Appendix 5
Dickey-Sargent Irrigation District Modernization Project
PIFR Technical Appendix Report

Prepared for:

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Contents

This technical appendix report is provided to document the field testing, analysis, preliminary design, and preliminary analysis work completed to assess feasibility of improvements to the Dickey-Sargent Irrigation District as required for the Preliminary Investigation of Feasibility. If the project were to move into a full Watershed Plan, substantial work to refine and improve this analysis would be completed.

1- Seepage

Fall 2022 Seepage Test Results

Design of the DSID Canal by the U.S. Bureau of Reclamation (USBR) incorporated a Parshall flume with stilling well for flow measurement at the start of the south lateral. Manual readings can be made within the stilling well to ascertain flow rate at that location and DSID maintains a long-term record. Additional stilling wells are present on the canal, upstream of the check structures associated with each turnout, however these are not tied into weirs or flumes for accurate flow measurements and records were not kept. Therefore, while it is clear to DSID that significant seepage from the canal is occurring, data to estimate seepage volume was not readily available. For that reason, completion of the PIFR economic feasibility evaluation required canal seepage testing.

The most accurate method to conduct canal seepage tests is to conduct controlled ponding tests measuring the rate of drop over 24-48 hours, with starting water depth at the normal canal operating water surface elevation (NRCS, 1999). ND NRCS staff developed a testing plan, in conjunction with DSID staff, based on ponded seepage test procedures outlined by Leigh and Fipps (2009) and USBR geologic drill logs available on the as-built drawings for the canal. Four, 600-foot sections of canal were identified as being representative and plans were made to construct modular dams with sand filled grain bags and plastic sheeting. A written testing plan was developed, staff gauges mounted on steel tripods constructed for manual measurements on either end of the test section, and a hobo automatic data logger purchased for automated measurements in middle of each test section. The canal was drained for the season the last week of September and testing commenced the first week of October in 2022. On the first test attempt the downstream modular dam failed as water was pumped into the canal, unfortunately, and caused erosion damage downstream in the process. Given that a borrow source for clay is not available in this local area to construct temporary earthen dams for testing and other alternatives, such as precast concrete blocks, would be expensive and require lead time to procure, DSID requested that seepage tests be completed using the existing check structures at the laterals/pump stations. As a result, final test section lengths ranged from 1,680 ft to 10,190 ft as shown in Figure 3. Testing on Section 2 was completed October 11-13 and Sections 3 and 4 were completed October 17-19.

The longer test section lengths do provide potential error into the seepage test results due to non-uniformity in the canal section. Slope stability failures, due to both muskrat holes and failed liner sections, and freeze-thaw action have generated geometry that is not uniform or exactly as depicted on USBR as-built drawings. NRCS completed cross section surveys on the canal utilizing survey grade RTK GPS equipment. The cross-section survey measurements confirmed the accuracy of the QL2 LiDAR topographic data available for the area, other than water in the bottom of the canal at the date of the LiDAR data collection. A combination of the as-built drawing cross sections and LiDAR data were utilized to determine wetted perimeter in the seepage computations. The advantage of longer test sections, is that there is no need to question whether selected test sections truly represent differences in underlying soils and existing liner conditions. The only section of canal not tested was the initial 3,818 ft from the lift station to the start of section 2A (see Exhibit 1). Geologic drilling logs on the USBR as-builts indicate that underlying soils in that section match to Section 2A fairly well, therefore that rate was applied. Of note is the fact that DSID staff indicated that the gate at the upstream end of Section 2a leaks, therefore the seepage rate measured in that section may be lower than actual as a result. No precipitation fell during the days of testing, so that did not need to be accounted for. Evaporation rates were determined from the average measured daily PET rate at the Oakes North Dakota Agricultural Network Weather Station within 4 miles of the test sections, during the time period of the tests. Note that the ft/day shown in the table below is common terminology in seepage studies and is shorthand for cubic feet of seepage per square feet of wetted area in a day.

Table 1- Seepage Test Results

Section	Length (ft)	Test Length (days)	Total Loss Rate (cft/day)	Evap Loss (cft/day)	Seepage Rate (cft/day)	Avg Wetted Per (ft)	Avg Depth (ft)	Seepage Rate (gal/sqft/ day)	Seepage Rate (ft/day)
2a	1,680	2.04	5,019	228	4,791	37.7	3.8	0.57	0.08
2b	5,090	2.04	19,197	873	18,325	48.3	5.7	0.56	0.07
3	10,080	1.97	25,275	304	24,415	47.1	5.0	0.39	0.05
4	10,190	1.98	25,489	302	24,415	36.0	3.2	0.51	0.07

Results indicate that the liner has deteriorated substantially, which is visually evident by the brittle appearance and multiple cracks in the material, as well as the long history of patching muskrat holes by district staff. Testing on PVC lined canals in excellent condition yields seepage rates of less than 0.01 ft/day (USBR, 2019) (Sonnichsen, 1993), which can be presumed to have been the condition of the DSID canal liner when construction was completed in 1983. Performance monitoring has found that PVC liners, even when protected from UV degradation by sand and gravel cover, as is the case on the DSID canal, stiffen over time due to leaching plasticizer, which leads to significant cracking (USBR, 2019). A high density of longitudinal cracks is apparent on the DSID liner material when it is exposed, consistent with other aging PVC liners. At the time of design, in the early 1980s, USBR engineers stated a performance expectation of a 40-year lifespan for the DSID canal liner, which has been met as of 2023. USBR (2019) currently recommends an assumed service life of 25 years for a covered PVC liner due to known degradation issues. Manufactures will warranty soil covered PVC liner for 15-20 years.

<u>Projected Canal Seepage Rate Estimate, No Action Alternative</u>

The NRCS Watershed Planning process requires consideration of the No Action alternative, to represent the future if no federal action is taken. In this case, DSID would continue attempts to patch the liner, as they do now, into the future. Lacking federal funding through PL-566 the district would not have the means to reconstruct, re-line, or convert the canal to a pipeline. That said, the existing pumps, motors, and control systems are well past their lifespan and over the next decade will no longer be able to limp along. By 2035 the district would have to make substantial investment in motors and control systems for the existing lift station and all 3 booster pump stations. The PVC liner would continue to deteriorate over time with further muskrat damage and plasticizer loss driven cracking. To determine the seepage rate at the point the liner was 100% failed, the geologic drill logs on the DSID as-built drawings were utilized in conjunction with unlined canal seepage rates by soil type from literature review presented in Sonnichsen (1993). A summary of soil types and associated total lengths are listed in Table 2, with the associated unlined seepage rates utilized from the available reference.

Table 2- Soil Types by Canal Length, Unlined Seepage Rates

Soil Type @ Canal Bottom	Length (ft)	Unlined Seepage Rate (ft/day)	% of Total
Poorly graded sand	6,576	1.3	22%
Sand	500	1.3	1.7%
Well Graded Sand	52	1.3	0.2%
Silty Sand	19,204	0.8	64.4%
Sandy Clay	1,693	0.4	5.7%
Clayey Silt	1,810	0.3	6.1%

The unlined seepage rates noted above were applied and weighted by length to determine averages for each test section and the total canal, listed in Table 3. Also shown is the length weighted average operating depth for each section of canal. This was determined based on field survey of water surface elevations during August of 2022, compared to the as-built data for the canal invert, to generate seepage loss volumes.

Table 3- Average Unlined Seepage Rates and Operating Depths

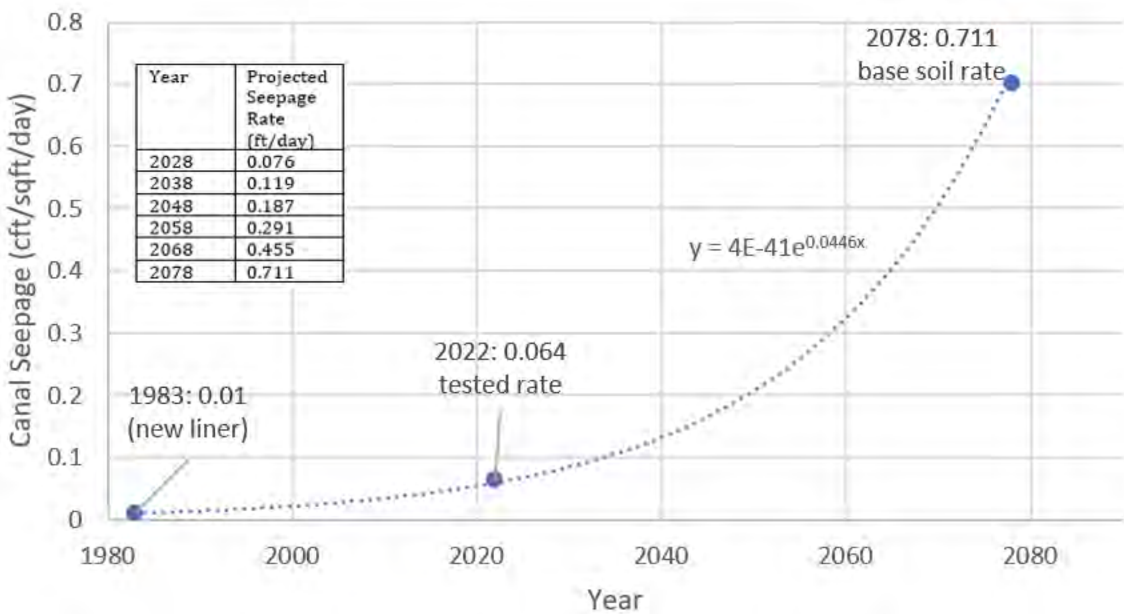
Section	PVC Lined Canal Length (ft)	1983 New Liner Seepage Rate (ft/day)	2022 Tested Seepage Rate (ft/day)	Seepage Rate, Underlying Soils (ft/day)	Average Operating Depth (ft)
Untested	2,295	0.01	0.08 (assumed)	1.22	----
2a	1,680	0.01	0.08	0.76	3.84
2b	5,090	0.01	0.07	0.74	5.72
3	10,080	0.01	0.05	0.82	5.03
4	10,190	0.01	0.07	0.93	3.17
Untested	4,161	0.01	0.07 (assumed)	0.93	----
Total Lined Canal	33,496	0.01	0.06	0.76	----

* Note that lengths listed here represent existing PVC lined canal length, i.e. length of siphons and concrete lined sections at check structures and other locations have been removed. Total canal length is 34,076 feet.

Clearly the liner, though past its design life and compromised with cracks and a high density of muskrat holes/patches, continues to provide significant seepage reduction compared to literature derived rates for the underlying soils. That said, the seepage rates summarized by Sonnichsen (1993) from previous research were for canals with deeper operating depths (5-8 feet); the fact that the DSID canal is relatively shallower and thus has lower hydraulic head may indicate that underlying soil seepage rates could be lower than those listed in Table 3. In addition, it may be logical to assume that the plastic remnants of failed liner material mixed with soils would provide a lower seepage rate than that of raw underlying soils at the bottom of the canal. In addition, Lentz and Freeborn (2007) found that canals which carry water with high suspended silt loads have reduced seepage rates due to gravitational settling and consolidation of clay particles; the James River has a high silt load and a sludge layer has formed on the bottom of the canal, although it appears to be comprised mainly of organic material.

For these reasons, projections of maximum future seepage rates were made on the basis of 80% of the calculated underlying soils seepage rates shown in Table 3. There is no technical reference to base a projected date for full liner failure, so an arbitrary assumption of 2078 was made (end date of the PIFR economic analysis). That is likely quite conservative, given that the expected lifespan of covered PVC liner is only 30 years, per current manufacturer recommendations for PVC liner, or 40 years, per the original USBR design engineers for the DSID project, and in 2078 it would be 95 years old. Based on the increasing rate of deterioration observed by the district, as well as the extensive patching, it was assumed that seepage rates will increase exponentially rather than linearly into the future. As shown in Figure 1, an exponential curve was fitted from the new liner rate, to the 2022 tested rate, to 80% of the underlying soils seepage rate in 2078. The table below lists the projected seepage assumptions utilized for the No Action alternative analysis.

Figure 1- Projected Canal Seepage Rates



Year	Projected Seepage Rate (ft/day)
2028	0.076
2038	0.119
2048	0.187
2058	0.291
2068	0.455
2078	0.711

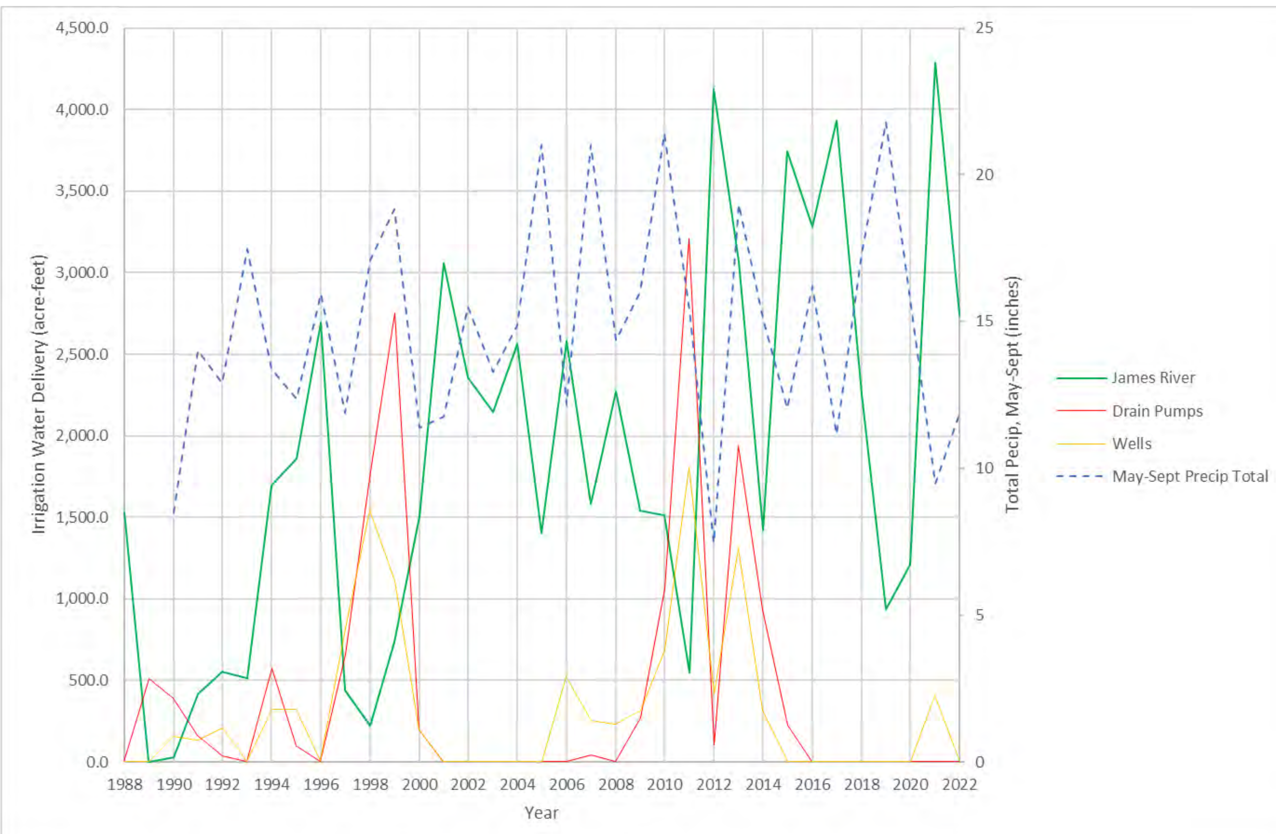
2- Historic Water Supply

DSID has limited water rights, therefore current seasonal water use by the district strongly reflects flow conditions in the James River. There are 58 pivots covering 6,279 acres serviced by the irrigation district. The DSID irrigation canal is supplied by the James River as well as outfalls from subsurface drainage pumps and irrigates 40 pivots covering 4,567 acres. An additional 18 pivots covering 1,712 acres are irrigated from DSID groundwater wells. During drier years, the canal is sometimes supplemented with water from the DSID well field, however pumping records could not separate out well delivery to the canal from well delivery to individual pivots. Therefore, the rest of the PIFR analysis assumes no well water delivered in an average year to the canal, which DSID verified as an accurate assumption. In addition, some privately owned shallow tile drainage systems are pumped into the canal. Both the DSID and privately owned drains are operated primarily in spring (also occasionally after heavy precipitation events) therefore would not be a supply during peak consumptive use time periods for irrigation. The oversized canal currently provides a storage capacity of 240 acre-feet. Either of the alternatives would reduce that storage volume, which in some years could reduce the input of drain pumps to the irrigation system. Records available for annual pumped volume from each source are summarized in Table 4 and plotted in Figure 2, along with precipitation totals for each year from the Oakes ND Agricultural Weather Network Station (NDAWN) since 1990 when it came online. The range of annual delivered irrigation water through the canal is wide, from a minimum of 220 ac-ft in 1998 to a maximum of 4,283 ac-ft in 2021. It is clear, however, that as the district was developing and more pivots were coming online the overall trend has been towards increased delivery volume.

Table 4- Average Annual DSID Water Deliveries by Source

Years	Average James River Delivery (ac-ft)	Average Drain Pump Delivery (ac-ft)	Total Canal Delivery (ac-ft)	Well Delivery (ac-ft)
1988-2022	1,849	426	2,276	317
1994-2022	2,127	477	2,604	365
2000-2022	2,356	371	2,727	299
2010-2022	2,542	575	3,117	381

Figure 2- Historical Annual DSID Water Supply by Source



The highest water use years largely match to low growing season precipitation years and vice-versa, as would be logical. Years such as 2012 and 2021 had May-Sept precipitation totals less than 10 inches and therefore exceeded 4,000 ac-ft of water delivered through the canal from the James River. Years with growing season precipitation exceeding 20 inches, such as 2005, 2007, 2010, and 2019 had canal water deliveries of 1,600 ac-ft or less. The Oakes Aquifer is a shallow, unconfined aquifer in sands and gravels buried by sands, silts, and clays left behind by Glacial Lake Dakota during the last ice age. Depth to water table ranges from 0-20 feet, typically, but is highly variable dependent on snowpack available for groundwater recharge. Hence the reason well deliveries to groundwater fed pivots in the district are low in many relatively dry growing seasons. Surface water via the canal is therefore a more reliable water supply, unfortunately the district is not able to get additional water rights from the James River.

If additional supply was available via the Garrison Diversion, as was originally intended, the irrigation district would have developed to the originally planned 44,000 acres. At this point in time DSID has no plans or desire to evaluate alternatives for increased water supply through sources other than seepage reduction, however, given past controversies and lawsuits that halted the original USBR project.

3- Historic Crop Types

Preliminary design work and economic analysis both require assumptions regarding typical crop types and acreages. Several sources were utilized in combination with each other to determine historic crop types on the canal irrigated pivot extents (4,567 acres):

- USDA National Agricultural Statistics Services (NASS) Cropland Data Layer (CDL) remote sensing derived raster data for annual crops. The NASS CDL data was better in some years than others, likely due to timing of the base satellite imagery and how it coincided with plant leaf development in DSID. In North Dakota, this is generally considered to be the most reliable data source for crop type estimates at a watershed scale.
- USDA Farm Service Agency Common Land Unit (CLU) based polygon data for crop type. Agriculture producers participating in FSA programs, such as crop insurance, are required to annually self-report planted crops on the FSA-578 form to their county office. While the hard copy versions of these forms are accurate, conversion of those to into the GIS layer is unreliable and all farmers do not participate in FSA programs or report every year. Data for fields without reporting is generated from the NASS CDL data, which necessarily involves conversion of individual rasters into polygon data; also a potential source of errors in the data.
- USDA National Agricultural Imagery Program (NAIP) aerial imagery. In situations where NASS and/or CLU data sources indicated that cropland was fallow, crops could be easily seen on aerial images. Corn is clearly identifiable in many of the photos as a distinct crop.
- Consultation with DSID producers.

Figures 4a-g provide annual crop maps for the district and Table 5 provides summary information. Of note is the fact that acreages planted to potatoes and onions, which are the highest value crops grown in the district, vary with drought conditions. The severe drought in 2017 resulted in a 28% decrease in the acreage planted to potatoes in 2018. The 2020-21 drought resulted in 72-73% decrease in potato acres and 50-100% decrease in onion acres in 2021-22. The low soybean planting acreage in 2018 reflects trade issues between the U.S. and China at the time. The 2016-2020 average both matches the available years of ERS normalized price data (see Section 9 and appears to capture a reasonable range of water supply conditions. Therefore, the 2016-2020 averages were utilized for the remainder of the PIFR preliminary design and analysis work.

Table 5- DSID Canal Irrigated Crops

Year	Corn (ac)	Soybeans (ac)	Potatoes (ac)	Onions (ac)	Alfalfa (ac)	Dry Beans (ac)
2016	2,817	967	640	143	0	0
2017	2,383	1,138	914	0	0	132
2018	3,220	380	661	127	180	0
2019	1,960	1,211	942	210	180	65
2020	2,037	855	913	386	180	196
2021	3,460	654	259	194	0	0
2022	2,616	1,579	245	0	0	126

Average 2016-2020	2,483	910	814	173	108	79
% 2016-2020	54.4%	19.9%	17.8%	3.8%	2.4%	1.7%
Average 2016-2022	2,642	969	654	152	77	74
% 2016-2022	57.8%	21.2%	14.3%	3.3%	1.7%	1.6%

4- Irrigation Water Requirements

Nearly all of the pivots in the irrigation district were sold, installed, and subsequently serviced by one of the two irrigation suppliers located in Oakes; General Irrigation is a Zimmatic Dealer and Hoffman Irrigation is a Reinke Dealer. NRCS was able to secure pivot packages from the dealers to determine exact mainspan and swingarm lengths, end gun data, and nozzle packages for all but 3 of the 40 canal supplied pivots. For those 3 pivots, NRCS went out and measured span lengths in the field and made assumptions on nozzle package performance based on an average gpm/ac of other 37 pivots. The typical pivot in the district is ¼ mile (1290 ft), has ¾" drops with ~6 ft of ground clearance, 20 psi pressure regulators, and Nelson rotator nozzles. Out of the 40 pivots, 2 have swing arms and 38 have endguns, most are Nelson SR100 operated with a booster pump, with an effective irrigation radius of ~100 feet. These systems fall into the mid-elevation spray application (MESA) category of center pivot nozzles. Based on the nozzle package information provided by the dealers, peak flow in the district with all 40 canal supplied pivots operating simultaneously would be 69.8 cfs. Note that this flow rate represents the nozzle packages in a new condition; over time nozzles may release more water due to wear or less water due to plugging with sediment. DSID indicated that flow measurements at the Parshall flume, located at the headworks of the canal, indicate typical peak flows in the range of 55-60 cfs, based on memory of operators. Data on historic flow rates was not available for the canal, operators manually read a staff gauge in the stilling well adjacent to the flume if they want to know the flow rate at a particular point in time; an automatic recording device is not present. If a full watershed planning effort is initiated, NRCS will install a datalogger in the stilling well starting in the 2023 irrigation season to gather data for further planning and design work.

ND NRCS utilizes the NRCS Irrigation Water Requirements- Penman-Montieth software package (IWRpm) with databases built from historic evapotranspiration and precipitation data from ND Agricultural Weather Network stations. DSID crops were run through the software using sandy loam soil, 1.0" carry over soil moisture, and the Oakes NDAWN climate station. Table 6 lists the summary results, as well as the area weighted average based on the crop averages for 2016-2020. Detailed IWR results by crop are provided in Figures 5a-e.

Table 6- Crop Irrigation Water Requirements

Crop	Peak Consumptive Use (in/day)	50% Normal Year Effective Growing Season Precip (in)	50% Normal Year Net Irrigation Requirement (in)	Dry Year Net Irrigation Requirement (in)
Alfalfa	0.31	5.11	10.20	11.22
Corn	0.28	7.58	14.58	16.10
Dry Beans	0.29	6.41	12.69	13.97
Onions	0.26	7.00	13.70	15.10
Potatoes	0.30	6.41	14.41	15.88
Soybeans	0.27	6.95	13.58	14.97
2016-2020 Area Weighted Average	0.28		14.18	15.65

NRCS utilizes the NRCS Farm Rating Index (FIRI) to estimate sprinkler system efficiency based on a variety of factors related to the equipment itself as well as operation and maintenance. FIRI results indicate 83% efficiency for a typical DSID pivot; detailed output is provided in Figure 6. A 60% assumption for endgun efficiency was utilized per NEH Part 623 (NRCS, 2008). Peak design flow estimates for the system were then completed on the basis of those two efficiency figures, area weighted crop averages, acres of end gun and mainspan by lateral, and an assumption of 22 hours/day average system availability (typically used to account for realistic equipment downtime due for repairs). The resulting NRCS design recommendation for peak flow on the system would be 67.9 cfs.

Table 7- Peak Flow Rate Estimates

Lateral	# of Pivots	Mainspan (ac)	End Gun (ac)	Total (ac)	Nozzle Package Peak Flow (cfs)	NRCS Recommended Peak Flow (cfs)
North	16	1,584.2	159.6	1,743.8	26.00	25.94
Central	15	1,574.4	146.3	1,720.8	27.13	25.54
South	9	1,005.9	96.8	1,102.8	16.64	16.38
Total	40	4,164.6	402.7	4,567.3	69.77	67.86

Note: flow rates and volumes listed here are gross, based on the efficiencies noted above.

The fact that peak flow based on nozzle package information is nearly identical to what NRCS would recommend appears to be an odd coincidence. The difference between NRCS recommended flow rates on individual pivots and dealer nozzle packages ranged between -6.45 gpm/ac and +5.61 gpm/ac, with an average difference of 0.86 gpm/ac. The decision was made to utilize the NRCS recommended flow rates for the PFIR preliminary design work. Additional consideration of design flow alternatives would be done during the full watershed planning effort if the project proceeds under PL-566.

Based on area weighted average seasonal irrigation water requirements listed in Table 6, the noted system efficiencies, and the mainspan and end gun acreages listed in Table 7, the following would be NRCS estimates of gross annual irrigation volume to 100% meet crop water needs for the canal irrigated pivots are:

- Normal Year = 6,723 ac-ft
- 80% Dry Year = 7,417 ac-ft

In comparison, the DSID average annual irrigation water delivery through the canal (detailed in Section 2) in the 2010-2022 time period indicates the district averaged 3,117 acre-feet a year. The highest recorded delivery volume was 5,002 acre-feet in 2021. Clearly this irrigation district, like many others in the western U.S., is functioning in a deficit irrigation scenario due to inadequate water supply. As a result, while applied irrigation water increases crop productivity over that of unirrigated crops, production is not optimized in many years. That said, this level of deficit irrigation is adequate to generate critical quality improvements to certain crops; unirrigated potato or onion production would not be possible in this geographic area but clearly is currently feasible within DSID.

5- Water Supply Projections

Comparison of alternatives requires projecting current and future available irrigation water to sprinkler systems served by the canal. If a PL-566 project was pursued for DSID, it is anticipated that the Watershed Plan-EA would be started in late 2023 and completed mid-2025. Final design would be completed by late 2026 and construction completed in a single year (2027) for Alternative 1 and over three years (2027-2029) for Alternative 2. The first year any part of the system would be in operation would be 2028 and an O&M period of 50 years is assumed for the PIFR, hence water supply projections were completed for each alternative through 2078 based on the seepage rates outlined in Section 1.

Pan evaporation data from the Jamestown Airport, as well as data for average daily PET at the Oakes North Dakota Agricultural Network Weather Station, was used in combination to determine the estimate of 37.83 inches of water lost to evaporation between April 15 and September 15 of each year (153 days). The LiDAR derived CAD surface at typical operating water surface levels (per Sept 2022 survey) was utilized to determine an average surface area of 1,211,094 square feet. The resulting annual evaporation from the canal surface was 88 ac-ft. Seepage losses due to the failing PVC liner were estimated as described in Section 1 for the 153-day annual operating period.

Table 8- No Action Water Supply Projection

Year	Seasonal Water Supply (ac-ft)	Seasonal Seepage Loss (ac-ft)	Seasonal Evaporation Loss (ac-ft)	Gross Irrigation Delivered (ac-ft)	Net Irrigation Delivered (in/ac)
2022	3,117	311	91	2,715	5.78
2028	3,117	373	91	2,653	5.64
2038	3,117	582	91	2,444	5.20
2048	3,117	910	91	2,116	4.50
2058	3,117	1,421	91	1,605	3.41
2068	3,117	2,219	91	807	1.72
2078	3,117	3,117	91	0	0

Alternative 1 would involve replacing the existing open canal with a buried pipeline, which would effectively eliminate all seepage and evaporation losses.

Table 9- Alternative 1 (Canal to Pipe) Water Supply Projection

Year	Seasonal Water Supply (ac-ft)	Seasonal Seepage Loss (ac-ft)	Seasonal Evaporation Loss (ac-ft)	Gross Irrigation Delivered (ac-ft)	Net Irrigation Delivered (in/ac)
2022	3,117	311	91	2,715	5.78
2028	3,117	0	0	3,117	6.63
2038	3,117	0	0	3,117	6.63
2048	3,117	0	0	3,117	6.63
2058	3,117	0	0	3,117	6.63
2068	3,117	0	0	3,117	6.63
2078	3,117	0	0	3,117	6.63

Alternative 2 would reconstruct a smaller canal section, with a double liner consisting of reinforced concrete underlain by geosynthetic membrane, see additional details in Section 6. Based on data provided in Sonichsen (1993), USBR (2019), and Han et al (2020) the following assumptions were made for the new liner seepage rates: 0.005 ft/day initially installed, 0.05 ft/day after 50-years. A linear relationship was applied between the two points. The top widths of the new canal were utilized to determined evaporation losses for this scenario.

Table 10- Alternative 2 (Concrete/Geomembrane Lined Canal)

Year	Seasonal Water Supply (ac-ft)	Seasonal Seepage Loss (ac-ft)	Seasonal Evaporation Loss (ac-ft)	Gross Irrigation Delivered (ac-ft)	Net Irrigation Delivered (in/ac)
2022	3,117	311	91	2,715	5.78
2028	3,117	28	50	3,039	6.47
2038	3,117	78	50	2,989	6.36
2048	3,117	128	50	2,939	6.25
2058	3,117	178	50	2,889	6.15
2068	3,117	228	50	2,839	6.04
2078	3,117	278	50	2,788	5.93

Over the 50-year lifespan of the PL-566 project, anticipated to be 2028-2078, the No Action would result in a total seepage loss of 68,770 ac-ft, Alternative 1 would result in no seepage loss, and Alternative 2 would results in 7,650 ac-ft of seepage loss. The water savings of 68,770 ac-ft under Alternative 1 or 61,120 ac-ft under Alternative 2 would provide additional irrigation water to increase crop production on the 4,567 acres of irrigated cropland served by the canal.

