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MISSOURI RIVER POTENTIAL INTAKE LOCATIONS INVESTIGATION

A comprehensive study of potential intake sites along the Missouri River from Washburn, ND to the Montana State Line.

May 14, 2025

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1 Executive Summary

The Missouri River is North Dakota's most abundant source of freshwater. Putting this water to beneficial use is one of the North Dakota Department of Water Resources' (DWR) goals in their five-year strategic plan. Toward that objective, the DWR initiated the Missouri River Potential Intake Locations Investigation (Study) with HDR Engineering Inc. (HDR) and its subconsultants to evaluate industrial intake locations along the Missouri River from the Montana state line to Washburn, ND. The goal of the Study was to identify a minimum of five surface water intake sites and five subsurface sites, each with a potential capacity of at least 15,000 acre-feet per year (AF/yr) or ~9,300 gallons per minute (GPM). The final surface water and subsurface sites are shown in Figure 1. The primary purpose of the intake sites would be to serve existing or new industrial water users, with a secondary purpose to serve additional irrigation and municipal water supply.

The Study focused on the Missouri River corridor from the Montana state line to Washburn, ND, as shown in Figure 1. The total length of the Study area is 231.6 river miles. Of this total, 178 miles are located within Lake Sakakawea, the reservoir created by Garrison Dam. The remaining 53.6 miles in the Study area consist of river channel that stretches from the Montana state line to Lake Sakakawea and from Garrison Dam to Washburn, ND. Given the distribution and characteristics of the reservoir and river channel segments, the Study area was split into ten sub-reaches for the surface water intake site analysis. The sub-reaches include the left and right banks of each of the five Study reaches, looking downstream.

Aquifers were identified based on their potential to meet the 15,000 AF/yr capacity criteria for subsurface intake sites as required by this Study. These aquifers were then categorized as either primary or secondary. Primary aquifers have sufficient data to confirm that capacity requirements can be met or exceeded with the installation of one or two horizontal collector wells. Secondary aquifers show potential to meet capacity requirements but did not have sufficient data to verify this potential. Since this Study did not include field analysis, field investigation is needed to fully assess the secondary aquifers.

In their Request for Proposal for the Study, the DWR listed several criteria that should be evaluated at a location to determine its suitability as an intake site including water availability, likelihood of future intake sedimentation, and distance to existing infrastructure, among other criteria. Through collaboration with DWR team members, definitions for the criteria were developed so that the criteria could be evaluated using a geospatial model.

A weighting factor for each criterion was calculated by first determining a score for each criteria using statistical pairwise comparison completed using professional judgement. A matrix was developed with the scores and using linear algebra, weighting factors for each criterion were established. Two separate spatial models were created as part of this Study, one for surface water intake sites and the other for subsurface intake sites. Each model is unique, with some shared criteria and similar ranking/weighting, but each uses a different grid system and calculations of scores were different between the two. The geospatial models used the criteria definitions and weighting factors to calculate an overall score for each grid cell. Higher scores indicate greater suitability as a potential intake site.

The grid cell with the highest overall score for each of the 10 sub-reaches was identified as the top-ranking surface water intake site in that reach and is shown in Table 1. The top five aquifers were determined by taking the average of all the grid cell scores for each aquifer and choosing the five aquifers with the highest average score. The grid cell with the highest score within each of the top five aquifers was identified as the most suitable location to develop a subsurface water intake site within those aquifers and are shown in Table 2. The identified surface and subsurface sites are shown in Figure 1.

While the Study was comprehensive in its review of data available for identifying an intake location, field verification of an identified site is beyond the scope of the Study but is strongly encouraged to confirm the Study findings.

In addition, it is recommended that a stakeholder workshop be held to coordinate with agencies, industries, regional water systems, and the project team to assist with identification of the most optimal site for construction of an industrial intake from the identified sites. This Study can be leveraged to refine the scope and reduce the cost of fieldwork needed to verify each site.

Table 1. Surface water sites summary.

Sub-Reach Name	*Rank*[1]	*Maximum Cell Score in Sub-Reach*
Garrison Dam to Washburn, Right	S-1	0.922
Garrison Dam to Washburn, Right Alternative	S-A-1	0.922
Garrison Dam to Washburn, Left	S-2	0.921
Fort Berthold to Garrison Dam, Left	S-3	0.873
Fort Berthold to Garrison Dam, Right	S-4	0.868
Fort Berthold, Right	S-5	0.832
Fort Berthold, Left	S-6	0.828
Williston to Fort Berthold, Left	S-7	0.737
Williston to Fort Berthold, Right	S-8	0.702
State Line to Willison, Left	S-9	0.639
State Line to Willison, Right	S-10	0.622

Table 2. Subsurface sites summary.

Aquifer Name	*Rank*[2]	*Maximum Cell Score in Aquifer*
1-14 Fort Mandan	SS-1	0.894
1-12 Lake Nettie	SS-2	0.850
1-10 Renner Bay	SS-3	0.841
1-13 Knife River	SS-4	0.816
1-13 Knife River Alternative	SS-A-4	0.801
1- 2 Trenton	SS-5	0.741

[1] "S" in the "Rank" column stands for "Surface" and the following number is the site's rank. "A" stands for "Alternative", indicating the site is an alternative to the site with the same rank.

[2] "SS" in the "Rank" column stands for "Subsurface" and the following number is the site's rank. "A" stands for "Alternative", indicating the site is an alternative to the site with the same rank.

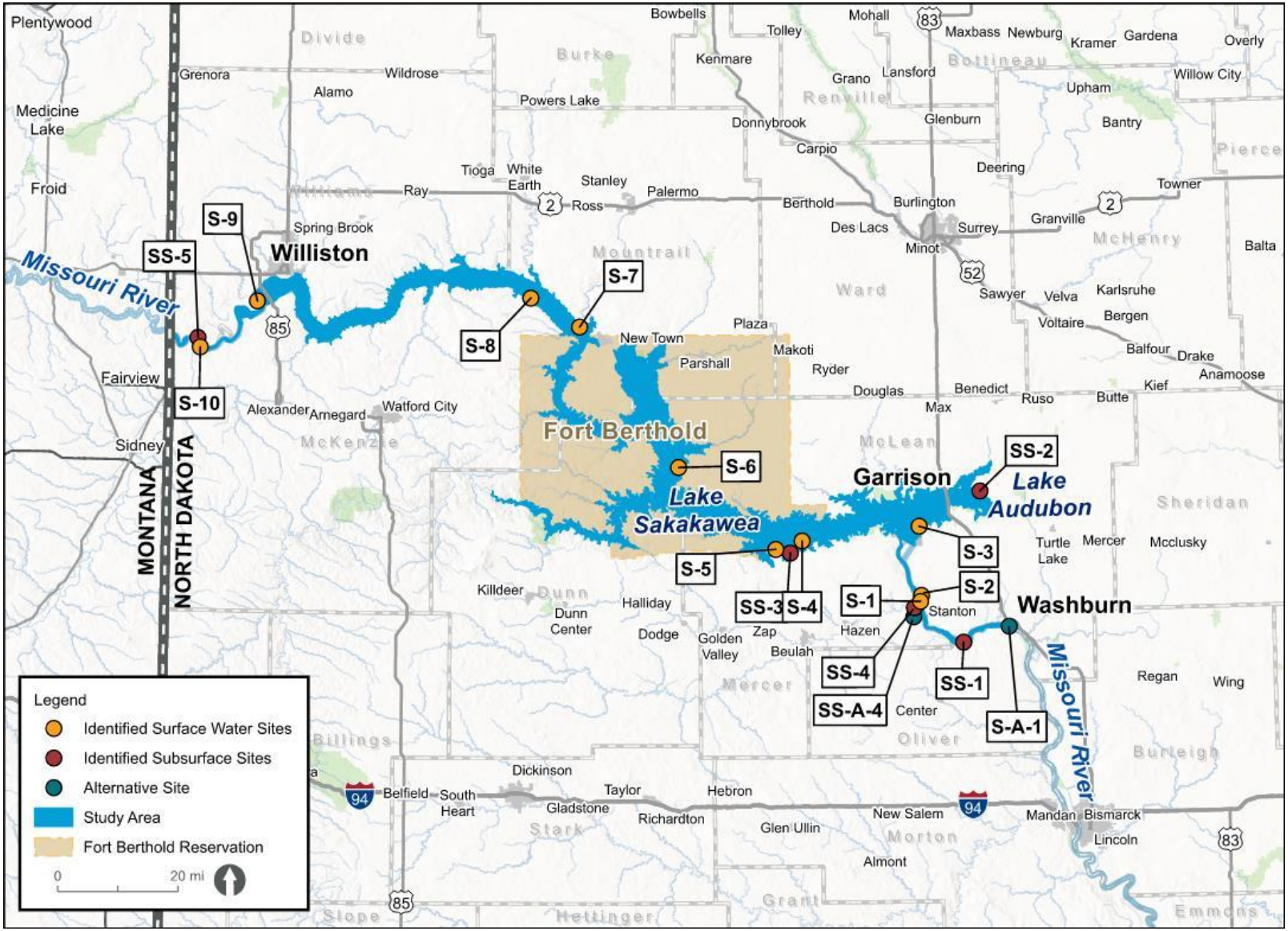


Figure 1. Surface water and subsurface sites overview.

2 Introduction

The North Dakota Department of Water Resources (DWR) hired HDR Engineering Inc. (HDR) and its subconsultants to evaluate industrial intake locations along the Missouri River corridor from the Montana state line to Washburn, ND. The primary purpose of the Missouri River Potential Intake Locations Investigation (Study) was to identify a minimum of five surface water intake locations and five subsurface locations that can support a capacity of at least 15,000 acre-feet per year (AF/yr), which is equivalent to approximately 9,300 gallons per minute (GPM), to serve industrial water users, with a secondary purpose or benefit of additional irrigation and municipal water supply.

2.1 Scope of Work

The Study was divided into four tasks, shown below in Figure 2.

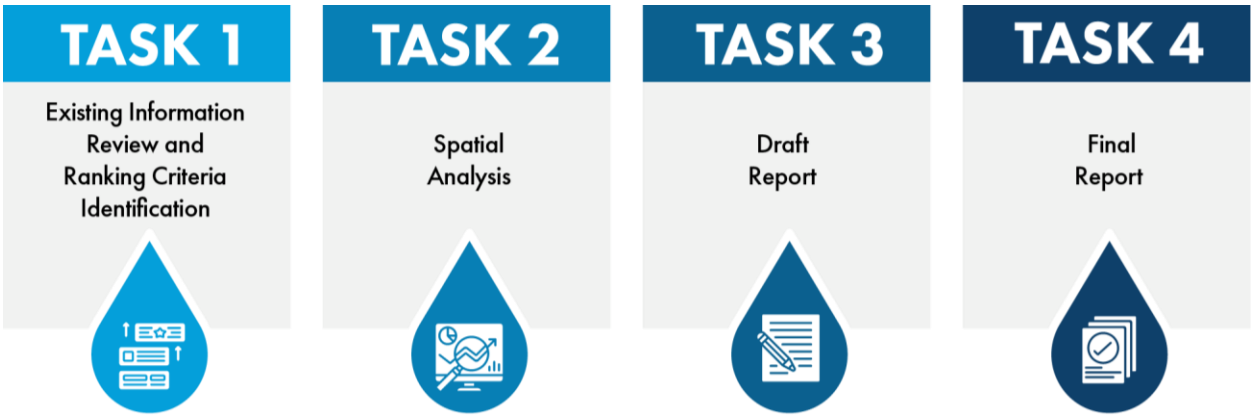


Figure 2. Study tasks.

HDR was tasked with researching, developing, ranking, and weighting the evaluation criteria to determine potential industrial intake locations. DWR provided the following 11 criteria to be included as part of the spatial analysis to identify at minimum five surface and five subsurface industrial intake sites, shown below in Table 3.

Table 3. Ranking and weighting criteria.

1	Water availability: water level fluctuations, hydrologic properties, and future upgrade limitations.	2	Expressed interest in nearby locations by industry.
3	Distance to infrastructure including rail, power, roads, and natural gas.	4	Water quality: turbidity, aquatic nuisance species, etc.
5	Distance to nearby towns and industrial facilities.	6	Impacts to areas of natural/cultural/historical significance: high biological diversity, cultural sites, etc.
7	Federal and state permitting requirements for intake construction and appropriation.	8	Distance from potential pollution sources.

9	Ease and cost of water delivery based on topography.
10	Impacts to recreation.
11	Likelihood of future intake sedimentation.

Task 1 involved reviewing existing information to develop criteria for determining appropriate intake locations. The criteria were then ranked and weighted to allow for scoring a site. Much of Task 1 was completed in parallel with Task 2.

Task 2 included completing a spatial analysis of the Study reach using the criteria, ranking, and weighting developed in Task 1. Higher scores indicate a location most likely to be more suitable for an intake site. During the scoping of the project, HDR identified the potential for this analysis to concentrate most of the intake locations into one small corridor of the Study reach. To address this, HDR proposed segmenting the Study area into sub-reaches, which was accepted by DWR. Surface water sub-reaches are described in Section 2.2.1 Surface Water Sites – Sub-Reaches and subsurface aquifers are described in Section 2.2.2 Subsurface Sites – Identified Aquifers.

Tasks 3 and 4 included drafting and finalizing this report, which documents methods, results, discussion, and sources of information used in the Study.

2.2 Study Area

The Study focused on the Missouri River corridor from the Montana state line to Washburn, ND, shown below in Figure 3. The total length of the Study area is 231.6 river miles. Of this total, 178 miles are located within Lake Sakakawea, the reservoir created by Garrison Dam. The remaining 53.6 miles in the Study area are river channel that stretches from the Montana state line to Lake Sakakawea and from Garrison Dam to Washburn, ND. The Study area includes the left and right banks of the identified reaches of the Missouri River and Lake Sakakawea, looking downstream.

Figure 3. Study area.

2.2.1 Surface Water Sites – Sub-Reaches

Due to its vast expanse, the Study area was split into ten sub-reaches, as illustrated in Figure 4. The sub-reaches include the left and right banks of each of the five Study reaches, looking downstream. The reaches were identified as part of HDR's scope, submitted as part of the proposal for this project, and refined during the Study phase. In the proposal, one set of sub-reaches spanned from the Montana state line to the Fort Berthold Reservation. The project team determined that there were considerable changes in surface water conditions that occurred between the Montana state line to the Fort Berthold Reservation, specifically, the fluctuating water surface elevation of Lake Sakakawea. The change in water surface elevation caused the section of the reach below Williston, ND to transition between riverine and lake conditions. For this reason, an additional set of sub-reaches was created below Williston, ND, to the Fort Berthold Reservation.

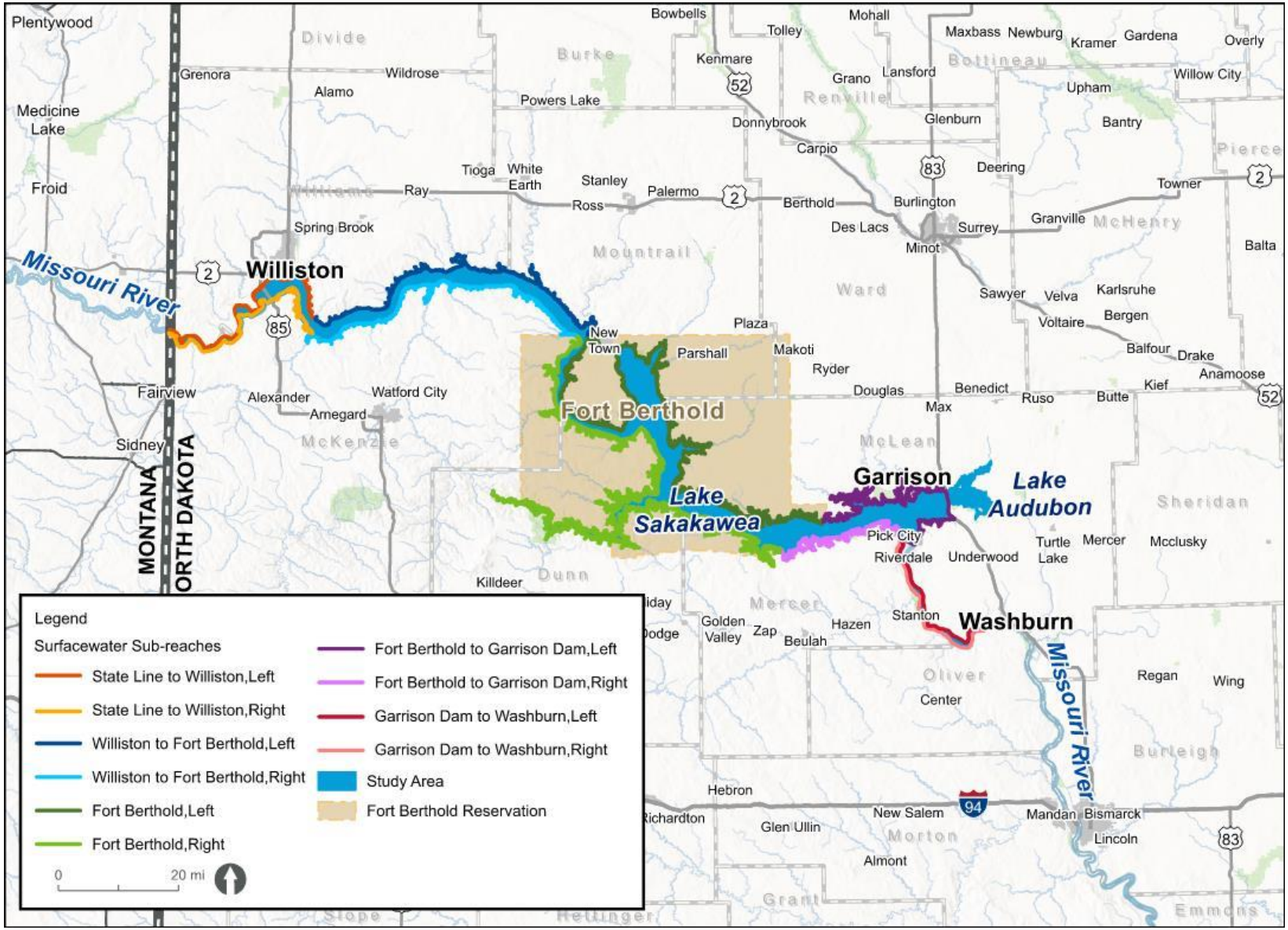
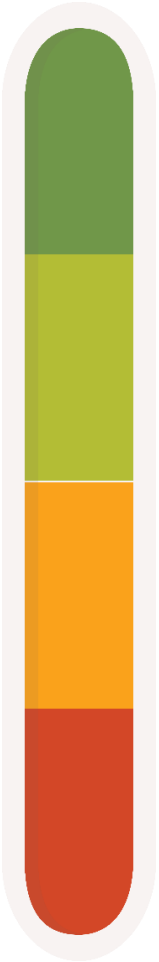


Figure 4. Surface water sub-reaches.

2.2.2 Subsurface Sites – Identified Aquifers

Well logs were reviewed within the areas upstream of Williston and downstream of Garrison Dam to determine the aquifer potential of the Missouri River alluvial valley. The desktop analysis did not consider existing water rights or prior drawdown impacts for identified aquifers. Both well logs within one mile of Lake Sakakawea and Lake Audubon as well as well logs along known preglacial channels were reviewed to identify potential sand and gravel aquifers adjacent to the lakes. The well logs with sufficient data were subjectively ranked into four categories based on the consultant team's review experience with siting and developing horizontal collector wells and high-capacity vertical wells in similar hydrogeologic settings. The four categories were:



Excellent

Appears capable of supporting more than 15,000 AF/yr from a single horizontal collector well or 4,000 AF/yr from a vertical well. In general, well logs indicate more than 100 feet of clean, saturated sand and gravel aquifer parallel to the anticipated elevation of Missouri River alluvium.

Good

Appears capable of supporting 15,000 AF/yr from a single horizontal collector well or 3,000 AF/yr from a vertical well. In general, well logs indicate more than 80 feet of clean, saturated sand and gravel aquifer parallel to the anticipated elevation of Missouri River alluvium.

Marginal

Appears capable of supporting 15,000 AF/yr with two horizontal collector wells or 1,500 AF/yr from a vertical well. In general, well logs indicate more than 50 feet of clean, saturated sand and gravel aquifer parallel to the anticipated elevation of Missouri River alluvium.

Would Not Support

There does not appear to be sufficient aquifer saturated thickness or aquifer quality to support a 7,500 AF/yr collector well, or saturated thickness and static water level of the aquifer does not appear to correspond with pre-lake alluvium elevation and lake water levels.

The ranked well data was color coded and posted back to a geographic information system (GIS) to identify aquifer areas (polygons) that appear capable of supporting the 15,000 AF/yr criteria. Driller logs and well logs were reviewed to further inform the delineation of the polygons. Delineated polygons contained mostly Excellent, Good, and Marginal data points, with some Would Not Support data points. This reflects the hydrogeologic variability in alluvial aquifers and the quality of the well log data.

Driller logs and well logs along the perimeter of the lakes, in areas without sufficient groundwater data, were reviewed to identify any additional glacial outwash aquifers capable of supporting the 15,000 AF/yr yield criteria. Most aquifer areas had suitable sand and gravel aquifers within 200 feet of ground surface. Those areas could be developed with either horizontal collector wells or vertical wells. Aquifer areas with depth to suitable sand and gravel greater than 200 feet can only support the development of vertical wells, as the feasibility of constructing horizontal collector well caissons is generally restricted to depths of 200 feet or less.

Aquifer polygons were identified based on areas where the 15,000 AF/yr capacity requirement could be met. These polygons were separated into two categories. Primary aquifers contain locations that should meet or exceed capacity requirements with the installation of one or two horizontal collector wells. Secondary aquifers contain locations that could meet capacity requirements but did not have sufficient data coverage to verify this potential. These sites require additional field investigation to further characterize the aquifer. Figure 5 illustrates the identified 14 primary aquifers and four secondary aquifers located throughout the Study area.

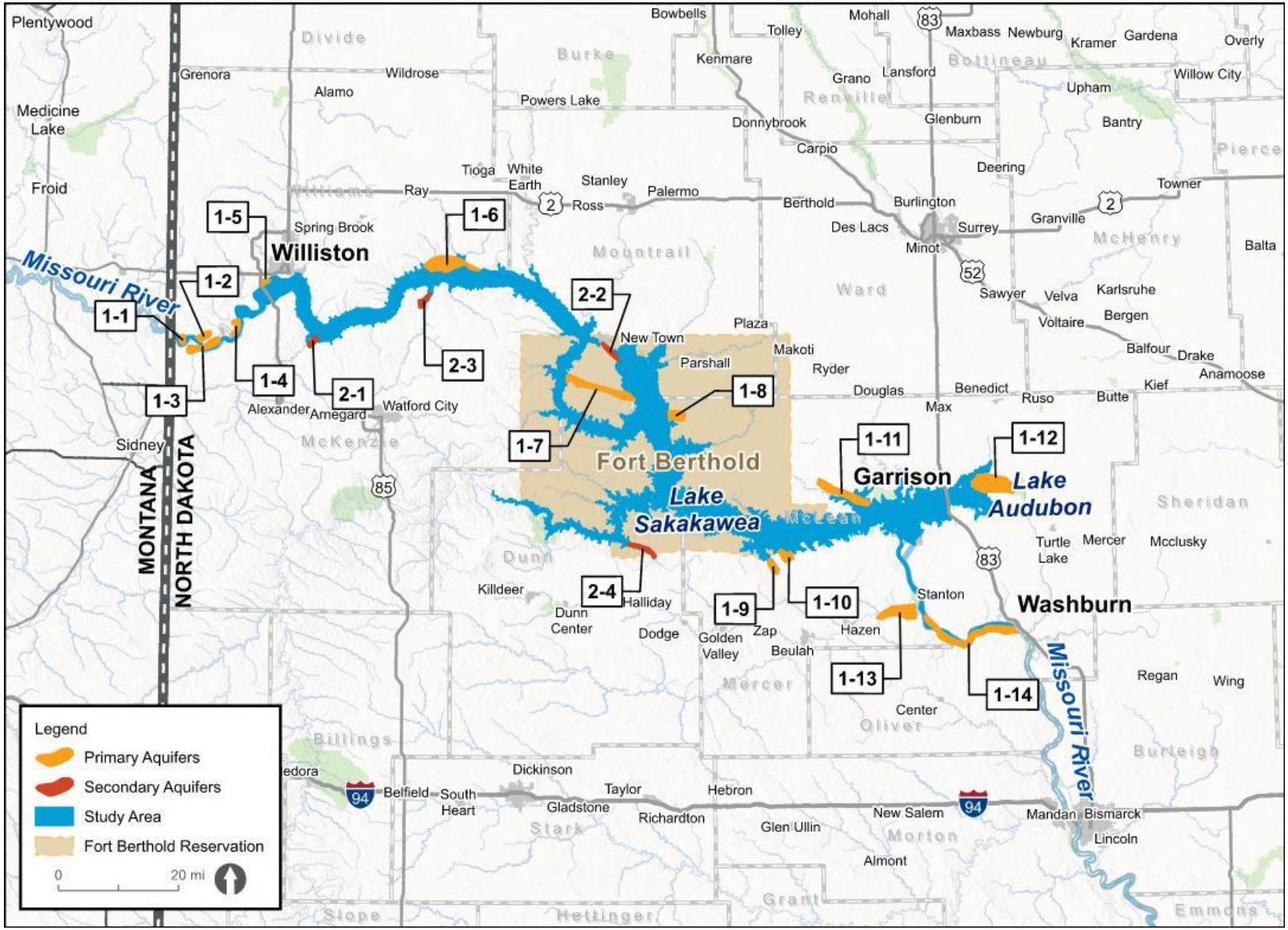


Figure 5. Potentially suitable aquifers identified throughout the project area.

3 Existing Information Review

Many different data sources were needed to determine the feasibility of intake locations. HDR and its subconsultants reviewed surface water studies, groundwater studies, geological information, geomorphology studies, environmental information, permit requirements, and information from existing regional water systems.

3.1 Surface Water Information Review

3.1.1 Riverine Reaches

Two different riverine reaches exist within the Study area, one upstream and one downstream of Lake Sakakawea.

3.1.1.1 Montana State Line to Lake Sakakawea

The Missouri River within the Study area is affected by the operation of Fort Peck and Garrison Dams, both of which are operated by the United States Army Corps of Engineers (USACE). Fort Peck and Garrison Dams are operated by following the Missouri River Mainstem Reservoir System Master Water Control Manual[1]. The reach between the Montana state line and the headwaters of Lake Sakakawea is significantly influenced by the operations of Fort Peck, the unregulated inflows from the Yellowstone River, and the backwater effects of Lake Sakakawea. The reach from the Montana state line to the headwaters of Lake Sakakawea is a consistent water source due to the contributions of the Yellowstone River and the outflows from Fort Peck Dam to meet its authorized purposes, which are listed in the Master Water Control Manual. However, it should also be noted that this reach experiences reduced water velocity as it transitions into Lake Sakakawea, which increases sediment deposition within the reach.

The only stream gage within the Montana state line to Lake Sakakawea reach is the United States Geological Survey (USGS) Missouri River near Williston, ND (USGS gage 06330000)[2]. The gage has been in operation since 1928 but has an irregular record due to the construction of Garrison Dam and the backwater of its reservoir changing measurement protocols. Stage data has been collected throughout the gage's life, but discharge measurements were only collected from 1928 to 1965. Consistent stage data is only available for this site from 1966 to present. Discharge measurements were discontinued due to backwater effects from Lake Sakakawea reaching full pool in 1966. Stage at this location is synonymous with depth. Mean monthly stage height, provided in Table 4, was sourced from the USGS and is included in the stream gage's summary of available information from 1966 to 2024. This data demonstrates there is water availability within the Montana State Line to Lake Sakakawea reach.

Table 4. Mean monthly stage at USGS gage 06330000.

Month	Mean Monthly Stage (Ft)
January	17.5
February	18.1
March	18.0
April	15.9
May	17.0
June	19.8
July	18.5
August	16.5
September	15.6
October	15.4
November	15.5
December	17.1

3.1.1.2 Garrison Dam to Washburn, ND

The reach between Garrison Dam and the City of Washburn is heavily influenced by the operations of Garrison Dam. It is impacted to a lesser extent by inflows from the Knife River, which outlets into the Missouri River approximately 19 miles upstream of Washburn, ND. The nearest gage downstream of Garrison Dam along the Missouri River with discharge data is the USGS Missouri River at Bismarck, ND (USGS gage 06342500)[3]. The mean monthly discharge at this location is estimated at approximately 22,000 cfs. The majority of this flow is outflow from Garrison Dam, with the Knife River at Hazen, ND mean monthly discharge only contributing approximately 516 cfs (USGS gage 06340500)[4]. The reach is a reliable water source due to the outflows from Garrison Dam to meet its authorized purposes, which are listed in the Master Water Control Manual.

3.1.2 Lake Sakakawea

Garrison Dam impounds Lake Sakakawea, which inundates approximately 307,000 acres and creates 1,340 miles of shoreline within North Dakota[5]. Garrison Dam was constructed to a local project datum (LPD) that is nearly equivalent to the National Geodetic Vertical Datum of 1929 (NGVD29). The LPD has a conversion factor to NGVD29 of -0.095 feet. Garrison Dam has a maximum operating pool elevation of 1854.0 feet (LPD) and a permanent pool elevation of 1775.0 feet (LPD)[6]. Table 5 provides the storage designations for Garrison Dam. Based on previous data available on Lake Sakakawea, the lowest monthly lake level was recorded in 2005 at 1805.8 feet mean sea level (msl)[6]. USACE indicates that "mean sea level" is roughly equivalent to NGVD29. During this time, the USACE modeled the effect of what another year of historic droughts could have on lake levels, estimating a minimum elevation of 1800.0 feet msl as described in its 2004-2005 Annual Operating Plan (AOP)[7].

Table 5. Garrison Dam storage designation.

Storage Designation (Zone)	Elevation (ft LPD)		Storage (ac-ft)
	From	To	
Exclusive Flood Control	1850.0	1854.0	1,495,000
Annual Flood Control and Multiple Use	1837.5	1850.0	4,211,000
Carryover Multiple Use	1775.0	1837.5	12,951,000
Permanent	1673.0	1775.0	4,794,000
Total Storage			**23,451,000**

Figure 6 provides the average operating elevation, actual elevations, and modeled elevations from the 2004-2005 AOP. Based on the availability of water and the water surface elevation fluctuations on this reservoir, the most conservative placement of an industrial intake would be at the permanent pool elevation at or below elevation 1775.0 feet (LPD), which was included as a surface water criterion described in Section 5.1.1.1 Proximity to Critical Water Elevations.

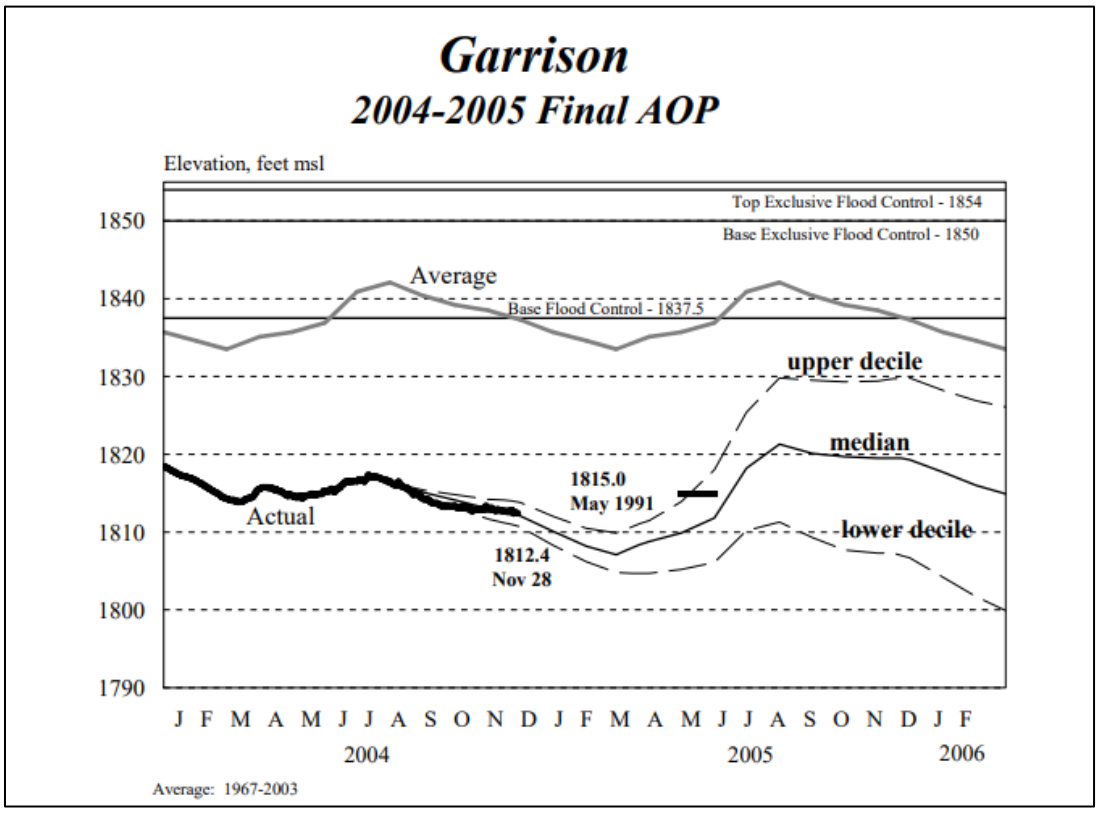


Figure 6. Projected Garrison elevations from 2004-2005 AOP.

3.2 Subsurface Information Review

Bank filtration systems include several technologies for preliminary treatment of surface water where surface water is indirectly drawn from rivers or lakes using vertical wells, infiltration galleries, or horizontal collector wells constructed on adjacent land. Bank filtration systems take advantage of the natural filtration and chemical contaminant attenuation processes that occur as water passes through bed sediments and flows through the underlying aquifer while mixing with groundwater.

Aquifers (groundwater sources) within the Study area were identified by HDR and its subconsultants by analyzing available data sources. These sources included hydrogeologic publications and maps prepared by or in cooperation with the North Dakota Geological Survey (NDGS) and included county groundwater studies, NDGS Guides to the Geology of Southwestern and Northwestern North Dakota, and a preliminary glacial map of North Dakota. The list of geology and groundwater studies are listed below in Table 6.

Table 6. Geology and groundwater studies.

North Dakota Geological Survey	Bulletin 25 Dunn County, ND
	Bulletin 48 Williams County, ND
	Bulletin 55 Mountrail County, ND
	Bulletin 56 Mercer/Oliver Counties, ND
	Bulletin 60 McLean County, ND
	Bulletin 80 McKenzie County, ND
	Educational Series 8 Northwestern, ND
	Educational Series 9 Southwestern, ND
USGS Misc Geol Inv Map I-331	Glacial Map North Dakota
USGS Open-File Report 77-273	Dunn County, ND
ND Western Groundwater Monitoring Program	Charbonneau Aquifer
	Hofflund Aquifer
	Little Muddy Aquifer
	Tobacco Garden Aquifer
	Trenton Aquifer

The purpose of this review was to determine areas where alluvial channels, preglacial streams, and glacial outwash deposits exist adjacent to the Missouri River, Lake Sakakawea, and Lake Audubon. Following the review, well data available on the DWR MapService was reviewed to determine the quality of the aquifer materials and develop polygons of aquifer areas that are expected to be capable of supporting the 15,000 AF/yr capacity requirement. A total of 18 potentially suitable aquifer areas were identified across the Study area.

3.3 Geological Characterization Review

A series of geologic characterizations were put together by the project team for the purpose of better understanding the geology of the Study area. One of HDR's subconsultants, Terracon, developed the following characterizations of the Study area based on information published by the North Dakota Geological Survey. The geological characterization of each sub-reach provides broad insights into anticipated conditions but was not used directly for site identification since localized conditions can vary. Site-specific geotechnical investigation is necessary to evaluate factors affecting detailed design and construction. The following characterizations are included for informational purposes and may help inform future analyses or planning phases.

3.3.1 State Line to Williston

The geology within this section of the project area includes the Sentinel Butte formation overlain by the Bullion Creek formation. The Sentinel Butte formation consists of alternating beds of sandstone, siltstone, mudstone, claystone, lignite, baked clay, and minor layers of limestone. Within the project area, this formation weathers to a "badlands" topography. The formation can be characterized as the product of deltaic, lacustrine, and riverine environments of deposition. The Bullion Creek formation is scattered along the eastern part of the project area. It consists of yellow-brown silt, sand, clay, sandstone, and lignite as well as river, lake, and swamp sediment. Windblown sand also occurs and is scattered on the south portion of the project area. Windblown sand consists of well-sorted, medium sand with obscure bedding.

3.3.2 Williston to Fort Berthold

The geology within this section of the project area includes the Bullion Creek formation, which is overlain by glacial sediment that drapes over pre-existing topography. River sediment also overlays glacial sediment on the northwestern portion of the project area. The Bullion Creek formation consists of yellow-brown silt, sand, clay, sandstone, and lignite as well as river, lake, and swamp sediment. The glacial sediment slightly modifies the non-glacial topography. The river sediment consists of dark, obscurely bedded clay and silt, along with generally overlaying cross-bedded sand.

3.3.3 Fort Berthold

The geology within this section of the project area includes the Sentinel Butte formation overlain by collapsed river sediment, glacial sediment, and river sediment scattered on the northern portion of the project area. The Sentinel Butte formation consists of alternating beds of sandstone, siltstone, mudstone, claystone, lignite, baked clay, and minor layers of limestone. Within the project area, this formation weathers to a "badlands" topography. The collapsed river sediment consists of faulted and contorted supraglacial sediment with hummocky topography. The glacial sediment slightly modifies the non-glacial topography. The river sediment consists of dark, obscurely bedded clay and silt, along with generally overlaying cross-bedded sand.

3.3.4 Fort Berthold to Garrison Dam

The geology within this section of the project area includes the Sentinel Butte formation, which is overlain by glacial sediment that drapes over pre-existing topography throughout the northern portion of the project area, windblown sediment scattered in the southern portion of the project area, collapsed glacial sediment in the eastern portion of the project area, and collapsed/draped transition sediment in the eastern portion of the project area. The Sentinel Butte formation consists of alternating beds of sandstone, siltstone, mudstone, claystone, lignite, baked clay, and minor layers of limestone. Within the project area, this formation weathers to a "badlands" topography. The collapsed river sediment consists of faulted and contorted supraglacial sediment with hummocky topography. The windblown sand is well-sorted, medium sand with obscure bedding. The glacial sediment drapes over and only slightly modifies the non-glacial topography. Collapsed glacial sediment is supraglacial sediment with hummocky topography. Collapsed/draped transition sediment consists of collapsed glacial sediment with hummocky topography draped over and partly obliterating the topography existing before the last glacial advance.

3.3.5 Garrison Dam to Washburn

The geology within this section of the project area includes the Sentinel Butte formation overlain by windblown sand and silt, uncollapsed river sediment, and glacial sediment that drapes over the pre-existing topography and is scattered throughout the project area. The Sentinel Butte formation consists of alternating beds of sandstone, siltstone, mudstone, claystone, lignite, baked clay, and minor layers of limestone. Within the project area, this formation weathers to a "badlands" topography. Windblown sand consists of well-sorted, medium sand with obscure bedding. Windblown silt consists of obscurely bedded paleosols as thick as six meters. Uncollapsed river sediment consists of flat-bedded sediment of gently sloping plains and terraces, commonly with braided-channel scars. The glacial sediment drapes over and only slightly modifies the non-glacial topography.

3.3.6 Glacial Till

Glacial till is an important factor to consider when siting and constructing a surface water intake using trenchless installation methods. Risk of encountering glacial till when drilling is based on the elevation and alignment of the drill. Glacial till (deposits of rocks, sand, and gravel) can be encountered at varying elevations within most geographic regions within the Study area; therefore, identifying the risk of encountering it is difficult at the scale of this Study. A geotechnical investigation of the proposed drilling or tunneling path would need to be completed to fully understand the likelihood of encountering glacial till and the impact to the construction means and methods. A geotechnical program specific to design location and construction methodology being considered is recommended during future advancement of any intake site identification to define the risk of potential drilling fluid loss, unstable borehole conditions, and tunneling path obstructions associated with the presence of glacial till.

3.3.7 Landslide Potential

The NDGS developed the landslide map where landslides were identified from hillshade maps created by the latest Light Detection and Ranging Data (LiDAR) and aerial photography ranging from 2016 to 2023. Based on the map, the upper reaches of the Study area are more susceptible to landslides, with the highest density of landslides falling on the right overbank of Lake Sakakawea between the Little Missouri confluence and Four Bears Village. Figure 7 illustrates the active landslides digitized by NDGS[8]. It was in this same stretch of shoreline in 2019 where the Fort Berthold Rural Water System experienced a significant landslide that impacted the operations of the Mandaree Intake for the West Segment of the Fort Berthold Reservation. An extensive geotechnical site investigation was completed that resulted in an expensive bank stabilization project needed to protect the existing infrastructure.

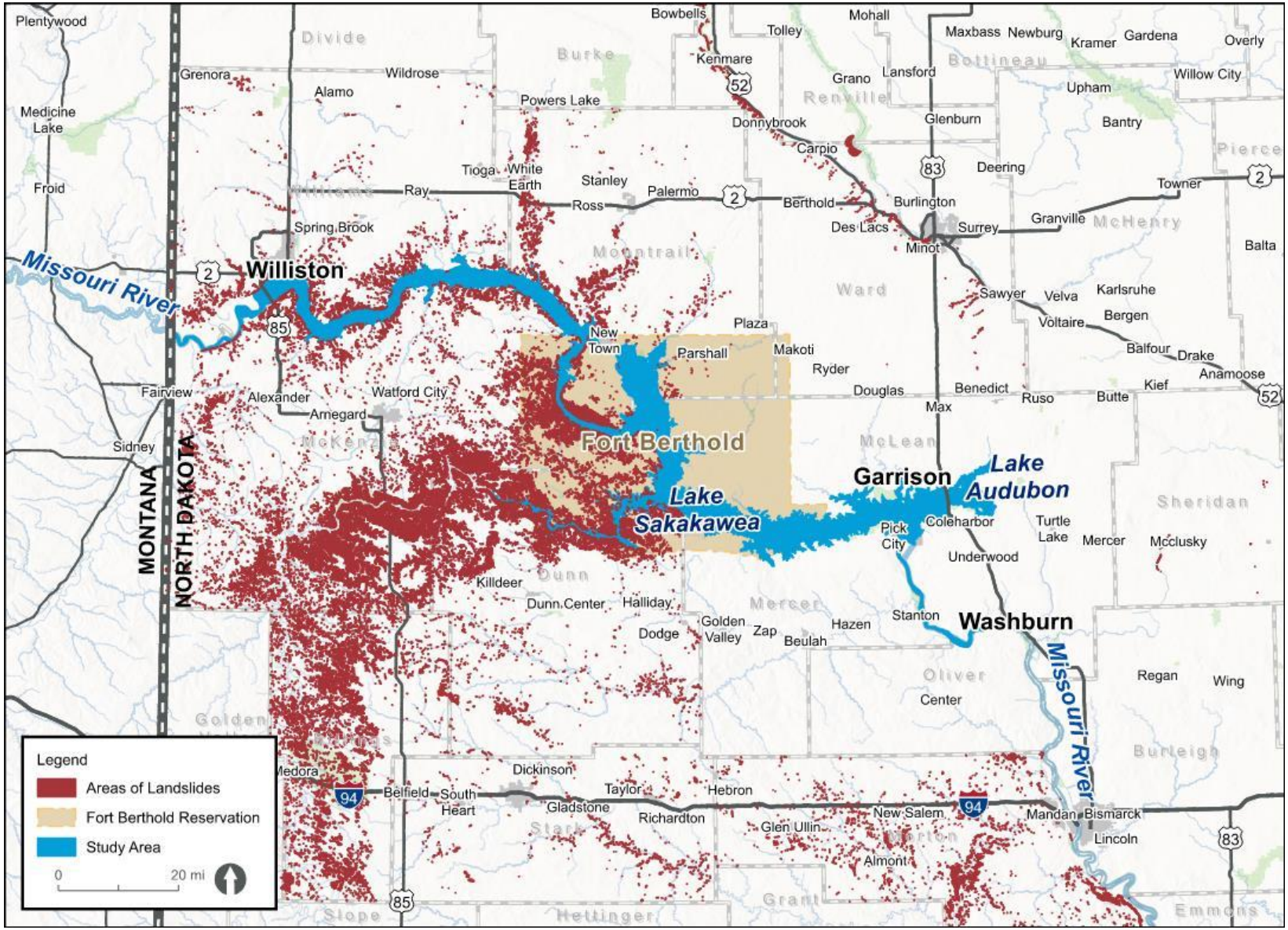


Figure 7. Map of active landslides based on NDGS data.

3.4 Geomorphology Information Review

Inter-dam geomorphology is present throughout the Study area as it falls between the Fort Peck, Garrison, and Oahe Dams of the Missouri River System. Figure 8, developed by the USGS, illustrates the five zones of idealized inter-dam geomorphology, which the USGS defines as follows:

- Dam Proximal – Removal of islands within the channel. This section is highly erosional.
- Attenuating – Sandbar islands remain, but island movement is steady. In this section, erosion and deposition are near equilibrium.
- River Dominated Transitional – Creation of large islands on the inside of bends from sediment drop off and backwater effects. This section is more depositional in nature.
- Reservoir Dominated Transitional – Inundated scroll bars with tree die-off due to changes in reservoir level. Contains submerged delta front created by low reservoir flows. This section is highly depositional in nature.
- Reservoir – This section has minor deposition.

Figure 8 mentions that there is creation of large islands on the outside of bends in the River Dominated Transitional zone. This differs from the common understanding that islands form on the inside of river bends due to lower velocities there compared to on outside bends. In this Study, the common understanding is used. The reach between the Montana state line to the City of Williston can best be described as River Dominated Transitional and the reach between the City of Williston and Lake Sakakawea can be described as a Reservoir Dominated Transitional. Both zones are highly depositional in nature, which causes increased sedimentation issues for intakes within these reaches. The Fort Berthold and Fort Berthold to Garrison Dam reaches are defined by the reservoir. These reaches are expected to have minor deposition. The Garrison Dam to Washburn reach can best be described as dam proximal or attenuating and is erosional in nature. Sedimentation is not expected to be an issue in this reach since erosional reaches generally have decreased sedimentation and, with appropriate design measures, an intake can be armored against erosion. These conditions make erosional reaches ideal for construction of a surface water intake.

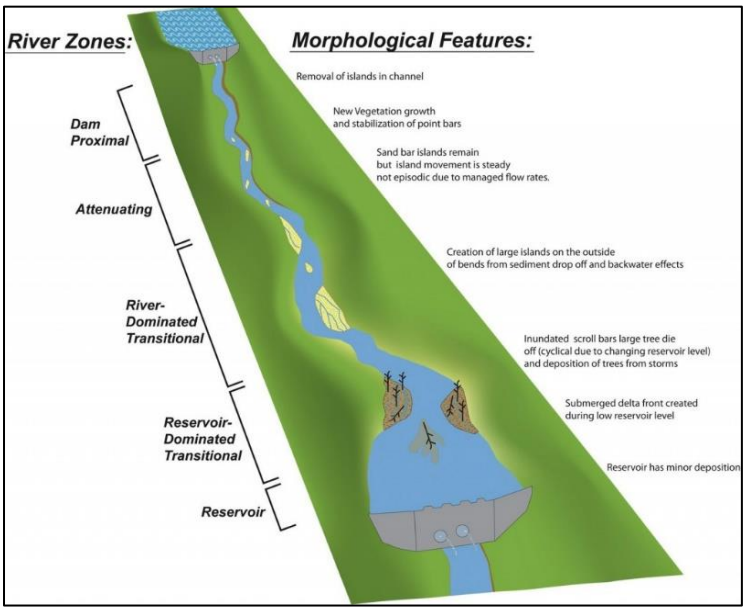


Figure 8. Inter-dam geomorphology.

Several geomorphology studies have been completed on the Missouri River downstream of Garrison Dam to understand the effects of the 2011 flood on river stability and sediment transport. In 2014, the USGS investigated the rate of change of the channel bottom (thalweg) downstream of Garrison Dam since the placement of the dam in the early-1950s and found that significant changes to the thalweg within the first 30 miles of the dam have not occurred since the mid-1970s. Figure 9 illustrates the findings presented by the USGS on channel thalweg changes on the Missouri River in the Geomorphic Change on the Missouri River During the Flood of 2011 report[9]. Additionally, the report found that the Missouri River downstream of Garrison Dam is located within a zone of the river that is erosional in nature, having little to no deposition.

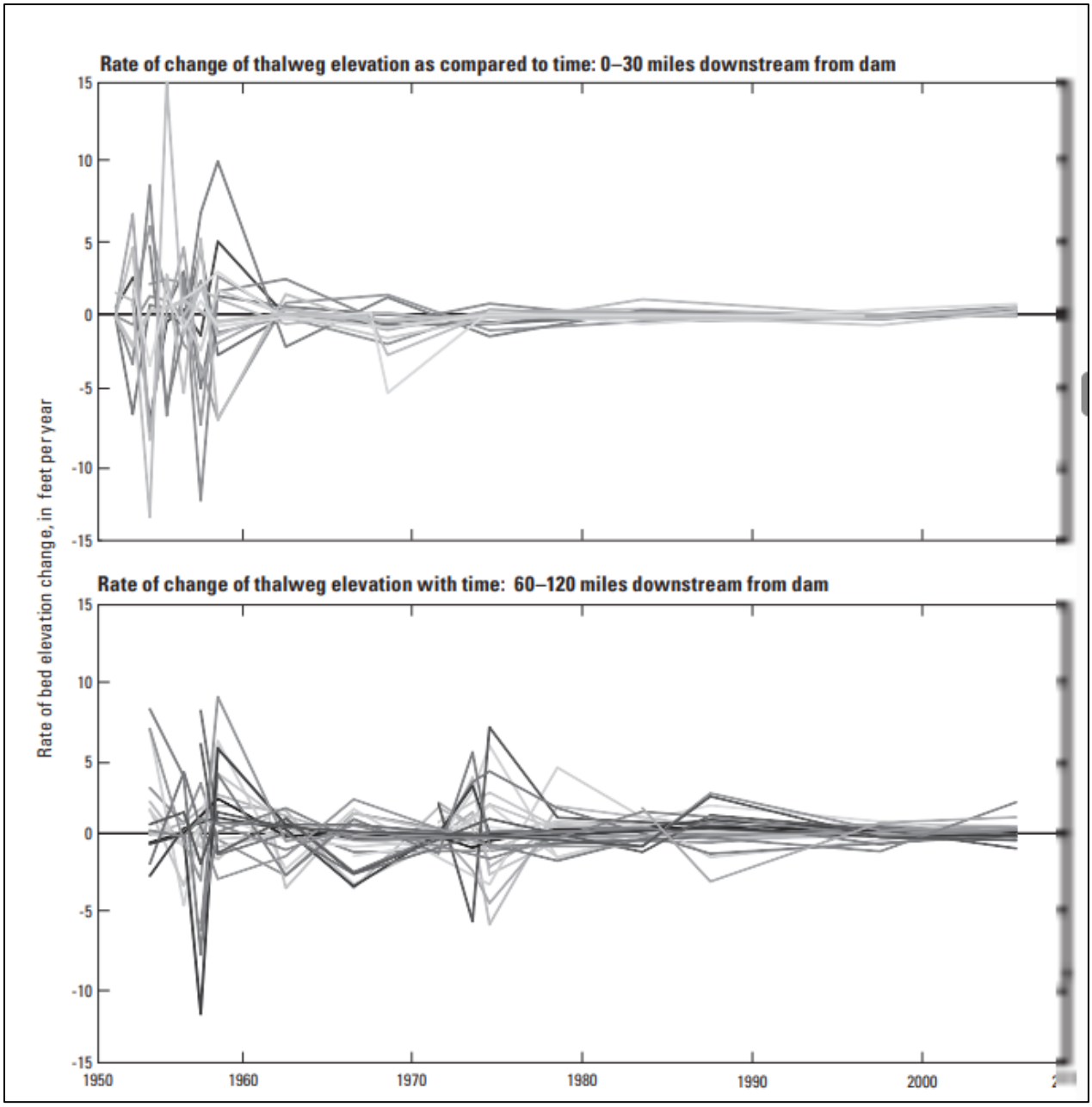


Figure 9. Thalweg elevation rate of change below Garrison Dam.

