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January 30, 2024

HAND DELIVERED

Mr. Steve Kahl
Executive Secretary Director
North Dakota Public Service Commission
600 E. Boulevard, Dept. 408
Bismarck, ND 58505-0480

RE: Case No. PU-22-391
SCS Carbon Transport LLC
Midwest Carbon Express Project
Response to Supplemental Filings 3.1.4

Dear Mr. Kahl:

On October 17, 2023, the North Dakota Public Service Commission ("Commission") submitted certain supplemental filings ("Supplemental Filings") and data requests ("Data Requests") to SCS Carbon Transport LLC ("Summit") in the above-referenced case. *See* Docket No. 409. Summit timely filed its response to the Data Requests on October 31, 2023. *See* Docket No. 411. The Commission requested Summit to provide the Supplemental Filings "at such time that it believes it has sufficient data and supporting documentation to adequately address the requested filings." *See* Docket No. 409.

Summit believes it has sufficient data and supporting documentation in response to Supplemental Filing 3.1.4 which requests:

> 3.1.4 A review of all areas prone to landslide or geologic instability discussed by the North Dakota Geological Survey and a demonstration tan no landslide prone areas identified by the North Dakota Geological Survey are within the project corridor.

Summit's response to Supplemental Filing 3.1.4 includes a *Phase I Geohazards Assessment* and the following supporting reports:

1. Phase I Hydrotechnical Assessment Report
2. Bois de Sioux River HDD Hydrotechnical Assessment Memo
3. James River HDD Hydrotechnical Assessment Memo
4. Missouri River HDD Hydrotechnical Assessment Memo
5. Sheyenne River HDD Hydrotechnical Assessment Memo

Summit directs the Commission's attention to Table A-3 of the *Phase I Geohazards Assessment* (pdf page 259) which provides a detailed summary of the landslide locations that were evaluated. Table A-4 of the *Phase I Geohazards Assessment* (pdf pages 260-262) provides a detailed description of the landslide sites and the mitigation strategy for each of said sites.

The aforementioned supporting reports provide the background assessment that was completed to develop the *Phase I Geohazards Assessment* and are referenced on page 20 (pdf page 24) of said assessment.

Accordingly, enclosed herewith, please find an original and seven (7) copies of Summit's response to Supplemental Filing 3.1.4. Summit's response to Supplemental Filing 3.1.4 was filed electronically by e-mailing the same to ndpsc@nd.gov.

Should you have any questions, please advise.

Sincerely,

LAWRENCE BENDER

LB/tjg
#81422695v1

Enclosures

cc: SCS Carbon Transport LLC

Geosyntec consultants

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Technical Memorandum

Date: 24 August 2023

To: Summit Carbon Solutions

From: Jeff Schneider and Bailey Theriault

Cc: David Vance (Geosyntec)

Subject: Summit Carbon Solutions Pipeline System, Phase I Hydrotechnical Hazard Assessment (Rev. 01)
Geosyntec Project No. TXG0353

INTRODUCTION

Geosyntec Consultants, Inc. (Geosyntec) was retained by Summit Carbon Solutions (SCS) to conduct a desktop Phase I Hydrotechnical Hazard Assessment (Phase I Assessment) for 72 waterbody crossings on the proposed Summit Carbon pipeline system. The following memorandum provides a summary of the assessment, methodology utilized for assigning hazard classifications, and the resultant hazard classifications for the 72 water body crossings that were provided to us by SCS.

DESKTOP REVIEW

Geosyntec conducted a desktop review of the proposed water body crossings. The purpose of the desktop review was to conduct a screening level review of the waterbody crossings along the proposed pipeline system to identify potential sites that should be considered for additional review or evaluation or crossing design modifications due to potential hydrotechnical hazards. The following data sources were reviewed as part of the Phase I Assessment as of the date of this memorandum:

- Available Google Earth™ aerial imagery, generally spanning the timeline from 1991 to 2022.
- United States Geologic Survey (USGS) 7.5-minute topographic quadrangle maps for the segment.

- Geospatial data (.kmz files) and crossing details provided by SCS and Gulf Interstate Engineering (GIE) including:
    - 72 water body crossing locations
    - Pipeline centerlines
    - Proposed installation method at crossing consisting of either horizontal direction drill (HDD) or open cut
    - Preliminary HDD plan and profile design drawings for each of the proposed HDD crossings (most recent revisions as of August 24, 2023).

The Phase I Assessment focused on identifying potential issues related to channel migration, stream bank slides, vertical streambed instability, and proximity of upgradient impoundment features, that may present potential future pipeline integrity issues related to pipe exposure or unsupported span lengths.

As part of the desktop review, Geosyntec obtained measurements in Google Earth™ based on aerial imagery of reach sinuosity (stream length/valley length), meander belt width, bankfull width, and pipe crossing length within bankfull (e.g., between left and right banks) and document the orientation between the pipeline and the stream alignments (e.g., perpendicular, or oblique) to aid in the hazard evaluation. Measurements were based on the most current available imagery where the existing channel and visual evidence of historic channels can be identified. Geomorphic evidence of hydrotechnical hazards (e.g., historical lateral instabilities and possible encroachment hazards on the pipeline alignment) were also documented.

HAZARD CLASSIFICATION RATINGS

Geosyntec developed a hazard classification rating system that qualitatively categorized the potential hydrotechnical threat for the proposed pipeline crossing as either low, moderate, or high. The rating system was based on a combination of factors including the following:

- Stream Morphology at crossing including sinuosity, meander belt width, bankfull width.
- Crossing orientation (e.g. perpendicular crossing, oblique crossing, parallel encroachment) and length within active channel.
- Proposed installation method (HDD or open cut) and preliminary crossing design. If HDD was proposed, Geosyntec reviewed the preliminary HDD plan and profile drawings to evaluate the proposed burial depth and lateral extents of the HDD relative to the waterbody crossing and hydrotechnical risks.
- Engineering/scientific judgement based on experience with similar type projects, pipeline construction, and principals of fluvial geomorphology and hydrology.

The hazards classifications were defined as follows:

- **Low Hazard** = Low likelihood for pipeline to be exposed due to hydrotechnical hazards within design life of project (assumed to be 50-years).
- **Moderate Hazard** = Moderate likelihood for pipeline to be exposed due to hydrotechnical hazards within design life of project.
- **High Hazard** = High likelihood for pipeline to be exposed due to hydrotechnical hazards within design life of project.

The hazards classifications defined for each crossing were based on the below assumptions.

Classification Assumptions:

- Pipeline would be installed using the techniques identified by SCS in the information provided to Geosyntec.
- For crossings identified as HDD installations, the proposed extents of the HDD would match those provided in the preliminary HDD plan and profile drawings.
- For crossings identified as open cut, the top of pipe would have a minimum depth of cover of 5-feet beneath the channel thalweg and the sag bends would be set back 15-feet from top of bank.
- HDD profile drawings show an accurate representation of channel bottom and proposed depth of cover for HDD crossings.
- River and creek crossings will be integrated into a pipeline system integrity management monitoring program to monitor potential changes in hydrologic and conditions.

Note that if the installation method is modified, or the preliminary HDD layout changes, the relative hazard rating for the crossing may change. Additionally, the HDD crossings were evaluated with respect to potential hydrotechnical hazards and not evaluated based on potential geotechnical or constructability risks associated with the HDD installation.

RESULTS

Geosyntec conducted an initial review of 59 of the 72 crossings in October and November of 2022 and an additional 13 crossings in July and August of 2023. After the initial review and preliminary hazards ranking, Geosyntec had design review meetings with SCS and GIE to provide recommended modifications to crossing designs to lower the crossing hazards ranking if feasible. Geosyntec then reviewed the updated designs as the basis for the hazard rating results presented in this memo.

A summary of the Phase I Assessment and hydrotechnical hazard classifications is provided in Table 1. Complete results of the Phase I Assessment, including geomorphic observations/measurements are provided in an Excel spreadsheet included with this submittal. After design modifications to various crossings, all 72 water body crossings, were classified as

"low hazard," for hydrotechnical hazard. Definitions for the are fields included in Table 1, Excel spreadsheet, Geographic Information System (GIS) geodatabase (.gdb) and Google Earth™ file (.kml) are provided with this submittal.

RECOMMENDATIONS

The primary focus of this desktop hydrotechnical assessment was to evaluate the 72 waterbody crossings provided by SCS and assess the potential for hydrotechnical hazards at each crossing which could potentially result in pipeline exposures. Based on the review and the crossing design changes made to date, Geosyntec recommends that if the proposed installation method or crossing designs change, that hydrotechnical hazards be re-evaluated. Geosyntec also recommends that these water body crossing be incorporated into the pipeline integrity management monitoring program for the proposed pipeline system.

CLOSING

We greatly appreciate the opportunity to support Summit Carbon Solutions on this project. Should you have any questions or need additional information, please do not hesitate to contact us.

Sincerely,

Bailey Theriault, PG (NH), LG (WA)
Senior Principal Geologist

Jeffrey Schneider, P.E.(WI, WA, OR, UT, MI, IN, MS)
Principal Engineer

Copies to: David Vance, Bailey Theriault, Geosyntec

Tables: 1: Phase 1 Hydrotechnical Assessment Summary Results

Appendices: A: Phase 1 Hydrotechnical Assessment Attribute Definitions

Tables

Table 1: Summit Carbon Solutions Phase I Hydrotechnical Assessment Summary Results

GEO ID	Feature_ID	Name	County	State	Latitude	Longitude	Route	Sta	Mile Post	Flow Regime	Crossing Method	HDD Drawing Number	Hazard Level
IO-01	**S_1_HD_008_DT**	South Fork Iowa River	HARDIN	IOWA	42.324394	-93.170262	IAL-301B	1529+24	29	Perennial	HDD	1927-100-PL-DWG-0036	Low
IO-02	**S1017HD010**	Iowa River	HARDIN	IOWA	42.437148	-93.069391	IAL-301B	2071+49	39.2	Perennial	HDD	1927-100-PL-DWG-0038	Low
IO-03	**S1017WR001**	Iowa River	WRIGHT	IOWA	42.637864	-93.507575	IAL-301A	3606+60	68.3	Perennial	HDD	1927-100-PL-DWG-0042	Low
IO-04	**S1005WE001**	Des Moines River	WEBSTER	IOWA	42.346304	-94.035222	IAL-302	1272+49	24.1	Perennial	HDD	1927-100-PL-DWG-0046	Low
IO-05	**S1019WR004**	Boone River	WRIGHT	IOWA	42.657008	-93.945866	IAL-302	2535+64	48	Perennial	HDD	1927-100-PL-DWG-0050	Low
IO-06	**S1015FM002**	East Nishnabotna River	FREMONT	IOWA	40.772480	-95.399492	IAL-306	69+34	1.3	Perennial	HDD	1927-100-PL-DWG-0053	Low
IO-07	**S1006PO031**	West Nishnabotna River	POTTAWATTAMIE	IOWA	41.365666	-95.388571	IAL-308	706+74	13.4	Perennial	HDD	1927-100-PL-DWG-0058	Low
IO-08	**S1014CR027**	Boyer River	CRAWFORD	IOWA	41.995942	-95.393747	IAL-308	3085+19	58.4	Perennial	HDD	1927-100-PL-DWG-0062	Low
IO-09	**S1014ID001**	Soldier River	IDA	IOWA	42.234724	-95.410201	IAL-308	3979+71	75.4	Perennial	Open Cut	1927-100-PL-DWG-0251	Low
IO-10	**S1002WO001**	Missouri River	WOODBURY	IOWA	42.353875	-96.417434	IAL-318A	620+86	11.8	Perennial	HDD	1927-000-PL-DWG-0033	Low
IO-11	**S1015PL009**	Floyd River	PLYMOUTH	IOWA	42.709874	-96.248723	IAL-318A	2261+34	42.8	Perennial	HDD	1927-100-PL-DWG-0068	Low
IO-12	**S1005CS001**	East Fork Wapsipinloon River	CHICKISAW	IOWA	43.078323	-92.296144	IAM-101	300+20	5.7	Perennial	HDD	1927-100-PL-DWG-0002	Low
IO-13	**S1005CS003**	Little Wapsipinicon River	CHICKASAW	IOWA	43.053425	-92.388469	IAM-101	615+33	11.7	Perennial	HDD	1927-100-PL-DWG-0003	Low
IO-14	**S1024CS002**	Wapsipinicon River	CHICKASAW	IOWA	43.052715	-92.436351	IAM-101	746+96	14.1	Perennial	HDD	1927-100-PL-DWG-0004	Low
IO-15	**S1024CS003**	Cedar River	CHICKASAW	IOWA	43.051292	-92.501116	IAM-101	921+16	17.4	Perennial	HDD	1927-100-PL-DWG-0006	Low
IO-16	**S1003FL008**	Cedar River	FLOYD	IOWA	43.050679	-92.644745	IAM-101	1328+17	25.2	Perennial	HDD	1927-100-PL-DWG-0008	Low
IO-17	**S1005FL002**	Shell Rock River	FLOYD	IOWA	43.061484	-92.957485	IAM-101	2207+62	41.8	Perennial	HDD	1927-100-PL-DWG-0011	Low
IO-18	**S1005FL004**	Winnebago River	FLOYD	IOWA	43.065630	-92.998247	IAM-101	2325+88	44.1	Perennial	HDD	1927-100-PL-DWG-0013	Low
IO-19	**S1003HC001**	East Branch Iowa River	HANCOCK	IOWA	43.038251	-93.642596	IAM-101	4160+65	78.8	Perennial	HDD	1927-100-PL-DWG-0018	Low
IO-20	**S1018HC004**	West Branch Iowa River	HANCOCK	IOWA	43.032263	-93.734015	IAM-101	4413+84	83.6	Perennial	HDD	1927-100-PL-DWG-0019	Low
IO-21	**S1018HC006**	East Branch Boone River	HANCOCK	IOWA	43.024369	-93.802644	IAM-101	4604+45	87.2	Perennial	Open Cut	N/A	Low
IO-22	**S1022HC001**	Boone River	HANCOCK	IOWA	43.023026	-93.940879	IAM-102	52+28	1	Perennial	HDD	N/A	Low
IO-23	**S1001KO003**	East Fork Des Moines River	KOSSUTH	IOWA	43.018207	-94.208517	IAM-102	784+99	14.9	Perennial	HDD	1927-100-PL-DWG-0020	Low
IO-24	**S1001PA002**	Des Moines River	PALO ALTO	IOWA	43.020497	-94.590294	IAM-102	1825+75	34.6	Perennial	HDD	1927-100-PL-DWG-0022	Low
IO-25	**S1001CL005**	Little Sioux River	CLAY	IOWA	43.022563	-95.050770	IAM-103A	70+43	1.3	Perennial	HDD	1927-100-PL-DWG-0023	Low
IO-26	**S1015SI009**	Floyd River	SIOUX	IOWA	43.047813	-95.938046	IAM-103B	2480+92	47	Perennial	HDD	1927-100-PL-DWG-0024	Low
IO-27	**S1002SI017**	West Branch Floyd River	SIOUX	IOWA	43.103490	-96.086619	IAM-103B	2956+69	56	Perennial	HDD	1927-100-PL-DWG-0262	Low
IO-28	**S1019WR008**	Boone River	WRIGHT	IOWA	42.889152	-93.912585	IAT-202	584+03	11.1	Perennial	HDD	1927-100-PL-DWG-0029	Low
IO-29	**S1019HC002**	Boone River	HANCOCK	IOWA	42.973181	-93.921144	IAT-202	901+80	17.1	Perennial	HDD	1927-100-PL-DWG-0202	Low
IO-30	**S1016ID021**	Maple River	IDA	IOWA	42.495307	-95.437168	IAT-204	93+84	1.8	Perennial	HDD	1927-100-PL-DWG-0261	Low
IO-31	**S1016CK002**	Little Sioux River	CHEROKEE	IOWA	42.639767	-95.629580	IAT-204	845+85	16	Perennial	HDD	1927-100-PL-DWG-0030	Low
IO-32	**S1016CK013**	West Fork Little Sioux River	CHEROKEE	IOWA	42.806847	-95.753812	IAT-204	1593+31	30.2	Perennial	HDD	1927-100-PL-DWG-0250	Low
IO-33	**S1001EM002**	Des Moines River	EMMET	IOWA	43.488704	-94.880658	MNL-305	1425+44	27	Perennial	HDD	1927-100-PL-DWG-0074	Low
IO-34	**S1020SI002**	Rock River	SIOUX	IOWA	43.242215	-96.253959	SDM-104A	486+70	9.2	Perennial	HDD	1927-100-PL-DWG-0071	Low
IO-35	**S1003LY012**	Big Sioux River	LYON	IOWA	43.350665	-96.526907	SDM-104A	1406+03	26.6	Perennial	HDD	1927-100-PL-DWG-0072	Low
IO-36		Pilot Creek	CERRO GORDO	Iowa	43.016578	-94.781153	IAM-102	2350+60	44.5189	Perennial	HDD	1927-100-PL-DWG-0199	Low
IO-37		Otter Creek	WRIGHT	Iowa	42.778475	-93.907658	IAT-202	163+08	3.08864	Perennial	HDD	1927-100-PL-DWG-0028	Low
IO-38	**S_1_HD_002_DT**	Honey Creek	HARDIN	Iowa	42.275961	-93.235603	IAL-301B	1251+05	23.6941	Perennial	HDD	1927-100-PL-DWG-0035	Low
IO-39		Beaver Creeek	HARDIN	Iowa	42.362163	-93.141329	IAL-301B	1718+06	32.539	Perennial	HDD	1927-100-PL-DWG-0037	Low
IO-40		White Fox Creek	WRIGHT	Iowa	42.671925	-93.715506	IAL-301A	4201+97	79.5828	Perennial	HDD	1927-100-PL-DWG-0043	Low
IO-41	**S1014MO004**	Walnut Creek	MONTGOMERY	Iowa	40.914418	-95.372492	IAL-306	635+24	12.0311	Perennial	HDD	1927-100-PL-DWG-0055	Low
IO-42		Coon Creek	CRAWFORD	Iowa	41.980999	-95.391703	IAL-308B	3022+97	57.2532	Perennial	HDD	1927-100-PL-DWG-0196	Low

Table 1: Summit Carbon Solutions Phase I Hydrotechnical Assessment Summary Results

GEO ID	Feature_ID	Name	County	State	Latitude	Longitude	Route	Sta	Mile Post	Flow Regime	Crossing Method	HDD Drawing Number	Hazard Level
MN-01	S1017YE002	Minnesota River	RENVILLE / YELLOW MEDICINE	MINNESOTA	44.713426	-95.397863	MNL-303A		11.7	Perennial	HDD	1927-100-PL-DWG-0099	Low
MN-02	S1013RE002	Redwood River	REDWOOD	MINNESOTA	44.502422	-95.399393	MNL-303B	1490+99	28.2	Perennial	HDD	1927-100-PL-DWG-0102	Low
MN-03	S1025RE002	Cottonwood River	REDWOOD	MINNESOTA	44.246956	-95.288989	MNL-303B	2743+76	52	Perennial	HDD	1927-100-PL-DWG-0103	Low
MN-04	S1002CO001	Heron Lake Outlet	COTTONWOOD	MINNESOTA	43.871074	-95.290495	MNL-304	1539+77	29.2	Perennial	HDD	1927-100-PL-DWG-0106	Low
MN-05	S1017MA002	East Fork Des Moines River	MARTIN	MINNESOTA	43.572829	-94.714653	MNL-305	806+50	15.3	Perennial	HDD	1927-100-PL-DWG-0110	Low
MN-06	S1002OT003	Pelican River	OTTER TAIL	MINNESOTA	46.295985	-96.151995	MNL-321A	99+89	1.9	Perennial	HDD	1927-000-PL-DWG-0111	Low
MN-07	S1002WI003	Otter Tail River	WILKIN	MINNESOTA	46.219892	-96.422277	MNL-321A	997+11	18.9	Perennial	HDD	1927-000-PL-DWG-0034	Low
MN-08	S1002WI001	Bois de Sioux River	WILKINS	MINNESOTA	46.212132	-96.588621	MNL-321A	1451+97	27.5	Perennial	HDD	1927-100-PL-DWG-0115	Low
MN-09		Hawk Creek	RENVILLE	MINNESOTA	44.797038	-95.456728	MNL-303A	109+48	2.1	Perennial	HDD	1927-100-PL-DWG-0098	Low
MN-10		Chetomba Creek	RENVILLE	MINNESOTA	44.869213	-95.363075	MNL-337	2105+31	39.9	Perennial	HDD	1927-100-PL-DWG-0208	Low
MN-11		Heron Lake Outlet -1 (Des Moines River)	COTTONWOOD	MINNESOTA	43.881846	-95.291136	MNL-304	1849+45	35.2	Perennial	HDD	1927-100-PL-DWG-0105	Low
ND-01	S2006RI017	Wild Rice River	RICHLAND	NORTH DAKOTA	46.203503	-96.746384	NDL-323	224+84	4.3	Perennial	HDD	1927-100-PL-DWG-0215	Low
ND-02	S_2_CA_042_DT	Maple River	CASS	NORTH DAKOTA	46.753519	-97.222370	NDL-324	641+10	12.1	Perennial	HDD	1927-100-PL-DWG-0192	Low
ND-03	S2006RI001	Sheyenne River	RICHLAND	NORTH DAKOTA	46.573469	-97.094092	NDL-324	1445+61	27.4	Perennial	HDD	1927-100-PL-DWG-0171	Low
ND-04	S2004MO017	Missouri River	MORTON	NORTH DAKOTA	46.963812	-100.933011	NDM-106	7348+00	139.2	Perennial	HDD	1927-000-PL-DWG-0032	Low
ND-05	S2007RI012	Wild Rice River	RICHLAND	NORTH DAKOTA	46.191806	-97.074787	NDT-211		3.3	Perennial	HDD	1927-100-PL-DWG-0211	Low
ND-06	S2006SA022	Wild Rice River	SARGENT	NORTH DAKOTA	46.190325	-97.293802	NDT-211	731+75	13.9	Perennial	HDD	1927-100-PL-DWG-0160	Low
ND-07	S_2_DI_013_DT	James River	DICKEY	NORTH DAKOTA	46.044830	-98.140255	NDT-211	3078+77	58.3	Perennial	HDD	1927-100-PL-DWG-0164	Low
ND-08	S2015DI024	Elm River	DICKEY	NORTH DAKOTA	45.946353	-98.679003	NDT-211	4623+51	87.6	Perennial	HDD	1927-100-PL-DWG-0166	Low
ND-09		Apple Creek	BURLEIGH	NORTH DAKOTA	46.852352	-100.583395	NDM-106	6314+84	119.60	Perennial	HDD	1927-100-PL-DWG-0190	Low
NE-05		Pigeon Creek	DAKOTA	Nebraska	42.366442	-96.615600	NEL-316/IAL-318B		2420+00	0.13 (IAL-318)	HDD	1927-100-PL-DWG-0205	Low
SD-01	S2002LA073	East Fork Vermillion River	LAKE	SOUTH DAKOTA	43.984638	-97.318659	SDM-104B	5091+15	96.4	Perennial	HDD	197-100-PL-DWG-0252	Low
SD-02	S2014SP003	James River	SPINK	SOUTH DAKOTA	45.168335	-98.397001	SDM-105B	2722+38	51.6	Perennial	HDD	1927-100-PL-DWG-0122	Low
SD-03	S_2_BE_046_DT	James River	BEADLE	SOUTH DAKOTA	44.471387	-98.124669	SDT-207	579+49	11.0	Perennial	HDD	1927-100-PL-DWG-0133	Low
SD-04	S2004SP009	James River	SPINK	SOUTH DAKOTA	44.913767	-98.485667	SDT-209	54+18	1.0	Perennial	HDD	1927-100-PL-DWG-0141	Low
SD-05		South Fork Moccasin Creek (Waterbody (S2001BR010)	BROWN	SOUTH DAKOTA	45.275770	-98.562027	SDM-105B	3373+28	63.9	Perennial	HDD	1927-100-PL-DWG-0125	Low
SD-06		Dry Run Creek	SPINK	SOUTH DAKOTA	44.956840	-98.325873	SDT-209	505+25	9.57	Perennial	HDD	1927-100-PL-DWG-0207	Low
SD-07		Big Sioux River	CODINGTON	SOUTH DAKOTA	44.879908	-97.107997	SDT-208	01+50	0.03		HDD	1927-100-PL-DWG-0136	Low
SD-08		Big Sioux River	CODINGTON	SOUTH DAKOTA	44.877242	-97.099405	SDT-208	33+24	0.63	Perennial	HDD	1927-100-PL-DWG-0135	Low
SD-09		Webber Gulch	BROWN	SOUTH DAKOTA	45.935589	-98.694584	NDT-211	4686+86	88.77		HDD	1927-100-PL-DWG-0152	Low

Appendix A: Phase 1 Hydrotechnical Assessment Attribute Definitions

APPENDIX B: TABLE DEFINITIONS

The following definitions are used for the columns in Tables 1 and Appendix A as well as the provided Excel file, geodatabase, and GoogleEarth file.

GEO_ID: This is a temporary identifier provided to facilitate discussion of the waterbody crossing. Each crossing was assigned a temporary identifier in the format of "State Abbreviation"+<< Unique Number Four Digit Number>>. For example, IO-01.

Feature_ID: Gulf/Summit Carbon unique feature ID for each waterbody crossing

Name: Waterbody crossing name

County: County where waterbody crossing is located

State: The USA state in which the waterbody crossing is located.

Lat/Long: The latitude/longitude of the center of the mapped geohazard.

State: The USA state in which the hydrotechnical hazard is located.

Route: The Summit Carbon pipeline segment/route for which the waterbody crossing is located. .

Sta: The Summit Carbon station for which the waterbody crossing is located.

Mile_Post: The Summit Carbon mile post for which the waterbody crossing is located.

Flow_Regime: The stream flow (perennial or intermittent) regime of the waterbody crossing.

Crossing_method: The proposed installation method (HDD or open-cut) of the waterbody crossing.

Valley_length_ft The straight line valley length, in feet, where waterbody crossing is located.

Valley_length_ft The stream length, in feet, of reach where waterbody crossing is located.

Sinuosity: Ratio of stream length to valley length

Bankfull_width_ft: Measured bankfull width in feet

Meander_Belt_Width_ft: lateral extent of the waterbody meanders as measured from outside bend of one meander to outside bend of upstream or downstream meander

MW_Ratio: Meander width ratio. Ratio of meander belt width to bankfull width.

Pipe_Length_within_bkf: Pipe length measured between desktop assessed left bank and right bank bankfull features.

Angle_of_crossing: Describes whether the pipe crosses the stream perpendicular to flow, oblique, or parallel.

