.50	40.50	42.00	101.50	29.50	1,560.00	20.00	1,625.00	1,465.00	1,375.00
Price	4.23	5.99	5.29	3.50	7.90	0.22	8.01	0.15	0.16	0.22
Revenue	272.49	242.61	222.12	355.25	232.98	343.20	160.01	238.15	231.46	295.60
Direct Costs										
Seed	13.60	23.75	15.73	78.30	65.75	55.28	14.40	51.25	32.25	45.00
Herbicide	23.70	25.70	25.70	21.00	20.00	45.80	28.50	21.30	33.20	35.30
Fungicide	13.00	13.00	9.00	-	-	20.00	-	-	-	-
Insecticide	-	-	-	-	2.00	-	-	-	5.00	10.00
Fertilizer	49.61	50.26	52.69	68.28	6.13	37.20	31.35	64.44	32.98	30.10
Crop Insurance	16.60	12.95	11.35	14.80	13.35	19.00	10.60	12.85	12.10	16.70
Fuel and Lubrication	10.59	9.62	9.67	14.06	8.35	11.55	16.18	9.31	10.34	10.22
Repairs	18.95	18.37	18.41	22.08	16.75	21.61	17.35	17.51	18.24	18.17
Drying	-	-	-	21.32	-	-	-	-	4.40	4.13
Miscellaneous	4.50	4.50	4.50	4.50	4.75	12.75	1.50	4.50	12.50	20.50
Operating Interest	3.20	3.36	3.13	5.20	2.92	4.74	2.58	3.85	3.43	4.04
Total	153.75	161.51	150.17	249.53	139.99	227.93	122.46	185.00	164.43	194.14
Indrect Costs										
Misc. Overhead	7.67	7.26	7.28	9.46	6.83	8.04	6.86	7.11	7.70	7.65
Mach. Depreciation	22.11	20.99	21.07	31.69	20.15	26.95	20.08	20.55	22.73	22.58
Mach. Investment	12.76	12.18	12.22	17.71	11.13	15.26	11.86	12.02	13.49	13.42
Land Charge	56.25	56.25	56.25	56.25	56.25	56.25	56.35	56.25	56.25	56.25
Total	98.78	96.67	96.81	115.10	94.35	106.49	95.15	95.92	100.16	99.90
Total Cost										
Return to Labor & Management	**19.97**	**(15.57)**	**(24.86)**	**(9.37)**	**(1.37)**	**8.78**	**(57.59)**	**(42.78)**	**(33.13)**	**1.57**

Irrigated Crop Budget (NDSU 2014 Baseline Methodology)

	Barley	HRS	Corn	Soybeans	Dry Beans	Potatoes	Beet	Alfalfa
Yield	100	70	160	55	2,200	360	32	5
Price	4.23	5.29	3.50	7.90	0.22	11	32	100
Revenue	$ 422.50	$ 370.30	$ 560.00	$ 434.50	$ 484.00	$ 3,960.00	$ 1,024.00	$ 500.00
Direct Costs								
Seed	16.50	18.38	71.00	69.60	45.00	368.26	82.47	16.88
Herbicides	23.50	26.00	20.00	20.00	45.30	73.07	116.78	4.93
Fungicides	5.50	5.50	-	-	-	113.59	-	-
Insecticides	-	-	-	-	-	80.53	-	-
Fertilizer	83.44	96.21	117.22	12.92	55.46	350.53	108.40	60.29
Crop Insurance	15.00	13.19	26.56	11.94	21.84	78.00	35.00	-
Fuel & Lubrication	19.02	17.61	25.56	14.48	20.40	67.65	64.77	27.22
Repairs	18.00	17.62	21.69	15.71	20.75	79.13	104.67	19.67
Irrigation Power	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.86
Irrigation Repairs	13.03	13.03	13.03	13.03	13.03	13.03	13.03	13.03
Drying	-	-	19.32	-	-	-	-	-
Misc	1.50	1.50	1.50	4.75	12.75	356.94	23.00	5.98
Operating Interest	3.13	3.26	5.38	3.04	4.29	55.41	24.72	5.62
Total	$ 208.48	$ 222.16	$ 331.12	$ 175.33	$ 248.68	$ 1,646.00	$ 582.70	$ 163.48
Indirect (Fixed) Costs								
Misc. Overhead	7.34	7.02	9.15	6.51	7.71	18.00	30.00	6.00
Machinery Depreciation	21.05	20.22	30.75	19.05	25.83	-	-	44.01
Machnery Investment	12.23	11.81	17.38	10.46	14.64	117.39	132.23	28.19
Irrigation Service	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
Irrigation Depreciation	57.03	57.03	57.03	57.03	57.03	57.03	57.03	57.03
Irrigation Investment	34.22	34.22	34.22	34.22	34.22	34.22	34.22	34.22
Land Charge	56.25	56.25	56.25	56.25	56.25	56.25	56.35	56.25
Total	$ 206.12	$ 204.55	$ 222.78	$ 201.52	$ 213.68	$ 300.89	$ 327.83	$ 243.70
Total Costs	$ 414.60	$ 426.71	$ 553.90	$ 376.85	$ 462.36	$ 1,946.89	$ 910.53	$ 407.18
Return to Labor & Management	**$ 7.90**	**$ (56.41)**	**$ 6.10**	**$ 57.65**	**$ 21.64**	**$ 2,013.11**	**$ 113.47**	**$ 92.82**

Appendix E: North Dakota State Water Commission Cost-Share Policy

NORTH DAKOTA STATE WATER COMMISSION

COST-SHARE POLICY, PROCEDURE, AND GENERAL REQUIREMENTS

The State Water Commission has adopted this policy to support local sponsors in development of sustainable water related projects in North Dakota. This policy reflects the State Water Commission's cost-share priorities and provides basic requirements for all projects considered for prioritization during the agency's budgeting process. Projects and studies that receive cost-share funding from the agency's appropriated funds are consistent with the public interest. The State Water Commission values and relies on local sponsors and their participation to assure on-the-ground support for projects and prudent expenditure of funding for evaluations and project construction. It is the policy of the State Water Commission that only the items described in this document will be eligible for cost-share upon approval by the State Water Commission, unless specifically authorized by State Water Commission action.