3.5 Environmental Considerations Review

The Environmental Protection Agency (EPA) and the United States Fish and Wildlife Service (USFWS) are the primary federal agencies that have recommendations regarding intake design or requirements aimed at avoiding and minimizing adverse impacts to aquatic species that occupy the Missouri River. The EPA requires owners or operators of new cooling water intakes to comply with one of the following Best Technology Available (BTA) Standards for impingement mortality and entrainment, explained in detail in 40 CFR 125.94(c). The USFWS also has recommendations for intakes on the Missouri River regarding federally listed threatened and endangered (T&E) species. The USFWS recommends that floating intakes should be installed in the Missouri River upstream of river mile 1519, located in the Williston to Fort Berthold reach, to minimize the potential impacts to endangered larval pallid sturgeon (*Scaphirhynchus albus*). The recommendation for this reach is that floating intakes should be installed over a minimum depth of 20 feet of water when possible. If the 20-foot depth is not attainable, the intake should be located over the deepest water available at the start of the irrigation season. If the intake is in a water depth of less than six feet, the intake should be moved, or the maximum intake velocity should be limited to 0.25 fps. The EPA, USFWS, and North Dakota Game and Fish Department (NDGFD) have also issued recommendations for intakes on Lake Sakakawea regarding pallid sturgeon. These recommendations can be found in Appendix A – Environmental Considerations and Permit Matrix.

In addition to these federal protections and recommendations, NDGFD recommends that during construction, if the quantity of any fill or dredged material being moved exceeds 25 cubic yards, water activities be avoided between April 15 and June 1 on the Missouri River and Lake Sakakawea and June 1 to July 1 in Missouri River marinas to protect spawning pallid sturgeon.

3.6 Permitting Requirements Review

Depending on the type, location, and intended use of water intakes along the Missouri River, there are numerous permits required from the federal, state, and local level. Examples of permits and the permitting agency are noted below in Table 7.

Table 7. Potential required permits and permit agencies.

Sovereign Lands Permit	North Dakota Department of Water Resources	**NPDES Permit**	Environmental Protection Agency
Conditional Water Permit	North Dakota Department of Water Resources	**Section 7 Consultation**	United States Fish and Wildlife Service
Section 408 Authorization	United States Army Corps of Engineers	**Floodway Authorization**	Local Zoning Authority
Section 404 Permit	United States Army Corps of Engineers	**Section 55-10**	North Dakota State Historic Preservation Office
Section 10 Permit	United States Army Corps of Engineers	**Section 106**	Advisory Council on Historic Preservation

Entrainment Permit	Environmental Protection Agency - North Dakota Department of Environmental Quality	**Other Permits related to Tribal lands**	Bureau of Indian Affairs

Information on each individual permit which may be required, the respective regulatory authority, application timeline, and contact information is detailed in Appendix A – Environmental Considerations and Permit Matrix.

3.7 Regional Water Systems Review

Several engineers and regional water managers were contacted during the Study. The goal of working with these regional water managers and engineers was to identify issues existing intakes experience within the Study area and determine if these issues could be incorporated into the models.

The Director of the Western Area Water Supply Authority (WAWSA) was contacted to determine any issues experienced during operation of the WAWSA intake at Williston, ND. The Director indicated that sedimentation and high turbidity were the primary issues that occurred at the WAWSA intake.

Moore Engineering was contacted due to their experience with intakes for the cities of Riverdale, Williston, and Garrison, as well as their experience with the Falkirk/Great River Energy industrial intake. Issues that were experienced by these intakes include sand sedimentation at the Williston/WAWSA intake and bank erosion/sloughing due to wave action at the Garrison Intake.

A call was held with Bartlett and West to discuss their experience with intakes within the Fort Berthold reservation, design of industrial intakes, and their experience designing the Southwest Pipeline Project (SWPP) intake. Issues they had experienced working with intakes in the Study reach included sedimentation issues in the upper reach of the Study, significant bank stabilization issues at the Mandaree Intake site, and issues with identifying power and infrastructure in the Mandaree region of the Study area.

Additionally, Bartlett and West discussed the need for increased coordination and collaboration with the Mandan, Hidatsa, and Arikara Nation and the Bureau of Indian Affairs for any sites identified on the Fort Berthold Reservation.

4 Spatial Analysis

Identification of industrial intake sites along the Missouri River from the Montana state line to Washburn, ND, was the focus of this Study. Developing a spatial analysis model using documented methodology to help identify these locations was the key for replicability and allowed sites to be identified based on developed criteria.

Two separate spatial models were created as part of this Study, one for surface water intake sites and the other for subsurface intake sites. Each model is unique, with some shared criteria and similar ranking/weighting, but each uses a different grid system. Several methods to develop the spatial model were discussed, but ultimately, ModelBuilder within ArcGIS Pro version 3.1.2 (ArcPro) was selected to develop the models.

4.1 Geospatial Grids

4.1.1 Surface Water Grid

The spatial analysis of surface water intake sites is based on 1,000 feet by 2,000 feet grid cells created along the shoreline throughout the project corridor. The original proposal for the grid was to use 1,000 feet by 1,000 feet cells centered on the shoreline, but the analysis for slope constructability in the water availability criterion required extension further into the waterbody and land portions of the grid cell. The larger grid cells allowed for the slope analysis to be clipped along the shoreline while maintaining enough Digital Elevation Model (DEM) data on the landward side to complete the slope constructability analysis.

The spatial grid was created using the ArcPro Strip Map Index Features tool. This tool generates grid cells of specified size (1,000 feet by 2,000 feet) along an input feature (sub-reach segment lines). Sub-reach information was populated in the attribute table for the index features including the sub-reach segment name. A unique ID field, "Name", was created and populated to identify each individual grid cell per sub-reach. The "Name" field structure was developed based on the sub-reach segment, the number of grid cells in the sub-reach, and the side of the river the cell is located on, moving downstream. For example, WG0006R is located in the Garrison Dam to Washburn sub-reach, on the right side of the river, and is the sixth grid along that sub-reach. Table 8 provides the number of cells in each sub-reach. Figure 10 illustrates the generated grid downstream of Garrison Dam. A total of 7,008 grid cells were generated within the project corridor.

Table 8. Grid cells per sub-reach for geospatial surface water analysis.

SUB-REACHES	NUMBER OF GRID CELLS
State Line to Williston, Left	260
State Line to Williston, Right	261
Williston to Fort Berthold, Left	589
Williston to Fort Berthold, Right	536
Fort Berthold, Left	1,457
Fort Berthold, Right	2,387
Fort Berthold to Garrison Dam, Left	709
Fort Berthold to Garrison Dam, Right	438
Garrison Dam to Washburn, Left	182
Garrison Dam to Washburn, Right	189
Total	**7,008**

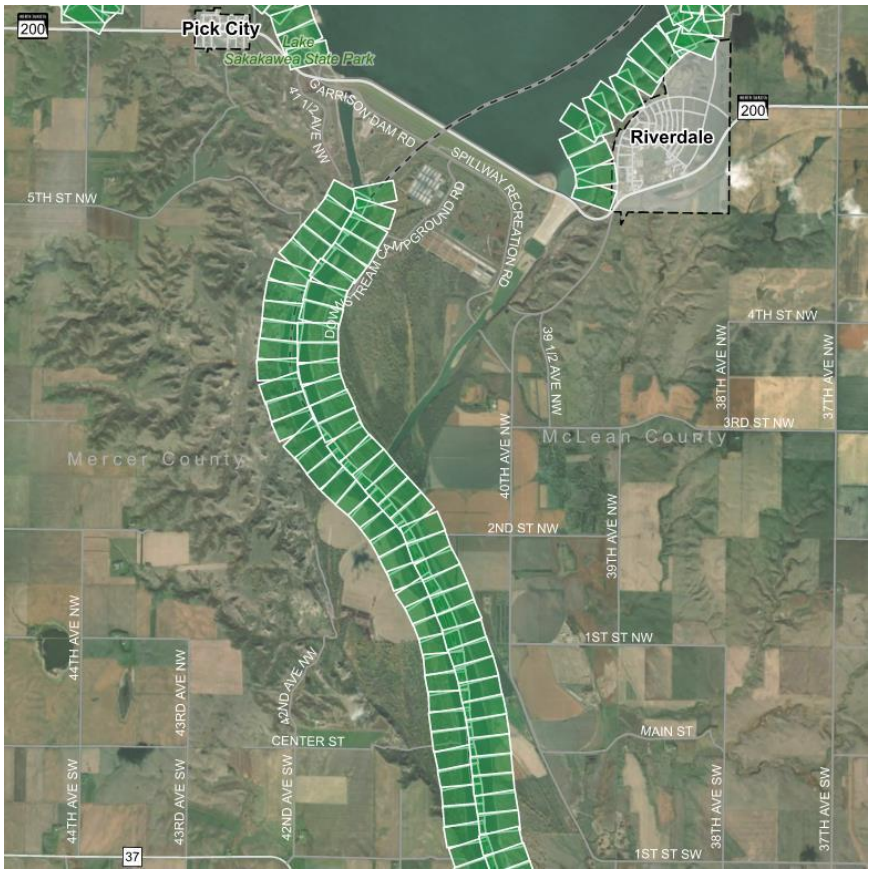


Figure 10. Surface water geospatial analysis grid illustration.

4.1.2 Subsurface Grid

Subsurface grids were developed within the 18 suitable primary and secondary aquifer locations identified as part of this Study. The average footprint required for a horizontal collector well is 500 feet by 500 feet. For this reason, 500 feet by 500 feet cells were developed within the aquifer polygons using ArcPro's Grid Index Features Tool. This tool generates grid cells of a specified size (500 feet by 500 feet) over an intersecting input feature (aquifer polygons). Aquifer area information was populated in the attribute table for the index features, including the primary aquifer location number and secondary aquifer location number. A unique ID field, "Name", was created and populated to identify each individual grid cell per aquifer area. The "Name" field structure was developed based on the primary aquifer number assigned, the number of grids in the aquifer, and the side of the river the cell is located on, moving downstream. For example, 1.14.0006R is located in aquifer 1-14, on the right side of the river, and is the sixth grid intersecting the aquifer area. A total of 6,955 cells were created.

Based on experience from HDR's design team, the maximum distance that a horizontal collector well should be placed from the shore of a water body and still achieve a high rate of induced infiltration is 5,000 feet. For this reason, a 5,000-foot buffer was created around the shoreline sub-reaches in the identified aquifer locations. All grid cells that did not intersect with the 5,000-foot buffer were removed from further analysis due to the lower likelihood of achieving the induced infiltration rate required to provide an adequate percentage of surface water. The remaining cells within 5,000 feet of the shoreline sub-reaches were used for the subsurface spatial analysis. The shoreline polygon uses the 1860-foot elevation contour to map the normal shoreline around Lake Sakakawea and the low water contour developed as part of the Study for the Missouri River. For this Study, the low water contour is defined as the approximate river's edge during low water years. The project team digitized a layer that represents the low water contour of the river using National Agricultural Imagery Program (NAIP) aerial imagery collected during various low water years. Table 9 provides the number of grid cells in each aquifer location. Figure 11 illustrates the grid cells that were identified within 5,000 feet of the shoreline of the river.

Table 9. Grid cells per aquifer for geospatial subsurface analysis.

Aquifer	*NUMBER OF GRID CELLS*
1-1 Trenton	132
1-2 Trenton	140
1-3 Trenton	465
1-4 Trenton	292
1-5 Yellowstone Buried	49
1-6 Hofflund	1,033
1-7 White Shield	499
1-8 White Shield	268
1-9 Antelope	223
1-10 Renner Bay	239
1-11 White Shield	489
1-12 Lake Nettie	743
1-13 Knife River	49
1-14 Fort Mandan	1,461
2-1 Charbonneau	231
2-2 New Town	240
2-3 Tobacco Garden	215
2-4 Hans Creek	187
Total	**6,955**

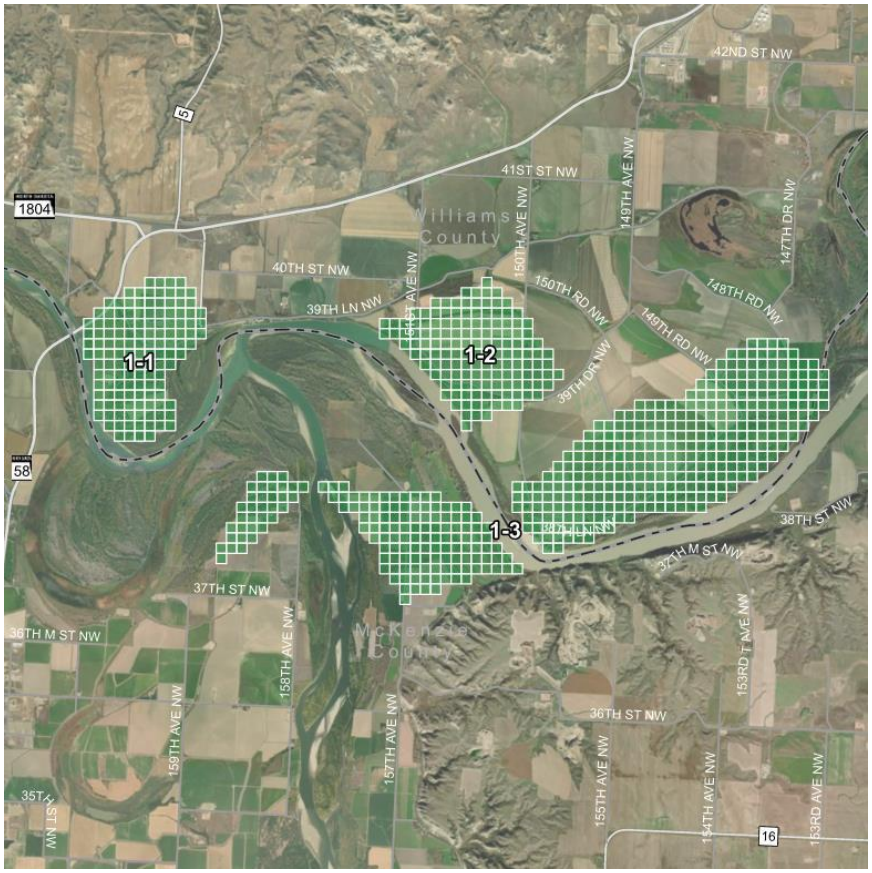


Figure 11. Subsurface geospatial analysis grid illustration.

4.1.2.1 1-1 to 1-4 Trenton

The Trenton aquifer consists of alluvial and preglacial channel deposits within the Missouri River alluvial plain upstream of Lake Sakakawea. Available well data suggests the aquifer material consists of clean to silty/clayey fine to coarse sands and gravels interbedded with silts and clays. This aquifer can be highly heterogenous over short lateral distances. While not highly prevalent, some of the interbedded clay units are significant and could impede riverbank filtration, which could be better understood with field investigations. Depth to the bottom of the aquifer can exceed 200 feet, with saturated sand and gravel thickness of as great as 130 feet. Depth to groundwater is relatively shallow at 5 to 20 feet. This aquifer is anticipated to be in good connection with surface water and could be exploited by both horizontal collector wells and vertical wells.

Available water quality data suggests water quality is highly variable within the aquifer, with total dissolved solids (TDS) ranging from 400 to 1,500 mg/l. Higher TDS is observed at the northern edge of the Missouri River alluvial plain. Within the alluvial plain, there was no discernable pattern of higher versus lower TDS. Geology in this region is described in Section 3.3.1 State Line to Williston.

4.1.2.2 1-5 Yellowstone Buried

The Yellowstone Buried Channel aquifer consists of preglacial Yellowstone River channel deposits on the north side of the Missouri River alluvial plain. The aquifer extends north from Williston generally under the present day Little Muddy River valley. Available well data suggests the aquifer material consists of clean to silty/clayey fine to coarse sands and gravels interbedded with silts and clays. Depth to the bottom of the aquifer can exceed 200 feet, with saturated sand and gravel thickness as great as 100 feet. Significant clay/silt layers in the upper 100 feet of the aquifer make this aquifer more suitable for development of vertical wells. Geology in this region is described in Section 3.3.1 State Line to Williston.

4.1.2.3 1-6 Hofflund

The Hofflund aquifer consists of alluvial deposits within an abandoned section of Missouri River valley that is adjacent to the Missouri River. The aquifer is located on the north bank of Lake Sakakawea where Beaver Creek discharges into the lake. Deeper parts of the aquifer consist of sand and gravel deposited by streams moving meltwater away from glaciers. The upper part of the aquifer consists of gravel, sand, silt, and clay layers more-recently deposited by the Missouri River. A clay layer separates the two major layers of the aquifer in its westernmost part. Available well data suggests the aquifer material consists of clean to silty/clayey fine to coarse sands and gravels interbedded with silts and clays. Deeper parts of the aquifer consist of glacial outwash. This aquifer can be highly heterogenous over short lateral distances. Depth to the bottom of the aquifer can exceed 200 feet, with saturated sand and gravel thickness of as great as 175 feet. Depth to groundwater is relatively shallow at 15 to 75 feet. This aquifer is anticipated to be in good connection with surface water, dependent on water surface elevations of Lake Sakakawea, and could be exploited by both horizontal collector wells and vertical wells. Geology in this region is described in Section 3.3.2 Williston to Fort Berthold.

4.1.2.4 1-7, 1-8 and 1-11 White Shield

The White Shield aquifer is part of a long band of glacial outwash deposits that consist of sand and gravel aquifer with interbedded silts and clays. Depth to the bottom of the aquifer can exceed 300 feet, with saturated sand and gravel thickness of as great as 150 feet. Depth to groundwater is relatively shallow to intermediate at 5 to 100 feet. This aquifer, near its margin with Lake Sakakawea, is anticipated to be in good connection with surface water and could be exploited by both horizontal collector wells and vertical wells. In the deeper portions of the aquifer, in area that have greater depth to groundwater, vertical wells may be the only option. Records indicate that TDS in the aquifer ranges from 1,000 to 1,500 mg/l. Geology in this region is described in Section 3.3.3 Fort Berthold and Section 3.3.4 Fort Berthold to Garrison Dam.

4.1.2.5 1-9 Antelope Creek

The Antelope Creek aquifer is a long, narrow, deep glacial outwash aquifer in a channel carved into the underlying bedrock and generally lying under a narrow valley extending from the Beaver Creek Bay arm of Lake Sakakawea toward Knife River. The aquifer is narrow at only one mile wide and consists of sand and gravel with interbedded silts and clays. Depth to the bottom of the aquifer can exceed 300 feet, with saturated sand and gravel thickness as great as 130 feet. Depth to groundwater is relatively shallow at 15 to 60 feet. This aquifer, near its margin with the Beaver Creek Bay arm of Lake Sakakawea, is anticipated to be in good connection with surface water. However, the connection is dependent on water surface elevations of Lake Sakakawea. The aquifer could be exploited by both horizontal collector wells and vertical wells. Geology in this region is described in Section 3.3.3 Fort Berthold.

4.1.2.6 1-10 Renner Bay

The Renner Bay aquifer is an isolated section of glacial outwash deposits near Renner Bay that consist of sand and gravel aquifer with interbedded silts and clays. Depth to the bottom of the aquifer can exceed 200 feet, with saturated sand and gravel thickness of as great as 100 feet. Depth to groundwater is relatively shallow to intermediate at 40 feet. This aquifer near its margin with Lake Sakakawea might not have a good connection with surface water and production of 15,000 AF is doubtful. Geology in this region is described in Section 3.3.4 Fort Berthold to Garrison Dam.

4.1.2.7 1-12 Lake Nettie

The Lake Nettie aquifer materials consist of sands and gravels that fill an ancient valley that was carved by meltwater from glaciers. The aquifer consists of up to three layers separated by clay tills deposited by glaciers. Some parts of the uppermost layer are overlain by clay till. The aquifer is over 300 feet thick in places and averages 70 feet thick. The uppermost layer of the aquifer ranges from 2-74 feet thick in McLean County and 10-185 feet thick in Sheridan County. Geology in this region is described in Section 3.3.4 Fort Berthold to Garrison Dam.

4.1.2.8 1-13 Knife River

The Knife River aquifer consists of alluvial deposits within the Knife River alluvial valley. Available well data suggests the aquifer material consists of clean to silty/clayey fine to coarse sands and gravels interbedded with silts and clays. This aquifer can be highly heterogenous over short lateral distances. Depth to the bottom of the aquifer can exceed 300 feet, with saturated sand and gravel thickness of as great as 200 feet. The presence of significant clay and silt units at shallower depth could impede induced infiltration of surface water in the Knife River. Depth to groundwater is relatively shallow at 20 to 60 feet. This aquifer near its margin with the Missouri River alluvial aquifer is anticipated to be in good connection with surface water and could be exploited by both horizontal collector wells and vertical wells. Geology in this region is described in Section 3.3.5 Garrison Dam to Washburn.

4.1.2.9 1-14 Fort Mandan

The Fort Mandan aquifer consists of alluvial deposits within the Missouri River alluvial plain downstream of Garrison Dam. Available well data suggests the aquifer material consists of clean to silty/clayey fine to coarse sands and gravels interbedded with silts and clays. This aquifer can be highly heterogenous over short lateral distances. While not highly prevalent, some of the interbedded clay units are significant and could impede riverbank filtration. Depth to the bottom of the aquifer can exceed 250 feet, with saturated sand and gravel thickness of as great as 200 feet. Depth to groundwater is relatively shallow at 5 to 50 feet. This aquifer is anticipated to be in good connection with surface water and could be exploited by both horizontal collector wells and vertical wells. Geology in this region is described in Section 3.3.5 Garrison Dam to Washburn.

4.1.2.10 2-1 Charbonneau

The Charbonneau aquifer consists of preglacial channel deposits lying generally under present day Timber Creek. Very little well data was available for this aquifer. Available well data suggests the aquifer material consists of clean to silty/clayey fine to coarse sands and gravels at the base of the aquifer. Aquifer deposits average around 50 feet thick. On average, the aquifer is one mile wide. This aquifer is not anticipated to be in as good of connection with surface water and most likely could not produce the desired 15,000 AF/yr. Available water quality data suggests water quality is somewhat variable within the aquifer, with TDS ranging from 900 to 1,800 mg/l. Geology in this region is described in Section 3.3.2 Williston to Fort Berthold.

4.1.2.11 2-2 New Town

The New Town aquifer is part of a band of glacial outwash deposits that consist of sand and gravel aquifer with interbedded silts and clays. Depth to the bottom of the aquifer can exceed 220 feet, with saturated sand and gravel thickness as great as 100 feet. Depth to groundwater is relatively shallow to intermediate at 20 to 80 feet. This aquifer near its margin with Lake Sakakawea is anticipated to be in good connection with surface water, dependent on water surface elevations of Lake Sakakawea, and could be exploited by both horizontal collector wells and vertical wells. Records indicate that TDS in the aquifer averages around 1,400 mg/l. Geology in this region is described in Section 3.3.3 Fort Berthold.

4.1.2.12 2-3 Tobacco Garden

The Tobacco Garden aquifer materials consist of sands and gravels that were deposited by streams in an ancient valley carved in the region's bedrock. Most of the aquifer is overlain by lake-bed deposits, clay of glacial origin, or slope-base deposits. Aquifer deposits average around 70 feet thick. The aquifer averages around a mile wide. Geology in this region is described in Section 3.3.2 Williston to Fort Berthold.

4.1.2.13 2-4 Hans Creek

The Hans Creek aquifer is a long, narrow, deep glacial outwash aquifer in a channel carved into the underlying bedrock and generally lying under Hans Creek. It is suspected to extend further west and lie under Hans Creek and connect back to the Little Missouri River arm of Lake Sakakawea. No test hole data was available adjacent to Hans Creek. The Hans Creek portion of the aquifer is narrow at only 1 to 1.5 miles wide and consists of sand and gravel. Depth to the bottom of the aquifer can exceed 250 feet, with saturated sand and gravel thickness as great as 200 feet. Depth to groundwater is relatively shallow at 5 to 50 feet. The presence of significant clay and silt units at shallower depth could impede induced infiltration of surface water in Hans Creek, which could be better understood through additional field analysis. This aquifer, near its margin with the Little Missouri River arm of Lake Sakakawea, is anticipated to be in good connection with surface water and could be exploited by both horizontal collector wells and vertical wells. Geology in this region is described in Section 3.3.3 Fort Berthold.

4.1.3 Modeling and Analysis

Geospatial models were configured in ArcGIS Pro ModelBuilder to evaluate surface water and subsurface criteria and their weighting factors. ArcPro uses various geoprocessing tools to analyze each criterion, with tool configurations tailored to the specific analysis needs for each criterion layer. ArcPro's geoprocessing tools utilized in the models include Make Feature Layer, Near, Spatial Join, Pairwise Buffer, Feature to Point, Calculate Field, Delete Field, Add Join, and Remove Join, along with custom python scripts. ArcPro's geoprocessing tools were used to compute the individual criterion scores and overall score of each grid cell. Scores at each grid cell for each criterion were calculated based on the score for each sub-analysis and its associated weight, as defined under Section 5 Criteria.

4.2 Spatial Data Management

4.2.1 Spatial Reference

The Study used the NAD 1983 State Plane North Dakota N FIPS 3301 (US Feet) coordinate system. With the Study including an expansive area, a single coordinate system did not encompass the entirety of the Study area. However, a majority of the Study is encompassed by NAD 1983 State Plane North Dakota N FIPS 3301 (US Feet), so it was identified as the best spatial reference to use.

4.2.2 Geodatabase/Data Bibliography

Data sources were tracked in a Microsoft Excel spreadsheet to create a spatial data bibliography, attached in Appendix B – Spatial Data Bibliography. The bibliography tracks the source of each dataset, when it was downloaded, and if available, the source date of the data. Data was compiled in a geodatabase and included all criteria data used in the spatial analysis for surface water and subsurface modeling. Other source datasets, not used in the geospatial models, were downloaded for generating figures or deriving data from multiple sources of information.

5 Criteria

The DWR determined the Study should evaluate potential industrial intake locations based on criteria in a geospatial model. HDR and its subconsultants reviewed existing information in an effort to define the criteria that DWR included as part of the project's scope. Based on the review of existing information and input from the project team on several criteria development meetings, the project team felt the list developed by the DWR was comprehensive. Identifying data sources, developing analyses to evaluate each criterion, incorporating the analyses into the models, and ranking and weighting the criteria were important steps in completing the site identification process. Methods and definitions of the criteria changed as the Study progressed. This section documents the criteria definitions and weighting factors developed as part of this Study, but previous iterations of the criteria developed are documented in technical memoranda provided in Appendix C – Technical Memoranda.

The following sections outline the criteria used in the geospatial analysis. Each criterion includes sub-criteria, which were evaluated and assigned sub-analysis weightings. For criteria with similar sub-analyses across both surface and subsurface sites, those evaluations are presented first, followed by sub-analyses specific to either surface or subsurface site evaluations. Each criterion section concludes with a summary of the sub-analysis weights.

5.1 Water Availability

Water availability is defined as a potential intake site's ability to meet or exceed a proposed capacity of 15,000 AF/yr. As part of HDR's assessment of water availability, each grid location was ranked based on changes in elevation and the distance of a potential intake (or setback) from the water source. This was then compared to the onshore location designated for gathering, processing, and subsequent delivery of the water. Connection between the water source and the onshore location was assumed to be an intake pipe with 36" diameter installed using trenchless methods of horizontal directional drilling (HDD) or micro-tunnelling. In order to limit the variables of the trenchless constructability analysis, the length was defined as 1,500 feet, which is an acceptable range for both HDD and micro-tunneling. As there are more variables that affect trenchless design and site construction suitability than the scope of this Study, this length allowed for an equal comparison of grid location's relative slope and amount of elevation change between onshore and offshore ends of the pipeline. Each of the sites also included an analysis for conditions that met the predetermined topographic criteria (specified the Ease and Cost of Water Delivery and Slope Constructability Criteria), covering an area that extended 1,000 feet onshore and 1,000 feet offshore.

While those criteria helped to establish the basis for siting applicability with both onshore and offshore locations during the first phase of the Study, the next phase will require a deeper understanding of the subsurface conditions that exist between what is generally referenced as entry and exit point locations for the proposed land-to-water trenchless installations. This additional evaluation of subsurface conditions will be critical to determining true applicability for the proposed trenchless installation(s). There are recognized concerns for having a geometrically-feasible location identified, but potentially identifying subsurface conditions between those two points that negate the applicability for the trenchless method that is proposed for construction. As identified in Section 3.3.6 Glacial Till, glacial till potentially exists in this region and can have significant impacts on the feasibility of trenchless installations. Therefore, it must be understood in advance that the initial findings and first phase considerations for siting require subsequent analyses.

The Water Availability criterion sub-analyses similar for both surface water and subsurface sites include proximity to critical water elevations, slope constructability, and straight and outer bend proximity. Additionally, subsurface site identification includes a sub-analysis for capacity.

5.1.1 Surface Water and Subsurface

5.1.1.1 Proximity to Critical Water Elevations

In order to guarantee the capacity requirement of at least 15,000 AF/yr is met, even during periods of prolonged drought, potential surface water industrial intakes should be placed below the permanent pool elevation of Lake Sakakawea or below the low water contour of the river stretches. In order to maximize capacity and induced infiltration rate of surface water, potential subsurface intakes should also be placed below the permanent pool elevation of the lake or the low water contour of the river. This approach prioritizes locations that are closer to permanently available water sources, ultimately indicating areas with greater water availability.

Water availability in the lake region of the Study area is defined by a site's proximity to an elevation at or below 1780 feet (msl). The permanent pool of Lake Sakakawea was defined at an elevation of 1775 feet (LPD); however, contour data is approximate and is only available in 10-foot intervals. Additionally, the contour data is from 1943 and lake bottom elevations may have changed due to sediment aggradation. To identify as many locations as possible, 1780 feet (msl) was selected over 1770 feet (msl).

Water availability in the river regions of the Study area is defined by a site's proximity to the low water contour of the river. As previously mentioned, the project team used NAIP aerial imagery from various low water years to digitize a layer that represents the low water contour of the river.

Grid cells along the lake reaches that were closer to the 1780-foot contour line, and grid cells along the river reaches that were closer to the low water contour were prioritized. The distance from the centroid of each grid cell to the 1780-foot contour line (for the lake reaches) and to the low water contour (for the river reaches) was computed using ArcPro's Near Tool. Each grid cell was linearly ranked based on the distance, with the shortest distance getting a score of 1, the longest getting a score of 0. All other grid cells received a score between 0 and 1 using linear interpolation.

5.1.1.2 Slope Constructability

To minimize intake construction costs, sites with terrain more suitable for construction were prioritized when evaluating potential intake locations. Terrain slope was the main factor used to assess constructability, as steeper slopes can present challenges for both surface water and subsurface intake construction.

DEM data for the Study area was identified and downloaded from the USGS's LidarExplorer. The LiDAR data was collected in 2017 in NAVD88. Slope of each raster cell within each grid cell was calculated using a custom tool. Constructability was then assessed by evaluating the raster cell slope values differently depending on the intake type.

For surface water intakes, slope constructability was evaluated using the average slope of all raster cells within a grid cell. This method provided a representative measure of the general terrain conditions at each potential surface water intake site. Surface water intake sites were analyzed to determine constructability assuming HDD and micro-tunneling construction methods. Additionally, grid cells with lower average slopes were considered more favorable, as they typically require less grading and earthwork.

For subsurface intakes, slope constructability was based on the maximum slope within each grid cell, with priority given to sites with a lower maximum slope. This method accounted for localized steep slopes that could present access and construction challenges. Subsurface intakes were assumed to be constructed using vertical drilling or caisson shaft construction. Access for construction equipment was prioritized in the subsurface slope constructability criterion, as minimizing grading needed for access improves the cost-effectiveness of vertical drilling and caisson shaft construction. Construction methods such as HDD and shallow depth micro-tunneling were considered unsuitable for subsurface intakes, so the average grid cell slope method used to analyze surface water sites was not used for analyzing constructability of subsurface sites.

The average and maximum slopes within each grid cell were computed using ArcPro's zonal statistics tool. Each grid cell was assigned a constructability score based on the corresponding slope ranges as shown in Table 10. For example, for surface water sites, if a grid cell contained mostly flat slopes (0-10%), it received a higher score compared to a grid cell with mostly steep slopes (25+%).

Table 10. Slope ranges.

Zone	Slope Range (%)	Score
1	0-10	1.0
2	10-20	0.5
3	20-25	0.25
4	25+	0.0

Landslide and bank erosion data was not included in the spatial analysis but was brought up in the existing information review and identified in discussions with engineers of the regional water systems in the area. Discussion of these issues are included on the top-ranking sites but were not explicitly modeled during the spatial analysis.

5.1.1.3 Straight and Outer River Bend Proximity

In order to maintain maximum operating capacity of surface water intakes, sites should not be located in areas with high likelihood of sediment aggradation. In meandering, alluvial rivers like the Missouri River, sediment tends to deposit along the inside bends of curves, where water velocity is lower, while erosion typically occurs along the outer bends, where flow is faster. Based on review of various years of NAIP aerial imagery, this was confirmed by the Study team. For this reason, it is deemed favorable to construct a potential intake site in areas on straights or outer bends. In order to maximize the induced infiltration rate of surface water, subsurface intakes should also be located in areas on straights or outer bends.

Surface and subsurface intakes placed on stable sections of the river channel will provide better water availability over time as the intake infrastructure is less likely to be impacted by a changing riverbank. Stable sections of the river upstream and downstream of Lake Sakakawea were identified by evaluating numerous years of historical NAIP imagery. The Study team determined that NAIP imagery serves as the best available dataset to identify channel migration within the Study area and for identifying the historical thalweg location, which influences erosion and deposition patterns. NAIP imagery across multiple years was analyzed to determine if the river channel experienced any shifts over the analyzed period. Banks were assumed to be stable if there were no drastic channel changes observed in the imagery that was reviewed.

The project team also used NAIP imagery from recent years to digitize a layer that captured straight and outer bends of the river. This layer was created to identify locations that might be nearer to the thalweg of the river, which would provide greater water availability and less sedimentation issues for surface water intakes, while providing increased induced infiltration for subsurface sites. Other segments were classified as inner bends, representing areas where sediment deposition and aggradation are more likely to occur, making the locations impractical to develop an intake. The geomorphology layer digitized by the project team is provided in Appendix D – Riverine Geomorphology Maps.

The distance to straight and outer bends was computed from the centroid of each grid cell using ArcGIS Pro's Near Tool. This analysis was completed using the straight and outer bends layer with both the surface and subsurface grid. Each grid cell was linearly ranked based on the distance, with the shortest distance getting a score of 1 and the longest getting a score of 0. All other grid cells received a score between 0 and 1 using linear interpolation.

5.1.2 Subsurface

5.1.2.1 Capacity

Capacity is defined as a potential site's expected water availability identified by parameters that were researched by the project team. The project team used ND GIS Hub data, driller logs, historical topographic maps, and areas of densely populated water well completion records to identify areas that were expected to meet the 15,000 AF/yr capacity requirements.

Documented information from driller logs included completion date, ground and/or casing elevation, aquifer top and bottom elevation, and cleanliness of aquifer. This information was used to calculate saturated thickness, identify any potentially problematic impermeable geologic formations of substantial thickness, and determine general aquifer quality. Available pump testing data was used to calculate specific capacity and analyze any water chemistry or quality testing information.

The project team digitized a layer that identified potential sites that were expected to meet or exceed the required capacity at different areas throughout the Study. The areas were ranked into two tiers based on potential maximum capacity. Tier 1 depicts areas that will meet or exceed the 15,000 AF/yr capacity requirement with one collector well or three to five vertical wells. Tier 2 depicts areas that will likely meet the 15,000 AF/yr capacity requirement with two collector wells or six to eight vertical wells. Additional analysis, including field assessment, would be required to determine the upper limit of capacity for the identified subsurface aquifers.

Each grid cell was prioritized based on the tier it fell into, with Tier 1 cells getting a score of 1 and Tier 2 cells getting a score of 0.75. The areas were truncated at a 5,000-foot distance away from the shoreline polygon to maximize the percentage of well production that is derived from surface water.

5.1.3 Water Availability Sub-Analyses Weights

The surface water and subsurface weights of the water availability criterion are summarized below in Table 11 and Table 12, respectively.

Table 11. Water availability criterion surface water sub-analyses.

Criterion Title	Surface Water Analysis	Analysis Weight
Water Availability	Proximity to Permanent Pool (Lake)	70%
	Slope Constructability (Lake)	30%
	Slope Constructability (River)	50%
	Straight and Outer Bend Proximity (River)	50%

Table 12. Water availability criterion subsurface sub-analyses.

Criterion Title	Subsurface Analysis	Analysis Weight
Water Availability	Capacity (Lake/River)	40%
	Slope Constructability (Lake/River)	10%
	Proximity to Permanent Pool (Lake)	50%
	Proximity to Permanent Pool (River)	30%
	Straight and Outer Bend Proximity (River)	20%

5.2 Likelihood of Future Intake Sedimentation

Removal of sedimentation around intakes can be a costly operation and maintenance expenditure and can ultimately disrupt water availability. Several geomorphology studies and sediment range data from USACE were reviewed to form the basis of assumptions for sedimentation considerations in the criterion. Inter-dam geomorphology, shown in Figure 8, indicates that the riverine reach from the Montana state line to the headwaters of Lake Sakakawea experiences heavy aggradation, which results in increased sediment deposition. In contrast, the riverine reach below Garrison Dam to Washburn experiences degradation, resulting in less sediment deposition than the other riverine reaches included in this Study. The Lake Sakakawea reach of the Study falls within the reservoir zone, which is prone to minor deposition. Sedimentation on Lake Sakakawea is present but is not expected to impact operation and maintenance of an intake located at any sites within this area of the Study.

A polygon of sedimentation areas was digitized to reflect areas of high sedimentation along the Study corridor for the purpose of evaluating this criterion. One large polygon was placed from the Montana state line to the low water contour of Lake Sakakawea to reflect the aggrading reach of the Missouri River and the increased sediment deposition that would occur in this reach, which would be challenging for the operation and maintenance of intakes. A secondary floating intake could be constructed at these locations to mitigate the effects of sediment deposition, but are not recommended as the primary intake source in North Dakota due to ice conditions.

Other polygons of sedimentation areas were digitized based on aerial photography to represent inflow regions that have naturally higher turbidity and sedimentation. The source of the aerial image used to create each record is included in Appendix B – Spatial Data Bibliography. The aerial images used for developing this layer were either a low or high-water year when turbidity or significant depositional areas were identifiable in the imagery. The project team digitized a layer that incorporated these areas for the purpose of identifying regions that have higher turbidity. Intake locations were given preference if they were not within the turbidity layer. Grid index cells that did not overlap the turbidity polygons received the maximum score, while cells that overlapped the turbidity layer received a score of 0. This criterion was used in both the subsurface and surface water geospatial models, but issues regarding turbidity and sedimentation were more impactful on surface water intake location identification. High turbidity can also reduce the effectiveness of subsurface intakes by clogging riverbed sediments, which limits the flow of water through the soils and weakens the hydraulic connection to the river.

5.2.1 Likelihood of Future Intake Sedimentation Sub-Analyses Weights

The surface water and subsurface weights of the likelihood of future intake sedimentation criterion are summarized below in Table 13 and Table 14, respectively.

Table 13. Likelihood of future intake sedimentation criterion surface water analysis.

Criterion Title	Surface Water Analysis	Analysis Weight
Likelihood of Future Intake Sedimentation	Turbidity	100%

Table 14. Likelihood of future intake sedimentation criterion subsurface analysis.

Criterion Title	Subsurface Analysis	Analysis Weight
Likelihood of Future Intake Sedimentation	Turbidity	100%

5.3 Ease and Cost of Water Delivery

Ease and cost of water delivery based on topography is an important factor when determining an intake's location. The project team discussed the challenges of this criterion, mainly the unknown location to where the industrial intake would be delivering water. For this reason, the project team decided to analyze the ease and cost of water delivery based on topography within a two-miles radius of the intake location. This two-mile radius was chosen to capture the immediate surrounding area, which directly impacts the infrastructure needed for transporting water. This helped identify areas that may require larger pumps, higher pressure class piping, and ultimately higher operational costs associated with delivering water from the river or lake. A customized GIS script was created to complete the analysis for this criterion. Each grid cell's centroid was input into a line generation algorithm. The nearest location on the shoreline perimeter to the centroid served as the line's starting point. The next point on the line was the grid cell's centroid. Each line extended to the closest locations on increasingly distant contour buffer polygons, out to two miles in length.

The generated lines were exported to a polyline feature class, then densified to a standard vertex spacing of 10 feet. Elevation values based on the input DEM raster were copied to all line vertices. The elevation for each vertex was calculated using bilinear interpolation, in which the elevation values of the four cells closest to the vertex were distance-weighted to calculate an interpolated elevation value.

To calculate minimum and maximum elevations, the elevation values assigned to each line vertex were examined and then recorded in the feature's attribute fields. Only the vertices within a user-specified range were examined. For this analysis, all vertices from 0 to 11,000 feet were used in the calculation. Additional attribute fields were then added to the line for calculating the overall elevation change and converting that change into an overall score. Scoring was specified as follows: 0 to 100 feet of change scored 1, 100 feet to 150 feet scored 0.75, 150 feet to 200 feet scored 0.5, 200 feet to 300 feet scored 0.25, and change of 300 feet or more scored 0.

5.3.1 Ease and Cost of Water Delivery Sub-Analyses Weights

The surface water and subsurface weights of the ease and cost of water delivery criterion are summarized below in Table 15 and Table 16, respectively.

Table 15. Ease and cost of water delivery criterion surface water analysis.

Criterion Title	Surface Water Analysis	Analysis Weight
Ease and Cost of Water Delivery	Topography	100%

Table 16. Ease and cost of water delivery criterion subsurface analysis.

Criterion Title	Subsurface Analysis	Analysis Weight
Ease and Cost of Water Delivery	Topography	100%

5.4 Distance to Infrastructure

Distance to infrastructure such as power, roadways, rail, and natural gas is crucial to development of industrial intakes. The project team deemed that power and roadways would be most crucial to identifying locations where intakes could be developed. The sub-analyses included in the Distance to Infrastructure criterion were used in both the surface water and subsurface geospatial models. Datasets for the Distance to Infrastructure criteria were split on the left and right bank to only analyze the criteria based on what was readily available on the same side of the river or lake.

The Distance to Infrastructure criterion sub-analyses similar for both surface water and subsurface sites include power, roadways, rail lines, and natural gas.

5.4.1 Power

The distance to power criterion is defined by the project team as a suitable intake location's proximity to three-phase power, identified by Homeland Infrastructure Foundation-Level Data (HIFLD), which is a requirement for the size of pumps necessary to deliver water from the intake site. Intake locations closer to three-phase power were prioritized in this analysis. The distance to power was computed from the

centroid of each grid cell to the nearest three-phase power line using ArcPro's Near Tool. Each grid cell was linearly ranked based on the distance, with the shortest distance getting a score of 1 and the longest getting a score of 0. All other grid cells received a score between 0 and 1 using linear interpolation.

5.4.2 Roadways

The distance to roadways criterion is defined by the distance from a suitable intake location to roadways, identified from ND GIS Hub data. Intake locations closer to roadways were prioritized in this analysis. The distance to roadways were computed from the centroid of each grid cell to the nearest roadway using ArcPro's Near Tool. Each grid cell was linearly ranked based on the distance, with the shortest distance getting a score of 1 and the longest getting a score of 0. All other grid cells received a score between 0 and 1 using linear interpolation.

5.4.3 Rail Lines

The distance to rail lines criterion is defined by an intake location's proximity to rail lines, identified by ND GIS Hub data. Intake locations closer to rail lines were prioritized in this analysis. The distance to rail lines was computed from the centroid of each grid cell to the nearest rail line using ArcPro's Near Tool. Each grid cell was linearly ranked based on the distance, with the shortest distance getting a score of 1 and the longest getting a score of 0. All other grid cells received a score between 0 and 1 using linear interpolation.

5.4.4 Natural Gas

The distance to natural gas criterion is defined by an intake location's proximity to natural gas pipeline facilities, identified by HIFLD. Intake locations closer to natural gas were prioritized in this analysis. The criterion considered the vicinity of a natural gas pipeline for the purposes of intake pump station facility heating and emergency backup power. Potential sites closer to natural gas were prioritized in this analysis. The distance to natural gas was computed from the centroid of each grid cell to the nearest natural gas pipeline using ArcPro's Near Tool. Each grid cell was linearly ranked based on the distance, with the shortest distance getting a score of 1 and the longest getting a score of 0. All other grid cells received a score between 0 and 1 using linear interpolation.

5.4.5 Distance to Infrastructure Sub-Analyses Weights

The surface water and subsurface weights of the distance to infrastructure criterion are summarized below in Table 17 and

Table 18, respectively.

Table 17. Distance to infrastructure criterion surface water sub-analyses.

Criterion Title	Surface Water Analysis	Analysis Weight
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	Distance to Power	35%
	Distance to Roadways	35%
	Distance to Rail Lines	15%
	Distance to Natural Gas	15%

Table 18. Distance to infrastructure criterion subsurface sub-analyses.

Criterion Title	Subsurface Analysis	Analysis Weight
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	Distance to Power	35%
	Distance to Roadways	35%
	Distance to Rail Lines	15%
	Distance to Natural Gas	15%

5.5 Interest Expressed by New Industry

New industry interests are important when considering the potential location of an industrial intake, as a proposed intake should be near the industrial facility that it will serve. The project team coordinated with the North Dakota Department of Commerce (DOC) to get a better understanding of industries that have expressed interest in using water from the Missouri River. DOC provided rough estimates of potential water use by potential new industries across the region. Certain industries expressed interest in broader regions while others expressed interest in using water at specific locations. For this reason, two sub-analyses were created to account for the data provided by DOC as part of this criterion.

The Interest Expressed by New Industry criterion sub-analyses similar for both surface water and subsurface sites include distance to potential new industry and potential new industries.

5.5.1 Distance to Potential New Industry

Distance to potential new industry is defined as a potential intake site's proximity to potential new industry interests, identified by inquiries provided by the DOC. GIS features were created to account for the sites provided by DOC for use in the geospatial analyses. Potential intake sites closer to new industry interests were prioritized in this analysis. The distance to the nearest new industry interest was computed from the centroid of each grid cell to the nearest potential industry interest location using ArcPro's Near Tool. Each grid cell was linearly ranked based on the distance, with the shortest distance getting a score of 1 and the longest getting a score of 0. All other grid cells received a score between 0 and 1 using linear interpolation.

5.5.2 Potential New Industries

The potential new industries criterion is defined as the number of new industry interests along a Study reach, identified from information provided by the DOC. A GIS feature was created along the reach shoreline segments, defined by areas of future industries potential provided by the DOC data. Industries included but were not limited to oil and gas, power generation, agriculture, data centers, and biofuel production.

Intake locations along reaches with a larger number of new industry interests were prioritized in this analysis. ArcPro's Spatial Join tool was used to determine what reach each grid cell overlapped to assign a future industry value for each grid cell. The maximum number of new industry interests along any Study reach was 7. Grid cells located in reaches with the maximum number of new industry interests received a value of 1. Grid cells located in other reaches were given a value calculated by dividing the number of new industry interests in that reach by 7, the maximum number of new industry interests located in any reach.

5.5.3 Interest Expressed by New Industry Sub-Analyses Weights

The sub-analyses included in this criterion were used in both the surface water and subsurface geospatial models, summarized below in Table 19.

Table 19. Interest expressed by new industry criterion sub-analyses.

Criterion Title	Surface Water & Subsurface Analysis	Analysis Weight
Locations Expressed by New Industry	Distance to Potential New Industry	50%
	Potential New Industries	50%

5.6 Water Quality

Water quality can be an important consideration for industries looking to develop industrial intakes. Depending on the industry, different water quality or treatment requirements might be needed to provide appropriate water quality for their uses. This criterion outlines some water quality considerations for intake development; however, depending on the industry, additional testing may be necessary to assess a site's suitability. Several sub-analyses were created as part of this criterion for both the subsurface and surface water geospatial models.

The Water Quality criterion sub-analyses similar for both surface water and subsurface sites include land based potential water quality impairments and water based potential water quality impairments. Additionally, the surface water sub-analyses include turbidity and aquatic nuisance species, and the subsurface sub-analyses includes total dissolved solids (TDS).

5.6.1 Surface Water and Subsurface

Potential water quality impairments are an important consideration when identifying an intake site, as the source water could be at a higher risk of contamination in comparison to sites across the Study area. The analysis was divided into two sub-analyses for land based and water-based impairment sources.

5.6.1.1 Land Based Potential Water Quality Impairments

Land based potential water quality impairments is defined as a site's proximity to land-based sources, activities, facilities, or conditions that may contribute to potential water quality impairment. A buffer of one mile was chosen based on project team expertise and was presented to DWR. This analysis gave preference to potential sites that did not fall within one mile of these locations. Data for potential impairment sources came from HIFLD, DWR's MapService ND Department of Mineral Resources Map Viewer, and ND GIS Hub data (landfills). The distance to potential impairments was computed from the centroid of each grid cell using ArcPro's Near Tool and Spatial Join. If a grid cell overlapped the one-mile buffer for each criteria dataset, the cell received a score of 0, and if a grid cell did not overlap the dataset buffer, the cell received a score of 1.

5.6.1.2 Water Based Potential Water Quality Impairments

Water based potential water quality impairments is defined as a site's proximity to water-based sources, activities, facilities, or conditions that may contribute to potential water quality impairment. Locations include oil pipelines, produced water pipelines, and natural gas pipelines. A buffer of half a mile was chosen based on project team expertise and was presented to DWR. This analysis gave preference to potential sites that did not fall within half a mile downstream of these sources. Data for potential impairment sources came from DWR-provided pipeline data. The distance to potential impairments was computed from the centroid of each grid cell using ArcPro's Spatial Join Tool. If a grid cell overlapped the half mile buffer for each criteria dataset, the cell received a score of 0. If a grid cell did not overlap the dataset buffer, the cell received a score of 1.

5.6.2 Surface Water

5.6.2.1 Turbidity

Turbidity is an important factor when determining overall surface water quality. Turbidity is worse in areas where existing tributaries spill their sediment load into the Missouri River or Lake Sakakawea. The project team digitized a GIS feature dataset that incorporated these areas for the purpose of identifying regions that have higher turbidity. Intake locations were given preference if they were not within the turbidity layer. ArcPro's Spatial Join tool was used to determine if a grid cell overlapped the turbidity polygon. If a grid cell overlapped the turbidity dataset, the grid cell received a score of 0. If a grid cell did not overlap the turbidity dataset, the cell received a score of 1.

5.6.2.2 Aquatic Nuisance Species

The likelihood of Aquatic Nuisance Species (ANS) infestation, particularly zebra mussels, is an important consideration when developing a surface water intake, as mussel buildup can reduce capacity and decrease water quality. The ANS water quality criterion for the Study is defined based on the potential for ANS infestation at a potential intake site. For the purpose of this sub-analysis, the Study area was divided into three regions. The three identified regions were upstream of the lake, the lake itself, and downstream of the lake.

The project team coordinated with NDGFD during the development of this criteria. NDGFD and the project team discussed multiple factors that contribute to ANS infestation risk. ANS often infest a body of water through deposition from recreational vehicles, so the most important factor when determining risk is normal recreation trends. Areas with high recreation have a higher risk of infestation. Based on this information, downstream of the lake has the lowest risk, upstream of the lake has medium risk, and the lake itself has the highest risk.

NDGFD indicated that lower temperatures found downstream of the lake impacts zebra mussel spawning. The spawning season is shorter due to the water not reaching adequate temperatures until later in the year. NDGFD also noted a higher mortality rate for the mussels in moving water. Based on this information, downstream of the lake has the lowest risk, upstream of the lake has medium risk, and the lake itself has the highest risk.

NDGFD described zebra mussels as drifters, meaning they move with the flow of water. This leads to low possibility of them moving upstream in a river system, with a higher probability that they travel downstream in a river system. Based on this information, downstream of the lake has the lowest risk, upstream of the lake has medium risk, and the lake itself has the highest risk.