6- Crop Yield Projection

NRCS does not have agency technical guidance for projecting crop yields on the basis of more or less available irrigation water, therefore methodology in FAO Paper 66 (Steduto et al, 2012) was utilized to make estimates of the impact of water supply alternatives on yield. FAO #66 presents the relationship below where relative yield reduction is related to the corresponding relative reduction in plant evapotranspiration:

$$\left(1 - \frac{Ya}{Yx}\right) = Ky * \left(1 - \frac{ETa}{ETx}\right)$$

Where:

Ya = a lower crop yield value. Typically used to represent an “actual” crop yield under a deficit irrigation scenario but for the DSID analysis was based on dryland crop yields determined as outlined below.

Yx = a higher crop yield value. Typically utilized to represent maximum yield under ideal water supply where agronomic factors (fertilizers, pests, and disease) are not limiting. Data is not available in ND for crop yield under these conditions given crops are largely grown in a water deficit (even when irrigation is available water rights are allocated at a low volume per acre compared to crop needs in the state). For the DSID analysis this represents the crop yield for the various water supply alternatives outlined in Section 4.

ETa = the combination of starting soil moisture + effective growing season precipitation + net irrigation water applied for the Ya yield. For the DSID analysis this was 1 “net available soil water + the 50% normal growing season precipitation for the particular crop (Table 6).

ETx = the combination of starting soil moisture + effective growing season precipitation + net irrigation water applied for the Ya yield. For the DSID analysis this was 1 “net available soil water + the 50% normal growing season precipitation for the particular crop (Table 6) + net irrigation for the water supply scenario (Table 10).

Ky = a yield response factor representing the effect of a reduction in evapotranspiration on yield losses, by crop. From FAO #66, alfalfa= 1.1, dry beans= 1.15, corn= 1.25, potatoes= 1.1, soybeans= 0.85.

Dryland yields utilized for the analysis were as follows and appear reasonably in-line with NDSU published regional yield estimates:

- Corn (grain) dryland yield 118 bu/ac. Back calculated from DSID producer average of 240/ac on irrigated assuming 5.86"/ac avg irrigation and 50% normal year precipitation. NDSU 2022 SE ND average 164/ac, which includes irrigated and non-irrigated acreage. SC ND, just to the west, lists 112 bu/ac, which matches well (this region has less irrigation). NDSU 2022 Irrigated E ND data indicates 220 bu/ac.

- Soybeans 64 bu/ac. NDSU (2022) Back calculated from DSID producer average of 100 bu/ac on irrigated, assuming 5.86 in/ac avg irrigation and 50% normal year precipitation. SE ND average 40 bu/ac, which includes irrigated and non-irrigated acreage. EC ND, to the north, lists 55 bu/ac which is closer. NDSU 2022 Irrigated E ND data indicates 70 bu/ac.

- Potatoes 245 cwt/ac. Back calculated from DSID producer average of 475 cwt/ac on irrigated, assuming 5.86 in/ac avg irrigation and 50% normal year precipitation. NDSU (2022) does not provide potato data, however this result is fairly close to the 240 cwt/ac determined during the economics work for unirrigated potatoes in NE North Dakota, for the NB Park River PL-566 Plan (similarly based on producer interviews).

- Dry beans 1575 lbs/ac. Back calculated from DSID producer average of 3200 lbs/ac on irrigated, assuming 5.86 in/ac avg irrigation and 50% normal year precipitation. NDSU 2022 SE ND average 1970/ac, which includes irrigated and non-irrigated acreage. NDSU 2022 Irrigated E ND indicates 2800 lbs/ac.

- Alfalfa 2.6 tons/ac. Back calculated from DSID producer average of 6 tons/ac on irrigated, assuming 5.86 in/ac avg irrigation and 50% normal year precipitation. NDSU 2022 Irrigated E ND data indicates 6 tons/ac.

Onions were not included in the analysis, for reasons noted in Section 9; that acreage was instead treated as potatoes, which would be the next highest value crop grown in the district. Crop acreage averages for 2016-2020 were utilized, for the reasons noted in Section 3. Results of total production estimates from the canal irrigated acreage in DSID, by alternative, are provided in the tables below.

Table 11- No Action Alternative Projected Yields

Crop	Acres	2022	2028	2038	2048	2058	2068	2078
Corn (bu)	2483	589,684	581,084	554,596	514,066	454,610	370,287	292,994
Soybeans (bu)	910	90,692	89,982	87,727	84,068	78,190	68,614	58,240
Potatoes (cwt)	987	466,853	460,953	442,567	413,795	370,128	305,025	241,815
Dry beans (lbs)	79	250,828	247,371	236,651	220,030	195,155	158,837	124,425
Alfalfa (tons)	108	604	595	568	526	463	370	281

Table 12- Alternative 1 (Pipeline) Projected Yields

Crop	Acres	2022	2028	2038	2048	2058	2068	2078
Corn (bu)	2483	589,684	643,761	643,761	643,761	643,761	643,761	643,761
Soybeans (bu)	910	90,692	94,934	94,934	94,934	94,934	94,934	94,934
Potatoes (cwt)	987	466,853	503,199	503,199	503,199	503,199	503,199	503,199
Dry beans (lbs)	79	250,828	272,298	272,298	272,298	272,298	272,298	272,298
Alfalfa (tons)	108	604	657	657	657	657	657	657

Table 13- Alternative 2 (Lined Canal) Projected Yields

Crop	Acres	2022	2028	2038	2048	2058	2068	2078
Corn (bu)	2483	589,684	633,330	626,228	619,181	612,822	605,880	598,992
Soybeans (bu)	910	90,692	94,145	93,600	93,053	92,554	92,003	91,450
Potatoes (cwt)	987	466,853	496,287	491,555	486,838	482,562	477,874	473,201
Dry beans (lbs)	79	250,828	268,191	265,386	262,595	260,070	257,306	254,556
Alfalfa (tons)	108	604	647	640	633	626	620	613

7- Preliminary Alternatives

Two approaches could be taken to address water losses on a long-term basis for the DSID canal. One would be to replace the open canal with a buried, pressurized pipeline and one would be to reconstruct and re-line the canal. For the purpose of determining economic feasibility of this potential PL-566 project an exhaustive engineering analysis involving every potential iteration of these alternatives (for example various pipe diameters or liner materials) was not completed. Assumptions made and additional analyses that would take place during the full planning effort are therefore noted for each.

<u>Alternative #1, Pipeline</u>

Lift Station

Replacement of the open canal with a pressurized pipeline offers a number of clear advantages over any other alternative and is the preferred option of the DSID board. This alternative provides the highest level of seepage reduction, eliminates evaporation losses, would have longest lifespan (beyond that of the 50-year analysis time period for the pipeline), lowest operation and maintenance costs, eliminates safety concerns with having an open irrigation canal, and allows for the current narrow bridges over the canal to be decommissioned (which are a restriction to modern farm equipment transport). An advantage DSID has over many other irrigation districts considering converting open canals to pipelines is that all 40 pivots supplied from the canal are already served by buried pressurized pipelines, currently operated by 3 booster pump stations. Therefore, the project does not require any modifications to laterals and on-farm irrigation infrastructure (other than control systems). The opportunity to decommission the 3 booster pump stations and pressurize the entire system from a single pump station located at the current lift station is also attractive, in terms of reduced operation and maintenance costs. In addition, electrical power at the lift station is subsidized through the Western Area Power Administration while the booster pump station power is not, which will be beneficial to the irrigation district. The existing pumps at the lift station are designed to generate only the head required to lift from the low river water surface elevation into the canal headworks and would therefore not be feasible as a supply for a pipeline. There are 8 available bays for vertical turbine pumps in the lift station, as well as an existing fish screen in place. Peak flow operating requirements, to meet the PCU rates as outlined in Tables 6 and 7, would require pipeline capacity of 67.86 cfs to the laterals originating from the North pump station, 41.92 cfs to the laterals at the Central pump station, and 16.38 cfs to the South pump station laterals. The critical point, in terms of hydraulics, is on the end of the longest south lateral, at the NE pivot point in Section 27 where the new single pump station would need to provide 40 psi, 3.5 below ground at the pivot point (see Figure 7). HDPE pipe was assumed, for reasons noted below, and diameters to generate operating velocities at peak flow in the 5-6 ft/sec range were selected for preliminary sizing (see Figure 9). Considering low water elevation in the James River, max system operating requirements require 185 ft of Total Dynamic Head at 30,456 gallons per minute from the refurbished pump station. As illustrated in Figure 8, if 8 of the existing 20MQ Byron Jackson turbine pumps at the booster pump stations were relocated (and refurbished as necessary) to the lift station with the project, with new motors and VFDs, they would generate adequate head for the system (see Figure 8). The lift station transformer would need to be converted to a 480-volt supply for the VFDs. Analysis of pressure capacities of the existing pipe manifold at the pumphouse and crossing below Highway 1 were not completed for this very preliminary analysis.

For a system with the wide range of flows that DSID has, at least one larger and one smaller capacity pump would likely be preferable and control systems for pumps would likely have them broken out by lateral. One component of the full watershed planning process would be to hire a mechanical/electrical engineering firm, with experience in similar sized irrigation pumping plants, to evaluate multiple alternatives for vertical turbine pumps, motors, VFDs, and control systems from an operational and energy efficiency standpoint. That analysis would include evaluation of existing equipment and alternatives for various pipe diameters, as well, considering tradeoffs of size versus energy costs over the lifespan of the project. That said, sedimentation concerns may, in the end, prevent selection of optimal pipe diameters given the need to maintain fairly high velocities in the low slope pipeline. Although a pipeline alternative does inherently require higher energy than a gravity canal, the 40-year old pumps, motors, and control systems on the existing system are not operating at high efficiency currently. As a result, it is possible that this alternative would have either higher or lower energy costs than the existing system, so neither was accounted for in the preliminary economics. The preliminary design assumes high density polyethylene (HDPE) pipe given that the ease and speed of installation of this pipe material typically makes it the overall lower construction cost alternative for this size of pipe and scale of project. Polyvinyl chloride pipe (PVC) would have a lower material cost than HDPE, but a higher installation cost. It requires careful handling during construction to avoid damage and incurs additional costs for pipe bedding and compaction over HDPE.

North

The high silt load in the James River, combined with the low topographic relief, is a concern for pipeline design. The existing canal was constructed at a slope of 0.00005 ft/ft (except the far south end which is at 0.0001 ft/ft) and has accumulated sediment and organic debris, particularly between the lift station and the check structure at the north pump station. By comparison, ND Practice Standard 430-Irrigation Pipeline requires a minimum slope of 0.005 ft/ft on a pipeline to ensure effective drainage and sediment movement (note that was written for typical PVC irrigation pipe used for on farm irrigation pipelines). The majority of the canal will be located within the frost zone (frost depth is ~ 6 feet in this area), therefore the pipeline will need to be drained after conclusion of each irrigation season. HDPE pipe with fusion welded joints is less prone to damage from ice formation than PVC if water was not fully evacuated prior to freezing, which is another reason why HDPE would be the preferred pipe material given the very flat topography. To both save on pipe materials and address sediment deposition issues, the preliminary design has the initial section of pipeline located outside of the existing canal. This allowed pipe slopes to be increased to a minimum grade of 0.003 ft/ft, which will help sediment move. To avoid extensive fill over the pipeline, the profile would need to be graded to pumpouts. While these do allow for increased grades, it would require a portable pump be utilized to drain the line each fall. The high points on the pipeline between pumpouts would have combination air relief/vacuum relief/air release valves (3-way ACV) in buried concrete manholes. Alternative locations and profile designs will be considered during the full planning effort.

To ensure a means of flushing sediment out of the initial 1.6 miles of pipeline, a butterfly valve would be installed at 83+15 on the mainline in a concrete manhole with a 3-way ACV upstream of it. Just upstream of that valve 12" pipeline to an existing drain ditch west of the pipeline (hydraulically connected to the James River) would be installed with a butterfly valve that would be closed during normal irrigation operations. This infrastructure would allow the system to be run, under pressure, to intentionally flush sediment out of the initial section of pipeline. The water surface in the outlet ditch for the drain line is hydraulically connected to the river. Interpolating between the USGS gauge at the SD state line (~14 river miles south) and the gauge at Lamoure (~20 river miles north), the September median flow is 287 cfs which would equate to a water surface elevation of 1291.3 ft onsite. The existing ditch bottom at the drain line outlet is unfortunately high enough that in some years backwater will create a condition where a pumpout would need to be utilized just upstream of the ditch in the fall to evacuate water from the pipeline. Sediment flushing would be best scheduled during low water time periods in the ditch. The drainline would also be utilized for fall drainage of the new spur installed to the north laterals and portions of the mainline.

The next 1.1 miles of mainline after the valve station would continue to have minimum 0.003 ft/ft grades and pumpouts, simply because that is necessary to avoid the need to construct fill sections over the pipeline. The last 4.3 miles of pipeline would be laid at the original canal bottom invert slope of 0.00005 and 0.0001 ft/ft, without pumpouts, and would be drained by gravity in the fall to the existing canal drain channel. Further analysis on potential for sedimentation in this section of pipeline and need for air control would be done with the more detailed preliminary design in the full watershed plan. Both the central and southern laterals would have butterfly valves to allow them to be shutoff for maintenance if necessary. A butterfly valve at the end of the mainline would be installed so it could be opened for either drainage or sediment flushing operations. Use of fusion welded HDPE pipe would be necessary at this low pipe slope, given that complete drainage may not be achieved prior to freezing conditions, particularly if settlement over time creates low spots in the pipeline. Preliminary drawings for this alternative are provided in Figure 10.

Table 14- Alternative 1, Pipe Materials Summary

Pipe Materials	Length (ft)	Peak Flow Rate (cfs)	Install Location
54" IPS SDR21 HDPE	8,230	67.9	Lift station to 82+30 (ends at new spur to N laterals/drain)
42" IPS SDR21 HDPE	8,120	41.9	82+30 to 163+50 (ends at C laterals)
30" IPS SDR26 HDPE	10,350	16.4	163+50 to 267+00 (ends at S laterals)
36" IPS SDR21 HDPE	2,030	25.9	New spur to N laterals
12" IPS SDR21 HDPE	3,900	-----	New drain line
Total new pipe	32,630		

Construction within the old canal section would involve excavating and removing organic materials and silt deposits from the bottom of the canal. The original construction involved placement of 6 inches of sand and gravel cover over the PVC liner, which would provide a suitable base for the new pipeline. Existing canal embankments would be stripped of sod/organic material, with remaining soils excavated, placed, and compacted to 70% of the new pipe depth across the full width of the existing canal section. A pipe trench would then be excavated into that fill section. HDPE pipe would be fusion welded on the bench adjacent to the trench, typically done in sections of over 1,000 feet at a time, after which it is pushed into the prepared pipe trench. At that point installation of valves, fittings, and thrust blocks would be completed, following which select sand and gravel backfill is placed and compacted along the sides of the pipe, up to the top of trench depth (70% of pipe depth). Typically, 85% of maximum dry density is required, which can be achieved with walk behind vibratory plate compactors. From that elevation to finished ground surface, earthfill from existing canal embankments would be placed and compacted. The preliminary design has a minimum of 24 inches of cover over the pipe. In addition to pipe materials, select backfill is often one of the major cost components of large pipeline projects. Therefore, a local sand source (within 5 miles of the project) was evaluated for conformance with NRCS select backfill requirements on HDPE pipelines. Gradation testing of the local sand source indicates that imported gravel would need to be mixed with it, therefore that was considered in the construction cost estimate. Electromagnetic flow meters (example: McCrometer UltraMag meters) would be placed on each of the three main laterals as well as at the pump station, with telemetry setup to allow DSID operators to monitor flows.

Fusion Welding HDPE Pipe

Placing HDPE Pipe in Trench

As noted previously, in very dry years water from the DSID well field is pumped into the canal as an additional supply source. Individual vertical turbine pumps in the wells feed into a 15" diameter 100 psi PVC pipeline, which outlets to the existing canal in a steel pipe. With a pipeline project, a centrifugal booster pump would need to be placed on that line near the junction with the new pipeline, to increase its outlet head above that of the pipeline for this supply alternative (if desired). The pipeline junction would then have a slide/check valve installed allow it to be drained in the fall. Likewise, pumps from the DSID subsurface drainage system currently outlet into the canal and would also need booster pumps and inlets to function with the new pipeline. The section of existing canal to be abandoned would be graded out and filled under this alternative, although a small ditch may be left to route discharge water from private tile outlets where necessary. The check structures and booster pumps not relocated to the new pump station would be removed and the buildings and land sold.

<u>Alternative #2, Lined Canal</u>

A newly lined canal, downsized appropriately to minimize lining material required, increase operating velocities to reduce sedimentation and algae issues, and minimize evaporation losses is the obvious alternative to a pipeline. Sizing was completed with 1 foot of freeboard depth, to allow for future sediment accumulation and localized surface water runoff that could enter the canal. The narrower and deeper canal section would reduce (but not eliminate) maintenance issues related to algal growth in the canal. Likewise, the smoother surface of the concrete liner as compared to the existing sand/gravel cover over the old liner, increases flow velocity which may help to reduce (but not eliminate) sediment deposition in the very low slope canal.

Given the muskrat population and the extensive damage they cause to the canal, despite significant population control efforts by DSID, canal lining would need to include concrete. Composite liners of concrete underlain by geomembrane are considered the state-of-the-art canal lining practice for long term seepage reduction and have been selected for many major canal lining projects across the U.S. in recent years. While lining projects in the southern portions of the country can simply place shotcrete or unreinforced concrete over the geomembrane, in northern climates steel reinforcement (typically #4 bar at 12" o.c.) is required for crack control; related cover requirements result in a 6-inch depth of concrete for the liner. Below the concrete, a multi-layer geosynthetic membrane comprised of top and bottom layers of 12-oz nonwoven geotextile and a center layer of 30-mil EVA nonpermeable membrane would be placed. An example of this type of product is Canal[3] 12-30-12 geocomposite manufactured by Huesker. The existing underdrain system in the canal appears to be functioning and would likely not need replacement with the project. Concrete would be poured directly over the geocomposite, with pumper trucks, as shown in the photo. The geomembrane would terminate in a 1 ft x 1 ft rectangular anchor trench, set 1 ft back from the top of the slope on both sides. At structures, the geomembrane would be anchored with steel batten strips and epoxy bolts existing concrete. Concrete lining would terminate at the top of the slope.

Pouring Concrete Slab Over Composite Liner

Construction within the old canal section would involve excavating and removing organic materials and silt deposits from the bottom of the canal. At that point, the sod would be stripped from the existing canal embankments and existing embankment material would be placed and compacted to form the new canal subgrade dimensions (over-excavated 0.53 ft for concrete/liner). Following fill placement, the anchor trenches would be excavated and membrane lining would be placed and seamed, after which reinforced concrete would be placed and cured. There would be limited time in which to work each fall (likely only 8-10 weeks), after irrigation season and before temperatures dropped too low for earthfill, membrane, and concrete placement; therefore, construction would need to be phased over the course of three years. A preliminary drawing, typical section, and select cross sections are provided in Figure 10 and summarized in Table 15. Earthwork was generated based on current LiDAR, therefore as-built elevations of the canal were converted from NGVD29 to NAVD88 elevations to match. The finished invert elevation of the new canal would match that of the original. Given that LiDAR data collection occurred with water in the canal, an average of 6 inches of deposition was assumed on the canal bottom that would need to be removed and end hauled to an off-site waste area. Sideslopes would remain at 2:1. At check structures and gates the canal would transition from the new cross section to the old to avoid the need for structure replacement. No changes to pump stations would be done through the PL-566 project, given that energy savings is not an eligible purpose under watershed operations. DSID would need to invest in replacement/reconstruction of the lift station and all three booster pump stations in the future, to keep them operating, which is incorporated into the O&M cost for this alternative. Preliminary drawings for this alternative are provided in Figure 11.

Table 15- Alternative 2, Reconstructed Canal Section Summary

Design Flow (cfs)	Lining Length (ft)	Total Depth (ft)	Bottom Width (ft)	Top Width (ft)	Slope (ft/ft)	Location
67.9	8,851	5.4	4.0	23.0	0.00005	0+00 to 93+83
42.0	14.062	4.7	3.0	22.3	0.00005	96+75 to 237+37
16.5	10,132	3.2	2.5	20.8	0.00001	239+54 to 340+86
Total	33,045					

*Note: lining length excludes concrete structures and siphons.

8- Preliminary Alternative Cost Estimates

NRCS economics evaluation of watershed projects incorporates total costs to implement the project including design and construction engineering costs and administrative, project management, and legal costs for the Sponsor to acquire land rights (including temporary construction easements) and implement/manage the construction contract. Construction cost share for PL-566 projects with an agricultural water management purpose typically match that utilized for similar practices within other Farm Bill Programs administered by NRCS. In North Dakota, EQIP is utilized for irrigation pipelines, canal lining, and pump stations for on-farm irrigation efficiency projects and those cost share rates are at 75%. Therefore 75% is the likely federal cost share rate for either alternative listed in this PIFR. Due to the fact that DSID owns the land in fee title on which the canal and pump stations are located, but is not an agricultural producer, EQIP is not a feasible funding option for this project (also a requirement for PL-566 funding). Even if eligibility could be resolved somehow, the payment limitation of $450,000 would make EQIP infeasible for a project of this scale. That said, an accompanying EQIP special project to encourage individual producers within DSID to adopt advanced irrigation water management, install functioning flow meters, renozzle sprinkler packages that are beyond their lifespan, install variable rate (zone control) irrigation technology on pivots with substantial wetland acreage below them, and adopt agronomic conservation practices would be supported and recommended by NRCS to the local county workgroup as a priority in parallel with the PL-566 project.

The construction cost estimate for Alternative 1 is based on the following assumptions:

- Construction would be completed in a 12-month timeframe. Approximately 58% of the total pipeline length could be installed in the summer because it is not located within the existing canal (9+75 to 141+100 of ML, drainline, and new N spur). The remaining 42% would be installed after irrigation season but prior to the ground freezing, typically a 6-8 week timeframe. Work on the pump station reconstruction would be completed in that same fall and the following winter to be ready for the next year's irrigation season.
- Developing a construction cost estimate for the pump station reconstruction is overly complex for a PIFR. That will require a new transformer and associated electrical work to reduce down to 480-volt, possible relocation of ~6 pumps from booster pump stations, new motors, VFDs, controls, new pumps, and any work required on the pipe manifold and crossing below the highway to accommodate the increased pressure of the new system. The $1 M cost estimate below is considered a conservative "guess" at these costs.
- Existing canal embankments would be excavated and material placed and compacted to 70% of the pipe depth. The pipe trench would then be excavated into that material, pipe laid, fittings/valves/thrust blocks installed, then select backfill placed and compacted, then remaining earthfill placed and compacted. Average sideslope of 05H:1V assumed for trench; in reality deeper sections would be constructed with a trench box so would have vertical sides, sandier soils may be somewhat flatter than 0.5:1 to hold (particularly on the side the pipe is fused on).
- It would be acceptable for old lining material to remain in place.

- A waste area could be located within a 30-minute round trip truck time of the project site; potentially an abandoned gravel pit.
- New 54" pipeline could be trenched across 99th St SE & 91st St SE with the contractor reconstructing and resurfacing the road back over the pipeline. The 12" drain line would be bored below the highway.
- Bridges in the old canal would be removed at pipeline stations ~164+00, 190+50 (93rd St SE), and 243+30 (94th St SE) to allow for pipe placement and backfill. Contractor would reconstruct and resurface road over the pipe. Traffic would be detoured around the crossings as needed.
- Most of the land rights for the new pipeline routes would be acquired from members of the DSID, with minimal or no cost, given that they will gain additional lands through decommissioning of the existing canal. Construction easements for the project, including staging and waste areas, would need to be purchased given those would take cropland out of production for a year.

Table 16- Alternative 1, Construction Cost Estimate

Item	Quantity	Rate	Estimated Cost
Purchase & delivery, 54" IPS DR21 HDPE- mainline	8,250 ft	$ 270.89/ft	$ 2,234,843
Purchase & delivery, 42" IPS DR21 HDPE- mainline	8,150 ft	$ 163.89/ft	$ 1,335,704
Purchase & delivery, 30" IPS DR26 HDPE- mainline	10,350 ft	$ 65.20/ft	$ 674,820
Purchase & delivery, 12" IPS DR21 HDPE Pipe- drain	3,900 ft	$ 14.72/ft	$ 57,408
Purchase & delivery, 36" IPS DR21 HDPE Pipe- N lateral spur	2,050 ft	$ 120.40/ft	$ 246,820
Fusion welding, placement of pipe, fittings, valves, thrust blocks	1	ls	$ 384,400
HDPE bends, tees, reducers, flange adaptors/fittings to PVC	1	ls	$ 201,972
Butterfly valves and 3-way air/vac-air relief valves	1	ls	$ 531,750
Electromagnetic flow meters with telemetry (1@54", 3 @ 36")	1	ls	$ 97,582
Excavation (includes grading adjacent canal banks)	291,220 cy	$ 2.25/cy	$ 655,245
Embankment (includes haul onsite/to waste area)	279,350 cy	$ 4/cy	$ 1,117,400
Purchase & delivery, select sand and gravel backfill	13,525 cy	$ 18/cy	$ 243,540
Pump station reconstruction, incl. transformer/power supply	1	ls	$ 1,000,000
Install control systems, with telemetry (PRVs included)	1	ls	$ 150,000
Decommission pump stations, construct 3 lateral connections	1	ls	$ 150,000
Mobilization, overhead, project mgt, QC, traffic control	1	ls	$ 500,000
Total			$ 9,635,603

*Note: all materials costs include delivery to the project site. Prices based on supplier quotes in April-May 2023.

The cost benefit evaluation for a PL-566 project requires consideration of total installation costs, which are roughly estimated below:

Table 17- Alternative 1, Implementation Cost Estimate

Category	Cost	NRCS Share	Local Share
Construction	$ 9,635,603	$ 7,226,702	$ 2,408,901
Final Engineering Design	$ 1,000,000	$ 1,000,000	$ 0
Construction Engineering	$ 500,000	$ 500,000	$ 0
Sponsor Legal/Contract Admin Costs	$ 150,000	$ 0	$ 150,000
Land rights costs	$ 50,000	$ 0	$ 50,000
Total	$ 11,335,603	$ 8,726,702	$ 2,608,901

Operation and maintenance costs for the irrigation district would be drastically reduced with replacement of the open canal with pipelines. In addition, only a single pump station would need to be maintained rather than four pump stations to operate the system. The pumps, motors, and control systems would be new rather than over forty years old, which would also provide a dramatic savings in operation and maintenance.

The construction cost estimate for Alternative 2 is based on the following assumptions:

- The project would require 3 years to construct, given the limited time period between completion of irrigation season and below freezing temperatures when soil compaction, liner placement, and pouring/curing concrete is infeasible.
- An average of 6 inches of accumulated sediment and organic materials would be removed from the canal, throughout, and hauled to a waste area.
- A waste area could be located within a 30-minute round trip truck time of the project site; potentially an abandoned gravel pit.
- It would be acceptable for old lining material to remain in place. The existing underdrain system would be tested and determined to not require replacement.

Table 18- Alternative 2, Construction Cost Estimate

Item	Quantity	Rate	Estimated Cost
Reinforced concrete, materials & installation	15,326 cy	$1,000/cy	$15,326,000
Composite geotextile/geomembrane liner, materials	179 rolls	$6,697/roll	$ 1,198,763
Composite geotextile/geomembrane liner, installation	1,118,750 sqft	$ 0.50/sqft	$ 223,750
Excavation, existing canal banks & accumulated sediment	302,138 cy	$ 2.25/cy	$ 679,881
Embankment, compaction, finish grading of subgrade	241,095 cy	$ 5/cy	$ 1,205,476
End haul, spread, compact excess soil materials to waste site	61,043 cy	$ 4/cy	$ 244,172
Erosion control, temporary/final seeding	70 ac	$ 800/ac	$ 56,000
Mobilization, contractor QA, project management, traffic control	1 ls	$ 750,000/ls	$ 750,000
Total Construction Cost Estimate			$ 19,683,971

Table 19- Alternative 2, Implementation Cost Estimate

Category	Cost	NRCS Share	Local Share
Construction	$ 19,683,971	$ 14,762,978	$ 4,920,993
Final Engineering Design	$ 500,000	$ 500,000	$ 0
Construction Engineering	$ 500,000	$ 500,000	$ 0
Sponsor Legal/Contract Admin Costs	$ 100,000	$ 0	$ 0
Land Rights Costs	$ 20,000	$ 0	$ 20,000
Total	$ 20,803,971	$ 15,762,978	$ 5,040,993

9- Preliminary Economic Analysis

The analysis relies on the procedures and guidance provided in the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G), the Principles and Requirements for Federal Investments in Water Resources (PR&G), and the National Resource Economics Handbook (NREH) part 611.

The analysis uses the Fiscal Year (FY) 2023 federal discount rate for water resources projects of 2.5%. Development of the Watershed Plan-EA is expected to be completed in 2024-2025, final engineering design completed in 2026, and construction commenced after completion of the 2027 irrigation season.

Table 20- Summary of Economic Benefits and Costs from Alternatives

	Alternative 1	Alternative 2	No Action Alternative
Description	Replace canal with 5.4-miles of new irrigation pipeline (pls 0.7-mile drain), reconstruct single pump station at existing lift station, decommission the three booster pump stations, install modern control system for the entire district.	Rebuild right-sized, newly lined, 6.5-mile canal. Continue to operate with lift station and three booster pump stations. Replace pumps/motors/control system in the future when no longer operational.	No federal action taken. Liner continues to deteriorate, current high O&M costs continue, replace pumps/motors/controls when no longer operational.
Project lifespan	50 years	50 years	n/a
Construction time	1 year 2027	3 years 2027-2029	n/a
Installation Costs (actual)			
Construction	$9,635,603	$19,683,971	n/a
Other implementation	$1,700,000	$1,120,000	n/a
Total installation	$11,335,603	$20,803,971	n/a
Operations and Maintenance (O&M) Costs			
Annual projected labor	$5,000	$126,000	$140,000
Annual projected O&M (non-labor)	$0	$17,962.40	$22,092
Pump replacement	Included in construction cost.	$1,000,000 (2035)	$1,000,000 (2035)
Explanation	In the absence of federal investment, the existing pumps on the canal (already 40 years old) are estimated to reach the end of their lifespan and will need to be replaced. The existing pumps will continue to be utilized under Alternative 2; they will need to be replaced in the future under that alternative as well. Due to the need to provide high head at the lift station, Alternative 1 would involve installation of new/refurbished pumps, motors, and control systems as required to generate adequate head in the pipeline.		
Benefits (as compared to No Action Alternative)			
Revenue impact from increased yields	Increased water savings will allow greater levels of irrigation, moving closer to optimal irrigation levels. This will improve yields on existing fields and so increase revenues. The benefits are not equal across alternatives as Alternative 2 remains vulnerable to evaporation and decreased water availability over time. As explained later in this section, the annual revenue change under Alternative 1 is projected to be constant, while the annual revenue impacts of Alternative 2 and the No Action Alternative will change over time.		
Projected annual revenue change	$602,890.36	2028-2037: $448,558.09 2038-2047: $370,063.90 2048-2057: $295,501.73 2058-2067: $221,162.64 2068-2077: $143,628.12	2028-2037: ($248,997.92) 2038-2047: ($636,737.43) 2048-2057: ($1,229,287.57) 2058-2067: ($2,113,416,88) 2067-2077: ($3,150,514.92)
Savings	The operations and maintenance costs (including labor) that are required under the No Action Alternative and that would be either eliminated or reduced under Alternative 1 or Alternative 2 will be realized in the form of cost savings.		
Projected annual O&M savings	$162,092	$18,129.60	$0

Considerations for the Benefit-Cost Analysis

Crops and Acreage

The area of interest includes 4,567 acres of irrigated crop land. Analysis of the average acres by crop during the period 2016-2020 shows that corn accounts for more than half of the total planted irrigable land. During the previous seven years, this acreage has been planted to six crops: corn, soybeans, potatoes, onions, alfalfa, and dry beans. The details were provided earlier in this document in Table 5.

