Turkey Creek Watershed

Watershed Assessment of River Stability & Sediment Supply

PREPARED FOR: Nebraska Game & Parks Commission

PREPARED BY: WaterVation
123 G Street, Suite 18
Salida, CO 81201

DATE: December 2022

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

GLOSSARY OF TERMS

- **Aggradation** – The process of sediment being deposited by a stream or river.
- Bankfull Flow – A frequently occurring peak flow that represents the incipient point of flooding between the primary stream and adjacent floodplain. It is often associated with a return period of 1-2 years.
- **Channel Evolution** – The process by which a stable channel transitions into a new stable form in response to hydromodification.
- **Cubic Feet per Second (cfs)** – Volumetric flow rate within a stream.
- **Degradation** – The process of sediment being removed from the bottom of a stream or river.
- **Entrenchment** – The degree to which the geomorphic floodplain is confined by physical barriers.
- **Flow Duration Curve** – A plot of a frequency distribution of mean daily discharge versus percentage of time a flow is equaled or exceeded.
- **Geomorphic Response** – The physical change that a stream system undergoes in reaction to hydromodification, change in sediment load, introduction of physical features, etc.
- **Hydromodification** – the alteration of the natural flow regime within a watershed.
- **Manning's Coefficient** – An empirically derived resistance (roughness) coefficient to compute velocity within a stream.
- **Riparian Area** – Includes both terrestrial and aquatic ecosystems. They extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain into the water, laterally into the terrestrial ecosystem, and along the watercourse at a variable width (Ilhardt et al. 2000).
- **Sediment Load** – The quantity of sediment delivered to any point along a stream. Includes both suspend sediment load (sediment suspended in water) and bed load (sediment moved along the channel bottom).
- **Sediment Supply** – The quantity of sediment produced by a watershed from overland and channel processes.
- **Sediment Transport Capacity** – The ability of a stream to transport the sediment load generated by the upstream contributing watershed.
- **Shear Stress** – The frictional force per unit area causing flow resistance along the channel boundary.
- **Stream Incision** – A process relating to abandonment of an active floodplain and a lowering of the channel bottom.
- **Stream Morphology** – The shape of streams and rivers and how they change over time.
- **Streambank Erosion** – Removal of sediment (land) along a stream bank.
- **Width/Depth Ratio** – The bankfull channel width divided by the average bankfull channel depth.

EXECUTIVE SUMMARY

Background

The headwaters of the Turkey Creek watershed begin in Elwood, Nebraska and encompasses Gosper and Furnas counties with a drainage area of 75 square-miles. Tri-Basin Natural Resources District (NRD) is proposing to implement a trans-basin diversion that will discharge surface water into the east branch of Turkey Creek in the northern extent of the Turkey Creek watershed. The proposed surface water diversion will run for 41 miles between this point and the confluence with the Republican River.

Purpose

In 2017, Tri-Basin NRD hired Olsson Associates to conduct a feasibility study for the proposed Platte-Republican Diversion Project. The results of this study were limited and did not include a geomorphic assessment or sediment transport analysis, both of which are required to evaluate impacts that the diversion could have on stream morphology and NGPC assets that include two Wildlife Management Areas (WMA) within the diversion route; Burtons Bend WMA and Oxford WMA. Therefore, the Nebraska Game and Parks Commission (NGPC) decided to hire a consultant (WaterVation, PLLC) to perform a watershed assessment to evaluate potential impacts on channel morphology and NGPC assets. The purpose of the Turkey Creek Watershed Assessment of River Stability & Sediment Supply Study (Study) was to:

- Quantify existing (baseline) watershed conditions for hydrology, stream morphology, riparian function, and aquatic habitat.
- Provide a predictive analysis of expected future conditions associated with the planned hydromodification within the Oxford WMA property.
- Identify areas at high-risk from the planned hydromodification that should be monitored.

Methodology

The Watershed Assessment of River Stability and Sediment Supply (WARSSS) was selected as the methodology for this Study because it is an accepted methodology by the United States Environmental Protection Agency (EPA) that provides a repeatable, quantifiable, defensible, and industry-accepted methodology for assessing watershed condition and predicting impacts associated with hydromodification. The WARSSS analysis is conducted through three stages: Reconnaissance Level Assessment (RLA), Rapid Resource Inventory for Sediment Stability Consequences (RRISSC), and the Predictive Level Assessment (PLA).

Results

Baseflows Increase by 67%

The proposed surface water diversion into Turkey Creek is estimated to be 40 cfs for the duration of September through April. For comparison, 98% of all flows recorded by the USGS Gage on Turkey Creek at Edison over the past 28 years have been below 40 cfs. A diversion of this magnitude would increase the baseflow within Turkey Creek by approximately 67% for the entire 41-mile diversion path between the headwaters and confluence with the Republican River.

Increase in Sediment Loading

The Bank Assessment for Non-point source Consequences of Sediment (BANCS) was used to calculate channel bank erosion for existing and proposed conditions using inputs of stream geometry, Rosgen stream type, and stream hydraulics. In existing conditions, the watershed generates approximately 68,202 tons/year from channel bank erosion.

After the diversion is active, Turkey Creek will transform according to the Channel Evolution Model (Schultz et al. 2000) to accommodate the additional flow. Projections of the Rosgen stream type in future conditions were made based on the assessment of how various stream reaches within the Turkey Creek watershed have transformed over time in response to hydromodification. Based on this process, the watershed will generate approximately 78,884 tons/year of sediment in proposed conditions, which represents a 14.2% increase compared to existing conditions. It is important to note that this increase is only attributable to the change in channel shape and will likely be higher during the incision and widening processes until a new stable condition is achieved.

The sediment impact analysis methods (SIAM) model was used to further assess the geomorphic impacts of increased sediment loading associated with the hydromodification associated with the proposed diversion. This model uses representative sediment transport characteristics of the study reaches to predict degradation or aggradation on an annualized basis. Sediment transport capacity is increased by 43% – 125,893% within the main stem of Turkey Creek when the proposed diversion of 40 cfs is active during the months of September through April.

Widespread Loss of Land & Infrastructure Impacts

This Study shows that the proposed diversion will trigger a geomorphic response for the entire length of Turkey Creek that is impacted by the diversion. The geomorphic response will follow the Channel Evolution Model (Schultz et al. 2000) where stable streams will incise and then widen until a new stable channel form is achieved. During this process, channel bank erosion will accelerate and will cause a widespread loss of public and private land.

As the stream incises, acute points of vertical incision will form along the main channel and migrate upstream through the connected tributaries. Increased sediment will then be transported downstream, which could impact in-stream infrastructure. A common occurrence is deposition upstream of bridges and culverts which can exacerbate flooding risks.

Impacts to Water Resources

The surface water elevation within the stream corridor will lower as the stream continues to incise. The lowering of the surface water elevation will then cause the lowering of the groundwater table adjacent to Turkey Creek. The process will cause the groundwater table to become disconnected from the riparian corridor, which will destroy both wetland and riparian vegetation critical for aquatic and terrestrial habitat. In-stream aquatic habitat will also be damaged and possibly eliminated during the channel transformation process.

The reduction in groundwater elevations will likely impact the ability of adjacent water users to pump water if their primary well is located within the limits of where groundwater elevations will be reduced. Deep wells in these locations will likely experience reduced well production and shallow wells could potentially become inoperable.

Additional Analysis

This Study focused on identifying and quantifying geomorphic change, and subsequent impacts, caused by hydromodification at a watershed scale. Additional analysis is recommended to further quantify impacts at a site-specific scale. Additional analysis could include, but is not limited to:

- Delineation of Waters of the United States (WOTUS).
- Groundwater modeling to evaluate impacts on groundwater elevations.
- Delineation of the channel migration zone to quantify potential land loss.

PURPOSE

The purpose of this Study is to evaluate the impacts that planned diversion will have on the Turkey Creek watershed. The planned diversion activities consist of a trans-basin diversion of surface water from the Platte River to the Republican River that will enter the Turkey Creek watershed as surface water. The amount and duration are based on the *Platte Republican Diversion Project (PRD) Feasibility Review* by Olsson Associates, July 2017. The following is an excerpt from the Olsson 2017 report:

> *If the diverted flow of 40 cfs is allowed down Turkey Creek during the months of September through April, the existing creek conditions appear to be sufficient to handle the additional flows. If diverted flows of 100 cfs are introduced into Turkey Creek during the same months, the number of continuous days in a row will need to be monitored. Based off existing conditions and capacity it is recommended that a flow of 100 cfs only be diverted into Turkey Creek for a maximum of 5 continuous days before reducing the diversion of excess flows. Longer periods of the diverted flow of 100 cfs would begin to affect the stability of Turkey Creek and could begin to cause sloughing along the banks and headcutting to the existing flowline. Therefore, it is recommended that the diverted flows be stopped for at least 7 days after the 5 days of continuous* 100 cfs of flow.

The goals of this Project are to:

- Quantify existing (baseline) watershed conditions for hydrology, stream morphology, riparian function, and aquatic habitat.
- Provide a predictive analysis of expected future conditions associated with the planned hydromodification within the WMA property.
- Identify areas at high-risk from the planned hydromodification that should be monitored.

The Watershed Assessment of River Stability and Sediment Supply (WARSSS) methodology was selected for this watershed study because it is a repeatable, quantifiable, defensible, and industry accepted methodology for assessing watershed impacts. The WARSSS methodology is a geomorphology-based procedure to quantify the effects of land uses on sediment relations and channel stability (Rosgen, 2006). WARSSS is an accepted methodology by the United States Environmental Protection Agency (EPA) as shown on the EPA's Healthy Watersheds website.

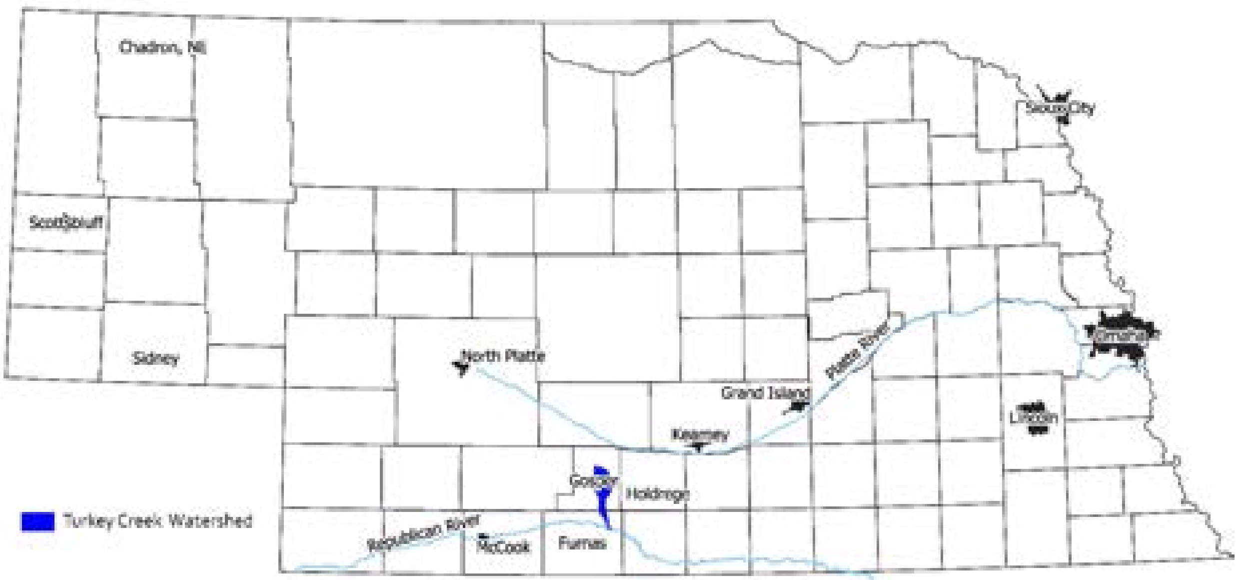
WARSSS identifies the hillslope, hydrologic and channel processes responsible for significant changes in erosion, sedimentation and related stream channel instability (Rosgen, 2006). This framework allows for:

- A baseline understanding of watershed conditions.
- A rapid screening process capable of identifying the major watershed stressors.
- Identification of high risk and high consequence locations.
- Prediction of future conditions.
- A national, flexible, framework for assessing river stability and sediment impacts.

LOCATION

The Turkey Creek watershed is located in Gosper and Furnas Counties in southern Nebraska as shown in Figure 1.

Figure 1: Watershed Vicinity Map



WATERSHED OVERVIEW

The watershed is located in the Upper Republican River hydrologic region. Land use within the watershed is dominated by grassland/herbaceous coverage and cultivated crops. The upper portion of the watershed is bifurcated into a west and east branch of Turkey Creek. At the confluence of the tributaries the watershed narrows and flows nearly directly south for approximately thirteen miles to the confluence with the Republican River. The watershed is dominated by stock ponds that are present in nearly all tributaries and stream orders 1 and 2. These stock ponds alter the natural flow regime of Turkey Creek by storing water and sediment and attenuating flows. In some cases, culverts provide a flow release from the stock pond, in others, it completely cuts off the drainage.

Hydrologic soils in the watershed are dominated by Class B within the drainage network and Class C outside of the drainage network and are generally well draining with higher infiltration rates. There is little to no influence of urbanization within the watershed, and it can be considered rural with land use influence from agricultural practices. Historical photography reveals that the watershed has experienced agricultural influences since the 1960's, and likely before that time. This indicates a relatively static watershed land use condition over the last 70 years.

The fluvial landscape (NRCS 2007) is a high-level classification that characterizes valleys based on how they were formed over geologic time. The Turkey Creek watershed is classified as a Confined Eolian: Sand Hills valley with stable Rosgen stream types A, B, C, and E. Unstable Rosgen stream types D, F, and G exist in this watershed, and could be considered for restoration to one of the stable stream types that naturally exists within this watershed.

Based on the Olsson 2017 PRD study, the East Branch of Turkey Creek will be used as the planned diversion route as highlighted in Figure 2.

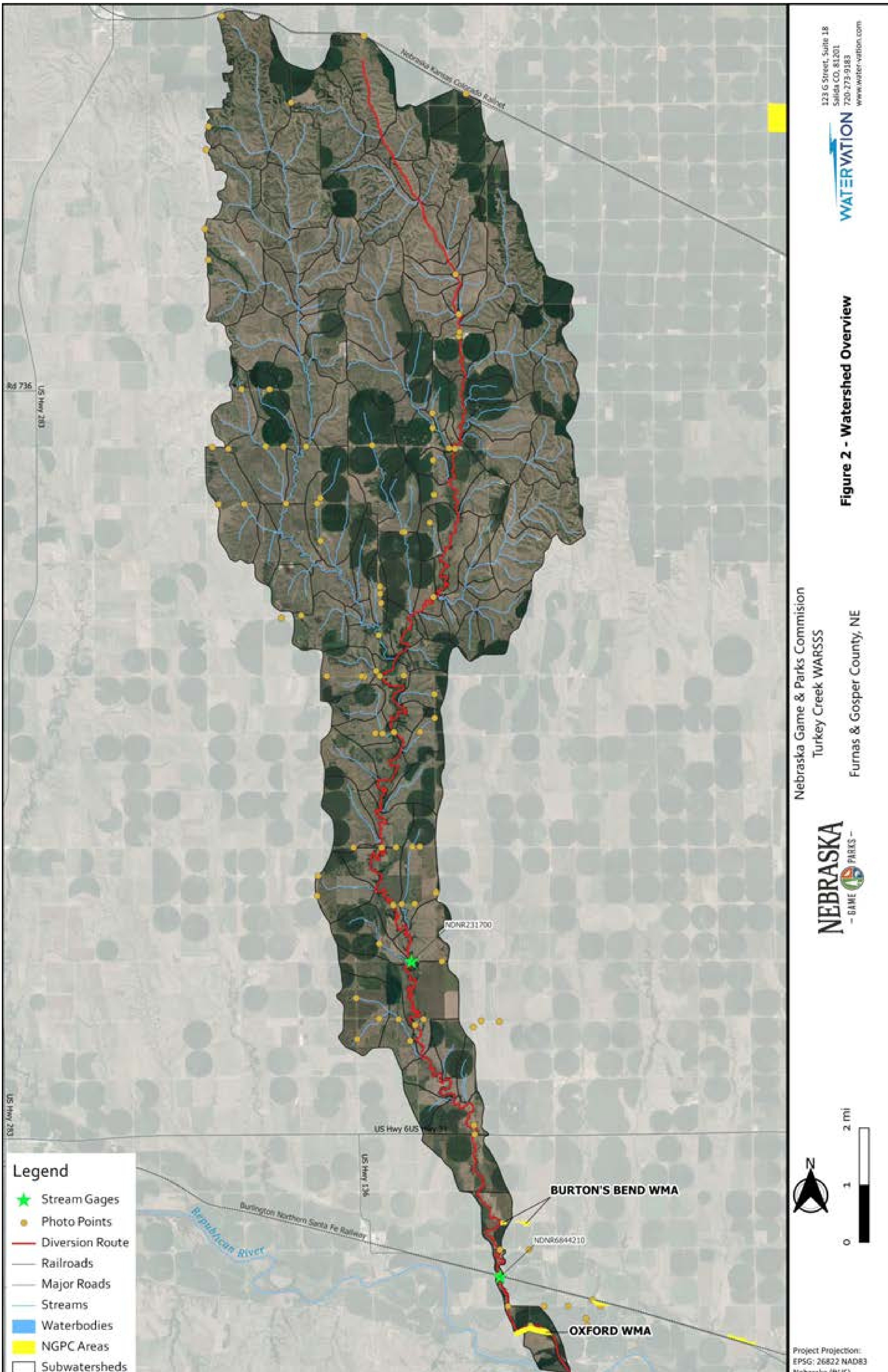
Flooding History

There are two stream gages located within the Turkey Creek watershed (Figure 2). Both are currently maintained and operated by the Nebraska Department of Natural Resources. The furthest upstream gage is located at the Furnas/Gosper County Line with a period of record from 2006 – current. The second gage is located at US Highway 136 (Turkey Creek at Edison) and was previously operated by the United States Geological Survey (USGS) with a period of record from 1978 – current.

In 2019 Turkey Creek experienced an extreme flooding event in early July. The stream gage at the Furnas/Gosper County Line recorded a peak discharge of 3,100 cfs which is the flood of record for that gage. The stream gage near Edison, just upstream of the Oxford WMA, recorded a peak discharge of 5,950 cfs which is the flood of record for that gage.

A watershed overview map is provided in Figure 2.

Figure 2: Watershed Overview



Watershed Tour

On May 4 – 7th 2021 WaterVation and NGPC staff conducted field surveys at the Oxford WMA Property and at a private landowner property that NGPC obtained access to. In addition, a watershed-wide tour was performed by visiting all major stream crossings and all stream reaches that were publicly accessible at the time. The project team took photographs at all accessed locations (Figure 2) to gain an overall understanding of the Turkey Creek watershed conditions.

Figure 3: Watershed Sensitivity

One of the major findings during the field surveys was the overall sensitivity of the watershed. This is highlighted in Figure 3, where the impact of hydromodification and concentrated flow in the form of a roadway culvert resulted in a channel succession state from D to G. This finding can be related to the concept of stream response potential (SPR) (Bledsoe, 2016). Where:

- **Fine-bed river systems** have greater susceptibility to change with a great range of flow regimes transporting sediment (High SPR).
- **Coarse-bed river systems** have a lower variability with a small range of flows transporting sediment (Low SPR).

Turkey Creek is a fine-bed river system with a high SPR. This means that it is very sensitive to land use or hydrologic changes.

Watershed Delineation & Stream Type Identification

Watershed delineation was primarily based on 2nd order streams from the National Hydrography Dataset (NHD). Stream classification was based on the Rosgen classification system. A Level 1 classification was performed, which was primarily based on valley types, watershed position, and major stream types. The Level 1 classification was supplemented by onsite photography, aerial imagery, and cross-section data based on available LiDAR data. The cross-sections were used to identify width to depth ratios (W/D).

The watershed is primarily composed of D, B, G, and F stream types. For the purpose of the study all D stream types are denoted as D* to indicate that slope criteria would result in slightly differing stream types. In this case B and D* stream types are considered stable and F and G stream types are considered as unstable. An example of each dominant stream type found in the watershed is shown in Figure 4 - and the watershed-wide classification and delineation is shown in Figure 8.

Figure 4: B Stream Type

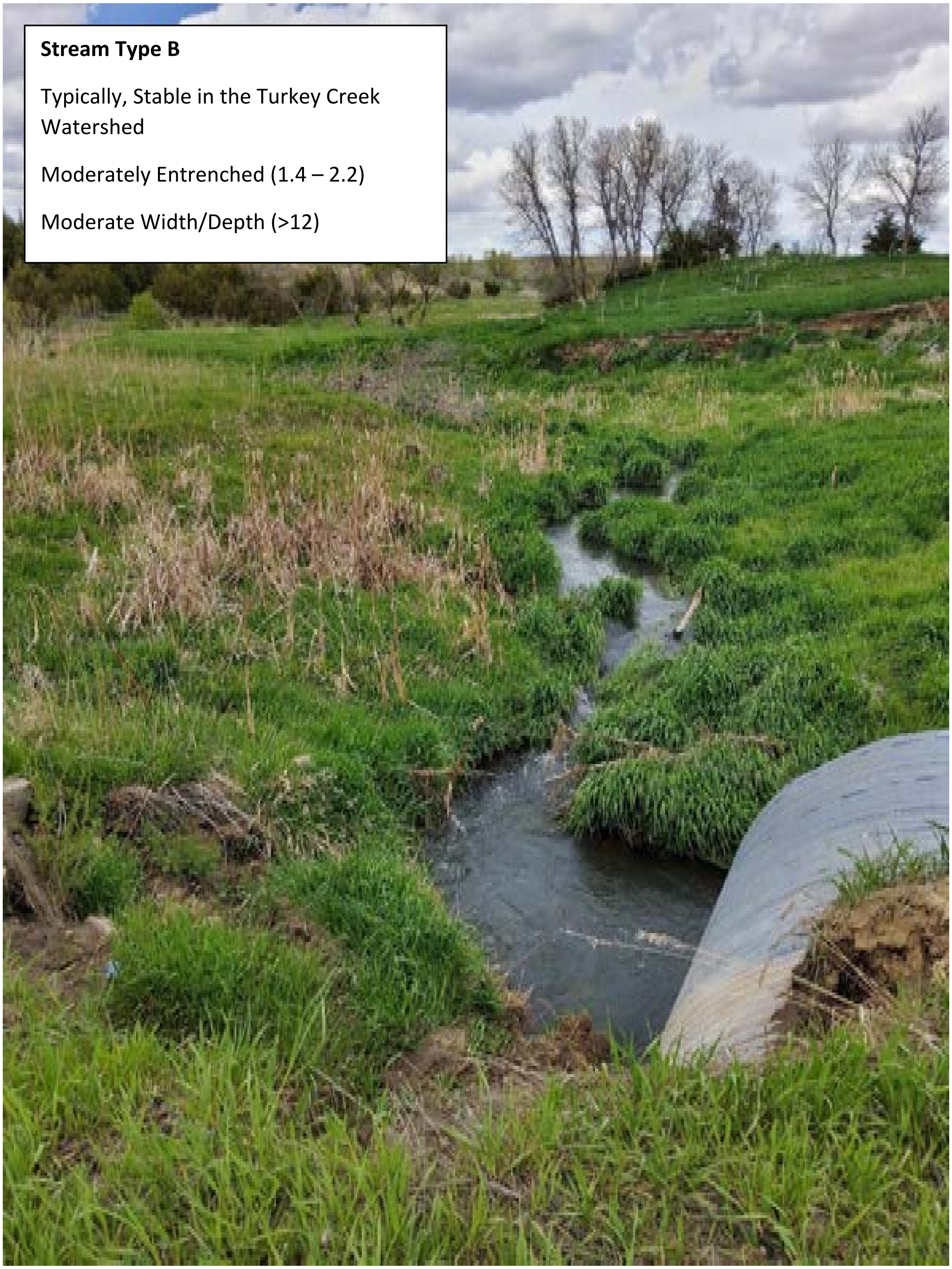


Figure 5: D Stream Type (Inactive Alluvial Fan)

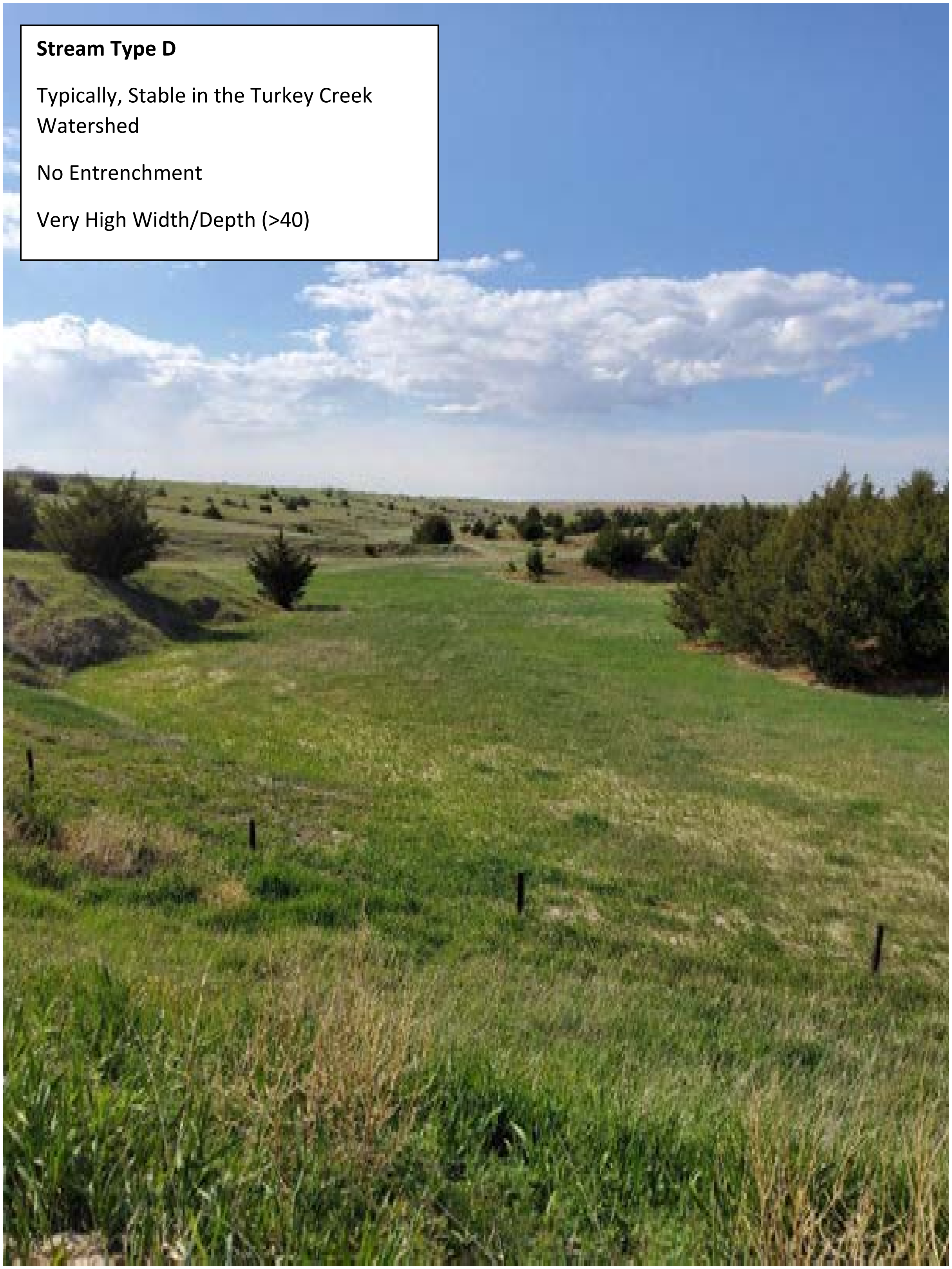
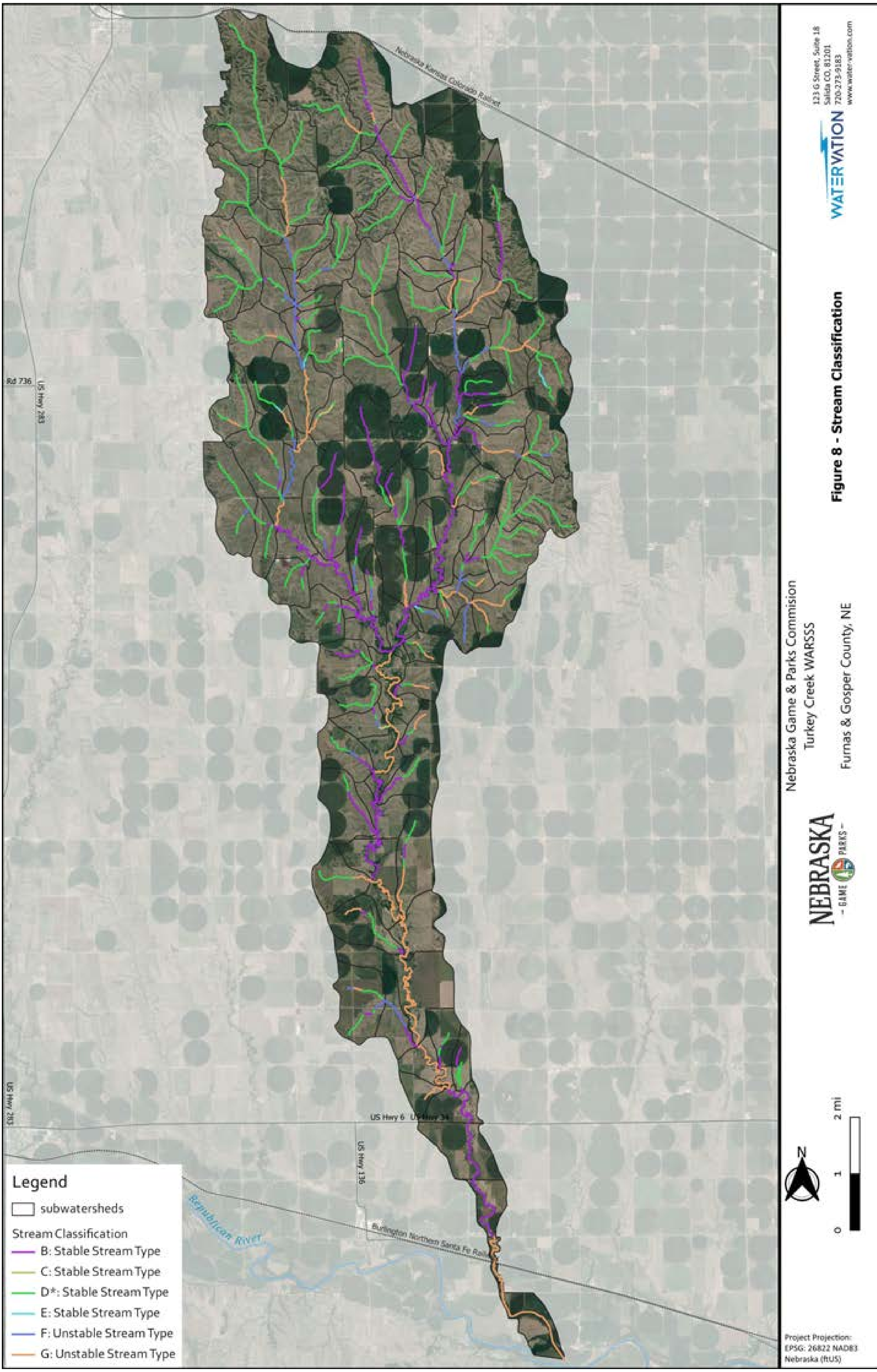


Figure 6: G Stream Type

Figure 7: F Stream Type

Figure 8: Stream Classification



RECONNAISSANCE LEVEL ASSESSMENT

Purpose

The Reconnaissance Level Assessment (RLA) has three primary objectives (Rosgen 2006):

1. To identify sediment sources and channel stability problems linked to specific processes influenced by land and river management activities.
2. To refine, clarify or, if necessary, redirect problem identification.
3. To locate potential problem areas and reaches within a large watershed that require a more detailed level of assessment.

The initial screening of the RLA process identifies watersheds or stream reaches that require a more detailed analysis and consideration.

Influences of Land Use Variables on Stream Channels and Sediment Supply

Influences of land use variables on stream channels and sediment supply is evaluated in the RLA. For each identified sub-watershed the land uses and potential influences are determined. The primary land use drivers within the Turkey Creek Watershed are:

- Agriculture influences
- Reservoir storage (in the form of stock ponds)
- Stream diversions and imports
- Grazing influences
- Road influences

A generalized table encompassing the range of impacts from land uses throughout the entirety of the Turkey Creek Watershed is summarized in Table 1.

Table 1: Land Use Influences

Land Uses	Potential Impacts											
	(1) Stream-flow changes (Magnitude/Timing/Duration)	(2) Riparian Vegetation Change (Composition/Density)	(3) Surface Disturbance (%Bare Ground/Compaction)	(4) Surface/Sub-surface Slope Hydrology	(5) Direct Channel Impacts that Destabilize Channel	(6) Clear Water Discharge)	(7) Loss of Stream Buffers, Surface Filters, Ground Cover	(8) Altered Dimension, Pattern and Profile	(9) Excess Sediment Deposition/Supply (All Sources)	(10) Large Woody Debris in Channel	(11) Stream Power Change (Energy Distribution)	(12) Floodplain Encroachment Channel Confinement (Lateral Containment)
Urban Development												
Silvicultural												
Agricultural		D	D	D	D		D	D	D			D
Channelization												
Fires												
Flood Control, Clearing, Vegetation Removal, Dredging,												
Reservoir Storage, Hydropower	D				D	D					D	
Diversions, Depletions, (-) Imported (+)	D				D				I/D			
Grazing		D	D	D	D		D		D			
Roads												
Mining												
In-Channel Mining												

D = Direct Potential Impact | I = Indirect Potential Impact | Blank - Little to No Impact | N/A For Watershed

Relation of Stream and Channel Variables to Erosional Processes

Impacts from erosional processes within each sub-watershed can be identified following the classification of land use-related impacts. The primary erosional processes that have been observed and are potential within the Turkey Creek Watershed are:

- Surface Erosion
- Gully Erosion
- Streambank Erosion
- Channel Enlargement
- Degradation
- Channel Succession State

As an example, the connection of land use-related impacts to specific erosional processes can be observed by studying sub-watershed M19. This sub-watershed is influenced by Roads. These land use pressures result in a series of potential erosional impacts such as streamflow changes, sedimentation, and floodplain encroachment as shown in Table 2.

Erosional processes can then be linked to a geomorphic channel response (Table 3). As an example, the erosional process of floodplain encroachment in sub-watershed M19 can trigger the geomorphic response of gully erosion, streambank erosion, channel enlargement, degradation, and channel succession state. This geomorphic channel response is a natural reaction to accommodate floodplain encroachment which typically results in acute channel responses and increased sediment delivery to downstream reaches.

This process is highlighted in Figure 9 and Figure 10 where a stable D* Stream Type was influenced by land use pressures by the installation of a culvert. The culvert resulted in a modified hydrology (hydromodification) to that reach. The channel adjusted to the land use pressure by downcutting forming a gully that will eventually widen.

Following this step of the RLA process a full list of potential erosional process impacts for each sub-watershed are determined and categorized.

Table 2: Sub-Watershed M19 Land Use Influences

Land Uses	Potential Impacts											
	(1) Stream-flow changes (Magnitude/Timing/Duration)	(2) Riparian Vegetation Change (Composition/Density)	(3) Surface Disturbance (%Bare Ground/Compaction)	(4) Surface/Sub-surface Slope Hydrology	(5) Direct Channel Impacts that Destabilize Channel	(6) Clear Water Discharge)	(7) Loss of Stream Buffers, Surface Filters, Ground Cover	(8) Altered Dimension, Pattern and Profile	(9) Excess Sediment Deposition/Supply (All Sources)	(10) Large Woody Debris in Channel	(11) Stream Power Change (Energy Distribution)	(12) Floodplain Encroachment Channel Confinement (Lateral Containment)
Urban Development												
Silvicultural												
Agricultural			D	D			D		D			
Channelization												
Fires												
Flood Control, Clearing, Vegetation Removal, Dredging,												
Reservoir Storage, Hydropower												
Diversions, Depletions, (-) Imported (+)												
Grazing		D	D	D	D		D		D			
Roads	D								D			D
Mining												
In-Channel Mining												

D = Direct Potential Impact	I = Indirect Potential Impact	Blank - Little to No Impact	N/A for Watershed

Table 3: Sub-watershed M19 Erosional Process Impacts

Variables Influenced	Potential Erosional Process Impacts								
	Surface Erosion	Mass Erosion	Gully Erosion	Streambank Erosion	Channel Enlargement	Aggradation	Degradation	Channel Succession State	Sediment Delivery Efficiency
(1) Streamflow Changes (Magnitude/Timing/Duration)			D	D	D		D	D	
(2) Riparian Vegetation Change (Composition/ Density)			D	D	D		D	D	
(3) Surface Disturbance (% Bare Ground/Compaction)	D		I	I	I		I	I	
(4) Surface/Sub-surface Slope Hydrology	D		D	I	I		I	I	
(5) Direct Channel Impacts that Destabilize Channel			D	D	D		D	D	
(6) Clear Water Discharge)									
(7) Loss of Stream Buffers, Surface Filters, Ground Cover	D		I						
(8) Altered Dimension, Pattern and Profile									
(9) Excess Sediment Deposition/Supply	D			D	D		D	D	
(10) Large Woody Debris in Channel									
(11) Stream Power Change (Energy Redistribution)									
(12) Floodplain Encroachment Channel Confinement (Lateral Containment)	I		D	D	D		I	D	

D = Direct Potential Impact | I = Indirect Potential Impact | Blank - Little to No Impact | N/A for Watershed

Figure 9. Stable Stream, Type D

Figure 10. Land Use Pressure (Culvert)

Figure 11. Gulley Erosion, Channel Incision

→Stable Stream

→Land Use Pressure (Culvert from Road)/Changed Hydrology

→Adverse Geomorphic Response

Risk Determination

All sub-watersheds were advanced to the final stage of the RLA where documentation of surface erosion, mass erosion, streamflow changes, channel processes, and direct channel impacts were assessed. Following this assessment, sub-watersheds were chosen for advancement to the Rapid Resource Inventory for Sediment and Stability Consequence (RRISSC) based on level of risk and other factors explained in this report.

For the Turkey Creek watershed, the primary drivers for identifying risks on a sub-watershed scale are:

- Surface Erosion
- Streamflow Change
- Channel Processes

Mass erosion is generally not present or observed in the Turkey Creek watershed. Direct Channel Impacts, such as alteration of dimension, pattern, and profile were not observed at this scale for the watershed study.

Surface erosion was directly observed by the presence of skid trails, roads, or grazing trails located within a sub-watershed based on the available aerial imagery. Streamflow change was identified by the presence of stock ponds, and by roads dissecting the watershed and directly blocking drainage pathways. Channel processes were determined from identification of unstable stream types located within the watershed as well as the potential increase of streamflow due to planned water diversions.

Given the purpose of this Study and the size of the study area (117 sub-watersheds), additional screening criteria were required to determine what sub-watersheds and reaches should be included in a more detailed assessment. In addition, land use is relatively stable in the Turkey Creek Watershed with minimal to no expected changes, excluding the hydrologic modification from the proposed streamflow diversion. More detailed assessment was performed for a sub-watershed if:

- It is located within the direct path of the proposed streamflow diversion.
- It contains an unstable stream type with a substantial length or that is connected to a main tributary.
- An unstable stream type is below a stock pond and located in the lower portion of a watershed (i.e. it is prone to clear-water scour).
- It is located within a critical watershed position and the stream order is 2 or greater.

A total of 48 sub-watersheds were selected for further analysis by implementing this screening criteria, which constitutes about 41% of the entire watershed.

It should be noted that a majority of Turkey Creek has achieved some degree of stability within the existing landscape and land use constraints. However, it is highly susceptible to land use changes, flood events, and climatic change as documented through the RLA process. Figure 12 identifies the sub-watersheds at high risk and selected for further analyses through the RRISSC phase of the WARSSS methodology.

If the planned diversion impacts are removed from the screening criteria 11 sub-watersheds would not have been selected for advancement to the RRISSC process. These 11 sub-watersheds are highlighted in Figure 13. This includes sub-watershed 29, which contains the Oxford WMA property.

Figure 12: RRISSC Sub-Watersheds

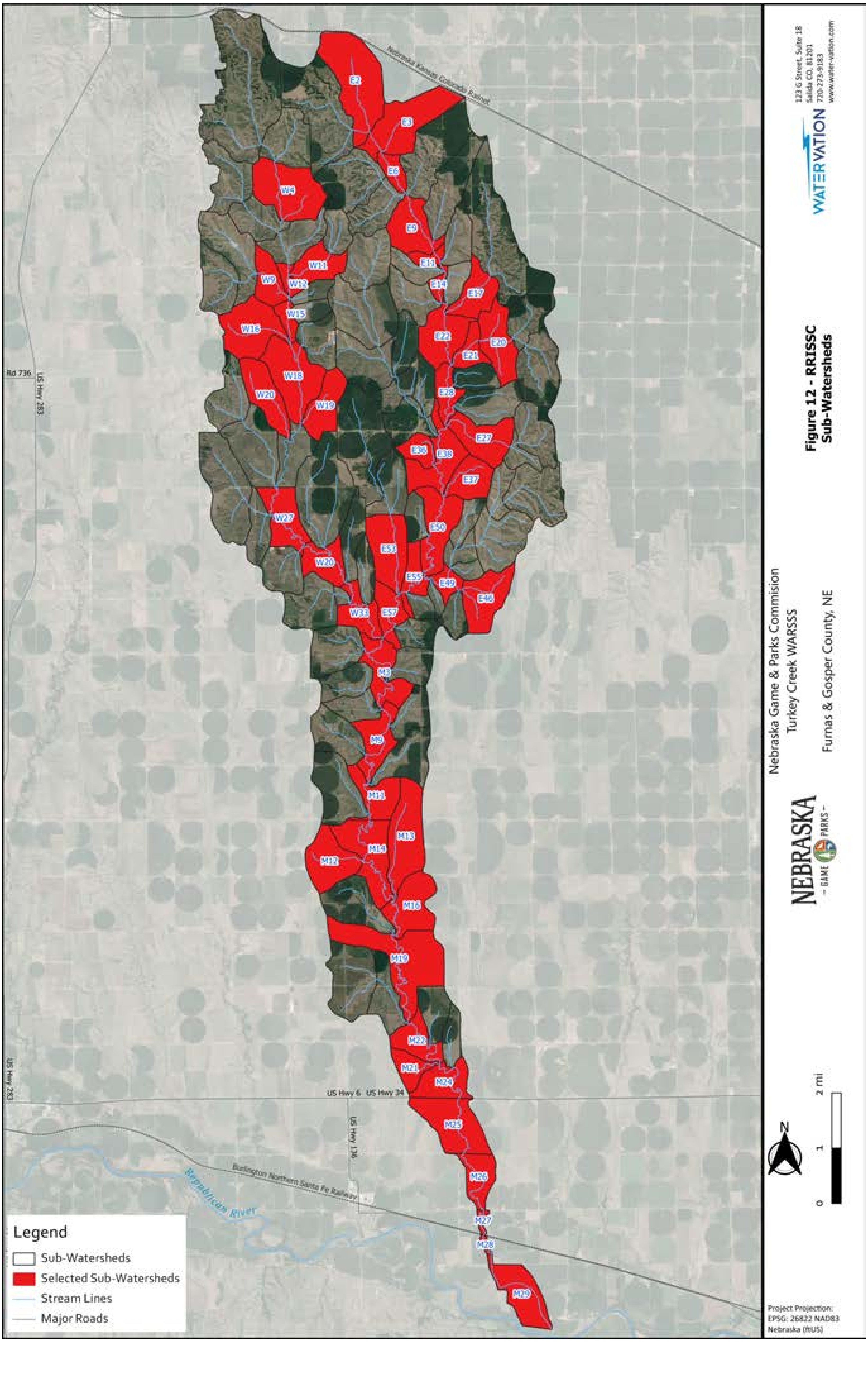
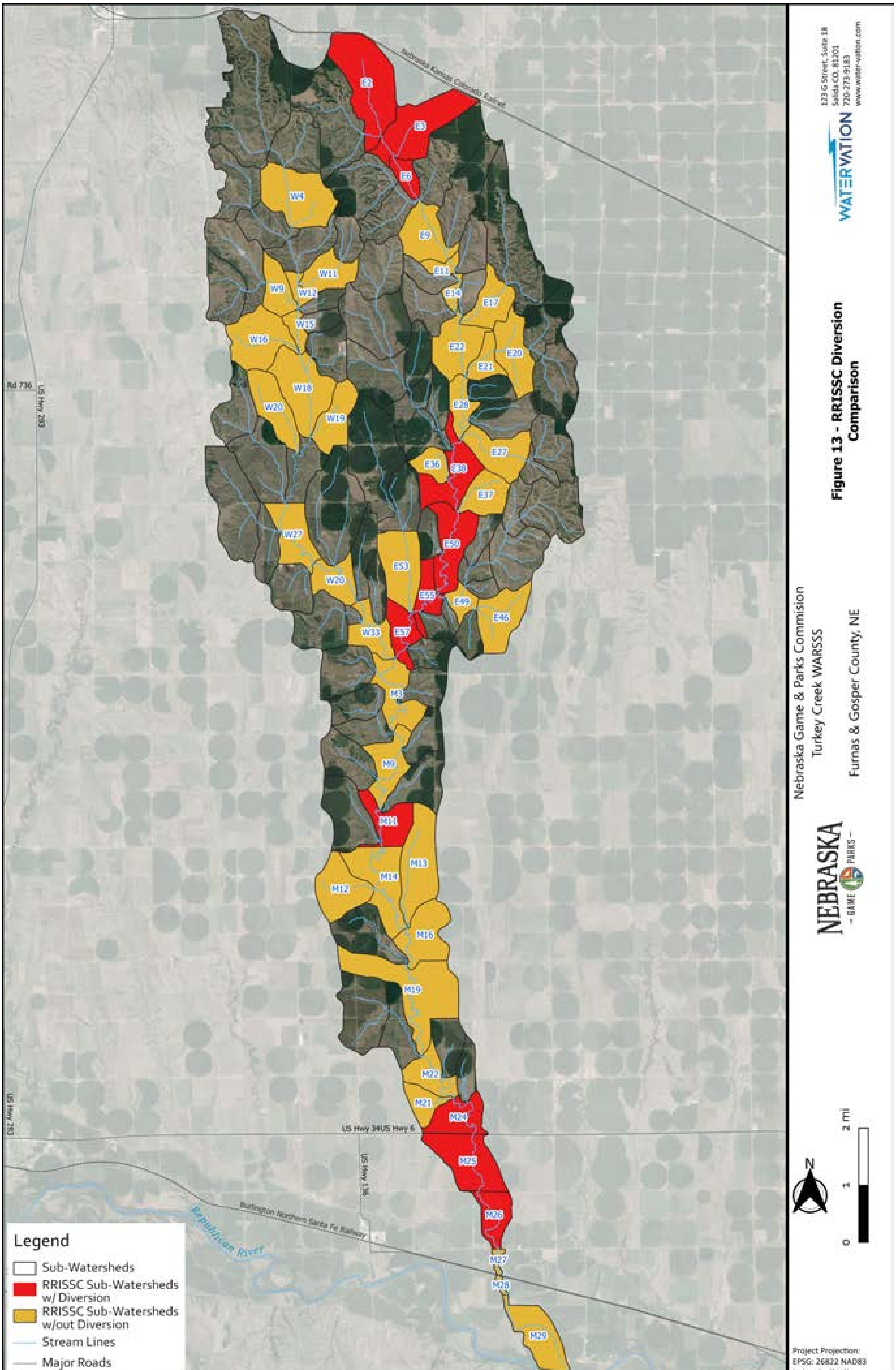


Figure 13: RRISSC Diversion Comparison



RAPID RESOURCE INVENTORY FOR SEDIMENT AND STABILITY CONSEQUENCE

Purpose

The Rapid Resource Inventory for Sediment and Stability Consequence (RRISSC) phase further screens the watershed using more refined hillslope, hydrologic, and channel process assessments to develop management actions based on risk rating:

- High or Very High Risk – Requires detailed assessment.
- Moderate Risk – Requires a change in resource management.
- Moderate Risk – Requires ongoing monitoring.
- Very Low or Low Risk - Excluded from further assessment.