Based on discussions with NDGFD about the factors that determine ANS infestation risk, it was decided that the area with the highest risk for infestation is the lake itself, followed by the river reach upstream of the lake and lastly by the reach downstream of the lake. The project team digitized a GIS feature dataset that incorporated these regions to give preference to sites with lower risk. ArcPro's Spatial Join tool was used to determine each individual grid cell's score for ANS. The three regions of ANS were assigned weighted values to determine a hierarchy of more suitable areas to avoid higher potential areas for ANS. Grid cells that overlapped high potential for ANS infestation were assigned 0, the lowest score, medium potential was assigned 0.5, and low potential was assigned 1.

5.6.3 Subsurface

5.6.3.1 Total Dissolved Solids

TDS is an important indicator when determining overall groundwater quality. TDS is a measure of the combined amount of inorganic and organic substances dissolved in water, including minerals, salts, and other compounds. High TDS levels can signify potential contamination or poor water quality, often impacting taste and causing scaling in pipes due to the presence of dissolved minerals. Very low TDS levels can also be undesirable due to a bland taste and potential corrosiveness to plumbing systems. Acceptable TDS levels vary depending on the water source and intended use. While TDS provides an overall picture of water quality, it is important to analyze specific water quality parameters for a complete assessment.

TDS levels used in the water quality criteria analysis are based on driller logs obtained from DWR's MapService. TDS levels can vary significantly throughout an aquifer. For this Study, an average TDS value was calculated from the driller logs for each aquifer. Sampling of other water quality parameters of concern is recommended to confirm the relative water quality at an identified site.

ArcPro's Spatial Join tool was used to show the average TDS at each grid cell. Each cell received a score for this criterion based on the following TDS ranges:

- TDS under 500 mg/L received a score of 1
- TDS between 501 mg/L and 1,000 mg/L received a score of 0.75
- TDS between 1,001 mg/L and 1,500 mg/L received a score of 0.5
- TDS between 1,501 mg/L and 2,000 mg/L received a score of 0.25
- TDS over 2,000 mg/L received a score of 0

5.6.4 Water Quality Sub-Analyses Weights

The surface water and subsurface weights of the water quality criterion are summarized below in Table 20 and Table 21, respectively.

Table 20. Water quality criterion surface water sub-analyses.

Criterion Title	Surface Water Analysis	Analysis Weight
Water Quality	Land Based Potential Water Quality Impairments	25%
	Water Based Potential Water Quality Impairments	15%
	Turbidity	35%
	Aquatic Nuisance Species	25%

Table 21. Water quality criterion subsurface sub-analyses.

Criterion Title	Subsurface Analysis	Analysis Weight
Water Quality	Land Based Potential Water Quality Impairments	30%
	Water Based Potential Water Quality Impairments	20%
	Total Dissolved Solids	50%

5.7 Distance to Nearby Towns and Existing Industrial Facilities

Distance to towns and existing industries should both be considered when determining an intake's location, as the primary purpose of the intake sites would be to serve industrial water users, with a secondary purpose or benefit of additional irrigation and municipal water supply. Distance to nearby towns and existing industrial facilities was analyzed as part of the geospatial model as two separate sub-analyses. Proximity to nearby towns is an important metric in determining available workforce and amenities for new and developing businesses seeking to develop industrial water supplies. Additionally, the potential for existing industrial facilities to expand their water use was another reason to include this criterion.

The Distance to Nearby Towns and Existing Industrial Facilities criterion sub-analyses similar for both surface water and subsurface sites include distance to nearby towns and distance to existing industrial facilities.

5.7.1 Distance to Nearby Towns

Distance to nearby towns criterion is defined as a potential site's proximity to communities based on distance and population size. Data obtained from ND GIS Hub included 2020 census data for each community within North Dakota. Potential sites closer to larger towns were prioritized in this analysis. The Study only considered communities on the same side of the river as the grid cell. The distance to the nearest town within each of the below population ranges was computed from the centroid of each grid cell using ArcPro's Near Tool. Each grid cell was linearly ranked based on the distance, with the shortest distance getting a score of 1 and the longest getting a score of 0. All other grid cells received a score between 0 and 1 using linear interpolation. The prioritization based on the population range of the city was calculated using the multiplication factors, shown below.

- Communities over 8,000 received a multiplication factor of 0.4
- Communities between 1,362 and 8,000 received a multiplication factor of 0.25
- Communities between 579 and 1,361 received a multiplication factor of 0.15
- Communities between 162 and 578 received a multiplication factor of 0.1
- Communities under 161 received a multiplication factor of 0.1

For instance, a grid cell that is farthest from a town with a population of over 8,000, but nearest to towns with populations between 1,362 and 8,000, between 579 and 1,361, between 162 and 578, and under 161 would receive the following score breakdown:

- Score of 0 multiplied by 0.4 for communities over 8,000
- Score of 1 multiplied by 0.25 for communities between 1,362 and 8,000
- Score of 1 multiplied by 0.15 for communities between 579 and 1,361
- Score of 1 multiplied by 0.1 for communities between 162 and 578
- Score of 1 multiplied by 0.1 for communities under 161

These scores would be summed together to calculate an overall score of 0.6 for the distance to nearby towns criterion.

5.7.2 Distance to Existing Industrial Facilities

Distance to existing industrial facilities criterion is defined as a potential site's proximity to existing industrial facilities. Existing industrial facilities considered in the analysis included natural gas facilities, power plants, processing plants, coal mines, coal power plants, and agricultural facilities identified by HIFLD and ND GIS Hub data. Intake locations closer to existing industrial facilities were prioritized in this analysis. The distance to existing industrial facilities was computed from the centroid of each grid cell using ArcPro's Near Tool. Facilities were attributed in each GIS dataset if the data is located spatially on the right or left shoreline downstream from the Montana state border. Each grid cell was linearly ranked based on the distance, with the shortest distance getting a score of 1, the longest getting a score of 0. All other grid cells received a score between 0 and 1 using linear interpolation.

5.7.3 Distance to Nearby Towns and Existing Industrial Facilities Sub-Analyses Weights

The sub-analyses included in this criterion were used in both the surface water and subsurface geospatial models, summarized below in Table 22.

Table 22. Distance to nearby towns and existing industrial facilities criterion sub-analyses.

Criterion Title	Surface Water & Subsurface Analysis	Analysis Weight
Distance to Nearby Towns and Existing Industrial Facilities	Distance to Nearby Towns	40%
	Distance to Existing Industrial Facilities	60%

5.8 Impacts to Areas of Natural, Cultural, and Historical Significance

The project team formulated several different sub-analyses to investigate impacts that could fall within this criterion. Historical and cultural sites, designated critical habitat, and unbroken grasslands were all identified as areas that could be impacted by intake development and were analyzed under this criterion.

The Impacts to Areas of Natural, Cultural, and Historical Significance criterion sub-analyses similar for both surface water and subsurface sites include cultural and historical significance, critical habitat, and unbroken grasslands.

5.8.1 Cultural and Historical Significance

It is important to consider areas of cultural or historical significance when siting an intake, as additional permitting and coordination requirements would likely impact the construction cost and schedule. National Register of Historic Places (NRHP) data was identified as a publicly available data source for evaluating areas that could have impacts to historical and cultural sites. While sites in the database are limited, a review of State Historic Preservation office (SHPO) data was completed on the top-ranking site locations identified.

Cultural sites within reservation boundaries are not always included in the SHPO information and will require coordination with the Tribal Historic Preservation Office (THPO). A buffer of a quarter mile was chosen based on project team expertise and was presented to DWR. Potential sites were given preference if they were not within a quarter mile of these sites. ArcPro's Spatial Join tool was used to determine if a grid cell overlapped the quarter mile buffer of NRHP data. If a grid cell overlapped the quarter mile buffer, the cell received a score of 0. If a grid cell did not overlap the dataset buffer, the cell received a score of 1.

5.8.2 Critical Habitat

It is important to consider critical habitat areas when siting an intake, as additional permitting and coordination requirements would likely impact intake construction cost and schedule. Proximity to designated critical habitats was identified as a potential criterion that could have impacts since a significant portion of the Study area lies within critical habitat of the Piping Plover, which is on the threatened and endangered species list. Areas over a half mile from the USFWS critical habitat layer were given preference for the intake siting.

Piping Plover habitat surveys and monitoring may be triggered for impacts within a half mile or within designated critical habitats if a federal nexus exists for a project, like permitting or funding, based on standard guidance from the USFWS. Many current intake projects, including Southwest Pipeline Project and the Northwest Area Water Supply Project, have been required to complete surveys and monitor during construction. ArcPro's Spatial Join tool was used to determine if a grid cell overlapped the half mile buffer of critical habitat data. If a grid cell overlapped the half mile buffer, the cell received a score of 0. If a grid cell did not overlap the dataset buffer, the cell received a score of 1.

Pallid sturgeon spawning and larval data was not included in the spatial analysis but was brought up in the existing information review and identified in an August 15, 2024, discussion with USFWS.

5.8.3 Unbroken Grasslands

Unbroken grasslands have a higher potential for impacting cultural sites and endangered species, like the Dakota Skipper, as they are areas where the ground has not been disturbed through agricultural or other uses. For this reason, unbroken grasslands/native prairie was another potential impact area identified within this criterion by the project team. The unbroken grasslands criterion is defined as a potential site's proximity to areas that are identified as unbroken grasslands by NDGFD. Locating an intake on unbroken grasslands could be a potential regulatory hurdle for the development of an industrial intake. Potential sites were given preference if they were not within an unbroken grassland. ArcPro's Spatial Join tool was used to determine if a grid cell overlapped the unbroken grassland data. If a grid cell overlapped the dataset, the cell received a score of 0. If a grid cell did not overlap the dataset, the cell received a score of 1.

5.8.4 Impacts to Areas of Natural, Cultural, and Historical Significance Sub-Analyses Weights

The sub-analyses included in this criterion were used in both the surface water and subsurface geospatial models, summarized below in Table 23.

Table 23. Impacts to areas of natural, cultural, and historical significance criterion sub-analyses.

Criterion Title	Surface Water & Subsurface Analysis	Analysis Weight
Impacts to Areas of Natural, Cultural, and Historical Significance	Cultural and Historical Significance	50%
	Critical Habitat	25%
	Unbroken Grasslands	25%

5.9 Federal and State Permitting Requirements

Construction and authorization of industrial intakes require many different local, state, and federal permits. It is important to consider the permits and coordination requirements associated with each site when considering an intake location. Information on each individual permit which may be required, the respective regulatory authority, application timeline, and contact information is detailed in Appendix A – Environmental Considerations and Permit Matrix.

The Federal and State Permitting Requirements criterion sub-analyses similar for both surface water and subsurface sites include jurisdictional boundaries requiring increased coordination and USACE Section 408 permitted structures.

5.9.1 Jurisdictional Boundaries Requiring Increased Coordination

Jurisdictional boundaries requiring increased coordination criterion is defined as a potential site's proximity to areas that are identified as federally owned or State Trust Lands by ND GIS Hub data. Potential sites that did not overlap properties managed by the USACE, United States Bureau of Land Management (BLM), United States Bureau of Reclamation (BOR), USFWS, or State Trust Lands were given preference with this analysis.

ArcPro's Spatial Join tool was used to determine if a grid cell overlapped each land management layer. If a grid cell overlapped the individual dataset, the cell received a score of 0. If a grid cell did not overlap the dataset, the cell received a score of 1.

Permits required within Ft. Berthold Reservation boundaries have not been extensively researched as part of this Study, and it is acknowledged that additional coordination with MHA Nation will need to be conducted in order to understand the full scale of necessary permits and approvals to develop an industrial intake within the reservation boundary.

5.9.2 USACE Section 408 Permitted Structures

USACE Section 408 permitted structures criterion is defined as a potential site's proximity to existing USACE-built structures including bank stabilization projects identified by DWR-provided data. While these structures are owned by state and local entities, USACE retains certain permitting responsibilities for them.

Other USACE structures in the Study area include Garrison Dam and the Snake Creek Embankment, but there are complexities and regulatory challenges associated with integrating an intake structure into a dam. Based on this and HDR's coordination with DWR, the USACE Section 408 permitted structures criterion analysis excluded Garrison Dam and the Snake Creek Embankment and focused solely on the bank stabilization structures built by USACE.

Proximity to an existing bank stabilization project built by USACE could trigger the requirement for a riverine USACE Section 408 permit submission, as it has potential to impact a USACE Civil Works project. This analysis was only conducted on potential sites located along riverine reaches within the Study. Potential sites that did not overlap existing bank stabilization projects built by USACE were given preference with this analysis. ArcPro's Spatial Join tool was used to determine if a grid cell overlapped the bank stabilization project layer. If a grid cell overlapped the individual dataset, the cell received a score of 0. If a grid cell did not overlap the dataset, the cell received a score of 1.

5.9.3 Federal and State Permitting Requirements Sub-Analyses Weights

The sub-analyses included in this criterion were used in both the surface water and subsurface geospatial models, summarized below in Table 24.

Table 24. Federal and state permitting requirements criterion sub-analyses.

Criterion Title	Surface Water & Subsurface Analysis	Analysis Weight
Federal and State Permitting Requirements	Jurisdictional Boundaries Requiring Increased Coordination (Lake)	100%
	Jurisdictional Boundaries Requiring Increased Coordination (River)	50%
	408 Permissions (River)	50%

5.10 Impacts to Recreation

During construction and operation of a proposed industrial intake, it is important to minimize impacts to recreational activities within the Missouri River and Lake Sakakawea. Impacts to recreation criteria is defined as a potential site's proximity to boat ramps, state parks, and wildlife management areas (WMA's) identified by NDGFD and ND GIS Hub data. A buffer of 1,500 feet was chosen based on project team expertise and was presented to DWR. Potential sites were given preference if they were not within 1,500 feet of these sites. ArcPro's Spatial Join tool was used to determine if a grid cell overlapped the 1,500-foot buffer of boat ramps, state parks, and WMA boundary data. If a grid cell overlapped the dataset buffer, the cell received a score of 0. If a grid cell did not overlap the dataset buffer, the cell received a score of 1.

5.10.1 Impacts to Recreation Sub-Analyses Weights

This criterion was used in both the surface water and subsurface geospatial models, summarized in Table 25.

Table 25. Impacts to recreation criterion analysis.

Criterion Title	Surface Water & Subsurface Analysis	Analysis Weight
Impacts to Recreation	Impacts to Boat Ramps, WMA's, and State Parks	100%

6 Weighting of Criteria

The driver of site identification was the ranking and weighting of the intake site criteria. Site identification based on the spatial grid required understanding what the main site identification criteria were and how important they were relative to one another. This section of the report discusses the tools used to determine the ranking and weighting of criteria, the work sessions completed to rank and weight the criteria, preliminary rankings, and final rankings.

6.1 HDR DecisionSPACE

HDR DecisionSPACE was selected to help identify the ranking and weighting of each criterion. DecisionSPACE is a Multi-Criteria Decision Analysis (MCDA) tool that was developed in Microsoft Access. The tool was determined to be appropriate for the Study because it can develop rankings and weights of criteria by determining the perceived level of importance of one criterion over another.

Criteria were scored using a standard statistical pairwise comparison tool. Pairwise comparisons evaluated criteria by comparing two options and assessing "Which is more important?" and "How much more (or less) important is it?" The scoring method consisted of a rating language, which is listed below with its corresponding score. Appendix E – DecisionSPACE Results also contains figures for all the criterion comparisons used for both the surface water and subsurface conditions.

- is extremely more important than – 9
- is much more important than – 6
- is more important than – 3
- is as important as – 1
- is less important than – 1/3
- is much less important than – 1/6
- is extremely less important than – 1/9

Using the scores, a matrix was developed, and then linear algebra was performed to calculate a weight for each criterion. A small group of the project team developed the initial rankings and weights of the criteria and sent the outputs to the larger project team for review. The project team and DWR confirmed that the weights reflected their understanding of which criteria are most important.

Two separate DecisionSPACE comparisons were prepared, one for subsurface and another for surface water.

6.2 Criteria Weights

The DecisionSPACE methodology was used to develop the ranking and weighting of criteria. DWR insight and further discussion on the importance of each criterion helped develop the surface water and subsurface rankings for the Study, shown in Figure 12 and Figure 13, respectively. There are two consistency check figures in Appendix E – DecisionSPACE Results; these figures summarize the weighting of one criterion coupled with the level of importance (i.e., "is more important than") compared to another criterion. The overall score for each preliminary site was calculated by multiplying the score for each criterion by its corresponding weight and then adding the weighted scores together, described in this section. Additionally, Appendix E –DecisionSPACE contains figures for all the criterion comparisons used for both the surface water and subsurface conditions.

The project team received direction from DWR that permitting criteria should not significantly dictate site identification. It is understood that there are permitting requirements for intake construction on land owned by local, state, federal and tribal entities that will affect all locations across the Study area. Potential permitting requirements are summarized in Table 7.

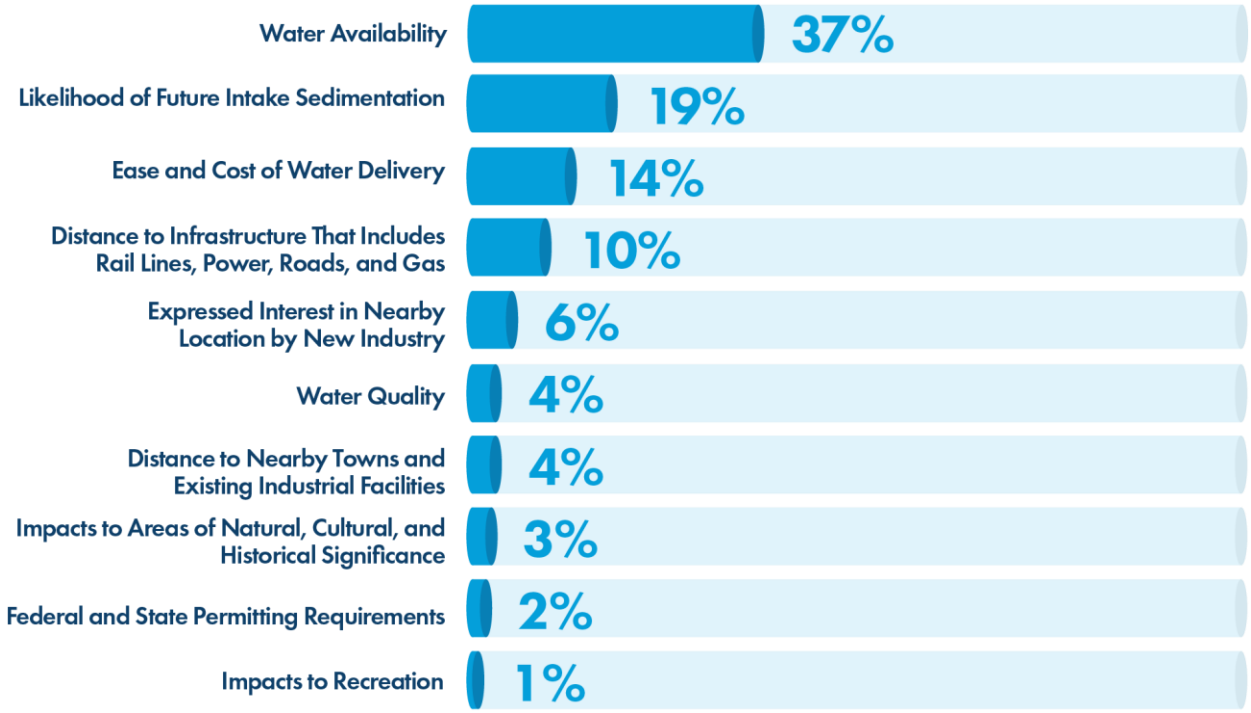


Figure 12. DecisionSPACE – Criteria weights for surface water.

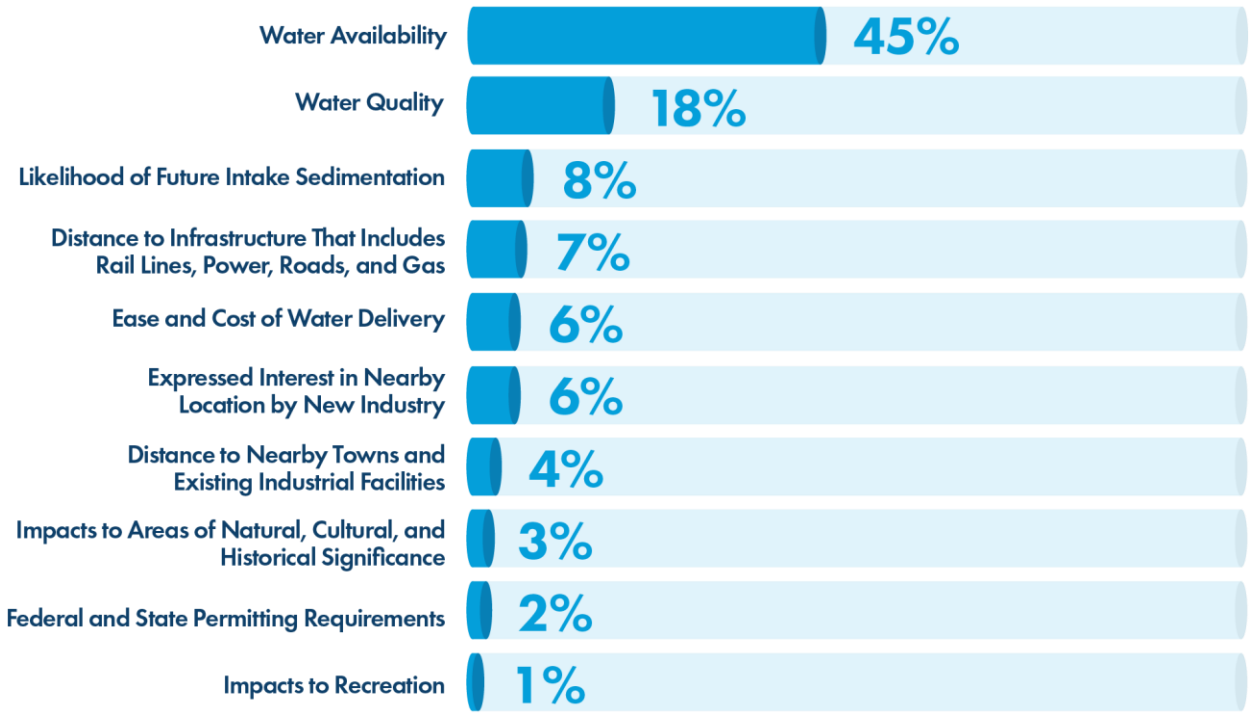


Figure 13. DecisionSPACE – Criteria weights for subsurface.

7 Site Identification

ArcPro's model builder tool was used for evaluating each criterion including the sub-analysis criteria created as part of this Study against the spatial grid system. Each grid cell was ranked based on the criteria developed throughout the earlier phases of the Study. The criteria were updated after the completion of the in-progress review meeting to account for multiple sub-analyses within each criterion. Appendix E – DecisionSPACE Results summarizes the weight for each criterion that was used for site identification.

Each criterion group was given a maximum potential value of 1.0 in the model, indicating that 100 percent of the criterion weight would be applied to a grid cell. The overall score for each preliminary site was calculated by multiplying the score for each criterion by its corresponding weight and then adding the weighted scores together. Cells with the highest cumulative score within each reach were then highlighted as most appropriate for an industrial intake site.

An example grid cell score breakdown is shown below in Table 26. The example cell is a high scoring cell in the Garrison Dam to Washburn Right reach. The overall score for this cell is 0.904, which is calculated by summing the weighted score of each criterion. The weighted score of each criterion is calculated by multiplying the criterion score by the criterion weight. For instance, the score that this cell received for the water availability criterion was a 1, which multiplied by the 37% weight for the water availability criterion leads to a 0.37 weighted score. The summation of weighted scores for each criterion at a grid cell is equal to the overall score that the grid cell received.

Table 26. Example grid cell score breakdown.

Garrison Dam to Washburn, Right				
GRID CELL NAME	**GW0058R**			
OVERALL SCORE	**0.904**			
Criterion	***Criterion Score***	***x***	***Criterion Weight***	***= Weighted Score***
Water Availability	1.000		37%	0.3700
Likelihood of Future Intake Sedimentation	1.000		19%	0.1900
Ease and Cost of Water Delivery	1.000		14%	0.1400
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.513		10%	0.0513
Expressed Interest in Nearby Location by New Industry	0.662		6%	0.0397
Water Quality	1.000		4%	0.0400
Distance to Nearby Towns and Existing Industrial Facilities	0.697		4%	0.0279
Impacts to Areas of Natural, Cultural, and Historical Significance	0.500		3%	0.0150
Federal and State Permitting Requirements	1.000		2%	0.0200
Impacts to Recreation	1.000		1%	0.0100

Initial site identification for the Study was conducted and presented to DWR during an in-progress review meeting to get feedback on Study results. The initial site identification was presented to DWR in a memorandum included in Appendix C – Technical Memoranda.

7.1 Intake Site Identification

The intake sites identified in the Study incorporated comments from DWR on the progress meeting presentation and technical memorandum dated August 26, 2024. Major refinements between the initial site identification and final site identification included:

- Updating the Likelihood of Future Intake Sedimentation criterion by digitizing and incorporating the latest version of the turbidity polygon to the model. This update impacted the cell scores for this criterion within the upper reaches of the Study.
- Splitting infrastructure data sources along the Study corridor thalweg. This update prevented instances of cells measuring the distance to pieces of infrastructure on the opposite bank of the river/lake.
- Narrowing down subsurface options to smaller sections of the identified aquifers by truncating the identified aquifers to within 5000 feet of the Study area shoreline.

7.1.1 Surface Water Intake Site Identification

The grid cell with the highest overall score in each reach was identified as the top-ranking intake site location in that reach. The top-ranking site, as well as maximum cell scores within each of the ten sub-reaches are shown below in order of highest scores in Table 27. The top-ranking surface water sites per sub-reach are shown below in Figure 14.

Table 27. Identified surface water sites summary.

Sub-Reach Name	*Rank*[3]	*Maximum Cell Score*
Garrison Dam to Washburn, Right	S-1	0.922
Garrison Dam to Washburn, Right Alternative	S-A-1	0.922
Garrison Dam to Washburn, Left	S-2	0.921
Fort Berthold to Garrison Dam, Left	S-3	0.873
Fort Berthold to Garrison Dam, Right	S-4	0.868
Fort Berthold, Right	S-5	0.832
Fort Berthold, Left	S-6	0.828
Williston to Fort Berthold, Left	S-7	0.737
Williston to Fort Berthold, Right	S-8	0.702
State Line to Willison, Left	S-9	0.639
State Line to Willison, Right	S-10	0.622

[3] "S" in the "Rank" column stands for "Surface" and the following number is the site's rank. "A" stands for "Alternative", indicating the site is an alternative to the site with the same rank.

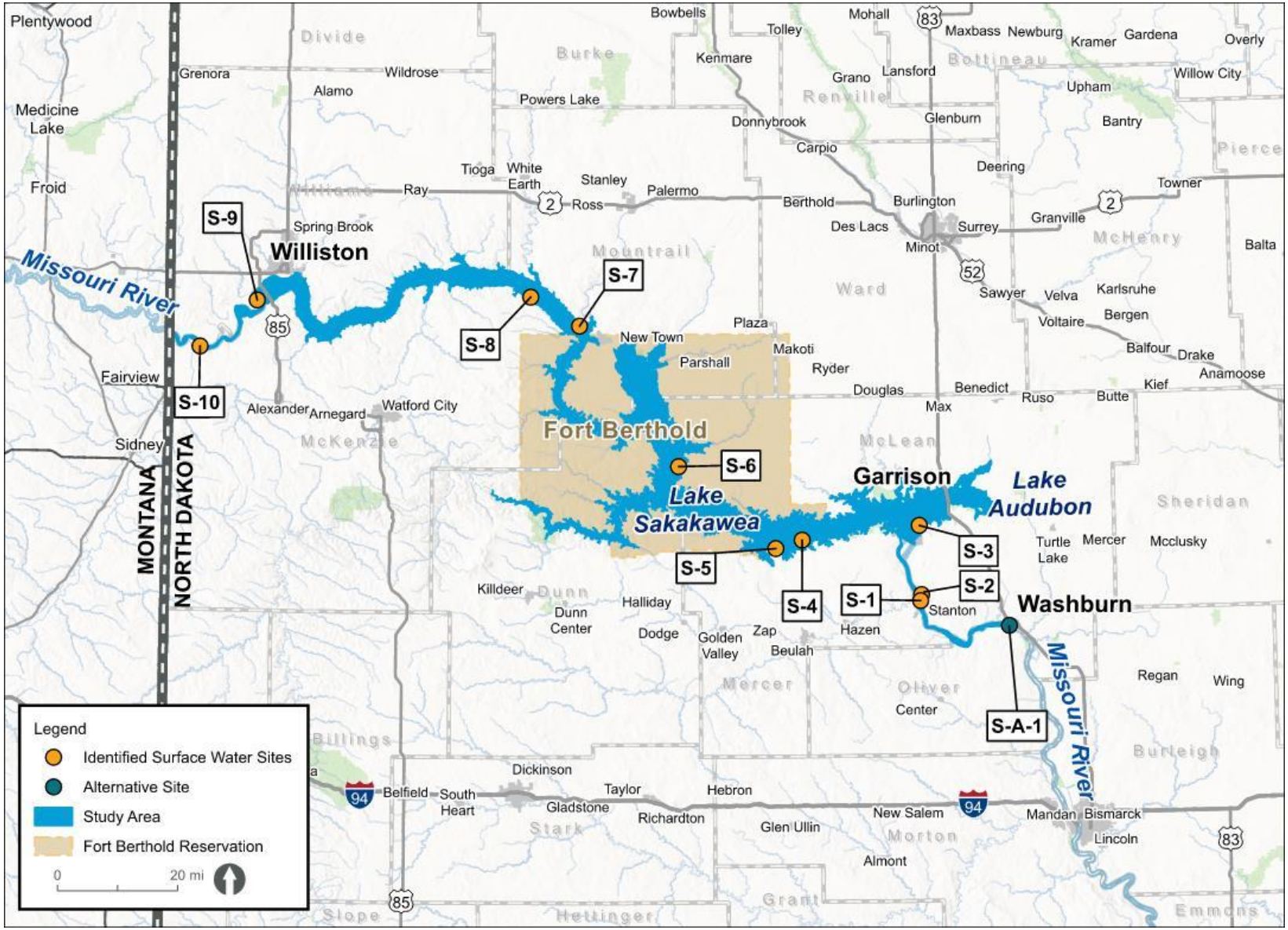


Figure 14. Top-ranking identified surface water sites.

7.1.1.1 State Line to Williston Left

The grid cell with the highest overall score in the State Line to Williston Left reach was WMT0135L. The grid cell and surrounding cells are illustrated in Figure 15. The overall score of the site is 0.639. Table 28 provides the overall and criteria group scores for the grid cell. The site offers a perfect score in Ease and Cost of Water Delivery.

This site is located in Williams County, approximately five miles southwest of the City of Williston. The site offers sufficient access from 141st Avenue Northwest. The site is located 2.5 miles from the nearest three-phase power source and is approximately 15 miles southeast of Pioneer Generating Station. The nearest rail line is 1.5 miles away and owned by Burlington Northern Santa Fe. The nearest natural gas pipeline identified by HIFLD is 0.7 miles away. Industries have expressed significant interest in this reach, with the nearest interest being approximately five miles away in Trenton.

The site is located in a historically turbid area with high sediment aggradation potential. It is adjacent to land-based sources, activities, facilities, or conditions that may contribute to potential water quality impairments. There is moderate risk of aquatic nuisance infestation within this reach, due to moderate recreation trends compared to other reaches in the Study. It is not near any known sites of cultural or historical significance. It is also not located within an unbroken grassland, as identified by the NDGFD. This reach is located within Piping Plover critical habitat, which may create additional coordination requirements with USFWS. It is not located within a state park or near any recreational facilities.

The land above the ordinary high-water mark at this site is owned by the USACE. This requires increased coordination to construct an industrial intake. Flooding at this site is unlikely, but potential for uncontrolled flows from the Yellowstone River and increased output from the Fort Peck Dam should be acknowledged when considering intake construction.

The State Line to Williston reach has some of the most difficult conditions for sedimentation of an intake due to the aggrading nature of the reach. This intake location as well as others in the reach will likely experience difficulties with sediment. Additionally, this area experiences high turbidity, as mentioned during coordination discussions with the Director of WAWSA. There are some engineered solutions to improve the sedimentation issue, but the risks cannot be completely mitigated. In-river strategies to mitigate sedimentation issues are listed below:

- Screening with the inclusion of an air burst or raw water back flush system.
- Incorporation of a dredging maintenance plan and permitting from the onset of the site development.
- Construction of in-river or bank-based features to manage potential sedimentation.
- Secondary floating intakes to reduce sedimentation in non-ice effected seasons.

Out-of-river strategies to improve quality of raw water associated with these sites include the inclusion of a pretreatment step prior to conveyance to the point of use of the water. Pretreatment options are listed below:

- Use of sedimentation ponds and coagulants.
- Construction of a vortex sediment/grit separation mechanical system.
- Construction of other mechanical systems for sediment removal.

Table 28. Top-ranking surface water intake site identified in the State Line to Williston Left reach.

STATE LINE TO WILLISTON, LEFT				
GRID CELL NAME	**MTW0135L**			
OVERALL SCORE	**0.639**			
Criterion	***Criterion Score***	***X***	***Criterion Weight***	***= Weighted Score***
Water Availability	0.750		37%	0.2775
Likelihood of Future Intake Sedimentation	0.000		19%	0.0000
Ease and Cost of Water Delivery	1.000		14%	0.1400
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.830		10%	0.0830
Expressed Interest in Nearby Location by New Industry	0.992		6%	0.0600
Water Quality	0.275		4%	0.0110
Distance to Nearby Towns and Existing Industrial Facilities	0.715		4%	0.0286
Impacts to Areas of Natural, Cultural, and Historical Significance	0.750		3%	0.0225
Federal and State Permitting Requirements	0.500		2%	0.0100
Impacts to Recreation	0.667		1%	0.0067

Figure 15. Top-ranking surface water intake site and adjacent cells identified in the State Line to Williston Left reach.

7.1.1.2 State Line to Williston Right

The grid cell with the highest overall score in the State Line to Williston Right reach was WMT0218R. The grid cell and surrounding cells are illustrated in Figure 16. The overall score of the site is 0.622. Table 29 provides the overall and criteria group scores for the grid cell. The site offers a perfect score in Ease and Cost of Water Delivery and Impacts to Recreation.

This site is located in McKenzie County, approximately three miles southeast of the City of Buford. The site lies in the floodplain of both the Missouri River and Yellowstone River. The site offers sufficient access from 157th Avenue Northwest. The site is located 4.6 miles from the nearest three-phase power source and is approximately 18.5 miles south of Pioneer Generating Station. The nearest rail line is owned by Burlington Northern Santa Fe and is located four miles away. The nearest natural gas pipeline identified by HIFLD is approximately 20 miles away. Industries have expressed moderate interest in this reach, with the nearest interest being approximately eight miles away in Trenton.

The site is located in a historically turbid area with high sediment aggradation potential. It is adjacent to land-based sources, activities, facilities, or conditions that may contribute to potential water quality impairments. There is moderate risk of aquatic nuisance infestation within this reach, due to moderate recreation trends compared to other reaches in the Study. It is not near any known sites of cultural or historical significance. It is also not located within an unbroken grassland, as identified by NDGFD. This reach is located within Piping Plover critical habitat, which may create additional coordination requirements with USFWS. It is not located within a state park or near any recreational facilities.

The land above the ordinary high-water mark at this site is privately owned, which may require less coordination and permitting with state and federal agencies. Potential for uncontrolled flows from the Yellowstone River and increased output from the Fort Peck Dam should be acknowledged when considering for flooding potential during detailed site analysis prior to intake construction. This site is in a region that is susceptible to landslides, as shown in Figure 7.

The State Line to Williston reach has some of the most difficult conditions for sedimentation of an intake due to the aggrading nature of the reach. This intake location as well as others in the reach will likely experience difficulties with sediment. Additionally, this area experiences high turbidity, as mentioned during coordination discussions with the Director of WAWSA. There are some engineered solutions to improve the sedimentation issue, but the risks cannot be completely mitigated. In-river strategies to mitigate sedimentation issues are listed below:

- Screening with the inclusion of an air burst or raw water back flush system.
- Incorporation of a dredging maintenance plan and permitting from the onset of the site development.
- Construction of in-river or bank-based features to manage potential sedimentation.
- Secondary floating intakes to reduce sedimentation in non-ice effected seasons.

Out-of-river strategies to improve quality of raw water associated with these sites include the inclusion of a pretreatment step prior to conveyance to the point of use of the water. Pretreatment options are listed below:

- Use of sedimentation ponds and coagulants.
- Construction of a vortex sediment/grit separation mechanical system.
- Construction of other mechanical systems for sediment removal.

Table 29. Top-ranking surface water intake site identified in the State Line to Williston Right reach.

STATE LINE TO WILLISTON, RIGHT				
GRID CELL NAME	**MTW0218R**			
OVERALL SCORE	**0.622**			
Criterion	***Criterion Score***	***X***	***Criterion Weight***	***= Weighted Score***
Water Availability	0.750		37%	0.2775
Likelihood of Future Intake Sedimentation	0.000		19%	0.0000
Ease and Cost of Water Delivery	1.000		14%	0.1400
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.731		10%	0.0731
Expressed Interest in Nearby Location by New Industry	0.835		6%	0.0501
Water Quality	0.275		4%	0.0110
Distance to Nearby Towns and Existing Industrial Facilities	0.516		4%	0.0206
Impacts to Areas of Natural, Cultural, and Historical Significance	1.000		3%	0.0300
Federal and State Permitting Requirements	0.500		2%	0.0100
Impacts to Recreation	1.000		1%	0.0100

Top-Ranking Identified Site - MTW0218R
State Line to Williston : Right

Identified Surface Water Grid Cells

0 2 mi

Figure 16. Top-ranking surface water intake site and adjacent cells identified in the State Line to Williston Right reach.

7.1.1.3 Williston to Fort Berthold Left

The grid cell with the highest overall score in the Williston to Fort Berthold Left reach was FBW0532L. The grid cell and surrounding cells are illustrated in Figure 17. The overall score of the site is 0.737. Table 30 provides the overall and criteria group scores for the grid cell. The site offers perfect scores in Likelihood of Future Intake Sedimentation and Impacts to Recreation.

This site is located upstream of Sanish Bay in Mountrail County, approximately three miles northwest of the City of New Town. The site offers sufficient access from ND State Highway 1804. The site is located approximately four miles from the nearest three-phase power source and is 10.5 miles southwest of Robinson Lake Gas Plant. The nearest rail line is approximately four miles away at the City of New Town and owned by Canadian Pacific. The nearest natural gas pipeline identified by HIFLD is approximately 20 miles away. Industries have expressed significant interest in this reach, with the nearest interest being approximately 59 miles away in Trenton.

Many of the banks along this reach are steep and the water level can vary drastically as Lake Sakakawea is managed as part of the Missouri River System. This could cause increased risk of wave action erosion and slides of the bank that may need to be accounted for in intake design. Flooding at this site is unlikely, as Lake Sakakawea water levels are monitored as part of the Missouri River System. The location is in close proximity to the permanent pool of Lake Sakakawea.

The site is not located in a historically turbid area, but it is adjacent to land-based sources, activities, facilities, or conditions that may contribute to potential water quality impairment. There is moderate risk of aquatic nuisance infestation within this reach, due to moderate recreation trends compared to other reaches in the Study. It is not near any known sites of cultural or historical significance. It is located within an unbroken grassland, as identified by NDGFD. This reach is located within Piping Plover critical habitat, which may create additional coordination requirements with USFWS. It is not located within a state park or near any recreational facilities.

The lands along the boundary of Lake Sakakawea are owned and managed by USACE below elevation 1854.0 (LPD), as the lands were procured for the management of Garrison Dam. This requires increased coordination to construct an industrial intake. The site is not located within the historic Missouri River channel and a Sovereign Lands permit is not required.

Table 30. Top-ranking surface water intake site identified in the Williston to Fort Berthold Left reach.

WILLISTON TO FORT BERTHOLD, LEFT				
GRID CELL NAME	**WFB0532L**			
OVERALL SCORE	**0.737**			
Criterion	***Criterion Score***	***X***	***Criterion Weight***	***= Weighted Score***
Water Availability	0.968		37%	0.3582
Likelihood of Future Intake Sedimentation	1.000		19%	0.1900
Ease and Cost of Water Delivery	0.250		14%	0.0350
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.397		10%	0.0397
Expressed Interest in Nearby Location by New Industry	0.508		6%	0.0305
Water Quality	0.625		4%	0.0250
Distance to Nearby Towns and Existing Industrial Facilities	0.832		4%	0.0333
Impacts to Areas of Natural, Cultural, and Historical Significance	0.500		3%	0.0150
Federal and State Permitting Requirements	0.000		2%	0.0000
Impacts to Recreation	1.000		1%	0.0100

Figure 17. Top-ranking surface water intake site and adjacent cells identified in the Williston to Fort Berthold Left reach.

7.1.1.4 Williston to Fort Berthold Right

The grid cell with the highest overall score in the Williston to Fort Berthold Right reach was FBW0450R. The grid cell and surrounding cells are illustrated in Figure 18. The overall score of the site is 0.702. Table 31 provides the overall and criteria group scores for the grid cell. The site offers a perfect score in Likelihood of Future Intake Sedimentation.

This site is located in McKenzie County, approximately ten miles northwest of the Four Bears Village and 18 miles northwest of Demicks Lake Gas Plant. A portion of the site exists within Antelope Creek WMA, which will require coordination with the NDGFD Director to construct an industrial intake. This causes the site to score lower in the Impacts to Recreation criterion. There is limited access from 99th Avenue Northwest and unnamed gravel roads that support oil development.

The site is located 4.5 miles from the nearest three-phase power source. The nearest rail line is approximately 40 miles away in Watford City and owned by Burlington Northern Sante Fe. The nearest natural gas pipeline identified by HIFLD is approximately 17 miles away near the City of Ross. Industries have expressed moderate interest in this reach, with the nearest interest being 50 miles away in Trenton.

Many of the banks along this reach are steep and the water level can vary drastically as Lake Sakakawea is managed as part of the Missouri River System. This could cause increased risk of wave action erosion and slides of the bank that may need to be accounted for in intake design. Flooding at this site is unlikely, as Lake Sakakawea water levels are monitored as part of the Missouri River System. This site is in a region that is susceptible to landslides, as shown in Figure 7. The location is in close proximity to the permanent pool of Lake Sakakawea.

The site is not located in a historically turbid area and is not adjacent to any locations included in the potential water quality impairments criterion. There is moderate risk of aquatic nuisance infestation within this reach, due to moderate recreation trends compared to other reaches in the Study. It is not near any known sites of cultural or historical significance. It is located within an unbroken grassland, as identified by NDGFD. This reach is located within Piping Plover critical habitat, which may create additional coordination requirements with USFWS. It is not located within a state park or near any recreational facilities.

The lands along the boundary of Lake Sakakawea are owned and managed by USACE below elevation 1854.0 (LPD), as the lands were procured for the management of Garrison Dam. Lands above elevation 1854.0 (LPD) are managed by NDGFD. This requires increased coordination to construct an industrial intake. The site is not located within the historic Missouri River channel and a Sovereign Lands permit is not required.

Table 31. Top-ranking surface water intake site identified in the Williston to Fort Berthold Right reach.

WILLISTON TO FORT BERTHOLD, RIGHT				
GRID CELL NAME	**WFB0450R**			
OVERALL SCORE	**0.702**			
Criterion	***Criterion Score***	***X***	***Criterion Weight***	***= Weighted Score***
Water Availability	0.915		37%	0.3386
Likelihood of Future Intake Sedimentation	1.000		19%	0.1900
Ease and Cost of Water Delivery	0.250		14%	0.0350
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.456		10%	0.0456
Expressed Interest in Nearby Location by New Industry	0.440		6%	0.0264
Water Quality	0.625		4%	0.0250
Distance to Nearby Towns and Existing Industrial Facilities	0.484		4%	0.0194
Impacts to Areas of Natural, Cultural, and Historical Significance	0.500		3%	0.0150
Federal and State Permitting Requirements	0.000		2%	0.0000
Impacts to Recreation	0.667		1%	0.0067

Figure 18. Top-ranking surface water intake site and adjacent cells identified in the Williston to Fort Berthold Right reach.

7.1.1.5 Fort Berthold Left

The grid cell with the highest overall score in the Fort Berthold Left reach was FB0923L. The grid cell and surrounding cells are illustrated in Figure 19. The overall score of the site is 0.828. Table 32 provides the overall and criteria group scores for the grid cell. The site offers perfect scores in Likelihood of Future Intake Sedimentation and Ease and Cost of Water Delivery.

This site is located in McLean County, approximately 18.5 miles south of the City of Parshall and approximately 2.5 miles south of Deepwater Creek Bay. There is limited roadway access from 19th Street Northwest. The site falls within the Deepwater Creek WMA, which will require coordination with the NDGFD Director to construct an industrial intake. This causes the site to score lower in the Impacts to Recreation criterion.

The site is located 17 miles from the nearest three-phase power source and is 28 miles northwest of Antelope Valley Coal-Fired Power Plant. The nearest rail line is owned by Dakota Missouri Valley Western and is located 22 miles away at the City of Garrison. The nearest natural gas pipeline identified by HIFLD is 43.5 miles away. Industries have expressed significant interest in this reach, with the nearest being approximately 57 miles away in Minot.

Many of the banks along this reach are steep and the water level can vary drastically as Lake Sakakawea is managed as part of the Missouri River System. This could cause increased risk of wave action erosion and slides of the bank that may need to be accounted for in intake design. Flooding at this site is unlikely, as Lake Sakakawea water levels are monitored as part of the Missouri River System. The location is in close proximity to the permanent pool of Lake Sakakawea.

The site is not located in a historically turbid area and is not adjacent to any locations included in the potential water quality impairments criterion. There is significant risk of aquatic nuisance infestation within this reach, due to high recreation trends compared to other reaches in the Study. It is not near any known sites of cultural or historical significance. It is located within an unbroken grassland, as identified by NDGFD. This reach is located within Piping Plover critical habitat, which may create additional coordination requirements with USFWS. It is not located within a state park or near any recreational facilities.

This site is within the boundary of the Fort Berthold Reservation, which is an independent territory of the Mandan, Hidatsa, and Arikara Nation, also known as the Three Affiliated Tribes. Coordination and permitting requirements within the Fort Berthold Reservation vary depending on whether the tract is individual trust property, tribal trust property, or fee property. Any trust property impacted by a project will need to be coordinated with both the Tribe and the Bureau of Indian Affairs. It will therefore be important to coordinate any projects that fall within the reservation boundary directly with the Three Affiliated Tribes.

Table 32. Top-ranking surface water intake site identified in the Fort Berthold Left reach.

FORT BERTHOLD, LEFT				
GRID CELL NAME	**FB0923L**			
OVERALL SCORE	**0.828**			
Criterion	***Criterion Score***	***X***	***Criterion Weight***	***= Weighted Score***
Water Availability	0.897		37%	0.3319
Likelihood of Future Intake Sedimentation	1.000		19%	0.1900
Ease and Cost of Water Delivery	1.000		14%	0.1400
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.463		10%	0.0463
Expressed Interest in Nearby Location by New Industry	0.722		6%	0.0433
Water Quality	0.750		4%	0.0300
Distance to Nearby Towns and Existing Industrial Facilities	0.622		4%	0.0249
Impacts to Areas of Natural, Cultural, and Historical Significance	0.500		3%	0.0150
Federal and State Permitting Requirements	0.000		2%	0.0000
Impacts to Recreation	0.667		1%	0.0067

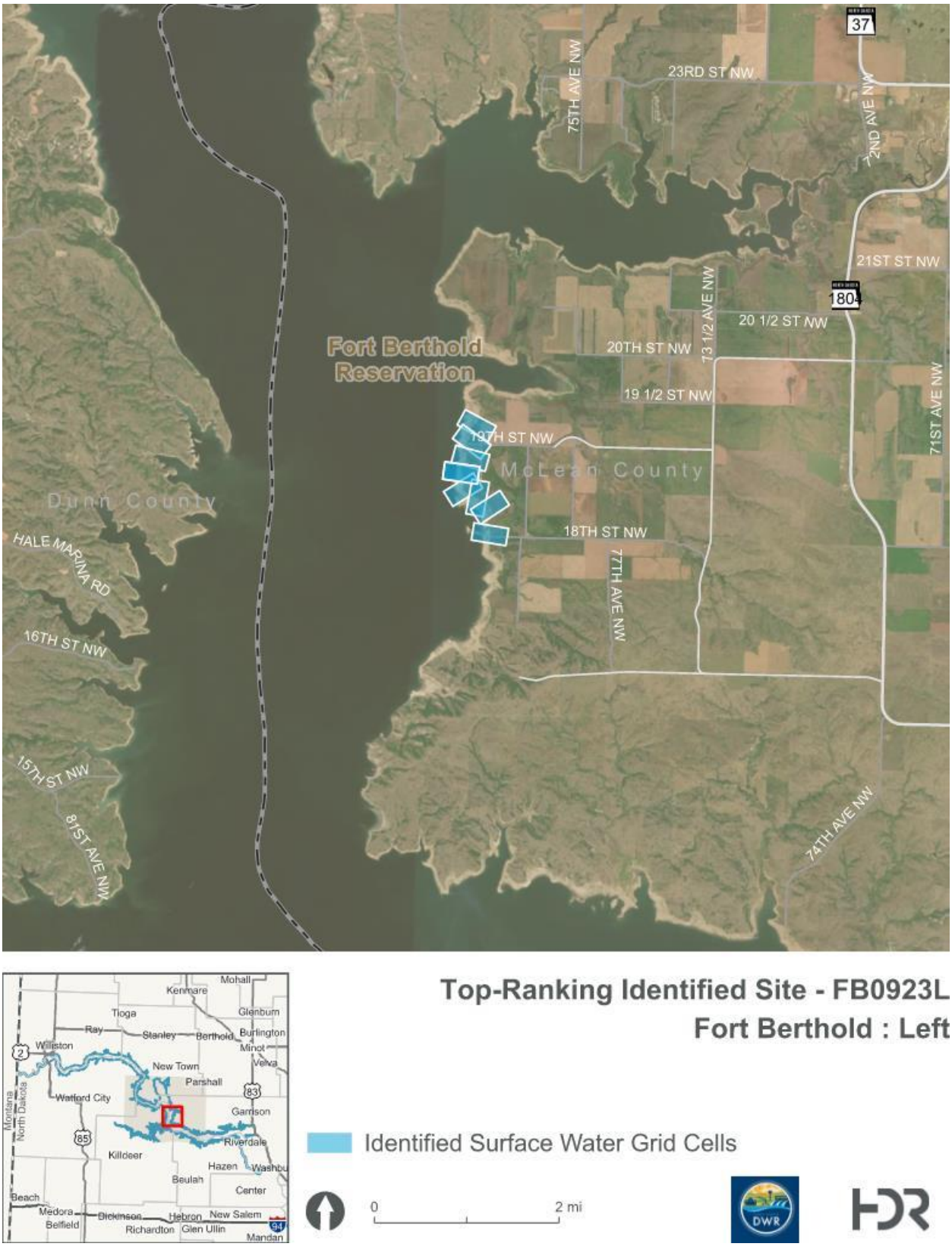


Figure 19. Top-ranking surface water intake site and adjacent cells identified in the Fort Berthold Left reach.

7.1.1.6 Fort Berthold Right

The grid cell with the highest overall score in the Fort Berthold Right reach was FB2386R. The grid cell and surrounding cells are illustrated in Figure 20. The overall score of the site is 0.832. Table 33 provides the overall and criteria group scores for the grid cell. The site offers perfect scores in the Likelihood of Future Intake Sedimentation and Ease and Cost of Water Delivery criteria.

This site is located in Mercer County at the southeast boundary of the Fort Berthold Reservation, approximately 13 miles north of the City of Zap. The site is within 1,500 feet of Hille State WMA. Constructing an intake within the boundaries of the WMA will require coordination with the NDGFD Director. This causes the site to score lower in the Impacts to Recreation criterion. The only access road is 62nd Avenue Northwest.