Meander_Pattern: Description of observed meander patterns within reach of waterbody crossing as described in Rosgen, 1996

Deposition_Features: Description of observed depositional features within reach of waterbody crossing as described in Rosgen, 1996

Blockages: Description of channel debris/blockages observed at the crossing as described in Rosgen, 1996

Lateral Instability: Geomorphic evidence of lateral instability or exposure risk (e.g., bank erosion, meander migration, parallel encroachment, etc.) is noted

Hazard Level: Hydrotechnical hazard rating.

Notes: Documentation of observations and/or recommendations based on hazard level.

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Memorandum

Rev. A - Issued for Review by Gulf Interstate

Date: 9 September 2022

To: David Ammerman, PE (Gulf Interstate)

From: David Vance, PG[1]; Jeremy Yeglin, PE[2]; and Robert Dunn

Cc: Al Preston, PhD, PE[3]; Brandon Klenzendorf, PhD, PE[4]; Muhammed Mustafa, PhD, PE[3]; Morgan L'Hoste (EIT); and Jai Panthail

Subject: Hydrotechnical Assessment (Bois de Sioux River HDD Crossing)
Geosyntec Project No. TXG0320

INTRODUCTION

The following is a summary of the hydrotechnical assessment for Gulf Interstate Engineering, Inc.'s (Gulf Interstate) proposed Bois de Sioux River horizontal directional drilling (HDD) crossing, which is part of the 2,000-mile pipeline system being installed by Summit Carbon Solutions in North Dakota. The crossing is located at milepost (MP) 26.9 in Richland County, North Dakota and Wilkin County, Minnesota. Geosyntec completed this hydrotechnical assessment to evaluate the lateral setbacks and riverine scour and define the lateral and depth hazards the river possesses at the proposed crossing. The methods, calculations, results, and recommendations of this assessment are described herein.

DATA SOURCES REVIEWED

The following data sources have been reviewed as part of the hydrotechnical assessment as of the date of this memorandum:

- 2016 1-meter (m) resolution LiDAR from the states of Minnesota's and North Dakota's LiDAR database; collected by the U.S. Army Corps of Engineers (St. Louis District).

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[1] Licensed in GA
[2] Licensed in ND, TX, and OK
[3] Licensed in CA
[4] Licensed in TX and LA

- Bathymetric survey data collected by TRC Companies (TRC) dated August 12, 2022.
- Available Google Earth™ aerial imagery, generally spanning the timeline from September 1991 to September 2021.
- United States Geologic Survey (USGS) 7.5 minute topographic quadrangle maps for the segment.
- Federal Emergency Management Agency (FEMA) *Richland County, North Dakota and Incorporated Areas Flood Insurance Study dated December 18, 2009*
- Federal Emergency Management Agency (FEMA) *Wilkin County, Minnesota and Incorporated Areas Flood Insurance Study dated May 18, 2015.*

METHODS

Geosyntec conducted a scour analysis and lateral migration assessment of the Bois de Sioux River crossing. The methods for the scour analysis and lateral migration assessment are described below.

Scour Analysis

The scour analysis consisted of evaluating appropriate burial depth based on the depth of anticipated total (vertical) scour at the Bois de Sioux River crossing location. Scour calculations required hydraulic analyses for the crossing. The methods and results of the hydraulic and scour analyses are summarized below based on the following assumptions:

- Longitudinal peak flows associated with the 100-year return period were taken from the *FEMA Richland County, North Dakota and Incorporated Areas Flood Insurance Study* dated December 18, 2009 and the *FEMA Wilkin County, Minnesota and Incorporated Areas Flood Insurance Study* dated May 18, 2015. The 100-year peak flow used for the hydraulic modeling was 6,200 cubic feet per second (cfs).
- Site-specific cross sections of the active channel were modeled upstream, downstream, and at the pipeline crossing location based on a mosaic digital elevation model (DEM) of the Minnesota and North Dakota LiDAR and the TRC bathymetric survey data.
- Longitudinal slope of 0.05% was estimated from the TRC bathymetry data.
- Median grain size (D_{50}) of the stream bed was estimated to be 0.125 millimeter (mm), which is representative of a fine sand bed dominated system.
- Manning's n-value was estimated to be 0.035, which is representative of a clean, winding river, with some weeds and stones.

Hydraulic analysis was performed using the Hydrologic Engineering Center River Analysis System (HEC-RAS) software program to calculate hydraulic design parameters (e.g., flow depth, width, velocity, and effective shear stress) for the peak flow obtained from the FEMA Flood Insurance Study. The flow profile modeled includes peak discharge associated with the 100-year

return period. The one-dimensional (1-D) HEC-RAS model was populated with channel geometry parameters (i.e., longitudinal slope and cross section) and Manning's roughness coefficient described above. The HEC-RAS model is representative of normal flow depth calculations at the stream crossing and was analyzed at three cross sections (upstream, at the pipeline crossing, and downstream). Additional cross sections were modeled farther upstream and downstream for model stability and to minimize the influence of boundary conditions at the pipeline crossing. The cross section geometry is based on the LiDAR and bathymetry data and is representative for the crossing. Known water surface elevations for the 100-year base flood elevation were obtained from the *FEMA Richland County, North Dakota and Incorporated Areas Flood Insurance Study* dated December 18, 2009 and the *FEMA Wilkin County, Minnesota and Incorporated Areas Flood Insurance Study* dated May 18, 2015. These known water surface elevations were assigned as the downstream boundary conditions. These water surface elevations are representative of normal depth conditions.

Total scour (z_{ts}) is the total depth of scour at a given location. It is applied to the thalweg of the channel and is the sum of all scour components that are applicable for the given location. Scour components considered include the following, which are described in the subsequent sections:

- **Long-Term Degradation (z_{lt})**
- **General Scour (z_{gs})**
- **Bend Scour (z_{bs})**
- **Local Scour (z_{ls})**
- **Contraction Scour (z_{cs})**
- **Bedform Scour (z_{bfs})**

Note these components of scour were included where applicable. For the Bois de Sioux River, bedform scour was not considered applicable and therefore not included in total scour. The scour components were calculated using applicable scour equations. If multiple scour equations were considered applicable for a component of scour, results were averaged. The average scour value for each component was then summed to generate a final total scour (z_{ts}) depth. The components of scour are described below.

Long-Term Degradation (z_{lt})

Long-Term degradation (z_{lt}) is the progressive lowering of the channel bed due to scour. This permanent or continuing degradation is an indicator that a change in the stream's discharge and sediment load characteristics is taking place. Degradation of the stream bed occurs due to downstream bed elevation changes or excess sediment-transporting capacity relative to the size of bed-material (e.g., resistance to movement) and quantity of bed-material sediment delivered from upstream reaches. Degradation continues until the existing longitudinal slope of the channel

decreases to an equilibrium (stable) slope or until an armor layer (i.e., comprised of gravel and/or cobble-sized particles) that mitigates long-term degradation develops on the stream bed.

Typically, long-term degradation scour is calculated by multiplying the channel distance to the nearest downstream grade control point (e.g., exposed bedrock or manmade drop structure) by the difference in the existing and equilibrium longitudinal slopes. This estimation requires understanding the distance to a grade level control, a process that requires individual assessment at each stream with access to extended portions of the stream upstream and downstream of the pipeline crossing. For this assessment, data are not readily available. Instead, Geosyntec estimated degradation associated with observed natural geomorphic processes associated with natural degradation described below. Long-term degradation was conservatively estimated to be 2 feet.

General Scour (z_{gs})

General scour is the lowering of the stream bed across the channel over relatively short time periods and is associated with the passing of a single flood. The Lacey Regime Equation (ASCE 2005), Zeller equation (USACE, 2021), U.S. Bureau of Reclamation (USBR) Envelope Curve (USACE, 2021), and the Neill competent velocity equation (USACE, 2021) were used to calculate general scour for this study. The average value of all four equations was used to estimate general scour depth. Calculated general scour (averaged from applicable equations) was 2.86 feet.

Bend Scour (z_{bs})

Bend scour is associated with meandering channels that can induce transverse or secondary currents. It is the scour associated with the outside of a bend. The USBR equation for sand bed rivers (USBR, 2019), which summarizes the charts for scour prediction contained in Plate B41 of Engineer Manual 1110-2-1601 (USACE, 1994), was used to calculate bend scour for this study. The estimated bankfull depth (based on the apparent channel dimensions identified from the bathymetric survey) at the upstream cross section was used to calculate bend scour. The Thorne (Thorne, 1988), Maynord (Maynord, 1996), and Zeller (USACE, 2021) equations were also calculated and considered in this study. The average value of all four equations was used to estimate bend scour depth. Calculated bend scour (averaged from applicable equations) was 3.74 feet.

Local Scour (z_{ls})

Local scour is the scour that results from an obstruction and abrupt change in the direction of flow. It is caused by an acceleration of flow and resulting vortices induced by the obstruction. The component of local scour considered in this analysis is large woody debris (LWD). Local scour from LWD was applied for the stream crossing to consider the potential for accumulation of LWD at or near the crossing that could lead to scour and pipeline exposure.

Large woody debris was considered as part of this analysis due to the prevalence of forested land cover throughout the pipeline alignment and in vicinity of the crossings and its associated

watersheds. An equation for pier scour, based on Hydrologic Engineering Circular No. 18 (FHWA, 2012), was used as a basis for estimating scour associated with in-stream LWD. Calculated local scour from LWD was 1.52 feet.

Contraction Scour (z_{cs})

Contraction scour is the scour that results when the flow area of a stream is reduced by a natural contraction or a bridge constricting the flow. An equation for contraction scour, based on Hydrologic Engineering Circular No. 18 (FHWA, 2012), was used as a basis for estimating contraction scour. Contraction scour was found to be negligible and therefore was not included in total scour.

Bedform Scour (z_{bfs})

Bedform scour is the scour that results when flow passes dunes and antidunes in sand bedded streams. Antidunes are generally associated with high velocity stream approaching supercritical flow (USACE, 2020). Hydraulic analysis performed using HEC-RAS demonstrated that flows at the Bois de Sioux River crossing did not approach supercritical, and Froude numbers stayed well below a value of 1.0. Therefore, bedform scour was not considered applicable and therefore was not included in total scour.

Total Scour (z_{ts})

Geosyntec calculated total scour depth by summing the average scour value for each component. Total scour results are presented in **Table 1** below.

Table 1. Summary of Calculated Scour Components and Total Scour

Scour Component	Calculated Scour Depth (ft)
Long-term Scour	2.0
General scour	2.9
Bend Scour	3.7
Local Scour	1.5
Contraction Scour	0.0
Bedform Scour	0.0
Total Scour	**10.1**

Lateral Migration Analysis

Geosyntec completed a lateral migration analysis of the crossing to assess potential lateral migration hazards relative to the proposed lateral setback locations. Using aerial recent and

historical imagery, Geosyntec observed less than 15 feet of lateral bank migration on both the east and west banks of the Bois de Sioux River over the observation period of aerial imagery (**Figure 1**). Additionally, Geosyntec observed minimal potential for channel avulsion on the east or west bank floodplains due to the presence of high terraces.

Figure 1. Bois de Sioux River Lateral Historic Streambank Delineation

RECOMMENDATIONS

Total scour depth was calculated to be 10.1'. Based on the current bathymetric data (supplied by TRC), the channel bottom elevation is 945.93' NAVD88 and the proposed HDD burial elevation is 920.59' NAVD88. A scour depth of 10.1' below the existing bed would result in 15.2 feet of

cover over the proposed HDD burial elevation. Given the depth of cover at the currently proposed HDD elevation, the proposed HDD elevation provides a minimum factor of safety of 1.5 and is sufficient to mitigate against the calculated total scour. As currently designed, Geosyntec does not recommend any changes to the HDD elevation.

Based on the lateral migration analysis, the west bank point of inflection (PI) at station 1419+10.6 and the east bank PI at station 1417+63.9 are not located beyond the ordinary high water mark (OHWM) of the Bois de Sioux River. Geosyntec recommends moving the west bank PI to station 1420+00 and moving the east bank PI to station 1417+00. The burial depth elevation of 920.59' should be maintained between these PIs. This will result in shifting the HDD entry and exit points further to the south and north, respectively.

CLOSING

We greatly appreciate the opportunity to support Gulf Interstate on this project. Should you have any questions or need additional information, please do not hesitate to contact David at Dvance@Geosyntec.com or (678) 361-4801 or Jeremy at JYeglin@Geosyntec.com or (832) 455-3684.

Sincerely,

Jeremy Yeglin, P.E.(ND, TX, OK)
Principal Engineer

David Vance, P.G.(GA)
Principal Geologist

REFERENCES

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Memorandum

Rev. A - Issued for Review by Gulf Interstate

Date: 14 September 2022

To: David Ammerman, PE (Gulf Interstate)

From: David Vance, PG[1]; Jeremy Yeglin, PE[2]; and Robert Dunn

Cc: Al Preston, PhD, PE[3]; Brandon Klenzendorf, PhD, PE[4]; Muhammed Mustafa, PhD, PE[3]; Morgan L'Hoste (EIT); and Jai Panthail (EIT)

Subject: Hydrotechnical Assessment (James River HDD Crossing)
Geosyntec Project No. TXG0320

INTRODUCTION

The following is a summary of the hydrotechnical assessment for Gulf Interstate Engineering, Inc.'s (Gulf Interstate) proposed James River horizontal directional drilling (HDD) crossing, which is part of the 2,000-mile pipeline system being installed by Summit Carbon Solutions in North Dakota. The crossing is located at milepost (MP) 58.3 in Dickey County, North Dakota. Geosyntec completed this hydrotechnical assessment to evaluate the lateral setbacks and riverine scour and define the lateral and depth hazards the river possesses at the proposed crossing. The methods, calculations, results, and recommendations of this assessment are described herein.

DATA SOURCES REVIEWED

The following data sources have been reviewed as part of the hydrotechnical assessment as of the date of this memorandum:

- 2016 1-meter (m) resolution LiDAR from the state of North Dakota's LiDAR database; collected by the U.S. Army Corps of Engineers (St. Louis District).
- Bathymetric survey data collected by TRC Companies (TRC) dated August 15, 2022.

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[1] Licensed in GA
[2] Licensed in ND, TX, and OK
[3] Licensed in CA
[4] Licensed in TX and LA

- Available Google Earth™ aerial imagery, generally spanning the timeline from September 1991 to September 2021.
- United States Geologic Survey (USGS) 7.5-minute topographic quadrangle maps for the segment.
- *FEMA Stutsman County*[5]*, North Dakota and Incorporated Areas Flood Insurance Study* dated June 7, 2017.
- United States Geologic Survey (USGS) peak streamflow data for Dickey County and Stutsman County in North Dakota.

METHODS

Geosyntec conducted a scour analysis and lateral migration assessment of the James River crossing. The methods for the scour analysis and lateral migration assessment are described below.

Scour Analysis

The scour analysis consisted of evaluating appropriate burial depth based on the depth of anticipated total (vertical) scour at the James River crossing location. Scour calculations required hydraulic analyses for the crossing. The methods and results of the hydraulic and scour analyses are summarized below based on the following assumptions:

- Longitudinal peak flows associated with the 100-year return period were estimated using the *FEMA Stutsman County, North Dakota and Incorporated Areas Flood Insurance Study* dated June 7, 2017, USGS peak streamflow data, and a project site drainage area ratio. The 100-year peak flow used for the hydraulic modeling was estimated to be 5,230 cubic feet per second (cfs).
- Site-specific cross sections of the active channel were modeled upstream, downstream, and at the pipeline crossing location based on a mosaic digital elevation model (DEM) of the North Dakota LiDAR and the TRC bathymetric survey data.
- Longitudinal slope of 0.2% was estimated from the TRC bathymetry data.
- Median grain size (D_{50}) of the stream bed was estimated to be 1.0 millimeter (mm), which is representative of a coarse/very coarse sand bed dominated system.
- Manning's n-value was estimated to be 0.04, which is representative of a clean, winding river, with some pools and shoals.

[5] A FEMA flood study is not available for the site within Dickey County, ND. Therefore, the discharge at the crossing was estimated using a watershed scaling factor of 2.78 applied to the 100-yr discharge at Jamestown from the FEMA flood study for Stutsman County, ND. A watershed scaling factor of 3.0 was initially obtained by comparing the peak flows at USGS Jamestown and USGS ND-SD Stateline. The 3.0 scaling factor was decreased to 2.78 by comparing the watershed areas upstream of the site and upstream of USGS ND-SD Stateline.

Hydraulic analysis was performed using the Hydrologic Engineering Center River Analysis System (HEC-RAS) software program to calculate hydraulic design parameters (e.g., flow depth, width, velocity, and effective shear stress) for the peak flow obtained from the FEMA Flood Insurance Study. The flow profile modeled includes peak discharge associated with the 100-year return period. The one-dimensional (1-D) HEC-RAS model was populated with channel geometry parameters (i.e., longitudinal slope and cross section) and Manning's roughness coefficient described above. The HEC-RAS model is representative of normal flow depth calculations at the stream crossing and was analyzed at three cross sections (upstream, at the pipeline crossing, and downstream). Additional cross sections were modeled farther upstream and downstream for model stability and to minimize the influence of boundary conditions at the pipeline crossing. The cross-section geometry is based on the LiDAR and bathymetry data and is representative for the crossing. Normal depth boundary conditions were assigned to the downstream cross section and were set to the longitudinal slope.

Total scour (z_{ts}) is the total depth of scour at a given location. It is applied to the thalweg of the channel and is the sum of all scour components that are applicable for the given location. Scour components considered include the following, which are described in the subsequent sections:

- **Long-Term Degradation (z_{lt})**
- **General Scour** (z_{gs})
- **Bend Scour** (z_{bs})
- **Local Scour** (z_{ls})
- **Contraction Scour** (z_{cs})
- **Bedform Scour** (z_{bfs})

Note these components of scour were included where applicable. For the James River, bedform scour was not considered applicable and therefore not included in total scour. The scour components were calculated using applicable scour equations. If multiple scour equations were considered applicable for a component of scour, results were averaged. The average scour value for each component was then summed to generate a final total scour (z_{ts}) depth. The components of scour are described below.

Long-Term Degradation (z_{lt})

Long-Term degradation (z_{lt}) is the progressive lowering of the channel bed due to scour. This permanent or continuing degradation is an indicator that a change in the stream's discharge and sediment load characteristics is taking place. Degradation of the stream bed occurs due to downstream bed elevation changes or excess sediment-transporting capacity relative to the size of bed-material (e.g., resistance to movement) and quantity of bed-material sediment delivered from upstream reaches. Degradation continues until the existing longitudinal slope of the channel

decreases to an equilibrium (stable) slope or until an armor layer (i.e., comprised of gravel and/or cobble-sized particles) that mitigates long-term degradation develops on the stream bed.

Typically, long-term degradation scour is calculated by multiplying the channel distance to the nearest downstream grade control point (e.g., exposed bedrock or manmade drop structure) by the difference in the existing and equilibrium longitudinal slopes. This estimation requires understanding the distance to a grade level control, a process that requires individual assessment at each stream with access to extended portions of the stream upstream and downstream of the pipeline crossing. For this assessment, data are not readily available. Instead, Geosyntec estimated degradation associated with observed natural geomorphic processes associated with natural degradation described below. Long-term degradation was conservatively estimated to be 2 feet.

General Scour **(z_{gs})**

General scour is the lowering of the stream bed across the channel over relatively short time periods and is associated with the passing of a single flood. The Lacey Regime Equation (ASCE 2005), Zeller equation (USACE, 2021), U.S. Bureau of Reclamation (USBR) Envelope Curve (USACE, 2021), and the Neill competent velocity equation (USACE, 2021) were used to calculate general scour for this study. The average value of all four equations was used to estimate general scour depth. Calculated general scour (averaged from applicable equations) was 3.93 feet.

Bend Scour **(z_{bs})**

Bend scour is associated with meandering channels that can induce transverse or secondary currents. It is the scour associated with the outside of a bend. The USBR equation for sand bed rivers (USBR, 2019), which summarizes the charts for scour prediction contained in Plate B41 of Engineer Manual 1110-2-1601 (USACE, 1994), was used to calculate bend scour for this study. The estimated bankfull depth (based on the apparent channel dimensions identified from the bathymetric survey) at the upstream cross section was used to calculate bend scour. The Thorne (Thorne, 1988), Maynord (Maynord, 1996), and Zeller (USACE, 2021) equations were also calculated and considered in this study. The average value of all four equations was used to estimate bend scour depth. Calculated bend scour (averaged from applicable equations) was 6.33 feet.

Local Scour **(z_{ls})**

Local scour is the scour that results from an obstruction and abrupt change in the direction of flow. It is caused by an acceleration of flow and resulting vortices induced by the obstruction. The component of local scour considered in this analysis is large woody debris (LWD). Local scour from LWD was applied for the stream crossing to consider the potential for accumulation of LWD at or near the crossing that could lead to scour and pipeline exposure.

Large woody debris was considered as part of this analysis due to the prevalence of forested land cover throughout the pipeline alignment and in vicinity of the crossings and its associated

watersheds. An equation for pier scour, based on Hydrologic Engineering Circular No. 18 (FHWA, 2012), was used as a basis for estimating scour associated with in-stream LWD. Calculated local scour from LWD was 1.84 feet.

Contraction Scour (z_{cs})

Contraction scour is the scour that results when the flow area of a stream is reduced by a natural contraction or a bridge constricting the flow. An equation for contraction scour, based on Hydrologic Engineering Circular No. 18 (FHWA, 2012), was used as a basis for estimating contraction scour. Calculated contraction scour was 0.05 feet.

Bedform Scour (z_{bfs})

Bedform scour is the scour that results when flow passes dunes and antidunes in sand bedded streams. Antidunes are generally associated with high velocity stream approaching supercritical flow (USACE, 2020). Hydraulic analysis performed using HEC-RAS demonstrated that flows at the James River crossing did not approach supercritical, and Froude numbers stayed well below a value of 1.0. Therefore, bedform scour was not considered applicable and therefore was not included in total scour.

Total Scour (z_{ts})

Geosyntec calculated total scour depth by summing the average scour value for each component. Total scour results are presented in **Table 1** below.

Table 1. Summary of Calculated Scour Components and Total Scour

Scour Component	Calculated Scour Depth (ft)[1]
Long-term Scour	2.0
General scour	3.9
Bend Scour	6.3
Local Scour	1.8
Contraction Scour	0.1
Bedform Scour	0.0
Total Scour	**14.1**

[1] Values rounded to two significant digits.

Lateral Migration Analysis

Geosyntec completed a lateral migration analysis of the crossing to assess potential lateral migration hazards relative to the proposed lateral setback locations. Using recent and historical aerial imagery, Geosyntec observed less than 20 feet of lateral bank migration on both the east and

west banks of the James River over the observation period of aerial imagery. Geosyntec observed potential for channel avulsion along the west bank, as indicated by the presence of inundation and secondary flow channels within the west bank floodplain. Further, a secondary flow path/back water area appears to have formed along the west bank floodplain upstream of the crossing and a back water area has formed in the west bank floodplain immediately downstream of the crossing. Together, these present an avulsion potential to the west at the crossing.

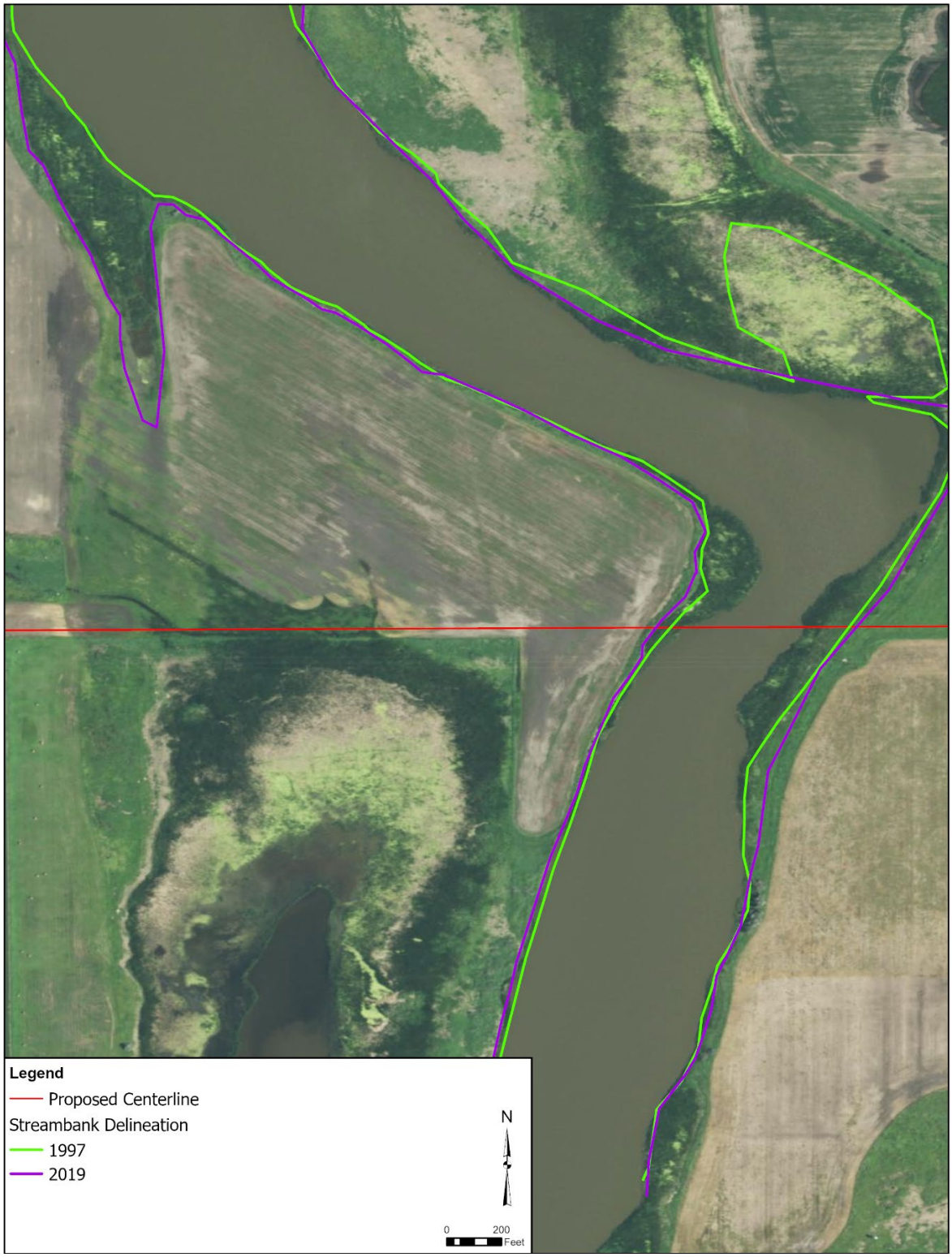

Figure 1. James River Lateral Historic Streambank Delineation

RECOMMENDATIONS

Total scour depth was calculated to be 14.1'. Based on the current bathymetric data (supplied by TRC), the channel bottom elevation is 1285.9' NAVD88 and the proposed HDD burial elevation is 1261.03' NAVD88. A scour depth of 14.1.' below the existing bed would result in 10.7 feet of cover over the proposed HDD burial elevation. Given the depth of cover at the currently proposed HDD elevation, the proposed HDD elevation provides a minimum factor of safety of 1.5 and is sufficient to mitigate against the calculated total scour. As currently designed, Geosyntec does not recommend any changes to the HDD burial elevation.