Risk Rating Analysis

The WARSSS methodology contains several process-related drivers that are linked to geomorphic channel response. The following process-related drivers apply to this Study:

- Hillslope Processes: Roads
- Hydrologic Processes: Streamflow Change
- Channel Processes: Streambank Erosion
- Channel Processes: Channel Enlargement
- Channel Processes: Channel Evolution/Succession States
- Channel Processes: Degradation

Other processes, not included but may be present within the watershed, but, were determined as non-dominant drivers of channel stability and sediment supply within the Turkey Creek watershed include surface erosion risk and direct channel impacts which include channel blockages, changed riparian vegetation composition, and direct channel works (straightening, dredging, levees). These items are not the primary drivers within the watershed and were deemed to currently not impact the overall risk ratings.

Risk ratings are directly tied to each erosional process and the associated impacts of this process. For example, road impacts are generally associated with streamflow changes (magnitude/timing/duration), excess sediment deposition/supply, and floodplain encroachment/channel confinement/lateral containment. Taking this to the next step, the streamflow changes generally result in erosional process impacts of gully erosion, streambank erosion, channel enlargement, degradation, and channel succession state. So, if there is a high-risk rating in the roadway category it is tied to the erosional process impacts associated with the potential impact categories.

Road Impact Risk

Road impact risk was assessed for each sub-watershed using five different categories:

1. Total acres of road disturbance within the sub-watershed
2. Number of stream crossings
3. Slope position of the roadway
4. Distance of road to the stream
5. Slope of the roadway

Each road impact risk category was assigned one of the following risk ratings, which are also used for the other risk categories in the RRISSC phase:

1. Very Low (1)
2. Low (2)
3. Moderate (3)
4. High (4)
5. Very High (5)

Overall road impact risk is determined by aggregating the risk rating for all five risk categories.

Many of the observed roads were gravel and or unmaintained roadways with a high sediment delivery potential. As a result, road risk ratings were not reduced based on construction age (i.e. newer roads do not decrease sediment delivery).

Potential for Streamflow Changes

The Turkey Creek watershed exists within a dominantly rural setting, therefore, streamflow impacts associated with urbanization (i.e., percent impervious) were not assessed for this Study. The risk rating for this category was primarily based on the percentage of cleared or harvested acreage and the stream type most susceptible to change in land use. The acreage of harvested land was based on the acreage of disturbed roads, as determined in the road impact risk, and the area of agricultural land use category as defined by the National Land Cover Database 2019 (NLCD2019) present within each sub-watershed. The stream type for all watersheds was determined to be either a B5, D5, F5, or G5. Based on this, a risk rating was developed for each sub-watershed.

Risk ratings for streamflow change can be adjusted based on how significantly predicted bankfull discharges exceed the existing bankfull discharge. Risk ratings were modified for sub-watersheds impacted by the proposed diversion using calculated bankfull flow values for existing conditions and where the proposed diversion flow of 40 cfs exceeded those bankfull values. This conservatively affected all sub-watershed on the East Branch of Turkey Creek through E50. This adjustment automatically placed all affected sub-watersheds into the highest risk category.

This estimate of risk rating related to streamflow change is considered conservative because the change in hydrology would likely affect the bankfull flow of all sub-watersheds within the diversion path. The change in hydrologic regime will negatively affect all sub-watersheds and reaches within the diversion path.

Streambank Erosion Risk

Streambank erosion risk is determined by vegetation composition, bank-height ratio, and the ratio of radius of curvature divided by bankfull width. These three categories were combined to then determine the overall risk of streambank erosion by stream type.

Most of the watershed is determined to have perennial grass, with some locations adjacent to agriculture having annual grasses, which places the vegetation composition in the High to Very high category. A majority of the Turkey Creek watershed can be classified as High for bank height ratio (BHR) and Moderate for the ratio of radius of curvature to bankfull width (Rc/Wbkf). In order to obtain resolution in risk categories, streambank erosion risk was determined directly from the dominant stream type within a given sub-watershed.

Risk ratings for streambank erosion vary from Moderate to Very High. This is consistent of what was observed in the field as well as from captured survey data.

Channel Enlargement Risk

Channel enlargement risk is determined by stream type with an overall potential rating coming from the risk associated with streamflow changes, streambank erosion, and direct channel impacts. Channel enlargement risks vary widely from Very Low to Very High throughout the watershed, based on the variable inputs as described.

Channel Evolution Potential

Channel evolution potential refers to how a channel changes shape to accommodate changes in streamflow, sediment loading, and physical constraints. Channel evolution is defined based on channel succession states of stream type. The dominant succession states used in this Study are shown in Table 4.

Table 4: Channel Succession States

Channel Successional States of Stream Type Evolution	Risk Rating
B, C, E, or D to G	Very High (5)
G to F	High (4)
F to C	Low (2)

Degradation Risk

Degradation risk is determined similarly to channel enlargement, with risk rating based on streamflow changes, in-channel mining, channel evolution, road drainage designs, and direct channel impacts. For this study risk ratings for degradation risk were associated with streamflow change and channel evolution. The highest listed risk category was used to determine the degradation risk for the sub-watershed.

The majority of watersheds have a High to Very High risk of degradation. This is consistent of what was observed in the field as well as from captured survey data.

Summary

All sub-watersheds selected for the RRISSC phase of the analysis result in at least one Very High (5) risk rating. These risk ratings were primarily associated with:

- Streambank Erosion
- Channel Enlargement
- Channel Evolution
- Degradation

Given the watershed context and the field observations, this outcome was expected. Much of the watershed is currently degraded with unstable streams that present a high risk of ongoing, and increased, sediment delivery that ultimately impacts channel stability.

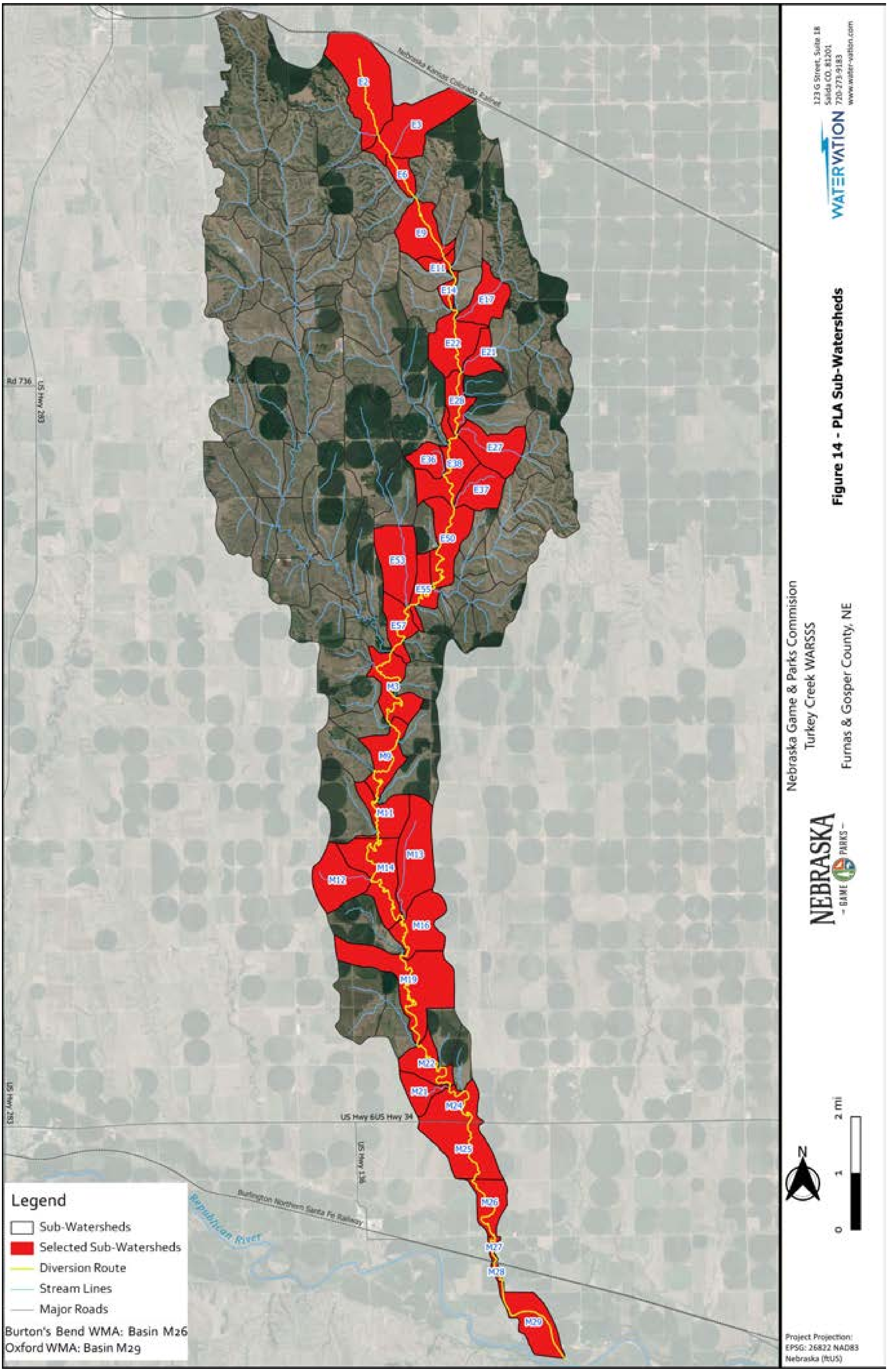
It was necessary to develop additional screening criteria for this Study to gain clarity on which reaches needed to be further evaluated with the PLA. The following additional screening criteria were developed to support the purpose of this Study, and the associated goals and objectives:

- **All sub-watersheds in the West Branch are excluded from PLA consideration.** Since they are not directly impacted by the planned water diversion and the land use is generally static no further analysis is required.

- **All sub-watersheds that are not directly connected to the diversion route are excluded from PLA consideration.** The greatest risk to these sub-watersheds is head cutting moving upstream. Since they are not directly connected the lower positioned sub-watershed presents greater current risks.

The additional screening results in 35 sub-watersheds selected for advancement to the PLA phase. All sub-watersheds should be considered for mitigation or monitoring. The selected watersheds for advancement are shown in Figure 14.

Figure 14: PLA Sub-Watersheds



PREDICTIVE LEVEL ANALYSIS (PLA)

Following the prescribed WARSSS processes, all 35 sub-watersheds would be selected for potential advancement to the PLA phase. However, the majority of the Turkey Creek Watershed is privately owned, and property access significantly limited the quantity of reaches that were accessible for detailed stream survey. Within sub-watershed M29 the NGPC owns and operated the Oxford Wildlife Management Area (WMA). This location was selected for the predictive level analysis (PLA) based on land access considerations.

The purpose of the PLA is to:

- Locate and quantify sediment sources.
- Link sediment sources to various land uses.
- Identify disproportionate sediment supply.
- Evaluate sediment impacts on river channels.
- Integrate hydrology, river morphology and river stability with land use impacts by specific location.
- Determine departure and degree of impairment due to sediment sources, watershed hydrology and riparian impacts.
- Provide sufficient detail to design site- and process-specific mitigation.

Bank Assessment for Non-point source Consequences of Sediment (BANCS)

This model is used for the prediction of streambank erosion rates. The model uses two bank erosion estimation tools:

- The Bank Erosion Hazard Index (BEHI)
- Near-Bank Stress (NBS)

The BEHI scores accounts for six categories/measurements to determine an overall BEHI score.

- Study Bank Height / Bankfull Height
- Root Depth / Study Bank Height
- Weighted Root Density
- Bank Angle
- Surface Protection
- Bank Material Adjustment

These categories are measured in select locations along the study reach to determine a calibrated BEHI score and rating that can be rapidly mapped across the entire study reach. BEHI scores vary from Low (L), Medium (M), High (H), Very High (VH), and Extreme (E).

The NBS scoring is the same as BEHI and is determined by the channel pattern and transverse and central bar positioning in the reach determined during the field reconnaissance.

During the field investigation BEHI, NBS, Bank Height, and Bank Length were mapped for the Oxford WMA and a site located on private land. The BEHI and NBS ratings are commensurate with streambank and channel changes. From that data, annual erosion rates can be estimates and when combined with Bank Height and Bank Length can provide a unit erosion rate in tons per year are developed.

The BANCS mapping at the two project sites was combined with stream classification to determine a unit erosion rate per stream type for the watershed. At the landowner site unit erosion rates for stream types B and C were developed. This resulted in 0.091 tons/year/foot for B stream types and 0.073 tons/year/foot for C stream types. The Oxford WMA is classified as a G stream type with a unit erosion rate of 0.186 tons/year/foot. The BEHI scoring for the Landowner site is shown in Figure 15 and the BEHI mapping for the Oxford WMA is shown in Figure 16.

Figure 15: Landowner Site BEHI Mapping

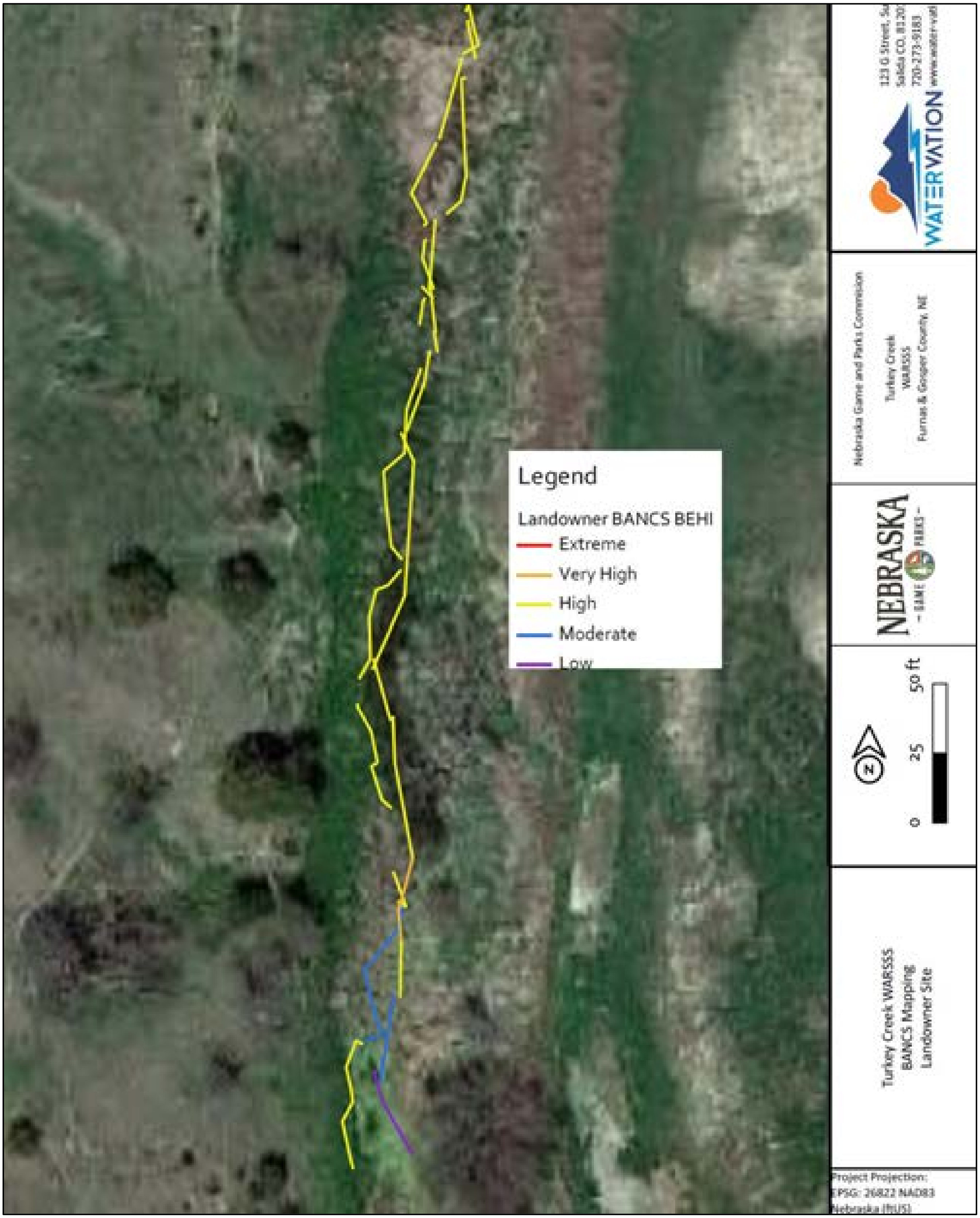
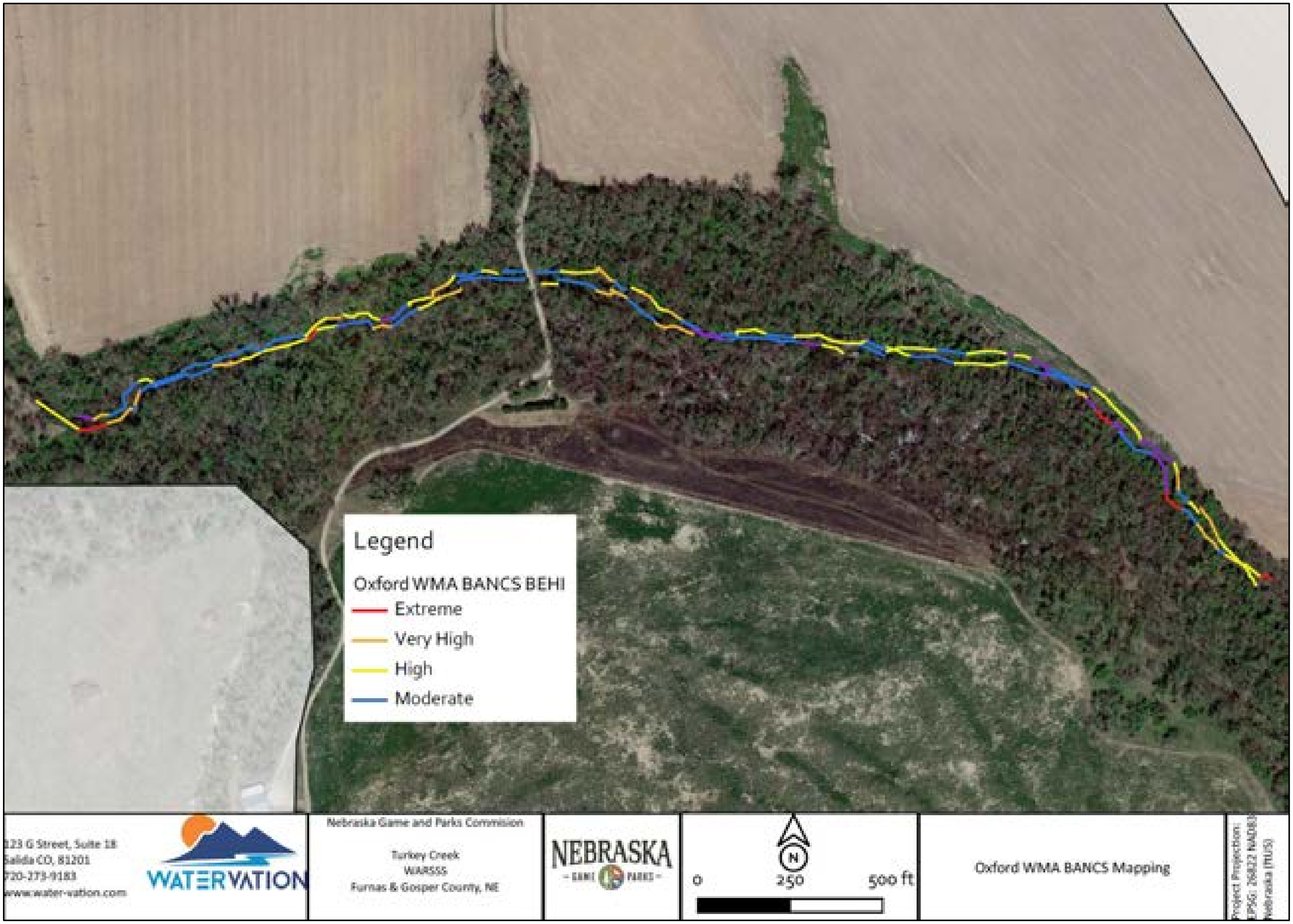


Figure 16: Oxford WMA BEHI Mapping



The unit erosion rates based on stream type and developed at each of the surveyed locations were extrapolated across the entire watershed to determine:

- Highest bank erosion sediment delivery reaches.
- Total watershed bank erosion sediment delivery estimates.

Bank erosion rates were not assigned to Type D streams. These are considered stable stream types with no bank erosion production. The unit erosion rate developed for G stream types was applied to F stream types in the Turkey Creek watershed. The differences between F and G stream types are minimal in the Turkey Creek watershed with unit erosion rates being generally comparable in this case.

In the current conditions, sub-watershed M19 is the highest producing bank erosion reach. This is based on the stream type designation and the reach length. The total watershed bank erosion yield is around 68,202 tons/year. The results of the analysis are shown in Figure 17.

After the diversion is active, Turkey Creek will transform according to the Channel Evolution Model (Schultz et al. 2000) to accommodate the additional flow. The channel succession states presented in Table 4 were used to predict the impact of the proposed diversion on the overall watershed bank erosion yield. In this case it is expected that the proposed diversion will result in the stable stream types D, B, and C transitioning into G or F stream types. To quantify changes from stable to unstable stream types, the unit erosion rate associated with unstable stream types were assigned to quantify the increase in sediment loading (Table 5). The analysis was only performed for the main stem of Turkey Creek, however, head cuts into the tributary basins are likely to occur when the main stem of Turkey Creek degrades, which will result in more bank erosion.

In these proposed conditions the total watershed bank erosion yield is estimated around 77,884 tons per year. This represents a 14.2% increase over the existing conditions sediment bank erosion yield. The increased bank erosion yield would be expected to continue within the watershed until the channel adjusted stream types due to the channel widening process, which will take several years. It is important to note that this increase is only attributable to the change in channel shape and will likely be higher during the incision and widening processes until a new stable condition is achieved.

The results of the proposed conditions are shown in Figure 18.

Figure 17: Existing Conditions BANCS Mapping

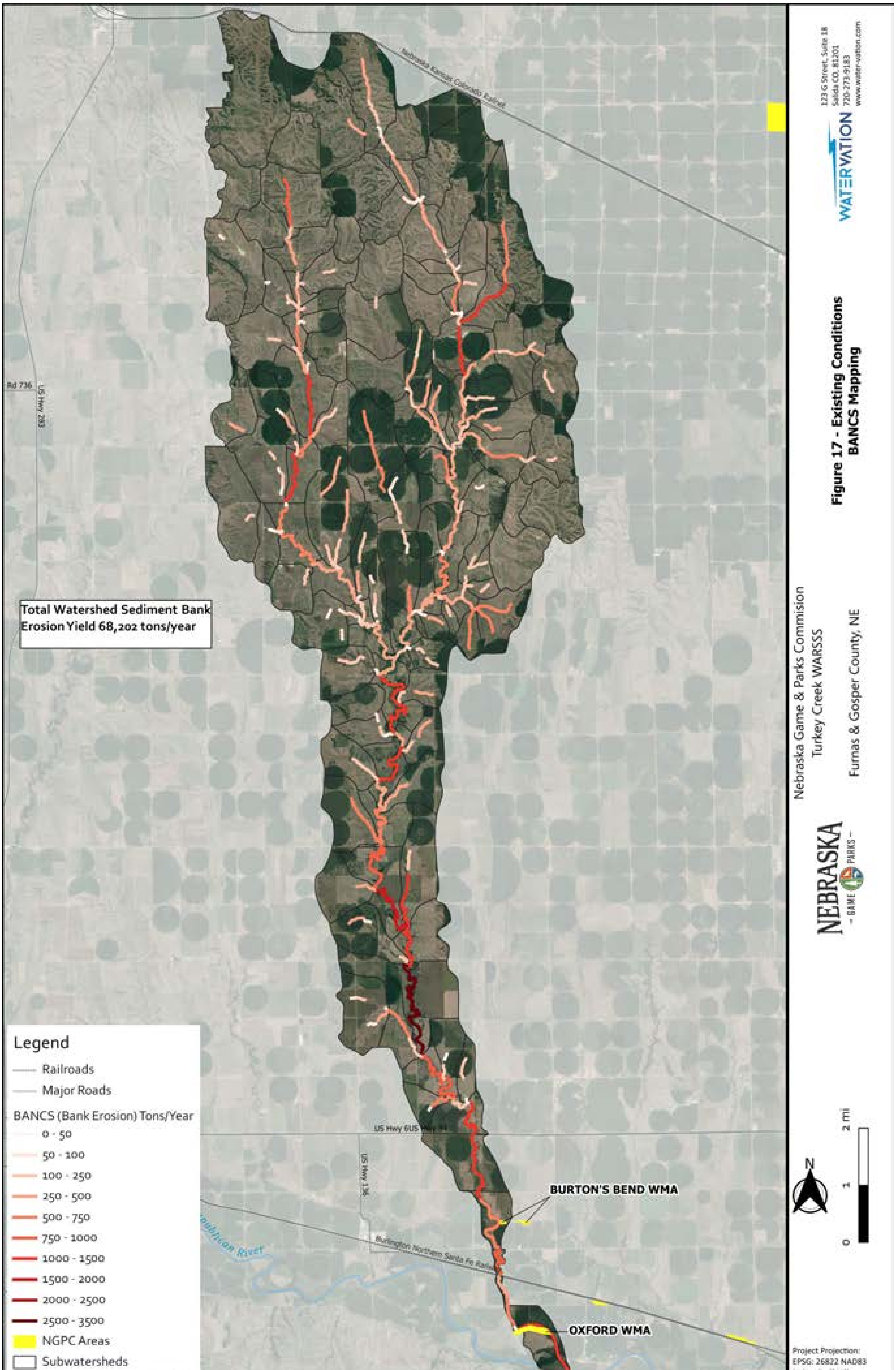


Figure 18: Proposed Conditions BANCS Mapping

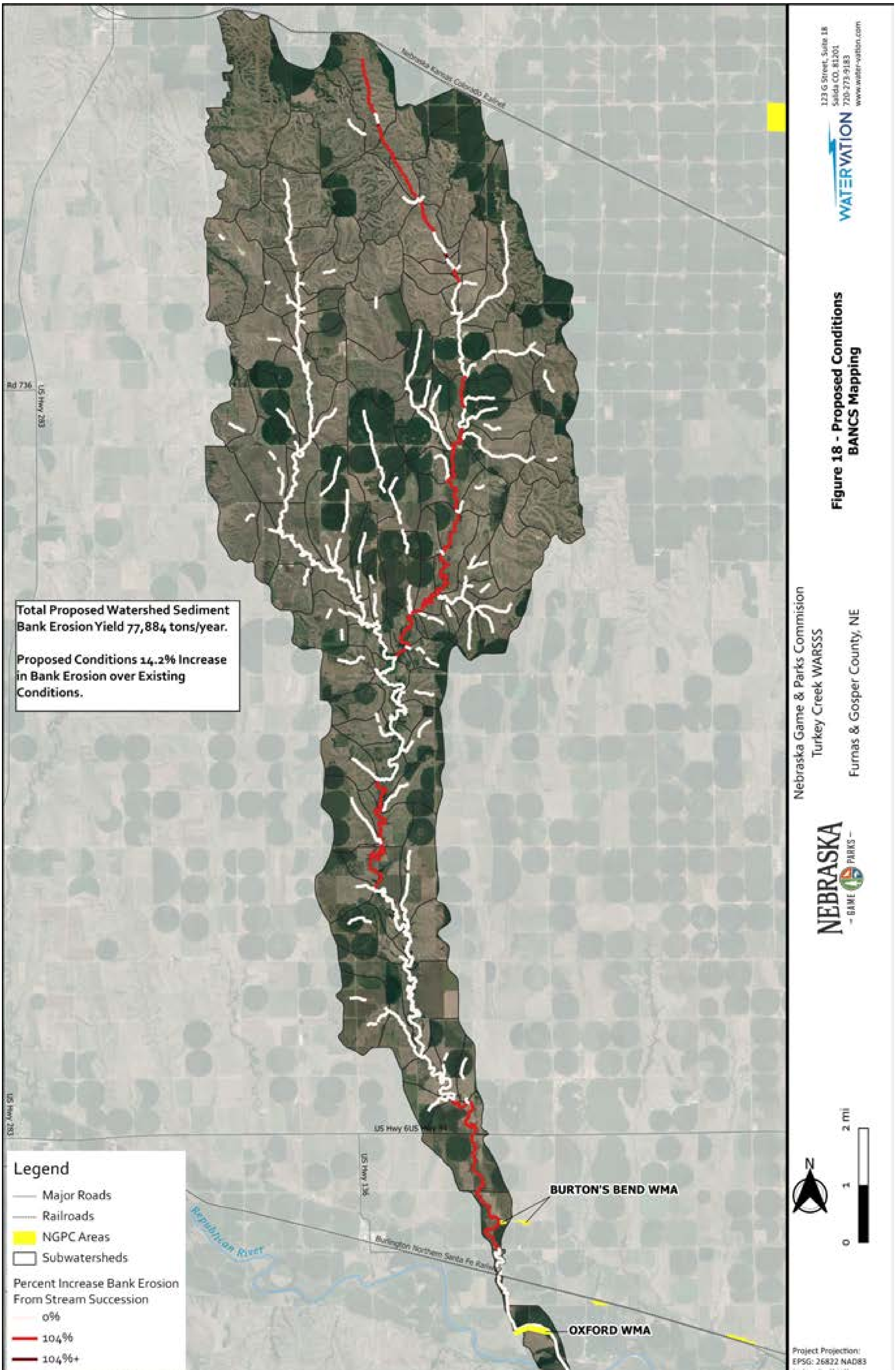


Table 5: Proposed BANCS Increases

Subwatershed	Reach Length (ft)	Existing Stream Type	Existing Erosion (tons/year)	Proposed Erosion (tons/year)	Percent Increase
E2	3,797	B	347	708	104%
	107	D*	0	20	104%+
	1,811	B	166	338	104%
	465	D*	0	87	104%+
	901	B	82	168	105%
E3	2,340	B	214	436	104%
E6	4,946	B	452	922	104%
E9	2,846	B	352	717	104%
	786	D*	0	147	104%+
E14	1,110	B	102	207	103%
E28	2,938	B	269	548	104%
	1,139	B	104	212	104%
E38	1,701	B	156	317	103%
	3,728	B	341	695	104%
	3,920	B	358	731	104%
E50	5,232	B	479	975	104%
	7,445	B	681	1,388	104%
E55	4,264	B	390	795	104%
	800	B	73	149	104%
E57	5,273	B	482	983	104%
	1,501	B	137	280	104%
M9	4,611	B	422	895	112%
M11	5,824	B	533	1,086	104%
M14	9,092	B	832	1,695	104%
M24	2,431	B	222	453	104%
M24/M25	13,062	B	1,195	2,435	104%
M26 (Burton's Bend WMA)	7,602	B	695	1,417	104%

STREAMFLOW DIVERSION IMPACTS

The WARSSS process provides a baseline understanding of watershed conditions through the RLA phase, identifies areas of high risk through the RRISSC phase, and a predicts future watershed impacts through the PLA phase. The PLA phase uses BANCS mapping and channel succession state to predict impacts from the proposed diversion project. However, the PLA phase is primarily limited to the Oxford WMA property due to access and data requirements. In addition, the BANCS mapping only compares the potential erosion rate changes by stream type but does not fully assess the hydrologic changes. Because of this, other tools were used to determine and supplement the analysis of impacts to the Turkey Creek watershed from the planned streamflow diversion.

Sediment Impact Analysis Methods (SIAM)

The SIAM model is used to evaluate watershed and reach scale sediment processes. For this application it was used as an annualized sediment budget analysis that compares bed material transport capacity (Capacity) to the inflowing bed material load (Supply) to evaluate the tendency for aggradation or degradation within a given reach for one year.

SIAM is not *a sediment routing model. A mobile bed model will update hydraulics in response to sediment deficits and surpluses generally resulting in mitigated rates of erosion or deficit over time, as the channel adjusts its morphology. SIAM does not update the bed and, therefore, does not account for changing capacities in response to erosion or deposition.*

Therefore, SIAM should be used as a screening tool for sediment budget assessment. The numbers reported should be treated cautiously and interpreted as general trends of surplus and deficit not *volumes of eroded or deposited material. One of the advantages of SIAM is the ease with which sensitivity, management or design alternatives can be evaluated. SIAM should be used to assess the impact of a wide range of alternatives in order to select the best few for more detailed modeling and analysis.*

(HEC-RAS 1D Sediment Transport Model)

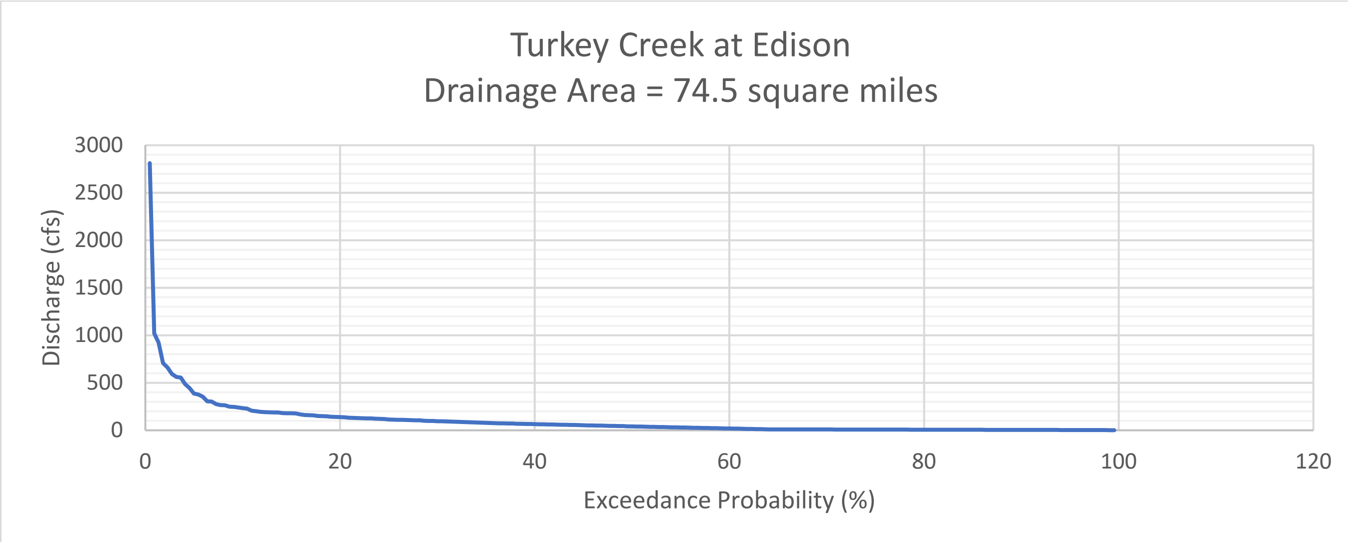
For the purposes of the Turkey Creek watershed study eight reaches were selected throughout the watershed to compare existing (pre-diversion) and proposed (post-diversion conditions). The seven reaches were selected based on watershed positioning to determine relative impacts across the differing hydrologic regimes.

Hydrology

A flow duration curve was created using the mean daily flow from the Turkey Creek at Edison stream gage with a period of record from 10-1-1993 to 4-29-2021 (Figure 19). To determine the proposed hydrologic conditions the mean daily flow was modified following the PRD feasibility review which considers 40 cfs between the months of September through April. This was completed for the entire period of record to create the proposed flow duration curve. Any recorded mean daily flow below 40 cfs between the months of September to April was modified to 40 cfs, any recorded mean daily flow above 40 cfs within those months were un-modified.

Based on USGS Gage Turkey Creek at Edison, there have been 9,872 days out of 10,073 with a mean daily flow below 40 cfs. With the proposed surface water diversion only 3,178 days would have recorded a mean daily flow below 40 cfs. This represents a change of 67%. An example of this is highlighted in the flow durations prepared for the SIAM model at sub-watershed M29. As shown a separate flow class was created for the 40 cfs in the proposed conditions. On this annualized basis the existing conditions experience around 358 days below 40 cfs, while the proposed conditions experience around 115 days.

Figure 19: Flow Duration Curve

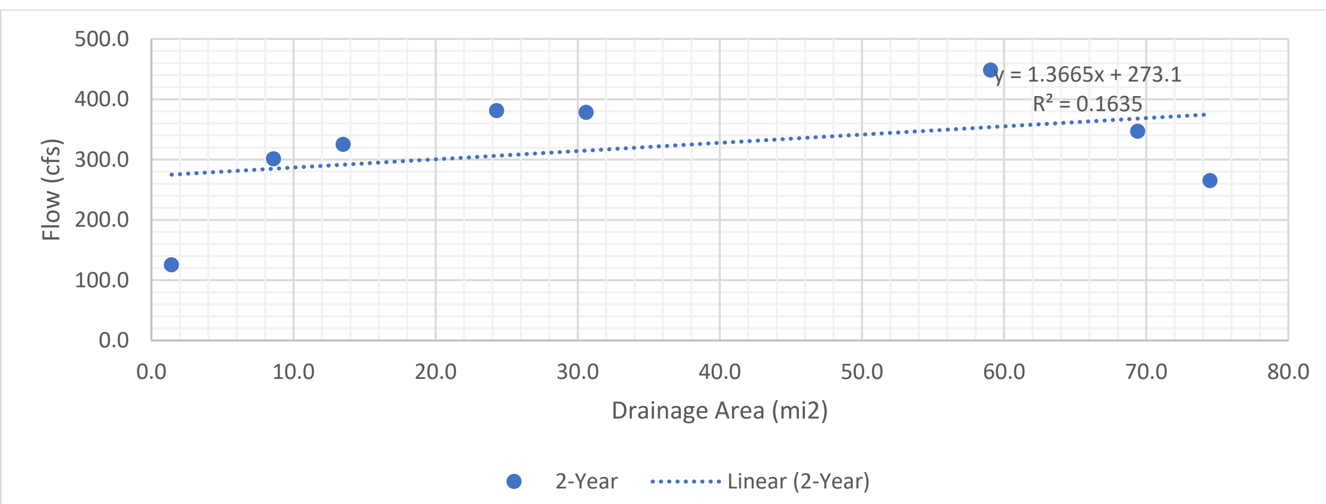


The eight sub-watersheds chosen for the SIAM model are.

- E2
- E9
- E22
- E38
- E55
- M3
- M19
- M29 (Oxford WMA Reach)

To transfer the flow duration curve at the Edison Gage to other locations in the watershed a non-dimensional discharge index was considered using the regionalized 2-year discharges (Q/Q_2) (Biedenharn, 2000). To determine the regionalized 2-year discharges the USGS Nebraska Peak Flow Equations for the Upper Republican River Region are chosen. At each proposed location the 2-year peak discharge was calculated. However, the peak flow calculations were highly reliant on main-channel slope which resulted in a non-linear relationship with drainage area (Figure 20) which was not desirable for transfer of the flow duration curve.

Figure 20: 2-year peak discharge regression



Another option for transferring the flow duration is the ratio of discharge to bankfull discharge (Q/Q_b) (Leopold, 1994). This resulted in a linear relationship with drainage area (Figure 21) and more realistic dimensionless ratios based on understanding of the watershed as shown in Table 6.

Figure 21: Bankfull Flow Regression

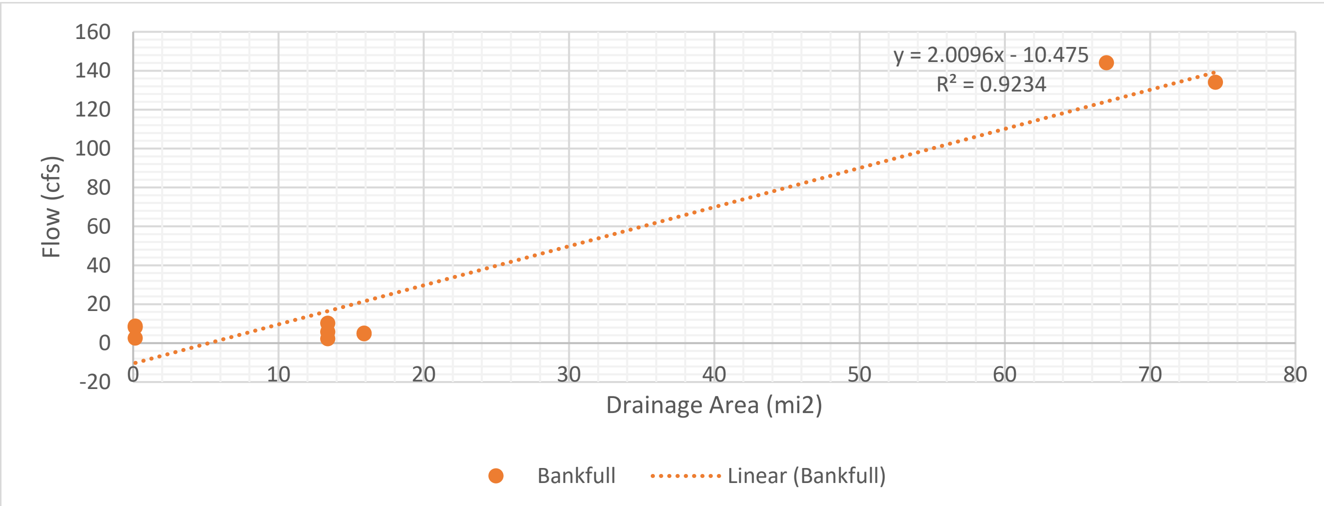


Table 6: Dimensionless Ratios

Location	Area (mi2)	BKF (cfs)	BKF ratio	2-year (cfs)	2-year ratio
Turkey Creek at Edison	74.5	134	-	265	-
Basin E2 SIAM R1	1.4	1	**0.007**	125	0.47
Basin E9 SIAM R2	8.6	7	**0.051**	301	1.14
Basin E22 SIAM R3	13.5	17	**0.124**	325	1.23
Basin E38 SIAM R4	24.3	38	**0.286**	381	1.44
Basin E55 SIAM R5	30.6	51	**0.381**	378	1.43
Basin M3 SIAM R6	29.1	48	**0.358**	448	1.69
Basin M19 SIAM R7	69.4	129	**0.963**	347	1.31

The bankfull ratios were applied to the entire period of record to transfer the existing and proposed flow duration curve to another location in the watershed. For the proposed conditions the 40 cfs was excluded from the ratio conversion.

The flow duration curve was split into nine flow classes (Table 7) based on standard deviation divided by four (Biedenharn, 2000). For proposed conditions an addition flow class was added to account for the 40 cfs class. For each class the duration was normalized for an annual duration for use in the SIAM model.

Table 7: Sub-Watershed M29 SIAM Flow Duration

Existing		Proposed	
Q	**Days**	**Q**	**Days**
4	5.22	4	1.09
8	79.36	8	27.76
15	243.32	15	72.87
25	29.93	26	13.33
-	-	40	242.78
60	4.28	60	4.28
143	1.74	143	1.74
304	0.69	304	0.69
717	0.22	717	0.22
2810	0.04	2810	0.04
Total	364.78		364.78

Hydraulics

SIAM is based on one-dimensional hydraulics derived from HEC-RAS. Generally, a Manning's n-value of 0.055 was used for the channel, based on stream types G5 and F5. A n-value of 0.07 is generally used for the overbanks. Hydraulics are un-modified between existing and proposed conditions, with the only modifications related to the changes in hydrology.

The goal of the SIAM model is to compare relative magnitude of sediment capacity from existing to proposed conditions based on hydrologic modifications in the form of the planned diversion. As a result of this, bridges and culverts are ignored in the hydraulic models. These represent locations of potential sinks or sediment deposition zones, which would reduce the overall degradational predictions of the SIAM model. Similarly, hydraulic cross-section spacing does not accurately represent impacts from tight bends, all constructions, or all widened areas. Due to these simplifications the model is conservative and showing more erosion than would likely occur. However, the same approach was taken for existing and proposed conditions, making the relative changes still valid.

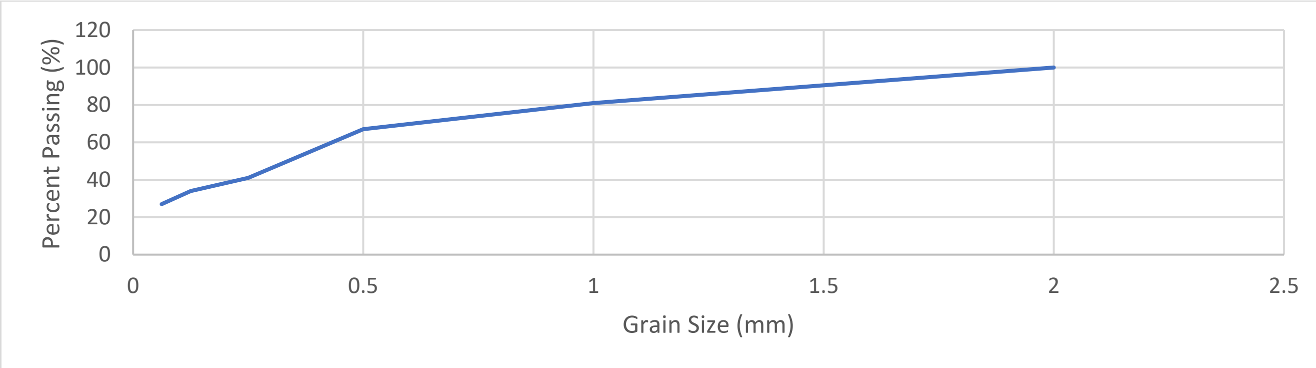
The same approach for the SIAM model hydraulics was taken for hydraulic models developed to estimate incoming sediment load (Supply). Three cross-sections at the upstream end of the sub-watershed were used to develop hydraulics used in a capacity analysis to estimate incoming sediment supply.

Sediment

As with the hydraulic properties, sediment properties remain static between existing and proposed conditions. The biggest change is the incoming sediment supply, which is directly related to the modified hydrology.

Sediment gradation for the SIAM analysis is based on a pebble count at the Oxford WMA property. From site investigations around the watershed, it is reasonable to apply this gradation to all sub-watersheds. The sediment gradation is shown in Figure 22.

Figure 22: Sediment Gradation



This represents the grain size classes that SIAM considers in the sediment capacity calculations. The assessed grain size classes are; very fine sand (VFS), fine sand (FS), medium sand (MS), coarse sand (CS), and very coarse sand (VCS). Anything below the VFS grain class (0.0625 – 0.125 mm) is considered wash load. According to Little, 2010; *The wash load is finer than the material found in the stream bed. It does not interact with the bed. From a transport point of view, the wash load is carried through the stream reach without bed interaction or deposition.* What this means is that the lower grain size classes aren't considered to interact with the channel geometry and affect deposition or aggradation. In the case of Turkey Creek this is a conservative assumption, and more material may be moving through the system and affecting channel morphology than the SIAM analysis reveals.

The Yang (1973) sediment transport equation is used in the analyses. Sediment size range for this equation is between 0.062 and 7.0 mm (Brunner, 2016). However, Yang (1984) expanded the equation to include gravel-sized sediments. HEC-RAS incorporates both Yang equations for field-sand and field-gravel into the equation for use in HEC-RAS. Yang is widely used for the sand and gravel sediment grain classes present in Turkey Creek and is considered applicable for this setting.

To determine incoming sediment supply, the sediment capacity at three cross-sections at the upstream of each reach was averaged by grain size and flow class. The averaged capacities were normalized by the annualized duration of each flow class to estimate the annual sediment supply for the reach. This was completed for all SIAM models except for Basin E2, where it was assumed no sediment supply from an upstream reach. Incoming sediment into Basin E2 would be nominal and a result of hillslope processes, sheet flow, and bank erosion.

Results

All assessed reaches for both existing and proposed conditions show degradation. This is consistent with field observations within the Turkey Creek watershed. As expected, the difference between the existing and proposed conditions lessens towards the downstream reaches, where sediment supply and capacity are increased, and the impacts of the diversion hydrology are present, but not as extreme.

Results for all SIAM reaches are shown in Figure 23 through Figure 30. Increased degradation in the proposed conditions is a result of greater sediment capacity due to flow regime changes from the diversion. The increased sediment capacity will result in increased channel bank erosion and vertical channel degradation. These processes will continue until the incoming sediment supply results in equilibrium, or the channel adjusts (through bank erosion and downcutting) to conform to the proposed flow regime.

The percent increases in sediment transport capacity as a result of the impacts from the proposed diversion project is shown in Table 8.