The site is located 1.7 miles from the nearest three-phase power source. Dakota Gasification Company, Coteau Mine, and Basin Electric Cooperative Antelope Station are located approximately eight miles south of the site. The nearest rail line is owned by Burlington Northern Santa Fe and is located at Coteau Mine. The nearest natural gas pipeline identified by HIFLD is 34.5 miles away. Industries have expressed moderate interest in this reach, with the nearest interest being approximately 15 miles away in Beulah. Additionally, the site is near Basin Electric's intake for Antelope Valley Station which also serves as the Southwest Pipeline Project's intake.

Many of the banks along this reach are steep and the water level can vary drastically as Lake Sakakawea is managed as part of the Missouri River System. This could cause increased risk of wave action erosion and slides of the bank that may need to be accounted for in intake design. Flooding at this site is unlikely, as Lake Sakakawea water levels are monitored as part of the Missouri River System. The location is in proximity to the permanent pool of Lake Sakakawea.

The site is not located in a historically turbid area and is not adjacent to any locations included in the potential water quality impairments criterion. There is significant risk of aquatic nuisance infestation within this reach, due to high recreation trends compared to other reaches in the Study. It is not near any known sites of cultural or historical significance. It is located within an unbroken grassland, as identified by NDGFD. This reach is located within Piping Plover critical habitat, which may create additional coordination requirements with USFWS. It is not located within a state park or near any recreational facilities.

This site is within the boundary of the Fort Berthold Reservation, which is an independent territory of the Mandan, Hidatsa, and Arikara Nation, also known as the Three Affiliated Tribes. Coordination and permitting requirements within the Fort Berthold Reservation vary depending on whether the tract is individual trust property, tribal trust property, or fee property. Any trust property impacted by a project will need to be coordinated with both the Tribe and the Bureau of Indian Affairs. It will therefore be important to coordinate any projects that fall within the reservation boundary directly with the Three Affiliated Tribes.

Table 33. Top-ranking surface water intake site identified in the Fort Berthold Right reach.

FORT BERTHOLD, RIGHT				
GRID CELL NAME	FB2386R			
OVERALL SCORE	0.832			
Criterion	*Criterion Score*	*X*	*Criterion Weight*	*= Weighted Score*
Water Availability	0.881		37%	0.3260
Likelihood of Future Intake Sedimentation	1.000		19%	0.1900
Ease and Cost of Water Delivery	1.000		14%	0.1400
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.552		10%	0.0552
Expressed Interest in Nearby Location by New Industry	0.769		6%	0.0461
Water Quality	0.750		4%	0.0300
Distance to Nearby Towns and Existing Industrial Facilities	0.566		4%	0.0226
Impacts to Areas of Natural, Cultural, and Historical Significance	0.500		3%	0.0150
Federal and State Permitting Requirements	0.000		2%	0.0000
Impacts to Recreation	0.667		1%	0.0067

Figure 20. Top-ranking surface water intake site and adjacent cells identified in the Fort Berthold Right reach.

7.1.1.7 Fort Berthold to Garrison Dam Left

The grid cell with the highest overall score in the Fort Berthold to Garrison Dam Left reach was GFB0039L. The grid cell and surrounding cells are illustrated in Figure 21. The overall score of the site is 0.873. Table 34 provides the overall and criteria group scores for the grid cell. The site offers perfect scores in Likelihood of Future Intake Sedimentation and Ease and Cost of Water Delivery.

This site is located in McLean County, approximately 1.5 miles north of the City of Riverdale. The site falls within the Wolf Creek WMA, which will require coordination with the NDGFD Director to construct an industrial intake. This causes the site to score lower in the Impacts to Recreation criterion. Due to the presence of a WMA, 38th Avenue Northwest is the only access road.

The site is located approximately two miles from the nearest three-phase power source and is 3.5 miles northwest of the Garrison Dam Hydroelectric Power Plant. The nearest rail line, owned by Dakota Missouri Valley Western, is located five miles northeast along Highway 83. The nearest natural gas pipeline identified by HIFLD is approximately 12 miles away. Industries have expressed significant interest in this reach, with the nearest interest being 12 miles away in Underwood.

Many of the banks along this reach are steep and the water level can vary drastically as Lake Sakakawea is managed as part of the Missouri River System. This could cause increased risk of wave action erosion and slides of the bank that may need to be accounted for in intake design. Flooding at this site is unlikely, as Lake Sakakawea water levels are monitored as part of the Missouri River System. The location is in close proximity to the permanent pool of Lake Sakakawea.

The site is not located in a historically turbid area and is not adjacent to any locations included in the potential water quality impairments criterion. There is significant risk of aquatic nuisance infestation within this reach, due to high recreation trends compared to other reaches in the Study. It is not near any known sites of cultural or historical significance. It is located within an unbroken grassland, as identified by NDGFD. This reach is located within Piping Plover critical habitat, which may create additional coordination requirements with USFWS. It is not located within a state park or near any recreational facilities.

The lands along the boundary of Lake Sakakawea are owned and managed by USACE below elevation 1854.0 (LPD), as the lands were procured for the management of Garrison Dam. Lands above elevation 1854.0 (LPD) are managed by NDGFD. This requires increased coordination to construct an industrial intake. The site is not located within the historic Missouri River channel and a Sovereign Lands permit is not required.

Table 34. Top-ranking surface water intake site identified in the Fort Berthold to Garrison Dam Left reach.

FORT BERTHOLD TO GARRISON DAM, LEFT			
GRID CELL NAME	**FBG0039L**		
OVERALL SCORE	**0.873**		
Criterion	***Criterion Score*** **X**	***Criterion Weight*** **=**	***Weighted Score***
Water Availability	0.961	37%	0.3556
Likelihood of Future Intake Sedimentation	1.000	19%	0.1900
Ease and Cost of Water Delivery	1.000	14%	0.1400
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.513	10%	0.0513
Expressed Interest in Nearby Location by New Industry	0.957	6%	0.0574
Water Quality	0.750	4%	0.0300
Distance to Nearby Towns and Existing Industrial Facilities	0.677	4%	0.0271
Impacts to Areas of Natural, Cultural, and Historical Significance	0.500	3%	0.0150
Federal and State Permitting Requirements	0.000	2%	0.0000
Impacts to Recreation	0.667	1%	0.0067

Figure 21. Top-ranking surface water intake site and adjacent cells identified in the Fort Berthold to Garrison Dam Left reach.

7.1.1.8 Fort Berthold to Garrison Dam Right

The grid cell with the highest overall score in the Fort Berthold to Garrison Dam Right reach was GFB0085R. The grid cell and surrounding cells are illustrated in Figure 22. The overall score of the site is 0.868. Table 35 provides the overall and criteria group scores for the grid cell. The site offers perfect scores in the Likelihood of Future Intake Sedimentation and Ease and Cost of Water Delivery criteria.

This site is located in Mercer County, approximately 15 miles north of the City of Beulah and 15 miles west of Pick City. It is located along 58th Avenue Northwest and spans several homes, the Hille State WMA, and the Beulah Bay Campground. The site scores lower on the Impacts to Recreation criterion due to its proximity to the WMA, which will require coordination with the NDGFD Director to construct an industrial intake.

The site is located 3.7 miles from the nearest three-phase power source and is approximately seven miles northwest of the nearest power plant. Dakota Gasification Company, Coteau Mine, and Basin Electric Cooperative Antelope Station are located approximately eight miles south of the site. The nearest rail line is owned by Burlington Northern Santa Fe and is located at Coteau Mine. The nearest natural gas pipeline identified by HIFLD is 37.5 miles away. Industries have expressed moderate interest in this reach, with the nearest interest being 15 miles away in Beulah.

Many of the banks along this reach are steep and the water level can vary drastically as Lake Sakakawea is managed as part of the Missouri River System. This could cause increased risk of wave action erosion and slides of the bank that may need to be accounted for in intake design. Flooding at this site is unlikely, as Lake Sakakawea water levels are monitored as part of the Missouri River System. The location is in close proximity to the permanent pool of Lake Sakakawea.

The site is not located in a historically turbid area and is not adjacent to any locations included in the potential water quality impairments criterion. There is significant risk of aquatic nuisance infestation within this reach, due to high recreation trends compared to other reaches in the Study. It is not near any known sites of cultural or historical significance. It is located within an unbroken grassland, as identified by NDGFD. This reach is located within Piping Plover critical habitat, which may create additional coordination requirements with USFWS.

The lands along the boundary of Lake Sakakawea are owned and managed by USACE below elevation 1854.0 (LPD), as the lands were procured for the management of Garrison Dam. Lands above elevation 1854.0 (LPD) are managed by NDGFD. This requires increased coordination to construct an industrial intake. The site is not located within the historic Missouri River channel and a Sovereign Lands permit is not required.

Table 35. Top-ranking surface water intake site identified in the Fort Berthold to Garrison Dam Right reach.

FORT BERTHOLD TO GARRISON DAM, RIGHT			
GRID CELL NAME	**FBG0085R**		
OVERALL SCORE	**0.868**		
Criterion	***Criterion Score*** ***X***	***Criterion Weight*** =	***Weighted Score***
Water Availability	0.961	37%	0.3556
Likelihood of Future Intake Sedimentation	1.000	19%	0.1900
Ease and Cost of Water Delivery	1.000	14%	0.1400
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.649	10%	0.0649
Expressed Interest in Nearby Location by New Industry	0.758	6%	0.0455
Water Quality	0.750	4%	0.0300
Distance to Nearby Towns and Existing Industrial Facilities	0.504	4%	0.0202
Impacts to Areas of Natural, Cultural, and Historical Significance	0.500	3%	0.0150
Federal and State Permitting Requirements	0.000	2%	0.0000
Impacts to Recreation	0.667	1%	0.0067

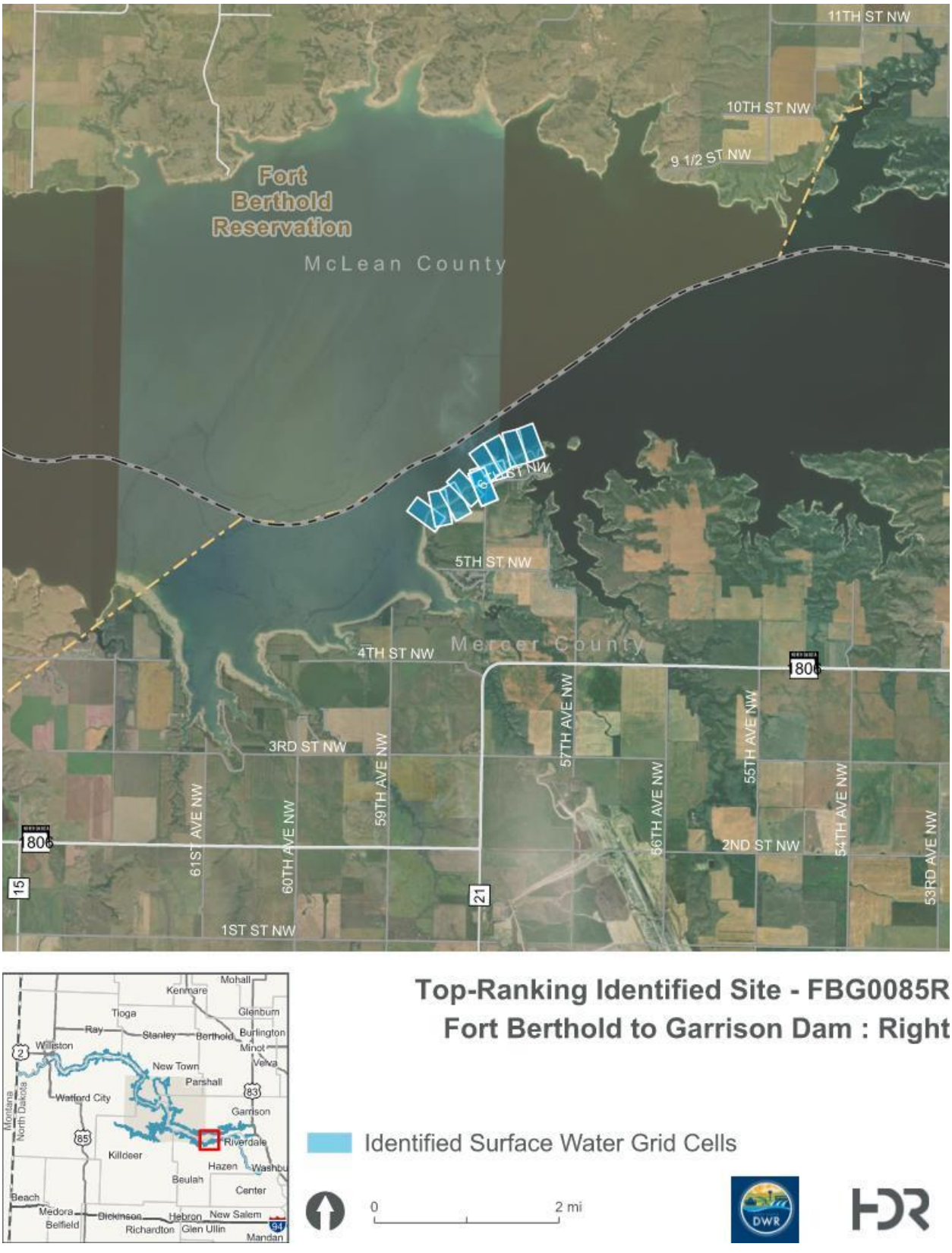


Figure 22. Top-ranking surface water intake site and adjacent cells identified in the Fort Berthold to Garrison Dam Right reach.

7.1.1.9 Garrison Dam to Washburn Left

The grid cell with the highest overall score in the Garrison Dam to Washburn Left reach was WG0052L. The grid cell and surrounding cells are illustrated in Figure 23. The overall score of the site is 0.921. Table 36 provides the overall and criteria group scores for the top-ranking cell. The site offers perfect scores in the Likelihood of Future Intake Sedimentation, Ease and Cost of Water Delivery, Water Quality, Federal and State Permitting Requirements, and Impacts to Recreation criteria.

This site is located in McLean County, approximately eight miles south of the City of Riverdale and 9.3 miles west of the Blue Flint Ethanol plant. It has sufficient access from 38th Avenue Southwest. The site is located within one mile of the nearest three-phase power source and is approximately ten miles west of Coal Creek Station. It is approximately ten miles away from the nearest rail line, owned by Dakota Missouri Valley Western. The nearest natural gas pipeline identified by HIFLD is approximately eight miles away. Industries have expressed little interest in this reach, with the nearest interest being 11 miles away in Underwood.

The site is located on an outer bend of the Missouri River, shown in Appendix D – Riverine Geomorphology Maps. There is relatively flat topography at and adjacent to the site, with little potential for landslides. Given the site's proximity to Garrison Dam, the channel thalweg is relatively stable, indicated in Figure 9. The thalweg is also located on the same side of the river as the site, leading to higher water availability. A sandbar exists upstream of this site and may contribute to increased sedimentation locally. Sandbar progression should be further analyzed for detailed intake design. However, sedimentation is generally less of a concern in this reach overall due to the erosional nature of dam proximal reaches, especially when compared to the Montana state line to Williston, ND reach of this Study. Based on aerial photography, the south side of the site may have a higher erosive potential than the north side. This is indicated by the top width and the channel being narrower at the downstream sections of the site.

Additionally, North Dakota procured aerial imagery within this reach during the 2011 flood event, which was an uncommon event with flows comparable to an annual exceedance probability (AEP) of 1 in 500 based on reporting from the USGS[11] and USACE[12]. This means a flood similar to the 2011 event has a 0.2% chance of occurring in any given year. The imagery depicts that flooding at this site did not occur, suggesting that flows or water levels less than or equal to those experienced during the 2011 event are unlikely to cause flooding at this location.

The site is not located in a historically turbid area and is not adjacent to any locations included in the potential water quality impairments criterion. There is little risk of aquatic nuisance infestation within this reach, due to colder temperatures and lower recreation trends compared to other reaches in the Study. It is not near any known sites of cultural or historical significance. It is located within an unbroken grassland, as identified by USFWS. This reach is located within Piping Plover critical habitat, which may create additional coordination requirements with USFWS. It is not located within a state park or near any recreational facilities.

The land above the ordinary high-water mark at this site is privately owned, which may require less coordination and permitting with state and federal agencies. There are several USACE-built bank stabilization structures downstream of Garrison Dam, but these structures are not located at this site. A Section 408 permit would not be required to develop an industrial intake at this location.

Table 36. Top-ranking surface water intake site identified in the Garrison Dam to Washburn Left reach.

GARRISON DAM TO WASHBURN, LEFT				
GRID CELL NAME	**GW0052L**			
OVERALL SCORE	**0.921**			
Criterion	***Criterion Score***	***X***	***Criterion Weight***	***= Weighted Score***
Water Availability	0.996		37%	0.3685
Likelihood of Future Intake Sedimentation	1.000		19%	0.1900
Ease and Cost of Water Delivery	1.000		14%	0.1400
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.692		10%	0.0692
Expressed Interest in Nearby Location by New Industry	0.739		6%	0.0443
Water Quality	1.000		4%	0.0400
Distance to Nearby Towns and Existing Industrial Facilities	0.599		4%	0.0240
Impacts to Areas of Natural, Cultural, and Historical Significance	0.500		3%	0.0150
Federal and State Permitting Requirements	1.000		2%	0.0200
Impacts to Recreation	1.000		1%	0.0100

Figure 23. Top-ranking surface water intake site and adjacent cells identified in the Garrison Dam to Washburn Left reach.

7.1.1.10 Garrison Dam to Washburn Right

The grid cell with the highest overall score in the Garrison Dam to Washburn Right reach was WG0066R. The grid cell and surrounding cells are illustrated in Figure 24. The overall score of the site is 0.922. Table 37 provides the overall and criteria group scores for the top-ranking cell. The site offers perfect scores in the Water Availability, Likelihood of Future Intake Sedimentation, Ease and Cost of Water Delivery, Water Quality, Federal and State Permitting Requirements, and Impacts to Recreation criteria.

This site is located in Mercer County, approximately three miles north of the City of Stanton and one mile east of the Knife River Indian Village. It is located at the end of 4th Street Southwest, abutting against the Missouri River. The site is located approximately 4.4 miles from the nearest available three-phase power source and is near a Basin Electric Power Cooperative coal-fired power plant. Additionally, it is near a Burlington Northern Sante Fe rail line that runs through the City of Stanton. The nearest natural gas pipeline identified by HIFLD is approximately 36 miles away. Natural gas is likely available in the City of Stanton; however, it is not reflected in the HIFLD natural gas pipeline data. Industries have expressed little interest in this reach, with the nearest interest being approximately 20 miles away in Beulah.

The site is located on a straight section of the Missouri River, transitioning out of an inner bend, shown in Appendix D – Riverine Geomorphology Maps. There is relatively flat topography at and adjacent to the site, with little potential for landslides. Given the site's proximity to Garrison Dam, the channel thalweg is relatively stable, indicated in Figure 9. Less aggradation is expected at this location given the stability of the channel compared to other riverine locations within the Study. Based on aerial photography, the east side of the identified site may have a higher erosive potential than the west side. This is indicated by the narrower channel observed at the downstream section of the site.

Additionally, North Dakota procured aerial imagery within this reach during the 2011 flood event, which was an uncommon event with flows comparable to an annual exceedance probability (AEP) of 1 in 500 based on reporting from the USGS[11] and USACE[12]. This means a flood similar to the 2011 event has a 0.2% chance of occurring in any given year. The imagery depicts that flooding at this site did not occur, suggesting that flows or water levels less than or equal to those experienced during the 2011 event are unlikely to cause flooding at this location.

The site is not located in a historically turbid area and is not adjacent to any locations included in the potential water quality impairments criterion. There is little risk of aquatic nuisance infestation within this reach, due to colder temperatures and lower recreation trends compared to other reaches in the Study. This reach is located within Piping Plover critical habitat, which may create additional coordination requirements with USFWS. It is not located within a state park or near any recreational facilities.

The land above the ordinary high-water mark at this site is privately owned, which may require less coordination and permitting with state and federal agencies. There are several USACE-built bank stabilization structures downstream of Garrison Dam, but these structures are not located at this site. A Section 408 permit would not be required to develop an industrial intake at this location.

A pipeline associated with a potential industrial intake located at this site would need to cross the boundary of the Knife River Indian Village Historic Site, which will require additional coordination with the National Park Service. For this reason, an alternative site has been chosen in this reach, discussed below in Section 7.1.1.10a Garrison Dam to Washburn Right Alternative.

Table 37. Top-ranking surface water intake site identified in the Garrison Dam to Washburn Right reach.

GARRISON DAM TO WASHBURN, RIGHT			
GRID CELL NAME	**GW0066R**		
OVERALL SCORE	**0.922**		
Criterion	***Criterion Score*** **X**	***Criterion Weight*** **=**	***Weighted Score***
Water Availability	1.000	37%	0.3700
Likelihood of Future Intake Sedimentation	1.000	19%	0.1900
Ease and Cost of Water Delivery	1.000	14%	0.1400
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.679	10%	0.0679
Expressed Interest in Nearby Location by New Industry	0.664	6%	0.0398
Water Quality	1.000	4%	0.0400
Distance to Nearby Towns and Existing Industrial Facilities	0.739	4%	0.0296
Impacts to Areas of Natural, Cultural, and Historical Significance	0.500	3%	0.0150
Federal and State Permitting Requirements	1.000	2%	0.0200
Impacts to Recreation	1.000	1%	0.0100

Figure 24. Top-ranking surface water intake site and adjacent cells identified in the Garrison Dam to Washburn Right reach.

7.1.1.10a Garrison Dam to Washburn Right Alternative

The grid cell with the highest overall score in the Garrison Dam to Washburn Right reach was WG0066R. A pipeline extending from this site would cross the Knife River Indian Villages Historic Site, which will require additional coordination with the National Park Service. For this reason, an alternative site has been chosen in this reach.

The alternative grid cell with the highest overall score in the Garrison Dam to Washburn Right reach was GW0191R. The grid cell and surrounding cells are illustrated in Figure 25. The overall score of the site is 0.922. Table 38 provides the overall and criteria group scores for the alternative cell. The site offers perfect scores in the Water Availability, Likelihood of Future Intake Sedimentation, Ease and Cost of Water Delivery, and Water Quality criteria. The site falls within the Lewis and Clark WMA, which will require coordination with the NDGFD Director to construct an industrial intake. This causes the site to score lower in the Impacts to Recreation criterion.

This site is located in Oliver County, approximately 0.5 miles west of the City of Washburn. It is located on 9th Street Southwest. The site is located approximately 6 miles from the nearest available three-phase power source and is approximately 12 miles east of a Basin Electric Power Cooperative coal-fired power plant. There is three-phase power located 0.1 miles away, across the river in Washburn, which may be able to be routed across the river at an existing bridge. Additionally, it is 2 miles from a Burlington Northern Sante Fe rail line. The nearest natural gas pipeline identified by HIFLD is approximately 30 miles away. Industries have expressed little interest in this reach, with the nearest interest being approximately 34 miles away in Beulah.

The site is located on a straight section of the Missouri River, transitioning out of an inner bend, shown in Appendix D – Riverine Geomorphology Maps. There is relatively flat topography at and adjacent to the site, with little potential for landslides. Given the site's proximity to Garrison Dam, the channel thalweg is relatively stable, indicated in Figure 9. Less aggradation is expected at this location given the stability of the channel compared to other riverine locations within the Study. Based on aerial photography, the north side of the identified site may have a higher erosive potential than the south side. This is indicated by the top width and the narrower channel observed at both the upstream and downstream sections of the site.

Additionally, North Dakota procured aerial imagery within this reach during the 2011 flood event, which was an uncommon event with flows comparable to an annual exceedance probability (AEP) of 1 in 500 based on reporting from the USGS[11] and USACE[12]. This means a flood similar to the 2011 event has a 0.2% chance of occurring in any given year. The imagery depicts that flooding at this site did not occur, suggesting that flows or water levels less than or equal to those experienced during the 2011 event are unlikely to cause flooding at this location.

The site is not located in a historically turbid area and is not adjacent to any locations included in the potential water quality impairments criterion. There is little risk of aquatic nuisance infestation within this reach, due to colder temperatures and lower recreation trends compared to other reaches in the Study. This reach is located within Piping Plover critical habitat, which may create additional coordination requirements with USFWS. It is not located within a state park or near any recreational facilities.

The land above the ordinary high-water mark at this site is owned by NDGFD, which may require increased coordination to construct an industrial intake. The site is located adjacent to Oliver County state mineral trust lands, causing it to score lower in the permitting requirements criterion. There are several USACE-built bank stabilization structures downstream of Garrison Dam, but these structures are not located at this site. A Section 408 permit would not be required to develop an industrial intake at this location.

Table 38. Alternative surface water intake site identified in the Garrison Dam to Washburn Right reach.

GARRISON DAM TO WASHBURN, RIGHT ALTERNATIVE				
GRID CELL NAME	**GW0191R**			
OVERALL SCORE	**0.922**			
Criterion	***Criterion Score***	***X***	***Criterion Weight***	***= Weighted Score***
Water Availability	1.000		37%	0.3700
Likelihood of Future Intake Sedimentation	1.000		19%	0.1900
Ease and Cost of Water Delivery	1.000		14%	0.1400
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.680		10%	0.0680
Expressed Interest in Nearby Location by New Industry	0.672		6%	0.0403
Water Quality	1.000		4%	0.0400
Distance to Nearby Towns and Existing Industrial Facilities	0.851		4%	0.0340
Impacts to Areas of Natural, Cultural, and Historical Significance	0.750		3%	0.0225
Federal and State Permitting Requirements	0.500		2%	0.0100
Impacts to Recreation	0.667		1%	0.0067

Figure 25. Alternative surface water intake site and adjacent cells identified in the Garrison Dam to Washburn Right reach.

7.1.2 Subsurface Intake Site Identification

The 14 primary and 4 secondary aquifers identified in the Study area were described in Section 2.2.2 Subsurface Sites – Identified Aquifers. From the 18 identified aquifers, the five top-ranking aquifers were shortlisted based on the average grid cell scores within each aquifer. This process was conducted to identify aquifers that would most likely support an industrial intake capable of producing at least 15,000 AF/yr, meeting the intent of the Study. Following identification of the top-ranking aquifers, the top-ranking grid cells were identified within each aquifer as the top-ranking subsurface intake sites.

Figure 26 shows the 14 primary and four secondary aquifers and identifies the five shortlisted aquifers. Subsurface sites were identified from each of the five shortlisted aquifers. The highest scoring site and its associated maximum cell score within each of the five shortlisted aquifers are shown below in order of highest scores in Table 39. The top-ranking subsurface sites are also shown in Figure 26.

Table 39. Top-ranking subsurface sites summary.

Aquifer Name	*Rank*[4]	*Maximum Cell Score*
1-14 Fort Mandan	SS-1	0.894
1-12 Lake Nettie	SS-2	0.850
1-10 Renner Bay	SS-3	0.841
1-13 Knife River	SS-4	0.816
1-13 Knife River Alternative	SS-A-4	0.801
1- 2 Trenton	SS-5	0.741

[4] "SS" in the "Rank" column stands for "Subsurface" and the following number is the site's rank. "A" stands for "Alternative", indicating the site is an alternative to the site with the same rank.

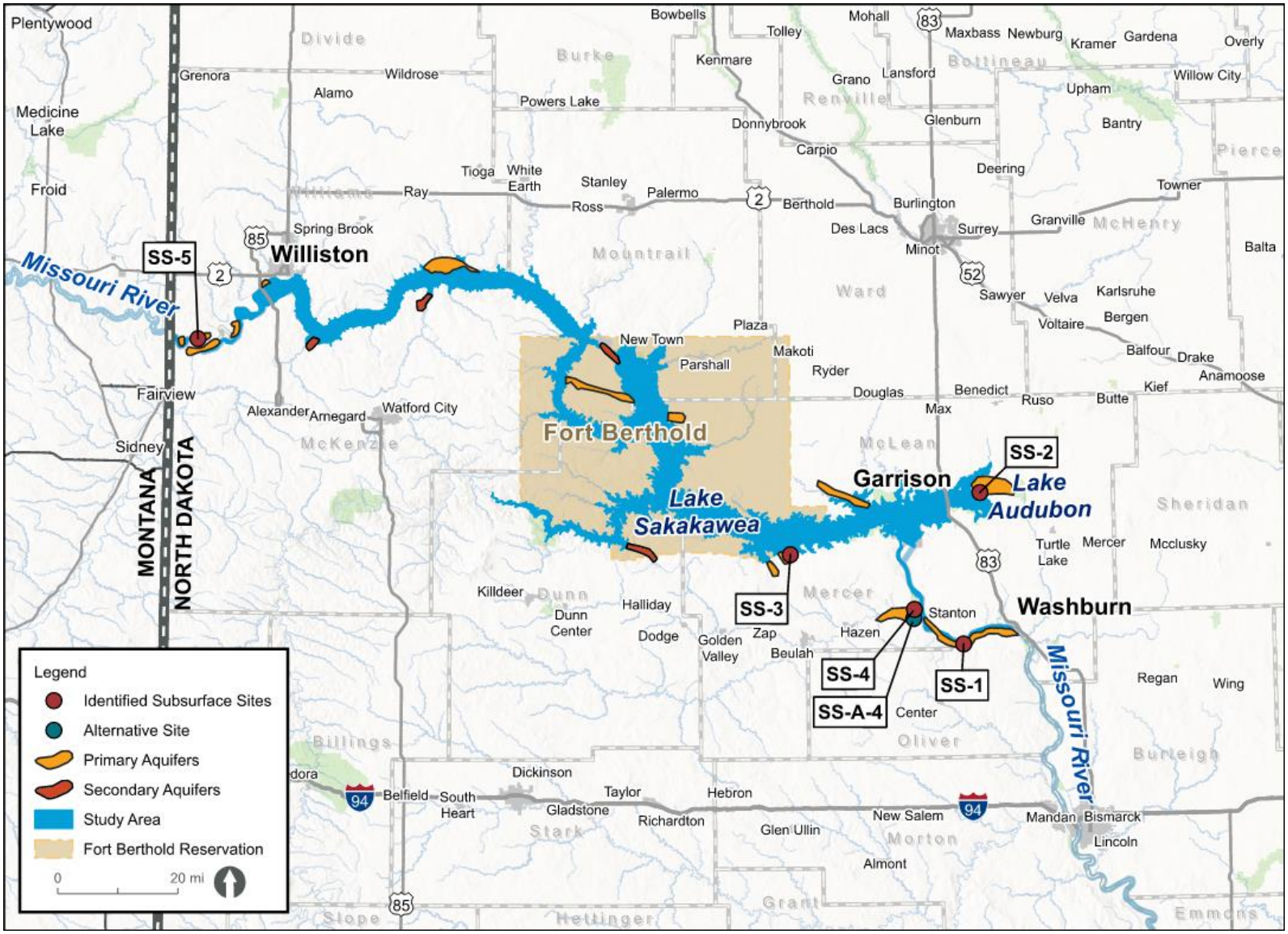


Figure 26. Top-ranking subsurface sites overview.

7.1.2.1 1-2 Trenton

The grid cell with the highest overall score in the Trenton aquifer was 1.2.0046L. The grid cell and surrounding cells are illustrated in Figure 27. The overall score of the site is 0.741. Table 40 provides the overall and criteria group scores for the top-ranking cell. The site offers perfect scores in the Ease and Cost of Water Delivery, Federal and State Permitting Requirements, and Impacts to Recreation criteria.

This site is located in Williams County, approximately eight miles southwest of the City of Trenton and five miles east of the Fort Union Trading Post National Historic Site. It has sufficient access from 151st Avenue Northwest. The site is located approximately 0.5 miles southeast of the nearest available three-phase power source and 17 miles south of Pioneer Generating Station. Additionally, it is one mile south of a Burlington Northern Sante Fe rail line. The nearest natural gas pipeline identified by HIFLD is one mile to the east and owned by Northern Border Pipeline Company. Industries have expressed significant interest in this reach, with the nearest interest being eight miles away in Trenton.

The site is located in a historically turbid area with high sediment aggradation potential. It is adjacent to land-based sources, activities, facilities, or conditions that may contribute to potential water quality impairments. There is moderate risk of aquatic nuisance infestation within this reach, due to moderate recreation trends compared to other reaches in the Study. It is not near any known sites of cultural or historical significance. It is also not located within an unbroken grassland, as identified by NDGFD. This reach is located within Piping Plover critical habitat, which may create additional coordination requirements with USFWS. It is not located within a state park or near any recreational facilities.

The site is located on an outer bend of the Missouri River, shown in Appendix D – Riverine Geomorphology Maps. There is relatively flat topography at and adjacent to the site, with little potential for landslides. Greater aggradation is expected at this location given the turbidity in the area. The site is not located within the historic Missouri River channel and a Sovereign Lands permit is not required.

Table 40. Top-ranking subsurface intake site identified in the 1-2 Trenton aquifer.

1-2 TRENTON				
GRID CELL NAME	**1.2.0046L**			
OVERALL SCORE	**0.741**			
Criterion	***Criterion Score***	***X***	***Criterion Weight***	***= Weighted Score***
Water Availability	0.837		45%	0.3767
Water Quality	0.750		18%	0.1350
Likelihood of Future Intake Sedimentation	0.000		8%	0.0000
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.645		7%	0.0452
Ease and Cost of Water Delivery	1.000		6%	0.0600
Expressed Interest in Nearby Location by New Industry	0.957		6%	0.0574
Distance to Nearby Towns and Existing Industrial Facilities	0.358		4%	0.0143
Impacts to Areas of Natural, Cultural, and Historical Significance	0.750		3%	0.0225
Federal and State Permitting Requirements	1.000		2%	0.0200
Impacts to Recreation	1.000		1%	0.0100

Figure 27. Top-ranking subsurface intake site and adjacent cells in the 1-2 Trenton aquifer.

7.1.2.2 1-10 Renner Bay

The grid cell with the highest overall score in the Renner Bay aquifer was 1.10.0057R. The grid cell and surrounding cells are illustrated in Figure 28. The overall score of the site is 0.841. Table 41 provides the overall and criteria group scores for the top-ranking cell. The site offers perfect scores in the likelihood of Future Intake Sedimentation, Ease and Cost of Water Delivery, and Federal and State Permitting Requirements criteria.

This site is located in Mercer County, approximately 15 miles north of the City of Beulah and 18 miles west of Pick City. It has sufficient access from 4th Street Northwest. The site is located 1.7 miles from the nearest available three-phase power source and is approximately seven miles north of Antelope Valley coal-fired power plant. Additionally, it is seven miles north of a Burlington Northern Sante Fe rail line that runs through the City of Beulah. The nearest natural gas pipeline identified by HIFLD is 30 miles to the east and is owned by Williston Basin Interstate Pipeline Company. Industries have expressed moderate interest in this reach, with the nearest interest located in Beulah.

There is relatively flat topography at and adjacent to the site, with little potential for landslides. Little aggradation is expected at this location. The site is not located in a historically turbid area. The site is adjacent to Hille State WMA. Coordination with the NDGFD Director will be required to construct an industrial intake within the boundaries of the WMA. It is also adjacent to Piping Plover critical habitat area, which could create additional coordination requirements with the USFWS. It is not located within a state park or near any recreational facilities. It is also not near any known sites of cultural or historical significance.

The site is not located in a historically turbid area and is not adjacent to any locations included in the potential water quality impairments criterion. There is significant risk of aquatic nuisance infestation within this reach, due to high recreation trends compared to other reaches in the Study.

The lands along the boundary of Lake Sakakawea are owned and managed by USACE below elevation 1854.0 (LPD), as the lands were procured for the management of Garrison Dam. This requires increased coordination to construct an industrial intake. The site is not located within the historic Missouri River channel and a Sovereign Lands permit is not required.

Table 41. Top-ranking subsurface intake site identified in the 1-10 Renner Bay aquifer.

1-10 RENNER BAY			
GRID CELL NAME	1.10.0057R		
OVERALL SCORE	0.841		
Criterion	*Criterion Score*	*X Criterion Weight*	*= Weighted Score*
Water Availability	0.936	45%	0.4212
Water Quality	0.750	18%	0.1350
Likelihood of Future Intake Sedimentation	1.000	8%	0.0800
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.590	7%	0.0413
Ease and Cost of Water Delivery	1.000	6%	0.0600
Expressed Interest in Nearby Location by New Industry	0.628	6%	0.0377
Distance to Nearby Towns and Existing Industrial Facilities	0.419	4%	0.0168
Impacts to Areas of Natural, Cultural, and Historical Significance	0.750	3%	0.0225
Federal and State Permitting Requirements	1.000	2%	0.0200
Impacts to Recreation	0.667	1%	0.0067

Figure 28. Top-ranking subsurface intake site and adjacent cells identified in the 1-10 Renner Bay aquifer.

7.1.2.3 1-12 Lake Nettie

The grid cell with the highest overall score in the Lake Nettie aquifer was 1.12.0662L. The grid cell and surrounding cells are illustrated in Figure 29. The overall score of the site is 0.850. Table 42 provides the overall and criteria group scores for the top-ranking cell. The site offers perfect scores in the Likelihood of Future Intake Sedimentation and Ease and Cost of Water Delivery criteria.

This site is located in McLean County, approximately 11 miles north of the City of Underwood and 13 miles east of the City of Garrison on the northeast side of Lake Audubon. It has sufficient access from 28th Avenue Northwest. The site scores lower on the Impacts to Recreation criterion due to its proximity to Audubon WMA, which would require coordination with the NDGFD Director to construct an industrial intake within the boundaries of the WMA. Lake Audubon could be drawn down if Lake Sakakawea's pool elevation falls more than 43 feet below Lake Audubon's pool elevation[10], which may impact water availability.

The site is located approximately 1.2 miles from the nearest three-phase power source, directly east of the site. Additionally, it is near a Dakota Missouri Valley Western rail line that runs from the City of Underwood to the City of Garrison. The nearest natural gas pipeline identified by HIFLD is approximately 7.5 miles to the east which is owned by Williston Basin Interstate Pipeline Company. Industries have expressed little interest in this reach, with the nearest interest in Underwood.

The site is not located in a historically turbid area and is not adjacent to any locations included in the potential water quality impairments criterion. There is significant risk of aquatic nuisance infestation within this reach, due to high recreation trends compared to other reaches in the Study. It is not near any known sites of cultural or historical significance, but this site is located within Piping Plover critical habitat, which may create additional coordination requirements with USFWS. It is not located within a state park or near any recreational facilities.

The lands along the boundary of Lake Audubon are owned and managed by USACE below elevation 1854.0 (LPD). Lands above elevation 1854.0 (LPD) are managed by NDGFD. This requires increased coordination to construct an industrial intake. The site is not located within the historic Missouri River channel and a Sovereign Lands permit is not required.

Table 42. Top-ranking subsurface intake site identified in the 1-12 Lake Nettie aquifer.

1-12 LAKE NETTIE			
GRID CELL NAME	**1.12.0662L**		
OVERALL SCORE	**0.850**		
Criterion	***Criterion Score***	***X Criterion Weight =***	***Weighted Score***
Water Availability	0.999	45%	0.4496
Water Quality	0.875	18%	0.1575
Likelihood of Future Intake Sedimentation	1.000	8%	0.0800
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.447	7%	0.0313
Ease and Cost of Water Delivery	1.000	6%	0.0600
Expressed Interest in Nearby Location by New Industry	0.417	6%	0.0250
Distance to Nearby Towns and Existing Industrial Facilities	0.439	4%	0.0176
Impacts to Areas of Natural, Cultural, and Historical Significance	0.750	3%	0.0225
Federal and State Permitting Requirements	0.000	1%	0.0000
Impacts to Recreation	0.667	1%	0.0067

Figure 29. Top-ranking subsurface intake site and adjacent cells identified in the 1-12 Lake Nettie aquifer.

7.1.2.4 1-13 Knife River

The grid cell with the highest overall score in the Knife River aquifer was 1.13.0005L. The grid cell and surrounding cells are illustrated in Figure 30. The overall score of the site is 0.816. Table 43 provides the overall and criteria group scores for the top-ranking cell. The site offers perfect scores in the Likelihood of Future Intake Sedimentation, Ease and Cost of Water Delivery, Federal and State Permitting Requirements, and Impacts to Recreation criteria.

This site is located on the west side of the Missouri River in Mercer County, approximately one mile north of the City of Stanton and 12 miles northeast of the City of Hazen. There is sufficient access from Mercer County Highway 37. The site is located approximately 4.7 miles from the Stanton coal-fired power plant and approximately three miles from the closest three-phase power source. Additionally, it is near a Burlington Northern Sante Fe rail line that runs through the City of Stanton. The nearest natural gas pipeline identified by HIFLD is approximately 35 miles away. Natural gas is likely available in the City of Stanton; however, it is not reflected in the HIFLD natural gas pipeline data. Industries have expressed little interest in this reach, with the nearest interest 20 miles away in Beulah.

The site is located near a straight section of the Missouri River, shown in Appendix D – Riverine Geomorphology Maps. There is relatively flat topography at and adjacent to the site, with little potential for landslides. Given the site's proximity to Garrison Dam, the channel thalweg is relatively stable, indicated in Figure 9. Little aggradation is expected at this location given the stability of the channel.

Additionally, North Dakota procured aerial imagery within this reach during the 2011 flood event, which was an uncommon event with flows comparable to an annual exceedance probability (AEP) of 1 in 500 based on reporting from the USGS[11] and USACE[12]. This means a flood similar to the 2011 event has a 0.2% chance of occurring in any given year. The imagery depicts that flooding at this site did not occur, suggesting that flows or water levels less than or equal to those experienced during the 2011 event are unlikely to cause flooding at this location.

The site is not located in a historically turbid area and is not adjacent to any locations included in the potential water quality impairments criterion. There is little risk of aquatic nuisance infestation within this reach, due to colder temperatures and lower recreation trends compared to other reaches in the Study. It is not located within a state park or near any recreational facilities.

The land above the ordinary high-water mark at this site is privately owned, which may require less coordination and permitting with state and federal agencies. There are several USACE-owned bank stabilization structures downstream of Garrison Dam, but these structures are not located at this site. A Section 408 permit would not be required to develop an industrial intake at this location.

This site is located within the boundary of the Knife River Indian Village Historic Site, which will require additional coordination with the National Park Service to construct an industrial intake. For this reason, an alternative site has been chosen in this aquifer, discussed below in Section 7.1.2.4a 1-13 Knife River Alternative.

Table 43. Top-ranking subsurface intake site identified in the 1-13 Knife River aquifer.

1-13 KNIFE RIVER			
GRID CELL NAME	**1.13.0005R**		
OVERALL SCORE	**0.816**		
Criterion	***Criterion Score*** ***X***	***Criterion Weight*** ***=***	***Weighted Score***
Water Availability	0.822	45%	0.3699
Water Quality	0.875	18%	0.1575
Likelihood of Future Intake Sedimentation	1.000	8%	0.0800
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.655	7%	0.0459
Ease and Cost of Water Delivery	1.000	6%	0.0600
Expressed Interest in Nearby Location by New Industry	0.481	6%	0.0289
Distance to Nearby Towns and Existing Industrial Facilities	0.529	4%	0.0212
Impacts to Areas of Natural, Cultural, and Historical Significance	0.750	3%	0.0225
Federal and State Permitting Requirements	1.000	2%	0.0200
Impacts to Recreation	1.000	1%	0.0100

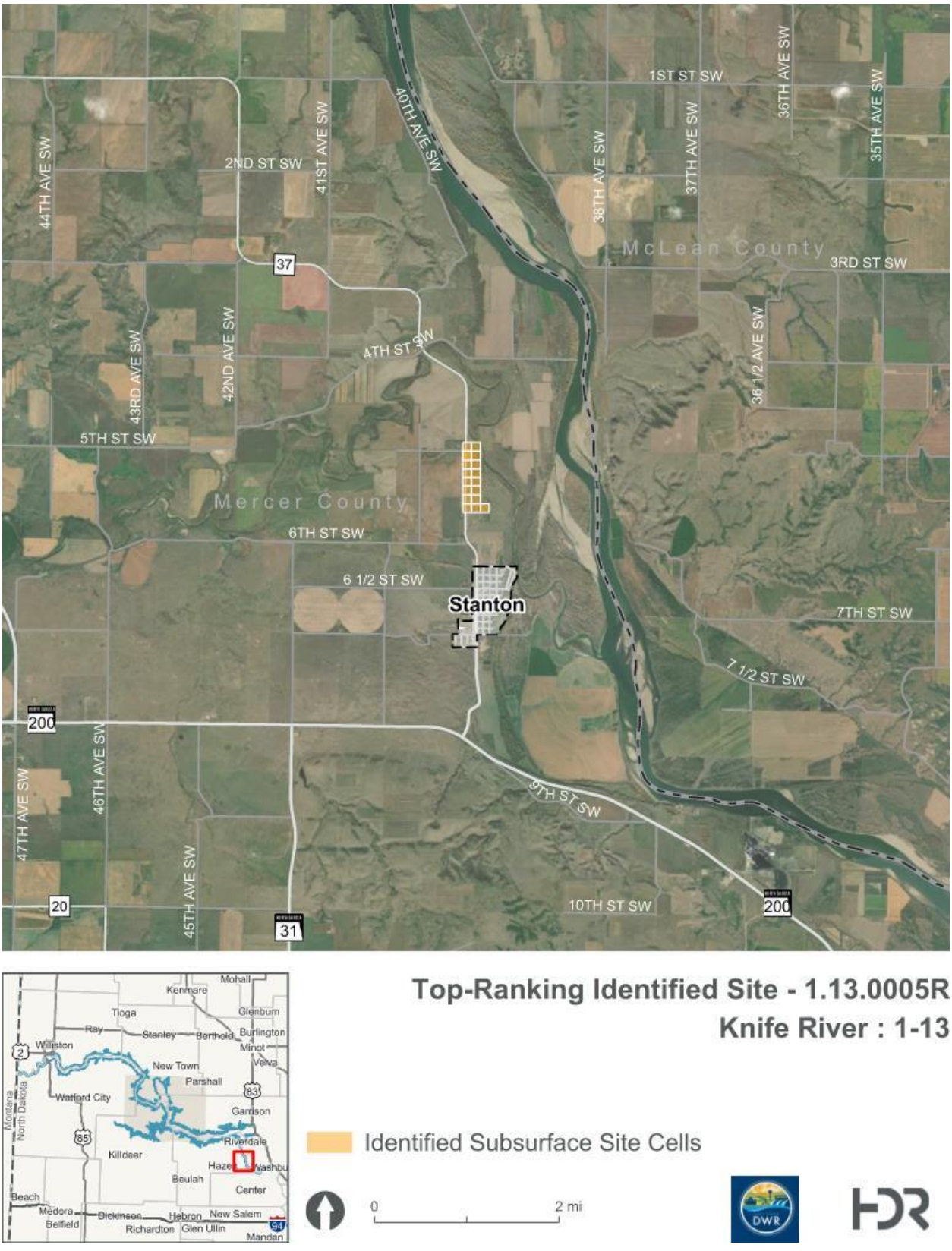


Figure 30. Top-ranking subsurface intake site and adjacent cells identified in the 1-13 Knife River aquifer.

7.1.2.4a 1-13 Knife River Alternative

The grid cell with the highest overall score in the Knife River aquifer was 1.13.0005R. This site falls within the boundary of the Knife River Indian Village Historic Site, which will require additional coordination with the National Park Service to construct an industrial intake. For this reason, an alternative site has been chosen in this aquifer.

The alternative grid cell with the highest overall score in the Knife River aquifer was 1.13.0042R. The alternative grid cell and surrounding cells are illustrated in Figure 31. The overall score of the site is 0.801. Table 44 provides the overall and criteria group scores for the top-ranking cell. The site offers perfect scores in the Likelihood of Future Intake Sedimentation, Ease and Cost of Water Delivery, Federal and State Permitting Requirements, and Impacts to Recreation criteria.

This site is located on the west side of the Missouri River in Mercer County, approximately 0.2 miles north of the City of Stanton and 11 miles northeast of the City of Hazen. There is sufficient access from Mercer County Highway 37. The site is located approximately 3.7 miles from the Stanton coal-fired power plant and approximately 2 miles from the closest three-phase power source. Additionally, it is near a Burlington Northern Sante Fe rail line that runs through the City of Stanton. The nearest natural gas pipeline identified by HIFLD is approximately 34 miles away. Natural gas is likely available in the City of Stanton; however, it is not reflected in the HIFLD natural gas pipeline data. Industries have expressed little interest in this reach, with the nearest interest 19 miles away in Beulah.

The site is located near a straight section of the Missouri River, shown in Appendix D – Riverine Geomorphology Maps. There is relatively flat topography at and adjacent to the site, with little potential for landslides. Given the site's proximity to Garrison Dam, the channel thalweg is relatively stable, indicated in Figure 9. This reach has been relatively stable since the 1970s based on USGS findings[9]. Less sedimentation is expected at this location due to the reach being within the dam proximal zone.

Additionally, North Dakota procured aerial imagery within this reach during the 2011 flood event, which was an uncommon event with flows comparable to an annual exceedance probability (AEP) of 1 in 500 based on reporting from the USGS[11] and USACE[12]. This means a flood similar to the 2011 event has a 0.2% chance of occurring in any given year. The imagery depicts that flooding at this site did not occur, suggesting that flows or water levels less than or equal to those experienced during the 2011 event are unlikely to cause flooding at this location.

The site is not located in a historically turbid area and is not adjacent to any locations included in the potential water quality impairments criterion. There is little risk of aquatic nuisance infestation within this reach, due to colder temperatures and lower recreation trends compared to other reaches in the Study. It is not located within a state park or near any recreational facilities.

The site is not located within any known cultural or historical areas. It is located within an unbroken grassland, as identified by NDGFD. The land above the ordinary high-water mark at this site is privately owned, which may require less coordination and permitting with state and federal agencies. There are several USACE-built bank stabilization structures downstream of Garrison Dam, but these structures are not located at this site. A Section 408 permit would not be required to develop an industrial intake at this location.

Table 44. Alternative subsurface intake site identified in the 1-13 Knife River aquifer.

1-13 KNIFE RIVER ALTERNATIVE				
GRID CELL NAME	1.13.0042R			
OVERALL SCORE	0.801			
Criterion	*Criterion Score*	*X*	*Criterion Weight*	*= Weighted Score*
Water Availability	0.785		45%	0.3533
Water Quality	0.875		18%	0.1575
Likelihood of Future Intake Sedimentation	1.000		8%	0.0800
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.701		7%	0.0491
Ease and Cost of Water Delivery	1.000		6%	0.0600
Expressed Interest in Nearby Location by New Industry	0.460		6%	0.0276
Distance to Nearby Towns and Existing Industrial Facilities	0.533		4%	0.0213
Impacts to Areas of Natural, Cultural, and Historical Significance	0.750		3%	0.0225
Federal and State Permitting Requirements	1.000		2%	0.0200
Impacts to Recreation	1.000		1%	0.0100

Figure 31. Alternative subsurface intake site and adjacent cells identified in the 1-13 Knife River aquifer.

7.1.2.5 1-14 Fort Mandan

The grid cell with the highest overall score in the Fort Mandan aquifer was 1.14.1364L. The grid cell and surrounding cells are illustrated in Figure 32. The overall score of the site is 0.894. Table 45 provides the overall and criteria group scores for the top-ranking cell. The site offers perfect scores in the Likelihood of Future Intake Sedimentation, Ease and Cost of Water Delivery, Federal and State Permitting Requirements, and Impacts to Recreation criteria.

This site is located on the east side of the Missouri River in McLean County, approximately nine miles southwest of the City of Washburn and 11 miles northeast of the City of Center. It has sufficient access from 11th Street Southwest. The site is located approximately 5.4 miles from a Basin Electric Power Cooperative coal-fired power plant and approximately 1.1 miles from the nearest three-phase power source. Additionally, there is a nearby rail line that runs through the City of Underwood, owned by Dakota Missouri Valley Western. The nearest natural gas pipeline identified by HIFLD is approximately ten miles away, near Coal Creek Station. Industries have expressed little interest in this reach, with the nearest interest in Underwood.

The site is located on a straight section that transitions into an inner bend of the Missouri River, shown in Appendix D – Riverine Geomorphology Maps. There is relatively flat topography at and adjacent to the site, with little potential for landslides. Given the site's proximity to Garrison Dam, the channel thalweg is relatively stable, indicated in Figure 9. This reach has been relatively stable since the 1970s based on USGS findings[9]. Less sedimentation is expected at this location due to the reach being within the dam proximal zone.