Based on the lateral migration analysis, the east bank point of inflection (PI) at station 3078+95.8 is not located beyond the ordinary high-water mark (OHWM) of the James River and is located within the active channel. Further, the west bank PI at station 3095+24.0 is not located sufficient to mitigate against the avulsion potential of the west bank. Geosyntec recommends moving the east bank PI at a minimum to station 3077+00 and moving the west bank PI to station 3097+00. The burial elevation of 1261.03' should be maintained between these PIs. This will result in shifting the HDD entry and exit points further to the east and west, respectively.

CLOSING

We greatly appreciate the opportunity to support Gulf Interstate on this project. Should you have any questions or need additional information, please do not hesitate to contact David at Dvance@Geosyntec.com or (678) 361-4801 or Jeremy at JYeglin@Geosyntec.com or (832) 455-3684.

Sincerely,

REGISTERED PROFESSIONAL ENGINEER
JEREMY L. YEGLIN
PE-9672
DATE
NORTH DAKOTA

September 14, 2022

Jeremy Yeglin, P.E.(ND, TX, OK)
Principal Engineer

David Vance, P.G.(GA)
Principal Geologist

REFERENCES

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Memorandum

Rev. A - Issued for Review by Gulf Interstate

Date: 26 August 2022

To: David Ammerman, PE (Gulf Interstate)

From: David Vance, PG[1]; Jeremy Yeglin, PE[2]; and Robert Dunn

Cc: Al Preston, PhD, PE[3]; Brandon Klenzendorf, PhD, PE[4]; Muhammed Mustafa, PhD, PE[3]; and Morgan L'Hoste (EIT); Jai Panthail

Subject: Hydrotechnical Assessment (Missouri River HDD Crossing)
Geosyntec Project No. TXG0320

INTRODUCTION

The following is a summary of the hydrotechnical assessment for Gulf Interstate Engineering, Inc's (Gulf Interstate) proposed Missouri River horizontal directional drilling (HDD) crossing, which is part of the 2,000-mile pipeline system being installed by Summit Carbon Solutions in North Dakota. The crossing is located at milepost (MP) 11.5 in Morton and Burleigh Counties, North Dakota. Geosyntec completed this hydrotechnical assessment to evaluate the lateral setbacks and riverine scour and define the lateral and depth hazards the river possesses at the proposed crossing. The methods, calculations, results, and recommendations of this assessment are described herein.

DATA SOURCES REVIEWED

The following data sources have been reviewed as part of the hydrotechnical assessment as of the date of this memorandum:

- 2016 1-meter (m) resolution LiDAR from the state of North Dakota's LiDAR database; collected by the U.S. Army Corps of Engineers (St. Louis District).

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[1] Licensed in GA
[2] Licensed in ND, TX, and OK
[3] Licensed in CA
[4] Licensed in TX and LA

- Bathymetric survey data collected by TRC Companies (TRC).
- Available Google Earth™ aerial imagery, generally spanning the timeline from September 1997 to September 2021.
- United States Geologic Survey (USGS) 7.5 minute topographic quadrangle maps for the segment.
- USGS StreamStats: Streamflow Statistics and Spatial Analysis Tools for Water-Resources Applications (https://streamstats.usgs.gov/ss/).
- Federal Emergency Management Agency (FEMA) *Burleigh County, North Dakota and Incorporated Areas Flood Insurance Study dated August 4, 2014.*

METHODS

Geosyntec conducted a scour analysis and lateral migration assessment of the Missouri River crossing. The methodology for the scour analysis and lateral migration assessment is described below.

Scour Analysis

The scour analysis consisted of evaluating appropriate burial depth based on the depth of anticipated total (vertical) scour at the Missouri River crossing location. Scour calculations required hydraulic analyses for each crossing. The methodology and results of the hydraulic and scour analyses are summarized below.

- Longitudinal peak flows associated with the 100-year return period were taken from the *FEMA Burleigh County, North Dakota and Incorporated Areas Flood Insurance Study* dated August 4, 2014. The 100-year peak flow used for the hydraulic modeling was 94,000 cubic feet per second (cfs).
- Site-specific cross sections of the active channel were cut upstream, downstream, and at the cross location from a mosaic digital elevation model (DEM) of the North Dakota LiDAR and the TRC bathymetric survey data.
- Longitudinal slope of 0.30% was measured from the TRC bathymetry data.
- Median grain size (D_{50}) of the stream bed was estimated to be 1 millimeter (mm), which is representative of a coarse/very coarse sand bed dominated system.
- Manning's n-value was estimated to be 0.035, which is a conservative estimate for large rivers.

Hydraulic analysis was performed using the Hydrologic Engineering Center River Analysis System (HEC-RAS) software program to calculate hydraulic parameters (e.g., flow depth, width, velocity, and effective shear stress) for the peak flows derived from the hydrologic analysis. The flow profiles modeled include peak discharges associated with the 100-year return period. The

one-dimensional (1-D) HEC-RAS models were populated with channel geometry parameters (i.e., longitudinal slope and cross section), and Manning's roughness described above. The HEC-RAS models are representative of normal flow depth calculations at each stream crossing and contain three cross sections (upstream, at crossing, and downstream). The cross section geometry is based on the LiDAR and bathymetry data and is representative for the crossing. Normal depth boundary conditions were assigned to the downstream cross section and were set to the longitudinal slope.

Total scour (z_{ts}) is the total depth of scour at a given location. It is applied to the thalweg of the channel and is the sum of all scour components that are applicable for the given location. Scour components considered include the following, which are described in the subsequent sections:

- Long-Term Degradation (z_{lt})
- General Scour (z_{gs})
- Bend Scour (z_{bs})
- Local Scour (z_{ls})
- Contraction Scour (z_{cs})
- Bedform Scour (z_{bfs})

Note these components of scour were included where applicable. For the Missouri River, bedform scour was not considered applicable and therefore not included in total scour. The scour components were calculated using applicable scour equations. If multiple scour equations were considered applicable for a component of scour, results were averaged. The average scour value for each component was then summed to generate total scour (z_{ts}) depth. The components of scour are described below.

Long Term Degradation **(z_{lt})**

Long-Term degradation (z_{lt}) is the progressive lowering of the channel bed due to scour. This permanent or continuing degradation is an indicator that a change in the stream's discharge and sediment load characteristics is taking place. Degradation of the stream bed occurs due to downstream bed elevation changes or excess sediment-transporting capacity relative to the size of bed-material (e.g., resistance to movement) and quantity of bed-material sediment delivered from upstream reaches. Degradation continues until the existing longitudinal slope of the channel decreases to an equilibrium (stable) slope or until an armor layer (i.e., comprised of gravel and/or cobble-sized particles) that mitigates long term degradation develops on the stream bed.

Typically, long-term degradation scour is calculated by multiplying the channel distance to the nearest downstream grade control point (e.g., exposed bedrock or manmade drop structure) by the difference in the existing and equilibrium longitudinal slopes. This estimation requires understanding the distance to a grade level control, a process that requires individual assessment at each stream with access to extended portions of the stream upstream and downstream of the

pipeline crossing. For this assessment, data is not readily available. Instead, Geosyntec estimated degradation associated with observed natural geomorphic processes associated with natural degradation described below. Long-term degradation was conservatively estimated to be 2 feet.

General Scour (z_{gs})

General scour is the lowering of the stream bed across the channel over relatively short time periods and is associated with the passing of a single flood. The Lacey Regime Equation (ASCE 2005), Zeller equation (USACE, 2021), U.S. Bureau of Reclamation (USBR) Envelope Curve (USACE, 2021), and the Neill competent velocity equation was used to calculate general scour for this study. The average value of all four equations was used to estimate general scour depth. Calculated general scour (averaged from applicable equations) was 4.8 feet.

Bend Scour (z_{bs})

Bend scour is associated with meandering channels that can induce transverse or secondary currents. It is the scour associated with the outside of a bend. The US Bureau of Reclamation equation for gravel bed rivers (USBR, 2019), which summarizes the charts for scour prediction contained in Plate B41 of Engineer Manual 1110-2-1601 (USACE, 1994), was used to calculate bend scour for this study. The Thorne (Thorne, 1988), Maynord (Maynord, 1996), and Zeller (USACE, 2021) equations were also calculated and considered in this study. The average value of all four equations was used to estimate general scour depth. Calculated bend scour (averaged from applicable equations) was 9.8 feet.

Local Scour (z_{ls})

Local scour is the scour that results from an obstruction and abrupt change in the direction of flow. It is caused by an acceleration of flow and resulting vortices induced by the obstruction. The component of local scour considered in this analysis is large woody debris (LWD). Local scour from LWD was applied for each stream crossing to consider the potential for accumulation of LWD at or near the crossing that could lead to scour and pipeline exposure.

Large woody debris was considered as part of this analysis due to the prevalence of forested land cover throughout the pipeline alignment and in vicinity of the crossings and its associated watersheds. An equation for pier scour, based on Hydrologic Engineering Circular No. 18 (FHWA, 2012), was used as a basis for estimating scour associated with in-stream LWD. Calculated local scour from LWD was 3.1 feet.

Contraction Scour (z_{cs})

Contraction scour is the scour that results when the flow area of a stream is reduced by a natural contraction or a bridge constricting the flow. An equation for contraction scour, based on Hydrologic Engineering Circular No. 18 (FHWA, 2012), was used as a basis for estimating contraction scour. Calculated contraction scour was 0.2 feet.

Total Scour (z_{ts})

Geosyntec calculated total scour depth by averaging the average scour value for each component. Total scour results are presented in **Table 1** below.

Table 1. Summary of Calculated Scour Components and Total Scour

Scour Component	Calculated Scour Depth (ft)
Long-term Scour	2.0
General scour	4.8
Bend Scour	9.8
Local Scour	3.1
Contraction Scour	0.2
Bedform Scour	0.0
Total Scour	**19.9**

Lateral Migration Analysis

Geosyntec completed a lateral migration analysis of the crossing to assess potential lateral migration hazards relative to the proposed lateral setback locations. Using aerial recent and historical imagery, Geosyntec observed less than 15 feet of lateral bank migration on both the east and west banks of the Missouri River over the observation period of aerial imagery (**Figure 1**). Further, Geosyntec observed minimal potential for channel avulsion on the east or west bank floodplains due to the presence of high terraces. It should be noted that the east bank, located on the inside bend, is depositional in nature and features a floodplain approximately 900+ feet wide before reaching a high terrace. The west bank is characterized by the presence of previously installed river training structures adjacent to the high terrace. These structures are presently providing lateral stability along the west bank. It was beyond Geosyntec's scope to identify who installed these structures and who is responsible for maintenance. It should be noted that these structures need to be maintained to continue to provide bank stability and protection.

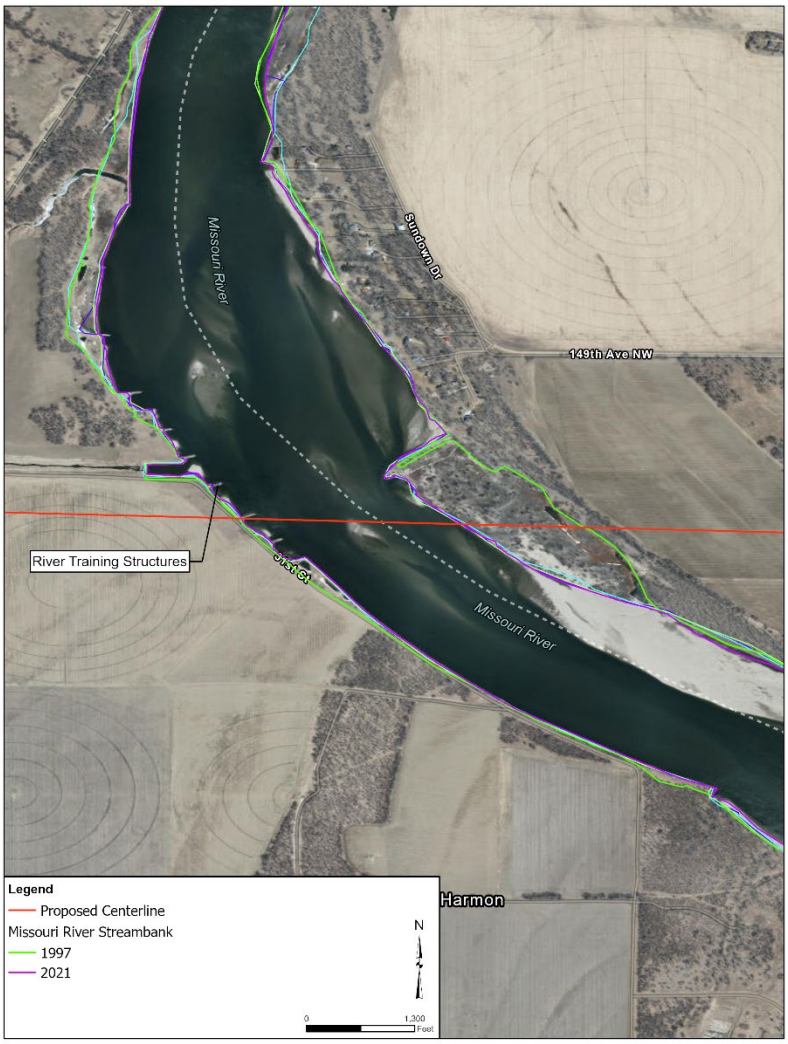


Figure 1. Missouri River Lateral Historic Streambank Delineation

RECOMMENDATIONS

Total scour depth was calculated to be 19.9'. Based on the current bathymetric data (supplied by TRC), the channel bottom elevation is 1,605.82' NAVD88 and the proposed HDD burial elevation is 1,584.79' NAVD88. A scour depth of 19.9' below the existing bed would result in only 1.13 ft of cover over the proposed HDD burial elevation. Given the estimated minimal amount of cover at the proposed HDD elevation, Geosyntec recommends lowering the HDD elevation by approximately 10 ft to provide for a minimum factor of safety of 1.5.

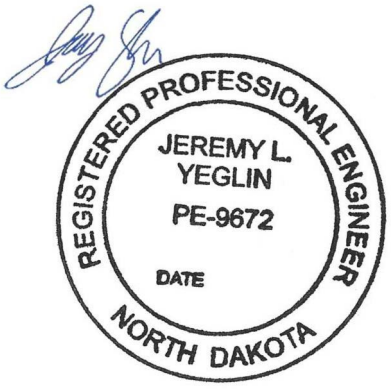
The east bank point of inflection (PI) at station 7338+47.1 for HDD burial depth elevation is located greater than 900 ft beyond the ordinary high-water mark (OHWM) of the Missouri River and the HDD exit at station 7333+32 is located atop a high terrace greater than 1,000 feet from the

OHWM. The west bank PI at station 7368+11.6 is located approximately 200 feet from the top of bank (TOB) and OHWM and the HDD entry point at station 7373+46 is approximately 700 feet from the TOB and OHWM. Based on the lateral migration analysis, the proposed east and west bank PIs for the HDD are sufficient to mitigate lateral migration, assuming the river training structures are maintained and functional over the service life of the pipeline.

CLOSING

We greatly appreciate the opportunity to support Gulf Interstate on this project. Should you have any questions or need additional information, please do not hesitate to contact David at Dvance@Geosyntec.com or (678) 361-4801 or Jeremy at JYeglin@Geosyntec.com or (832) 455-3684.

Sincerely,



August 26, 2022

Jeremy Yeglin, P.E.(ND, TX, OK)
Principal Engineer

David Vance, P.G.(GA)
Principal Geologist

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Memorandum

Rev. A - Issued for Review by Gulf Interstate

Date: 7 September 2022

To: David Ammerman, PE (Gulf Interstate)

From: David Vance, PG[1]; Jeremy Yeglin, PE[2]; and Robert Dunn

Cc: Al Preston, PhD, PE[3]; Brandon Klenzendorf, PhD, PE[4]; Muhammed Mustafa, PhD, PE[3]; Morgan L'Hoste (EIT); and Jai Panthail

Subject: Hydrotechnical Assessment (Sheyenne River HDD Crossing)
Geosyntec Project No. TXG0320

INTRODUCTION

The following is a summary of the hydrotechnical assessment for Gulf Interstate Engineering, Inc.'s (Gulf Interstate) proposed Sheyenne River horizontal directional drilling (HDD) crossing, which is part of the 2,000-mile pipeline system being installed by Summit Carbon Solutions in North Dakota. The crossing is located at milepost (MP) 27.3 in Richland County, North Dakota. Geosyntec completed this hydrotechnical assessment to evaluate the lateral setbacks and riverine scour and define the lateral and depth hazards the river possesses at the proposed crossing. The methods, calculations, results, and recommendations of this assessment are described herein.

DATA SOURCES REVIEWED

The following data sources have been reviewed as part of the hydrotechnical assessment as of the date of this memorandum:

- 2016 1-meter (m) resolution LiDAR from the state of North Dakota's LiDAR database; collected by the U.S. Army Corps of Engineers (St. Louis District).
- Bathymetric survey data collected by TRC Companies (TRC) dated August 12, 2022.

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[1] Licensed in GA
[2] Licensed in ND, TX, and OK
[3] Licensed in CA
[4] Licensed in TX and LA

- Available Google Earth™ aerial imagery, generally spanning the timeline from September 1997 to September 2021.
- United States Geologic Survey (USGS) 7.5 minute topographic quadrangle maps for the segment.
- Federal Emergency Management Agency (FEMA) *Richland County, North Dakota and Incorporated Areas Flood Insurance Study* dated December 18, 2009.

METHODS

Geosyntec conducted a scour analysis and lateral migration assessment of the Sheyenne River crossing. The methods for the scour analysis and lateral migration assessment are described below.

Scour Analysis

The scour analysis consisted of evaluating appropriate burial depth based on the depth of anticipated total (vertical) scour at the Sheyenne River crossing location. Scour calculations required hydraulic analyses for the crossing. The methods and results of the hydraulic and scour analyses are summarized below based on the following assumptions:

- Longitudinal peak flows associated with the 100-year return period were taken from the *FEMA Richland County, North Dakota and Incorporated Areas Flood Insurance Study* dated December 18, 2009. The 100-year peak flow used for the hydraulic modeling was 7,340 cubic feet per second (cfs).
- Site-specific cross sections of the active channel were modeled upstream, downstream, and at the pipeline crossing location based on a mosaic digital elevation model (DEM) of the North Dakota LiDAR and the TRC bathymetric survey data.
- Longitudinal slope of 1.29% was estimated from the TRC bathymetry data.
- Median grain size (D_{50}) of the stream bed was estimated to be 0.125 millimeter (mm), which is representative of a fine sand bed dominated system.
- Manning's n-value was estimated to be 0.035, which is representative of a clean, winding river, with some weeds and stones.

Hydraulic analysis was performed using the Hydrologic Engineering Center River Analysis System (HEC-RAS) software program to calculate hydraulic design parameters (e.g., flow depth, width, velocity, and effective shear stress) for the peak flow obtained from the FEMA Flood Insurance Study. The flow profile modeled includes peak discharge associated with the 100-year return period. The one-dimensional (1-D) HEC-RAS model was populated with channel geometry parameters (i.e., longitudinal slope and cross section) and Manning's roughness coefficient described above. The HEC-RAS model is representative of normal flow depth calculations at the stream crossing and was analyzed at three cross sections (upstream, at the pipeline crossing, and downstream). Additional cross sections were modeled farther upstream and downstream for model

stability and to minimize the influence of boundary conditions at the pipeline crossing. The cross section geometry is based on the LiDAR and bathymetry data and is representative for the crossing. Known water surface elevations for the 100-year base flood elevation were obtained from the *FEMA Richland County, North Dakota and Incorporated Areas Flood Insurance Study* dated December 18, 2009 and assigned as the downstream boundary conditions. These water surface elevations are representative of normal depth conditions.

Total scour (z_{ts}) is the total depth of scour at a given location. It is applied to the thalweg of the channel and is the sum of all scour components that are applicable for the given location. Scour components considered include the following, which are described in the subsequent sections:

- **Long-Term Degradation (z_{lt})**
- **General Scour (z_{gs})**
- **Bend Scour (z_{bs})**
- **Local Scour (z_{ls})**
- **Contraction Scour (z_{cs})**
- **Bedform Scour (z_{bfs})**

Note these components of scour were included where applicable. For the Sheyenne River, bedform scour was not considered applicable and therefore not included in total scour. The scour components were calculated using applicable scour equations. If multiple scour equations were considered applicable for a component of scour, results were averaged. The average scour value for each component was then summed to generate a final total scour (z_{ts}) depth. The components of scour are described below.

Long-Term Degradation (z_{lt})

Long-Term degradation (z_{lt}) is the progressive lowering of the channel bed due to scour. This permanent or continuing degradation is an indicator that a change in the stream's discharge and sediment load characteristics is taking place. Degradation of the stream bed occurs due to downstream bed elevation changes or excess sediment-transporting capacity relative to the size of bed-material (e.g., resistance to movement) and quantity of bed-material sediment delivered from upstream reaches. Degradation continues until the existing longitudinal slope of the channel decreases to an equilibrium (stable) slope or until an armor layer (i.e., comprised of gravel and/or cobble-sized particles) that mitigates long-term degradation develops on the stream bed.

Typically, long-term degradation scour is calculated by multiplying the channel distance to the nearest downstream grade control point (e.g., exposed bedrock or manmade drop structure) by the difference in the existing and equilibrium longitudinal slopes. This estimation requires understanding the distance to a grade level control, a process that requires individual assessment at each stream with access to extended portions of the stream upstream and downstream of the

pipeline crossing. For this assessment, data are not readily available. Instead, Geosyntec estimated degradation associated with observed natural geomorphic processes associated with natural degradation described below. Long-term degradation was conservatively estimated to be 2 feet.

General Scour (z_{gs})

General scour is the lowering of the stream bed across the channel over relatively short time periods and is associated with the passing of a single flood. The Lacey Regime Equation (ASCE 2005), Zeller equation (USACE, 2021), U.S. Bureau of Reclamation (USBR) Envelope Curve (USACE, 2021), and the Neill competent velocity equation (USACE, 2021) were used to calculate general scour for this study. The average value of all four equations was used to estimate general scour depth. Calculated general scour (averaged from applicable equations) was 3.57 feet.

Bend Scour (z_{bs})

Bend scour is associated with meandering channels that can induce transverse or secondary currents. It is the scour associated with the outside of a bend. The USBR equation for sand bed rivers (USBR, 2019), which summarizes the charts for scour prediction contained in Plate B41 of Engineer Manual 1110-2-1601 (USACE, 1994), was used to calculate bend scour for this study. The estimated bankfull depth (based on the apparent channel dimensions identified from the bathymetric survey) at the upstream cross section was used to calculate bend scour. The Thorne (Thorne, 1988), Maynord (Maynord, 1996), and Zeller (USACE, 2021) equations were also calculated and considered in this study. The average value of all four equations was used to estimate bend scour depth. Calculated bend scour (averaged from applicable equations) was 9.26 feet.

Local Scour (z_{ls})

Local scour is the scour that results from an obstruction and abrupt change in the direction of flow. It is caused by an acceleration of flow and resulting vortices induced by the obstruction. The component of local scour considered in this analysis is large woody debris (LWD). Local scour from LWD was applied for the stream crossing to consider the potential for accumulation of LWD at or near the crossing that could lead to scour and pipeline exposure.

Large woody debris was considered as part of this analysis due to the prevalence of forested land cover throughout the pipeline alignment and in vicinity of the crossings and its associated watersheds. An equation for pier scour, based on Hydrologic Engineering Circular No. 18 (FHWA, 2012), was used as a basis for estimating scour associated with in-stream LWD. Calculated local scour from LWD was 2.11 feet.

Contraction Scour (z_{cs})

Contraction scour is the scour that results when the flow area of a stream is reduced by a natural contraction or a bridge constricting the flow. An equation for contraction scour, based on

Hydrologic Engineering Circular No. 18 (FHWA, 2012), was used as a basis for estimating contraction scour. Calculated contraction scour was 2.24 feet.

Bedform Scour (z_{bfs})

Bedform scour is the scour that results when flow passes dunes and antidunes in sand bedded streams. Antidunes are generally associated with high velocity stream approaching supercritical flow (USACE, 2020). Hydraulic analysis performed using HEC-RAS demonstrated that flows at the Sheyenne River crossing did not approach supercritical, and Froude numbers stayed well below a value of 1.0. Therefore, bedform scour was not considered applicable and not included in total scour.

Total Scour (z_{ts})

Geosyntec calculated total scour depth by summing the average scour value for each component. Total scour results are presented in **Table 1** below.

Table 1. Summary of Calculated Scour Components and Total Scour

Scour Component	Calculated Scour Depth (ft)
Long-term Scour	2.0
General scour	3.6
Bend Scour	9.3
Local Scour	2.1
Contraction Scour	2.2
Bedform Scour	0.0
Total Scour	**19.2**

Lateral Migration Analysis

Geosyntec completed a lateral migration analysis of the crossing to assess potential lateral migration hazards relative to the proposed lateral setback locations. The lateral migration analysis revealed significant lateral migration. Using aerial recent and historical imagery, Geosyntec observed approximately 50 feet of lateral bank migration on both the north and south banks of the Sheyenne River over the observation period of aerial imagery (**Figure 1**). Additionally, Geosyntec observed significant channel avulsion potential as evident from the presence of meander cutoffs which have formed oxbow lakes within the floodplain in the vicinity of the crossing and the presence of meander scrolls in the LiDAR signature (**Figure 2**). The Sheyenne River has the potential to rapidly shift its planform within the valley bottom and lateral migration hazard exists from valley wall to valley wall.