Table 8: SIAM Results Percent Increase

Sub-watershed	Percent Increase
E2	125893%
E9	476%
E22	881%
E38	1174%
E55	989%
M3	43%
M19	74%
M29 (Oxford WMA Reach)	71%

Figure 23: Sub-watershed E2 SIAM Results

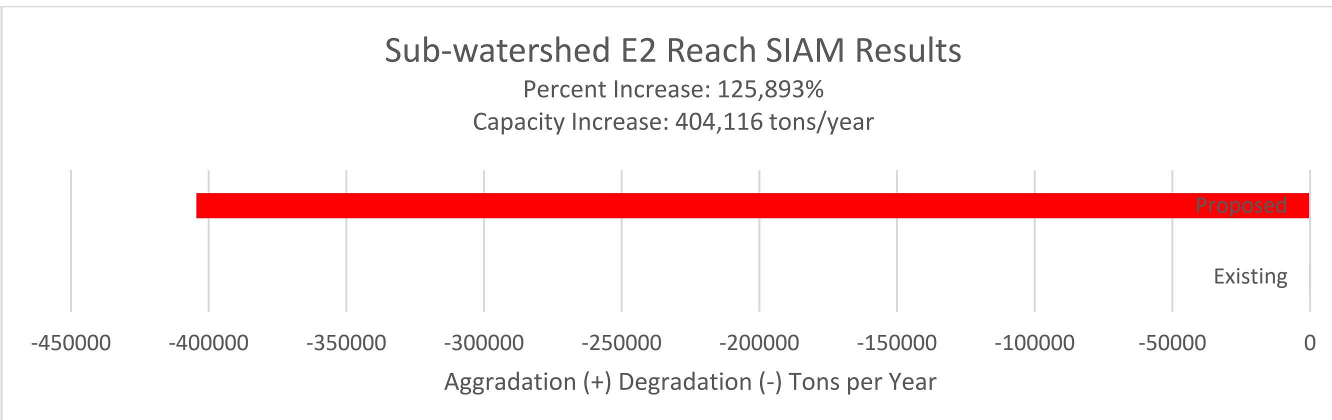


Figure 24: Sub-watershed E9 SIAM Results

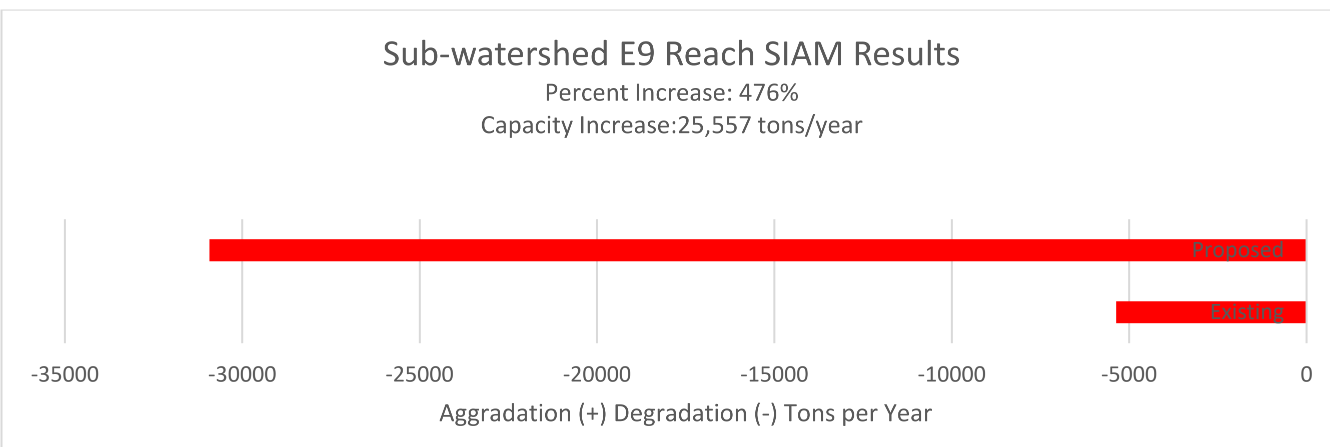


Figure 25: Sub-watershed E22 SIAM Results

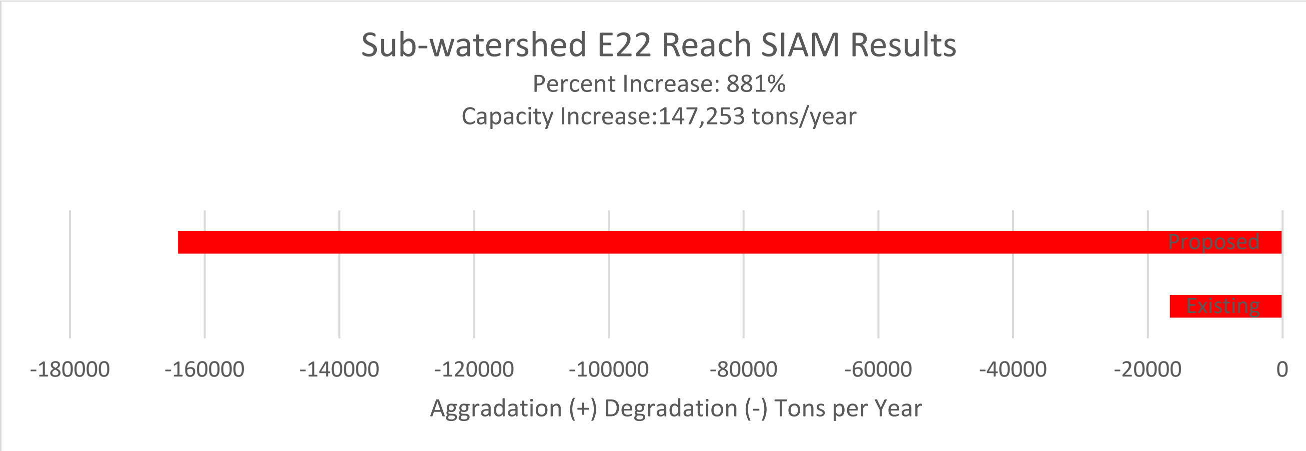


Figure 26: Sub-watershed E38 SIAM Results

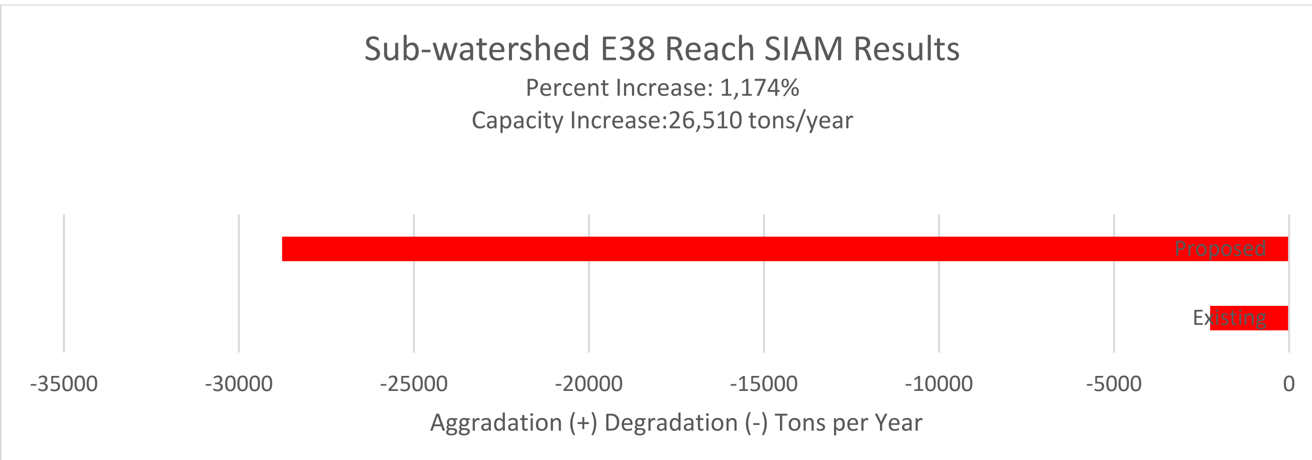


Figure 27: Sub-watershed E55 SIAM Results

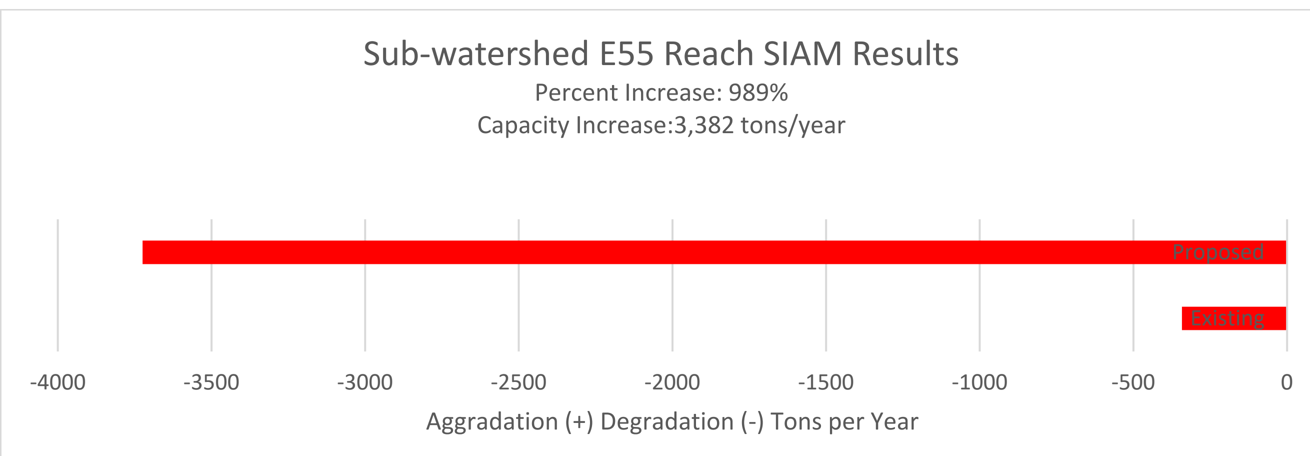


Figure 28: Sub-watershed M3 SIAM Results

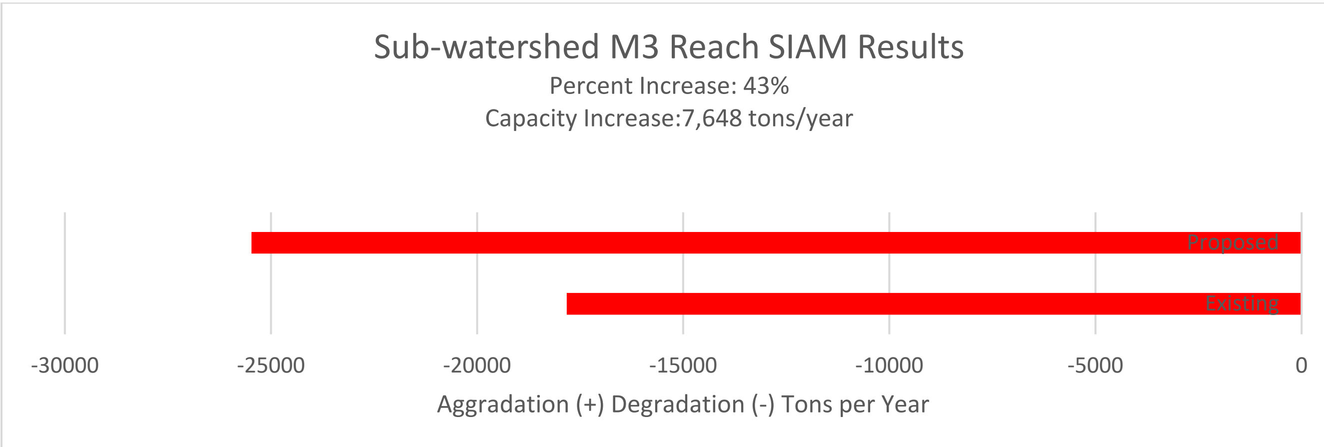


Figure 29: Sub-watershed M19 SIAM Results

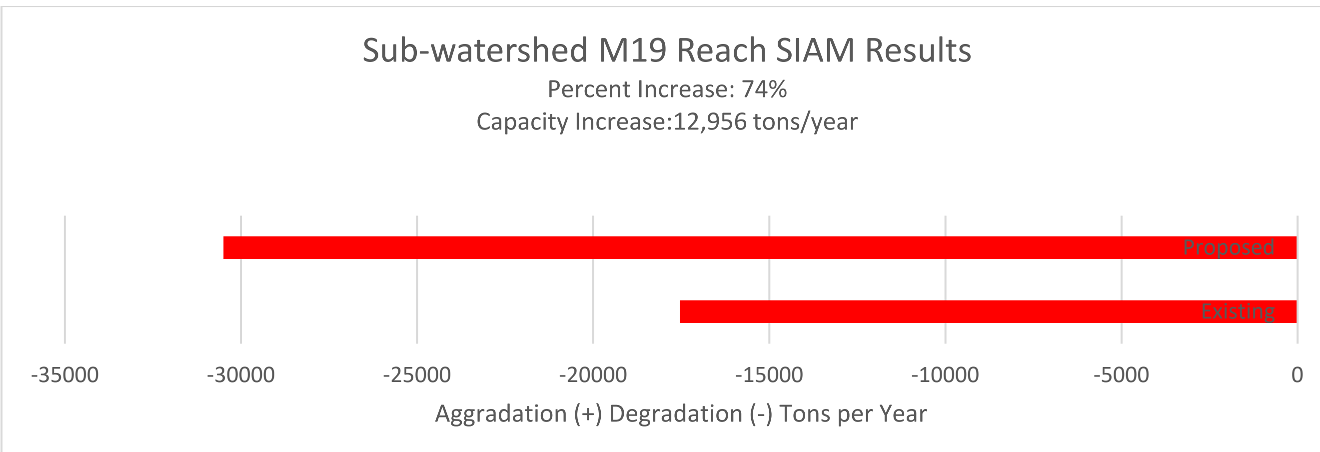
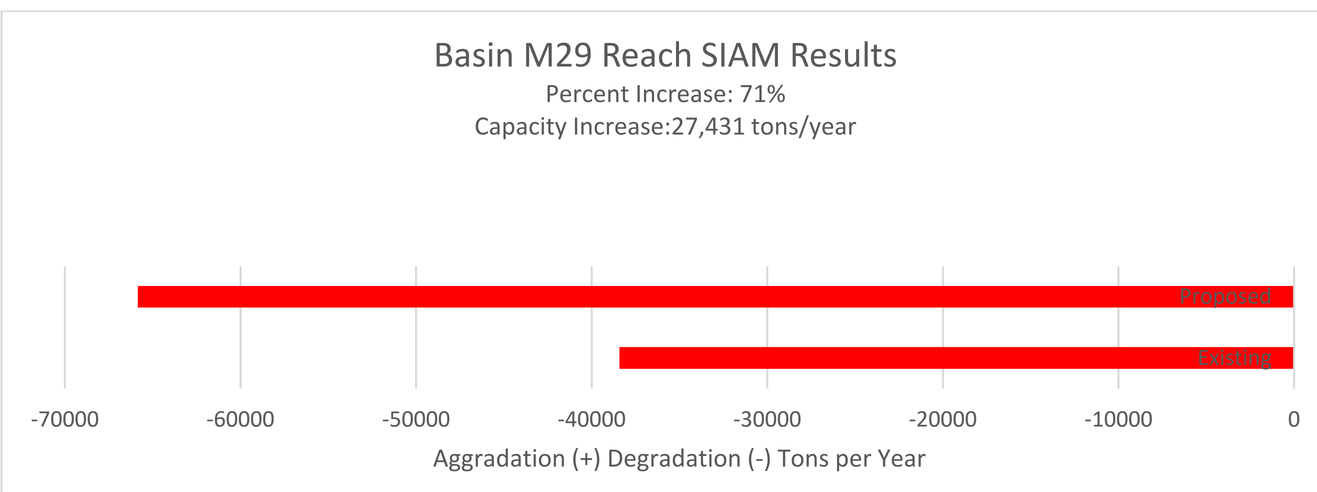


Figure 30: Sub-watershed M29 SIAM Results



Mobile Bed Sediment Transport Model

The HEC-RAS sediment transport modeling methods are based on HEC-6 and require the following inputs.

- Hydrology
- Sediment Data
- Channel Geometry

Hydrology

For existing conditions, flow series hydrographs were generated at 13 locations (Table 9) where drainage area changed significantly. Flow series hydrographs at each location were generated by scaling daily data from USGS Gage 6844210 – Turkey Creek at Edison by drainage area for the period between January 1st, 2017 through January 1st, 2018. This time period was selected because it corresponds to the date of the most current aerial imagery and topography.

Table 9. Flow Change Locations

FLOW CHANGE LOCATION	DRAINAGE AREA (MI^2)	DRAINAGE AREA RATIO[1]
Sub-Watershed E2	3.0	0.044
Sub-Watershed E3	4.1	0.060
Sub-Watershed E9	8.6	0.124
Sub-Watershed E14	9.5	0.137
Sub-Watershed E22	13.4	0.193
Sub-Watershed E28	17.2	0.249
Sub-Watershed E38	24.2	0.350
Sub-Watershed E55	30.5	0.440
Sub-Watershed E57	34.1	0.493
Sub-Watershed M3	55.3	0.799
Sub-Watershed M14	61.1	0.883
Sub-Watershed M24	67.7	0.979

[1] USGS Gage 6844210 – Turkey Creek at Edison, DA=69.2 mi^2

For future conditions, after the diversion is active, flow series hydrographs were modified by overwriting the scaled daily flow with the diversion flow of 40 cfs for the period when the diversion is active.

Each model condition was run for a one-year period. Each flow series was run for a 24-hour period with a calculation timestep of one hour. For graphical reference, the flow series for existing and proposed conditions for Sub-Watershed E2 are provided in Figure 31 and Figure 32, respectively.

Figure 31. Flow Series for Sub-Watershed E2 (Existing Conditions)

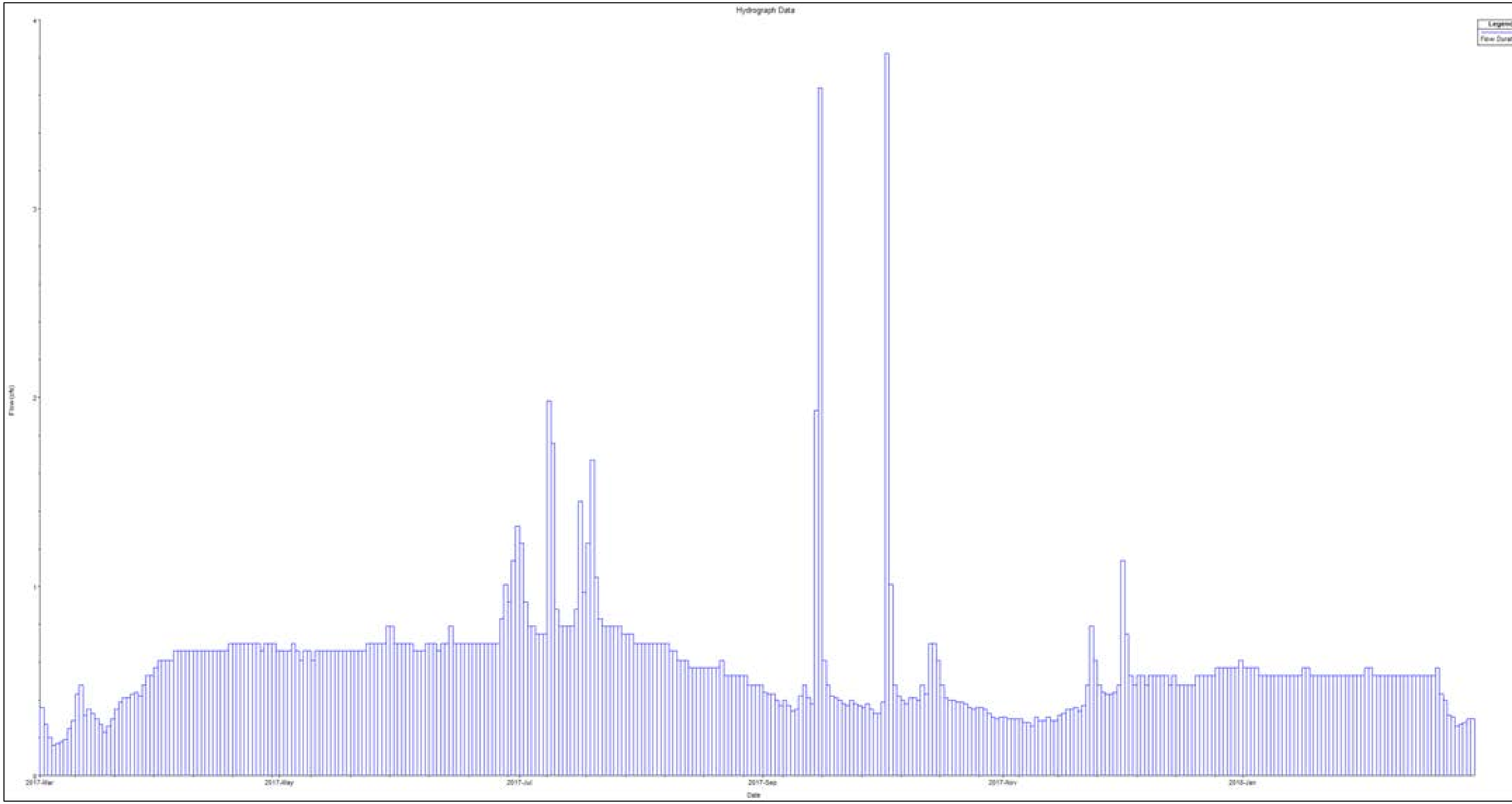
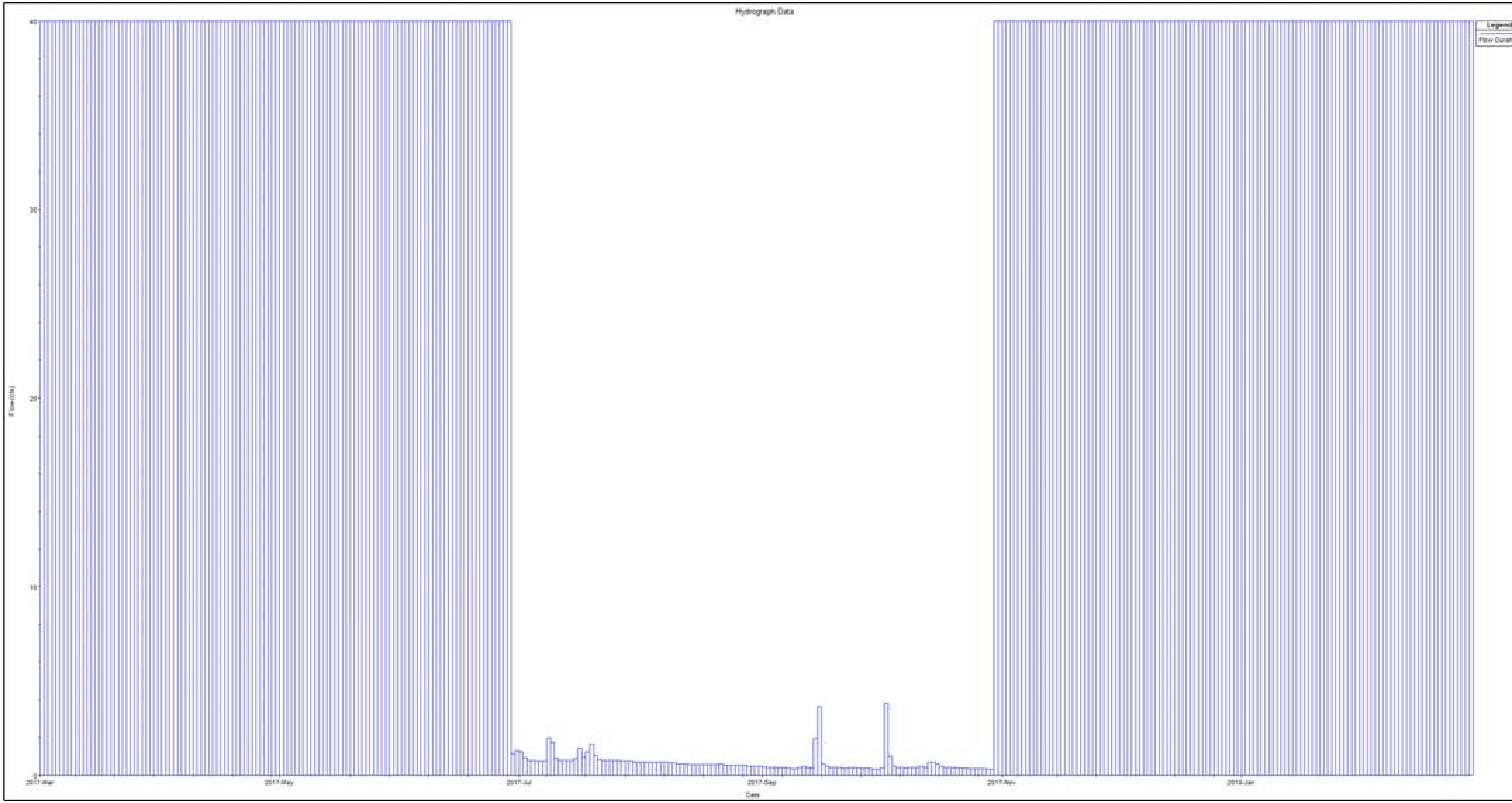


Figure 32. Flow Series for Sub-Watershed E2 (Future Conditions)



The sediment transport analysis is limited by the assumptions of hydrologic inflow, lack of gage streamflow data in the watershed, and is intended to represent theoretical conditions. A water temperature of 60 degrees Fahrenheit is assumed for the full flow duration.

Sediment Data

Required sediment data for the modeling requires a bed gradation, inflowing sediment load, cross-sectional limits of erosion, allowable depth of erosion, and transport function.

Sediment samples were collected at four locations (Figure 33-Figure 36) and evaluated using the Wolman Pebble Count procedure.

Figure 33. Sediment Gradation at Dawson Property

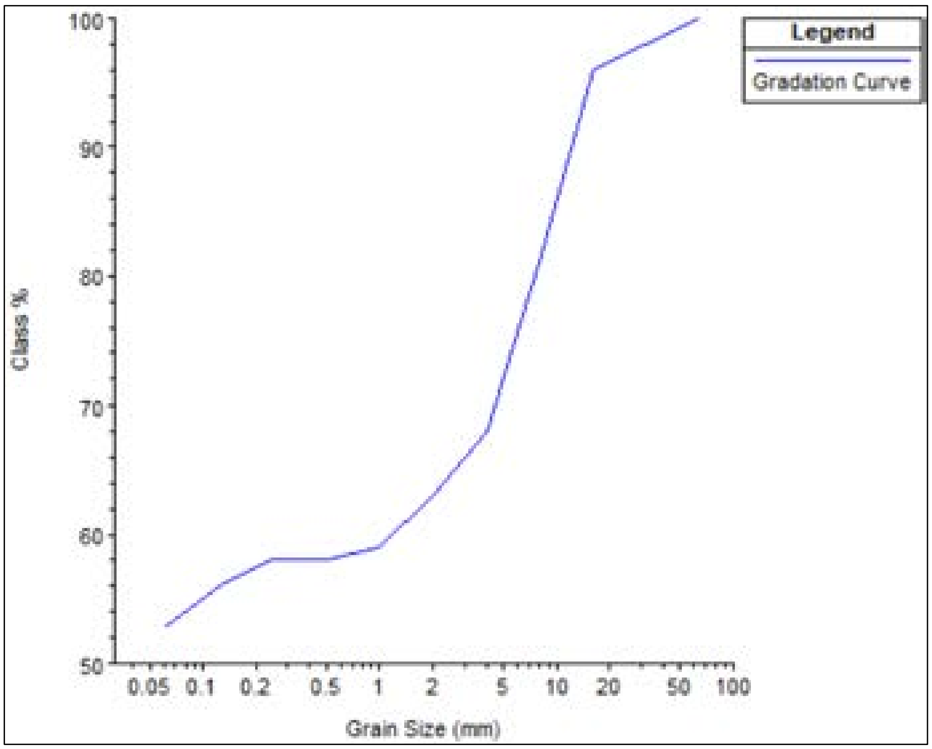


Figure 34. Sediment Gradation at BELF Property

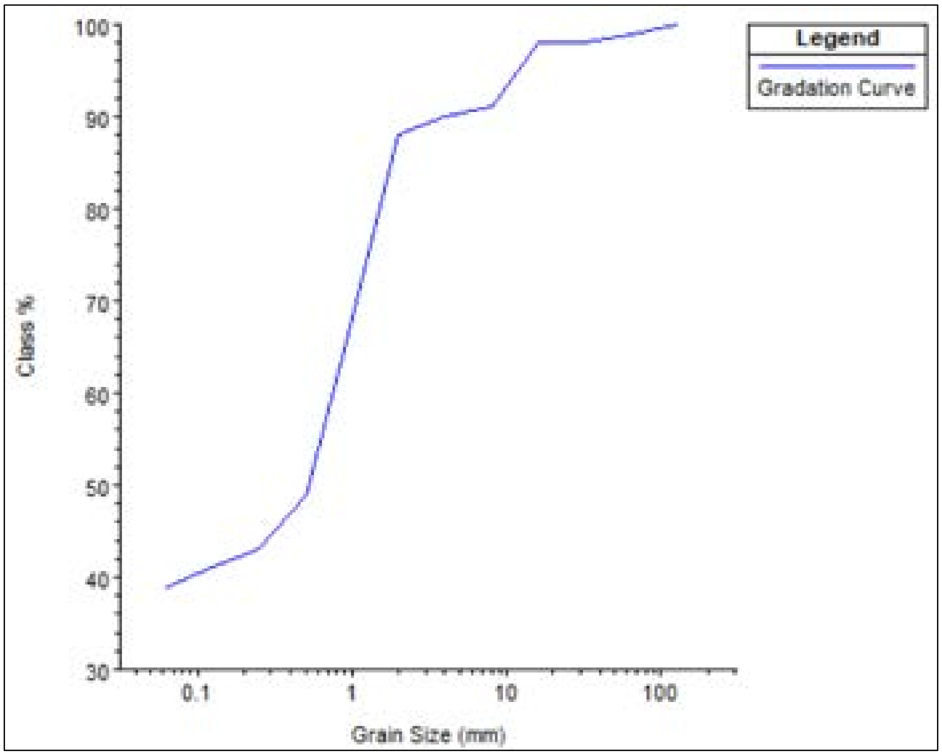


Figure 35. Sediment Gradation at Oxford WMA

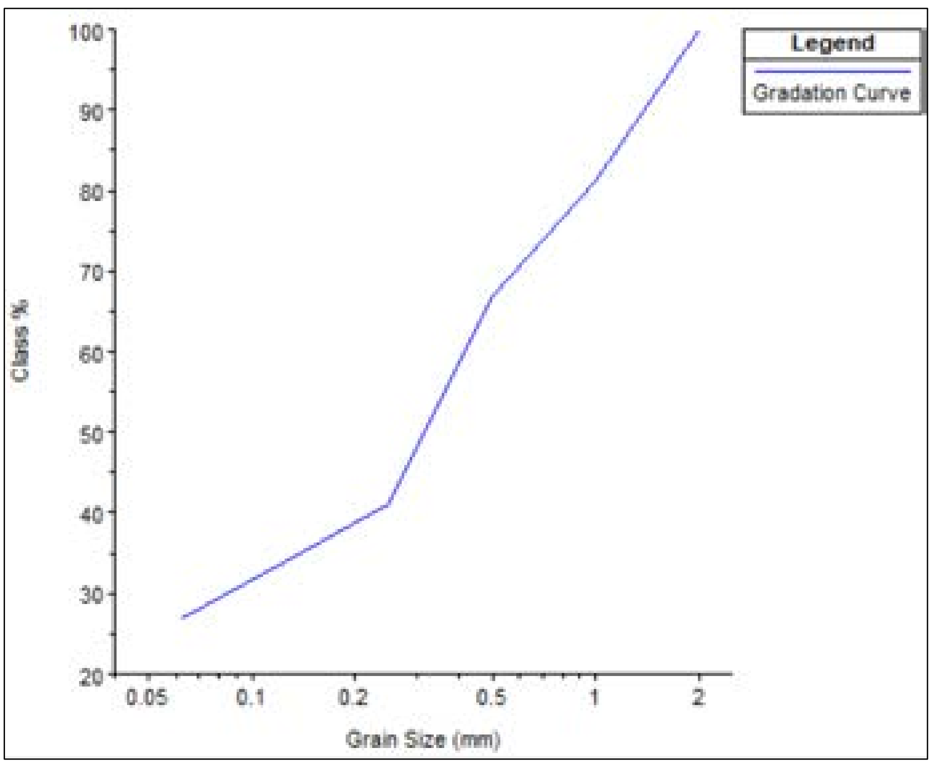
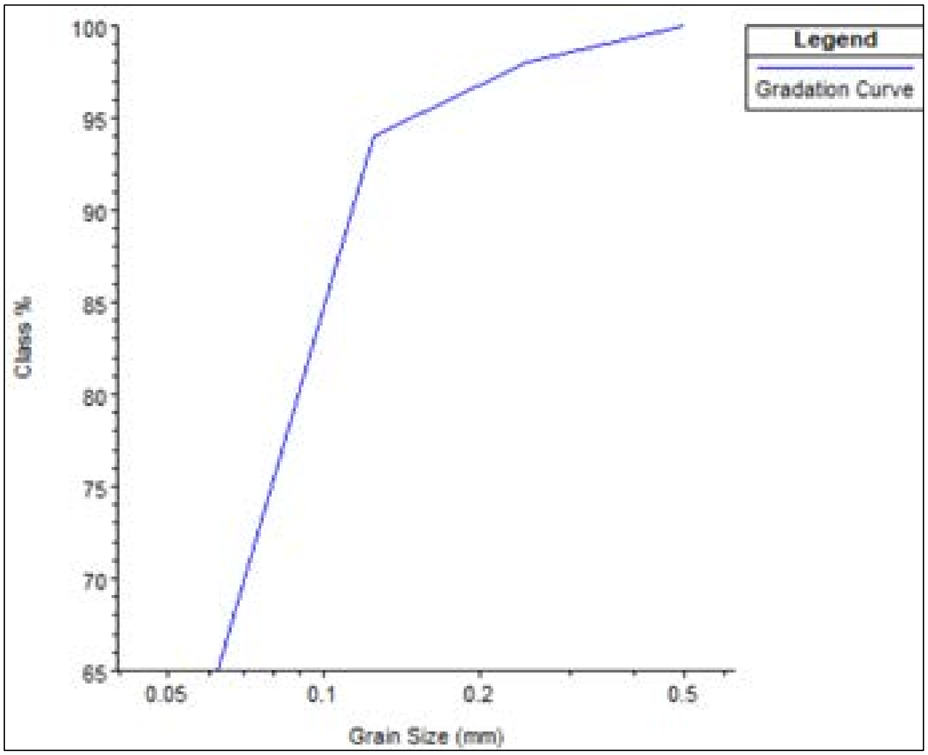


Figure 36. Sediment Gradation at Fischer Property



Inflowing sediment load at each flow change location was estimated by creating a sediment transport rating curve based on the sediment transport capacity of the channel cross section at each flow change location.

The cross-sectional erosion limits were set at the point where overbank flow occurs. Deposition is allowed to occur outside of the extent of the bankfull width into the floodplain. Also, the maximum vertical erosional limit was set to be 20 feet.

The transport function is one of the most important parameters for the sediment transport model and possessed the greatest variability of results. Sediment transport functions were selected based on the applicability of grain size. The three different sediment transport functions were checked:

- Ackers-White (particle size diameter 0.04 – 7.0 mm)
- Yang (particle size diameter 0.15 – 7.0 mm)
- Laursen (Copeland) (D_{50} 0.011 – 29 mm)

Ackers-White has been known to over-predict transport capacities for grain sizes outside of its applicable range, while Yang has been known to under-predict transport capacity. Significantly less literature has been devoted to the Laursen (Copeland) method. Based on previous studies Yang was determined to be the most applicable transport function to the current setting.

Results

The results of the sediment transport analysis show that diversion flows will likely cause Turkey Creek to degrade by approximately 1-2 feet for the first seven miles of the diversion path during the first year of operation. After this point, Turkey Creek will likely aggrade by about 1 for the next eight miles, then continue to transition between aggradation and degradation in the +/- one foot range for the remaining 30 miles.

The results of the sediment transport analysis are provided in the Appendix.

CONCLUSION

The Turkey Creek watershed is highly sensitive to increased base flows and storm flows caused by land use modifications because it has a high stream response potential meaning that erosion will occur easily as in-stream flows incrementally increase. This has been observed on an annual basis with field observations, during flooding that occurred in 2019, and validated with the RLA and RRISSC processes. Much of the watershed is degraded and comprised of an unstable stream type (41%, see RLA Phase). However, locations of stable and healthy stream types were identified through the study that would be subject to modification. Both unstable and stable portions of Turkey Creek are expected to be adversely impacted by the proposed diversion:

Baseflows Increase by 67%

Potential hydrologic modifications from the stream flow diversion of 40 cfs in the months of September through April represent a significant risk to stream stability and sediment supply. For comparison, 98% of all flows recorded by the USGS Gage on Turkey Creek at Edison over the past 28 years have been below 40 cfs. A diversion of this magnitude would increase the baseflow within Turkey Creek by approximately 67% for the entire 41-mile diversion path between the headwaters and confluence with the Republican River. The 100 cfs alternative was not evaluated as a part of this study, but would likely impact Turkey Creek to a higher degree than the 40 cfs diversion flow.

The proposed mitigation reach of approximately 3,000 feet at the upper end of the diversion route presented in the PRD Feasibility Review is insufficient to mitigate all of the expected erosion associated with the proposed diversion. The proposed mitigation length of 3,000 feet represents only 1.4% of the total 41 stream miles that will be impacted by the diversion flows, therefore additional downstream mitigation measures should be considered.

Increase in Sediment Loading

The Bank Assessment for Non-point source Consequences of Sediment (BANCS) was used to calculate channel bank erosion for existing and proposed conditions using inputs of stream geometry, Rosgen stream type, and stream hydraulics. In existing conditions, the watershed generates approximately 68,202 tons/year from channel bank erosion.

After the diversion is active, Turkey Creek will transform according to the Channel Evolution Model (Schultz et al. 2000) to accommodate the additional flow. Projections of the Rosgen stream type in future conditions were made based on the assessment of how various stream reaches within the Turkey Creek watershed have transformed over time in response to hydromodification. Based on this process, the watershed will generate approximately 78,884 tons/year of sediment in proposed conditions, which represents a 14.2% increase compared to existing conditions. It is important to note that this increase is only attributable to the change in channel shape and will likely be higher during the incision and widening processes until a new stable condition is achieved.

The sediment impact analysis methods (SIAM) model was used to further assess the geomorphic impacts of increased sediment loading associated with the hydromodification associated with the proposed diversion. This model uses representative sediment transport characteristics of the study reaches to predict degradation or aggradation on an annualized basis. Sediment transport capacity is increased by 43% – 125,893% within the main stem of Turkey Creek when the proposed diversion of 40 cfs is active during the months of September through April.

Widespread Loss of Land & Infrastructure Impacts

This Study shows that the proposed diversion will trigger a geomorphic response for the entire length of Turkey Creek that is impacted by the diversion. The geomorphic response will follow the Channel Evolution Model (Schultz et al. 2000) where stable streams will incise and then widen until a new stable channel form is achieved. During this process, channel bank erosion will accelerate and will cause a widespread loss of public and private land.

As the stream incises, acute points of vertical incision will form along the main channel and migrate upstream through the connected tributaries. Increased sediment will then be transported downstream, which could impact in-stream infrastructure. A common occurrence is deposition upstream of bridges and culverts which can exacerbate flooding risks.

Impacts to Water Resources

The surface water elevation within the stream corridor will lower as the stream continues to incise. The lowering of the surface water elevation will then cause the lowering of the groundwater table adjacent to Turkey Creek. The process will cause the groundwater table to become disconnected from the riparian corridor, which will destroy both wetland and riparian vegetation critical for aquatic and terrestrial habitat. In-stream aquatic habitat will also be damaged and possibly eliminated during the channel transformation process.

The reduction in groundwater elevations will likely impact the ability of adjacent water users to pump water if their primary well is located within the limits of where groundwater elevations will be reduced. Deep wells in these locations will likely experience reduced well production and shallow wells could potentially become inoperable.

Collectively, these impacts are expected to accelerate streambank erosion, vertical stream incision, and channel widening throughout the 41-mile diversion path of Turkey Creek. These stream processes will lead to a massive increase in sediment loading within Turkey Creek. It is the conclusion of this report that the proposed streamflow diversion would result in an overall adverse impact to the East Branch and Main Branch of Turkey Creek.

REFERENCES

Biedenharn, D. S., Copeland, R. R., Thorne, C. T., Soar, P. J., Hey, R. D., and Watson, C. C. (August 2000) “Effective discharge calculation; a practical guide,” Technical Report, U.S. Army Engineer Research and Development Center, Vicksburg MS.

Brunner, HEC-RAS River Analysis System Hydraulic Reference Manual Version 5.0 February 2016, US Army Corps of Engineers Hydrologic Engineering Center.

Bledsoe, September 2016, *Design Hydrology for Stream Restoration and Channel Stability at Stream Crossings.*

Gibson, Sanchez, HEC-RAS Sediment Transport User’s Manual Version 6.0 September 2020, US Army Corps of Engineers Hydrologic Engineering Center.

Leopold, L.B. (1994) *A view of the river,* Harvard University Press, Cambridge.

Little, Jonas (2010) *Sediment Impact Analysis Methods (SIAM): Overview of Model Capabilities, Applications, and Limitations,* 2nd Joint Federal Interagency Conference, Las Vegas, NV, June 27 – July 1, 2010.

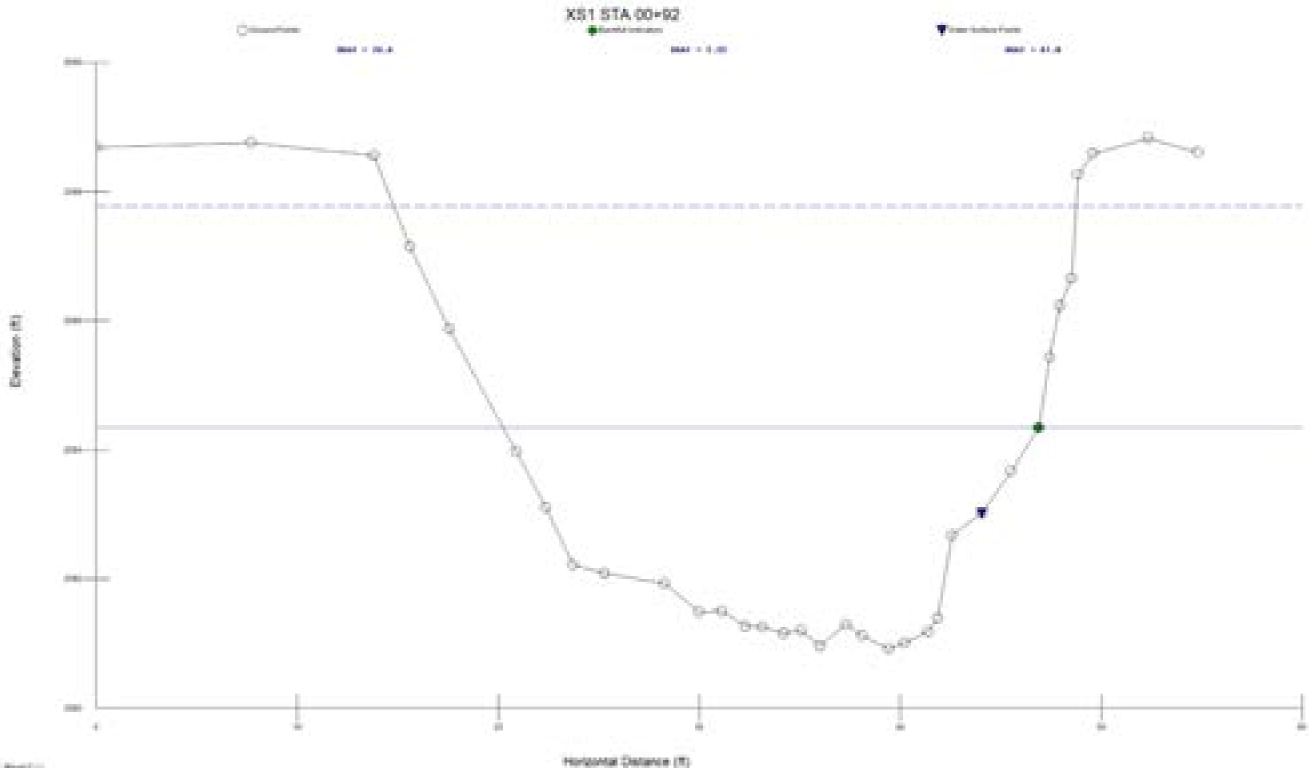
Olsson Associates (July 2017) *Platte Republican Diversion Project Feasibility Review.*

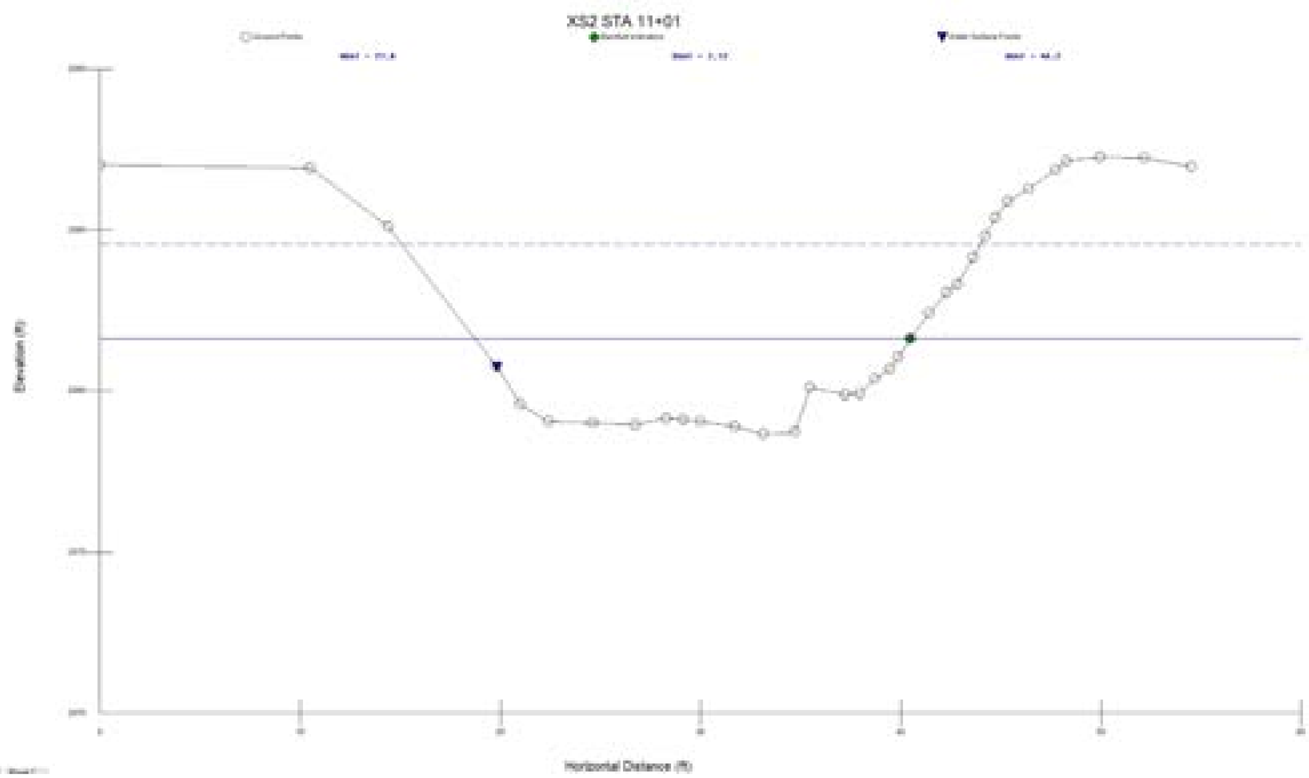
Rosgen, (2006) *Watershed Assessment of River Stability and Sediment Supply (WARSSS),* Friesens, Altona, Manitoba, Canada.

Soenksen, P.J., Miller, L.D., Sharpe, J.B., and Watton, J.R., Peak-Flow Frequency Relations and Evaluation of the Peak-Flow Gaging Network in Nebraska (1999): U.S. Geological Survey Water-Resources Investigations Report 99-4032.