Additionally, North Dakota procured aerial imagery within this reach during the 2011 flood event, which was an uncommon event with flows comparable to an annual exceedance probability (AEP) of 1 in 500 based on reporting from the USGS[11] and USACE[12]. This means a flood similar to the 2011 event has a 0.2% chance of occurring in any given year. The imagery depicts that flooding at this site did not occur, suggesting that flows or water levels less than or equal to those experienced during the 2011 event are unlikely to cause flooding at this location.

The site is not located in a historically turbid area. There is little risk of aquatic nuisance infestation within this reach, due to colder temperatures and lower recreation trends compared to other reaches in the Study. It is not located within a state park or near any recreational facilities. The site is not adjacent to any locations included in the potential water quality impairments criterion or any known cultural or historical sites.

The site is adjacent to Piping Plover critical habitat, which may require additional coordination with the USFWS. There are also USACE-owned bank stabilization structures downstream of Garrison Dam. Several of these structures are located adjacent to the site. A Section 408 permit may be required to develop an industrial intake at this location.

Table 45. Top-ranking subsurface intake site identified in the 1-14 Fort Mandan aquifer.

1-14 FORT MANDAN				
GRID CELL NAME	**1.14.1364L**			
OVERALL SCORE	**0.894**			
Criterion	***Criterion Score***	***X***	***Criterion Weight***	***= Weighted Score***
Water Availability	0.992		45%	0.4464
Water Quality	0.750		18%	0.1350
Likelihood of Future Intake Sedimentation	1.000		8%	0.0800
Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas	0.798		7%	0.0559
Ease and Cost of Water Delivery	1.000		6%	0.0600
Expressed Interest in Nearby Location by New Industry	0.548		6%	0.0329
Distance to Nearby Towns and Existing Industrial Facilities	0.793		4%	0.0317
Impacts to Areas of Natural, Cultural, and Historical Significance	0.750		3%	0.0225
Federal and State Permitting Requirements	1.000		2%	0.0200
Impacts to Recreation	1.000		1%	0.0100

Figure 32. Top-ranking subsurface intake site and adjacent cells identified in the 1-14 Fort Mandan aquifer.

8 Next Steps

8.1 Collaborative Site Identification

The primary purpose of the Study is to determine intake sites that could best serve industrial water users with the secondary purpose to support additional irrigation and municipal water supply needs. Sites with the highest scores based on the desktop spatial analysis can be identified by reviewing the intake Study results; however, hosting a stakeholder workshop is recommended to coordinate with agencies, industries, regional water systems, and the project team to identify which sites may have priority. This effort could narrow down the scope and cost of the fieldwork needed to verify each site.

Agencies, industries, and regional water systems may be interested in constructing an intake at a location that was not identified by this Study. These groups and the DWR could work together using the geospatial models developed as part of this Study to understand a location's suitability for the construction and operation of a potential intake.

8.2 Field Verification

While the Study was comprehensive in its review of conditions needed to identify an intake location, field verification is still required. Funding must also be procured to field verify site(s) identified in the Study. The project team can support DWR with allocating funding and testing when verifying the identified site(s).

On August 19, 2024, a memorandum outlining recommended fieldwork for verifying these sites was submitted to DWR and is included as Appendix F – Field Analysis Memorandum. The memorandum summarizes expected costs of fieldwork in two phases. Phase 1 can be described as a cost-effective fieldwork scenario designed to yield high-level results for assessing site suitability and identifying which of the identified sites might be worth further exploration. Phase 2 would take place after the conclusion of Phase 1 and is best described as a more comprehensive fieldwork campaign that can verify a site's total suitability. Table 46 provides the cost estimate of fieldwork for surface water and subsurface intakes based on the assumptions provided in the memorandum in Appendix F – Field Analysis Memorandum.

Table 46. Fieldwork costs associated with surface and subsurface site scoping.

Field Tests	*Estimated Cost*
Surface Water - Phase 1	$ 37,500.00
Surface Water - Phase 2	$ 75,000.00
Surface Water - Total	***$ 112,500.00***
Subsurface - Phase 1	$ 70,000.00
Subsurface - Phase 2	$ 405,000.00
Subsurface - Total	***$ 475,000.00***

9 References

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[11] - United States Geological Survey. (2014). Annual Exceedence Probabilities and Trends for Peak Streamflows and Annual Runoff Volumes for the Central United States During the 2011 Floods. 2011 Floods of the Central United States.

[12] - United States Army Corps of Engineers. (n.d.) Review of the Regulation of the Missouri River Mainstem Reservoir System During the Flood of 2011.

Appendix A – Environmental Considerations and Permit Matrix

The EPA and USFWS issued recommendations for intakes on Lake Sakakawea regarding pallid sturgeon:

- The USFWS recommends that intake velocities should not exceed 0.5 fps.
- Mesh size at intake screens should have a maximum mesh opening of 1/4 inch to reduce the size of aquatic organisms that can be entrained (Environmental Protection Agency 1976).
- A Johnson (or Johnson type) screen/intake should be used if feasible.
    - Moveable screens should be used to minimize impacts to impinged organisms (U.S. Fish and Wildlife Service 1978, Environmental Protection Agency 1976).
- Use of continuous rotating screens is recommended, when feasible. Otherwise, the time duration between rotation of screens should not exceed two hours (King et al. 1978, Tatham 1978).
- Use of a low-pressure wash system (maximum spray pressure of 50 pounds per square inch) prior to a high-pressure wash increases the survival of fish removed from screens (Environmental Protection Agency 1976, King et al. 1978).
- A minimum of two inches of water should be maintained in discharge troughs to prevent fish escape and re-impingement from occurring (Environmental Protection Agency 1976).
- Fish removed from the discharge troughs should be quickly returned to a sufficient distance from the intake to prevent re-impingement (Environmental Protection Agency 1976).
- If a vertical opening intake is used, a velocity cap should be installed. Velocity caps substantially reduce the number of organisms drawn into pumps and cooling systems (Richards 1977).
- Perforated pipe inlets with an internal perforated sleeve placed parallel to the current appear to have the least impact on aquatic organisms (Environmental Protection Agency 1976, Richards 1977).
- Intakes should not be placed within the littoral (or photic) zone.
- Intakes should not be placed within 50 meters of the littoral (or photic) zone.
    - Placement of intakes in canals or small coves should be avoided.
    - If intakes are placed in canals or small coves, a porous rock dike should isolate the intake area from the main water body.

PERMITTING MATRIX

The matrix below identifies permits and approvals that may be required by the project at the federal, state and local levels in North Dakota.

Regulatory Authority	Statute	Permit/ Approval	Description	Trigger	Fee	Application Timeline	Website	Contact Information	Notes on any requirements (setbacks, etc.)
FEDERAL									
U.S. Army Corps of Engineers	**Clean Water Act**	Section 404 Permit Required for the discharge of dredged or fill material into waters of U.S. Minimal levels of fill may be covered under existing Nationwide Permits	Complete an application under the Clean Water Act for impacts to wetland and waters of the U.S.	Impacts to waters of the U.S.	No fee.	Prior to ground disturbing activities. Bismarck Regulatory Office has been backlogged. Nationwide permits generally take 45 days but are now estimated to take 3-4 months.	http://www.usace.army	Ben Soiseth, Manager Bismarck Regulatory Office 3319 University Drive, Bismarck, ND 58504 701-255-0015 Submittals to: CENWO-OD-RND@usace.army.mil	NWP 13 Bank Stabilization Thresholds: 500' along the bank; 1 cubic yard/running foot NWP 33 Temporary Construction, Access, and Dewatering Thresholds: none *Other set-backs may be required depending upon which NWP is most appropriate.
	Rivers and Harbors Act of 1899. Section 10, 33 USC 403	Section 10 Permit Required for the crossing of a Section 10 river	Complete an application under the Rivers and Harbors Appropriation Act to cross a Section 10 regulated river (St. James River)	Impacts to specific waters of the U.S.	No Fee	Prior to ground disturbing activities. Involves public notice and additional coordination with tribes and USFWS. 3 – 6 months.			
	Rivers and Harbors Act of 1899. Section 408, 33 USC	Section 408 Authorization for the temporary or permanent alteration or use of a USACE civil works project.	Complete an application under the Rivers and Harbors Appropriation Act to review impacts to Section 408 civil works project.	Impacts to federal project/USACE civil works projects.	No fee.	Prior to Section 404 or Section 10 application submittals. Typically 30-90 days.		Michelle Prosser Michelle.e.prosser@usace.army.mil	
	10 U.S.C. 2667	Real Estate Outgrant - Realty Permit	Complete an application with the USACE Real Estate District Office to develop an easement on USACE-owned lands.	Project development on USACE-owned lands.	No Fee	Prior to ground disturbing activities. 3 – 6 months.		Amanda Young Senior Realty Specialist 701-654-7705 Amanda.M.Young@usace.army.mil	May require additional surveys and/or permits to obtain an easement through USACE-owned lands.

Regulatory Authority	Statute	Permit/ Approval	Description	Trigger	Fee	Application Timeline	Website	Contact Information	Notes on any requirements (setbacks, etc.)
Federal Emergency Management Agency (FEMA)	**Floodplain Management Executive Order 11988**	Floodway Authorization	A CLOMR (Conditional Letter of Map Revision) is needed for projects falling within the floodplain.	Needed for projects that impact a regulated floodway	None				
U.S. Fish and Wildlife Service (USFWS)	**Consultation on Section 7 of Endangered Species Act (ESA) of 1973, Migratory Bird treaty Act of 1918, Bald and Golden Eagle Protection Act of 1940**	Consultation with agency pursuant to the applicable federal laws noted. USFWS and project proponent to coordinate on how to implement proposed project while avoiding impacts to federally-listed endangered species, migratory birds, and bald and golden eagles to the greatest extent feasible	Determination of effect on federally listed species. Coordination on migratory birds and bald and golden eagles.	Section 7 process occurs if there is a federal nexus (i.e., USACE Section 404 permit). If no impacts are anticipated, formal consultation with USFWS is not required. If impacts are anticipated, formal consultation is required.	No fee.	Prior to ground disturbing activities. USFWS typically responds within 30 days during consultation, but coordination regarding field studies, if required, may add additional time.	http://fws.gov	Luke Tuso, Manager US Fish and Wildlife Service ND Ecological Services Field Office 3425 Miriam Avenue Bismarck, ND 58501-7926 luke_toso@fws.gov	

Regulatory Authority	Statute	Permit/ Approval	Description	Trigger	Fee	Application Timeline	Website	Contact Information	Notes on any requirements (setbacks, etc.)
Environmental Protection Agency (EPA)	**40 CFR 125.94**	Entrainment Permit	Section 316(b) of the Clean Water Act requires EPA to issue regulations on the design and operation of intake structures, in order to minimize adverse impacts.	Operation of a new water intake facility.	No fee.	Prior to construction activities.	https://www.epa.gov/		Guidance varies depending on type and location of intake structure.
NORTH DAKOTA (STATE)									
North Dakota Game and Fish Department	**Required consultation to comply with state permits**	Wildlife conservation recommendation	Consultation of project impacts to wildlife.	Consultation required as part of state permit approval (i.e. sovereign lands)	No Fee.	Prior to construction	http://gf.nd.gov/	Bruce Kreft, Supervisor Conservation Section ND Game & Fish Department 100 N Bismarck Expressway Bismarck, ND 58501 701-328-6224 bkreft@nd.gov	

Regulatory Authority	Statute	Permit/ Approval	Description	Trigger	Fee	Application Timeline	Website	Contact Information	Notes on any requirements (setbacks, etc.)
State Historic Preservation Office	**1.Section 55-10, North Dakota Century Code** **2. Section 106 Compliance Approval (if applicable)**	1. Section 55-10 compliance is required for projects under state jurisdiction (i.e., NDDEQ) 2. Section 106 Compliance Approval is required if there is federal involvement in the Project (i.e., USACE)	Section 106 requires agencies to analyze how their activities will affect historic properties. Historic properties are defined as significant cultural resources and may include archaeological sites, historic buildings, and places of traditional cultural importance. Significance is to be determined in consultation with the State Historic Preservation Officer, Tribal governments, and interested members of the public.	Any Federal undertaking (permit, funding, approval) must demonstrate compliance with Section 106 of the National Historic Preservation Act (NHPA).	No Fee.	30-day consultation period.	http://history.nd.gov/hp/index.html	Andrew Clark, Deputy State Historic Preservation Officer State Historical Society of North Dakota 612 East Boulevard Ave. Bismarck, North Dakota 58505 701-328-2666 andrewclark@nd.gov	
North Dakota Department of Environmental Quality	**1. Compliance with North Dakota's General Stormwater permit** **2. Compliance with North Dakota's 401 water quality certification process**	1. NPDES Permit: General Construction Storm Water NDR10-0000 2. 401 Water Quality Certification (if applicable)	Identify potential sources of stormwater pollution from construction activity and to ensure practices are implemented to minimize the contribution of pollutants to stormwater runoff.	1. Required for disturbance of more than one acre of land. Must prepare a Storm Water Pollution Prevention Plan (SWPPP). 2. Required by applicant when completing an Individual Permit for Section 404. Applicant does not need to provide if completing a nationwide permit.	No fee.	Prior to Construction – one month.	http://www.ndhealth.gov	NDPES: Online submittal through ERIS (Electronic Reporting System). Dave Glatt, Director ND Department of Environmental Quality 918 E Divide Ave, 4th Floor Bismarck, ND 58501 dglatt@nd.gov 701-328-5150	

Regulatory Authority	Statute	Permit/ Approval	Description	Trigger	Fee	Application Timeline	Website	Contact Information	Notes on any requirements (setbacks, etc.)
North Dakota Department of Water Resources	**Compliance with ND Administrative Code 89-10 and North Dakota Century Code 61-33.**	Sovereign Lands Permit	Complete an application to impact areas considered 'sovereign lands' for the state of North Dakota	Impacts below the ordinary high water mark of the Missouri River	None.	Prior to construction – due to backlog, estimate 6-9 months	navigating_sovereign_lands_waters.pdf	Submittal to: sovereignlands@nd.gov Jerry Heiser, ND Department of Water Resources 12 Memorial Highway Bismarck, ND 58504-5262 701-328-3696	
	Compliance with ND Administrative Code 61-04-02 and North Dakota Century Code 89-03	Conditional Water Permits	Authorization required for acquiring water from the Missouri River. Public notice is required.	A water permit is required before putting water to beneficial use.	$500	60 days	Department of Water Resources (nd.gov)	Andrew Nygren, Director Water Appropriation Division ND Department of Water Resources 12 Memorial Highway Bismarck, ND 58504-5262 701-328-2754 APPROPINFO@ND.GOV	
LOCAL (CITY AND COUNTY)									
Local Authority		Floodplain Permit	Floodplain development permits are required from any entity with jurisdiction and an identified floodplain. This can be a county, city, or township.				Floodplain Administration | Burleigh County	Brady Blaskowski Bismarck Floodplain Administrator 221 N 5th Street Bismarck ND 58501 701-355-1467 bblaskowski@bismarcknd.gov	

**Depending on location of intake structure, additional local permits may be required.*

Appendix B – Spatial Data Bibliography

Status (Find, In Work, Downloaded)	Data Name	Source Name	URL Website	Date of Data	Date Accessed Data
Complete	1943 Sakakawea Lake Contours	State of ND	Emailed		6/7/2024
Jarrett Email	Ag Agronomy/Fertilizer Plants				
Complete	Aquifers	ND Mapservice	https://mapservice.dwr.nd.gov/index.php?		6/26/2024
Complete	Assessed Category Lakes	NDGISHUB	NDGISHUB Assessed Category Lakes | NDGISHUB Assessed Category Lakes | Nor	2/2/2024	5/24/2024
Complete	Bedrock	NDGISHUB	NDGISHUB Bedrock Geology | NDGISHUB Bedrock Geology | North Dakota GIS H	9/28/2023	6/26/2024
Complete	Boat Ramps/Fishing Facilities	ND Game and Fish	Missouri River System and Devils Lake Boat Ramps - Overview (arcgis.com)	3/28/2013	6/7/2024
Complete	Campgrounds	ND State Parks Dept (requested da	Via email to BW "ND Parks and Rec POIs"		
Complete	City Locations for Pop Data	NDGISHUB	NDGISHUB City Locations | NDGISHUB City Locations | North Dakota GIS Hub Da	7/25/2023	6/26/2024
GDB	Coal Mines		Surface and Underground Coal Mines in the U.S. - Overview (arcgis.com)	3/11/2024	7/18/2024
Complete	Communication Towers	HIFLD	Cellular Towers | Cellular Towers | HIFLD (arcgis.com)	1/24/2024	6/26/2024
Complete	Contours 24k	NDGISHUB	NDGISHUB Statewide Contours 24k | NDGISHUB Statewide Contours 24k | Nortl	4/25/2023	5/24/2024
Complete	County Boundaries	NDGISHUB	NDGISHUB County Boundaries | NDGISHUB County Boundaries | North Dakota (	2/13/2023	6/26/2024
Complete	Electric Transmission	HIFLD	Transmission Lines | Transmission Lines | HIFLD (arcgis.com)	12/11/2023	6/7/2024
Find	Gas Pipelines	ND Dept of Mineral Resources			
Complete	Gas Plants	ND Dept of Mineral Resources	https://gis.dmr.nd.gov/gisdownload.asp	6/26/2024	6/26/2024
Requested	Grain Elevators				
Complete	Dams	USACE	National Inventory of Dams - NID | GeoSpatial (arcgis.com)	4/28/2022	5/24/2024
Complete	Lake Contours	NDGISHUB	NDGISHUB Lake Contours | NDGISHUB Lake Contours | North Dakota GIS Hub D	2/1/2022	5/24/2024
Complete	Lakes and Ponds 100k	NDGISHUB	NDGISHUB Lakes and Ponds 100k | NDGISHUB Lakes and Ponds 100k | North Da	3/25/2020	5/24/2024
Complete	Lakes and Ponds 24k	NDGISHUB	NDGISHUB Lakes and Ponds 24k | NDGISHUB Lakes and Ponds 24k | North Dako	12/2/2021	5/24/2024
Complete	Landfills	NDGISHUB	NDGISHUB Landfills | NDGISHUB Landfills | North Dakota GIS Hub Data Portal (a	9/25/2023	6/23/2024
Complete	Landslides	NDGISHUB	North Dakota Geologic Survey (nd.gov)		6/26/2024
Complete	Levees	US ACE	https://levees.sec.usace.army.mil/search		6/26/2024
Complete	Liquid Gas Pipelines	HIFLD	Hydrocarbon Gas Liquid Pipelines | Hydrocarbon Gas Liquid Pipelines | HIFLD (a	6/25/2024	6/26/2024
Complete	Municipal Boundaries	NDGISHUB	NDGISHUB City Boundaries | NDGISHUB City Boundaries | North Dakota GIS Hut	4/8/2024	6/26/2024
Complete	National Registrar of Historic Places Cultural & Historic	US Forest Service	DataStore - National Register of Historic Places (nps.gov)	1/1/2021	6/26/2024
Complete	Natural Gas Pipelines	NDGISHUB	https://hifld-geoplatform.hub.arcgis.com/pages/hifld-open	4/22/2024	6/26/2024
Complete	ND Forest Service	NDGISHUB	NDGISHUB State Forest Lands	3/22/2022	6/24/2024
Complete	ND GF Unbroken Grasslands	ND Game and Fish	Emailed to Josh	5/13/2022	3/21/2024
Complete	ND Mineral Trust Lands	NDGISHUB	NDGISHUB Mineral Trust Lands | NDGISHUB Mineral Trust Lands | North Dakota	6/26/2024	6/26/2024
Complete	ND Parks and Rec	Requested from ND State Parks en	email transaction from ND State Parks to BW (trails and rereation data)	1/31/2024	6/27/2024
Complete	ND State Parks	NDGISHUB	NDGISHUB State Parks	3/22/2022	6/12/2024
Complete	ND Surface Trust Lands	NDGISHUB	NDGISHUB Surface Trust Lands | NDGISHUB Surface Trust Lands | North Dakota	5/15/2023	6/26/2024

Complete	ND Wildlife Management Areas	NDGISHUB	https://gishubdata-ndgov.hub.arcgis.com/maps/fb49002e15cf4dd08df1cc995a9	2/28/2022	6/24/2024
Complete	NHD	USGS	TNM Download v2 (nationalmap.gov)	12/27/2023	6/26/2024
Complete	NWI	USFWS	Download Seamless Wetlands Data by State | U.S. Fish & Wildlife Service (fws.gov)		6/25/2024
Complete	Oil & Natural Gas Fields	ND Dept of Mineral Resources	DMR GIS (nd.gov)	6/26/2024	6/26/2024
Complete	Oil & Natural Gas Wells	ND Dept of Mineral Resources	https://gis.dmr.nd.gov/dmrpublicservices/rest/services/OilGasPublicMapDataVe	7/17/2023	5/24/2024
Find	Oil Pipelines	ND Dept of Mineral Resources			
Complete	Ordinary High Water Mark	ND Mapservice	ND Department of Water Resources MapService		6/7/2024
Complete	Parcels	NDGISHUB	ND Parcel Data	6/23/2024	6/26/2024
Complete	Pipeline Crossings	Clay - NDDWR	Emailed to Josh		6/12/2024
Complete	Power Plants	HIFLD	Power Plants | Power Plants | HIFLD (arcgis.com)	9/21/2023	6/26/2024
Complete	Railroads	NDGISHUB	https://gishubdata-ndgov.hub.arcgis.com/datasets/ad438e42bf1b4ea5b0488c6	10/13/2022	6/26/2024
Complete	River Guage Information - Low Avg Weekly Flows	ND Mapservice	ND Department of Water Resources MapService		6/26/2024
Complete	River Mile Markers	ND DWR	https://mapservice.dwr.nd.gov/index.php?		6/25/2024
Complete	Roads - State & Federal	NDGISHUB	NDGISHUB State and Federal Roads | NDGISHUB State and Federal Roads | Nort	2/11/2022	6/26/2024
Complete	Roads - County & City	NDGISHUB	NDGISHUB County Roads | NDGISHUB County Roads | North Dakota GIS Hub Da	4/3/2024	6/26/2024
Complete	Sections	NDGISHUB	NDGISHUB PLSS Sections | NDGISHUB PLSS Sections | North Dakota GIS Hub Dat	4/1/2020	6/25/2024
Chris	Sediment Characteristics				
Hold	SHPO Cultural Data	Not at this time.			
Complete	Soils/Prime Farmland/Corrosive	USDA NRCS	Gridded Soil Survey Geographic (gSSURGO) Database | Natural Resources Conse	2/26/2024	6/26/2024
Complete	Stream Guages	ND Mapservice	ND Department of Water Resources MapService		
Complete	Townships	NDGISHUB	NDGISHUB Civil Townships | NDGISHUB Civil Townships | North Dakota GIS Hub	1/1/2007	6/25/2024
Complete	Trails	ND State Parks Dept (requested da	ND Parks and Rec via email communication with BW	1/31/2024	6/27/2024
Complete	Turbidity	Used aerial imagery as described i	Turbidity_Polygons		
Complete	US Army Corp of Engineer Lands	NDGISHUB	NDGISHUB Army Corps Lands | NDGISHUB Army Corps Lands | North Dakota GIS	3/22/2022	6/26/2024
Complete	US BLM Lands	NDGISHUB	NDGISHUB BLM Surface and Mineral Lands | NDGISHUB BLM Surface and Miner	3/22/2022	6/26/2024
Complete	US Bureau of Rec Lands	NDGISHUB	NDGISHUB Reclamation Lands | NDGISHUB Reclamation Lands | North Dakota G	3/22/2022	6/12/2024
Complete	US Forest Service	ND State Parks Trails Database	FS National Forests Datasets US (included with ND State Parks and Rec Dataset)	5/23/2023	6/27/2024
Complete	US FWS Tracts	USFWS	U.S. Fish and Wildlife Service National Realty Tracts | U.S. Fish and Wildlife Servi	4/11/2024	6/27/2024
Complete	US National Parks	NDGISHUB	National Parks Within ND	3/22/2022	6/12/2024
Complete	USFWS Critical Habitat / T&E Species	USFWS	USFWS Threatened & Endangered Species Active Critical Habitat Report	5/23/2024	6/26/2024
Complete	Wind Turbines	NDGISHUB	NDGISHUB Wind Turbines | NDGISHUB Wind Turbines | North Dakota GIS Hub D	6/25/2024	6/26/2024
In Work (Doug)	Well Logs	ND Mapservice			

Appendix C – Technical Memoranda

Memo

Date:	Monday, June 24, 2024
Project:	Missouri River Intake Study
To:	Clay Careful, North Dakota Department of Water Resources
From:	Jarrett Hillius, P.E., HDR Engineering Inc. Chris Korkowski, P.E., HDR Engineering Inc.
Subject:	Criteria Development & Preliminary Ranking/Weighting

Introduction

HDR Engineering, Inc. (HDR) has prepared this memorandum to discuss the preliminary development of criteria for selecting industrial intakes along the Missouri River from Washburn, ND to the Montana State Line. This work is being completed as part of the Missouri River Intake Study (Study) on behalf of the North Dakota Department of Water Resources (DWR). DWR had identified preliminary criteria to be evaluated as part of the Study in the Request for Proposal (RFP). The criteria listed in the RFP include the following:

- Water availability: water level fluctuations, hydrogeologic properties, future upgrade limitations.
- Distance to infrastructure including rail, power, roads, and gas.
- Distance to nearby towns and industrial facilities.
- Federal and state permitting requirements for intake construction and water appropriation.
    - Permits that may need to be obtained from the Department of Water Resources include sovereign land, water appropriation, and construction permits.
- Ease and cost of water delivery based on topography.
- Expressed interest in nearby locations by industry.
- Water quality: turbidity, aquatic nuisance species, etc.
- Likelihood of future intake sedimentation.
- Impacts to areas of natural/cultural/historical significance: high biological diversity, tribal sites, etc.
- Distance from pollution sources.
- Impacts to recreation.
- Other conditions as determined by the Study Consultant.

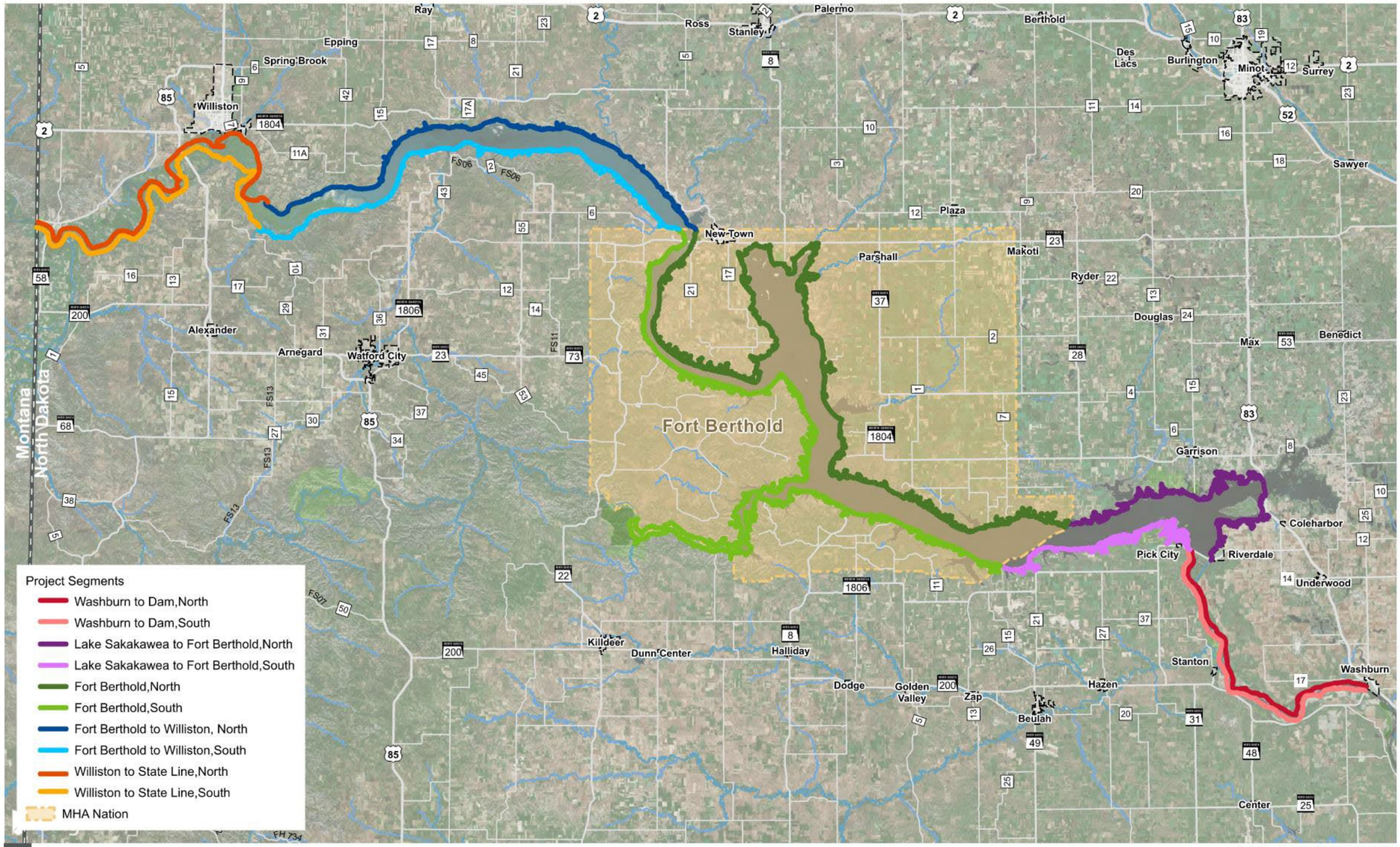
Study Area and Sub-Areas

HDR proposed evaluating the study area into several sub reaches. HDR's proposal included 8 subreaches:

- Washburn to Garrison Dam Left Overbank
- Washburn to Garrison Dam Right Overbank
- Garrison Dam to Fort Berthold Reservation Left Overbank
- Garrison Dam to Fort Berthold Reservation Right Overbank
- Fort Berthold Reservation Left Overbank
- Fort Berthold Reservation Right Overbank
- Fort Berthold Reservation to the Montana State Line Left Overbank
- Fort Berthold Reservation to the Montana State Line Right Overbank

Upon evaluation of sedimentation and lake contours within Lake Sakakawea, the project team determined that another set of subreaches would be beneficial to better capture the zone of Lake Sakakawea that exists above the permanent pool (near the boundary of Fort Berthold reservation) and the headwaters of Lake Sakakawea. For this reason, the Fort Berthold Reservation to the Montana State Line subreaches were split into the following:

- Fort Berthold to the Missouri River below Williston Left Overbank
- Fort Berthold to the Missouri River below Williston Right Overbank
- Missouri River Below Williston to the Montana State Line Left Overbank
- Missouri River Below Williston to the Montana State Line Right Overbank


Project Segments
Washburn to Dam,North
Washburn to Dam,South
Lake Sakakawea to Fort Berthold,North
Lake Sakakawea to Fort Berthold,South
Fort Berthold,North
Fort Berthold,South
Fort Berthold to Williston, North
Fort Berthold to Williston,South
Williston to State Line,North
Williston to State Line,South
MHA Nation
Fort Berthold
Montana
North Dakota
Williston
Epping
Spring Brook
Ray
Ross
Stanley
Palermo
Berthold
Des Lacs
Burlington
Minot
Surrey
Sawyer
Plaza
New-Town
Parshall
Makoti
Ryder
Douglas
Max
Benedict
Alexander
Arnegard
Watford City
Garrison
Coleharbor
Riverdale
Pick City
Underwood
Killdeer
Dunn Center
Halliday
Dodge
Golden Valley
Zap
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PROJECT SEGMENTS
NDDWR MISSOURI RIVER INTAKE STUDY

Criterion Development

HDR and its team of subconsultants held several meetings to discuss the importance of certain criteria and discuss data sources and methodologies that could be used to spatially analyze each criterion. Industrial raw water intakes and riverbank filtration criteria are being developed in parallel in order to assign importance of each criterion and to take advantage of criteria that overlap. The project team reviewed the RFP criteria and determined they were extremely comprehensive, but in many cases encompassed additional analyses and different spatial analyses that could fit within those listed in the RFP. The following sections describe each criterion being developed as part of the study and the level of definition developed to date. Many of these definitions will be used in the preliminary siting of intakes and developed further as the study progresses. The project team discussed grouping multiple sub analyses within each category, rather than developing additional criteria, as additional criteria in the weighting process could dilute the impact of some criteria. In HDR's experience, during a multi-criteria decision analysis, such as this study, 5-10 criteria produce the most relevant results by reducing skewed results when too many criteria are used and overlapping or double counting occurs.

Water Availability

The project team's discussion on water availability focused on the ability of an intake location to be constructed with the capability of providing at least 15,000 acre-feet per year (13.4 million gallons per day, 320,000 barrels per day, 20.7 cubic feet per second, 9300 gallons per minute). It is assumed this amount would be pumped in a constant 24 hour per day capacity for the purpose of conceptual sizing. Conceptual sizing does not include peaking or pumping redundancy. To provide this capacity, surface water intakes need to be in locations that will remain inundated during severe drought and groundwater intakes must have the geologic capacity to allow subsurface withdrawals at the required rate. Additionally, the intakes must meet constructability requirements laid out by the project team which are based on topographic and geologic conditions.

SURFACE WATER

Surface water availability differs between Lake Sakakawea and the Missouri River. The project team assumed that surface water intakes on Lake Sakakawea be near or below the permanent pool elevation of the lake to ensure viability. Based on data available through the master manual for Garrison Dam, this elevation is noted at 1775 ft (msl) (reference). The project team has identified 1940s contour data for the region within the lake and is comparing the boundary contour of 1780 ft (msl) to the edge of the lake. For many criteria, an edited layer of the 24k and 100k lakes and rivers polygon layer available through NDGIShub is being utilized to represent the lake and river edge, as it closely matches many aerial photos of the lake and its bays observed in aerial photos. The spatial analysis conducted for this criterion will evaluate the distance between lake edge and the permanent pool of Lake Sakakawea.

To identify locations of surface water availability on the river, the lake and river edge data was compared to locations on straight sections of the main channel of the Missouri River and outside bends of the river, which are being digitized by the project team. Digitizing these sections of

river was performed using several years of National Agricultural Imagery Program's (NAIP) aerial photography and ArcGIS Pro to indicate the river sections were stable and therefore appropriately placed on each bank. These locations generally represent deeper sections of the lake, as well as areas less likely to experience significant sediment accumulation, which is an additional criterion being evaluated.

Additional efforts are being undertaken by the study's engineering, geotechnical, trenchless, and hydrogeology team members to develop criteria that identify locations on the river and lake that do not meet specific constructability parameters. Constructability is a broad criterion as it relates to the scope of this study. Site specific data is key to the development of final design construction documents, but for the purpose of this high level – large area study, the constructability criterion is focusing on ideal trenchless conditions that are most likely to allow for the successful construction of a raw water pipeline into a lake or river via a microtunneling application or horizontal directional drilling. Based on the 13.4 MGD capacity criterion, the study assumes a pipeline of at least 36" is needed to reduce velocities to less than 5 feet per second and reduce friction losses. The likelihood of success of the intake construction is planned to be broken in to 3 zones:

- Zone 1 – Optimal 0-10 Degrees of slope within 1000' of the lake or river.
- Zone 2 – Optimal 10-20 Degrees of slope within 1000' of the lake or river.
- Zone 3 – Optimal 20+ Degrees of slope within 1000' of the lake or river.

The zone's will be created using the contour data described above and project team derived percent slope data. The GIS model script will incorporate ideal construction conditions to include maximum vertical conditions between to the intake elevation and land where the intake pump station would be located, as well as relatively flat terrain for the pump station. The criterion will also include the removal of known active landslide data available through the North Dakota Geological Survey.

GROUNDWATER

Groundwater availability will be based on review of published data. The primary source of data will be the North Dakota Division of Water Resources MapService to include Drillers Logs and Ground Water Sites layers data, supplemented by North Dakota Geological Survey and United States Geological Survey publications and data. A review of NDGS County Ground Water Studies will be initially conducted to identify areas of alluvial and pre-glacial sand and gravel aquifers adjacent to the Missouri River and Lake Sakakawea.

MapService Drillers Logs and Ground Water Sites layers point data shapefiles will be downloaded for identified areas. As the shapefile tables do not contain sufficient hydrogeologic attributes associated with each data point, well and drillers log data will be individually reviewed to collect hydrogeologic parameters, when available, of:

- Saturated thickness
- Aquifer quality (grain-size coarseness)
- Elevation of quality aquifer
- Presence of fines layers inhibiting induced infiltration

- Well testing data (specific capacity)
- Water quality (TDS, specific conductance)

Hydrogeologic parameter values will be posted geographically to identify areas adjacent to the Missouri River and Lake Sakakawea showing potential to support a 15,000 AF groundwater supply. Additional hydrogeologic data for the identified potential areas from NDGS and USGS sources, if available, will be reviewed for further aquifer characterization. These data include seasonal groundwater and surface water fluctuations that may impact well yield.

Initial wellfield concepts of two horizontal collector wells or seven vertical wells would minimally require 50 feet of saturated sand and gravel aquifer with good connection to the surface water source (lack of fines layers, distance from surface water source).

Likelihood of Future Intake Sedimentation

SURFACE WATER

Intake sedimentation can be a costly operation and maintenance item and can ultimately disrupt water availability. Several geomorphology studies and sediment range data from the United States Army Corps of Engineers was reviewed to form the basis of assumptions for sedimentation considerations in the preliminary criterion. A series of shapefiles are being developed ranging from low risk to high risk for sedimentation along the study reach for the purpose of evaluating this criterion. In addition to these shapefiles, the study is currently digitizing a map that delineates outer bend of reaches and straight sections of the main channel, signifying regions with less likelihood of sedimentation. These regions were then compared to the edited 24k and 100k lakes and rivers polygon to identify intake locations that corresponded with more suitable locations to prevent or reduce the risk of sedimentation.

GROUNDWATER

Groundwater Intakes that pull a combination of groundwater and surface water through bank filtration can be greatly affected by sedimentation. Placing intakes in areas of high sedimentation can result in reduced capacity over time due to the continued sedimentation deposition. The groundwater likelihood of future intake and sedimentation will use the same shapefiles digitized by the project team that were described in the surface water section. This will help preference areas where bank filtration has the highest likelihood of success.

Distance to infrastructure including rail, power, roads, and natural gas.

Distance to infrastructure such as power and roadways can be crucial to development of industrial intakes, while rail and natural gas can lead to regions where industrial facilities could be developed in the future. The DWR included this criterion in the RFP to ensure these would be analyzed, and the project team deemed that power, and roadways would be most crucial to identifying locations where intakes could be developed.

POWER

The distance from power criterion was defined by the project team as suitable intake locations proximity to three phase power, identified by data from the Homeland Infrastructure Foundation Level Data, which is a requirement for pumps to deliver water from the intake site. Intake locations closer to three phase power/kv rating take priority with this analysis. The GIS analysis will utilize the distance from the lake or river as defined using boundary data to determine a length to available power.

ROADWAYS

The distance from roadways criterion was defined by the distance from a suitable intake location to roadways, identified from NDGIS Hub data or TIGER data - based on hierarchy. Roadway hierarchy is based the roadway priority code (primary, secondary, and local designation) with higher weighting towards the roadway's primary priority code. Intake locations closer to roadways and roadways with higher priority codes take priority with this analysis. The GIS analysis will utilize the distance from the lake or river as defined using boundary data to determine a length to roadways of each priority code.

RAIL

The distance to rail lines criterion was defined by an intake locations proximity to rail lines, identified by NDGIS hub data. Intake locations closer to rail lines take priority with this analysis. The GIS analysis will utilize the distance from the lake or river as defined using boundary data to determine a length to rail lines.

NATURAL GAS

The distance to natural gas criterion was defined by an intake locations proximity to natural gas pipeline facilities, identified by Homeland Infrastructure Foundation Level Data. Intake locations closer to natural gas take priority with this analysis. The criterion will consider vicinity to a natural gas pipeline for the purposes of intake pump station facility heating and emergency backup power. The GIS analysis will utilize the distance from the lake or river as defined using boundary data to determine a length to existing natural gas pipeline facilities.

Distance To Nearby Towns and Existing Industrial Facilities

An additional criterion included in the study is the vicinity of nearby towns & population centers, and existing industrial facilities when evaluating intake locations. A corresponding criterion listed in the RFP was to consider areas of industry interest. The project team determined these preliminary criteria were relevant to the study given the possibility of additional development of future industry in or near communities and existing industrial facilities. The study team also is coordinating with the Department of Commerce to develop a data set of previous industrial water use projects and regions that industries have expressed interest in previously.

DISTANCE TO NEARBY TOWNS

The project team determined all towns should be evaluated, but to test putting a preference on communities with higher population. This preliminary criterion will be based on the 2020 census population estimates for towns within North Dakota. City boundary data from NDGIS hub will be used for the location of the town and 2020 city population data will be used from NDGIS Hub. Higher priority will be given to locations closer to more populated communities. Hub communities such as Bismarck/Mandan, Dickinson, Williston, Minot, Watford City, and New

Town will be given a higher priority. Smaller communities within 100 miles will also be weighed into this criterion. As this is a study for the benefit of the entire State of North Dakota, larger eastern communities such as Fargo and Grand Forks will carry a small amount of importance due to the vast distance and weight in selecting an intake in the study area. The lake and river will be defined using boundary data from the 24k and 100k lakes and ponds data from NDGIS hub.

DISTANCE TO NEARBY EXISTING INDUSTRIAL FACILITIES

The project team determined this criterion would look at the distance from industrial facilities, including natural gas facilities (power plants & processing plants), coal mines, coal power plants, and agricultural facilities. This criterion will give preference to intake locations closer to these industries. Data sources for these facilities include data from the Homeland Infrastructure Foundation Level Data and NDGIS hub The lake and river will be defined using boundary data from the 24k and 100k lakes and ponds data from NDGIS hub.

Federal and State Permitting Requirements

While federal and state permitting requirements do not necessarily limit where potential intake locations can be, they do generally provide challenges with budgeting and timelines associated with developing a project. Ultimately, there are areas where additional oversight is required due to federal or state interests. These areas include property considered sovereign lands by the State, State trust lands, and properties managed by the United States Army Corps of Engineers (USACE), United States Bureau of Land Management (BLM), and United States Fish and Wildlife Services (USFWS). Preference will be given to intake locations that do not fall within these areas, but ultimately much of the land within the project area fall within the boundaries of land managed by these agencies. Authorization for work within Tribal reservation boundaries also requires additional coordination and permitting.

Riverine reaches within the study area will potentially require several permits or authorizations, including state sovereign lands permits, USACE Section 404 permits, and Section 10 authorization. Many of these permits or authorizations result from impacts below the ordinary high-water mark of certain waterways. Several USACE bank stabilization projects exist in the reach downstream of Garrison Dam and the focus will be on avoiding areas that require USACE Section 408 authorization. Section 408 authorization is triggered when a project impacts USACE civil works projects.

Additionally, the region around the lake consists primarily of federal properties and would require increased coordination as described above. State trust lands are located throughout the area and also require permits. Impacts within Lake Sakakawea also require Section 408 authorization due to its association with the Garrison Dam.

Ease and Cost of Water Delivery Based on Topography

Ease and cost of water delivery based on topography is an important factor when determining an intake's location. The project team discussed the challenges of this criterion, specifically the unknown location to where the industrial intake could be sending water. For this reason, the project team determined that identifying the ease and cost based on topography within 10 miles of the river would be analyzed. This would help determine areas that would require larger

pumps, higher pressure class piping, and ultimately higher operational costs associated in delivering water from the river and lake. The analysis to determine this criterion is still in development. An edited layer of the 24k and 100k lakes and rivers polygon layer available through NDGIShub will be utilized to evaluate the elevation change from the lake to a location 10 miles away. It is currently assumed the 36" pipeline would be DR 25 C900 PVC pipe as a basis of comparison. This assumption would allow for approximately 80' ft of friction and minor fitting losses as well as 300' of elevation change.

Expressed Interested in Nearby Locations by New Industry

The project team discussed several ways to evaluate this criterion. Since the project kickoff, interest has increased in reviewing specific regions of the river as part of the study. HDR and DWR discussed utilizing information from the Department of Commerce (DOC) for evaluating this criterion. The DOC has expressed interest in supporting this study and is currently assembling relevant information to be passed to the HDR team. Additionally, DWR's appropriation division has kept track of questions regarding water availability at specific locations that could also be evaluated under this criterion. This information has been provided to the project team as well. These locations would be evaluated against the 24k and 100k lakes and ponds layer to give preference to locations that are closer to locations identified by new industry.

Water Quality, Turbidity, and Aquatic Nuisance Species

The project team discussed water quality, turbidity, and aquatic nuisance species during an early criteria development meeting. Water quality, excluding turbidity, is relatively uniform without knowing which industries would use the water. Certain industries may require treatment or greater levels of treatment than others, but since treatment methods look at different parameters, it is not something that can be easily included in a scoping level analysis unless the specifics to the industry are understood. For this reason, turbidity was the only parameter that was included in water quality ranking.

TURBIDITY

The project team is working to develop shapefiles that include areas of higher turbidity from runoff into the Missouri River or Lake Sakakawea based on aerial photography. Areas of higher turbidity can be observed in aerial photography based on the coloration of the water near tributaries. Areas outside of the digitized shapefile will be given preference when selecting the intake location. The 24k and 100k lakes and ponds layer will be used to define the boundary of the river and lake.

AQUATIC NUISANCE SPECIES

The critical aquatic nuisance species of concern in the region that impact development includes Zebra Mussels, which are now located in the Garrison Reach of the Missouri River. Since the intake analysis is being conducted in regions, this would likely not affect the siting methodology HDR outlined in its proposal, but would be a factor when comparing the impacts between project reaches. The reach currently affected, below the Garrison Dam, will be evaluated as it currently has a higher level of impact of ANS.

GROUNDWATER

Groundwater quality parameters available within well logs vary. Quality data available in individual logs reviewed by the team will be entered into a data set to determine parameters used to evaluate the quality criteria. Total dissolved solids TDS and hardness are expected to present on a majority of well logs to be reviewed. Additional groundwater quality data for the identified potential areas from NDGS and USGS sources, if available, will be reviewed for further aquifer characterization.

Impacts to Areas of Natural, Cultural, and Historical Significance

Several different sub analyses were formulated by the project team to look at impacts that could fall within this criterion. Impacts to historical and cultural sites, designated critical habitat, and unbroken grasslands were all identified as things that could be impacted by intake development and analyzed under this criterion.

CULTURAL AND HISTORICAL SIGNIFICANCE

National Register data was identified as a preliminary publicly available data source for evaluating areas that could have impacts to historical and cultural sites. While sites in the database are limited, once potential site locations are known, a review of State Historic Preservation office (SHPO) data could be completed on the identified sites at a later date. It is noted that cultural sites within reservation boundaries are not always included in the SHPO information and would require coordination with the Tribal Historic Preservation Office (THPO). The project team determined intake locations will be given preference in this preliminary criterion if they do not fall within a quarter of a mile of these locations, using the 24k and 100k lakes and ponds data as the boundary of the river and lake.

IMPACTS TO AREAS OF NATURAL SIGNIFICANCE

Proximity to designated critical habitat was identified as a potential criterion that could have impacts since a significant portion of the area lies within critical habitat of the Piping Plover. Areas over a half of a mile from the United States Fish and Wildlife (USFWS) critical habitat layer will be given preference, in order to minimize impacts. Piping plover habitat surveys and monitoring may be triggered for impacts within a half-mile or within designated critical habitat, based on standard guidance from US Fish and Wildlife Service. The 24k and 100k lakes and ponds data from NDGIS hub would serve as the boundary of the river and lake for this criterion.

Unbroken grasslands/native prairie are another potential impact area identified within this criterion by the project team. Unbroken grasslands have a higher potential for impacting cultural sites and endangered species, like the Dakota Skipper, as they are areas where the ground has not been disturbed through agricultural or other uses.

Distance From Pollution Sources

The preliminary criterion for pollution sources is still in development. The group discussed potential pollution sources such as landfills and the potential for spills from oil and natural gas facilities. The project team discussed having one analysis include impacts from potential spills from land-based sources such as landfills, oil wells, and natural gas fields, while having another analysis look at regions immediately downstream from pipelines crossing the river. This is

currently the preferred method, but ultimately the analysis for this criterion is still in development.

Impacts to Recreation

The project team discussed ways to evaluate impacts to recreation and defined the preliminary criterion as occurring within 1,500 feet of boat ramps and state parks. This distance was determined in order to avoid construction and operation of the intake causing negative impacts to these facilities. State Parks data was retrieved through the NDGIS hub and boat ramp data was collected from the North Dakota Game and Fish Department. The criterion puts preference on locations not within 1500 feet of these locations using the 24k and 100k lakes and ponds data to define the shoreline.

Criterion Ranking and Weighting

HDR DecisionSPACE was selected to help identify the ranking and weighting of each criterion. DecisionSPACE is a Multi-Criteria Decision Analysis tool that was developed in Microsoft Access. The Multi-Criteria Decision Analysis is a means of semi-quantitatively comparing outcomes. The tool was determined to be appropriate for the Study because it can develop ranking and weights of criteria by determining the perceived level of importance of one criterion over another. A small group of the project team developed the initial ranking and weighting of the criteria and sent the outputs to the larger project team for comment. Ranking and weighting of criteria is developed through DecisionSPACE by evaluating each criterion against one another. Comparison between two criteria is evaluated on the following metrics:

- is extremely more important than
- is much more important than
- is more important than
- is less important than
- is much less important than
- is extremely less important than

Two separate DecisionSPACE comparisons were prepared, one for groundwater and another for surface water. The two types of intakes were separate due to the project team understanding water availability may be more restricted for groundwater, thus making its weighting more important. The criteria titles and initial ranking and weighting is provided in the tables below based on the preliminary definitions noted previously in this Technical Memo.