In accordance with the National Resource Economics Handbook, the base yield analysis must be from identical years as the ERS normalized price data.

An examination of the crop history (Section 3, Table 5) makes clear that onions are regularly grown within the area of interest. For reasons related to data availability and privacy, the onion acreage will be assigned to another crop (per consultation with Bryon Kirwan, National Technology Center Economist, February 10, 2023). For the purpose of this analysis, the average onion acreage has been assigned to potatoes.

Building from the information in Table 5, the revised acreage breakdown is below.

Table 21- Revised Acreage

	Planted Acres, Onion Acreage to Potatoes					
	Corn	Soybeans	Potatoes	Alfalfa	Dry Beans	Total
Average 2016-2020	2,483	910	987	108	79	4,567
% of Total 2016-2020	54.37%	19.93%	21.61%	2.36%	1.73%	100.00%

Basic and Non-Basic Crops

Per the 1983 P&G 2.3.2(b)(1): "Basic crops (rice, cotton, soybeans, wheat, milo, barley, oats, hay, and pasture) are crops that are grown throughout the United States in quantities such that no water resources project would affect the price and thus cause transfers of crop production from one area to another." Based on the crops listed in this definition, there are two non-basic crops that are grown within the area of interest and included in the analysis: potatoes and dry beans. The tables below use planted acreage information from the 2022 North Dakota Agricultural Statistics Bulletin and the acreage information for the area of interest detailed earlier.

Table 22 documents the acreage planted to dry beans during the period 2016-2020 as a share of the total acreage planted to the same crop in North Dakota over the same time period. The time period 2016 – 2020 matches the years included in the normalized price data from the Economic Research Service. In this table and the one for potatoes, the OTA acreage refers to the irrigated acreage in the project area.

Table 22- Dry Beans (all classes), Share of ND Acres

Year	ND	OTA	OTA % of ND Acres
2016	625,000	0	0.00%
2017	705,000	132	0.02%
2018	635,000	0	0.00%

2019	616,500	65	0.01%
2020	815,000	196	0.02%

The information in the above table makes clear that the acres planted to dry beans in the area of interest within the Oakes Test Area (OTA) is so small, relative to the amount planted statewide, that this proposed project would not have a sufficiently large impact to influence market conditions for dry beans.

The table below shows the acreage planted to potatoes during the period 2016-2020 as a share of all acreage planted to potatoes in North Dakota during the same time period. A producer did indicate that it would be possible to increase the acres he plants to potatoes by 130-260 acres per year as a result of the project. The table shows the historical acreage planted (acres and share of the statewide total) as well as recalculations of those values at the maximum value of the potential increase.

Table 23- Potatoes, Share of ND Acres

	Acres Planted					OTA % of ND Acres Planted			
Year	ND	OTA	OTA + Onions	OTA + 260	OTA + Onions + 260	OTA	OTA + Onions	OTA + 260	OTA + Onions + 260
2016	80,000	640	813	900	1,073	0.80%	1.02%	1.13%	1.34%
2017	75,000	914	1,087	1,174	1,347	1.22%	1.45%	1.57%	1.80%
2018	74,500	661	834	921	1,094	0.89%	1.12%	1.24%	1.47%
2019	73,000	942	1,115	1,202	1,375	1.29%	1.53%	1.65%	1.88%
2020	72,000	913	1,086	1,173	1,346	1.27%	1.51%	1.63%	1.87%

The table shows the maximum projected increase in acreage from both the producer's potential increase and also from the reassignment of onion acreage. Even at that level, the acreage accounts for less than 2% of potatoes planted statewide. The potential increase in potato production is not sufficiently large to impact market conditions for potatoes.

Both dry beans and potatoes are most appropriately considered basic crops for this analysis.

Prices

The National Resource Economics Handbook 611.0102(b)(1) directs use of current normalized prices for economic evaluations of projects that would be covered by the P&G. The discussion references determining price differentials between states; this analysis relies on the state-level normalized prices as provided by the Economic Research Service (ERS). The prices used in the analysis are detailed in Table 24.

Table 24- Pricing

Crop (unit)	Price	Source
Corn (bu)	$3.41	2022 ERS state normalized
Soybeans (bu)	$8.75	2022 ERS state normalized
Potatoes (cwt)	$10.79	2022 ERS state normalized
Alfalfa (ton)	$90.80	2022 ND Agricultural Statistics bulletin, 2016-2020 average price
Dry Beans (cwt)	$28.90	2022 ERS state normalized

Tables 11 – 13 in Section 6 reported the projected yields of dry beans in lbs. However, the pricing from the ERS is reported per cwt. In the calculations that follow for the economic analysis, that adjustment has been made (and is noted in the tables).

Based on discussion with NRCS colleagues, the alfalfa crop is qualitatively distinct and, for pricing purposes, should be considered separately from hay. The ERS normalized prices do not account for alfalfa as a separate crop; the price listed is for "hay-all types". This analysis instead relies on pricing from the North Dakota Agricultural Statistics bulletin. The price used is the five-year average price for alfalfa, for the period 2016-2020. This period matches the five-year period used in the 2022 ERS report.

The range of prices from three sources is shown below. The table compares the per-unit crop prices from the Economic Research Service for both state and national-level normalized prices and the prices from the North Dakota Agricultural Statistics Bulletin. The latter are a five-year average taken to match the time period included in the ERS prices.

Table 25- Price Variation

Price Comparison	ERS 2022 Normalized 2016-20		2016-20 Average ND AgStats
	State	National	
Corn (bu)	$3.41	$3.68	$3.38
Soybeans (bu)	$8.75	$9.33	$8.79
Potatoes (cwt)	$10.79	$9.28	$10.43
Alfalfa (ton)	$79.81	$151.20	$90.80
Dry Beans (cwt)	$28.90	$28.86	$26.68

Economic Analysis

Summary

The evaluation of the benefit-cost (B:C) evaluation is summarized below.

Table 26- Benefit-Cost Summary

Alternative	Estimated benefit-cost (B:C) ratio	Net benefit (loss) over evaluation period	Average Annual Equivalent
No action		($33,379,661.60)	($1,123,225.61)
1: Pipeline	1.89	$9,009,129.91	$303,157.22
2: Canal	0.38	($13,946,587.89)	($469,302.68)

Costs

The construction cost estimates for each alternative were previously detailed in Section 8.

Each alternative will incur regular operations and maintenance (O&M) costs; these estimates were provided by the DSID Board. The current canal requires regular maintenance. Under Alternative 1, these costs would be saved. The Board has estimated new O&M costs for Alternative 1 to be approximately $5,000; the annual contracted costs will include $3,000 for winterization and $2,000 for maintenance.

Under Alternative 2, the canal maintenance requirements would continue. The DSID Board expects that labor, vehicle, and fuel costs would decrease by an estimated 10%. Existing costs for chemicals are projected to decrease by 50%; other repairs and maintenance costs are projected to continue at existing levels.

As described earlier in Section 7, the construction plans for Alternative 1 include new pumps and controls. This is not true under Alternative 2, which will continue to use the existing pumps and controls for the remainder of their usable life. These materials will likely need to be replaced within the next several years. The same is true for the No Action alternative.

Neither Alternative 1 nor Alternative 2 is expected to lead to a reduction in revenue. However, under the No Action Alternative, the canal is predicted to continue to deteriorate, reducing the water available for irrigation. This water loss will result in decreased yields over time, which will result in lower revenue. This is consistent with the information from Section 6, Table 11.

Benefits

The primary benefit from this project is the increased revenue that results from increased yields. Cost savings will accrue primarily to Alternative 1. Sources of cost savings include labor costs as well other O&M costs, including herbicides, vehicle repair, fuel, and other repairs and maintenance.

Increased Yields

Crop yields are expected to increase under both alternatives, as they both mitigate the water seepage and increase water available for irrigation. Under Alternative 1, this benefit accrues at a constant rate, after project completion, over the lifespan of the project. Alternative 2 provides this benefit to a lesser, and diminishing, extent as the canal would be vulnerable to degradation over time. This is evident in Tables 12 and 13 in Section 6.

The analysis in both cases accounts for the increased yield returned on existing planted acres. While variable costs – those that change as yield changes – are included in this evaluation, the costs associated with the amount of land planted are not because the revenue change is coming from improved yields, not an increase in the area planted.

The costs that are included in this section include drying, baling, loading, and hauling costs, though these are not all applicable to each crop. The cost information relies on published custom rates as well as information provided by the DSID board members. Harvesting costs were not included because the custom rates identified those as per-acre, and this benefit results from an increase in yield rather than an increase in aces planted. When available, these estimates rely on the most frequent rate cited in the NDSU Custom Rates for 2020 (the most recent year available).

Table 27- Per-unit Costs

Crop	Cost	Source
Corn (bu)	Drying: $0.05 / bu Hauling: $0.12 / bu	Custom rates; DSID confirmed Custom rates; DSID confirmed
Soybeans (bu)	Drying: $0.08 / bu Hauling: $0.12 / bu	Custom rates; DSID confirmed DSID provided
Potatoes (cwt)	Hauling: $0.30 / cwt	DSID provided
Dry Beans (cwt)	Hauling: $0.40 / cwt	Agronomist communication; DSID confirmed
Alfalfa (ton)	Baling: $10 / bale	Custom rates; DSID confirmed

	Hauling: $5 / mile / load Loading: $30 / load	Custom rates; DSID confirmed DSID provided

The cost calculations for alfalfa (baling, loading, and hauling) are below.

Table 28- Cost Calculations for Alfalfa

Alfalfa Costs								
Alternative	Change (tons)	Lbs	Bales	Baling Cost	Additional Loads	Hauling Costs	Loading Costs	Total Costs
calculations (assuming 30 bales / load)		*multiply tons by 2,000*	*divide lbs by 1,500*	*multiply bales by $10*	*divide bales by 30*	*multiply loads by $5*	*multiply loads by $30*	*add baling, hauling, & loading costs*
1: Pipeline	53	106,000	70.67	$706.67	2.36	$11.78	$70.67	$789.11
2: Canal (37)	39	78,000	52.00	$520.00	1.73	$8.67	$52.00	$580.67
2: Canal (47)	32	64,000	42.67	$426.67	1.42	$7.11	$42.67	$476.44
2: Canal (57)	26	52,000	34.67	$346.67	1.16	$5.78	$34.67	$387.11
2: Canal (67)	19	38,000	25.33	$253.33	0.84	$4.22	$25.33	$282.89
2: Canal (77)	12	24,000	16.00	$160.00	0.53	$2.67	$16.00	$178.67
No-action (37)	-22	-44,000	-29.33	($293.33)	-0.98	($4.89)	($29.33)	($327.56)
No-action (47)	-57	-114,000	-76.00	($760.00)	-2.53	($12.67)	($76.00)	($848.67)
No-action (57)	-109	-218,000	-145.33	($1,453.33)	-4.84	($24.22)	($145.33)	($1,622.89)
No-action (67)	-187	-374,000	-249.33	($2,493.33)	-8.31	($41.56)	($249.33)	($2,784.22)
No-action (77)	-278	-556,000	-370.67	($3,706.67)	-12.36	($61.78)	($370.67)	($4,139.11)

The total costs values from Table 28 are incorporated into the projected annual revenue impact tables that follow (Baling, Loading, and Hauling Costs).

The next table summarizes the benefits from increased yield under Alternative 1. This scenario relies on the projected yields provided earlier in Section 6, Table 12.

Table 29- Projected Annual Revenue Impact from Increased Yields, Alternative 1

Alternative 1 (Pipeline)											
		Total Yield				Unit Variable Costs				Final Revenue Calculations	
Crop	Acres	Pre-Project	Post-Project	Yield Change	Unit Price	Drying	Hauling	Unit Revenue	Initial Revenue Change	Baling, Loading, & Hauling	Revenue Change
Corn (bu)	2,483	589,684	643,761	54,077	$3.41	($0.05)	($0.12)	$3.24	$175,209.48	$ -	$175,209.48
Soybeans (bu)	910	90,692	94,934	4,242	$8.75	($0.08)	($0.12)	$8.55	$36,269.10	$ -	$36,269.10
Potatoes (cwt)	987	466,853	503,199	36,346	$10.79	$ -	($0.30)	$10.49	$381,269.54	$ -	$381,269.54
Dry Beans *	79	250,828	272,298	21,470	$28.90	$ -	($0.40)	$28.50	$6,118.95	$ -	$6,118.95
Alfalfa (tons) **	108	604	657	53	$90.80	$ -	$ -	$90.80	$4,812.40	($789.11)	$4,023.29
Total	4,567										$602,890.36
* Dry bean yield information in lbs but pricing per cwt; initial revenue calculation divides by 100 to convert yield gain for pricing calculation.											
** Alfalfa baling and hauling costs are calculated in a separate table.											

In these calculations, the unit revenue is the price per unit minus the unit variable costs.

For example: for corn, the total projected yield change from the proposed alternative is 54,077 bu. The price is $3.41/bu, but that does not take into account the per-bushel costs of drying and hauling. Once those are taken into account, the price the producer receives is more accurately presented as $3.24/bu. At that price, the revenue impact from the projected increase in yield is $175,209.48.

The analysis for Alternative 2 differs from the previous analysis because the benefits will decrease over time as the canal ages. As presented earlier, the net delivered irrigation water (in/ac) is projected to decrease over the lifespan of the project, resulting in projected crop yields that, while greater than in the No Action alternative, decrease over time. This analysis builds on the data provided in Section 6, Table 13. That table provided the projected yields under this scenario at ten-year intervals. In order to calculate the revenue changes under this scenario, the beginning and ending projected yield values were averaged; that average value is used for the ten-year period from the initial year. For example, the projected total corn yield for the years 2028-2037 is an average of the projected yields in 2028 and 2038.

Table 30- Projected Average Yield Values under Alternative 2

Alternative 2 (Lined Canal) Average Yields					
Crop	2028-2037	2038-2047	2048-2057	2058-2067	2068-2077
Corn (bu)	629,779	622,704	616,002	609,351	602,436
Soybeans(bu)	93,873	93,326	92,803	92,278	91,726
Potatoes (cwt)	493,921	489,196	484,700	480,218	475,538
Dry Beans (lbs)	266,789	263,990	261,332	258,688	255,931
Alfalfa (tons)	643	636	630	623	616

The projected average yield values were used to calculate the projected annual benefits of increased yield that would result from completing Alternative 2. The impact is calculated at ten-year intervals to match the data from Table 30. The detailed calculations are below.

Table 31- Projected Annual Revenue Impact from Increased Yields, Alternative 2

Alternative 2 (Lined Canal) 2028-2037											
		Total Yield				Unit Variable Costs				Final Revenue Calculations	
Crop	Acres	Pre-Project	Post-Project	Yield Change	Unit Price	Drying	Hauling	Unit Revenue	Initial Revenue Change	Baling, Loading, & Hauling	Revenue Change
Corn (bu)	2,483	589,684	629,779	40,095	$3.41	($0.05)	($0.12)	$3.24	$129,907.80	$ -	$129,907.80
Soybeans (bu)	910	90,692	93,873	3,181	$8.75	($0.08)	($0.12)	$8.55	$27,197.55	$ -	$27,197.55
Potatoes (cwt)	987	466,853	493,921	27,068	$10.79	$ -	($0.30)	$10.49	$283,943.32	$ -	$283,943.32
Dry Beans *	79	250,828	266,789	15,961	$28.90	$ -	($0.40)	$28.50	$4,548.89	$ -	$4,548.89
Alfalfa (tons) **	108	604	643	39	$90.80	$ -	$ -	$90.80	$3,541.20	($580.67)	$2,960.53
Total	4,567										$448,558.09
* Dry bean yield information in lbs but pricing per cwt; initial revenue calculation divides by 100 to convert yield gain for pricing calculation.											
** Alfalfa baling and hauling costs are calculated in a separate table.											

Alternative 2 (Lined Canal) 2038-2047											
		Total Yield				Unit Variable Costs				Final Revenue Calculations	
Crop	Acres	Pre-Project	Post-Project	Yield Change	Unit Price	Drying	Hauling	Unit Revenue	Initial Revenue Change	Baling, Loading, & Hauling	Revenue Change
Corn (bu)	2,483	589,684	622,704	33,020	$3.41	($0.05)	($0.12)	$3.24	$106,984.80	$ -	$106,984.80
Soybeans (bu)	910	90,692	93,326	2,634	$8.75	($0.08)	($0.12)	$8.55	$22,520.70	$ -	$22,520.70
Potatoes (cwt)	987	466,853	489,196	22,343	$10.79	$ -	($0.30)	$10.49	$234,378.07	$ -	$234,378.07
Dry Beans *	79	250,828	263,990	13,162	$28.90	$ -	($0.40)	$28.50	$3,751.17	$ -	$3,751.17
Alfalfa (tons) **	108	604	636	32	$90.80	$ -	$ -	$90.80	$2,905.60	($476.44)	$2,429.16
Total	4,567										$370,063.90
* Dry bean yield information in lbs but pricing per cwt; initial revenue calculation divides by 100 to convert yield gain for pricing calculation.											
** Alfalfa baling and hauling costs are calculated in a separate table.											

Alternative 2 (Lined Canal) 2048-2057											
		Total Yield				Unit Variable Costs				Final Revenue Calculations	
Crop	Acres	Pre-Project	Post-Project	Yield Change	Unit Price	Drying	Hauling	Unit Revenue	Initial Revenue Change	Baling, Loading, & Hauling	Revenue Change
Corn (bu)	2,483	589,684	616,002	26,318	$3.41	($0.05)	($0.12)	$3.24	$85,270.32	$ -	$85,270.32
Soybeans (bu)	910	90,692	92,803	2,111	$8.75	($0.08)	($0.12)	$8.55	$18,049.05	$ -	$18,049.05
Potatoes (cwt)	987	466,853	484,700	17,847	$10.79	$ -	($0.30)	$10.49	$187,215.03	$ -	$187,215.03
Dry Beans *	79	250,828	261,332	10,504	$28.90	$ -	($0.40)	$28.50	$2,993.64	$ -	$2,993.64
Alfalfa (tons) **	108	604	630	26	$90.80	$ -	$ -	$90.80	$2,360.80	($387.11)	$1,973.69
Total	4,567										$295,501.73
* Dry bean yield information in lbs but pricing per cwt; initial revenue calculation divides by 100 to convert yield gain for pricing calculation.											
** Alfalfa baling and hauling costs are calculated in a separate table.											

Alternative 2 (Lined Canal) 2058-2067											
		Total Yield				Unit Variable Costs				Final Revenue Calculations	
Crop	Acres	Pre-Project	Post-Project	Yield Change	Unit Price	Drying	Hauling	Unit Revenue	Initial Revenue Change	Baling, Loading, & Hauling	Revenue Change
Corn (bu)	2,483	589,684	609,351	19,667	$3.41	($0.05)	($0.12)	$3.24	$63,721.08	$ -	$63,721.08
Soybeans (bu)	910	90,692	92,278	1,586	$8.75	($0.08)	($0.12)	$8.55	$13,560.30	$ -	$13,560.30
Potatoes (cwt)	987	466,853	480,218	13,365	$10.79	$ -	($0.30)	$10.49	$140,198.85	$ -	$140,198.85
Dry Beans *	79	250,828	258,688	7,860	$28.90	$ -	($0.40)	$28.50	$2,240.10	$ -	$2,240.10
Alfalfa (tons) **	108	604	623	19	$90.80	$ -	$ -	$90.80	$1,725.20	($282.89)	$1,442.31

Total	4,567										$221,162.64
* Dry bean yield information in lbs but pricing per cwt; initial revenue calculation divides by 100 to convert yield gain for pricing calculation.											
** Alfalfa baling and hauling costs are calculated in a separate table.											

Alternative 2 (Lined Canal) 2068-2077											
		Total Yield				Unit Variable Costs				Final Revenue Calculations	
Crop	Acres	Pre-Project	Post-Project	Yield Change	Unit Price	Drying	Hauling	Unit Revenue	Initial Revenue Change	Baling, Loading, & Hauling	Revenue Change
Corn (bu)	2,483	589,684	602,436	12,752	$3.41	($0.05)	($0.12)	$3.24	$41,316.48	$ -	$41,316.48
Soybeans (bu)	910	90,692	91,726	1,034	$8.75	($0.08)	($0.12)	$8.55	$8,840.70	$ -	$8,840.70
Potatoes (cwt)	987	466,853	475,538	8,685	$10.79	$ -	($0.30)	$10.49	$91,105.65	$ -	$91,105.65
Dry Beans *	79	250,828	255,931	5,103	$28.90	$ -	($0.40)	$28.50	$1,454.36	$ -	$1,454.36
Alfalfa (tons) **	108	604	616	12	$90.80	$ -	$ -	$90.80	$1,089.60	($178.67)	$910.93
Total	4,567										$143,628.12
* Dry bean yield information in lbs but pricing per cwt; initial revenue calculation divides by 100 to convert yield gain for pricing calculation.											
** Alfalfa baling and hauling costs are calculated in a separate table.											

The projected impact on revenue decreases in each subsequent ten-year period under Alternative 2. Over time the estimate decreases from an estimated annual increase of $448,558.09 in 2028 to a smaller annual estimated annual increase of $143,628.12 in 2077. The benefits of increased yields on existing croplands are smaller under Alternative 2 than they are under Alternative 1, though they are appreciably better than the outcome under the No Action Alternative.

Table 11 from Section 6 documents the yield projections under the No Action Alternative. As with Alternative 2, the yield projections are not constant over the 50-year period. In the same manner as was done for Alternative 2, average values were calculated for each ten-year period to be used in the revenue impact calculations.

Table 32- Projected Average Yield Values under the No Action Alternative

No Action Alternative Average Yields					
Crop	2028-2037	2038-2047	2048-2057	2058-2067	2068-2077
Corn (bu)	567,840	534,331	484,338	412,448	331,640
Soybeans(bu)	88,854	85,898	81,129	73,402	63,427
Potatoes (cwt)	451,760	428,181	391,962	337,577	273,420
Dry Beans (lbs)	242,011	228,341	207,593	176,996	141,631
Alfalfa (tons)	582	547	495	417	326

These projected average yield values were used to calculate the projected annual revenue impact under the No Action Alternative.

Once critical difference between the projected revenue impact under the No Action Alternative and the impact under the remaining two alternatives is that under the revenue is projected to decrease over time. The projected decrease will be reduced by the avoided variable costs.

For example, in 2053 under the No Action Alternative, the total estimated alfalfa yield is projected to decrease from 604 to 495 tons per year, where each ton is valued at $90.80. The actual projected loss, though, would be smaller than $9,897.20 because the variable costs will decrease as yield decreases. In 2053, the projected revenue loss from alfalfa is $8,274.31 ($9,897.20 – variable costs of $1,622.89).

Table 33- Projected Annual Revenue Impact under the No Action Alternative

No Action Alternative 2028-2037											
		Total Yield				Unit Variable Costs				Final Revenue Calculations	
Crop	Acres	Pre-Project	Post-Project	Yield Change	Unit Price	Drying	Hauling	Unit Revenue	Initial Revenue Change	Baling, Loading, & Hauling	Revenue Change
Corn (bu)	2,483	589,684	567,840	-21,844	$3.41	($0.05)	($0.12)	$3.24	($70,774.56)	$ -	($70,774.56)
Soybeans (bu)	910	90,692	88,854	-1,838	$8.75	($0.08)	($0.12)	$8.55	($15,714.90)	$ -	($15,714.90)
Potatoes (cwt)	987	466,853	451,760	-15,093	$10.79	$ -	($0.30)	$10.49	($158,325.57)	$ -	($158,325.57)
Dry Beans *	79	250,828	242,011	-8,817	$28.90	$ -	($0.40)	$28.50	($2,512.85)	$ -	($2,512.85)
Alfalfa (tons) **	108	604	582	-22	$90.80	$ -	$ -	$90.80	($1,997.60)	$327.56	($1,670.04)
Total	4,567										($248,997.92)
* Dry bean yield information in lbs but pricing per cwt; initial revenue calculation divides by 100 to convert yield gain for pricing calculation.											
** Alfalfa baling and hauling costs are calculated in a separate table.											

No Action Alternative 2038-2047											
		Total Yield				Unit Variable Costs				Final Revenue Calculations	
Crop	Acres	Pre-Project	Post-Project	Yield Change	Unit Price	Drying	Hauling	Unit Revenue	Initial Revenue Change	Baling, Loading, & Hauling	Revenue Change
Corn (bu)	2,483	589,684	534,331	-55,353	$3.41	($0.05)	($0.12)	$3.24	($179,343.72)	$ -	($179,343.72)
Soybeans (bu)	910	90,692	85,898	-4,794	$8.75	($0.08)	($0.12)	$8.55	($40,988.70)	$ -	($40,988.70)
Potatoes (cwt)	987	466,853	428,181	-38,672	$10.79	$ -	($0.30)	$10.49	($405,669.28)	$ -	($405,669.28)
Dry Beans *	79	250,828	228,341	-22,487	$28.90	$ -	($0.40)	$28.50	($6,408.80)	$ -	($6,408.80)
Alfalfa (tons) **	108	604	547	-57	$90.80	$ -	$ -	$90.80	($5,175.60)	$848.67	($4,326.93)
Total	4,567										($636,737.43)
* Dry bean yield information in lbs but pricing per cwt; initial revenue calculation divides by 100 to convert yield gain for pricing calculation.											
** Alfalfa baling and hauling costs are calculated in a separate table.											

No Action Alternative 2048-2057											
		Total Yield				Unit Variable Costs				Final Revenue Calculations	
Crop	Acres	Pre-Project	Post-Project	Yield Change	Unit Price	Drying	Hauling	Unit Revenue	Initial Revenue Change	Baling, Loading, & Hauling	Revenue Change
Corn (bu)	2,483	589,684	484,338	-105,346	$3.41	($0.05)	($0.12)	$3.24	($341,321.04)	$ -	($341,321.04)
Soybeans (bu)	910	90,692	81,129	-9,563	$8.75	($0.08)	($0.12)	$8.55	($81,763.65)	$ -	($81,763.65)
Potatoes (cwt)	987	466,853	391,962	-74,891	$10.79	$ -	($0.30)	$10.49	($785,606.59)	$ -	($785,606.59)
Dry Beans *	79	250,828	207,593	-43,235	$28.90	$ -	($0.40)	$28.50	($12,321.98)	$ -	($12,321.98)
Alfalfa (tons) **	108	604	495	-109	$90.80	$ -	$ -	$90.80	($9,897.20)	$1,622.89	($8,274.31)
Total	4,567										($1,229,287.57)
* Dry bean yield information in lbs but pricing per cwt; initial revenue calculation divides by 100 to convert yield gain for pricing calculation.											
** Alfalfa baling and hauling costs are calculated in a separate table.											

No Action Alternative 2058-2067											
		Total Yield				Unit Variable Costs				Final Revenue Calculations	
Crop	Acres	Pre-Project	Post-Project	Yield Change	Unit Price	Drying	Hauling	Unit Revenue	Initial Revenue Change	Baling, Loading, & Hauling	Revenue Change
Corn (bu)	2,483	589,684	412,448	-177,236	$3.41	($0.05)	($0.12)	$3.24	($574,244.64)	$ -	($574,244.64)
Soybeans (bu)	910	90,692	73,402	-17,290	$8.75	($0.08)	($0.12)	$8.55	($147,829.50)	$ -	($147,829.50)
Potatoes (cwt)	987	466,853	337,577	-129,276	$10.79	$ -	($0.30)	$10.49	($1,356,105.24)	$ -	($1,356,105.24)
Dry Beans *	79	250,828	176,996	-73,832	$28.90	$ -	($0.40)	$28.50	($21,042.12)	$ -	($21,042.12)
Alfalfa (tons) **	108	604	417	-187	$90.80	$ -	$ -	$90.80	($16,979.60)	$2,784.22	($14,195.38)
Total	4,567										($2,113,416.88)
* Dry bean yield information in lbs but pricing per cwt; initial revenue calculation divides by 100 to convert yield gain for pricing calculation.											
** Alfalfa baling and hauling costs are calculated in a separate table.											

No Action Alternative 2068-2077											
		Total Yield				Unit Variable Costs				Final Revenue Calculations	
Crop	Acres	Pre-Project	Post-Project	Yield Change	Unit Price	Drying	Hauling	Unit Revenue	Initial Revenue Change	Baling, Loading, & Hauling	Revenue Change
Corn (bu)	2,483	589,684	331,640	-258,044	$3.41	($0.05)	($0.12)	$3.24	($836,062.56)	$ -	($836,062.56)
Soybeans (bu)	910	90,692	63,427	-27,265	$8.75	($0.08)	($0.12)	$8.55	($233,115.75)	$ -	($233,115.75)
Potatoes (cwt)	987	466,853	273,420	-193,433	$10.79	$ -	($0.30)	$10.49	($2,029,112.17)	$ -	($2,029,112.17)
Dry Beans *	79	250,828	141,631	-109,197	$28.90	$ -	($0.40)	$28.50	($31,121.15)	$ -	($31,121.15)
Alfalfa (tons) **	108	604	326	-278	$90.80	$ -	$ -	$90.80	($25,242.40)	$4,139.11	($21,103.29)
Total	4,567										($3,150,514.92)
* Dry bean yield information in lbs but pricing per cwt; initial revenue calculation divides by 100 to convert yield gain for pricing calculation.											
** Alfalfa baling and hauling costs are calculated in a separate table.											

Cost Savings

The DSID Board estimates that the reductions in required operations and maintenance under Alternative 1 would result in significant labor savings. Labor requirements would be reduced under Alternative 2, but to a lesser extent.

Alternative 1 provides the opportunity for additional savings, as many expenses associated with canal maintenance would no longer be required. The cost savings estimates were provided by the DSID Board and from the State Engineer.