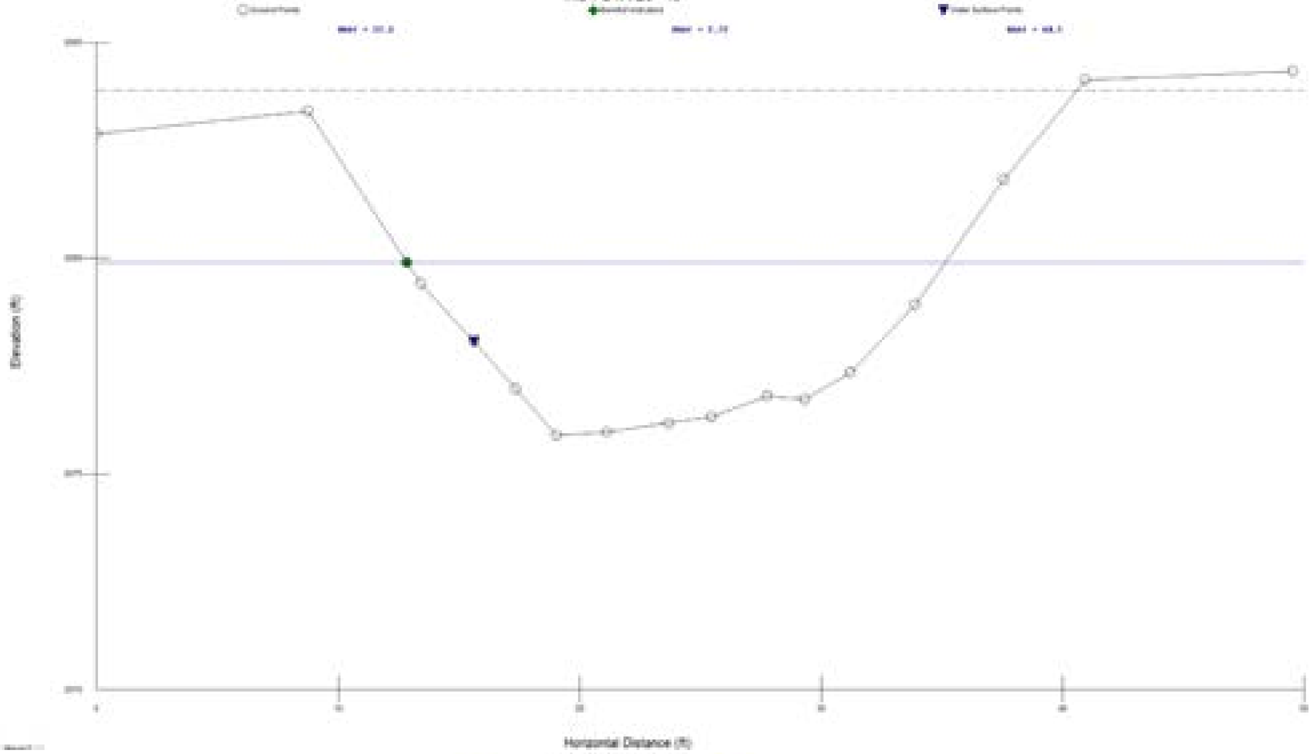
United States Department of Agriculture and The Natural Resources Conservation Service, August 2007, The National Engineering Handbook Part 654: Stream Restoration Guide.

APPENDIX

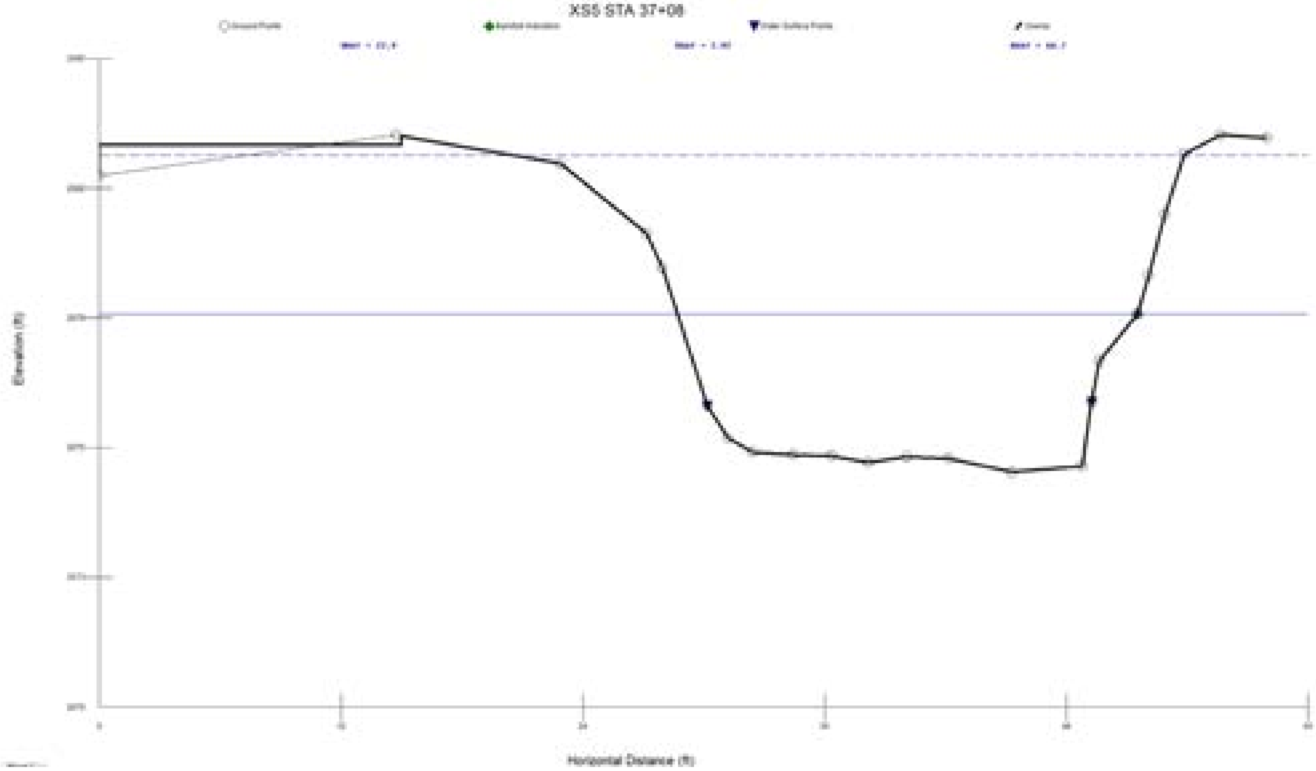

XS1 STA 00+92
Elevation (ft)
Horizontal Distance (ft)

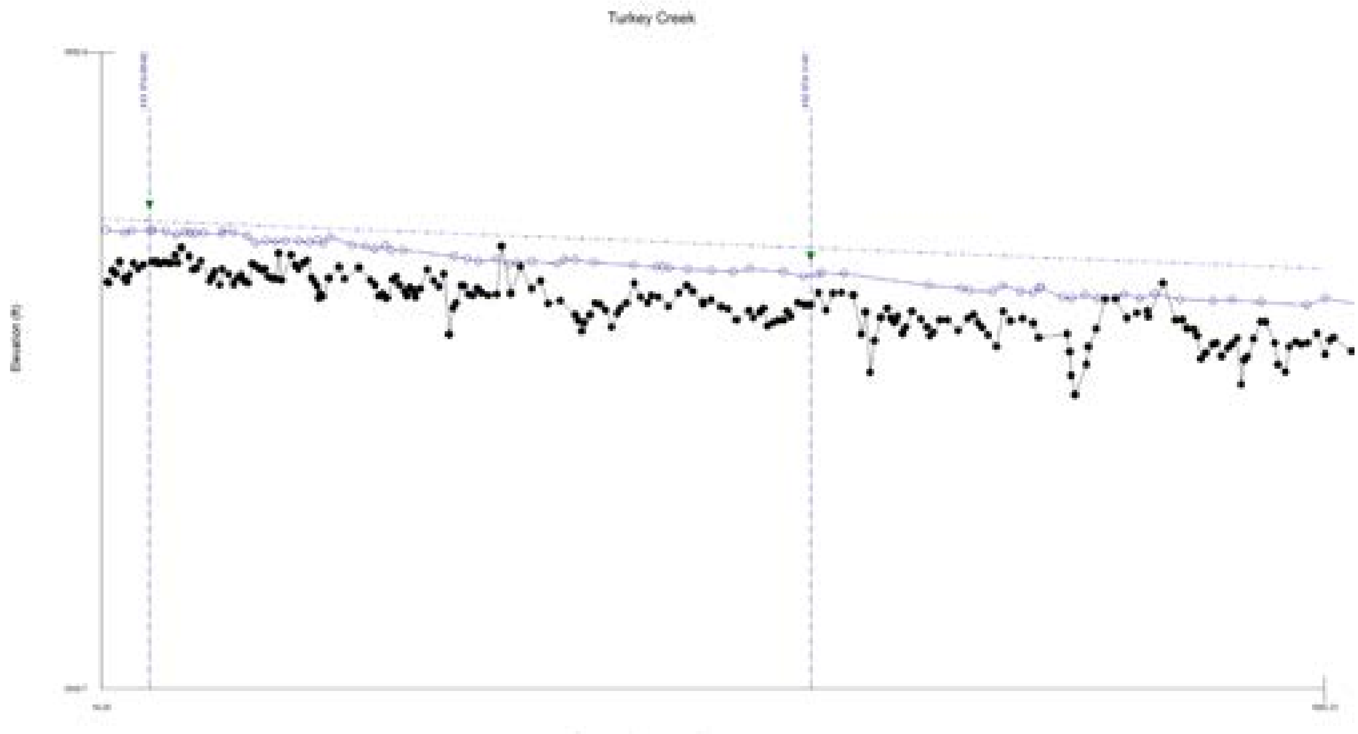

XS2 STA 11+01
Elevation (ft)
Horizontal Distance (ft)

XS4 STA 29+40

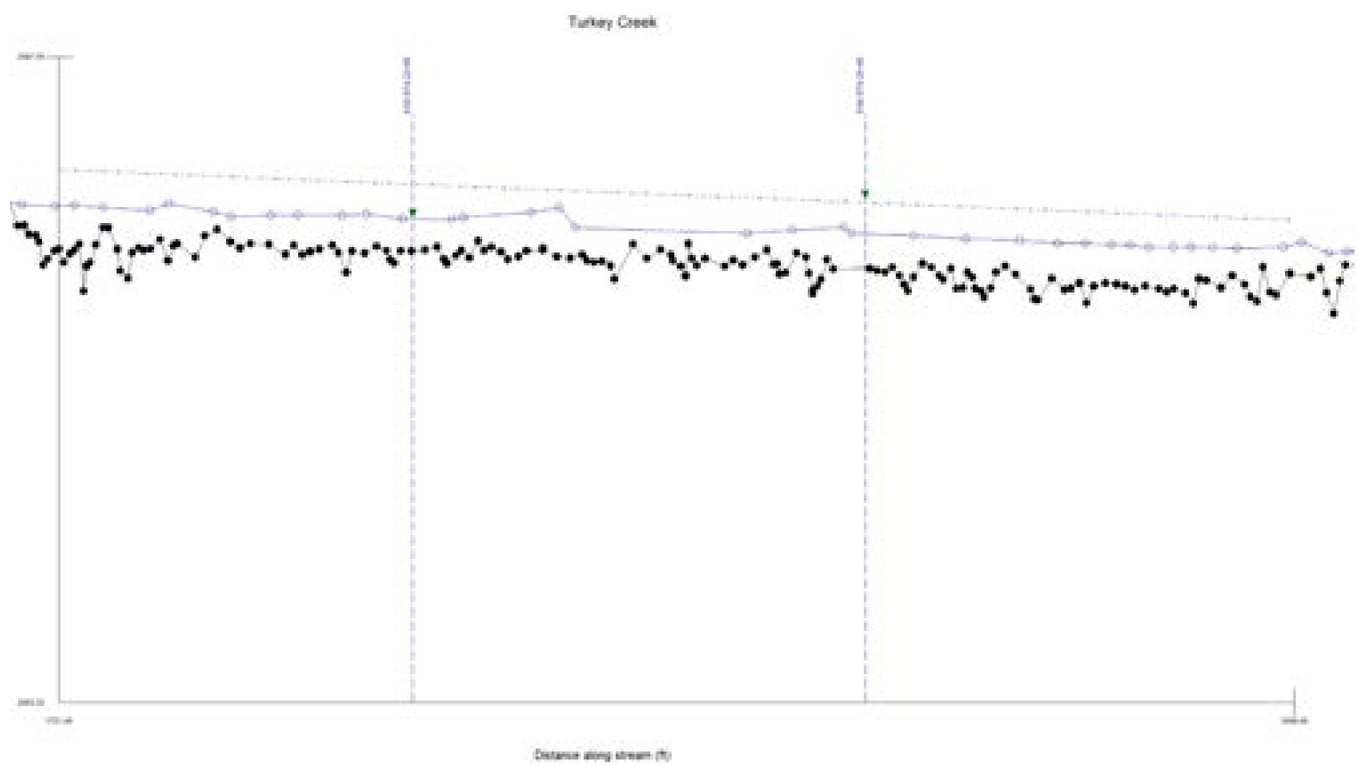


XS5 STA 37+08

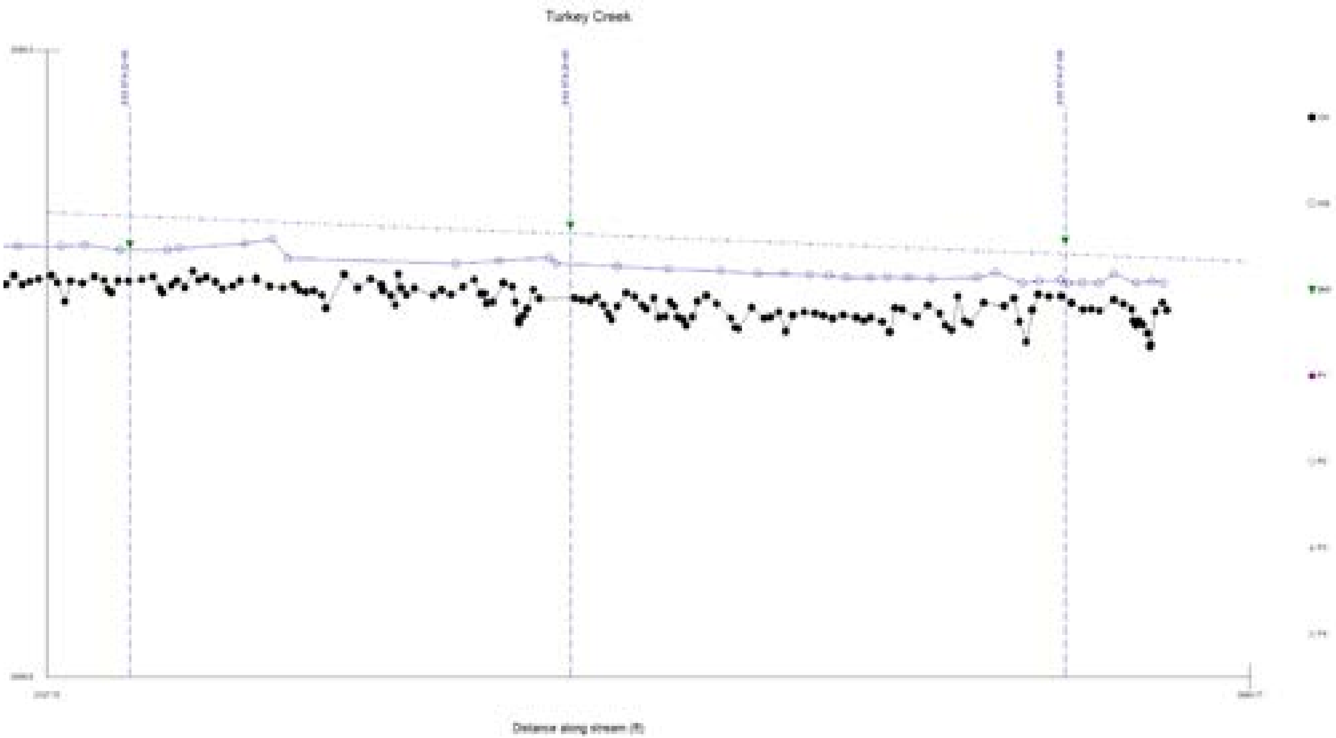


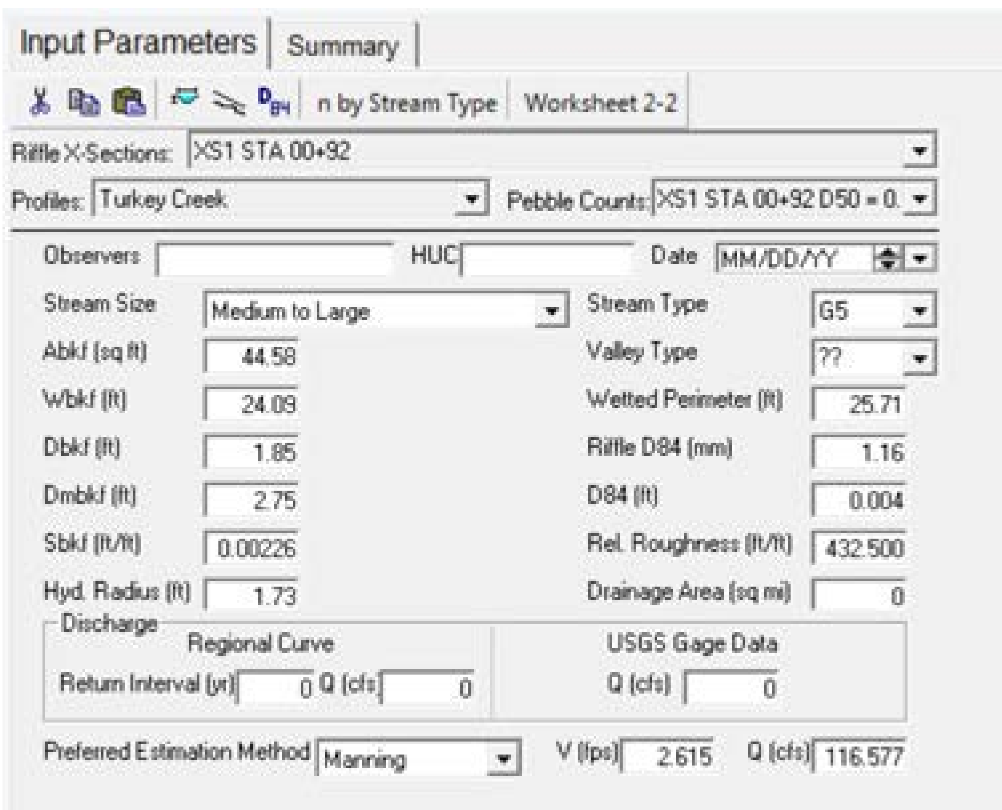


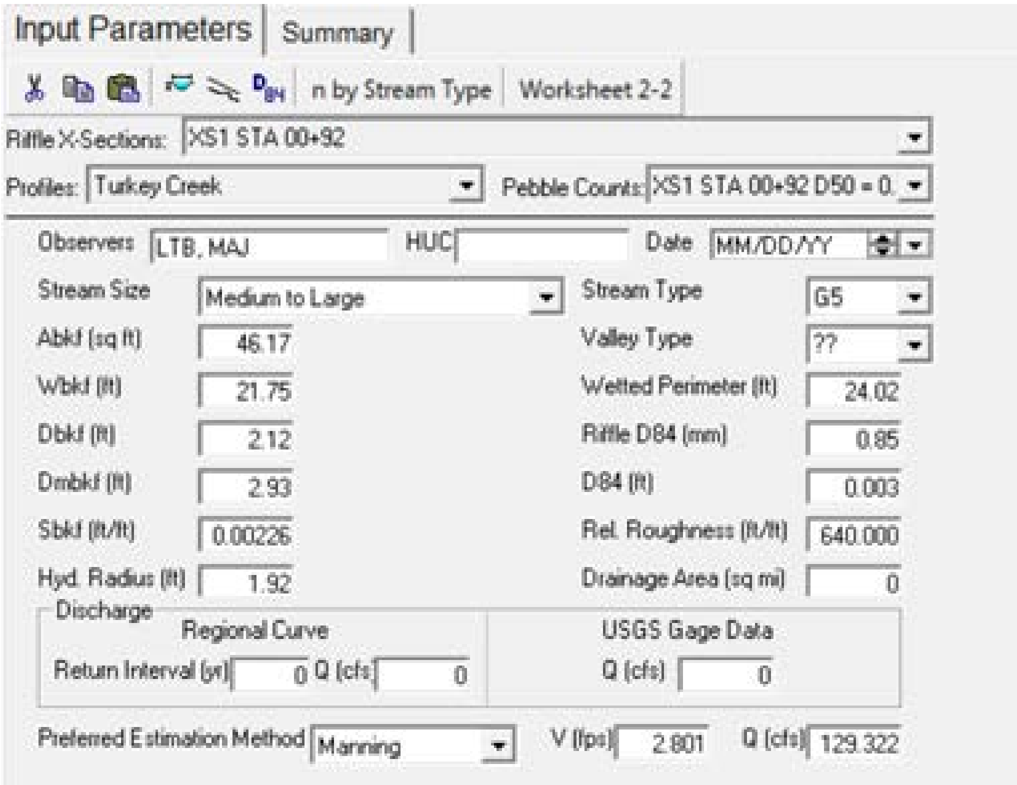
Turkey Creek
Elevation (ft)

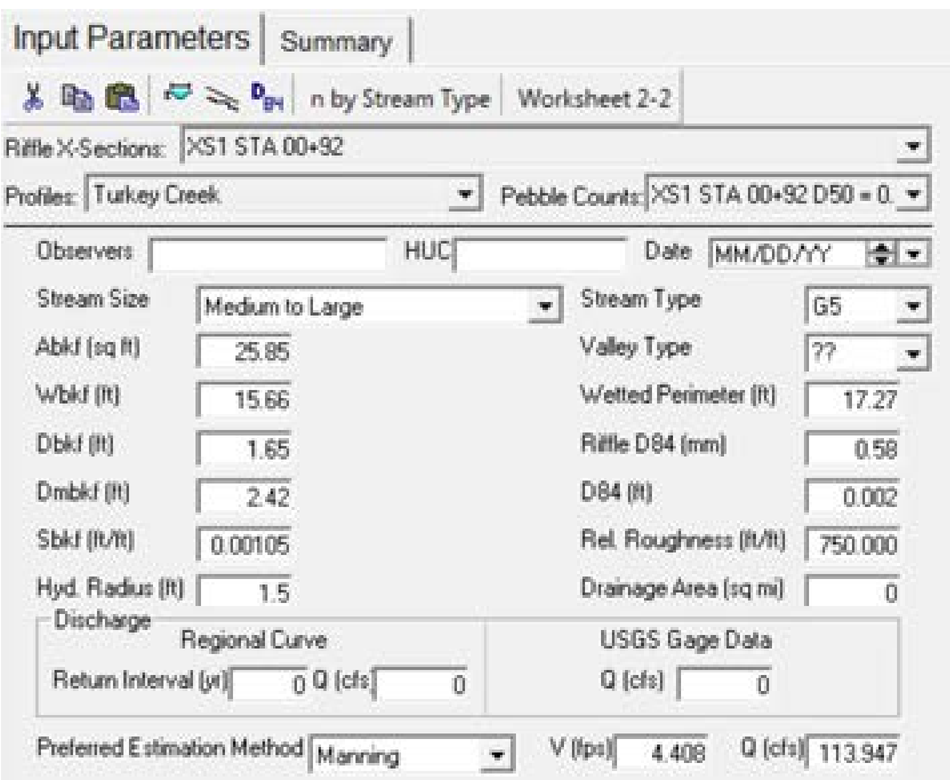


Turkey Creek
Distance along stream (ft)

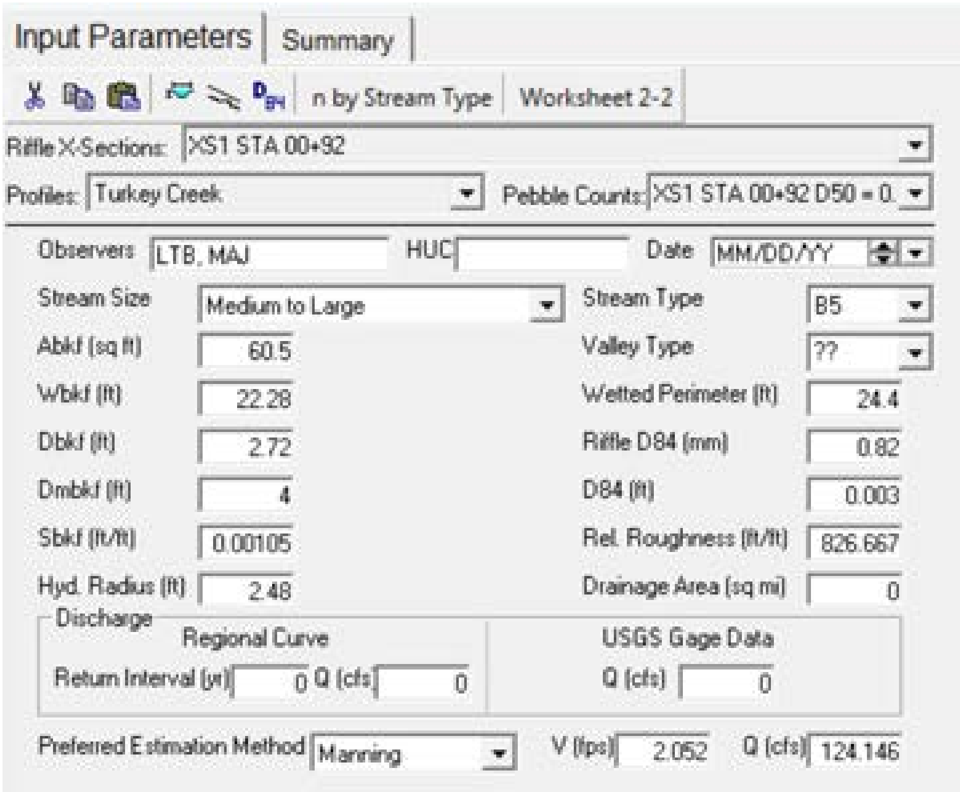

Turkey Creek
Distance along stream (ft)

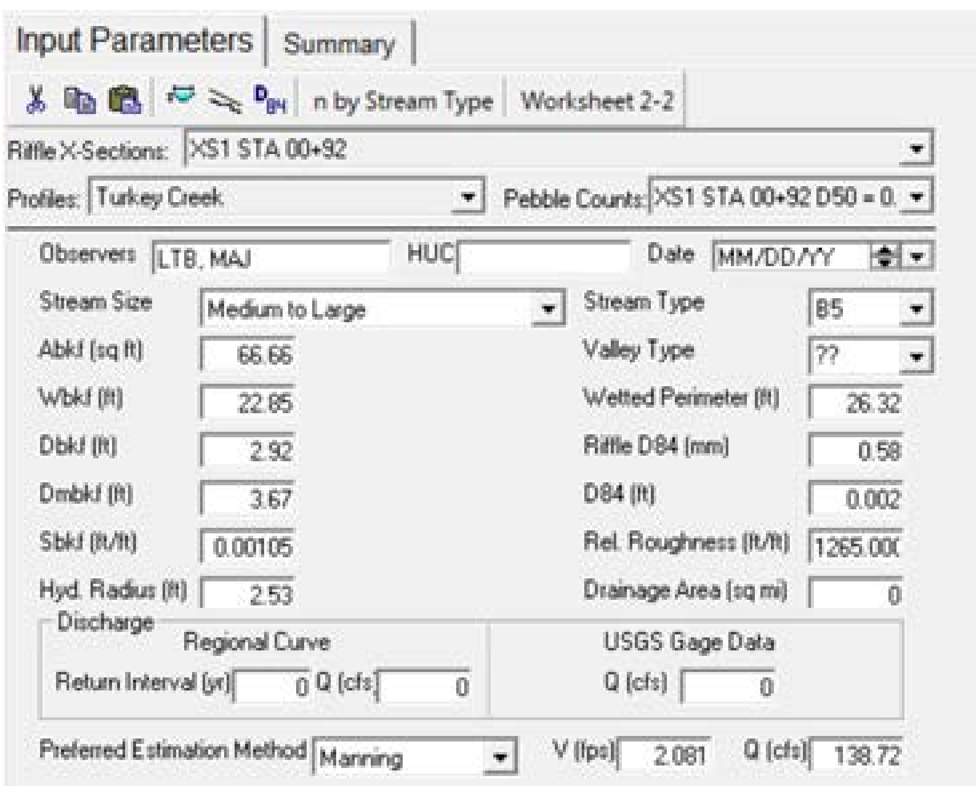

Input Parameters
Summary
n by Stream Type
Worksheet 2-2
Riffle X-Sections: XS1 STA 00+92
Profiles: Turkey Creek
Pebble Counts: XS1 STA 00+92 D50 = 0.
Observers
HUC
Date MM/DD/YY
Stream Size Medium to Large
Stream Type G5
Abkf (sq ft) 44.58
Valley Type ??
Wbkf (ft) 24.09
Wetted Perimeter (ft) 25.71
Dbkf (ft) 1.85
Riffle D84 (mm) 1.16
Dmbkf (ft) 2.75
D84 (ft) 0.004
Sbkf (ft/ft) 0.00226
Rel. Roughness (ft/ft) 432.500
Hyd. Radius (ft) 1.73
Drainage Area (sq mi) 0
Discharge
Regional Curve
Return Interval (yr) 0 Q (cfs) 0
USGS Gage Data
Q (cfs) 0
Preferred Estimation Method Manning
V (fps) 2.615
Q (cfs) 116.577


Input Parameters
Summary
n by Stream Type
Worksheet 2-2
Riffle X-Sections: XS1 STA 00+92
Profiles: Turkey Creek
Pebble Counts: XS1 STA 00+92 D50 = 0.
Observers LTB, MAJ
HUC
Date MM/DD/YY
Stream Size Medium to Large
Stream Type G5
Abkf (sq ft) 46.17
Valley Type ??
Wbkf (ft) 21.75
Wetted Perimeter (ft) 24.02
Dbkf (ft) 2.12
Riffle D84 (mm) 0.85
Dmbkf (ft) 2.93
D84 (ft) 0.003
Sbkf (ft/ft) 0.00226
Rel. Roughness (ft/ft) 640.000
Hyd. Radius (ft) 1.92
Drainage Area (sq mi) 0
Discharge
Regional Curve
Return Interval (yr) 0
Q (cfs) 0
USGS Gage Data
Q (cfs) 0
Preferred Estimation Method Manning
V (fps) 2.801
Q (cfs) 129.322


Input Parameters
Summary
n by Stream Type
Worksheet 2-2
Riffle X-Sections: XS1 STA 00+92
Profiles: Turkey Creek
Pebble Counts: XS1 STA 00+92 D50 = 0.
Observers
HUC
Date MM/DD/YY
Stream Size Medium to Large
Stream Type G5
Abkf (sq ft) 25.85
Valley Type ??
Wbkf (ft) 15.66
Wetted Perimeter (ft) 17.27
Dbkf (ft) 1.65
Riffle D84 (mm) 0.58
Dmbkf (ft) 2.42
D84 (ft) 0.002
Sbkf (ft/ft) 0.00105
Rel. Roughness (ft/ft) 750.000
Hyd. Radius (ft) 1.5
Drainage Area (sq mi) 0
Discharge
Regional Curve
Return Interval (yr) 0
Q (cfs) 0
USGS Gage Data
Q (cfs) 0
Preferred Estimation Method Manning
V (fps) 4.408
Q (cfs) 113.947

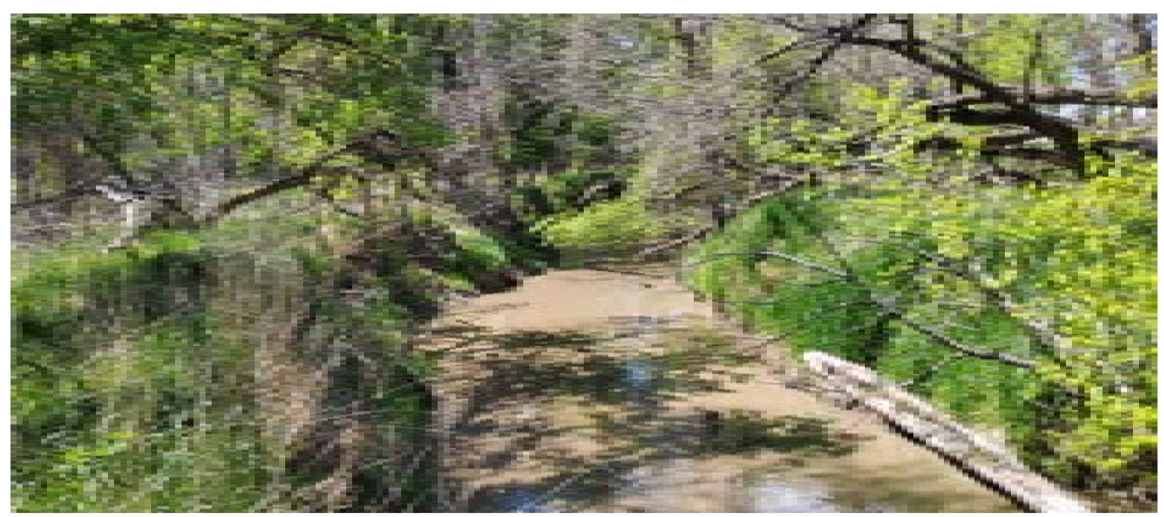
WATERVATION





Mobile Bed Sediment Transport Model Figures

TURKEY CREEK
WATERSHED ASSESSMENT OF RIVER STABILITY & SEDIMENT SUPPLY
MOBILE BED SEDIMENT TRANSPORT MODEL RESULTS



NEBRASKA
GAME PARKS

JUNE 2022

WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

Legend

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	Dwn.	Chkd.	Dsgn.	YY.MM.DD
	LTB	MAJ	LTB	22.06.30

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

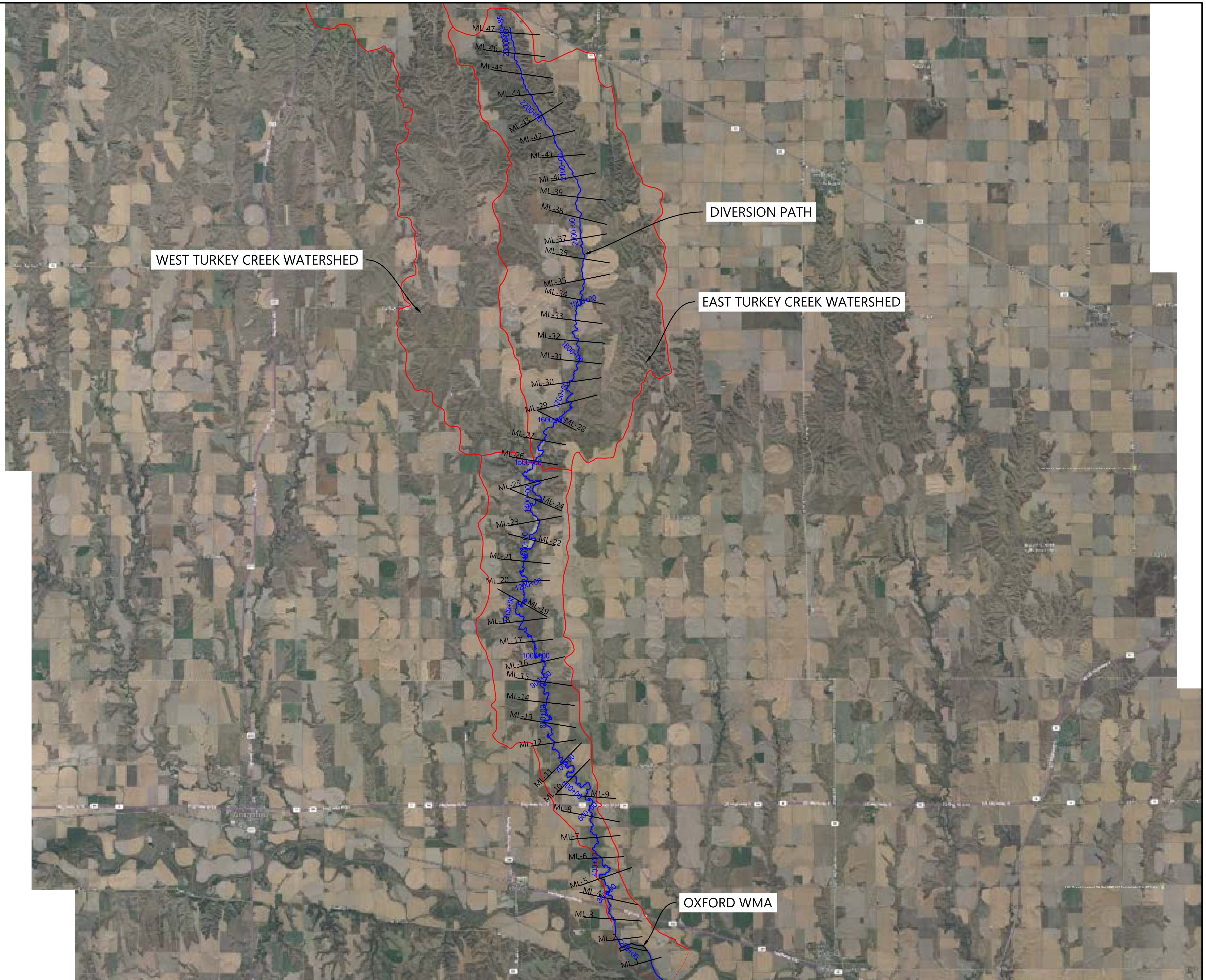
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
COVER

Project No.	Horizontal Scale
2021002022	NTS

Sheet 1 of 50

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 12000 24000

Legend

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

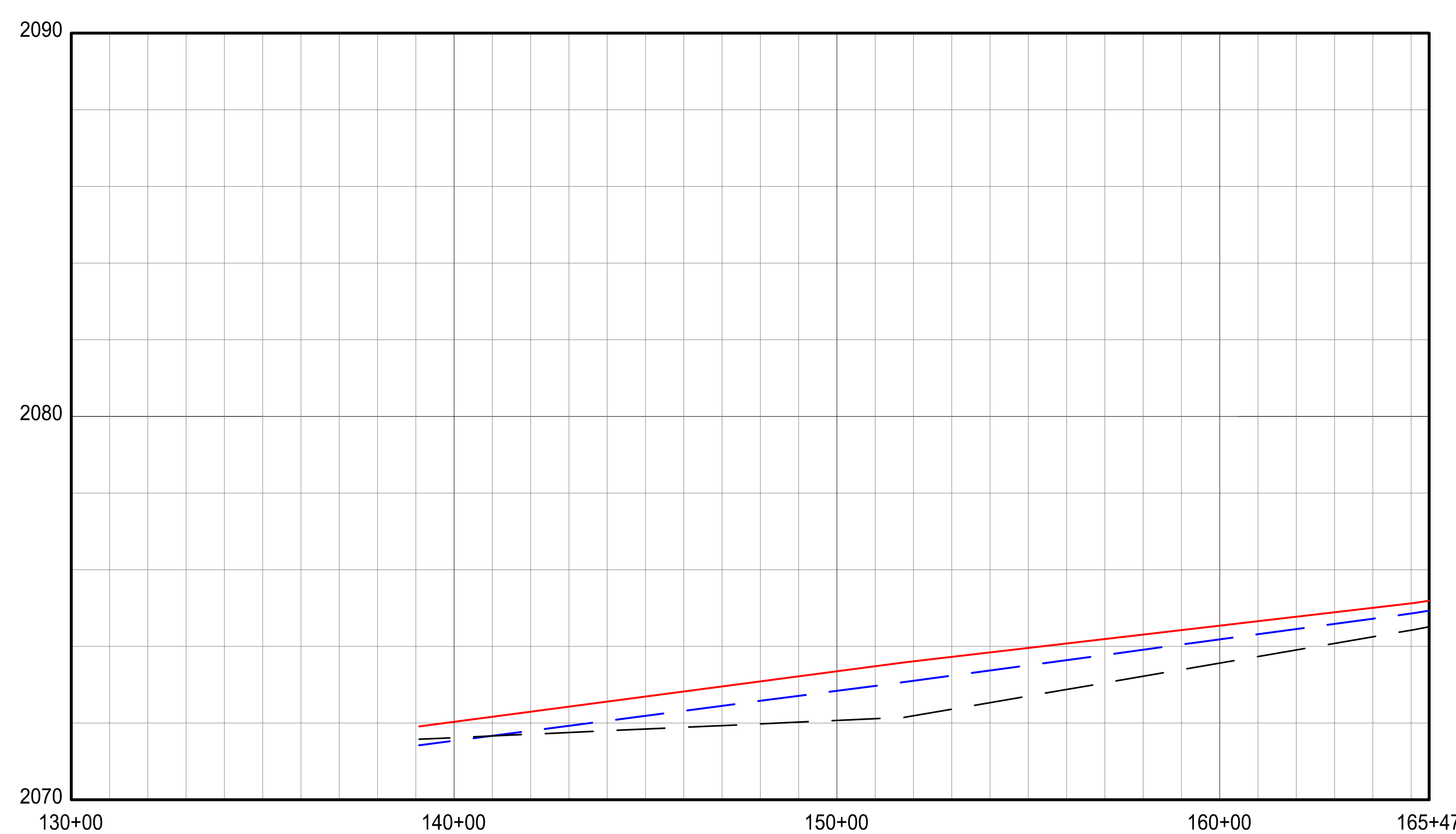
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
OVERVIEW

2021002022	1" = 12000'
Project No.	Horizontal Scale

Sheet 2 of 50

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone

SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name

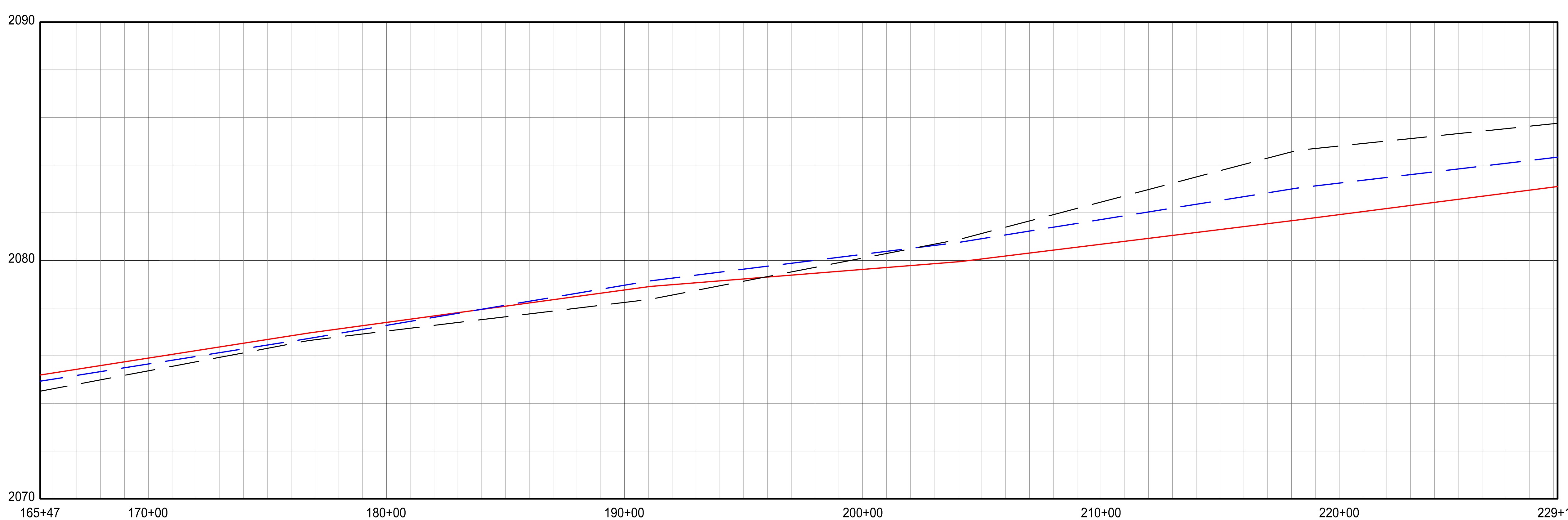
SEDIMENT MODELING RESULTS - (1)

2021002022	1" = 500'
Project No.	Horizontal Scale

Sheet 3 of 50

C:\Users\lucasbabbitt\watervation Dropbox\Projects\2021002022_turkey Creek Warsss\3_CAD\Sheet_Files\SEDIMENT MODELING RESULTS_FINAL1 - (1).dwg
2022/07/11 4:32 PM By: Lucas Babbitt

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision — By — Appd. — YY.MM.DD

Issued — By — Appd. — YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

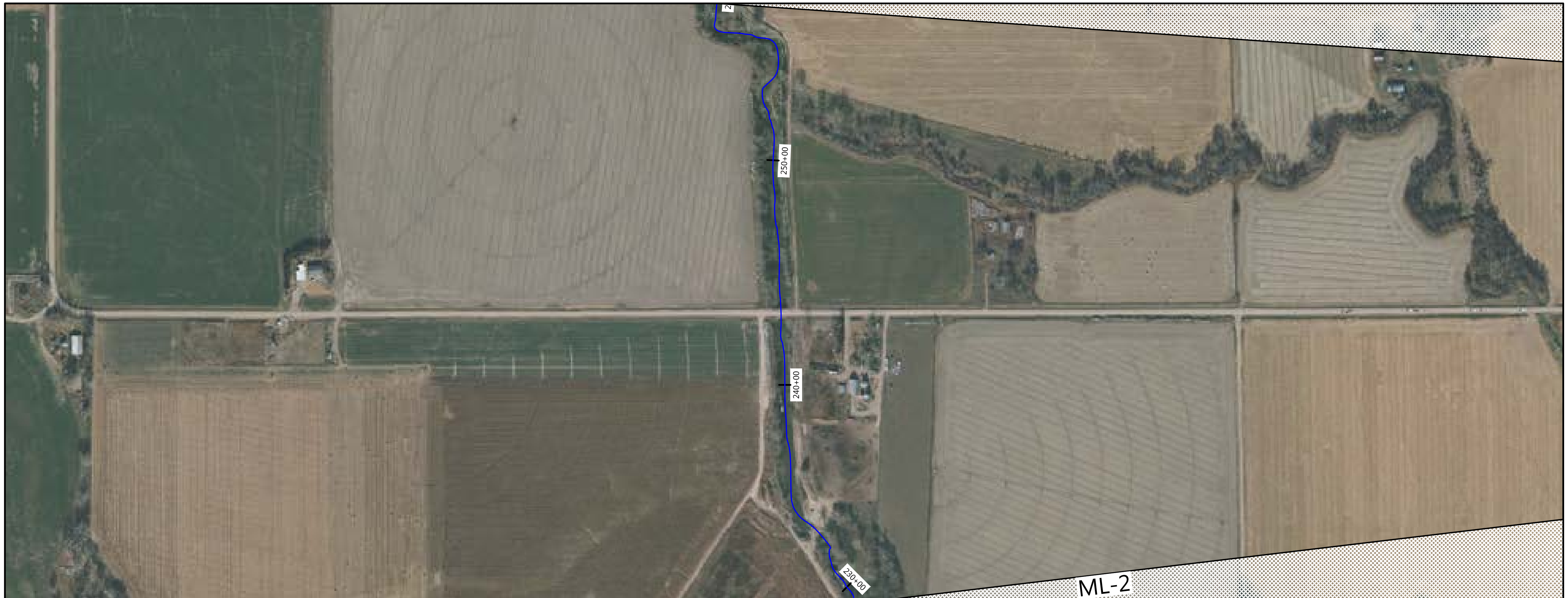
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