I. DEFINITIONS AND ELIGIBILITY

A. CONSTRUCTION COSTS include earthwork, concrete, mobilization and demobilization, dewatering, materials, seeding, rip-rap, crop damages, re-routing electrical transmission lines, moving storm and sanitary sewer system and other underground utilities and conveyance systems affected by construction, mitigation required by law related to the construction contract, irrigation supply works, and other items and services provided by the contractor. Construction costs are only eligible for cost-share if incurred after State Water Commission approval and if the local sponsor has complied with North Dakota Century Code (N.D.C.C.) in soliciting and awarding bids and contracts, and complied with all applicable federal, state, and local laws.

B. COST-SHARE is grant or loan funds provided through the State Water Commission.

C. ENGINEERING SERVICES include pre-construction and construction engineering. Pre-construction engineering is the engineering necessary to develop plans and specifications for permitting and construction of a project including preliminary and final design, material testing, flood insurance studies, hydraulic models, and geotechnical investigations. Construction engineering is the engineering necessary to build the project designed in the pre-construction phase including construction contract management, and project inspection. Administrative and support services not specific to the approved project are not engineering services. Engineering services are eligible costs if incurred after State Water Commission approval. If cost-share is expected to be greater than $25,000, the local sponsor must follow the engineering selection process in NDCC 54-44.7 and provide a copy of the selection committee report to the Chief Engineer. The local sponsor will be considered to have complied with this requirement if they have completed this selection process for a general engineering services agreement at least once every three years and have formally assigned work to a firm or firms under an agreement. The local sponsor must inform the Chief Engineer of any change in the provider of general engineering services.

D. **IMPROVEMENTS** are construction related projects that upgrade a facility to provide increased efficiency or capacity. Improvements do not include any activities that are maintenance, replacement, or reconstruction.

E. **INELIGIBLE ITEMS** excluded from cost-share include:

1. Administrative and easement costs, including those related to permits;
2. Property acquisitions, property surveys, and legal expenses unless specifically identified as eligible within the Flood Recovery Property Acquisition Program, the Flood Protection Program, or the Water Retention Projects;
3. Work and costs incurred prior to a cost-share approval date, except for emergencies as determined by the Chief Engineer;
4. Project related operation and regular maintenance costs;
5. Funding contributions provided by federal, other state, or other North Dakota state entities that supplant costs;
6. Work incurred outside the scope of the approved study or project.

F. **EXPANSIONS** are construction related projects that increase the project area or users served. Expansions do not include maintenance, replacement, or reconstruction activities.

G. **LOCAL SPONSOR** is the entity submitting a cost-share application and must be a political subdivision, state entity, or commission legislatively granted North Dakota recognition that applies the necessary local share of funding to match State Water Commission cost-share. They provide direction for studies and projects, public point of contact for communication on public benefits and local concerns, and acquire necessary permits and rights-of-way.

H. **REGULAR MAINTENANCE COSTS** include normal repairs and general upkeep of facilities to allow facilities to continue proper operation and function. These maintenance items occur on a regular or annual basis. Regular maintenance activities simply help ensure the asset will remain serviceable throughout its originally predicted useful life.

I. **PROGRAM** is a subcategory of cost-share that is typically associated with a federal initiative and may cover all phases of a study or implementation of a project.

J. **PROJECT** is the water-related construction activity.

K. **EXTRAORDINARY MAINTENANCE COSTS** include the repair or replacement of portions of facilities or components that extends the overall life of the system or components that are above and beyond regular or normal maintenance. Extraordinary maintenance activities extend the asset's useful life beyond its originally predicted useful life.

L. **SUSTAINABLE OPERATION, MAINTENANCE, AND REPLACEMENT PLAN** is a description of the anticipated operation, maintenance, and replacement costs with a statement that the operation, maintenance, and replacement of the project will be sustainable by the local sponsor. For water supply projects, a summary of the project sponsor's Capital Improvement Fund must also be included.

M. CAPITAL IMPROVEMENT FUND is money set aside using a portion of user fees for future asset replacement and a cost share application shall include documentation of the following:

1. Current capital improvement fund balance
2. Existing and new assets
3. Replacement cost of assets
4. Average life of assets
5. Current and future monthly reserve per user

II. COST-SHARE APPLICATION AND APPROVAL PROCEDURES.

The State Water Commission will not consider any cost-share applications for water related projects or studies unless the local sponsor first makes an application to the Chief Engineer. No funds will be used in violation of Article X, § 18 of the North Dakota Constitution (Anti-Gift Clause).

A. **APPLICATION REQUIRED**. An application for cost-share is required in all cases and must be submitted by the local sponsor on the State Water Commission Cost-Share Application form. Applications for cost-share are accepted at any time. Applications received less than 30 days before a State Water Commission meeting will not be considered at that meeting and will be held for consideration at a future meeting. The application form is maintained and updated by the Chief Engineer and must include the following:

1 Category of cost-share activity
2 Location of the proposed project or study area
3 Description, purpose, goal, objective, narrative of the proposed activities
4 Delineation of costs
5 Potential federal, other state, or other North Dakota state entity participation
6 Engineering plans, if applicable
7 Status of required permitting
8 Potential territorial service area conflicts or service area agreements, if applicable
9 Sustainable operation, maintenance, and replacement plan for projects
10 Additional information as deemed appropriate by the Chief Engineer

Applications for cost-share are separate and distinct from the State Water Commission biennial project information collection effort that is part of the budgeting process and published as the State Water Plan. All local sponsors are encouraged to submit project and study financial needs for the State Water Plan. Projects and studies not submitted as part of the State Water Plan development process may be held until action can be taken on those that were included during budgeting, unless determined to be an emergency that directly impacts human health and safety or that are a direct result of a natural disaster.

B. **PRE-APPLICATION**. A pre-application process is allowed for cost-share of assessment projects. This process will require the local sponsor to submit a brief narrative of the project, preliminary designs, and a delineation of costs. The Chief Engineer will then review the material presented, make a determination of project eligibility, and estimate the cost-share funding the project may anticipate receiving. A project eligibility letter will then be sent to the local sponsor noting the percent of cost-share assistance that may be expected on eligible items as well as listing those items that are not considered to be eligible costs. In addition, the project eligibility letter will state that the Chief Engineer will recommend approval when all cost-share requirements are addressed. The local sponsor may use the project eligibility letter to develop a project budget for use in the assessment voting process. Upon completion of the assessment vote and all other requirements an application for cost-share can be submitted.