Table 34- Estimated Annual O&M Savings from Canal Modernization (Relative to the No Action Alternative)

	Projected Cost Savings	
Item	Alternative 1	Alternative 2
Personnel	$140,000	$14,000
Chemicals	$6,038	$3,019
Vehicle Repairs	$979	$97.90
Other Repairs and Maintenance	$4,948	$0
Fuel	$10,127	$1,012.70
Total	$162,092	$18,129.60

There are potential one-tine benefits that may be realized under Alternative 1 regarding the land and buildings currently used for the canal pump stations. These potential benefits are superfluous for the PIFR analysis but will be addressed as necessary in future analysis.

The Present Value of the Alternatives

The net present values of the alternatives are laid out in the tables that follow. These analyses utilize the discount rate set in National Bulletin ND 200-23-2 ECN and rely on the construction estimates and timelines detailed in earlier sections.

Table 35- Summary of Benefit-Cost Information for Alternative 1

Alternative 1 (Pipeline)			
Discount Rate	2.50%	AAE Factor	0.03365
Construction + Project Life	51 years	Construction Year(s)	2027
Construction Cost	$9,635,603.00	Project Life	50 years
Summary			
Item	Present Value (PV)		Average Annual Equivalent (AAE)
Increased Costs / Reduced Revenues			
Construction Costs	($8,516,469.03)		($286,579.18)
Final Engineering Design	($905,950.64)		($30,485.24)
Construction Engineering	($441,927.14)		($14,870.85)
Sponsor Legal / Contract Admin Costs	($132,578.14)		($4,461.25)
Land Rights Costs	($45,297.53)		($1,524.26)
Future Annual O&M: Winterization Costs	($75,204.45)		($2,530.63)
Future Annual O&M: Annual Maintenance Costs	($50,136.30)		($1,687.09)
Total Costs	**($10,167,563.24)**		**($342,138.50)**
Increased Revenues / Reduced Costs			
Net Revenue: Increased Yields	$15,113,346.45		$508,564.11
Savings: Labor	$3,509,541.11		$118,096.06
Savings: Herbicide	$151,361.49		$5,093.31
Savings: Vehicle Repair	$24,541.72		$825.83
Savings: Fuel	$253,865.16		$8,542.56
Savings: Other Repairs and Maintenance	$124,037.21		$4,173.85
Total Benefits	**$19,176,693.15**		**$645,295.72**
Net (Benefits - Costs)	**$9,009,129.91**		**$303,157.22**
Benefit-Cost Ratio (Benefits/Costs)	**1.89**		**1.89**

For PIFR analysis, all values discounted to 2023.
Note: This does not yet include power costs for pumping under each alternative. That would be evaluated during a full watershed planning effort..

The details for Alternative 2 are below.

Table 36- Summary of Benefit-Cost Information for Alternative 2

Alternative 2 (Canal)			
Discount Rate	2.50%	AAE Factor	0.03365
Construction + Project Life	51 years	Construction Year(s)	2027-2029
Construction Cost	$19,683,971.00	Project Life	50 years

Summary		
Item	Present Value (PV)	Average Annual Equivalent (AAE)
Increased Costs / Reduced Revenues		
Construction Costs	($16,976,876.39)	($571,271.89)
Final Engineering Design	($452,975.32)	($15,242.62)
Construction Engineering	($441,927.14)	($14,870.85)
Sponsor Legal/Contract Admin Costs	($88,385.43)	($2,974.17)
Land Rights Costs	($18,119.01)	($609.70)
Future Annual O&M: Labor	($3,170,561.01)	($106,689.38)
Future Annual O&M: Herbicide	($78,262.86)	($2,633.55)
Future Annual O&M: Vehicle Repair	($22,171.28)	($746.06)
Future Annual O&M: Fuel	($229,344.80)	($7,717.45)
Future Annual O&M: Other Maintenance and Repairs	($128,410.52)	($4,321.01)
Pump Station and Controls Replacement	($725,420.38)	($24,410.40)
Total Costs	**($22,332,454.13)**	**($751,487.08)**
Increased Revenues / Reduced Costs		
Net Revenue: Increased Yields	$7,946,896.69	$267,413.07
Savings: Labor	$338,980.10	$11,406.68
Savings: Herbicide	$73,098.64	$2,459.77
Savings: Vehicle Repair	$2,370.44	$79.77
Savings: Fuel	$24,520.37	$825.11
Total Benefits	**$8,385,866.24**	**$282,184.40**
Net (Benefits - Costs)	**($13,946,587.89)**	**($469,302.68)**
Benefit-Cost Ratio (Benefits/Costs)	**0.38**	**0.38**

For PIFR analysis, all values discounted to 2023.

As noted earlier (Section 7), Alternative 2 would be constructed over three years beginning after the conclusion of the 2027 growing season. Benefits would begin to accrue, estimated at ~33% of the total projected benefit, in 2028, with ~67% of the benefits realized the following year. Full benefits would be realized beginning with the 2030 growing season.

This manifests itself as follows: Current annual labor costs are $140,000. Upon project completion, labor costs are expected to decrease by 10%. After the first year of construction, labor costs will be reduced by 3.33% (10% labor savings multiplied by 0.33 to reflect 1/3 of the benefits). At the same time, the labor savings ($4,666.67) will be documented as a benefit in the analysis.

Costs under Alternative 2 include construction and implementation, future operations and maintenance, and the anticipated replacement of the pumps and controls, projected to occur in 2035. Benefits include a projected increase in revenue driven by increased yields, as well as savings from the reduced operations and maintenance costs.

The No Action Alternative relies on the continued use of the existing canal. Unlike Alternatives 1 and 2, yields under the No Action Alternative are projected to decrease over time as the canal continues to deteriorate. The projected yield decrease was detailed earlier in this appendix. The future operations and maintenance costs are an extension of the current costs, as reported by the DSID Board. The costs also include the anticipated necessary replacement of the pumps, motors, and controls, projected to occur in 2035.

The details for the No Action Alternative are below.

Table 37- Summary of Benefit-Cost Information for the No Action Alternative

No Action Alternative		
Discount Rate	2.50% AAE Factor	0.03365
Summary		
Item	Present Value (PV)	Average Annual Equivalent (AAE)
Increased Costs / Reduced Revenues		
Net Revenue: Yield Reduction	($28,447,628.82)	($957,262.71)
Future Annual O&M: Labor	($3,633,280.71)	($122,259.90)
Future Annual O&M: Herbicide	($156,698.21)	($5,272.89)
Future Annual O&M: Vehicle Repair	($25,407.01)	($854.95)
Future Annual O&M: Fuel	($262,815.96)	($8,843.76)
Future Annual O&M: Other Maintenance and Repairs	($128,410.52)	($4,321.01)
Pump Station and Controls Replacement	($725,420.38)	($24,410.40)
Total Costs	**($33,379,661.60)**	**($1,123,225.61)**

For PIFR analysis, all values discounted to 2023.

Sources of Uncertainty

The benefit-cost and net benefit estimates are preliminary and are subject to the uncertainty factors discussed below.

This study makes assumptions regarding crop patterns and the impact of changes in available irrigation water on crop yield. Changes in the assumptions would influence the outcome of the analysis.

Assumptions:

1. Future crop patterns will conform to historical averages.
2. Producer behavior with respect to crop inputs will not vary as a result of the project.

This analysis relies on modeled impacts: the impact of changing levels of irrigation water availability on yield and the rate of canal deterioration. To the extent that the actual impacts may differ from the modeled impacts, these areas are both sources of uncertainty.

This analysis uses state-level normalized prices and relies on estimates from the projected crop budgets, a published list of custom rates, and from producer input for input costs. As those values change for producers, either increasing or decreasing, benefits will change accordingly.

Any changes in construction cost or construction timing estimates would impact the benefit-cost analysis. The changes in operations and maintenance costs were estimated by the DSID Board and would be further refined during the full watershed planning effort. To the extent that actual savings as a result of the project differ from the estimate, benefit-cost estimates will change.

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Figure 3

Date:12/14/2022

DSID Seepage Test Sections

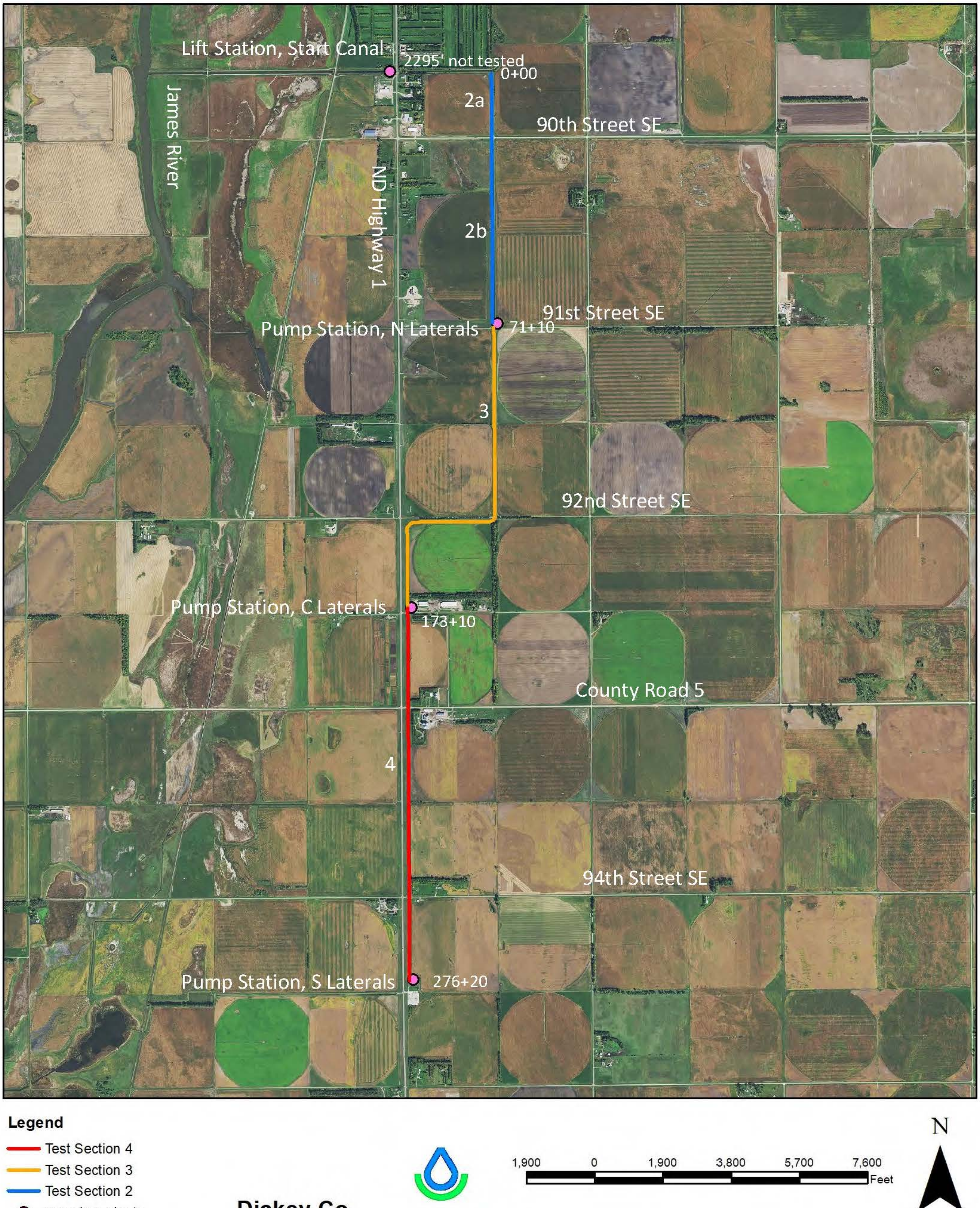


Figure 4a: 2016 Crop Data

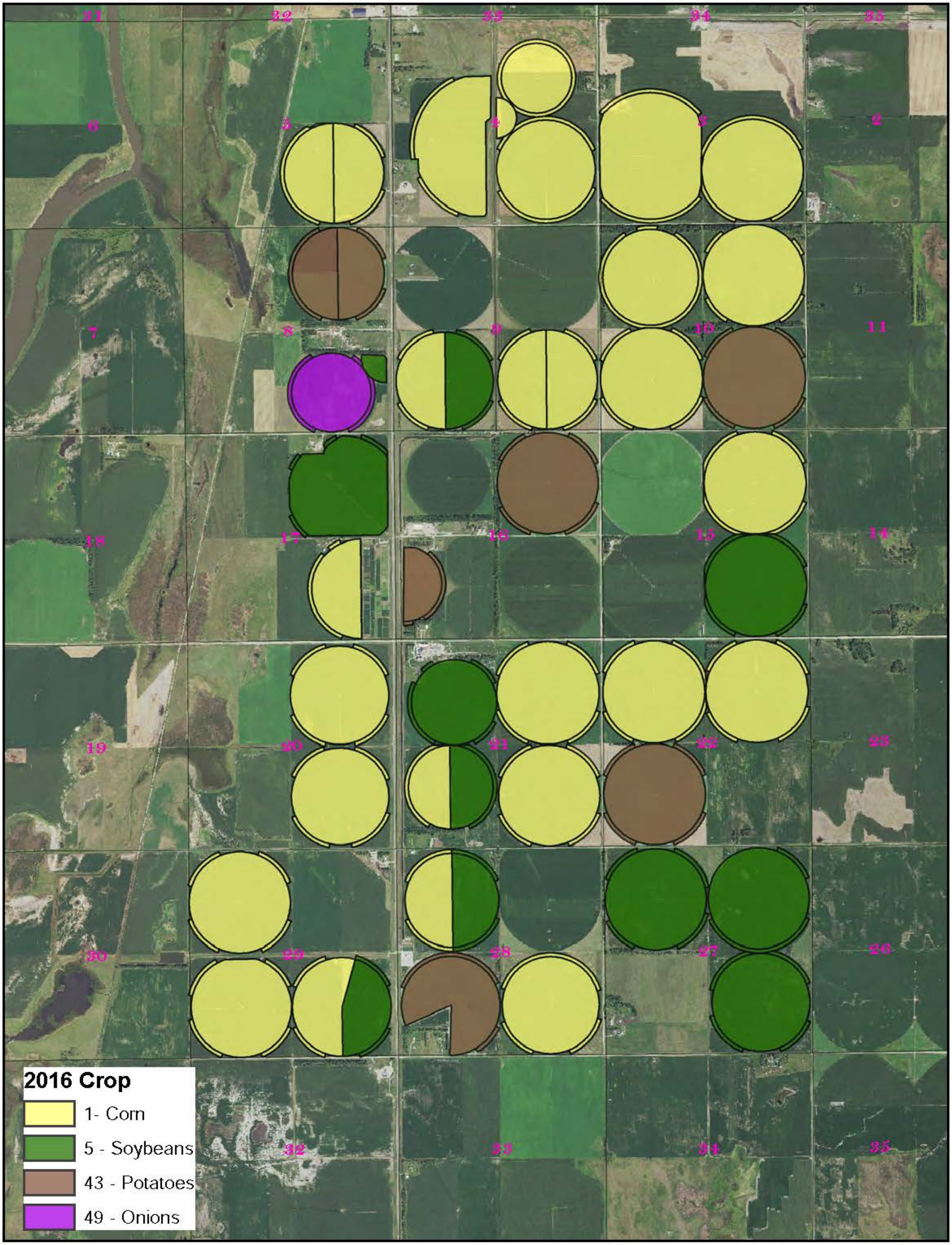


Figure 4b: 2017 Crop Data

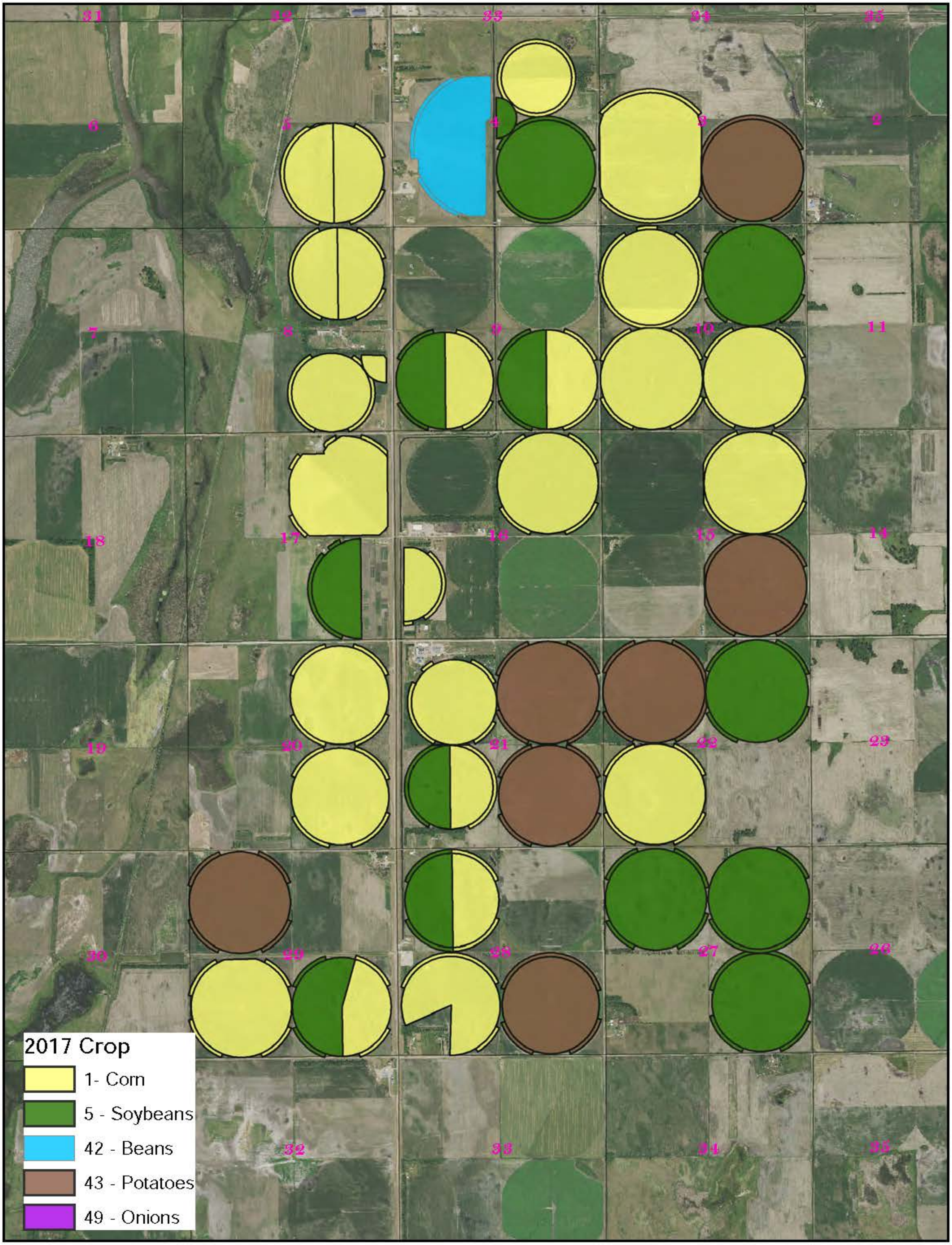


Figure 4c: 2018 Crop Data

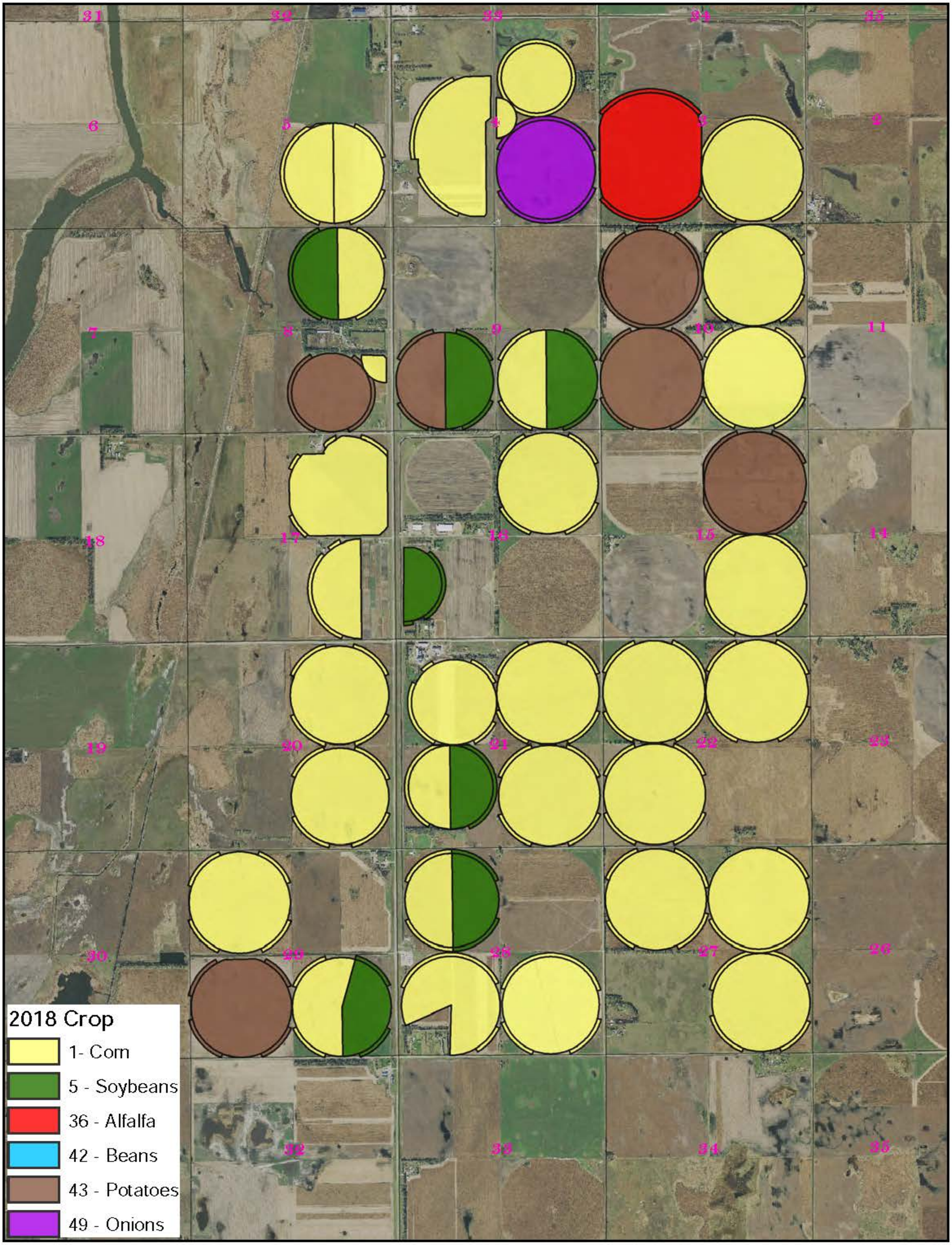


Figure 4d: 2019 Crop Data

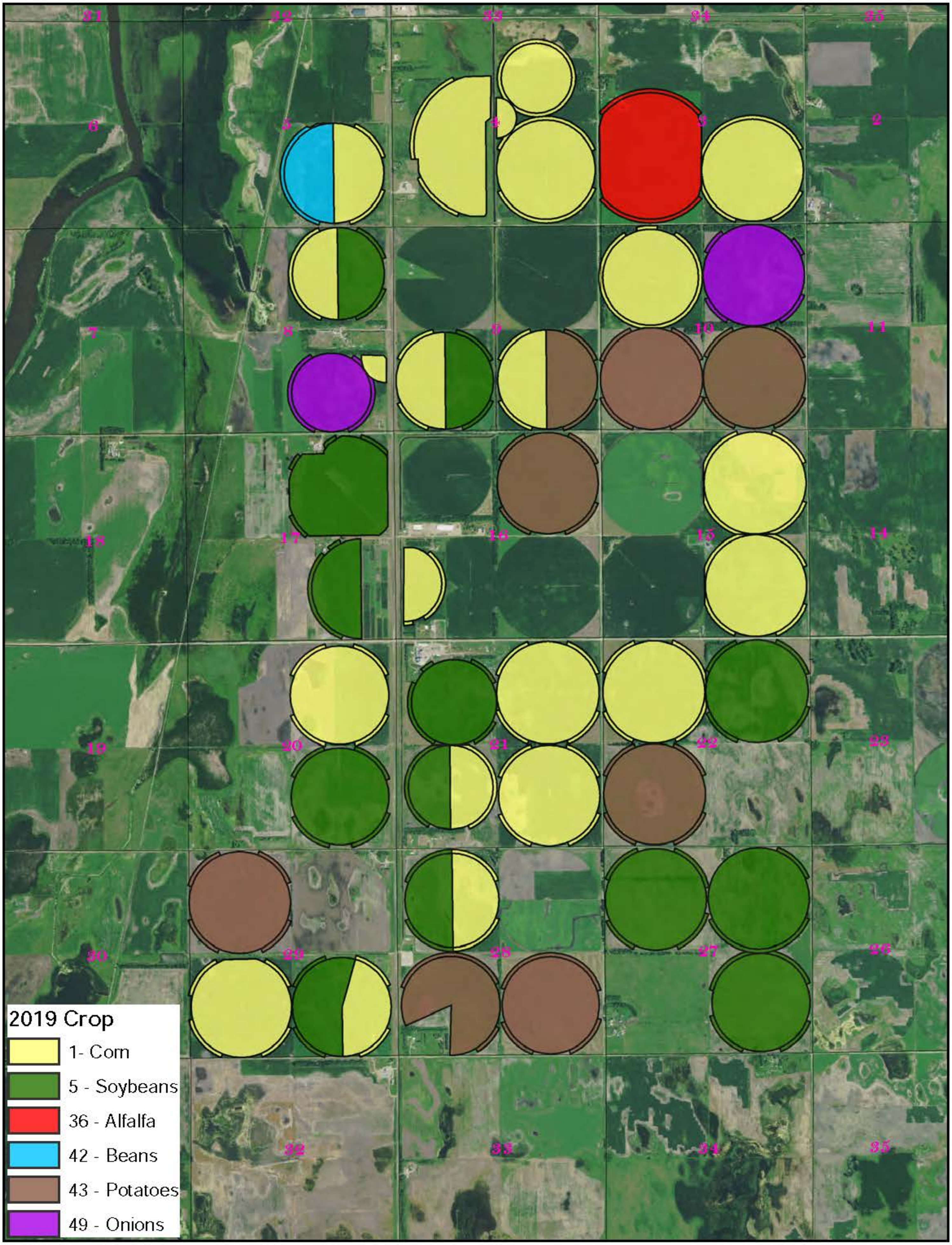


Figure 4e: 2020 Crop Data

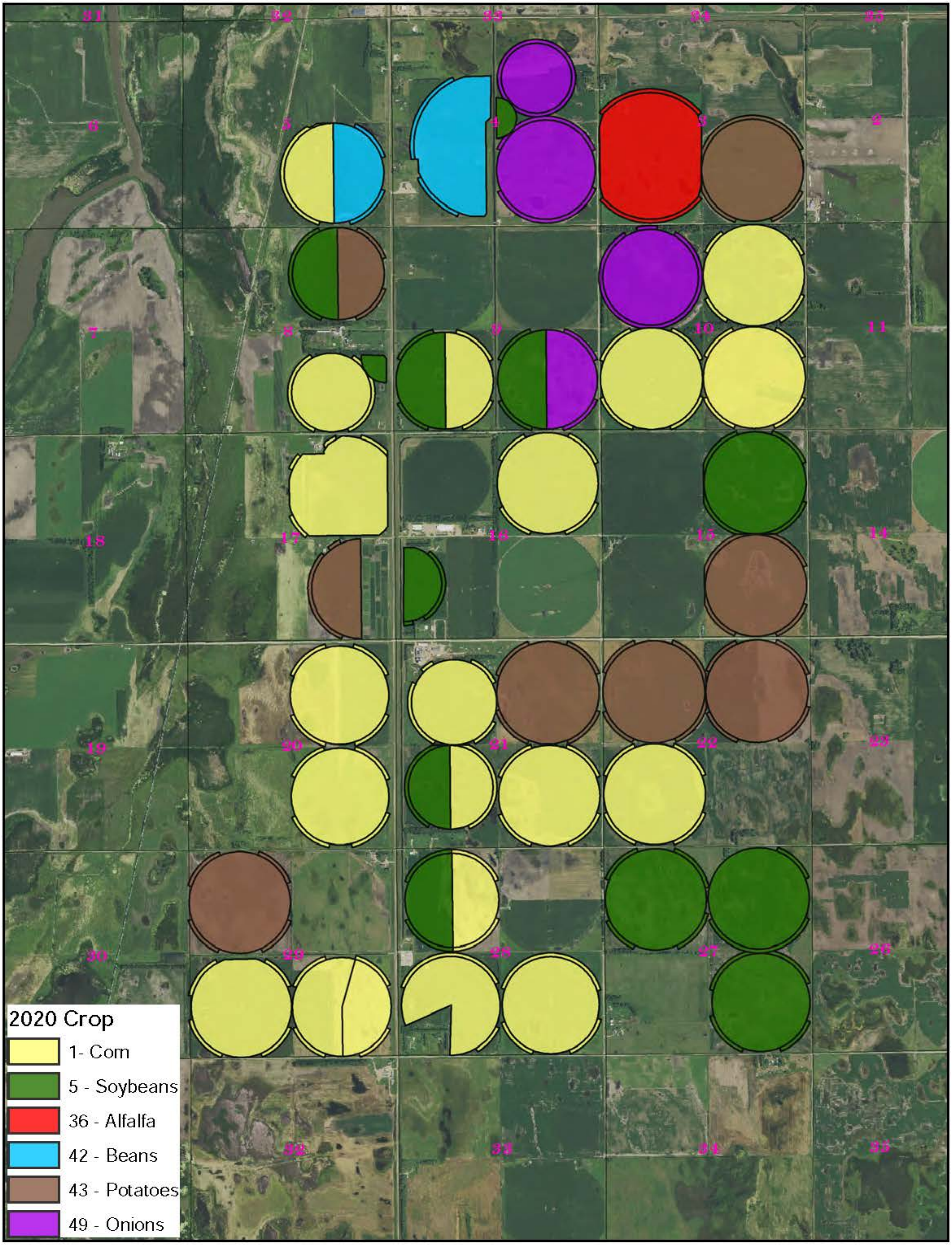


Figure 4f: 2021 Crop Data

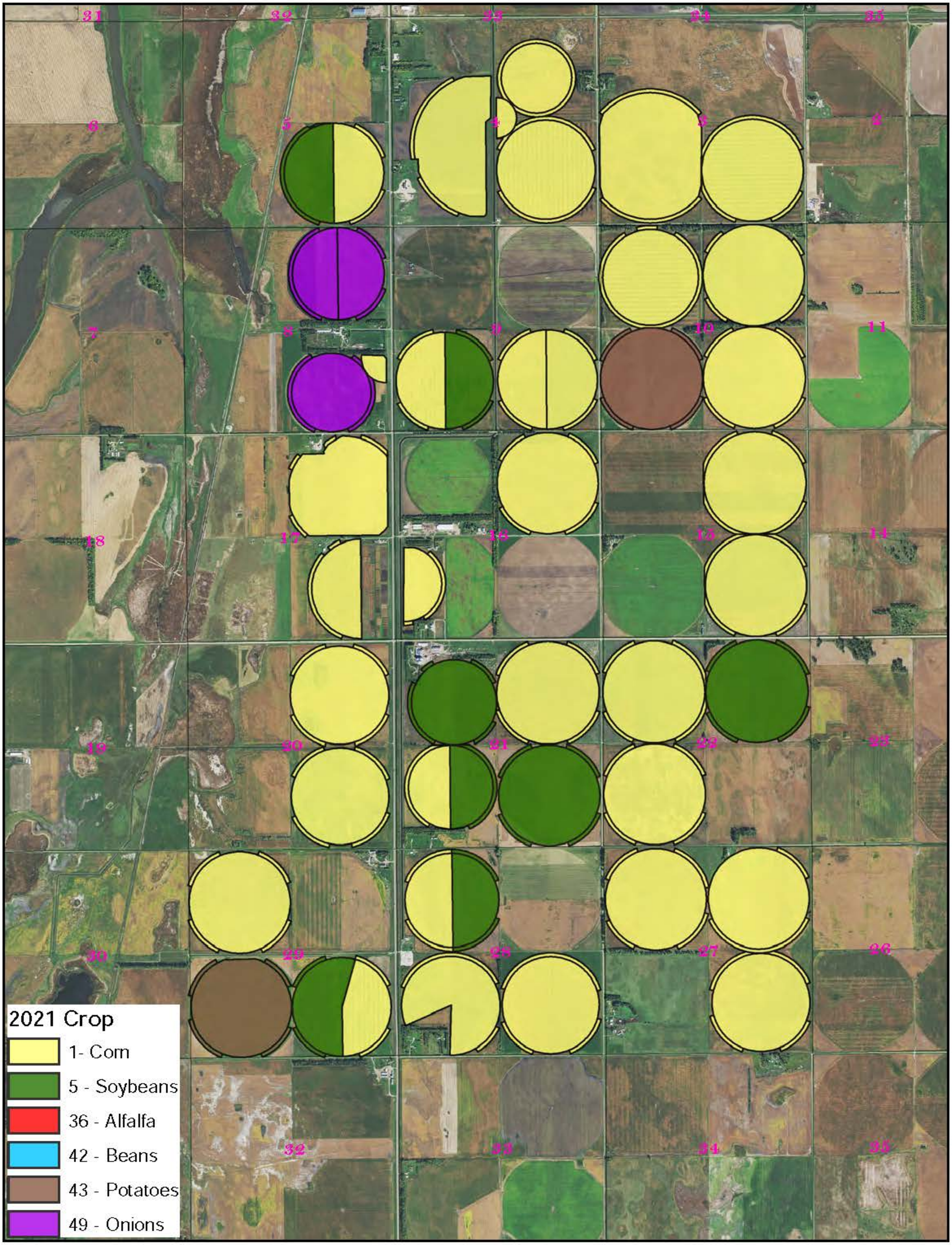


Figure 4g: 2022 Crop Data (2021 Aerial)