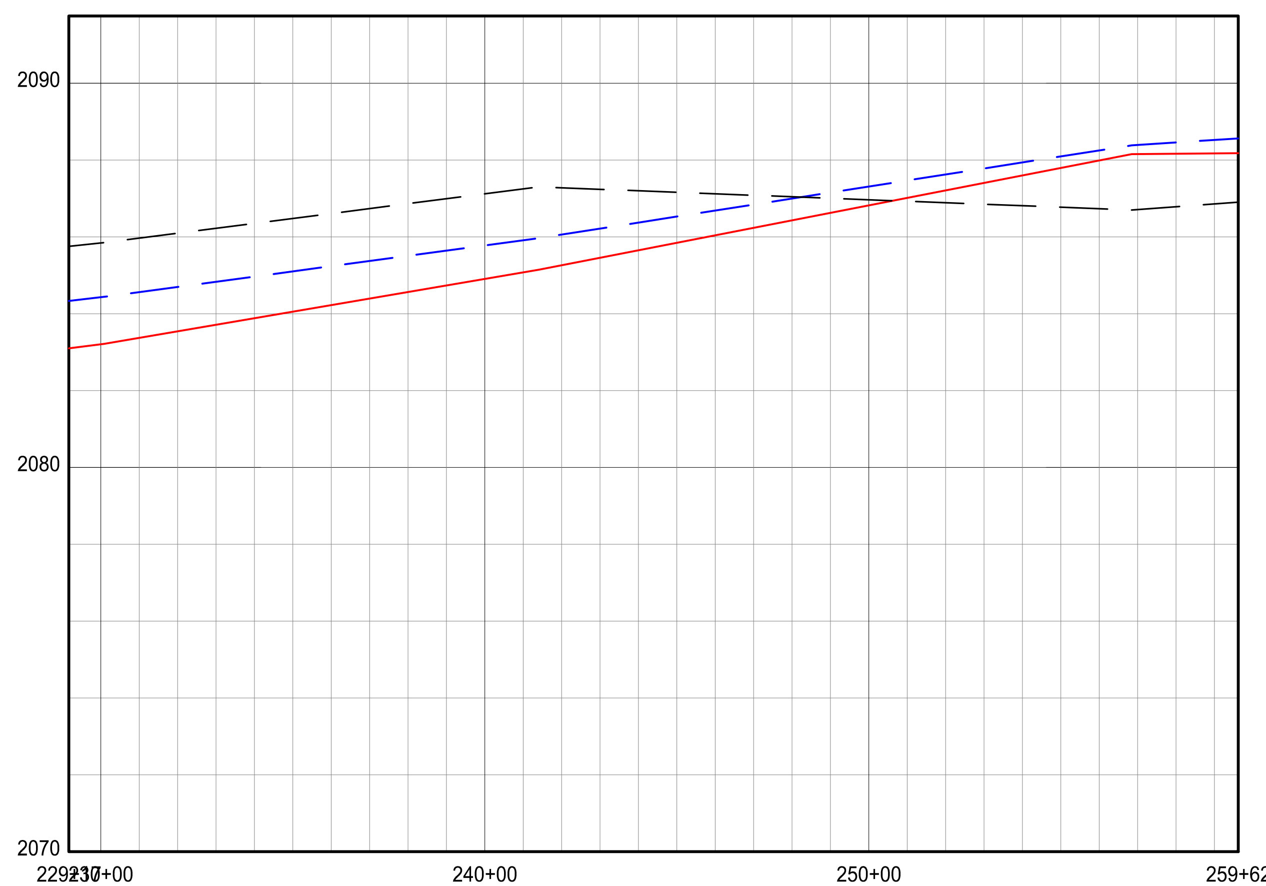
Sheet Name
SEDIMENT MODELING RESULTS - (2)

2021002022 — 1" = 500'
Project No. — Horizontal Scale

Sheet 4 of 50

ORIGINAL SHEET - ANSI B





WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Copyright Reserved

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

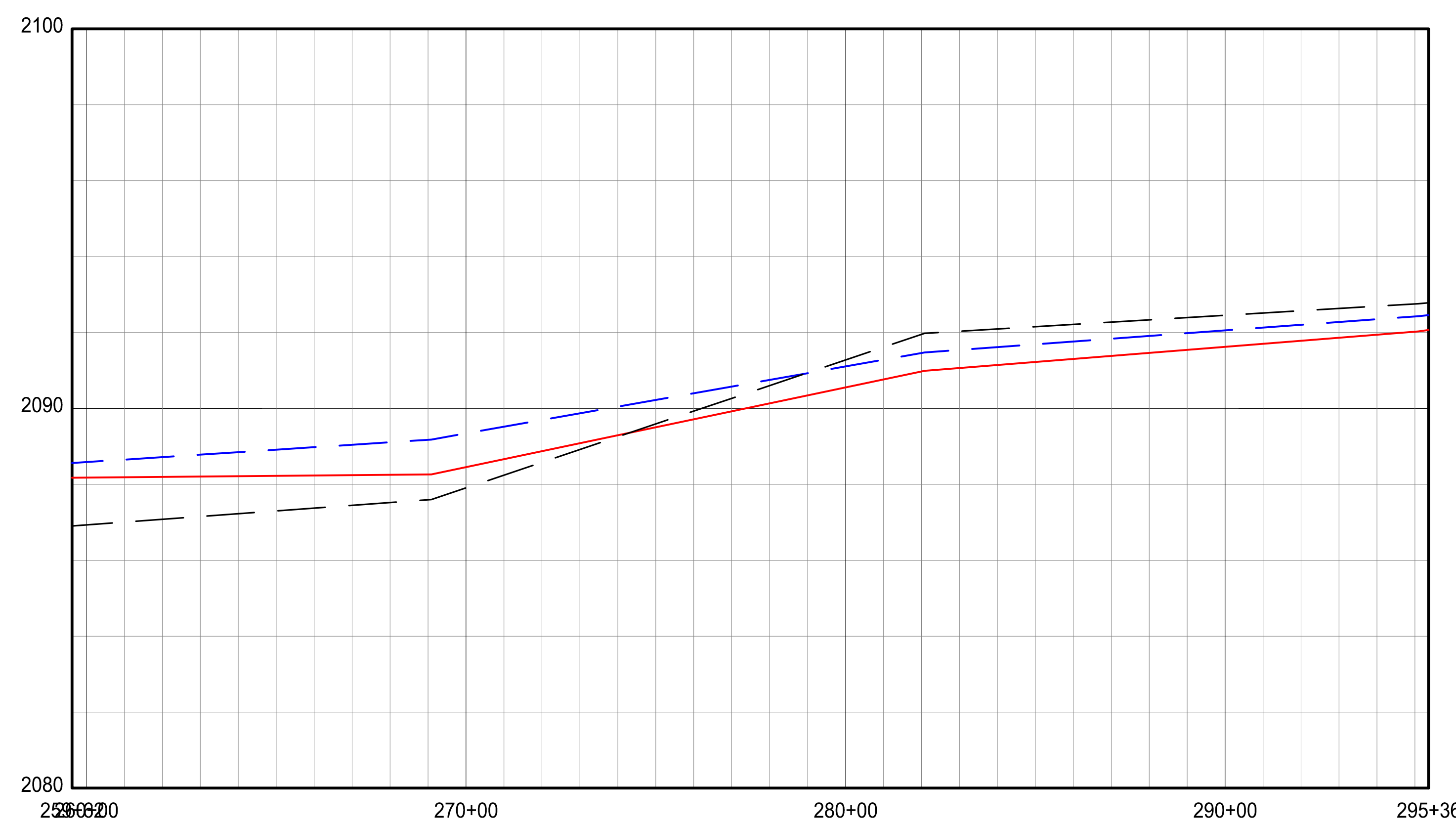
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (3)

2021002022 1" = 500'
Project No. Horizontal Scale

Sheet 5 of 50

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

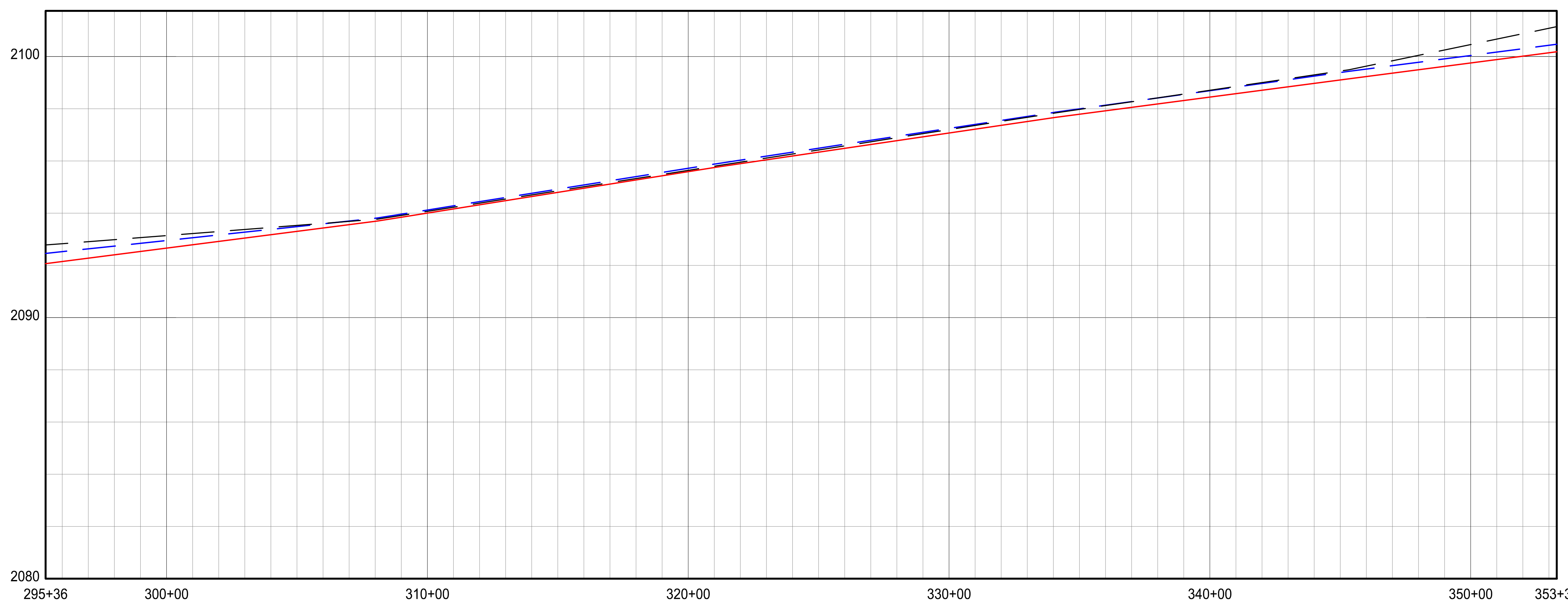
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (4)

2021002022	1" = 500'
Project No.	Horizontal Scale

Sheet 6 of 50

ORIGINAL SHEET - ANSI B



WATERVATION

123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	Dwn.	Chkd.	Dsgn.	YY.MM.DD
	LTB	MAJ	LTB	22.06.30

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone

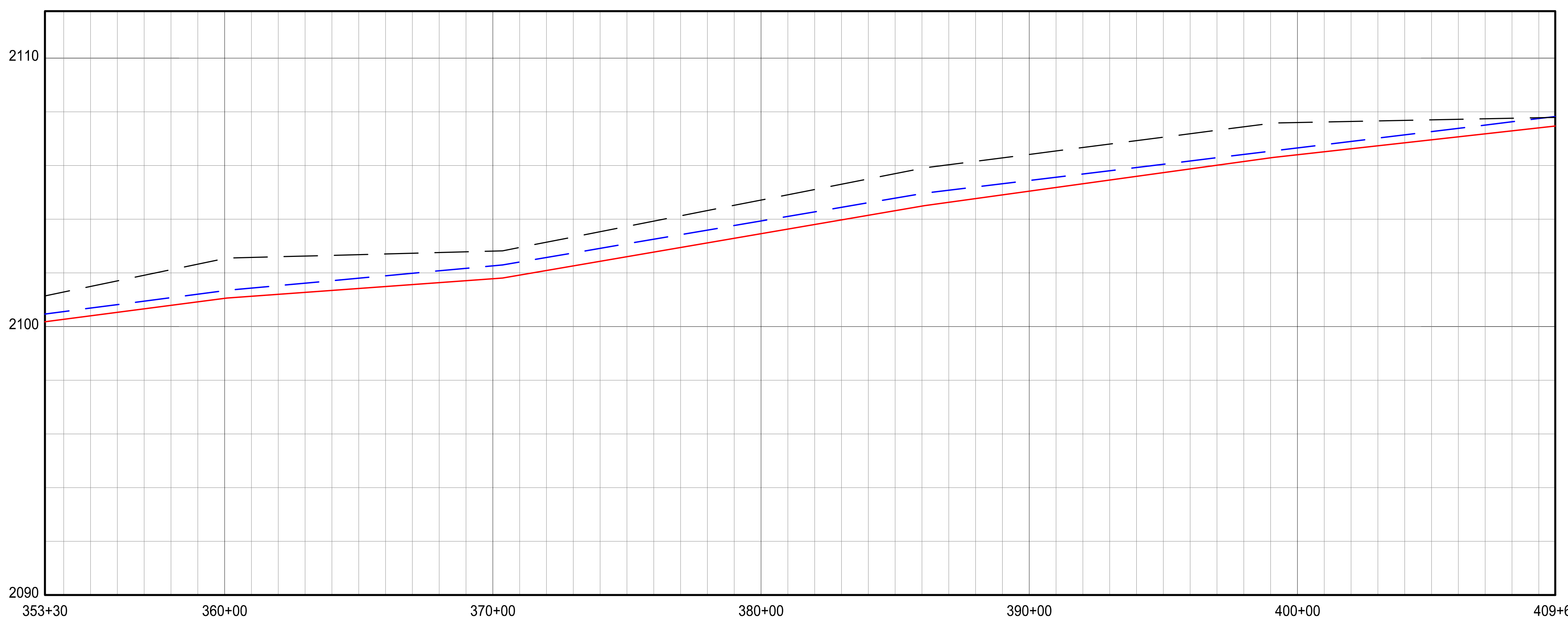
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name

SEDIMENT MODELING RESULTS - (5)

2021002022	1" = 500'
Project No.	Horizontal Scale

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB Dwn.	MAJ Chkd.	LTB Dsgn.	22.06.30 YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

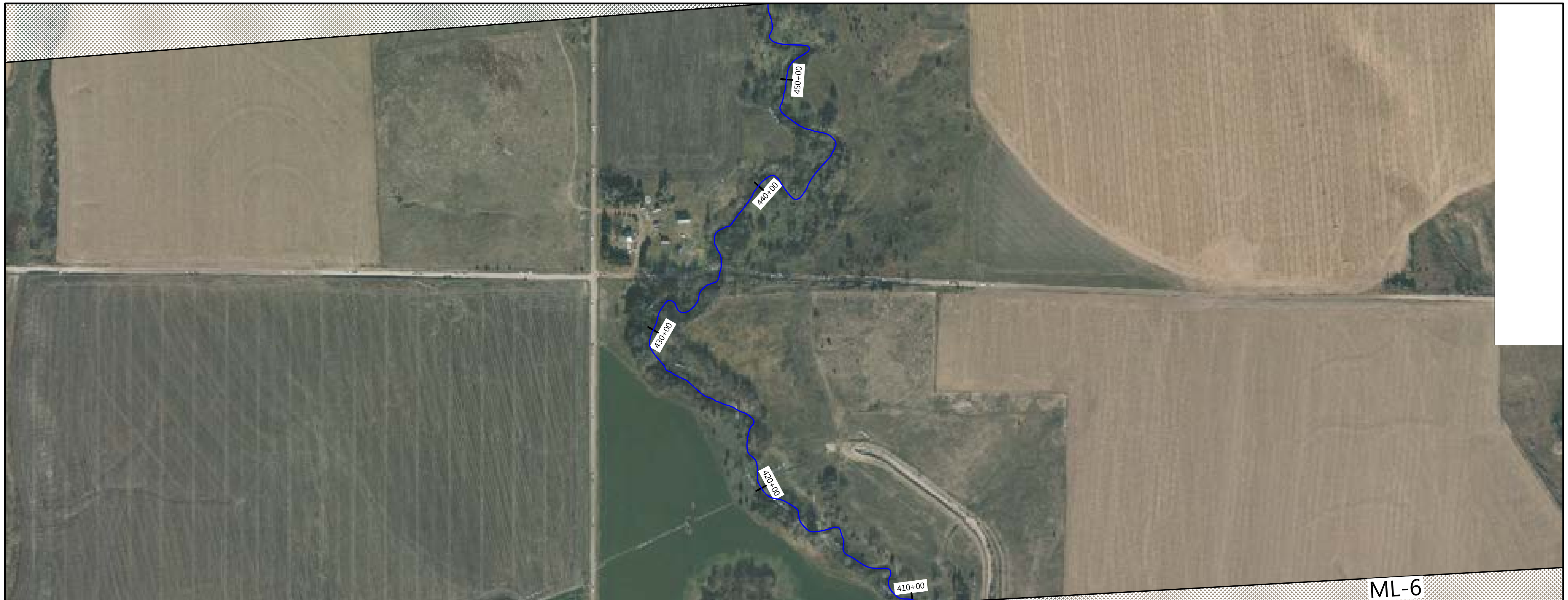
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

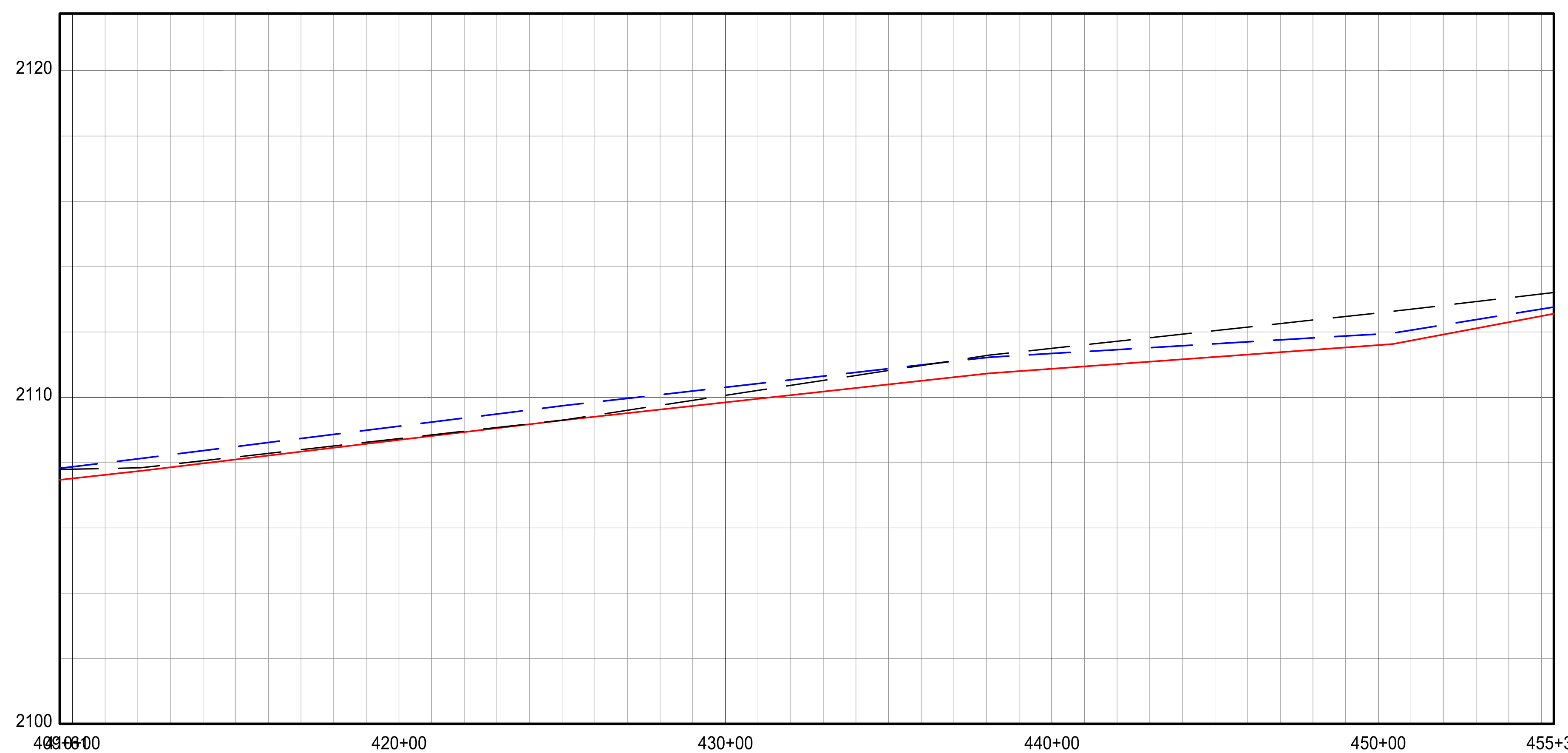
Sheet Name
SEDIMENT MODELING RESULTS - (6)

2021002022 1" = 500'
Project No. Horizontal Scale

Sheet 8 of 50

ORIGINAL SHEET - ANSI B





WATERVATION

123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	Dwn.	Chkd.	Dsgn.	YY.MM.DD
	LTB	MAJ	LTB	22.06.30

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone

SEDIMENT TRANSPORT MODEL RESULTS

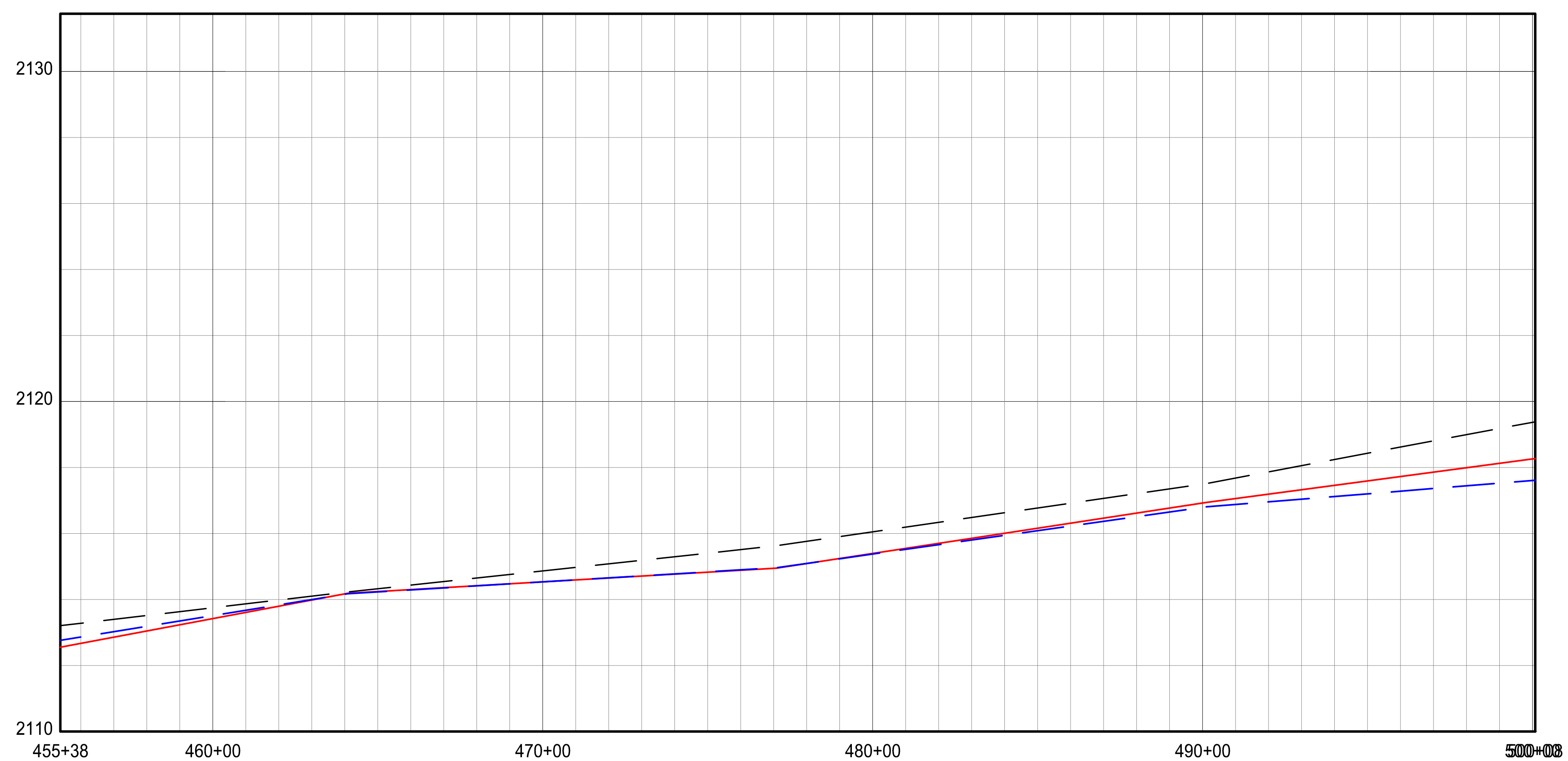
Sheet Name

SEDIMENT MODELING RESULTS - (7)

Project No.	Horizontal Scale
2021002022	1" = 500'

Sheet 9 of 50

ORIGINAL SHEET - ANSI B



WATERVATION

123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

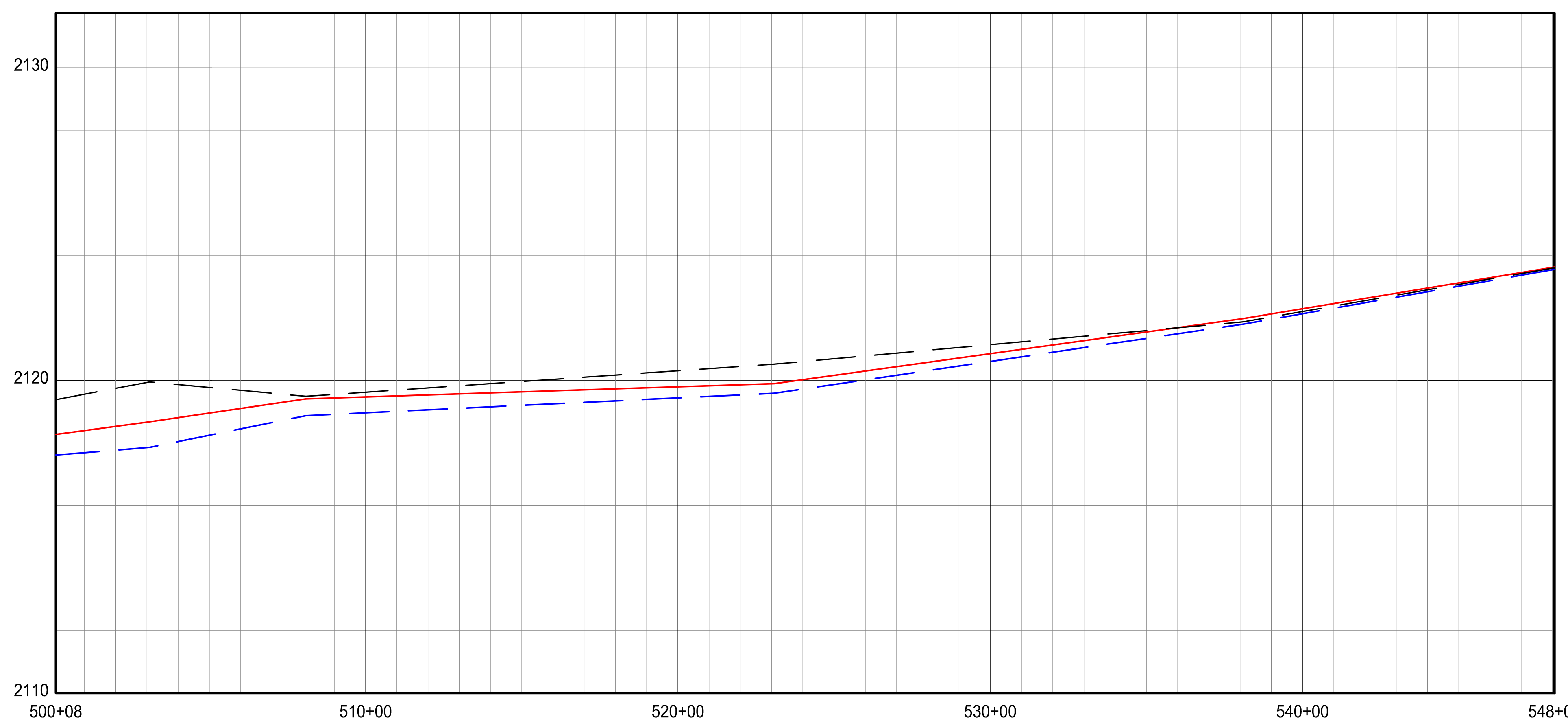
Project Milestone

SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name

SEDIMENT MODELING RESULTS - (8)

2021002022	1" = 500'
Project No.	Horizontal Scale



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	Dwn.	Chkd.	Dsgn.	YY.MM.DD
	LTB	MAJ	LTB	22.06.30

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

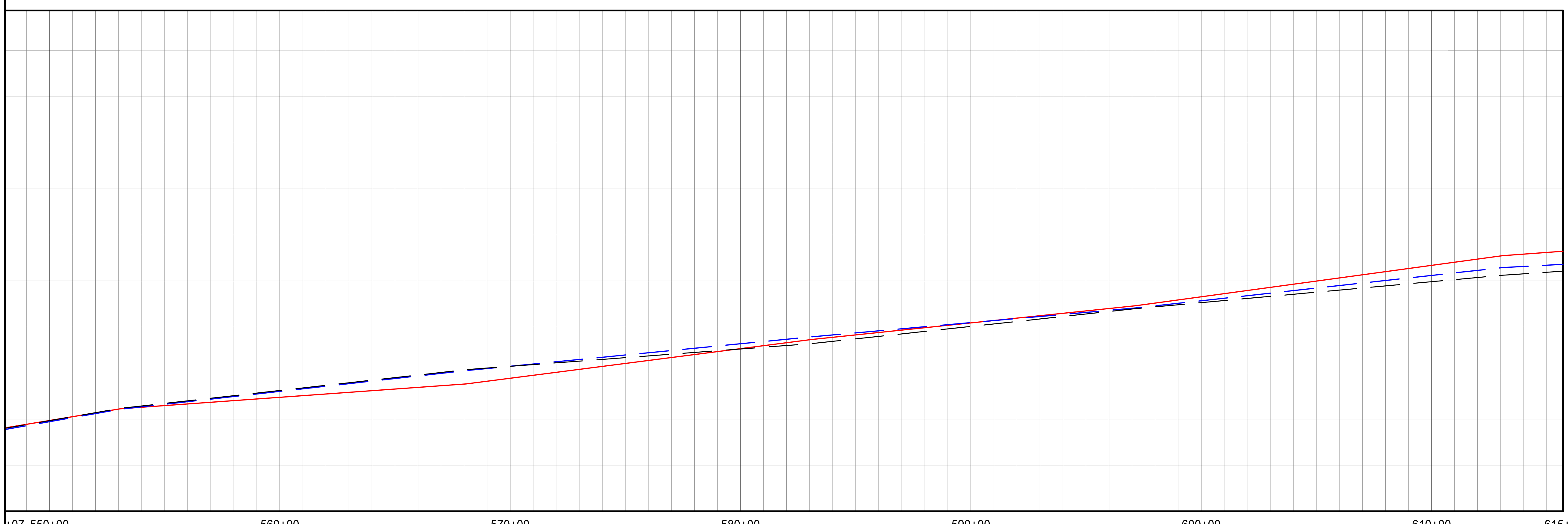
HOLDREGE, NE

Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (9)

2021002022 1" = 500'
Project No. Horizontal Scale

ORIGINAL SHEET - ANSI B



ORIGINAL SHEET - ANSI B

WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

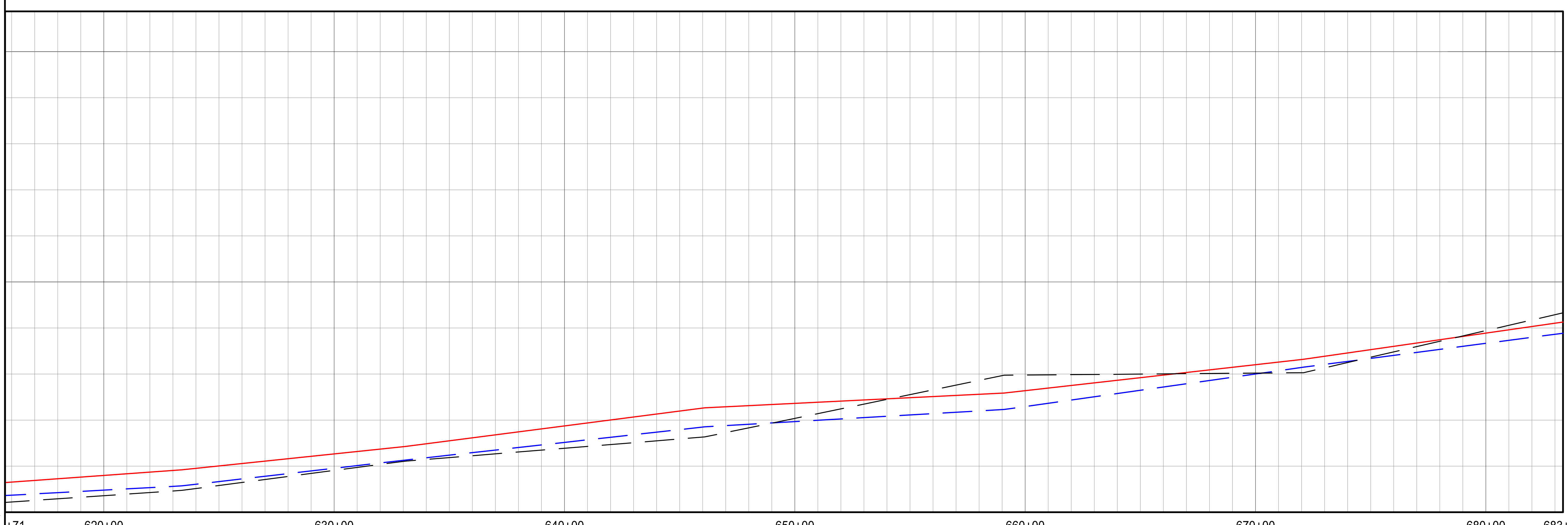
Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (10)

2021002022	1" = 500'
Project No.	Horizontal Scale



ORIGINAL SHEET - ANSI B

WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

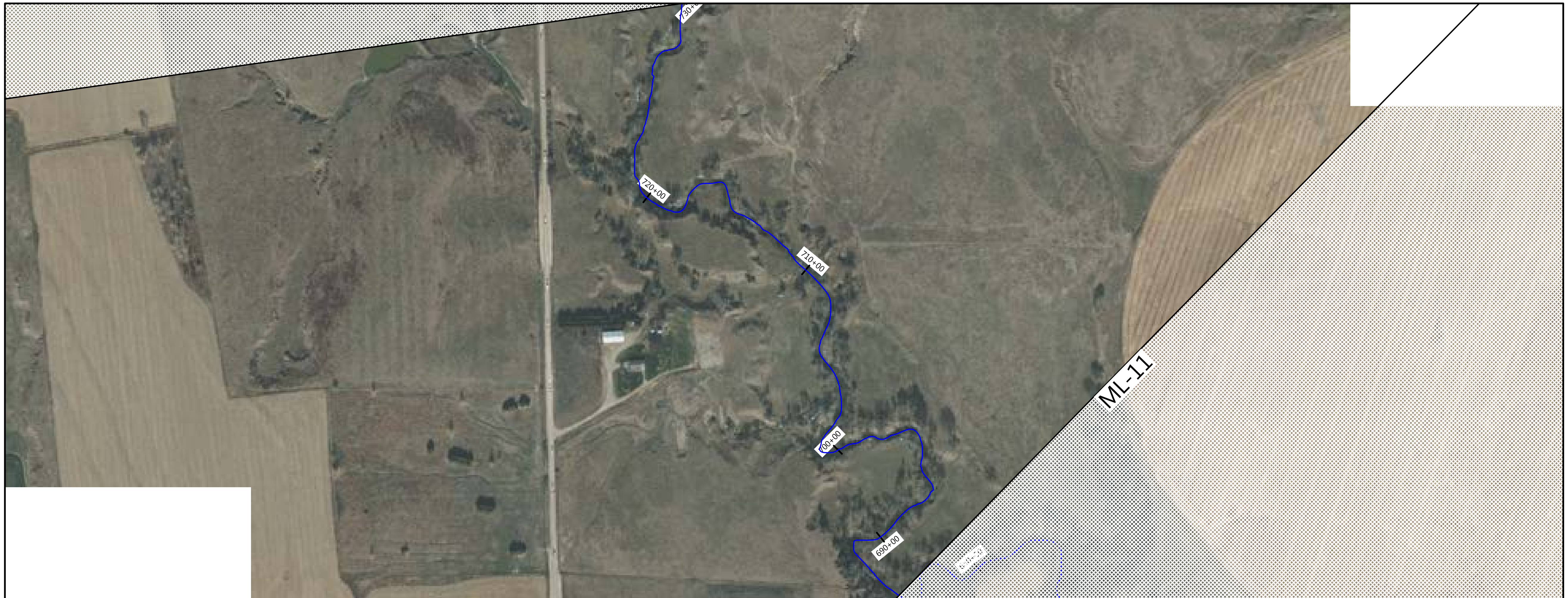
HOLDREGE, NE

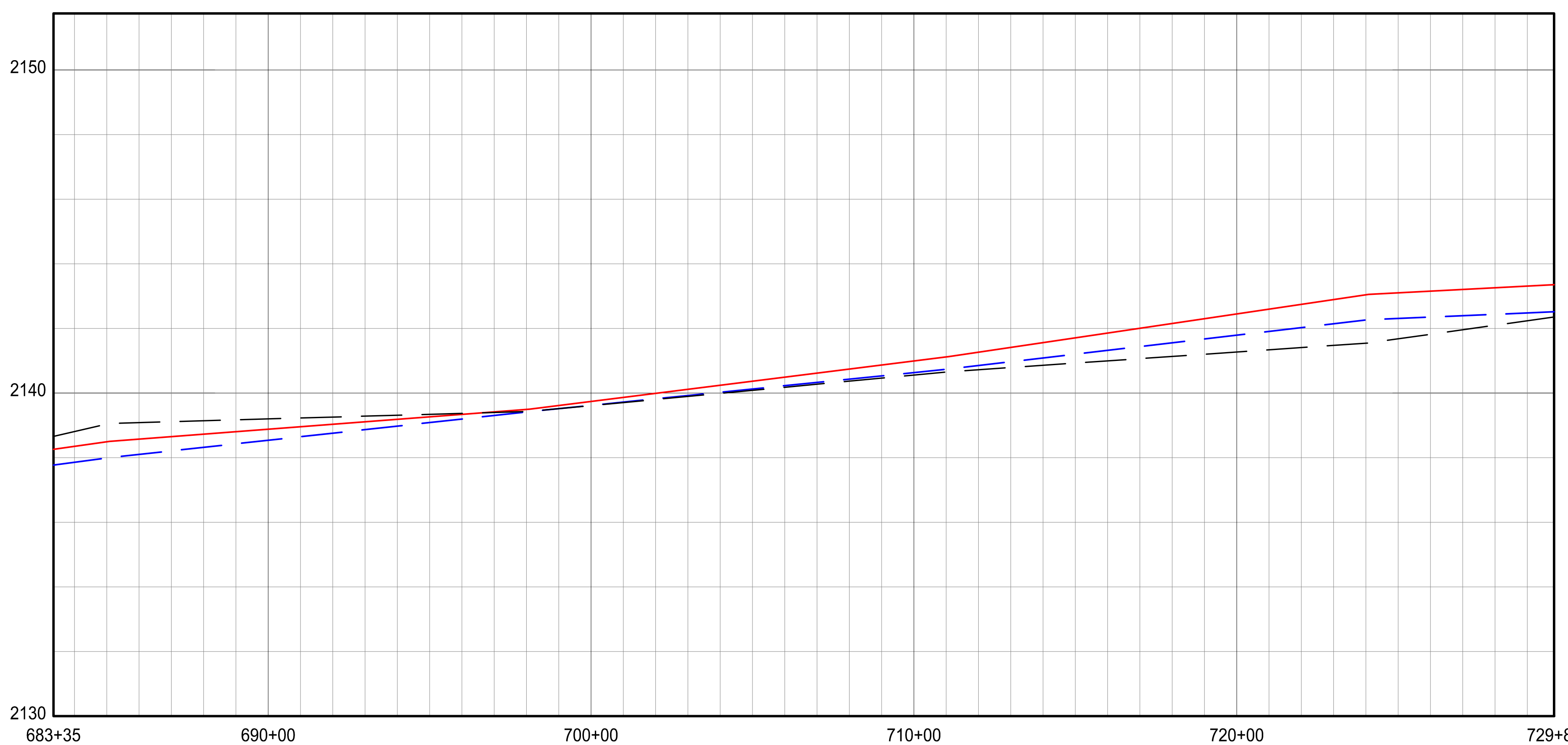
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (11)

2021002022 1" = 500'
Project No. Horizontal Scale

Sheet 13 of 50





WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

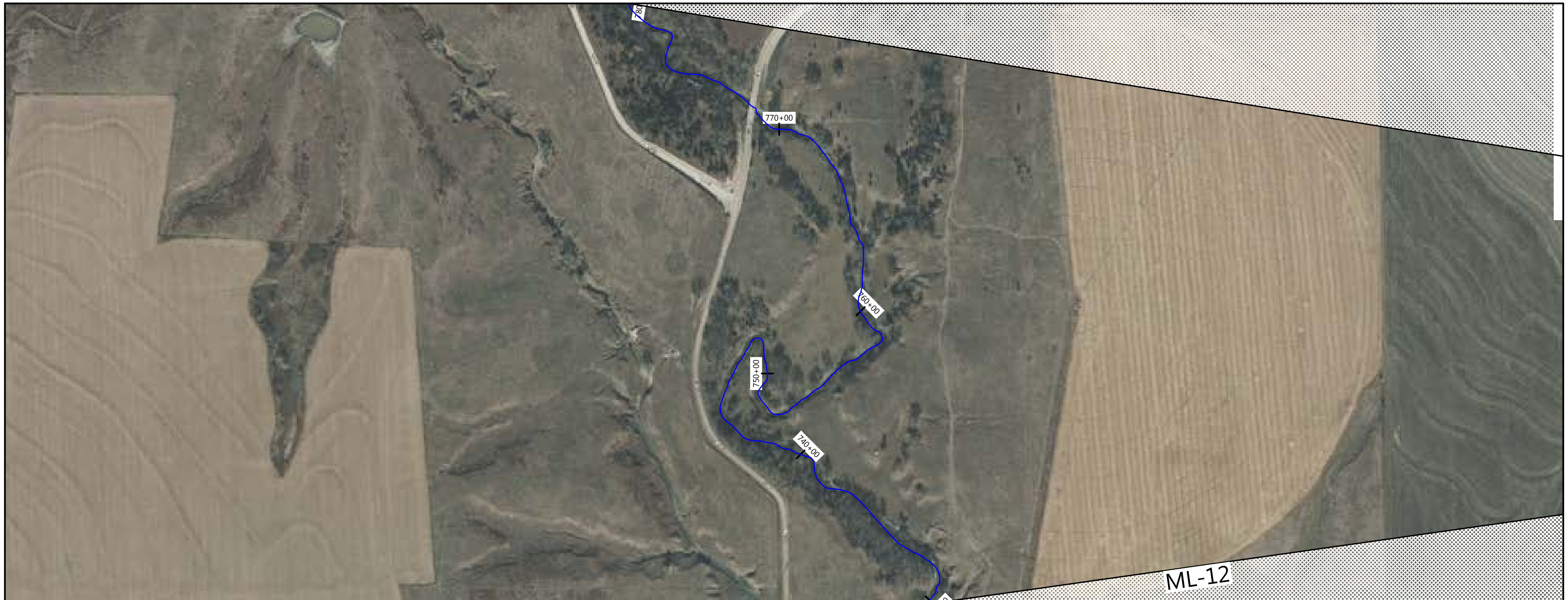
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

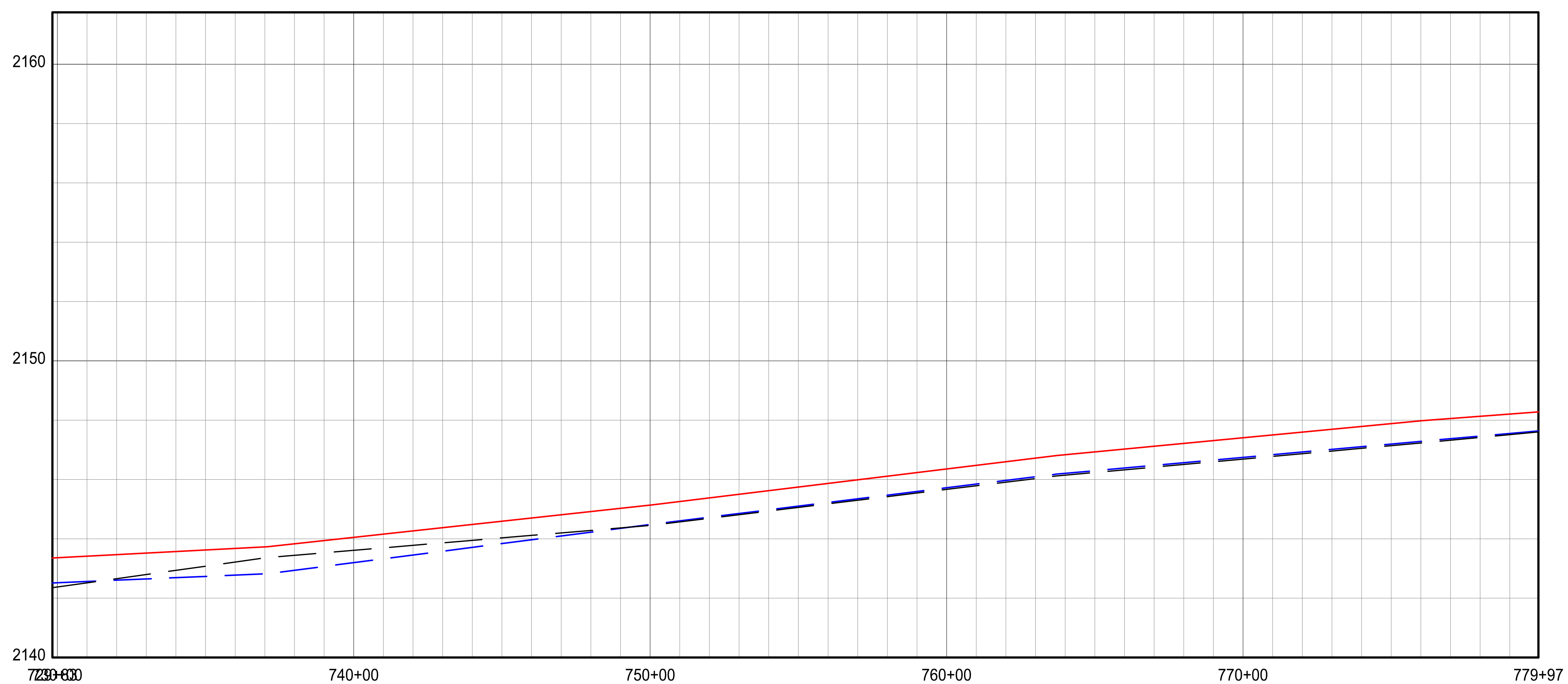
Sheet Name
SEDIMENT MODELING RESULTS - (12)

2021002022	1" = 500'
Project No.	Horizontal Scale

Sheet 14 of 50

ORIGINAL SHEET - ANSI B





WATERVATION

123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Copyright Reserved

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone

SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name

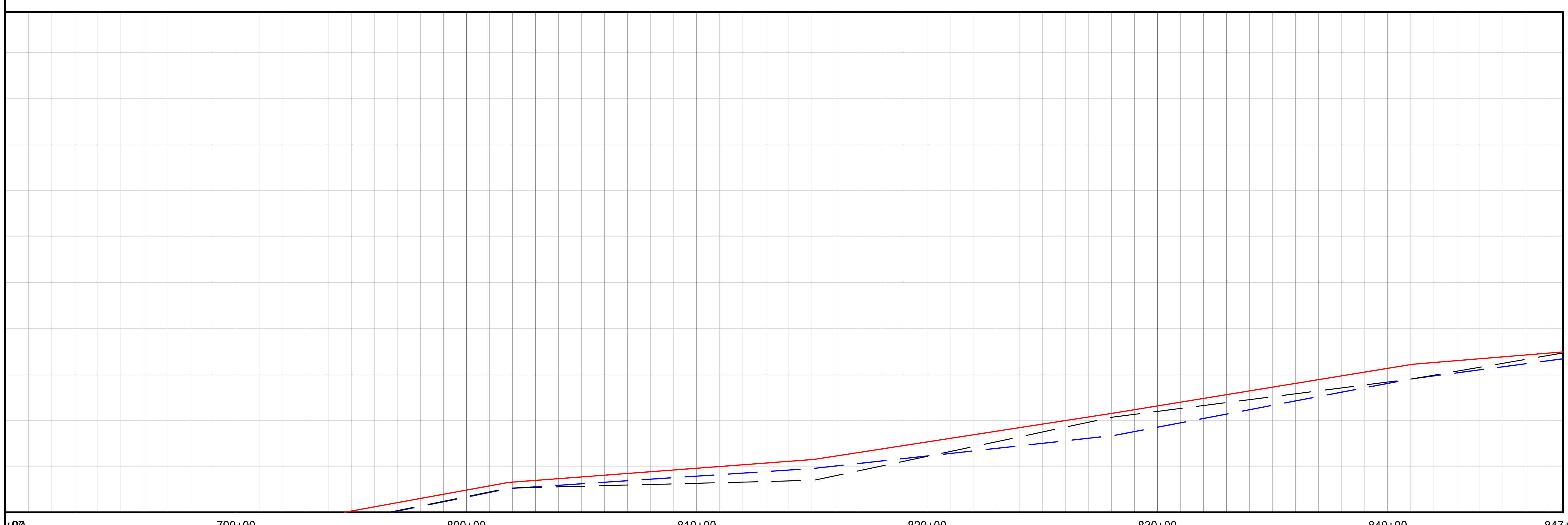
SEDIMENT MODELING RESULTS - (13)