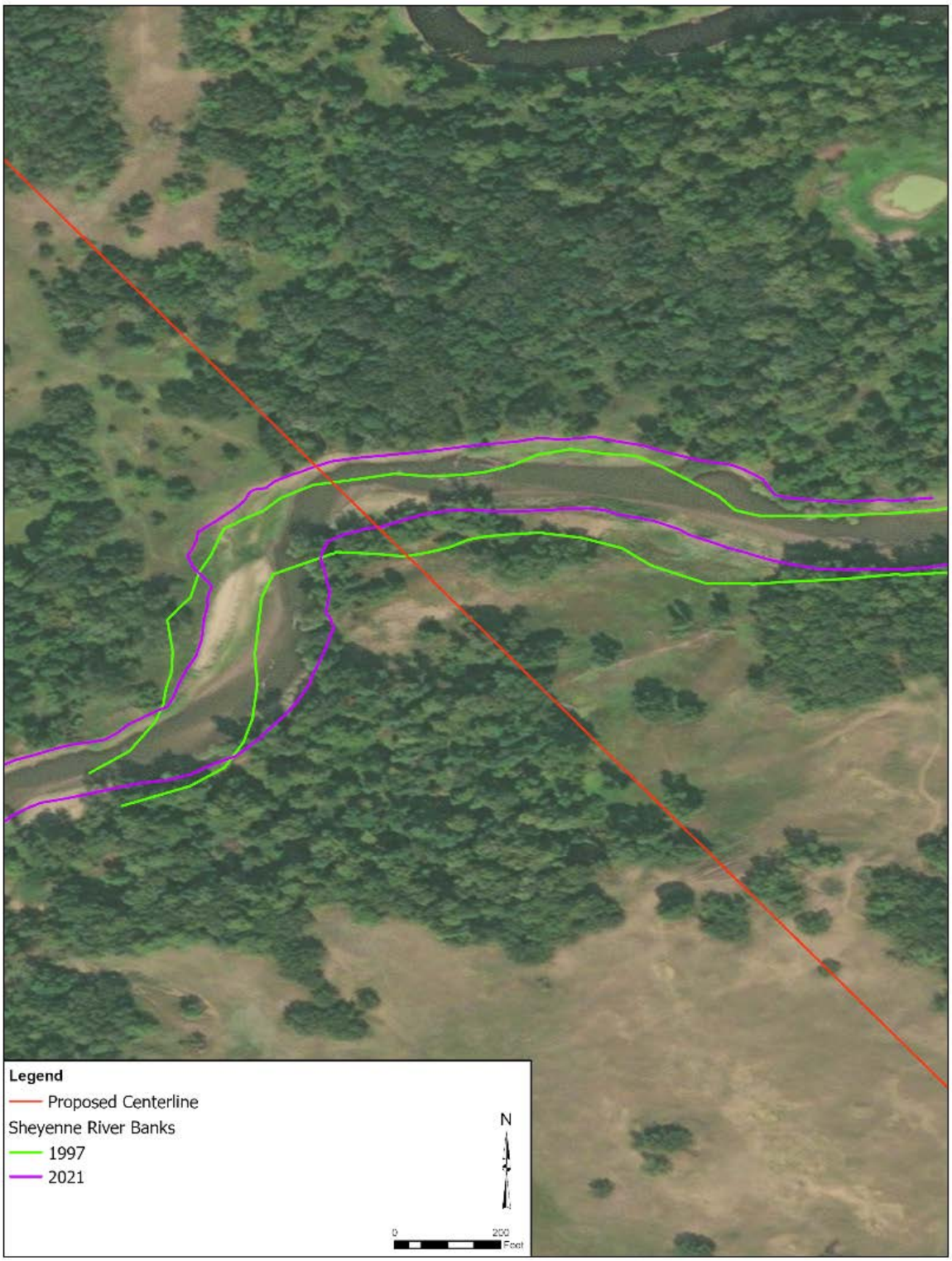

Figure 1. Sheyenne River Lateral Historic Streambank Delineation

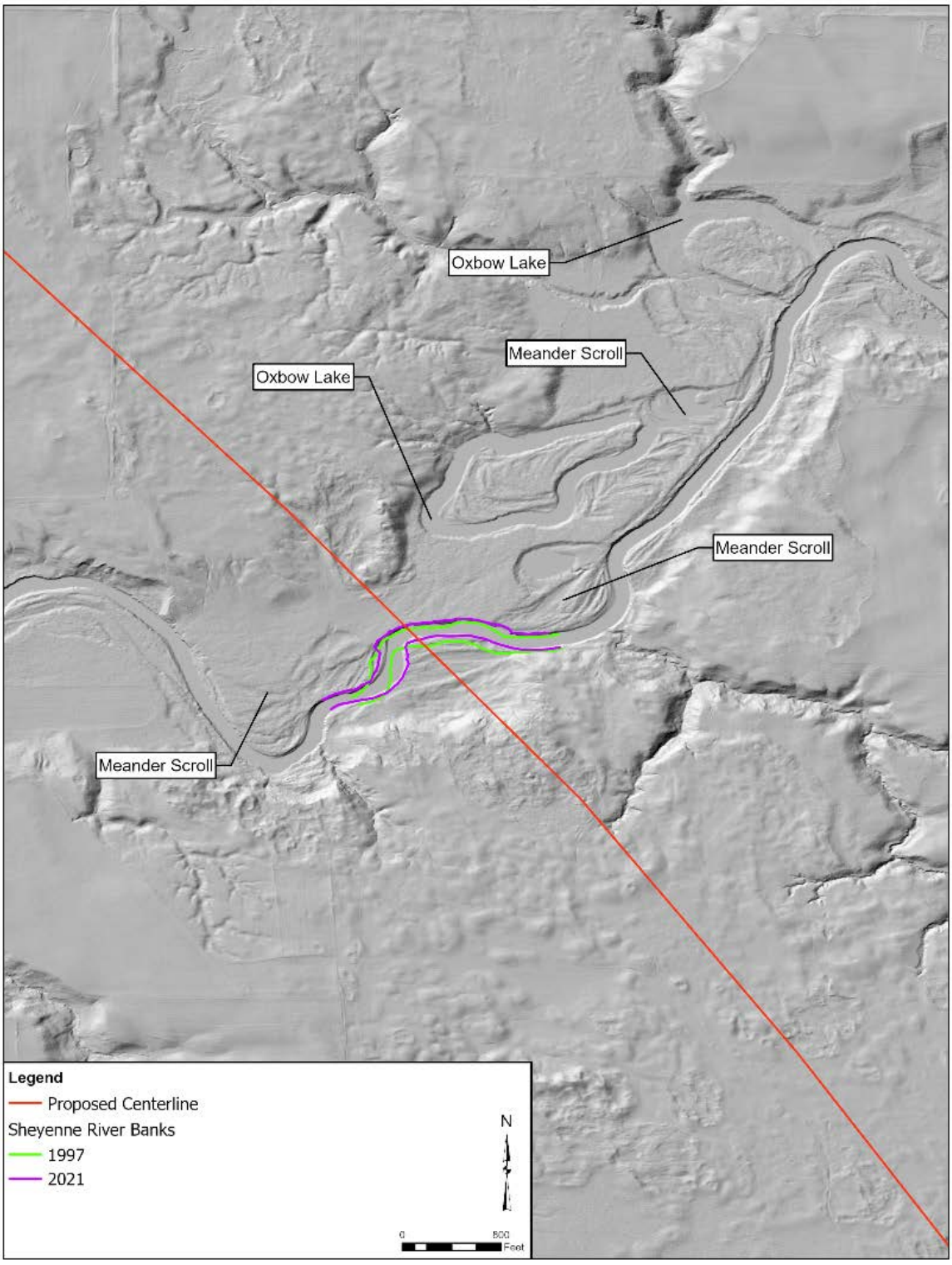

Figure 2. Sheyenne River Channel Avulsion Observations

RECOMMENDATIONS

Total scour depth was calculated to be 19.2'. Based on the current bathymetric data (supplied by TRC), the channel bottom elevation is 931.84' NAVD88 and the proposed HDD burial elevation is 913.57' NAVD88. A scour depth of 19.2' below the existing bed would result in a fully exposed pipe subjected to hydrotechnical forces. Given the estimated minimal amount of cover at the proposed HDD elevation, Geosyntec recommends lowering the HDD elevation by approximately 10.5 (ELEV 903.04') ft to provide for a minimum factor of safety of 1.5.

Based on the lateral migration analysis, the north bank point of inflection (PI) at station 1442+21.8 and the south bank PI at station 1445+01.7 are not sufficient to mitigate against the lateral migration hazards observed at the Sheyenne River crossing. Geosyntec recommends moving the north bank PI approximately 221 feet north to station 1440+00 and moving the south bank PI approximately 200 feet south to station 1447+00. The recommended burial depth elevation of 903.04' should be maintained between these PIs. This will result in shifting the HDD entry and exit points further to the south and north, respectively.

CLOSING

We greatly appreciate the opportunity to support Gulf Interstate on this project. Should you have any questions or need additional information, please do not hesitate to contact David at Dvance@Geosyntec.com or (678) 361-4801 or Jeremy at JYeglin@Geosyntec.com or (832) 455-3684.

Sincerely,

September 7, 2022

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Principal Engineer

David Vance, P.G.(GA)
Principal Geologist

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Prepared for

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Phase I Geohazards Assessment

North Dakota

Rev 0

Prepared by

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10 Corporate Drive, Suite 1600
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Project Number TXG0450

January 30, 2024

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1. INTRODUCTION

This report summarizes a Phase I Geohazards Assessment (Phase I Assessment) conducted by Geosyntec Consultants, Inc. (Geosyntec) for Summit Carbon Solutions (SCS), for approximately 315.2 miles of proposed carbon capture pipelines (pipelines) in North Dakota (Figure 1).

The Phase I Assessment is a desktop assessment intended to identify and assess potential geohazards (i.e., naturally occurring or human-triggered geologic conditions, ongoing geologic processes, or potential natural events that could adversely affect construction and/or operation of a pipeline) along the planned pipeline route. The information collected during the Phase I Assessment can be used to understand where potentially hazardous geologic, hydrologic, or atmospheric features and conditions may be present along the proposed pipelines and may ultimately be used to guide best management practices during pipeline construction and operation to avoid, mitigate, and/or monitor possible geohazards. Based on the perceived threat potential, select hazards identified during a Phase I Assessment may be further assessed through more detailed assessment(s), such as Phase II Assessment (e.g., field reconnaissance), and possibly Phase III Assessment (site-specific investigations), where necessary, to improve understanding and characterization of the selected hazard(s).

2. SCOPE OF WORK

The assessment included compilation and/or reporting of the following conditions present along the proposed pipelines:

- Physiographic provinces
- Surficial geology based on published maps
- Shallow bedrock areas (i.e., within upper 5-feet)
- Depth to groundwater
- Flood frequency
- Frost heave
- Shrink/Swell potential

The assessment of geohazards included the areas within 250 feet of the proposed pipeline centerlines (Revision 9, dated January 20, 2024, and provided to Geosyntec by SCS on January 23, 2024) and involved desktop assessment of the following hazard types:

- Unstable Slopes (e.g., landslides)
- Seismic (e.g., strong ground shaking, soil liquefaction, surface fault rupture)
- Ground Subsidence (e.g., karst/pseudo-karst, fluid withdrawal, underground mines)
- Hydrotechnical (e.g., watercourse crossing erosion, scour, and channel migration hazards)
- Meteorologic (e.g., tornadoes, lightning strikes, hurricanes)

3. METHODOLOGY

3.1. Data Collection and Review

Geosyntec compiled and reviewed publicly available information relevant to this assessment (e.g., surficial geology and bedrock geologic maps, geologic hazard maps, soil and land-use data, National Hydrography Plus High-Resolution flowline datasets) for North Dakota. The data were acquired through the North Dakota Geological Survey (NDGS), the U.S. Geological Survey (USGS), the United States Department of Agriculture, Natural Resources Conservation Service (USDA NRCS), various academic institutions, and related publications.

3.2. Remote Sensing Review

A remote sensing data review was conducted for an area within 250 feet to either side of the proposed pipeline alignment (i.e., a 500-foot-wide mapping corridor) to identify possible geomorphic evidence of geohazards located within the assessment area. Remote sensing datasets reviewed included multi-resolution digital elevation models (DEMs) derived from Light Detection and Ranging (LiDAR) data provided through the North Dakota LiDAR Dissemination MapService (NDDWR 2023) and the USGS's National Map 3D Elevation Program (USGS 2023), supplemented by publicly available aerial imagery (i.e., ESRI Imagery and Google Earth™). The remote sensing review focused on identifying hazards which can typically be identify by geomorphic features visible in aerial imagery and/or LiDAR data, including landslides, subsidence features (e.g., depressions), and hydrotechnical hazards. Mapped and identified geohazards were compiled into an ESRI compatible geodatabase.

Appendix B provides summaries for each hazard type, their relevance to buried pipelines, and the respective classification criteria developed (as applicable) for possible geohazards identified during this assessment.

4. SUMMARY OF RESULTS

Table 1 below summarizes the results of the Phase I Assessment. The natural conditions summarized in Table 1 are based on information extracted from the Natural Resources Conservation Service (NRCS) soils survey; as such, local conditions may vary from those presented. Some areas of the pipeline alignment were identified to be underlain by soils with a higher potential for shrink/swell and/or frost heaving; however, additional processes (e.g., cyclical wetting/drying or freezing/thawing of soils) must occur and conditions must exist (e.g., shallow ground water, freeze depth to below pipe depth) for these conditions to impact a pipeline, minimizing the overall likelihood of pipeline impacts to occur. For detailed discussions on each natural condition and geohazard listed in Table 1, see the corresponding results section below and Appendix B.

Table 1 – Summary of Natural Conditions, Geohazards, and Meteorological Hazards Located Along the Alignment

NATURAL CONDITIONS			
Condition	**Qualification for Higher Potential**	**Total Miles Crossed by the Proposed Pipelines**	**Recommendations**
Shallow Bedrock	Bedrock within 5 feet below ground surface.	**51.7**	Potential investigations in areas identified as shallow bedrock, but not considered critical for construction planning.
Shallow Groundwater	Groundwater within 6 feet below ground surface	**191.8**	- Proper construction techniques and preparation for trench dewatering. - Avoid leaving the trench open for long periods of time in areas of shallow groundwater. - Evaluate groundwater conditions at proposed HDD crossings.
Flooding Frequency	Frequent Flooding – Areas where there is a 50 percent or more chance of flooding in any year, or 50 times or more in 100 years but less than 50 percent in all months of any year.	**2**	Incorporate increased frequency of aerial or ground reconnaissance after major flooding events.
Frost Heave	Areas underlain by soil with a higher frost action potential value.	**81.3**	Best management practices during design and construction. Periodic assessment and monitoring to support early identification, evaluation, and mitigation of potential integrity concerns.
Shrink/Swell Potential	Areas underlain by soil with linear extensibility percent (LEP) values greater than 6.	**68.9**	Best management practices during design and construction. Periodic assessment and monitoring to support early identification, evaluation, and mitigation of potential integrity concerns.

Table 1 Continued – Summary of Natural Conditions, Geohazards, and Meteorological Hazards Located Along the Alignment

GEOHAZARDS		
Geohazard	**Result**	**Recommendations**
Unstable Slopes		
Landslides	15 landslides and possible landslides, and 3 landforms mapped by others as landslides that do not appear to be landslide related, were identified within 250 feet of the proposed pipeline alignment	Refer to the recommended mitigation strategies presented in Table A-4 (Appendix A).
Seismic Hazards		
Strong Ground Shaking	No high hazard seismic areas were identified along the proposed pipeline alignment.	Aerial or ground reconnaissance after strong earthquake events near the pipeline to identify possible integrity issues
Soil Liquefaction		
Surface Fault Rupture		
Ground Subsidence		
Karst	No karst features or high hazard subsidence areas were identified along the proposed pipeline alignment.	Best management practices during design and construction. Periodic assessment and monitoring to support early identification, evaluation, and mitigation of potential integrity concerns.
Fluid Withdrawal		
Underground Mines		
METEOROLOGICAL HAZARDS		
Meteorological Event	**Result**	**Recommendations**
Tornadoes	The area in eastern North Dakota is designated as being in a medium tornado hazard potential.	Aerial or ground reconnaissance at above ground infrastructure located within the impacted area after severe storm events to determine possible integrity issues.
Lightning Strikes	The area in eastern North Dakota is designated as being in a medium lightning strike potential threat.	
Hurricanes	No threat from hurricanes was identified	

5. NATURAL CONDITIONS ALONG THE PROPOSED PIPELINES

The following sections provide an overview of various natural conditions identified along the proposed pipelines. See Mapbook 1 for the general locations of conditions along the proposed pipelines. See Mapbook 2 for general locations of each surficial geologic unit crossed by the proposed pipelines.

5.1. Physiography

Physiographic provinces are regions that are defined by their characteristic landforms and topography, which reflect their underlying geology and climatic histories. The proposed pipelines in North Dakota are located within four major physiographic provinces. From west to east, these are the Missouri Slope, Missouri Coteau, Drift Prairie, and the Red River Valley provinces

(Bluemle and Biek 2007, NDGFD 2023). The following sections summarize these provinces, which are shown on Figure 2.

5.1.1. Missouri Slope

The following segments of the proposed pipelines cross the Missouri Slope physiographic province, as shown in Figure 2:

- NDM-106
- NDL-328

The Missouri Slope is characterized by gently sloping upland topography due to the prevalence of sandstone and shale bedrock, which was largely unaffected by the past glacial episodes that occupied the eastern half of North Dakota (Bluemle and Biek 2007; NDGFD 2023). The upland topography is commonly divided by a complex network of dendritic drainage systems that form the irregular topography that is characteristic of the province. Due to the irregular topography, livestock grazing is the predominant land use (Bluemle and Biek 2007; NDGFD 2023).

5.1.2. Missouri Coteau

The majority of the proposed NDM-106 pipeline crosses the Missouri Coteau physiographic province (see Figure 2). The Missouri Coteau marks the western edge of glacial occupation in North Dakota. The topography of the region is highly variable due to its formation through multiple glacial advances that deposited glacial drift (i.e., variable mixtures of clay, silt, sand, gravel, cobbles, and boulders that were transported and deposited by glaciers and glacial outwash), which formed irregular hummocky terrain amidst relatively flat farmland (Bluemle and Biek 2007; NDGFD 2023). There are no major rivers or streams that drain the Missouri Coteau, so alluvial deposits are rare and typically confined to the occasional east-reaching tributaries of the Missouri River. The eastern edge of the Missouri Coteau contains numerous wetlands that decrease westward toward the Missouri River and are largely absent along the proposed alignment. Farming and livestock grazing are the predominant land use (Bluemle and Biek 2007; NDGFD 2023).

5.1.3. Drift Prairie

The majority of the proposed NDT-211 pipeline, primarily along the western portion, crosses the Drift Prairie physiographic province in North Dakota (see Figure 2). The Drift Prairie, also known as the Glaciated Plains due to its glacial history, is characterized by generally flat topography divided by gently sloping rolling hills that form washboard-like undulations (Bluemle and Biek 2007; NDGFD 2023). The gentle topography supports seasonal and temporary wetlands that are common throughout the province. Locally, a variety of glacial landforms exist within the Drift Prairie, such as end moraines, eskers, ice-thrust hills, outwash channels, and paleo-shorelines from glacial lakes (Bluemle and Biek 2007). Most of these landforms were developed late in the Pleistocene during the most recent Wisconsin glacial episode, which spanned the time from about

70,000 until 10,000 years ago. Many of the Drift Prairie's glacial features have been concealed by post-glacial sediments such as wind-blown loess and river and lake deposits (Clayton 1980, Bluemle and Biek 2007).

5.1.4. Red River Valley

The following segments of the proposed pipelines cross the Red River Valley physiographic province, as shown in Figure 2:

- NDL-323
- NDL-324
- MNL-321
- NDT-211

The Red River Valley forms the eastern border of North Dakota and extends 30 to 40 miles on either side of the Red River. The Red River is characterized by exceptionally flat terrain that was once the bed of glacial Lake Agassiz, which was once the largest freshwater lake in North America (Bluemle and Biek 2007; NDGFD 2023). The majority of the province is covered by glaciolacustrine deposits (i.e., silt and clay lake deposits). Along the margins of the province, paleo-shorelines of Lake Agassiz are marked by wave-eroded scarps and beach sand deposits that form escarpments rising up to 400 to 500 feet above the Red River Valley in the northeastern corner of the state (Bluemle and Biek 2007; NDGFD 2023). Due to the remarkably flat topography, farming is the predominant mode of land use in the province.

5.2. Surficial Geology

The surficial geology underlying the proposed pipelines in North Dakota is dominated by variable glacial deposits east of the Missouri Coteau physiographic province and predominantly bedrock generally consisting of silt, sand, clay, sandstone and lignite deposits west of the Missouri Coteau (Clayton 1980, Bluemle 1988). Figure 3 shows the surficial geology underlying the proposed pipelines in North Dakota and Table 2 shows the miles of each geologic unit crossed by the proposed pipelines. See Mapbook 2 for general locations of each geologic unit crossed by the proposed pipelines. See Table A-1 in Appendix A for a detailed geologic description of each unit and a mileage breakdown for each segment of pipeline.

Table 2 – Surficial Geology Summary Along the Proposed Pipeline

Surficial Geologic Unit[1]	Map Label[1]	Total Miles Crossed by the Proposed Pipelines
Fox Hills Formation	Kf	**39.8**
Hell Creek Formation	Kh	**36.0**
Niobrara and Carlile Formations, Undivided	Kn	**33.4**
Pierre Formation	Kp	**26.7**
Bullion Creek Formation	Tb	**29.7**
Cannonball Formation	Tc	**20.0**
Sentinel Butte Formation	Ts	**20.9**
Beile Fourche-Skull Creek, Undivides	Kbs	**58.6**
Carlile Formation	Kc	**26.6**
Greenhorn Formation	Kg	**12.3**
Inyan Kara Formation	Ki	**1.4**
Pre Cambrian Rocks	pCA	**10.0**
	TOTAL	**315.2**

Note: 1 – Geologic Unit and Map Label derived from SGMC USGS 2017.

5.3. Shallow Bedrock

Depth to bedrock was determined from the NRCS Soils Data (USDA-NRCS 2023) and was categorized as less than 5 feet below ground surface (bgs) or greater than 5 feet bgs. Based on review of the NRCS soils data, about 51.7 miles of the total 315.2 miles of proposed pipelines traverse areas characterized as having bedrock less than 5 feet bgs. See Mapbook 1 for general locations of shallow bedrock and Table A-2 in Appendix A for a mileage breakdown of shallow bedrock for each segment of pipeline.

Shallow Bedrock - Recommendations

Shallow bedrock is not considered a geohazard, but rather a condition that should be considered for construction planning, as the presence of shallow bedrock may slow down excavation of the pipeline trench and require ripping or blasting depending on the rock characteristics. In areas identified as having possible shallow bedrock that could be encountered during construction, additional investigations such as hand augers, boreholes, or geophysics, could be considered to confirm the presence of shallow bedrock and to evaluate engineering properties of the rock to assess rippability or blasting requirements. However, the areas categorized as having potential shallow bedrock along the proposed pipe alignment are predominantly mapped as being underlain by poorly consolidated sedimentary deposits (e.g., shale, residual soils, etc.) which tend to be weak and easily erodible; therefore, bedrock that may be encountered is expected to be excavatable using standard pipeline construction equipment and blasting is anticipated to be minimal or unnecessary. As such, additional investigations to evaluate the presence of bedrock are not considered critical for construction planning.

5.4. Depth to Groundwater

Estimated depth to groundwater (i.e., the water table) was determined from the NRCS Soils Data (NRCS 2023) and was categorized as less than 6 feet bgs or greater than 6 feet bgs. Based on review of the NRCS soils data, approximately 191.8 miles (~61%) of the proposed pipelines traverse areas where groundwater is estimated to be within 6 feet of the ground surface. See Mapbook 1 for general locations of shallow groundwater and Table A-2 in Appendix A for a mileage breakdown of areas of shallow groundwater for each segment of pipeline.

Shallow Groundwater - Recommendations

Shallow groundwater is not considered a geohazard, but rather a condition that should be considered for construction planning, or in some cases, for temporary or permanent buoyancy control measures to be installed on the pipeline. Potential issues associated with shallow groundwater can be mitigated during pipeline design and construction with industry best management practices (BMPs) and/or construction guidelines, such as proper trench dewatering plans and equipment on-site during construction. In areas with shallow groundwater, avoid leaving the pipe trench open for long periods of time to minimize the need for trench dewatering.

Pipe buoyancy control measures are typically applied to areas where the pipeline crosses swamps or muskeg areas (i.e., low weight/highly organic soils with shallow groundwater) or at watercourse crossings. No swamp/muskeg areas were identified as occurring along the pipeline alignment. Proper watercourse crossing design, including deeper burial depth, can mitigate the potential buoyancy risks at watercourse crossings.

The presence of shallow, confined, or artesian groundwater conditions do present a potential risk to trenchless crossings, especially at proposed horizontal directional drill (HDD) crossings that have elevation changes between the entry and exit locations. Site-specific subsurface geotechnical investigations to evaluate the groundwater conditions are recommended at proposed HDD or horizontal auger bore crossings or other areas where deep trench excavations are expected.

5.5. Flooding Frequency

Flooding frequency was determined from the NRCS Soils Data (NRCS 2023a) and USDA-NRCS SSURGO Flooding Frequency dataset (USDA-NRCS 2023b; i.e., used to fill in where NRCS 2023a data were blank), where ‘Flooding’ is defined as the temporary inundation by flowing water from any source. Standing water or areas of ponding are excluded from this definition. Based on review of the NRCS soils data, approximately 4.2 miles (~1.3%) of the proposed pipelines are under threat of Occasional flooding (5 to 50% chance of flooding in any year). Approximately 2 miles (~0.6%) of the proposed pipelines are under threat of Frequent flooding (more than 50% chance of flooding in any year).

Table 3 summarizes the mileage of each class of flooding frequency encountered along the proposed pipelines. See Mapbook 1 for general areas of ‘Occasional’ and ‘Frequent’ flooding. See

Table A-2 in Appendix A for a mileage breakdown of areas of frequent flooding for each segment of pipeline.