Figure 1. DecisionSPACE – Preliminary Criteria Ranking/Weighting for Surface Water

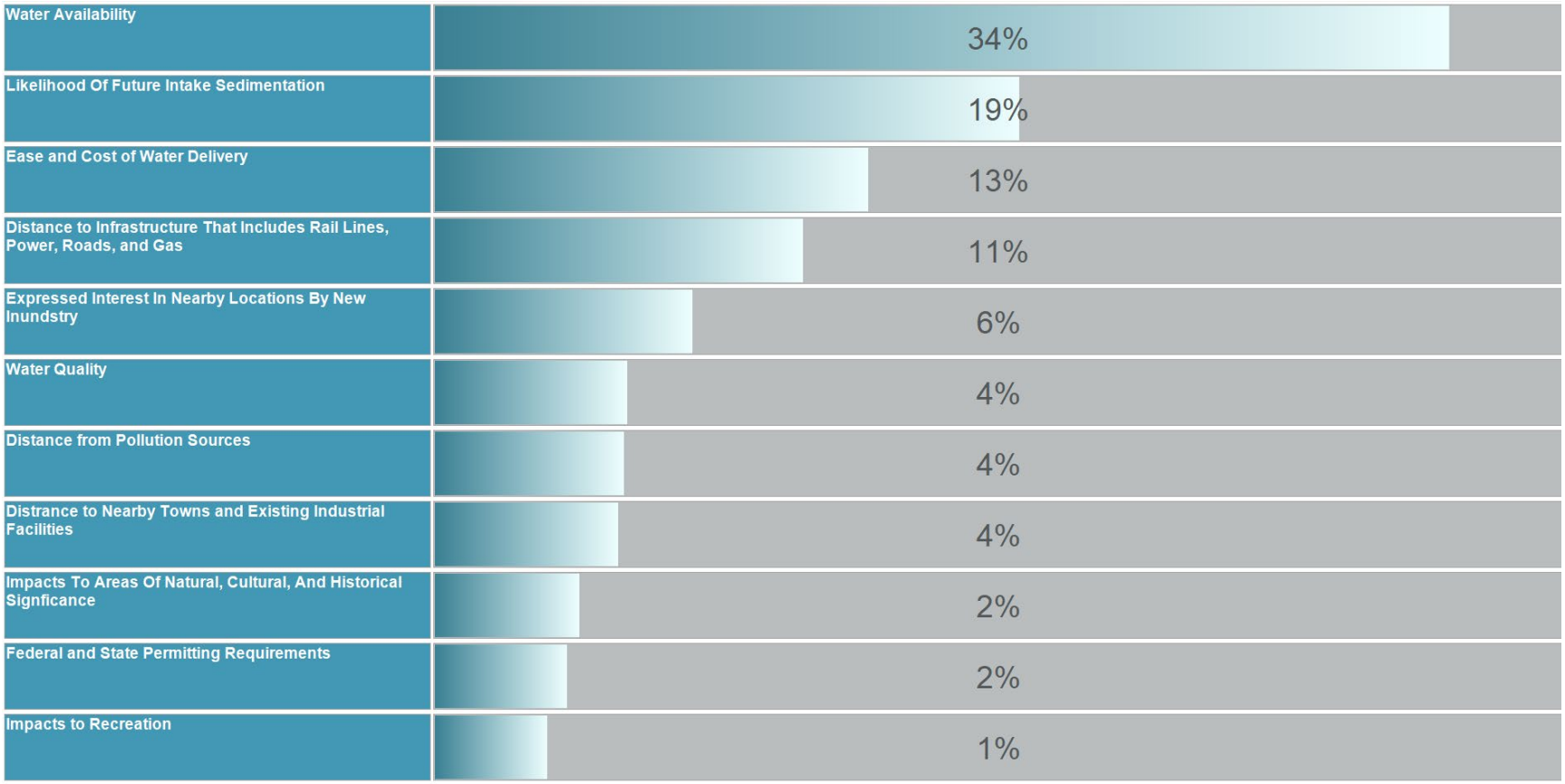
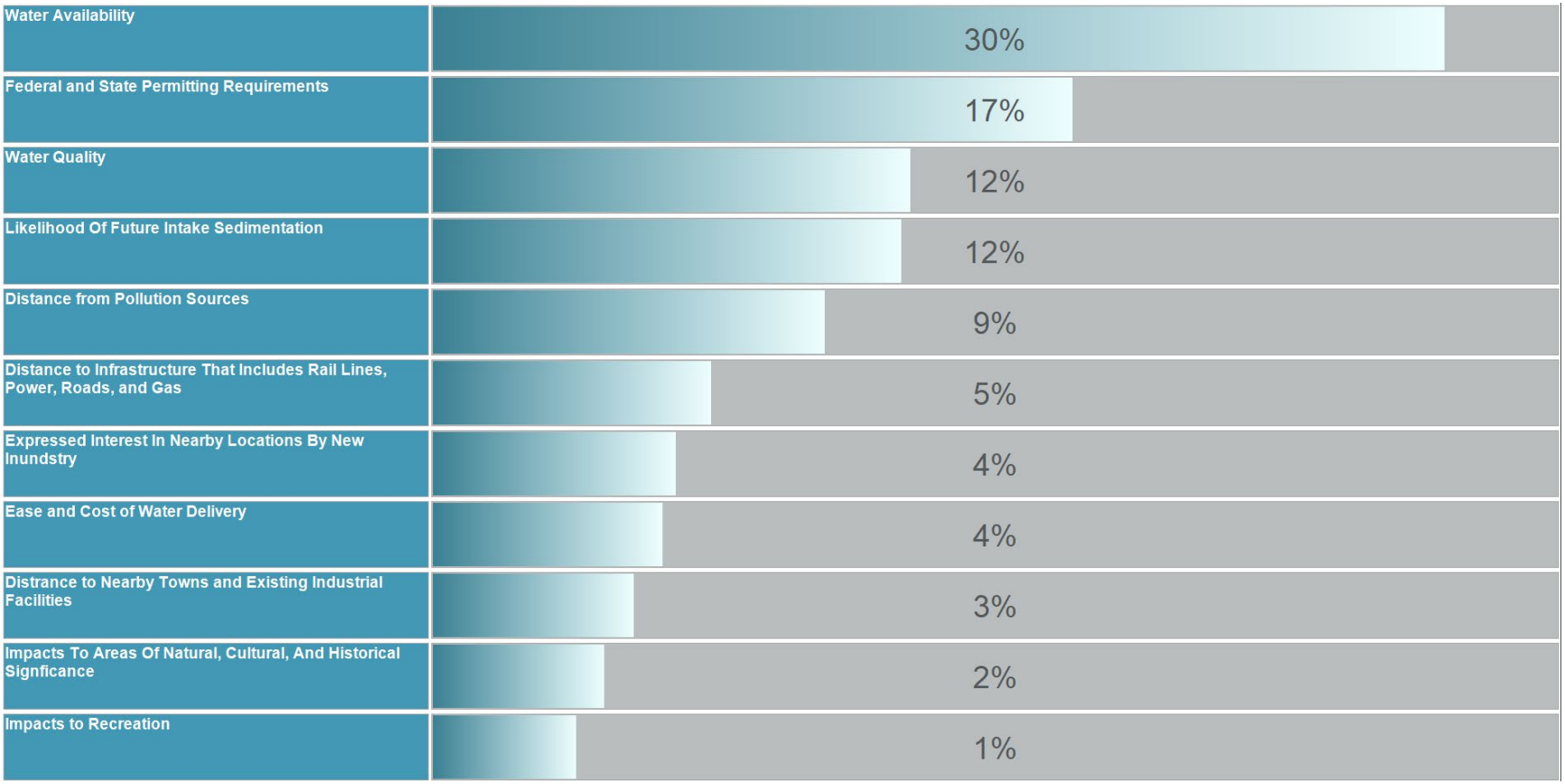


Figure 2. DecisionSPACE – Preliminary Criteria Ranking/Weighting for Ground Water



Next Steps

Following the adoption of preliminary ranking and weighting, the remainder of the analysis for each criterion will be completed and the GIS model will be developed. Iterations of the analysis will need to be conducted to refine intake locations, as the first output of the analysis will likely need to be refined. HDR plans to provide preliminary intake siting locations to the DWR by August 19th, 2024, with a schedule in-progress review meeting on August 28th, 2024.

Appendix A

Data Bibliography - Draft

Status (Find, In Work, Downloaded)	Data Name	Source Name	URL Website	Date of Data	Date Accessed Data	File Path
Emailed to Josh	1943 Sakakawea Lake Contours	State of ND				
Find	Ag Agronomy/Fertilizer Plants					
Find	Aquifers	NDGISHUB				
Downloaded	Assessed Category Lakes	NDGISHUB	NDGISHUB Assessed Category Lakes | NDGISHUB Assessed Category Lakes | Nc	2/2/2024	5/24/2024	Base_Data.GDB
Find	Bedrock	NDGISHUB				
Downloaded	Boat Ramps	ND Game and Fish	Missouri River System and Devils Lake Boat Ramps - Overview (arcgis.com)	3/28/2013	6/7/2024	
In work (BW)	Campgrounds	ND State Parks Dept (requested dataset).				
Find	City Locations for Pop Data	NDGISHUB				
Find	Coal Mines					
Downloaded	Contours 24k	NDGISHUB	NDGISHUB Statewide Contours 24k | NDGISHUB Statewide Contours 24k | Nor	4/25/2023	5/24/2024	Base_Data.GDB
Downloaded	Electric Transmission	HIFLD	Transmission Lines | Transmission Lines | HIFLD (arcgis.com)	12/11/2023	6/7/2024	
Find	Gas Pipelines	ND Dept of Mineral Resources				
Find	Gas Plants	ND Dept of Mineral Resources	https://gis.dmr.nd.gov/gisdownload.asp			
Find	Grain Elevators					
Downloaded	Inventory of Dams	USACE	National Inventory of Dams - NID | GeoSpatial (arcgis.com)	4/28/2022	5/24/2024	Base_Data.GDB
Downloaded	Lake Contours	NDGISHUB	NDGISHUB Lake Contours | NDGISHUB Lake Contours | North Dakota GIS Hub I	2/1/2022	5/24/2024	Base_Data.GDB
Downloaded	Lakes and Ponds 100k	NDGISHUB	NDGISHUB Lakes and Ponds 100k | NDGISHUB Lakes and Ponds 100k | North D	3/25/2020	5/24/2024	Base_Data.GDB
Downloaded	Lakes and Ponds 24k	NDGISHUB	NDGISHUB Lakes and Ponds 24k | NDGISHUB Lakes and Ponds 24k | North Dak	12/2/2021	5/24/2024	Base_Data.GDB
Downloaded	Landfills	NDGISHUB	NDGISHUB Landfills | NDGISHUB Landfills | North Dakota GIS Hub Data Portal (	9/25/2023	6/23/2024	Base_Data.GDB
Link	Levees/Dams	US ACE	https://levees.sec.usace.army.mil/search			
Find	Municipal Boundaries	NDGISHUB				
Find	National Registrar of Historic Places Cultural & Historic	US Forest Service				
Find	Natural Gas Pipelines	NDGISHUB				
Downloaded	ND Forest Service	NDGISHUB	NDGISHUB State Forest Lands	3/22/2022	6/24/2024	Base_Data.GDB
Emailed to Josh	ND GF Unbroken Grasslands	ND Game and Fish		5/13/2022	3/21/2024	
Find	ND Mineral Trust Lands	NDGISHUB				
In work (BW)	ND Parks and Rec / State Parks	Requested from ND State Parks				
Downloaded	ND State Parks	NDGISHUB	NDGISHUB State Parks	3/22/2022	6/12/2024	
Find	ND Surface Trust Lands	NDGISHUB				
Downloaded	ND Wildlife Management Areas	NDGISHUB	https://gishubdata-ndgov.hub.arcgis.com/maps/fb49002e15cf4dd08df1cc995a	2/28/2022	6/24/2024	Base_Data.GDB
Find	NHD	USGS				
Link	NWI	USFWS	NWI Inventory			
Find	Oil & Natural Gas Fields	ND Dept of Mineral Resources				
Downloaded	Oil & Natural Gas Wells	ND Dept of Mineral Resources	https://gis.dmr.nd.gov/dmrpublicservices/rest/services/OilGasPublicMapDataV	7/17/2023	5/24/2024	
Find	Oil Pipelines	ND Dept of Mineral Resources				
Downloaded	Ordinary High Water Mark	ND Mapservice	ND Department of Water Resources MapService		6/7/2024	Base_Data.GDB
Link	Parcels	NDGISHUB	ND Parcel Data	6/9/2024	6/12/2024	
Emailed to Josh	Pipeline Crossings	Clay - NDDWR			6/12/2024	
Find	Power Plants					
Find	Railroads	NDGISHUB				
Find	River Guage Information - Low Avg Weekly Flows					
Find	Roads	NDGISHUB				
Talk to Chris	Sediment Characteristics					
Find	SHPO Cultural Data					
Find	Soils/Prime Farmland/Corrosive					
Find	Stream Guages	ND Mapservice				
In work (BW)	Trails	ND State Parks Dept (requested dataset).				
Create	Turbidity		Sierra Creating			
Find	US Army Corp of Engineer Lands	USACE				
Find	US BLM Lands					
Link	US Bureau of Rec Lands	NDGISHUB	Reclamation Lands	3/22/2022	6/12/2024	
In work (BW)	US Forest Service	ND State Parks Trails Database				
In work (BW)	US FWS Tracts	USFWS				
Link	US National Parks	NDGISHUB	National Parks Within ND	3/22/2022	6/12/2024	
Find	US Surface Management Agency Boundaries	US DOI				
Find	USFWS Critical Habitat / T&E Species	USFWS				
Find	USGS Contours/DEM/Lidar	USGS				
Find	Well Logs	ND Mapservice				

MEMO

Date:	
Project:	Missouri River Intake Study
To:	Clay Carufel, North Dakota Department of Water Resources
From:	HDR Engineering Inc. Jarrett Hillius, P.E., & Chris Korkowski, P.E.
Subject:	IPR Meeting 2 Memorandum – Spatial Analysis & Initial Siting

Introduction

HDR Engineering, Inc. (HDR) prepared this memorandum to outline the setup of the spatial analysis and to evaluate initial surface and groundwater sites identified as part of the Missouri River Intake Study (Study). A review of necessary field work required to assist with site verification was described separately in the August 19, 2024, memorandum to assist the North Dakota Department of Water Resources (DWR) with its efforts. Information within this memorandum summarizes the progress made since IPR Meeting 1, focusing on the spatial analysis and initial siting locations. Updates to criteria or weighting of sub criteria were not described within this memorandum but are captured briefly in Appendix A of this memorandum. Final edits to the criteria ranking and weighting will be captured within the final report.

Spatial Analysis

HDR and its project team developed the spatial analysis in ESRI ArcGIS Pro (ArcPro) version 3.1.2 based on the criteria described in the IPR 1 memorandum. The basis of the analysis required two different spatial analysis models to be developed to identify surface water and groundwater (riverbank filtration) industrial intake locations.

Surface Water

Surface water intake sites within the spatial analysis are based on 1,000’ by 2,000’ grid cells created along the shoreline throughout the project corridor. The grid was utilized to help identify intake locations without identifying an exact location, since the analysis is based on approximate data with varying degrees of spatial accuracy. The original proposal for the grid was to use 1,000’ by 1,000’ cells, but the slope constructability analysis of the water availability criterion had difficulty analyzing areas where the majority of a grid cell extended into water. The larger grid cell allowed for the slope analysis to be clipped along the shoreline while maintaining enough DEM (Digital Elevation Model) data on the landward side to adequately identify suitable slopes. The spatial grid was created using the ArcPro Strip Map Index Features tool. **Figure 1** illustrates the generated grid downstream of Garrison Dam. A total of 6,978 grid cells exist within the project corridor. **Table 1** provides the number of cells for each sub-reach and **Figure 2** illustrates the sub-reaches used for the study.

Figure 1. Surface water spatial analysis grid.

Table 1. Grid cells per sub-reach for surface water analysis.

SUB-REACHES	NUMBER OF GRID CELLS
Williston to State Line, Left	264
Williston to State Line, Right	227
Fort Berthold to Williston, Left	589
Fort Berthold to Williston, Right	536
Fort Berthold, Left	1457
Fort Berthold, Right	2387
Garrison Dam to Fort Berthold, Left	709
Garrison Dam to Fort Berthold, Right	438
Washburn to Garrison Dam, Left	182
Washburn to Garrison Dam, Right	189
Total	**6978**

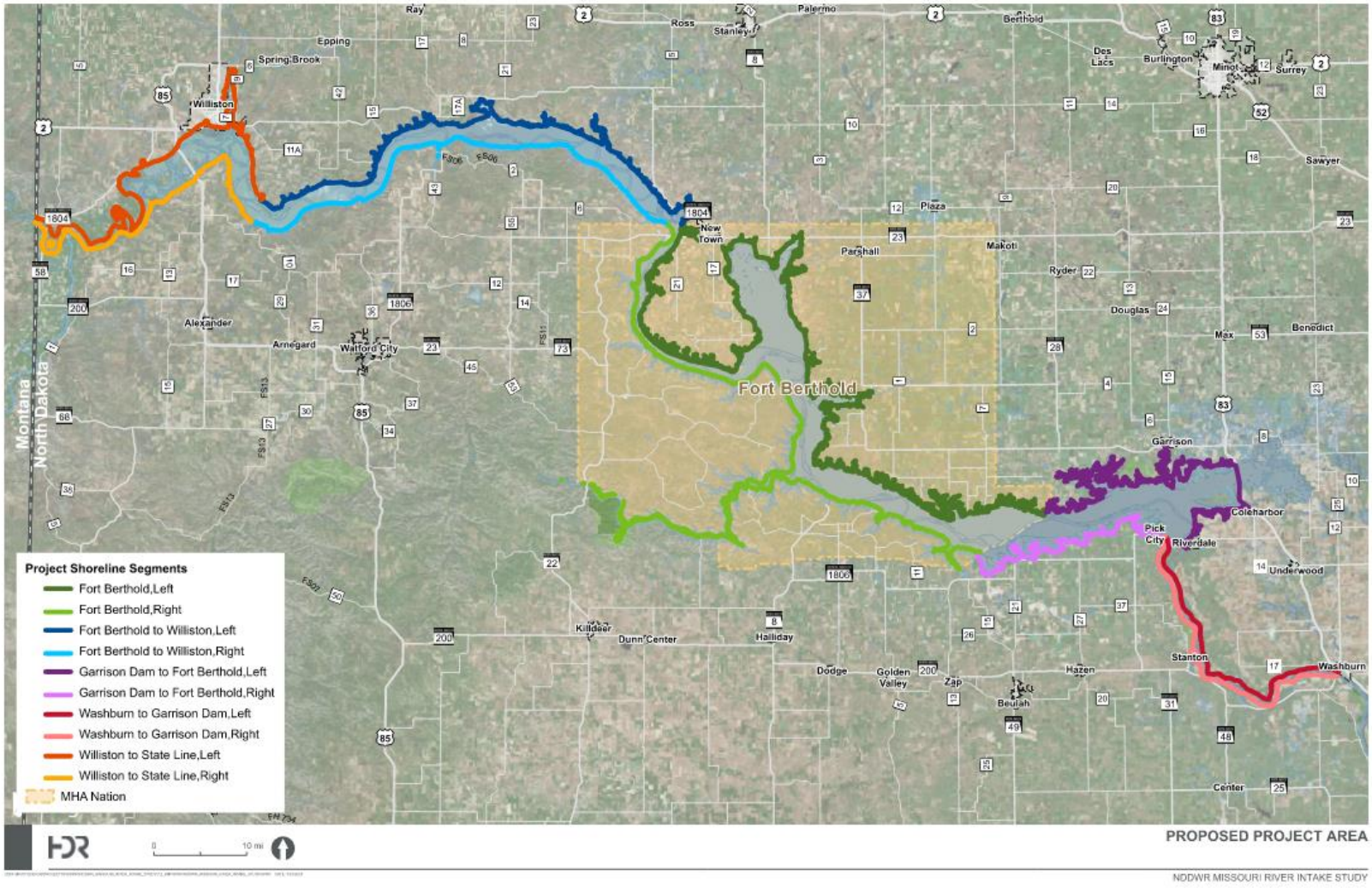


Figure 2. Sub-reaches used for site identification.

Groundwater

Aquifers suitable to meet the study's required yield were identified by the project team by analyzing available data sources. These sources included hydrogeologic publications and maps prepared by or in cooperation with the North Dakota Geological Survey (NDGS) to include county ground water studies, NDGS Guides to the Geology of Southwestern and Northwestern North Dakota, and a preliminary glacial map of North Dakota. The purpose of this review was to determine areas where alluvial channels, preglacial streams, and glacial outwash deposits exist adjacent to the Missouri River, Lake Sakakawea, and Lake Audubon. HDR held a meeting with DWR staff to discuss how to appropriately include groundwater sites in the geospatial model due to much of the study reach not having suitable aquifers. During the meeting, HDR proposed only analyzing groundwater sites that could provide the water availability needed for the industrial intakes, to which DWR concurred. Across the study area, 18 suitable aquifer areas were identified.

Once the major sand and gravel aquifer locations were identified, available well logs were reviewed to develop aquifer area polygons that should support the 15,000 acre-ft (AF/yr), or 13.4 million gallons per day (MGD), capacity requirement. Well logs available on the DWR MapService were reviewed for lithology, static water levels, and water quality. Well logs in the Ground Water Sites layer were given more weight than those in the Drillers Logs layers because they contained more comprehensive and higher quality data. It should be noted that most of the Drillers Logs did not indicate penetration into the underlying bedrock, as wells are typically drilled only as deep as necessary for their intended use. The reported physical location of well logs is not exact. Data in the Drillers Logs layer was more subjective, as all well drillers do not identify formation material in a uniform manner. As such, well locations for logs in the Drillers Logs layer may be unreliable due to the self-reported nature of the logs.

Ground Water Sites well logs were reviewed within the areas upstream of Williston and downstream of Garrison Dam to determine the aquifer potential of the Missouri River alluvial valley. Both Ground Water Sites well logs within one mile of Lake Sakakawea and Lake Audubon and well logs along known preglacial channels were reviewed to identify potential sand and gravel aquifers adjacent to the lakes. The well logs, where enough data was present, were subjectively ranked into four categories based on the reviewer's experience with siting and developing horizontal collector wells and high-capacity vertical wells in similar hydrogeologic settings. The four categories were:

- **Excellent** – appears capable of supporting more than 15,000 AF/yr to a single horizontal collector well or 4,000 AF/yr to a vertical well. In general, these logs indicate more than 100 feet of clean saturated sand and gravel aquifer parallel to the anticipated elevation of Missouri River alluvium.
- **Good** – appears capable of supporting 15,000 AF/yr to a single horizontal collector well or 3,000 AF/yr to a vertical well. In general, these logs indicate more than 80 feet of clean saturated sand and gravel aquifer parallel to the anticipated elevation of Missouri River alluvium.

- **Marginal** - appears capable of supporting 15,000 AF/yr with two horizontal collector wells or 1,500 AF/yr to a vertical well. In general, these logs indicate more than 50 feet of clean saturated sand and gravel aquifer parallel to the anticipated elevation of Missouri River alluvium.
- **Would Not Support** – there does not appear to be sufficient aquifer saturated thickness or aquifer quality to support a 7,500 AF/yr collector well, or saturated thickness and static water level of the aquifer does not appear to line up with pre-lake alluvium elevation and lake water levels.

The ranked well data was color coded and posted back to GIS to identify aquifer areas (polygons) that appear capable of supporting the 15,000 AF/yr target. Drillers Logs and well logs were reviewed within polygons to further inform the delineation of the polygons. Delineated polygons contained mostly Excellent, Good, and Marginal data points, with some Would Not Support data points. This reflects the hydrogeologic variability in alluvial aquifers and the quality of the well log data.

Lasty, Drillers Logs and well logs along the perimeter of the lakes, in areas without sufficient Ground Water Site data coverage, were reviewed to identify any additional glacial outwash aquifers capable of supporting the 15,000 AF/yr. Most aquifer areas had suitable sand and gravel aquifer within 200 feet of ground surface. Those areas could be developed with either horizontal collector wells or vertical wells. The aquifer areas where depth to suitable sand and gravel aquifer is greater than 200 feet are only an option for developing vertical wells as horizontal collector well caisson constructability is typically limited to 200 feet deep.

Groundwater polygons were identified based on areas where the 15,000 AF/yr capacity requirement could be met. These polygons were separated into two categories. Category 1 contains aquifer area locations that should meet or exceed capacity requirements with the installation of one or two horizontal collector wells. Category 2 contains aquifer area locations that could meet capacity requirements but did not have sufficient data coverage to verify this potential. These sites would require additional field investigation to further characterize the aquifer.

Groundwater cells were generated within each groundwater polygon identified by the team. The average footprint required for a horizontal collector well is 500' by 500'. For this reason, 500' by 500' cells were developed within the groundwater polygons using ArcPro's Index Tool. The maximum distance that a horizontal collector well should be placed from the shore of a water body and still achieve a high rate of induced infiltration is 5,000 feet. For this reason, a 5,000-foot buffer was created around the shoreline polygon and then intersected with the groundwater cell centroids grid using ArcPro's Spatial Join tool. All cells whose centroids did not intersect with the 5,000-foot buffer were removed from consideration due to the lower likelihood of achieving the induced infiltration rate required to provide an adequate percentage of surface water. The remaining cells were then filtered using ArcPro's Spatial Join tool to select cells whose centroid intersected the shoreline polygon. The shoreline polygon uses the 1,860-foot elevation contour to map the normal shoreline around the Missouri River corridor, including Lake Sakakawea.

Suitable aquifers were then buffered to 5,000 feet of the low water boundaries for the Missouri River, Lake Sakakawea, and Lake Audubon. The 5,000-foot buffer was developed due to constraints of blending surface water and groundwater with bank filtration. Since the study explicitly looked at bank filtration, aquifers greater than 5,000 feet away would likely be withdrawing a higher percentage of groundwater. The ArcPro Strip Map Index Features tool was used to create the spatial grid over the buffered aquifers for the groundwater spatial analysis. 500' by 500' cells were used on the project corridor with the number of cells totaling 6,213. **Figure 3** illustrates the generated grid for groundwater analysis and **Table 2** provides the number of cells per sub-reach of the study. The yellow grid cells in Figure 3 denote suitable aquifers locations that were identified. The yellow grid cells were only generated with 5,000 feet of the low water contours of the river (depicted in teal).

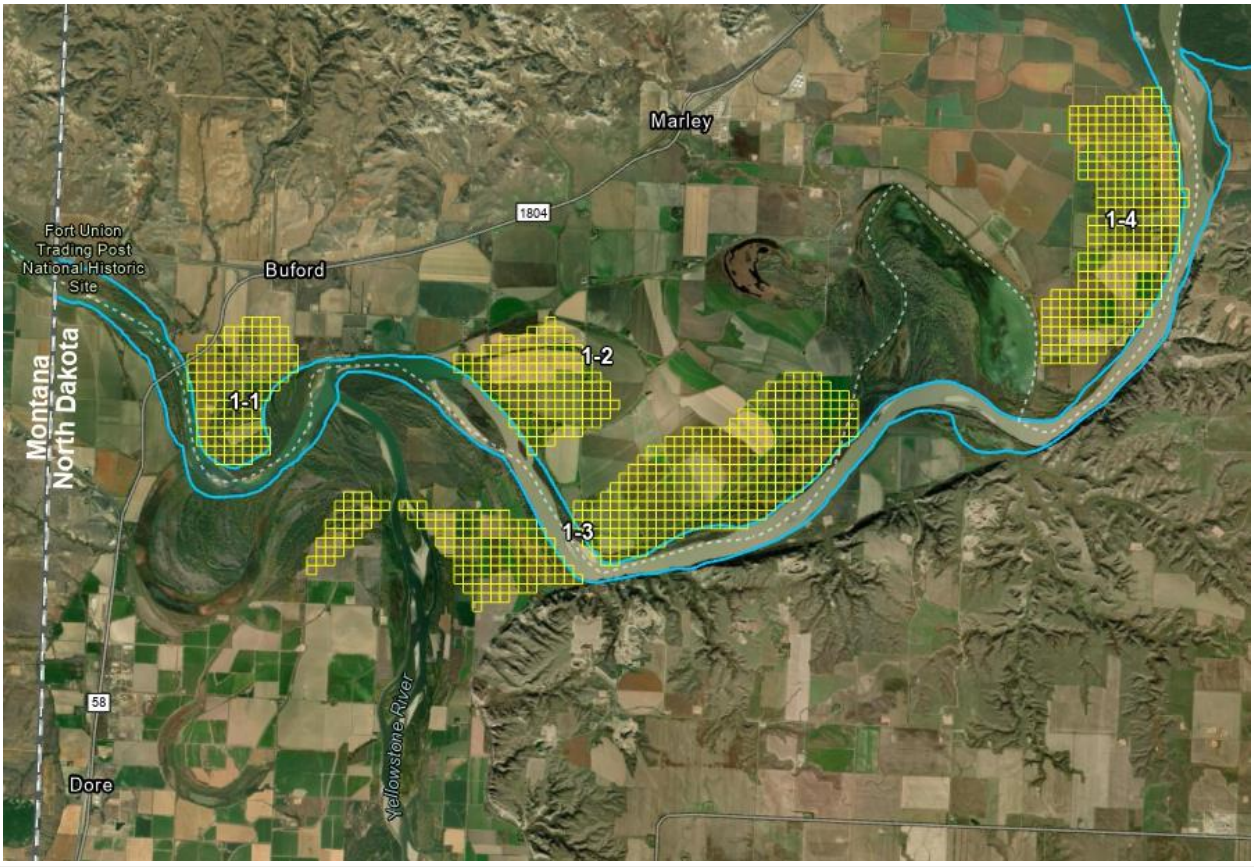


Figure 3. Groundwater spatial analysis grid.

Table 2. Grid cells per groundwater grid.

GROUNDWATER GRIDS	NUMBER OF GRID CELLS
1-5 Yellowstone Buried	**49**
1-11 White Shield	**489**
1-8 White Shield	**268**

1-1 Trenton	132
1-2 Trenton	140
1-3 Trenton	465
1-4 Trenton	292
2-3 Tobacco Garden	215
1-10 Renner Bay	239
1-7 Outwash	499
2-2 New Town	240
1-13 Knife River	49
1-6 Hofflund	1033
2-5 Hans Creek	187
1-14 Fort Mandan	1461
2-1 Charbonneau	231
1-9 Antelope	223
Total	6212

Grid Cell Scoring

ArcPro's model builder tool was used as a basis for evaluating each criterion and sub-analysis created as part of this study against the newly-developed spatial grid system. Each spatial grid cell was ranked based on the criteria developed throughout the earlier phases of the study. The criteria were updated after the completion of the in-progress review meeting to account for multiple sub-analyses within each criterion. Appendix A summarizes each sub-analysis weight within the overall criterion that was used for preliminary site selection.

Each criterion group was given a maximum potential value of 1.0 in the model, indicating that 100-percent of the criterion weight would be applied to a grid cell. The overall criteria score for each grid cell was the sum of criterion group scores multiplied by the criterion weighting. **Table 3** provides the criteria group scores and the overall score for a surface water cell FB0358R, which is in the Fort Berthold right reach. Cells with the highest cumulative ranking were then highlighted and reviewed to determine which sites are appropriate for an industrial intake site.

Table 3. Score summary for FB0358R.

FORT BERTHOLD, RIGHT	
GRID CELL NAME	**FB0358R**
OVERALL SCORE	**0.440**
Criteria Group Scores	
Water Availability Score	**0.374**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**0.000**
Distance to Infrastructure Score	**0.244**
Water Quality Score	**0.500**
Distance to Nearby Towns and Existing Industry Score	**0.368**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**0.500**
Federal and State Permitting Requirements Score	**0.000**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.455**

Initial Sites

The summation of overall scores was used to determine the most suitable surface water and groundwater industrial intake sites based on their respective spatial analysis. Surface water grid cells had an average score of 0.52, with a maximum score of 0.88. Groundwater grid cells had an average score of 0.73, with a maximum score of 0.87. The project was incorporated into ArcGIS Online (AGOL) so that individual grid cells could be viewed by DWR and the project team. AGOL also includes reach ranking parameters, allowing the user to examine the top-ranking grid cell in each reach including the top 10 or top 100 grid cells within a reach.

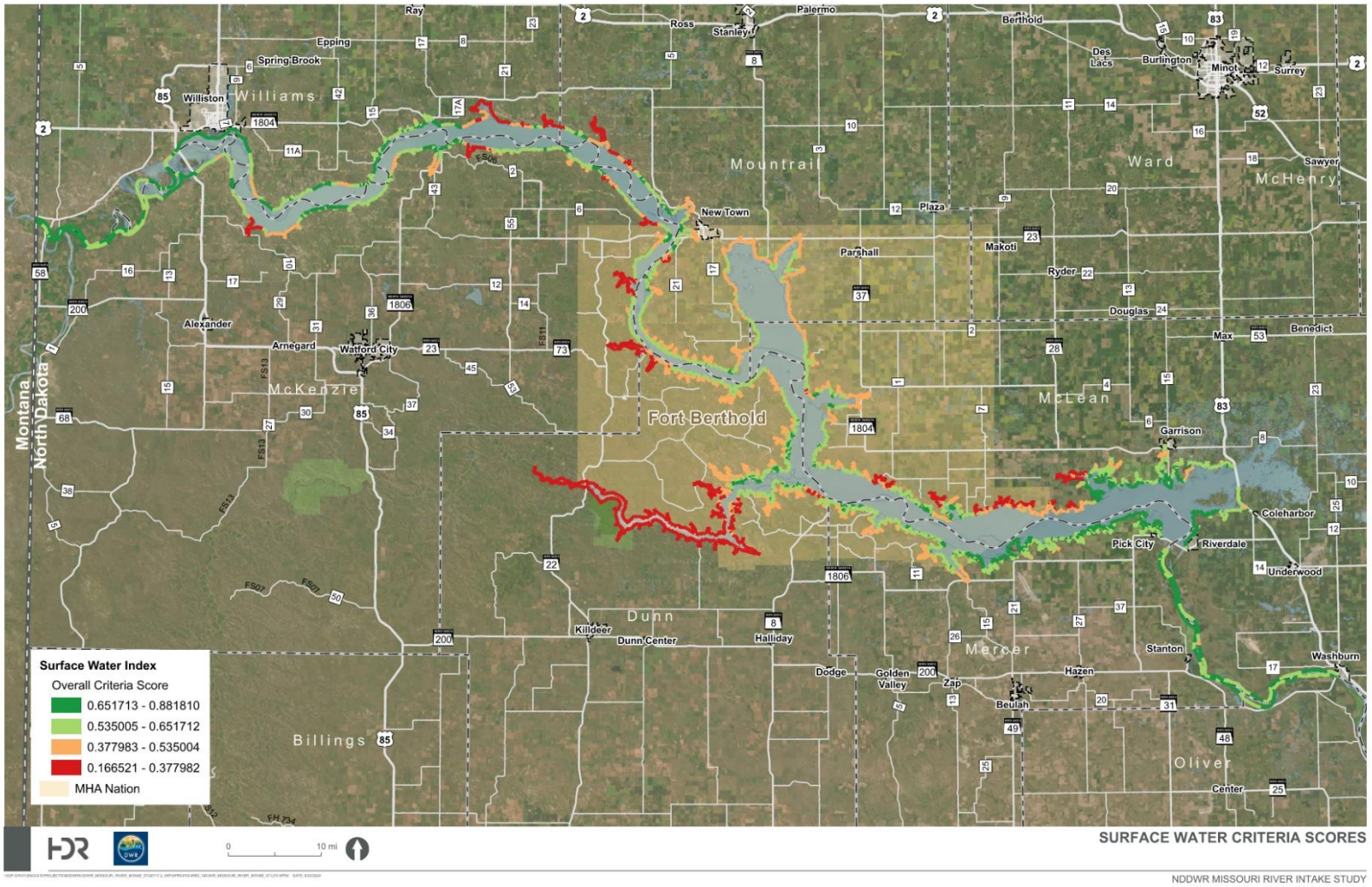


Figure 4. Overall site ranking for surface water spatial analysis.

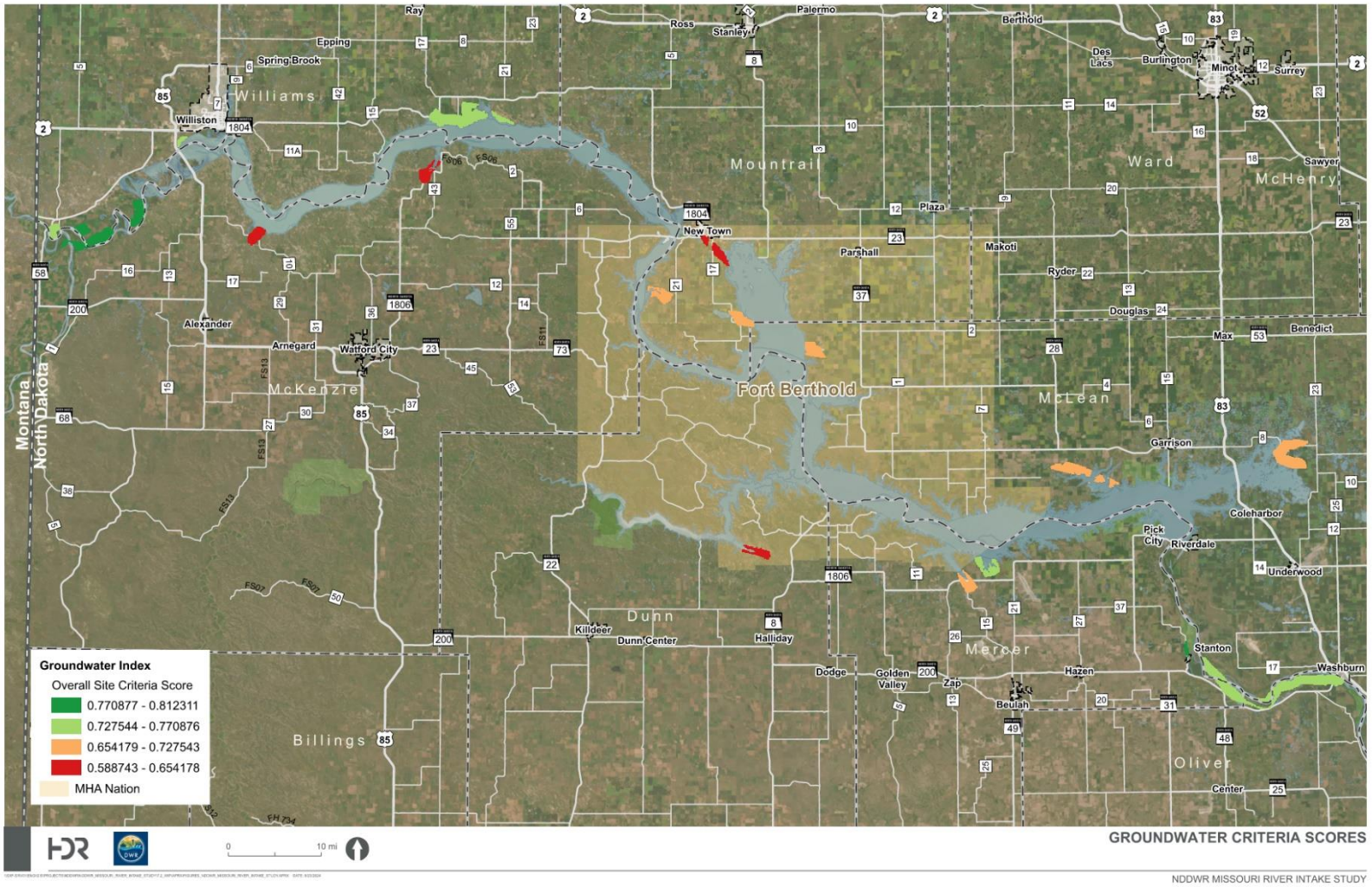


Figure 5. Overall site ranking for groundwater spatial analysis.

Surface Water Sites

The top-ranking grid cell in each sub-reach, illustrated in **Figure 2**, was determined via the surface water spatial analysis. The region around the top-ranking cell is described in this memorandum from the most downstream reach to the Montana state line. The scores of the top-ranking cell are described within this section, but the surrounding cells are highlighted in the site maps to avoid identifying only the sole location that contributed to the highest-ranking cell. In some cases, the top-ranking cell falls within an area that may need to be refined in future iterations of the spatial model through refinement of criteria or developing model constraints.

WASHBURN TO GARRISON DAM (RIGHT)

The top-ranking cell in the Washburn to Garrison Dam (Right) reach was WG0066R. This site is located north of the City of Stanton, just east of the Knife River Indian village. **Table 4** provides the overall and criteria group scores for the grid cell. The site offers easy access from the west on County Road 18 and has nearly perfect scores in the highest weighted criteria.

Table 4. Top ranking cell for Washburn to Garrison Dam (Right).

WASHBURN TO GARRISON DAM, RIGHT	
GRID CELL NAME	**WG0066R**
OVERALL SCORE	**0.857**
Criteria Group Scores	
Water Availability Score	**1.000**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**0.500**
Distance to Infrastructure Score	**0.906**
Water Quality Score	**0.625**
Distance to Nearby Towns and Existing Industry Score	**0.658**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**0.500**
Federal and State Permitting Requirements Score	**1.000**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.667**

WASHBURN TO GARRISON DAM (LEFT)

The top-ranking cell in the Washburn to Garrison Dam (Left) reach was WG0021L. This site is located several miles south of the City of Riverdale and immediately downstream from the exit channel for Garrison Dam's emergency spillway. **Table 5** provides the overall and criteria group scores for the grid cell. The site offers moderate access from the east off of 40th Avenue NW and has high scores in water availability and likelihood of future intake sedimentation.

Table 5. Top ranking cell for Washburn to Garrison Dam (Left).

WASHBURN TO GARRISON DAM, LEFT	
GRID CELL NAME	**WG0021L**
OVERALL SCORE	**0.788**
Criteria Group Scores	
Water Availability Score	**0.992**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**0.000**
Distance to Infrastructure Score	**0.832**
Water Quality Score	**0.625**
Distance to Nearby Towns and Existing Industry Score	**0.659**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**0.750**
Federal and State Permitting Requirements Score	**1.000**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.731**

GARRISON DAM TO FORT BERTHOLD (RIGHT)

The top-ranking cell in the Garrison Dam to Fort Berthold (Right) reach was GFB0417R. This site is in Lake Sakakawea State Park. **Table 6** provides the overall and criteria group scores for the grid cell. State parks were included as a criterion to weight sites away from these areas of land, as shown in the zero score for impacts to recreation and federal and state permitting requirements. This reach offers great access to permanent pool elevations in Lake Sakakawea equating to high scoring for Water Availability and other high criteria groups.

Table 6. Top ranking cell for Garrison Dam to Fort Berthold (Right).

GARRISON DAM TO FORT BERTHOLD, RIGHT	
GRID CELL NAME	**GFB0417R**
OVERALL SCORE	**0.867**
Criteria Group Scores	
Water Availability Score	**0.925**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**1.000**
Distance to Infrastructure Score	**0.861**
Water Quality Score	**0.500**
Distance to Nearby Towns and Existing Industry Score	**0.699**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**0.500**
Federal and State Permitting Requirements Score	**0.000**
Impacts to Recreation Score	**0.000**
New Industry Score	**0.763**

GARRISON DAM TO FORT BERTHOLD (LEFT)

The top-ranking cell in the Garrison Dam to Fort Berthold (Left) reach was GFB0048L. This site is located north of the City of Riverdale and due west of the Wolf Creek Campground. **Table 7** provides the overall and criteria group scores for the grid cell. The grid cell falls within a North Dakota Game and Fish (NDGF) wildlife management area but offers high scores in all the major criteria.

Table 7. Top ranking cell for Garrison Dam to Fort Berthold (Left).

GARRISON DAM TO FORT BERTHOLD, LEFT	
GRID CELL NAME	**GFB0048L**
OVERALL SCORE	**0.882**
Criteria Group Scores	
Water Availability Score	**0.915**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**1.000**
Distance to Infrastructure Score	**0.834**
Water Quality Score	**0.500**
Distance to Nearby Towns and Existing Industry Score	**0.687**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**0.500**
Federal and State Permitting Requirements Score	**0.000**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.955**

FORT BERTHOLD (RIGHT)

The top-ranking cell in the Fort Berthold (Right) reach was FB2386R. This site is located on the extreme southeast boundary of the Fort Berthold reservation and north of the City of Zap, between the Beaver Creek Bay and Renner Bay. **Table 8** provides the overall and criteria group scores for the grid cell. The cell provides high scores in water availability, likelihood of future intake sedimentation, and ease and cost of water delivery.

Table 8. Top ranking cell for Fort Berthold (Right).

FORT BERTHOLD, RIGHT	
GRID CELL NAME	**FB2386R**
OVERALL SCORE	**0.797**
Criteria Group Scores	
Water Availability Score	**0.888**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**1.000**
Distance to Infrastructure Score	**0.454**
Water Quality Score	**0.563**
Distance to Nearby Towns and Existing Industry Score	**0.482**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**0.500**
Federal and State Permitting Requirements Score	**0.000**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.427**

FORT BERTHOLD (LEFT)

The top-ranking cell in the Fort Berthold (Left) reach was FB1289L. This site is located in Nishu Bay but has limited access. **Table 9** provides the overall and criteria group scores for the grid cell. The cell provides high scores in water availability, likelihood of future intake sedimentation, and ease and cost of water delivery.

Table 9. Top ranking cell for Fort Berthold (Left).

FORT BERTHOLD, LEFT	
GRID CELL NAME	**FB1289L**
OVERALL SCORE	**0.777**
Criteria Group Scores	
Water Availability Score	**0.811**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**1.000**
Distance to Infrastructure Score	**0.388**
Water Quality Score	**0.500**
Distance to Nearby Towns and Existing Industry Score	**0.323**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**0.500**
Federal and State Permitting Requirements Score	**0.000**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.836**

FORT BERTHOLD TO WILLISTON (RIGHT)

The top-ranking cell in the Fort Berthold to Williston (Right) reach was FBW0459R. This site is downstream of Phelps Bay several miles upstream of Four Bears Village, across the river from New Town. **Table 10** provides the overall and criteria group scores for the grid cell. The cell provides high scores in water availability, likelihood of future intake sedimentation, and ease and cost of water delivery.

Table 10. Top ranking cell for Fort Berthold to Williston (Right).

FORT BERTHOLD TO WILLISTON, RIGHT	
GRID CELL NAME	**FBW0459R**
OVERALL SCORE	**0.797**
Criteria Group Scores	
Water Availability Score	**0.888**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**1.000**
Distance to Infrastructure Score	**0.454**
Water Quality Score	**0.563**
Distance to Nearby Towns and Existing Industry Score	**0.482**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**0.500**
Federal and State Permitting Requirements Score	**0.000**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.427**

FORT BERTHOLD TO WILLISTON (LEFT)

The top-ranking cell in the Fort Berthold to Williston (Left) reach was FBW0005L. This site is on the south end of Stony Creek, near the border where the spatial model defines lakes and rivers. **Table 11** provides the overall and criteria group scores for the grid cell. Due to an inconsistency with the data that defines the likelihood of future intake sedimentation, this site is currently scoring higher than expected. The HDR team created a turbidity layer which included a polygon for this reach due to the variability of lake becoming a river. This polygon will be reviewed for consistency prior to the draft report. The lowest scoring sites in the study area are expected from this location in regard to intake sedimentation.

Table 11. Top ranking cell for Fort Berthold to Williston (Left).

FORT BERTHOLD TO WILLISTON, LEFT	
GRID CELL NAME	**FBW0005L**
OVERALL SCORE	**0.726**
Criteria Group Scores	
Water Availability Score	**0.962**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**0.000**
Distance to Infrastructure Score	**0.643**
Water Quality Score	**0.563**
Distance to Nearby Towns and Existing Industry Score	**0.550**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**0.500**
Federal and State Permitting Requirements Score	**0.000**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.778**

WILLISTON TO STATE LINE (RIGHT)

The top-ranking cell in the Williston to State Line (Right) reach was WMT0155R. This site is upstream of the Yellowstone River confluence, south of the City of Buford. **Table 12** provides the overall and criteria group scores for the grid cell. The cell provides high scores in water availability, likelihood of future intake sedimentation, and ease and cost of water delivery.

Table 12. Top ranking cell for Williston to State Line (Right).

WILLISTON TO STATE LINE, RIGHT	
GRID CELL NAME	**WMT0155R**
OVERALL SCORE	**0.796**
Criteria Group Scores	
Water Availability Score	**0.750**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**1.000**
Distance to Infrastructure Score	**0.619**
Water Quality Score	**0.563**
Distance to Nearby Towns and Existing Industry Score	**0.301**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**0.750**
Federal and State Permitting Requirements Score	**0.500**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.829**

WILLISTON TO STATE LINE (LEFT)

The top-ranking cell in the Williston to State Line (Left) reach was WMT0134R. This site is immediately west of Trenton. **Table 13** provides the overall and criteria group scores for the grid cell. The cell provides high scores in nearly all categories, but a lower water availability score than other top ranked sub-reach cells.

Table 13. Top ranking cell for Williston to State Line (Left).

WILLISTON TO STATE LINE, LEFT	
GRID CELL NAME	**WMT0134R**
OVERALL SCORE	**0.844**
Criteria Group Scores	
Water Availability Score	**0.750**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**1.000**
Distance to Infrastructure Score	**0.862**
Water Quality Score	**0.813**
Distance to Nearby Towns and Existing Industry Score	**0.609**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**0.750**
Federal and State Permitting Requirements Score	**0.500**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.852**

Groundwater Sites

Throughout the study area, a total of 18 locations were identified to have suitable aquifers with the ability to support an industrial intake of 15,000 acre-feet per year. Average overall scores were generated to determine which aquifers had the best conditions for an industrial intake. The six highest groundwater sites are described in this memorandum. All six groundwater sites exist in the riverine reaches of the study area and are ordered from downstream to upstream.

1-14 FORT MANDAN

The top-ranking cell in the 1-14 Fort Mandan aquifer was 1.14.0681R. This site is on the right bank of the Missouri River and extends from Washburn to past Fort Clark. **Table 14** provides the overall and criteria group scores for the grid cell.

Table 14. Top ranking cell for 1-14 Fort Mandan.

1-14 Fort Mandan	
GRID CELL NAME	**1.14.0681R**
AQUIFER AVERAGE OVERALL SCORE	**0.771**
Criteria Group Scores	
Water Availability Score	**1.000**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**1.000**
Water Quality Score	**0.450**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.584**
Federal and State Permitting Requirements Score	**1.000**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**1.000**
Distance to Nearby Towns and Existing Industry Score	**0.585**
Distance to Infrastructure Score	**0.826**

1-13 KNIFE RIVER

The top-ranking cell in the 1-13 Knife River aquifer was 1.13.0021R. This site is near the right bank of the Missouri River, with part of the aquifer existing under the City of Stanton. **Table 15** provides the overall and criteria group scores for the grid cell.

Table 15. Top ranking cell for 1-13 Knife River.

1-13 Knife River	
GRID CELL NAME	**1.13.0021R**
AQUIFER AVERAGE OVERALL SCORE	**0.782**
Criteria Group Scores	
Water Availability Score	**0.800**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**1.000**
Water Quality Score	**0.575**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.474**
Federal and State Permitting Requirements Score	**1.000**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**0.750**
Distance to Nearby Towns and Existing Industry Score	**0.713**
Distance to Infrastructure Score	**0.686**

1-4 TRENTON

The top-ranking cell in the 1-4 Trenton aquifer was 1.4.0165L. This site is on the left bank of the Missouri River south of the City of Trenton. **Table 16** provides the overall and criteria group scores for the grid cell.

Table 16. Top ranking cell for 1-4 Trenton.

1-4 Trenton	
GRID CELL NAME	**1.4.0165L**
AQUIFER AVERAGE OVERALL SCORE	**0.783**
Criteria Group Scores	
Water Availability Score	**0.900**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**1.000**
Water Quality Score	**0.450**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.989**
Federal and State Permitting Requirements Score	**1.000**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**1.000**
Distance to Nearby Towns and Existing Industry Score	**0.494**
Distance to Infrastructure Score	**0.829**

1-3 TRENTON

The top-ranking cell in the 1-3 Trenton aquifer was 1.3.0163L. This site is on the left bank of the Missouri River southeast of the City of Trenton. **Table 17** provides the overall and criteria group scores for the grid cell.

Table 17. Top ranking cell for 1-3 Trenton.

1-3 Trenton	
GRID CELL NAME	**1.3.0163L**
AQUIFER AVERAGE OVERALL SCORE	**0.785**
Criteria Group Scores	
Water Availability Score	**0.900**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**1.000**
Water Quality Score	**0.750**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.950**
Federal and State Permitting Requirements Score	**1.000**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**1.000**
Distance to Nearby Towns and Existing Industry Score	**0.329**
Distance to Infrastructure Score	**0.586**

1-2 TRENTON

The top-ranking cell in the 1-2 Trenton aquifer was 1.2.0039L. This site is on the left bank of the Missouri River southeast of the City of Trenton. **Table 18** provides the overall and criteria group scores for the grid cell.

Table 18. Top ranking cell for 1-2 Trenton.

1-2 Trenton	
GRID CELL NAME	**1.2.0039L**
AQUIFER AVERAGE OVERALL SCORE	**0.812**
Criteria Group Scores	
Water Availability Score	**0.900**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**1.000**
Water Quality Score	**0.750**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.970**
Federal and State Permitting Requirements Score	**1.000**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**1.000**
Distance to Nearby Towns and Existing Industry Score	**0.326**
Distance to Infrastructure Score	**0.830**

1-1 TRENTON

The top-ranking cell in the 1-1 Trenton aquifer was 1.1.0073L. This site is on the left bank of the Missouri River south of the City of Buford. **Table 19** provides the overall and criteria group scores for the grid cell.

Table 19. Top ranking cell for 1-1 Trenton.

1-1 Trenton	
GRID CELL NAME	**1.1.0073L**
AQUIFER AVERAGE OVERALL SCORE	**0.771**
Criteria Group Scores	
Water Availability Score	**0.900**
Likelihood of Future Intake Sedimentation Score	**1.000**
Ease and Cost of Water Delivery Score	**1.000**
Water Quality Score	**0.450**
Impacts to Recreation Score	**1.000**
New Industry Score	**0.930**
Federal and State Permitting Requirements Score	**1.000**
Impacts to Areas of Natural, Cultural, and Historical Significance Score	**1.000**
Distance to Nearby Towns and Existing Industry Score	**0.263**
Distance to Infrastructure Score	**0.735**

Preliminary Siting Results & Final Development Criteria

The main lessons learned from the preliminary model runs revolve around developing constraints, refining criteria and data, and verifying grid boundaries. As noted during the initial phases of this study, the HDR team will continue to iterate and verify the results of the model. The currently identified model clarifications and modifications that will be considered prior to completion of the draft report include:

- Change the low water dataset in the Fort Berthold to Williston reach to only reflect the permanent pool given the unknowns of river/lake bathymetry upstream of New Town.
- Change the turbidity layer in the Fort Berthol to Williston Reach to reflect the zone where the lake can become a river. This was originally done but appears to not have made it into the first round of modeling.
- Discuss the state's desire to include or exclude areas within state parks and cities.
- Discuss including NDGF wildlife management areas into the spatial model.
- Discuss including active slide areas into the spatial model.
- Discuss setting an exclusion zone for National Historic Places.
- Discuss adding a criterion or adding description of Pallid Sturgeon spawning on the upstream reaches of the study.