C. **REVIEW.** Upon receiving an application for cost-share, the Chief Engineer will review the application and accompanying information. If the Chief Engineer is satisfied that the proposal meets all requirements, the Chief Engineer will present the application along with a recommendation to the State Water Commission for its action. The Chief Engineer's review of the application will include the following items and any other considerations that the Chief Engineer deems necessary and appropriate.

1 Applicable engineering plans;
2 Field inspection, if deemed necessary by the Chief Engineer;
3 The percent and limit of proposed cost-share determined by category of cost-share activity and eligible expenses;
4 Assurance of sustainable operation, maintenance, and replacement of project facilities by the local sponsor;
5 Status of permitting and service area agreements;
6 Available funding in the State Water Commission budget, if in the State Water Plan, and a priority ranking when appropriate.

For cost-share applications over $100 million, additional information requested by the State Water Commission will be used to determine cost-share.

The Chief Engineer is authorized to approve cost-share up to $75,000 in state funds and also approve cost overruns up to $75,000 in state funds without State Water Commission action.

D. **NOTICE**. The Chief Engineer will give notice to local sponsors when their application for cost-share is placed on the tentative agenda of the State Water Commission's next meeting.

E. **AGREEMENT AND DISTRIBUTION OF FUNDS**. No funds will be disbursed until the State Water Commission and local sponsor have entered into an agreement for cost-share participation. No agreement for construction funding will be entered into until all required State Engineer permits have been acquired.

For construction projects, the agreement will address indemnification and vicarious liability language. The local sponsor must require that the local sponsor and the state be made an additional insured on the contractor's commercial general liability policy including any excess policies, to the extent applicable. The levels and types of insurance required in any contract must be reviewed and agreed to by the Chief Engineer. The local sponsor may not agree to any provision that indemnifies or limits the liability of a contractor.

For any property acquisition, the agreement will specify that if the property is later sold, the local sponsor is required to reimburse the Commission the percent of sale price equal to the percent of original cost-share.

The Chief Engineer may make partial payment of cost-sharing funds as deemed appropriate. Upon notice by the local sponsor that all work or construction has been completed, the Chief Engineer may conduct a final field inspection. If the Chief Engineer is satisfied that the work has been completed in accordance with the agreement, the final payment will be disbursed to the local sponsor, less any partial payment previously made.

F. **LITIGATION**. If a project submitted for cost-share is the subject of litigation, the application may be deferred until the litigation is resolved. If a project approved for cost-share becomes the subject of litigation before all funds have been disbursed, the Chief Engineer may withhold funds until the litigation is resolved. Litigation for this policy is defined as legal action that would materially affect the ability of the local sponsor to construct the project; that would delay construction such that the authorized funds could not be spent; or is between political subdivisions related to the project.

III. <u>COST-SHARE CATEGORIES</u>.

The State Water Commission supports the following categories of projects and studies for cost-share. Engineering expenses related to construction are cost-shared at the same percent as the construction costs when approved by the State Water Commission.

A. **PRE-CONSTRUCTION EXPENSES.** The State Water Commission supports local sponsor development of feasibility studies, engineering designs, and mapping as part of pre-construction activities to develop support for projects within this cost-share policy. Pre-construction expenses approved by the State Water Commission are cost-shared up to 35 percent. The following projects and studies are eligible.

1 Feasibility studies to identify water related problems, evaluate options to solve or alleviate the problems based on technical and financial feasibility, and provide recommendation and cost estimate, of the best option to pursue.

2 Engineering design to develop plans and specifications for permitting and construction of a project, including associated cultural resource and archeological studies.

3 Mapping and surveying to gather data for a specific task such as flood insurance studies and flood plain mapping, LiDAR acquisition, and flood imagery attainment, which are valuable to managing water resources.

Copies of the deliverables must be provided to the Chief Engineer upon completion. The Chief Engineer will determine the payment schedule and interim progress report requirements.

B. WATER SUPPLY

1 **WATER SUPPLY PROJECT**. The State Water Commission supports water supply efforts and will use a grant and loan program. The local sponsor may apply for water supply funding, and the application will be reviewed to determine project priority. Projects within category (1) may be considered for grant funding up to 75 percent cost-share. Projects in category (2) may be considered for grant funding up to 60 percent of cost-share. Grant funding within category (3) will be on a case-by-case basis. Projects within categories (1) through (4) may be considered for loan funding. After cost-share for grant funding has been determined, the local sponsor may be considered for loan funding in addition to the grant funding. The combination of grant and loan funding will not exceed 80 percent from the State Water Commission.

(1) In most cases a 75% cost-share is intended to address improvements to meet primary drinking water standards or expansion into new rural water service areas. Factors considered include:

(a) Connection of communities to the regional system as part of this expansion as determined by the Chief Engineer.

(b) Willingness of water users at far reaches of the system to pay additional costs for water service as an indicator of greater need for access to water and local commitment in the project as determined by the Chief Engineer.

(c) Affordable and sustainable water rate as determined by the Chief Engineer.

Lower rates of cost-share up to 60% may be made available to address other necessary improvements in rural water systems as defined in I-D.

(2) Supports improvements or connection of new customers within the existing service area of a municipal water system. Population growth and affordability may be used in prioritizing projects in this category.

(3) Water treatment improvements that address impacts from other State Water Commission projects. Grant funding is based on level of impact as determined by the State Water Commission.

(4) Addresses extraordinary repairs or replacement needs of a water supply system due to damages from a recent natural disaster.

Debt per capita, either actual or anticipated, may be used as an additional determinant of financial need.

Water Depots for industrial use receiving water from facilities constructed using State Water Commission funding or loans have the following additional requirements:

a) Domestic water supply has priority over industrial water supply in times of shortage. This must be explicit in the water service contracts with industrial users.

b) If water service will be contracted, public notice of availability of water service contracts is required when the depot becomes operational.

c) A portion of the water supply at any depot must be available on a non-contracted basis for public access.