Table 3 – Flooding Frequency Along the Proposed Pipeline

Frequency Class[1]	Description[1]	Miles of Pipeline
None	No reasonable possibility of flooding; less than 0.2 percent chance of flooding in any year or less than 1 time in 500 years.	**307.0**
Rare	Flooding is unlikely but is possible; 1 to less than 5 percent chance of flooding in any year, or 1 time or more in 100 years but less than 5 times in 100 years.	**2.0**
Occasional	Flooding is expected infrequently; 5 to less than 50 percent chance of flooding in any year, or 5 times or more in 100 years but less than 50 times in 100 years.	**4.2**
Frequent	Flooding is likely to occur often; 50 percent or more chance of flooding in any year, or 50 times or more in 100 years but less than 50 percent in all months of any year.	**2.0**
	TOTAL	**315.2**

Note: 1 – Frequency Class and the Description derived from the USDA NRCS National Soil Survey Handbook (2022)

Frequently Flooded Areas – Recommendations

Areas that are identified as frequent flood areas may experience increased levels of surface erosion and scour during flood events. For areas that experience frequent flooding, increased frequency of aerial or ground reconnaissance of the pipeline alignment after extreme flooding events is recommended to be incorporated into the Integrity Management Program (IMP), in order to identify possible areas of concern.

5.6. Frost Heave

Frost heave occurs when saturated soil is subject to freezing (e.g., during the winter season) and subsequently thaws out (e.g., during the summer season); it typically occurs only near the ground surface. Frost heave results from the formation of segregated ice crystals and ice lenses in the soil and the subsequent loss of soil strength when the ground thaws. Frost heave can cause an initially level trench-bottom profile to become uneven, causing upheaval buckling. Upheaval buckling is a well-known phenomenon in buried pipelines that can lead to upward movements of a pipeline; it is caused by the interaction between the longitudinal compressive force present during operation and overbend irregularities in the profile (Palmer and Williams 2003). Frost heave is dependent on freezing temperatures, soil moisture, and susceptible soils.

The potential for frost heave to occur along the proposed pipelines was estimated based on the highest frost action potential values for a given area as categorized by the NRCS Soils Data (NRCS 2023). Values for frost action potential are based on the susceptibility of a soil to the formation of ice lenses and are categorized as having a higher frost action potential, a medium frost action

potential, or a lower frost action potential. See Appendix B for a detailed discussion of frost heave and frost action potential.

Approximately 165.3 miles (~52%) of the proposed pipelines are underlain by soils with medium frost action potential and approximately 81.3 miles (26%) of the proposed pipelines are underlain by soils with higher frost action potential. Table 4 summarizes the mileage of frost action potential encountered along the proposed pipelines. See Mapbook 1 for general locations of medium and higher frost action potential values. See Table A-2 in Appendix A for a mileage breakdown of the frost action potential categories for each segment of pipeline.

Table 4 – Frost Action Potential Along the Proposed Pipeline

Frost Action Potential[1]	Miles of Pipeline
Unknown	**18.3**
Lower	**50.3**
Medium	**165.3**
Higher	**81.3**
TOTAL	**315.2**

Note: 1 – Frost action potential derived from the USDA NRCS National Soil Survey Handbook (2022).

Although there is a relatively high frost action potential along much of the proposed pipelines, these areas may not result in frost heave. In order for frost heave to occur at pipe depth, not only must the soil conditions be conducive to frost heave (i.e., high frost action potential), but also the ground must freeze down to pipe depth, and where groundwater is present (i.e., shallow) to form ice lenses, on a recurring basis (e.g., year over year). These conditions are typically associated with areas that have permafrost, which is not present along the proposed pipeline alignments.

The proposed pipelines traverse areas where the maximum depth of frost penetration estimated for a 100-year return air-freezing index (based on data from 1981-2010) (Bilotta et al. 2015) is greater than 5 feet bgs. However, we consider this to be a conservative estimate, as it presents the maximum estimated frost penetration depth over a 100-year period. In a separate assessment by Gulf Interstate Engineering (Gulf) (2023), 10-years of measured soil temperature readings from a USDA monitoring station near Mandan, North Dakota were assessed. The measurements reflected a maximum frost depth of 40-inches over the 10-year period, which would be above the expected burial depth of the proposed pipelines.

The results of the Gulf study are based on soil temperature readings at a single USDA monitoring station, which Gulf selected as being representative of the maximum frost depth relative to the proposed pipelines in the Midwest region based on their comparison of soil temperature readings from multiple USDA monitoring stations. Although the soil temperature readings at the USDA monitoring station near Mandan can be influenced by local conditions such as soil type(s), soil moisture, and topography, which vary widely across the Midwest region, their results indicate that the frost depths estimated by Bilotta et al. 2015 may be overly conservative and not representative of average soil temperatures year to year. As such, the proposed pipelines may have the potential

for exposure to frost heave, but frost heave is considered to be limited and localized in occurrence, and likely not to occur to a degree that causes integrity concerns.

High Frost Heave Potential - Recommendations

The likelihood for frost heave to impact the proposed pipelines is considered to be low. Pipeline design and construction should follow industry best management practices (BMPs) to maintain the minimum required pipe burial depth of 48-inches and utilize trench backfill that does not contain significant percentage of silt which will help to minimize the potential for frost heave impacts. In areas where native soils are categorized as having higher frost action potential and shallow groundwater is encountered during construction, additional burial depth or use of select backfill with a low percentage of fines may be considered as additional mitigation.

5.7. Shrink/Swell Potential

Some types of clay-rich soils can undergo volume changes when moisture content decreases (i.e., shrink) or increases (i.e., swell). Significant shrinking and/or swelling of soils can impart stresses from differential settlement and/or heave, respectively, that can damage vulnerable infrastructure including buildings, roads, and buried pipelines. To assess the shrink/swell potential of soils, we compiled soils data from NRCS (2023) and used the highest value for *linear extensibility percent* that is assigned to each soil unit to classify the soils within the project area. Linear extensibility percent (LEP) represents the potential for a soil to undergo volume changes in response to wetting or drying. See Appendix B for definition of the hazard rating system for shrink/swell potential.

Approximately 64 miles (~20%) of the proposed pipelines traverse soils with a medium potential (LEP 3-6), and approximately 68.9 miles (~22%) traverse soils with a higher potential (LEP >6). The remainder of the pipelines traverse soils with either lower shrink/swell potential (approximately 152.7 miles), or the LEP values are unknown (approximately 29.6 miles). Table 5 below summarizes the mileage of each LEP class encountered along the pipeline. See Mapbook 1 for general locations of medium and higher LEP values. See Table A-2 in Appendix A for a mileage breakdown of the LEP values for each segment of pipeline.

Table 5 – Linear Extensibility Percent (LEP) Values Along the Proposed Pipeline

Shrink/Swell Potential[1]	LEP Values[1]	Miles of Pipeline
Unknown	Unknown	**29.6**
Lower	<3	**152.7**
Medium	3-6	**64.0**
Higher	>6	**68.9**
	TOTAL	**315.2**

Note: 1 – Shrink/Swell Class and Values derived from the USDA NRCS National Soil Survey Handbook (2022).

Although there is a relatively high shrink/swell potential along much of the proposed pipelines, in order for heave to occur at pipe depth, the soil conditions must be present at pipe depth and water content must fluctuate to allow wetting and drying of the soils at pipe depth to occur. As such, the proposed pipelines may have the potential to be impacted by shrinking/swelling soil processes, but

it may be limited and localized in occurrence, and may not occur to a degree that causes integrity concerns.

High Shrink/Swell Potential - Recommendations

The likelihood for soil shrink/swell processes to impact the proposed pipelines is considered to be relatively low. Pipeline design and construction should follow industry best management practices (BMPs) to maintain good trench drainage and utilize well compacted granular trench backfill will help to minimize the potential for shrink/swell impacts.

6. GEOHAZARD ASSESSMENT RESULTS

In the following sections, we summarize our findings based on the relevant data source(s) used to assess each geohazard.

6.1. Unstable Slopes (Landslides)

A landslide is the "movement of a mass of rock, debris, or earth down a slope" and encompasses geologic processes such as debris or mud flows, rotational slides (slumps), translational slides, earth flows, rockfalls, or debris slides (Cruden 1991; Cruden and Varnes 1996). Landslide hazards can potentially pose a serious threat to pipeline integrity because the nature and magnitude of ground movement can impose differential loading on pipelines that may ultimately exceed pipe strength capacity (INGAA 2016). Landslides can damage pipelines by shearing or bending the pipe along the lateral limits or failure planes of the landslide, by compressing and tensioning the pipe during downslope movement of soil and rock, by undercutting and exposing the pipe (in the event that material flows out from underneath the pipeline), or by physically impacting the pipe in the event of a rapid debris flow or rockfall.

To evaluate landslide hazards along the assessment corridor, the following were reviewed for the 500-ft wide swath along the proposed pipeline alignment to identify mapped or observable geomorphic features that appear to be indicative of landslides:

- 1:24,000 scale landslide maps prepared by the North Dakota Geological Survey (NDGS 2023a).
- Publicly available LiDAR data provided through the North Dakota LiDAR Dissemination MapService (NDDWR 2023) and the USGS 3D Elevation Program (3DEP) (USGS 2023).
- Publicly available LiDAR maps provided by the North Dakota Geological Survey (NDGS 2023c)
- Publicly available aerial imagery (ESRI Imagery and Google Earth™)

Based on the results of our review, Geosyntec developed landslide categories to provide guidance on an appropriate level of construction response for each landslide. Our landslide categories are provided in Appendix B and summarized in Table 6 below.

Table 6: Landslide Categories

Category	Recommended Response	Definition and Recommended Action
Class A	None Required	Landslides that do not appear to pose a challenge to pipeline constructability nor appear to pose a threat to pipeline integrity such that no mitigative action is required beyond implementation of standard best management practices (BMPs). Typically, Class A landslides would be partially or wholly removed by standard construction practices within the construction limits of disturbance (LOD).
Class B	Avoidance	Landslides that appear unlikely to pose a challenge to pipeline construction and appear unlikely to pose a threat to pipeline integrity if the landslide can be avoided either by circumvention around the landslide or via trenchless pipeline installation (i.e., HDD) beneath the landslide. Typically, avoidance of Class B landslides appears feasible due to apparent allowable workspace tolerances or due to proposed HDD installations planned for river crossings that coincide with the landslide. If a Class B landslide cannot be avoided, then Class C mitigative actions should apply.
Class C	Mitigation	Landslides that appear likely to be disturbed and/or impacted by pipeline construction activities such that landslide activity may be more likely to occur as a result of pipeline construction. Depending on the conditions encountered during construction, mitigative measures may be warranted to maintain or improve drainage and slope stability such as trench breakers, subsurface drains, water bars, etc.

Based on our review, we identified 18 total landslide sites located within 250 ft of the proposed pipelines. Seventeen of the landslide sites were identified from 1:24,000 scale NDGS landslide maps (NDGS 2023a) and one landslide was mapped by Geosyntec during a July 2023 ground reconnaissance (Geosyntec 2023). During the July 2023 ground reconnaissance, Geosyntec conducted field assessments for 11 of the 17 identified landslide sites mapped by the NDGS. Based on the conditions observed, Geosyntec determined that three of the landslide sites mapped by the NDGS did not exhibit features that are consistent with landslide morphology and Geosyntec classified these features as 'Not a Landslide' (Geosyntec 2023). These three non-landslide sites are included in this assessment to document that all NDGS-mapped landslides within 250 feet of the proposed pipelines were identified and reviewed for this assessment. Therefore, Geosyntec identified 15 landslides and possible landslides within 250 ft of the proposed pipelines. Table 7 below summarizes the results of our assessment of landslide hazards. Table A-3 provides more detailed information about the landslide sites identified during this assessment and Table A-4 provides site descriptions and applicable landslide mitigation strategies.

Table 7: Summary of Landslide Results

Site ID	Ground Reconnaissance	Feature Type	Approx. Distance to Proposed Pipeline (ft)	Landslide Category
SCS-ND-LS-001	Yes	Landslide	18	Class A
SCS-ND-LS-002	Yes	Landslide	200	Class B
SCS-ND-LS-003	Yes	Landslide	220	Class B
SCS-ND-LS-004	-	Possible Landslide	115	Class B
SCS-ND-LS-005	-	Possible Landslide	215	Class B
SCS-ND-LS-006	-	Possible Landslide	25	Class A
SCS-ND-LS-007	Yes	Landslide	175	Class B
SCS-ND-LS-008	-	Possible Landslide	40	Class B (HDD Crossing)
SCS-ND-LS-009	Yes	Not a Landslide	20	N/A
SCS-ND-LS-010	-	Possible Landslide	160	Class B
SCS-ND-LS-011	Yes	Not a Landslide	105	N/A (HDD Crossing)
SCS-ND-LS-012	Yes	Landslide	0	Class B (HDD Crossing)
SCS-ND-LS-013	Yes	Not a Landslide	0	N/A (HDD Crossing)
SCS-ND-LS-014	Yes	Landslide	0	Class B (HDD Crossing)
SCS-ND-LS-015	Yes	Landslide	85	Class B
SCS-ND-LS-016	Yes	Landslide	120	Class B
SCS-ND-LS-017	-	Possible Landslide	110	Class B
SCS-ND-LS-018	-	Possible Landslide	230	Class B

6.2. Seismic Hazards

The proposed alignment in North Dakota is in an area of low historical seismic activity (Rukstales and Petersen 2019).

Based on the USGS Earthquake Catalogue (USGS 2017a), no earthquakes with magnitudes (M) between M 3.0 and M 4.6 (largest recorded) have occurred within 100 miles of the proposed pipeline since 1872 (Figure 4).

Below, we provide additional details for each type of seismic hazard.

6.2.1. Strong Ground Shaking

Strong ground shaking from large earthquakes can potentially strain and damage pipelines because of lateral and vertical ground movements, or accelerations from seismic wave propagation (O'Rourke and Liu 1999; 2012). The potential hazard from earthquake wave propagation is commonly measured by the ground shaking parameter of peak horizontal ground acceleration (PGA), expressed as a percentage of the Earth's gravitational acceleration (g). Earthquake strong ground shaking may also trigger liquefaction and lateral spreading of saturated soil, as well as landslides. See Appendix B for a detailed discussion of strong ground shaking and our defined threat classification categories.

Based on the seismic hazard mapping developed by the USGS for ground motions having a 10-percent probability of exceedance in 50 years, which represents a return period of 475 years (Petersen et al. 2021; Rukstales and Petersen 2019), the proposed pipelines are in an area with PGA values of less than 0.02 g (Figure 4) and therefore are within the lower ground shaking potential threat category (Appendix B).

Strong Ground Shaking - Recommendations

An earthquake action plan should be developed as part of an IMP, to outline response after the occurrence of a strong earthquake (e.g., Magnitude 5 and above) near the constructed pipelines (e.g., 50 miles).

6.2.2. Soil Liquefaction

Liquefaction involves the transformation of a granular material from a solid to a liquefied state because of increased pore-water pressure and reduced effective stress (Youd et al. 2001). Seismic liquefaction typically occurs when loose to moderately dense granular soils with poor drainage such as silty sands, or sands and gravels containing seams of impermeable sediment, are saturated during strong ground shaking events (Youd et al. 2001). Liquefaction of soils involving a pipeline can potentially result in pipe strain or rupture from settlement, heave (buoyancy), and/or lateral displacements when liquefaction occurs on sloping ground. Mass movements, including permanent ground deformation, may also develop because of lateral spreading, which occurs when liquefied ground cannot support even shallow slope gradients such that liquefied material flows downslope (O'Rourke and Liu 1999; 2012). See Appendix B for a detailed discussion of soil liquefaction and our defined threat classification categories.

Areas that were interpreted to be frequently or permanently saturated near the ground surface (e.g., less than 30 feet below ground surface), that are interpreted to contain relatively young (i.e., Holocene) alluvium, lacustrine (i.e., lakebed) deposits, or similar, and that appear to consist of loose to moderately dense granular soils were assumed to have liquefaction potential if subjected to strong ground shaking.

Approximately 50.6 miles of the North Dakota proposed pipelines are underlain by material typically considered liquefiable (i.e., alluvium or fine-grained lacustrine or lakebed deposits). The approximate length of each geologic unit crossed by the proposed pipeline segments is summarized in Table A-1 in Appendix A.

Only about 61% of the proposed pipelines is estimated to be underlain by shallow groundwater (i.e., < 6 feet bgs) and thus may possess conditions necessary for liquefaction to occur. However, the absence of large (> M 6.0) earthquakes and low PGA values for the region suggests there is low potential for sufficient ground shaking to occur that could result in liquefaction, even where soil and water conditions are right for liquefaction (Cross et al. 2018). Approximately 14.34 miles of the proposed pipelines underlain by liquefiable soil types and shallow groundwater thus fall into the lower liquefaction potential threat category (Figure 4) (Appendix B).

Soil Liquefaction - Recommendations

An earthquake action plan should be developed as part of an IMP, to outline response after the occurrence of a strong earthquake (e.g., Magnitude 5 and above) near the constructed pipelines (e.g., 50 miles).

6.2.3. Surface Fault Rupture

Surface fault rupture from earthquakes causes permanent ground deformation (PGD) that induces tensile and compressional forces on pipelines, which have resulted in many pipeline breaks (e.g., rupture, buckling) from fault movement during past earthquakes (O'Rourke and Liu 1999; 2012).

Based on review of the USGS Quaternary Fault and Fold Database (USGS 2020), no Quaternary faults were identified crossing or within 500 feet of the proposed pipelines.

Surface Fault Rupture - Recommendations

An earthquake action plan should be developed as part of an IMP, to outline response after the occurrence of a strong earthquake (e.g., Magnitude 5 and above) near the constructed pipelines (e.g., 50 miles).

6.3. Ground Subsidence

Ground subsidence can be caused by various natural and human-induced processes but generally results in the formation of localized or regional ground depressions. Based on the references reviewed, ground subsidence hazards related to karst, underground mining, or fluid withdrawal (i.e., extraction of oil and gas or groundwater) within North Dakota generally appear to be absent along the proposed alignment. Each of these potential ground subsidence mechanisms are described further below and in Appendix B.

6.3.1. Karst

Karst generally refers to topography and features that typically form because of dissolution of carbonate rocks such as limestone and dolomite. Common karst features observed in karst topography include sinkholes, ridgetop ponds, caves, disappearing streams (i.e., sinks), and reappearing streams (i.e., springs) that are often interrelated through complex subsurface drainage networks. Karst processes that mainly result in potential hazards to pipelines involve the formation of sinkholes. See Appendix B for a detailed discussion of karst hazards.

To evaluate potential karst hazards along the assessment corridor the following were reviewed for the 500-ft wide swath along the proposed pipeline alignment to identify mapped or observable geomorphic features that appear to be indicative of karst conditions:

- Published geologic maps of North Dakota (e.g., Clayton 1980, Bluemle 2003)
- U.S. Geological Survey Open-File Report 2014–1156 (Weary and Doctor 2014)
- Publicly available LiDAR data provided through the North Dakota LiDAR Dissemination MapService (NDDWR 2023) and USGS 3D Elevation Program (3DEP) (USGS 2023)
- Publicly available aerial imagery (ESRI Imagery and Google Earth™)

No geomorphic evidence of ground subsidence related to karst was identified within 250 feet of the proposed pipelines during our remote sensing review of public LiDAR data and aerial imagery. A portion of the proposed NDT-211 pipeline is mapped as being underlain by carbonate rocks of the Niobrara Formation; however, the data reviewed suggested the carbonate rocks are mantled by more than 50 feet of glacial deposits (e.g., Weary and Doctor 2014) (Figure 5). Additionally, no reports of karst hazards related to the Niobrara formation, or other geologic formations, could be identified for North Dakota. Therefore, we consider the Niobrara Formation to pose a low potential for karst-related ground subsidence where it is crossed by the proposed NDT-211 pipeline.

A portion of the proposed NDM-106 pipeline segment is mapped as being underlain by evaporite basins of the Sentinel Butte Formation; however, the data reviewed suggest these areas are mantled by more than 50 feet of glacial deposits (e.g., Weary and Doctor 2014) (Figure 5). Additionally, no reports of karst hazards related to the Sentinel Butte formation, or other geologic formations, could be identified for North Dakota. Therefore, we consider the Sentinel Butte Formation to pose a low potential for karst-related ground subsidence where it is crossed by the proposed pipeline.

6.3.2. Fluid Withdrawal

Subsidence from fluid withdrawal can cause permanent ground deformation that may stress pipelines and ultimately lead to pipe rupture. Noticeable or measurable fluid withdrawal subsidence occurs through withdrawal and drawdown of underground fluids in combination with geologic conditions favorable to subsidence (Poland 1984). Typically, fluid withdrawal subsidence

occurs when the volume of fluids being removed from a subsurface aquifer is greater than the volume of fluids recharging the aquifer, and when soil or bedrock within the aquifer is compressible (Galloway et al. 1999).

The Dakota Aquifer, which underlies much of the alignment, has been highly developed for the purposes of irrigation. Although groundwater depletion within the Dakota Aquifer has been documented (Konikow 2013), no examples of ground subsidence from groundwater withdrawal were identified as part of this study within areas underlain by this aquifer (Galloway and Sneed 2013).

Areas of oil and gas production are located in eastern North Dakota, but these areas are not traversed by the proposed pipelines (North Dakota Department of Mineral Resources – Oil and Gas Division – Oil and Gas Information 2023).

6.3.3. Underground Mines

Collapse or subsidence of underground voids left by underground mining can produce sinkholes similar to sinkholes produced by karst. These sinkholes can result from collapse of overlying overburden into a mine or mine related feature (such as air shafts), or the gradual or sudden collapse of the mine itself.

To evaluate potential underground mine hazards along the assessment corridor, the following were reviewed for the 500-ft wide swath along the proposed pipeline alignment to identify mapped or observable geomorphic features that appear to be indicative of mine subsidence:

- North Dakota's Abandoned Mine Lands (AML) Site Location Map (NDPSC 2023)
- Publicly available LiDAR data provided through the North Dakota LiDAR Dissemination MapService (NDDWR 2023) and USGS 3D Elevation Program (3DEP) (USGS 2023)
- Publicly available aerial imagery (ESRI Imagery and Google Earth™)

Based on review of North Dakota's Abandoned Mine Lands (AML) Site Location Map (NDPSC 2023), no mapped underground mines are documented within 250 feet of the proposed pipelines. Additionally, no geomorphic evidence of ground subsidence related to underground mines was identified within 250 feet of the proposed pipelines during our remote sensing review of public LiDAR data and aerial imagery.

6.4. Hydrotechnical Hazards

Hydrotechnical impacts at pipeline stream crossings are typically caused by channel changes and bed and bank material movement. Undesirable channel changes include vertical movement, lateral movement, and complete channel relocation (i.e., vertical and/or lateral instabilities). Vertical movement can result from scour, degradation, and aggradation. Lateral movement can occur due to bank erosion, and complete channel relocation can occur from avulsion and meander cutoffs.

An exposed and unsupported pipeline span within a waterbody is vulnerable to fatigue due to vortex-induced vibration (VIV), and localized scour around an exposed pipeline can further increase the unsupported length of the pipeline. Other damages to an exposed pipeline can be caused by impacts from debris, which may dent, puncture, or rupture the pipeline, damage pipeline coating, and increase hydrodynamic drag forces on the pipeline.

To evaluate potential hydrotechnical hazards, an initial pipeline-stream crossing dataset was created by identifying locations where the pipeline alignment intersected flowline features from the USGS NHDPlus High Resolution dataset (USGS, 2017b) that had *StreamRiver*, *ArtificialPath*, and *Canal/Ditch* designations. Using the NHDPlus data, each identified crossing was assigned a Strahler Stream Order (i.e., first, second, third, fourth, etc.). The Strahler stream ordering system (Strahler 1957) classifies streams based on stream/tributary relationships, with the uppermost channels in a drainage network (headwater channels with no tributaries) designated as first order streams down to their first confluence. Second order streams form below the confluence of two first order streams and third order streams are formed when two second order streams join, and so on. Stream order correlates well with other basin parameters such as drainage area and provides an understanding of stream characteristics such as relative channel size and depth. Table 8 provides a summary of the number of crossings based on stream order for the pipeline alignment.

Table 8 – Number of Waterbody Crossings by Stream Order

Stream Order	Number of Crossings
10	1
6	3
5	10
4	8
3	16
2	39
1	112
No Designation	3
TOTAL	**192**

Geosyntec identified 192 total waterbody crossings with stream orders ranging from 1 through 6 and one waterbody crossing with a stream order of 10, which was identified as the Missouri River Crossing, and three crossings that did not have a designation. Typically, waterbodies with a stream order of 3 or less in low relief topographic areas are smaller channels that have bankfull widths less than 20-feet, have smaller watersheds, and likely do not contain water velocities and flow depths of a magnitude sufficient to result in scour depths that would present a hydrotechnical hazard for a pipeline with a standard burial depth of five feet below the channel. Therefore, 167 identified crossings with a stream order of 3 or lower are considered Low hazard crossings. Additionally, the three crossings that had no stream order designation were reviewed and considered to be Low hazard crossings.

Of the 22-crossings identified with stream order of 4 or greater, eleven (11) were evaluated for hydrotechnical hazards under a separate effort and results of that evaluation are contained in a separate report (Geosyntec 2023b). Geosyntec evaluated the remaining 11 crossings based on the criteria detailed in Appendix B and assuming open cut trench installation methods and the results are summarized in Table 9. See Mapbook 1 for general locations of the identified stream crossings. A summary of the stream crossings is provided in Table A-5 in Appendix A.

Table 9 – Waterbody Crossing Hazard Rating (Fourth order and higher crossings)

Hazard ID	Latitude	Longitude	Stream Name	Stream Order	Hazard Rating
HH-ND-0001	46.282516	-99.89103	Beaver Creek	5	Moderate
HH-ND-0004	47.016713	-101.184606	NA	4	Moderate
HH-ND-0046	45.956853	-98.446868	NA	4	Moderate
HH-ND-0052	46.98707	-101.399387	Maple River	6	Low
HH-ND-0054	46.964118	-100.94938	NA	4	Low
HH-ND-0094	47.012474	-100.751998	Square Butte Creek	5	Low
HH-ND-0120	46.834864	-97.285611	Burnt Creek	4	Moderate
HH-ND-0196	46.83413	-97.285621	West Branch Long Lake Creek	4	Low
HH-ND-0210	46.83186	-97.285185	Buffalo Creek	4	Low
HH-ND-0211	46.282516	-99.89103	Buffalo Creek	4	Low
HH-ND-0212	47.016713	-101.184606	Buffalo Creek	4	Moderate

Geosyntec recommends review of the proposed crossing designs for those rated as Moderate to further evaluate hazard rating and provide additional recommendations to the crossing design. Modification of the installation technique to horizontal directional drill or review of the site-specific open cut installation design at these locations may reduce the hydrotechnical hazard rating to Low.

6.5. Meteorological Hazards

The following sections present the results of our assessment of meteorological hazards.