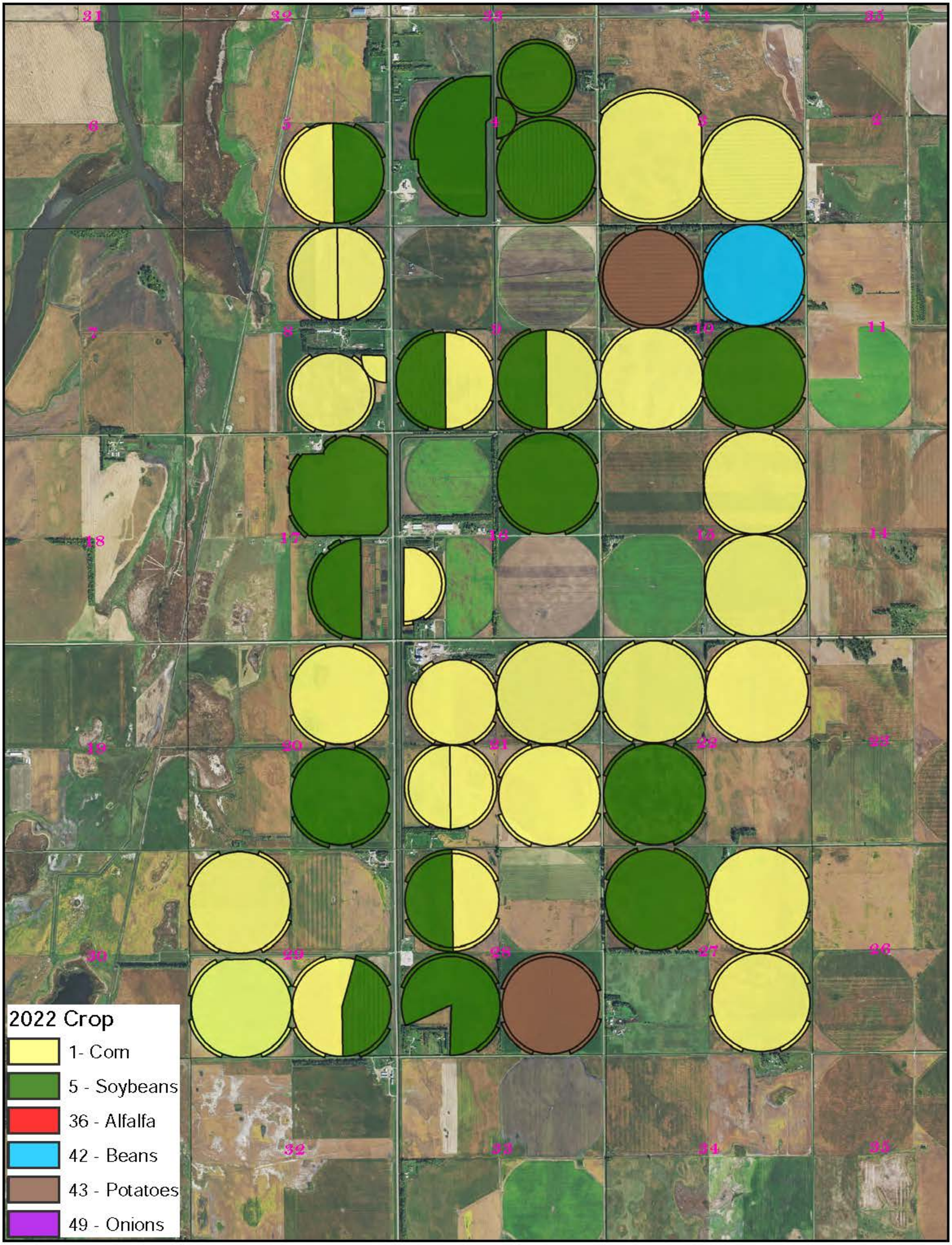


Figure 5a

Irrigation Water Requirements
Crop Data Summary

Job: **Oakes FSL**
Location: **Oakes**
Land User: **Oakes Test area**
By: **EAA**
Weather Station: **Oakes**
Latitude: **4607** Longitude: **9809**
Compute Method: **FAO Penman-Monteith,NEH2**
Crop Curve: **Grasses and forage legumes**
Begin Growth: **4/20** End Growth: **7/15**
Irrigation Type: **Sprinklers- above canopy**
Surface Soil: **Sandy Loam**
Wetting (Development): **7** days (Mature): **3** days

Crop: **Alfalfa**
County: **Dickey, ND**
Date: **11/07/22**
ID: **1** JobClass: **II**
Sta No: **ND0047**
Elevation: **1318** feet above sea level
Net irrigation application: **1** inches
Estimated carryover moisture used at season:
Begin: **0.5** inches End: **0.5** inches
Water stress factor: **1.00**
Number of Cuttings: **3**
1st cut: **7/15** Last Cut: **9/15**

Month	Total Monthly ET (3) inches	Dry Year 80% Chance (1)		Normal Year 50% Chance (1)		Average Daily ETc inches	Peak Daily ETPk inches
		Effective Precipitation inches	Net Irrigation Reqirements inches (2)	Effective Precipitation inches	Net Irrigation Reqirements inches (2)		
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.80	0.20	0.10	0.26	0.05	0.08	
May	4.49	1.19	3.30	1.48	3.00	0.14	0.19
June	7.05	1.95	5.10	2.43	4.62	0.24	0.31
July	3.97	0.75	2.72	0.94	2.53	0.26	
August	0.00	0.00	0.00	0.00	0.00	0.00	
September	0.00	0.00	0.00	0.00	0.00	0.00	
October	0.00	0.00	0.00	0.00	0.00	0.00	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**16.31**	**4.09**	**11.22**	**5.11**	**10.20**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

Date: 1/24/2023

Figure 5b

Irrigation Water Requirements
Crop Data Summary

Job: **Oakes FSL**
Location: **Oakes**
Land User: **Oakes Test area**
By: **EAA**
Weather Station: **Oakes**
Latitude: **4607** Longitude: **9809**
Compute Method: **FAO Penman-Monteith,NEH2**
Crop Curve: **Field and vegetable crops**
Begin Growth: **5/15** End Growth: **10/15**
Irrigation Type: **Sprinklers- above canopy**
Surface Soil: **Sandy Loam**
Wetting (Development): **7** days (Mature): **3** days

Crop: **Corn, Grain**
County: **Dickey, ND**
Date: **11/07/22**
ID: **1** JobClass: **II**
Sta No: **ND0047**
Elevation: **1318** feet above sea level
Net irrigation application: **1** inches
Estimated carryover moisture used at season:
Begin: **0.5** inches End: **0.5** inches
Water stress factor: **1.00**

Month	Total Monthly ET (3) inches	Dry Year 80% Chance (1)		Normal Year 50% Chance (1)		Average Daily ETc inches	Peak Daily ETPk inches
		Effective Precipitation inches	Net Irrigation Reqirements inches (2)	Effective Precipitation inches	Net Irrigation Reqirements inches (2)		
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.00	0.00	0.00	0.00	0.00	0.00	
May	1.09	0.54	0.05	0.67	0.00	0.07	
June	3.14	1.57	1.58	1.96	1.10	0.10	0.14
July	6.33	1.39	4.94	1.74	4.59	0.20	0.27
August	6.58	1.03	5.54	1.29	5.28	0.21	0.28
September	4.81	1.14	3.67	1.43	3.38	0.16	0.20
October	1.21	0.39	0.32	0.48	0.22	0.08	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**23.16**	**6.06**	**16.10**	**7.58**	**14.58**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

Date: 1/24/2023

Figure 5c

Irrigation Water Requirements
Crop Data Summary

Job: **Oakes FSL**
Location: **Oakes**
Land User: **Oakes Test area**
By: **EAA**
Weather Station: **Oakes**
Latitude: **4607** Longitude: **9809**
Compute Method: **FAO Penman-Monteith,NEH2**
Crop Curve: **Field and vegetable crops**
Begin Growth: **5/20** End Growth: **9/20**
Irrigation Type: **Sprinklers- above canopy**
Surface Soil: **Sandy Loam**
Wetting (Development): **7** days (Mature): **3** days

Crop: **Dry beans**
County: **Dickey, ND**
Date: **11/07/22**
ID: **1** JobClass: **II**
Sta No: **ND0047**
Elevation: **1318** feet above sea level
Net irrigation application: **1** inches
Estimated carryover moisture used at season:
Begin: **0.5** inches End: **0.5** inches

Water stress factor: **1.00**

Month	Total Monthly ET (3) inches	Dry Year 80% Chance (1)		Normal Year 50% Chance (1)		Average Daily ETc inches	Peak Daily ETPk inches
		Effective Precipitation inches	Net Irrigation Reqirements inches (2)	Effective Precipitation inches	Net Irrigation Reqirements inches (2)		
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.00	0.00	0.00	0.00	0.00	0.00	
May	0.75	0.37	0.00	0.46	0.00	0.07	
June	3.41	1.59	1.70	1.99	1.21	0.11	0.15
July	6.94	1.44	5.50	1.80	5.14	0.22	0.29
August	6.45	1.03	5.42	1.28	5.17	0.21	0.27
September	2.55	0.70	1.34	0.88	1.17	0.13	
October	0.00	0.00	0.00	0.00	0.00	0.00	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**20.10**	**5.13**	**13.97**	**6.41**	**12.69**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

Date: 1/24/2023

Figure 5d

Irrigation Water Requirements
Crop Data Summary

Job: **Oakes FSL**
Location: **Oakes**
Land User: **Oakes Test area**
By: **EAA**
Weather Station: **Oakes**
Latitude: **4607** Longitude: **9809**
Compute Method: **FAO Penman-Monteith,NEH2**
Crop Curve: **Field and vegetable crops**
Begin Growth: **4/15** End Growth: **9/1**
Irrigation Type: **Sprinklers- above canopy**
Surface Soil: **Sandy Loam**
Wetting (Development): **7** days (Mature): **3** days

Crop: **Onion**
County: **Dickey, ND**
Date: **11/07/22**
ID: **1** JobClass: **II**
Sta No: **ND0047**
Elevation: **1318** feet above sea level
Net irrigation application: **1** inches
Estimated carryover moisture used at season:
Begin: **0.5** inches End: **0.5** inches

Water stress factor: **1.00**

Month	Total Monthly ET (3) inches	Dry Year 80% Chance (1)		Normal Year 50% Chance (1)		Average Daily ETc inches	Peak Daily ETPk inches
		Effective Precipitation inches	Net Irrigation Reqirements inches (2)	Effective Precipitation inches	Net Irrigation Reqirements inches (2)		
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.72	0.29	0.00	0.36	0.00	0.05	
May	3.71	1.14	2.51	1.42	2.15	0.12	0.16
June	5.36	1.77	3.59	2.22	3.15	0.18	0.23
July	6.24	1.39	4.85	1.73	4.51	0.20	0.26
August	5.52	0.98	4.15	1.22	3.89	0.18	0.23
September	0.14	0.04	0.00	0.04	0.00	0.14	
October	0.00	0.00	0.00	0.00	0.00	0.00	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**21.69**	**5.60**	**15.10**	**7.00**	**13.70**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

Date: 1/24/2023

Figure 5e

Irrigation Water Requirements
Crop Data Summary

Job: **Oakes FSL**
Location: **Oakes**
Land User: **Oakes Test area**
By: **EAA**
Weather Station: **Oakes**
Latitude: **4607** Longitude: **9809**
Compute Method: **FAO Penman-Monteith,NEH2**
Crop Curve: **Field and vegetable crops**
Begin Growth: **5/1** End Growth: **9/20**
Irrigation Type: **Sprinklers- above canopy**
Surface Soil: **Sandy Loam**
Wetting (Development): **7** days (Mature): **3** days

Crop: **Potato**
County: **Dickey, ND**
Date: **11/07/22**
ID: **1** JobClass: **II**
Sta No: **ND0047**
Elevation: **1318** feet above sea level
Net irrigation application: **1** inches
Estimated carryover moisture used at season:
Begin: **0.5** inches End: **0.5** inches

Water stress factor: **1.00**

Month	Total Monthly ET (3) inches	Dry Year 80% Chance (1)		Normal Year 50% Chance (1)		Average Daily ETc inches	Peak Daily ETPk inches
		Effective Precipitation inches	Net Irrigation Reqirements inches (2)	Effective Precipitation inches	Net Irrigation Reqirements inches (2)		
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.00	0.00	0.00	0.00	0.00	0.00	
May	2.05	1.01	0.54	1.26	0.29	0.07	
June	4.27	1.67	2.60	2.08	2.18	0.14	0.19
July	7.18	1.46	5.72	1.83	5.36	0.23	0.30
August	6.43	1.03	5.40	1.28	5.15	0.21	0.27
September	2.83	0.72	1.61	0.90	1.43	0.14	
October	0.00	0.00	0.00	0.00	0.00	0.00	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**22.76**	**5.88**	**15.88**	**7.35**	**14.41**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

Date: 1/24/2023

Figure 5f

Irrigation Water Requirements
Crop Data Summary

Job: **Oakes FSL**
Location: **Oakes**
Land User: **Oakes Test area**
By: **EAA**
Weather Station: **Oakes**
Latitude: **4607** Longitude: **9809**
Compute Method: **FAO Penman-Monteith,NEH2**
Crop Curve: **Field and vegetable crops**
Begin Growth: **5/25** End Growth: **10/10**
Irrigation Type: **Sprinklers- above canopy**
Surface Soil: **Sandy Loam**
Wetting (Development): **7** days (Mature): **3** days

Crop: **Soybean**
County: **Dickey, ND**
Date: **11/07/22**
ID: **1** JobClass: **II**
Sta No: **ND0047**
Elevation: **1318** feet above sea level
Net irrigation application: **1** inches
Estimated carryover moisture used at season:
Begin: **0.5** inches End: **0.5** inches
Water stress factor: **1.00**

Month	Total Monthly ET (3) inches	Dry Year 80% Chance (1)		Normal Year 50% Chance (1)		Average Daily ETc inches	Peak Daily ETPk inches
		Effective Precipitation inches	Net Irrigation Reqirements inches (2)	Effective Precipitation inches	Net Irrigation Reqirements inches (2)		
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.00	0.00	0.00	0.00	0.00	0.00	
May	0.41	0.20	0.00	0.25	0.00	0.07	
June	3.01	1.55	1.16	1.94	0.73	0.10	0.13
July	6.42	1.40	5.02	1.75	4.67	0.21	0.27
August	6.28	1.02	5.26	1.27	5.00	0.20	0.26
September	4.66	1.13	3.53	1.42	3.19	0.15	0.20
October	0.76	0.26	0.01	0.32	0.00	0.08	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**21.54**	**5.56**	**14.97**	**6.95**	**13.58**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

Date: 1/24/2023

Figure 6- FIRI Results, Typical DSID Pivot

NRCS USDA	Farm Irrigation Rating Tool *Detail Report* Natural Resources Conservation Service (NRCS)						
Client:	DSID Typical Irrigation		**Date:**	5/16/23	**Planner:**		
Tract No.	0	**Farm No.**	0	**Field No.**	0	**Description:**	

	Current System Status	Planned improvements or Management
FIRI Rating Index	**71.0**	
Net Irrigation Applied	0.0	0.0
Gross Irrigation Available	0.0	0.0
Runoff		
Deep Percolation		

	FIRI Factors		**Practice**	**Rating**	**Practice**	**Rating**
	System Type		Center Pivot - Mid Elevation Spray application(MESA)	85	N/A	
Management	Water Measurement	Md	No flow measuring devices	0.90	N/A	
Management	Irrigation Scheduling	S	Visual crop stress	0.94	N/A	
Management	Irrigation Knowledge or Skill	I	Good-Lack of full attention	0.92	N/A	
Management	System Maintenance	M	Good	0.98	N/A	
Management	Water Availability and Delivery	D	Demand -- Limited rate	0.98	N/A	
Management	Soil Condition or health	Sc	Soil Condition Index from SCI = 0.8	0.98	N/A	
Hardware Design	Water delivery Control	Wc	All flow rates to each set are adequately controlled.	1.00	N/A	
Hardware Design	Type of water Conveyance used	Ce	N/A		N/A	
Hardware Design	Field Levelness	L	A sprinkler or drip system utilized	1.00	N/A	
Hardware Design	Tailwater reuse	R	0%	1.00	N/A	
Hardware Design	Climate	C	Warm -- peak avg et 0.30	1.00	N/A	
Hardware Design	Wind	W	Medium spray wind speed 4 -10 MPH	0.93	N/A	
Hardware Design	Sprinkler Design	Sd	Pressure variation 20-30%, Uniformity 70-80%, Application rate <= soil intake	0.97	N/A	
Hardware Design	Emitter selection/care	E	Surface or Sprinkler System N/A		N/A	
Hardware Design	Drip-Micro Design	T	Surface or Sprinkler System N/A		N/A	
	Percent of maximum potential rating			84%		

Notes:

Figure 7 - SE Sec 27 Pivot Operating Requirements

United States Department of Agriculture | NRCS - North Dakota

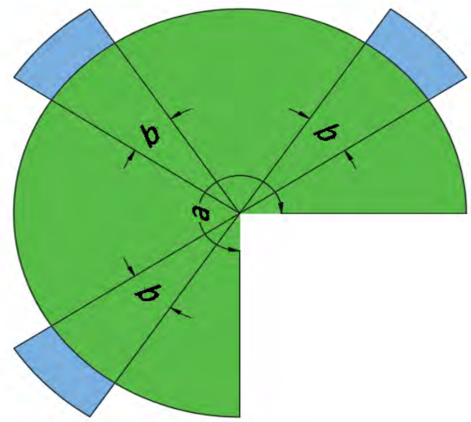
Natural Resources Conservation Service | Version: 1.3

PIVOT PLANNING AND DESIGN WORKSHEET

Producer:	DSID Average System	Field Office:	Ellendale
Legal Desc:	DSID	Details:	
Designed by:	Erica Althoff	Date:	4/3/2023
Checked by:		Date:	

Flow Rate Analysis

Irrigated Crop	Corn
d' = Crop Peak Consumptive Use (in)	0.29
PL = Pivot Length (ft)	1254
SL = Swing Arm Length (ft)	0
EGR = End Gun Radius (effective) (ft)	100
T = Operating time (hr/day)	23
Pivot Area (acre)	113.4 ac
Swing Arm Area (acre)	
End Gun Area (acre)	9.4 ac
Total Irrigated Area (acre)	122.8 ac
Pivot Application Efficiency (%)	85
End Gun Application Efficiency (%)	65



a = Pivot Coverage:	360 deg
b = End Gun Coverage (total):	180 deg

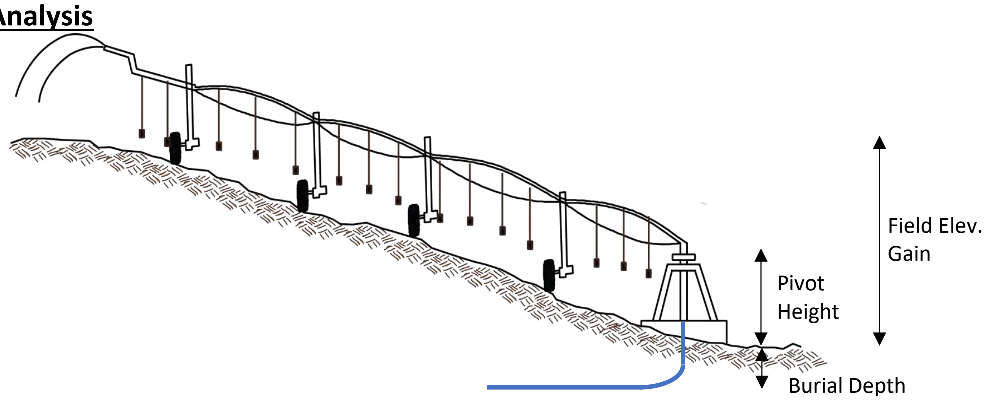
$$Q_{pivot} = \frac{453A_{pivot} * d'}{T * P_{eff}} = \text{762.1 gpm}$$

$$Q_{sa} = \frac{453A_{sa} * d'}{T * P_{eff}} = \text{0.0 gpm}$$

$$Q_{eg} = \frac{453A_{eg} * d'}{T * EG_{eff}} = \text{82.6 gpm}$$

$$Q = Q_{pivot} + Q_{sa} + Q_{eg} = \underline{\text{845 gpm}}$$

Pivot Analysis



Pivot pipe size	6-5/8
Sprinkler type selected	Rotator
Sprinkler plate style/color	Orange
Ground height clearance	6 ft
Sprinker operating pressure	15 PSI
Sprinkler wetted diameter selected	62 ft
Sprinklers Application rate	1.89 in/hr
Maximum Application rate "Ix"	2.40 in/hr
Select Net Irrigation "I"	1.0 in
Pivots min sprinkler diameter "W"	62 ft
Travel Time (one revolution) "T"	79 hr
Max. Sprinkler Spacing (based on nozzle)	25 ft

	Feet	PSI
Max. field elevation gain	5.0	2.2
Pressure of last pivot nozzle	46.2	20.0
Friction loss through pivot	27.1	11.8
Height of Pivot	12.0	5.2
Pipeline burial depth @ pivot	3.5	1.5
Pressure Needed at Pivot Point: (at pipeline invert)	***93.78***	***40.64***

Figure 8 - Existing Booster Pump Station Pumps (evaluation for relocation) vs System Curve for Proposed Pipeline

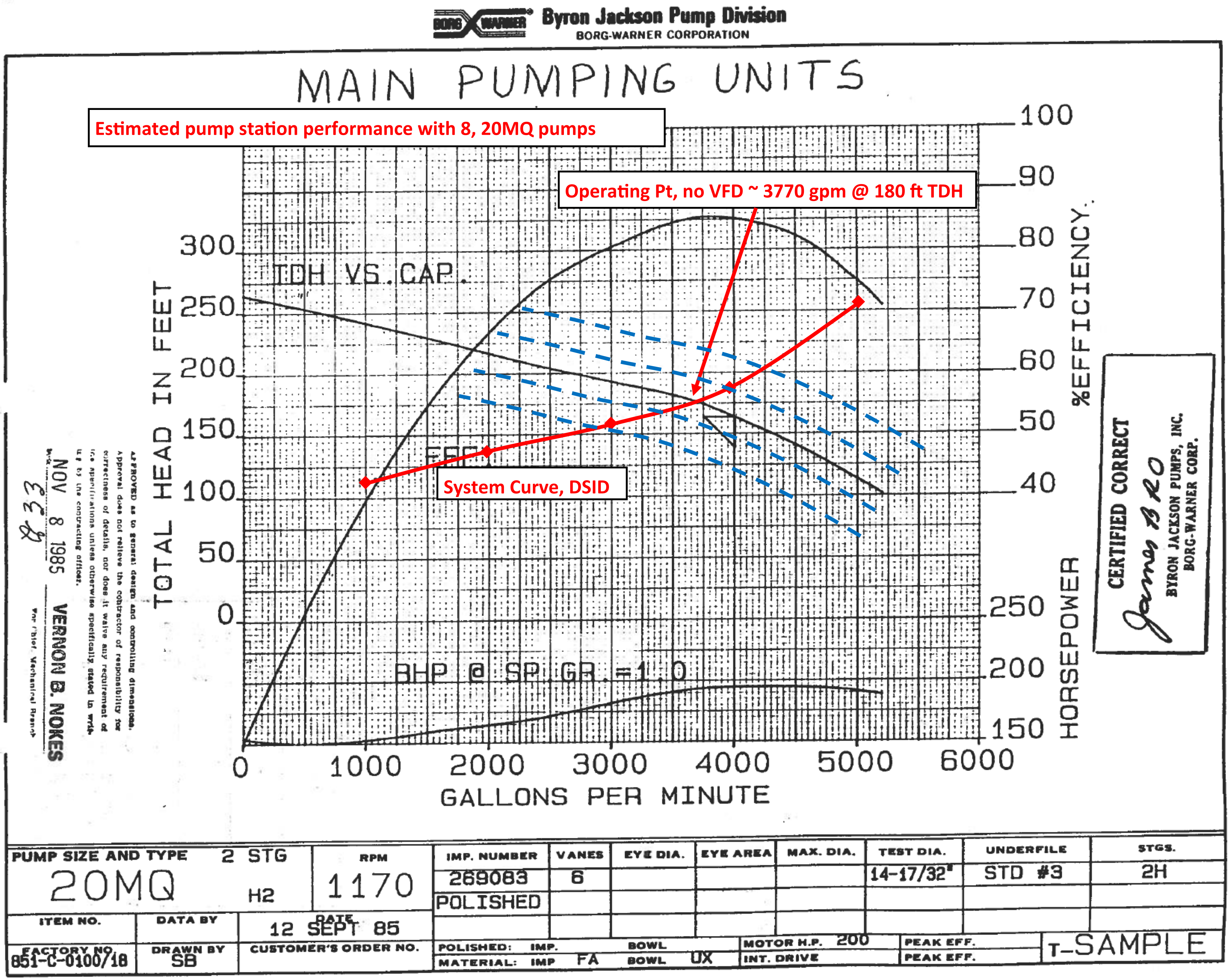


Figure 9- Prelim Pipeline Hydraulics

PIPELINE COMPUTATION WORKSHEET | **Project Name:** DSID Preliminary Pipeline | **Notes:** Need 40 psi @ pivot point, NW 1/4 Sec 27

USDA - Natural Resources Conservation Service | **By:** CF

hecked By:

COMPONENT DESCRIPTION	REACH No.	STATION	PIPE INVERT ELEVATION	FLOW RATE	FLOW RATE	PIPE TYPE	NOMINAL PIPE DIAMETER	PIPE CLASS	SDR	OUTSIDE PIPE DIAMETER	INSIDE PIPE DIAMETER	HAZEN-WILLIAMS COEFICIENT	FLOW VELOCITY	MINOR LOSS K factor	TDH from PUMP	PRESSURE REGULATION @ STATION	ENERGY GRADELINE AT WORK	HYDRAULIC GRADELINE AT WORK	WORKING PRESSURE		ENERGY GRADE LINE AT PEAK	STATIC PRESSURE	
UNITS -->>		(ft)	(ft)	(gpm)	(ft^3/s)		(Inches)	(Press Rating)		(in)	(in)	(CH)	(ft/s)	$K = h_L/(V^2/2g)$	(ft)	(psi)	(ft)	(ft)	(ft)	(psi)	(ft)	(ft)	(psi)
(Data Entry Column)		(Entry Column)	(Entry Column)	Entry Column)		(Entry Column)	(Entry Column)	(Entry Column)				(Entry Column)		(Entry Column)	(Entry Column)	(Entry Column)		(Entry Cell)					
Pump Sta / River WS		+0	1290.20												185			1475.20			1475.20		
Pump Sta Outlet	1	+1	1302.00	30456	67.86	HDPE	54 IPS	100	21	54.000	48.549	150	5.27	10.00			1471.3	1470.87	166.84	72.23	1475.20	171.18	74.10
Leave old canal	2	9+75	1307.86	30456	67.86	HDPE	54 IPS	100	21	54.000	48.549	150	5.27	0.42			1469.9	1469.51	159.63	69.10	1475.20	165.32	71.57
pumppout	3	28+00	1298.50	30456	67.86	HDPE	54 IPS	100	21	54.000	48.549	150	5.27	0.58			1467.5	1467.07	166.55	72.10	1475.20	174.68	75.62
3-way	4	45+65	1306.10	30456	67.86	HDPE	54 IPS	100	21	54.000	48.549	150	5.27	0.76			1465.1	1464.62	156.50	67.75	1475.20	167.08	72.33
tee o N laterals	5	82+30	1295.20	30456	67.86	HDPE	54 IPS	100	21	54.000	48.549	150	5.27	3.66			1459.1	1458.64	161.42	69.88	1475.20	177.98	77.05
tee to drain	6	83+10	1295.00	18813	41.92	HDPE	42 IPS	100	21	42.000	37.760	150	5.39	0.80			1458.6	1458.15	161.57	69.94	1475.20	178.63	77.33
pumpout	7	83+11	1295.00	18813	41.92	HDPE	42 IPS	100	21	42.000	37.760	150	5.39	0.40			1458.4	1457.96	161.39	69.87	1475.20	178.63	77.33
3-way	8	118+00	1310.00	18813	41.92	HDPE	42 IPS	100	21	42.000	37.760	150	5.39	0.58			1452.3	1451.86	140.29	60.73	1475.20	163.63	70.83
pumpout	9	140+30	1297.00	18813	41.92	HDPE	42 IPS	100	21	42.000	37.760	150	5.39	0.40			1448.4	1447.95	149.37	64.66	1475.20	176.63	76.46
Back into old canal	10	141+00	1297.42	18813	41.92	HDPE	42 IPS	100	21	42.000	37.760	150	5.39	0.20			1448.2	1447.74	148.75	64.39	1475.20	176.21	76.28
tee to C laterals	11	163+50	1306.41	18813	41.92	HDPE	42 IPS	100	21	42.000	37.760	150	5.39	3.60			1442.8	1442.35	134.37	58.17	1475.20	167.22	72.39
S laterals, end new pipe	12	267+00	1305.00	7352	16.38	HDPE	30 IPS	100	21	30.000	26.970	150	4.13	3.30			1426.1	1425.81	119.69	51.81	1475.20	169.08	73.19
turnout	13	307+21	1306.87	4916	10.95	PVC	30 IPS	100	41	30.000	28.537	150	2.46	4.72			1423.3	1423.17	115.12	49.83	1475.20	167.14	72.36
size change	14	319+82	1306.87	3655	8.14	PVC	27 PIP	100	41	27.953	26.504	150	2.12	2.18			1422.5	1422.45	114.48	49.56	1475.20	167.23	72.39
turnout	15	335+14	1307.42	2258	5.03	PVC	21 PIP	100	41	22.047	20.904	150	2.11	2.84			1421.4	1421.35	113.06	48.95	1475.20	166.91	72.25
end DSID lateral	16	347+41	1307.85	1489	3.32	PVC	15 PIP	100	41	15.300	14.507	150	2.89	2.24			1419.2	1419.09	110.63	47.89	1475.20	166.75	72.18
NE 1/4 Sec 27 pivot	17	365+74	1308.50	767	1.71	PVC	8 PIP	80	51	8.160	7.820	150	5.12	2.24			1401.0	1400.64	91.81	39.74	1475.20	166.37	72.02
	18																						
	19																						
	20																						
Totals																							

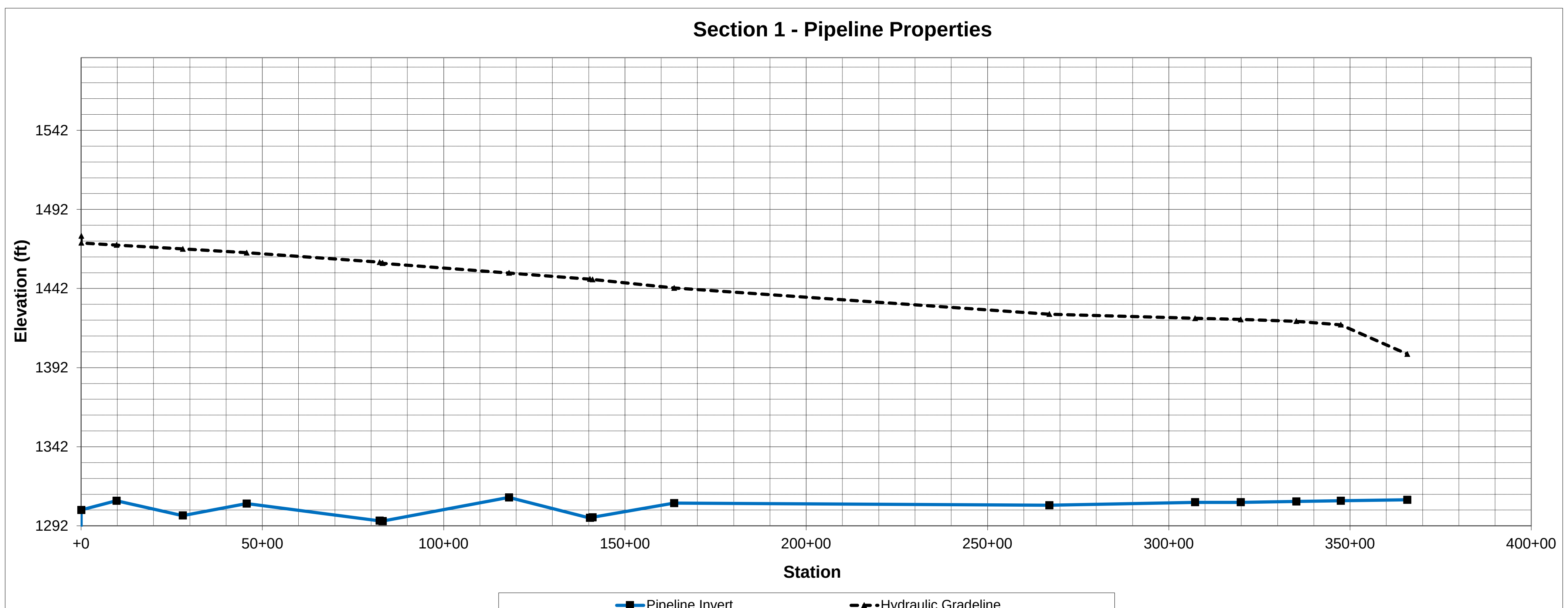
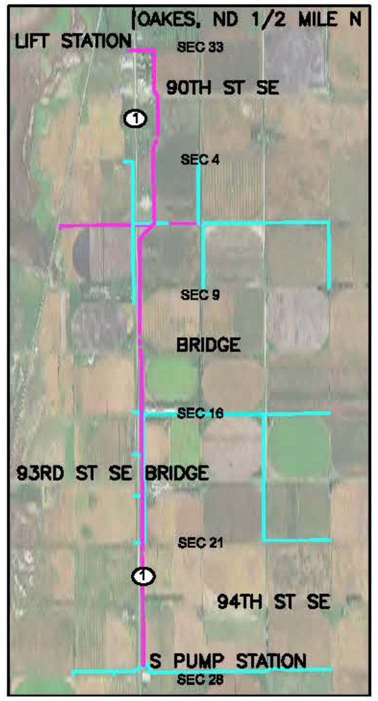


Figure 10- Preliminary Design Alternative #1



PROJECT LOCATION MAP
1" = 1.5 miles
T 130N R 59W
DICKEY COUNTY

PRELIMINARY PLANS FOR THE CONSTRUCTION OF DICKEY-SARGENT IRRIGATION MODERNIZATION PROJECT FOR DICKEY SARGENT IRRIGATION DISTRICT IN DICKEY COUNTY, NORTH DAKOTA

PREPARED BY U.S. DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE

INDEX OF DRAWINGS

GENERAL NOTES:

1. ND Century Code 49-23 and NRCS policy requires that the installer contact the North Dakota One Call Center at 1-800-795-0555 at least 48 hours prior to any excavation work. The Contractor is responsible for the notification of all utility companies affected by the project.

2. The Owner is responsible for acquiring all necessary approvals, permits, and easements required for installation of the project. The Owner and Contractor are responsible for compliance with all ordinances and laws pertaining to installation of the project.

3. Survey work for the project was completed with a Survey Grade GPS with a local site calibration mode with the following settings: UTM NAD83 (Conus MOL), Zone 14N, Geoid Model 12, US Survey Feet for vertical and horizontal datums. Coordinates shown throughout the drawings are in reference to UTM NAD83 Zone 14N. Any property lines, easements, or right-of-ways depicted on the drawings are approximate.

4. All stationing and distances shown on the drawings are measured horizontal distance. All pipeline elevations shown throughout the drawings indicate invert elevations. All quantities are listed as in-place yardage.

5. The project will be staked in the field by NRCS immediately prior to construction. Survey control point markers will be preserved during construction to the extent practical.

6. The Contractor will be responsible for final erosion control measures, as required by regulatory permits for the project and construction specifications.

ESTIMATED QUANTITIES

Item	Quantity	Unit
54" IPS DR21 HDPE- Mainline	8,250	FT
42" IPS DR21 HDPE- Mainline	8,150	FT
30" IPS DR26 HDPE- Mainline	10,350	FT
12" IPS DR21 HDPE- Drainline	3,900	FT
36" IPS DR21 HDPE- Spur to N lateral Line	2,050	FT
Excavation	291,220	CY
Earthfill (Canal fill and Pipe Trench fill)	279,350	CY
Select Sand & Gravel Pipe Backfill	13,530	CY
Concrete- 3,000 psi (Thrust blocks)	112	CY
Electromagnetic Flow Meters w/ Telemetry (McCrometer Ultra Mag)	4	EA
Gear Operated Butterfly Valves	5	EA
3-way combination Air/Vac valves (APCO Models 153 & 155, CLA-VAL Model 50-01)	10	EA
Pumpout Riser Assemblies	4	EA
Precast Concrete Utility Boxes w/ Locking Steel Lids	14	EA
Precast Concrete Manholes w/ Locking Steel Lids	5	EA
Refurbish Existing Lift Station- Convert to 480 volt, 8 New/Refurbished Vertical Turbine Pumps w/ Associated Motors, VFDs, Manifold, Controls. Max Capacity Q= 30,456 gpm, TDH= 185 FT	1	LS
Install New Control Systems on Pipeline (Includes Pressure Sustaining/Relief Valves, Pressure Gauges)	1	LS
Decommission Existing Booster Pump Stations, Construct Lateral Connections	3	EA
Note: manufacturer/model numbers provided as examples only		

ESTIMATED FITTING QUANTITIES

Item	Quantity	Unit
54" DR 21, 90 degree	1	EA
54" DR 21, 45 degree	1	EA
54" DR 21, 30 degree	3	EA
54" DR 21, 22.5 degree	2	EA
54" DR 21, 11.25 degree	2	EA
54" x 12" DR21 Reducing Tee	3	EA
54"x 36" DR21 Reducing Tee	1	EA
54" to 42" DR21 Reducer	1	EA
42" DR21 45 degree	1	EA
42" DR21 11.25 degree	3	EA
42" x 12" DR21 Reducing Tee	3	EA
42" DR21 x 30" Reducing Tee	1	EA
42" x 36" DR21 Reducing Tee	1	EA
36" IPS Flange Adatper HDPE	2	EA
36" IPS Backup Ring Ductile Iron	2	EA
30" Flange Adapter HDPE	1	EA
30" Backup Ring Ductile Iron	1	EA

JOB APPROVAL AUTHORITY

PRACTICE NAME	CODE	JOB CLASS
Critical Area Seeding	342	IV
Irrigation Pipeline	430	VI
Precision Land Forming and Smoothing	462	III
Mulching	484	IV
Pasture & Hayland Planting	512	V
Pumping Plant	533	VII

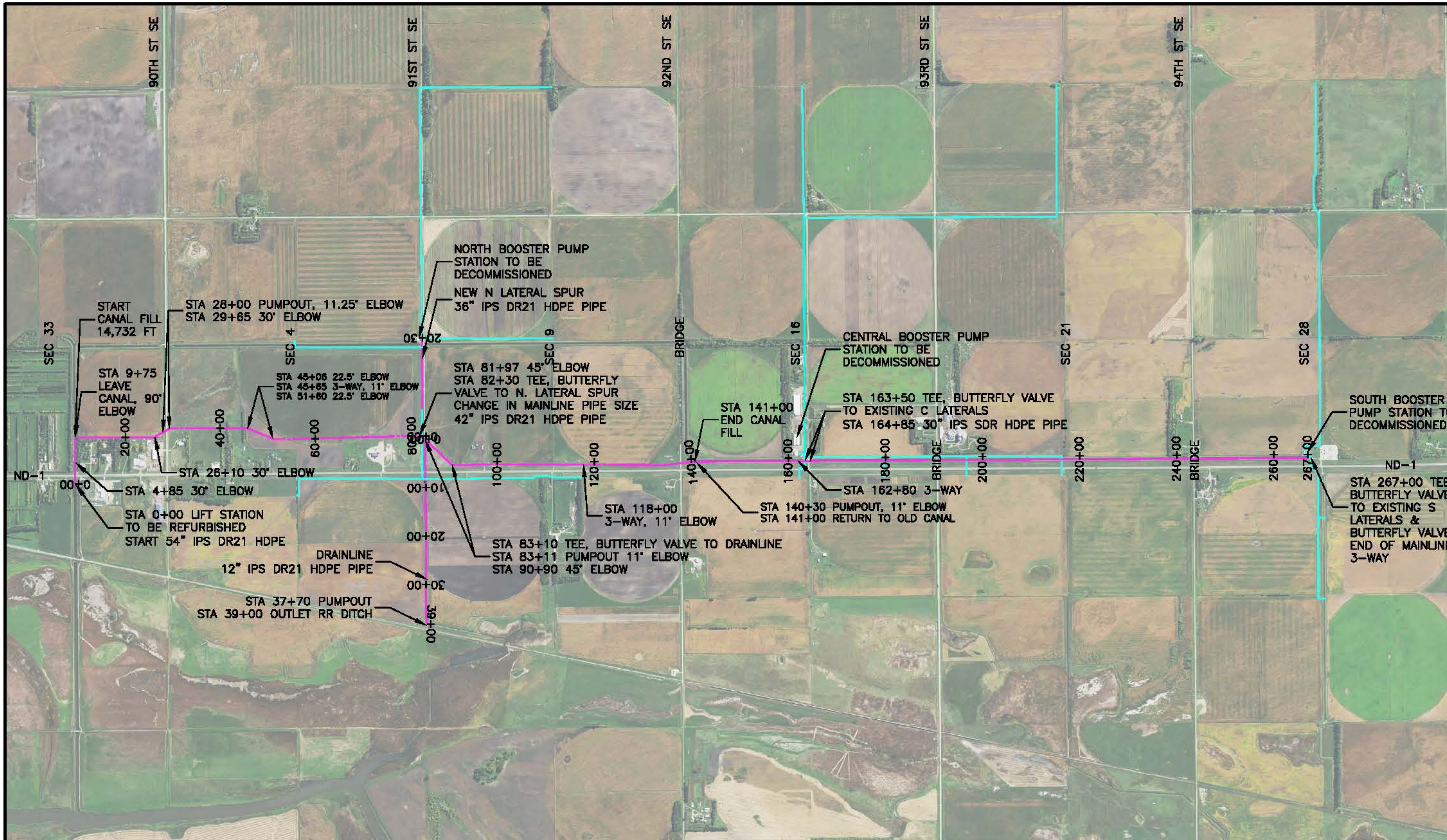
		Date
Designed	----	----
Drawn	C. Ahmed	5/2023
Checked	----	----
Approved	----	

PRELIMINARY
Not for Construction

COVER SHEET
DICKEY–SARGENT IRRIGATION MODERNIZATION PROJECT
OWNER: DICKEY SARGENT IRRIGATION DISTRICT
COUNTY: DICKEY

USDA United States Department of Agriculture
Natural Resources Conservation Service

File Name DSID_Pipeline.dwg
Date 6/13/2023
Sheet 1 of 12



LEGEND

Proposed Irrigation Main Line

Existing DSID Irrigation Pipelines

PLAN VIEW

NOTES:

1.) PRESSURE SUSTAINING / PRESSURE RELIEF VALVES NOT SHOWN

2.) PRECAST CONCRETE MANHOLES AT BUTTERFLY VALVES W/ FLOW METER

3.) PRECAST CONCRETE UTILITY BOXES AT AIR VAC & PUMPOUT RISERS. EXCEPT AT STA 37+70 OF DRAINLINE

N

0 2000 4000

Scale in Feet

USDA United States Department of Agriculture
Natural Resources Conservation Service

File Name DSID_Pipeline.dwg

Date 6/13/2023

Sheet 2 of 12

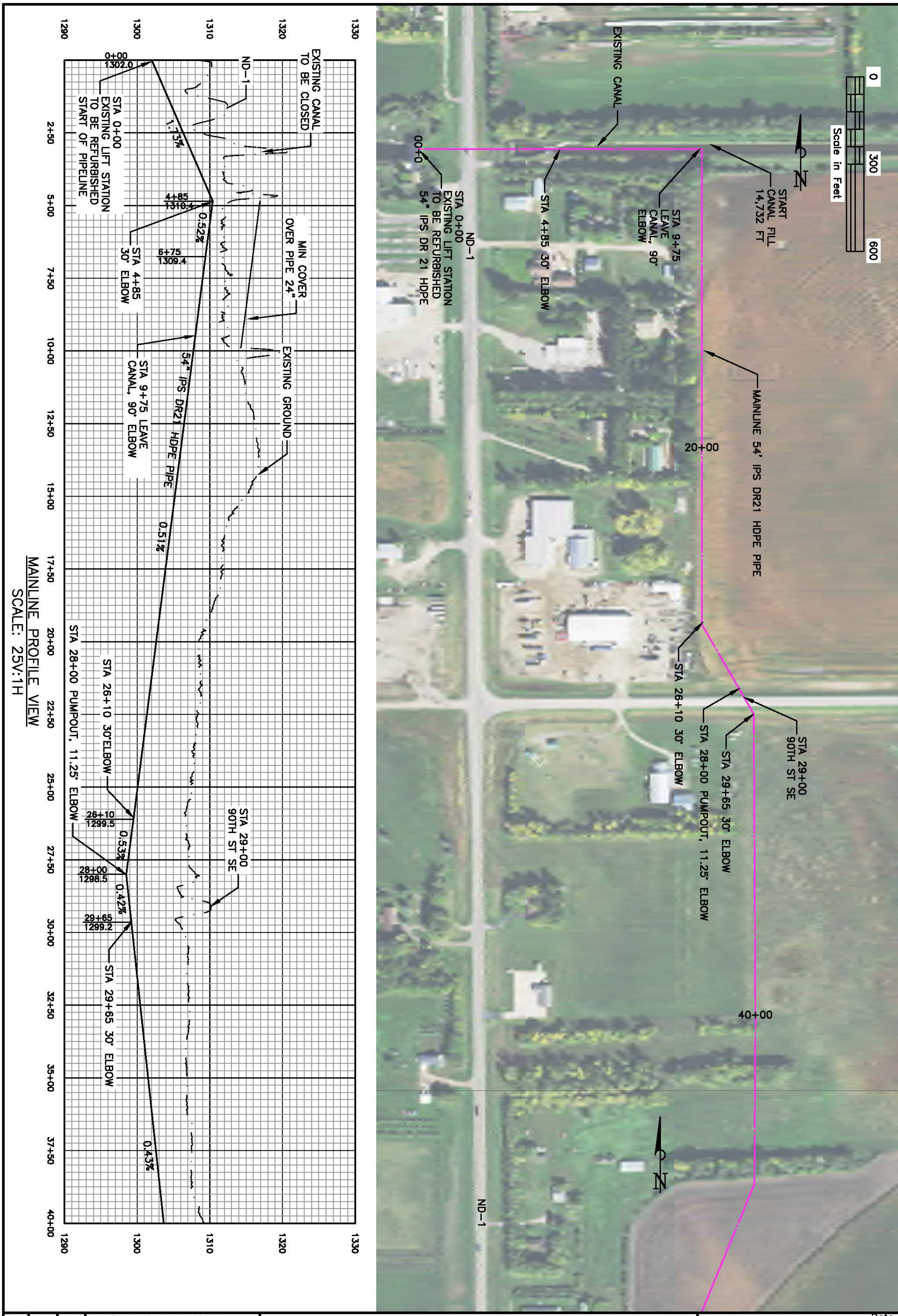
PLAN VIEW
DICKEY-SARGENT IRRIGATION MODERNIZATION PROJECT

OWNER: DICKEY SARGENT IRRIGATION DISTRICT

COUNTY: DICKEY

		Date
Designed	----	----
Drawn	C. Ahmed	5/2023
Checked	----	----
Approved	----	

PRELIMINARY Not for Construction



Sheet	3 of 12
Date	6/13/2023
File Name	DSID_Pipeline.dwg

USDA United States Department of Agriculture
Natural Resources Conservation Service

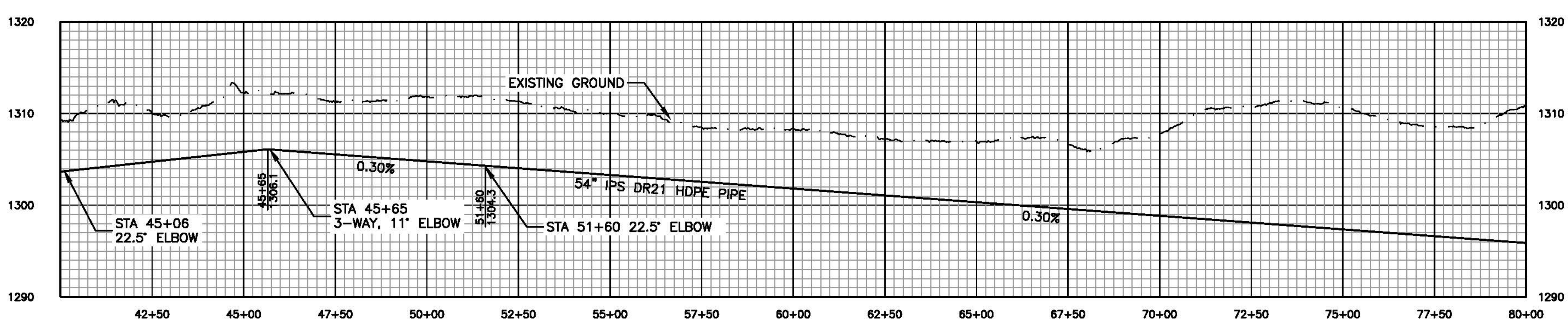
MAINLINE PLAN & PROFILE VIEW STA 0+00 TO STA 40+00
DICKEY–SARGENT IRRIGATION MODERNIZATION PROJECT

OWNER: DICKEY SARGENT IRRIGATION DISTRICT

COUNTY: DICKEY

		Date
Designed	----	----
Drawn	C. Ahmed	5/2023
Checked	----	----
Approved	----	

PRELIMINARY Not for Construction



MAINLINE PROFILE VIEW
SCALE: 25V:1H

1330

MAINLINE PLAN & PROFILE VIEW STA 40+00 TO STA 80+00
DICKEY–SARGENT IRRIGATION MODERNIZATION PROJECT

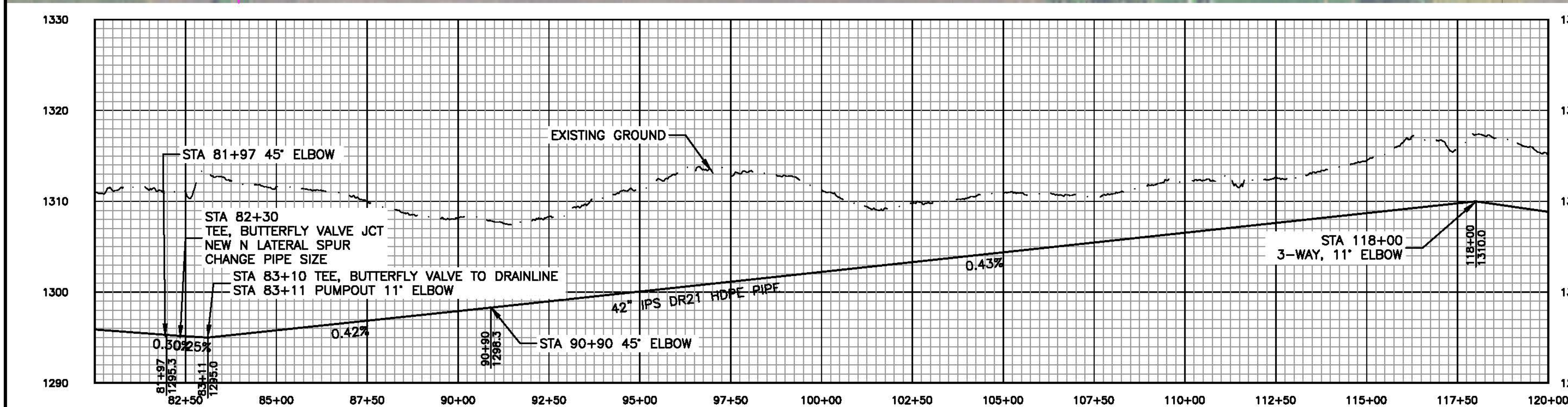
OWNER: DICKEY SARGENT IRRIGATION DISTRICT
COUNTY: DICKEY

USDA United States Department of Agriculture
Natural Resources Conservation Service

		Date
Designed	----	----
Drawn	C. Ahmed	5/2023
Checked	----	----
Approved	----	

PRELIMINARY
Not for Construction

File Name DSID_Pipeline.dwg
Date 6/13/2023
Sheet 4 of 12



MAINLINE PROFILE VIEW
SCALE: 25V:1H

MAINLINE PLAN & PROFILE VIEW STA 80+00 TO STA 120+00
DICKEY–SARGENT IRRIGATION MODERNIZATION PROJECT

OWNER: DICKEY SARGENT IRRIGATION DISTRICT

COUNTY: DICKEY

		Date
Designed	----	----
Drawn	C. Ahmed	5/2023
Checked	----	----
Approved	----	

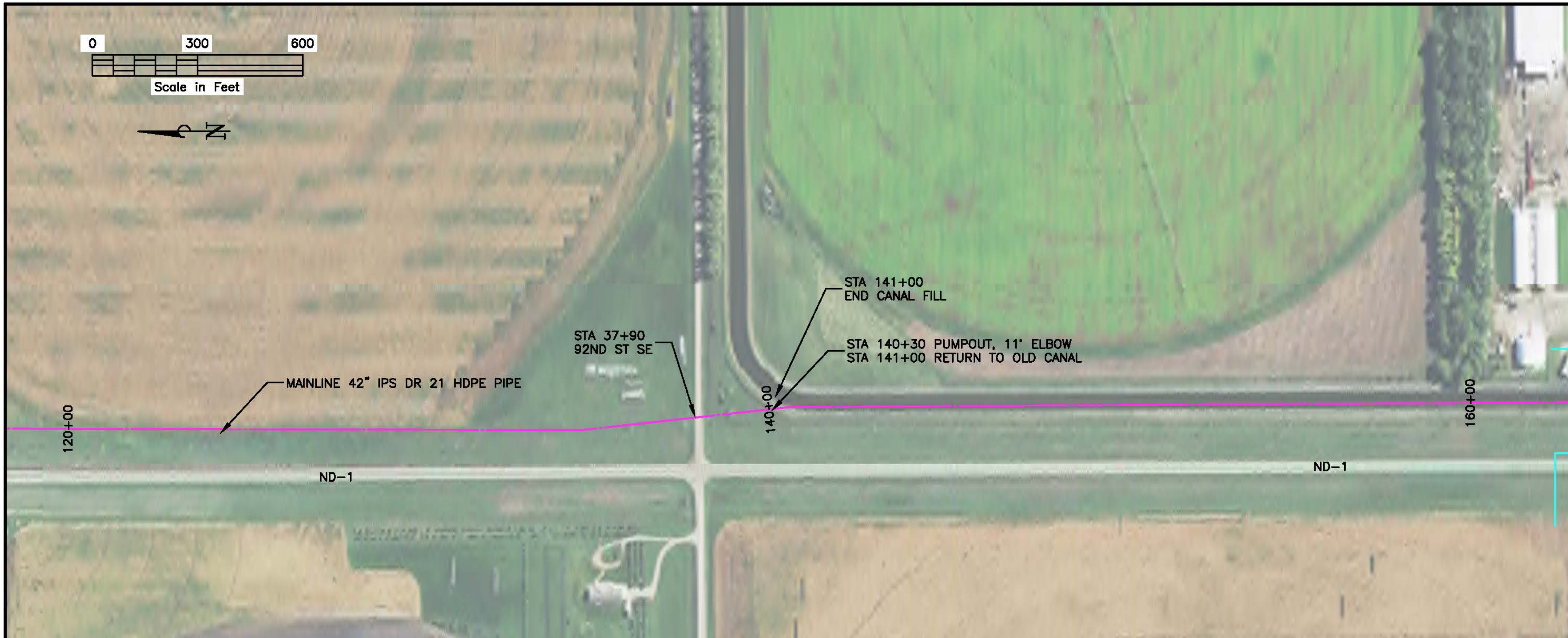
PRELIMINARY
Not for Construction

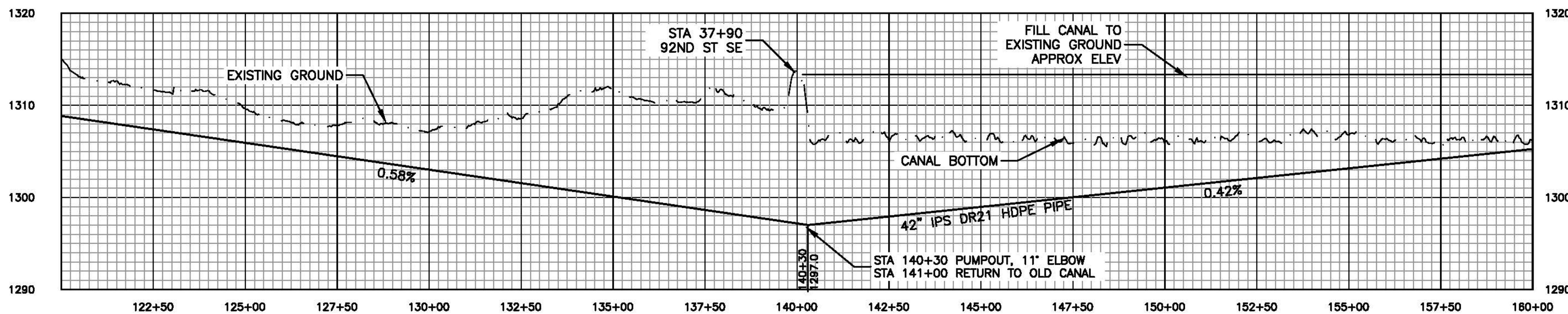
USDA United States Department of Agriculture
Natural Resources Conservation Service