2 **MUNICIPAL, RURAL, AND INDUSTRIAL WATER SUPPLY PROGRAM**. The Municipal, Rural, and Industrial Water Supply Program, which uses federal funds, is administered according to North Dakota Administrative Code Article 89-12.

3 **DROUGHT DISASTER LIVESTOCK WATER SUPPLY PROJECT ASSISTANCE PROGRAM**. This program is to provide assistance with water supply for livestock impacted during drought declarations and is administered according to North Dakota Administrative Code Article 89-11.

C. FLOOD CONTROL. The State Water Commission may provide cost-share for eligible items of flood control projects protecting communities from flooding and may include the repair of dams that provide a flood control benefit.

1 **FLOOD RECOVERY PROPERTY ACQUISITION GRANT PROGRAM.** This program is used to assist local sponsors with flood recovery expenses that provide long term flood damage reduction benefits through purchase and removal of structures in areas where flood damage has occurred. All contracted costs directly associated with the acquisition will be considered eligible for cost-share. Contracted costs may include: appraisals, legal fees (title and abstract search or update, etc.), property survey, closing costs, hazardous materials abatement needs (asbestos, lead paint, etc.), and site restoration.

The State Water Commission may provide cost-share of the eligible costs of approved flood recovery expenses that provide long term flood reduction benefits based on the following criteria and priority order:

a) Local Sponsor has flood damage and property may be needed for construction of temporary or long-term flood control projects, may be cost-shared up to 75 percent.
b) Local Sponsor has flood damage and property would increase conveyance or provide other flood control benefits, may be cost-shared up to 60 percent.

Prior to applying for assistance, the local sponsor must adopt and provide to the Chief Engineer an acquisition plan (similar to plans required by Hazard Mitigation Grant Program (HMGP)) that includes the description and map of properties to be acquired, the estimated cost of property acquisition including contract costs, removal of structures, the benefit of acquiring the properties, and information regarding the ineligibility for HMGP funding. Property eligible for HMGP funding is not eligible for this program. The acquisition plan must also include a description of how the local sponsor will insure there is not a duplication of benefits.

Over the long-term development of a flood control project following a voluntary acquisition program, the local sponsor's governing body must officially adopt a flood risk reduction plan or proposal including the flow to be mitigated. The flow used to develop the flood risk reduction plan must be included in zoning discussions to limit new development on other flood-prone property. An excerpt of the meeting minutes documenting the local sponsor's official action must be provided to the Chief Engineer.

Local sponsor must fund the local share for acquisitions; this requirement will not be waived. Federal funds are considered "local" for this program if they are entirely under the authority and control of the local sponsor.

The local sponsor must include a perpetual restrictive covenant similar to the restrictions required by the federal HMGP funding with the additional exceptions being that the property may be utilized for flood control structures and related infrastructure, paved surfaces, and bridges. These covenants must be recorded either in the deed or in a restrictive covenant that would apply to multiple deeds.

The local sponsor must provide justification, acceptable to the Chief Engineer, describing the property's ineligibility to receive federal HMGP funding. This is not meant to require submission and rejection by the federal government, but rather an explanation of why the property would not be eligible for federal funding. Example explanations include: permanent flood control structures may be built on the property; project will not achieve required benefit-cost analysis to support HMGP eligibility; or lack of available HMGP funding. If inability to receive federal funding is not shown to the satisfaction of the Chief Engineer, following consultation with the North Dakota Department of Emergency

Services, the cost-share application will be returned to the local sponsor for submittal for federal funding prior to use of these funds.

2 **FLOOD PROTECTION PROGRAM.** This program supports local sponsor efforts to prevent future property damage due to flood events. The State Water Commission may provide cost-share grants for up to 60 percent of eligible costs. For projects with federal participation, the cost-share may be up to 50 percent of eligible costs.

The cost-share application must include the return interval or design flow for which the structure will provide protection. Local share must be provided on a timely basis. The State Water Commission may lend a portion of the local share based on demonstrated financial need.

Property acquisition costs limited to the purchase price of the property that is not eligible for HMGP funding and within the footprint of a project may be eligible under this program. The local sponsor must include a perpetual restrictive covenant on any properties purchased under this program similar to the restrictions required by the federal HMGP funding with the additional exceptions being that the property may be utilized for flood control structures and related infrastructure, paved surfaces, and bridges. These covenants must be recorded either in the deed or in a restrictive covenant that would apply to multiple deeds.

3 **FEMA LEVEE SYSTEM ACCREDITATION PROGRAM**. The State Water Commission may provide cost-share up to 60 percent for eligible services for FEMA 44 CFR 65.10 flood control or reduction levee system certification analysis. The analysis is required for FEMA to accredit the levee system for flood insurance mapping purposes. Typical eligible costs include site visits and field surveys to include travel expenses, hydraulic evaluations, closure evaluations, geotechnical evaluations, embankment protection, soils investigations, interior drainage evaluations, internal drainage hydrology and hydraulic reports, system modifications, break-out flows and all other engineering services required by FEMA. The analysis will result in a comprehensive report to be submitted to FEMA and the Chief Engineer.

Administrative costs to gather existing information or to recreate required documents, maintenance and operations plans and updates, and emergency warning systems implementation are not eligible.

4 **DAM SAFETY AND EMERGENCY ACTION PLANS.** The State Water Commission supports dam safety including repairs and removals, as well as emergency action plans. The State Water Commission may provide cost-share for up to 75 percent of the eligible items for dam safety repair projects and dam breach or removal projects. Dam safety repair projects that are funded with federal or other agency funds may be cost-shared up to 75 percent of the eligible non-matched costs. The intent of these projects is to return the dam to a state of being safe from the condition of failure, damage, error, accidents, harm or other events that are considered non-desirable. The State Water Commission may lend a portion of the local share based on demonstrated financial need.

The State Water Commission may provide cost-share up to 80 percent, for emergency action plans (EAPs) of each dam classified as high or medium significant hazard. The cost of a dam break model is only eligible for reimbursement for dams classified as a high hazard.