6.5.1. Tornadoes

Although tornadoes do not typically pose a significant threat to buried pipelines, they can pose a threat to surface structures associated with pipelines. We assessed tornado hazards by utilizing mapping performed by the National Oceanic and Atmospheric Administration's (NOAA's) National Severe Storms Laboratory (NSSL) (2015). The NSSL has prepared a tornado probability map based on historical data from 1986 to 2015. The probability of a tornado occurring is expressed in terms of *tornado days per decade* which is the number of days an Enhanced Fujita (EF) scale of EF2 or greater tornado is expected to occur within 25 miles of a given point in an average decade. Areas mapped with more than 2.0 tornado days per decade are areas where

tornadoes are historically most likely to occur in a given decade; areas mapped as having between 0.5 and 2.0 tornado days per decade are areas where tornadoes are historically less likely to occur but are still areas where tornadoes can be expected; and areas with less than 0.5 tornado days per decade are areas where tornadoes are considered unlikely to occur.

The entire project area in North Dakota is designated as having less than 1.5 mean number of EF2+ within 25 miles of a point (NOAA 2015), which corresponds with our low and medium tornado hazard potential threat categories (refer to Appendix B).

Tornadoes - Recommendations

An action plan should be developed as part of an IMP, to outline response after an extreme storm event occurs near the constructed pipelines that could impact above ground infrastructure or buried pipelines.

6.5.2. Lightning Strikes

Lightning strikes are natural forces that can damage pipelines and related infrastructure. We assessed lightning hazards by utilizing a map generated by Vaisala (2019) that shows cloud-to-ground lightning incidence in the continental U.S. Vaisala, a private company, maintains a U.S. National Lightning Detection Network used by NOAA and the National Weather Service (NWS). The map is based on data collected between 2009 and 2018 and shows the average cloud-to-ground lightning incidence per square kilometer per year.

The entire project area in North Dakota is designated as having an average of between 1 and 4 lightning strikes per square kilometer per year, which corresponds with our medium lightning strike potential threat category (refer to Appendix B).

Lightning Strikes - Recommendations

An action plan should be developed as part of an IMP, to outline response after an extreme storm event occurs near the constructed pipelines that could impact above ground infrastructure or buried pipelines.

6.5.3. Hurricanes

FEMA's national hurricane risk index (FEMA 2023), which represent a region's relative risk from hurricanes when compared to the rest of the U.S., ranks the entire project area in North Dakota as *Not Applicable*; indicating that there is no threat from hurricanes based on historic data.

7. RECOMMENDATIONS

Many of the potential hazard identified along the proposed pipelines can be mitigated during pipeline design and construction with industry best management practices (BMPs) and/or construction guidelines. Construction progress can be supervised through multiple stages of

construction (e.g., clearing, grading, excavation) by competent personnel who can direct the implementation of BMPs, as appropriate, and recognize conditions that require further evaluation by a subject matter expert. Following construction, we recommend that SCS develop an integrity management plan (IMP) that involves periodic assessment and monitoring of their system utilizing a combination of methods and technologies that would support early identification, evaluation, and mitigation of potential integrity concerns (see discussion of IMP in Section 7.1 below).

7.1. Integrity Management Plan

Changes to conditions can be identified through development of an IMP (INGAA 2023), which is an assessment, monitoring, and management process that involves periodic reassessment and systematic monitoring to evaluate changes that may develop since the baseline assessment(s). This can be achieved through the application of technologies like repeat collection of LiDAR data, repeat in-line inspection (ILI) surveys employing an inertial measurement unit (IMU) to identify possible bending strain, and/or satellite technologies like InSAR (Interferometric Synthetic Aperture Radar). These technologies can be used to monitor not only known geohazards, but also identify the formation of new geohazards (and their effects) caused by geologic processes, human-triggered processes, or extreme weather events (see discussion of climate change in Section 6.2 below). Additional methods including visual assessment during routine aerial and ground patrols could be useful in identifying changes locally. Any combination of these approaches could be implemented as part of a comprehensive IMP that would allow SCS to assess whether conditions have changed, and if so, allow SCS to take appropriate action(s) to manage those changes.

7.2. Managing Climate Change

The effects of climate change are leading to a rise in uncharacteristic weather patterns across the globe, resulting in greater frequency and severity of weather and related events including (but not limited to) temperature extremes, droughts, wildfires, precipitation, flooding, tornadoes, and hurricanes (IPCC 2022). Because some types of geohazards are heavily influenced by weather and climate, among other factors, near- and long-term changes in climate may contribute to an increase or decrease in geohazard-related occurrences for a given area; depending on the geohazard type and the changes experienced in local weather patterns. For pipeline operators to respond to and manage the effects climate change on their pipeline systems, the development of a well-balanced IMP utilizing a combination of technologies and resources available (e.g., repeat LiDAR, IMU bending strain, and/or satellite technology) is beneficial for identifying and addressing changes from natural processes that could adversely affect pipeline operation. These types of repeat assessments will pipeline operators to assess if conditions have changed, and if so, to take appropriate action to manage those changes.

8. LIMITATIONS

This desktop assessment was based on public information reported by others and included an interpretive remote sensing review using publicly available aerial imagery and multi-resolution LiDAR data along the proposed pipelines. As such, the results presented herein represent our overall knowledge and understanding of the conditions present along the proposed pipelines, which are dependent upon the age, quality, and accuracy of the resources available at the time of assessment. Although we strived to compile the most up-to-date and reliable information that we could identify, it is possible that conditions along the proposed pipelines may have been misrepresented or misinterpreted, lacked information, or may have changed since the resources available were published. Although field work was conducted by Geosyntec for some landslides identified by others prior to this assessment, no other field work was conducted as part of this assessment to verify the results presented by others or interpreted by Geosyntec. Therefore, the results of this assessment are preliminary, regional in scale, and are intended to support project planning by providing awareness of the geologic, hydrologic, and meteorologic conditions, and any related geohazards, reported or interpreted to be present along the proposed pipeline alignment. Additional assessment, including ground reconnaissance and site-specific investigations, should be undertaken to verify conditions and obtain further information when necessary.

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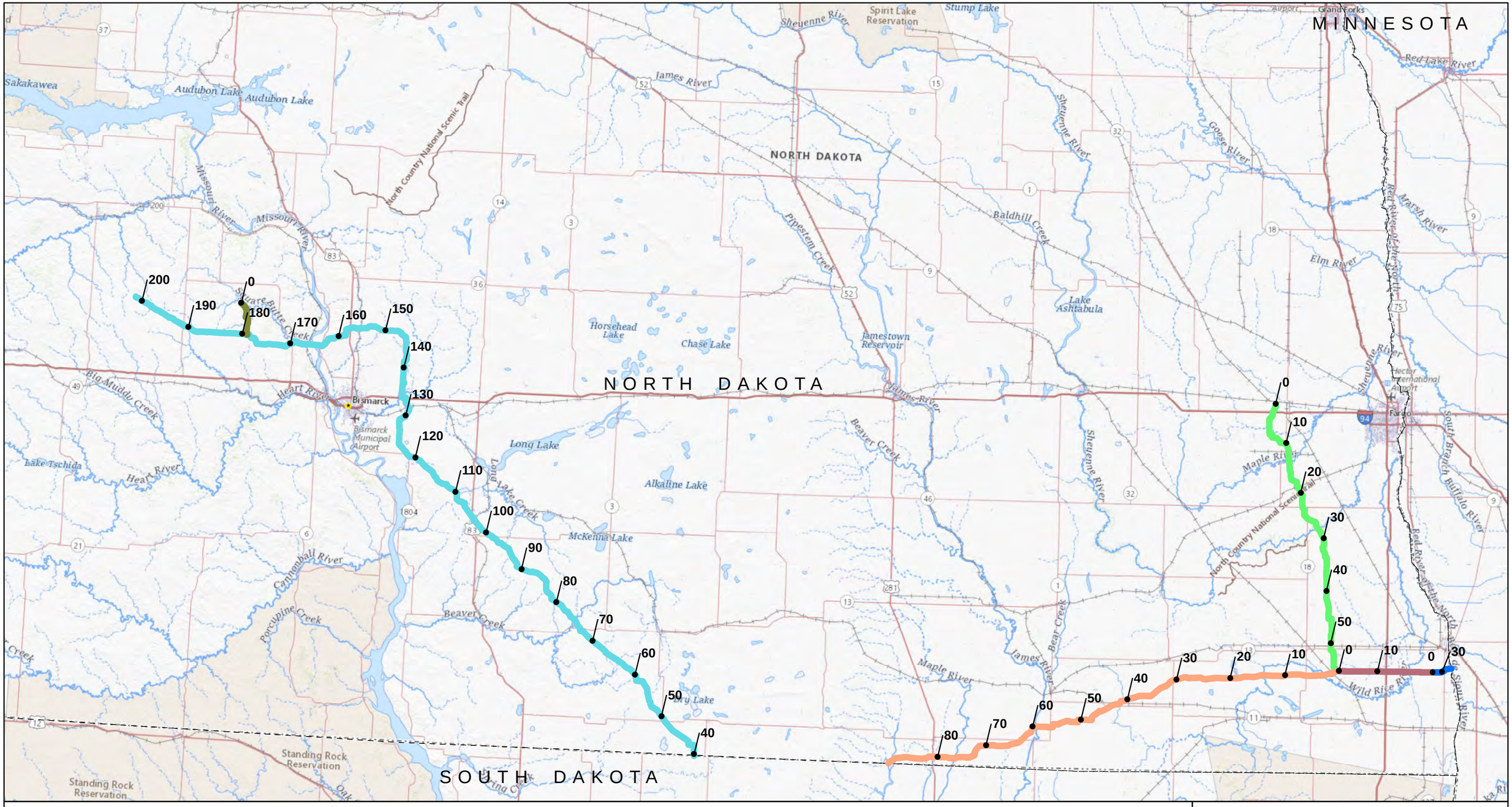
FIGURES



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- STATES
- REVISION 9 ROUTE MILEPOSTS

REVISION 9 ROUTE

- MNL-321
- NDL-323
- NDL-324
- NDL-328
- NDM-106
- NDT-211

NOTES:
PIPELINE ALIGNMENTS RECEIVED 1/24/2024
SERVICE LAYER CREDITS: USGS THE NATIONAL MAP: NATIONAL BOUNDARIES DATASET, 3DEP ELEVATION PROGRAM, GEOGRAPHIC NAMES INFORMATION SYSTEM, NATIONAL HYDROGRAPHY DATASET, NATIONAL LAND COVER DATABASE, NATIONAL STRUCTURES DATASET, AND NATIONAL TRANSPORTATION DATASET; USGS GLOBAL ECOSYSTEMS; U.S. CENSUS BUREAU TIGER/LINE DATA; USFS ROAD DATA; NATURAL EARTH DATA; U.S. DEPARTMENT OF STATE

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Location Map

Summit Carbon Solutions
North Dakota Phase I Assessment

Geosyntec consultants

Figure **1**

TXG0450 | January 2024

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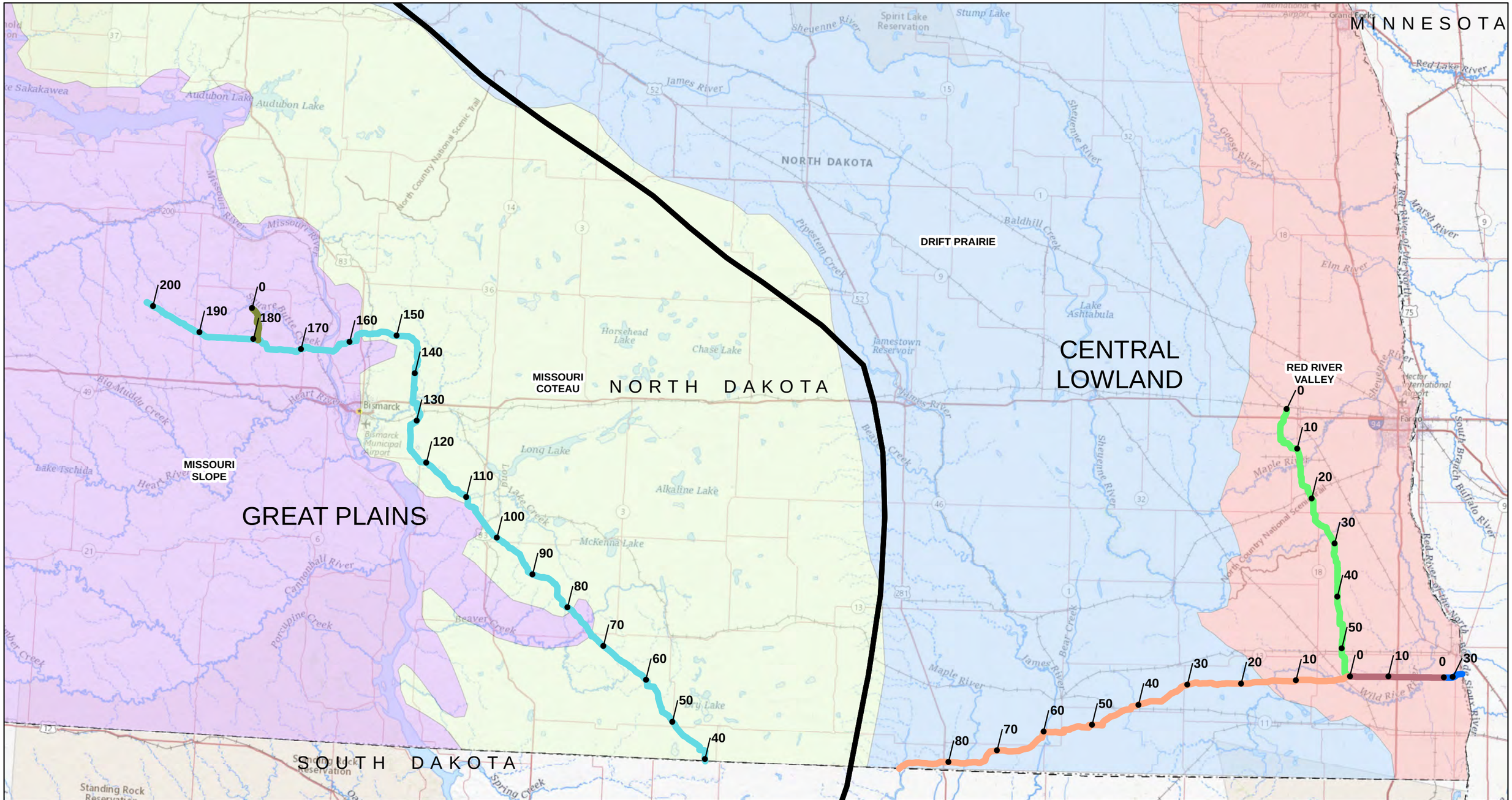

Legend

- REVISION 9 ROUTE MILEPOSTS
- REVISION 9 ROUTE
  - MNL-321
  - NDL-323
  - NDL-324
  - NDL-328
- NDM-106
- NDT-211
- REGION NAME
  - DRIFT PRAIRIE
  - MISSOURI COTEAU
  - MISSOURI SLOPE
- RED RIVER VALLEY
- STATES
- PHYSIOGRAPHIC SECTION (FENNEMAN & JOHNSON 1946)

NOTES:
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N

0 5 10 20 Miles

Physiography
Summit Carbon Solutions
North Dakota Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 2

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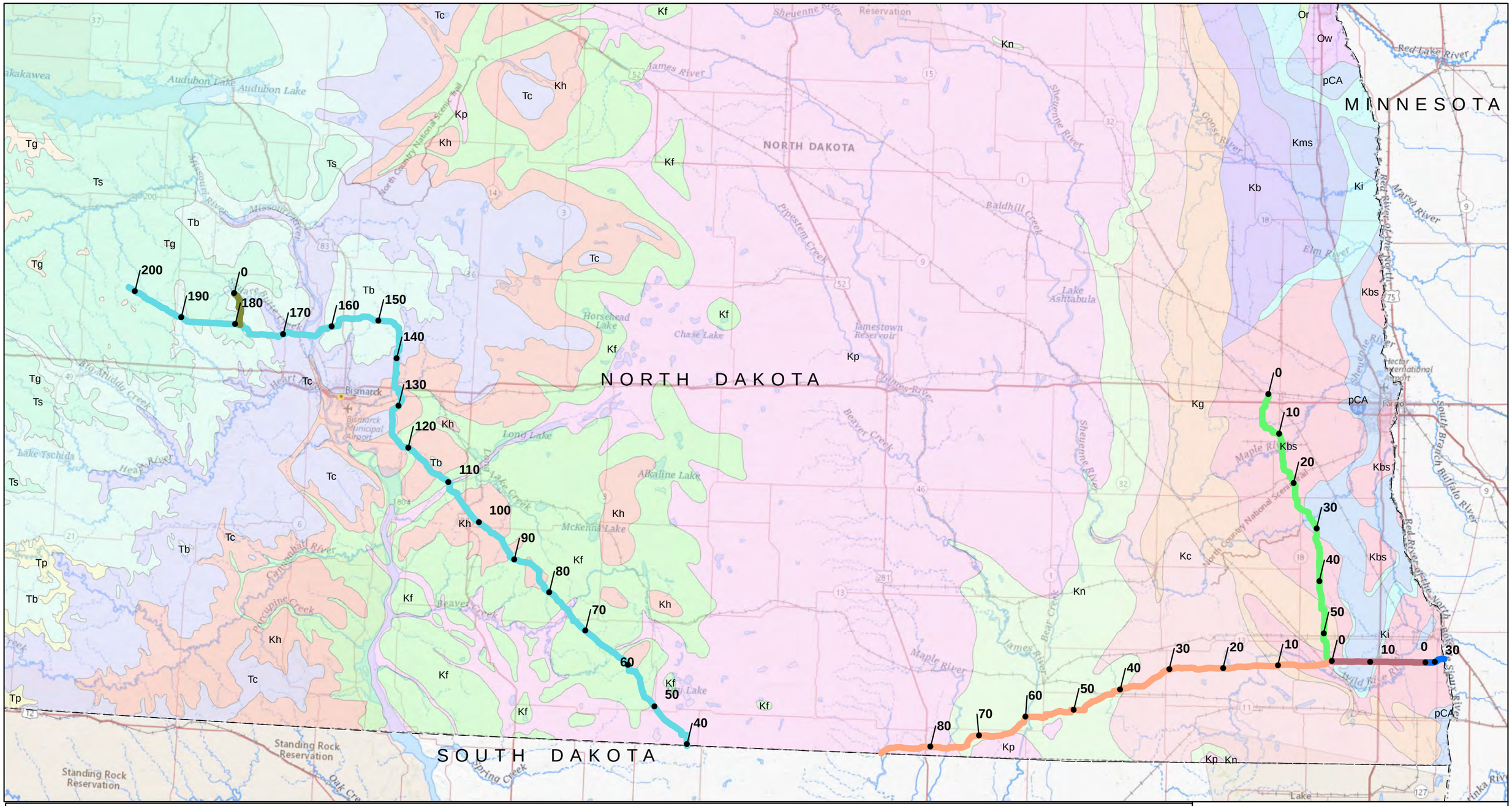

Legend

- REVISION 9 ROUTE MILEPOSTS
- REVISION 9 ROUTE
  - MNL-321
  - NDL-323
  - NDL-324
  - NDL-328
  - NDM-106
- NDT-211
- STATES
- GEOLOGIC UNIT CROSSED BY THE PIPELINE (USGS SGMC 2017)
  - JP
  - JU
  - KB
  - KBS
  - KC
  - KF
  - KG
  - KH
  - KI
  - KMS
  - KN
  - KP
  - OR
  - OW
  - TB
  - TC
  - TG
  - TL
  - TM
  - TP
  - TS
  - TW
  - PCA

NOTES:
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N

0 5 10 20 Miles

Surficial Geology

Summit Carbon Solutions
North Dakota Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 3

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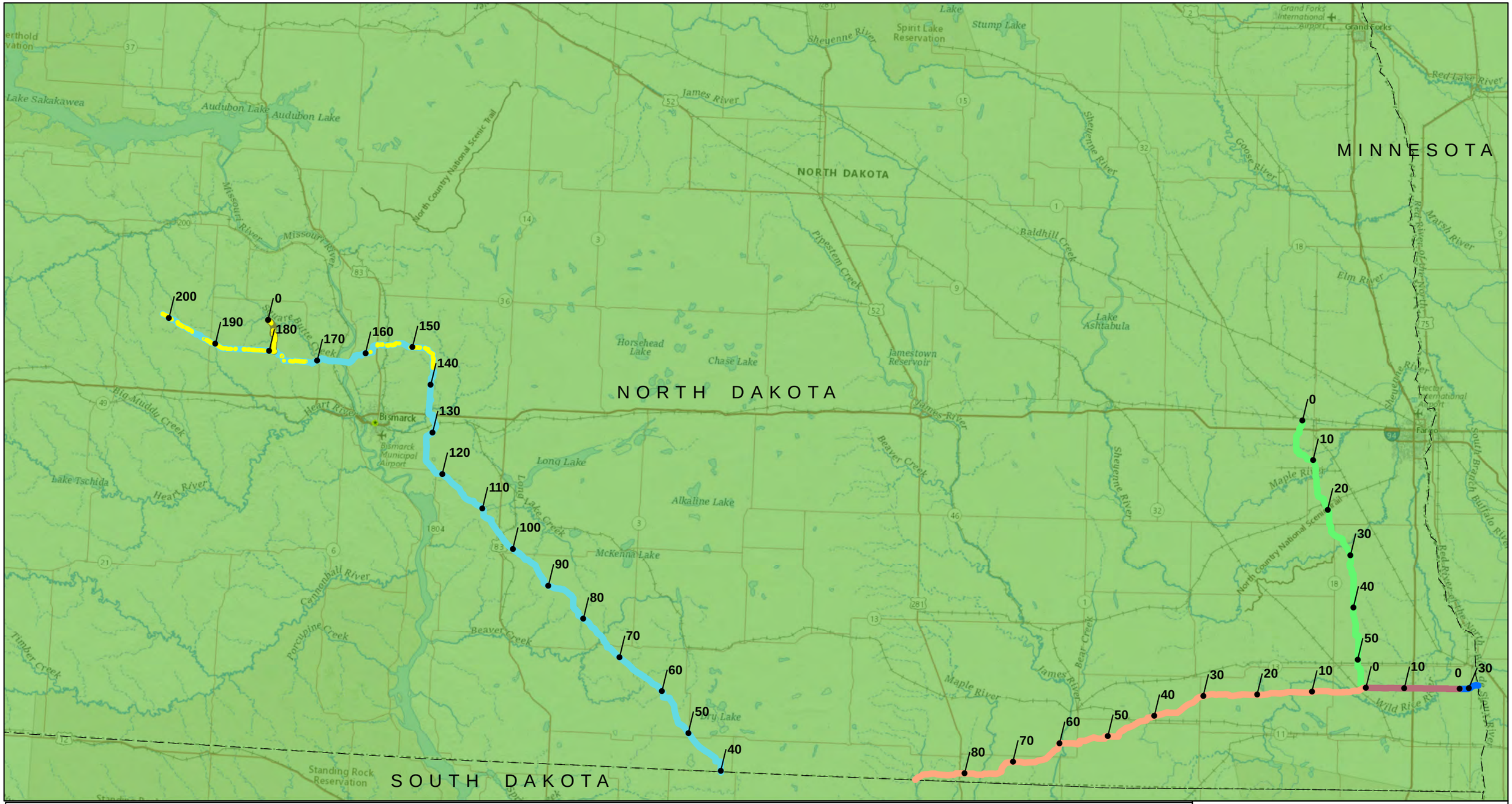

Legend

- REVISION 9 ROUTE MILEPOSTS
- LOW LIQUEFACTION HAZARD
- REVISION 9 ROUTE
- MNL-321
- NDL-323
- NDL-324
- NDL-328
- NDM-106
- NDT-211
- STATES
- GROUND SHAKING (PGA)
- 10% IN 50 YRS
- <0.02 G
- 0.02 - 0.04 G
- 0.04 - 0.06 G
- 0.06 - 0.08 G
- 0.08 - 1.04 G

NOTES:
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N

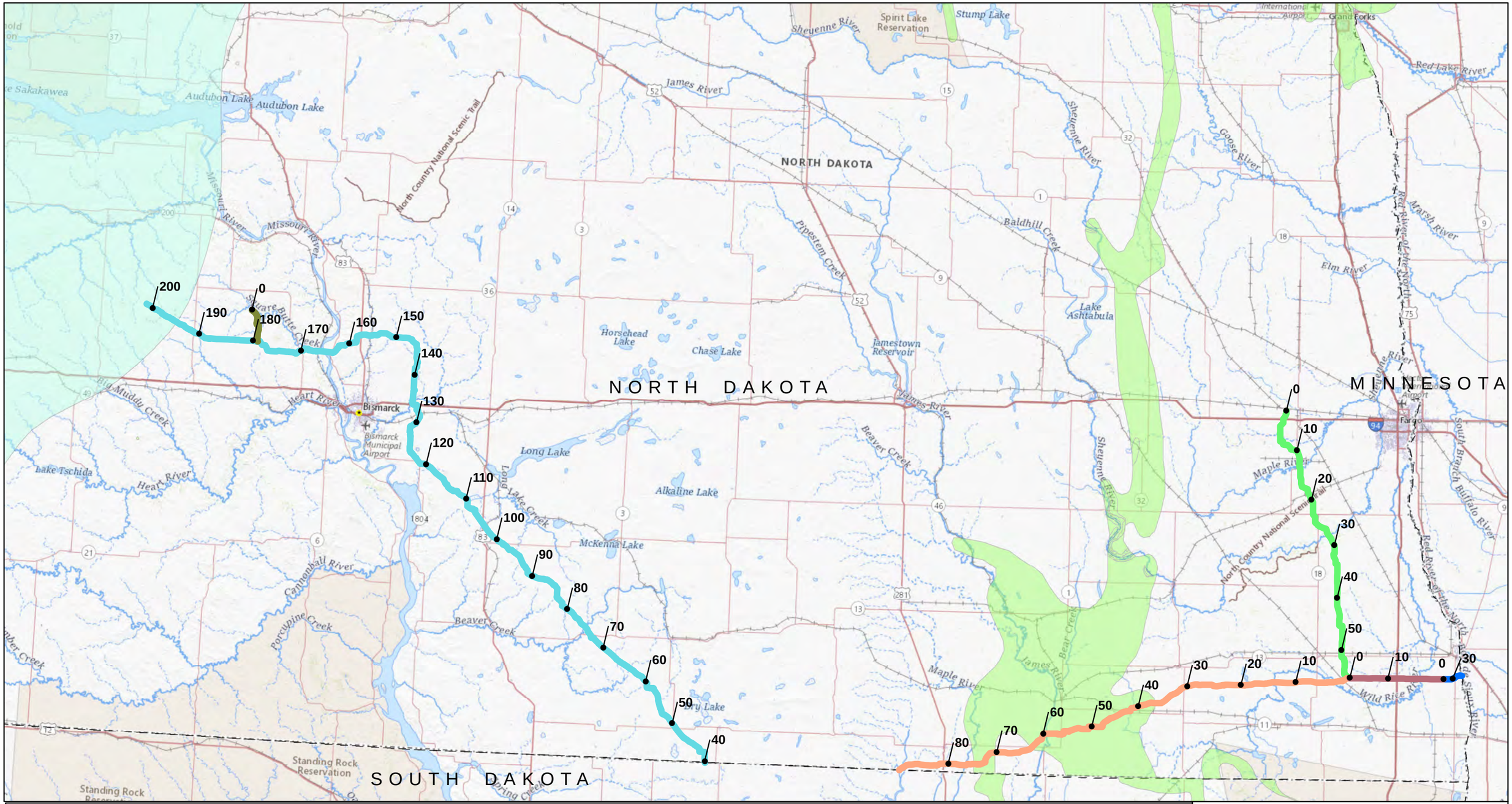
0 5 10 20 Miles

Seismic Hazards

Summit Carbon Solutions
North Dakota Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 4