APPENDIX A

Updated Criteria Weighting/Ranking

SURFACE WATER CRITERIA

CRITERIA TITLE	CRITERIA OVERALL WEIGHT	ANALYSIS	INDIVIDUAL ANALYSIS WEIGHT	ANALYSIS WEIGHTED PERCENTAGE
Water Availability	37%	Proximity to Permanent Pool (Lake)	70%	25.90%
		Slope Constructability (Lake)	30%	11.10%
		Slope Constructability (River)	50%	18.50%
		Straight and Outer Bend Proximity (River)	50%	18.50%
Likelihood of Future Intake Sedimentation	19%	Turbidity	100%	19.00%
Ease and Cost of Water Delivery	14%	Ease and Cost of Water Delivery	100%	14.00%
Distance to Infrastructure That Includes Rail Lines, Power, Roads, and Gas	10%	Distance to Rail Lines	15%	1.50%
		Distance to Roads	35%	3.50%
		Distance to Power	35%	3.50%
	6%	Distance to New Industry	50%	3.00%

Locations Expressed by New Industry		Distance to Natural Gas	15%	1.50%
		Total New Industry	50%	3.00%
Water Quality	4%	Turbidity	35%	1.40%
		Aquatic Nuisance Species	25%	1.00%
		Land Based Potential Water Quality Impairments	25%	1.00%
		Water Based Potential Water Quality Impairments	15%	0.60%
		Distance to Existing Industrial Facilities	60%	2.40%
Distance to Nearby Towns and Existing Industrial Facilities	4%	Distance to Nearby Towns	40%	1.60%
Impacts to Areas of Natural, Cultural, and Historical Significance	3%	Cultural and Historical Significance	50%	1.50%
		Critical Habitat	25%	0.75%
		Unbroken Grasslands	25%	0.75%
Federal and State Permitting Requirements	2%	Jurisdictional Boundaries Requiring Increased Coordination (Lake)	100%	2.00%
		Jurisdictional Boundaries Requiring Increased Coordination (River)	50%	1.00%
		408 Permissions (River)	50%	1.00%

Impacts to Recreation	1%	Impacts to Boat Ramps and State Parks	100%	1.00%
Total	**100%**		**100%**	**100.00%**

GROUNDWATER CRITERIA

CRITERIA TITLE	CRITERIA OVERALL WEIGHT	ANALYSIS	INDIVIDUAL ANALYSIS WEIGHT	ANALYSIS WEIGHTED PERCENTAGE
Water Availability	45%	Capacity (Lake/River)	60%	27.00%
		Slope Constructability (Lake/River)	20%	9.00%
		Proximity to Permanent Pool (Lake)	20%	9.00%
		Straight and Outer Bend Proximity (River)	20%	9.00%
Water Quality	18%	Total Dissolved Solids	50%	9.00%
		Land Based Potential Water Quality Impairments	30%	5.40%
		Water Based Potential Water Quality Impairments	20%	3.60%

Likelihood of Future Intake Sedimentation	8%	Turbidity (Lake)	100%	8.00%
Distance to Infrastructure That Includes Rail Lines, Power, Roads, and Gas	7%	Distance to Rail Lines	15%	2.45%
		Distance to Roads	35%	2.45%
		Distance to Power	35%	1.05%
		Distance to Natural Gas	15%	2.45%
Ease and Cost of Water Delivery	6%	Ease and Cost of Water Delivery	100%	6.00%
Locations Expressed by New Industry	6%	Distance to New Industry	50%	3.00%
		Total New Industry	50%	3.00%
Distance to Nearby Towns and Existing Industrial Facilities	4%	Turbidity	35%	1.40%
		Aquatic Nuisance Species	25%	1.00%
Impacts to Areas of Natural, Cultural, and Historical Significance	3%	Cultural and Historical Significance	50%	1.50%
		Critical Habitat	25%	0.75%

		Unbroken Grasslands	25%	0.75%
Federal and State Permitting Requirements	2%	Jurisdictional Boundaries Requiring Increased Coordination (Lake)	100%	2.00%
		Jurisdictional Boundaries Requiring Increased Coordination (River)	50%	1.00%
		408 Permissions (River)	50%	1.00%
Impacts to Recreation	1%	Impacts to Boat Ramps and State Parks	100%	1.00%
Total	**100%**		**100%**	**100.00%**

APPENDIX B

Surface Water Site Maps

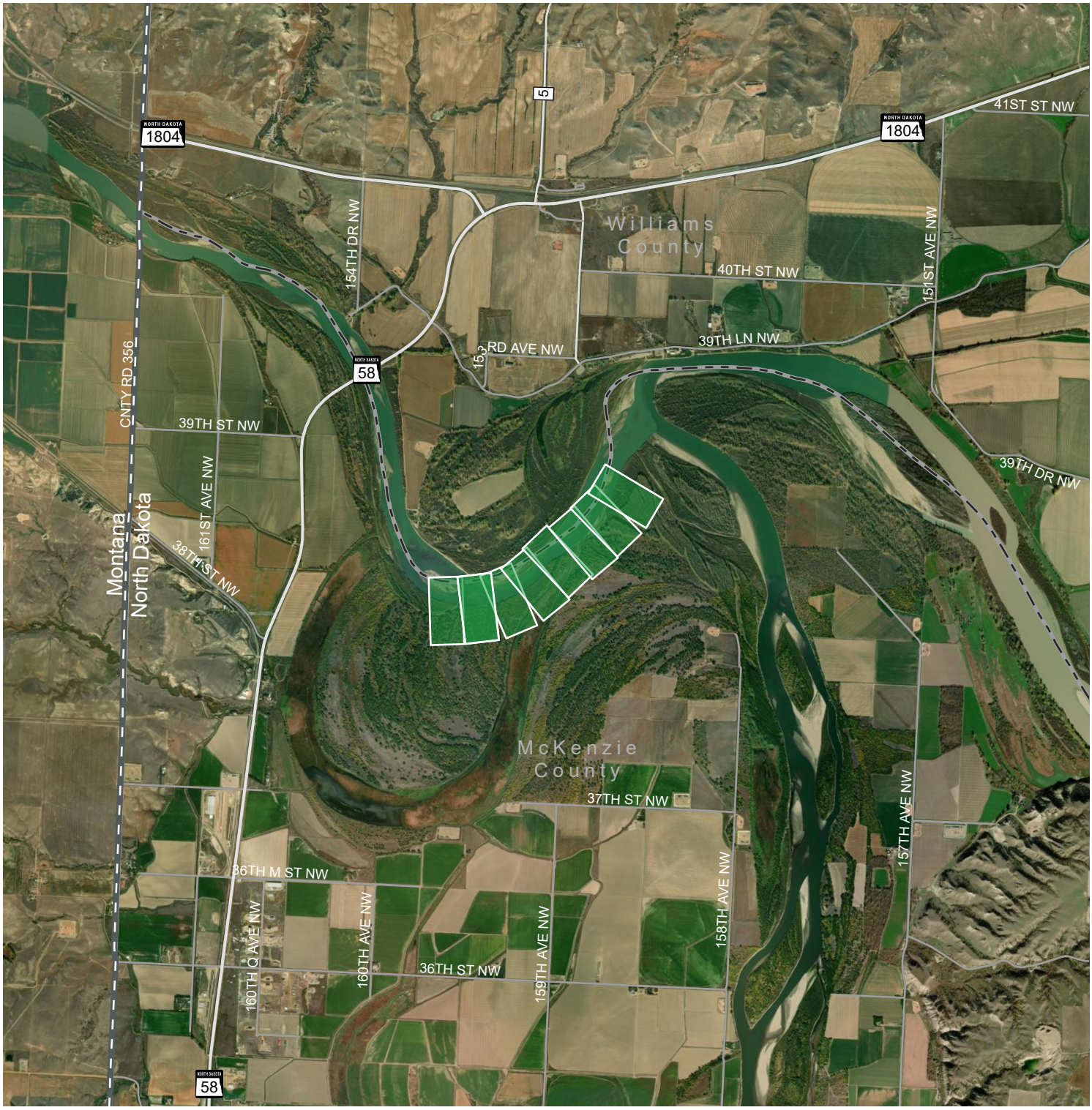
Selected Site - WMT0134L
Williston - State Line : Left

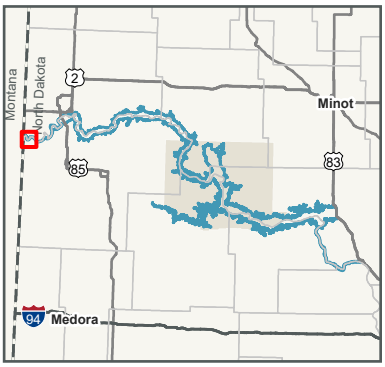
WMT0134L
Overall Criteria Score: 0.844

Selected Surface Water Grid Cells

0 1 mi

*Results shown are subject to change.





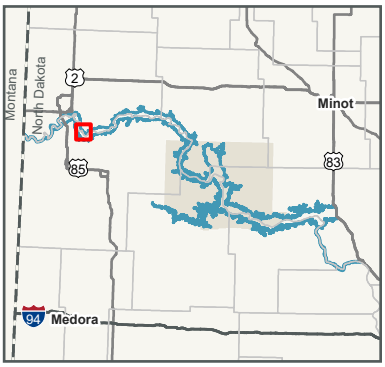
Selected Site - WMT0155R
Williston - State Line : Right

WMT0155R
Overall Criteria Score: 0.796

Selected Surface Water Grid Cells

0 1 mi

*Results shown are subject to change.



Selected Site - FBW0005L
Fort Berthold - Williston : Left

FBW0005L
Overall Criteria Score: 0.726

Selected Surface Water Grid Cells

0 1 mi

*Results shown are subject to change.

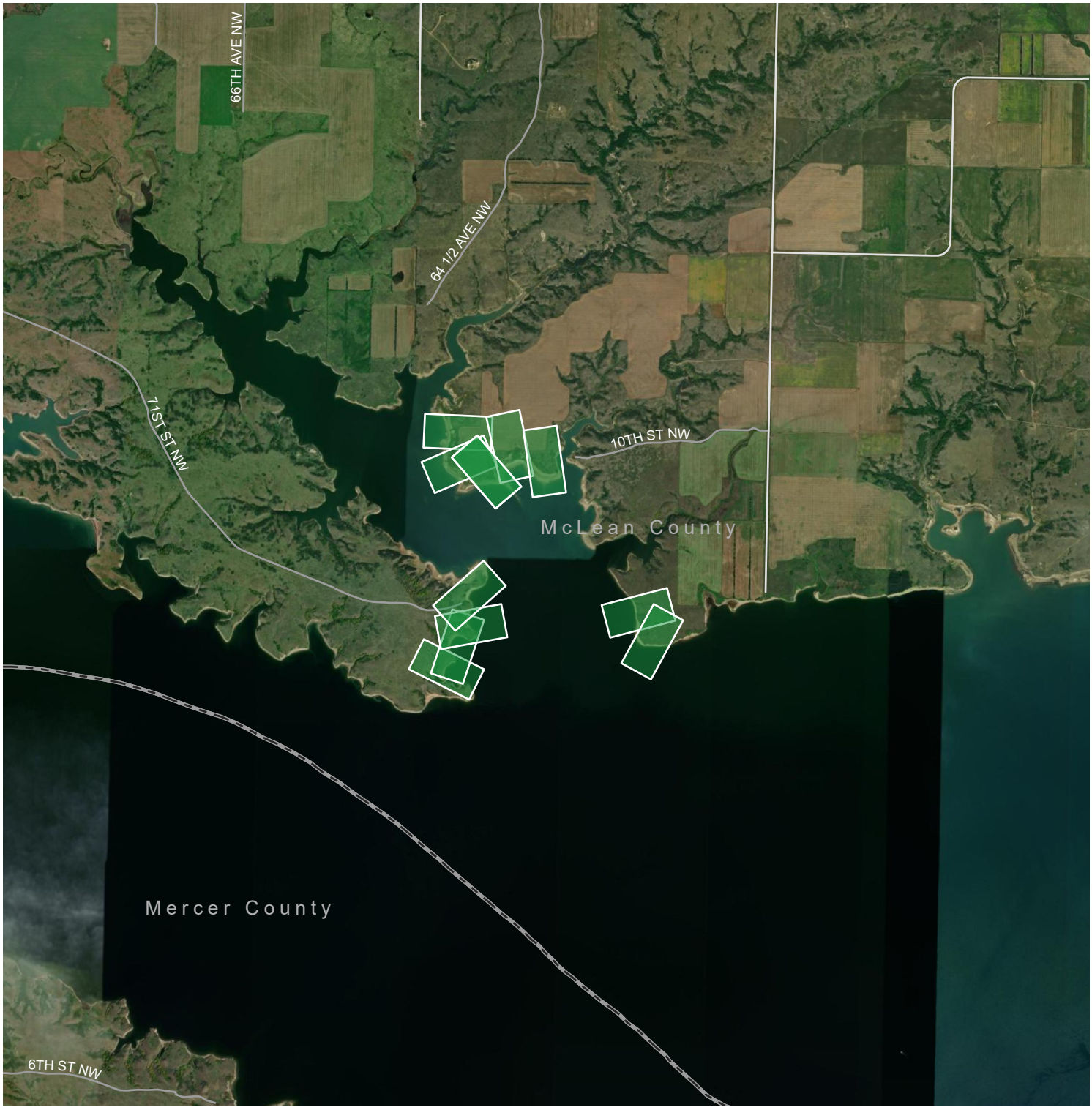
Selected Site - FBW0459R
Fort Berthold - Williston : Right

FBW0459R
Overall Criteria Score: 0.797

Selected Surface Water Grid Cells

0 1 mi

*Results shown are subject to change.



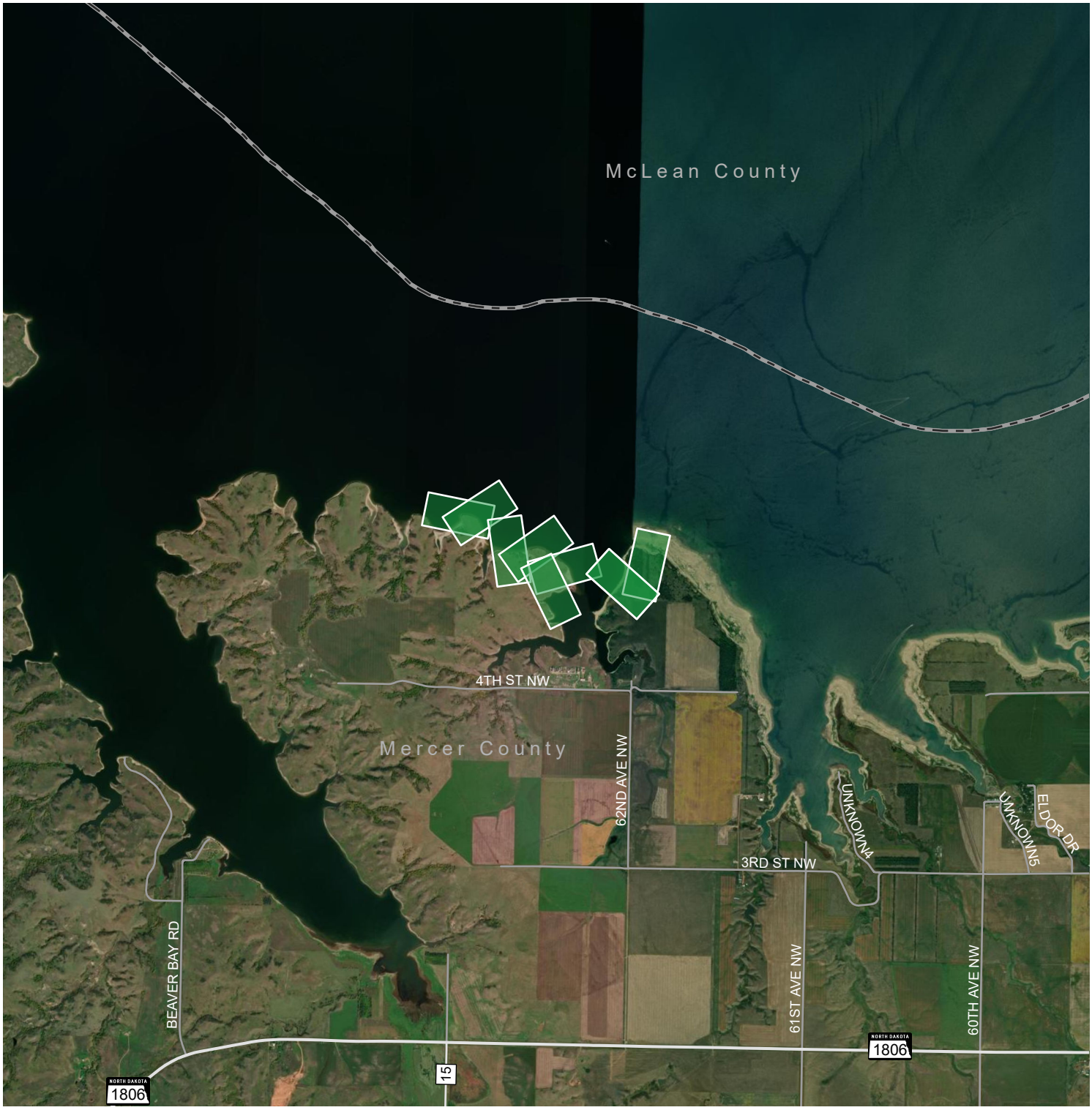
FB1289L
Overall Criteria Score: 0.777

Selected Surface Water Grid Cells

*Results shown are subject to change.

Selected Site - FB1289L
Fort Berthold : Left

0 1 mi



Selected Site - FB2386R
Fort Berthold : Right

FB2386R
Overall Criteria Score: 0.793

Selected Surface Water Grid Cells

0 1 mi

*Results shown are subject to change.

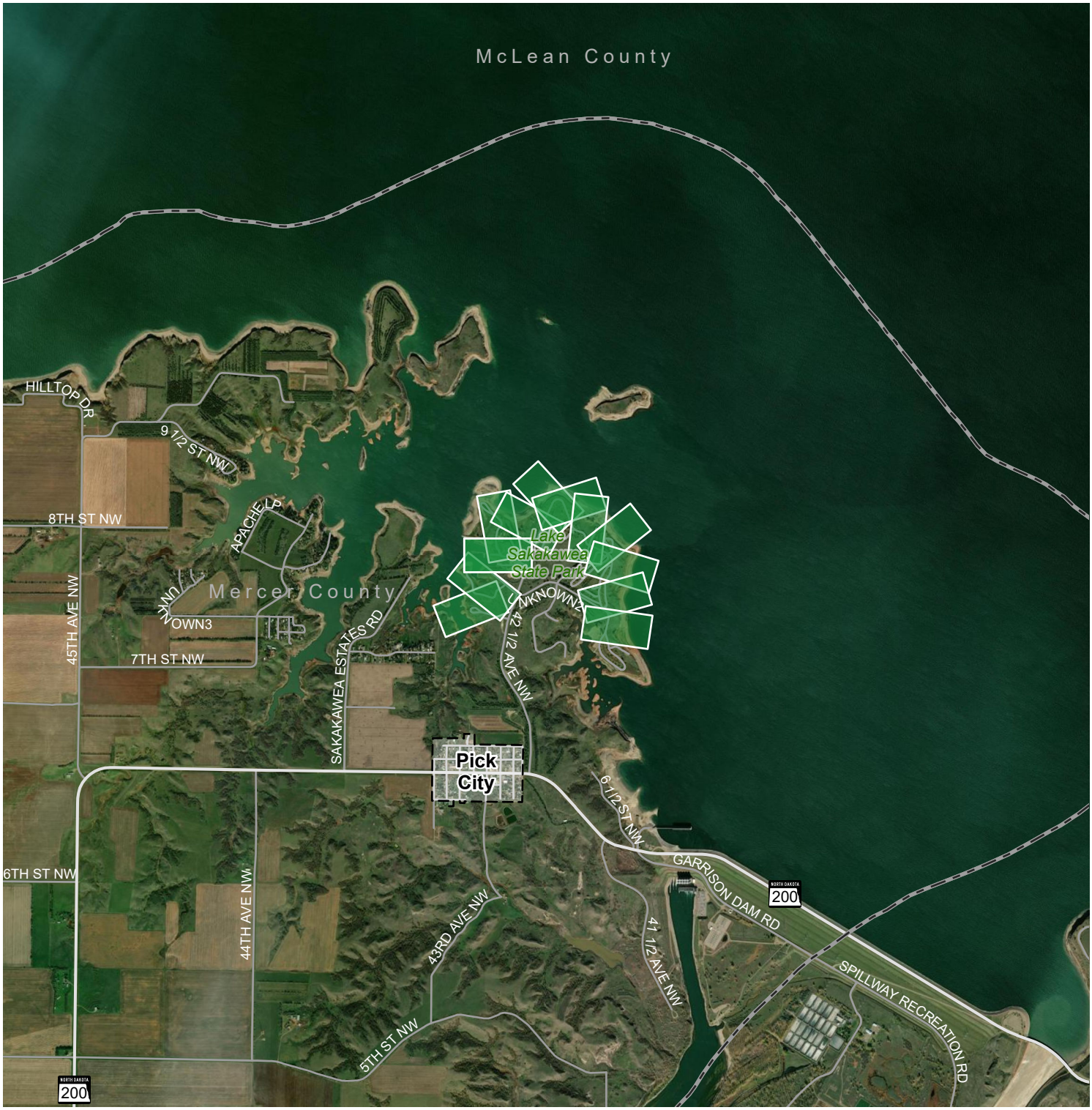
Selected Site - GFB0048L
Garrison Dam - Fort Berthold : Left

GFB0048L
Overall Criteria Score: 0.882

Selected Surface Water Grid Cells

0 1 mi

*Results shown are subject to change.



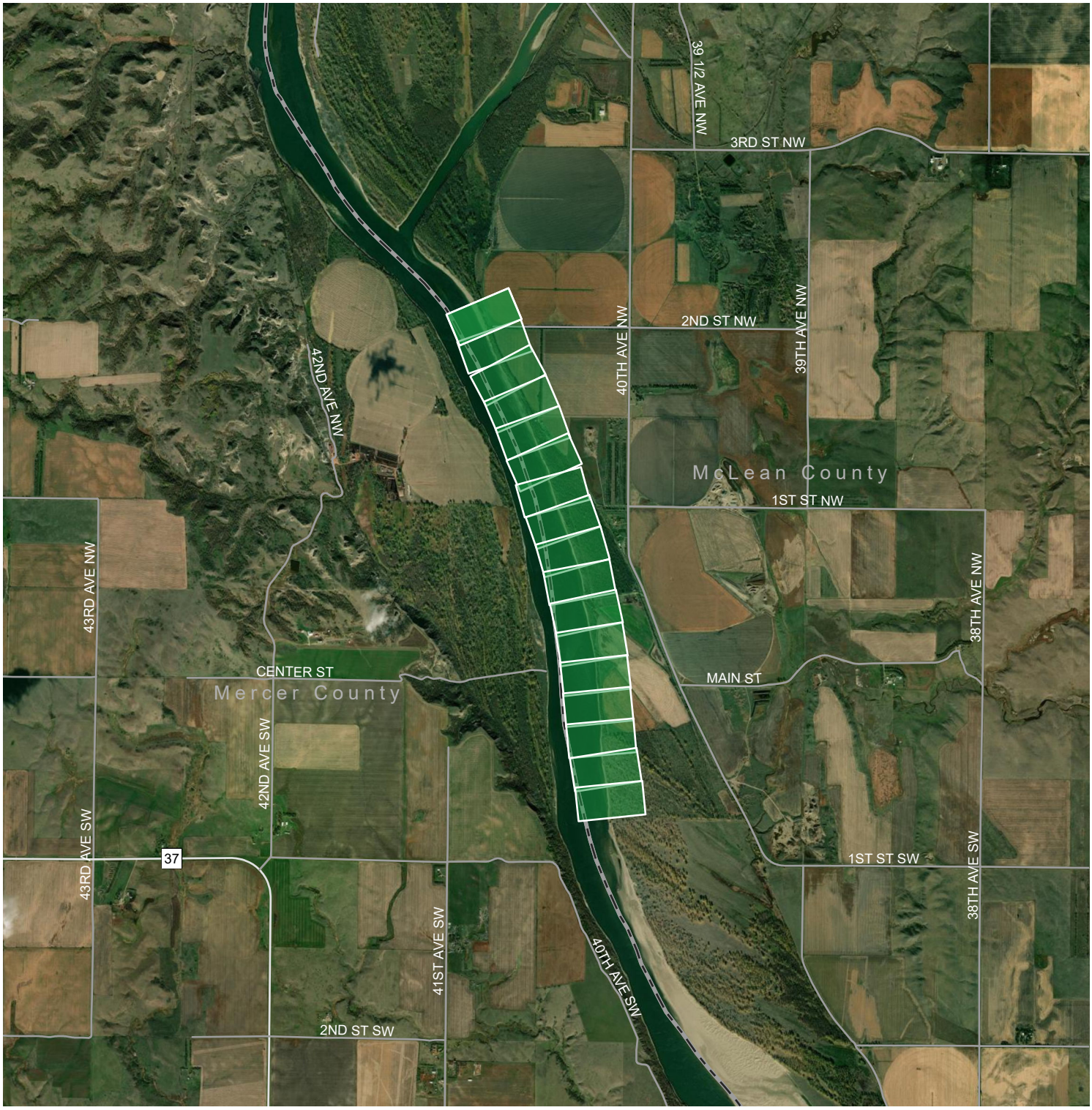
Selected Site - GFB0417R
Garrison Dam - Fort Berthold : Right

GFB0417R
Overall Criteria Score: 0.867

Selected Surface Water Grid Cells

0 1 mi

*Results shown are subject to change.



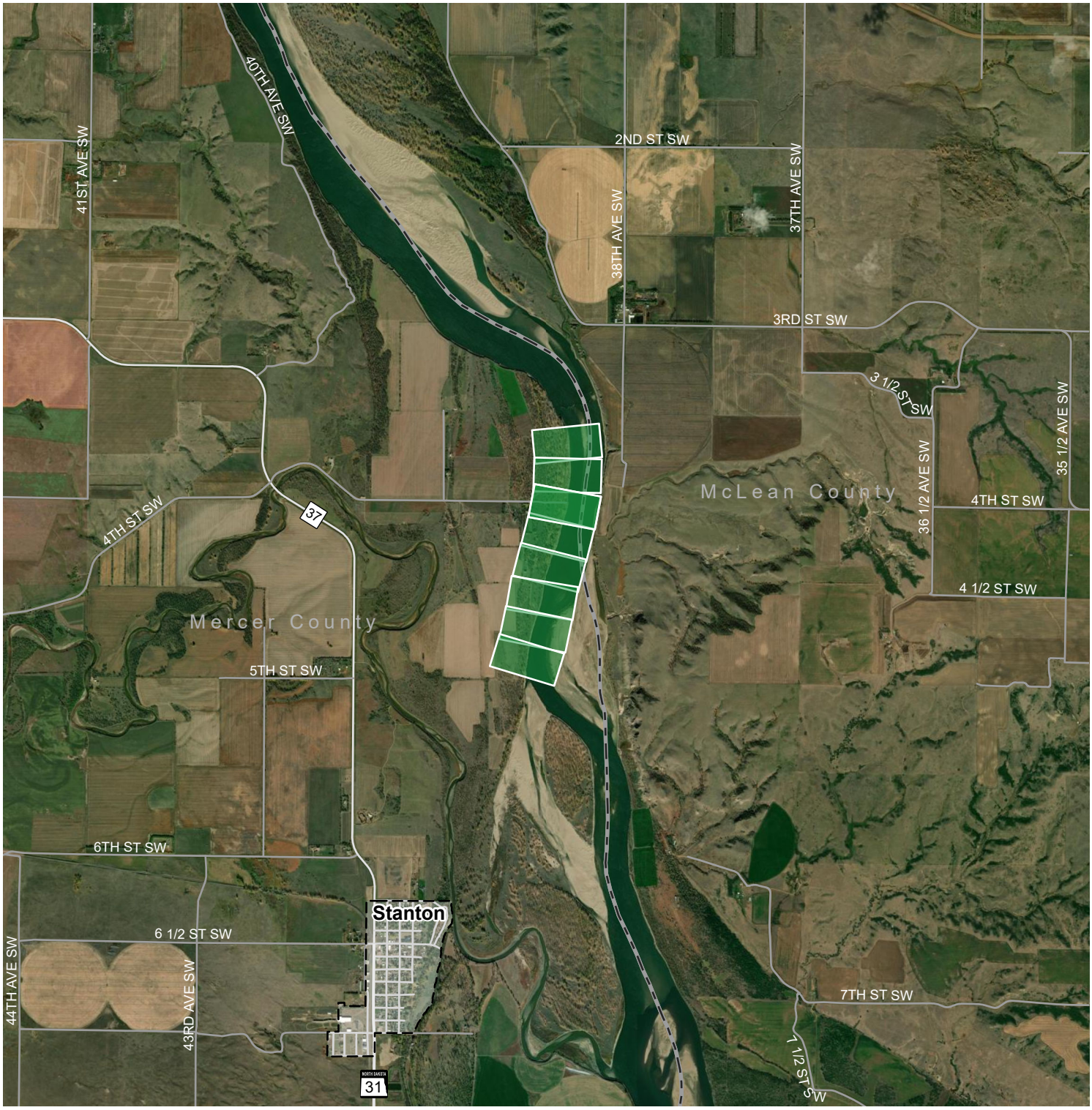
Selected Site - WG0021L
Washburn - Garrison Dam : Left

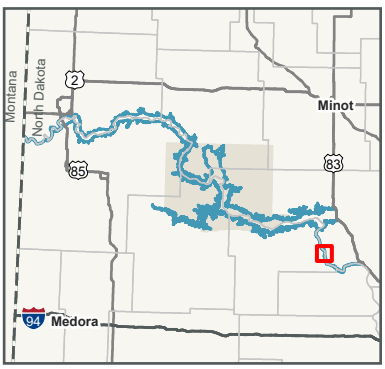
WG0021L
Overall Criteria Score: 0.788

Selected Surface Water Grid Cells

0 1 mi

*Results shown are subject to change.





Selected Site - WG0066R
Washburn - Garrison Dam : Right

WG0066R
Overall Criteria Score: 0.857

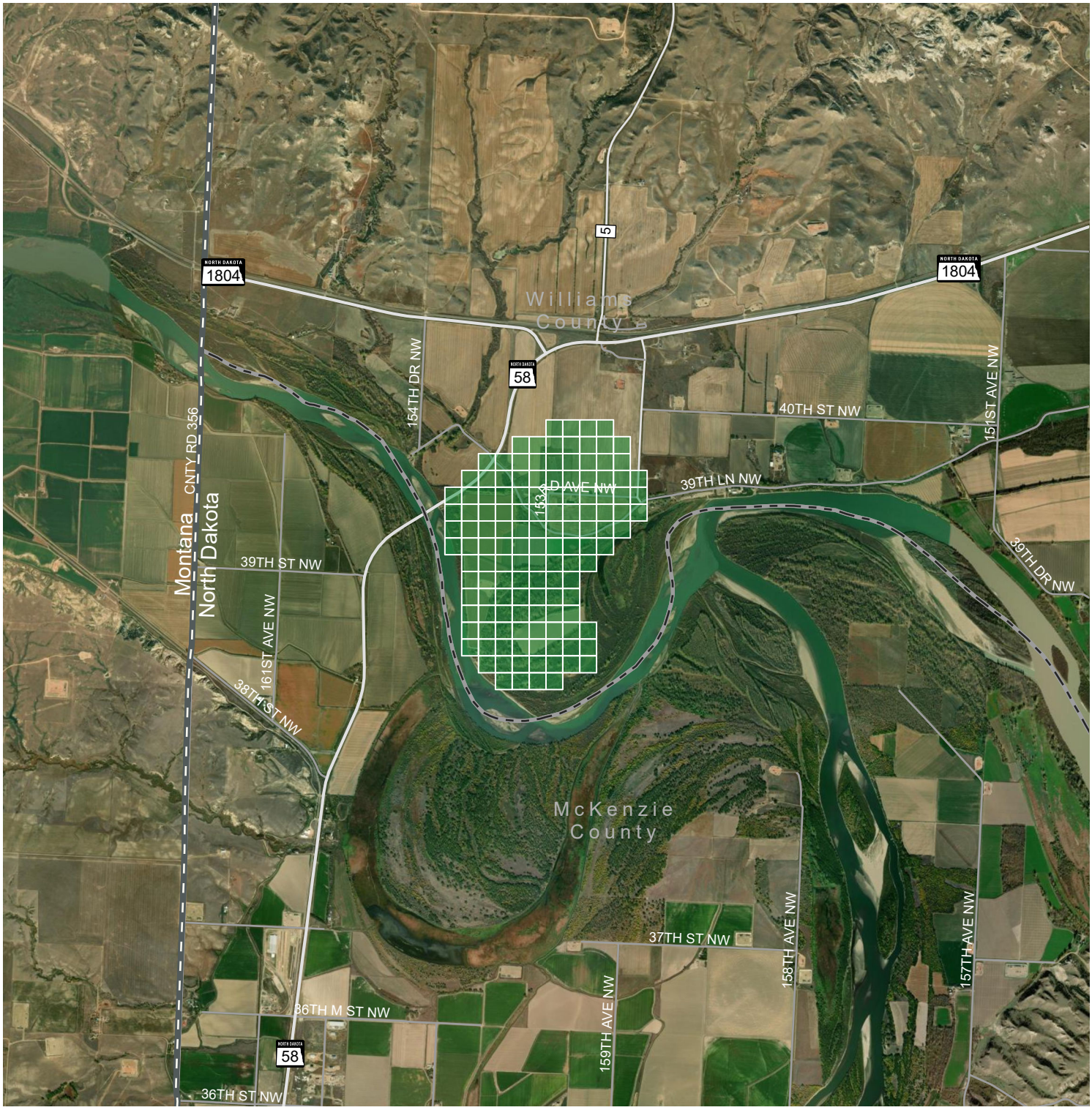
Selected Surface Water Grid Cells

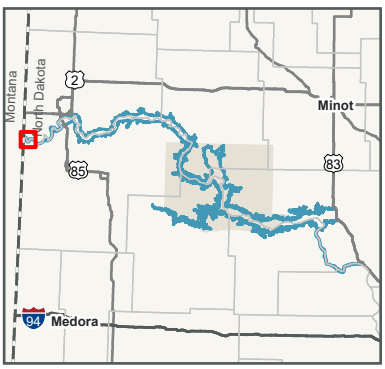
0 1 mi

*Results shown are subject to change.

APPENDIX B

Groundwater Site Maps





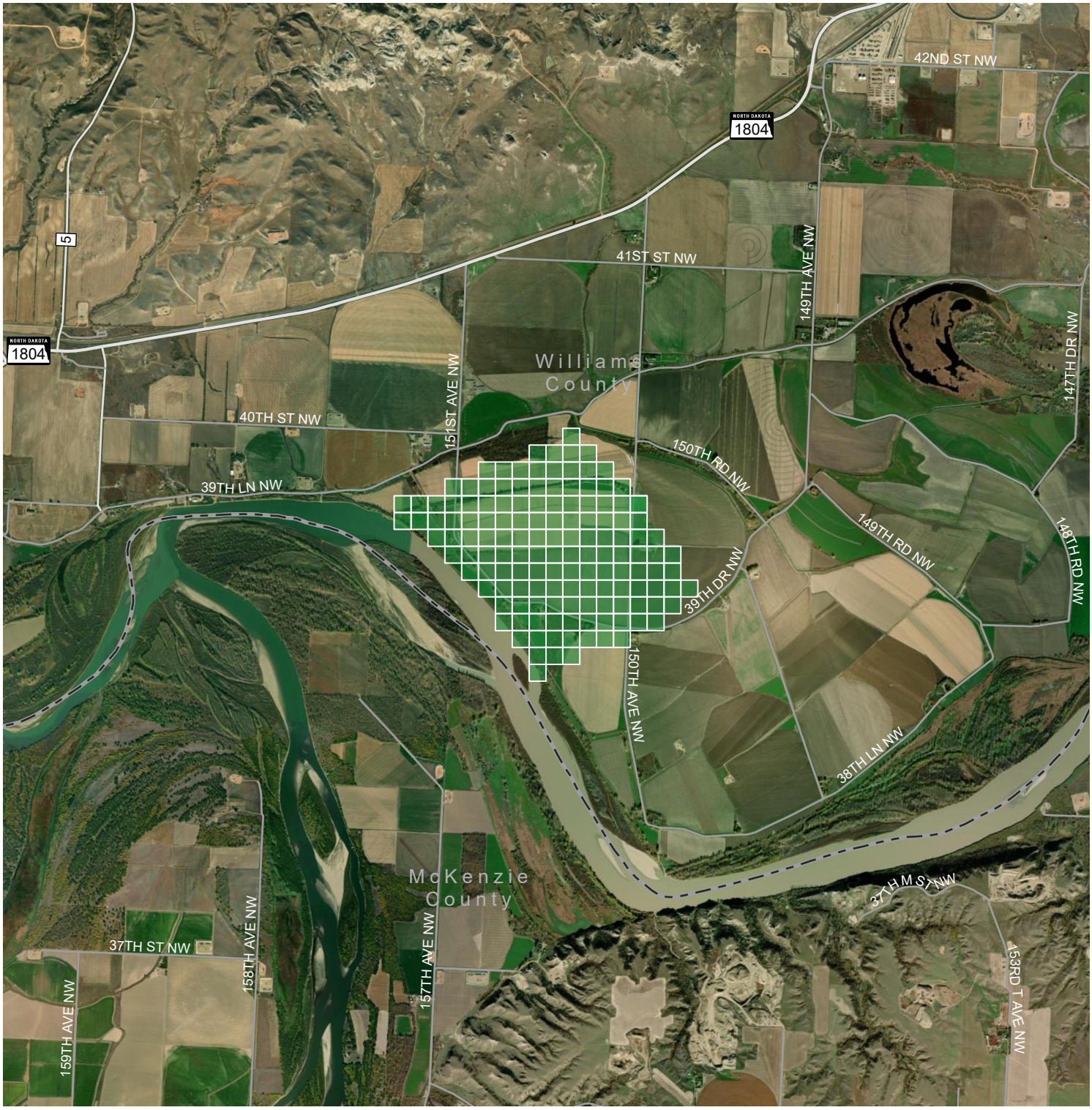
1-1
Overall Criteria Score: 0.771

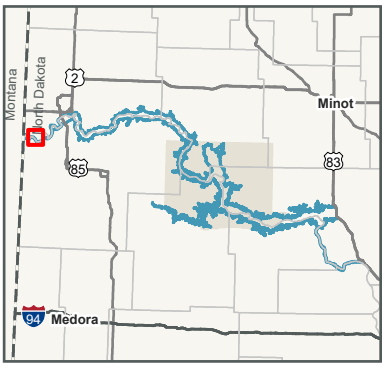
Selected Groundwater Site

*Results shown are subject to change.

Selected Site - Trenton 1-1

0 1 mi





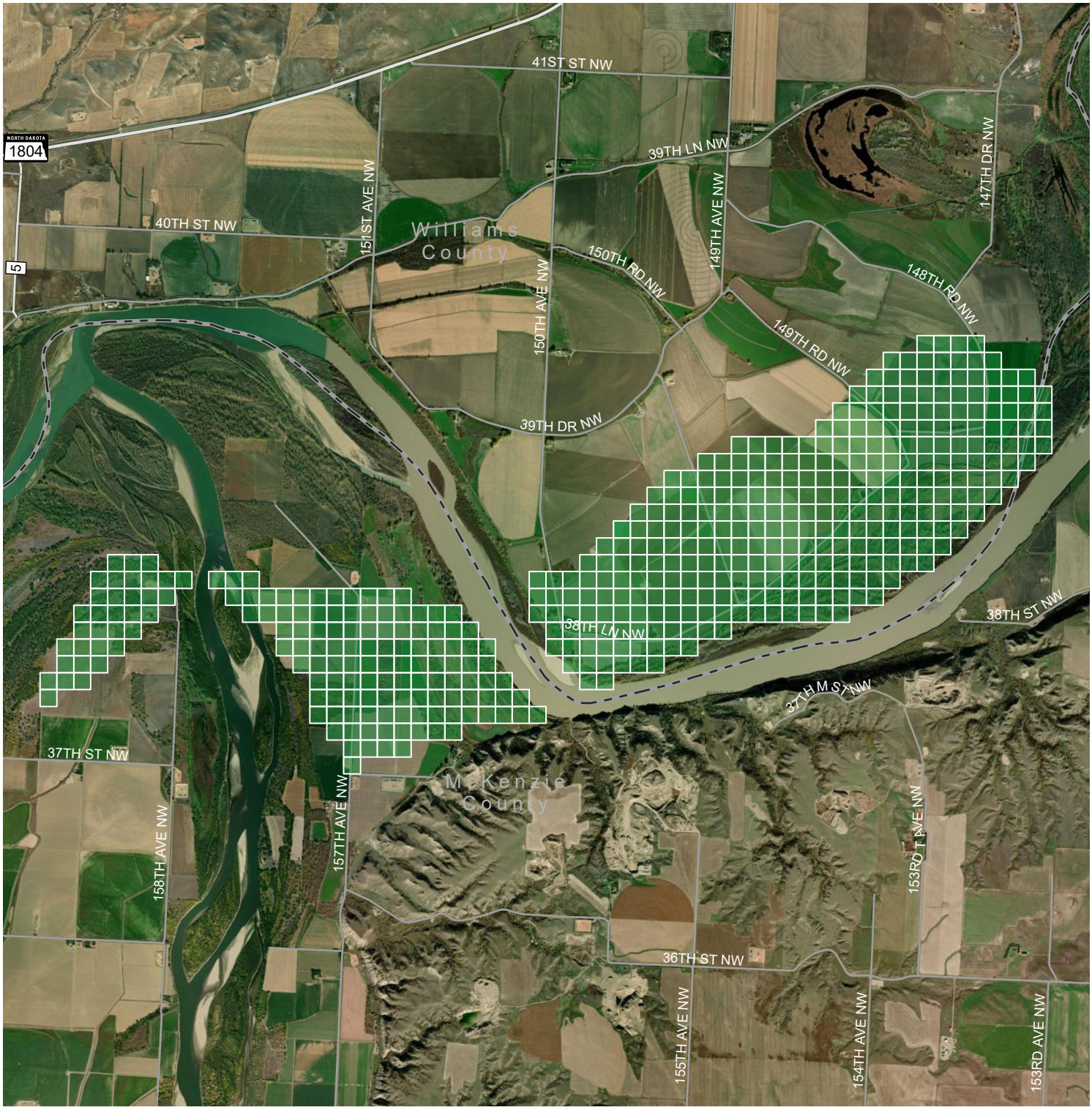
1-2
Overall Criteria Score: 0.812

Selected Groundwater Site

*Results shown are subject to change.

Selected Site - Trenton
1-2

0 1 mi



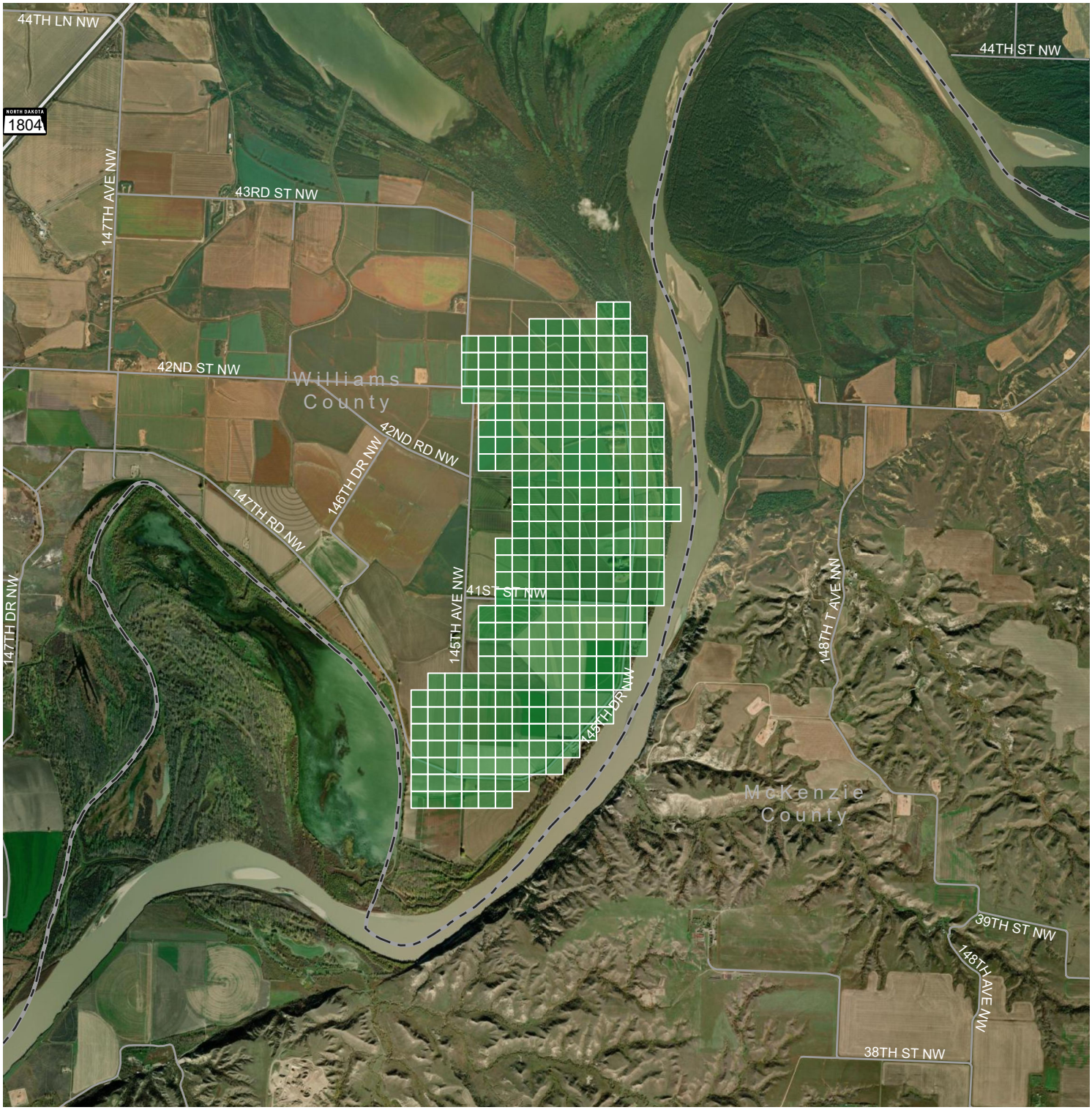
1-3
Overall Criteria Score: 0.785

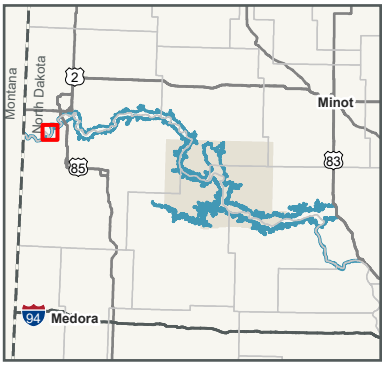
Selected Groundwater Site

*Results shown are subject to change.

Selected Site - Trenton
1-3

0 1 mi





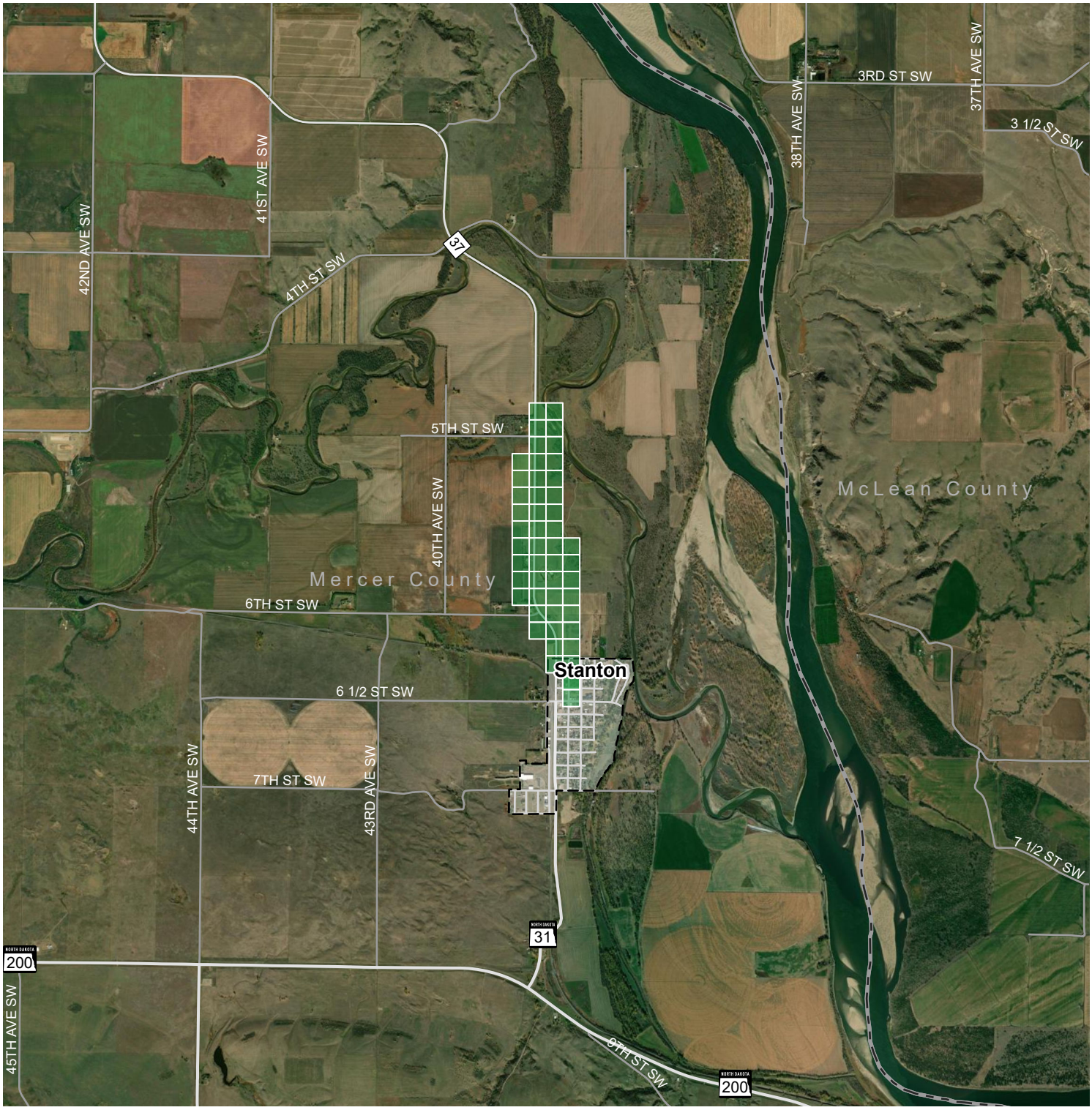
1-4
Overall Criteria Score: 0.783

Selected Groundwater Site

*Results shown are subject to change.