5 **WATER RETENTION PROJECTS.** The goal of water retention projects is to reduce flood damages by storing floodwater upstream of areas prone to flood damage. The State Water Commission may provide cost-share up to 60 percent of eligible costs for flood retention projects including purchase price of the property. For projects with federal participation, the cost-share may be up to 50 percent. Water retention structures constructed with State Water Commission cost-share must meet state dam safety requirements, including the potential of cascade failure. A hydrologic analysis including the operation plan, quantifying the flood reduction benefits for 25, 50, and 100-year events must be submitted with the cost-share application.

6 **SNAGGING AND CLEARING PROJECTS.** Snagging and clearing projects consist of the removal and disposal of fallen trees and associated debris encountered within or along the channel. Snagging and clearing projects are intended to prevent damage to structures such as bridges, and maintain the hydraulic capacity of the channel during flood flows. The State Water Commission may provide cost-share for up to 50 percent of the eligible items for snagging and clearing as well as any sediment that has accumulated in the immediate vicinity of snags and any trees in imminent danger of falling in the channel on watercourses as defined in N.D.C.C. § 61-01-06. Items that are not eligible include snagging and clearing of man-made channels; the dredging of watercourses for sediment removal; the clearing and grubbing of cattails and other plant vegetation; or the removal of any other unwanted materials.

D. RURAL FLOOD CONTROL. The primary purpose of rural flood control projects is to manage runoff or drainage from agricultural sources or to provide flood control in a rural setting. Typically, rural flood control projects consist of drains, channels, diversion ditches, or ring dikes. Items that are not eligible include projects that are managing runoff or drainage from residential or urban sources.

1 **DRAINS, CHANNELS, OR DIVERSION PROJECTS.** These projects are intended to improve the drainage and management of runoff from agricultural sources. The State Water Commission may provide cost-share up to 45 percent of the eligible items for the construction of drains, channels, or diversion ditches. Expansions and improvements may be cost-shared on the basis of increased drainage capacity achieved or increased area served. Construction costs for public road crossings that are integral to the project are eligible for cost-share as defined in N.D.C.C. § 61-21-31 and 61-21-32. If an assessment-based rural flood control project involves multiple districts, each district involved must join in the cost-share application.

Cost-share applications for rural assessment drains will only be processed after the assessment vote has passed, the final design is complete, and a drain permit has been obtained. If the local sponsor wishes to submit a cost-share application prior to completion of the aforementioned steps, a pre-application process will be followed.

2 **Ring Dike Program**. This program is intended to protect individual rural homes and farmsteads through ring dike programs established by water resource districts. All ring dikes within the program are subject to the Commission's Individual Rural and Farmstead Ring Dike Criteria provided in Attachment A. Cost-share is limited to $40,000 per ring dike. Protection of a city, community or development area does not fall under this program, but may be eligible for the flood control program. The State Water Commission may provide up to 60 percent cost-share of eligible items for ring dikes.

Landowners enrolled in the Natural Resource Conservation Service's (NRCS) Environmental Quality Incentive Program (EQIP) who intend to construct rural or farmstead ring dikes that meet the State Water Commission's elevation design criteria are eligible for a cost-share reimbursement of 20 percent of the NRCS construction payment, limited to a combined NRCS and State Water Commission contribution of 80 percent of project costs.

E. Recreation. The State Water Commission may provide cost-share up to 40 percent for projects intended to provide water-based recreation. Typical projects provide or complement water-based recreation associated with dams.

F. Irrigation. The State Water Commission may provide cost-share for up to 50 percent of the eligible items for irrigation projects. The items eligible for cost-share are those associated with new central supply works, including water storage facilities, intake structures, wells, pumps, power units, primary water conveyance facilities, and electrical transmission and control facilities.

G. Bank Stabilization. The State Water Commission may provide cost-share up to 50 percent of eligible items for bank stabilization projects on public lands or those lands under easement by federal, state, or political subdivisions. Bank stabilization projects are intended to stabilize the banks of lakes or watercourses, as defined in N.D.C.C § 61-01-06, with the purpose of protecting public facilities. Drop structures and outlets are not considered for funding as bank stabilization projects, but may be eligible under other cost-share program categories. Bank stabilization projects typically consist of a rock or vegetative design and are intended to prevent damage to public facilities including utilities, roads, or buildings adjacent to a lake or watercourse.

ATTACHMENT A
INDIVIDUAL RURAL AND FARMSTEAD RING DIKE CRITERIA

MINIMUM DESIGN CRITERIA

- HEIGHT: The dike must be built to an elevation 2 ft above either the 100-year flood or the documented high water mark of a flood event of greater magnitude, whichever is greater.
- TOP WIDTH:
  - If dike height is 5 ft or less: 4 ft top width
  - If dike height is between 5 ft and 14 ft: 6 ft top width
  - If dike height is greater than 14 ft: 8 ft top width
- SIDE SLOPES: 3 horizontal to 1 vertical
- STRIP TOPSOIL AND VEGETATION: 1 ft
- ADEQUATE EMBANKMENT COMPACTION: Fill in 6-8 inch layers, compact with passes of equipment
- SPREAD TOPSOIL AND SEED ON RING DIKE

LANDOWNER RESPONSIBILITY

Landowners are responsible to address internal drainage on ring dikes. If culverts and flap gates are installed, these costs are eligible for cost-share. The landowner has the option of completing the work or hiring a contractor to complete the work.

If contractor does the work, payment is for actual costs with documented receipts.
If landowner does the work, payment is based on the following unit prices:

- STRIPPING, SPREADING TOPSOIL, AND EMBANKMENT FILL: Chief Engineer will determine rate schedule based on current local rates
- SEEDING: Cost of seed times 200%
- CULVERTS: Cost of culverts times 150%
- FLAP GATES: Cost of flap gates times 150%

OTHER FACTS AND CRITERIA

- The topsoil and embankment quantities will be estimated based on dike dimensions. Construction costs in excess of the 3:1 side slope standard will be the responsibility of the landowner. Invoices will be used for the cost of seed, culverts, and flap gates.
- Height can be determined by existing FIRM data or known elevations available at county floodplain management offices. Engineers or surveyors may also assist in establishing height elevations.
- The projects will not require extensive engineering design or extensive cross sections.
- A dike permit is required if the interior volume of the dike consists of 50 acre-feet, or more.