Legend

- REVISION 9 ROUTE MILEPOSTS

REVISION 9 ROUTE

- MNL-321
- NDL-323
- NDL-324
- NDL-328
- NDM-106
- NDT-211

- LOW KARST THREAT: CARBONATE BEDROCK (WEARY & DOCTOR 2014)
- LOW KARST THREAT: EVAPORITE BASINS (WEARY & DOCTOR 2014)
- STATES

NOTES:
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N

0 5 10 20 Miles

Subsidence Hazard Areas

Summit Carbon Solutions
North Dakota Phase I Assessment

Geosyntec consultants

Figure **5**

TXG0450 | January 2024

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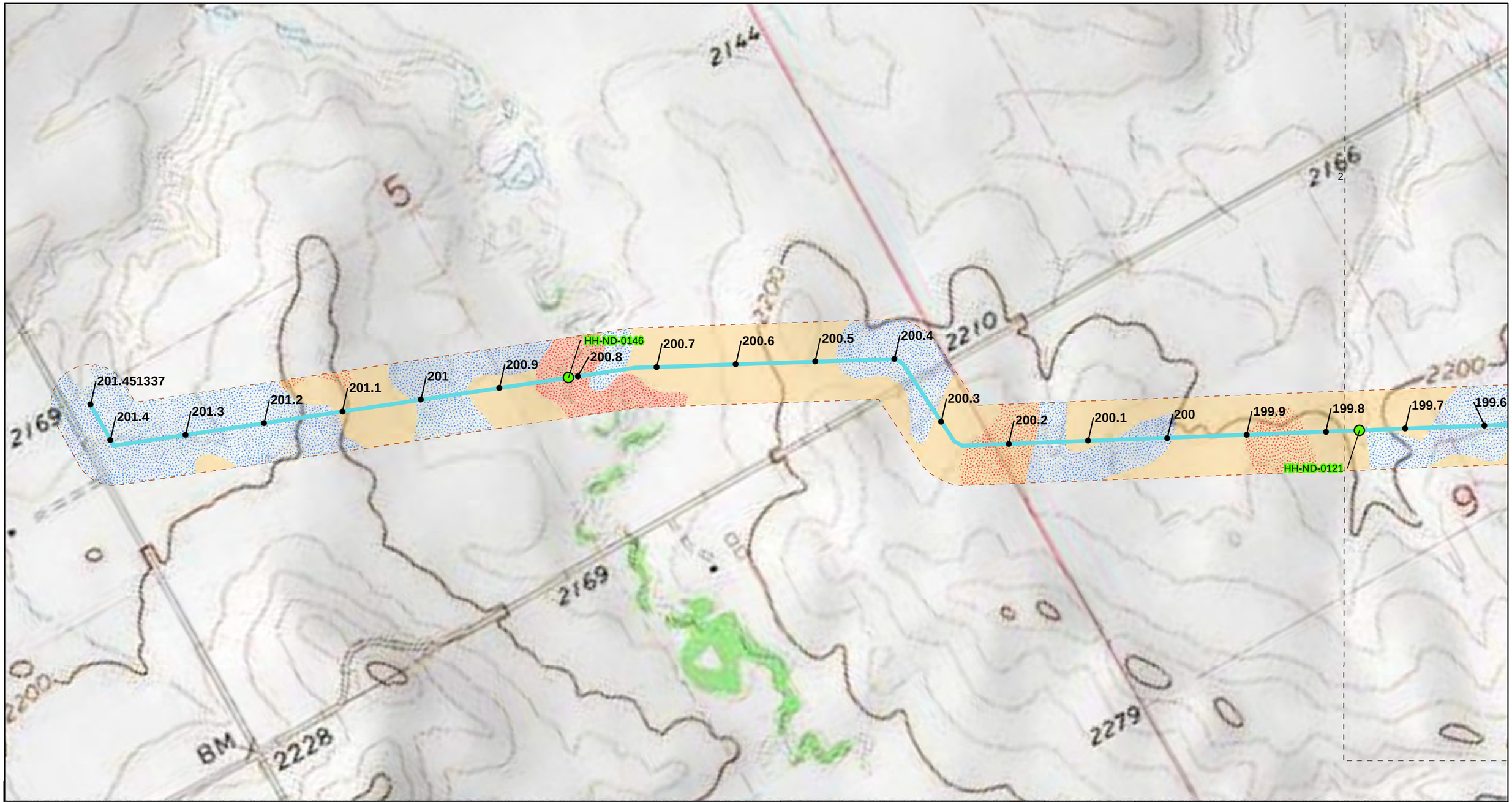

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
PIPELINE ALIGNMENTS RECEIVED 1/24/2024.
LINEAR EXTENSIBILITY PERCENT (LEP) AND FROST ACTION FROM NRCS SOILS DATA.
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-1

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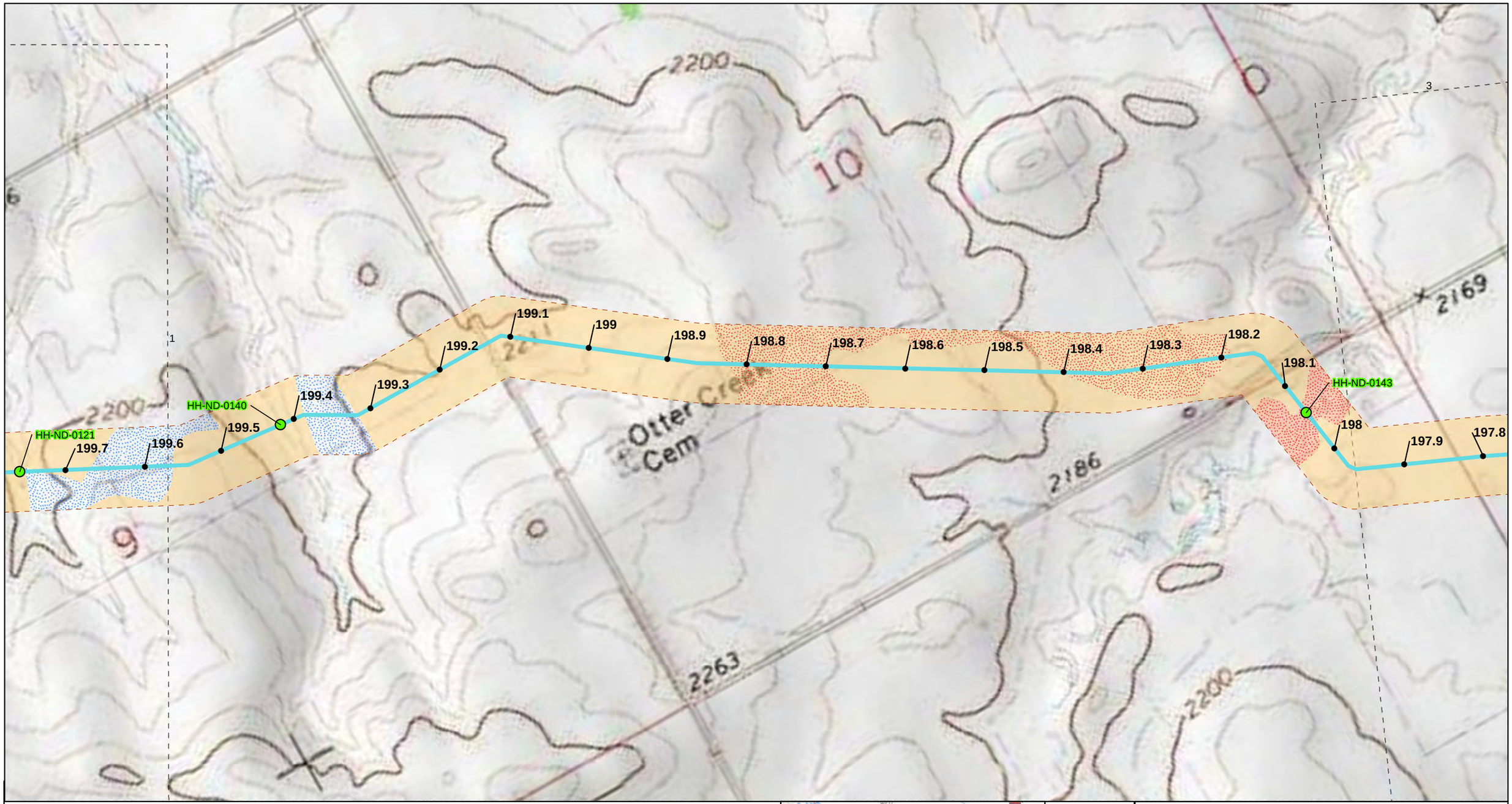

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-2

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY

- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

Figure **1-3**

TXG0450 | January 2024

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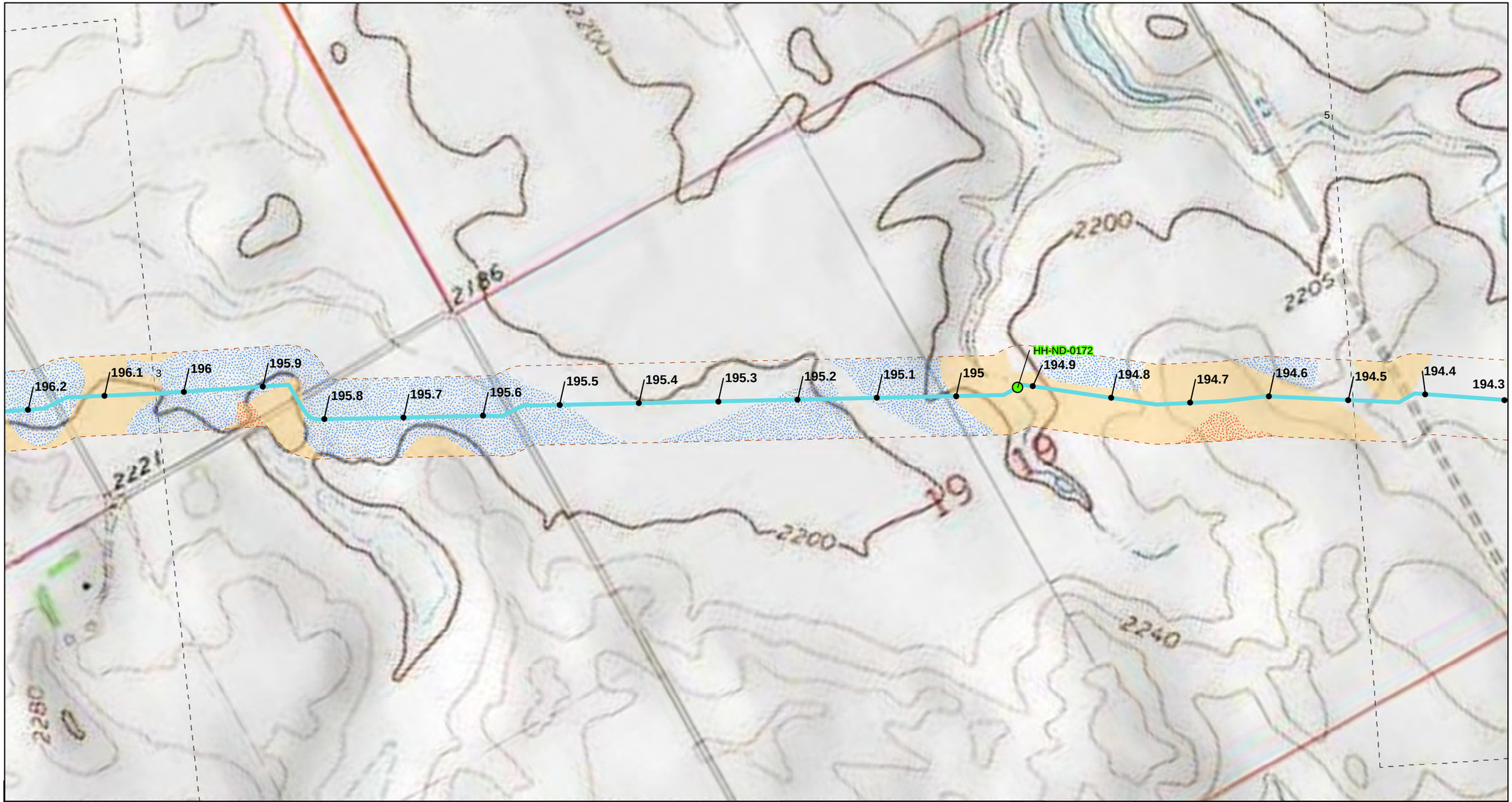

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-4

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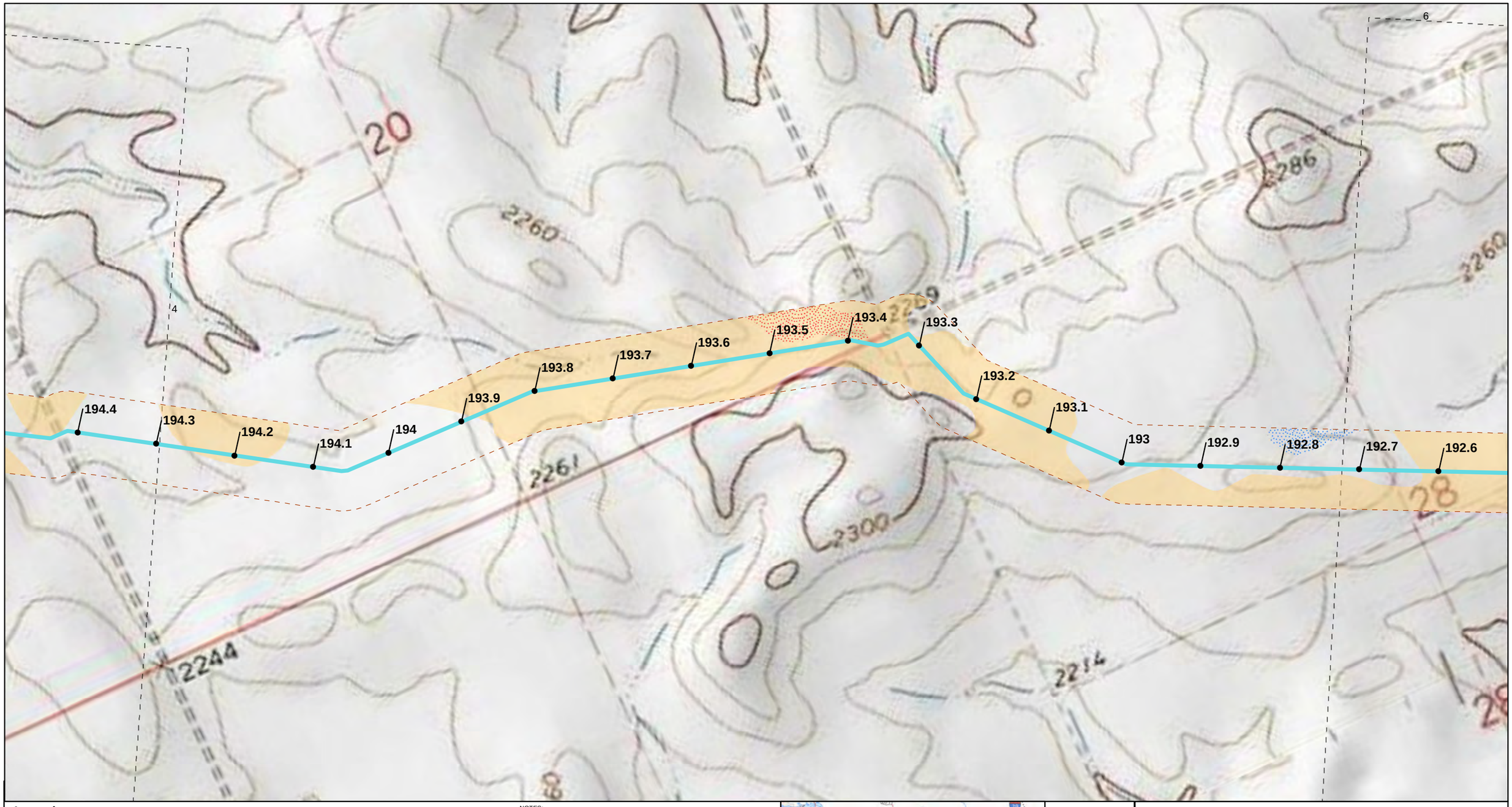

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-5

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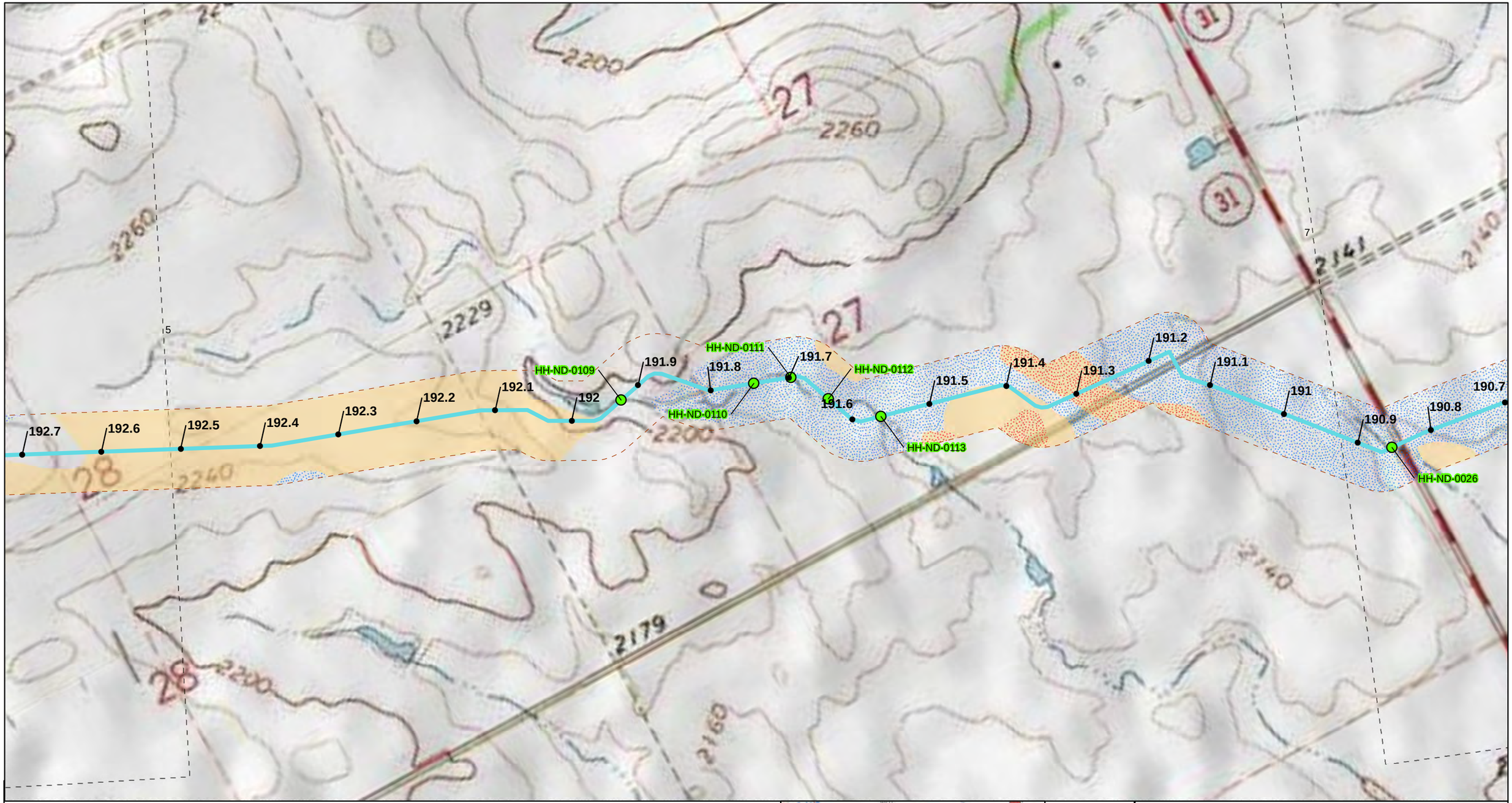

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-6

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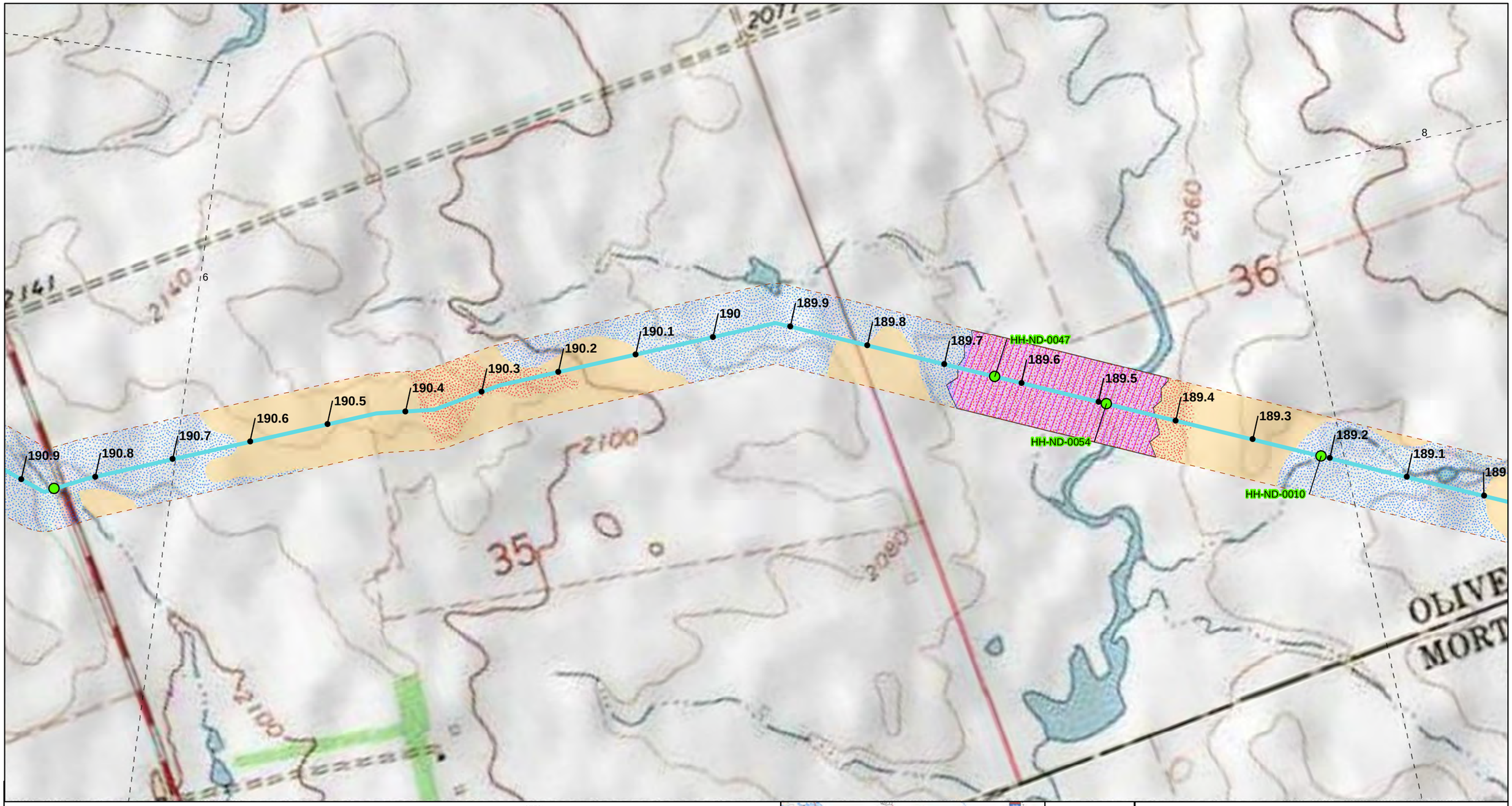