File Name DSID_Pipeline.dwg

Date 6/13/2023

Sheet 5 of 12





MAINLINE PROFILE VIEW
SCALE: 25V:1H

MAINLINE PLAN & PROFILE VIEW STA 120+00 TO STA 160+00
DICKEY–SARGENT IRRIGATION MODERNIZATION PROJECT

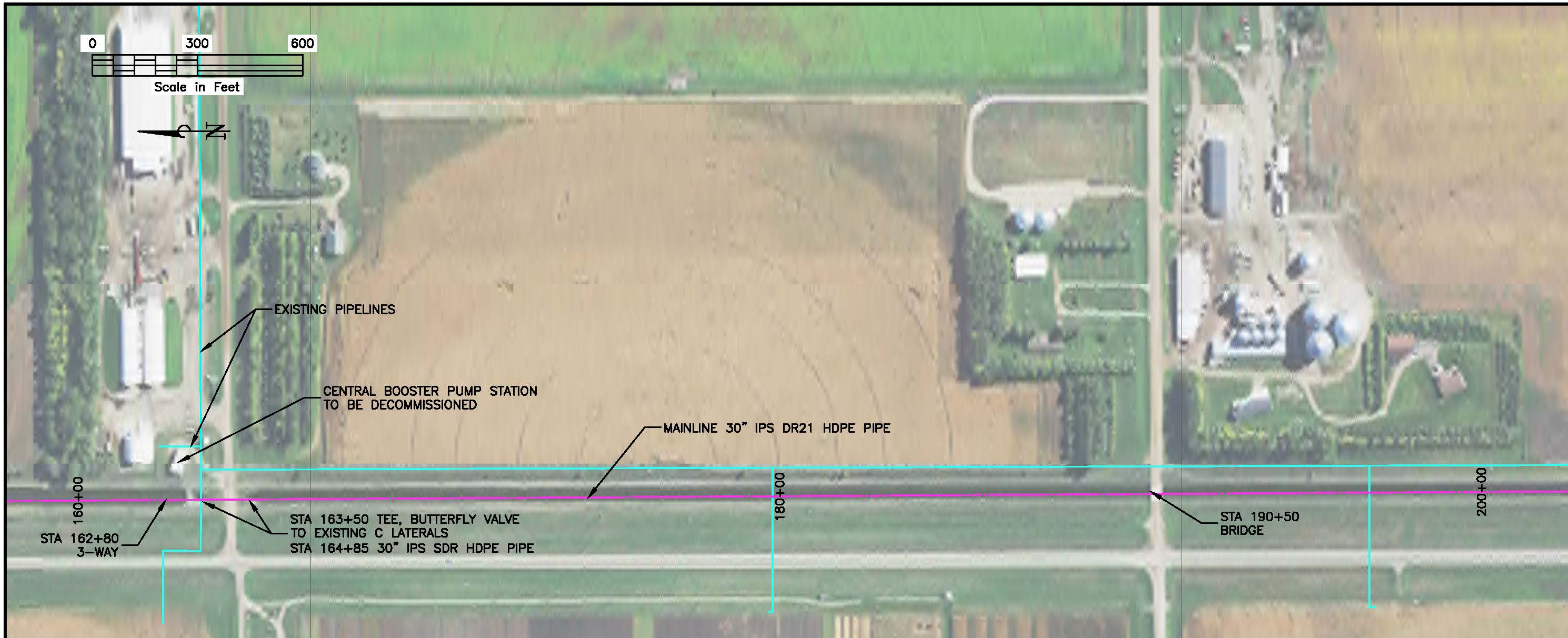
OWNER: DICKEY SARGENT IRRIGATION DISTRICT
COUNTY: DICKEY

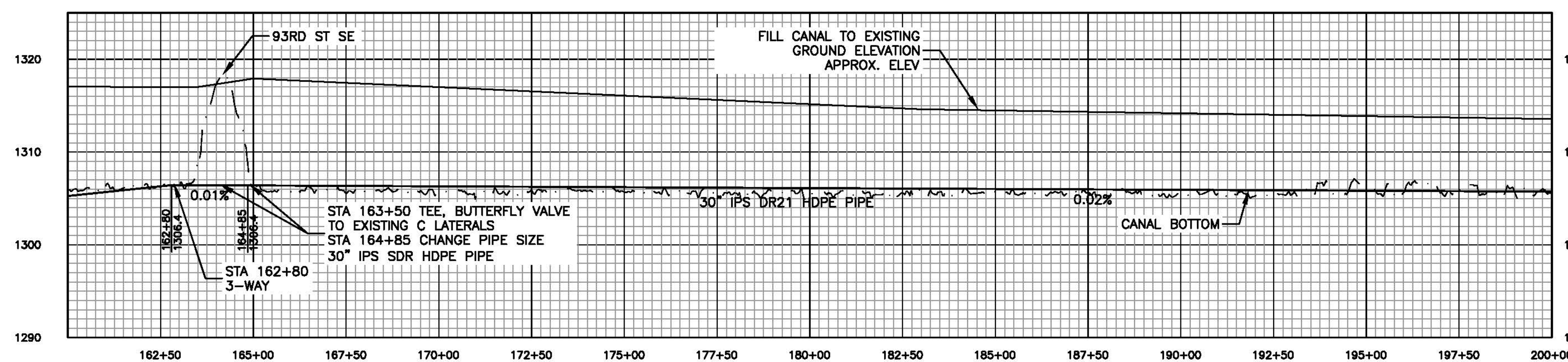
USDA United States Department of Agriculture
Natural Resources Conservation Service

File Name DSID_Pipeline.dwg
Date 6/13/2023
Sheet 6 of 12

		Date
Designed	----	----
Drawn	C. Ahmed	5/2023
Checked	----	----
Approved	----	.

PRELIMINARY
Not for Construction





MAINLINE PROFILE VIEW
SCALE: 25V:1H

MAINLINE PLAN & PROFILE VIEW STA 160+00 TO STA 200+00
DICKEY–SARGENT IRRIGATION MODERNIZATION PROJECT

OWNER: DICKEY SARGENT IRRIGATION DISTRICT
COUNTY: DICKEY

		Date
Designed	----	----
Drawn	C. Ahmed	5/2023
Checked	----	----
Approved	----	.

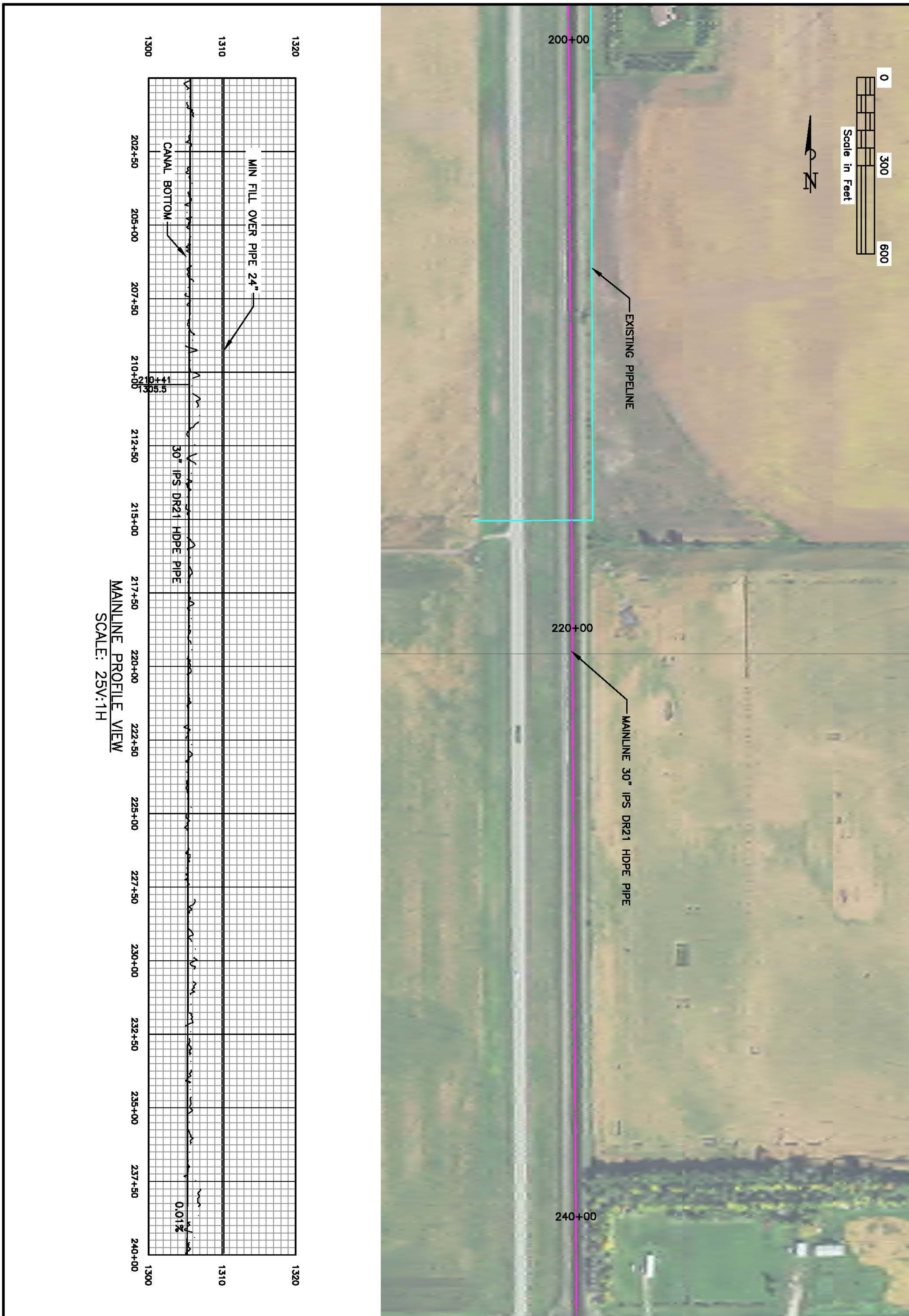
PRELIMINARY
Not for Construction

USDA United States Department of Agriculture
Natural Resources Conservation Service

File Name DSID_Pipeline.dwg

Date 6/13/2023

Sheet 7 of 12



Sheet 8 of 12	Date 6/13/2023	File Name DSID_Pipeline.dwg	USDA United States Department of Agriculture Natural Resources Conservation Service

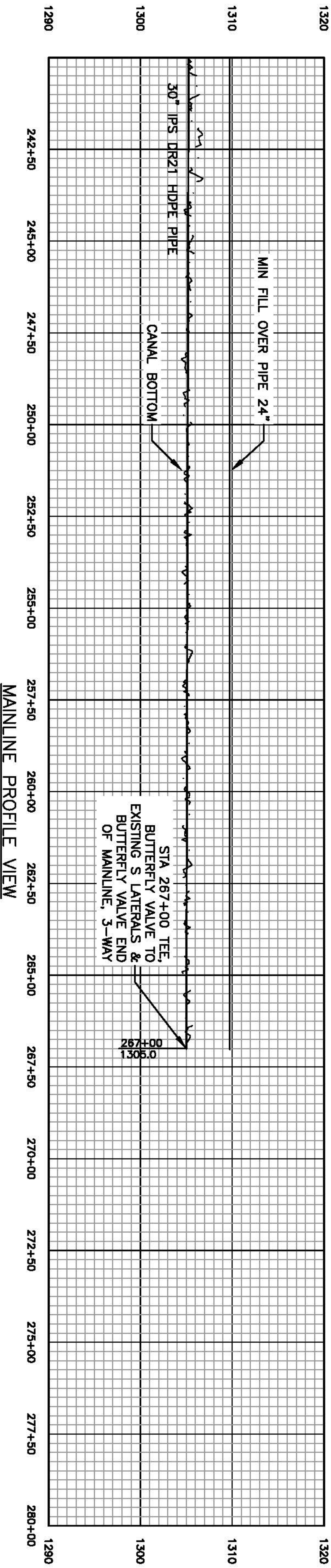
MAINLINE PLAN & PROFILE VIEW STA 200+00 TO STA 240+00
DICKEY–SARGENT IRRIGATION MODERNIZATION PROJECT

OWNER: DICKEY SARGENT IRRIGATION DISTRICT

COUNTY: DICKEY

		Date
Designed	----	----
Drawn	C. Ahmed	5/2023
Checked	----	----
Approved	----	

PRELIMINARY Not for Construction



MAINLINE PROFILE VIEW
SCALE: 25V:1H

Sheet 9 of 12

Date 6/13/2023

File Name DSID_Pipeline.dwg

USDA United States Department of Agriculture
Natural Resources Conservation Service

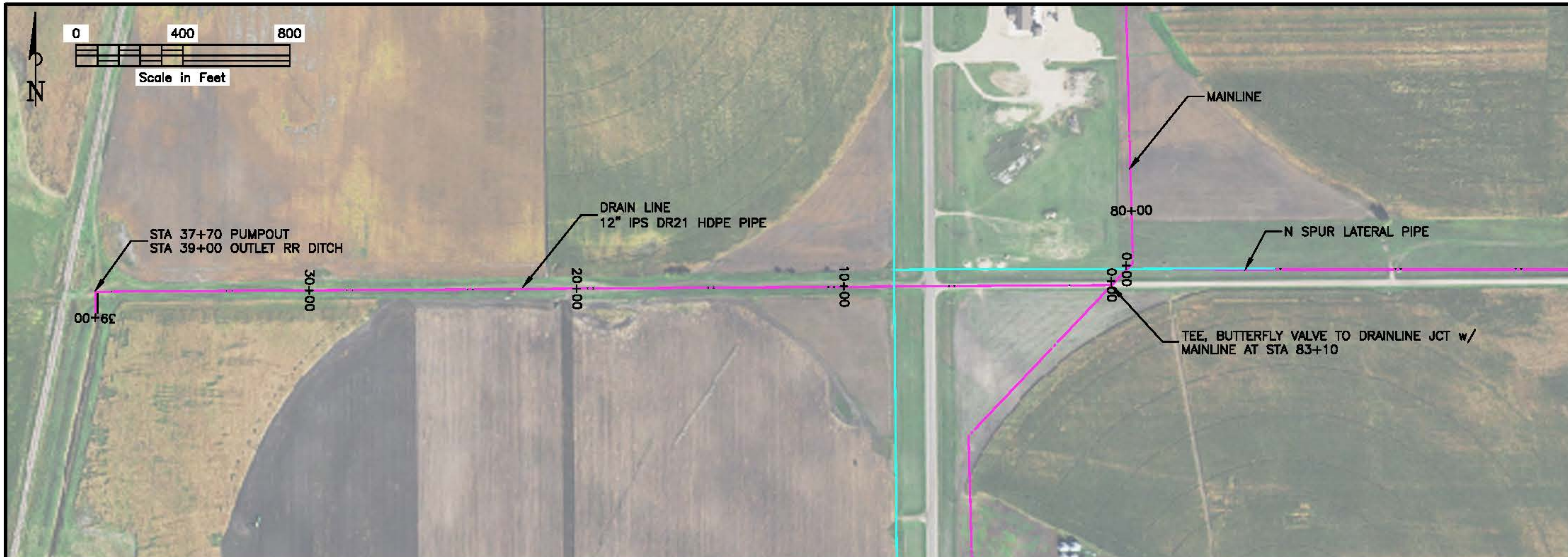
MAINLINE PLAN & PROFILE VIEW STA 240+00 TO STA 267+00
DICKEY–SARGENT IRRIGATION MODERNIZATION PROJECT

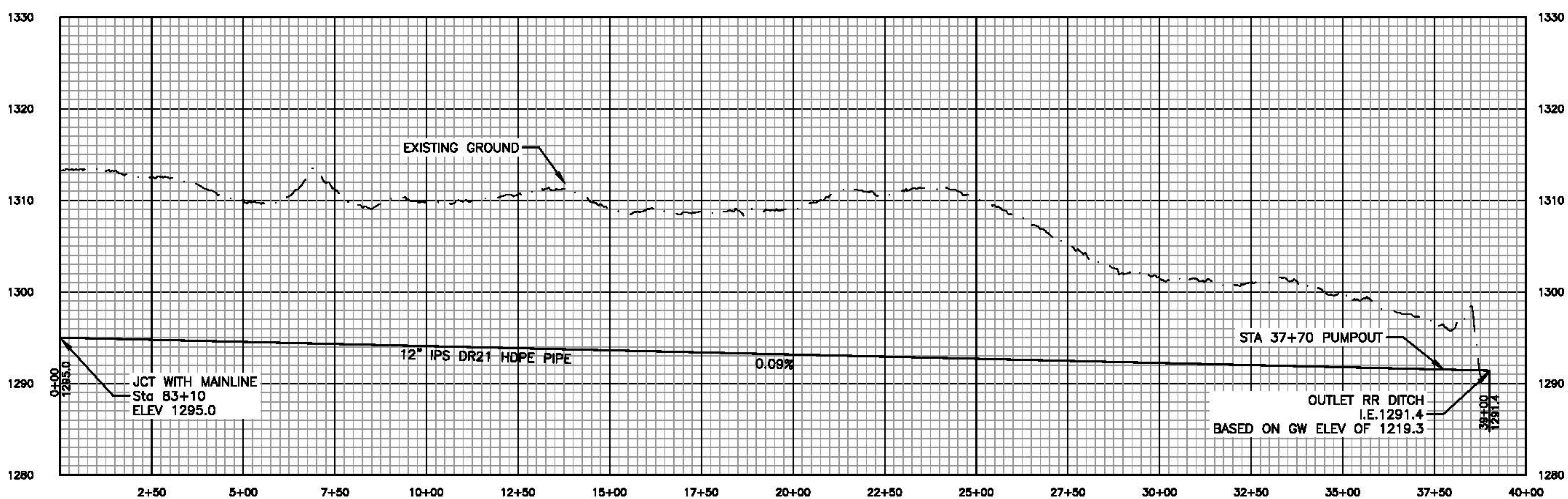
OWNER: DICKEY SARGENT IRRIGATION DISTRICT

COUNTY: DICKEY

		Date
Designed	----	----
Drawn	C. Ahmed	5/2023
Checked	----	----
Approved	----	

PRELIMINARY
Not for Construction





DRAINLINE PROFILE VIEW
SCALE: 25V:1H

USDA United States Department of Agriculture
Natural Resources Conservation Service

File Name DSID_Pipeline.dwg

Date 6/13/2023

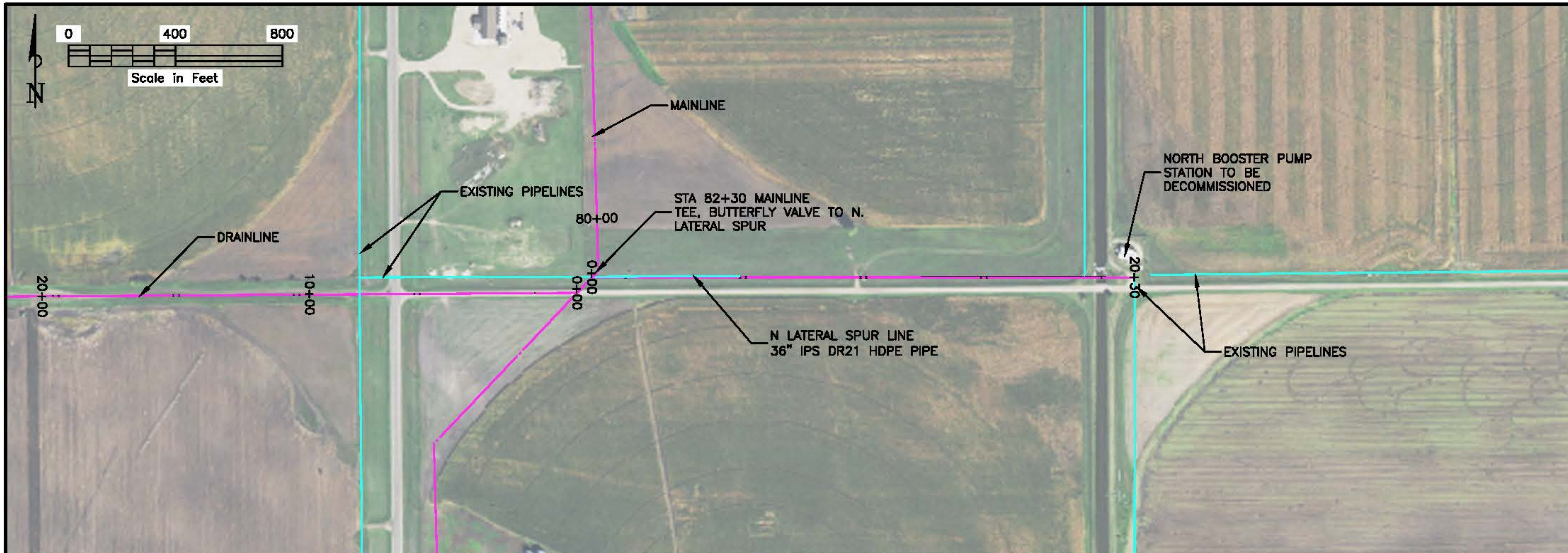
Sheet 10 of 12

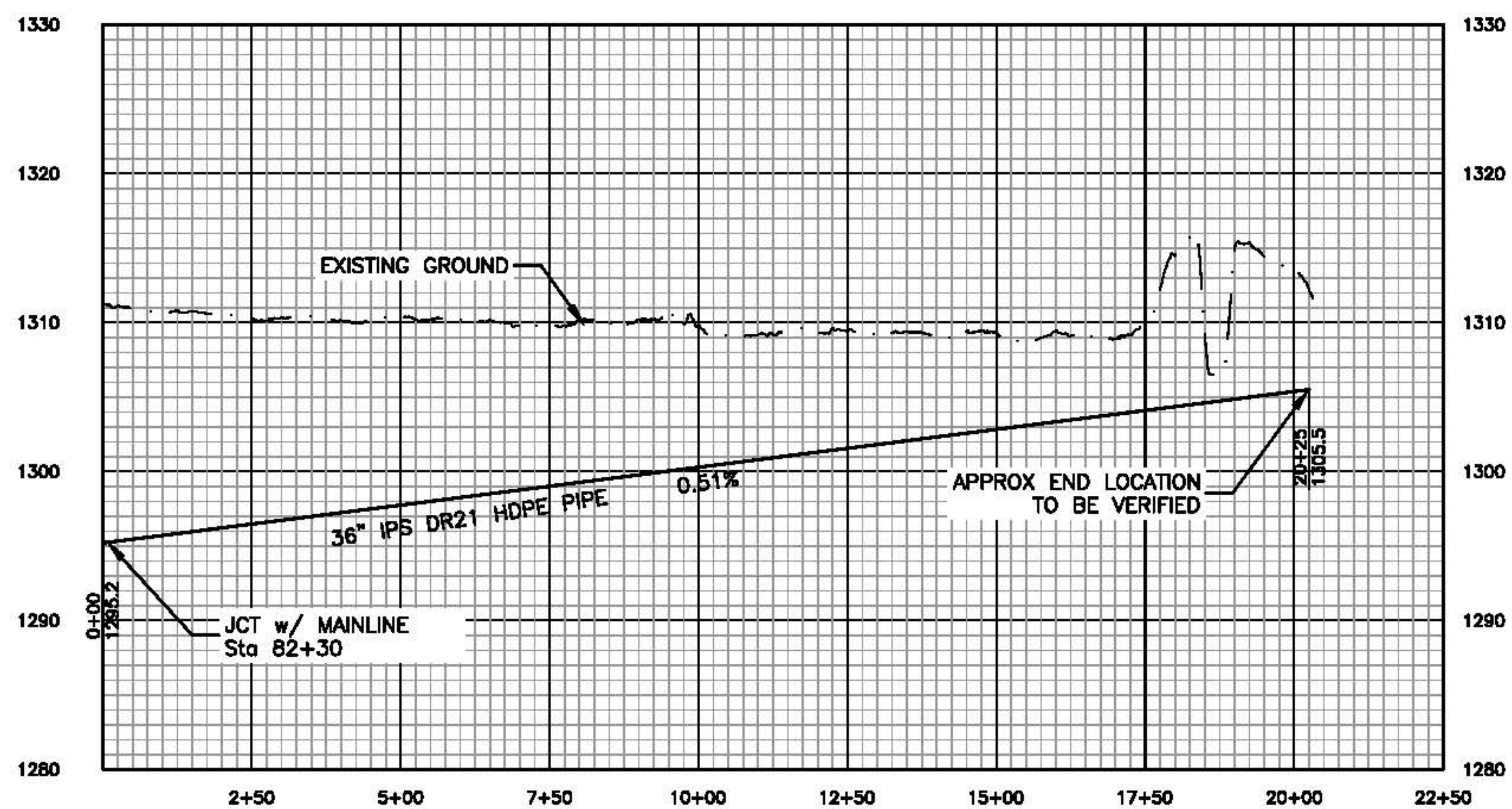
DRAINLINE PLAN & PROFILE VIEW
DICKEY-SARGENT IRRIGATION MODERNIZATION PROJECT

OWNER: DICKEY SARGENT IRRIGATION DISTRICT
COUNTY: DICKEY

		Date
Designed	----	----
Drawn	C. Ahmed	5/2023
Checked	----	----
Approved	----	

PRELIMINARY
Not for Construction





N LATERAL SPUR LINE PROFILE VIEW
SCALE: 25V:1H

N LATERAL SPUR LINE PROFILE & PLAN VIEW
DICKEY–SARGENT IRRIGATION MODERNIZATION PROJECT

OWNER: DICKEY SARGENT IRRIGATION DISTRICT
COUNTY: DICKEY

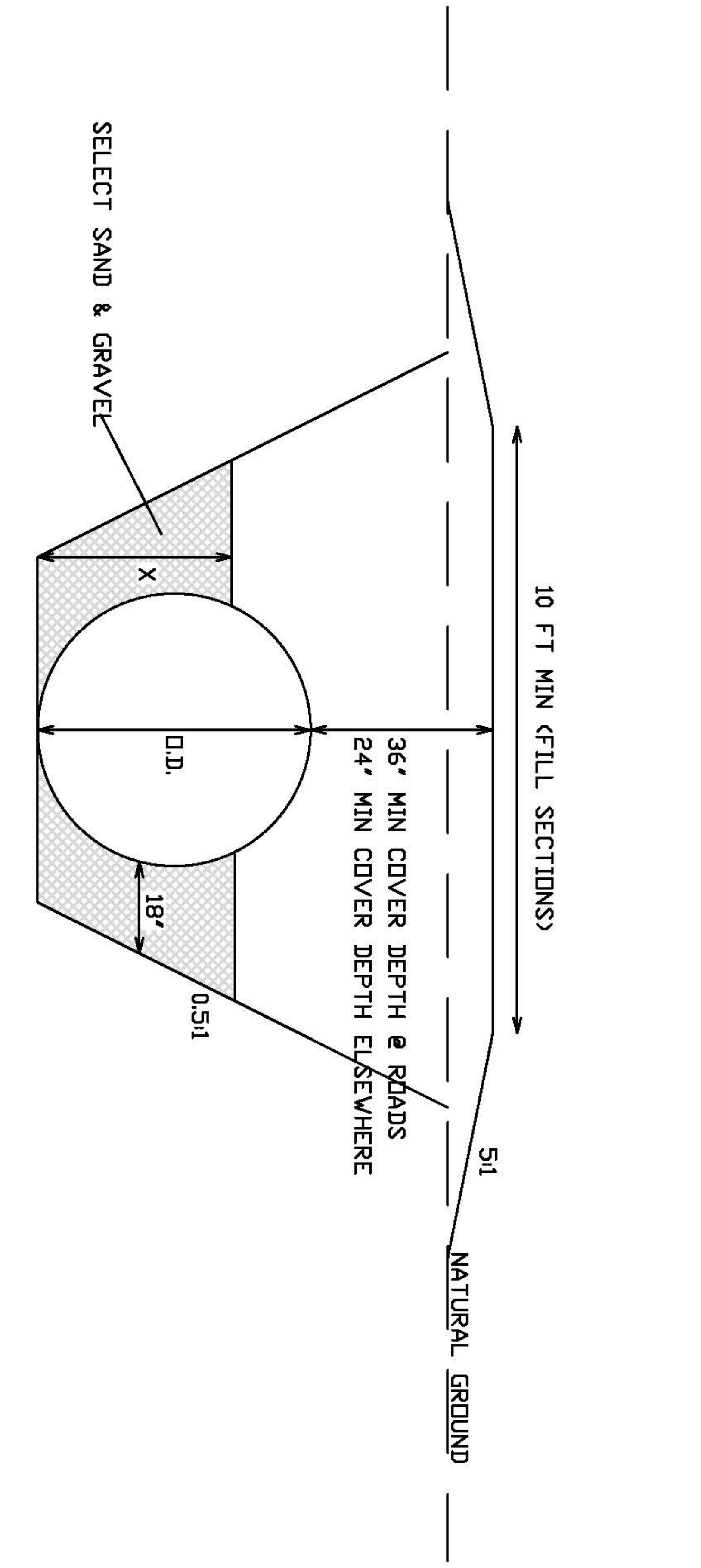
		Date
Designed	----	----
Drawn	C. Ahmed	5/2023
Checked	----	----
Approved	----	

PRELIMINARY
Not for Construction

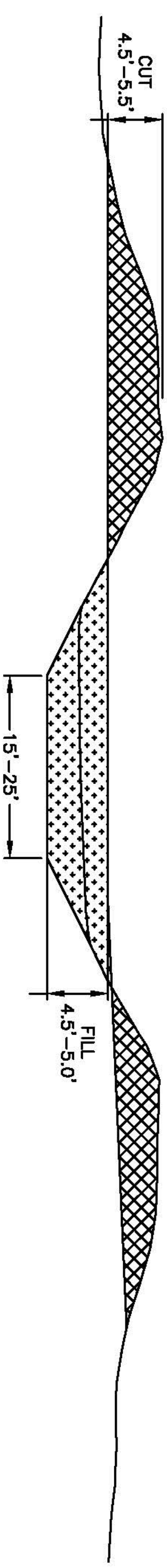
USDA United States Department of Agriculture
Natural Resources Conservation Service

File Name DSID_Pipeline.dwg

Date 6/13/2023



TYPICAL X-SECTION PIPE
(NTS)



TYPICAL X-SECTION CANAL FILL
(NTS)

PIPE X-SECTION DETAILS

	O.D.	X
MAINLINE STA 0+00 TO STA 82+30	54"	38"
MAINLINE STA 82+30 TO STA 164+85	42"	34"
MAINLINE STA 164+85 TO STA 267+00	30"	21"
N LATERAL SPUR LINE	36"	30"
DRAINLINE	12"	9"