Appendix F: Summary of Farm-Level Returns and Economic Feasibility of Irrigation Along the McClusky Canal

Summary of
Economic Feasibility of Irrigation Along the McClusky Canal in North Dakota: Farm-level Returns

Agribusiness & Applied Economics Report No. 734

North Dakota State University (NDSU) completed an economic feasibility analysis for the Garrison Diversion Conservancy District (GDCD) to determine the potential economic benefit at the farm level from providing irrigation service along the McClusky Canal. The analysis used two related methods to determine a potential increase in land value of $1,418 and $1,700, respectively.

Background

Congress authorized the construction of Garrison Dam on the Missouri River in North Dakota in the 1940s and construction began in the 1950s. As part of the authorization, GDCD was created to maintain and operate the Garrison Dam as well as associated canals and infrastructure. To compensate the State for the loss of land from construction of the Garrison Dam, Congress authorized the GDCD to provide irrigation from the related infrastructure. Over the years, the acreage authorized by Congress has been reduced to the current 51,700 acres.

Study Nuances

Changes in market prices, technology, climate, government policy, and production practices have altered the economics of crop production. Increased demand for agricultural products and limited ability to supply them have placed upward pressure on prices, incentivizing increased production. At the same time, high levels of price volatility and production risk have led many farmers to be conservative when considering new practices or investments as well as seeking ways that reduce these risks. Irrigated production may provide for increased production while decreasing variability due to limited water availability.

Purpose

The purpose of the study is to estimate the returns of irrigated crop production along the McClusky Canal with a consideration of the impact of production risk. A second study (Bangsund, Saxowsky, and Ripplinger 2014) considers the regional economic impacts of irrigation development. For this study, NDSU focused on the following research questions:

1. What dryland crops are grown in the region?
2. What dryland crop rotations prevail?
3. What are the returns to dryland crop production and crop rotations?
4. What irrigated rotations are possible?
5. What are the returns to the most likely irrigated cropping system(s)?
6. How much do regional dryland and irrigated crop yields vary?
7. What are the expected returns to representative dryland and irrigated crops when yield variability is considered?

Analysis

By evaluating and answering the seven research questions, the NDSU team was able to determine the overall economic potential from irrigation. Traditionally, farm-level economics are evaluated on the basis of anticipated revenues, costs, and returns of crop enterprises using crop budgets. This process occasionally includes identification of representative crop rotations, and weighting the revenues, costs, and returns of individual crops to create a composite-acre budget. Composite-acre budgets allow a direct comparison between alternative cropping systems. By reorganizing the data, the analysis can be broken into three core sections:

1. Baseline (non-irrigated) farm profitability
2. Irrigated (single year) farm profitability
3. "Average" year (stochastic) farm profitability for non-irrigated and irrigated crops

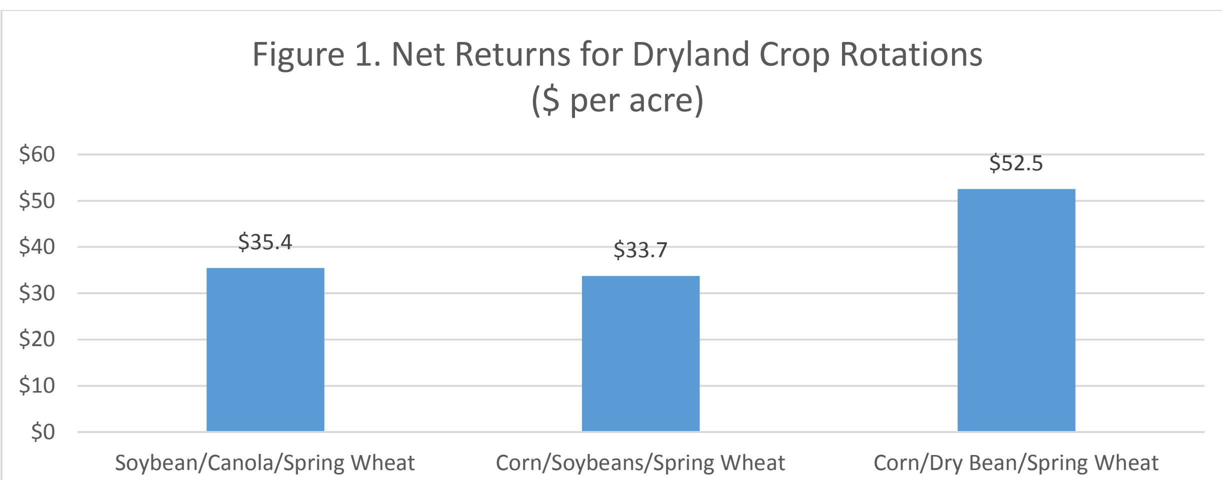
Baseline and irrigated farm profitability provided evidence that a more sophisticated model should be used to provide a more reliable result. Therefore, the report summarizes a stochastic model to evaluate "good" and "bad" years in order to generalize over a 20-year timeframe.

Baseline Non-Irrigated Farm Profitability

To calculate baseline farm profitability, the three representative dryland rotations were identified to illustrate potential returns. The rotations are:

- spring wheat-canola-spring wheat-soybean
- corn-soybean-spring wheat
- corn-dry bean-spring wheat

Using NDSU data on trial yields for spring wheat, canola, and soybean from the 2014 North Central (Minot) Research Extension Center (NCREC) the report models variations in dryland yields and returns. While 2014 data is used, variation in crop production in any given year can be affected by variable weather patterns and other conditions. Based on this information, the report determined baseline profitability based on net returns for dryland crop rotations. Figure 1 shows the resulting returns.