2021002022 1" = 500'

Project No. Horizontal Scale

Sheet 15 of 50

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

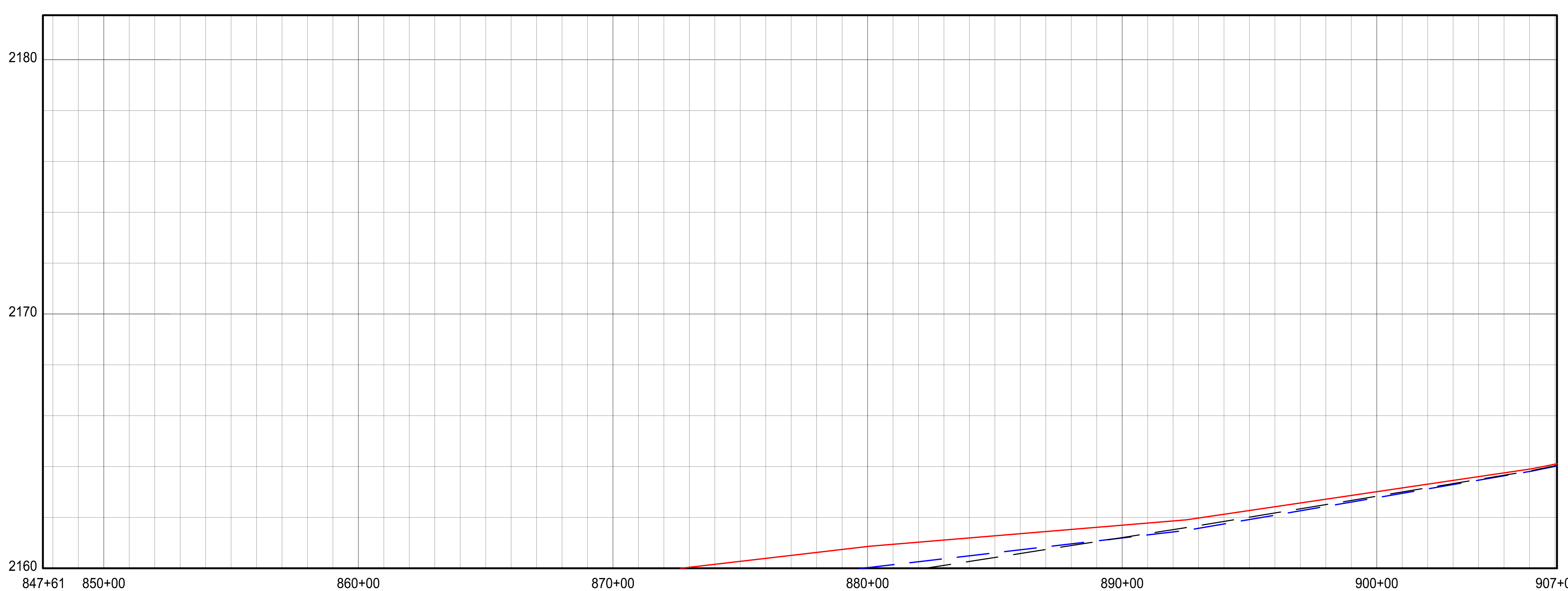
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (14)

2021002022 1" = 500'
Project No. Horizontal Scale

Sheet 16 of 50

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone

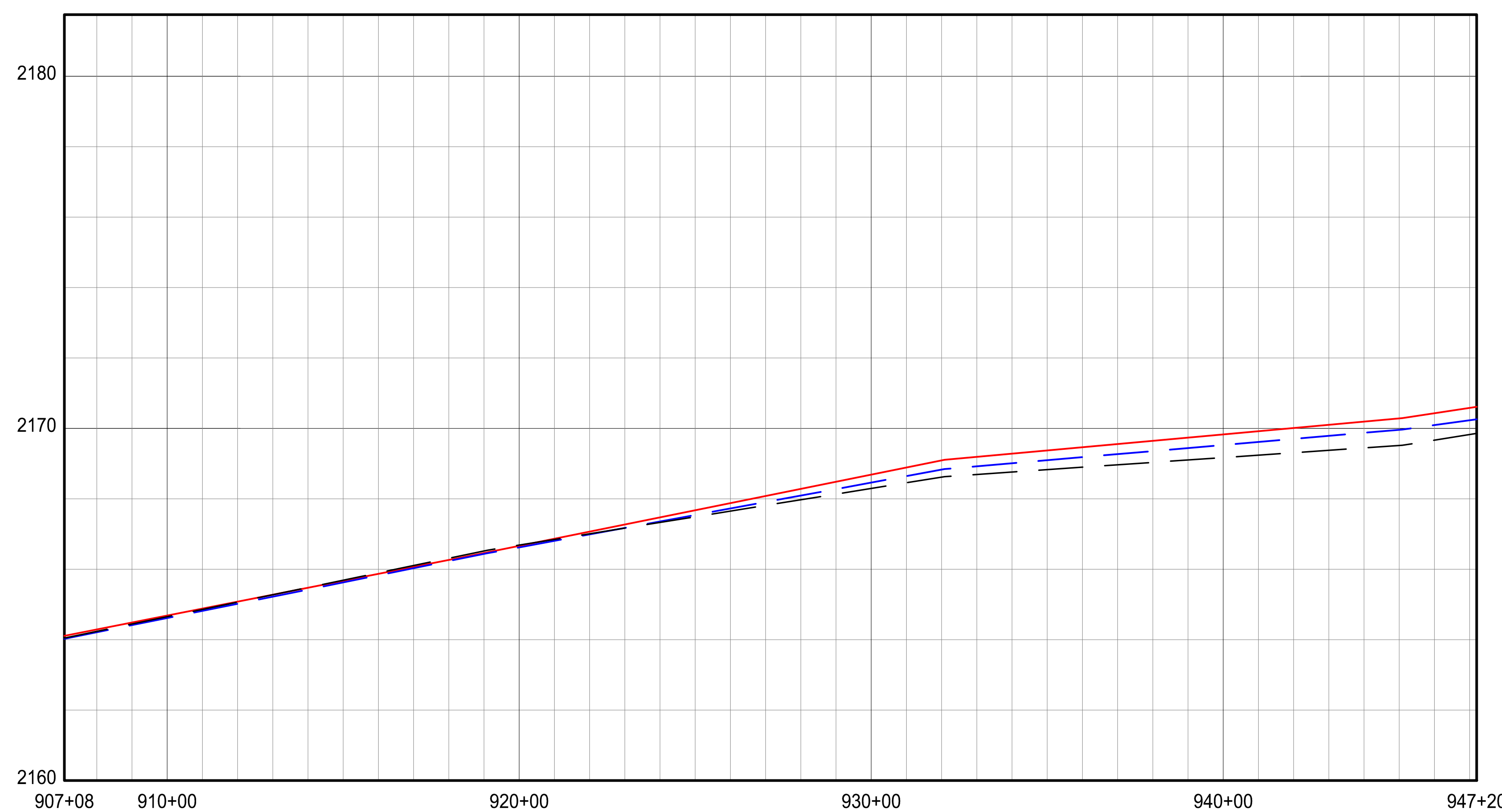
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name

SEDIMENT MODELING RESULTS - (15)

2021002022	1" = 500'
Project No.	Horizontal Scale

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

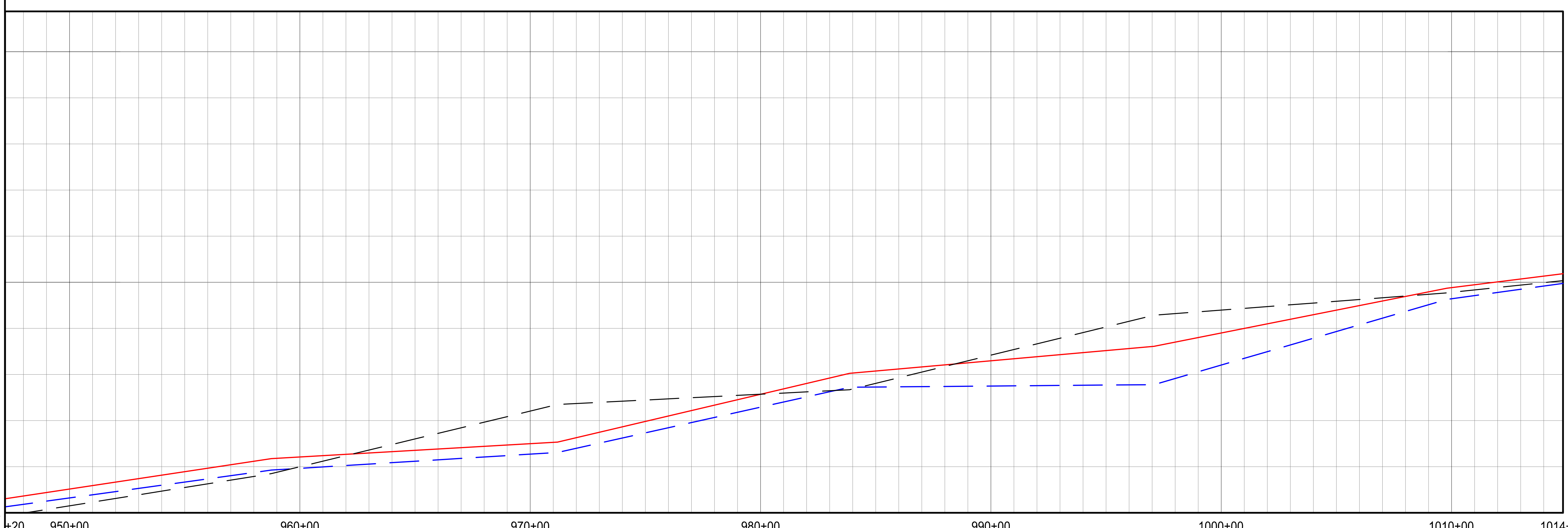
HOLDREGE, NE

Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (16)

2021002022 1" = 500'
Project No. Horizontal Scale

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone

SEDIMENT TRANSPORT MODEL RESULTS

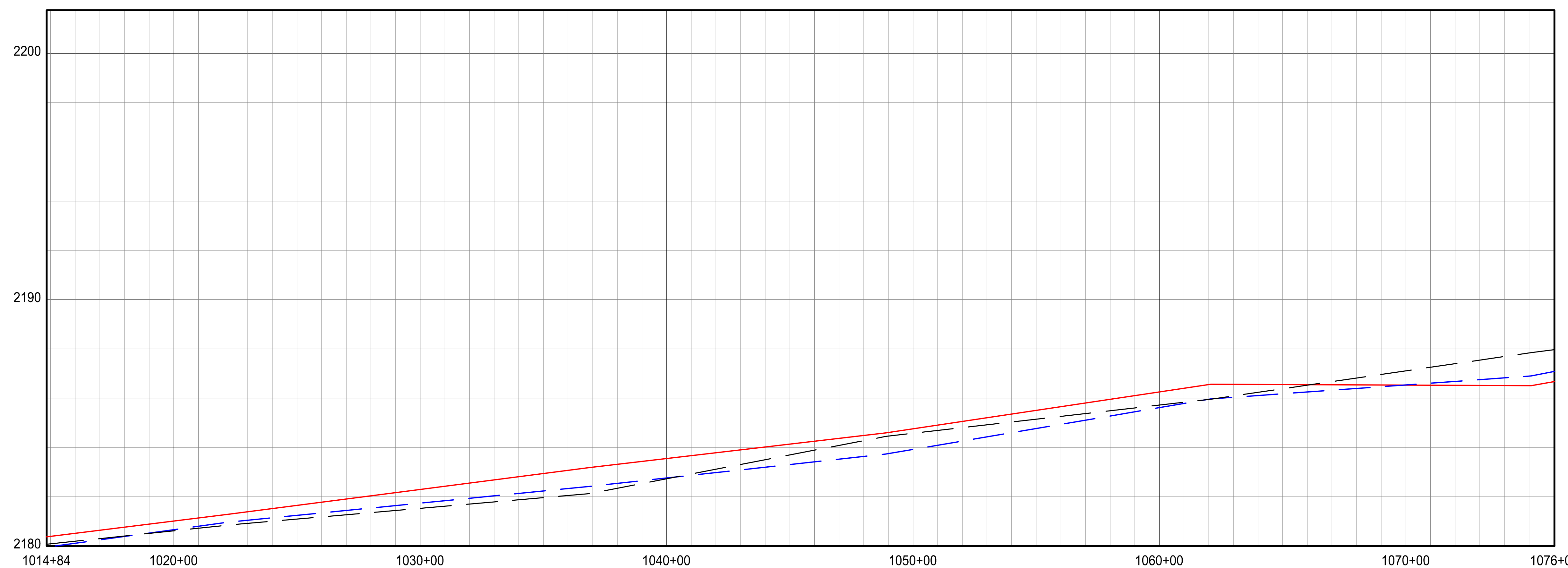
Sheet Name

SEDIMENT MODELING RESULTS - (17)

2021002022	1" = 500'
Project No.	Horizontal Scale

Sheet 19 of 50

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision — By — Appd. — YY.MM.DD

Issued — By — Appd. — YY.MM.DD

File Name: — LTB Dwn. — MAJ Chkd. — LTB Dsgn. — 22.06.30 YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

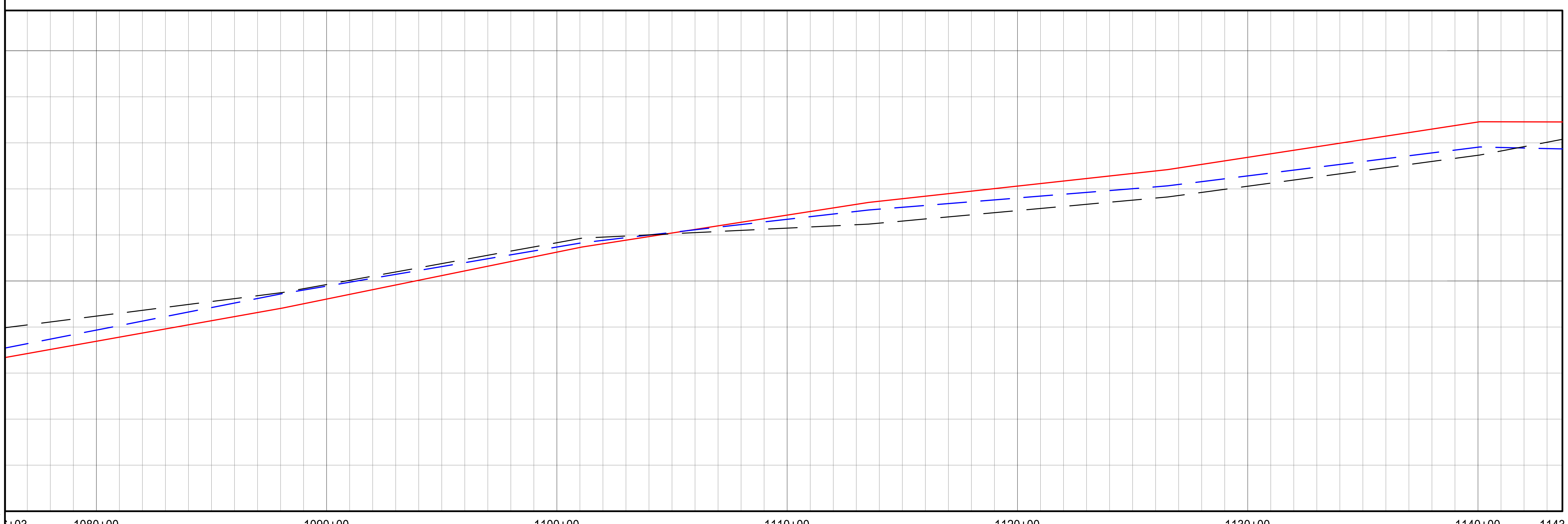
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (18)

2021002022 — 1" = 500'
Project No. — Horizontal Scale

Sheet 20 of 50

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE ONE YEAR AFTER DIVERSION GOES ONLINE

Revision | By | Appd. | YY.MM.DD

Issued | By | Appd. | YY.MM.DD

File Name: | LTB Dwn. | MAJ Chkd. | LTB Dsgn. | 22.06.30 YY.MM.DD

Permit-Seal

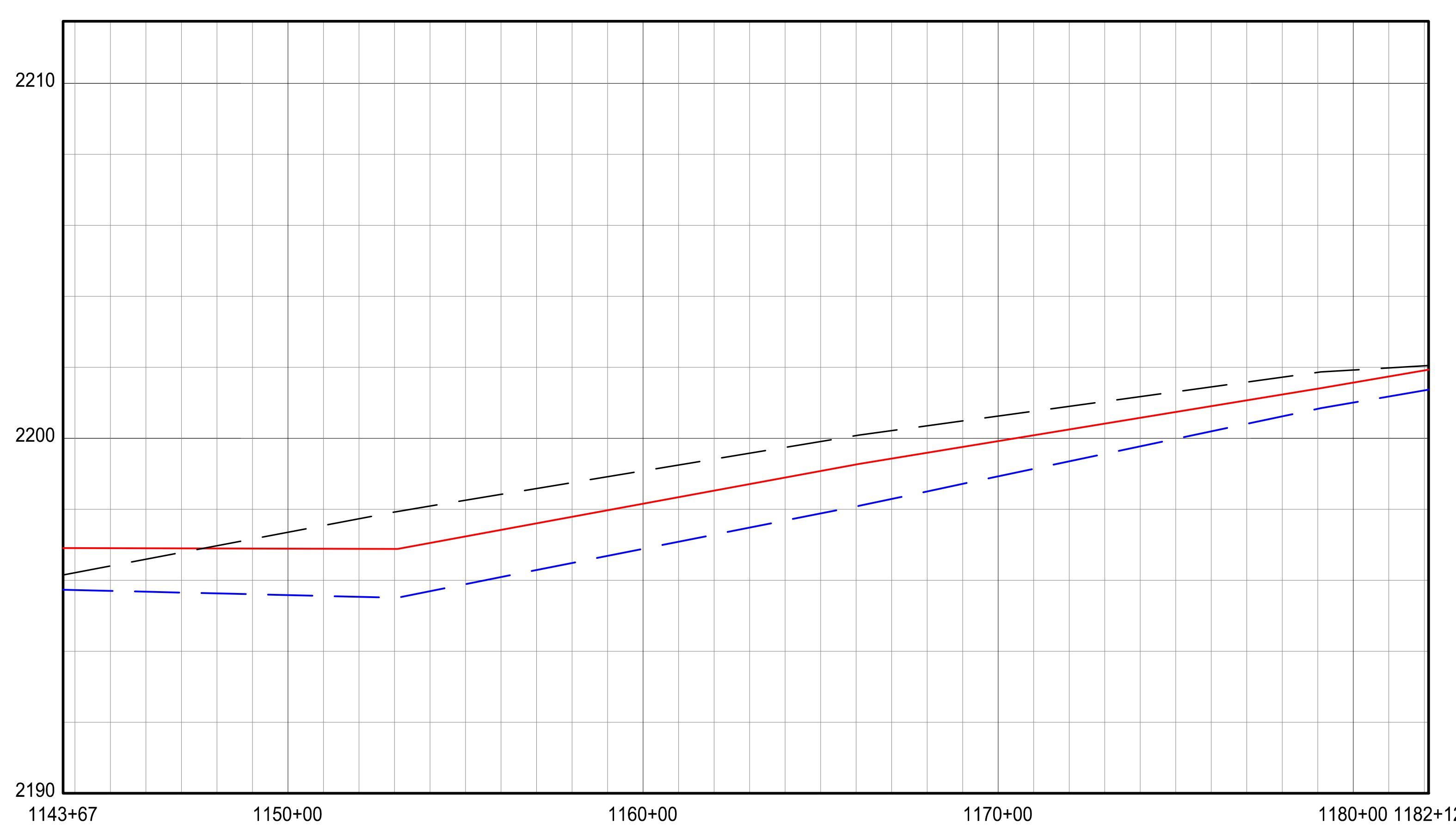
Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (19)

2021002022 — Project No.
1" = 500' — Horizontal Scale



WATERVATION

123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	Dwn.	Chkd.	Dsgn.	YY.MM.DD
	LTB	MAJ	LTB	22.06.30

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone

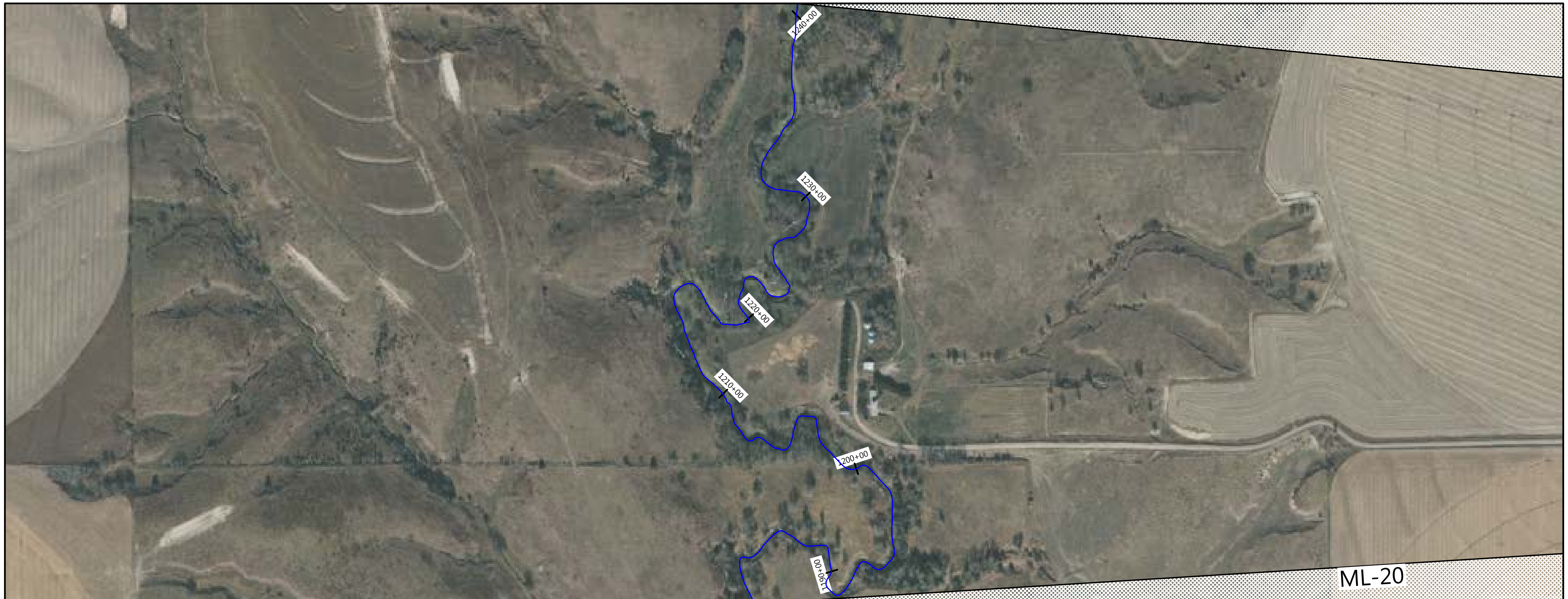
SEDIMENT TRANSPORT MODEL RESULTS

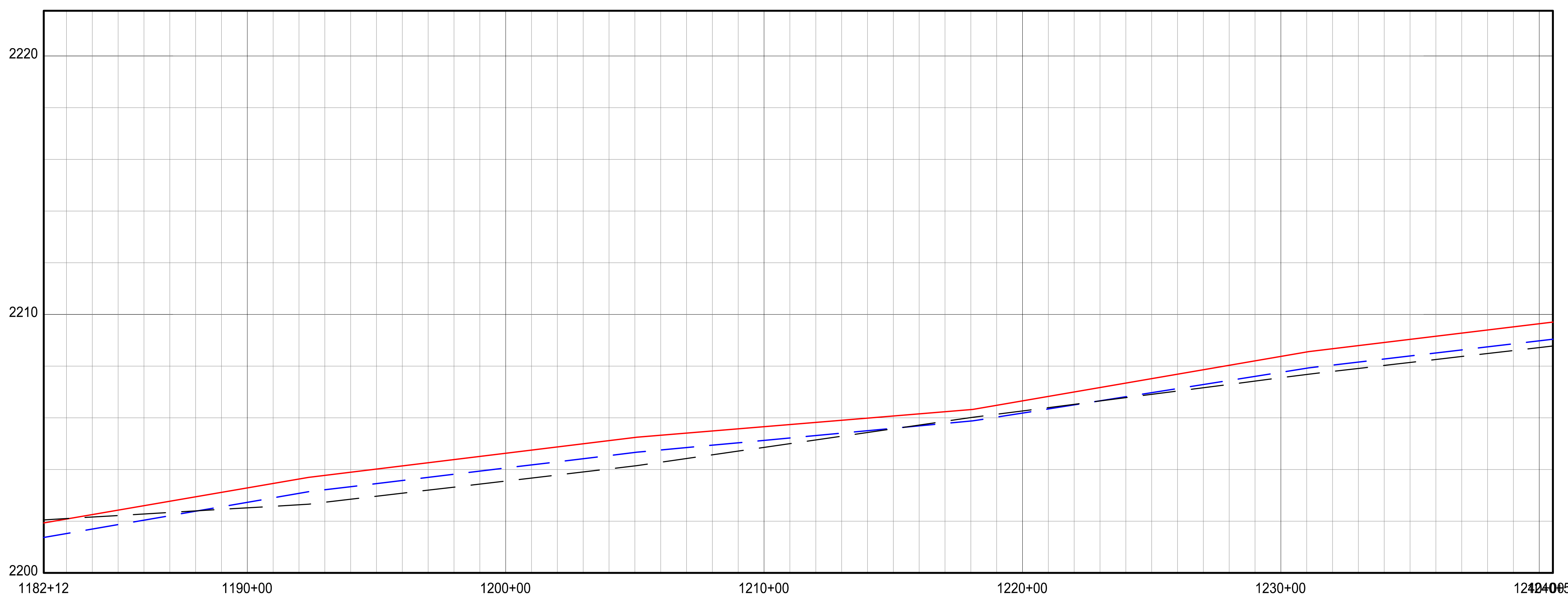
Sheet Name

SEDIMENT MODELING RESULTS - (20)

Project No.	Horizontal Scale
2021002022	1" = 500'

ORIGINAL SHEET - ANSI B





WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

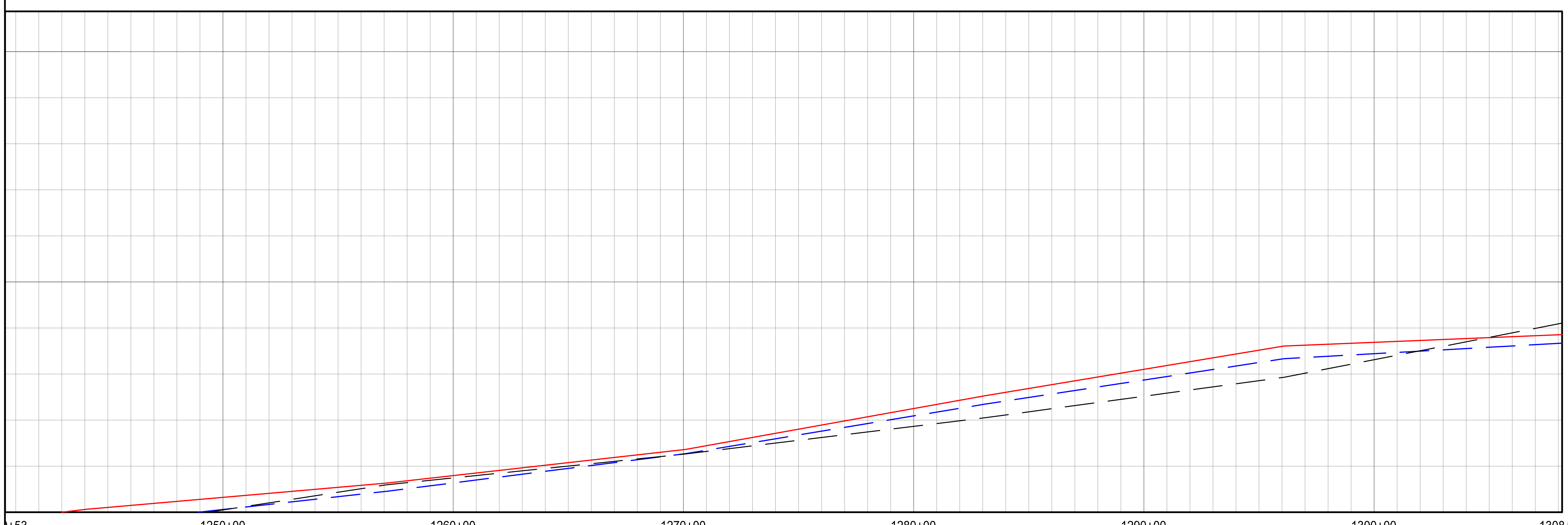
HOLDREGE, NE

Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (21)

2021002022	1" = 500'
Project No.	Horizontal Scale

ORIGINAL SHEET - ANSI B



ORIGINAL SHEET - ANSI B

WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

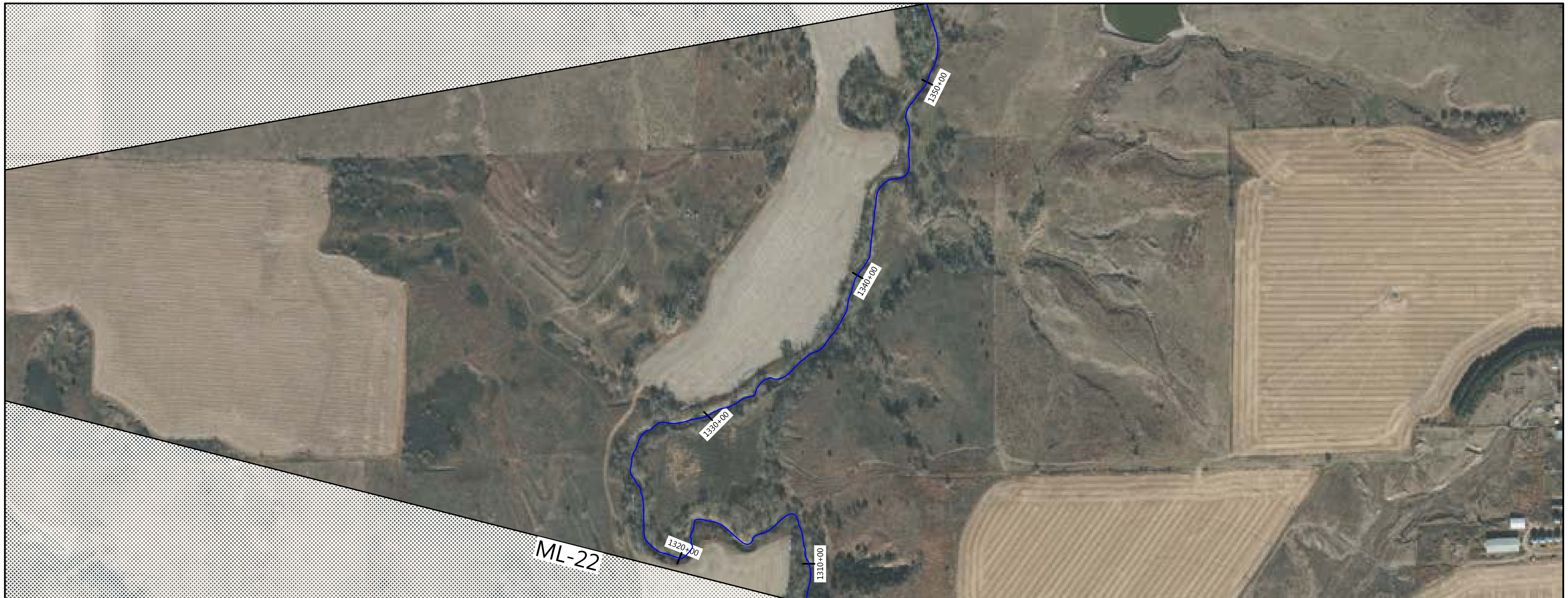
Project Milestone

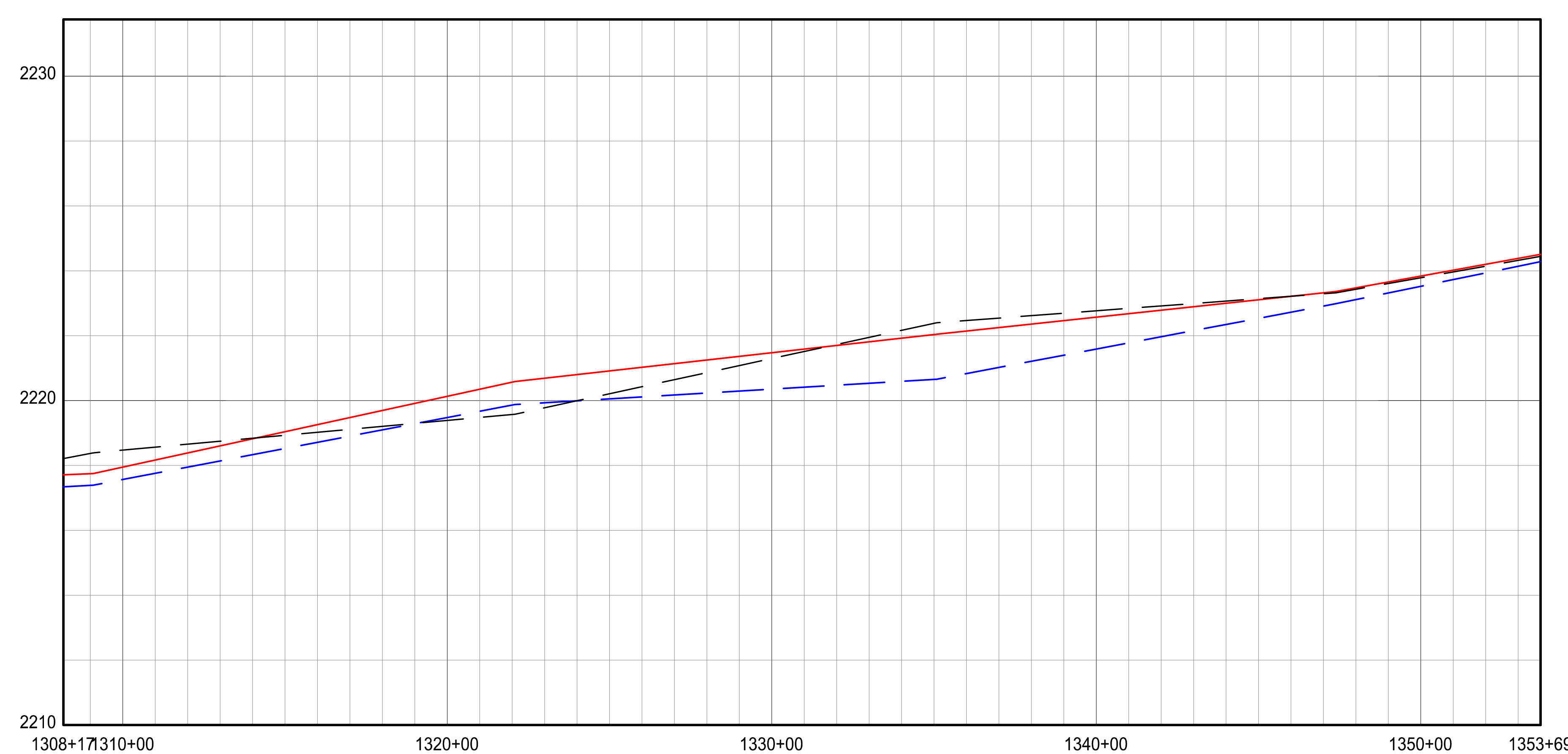
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name

SEDIMENT MODELING RESULTS - (22)

2021002022	1" = 500'
Project No.	Horizontal Scale





WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone

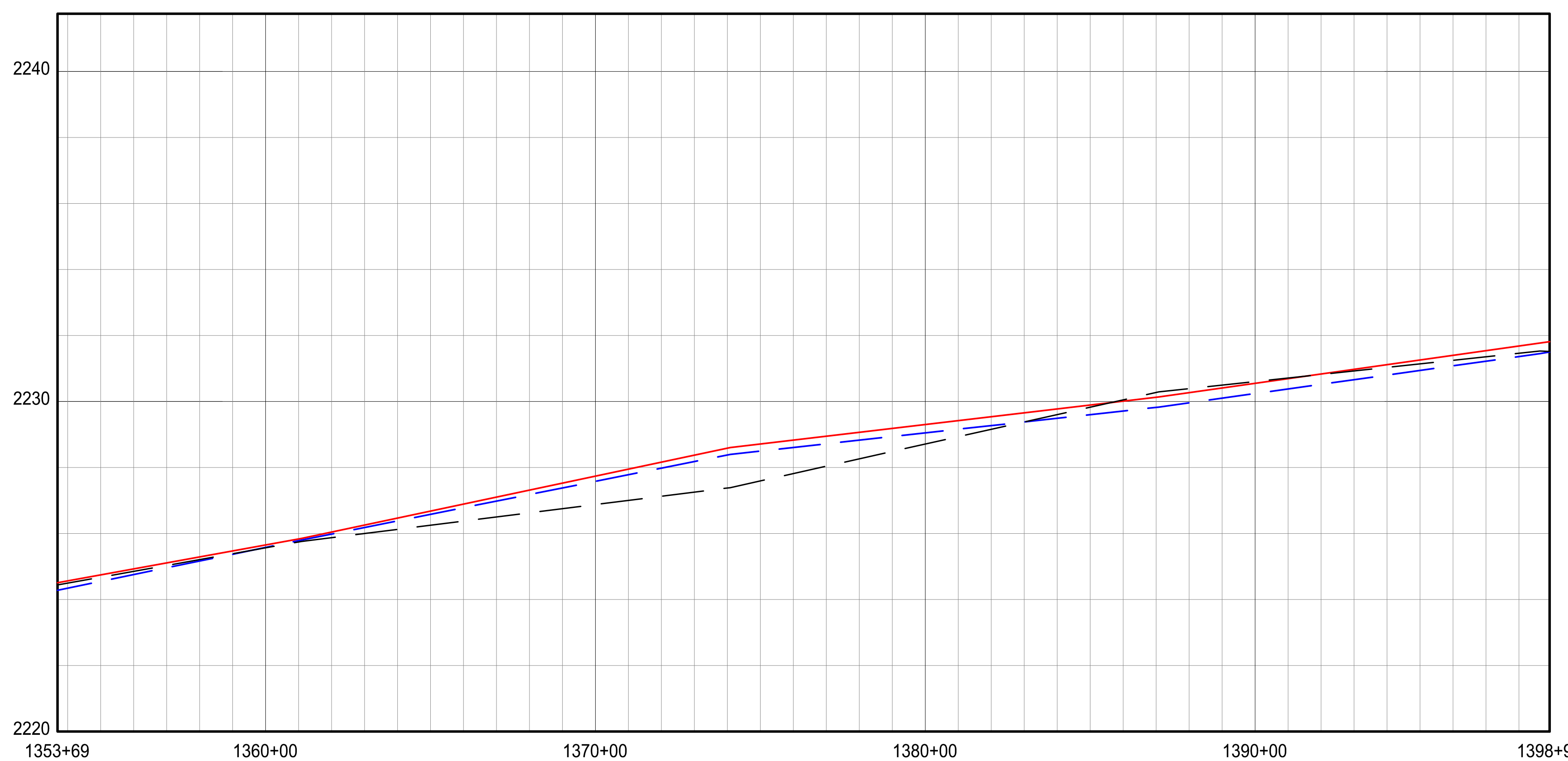
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name

SEDIMENT MODELING RESULTS - (23)

2021002022	1" = 500'
Project No.	Horizontal Scale

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision | By | Appd. | YY.MM.DD

Issued | By | Appd. | YY.MM.DD

File Name: | LTB Dwn. | MAJ Chkd. | LTB Dsgn. | 22.06.30 YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

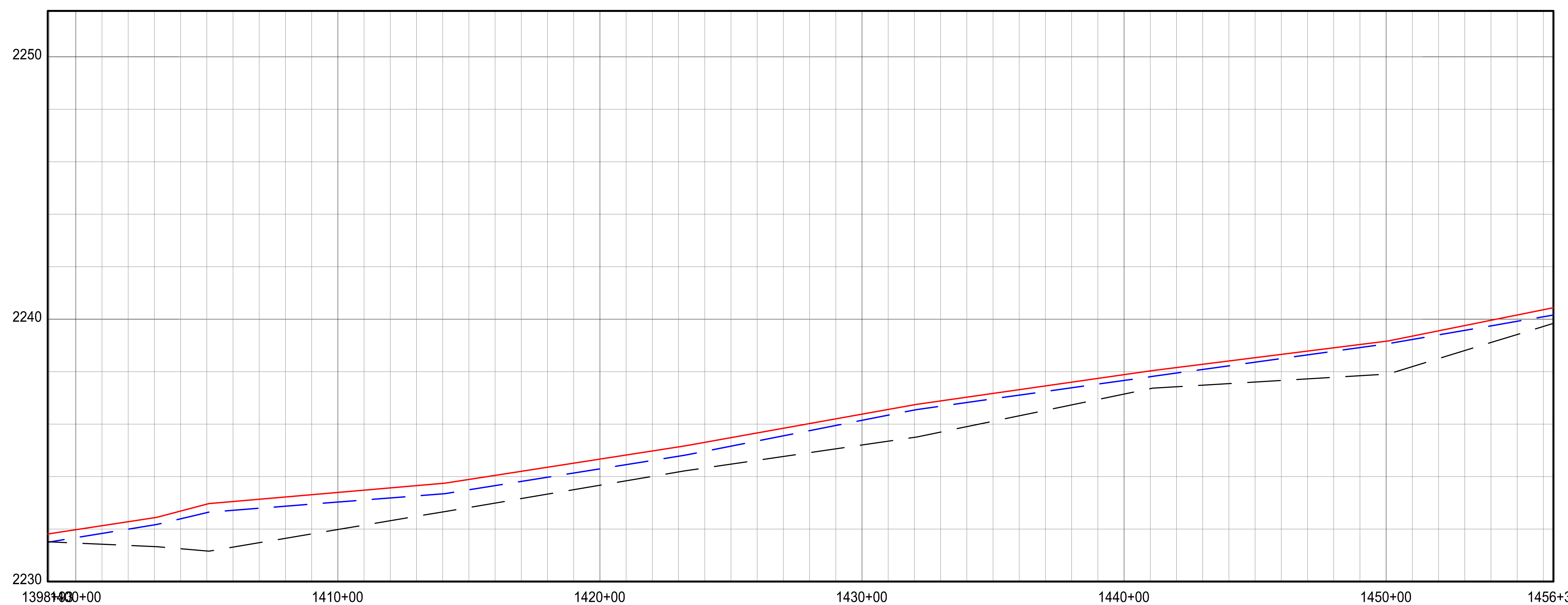
HOLDREGE, NE

Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (24)

2021002022 | 1" = 500'
Project No. | Horizontal Scale

ORIGINAL SHEET - ANSI B



WATERVATION

123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone

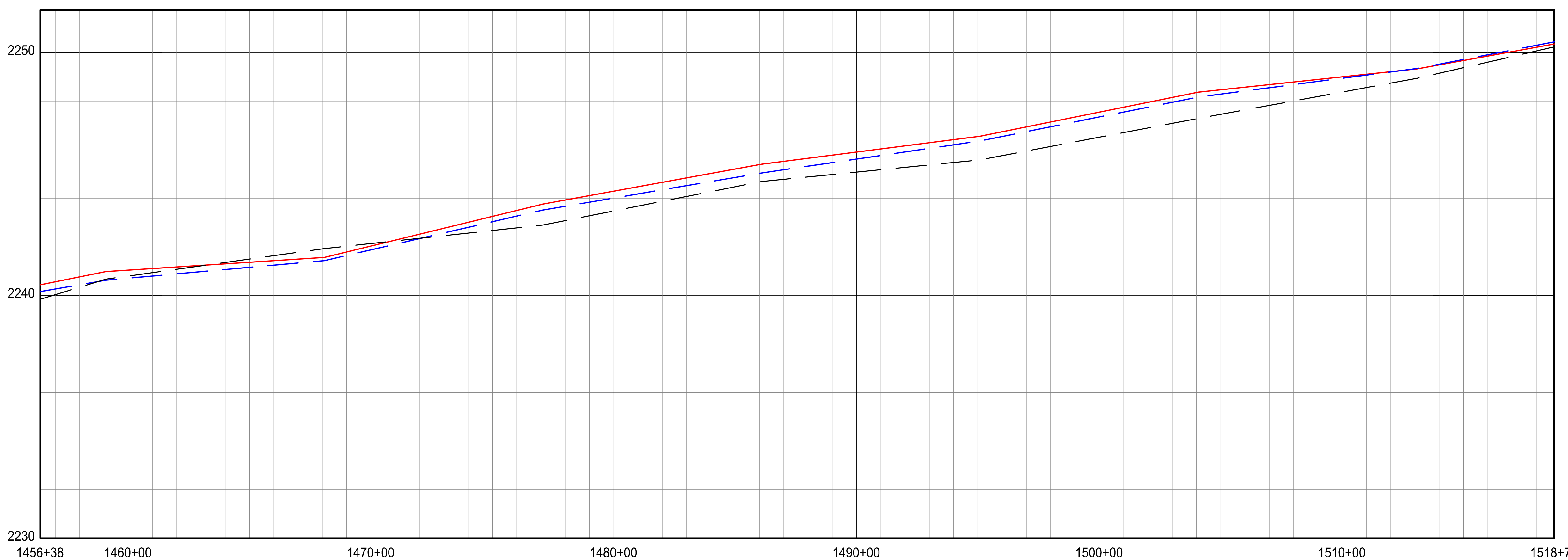
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name

SEDIMENT MODELING RESULTS - (25)

2021002022	1" = 500'
Project No.	Horizontal Scale

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	Dwn.	Chkd.	Dsgn.	YY.MM.DD
	LTB	MAJ	LTB	22.06.30