Selected Site - Trenton
1-4

0 1 mi



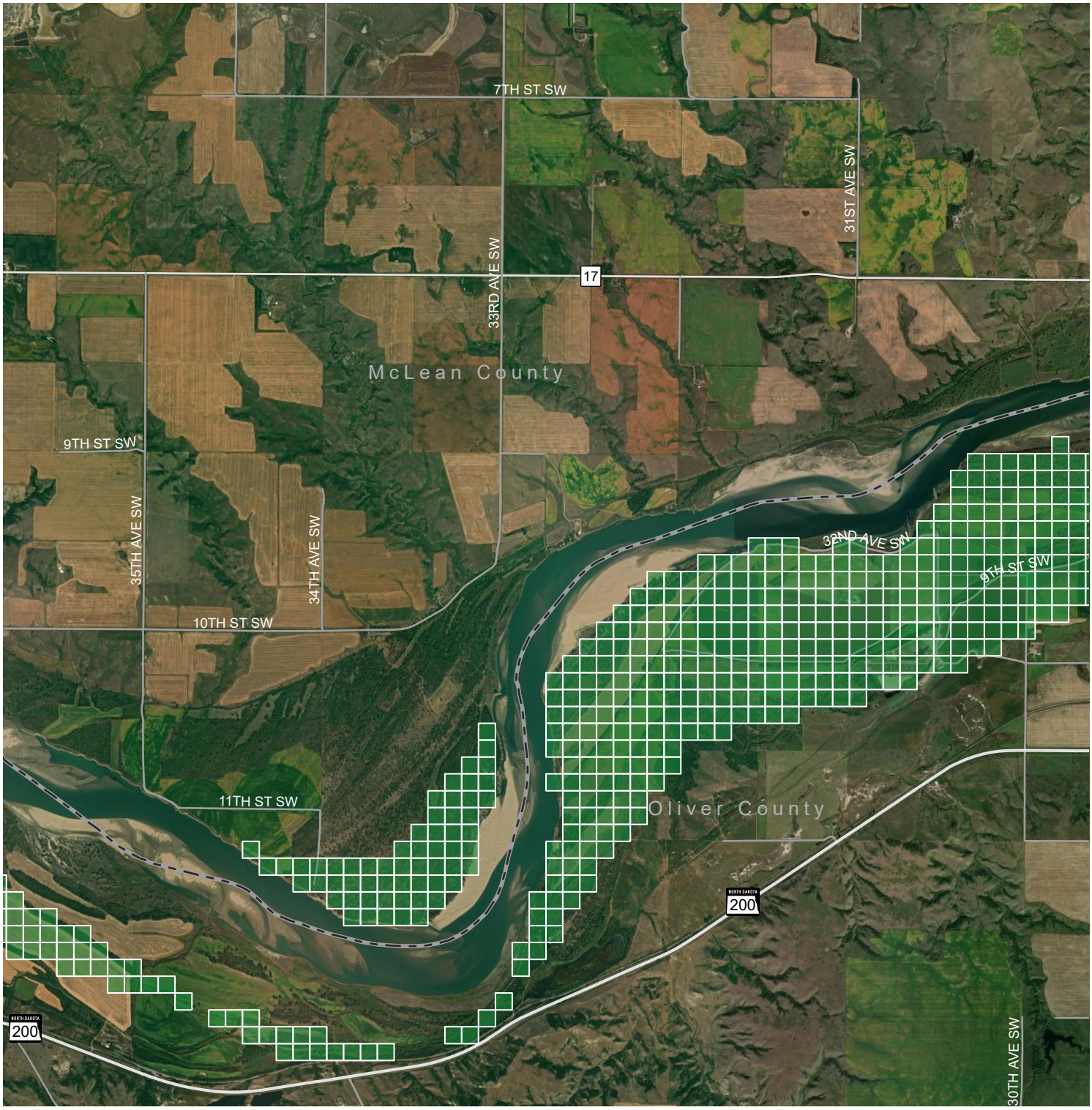
Selected Site - Knife River 1-13

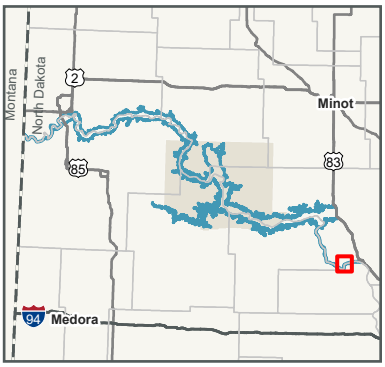
1-13
Overall Criteria Score: 0.782

Selected Groundwater Site

0 1 mi

*Results shown are subject to change.





1-14
Overall Criteria Score: 0.771

Selected Groundwater Site

*Results shown are subject to change.

Selected Site - Ft Mandan 1-14

0 1 mi

Appendix D – Riverine Geomorphology Maps

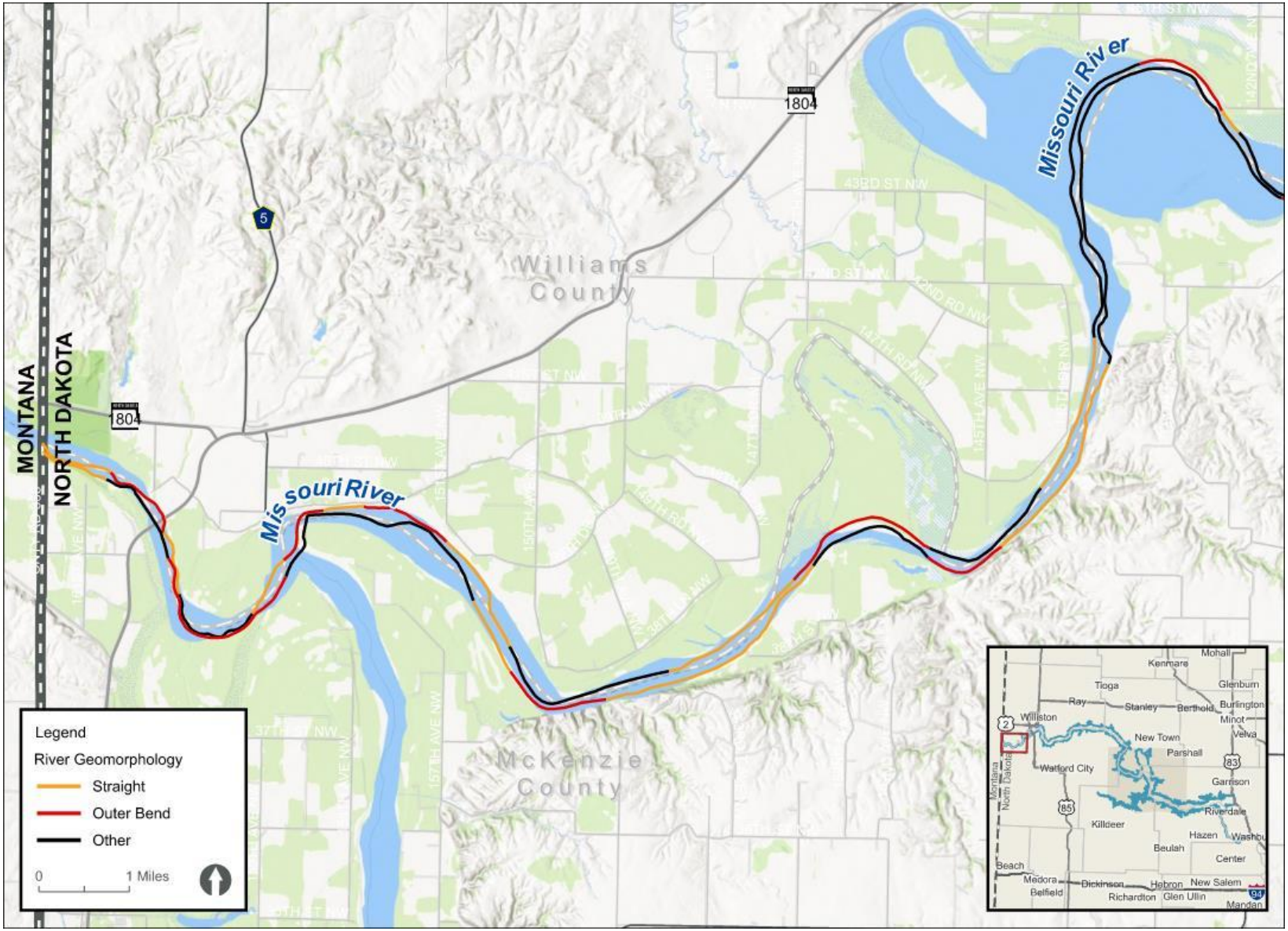


Figure 1. State Line to Williston Reach upper geomorphology.

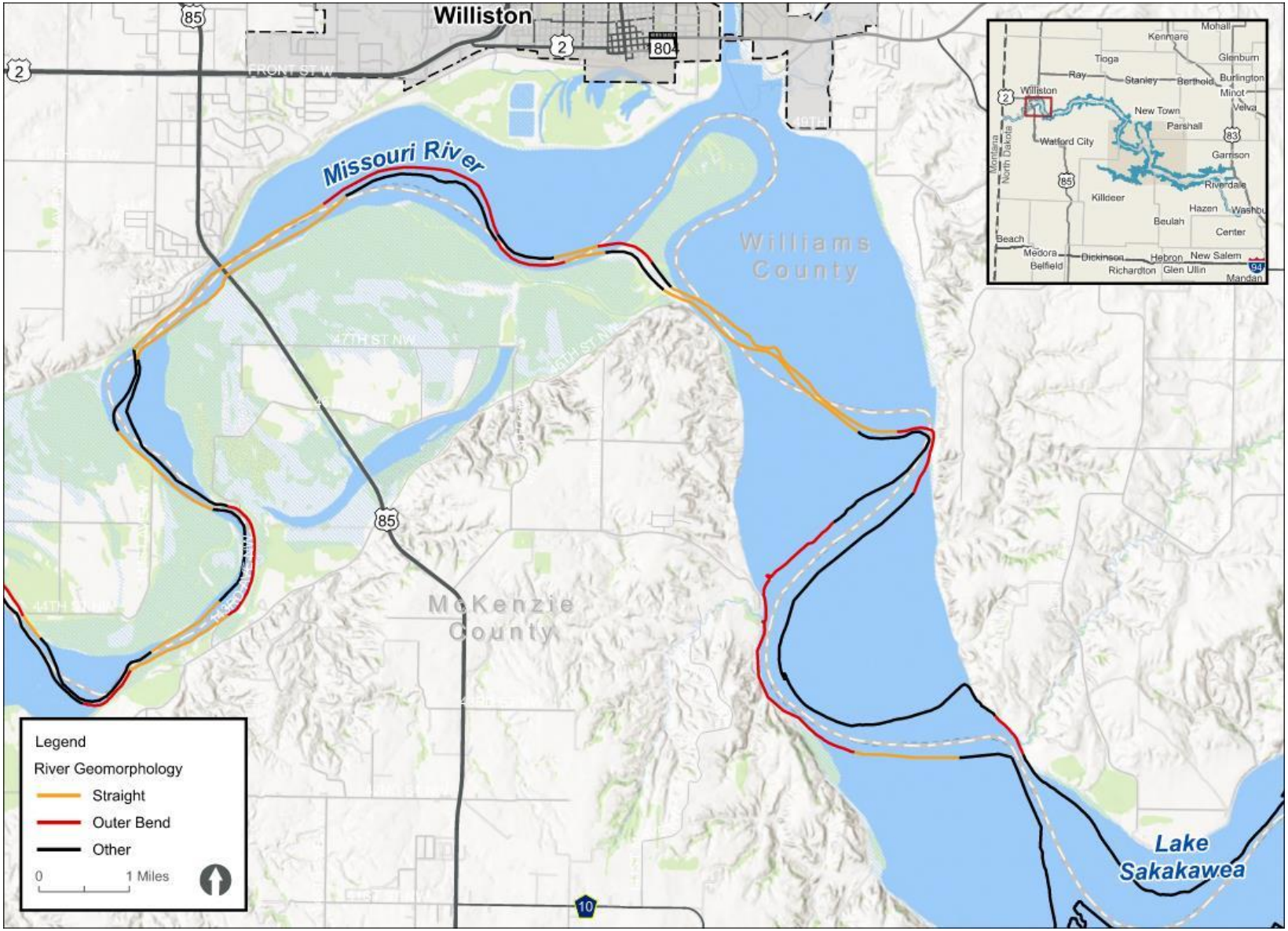


Figure 2. State Line to Williston Reach lower geomorphology.

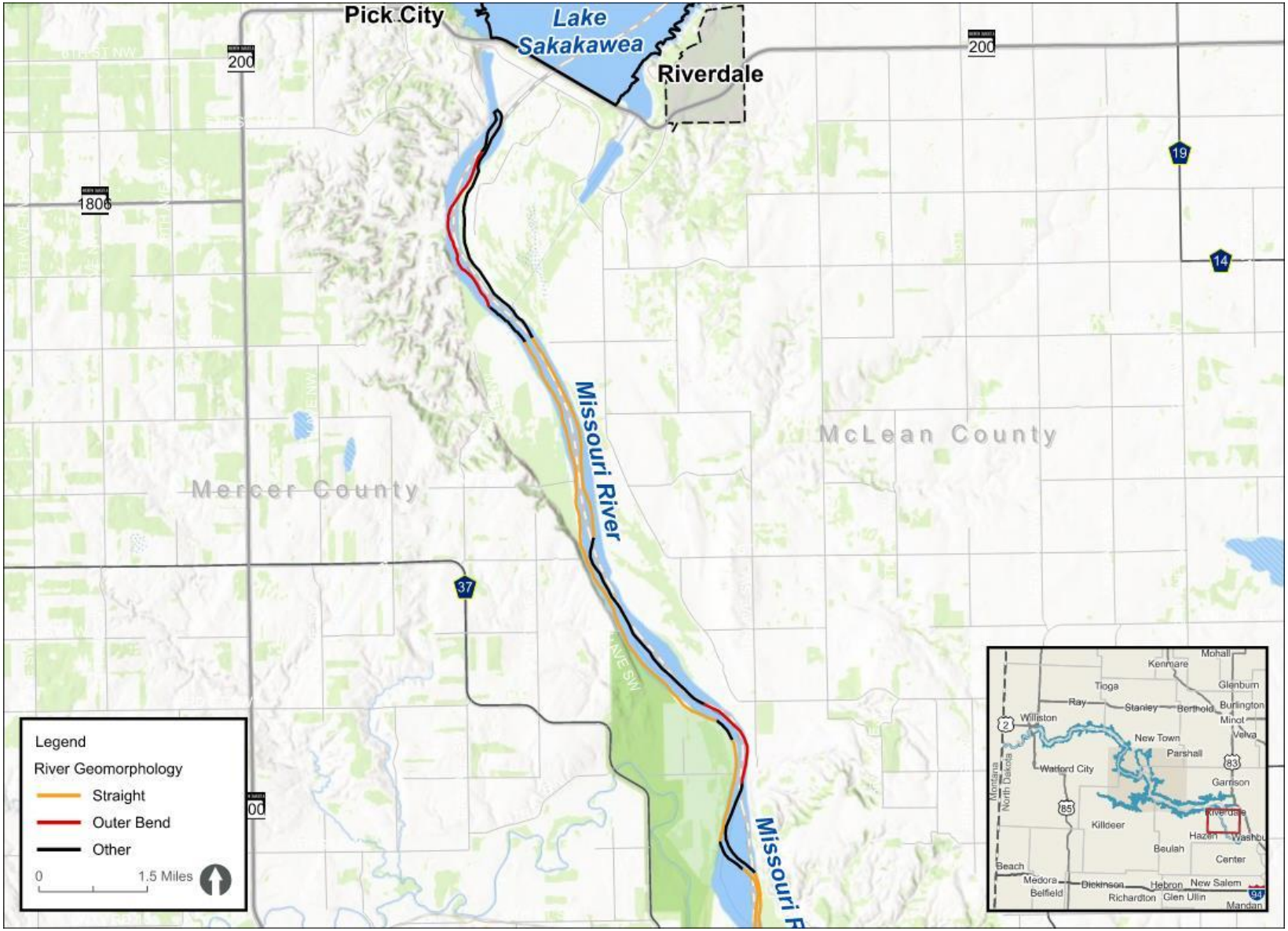


Figure 3. Garrison Dam to Washburn Reach upper geomorphology.

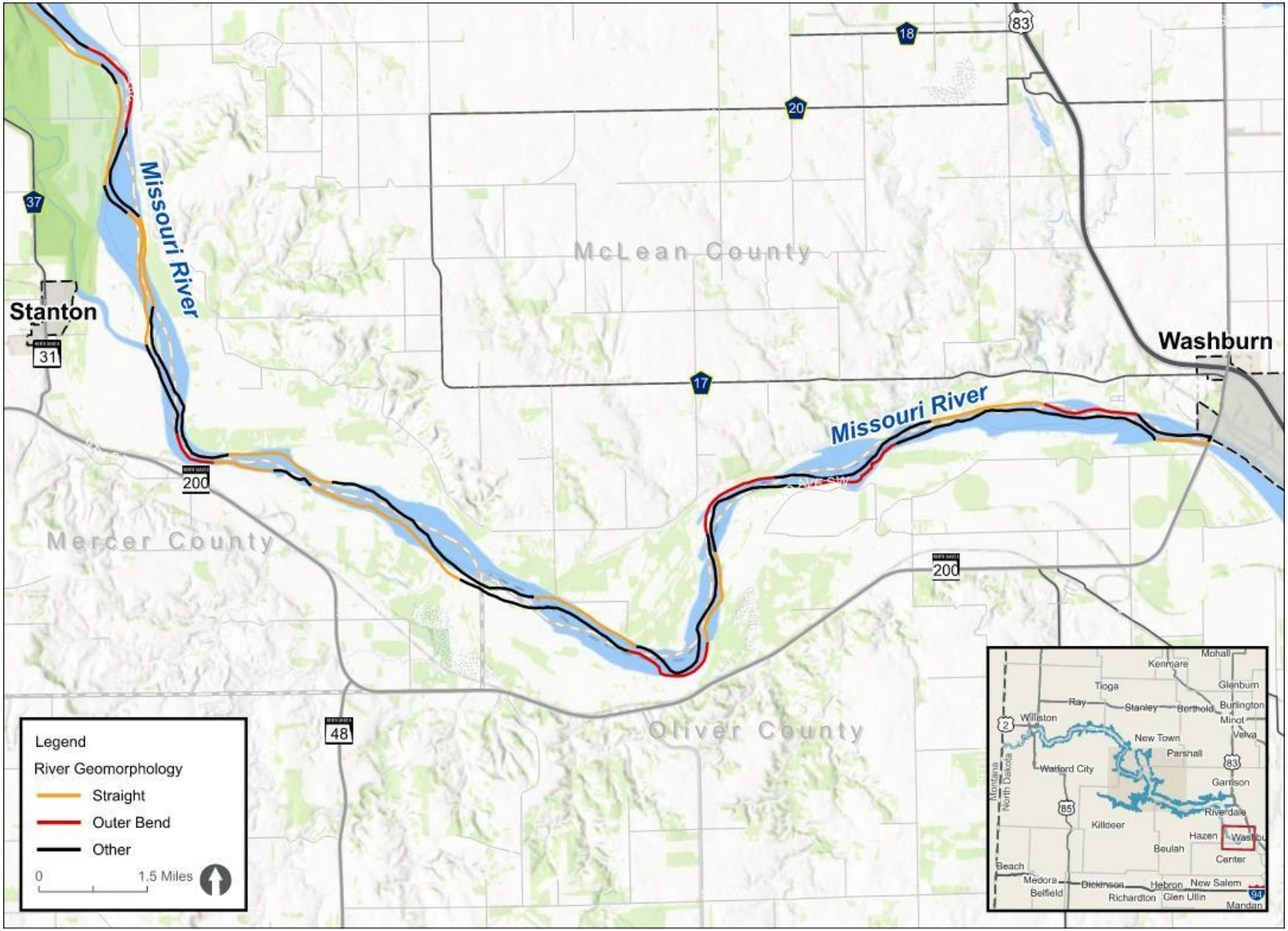


Figure 4. Garrison Dam to Washburn Reach upper geomorphology.

Appendix E – DecisionSPACE Results

Surface Water Criteria Comparisons

Figure E1. DecisionSPACE- Water Availability compared to remaining criteria

Figure E2. DecisionSPACE- Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas compared to remaining criteria

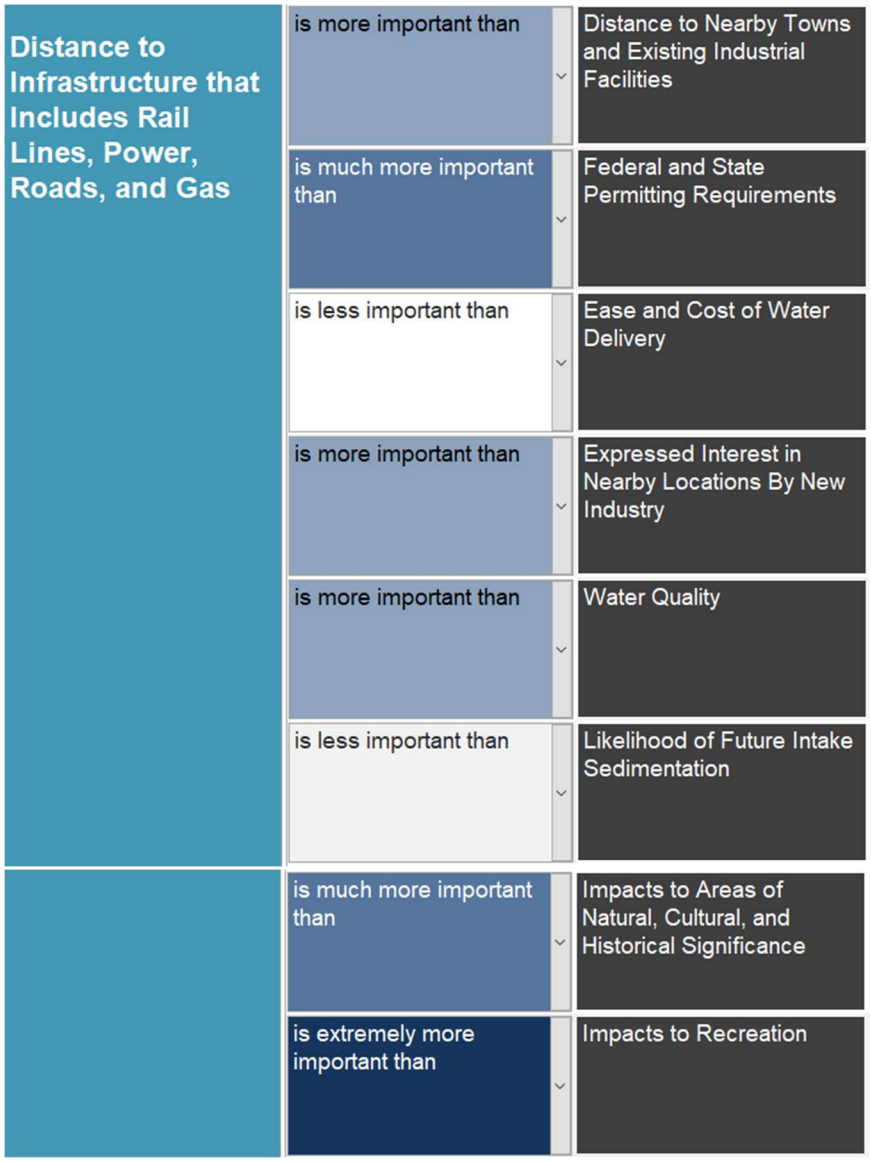


Figure E3. DecisionSPACE- Distance to Nearby Towns and Existing Industrial Facilities compared to remaining criteria

Figure E4. DecisionSPACE- Federal and State Permitting Requirements compared to remaining criteria

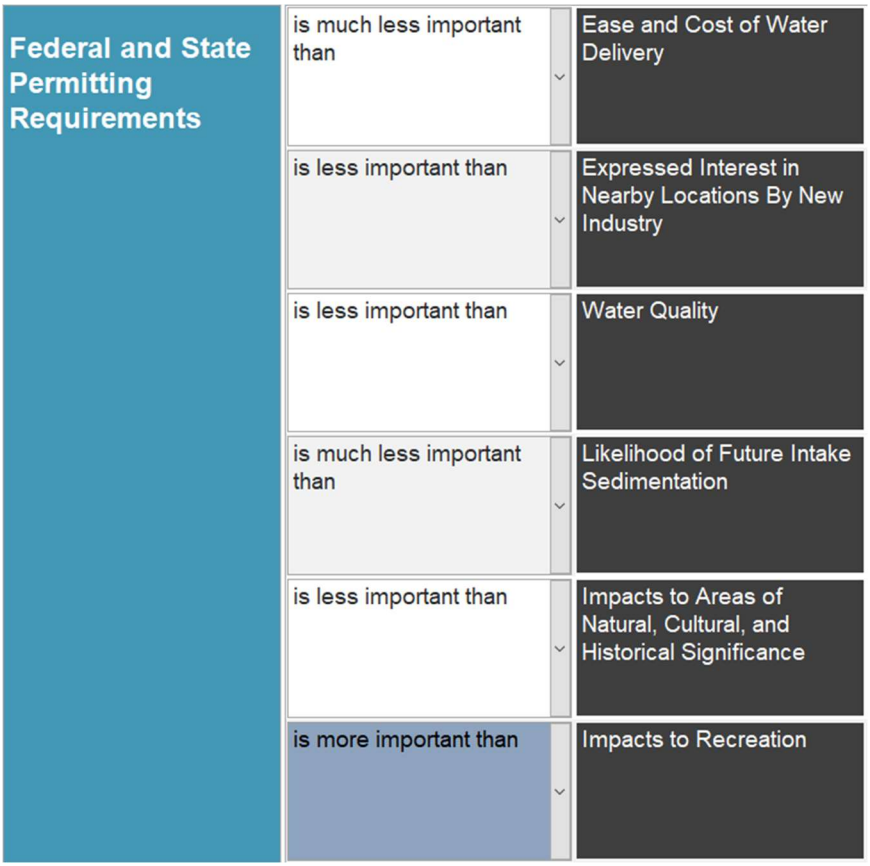


Figure E5. DecisionSPACE- Ease and Cost of Water Delivery compared to remaining criteria

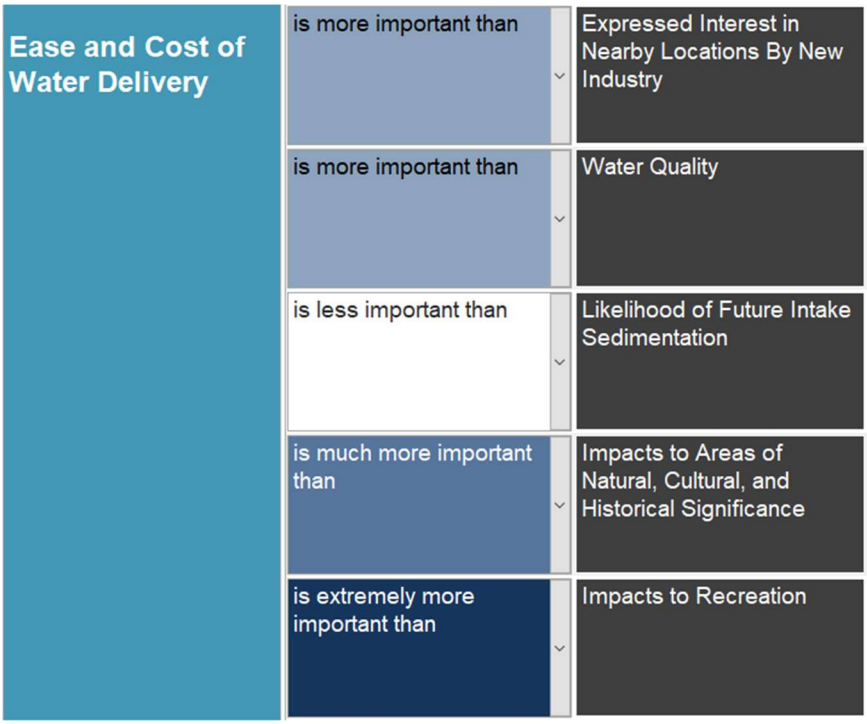


Figure E6. DecisionSPACE- Expressed Interest in Nearby Locations By New Industry compared to remaining criteria

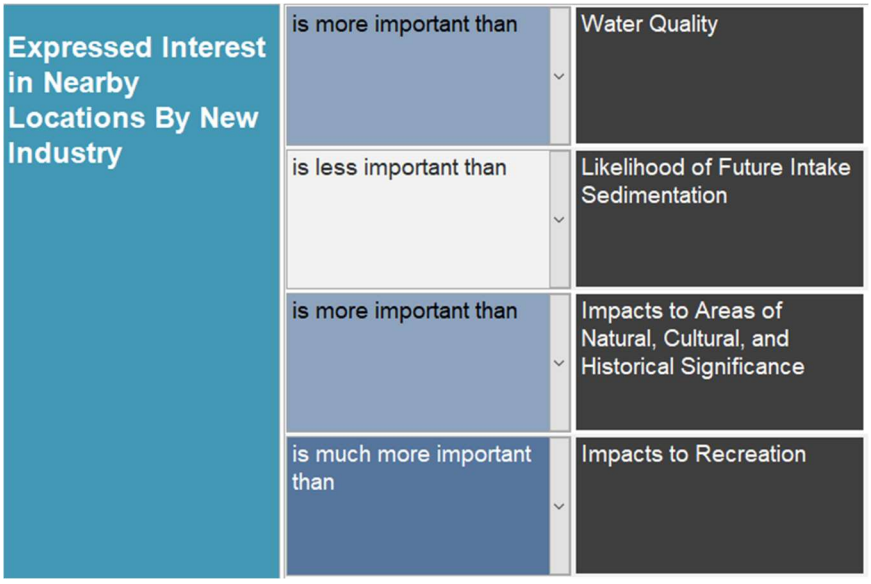


Figure E7. DecisionSPACE- Water Quality compared to remaining criteria

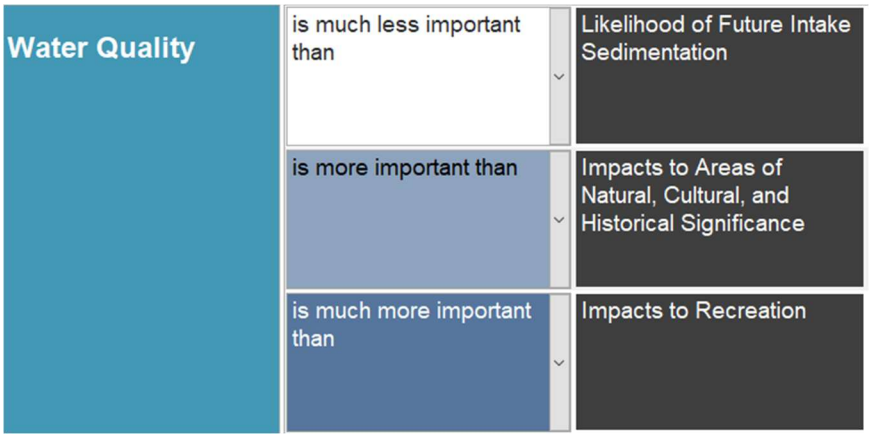


Figure E8. DecisionSPACE- Likelihood of Future Intake Sedimentation compared to remaining criteria

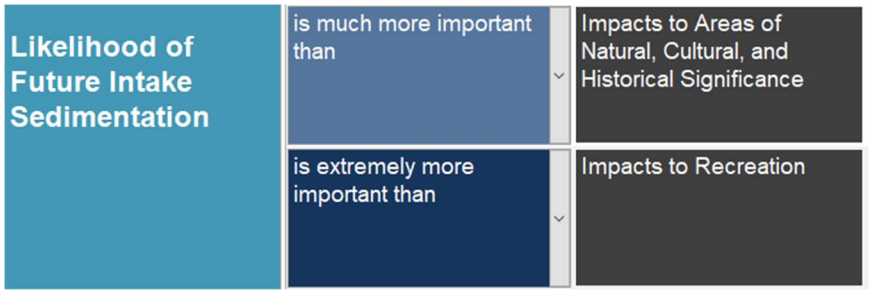


Figure E9. DecisionSPACE- Impacts to Areas of Natural, Cultural, and Historical Significance compared to remaining criteria

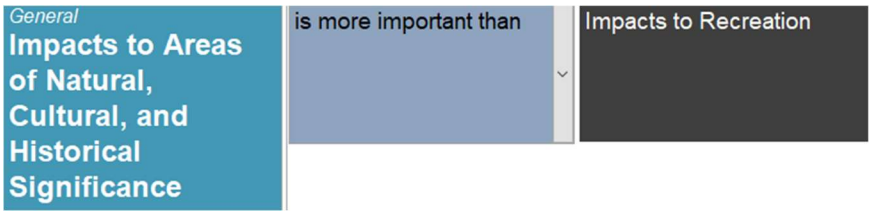


Figure E10. DecisionSPACE- Consistency Check

Source Criteria	Weight	Comparison	Object Criteria	Weight
Water Availability	36.7%	is extremely more important than	Impacts to Recreation	1.3%

Groundwater Criteria Comparisons

Figure E11. DecisionSPACE- Water Availability compared to remaining criteria

Figure E12. DecisionSPACE- Distance to Infrastructure that Includes Rail Lines, Power, Roads, and Gas compared to remaining criteria

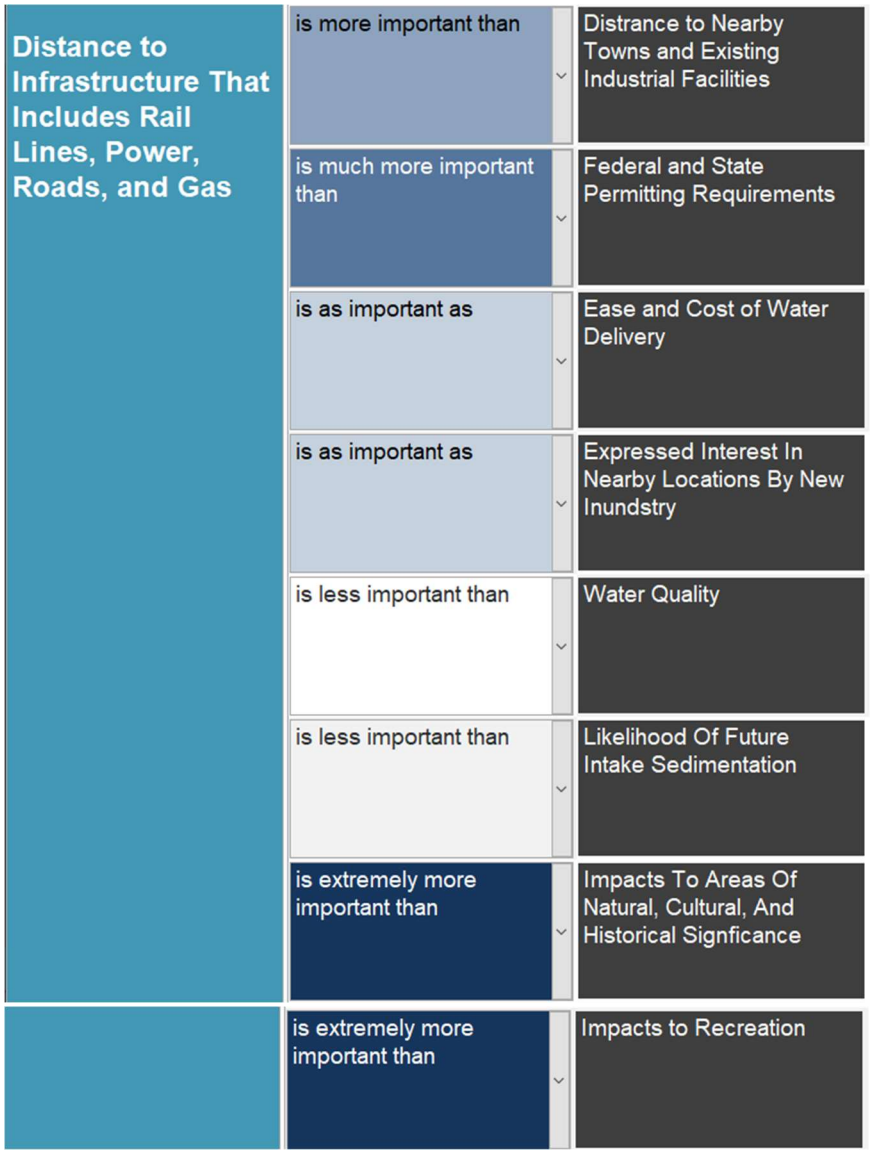


Figure E13. DecisionSPACE- Distance to Nearby Towns and Existing Industrial Facilities compared to remaining criteria

Figure E14. DecisionSPACE- Federal and State Permitting Requirements compared to remaining criteria

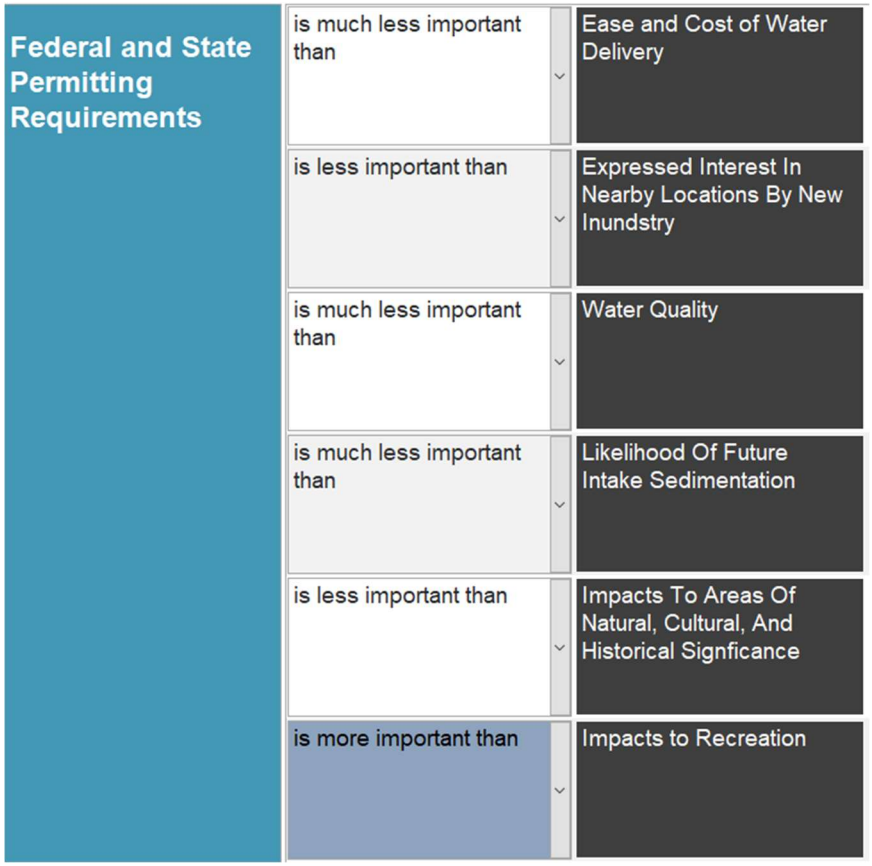


Figure E15. DecisionSPACE- Ease and Cost of Water Delivery compared to remaining criteria

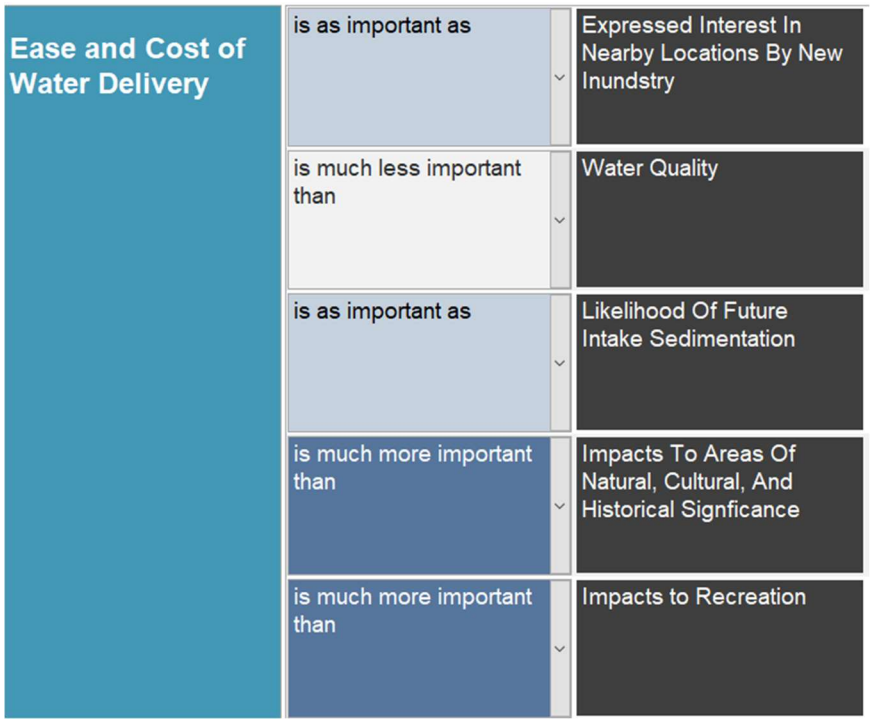


Figure E16. DecisionSPACE- Expressed Interest in Nearby Locations by New Industry compared to remaining criteria

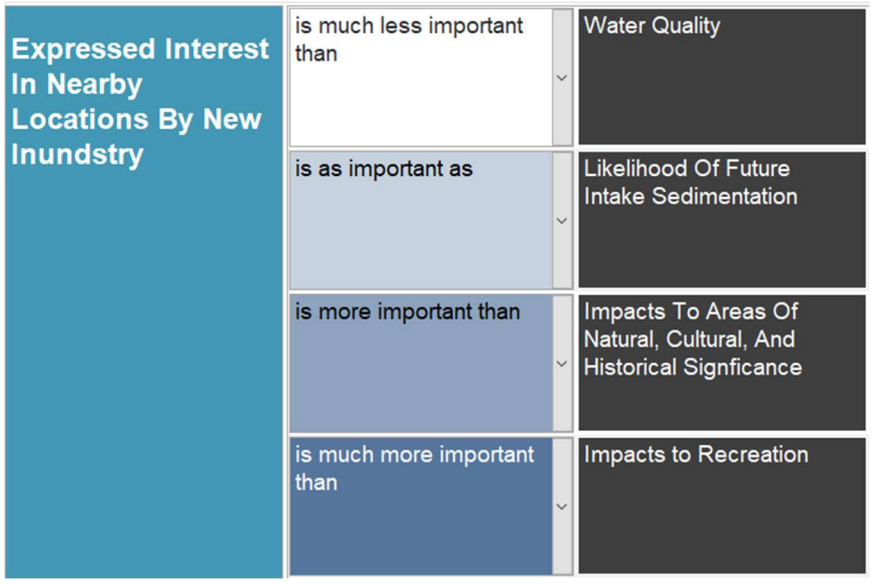


Figure E17. DecisionSPACE- Water Quality compared to remaining criteria

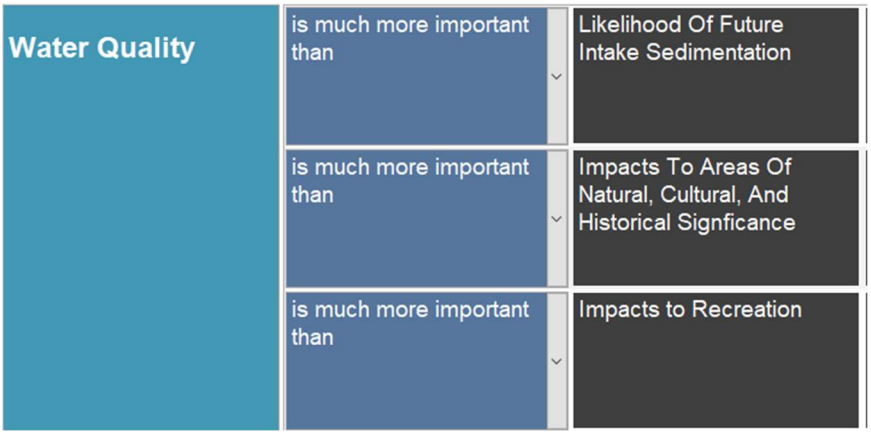


Figure E18. DecisionSPACE- Likelihood of Future Intake Sedimentation compared to remaining criteria

Figure E19. DecisionSPACE- Impacts to Areas of Natural, Cultural, and Historical Significance compared to remaining criteria

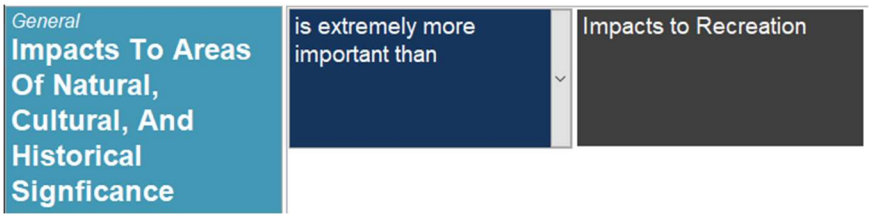


Figure E20. DecisionSPACE- Consistency Check

Source Criteria	Weight	Comparison	Object Criteria	Weight
Water Availability	44.5%	is extremely more important than	Water Quality	18.3%
Water Availability	44.5%	is extremely more important than	Impacts to Recreation	1.2%
Distance to Infrastructure That Includes Rail Lines, Power, Roads, and Gas	7.4%	is extremely more important than	Impacts To Areas Of Natural, Cultural, And Historical Signficance	2.7%
Impacts To Areas Of Natural, Cultural, And Historical Signficance	2.7%	is extremely more important than	Impacts to Recreation	1.2%

Appendix F – Field Analysis Memorandum

Memo

Date:	Monday, August 19, 2024
Project:	Missouri River Intake Study
To:	Clay Carufel, North Dakota Department of Water Resources
From:	Jarrett Hillius, P.E., HDR Engineering Inc. Chris Korkowski, P.E., HDR Engineering Inc.
Subject:	Field Testing

The project team held several review workshops to collectively define the field work needed to characterize and support potential industrial intake sites. During these discussions, the project team elaborated on the varied options and alternative levels of investigation considered necessary for supporting groundwater (through riverbank filtration) and surface water intake sites. Additionally, the team collaboratively determined that groundwater and surface water intake sites ideally would be broken into two phases of fieldwork that can be completed in order to inform the suitability of each site.

Given that the goal of the study is to identify five suitable 1000'x2000' surface water and five suitable 500'x500' groundwater sites, completing detailed fieldwork to assess whether a site is ready for construction would be extremely expensive. Phase 1 can be described as the more cost-effective fieldwork scenario that can be completed to provide high-level results for the screening of site suitability and to determine which of the 10 sites might be worth additional funds for further study. Phase 2 would take place after the conclusion of Phase 1 and is best described as a more comprehensive fieldwork campaign that can verify a site's total suitability.

The descriptions below further elaborate on optional Phase 1 and Phase 2 services that can be selected to test identified surface water and groundwater sites.

Surface water:

Phase 1 –

1. A bathymetric survey to verify elevations and verifications of 1940 contour data (if within the lake boundary). This survey could likely be completed by NDDWR survey staff depending on their availability.
2. A LiDAR survey to provide higher resolution ground surface elevations. The typical cost is approximately $25,000 per site.

3. A geotechnical desktop study to review publicly available data and company-owned historical data for expected geotechnical conditions. The typical cost range is $1500 (up to 20 acres) to $3,500 (under 5000 acres) per site.
4. Conduct geotechnical sampling. Ideal procedures include split spoon and thin-wall tube sampling (one to two borings per site) using continuous flight augers or rotary wash boring techniques. The cost for drilling a 100-foot borehole is expected to be between $3,500 and $4,500.

Phase 2 –

1. Complete a cultural resource field survey. This would be done to identify any cultural resources on the sites which could preclude development or complicate necessary permitting. Qualified archeologists would complete a Class III cultural resources inventory on identified sites (anticipated to be 1,000-ft by 2,000-ft). The cost for this survey varies based on items found and distance to site but would range from approximately $8,000 to $15,000 per site. Aquatic resource delineations could also be considered at this stage to assist with permitting, depending on if site development is expected within five years. These costs would be similar to cultural resources. If project development would not occur within five years, aquatic resource delineations are not recommended until closer to the permitting stage.
2. Conduct geotechnical sampling. Ideal procedures include split spoon and thin-wall tube sampling (one to two borings per site) using continuous flight augers or rotary wash boring techniques or sonic sampling. Two tests on land and in the water at each site are recommended with an estimated cost range of $30,000 to $60,000. The primary cost increase from Phase 1 to Phase 2 geotechnical sampling is due to the need for a barge to complete the water geotechnical sampling.

Groundwater:

1. Phase 1 – Perform test hole drilling to better define the lithology where existing test hole and well data is scarce.
    a. Option 1: Mud rotary drilling with geologic logging of drilling returns or geophysics (minimally gamma and electrical resistivity). The cost for a driller is approximately $20,000 to $30,000 per 200-ft hole. The cost for this process could be reduced with a geotechnical driller utilizing continuous split-spoon sampling.
    b. Option 1A: Rotosonic drilling with geologic logging of retrieved cores. The cost for a driller is approximately $20,000 to $30,000 per 200-ft hole.
2. Perform Ground-based Electrical Resistivity Tomography (ERT). ERT has a better resolution and is more cost-effective than an Aerial Electromagnetic Survey (AEM) on a site-by-site basis. The intent is to run survey lines to delineate the depth and quality of productive sand and gravel formation and any significant fines layers that could impede induced infiltration.

This testing can run from $25,000 to $40,000 per site depending on the amount of area to be investigated.

Phase 2 –

1. Complete a cultural resource field survey. This would be done to identify any cultural resources on the sites which could preclude development or complicate necessary permitting. Qualified archeologists would complete a Class III cultural resources inventory on identified sites (anticipated to be 500-ft by 500-ft). The cost for the survey varies based on items found and distance to site but would range from approximately $5,000 to $10,000 per site. Aquatic resource delineations could also be considered at this stage to assist with permitting, depending on if site development is expected within five years. These costs would be similar to cultural resources. If project development would not occur within five years, aquatic resource delineations are not recommended until closer to the permitting stage.
2. Perform rotosonic drilling with hydraulic interval testing to get estimates of aquifer transmissivity. With this service, a small capacity temporary well is set in the rotosonic test hole before running a two-hour step test run. The cost for a driller is approximately $35,000 to $45,000 per 200-ft hole and assumes one test per site.
3. Aquifer testing:
    a. Conduct aquifer testing to determine the aquifer parameters of transmissivity and coefficient of storage. Install a 4 to 10-inch well and a monitoring well. Run a 24-to-72-hour constant rate test. Starting from scratch, the drilling contractor cost can run approximately $100,000 to $180,000 per test site (200-ft wells) depending on the size of the test well and the duration of the pumping test. Using existing high-capacity wells for the pump test can lower this cost.
    b. (Preferred test) Conduct aquifer testing to determine the aquifer parameters of transmissivity and coefficient of storage and to assess the degree of connection to the surface water source (distance to recharge). This process involves a three-day constant-rate pumping test that operates at 1,000 gallons per minute (gpm) or higher on a test well located within 200 feet of the surface water. At minimum, six 2-inch observation wells should be installed in a cross pattern centered on the test well. Starting from scratch, the drilling contractor cost can run approximately $250,000 to $350,000 per test site. Using existing high-capacity wells for the pump test can lower this cost. This testing is usually only done to determine design parameters once a site has been selected for development.

The forecasted costs presented here are approximated and are based on bid results associated with similar project scopes identified over the past 12-18 months. They do not include costs for mobilization, professional staff time (such as a hydrogeologist to conduct log cuttings or pumping tests), or for transducers to monitor wells during aquifer pumping tests.

In summary, if DWR elects to perform Phase 1 services, the intended outcome of their delivery will aid DWR in determining whether the site should remain on the list and if advancing to Phase 2 services is necessary. Once the sites are determined acceptable for advancing to Phase 2 services and DWR elects to perform those evaluations, the results of the Phase 2 study are intended to provide DWR with results that verify if the site is acceptable for advancing to the next level of design. The table below summarizes the costs for Phase 1, Phase 2, and the total cost to field test each site based on the assumptions provided above.

Field Tests	Estimated Cost
Surface Water- Phase 1	$ 37,500.00
Surface Water- Phase 2	$ 75,000.00
Surface Water - Total	***$ 112,500.00***
Groundwater- Phase 1	$ 70,000.00
Groundwater- Phase 2	$ 405,000.00
Groundwater - Total	***$ 475,000.00***