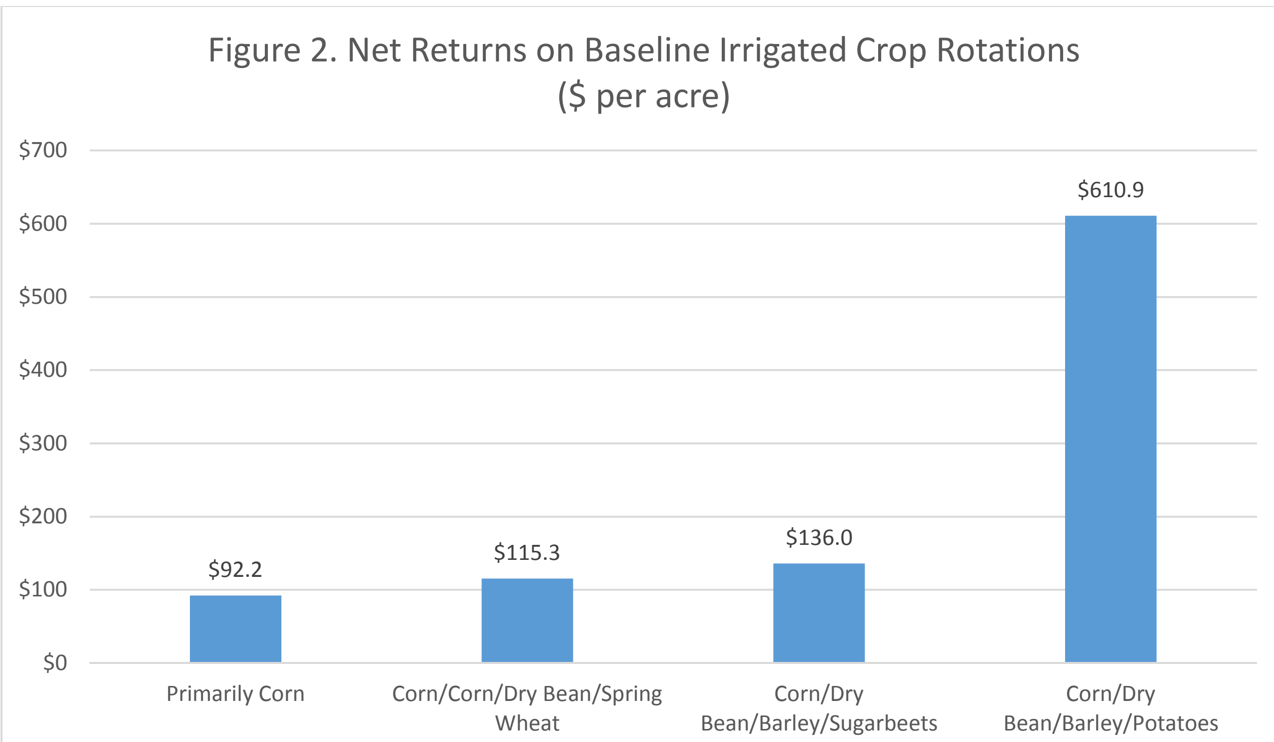


Irrigated (single year) Farm Profitability

Similar to the dryland profitability analysis, the on-farm profitability of irrigated crops is calculated using crop budgets as calculated by NDSU. Specifically, costs are estimated using a model develop by Aakre (2013) and is included in Appendix III of the original report. In the analysis the level of selected inputs (e.g., nitrogen fertilizer for corn) is increased to match the higher target yield of irrigated crops. Four irrigated crop rotations were selected:

- Primarily Corn
- Corn/Corn/Dry Bean/Wheat
- Corn/Dry Bean/ Barley/Beets
- Corn/Dry Bean/ Barley/Potatoes

The returns to labor and management for the composite irrigated acre (that is, the irrigated crop rotations) are showing in Figure 2.

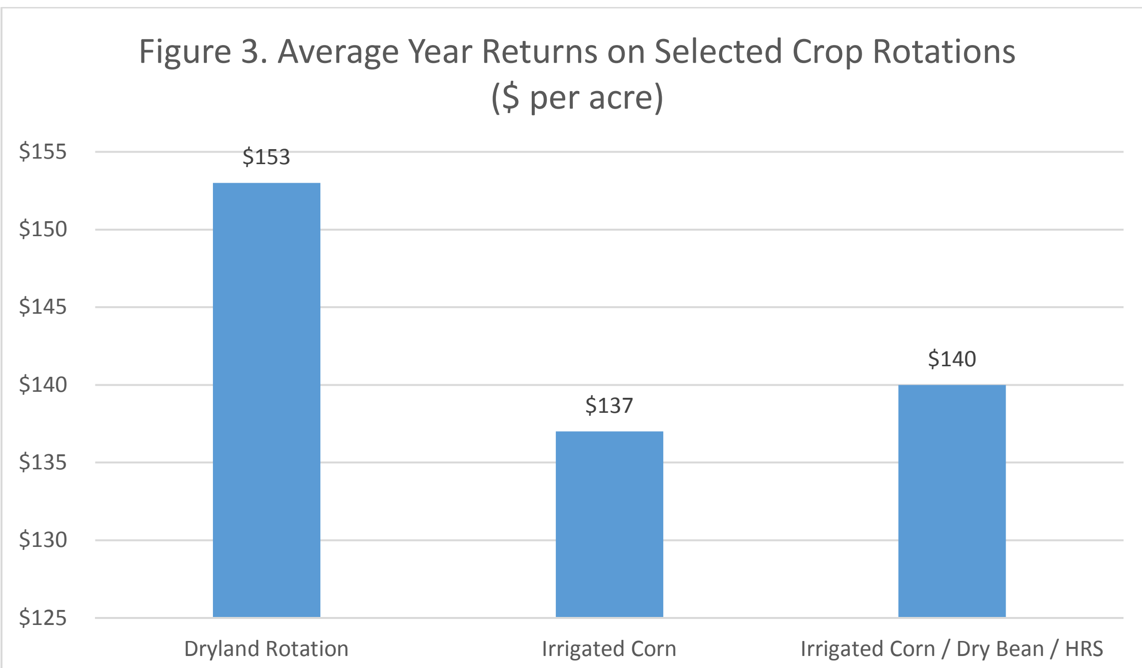


Irrigated & Non-Irrigated ("average" year) Farm Profitability

More detailed analytical tools can produce budgets that include stochastic elements (i.e., an analysis using probability), to generate a range of results, such as a distribution of net returns for both dryland and irrigated production systems. The use of stochastic modeling can provide a better long-range assessment of the variability of returns than could be obtained using simple averages or expected yields from budget programs. The stochastic model looks at both best and worst years over 10 and 20 year timeframes and the average across the 20 year timeframe. To evaluate overall profitability, three rotations were used:

- Dryland Corn/ Dry Bean/ Wheat
- Irrigated Corn
- Irrigated Corn/ Dry Bean/ Wheat

Average year returns would expect dryland rotations to result in a higher return on management and labor. The report identifies other management practices and recent wet years based on the variability found in the stochastic model results, the report further identifies potential benefits by increased yield potential on irrigated corn acreage, which is expected to increase at a faster rate than other crops.