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone

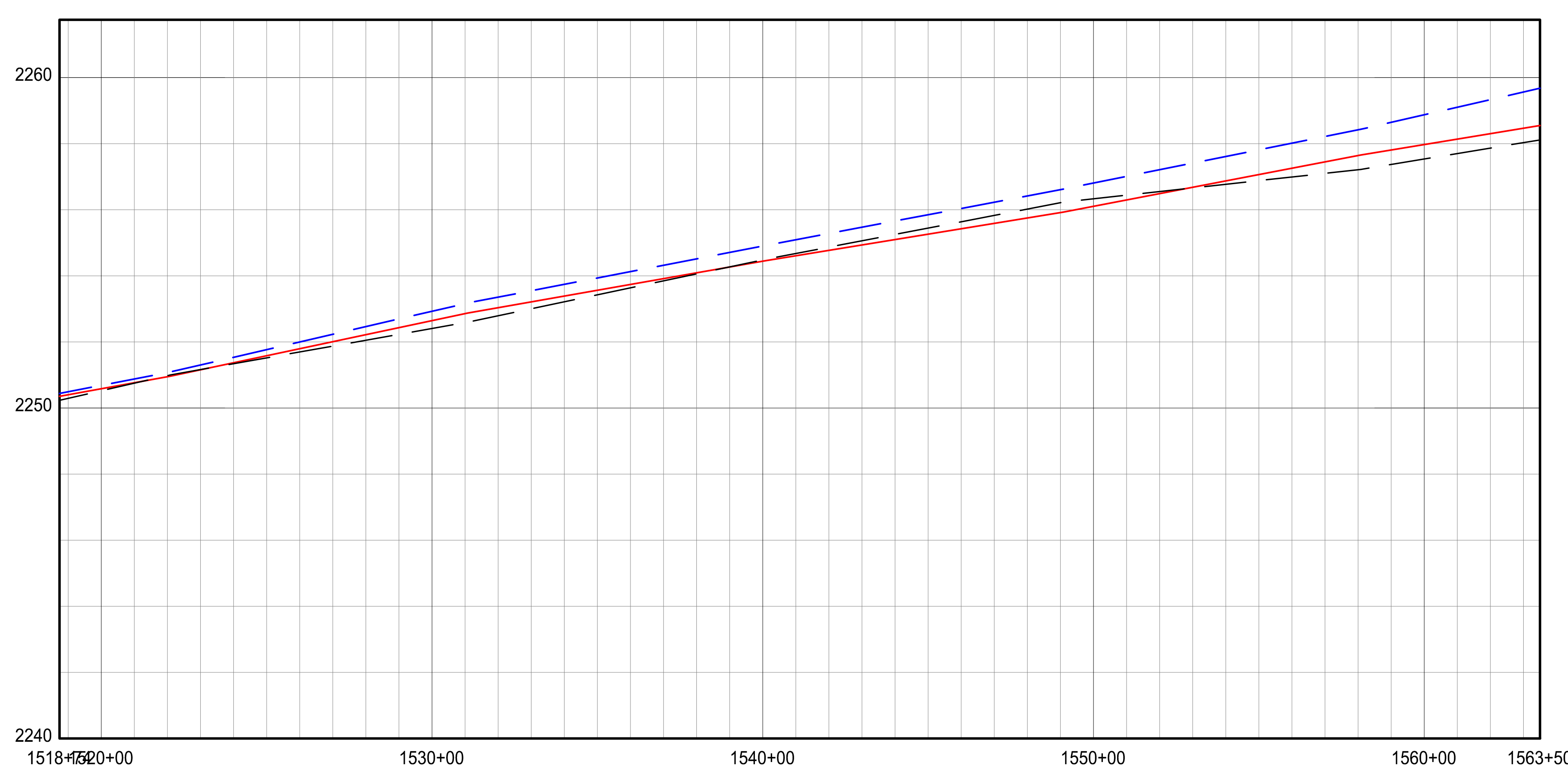
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name

SEDIMENT MODELING RESULTS - (26)

2021002022	1" = 500'
Project No.	Horizontal Scale

ORIGINAL SHEET - ANSI B



ORIGINAL SHEET - ANSI B

WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

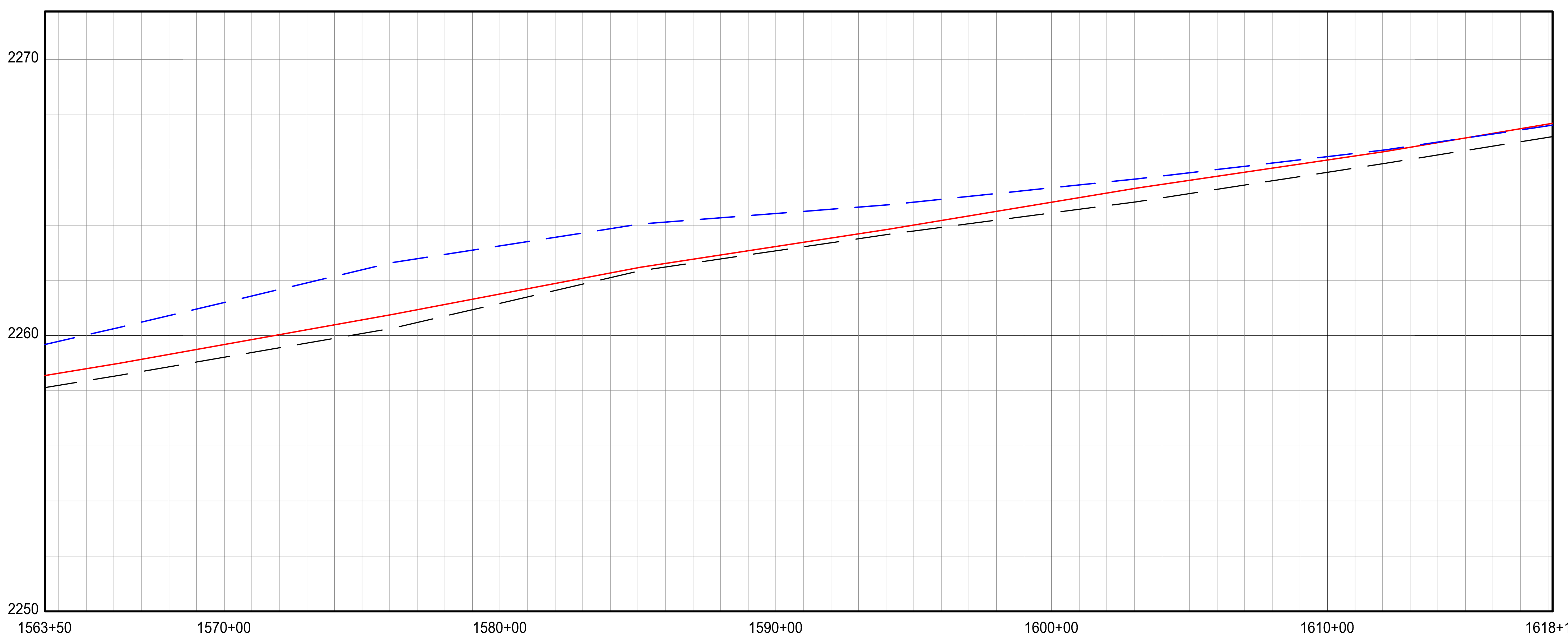
Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (27)

2021002022	1" = 500'
Project No.	Horizontal Scale



ORIGINAL SHEET - ANSI B

WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

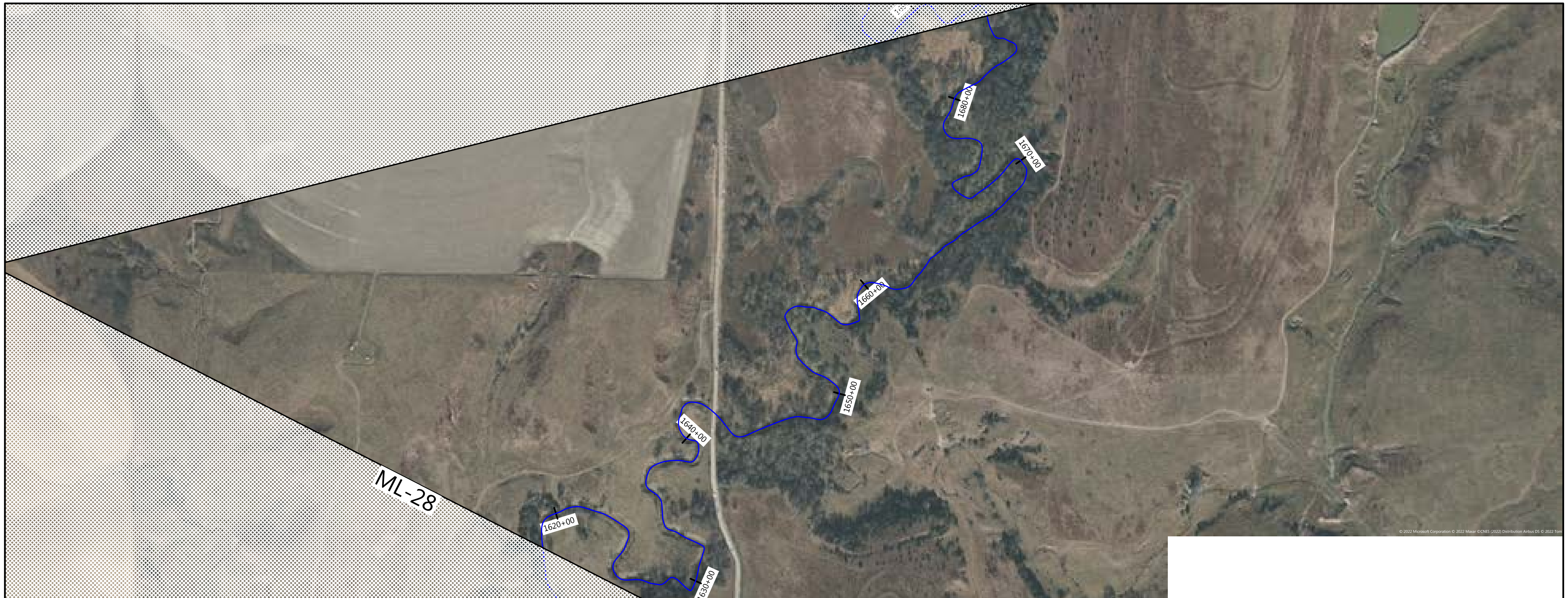
Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

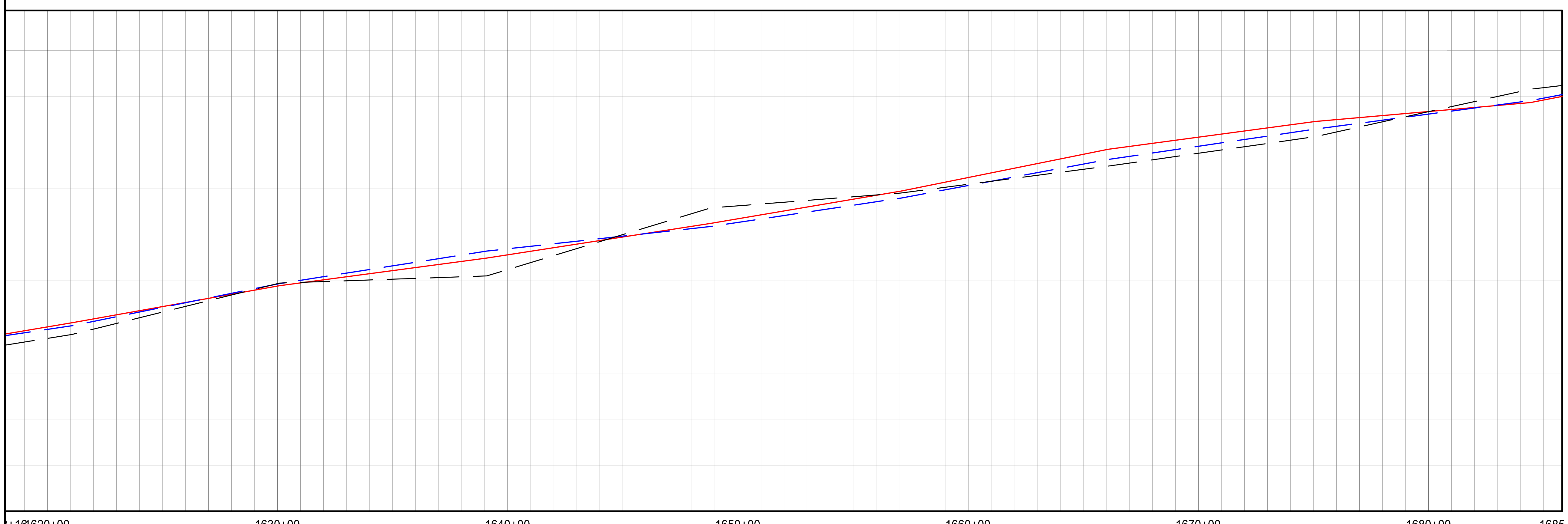
HOLDREGE, NE

Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (28)

2021002022	1" = 500'
Project No.	Horizontal Scale





WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

- THALWEG PROFILE (JANUARY 1, 2017)
- THALWEG PROFILE (DECEMBER 31, 2017)
- THALWEG PROFILE ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone

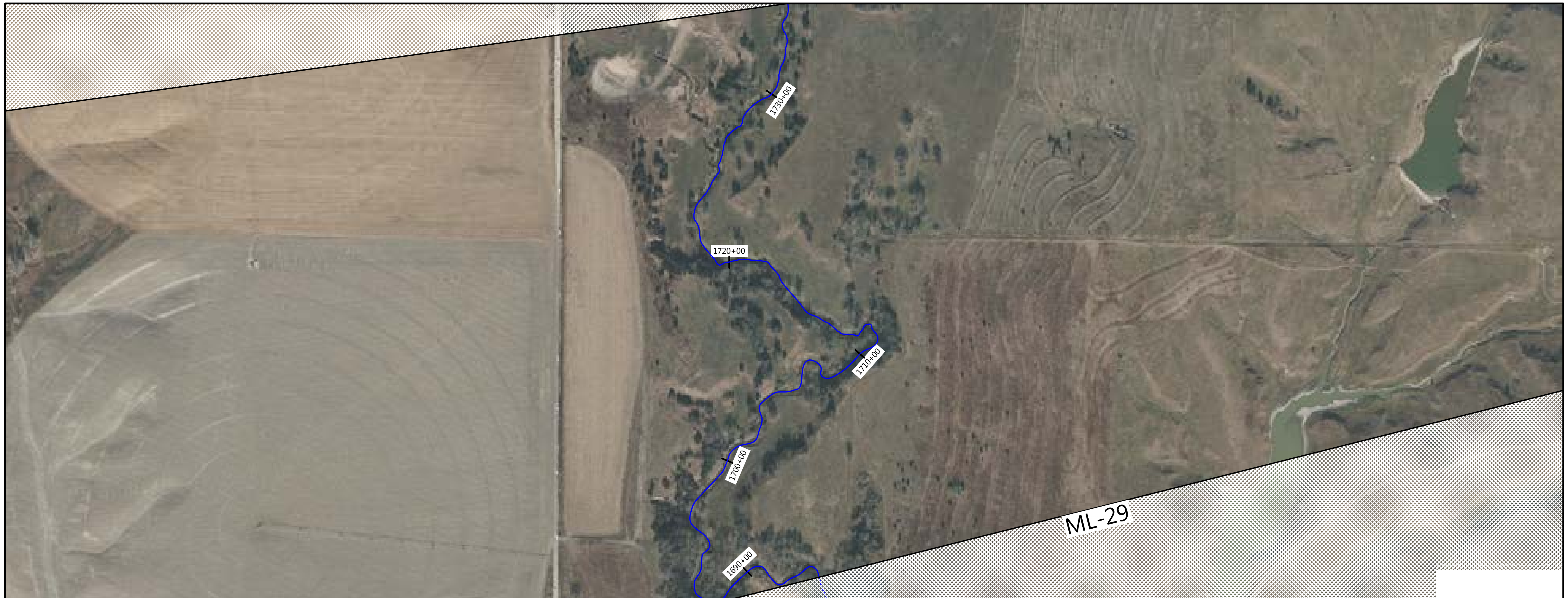
SEDIMENT TRANSPORT MODEL RESULTS

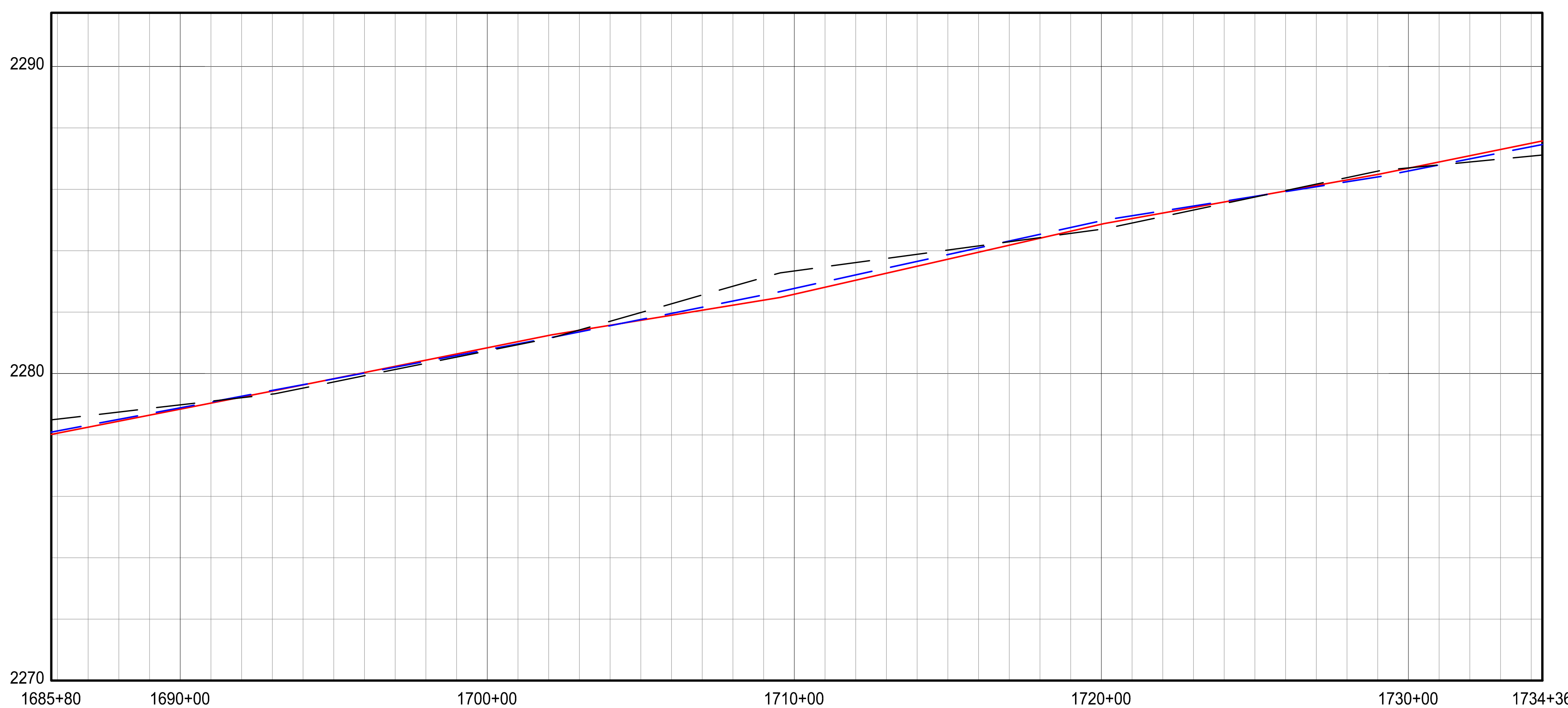
Sheet Name

SEDIMENT MODELING RESULTS - (29)

2021002022	1" = 500'
Project No.	Horizontal Scale

ORIGINAL SHEET - ANSI B





WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone

SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name

SEDIMENT MODELING RESULTS - (30)

2021002022 — 1" = 500'

Project No. — Horizontal Scale

Sheet 32 of 50

ORIGINAL SHEET - ANSI B

WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

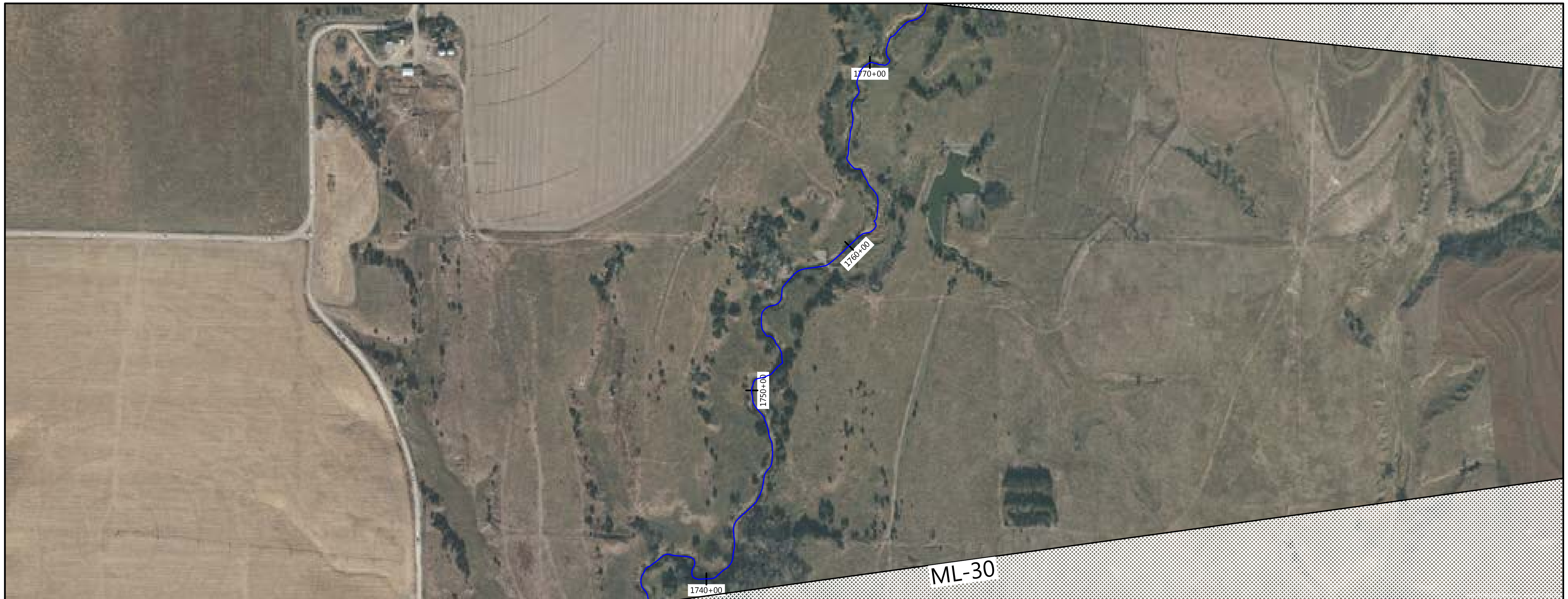
0 500 1000

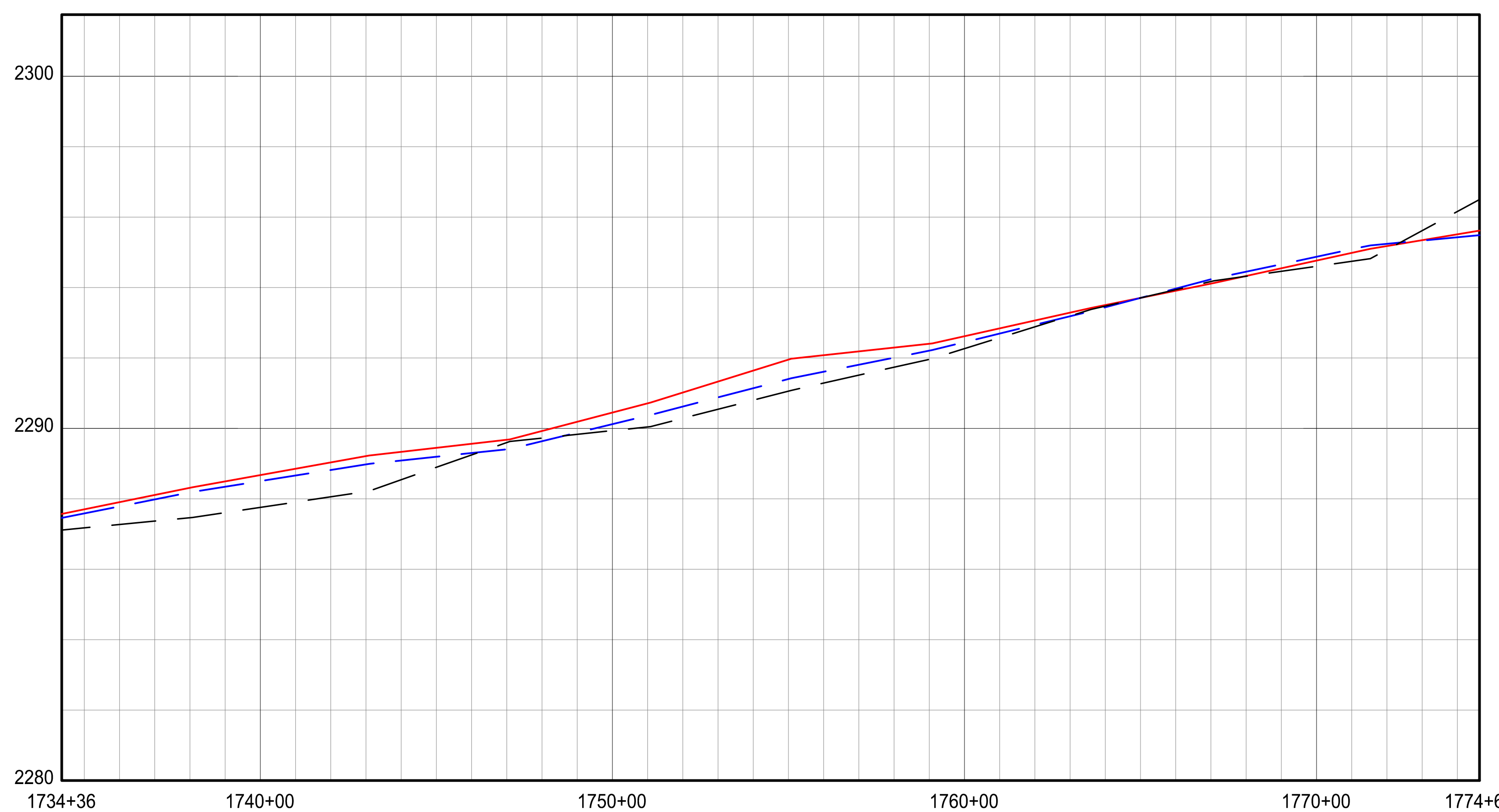
Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE





Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

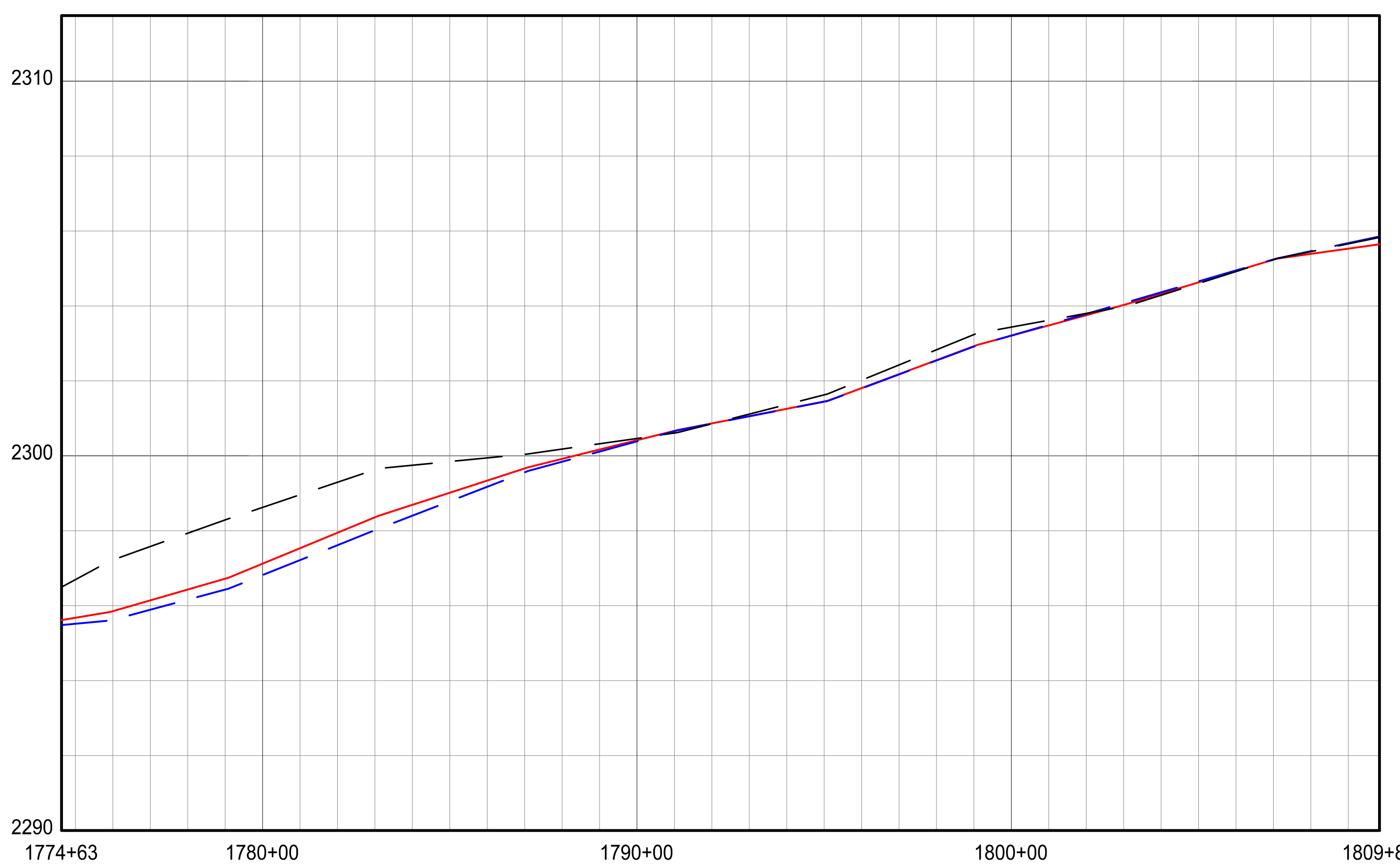
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (31)

2021002022 1" = 500'
Project No. Horizontal Scale

Sheet 33 of 50

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

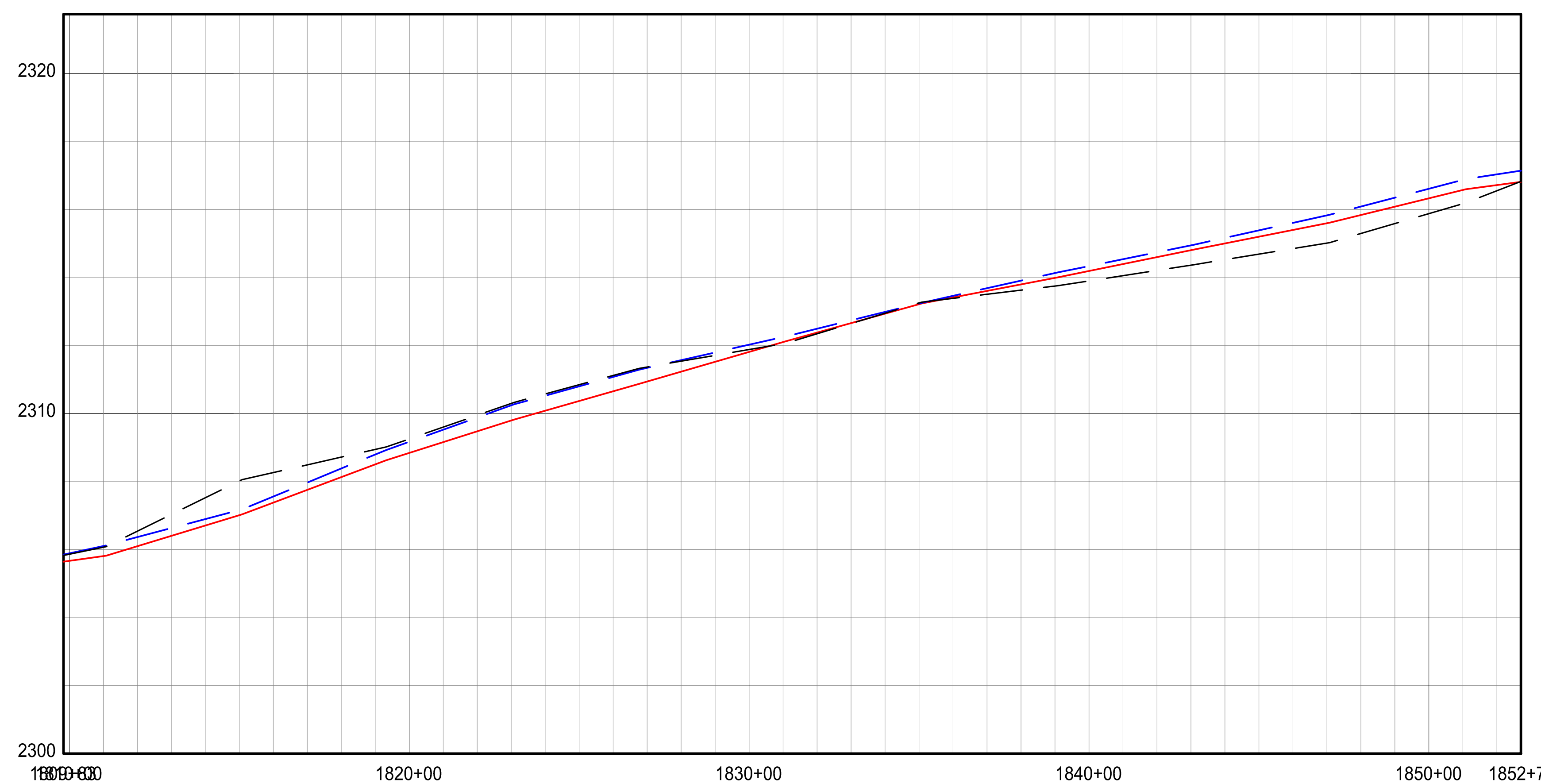
HOLDREGE, NE

Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (32)

2021002022 — Project No.
1" = 500' — Horizontal Scale

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

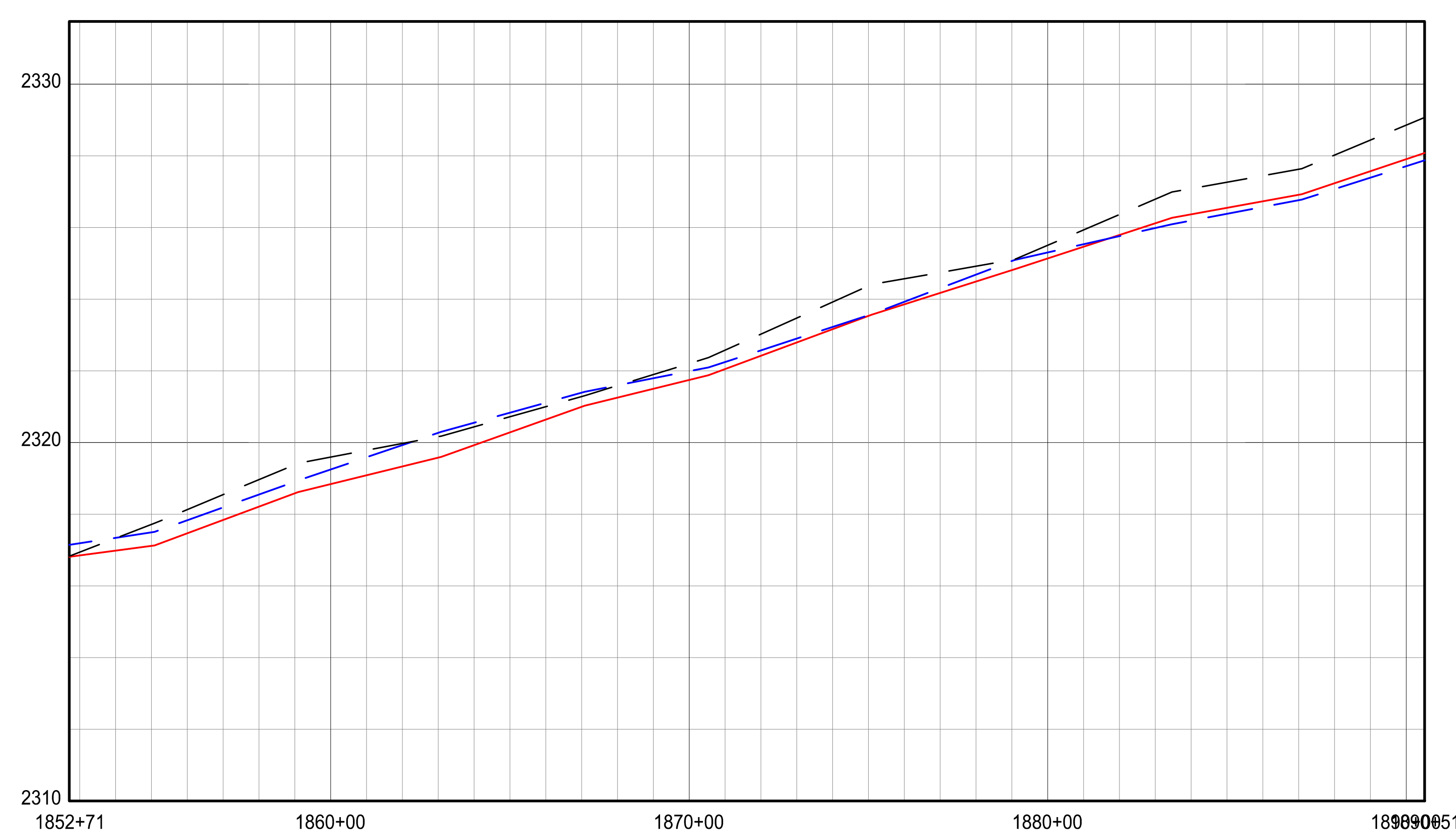
HOLDREGE, NE

Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (33)

2021002022 1" = 500'
Project No. Horizontal Scale

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

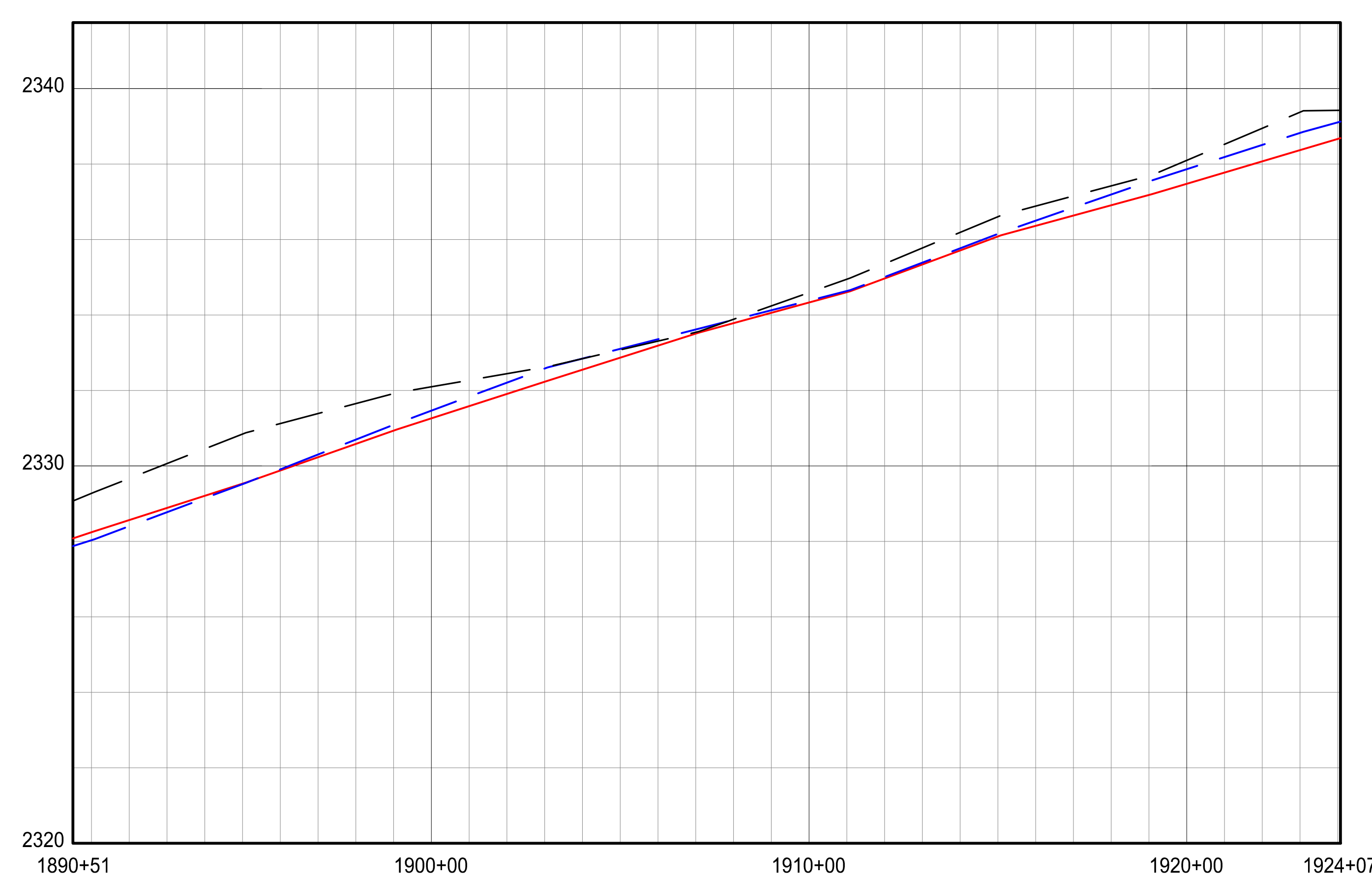
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (34)

2021002022 1" = 500'
Project No. Horizontal Scale

Sheet 36 of 50

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	Dwn.	Chkd.	Dsgn.	YY.MM.DD
	LTB	MAJ	LTB	22.06.30

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

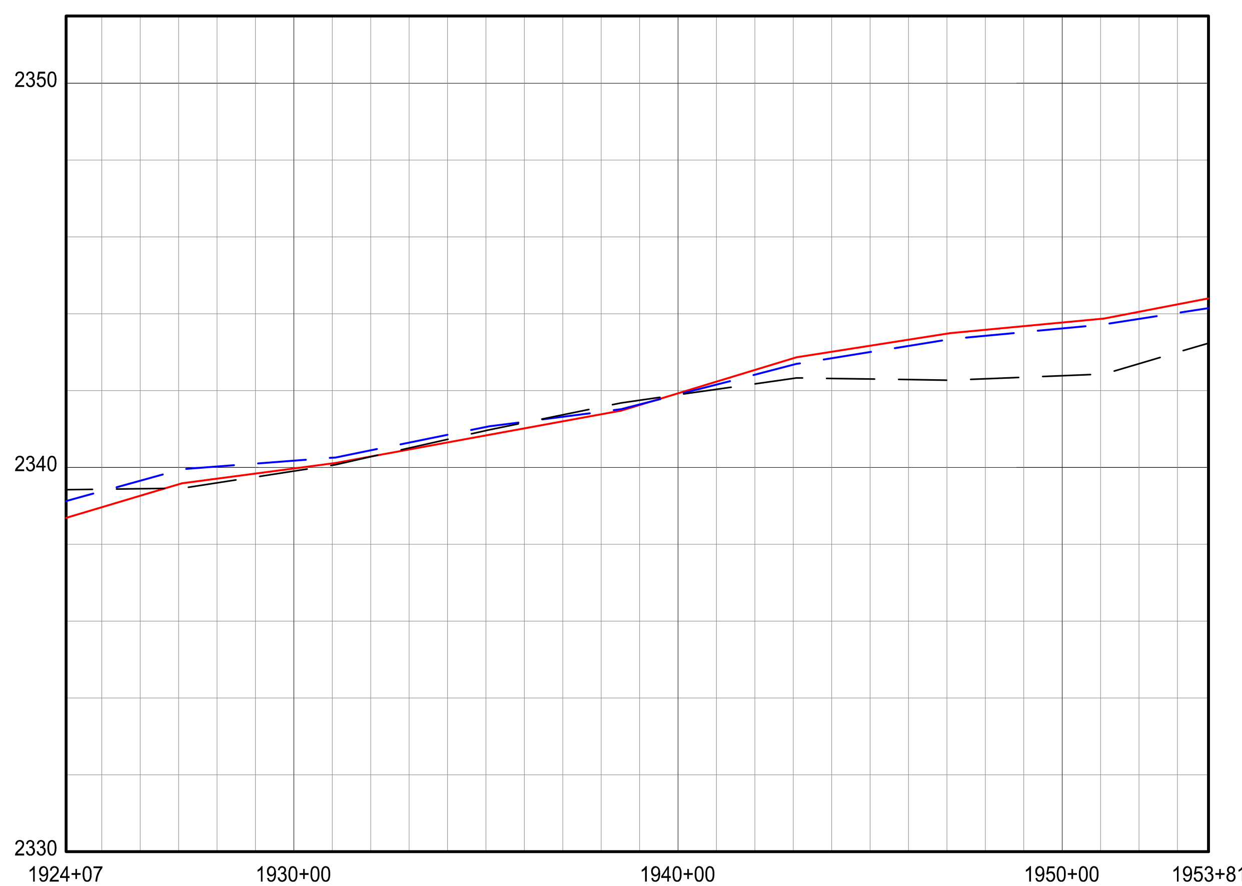
HOLDREGE, NE

Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (35)

Project No.	Horizontal Scale
2021002022	1" = 500'

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

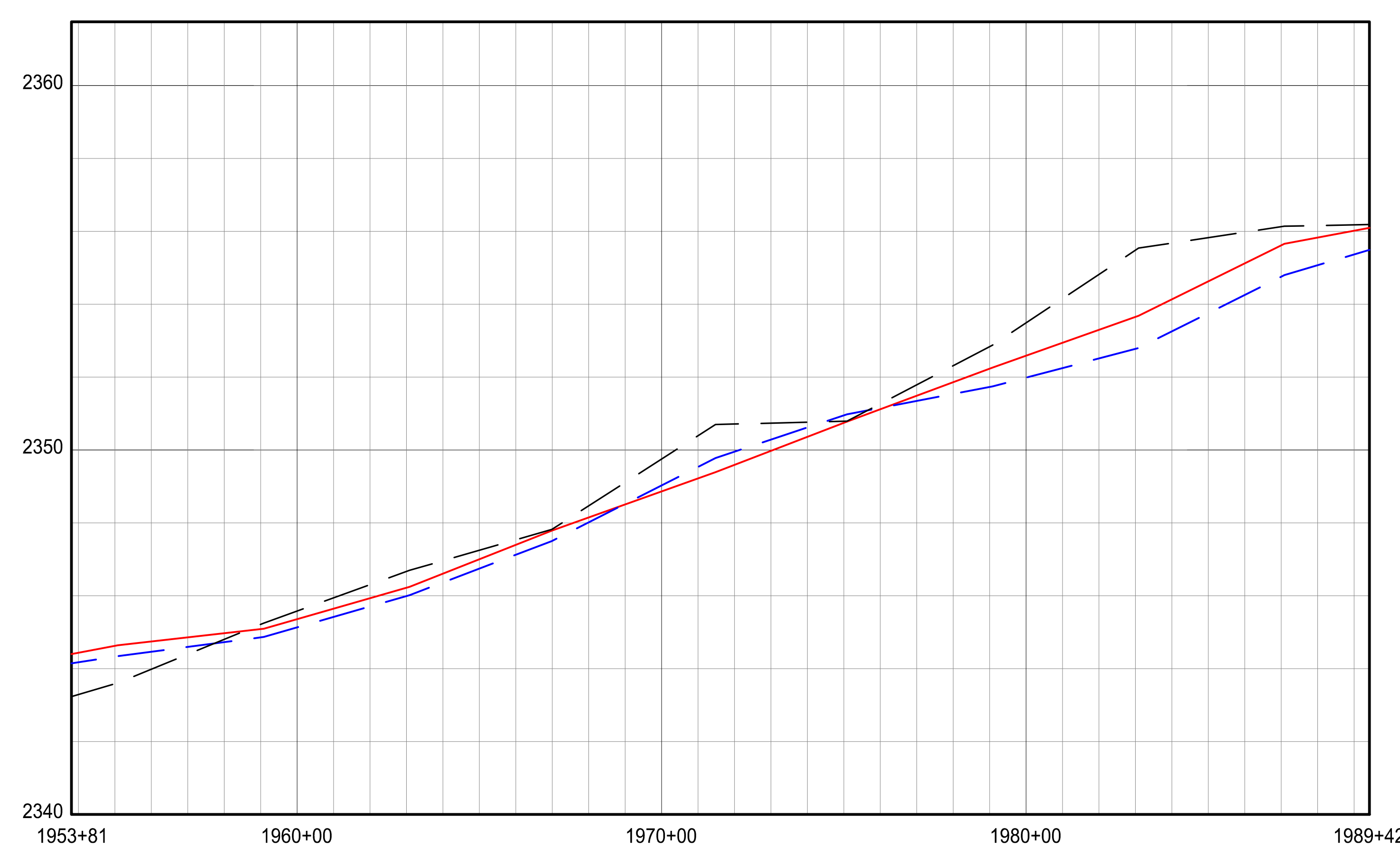
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (36)

2021002022	1" = 500'
Project No.	Horizontal Scale

Sheet 38 of 50

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	Dwn.	Chkd.	Dsgn.	YY.MM.DD
	LTB	MAJ	LTB	22.06.30