Date 6/7/2023
File Name DSID_Pipeline.dwg

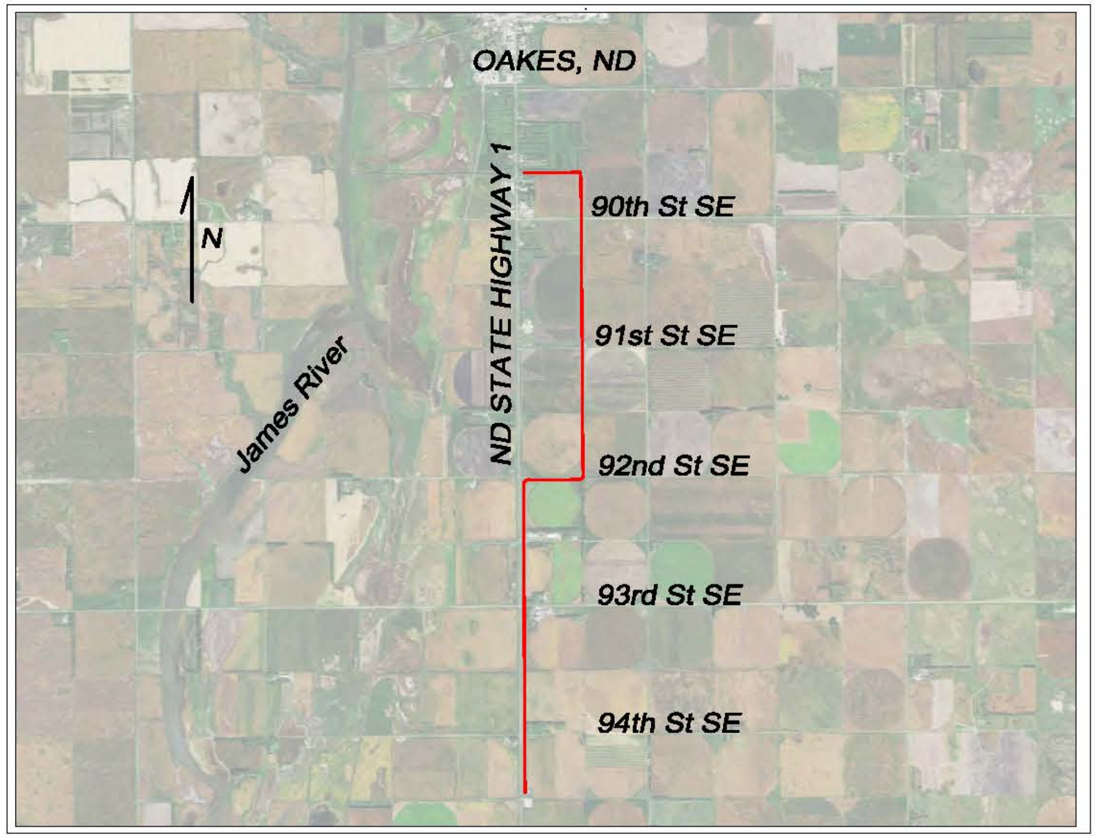
USDA United States Department of Agriculture
Natural Resources Conservation Service

DETAILS
DICKEY–SARGENT IRRIGATION MODERNIZATION PROJECT
OWNER: DICKEY SARGENT IRRIGATION DISTRICT
COUNTY: DICKEY

		Date
Designed	----	----
Drawn	C. Ahmed	5/2023
Checked	----	----
Approved	----	----

PRELIMINARY Not for Construction

Figure 11- Preliminary Drawings, Alterantive #2

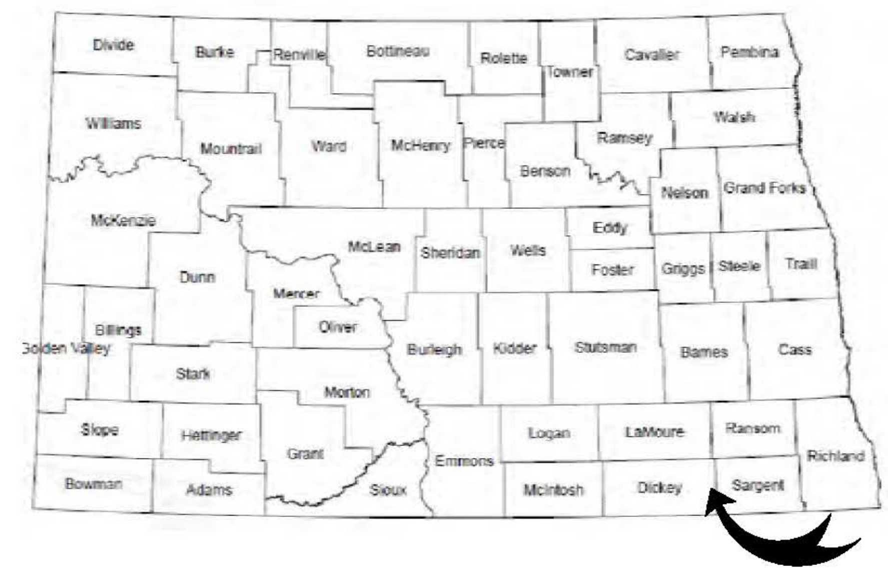


PROJECT LOCATION MAP
(NOT TO SCALE)

T 130 N, R 59 W

PIFR ALTERNATIVE #2 - CANAL RECONSTRUCTION
DICKEY-SARGENT IRRIGATION DISTRICT MODERNIZATION
IN
DICKEY COUNTY, NORTH DAKOTA

PREPARED BY
U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE



GENERAL NOTES:

1. ND Century Code 49-23 and NRCS policy requires that the installer contact the North Dakota One Call Center at 1-800-795-0555 at least 48 hours prior to any excavation work. The Contractor is responsible for the notification of all utility companies affected by the project.

2. The Owner is responsible for acquiring all necessary approvals, permits, and easements required for installation of the project. The Owner and Contractor are responsible for compliance with all ordinances and laws pertaining to installation of the project.

3. Survey work for the project was completed with a Survey Grade GPS with a local site calibration mode with the following settings: UTM NAD83 (Conus MOL), Zone 14N, Geoid Model 12, US Survey Feet for vertical and horizontal datums. Coordinates shown throughout the drawings are in reference to UTM NAD83 Zone 14N. Any property lines, easements, or right-of-ways depicted on the drawings are approximate.

4. All stationing and distances shown on the drawings are measured horizontal distance. All pipeline elevations shown throughout the drawings indicate invert elevations. All quantities are listed as in-place yardage.

5. The project will be staked in the field by NRCS immediately prior to construction. Survey control point markers will be preserved during construction to the extent practical.

6. The Contractor will be responsible for final erosion control measures, as required by regulatory permits for the project and construction specifications.

ESTIMATED PROJECT QUANTITIES

ITEM	EST QTY	UNIT
Excavation	301,128	CY
Embankment	61,043	CY
End Haul to Offsite Waste Area	241,095	CY
Composite geotextile/geomembrane liner (Canal 12–30–120)	124,306	SY
Reinforced Concrete	15,326	CY
Seeding (project + waste areas)	70	AC

*Earthwork listed as in-place volume.

JOB APPROVAL AUTHORITY

PRACTICE NAME	CODE	JOB CLASS
IRRIGATION CANAL LINING	428	VI
PRECISION LAND FORMING	462	III
CRITICAL AREA SEEDING	342	IV
MULCHING	484	IV
PASTURE AND HAYLAND PLANTING	512	V

INDEX OF DRAWINGS

SHT #	TITLE
1	COVERSHEET
2	PLAN VIEW
3	CROSS SECTIONS
4	CROSS SECTIONS, TYPICAL SECTION

Designed ______ Date
Drawn C. Fisher 6/2023
Checked ______
Approved ______

PRELIMINARY
Not for Construction

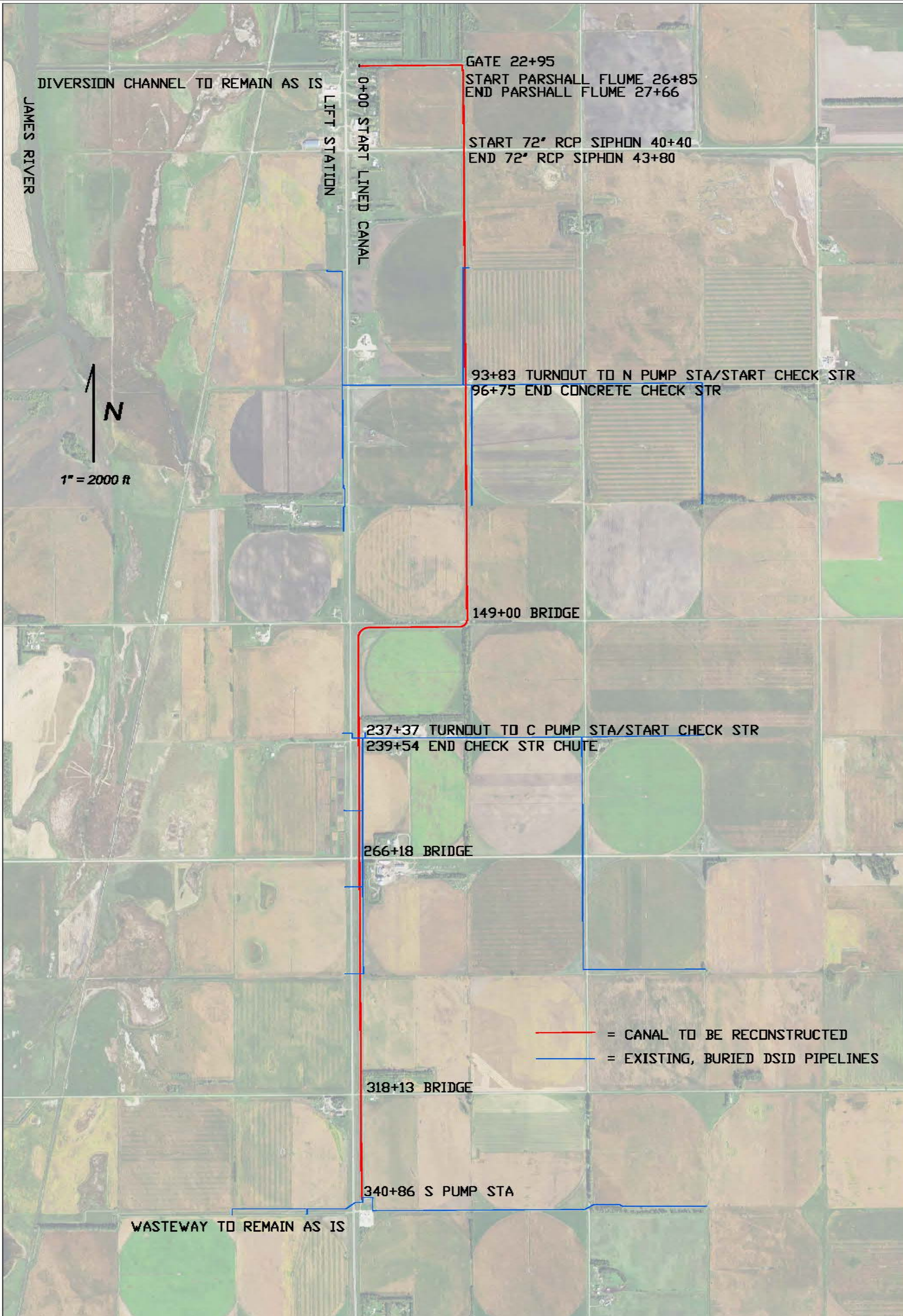
COVER SHEET
DSID Irrigation Modernization Project– Alternative #2
OWNER: *Dickey Sargent Irrigation District*
COUNTY: *Dickey*

NRCS
Natural Resources Conservation Service

File Name
DSID–HECRAScf.dwg

Date
6/12/2023

Sheet 1 of 4

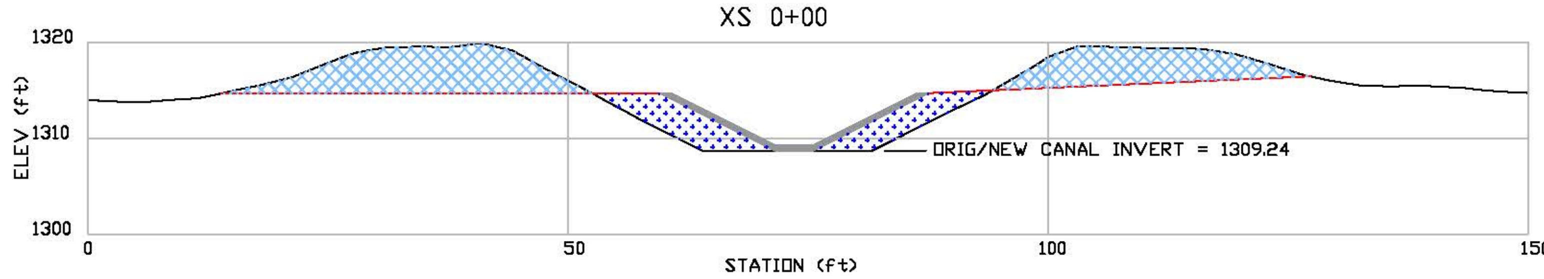


Sheet 2 of 4	Date 6/12/2023	File Name	NRCS Natural Resources Conservation Service	PLAN VIEW DSID Irrigation Modernization Project– Alternative #2 OWNER: Dickey Sargent Irrigation District COUNTY: Dickey	Designed ____ Date ____ Drawn C. Fisher 6/2023 Checked ____ Approved ____ PRELIMINARY Not for Construction

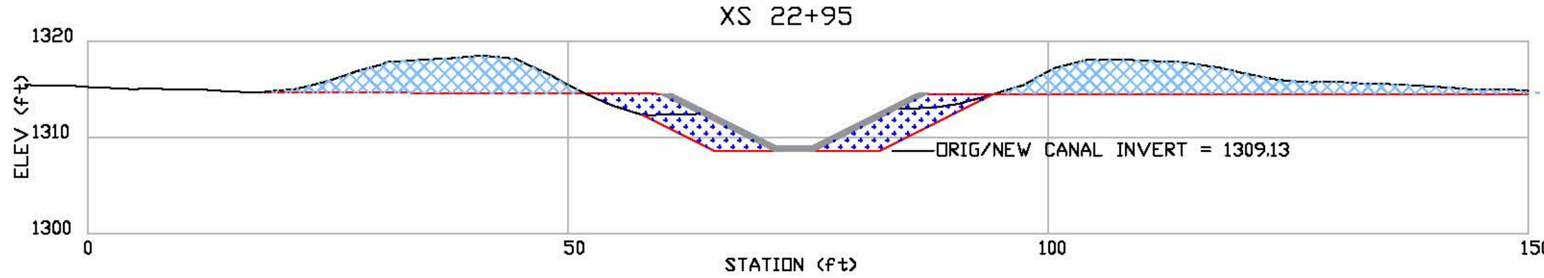
——— = EXISTING GROUND ——— = RECONSTRUCTED CANAL

= CONCRETE = EXCAVATION = EMBANKMENT

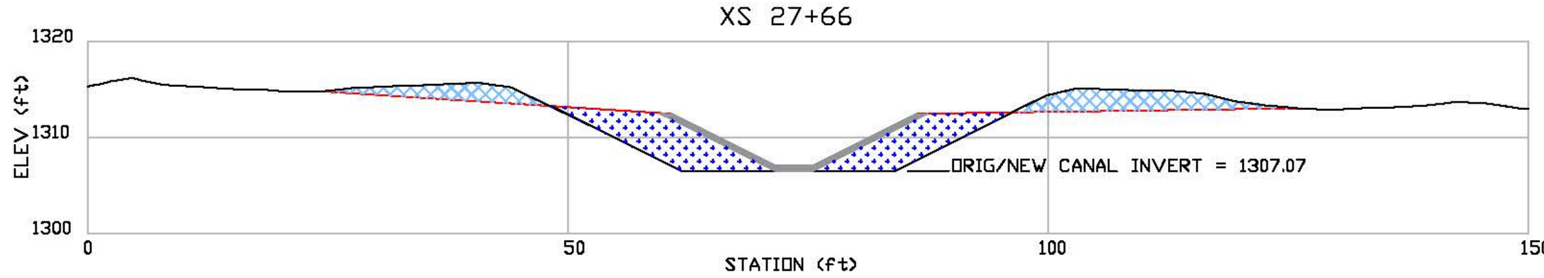
XS 0+00



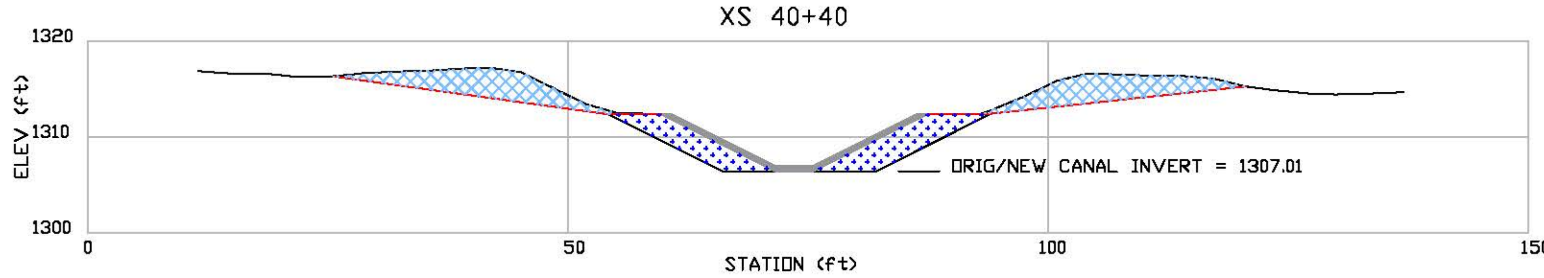
XS 22+95



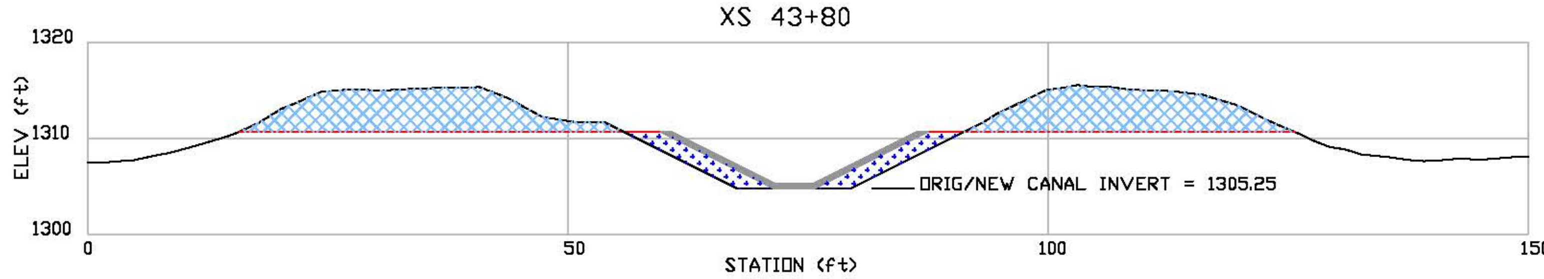
XS 27+66



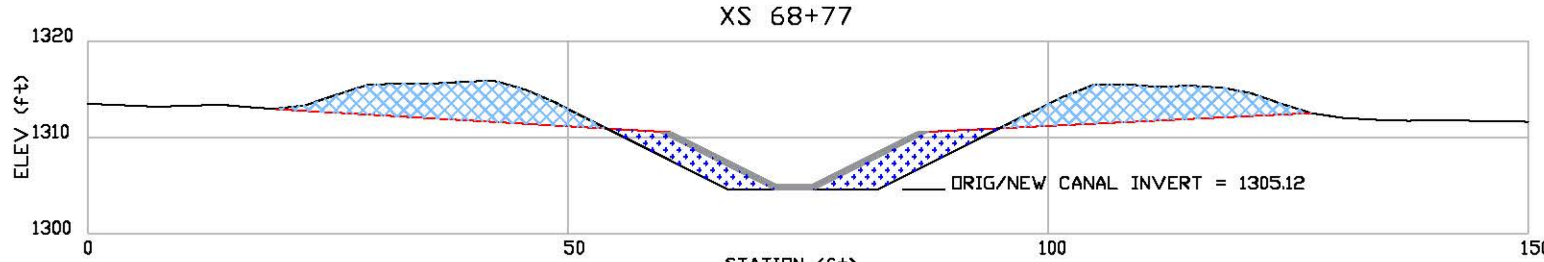
XS 40+40



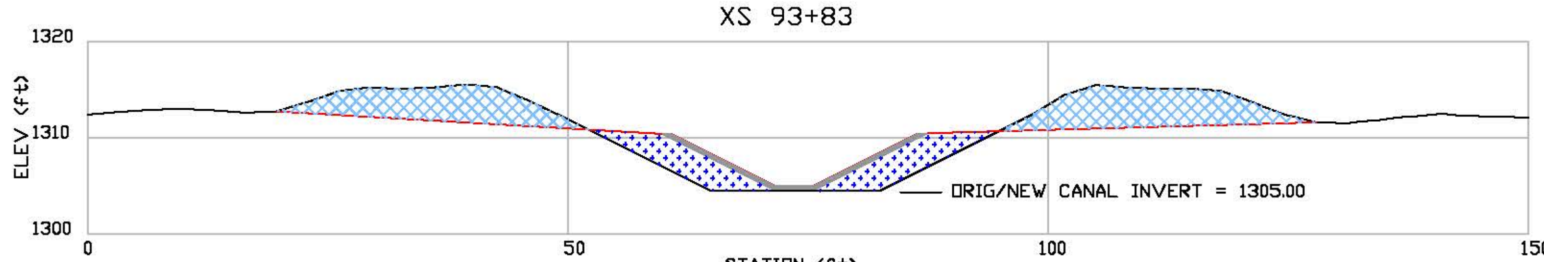
XS 43+80



XS 68+77



XS 93+83



1" = 10 FT

Sheet 3 of 4

Date 6/12/2023

File Name

NRCS
Natural Resources Conservation Service

CROSS SECTIONS

DSID Irrigation Modernization Project— Alternative #2

OWNER: *Dickey Sargent Irrigation District*

COUNTY: *Dickey*

		Date
Designed		
Drawn	C. Fisher	6/2023
Checked		
Approved		

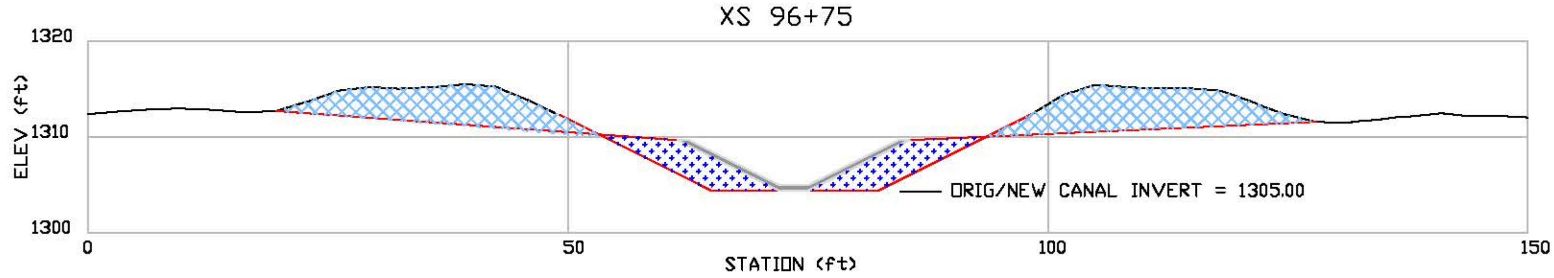
PRELIMINARY
Not for Construction

— = EXISTING GROUND — = RECONSTRUCTED CANAL

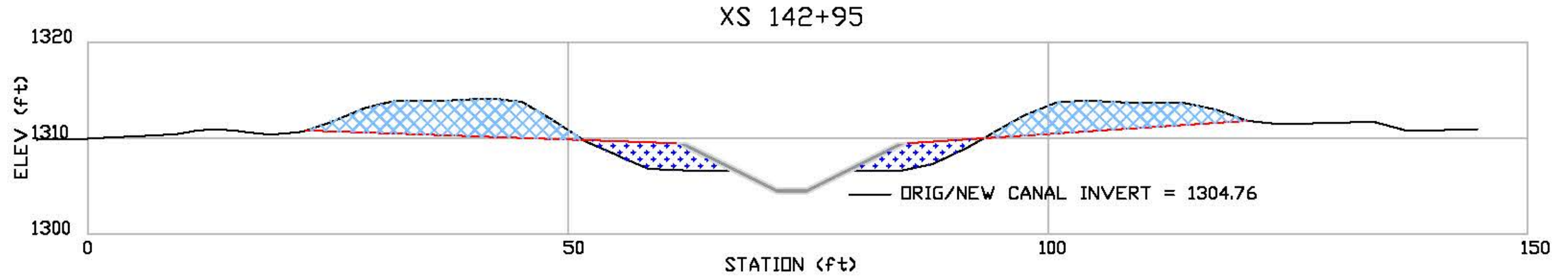
= CONCRETE = EXCAVATION = EMBANKMENT

1" = 10 FT

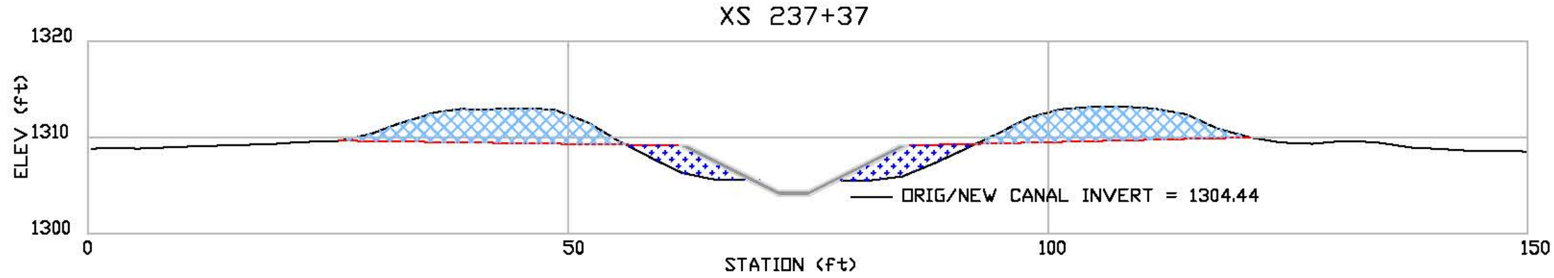
XS 96+75



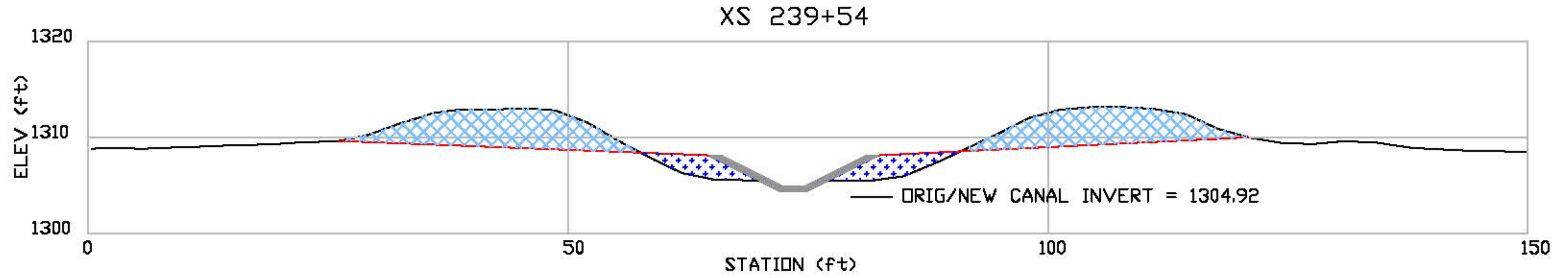
XS 142+95



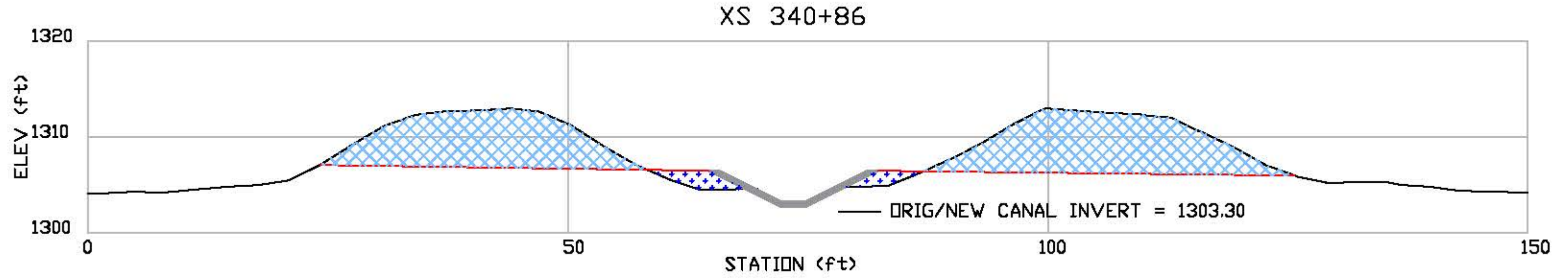
XS 237+37



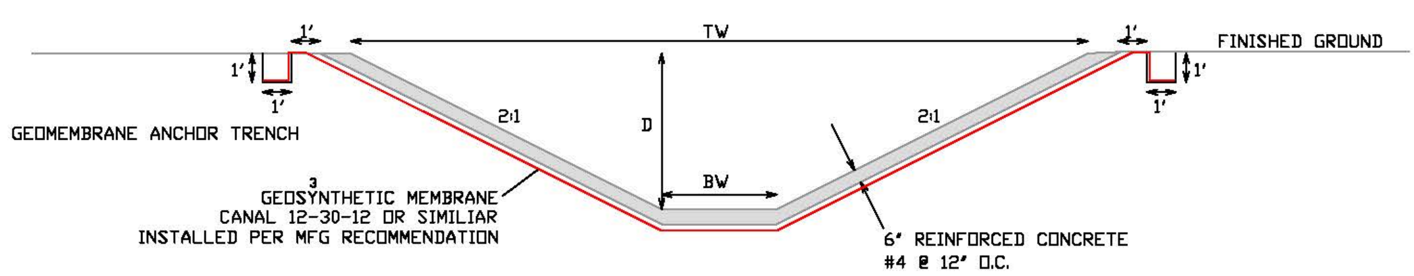
XS 239+54



XS 340+86



TYPICAL RECONSTRUCTED CANAL SECTION
(NOT TO SCALE)



Design Flow (cfs)	Lining Length (ft)	Total Depth (ft)	Bottom Width (ft)	Top Width (ft)	Slope (ft/ft)	Location
67.9	8,851	5.4	4.0	23.0	0.00005	0+00 to 93+83
42.0	14.062	4.7	3.0	22.3	0.00005	96+75 to 237+37
16.5	10,132	3.2	2.5	20.8	0.00001	239+54 to 340+86
Total	33,045					

*Note: lining length excludes concrete structures and siphons.

Date 6/12/2023

File Name DSID-HECRAScf.dwg

NRCS
Natural Resources Conservation Service

CROSS SECTIONS, TYPICAL SECTION
DSID Irrigation Modernization Project– Alternative #2

OWNER: *Dickey Sargent Irrigation District*

COUNTY: *Dickey*

Designed ________ Date ____

Drawn C. Fisher 6/2023

Checked ________

Approved ________

PRELIMINARY Not for Construction