Conclusion Summary

The duel approach presented in the report provides two ways to measure benefits to farmers: baseline dry vs baseline irrigated benefit (section one and section two) and average increase in land values (section three). In both approaches, the benefit is capitalized to the land itself at a four percent interest rate.

Baseline Method

Based on average dryland and irrigation yields, the annual benefit of irrigation to the farm operator is $56.71 (92.15-35.44) per acre. A capitalization rate of four percent indicates that the value of irrigable land increases $1,418 (56.71/.04) per acre.

"Average" Year Method

Selecting irrigated corn as the baseline crop, the analysis considered the yield trends which give corn an advantage (i.e., projected increases in corn yields into the future). The benefit of irrigating a rotation that is primarily corn increases the value of irrigable land by $1,700 (68/.04) per acre over the next decade. The benefit of irrigating will also increase if precipitation in central North Dakota returns to conditions experienced prior to the past two decades.

Appendix G: Summary of Regional Economic Effects of Irrigation Along the McClusky Canal

Summary[1] of Regional Economic Effects of Irrigation Along the McClusky Canal in North Dakota

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The Dakota Water Resources Act passed in 2000 by the 106th Congress mandated the maintenance of the McClusky Canal and authorized development of irrigation along the canal. The McClusky Canal is currently blocked near the continental divide between the Missouri River and Red River basins. Development of authorized land along the canal could result in irrigation on 13,700 acres in the Turtle Lake service area, 10,000 acres near the McClusky Canal service area, and up to 28,000 acres in other undesignated areas. The vision is to construct additional irrigation "units" along the 60-mile length of the Canal in McLean and Sheridan Counties in central North Dakota. Full development would result in about 404 center pivots based on approximately 51,700 authorized acres.

The purpose of this study was to estimate the state-level economic effects of converting land along the McClusky Canal from dry land crop production to irrigated crop production. Direct effects are the first round of economic change associated with a project, program, policy, or activity and usually represent changes in business output, employment, or personal income. The IMPLAN modeling system was used to estimate the indirect and induced economic effects as the direct effects work through a given economy. Indirect impacts are estimated as the additional business activity created as affected businesses have to change their purchases of inputs and services to expand their output. Induced impacts are generated as an increase in personal income results in a change in personal consumption, and how changes in spending affects purchases of goods and services in the economy.

Acquisition and installation of irrigation equipment would create a one-time set of economic impacts. Average total investment for infrastructure and development was estimated at $246,300 per center pivot, although about $227,300 was considered in-state expenditures. In-state expenditures were further adjusted to reflect the percentage of in-state and out-of-state sourcing for irrigation equipment. After those adjustments, IMPLAN estimated direct impacts of $132,100 per center pivot system.

Each center pivot was estimated to create $202,900 in gross business activity in the state economy. Of the total business activity, around $30,100 was associated with indirect effects and $40,700 was associated with induced effects. Labor income was estimated at $77,700 and value-added effects were estimated at $110,500. A total of 1.5 jobs would be supported by the development of each center pivot system, assuming the full development process occurred over the course of one year.

The total economic impact (i.e., sum of direct, indirect, and induced effects) on the state economy of developing all 404 center pivots would be $82 million, economy-wide personal

[1] The study summary presented below has been excerpted from the original report and presented in stand-alone fashion with minor revisions.

income would be $31 million, and value-added to the state economy would be nearly $45 million. If total development occurred over a one-year period, statewide change in employment would be 598 jobs. State and local government revenues from the development of each center pivot system were estimated at $14,000 with about $5.6 million in state and local government revenues associated with full development.

Irrigated rotations of primarily corn and dryland rotations of soybean-canola-spring wheat were selected for modeling annual economic effects of irrigation crop production. Irrigated corn was expected to generate about $355 per acre more in crop sales per year than the dryland rotation of soybean-canola-spring wheat, based on yield estimates from North Dakota State University extension crop budgets and expected 2014 crop prices. The direct impacts for a center pivot system were based on 128 acres under irrigation, and represented a change of $39,870 in gross revenues on those acres over what would have been generated under dryland production. Full development of all authorized land was estimated to increase crop sales in the state by $16,104,000 annually.

Each center pivot system was estimated to create about $73,800 in additional gross business activity, economy-wide personal income of $21,100 and value-added effects were estimated at $29,000. The total economic impact (i.e., sum of direct, indirect, and induced effects) on the state economy of developing all 404 center pivots would be about $30 million annually, with economy-wide personal income of $8.5 million, and value-added impacts of nearly $11.7 million. Each center pivot irrigation system was estimated to increase employment in the state by 0.6 jobs. Under full development of all authorized acres, irrigated production would increase employment in the state by 242 jobs. Overall change in state and local tax revenues were estimated at $2,800 per year for each center pivot system. Total development of authorized acreage would result in an increase of about $1.1 million annually in state and local government revenues.

Irrigated crop production is not expected to induce any significant changes in agricultural processing within the state. Irrigation could potentially influence both feed availability and quality, but the addition of irrigated land in the study region was not perceived at this time to alter or change existing trends in livestock production in the state.

From an economy-wide perspective, the strongest likelihood of changes in economic activity associated with development of irrigated land along the McClusky Canal at this time would associated with crop production. The economic effects of irrigation would result in an increase of $575 in gross business volume per irrigated acre, without adoption of any high-value specialty crops. If processing, and associated production of specialty crops (e.g., industrial sugar beets) were to occur, the economic benefits to the state economy would be considerably larger than estimated in this study. The expansion of irrigation in the region is not likely to produce meaningful changes in economic activity related to livestock production, although some local producers may benefit from co-products associated with irrigation (e.g., crop aftermath grazing).