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

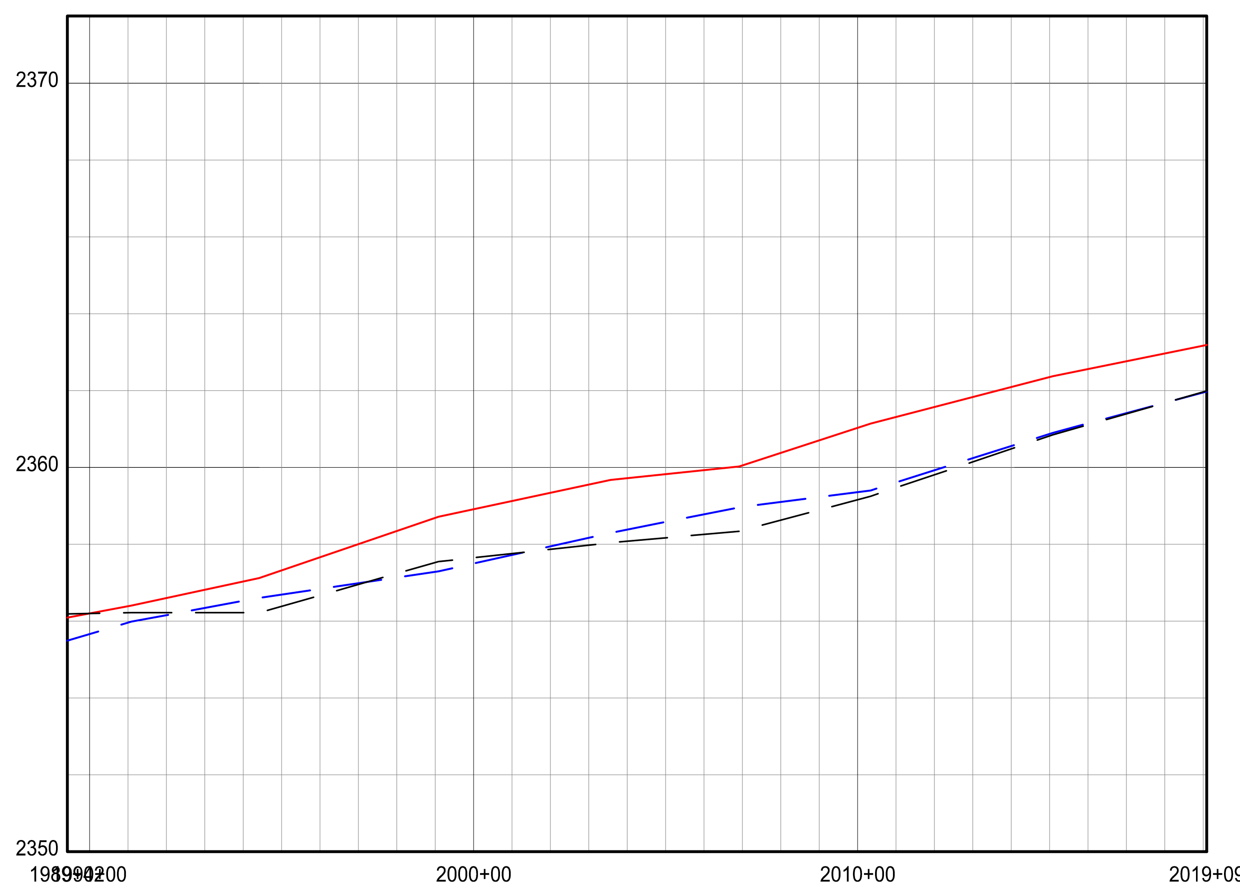
HOLDREGE, NE

Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (37)

2021002022 1" = 500'
Project No. Horizontal Scale

ORIGINAL SHEET - ANSI B



WATERVATION

123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone

SEDIMENT TRANSPORT MODEL RESULTS

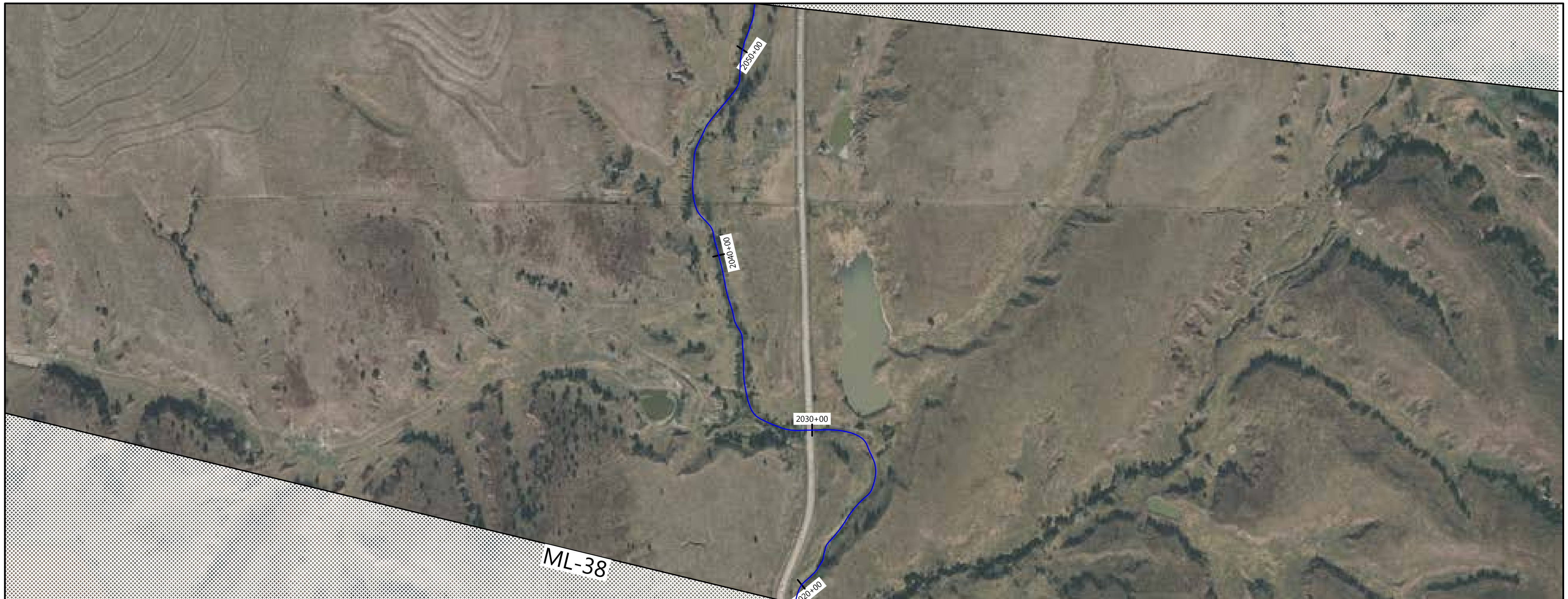
Sheet Name

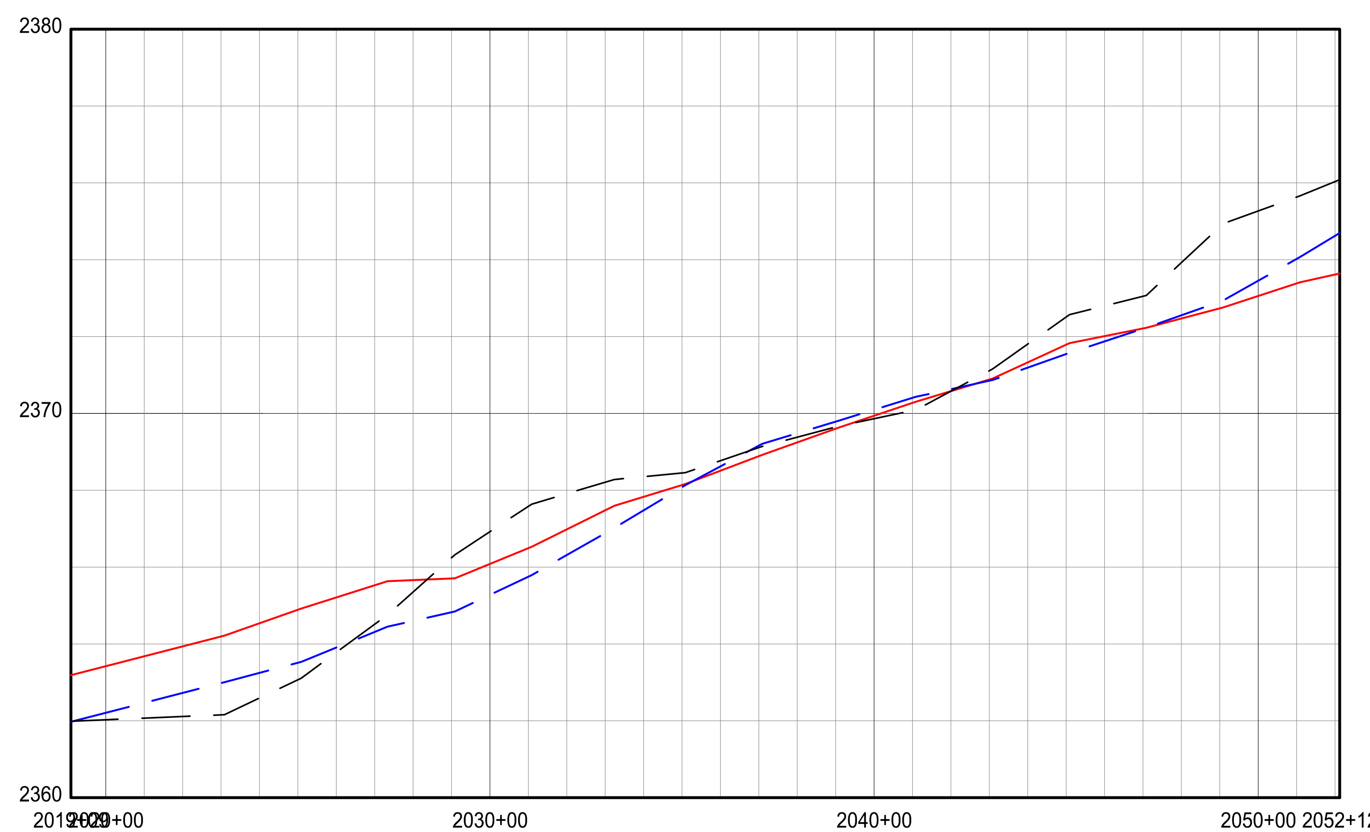
SEDIMENT MODELING RESULTS - (38)

2021002022	1" = 500'
Project No.	Horizontal Scale

Sheet 40 of 50

ORIGINAL SHEET - ANSI B





WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

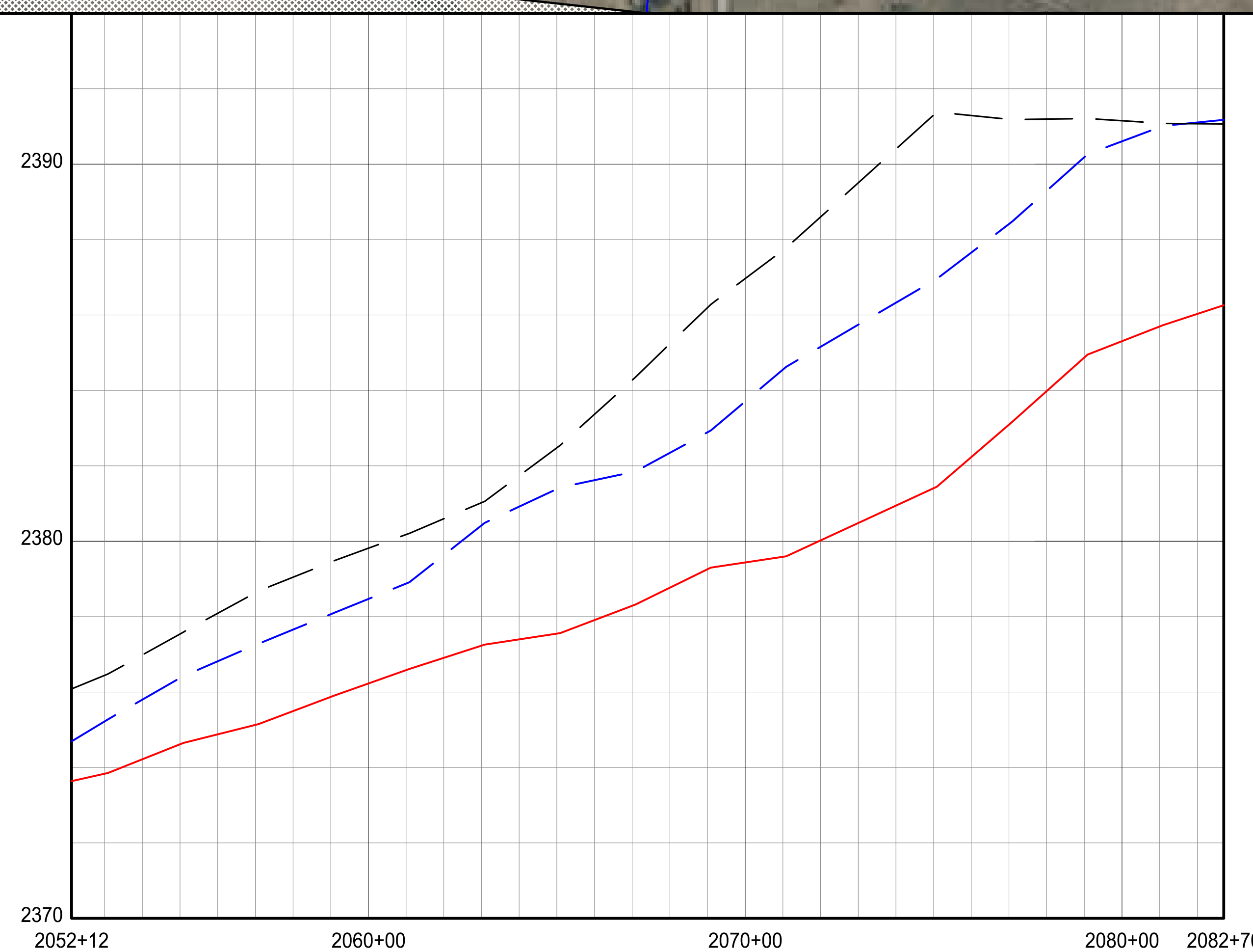
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (39)

2021002022 1" = 500'
Project No. Horizontal Scale

Sheet 41 of 50

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

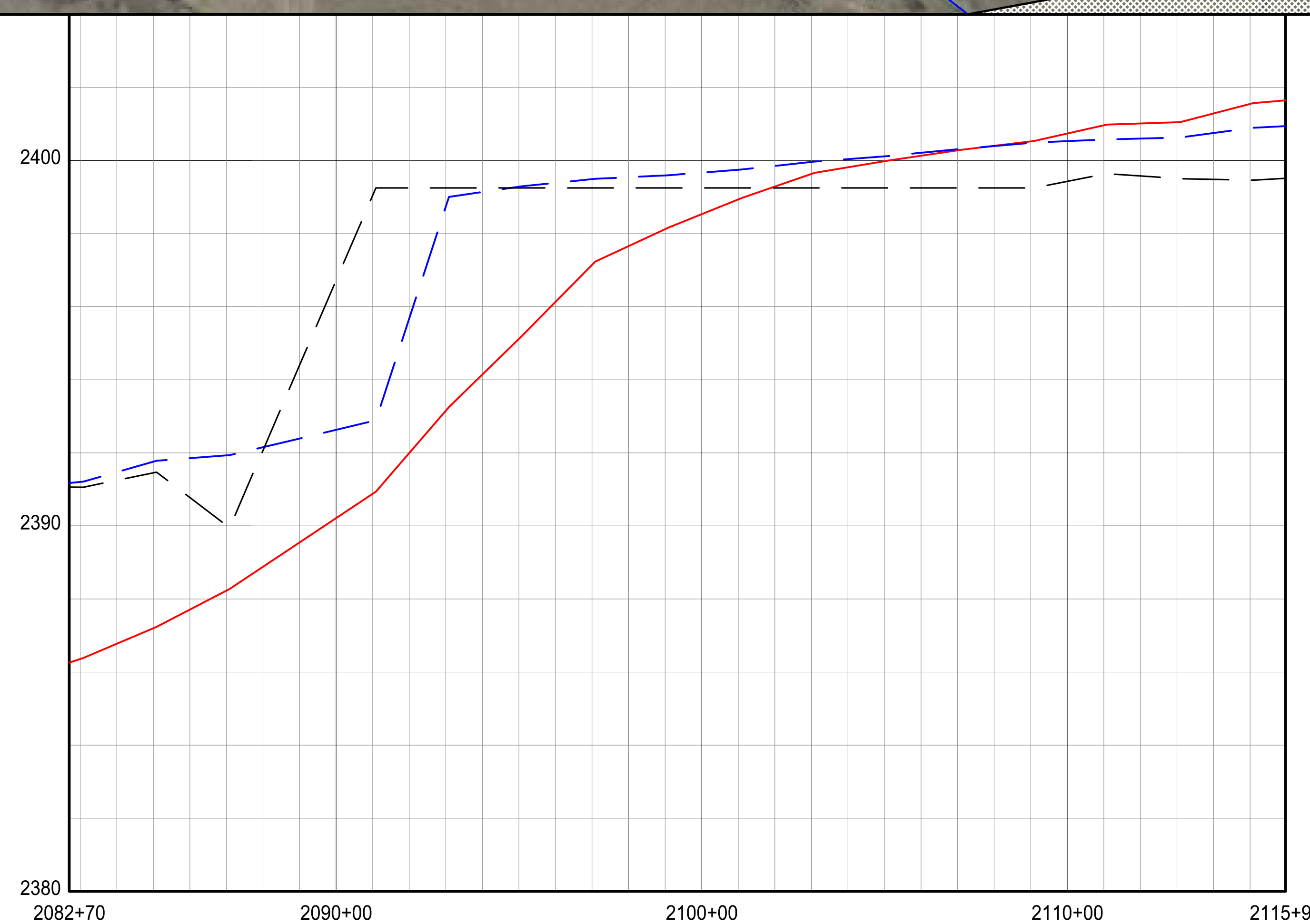
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (40)

2021002022	1" = 500'
Project No.	Horizontal Scale

Sheet 42 of 50

ORIGINAL SHEET - ANSI B



WATERVATION

123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

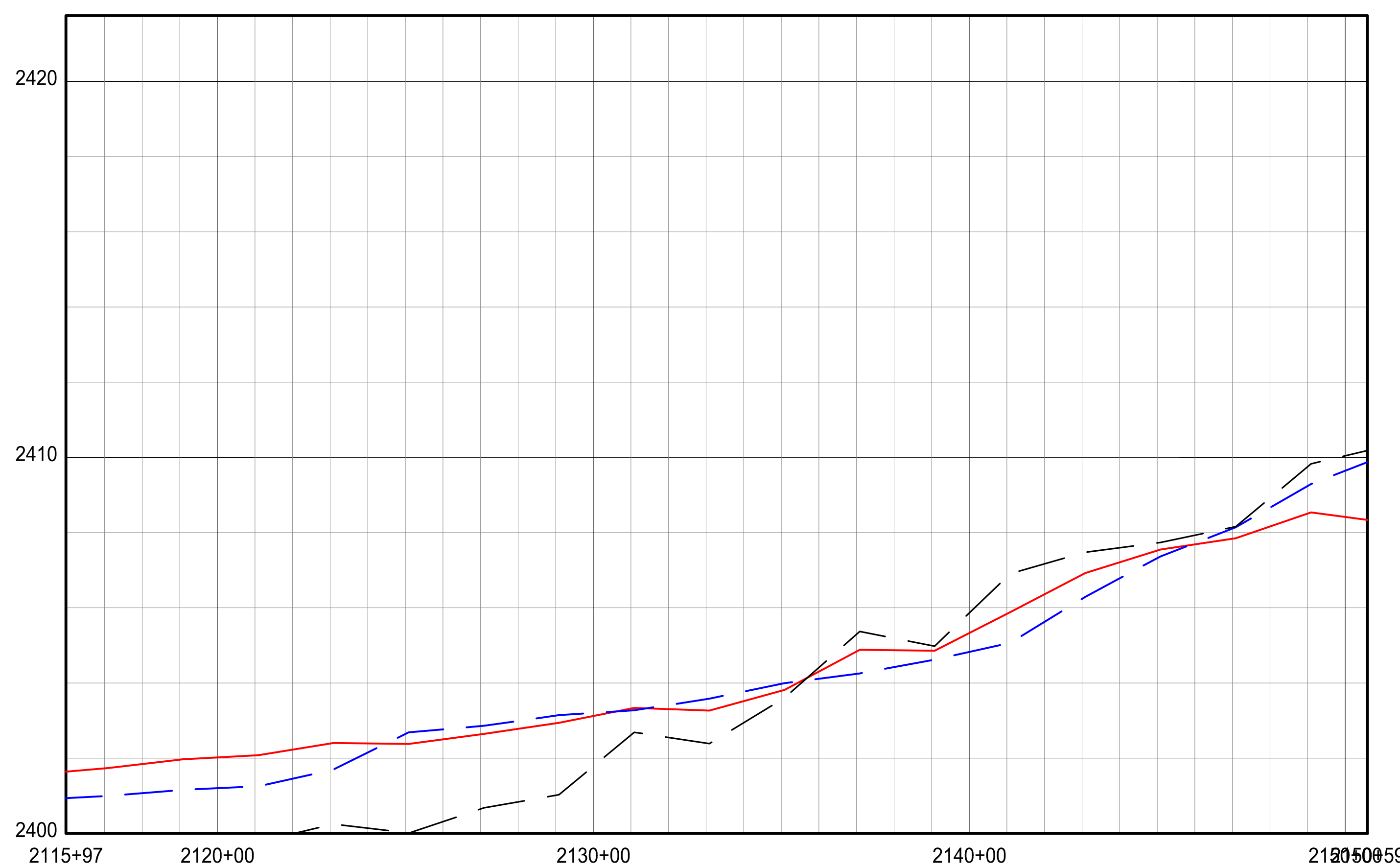
Project Milestone

SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name

SEDIMENT MODELING RESULTS - (41)

2021002022	1" = 500'
Project No.	Horizontal Scale



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	Dwn.	Chkd.	Dsgn.	YY.MM.DD
	LTB	MAJ	LTB	22.06.30

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone

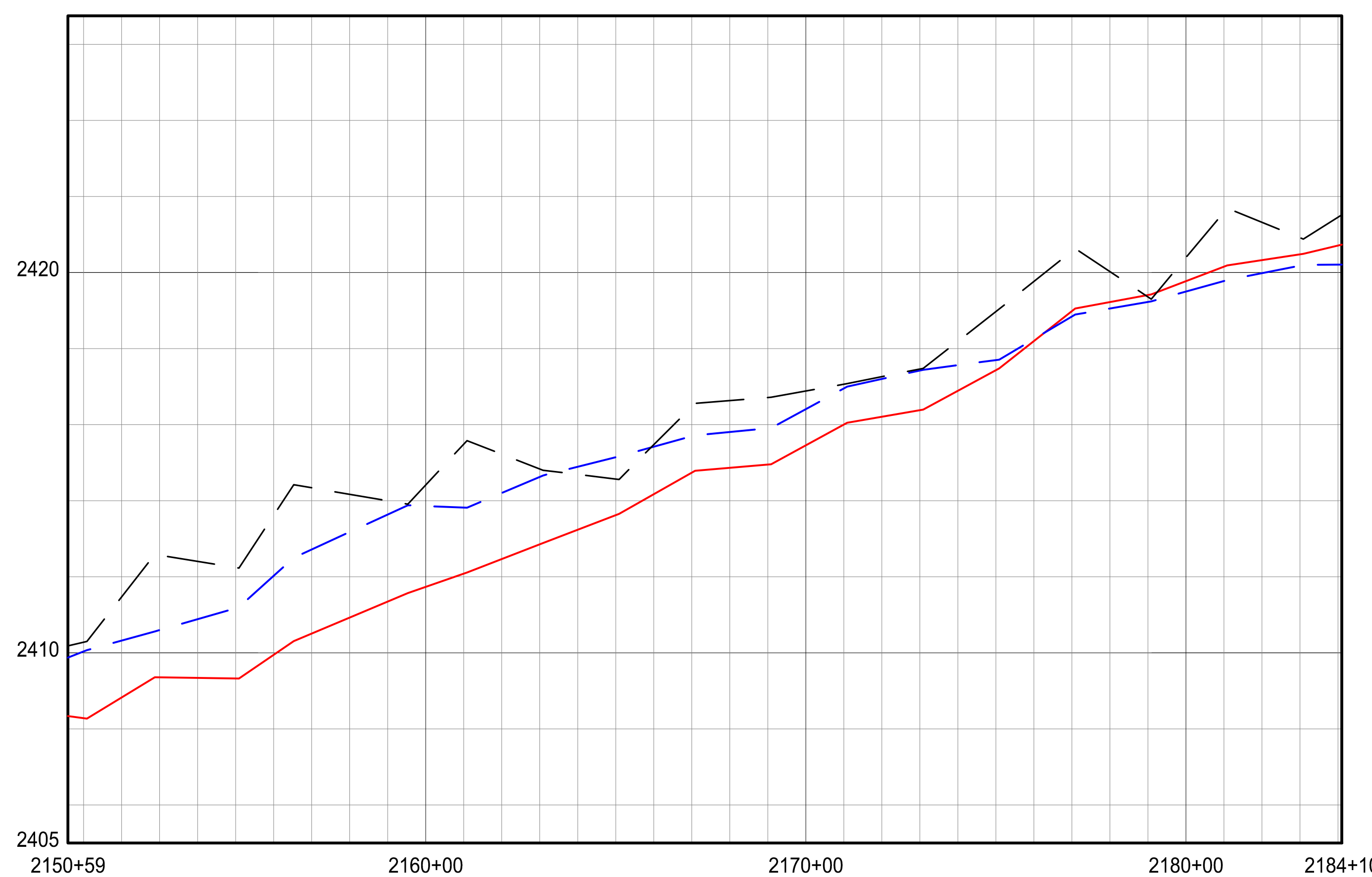
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name

SEDIMENT MODELING RESULTS - (42)

2021002022	1" = 500'
Project No.	Horizontal Scale

ORIGINAL SHEET - ANSI B



WATERVATION

123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	Dwn.	Chkd.	Dsgn.	YY.MM.DD
	LTB	MAJ	LTB	22.06.30

Permit-Seal

Client/Project

NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone

SEDIMENT TRANSPORT MODEL RESULTS

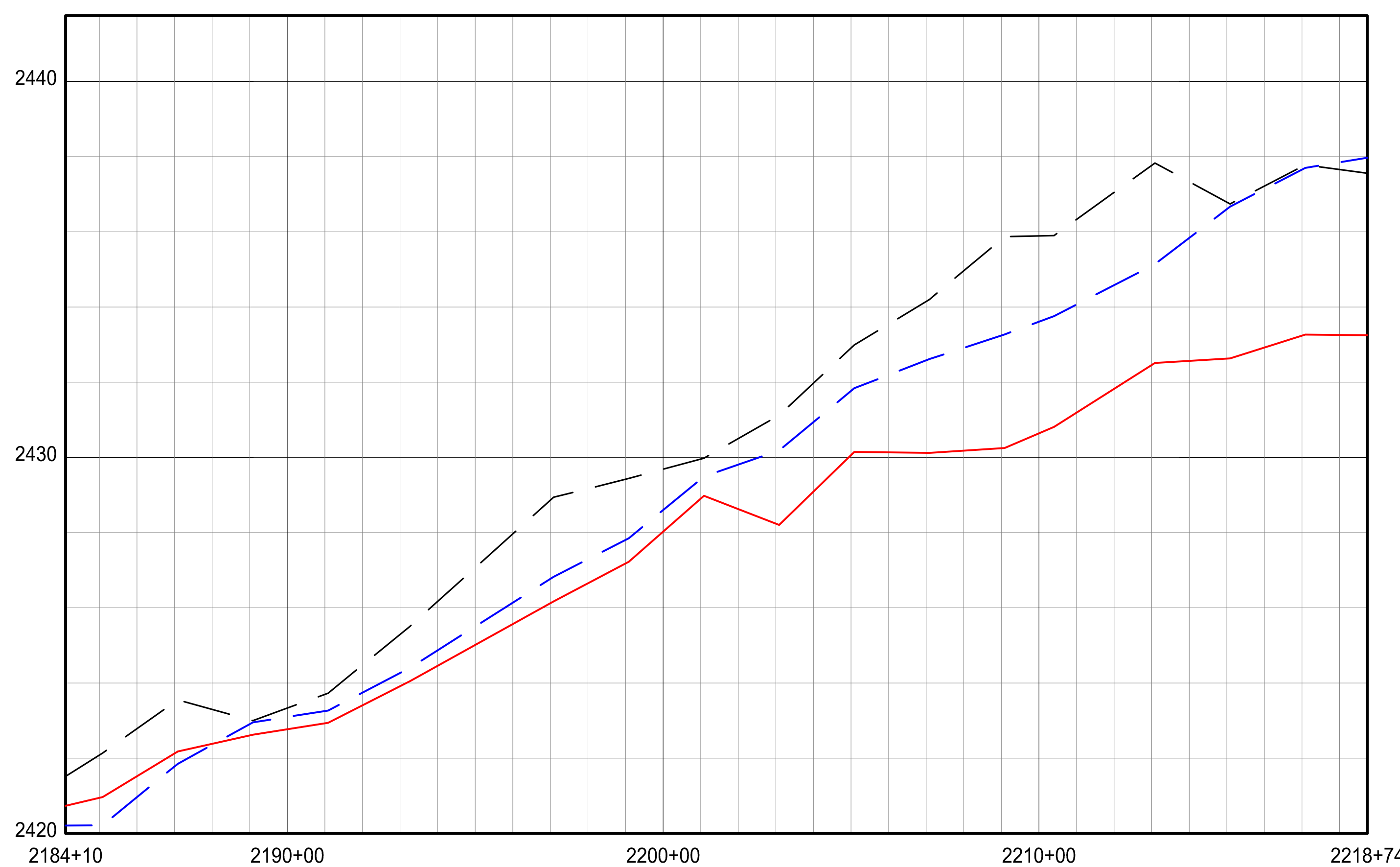
Sheet Name

SEDIMENT MODELING RESULTS - (43)

2021002022	1" = 500'
Project No.	Horizontal Scale

Sheet 45 of 50

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

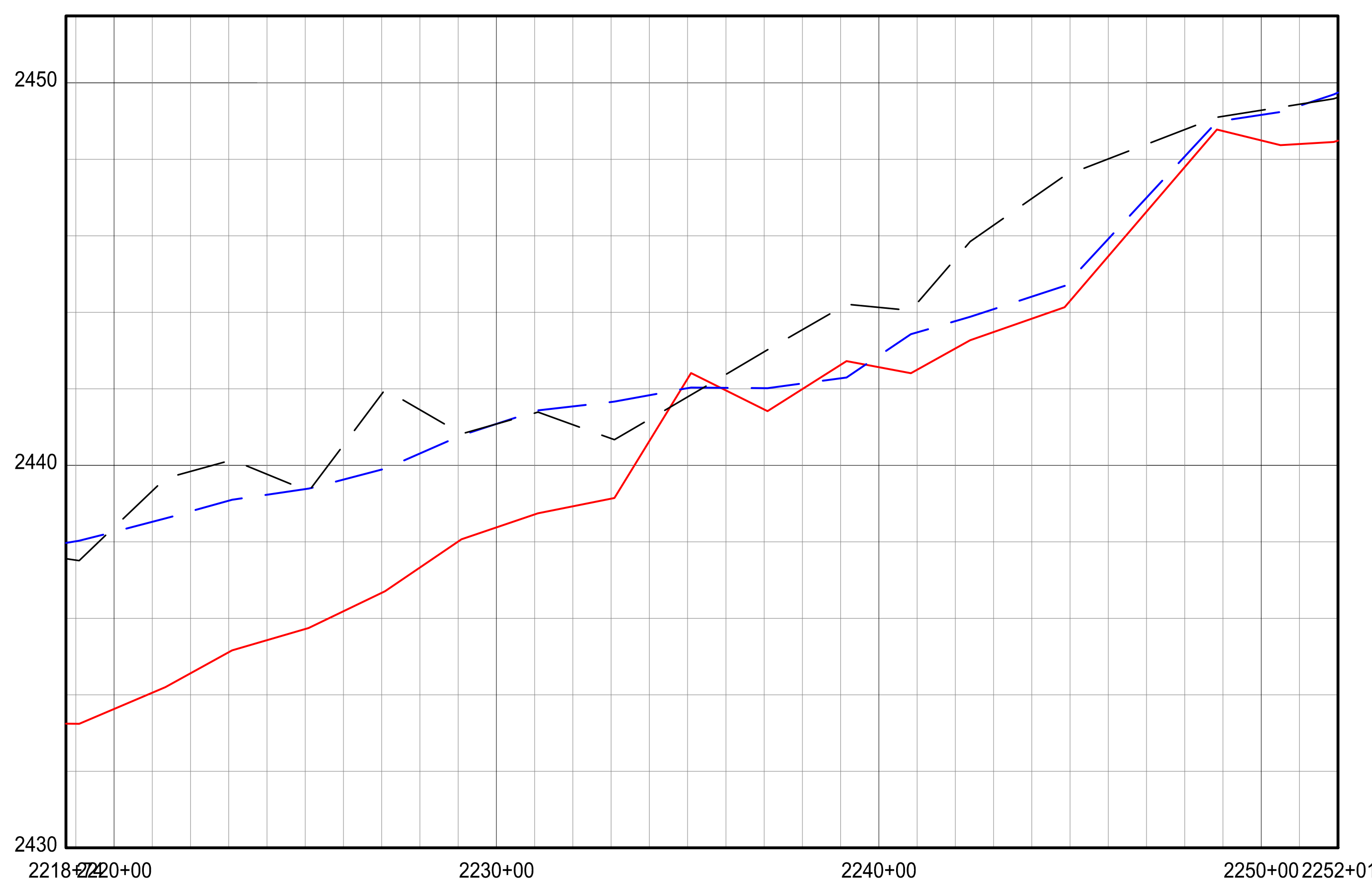
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (44)

2021002022 — Project No.
1" = 500' — Horizontal Scale

Sheet 46 of 50

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

- THALWEG PROFILE (JANUARY 1, 2017)
- THALWEG PROFILE (DECEMBER 31, 2017)
- THALWEG PROFILE ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	Dwn.	Chkd.	Dsgn.	YY.MM.DD
	LTB	MAJ	LTB	22.06.30

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

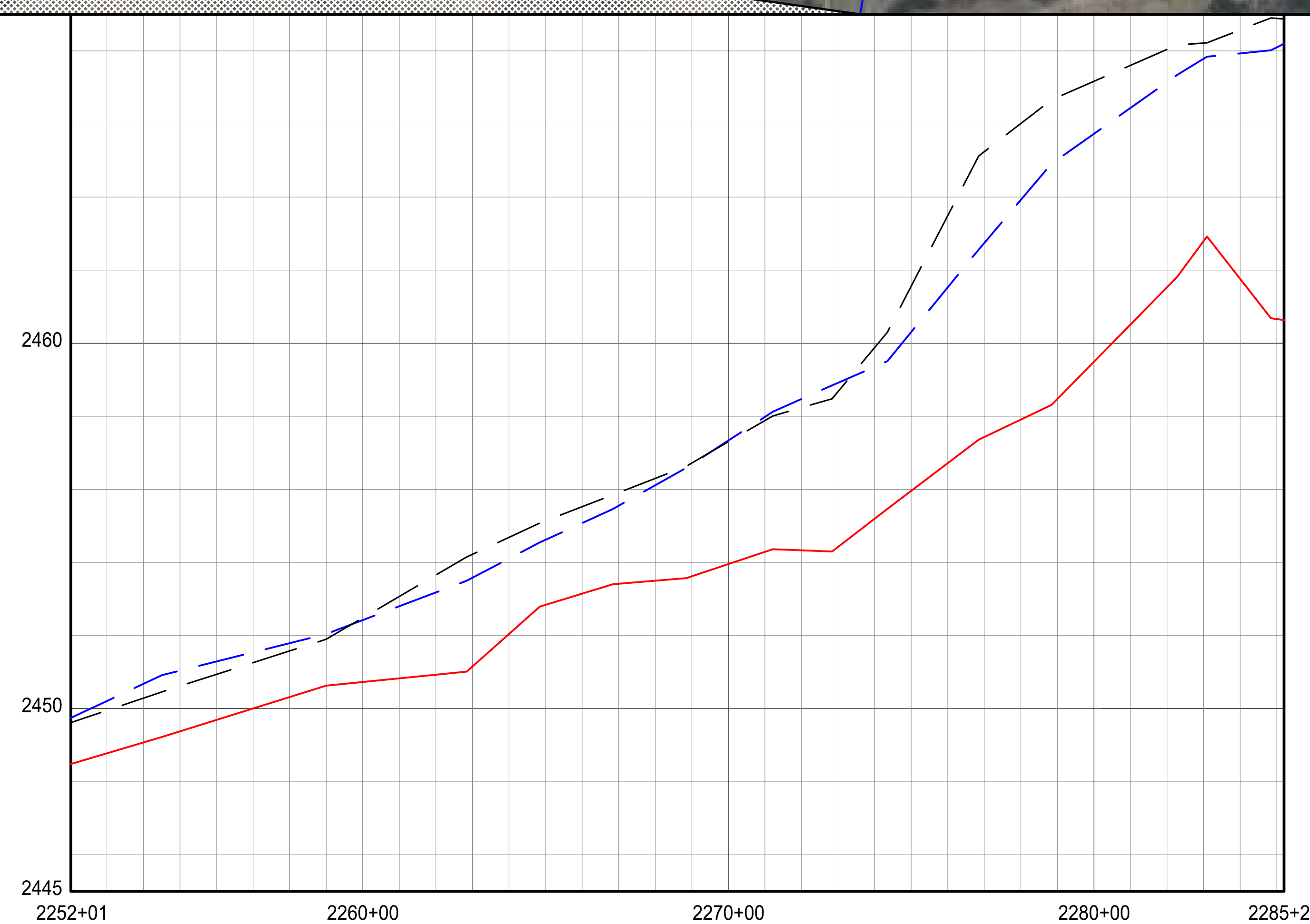
HOLDREGE, NE

Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (45)

Project No.	Horizontal Scale
2021002022	1" = 500'

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision	By	Appd.	YY.MM.DD

Issued	By	Appd.	YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

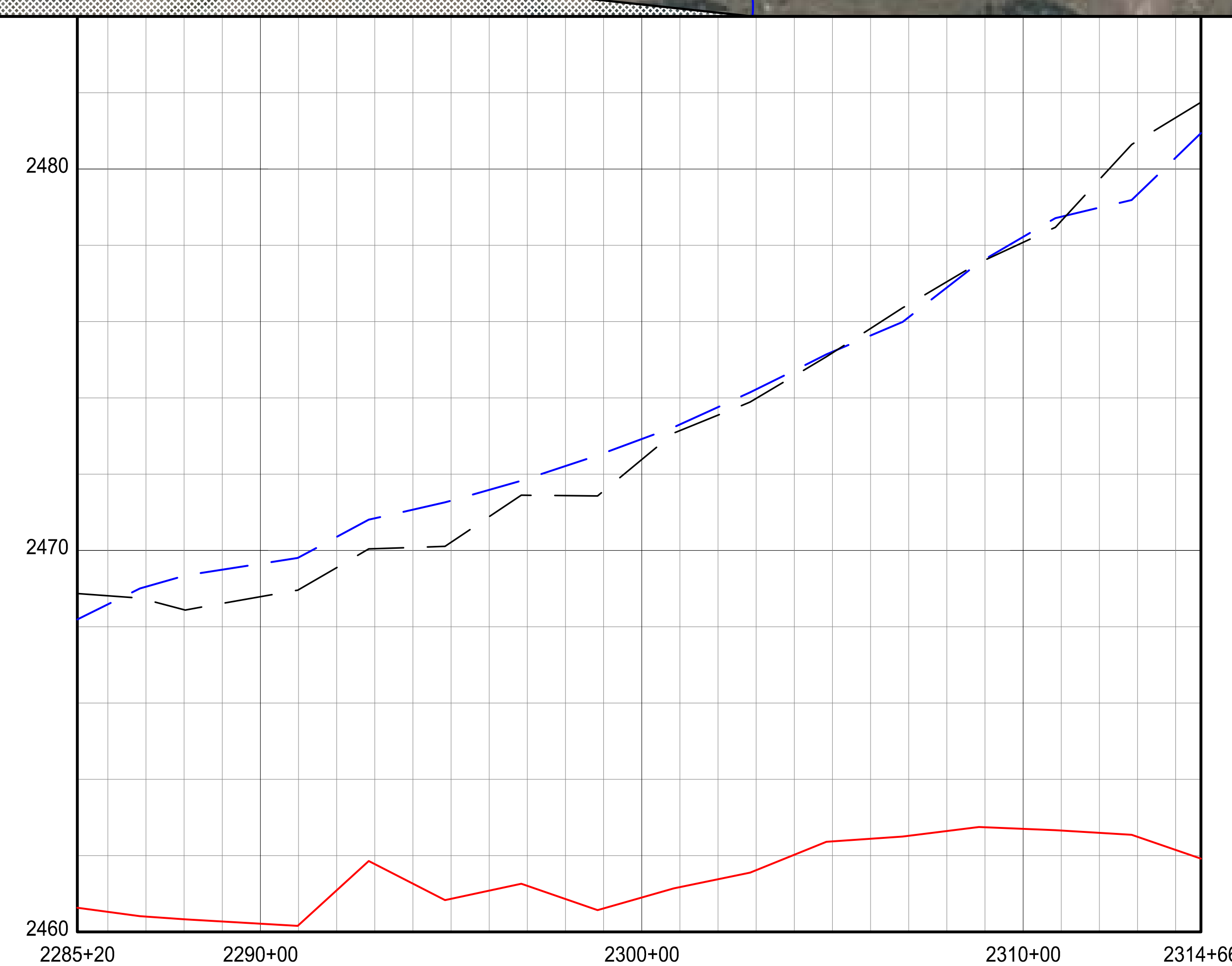
HOLDREGE, NE

Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (46)

2021002022	1" = 500'
Project No.	Horizontal Scale

ORIGINAL SHEET - ANSI B



WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision | By | Appd. | YY.MM.DD

Issued | By | Appd. | YY.MM.DD

File Name:	LTB	MAJ	LTB	22.06.30
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

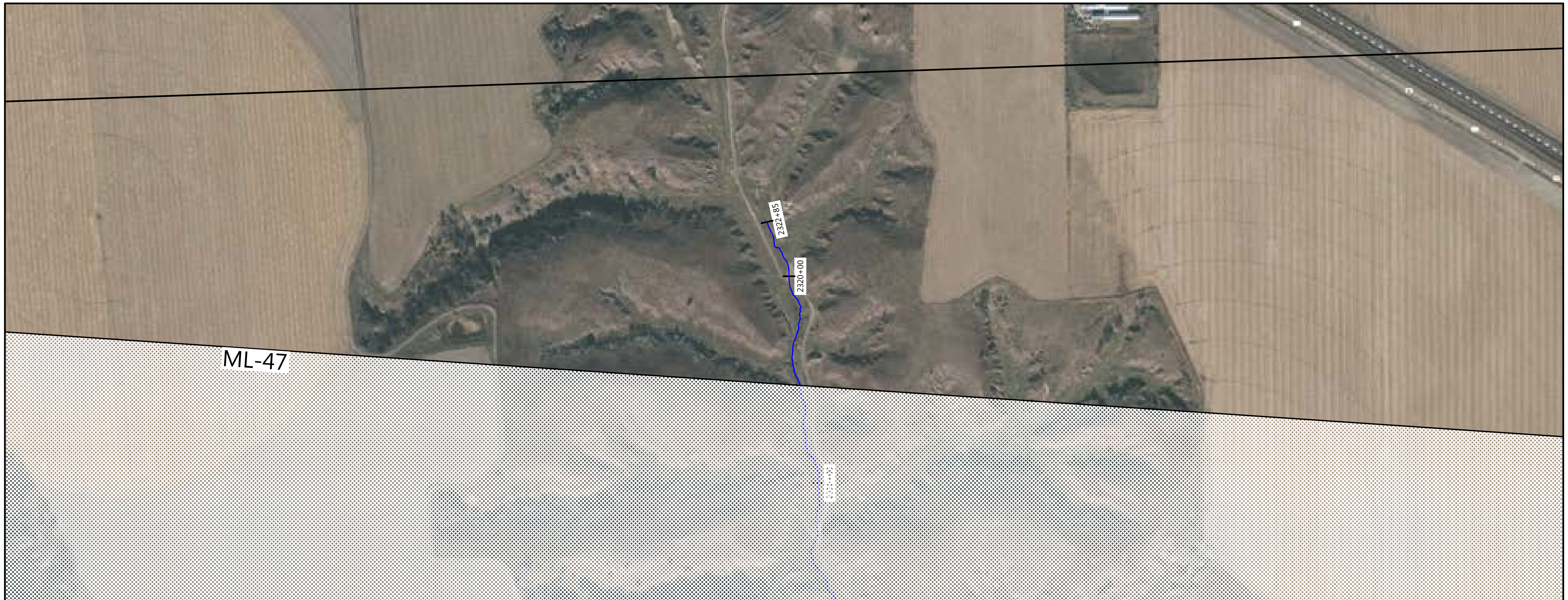
Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

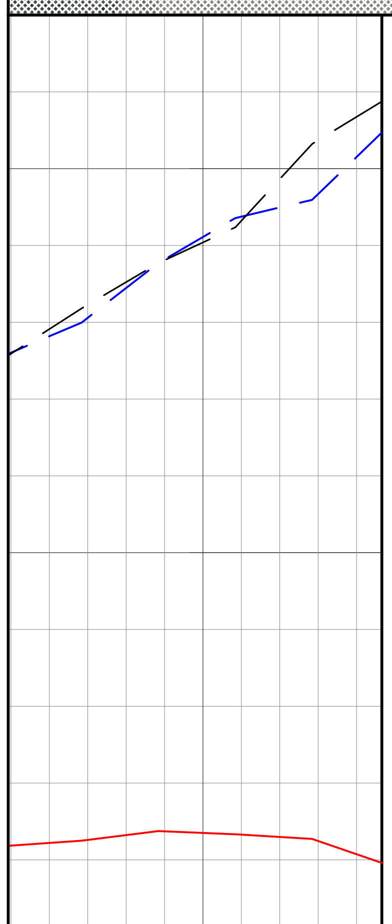
Sheet Name
SEDIMENT MODELING RESULTS - (47)

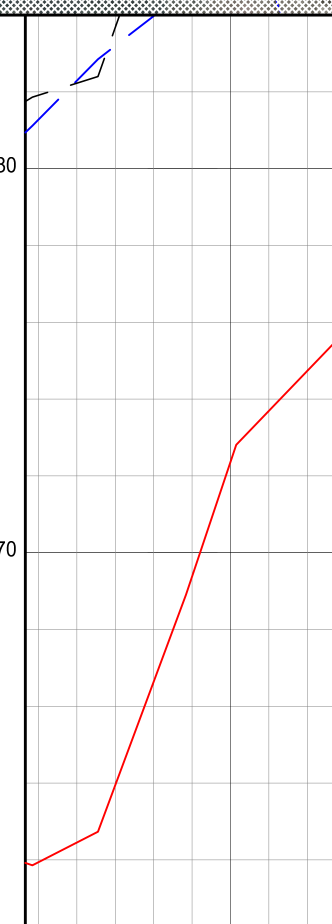
2021002022 1" = 500'
Project No. Horizontal Scale

Sheet 49 of 50

ORIGINAL SHEET - ANSI B







WATERVATION
123 G Street, Suite 18
Salida, CO 81201
www.water-vation.com

Sub-Consultants

Horizontal Scale & Orientation

N

0 500 1000

Legend

THALWEG PROFILE (JANUARY 1, 2017)

THALWEG PROFILE (DECEMBER 31, 2017)

THALWEG PROFILE
ONE YEAR AFTER DIVERSION GOES ONLINE

Revision — By — Appd. — YY.MM.DD

Issued — By — Appd. — YY.MM.DD

File Name:

LTB	MAJ	LTB	22.06.30
Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project
NEBRASKA GAME & PARKS COMMISSION
TURKEY CREEK WARSSS

HOLDREGE, NE

Project Milestone
SEDIMENT TRANSPORT MODEL RESULTS

Sheet Name
SEDIMENT MODELING RESULTS - (48)

2021002022 — 1" = 500'
Project No. — Horizontal Scale