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-7

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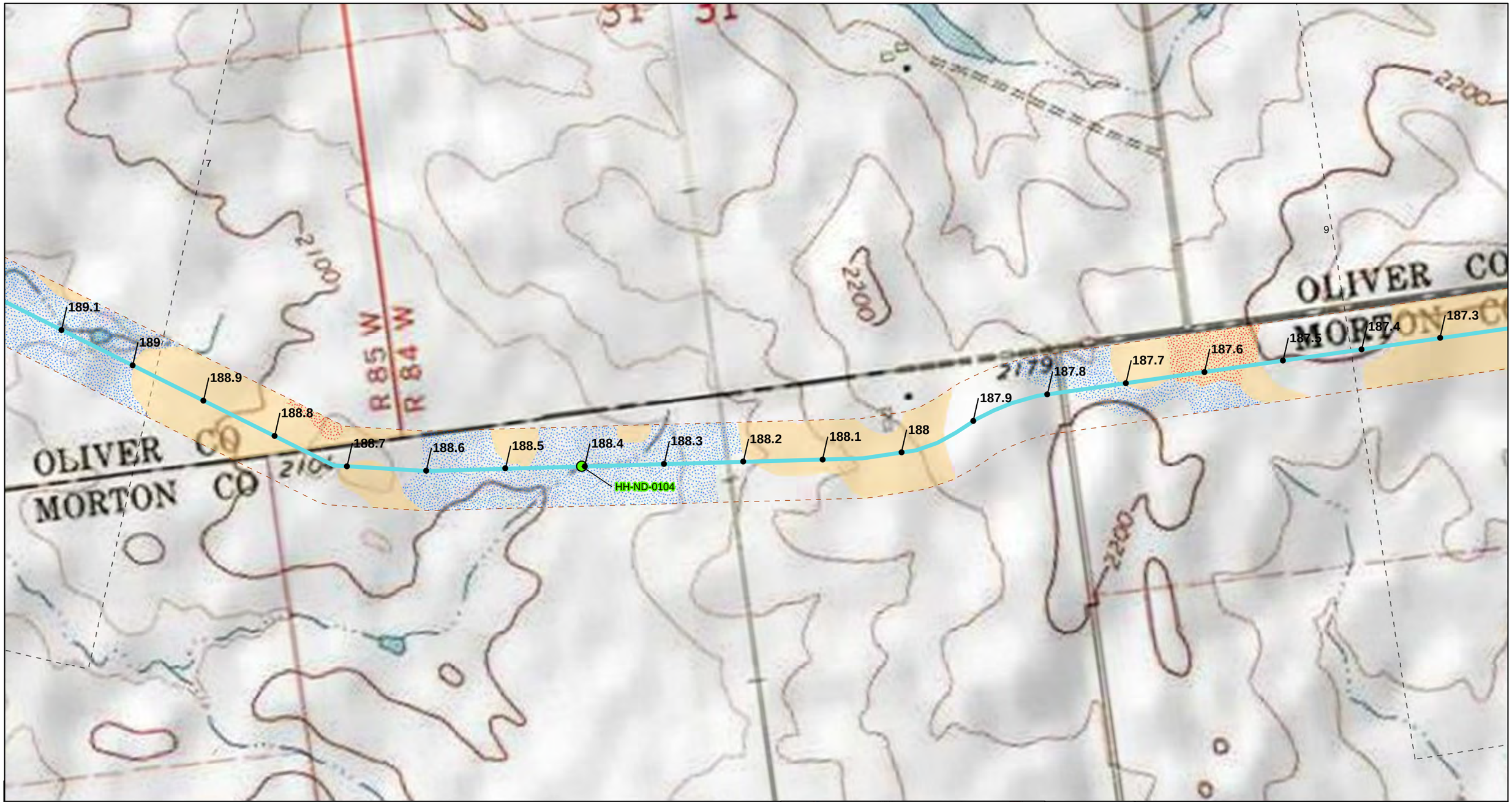

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
HIGHER: LEP >6
FROST ACTION CATEGORY
MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-8

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-9

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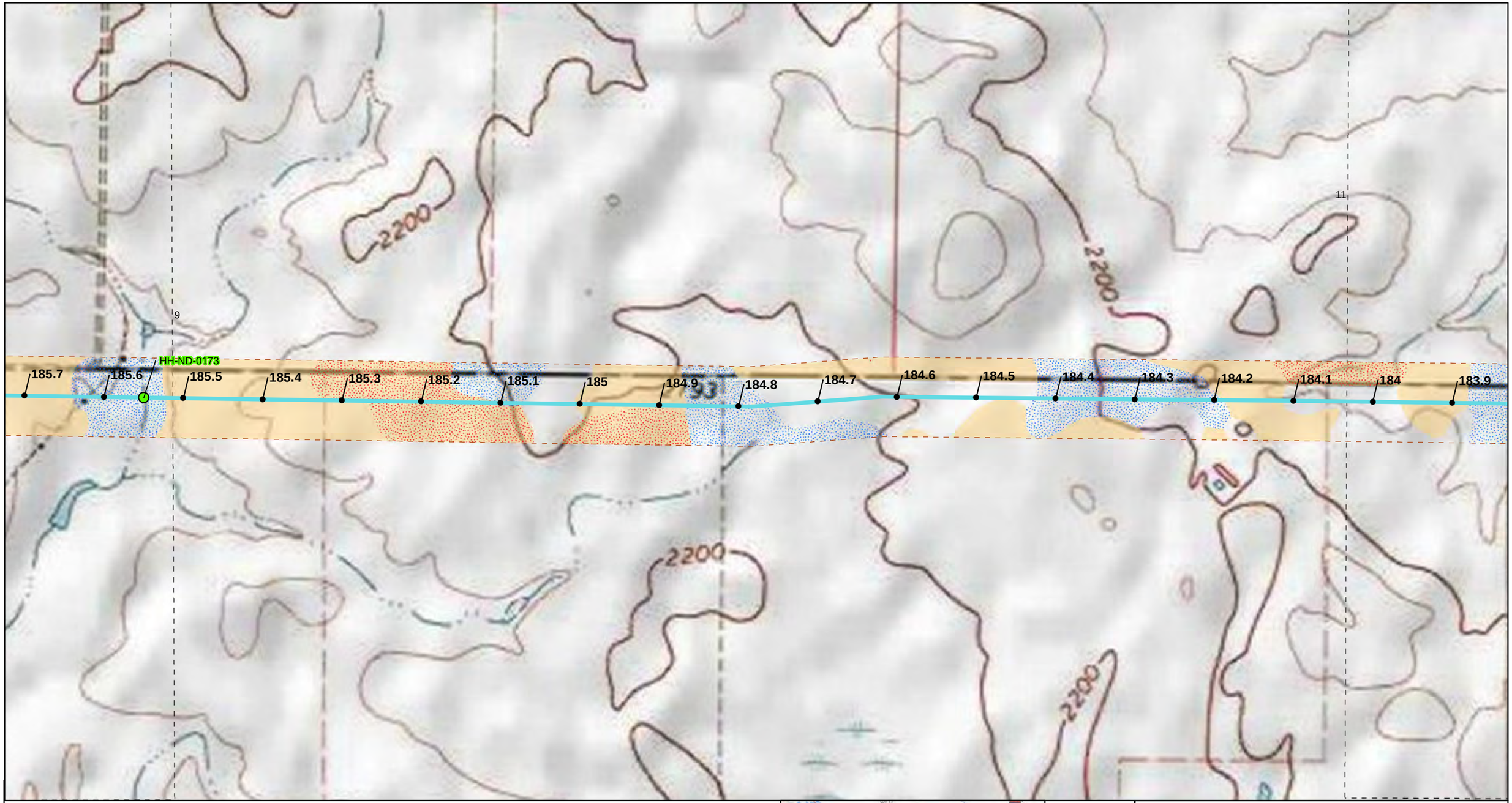

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
HIGHER: LEP >6
FROST ACTION CATEGORY
MEDIUM

NOTES:
PIPELINE ALIGNMENTS RECEIVED 1/24/2024.
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024

Figure **1-10**

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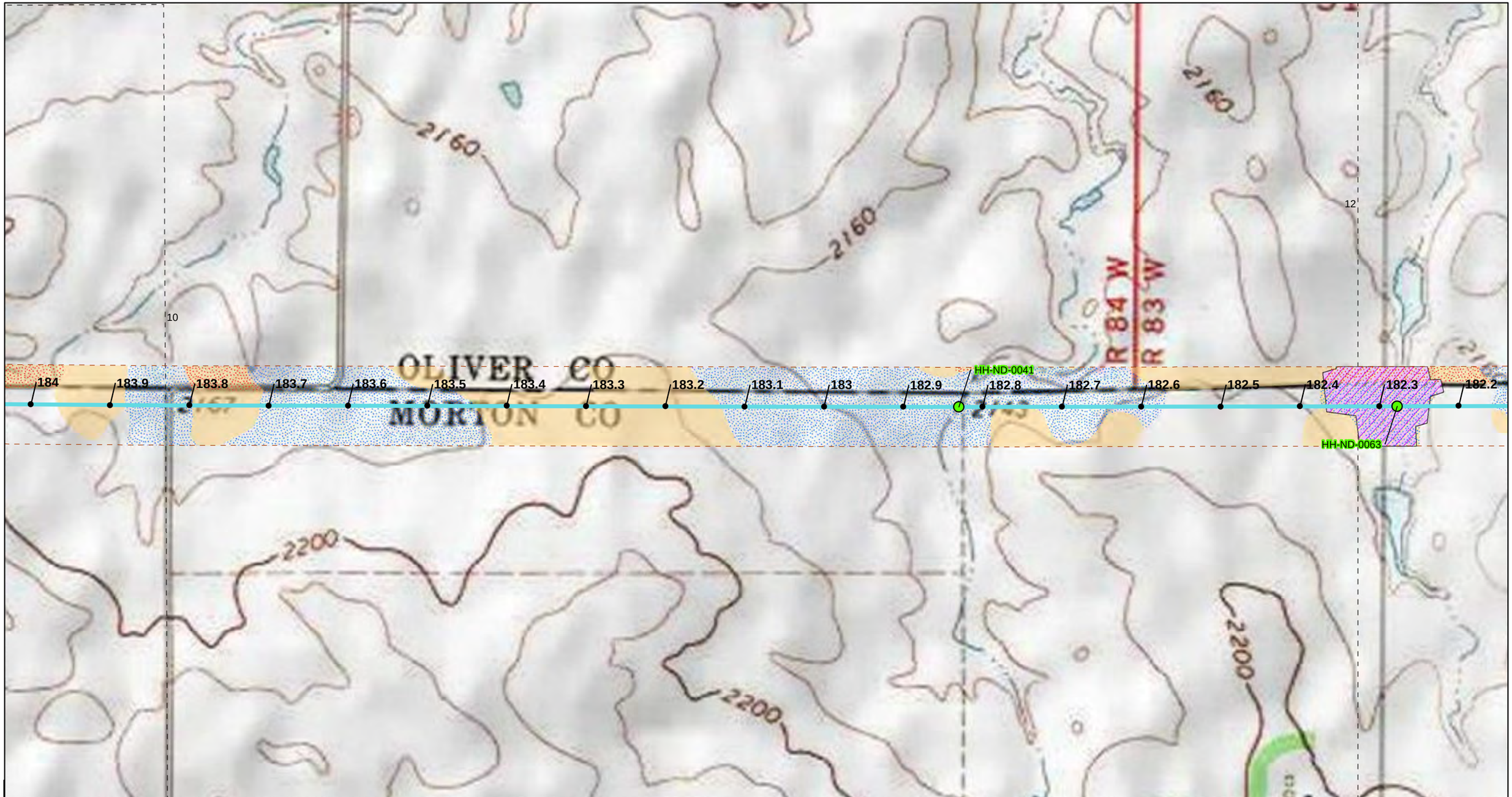

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-11

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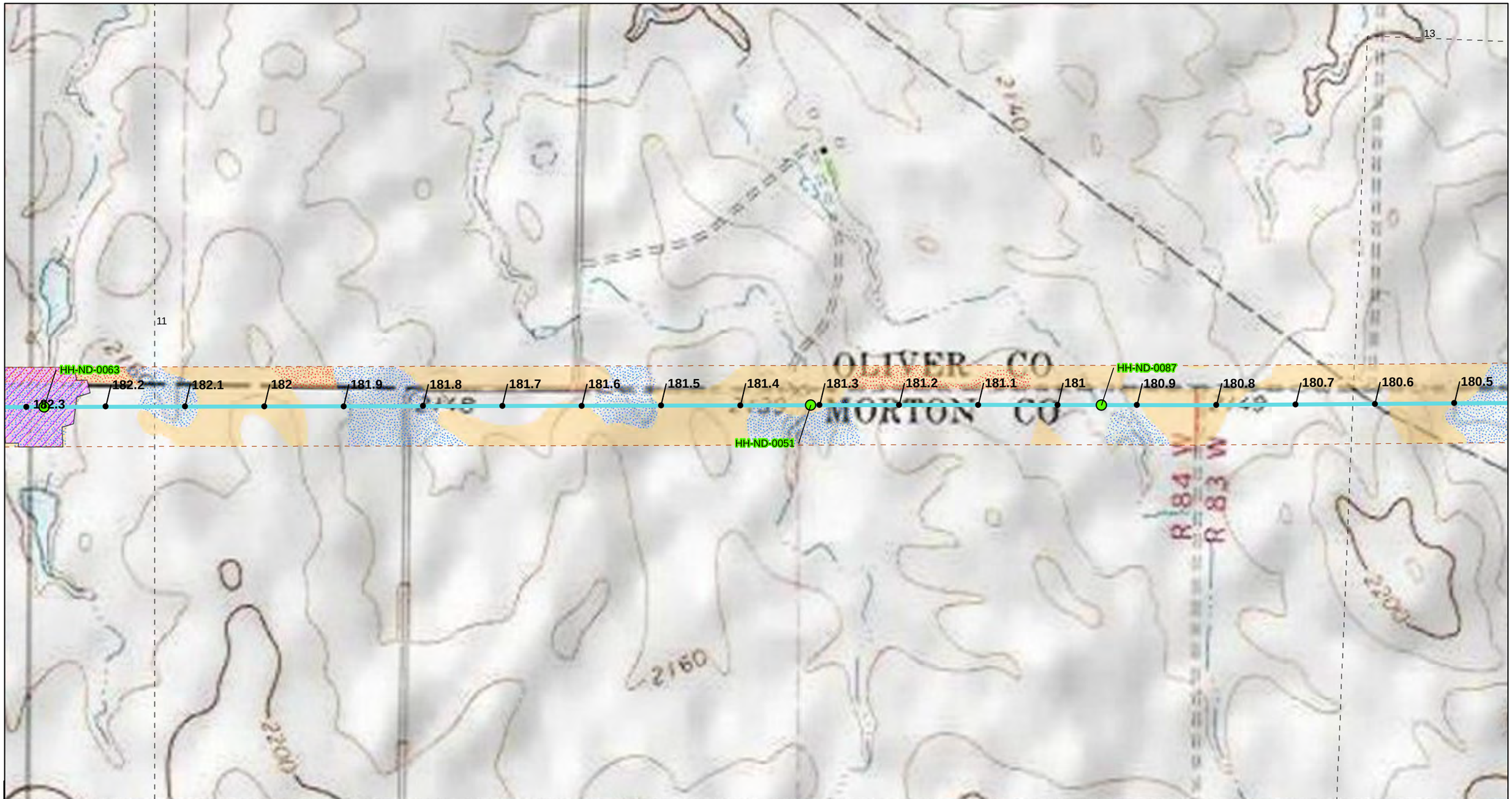

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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Phase I Assessment

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Figure **1-12**

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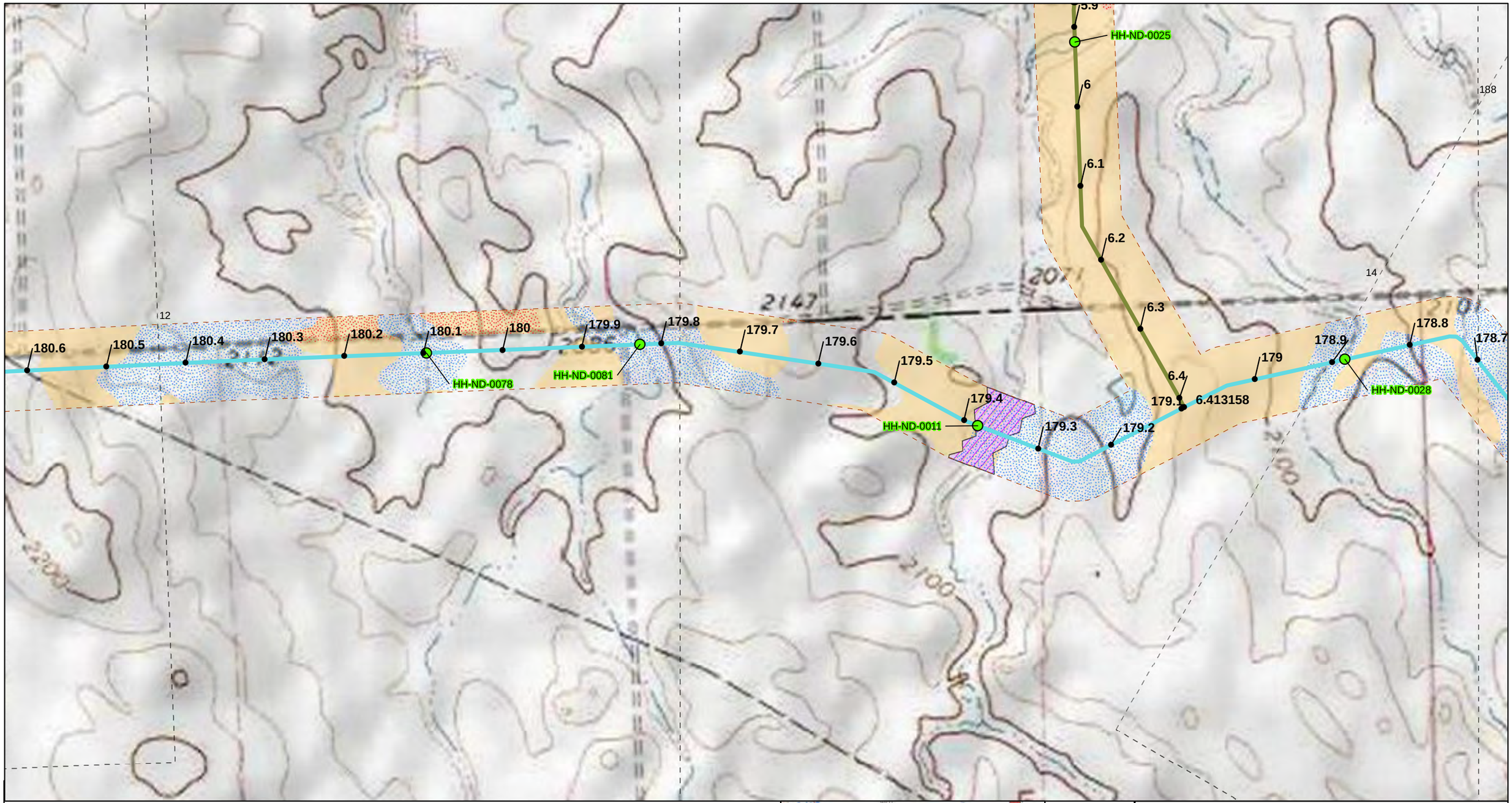

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-328
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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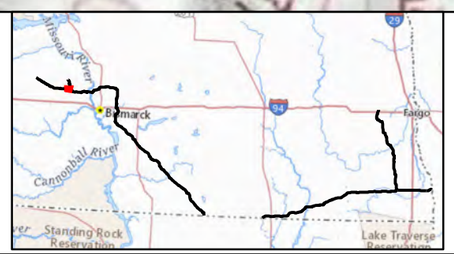

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-13

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-14

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
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TXG0450	January 2024	Figure 1-15

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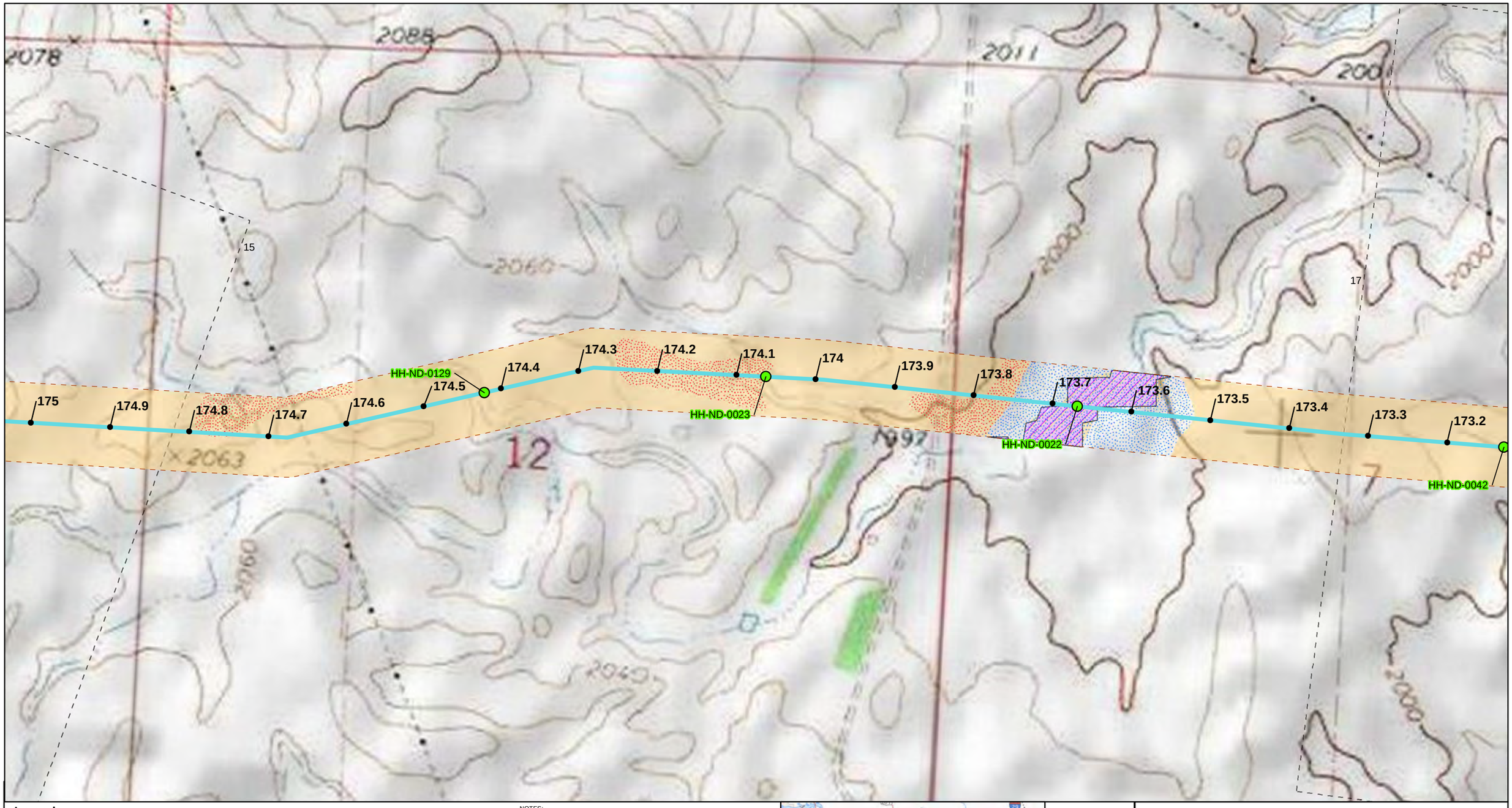

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
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TXG0450	January 2024

Figure **1-16**

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-17

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171.4
171.3
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170.7
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170.4
170.3
170.2
HH-ND-0144
170.1
170
169.9
169.8
169.7
HH-ND-0119
169.6

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
HIGHER: LEP >6
FROST ACTION CATEGORY
MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-18

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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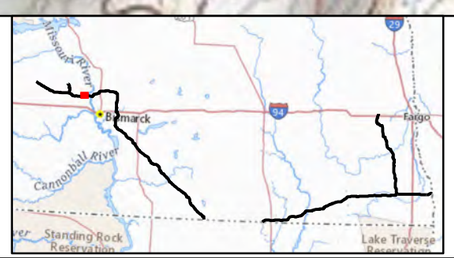

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-19

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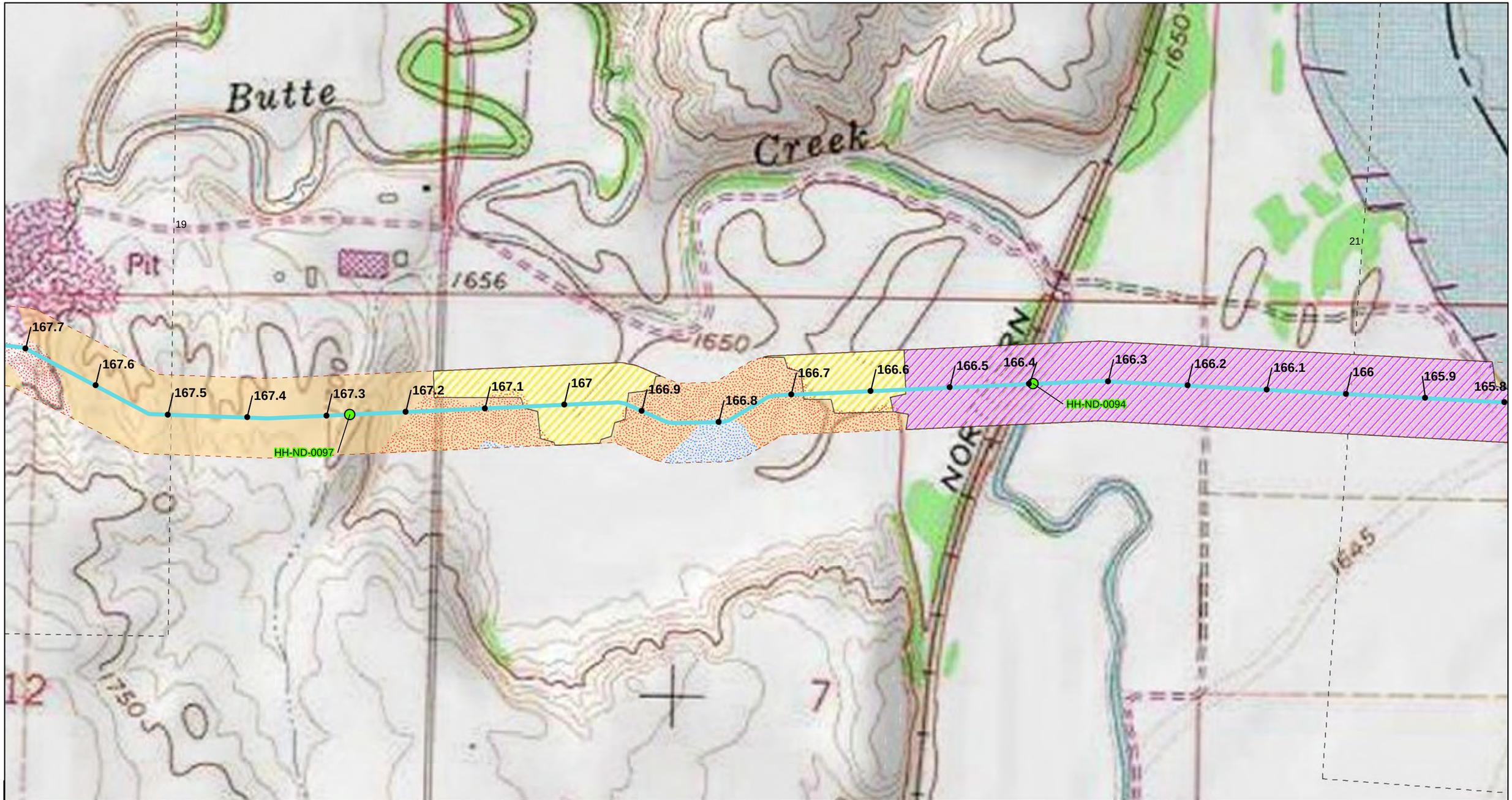

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: OCCASIONAL
- FLOODING FREQUENCY: RARE

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-20

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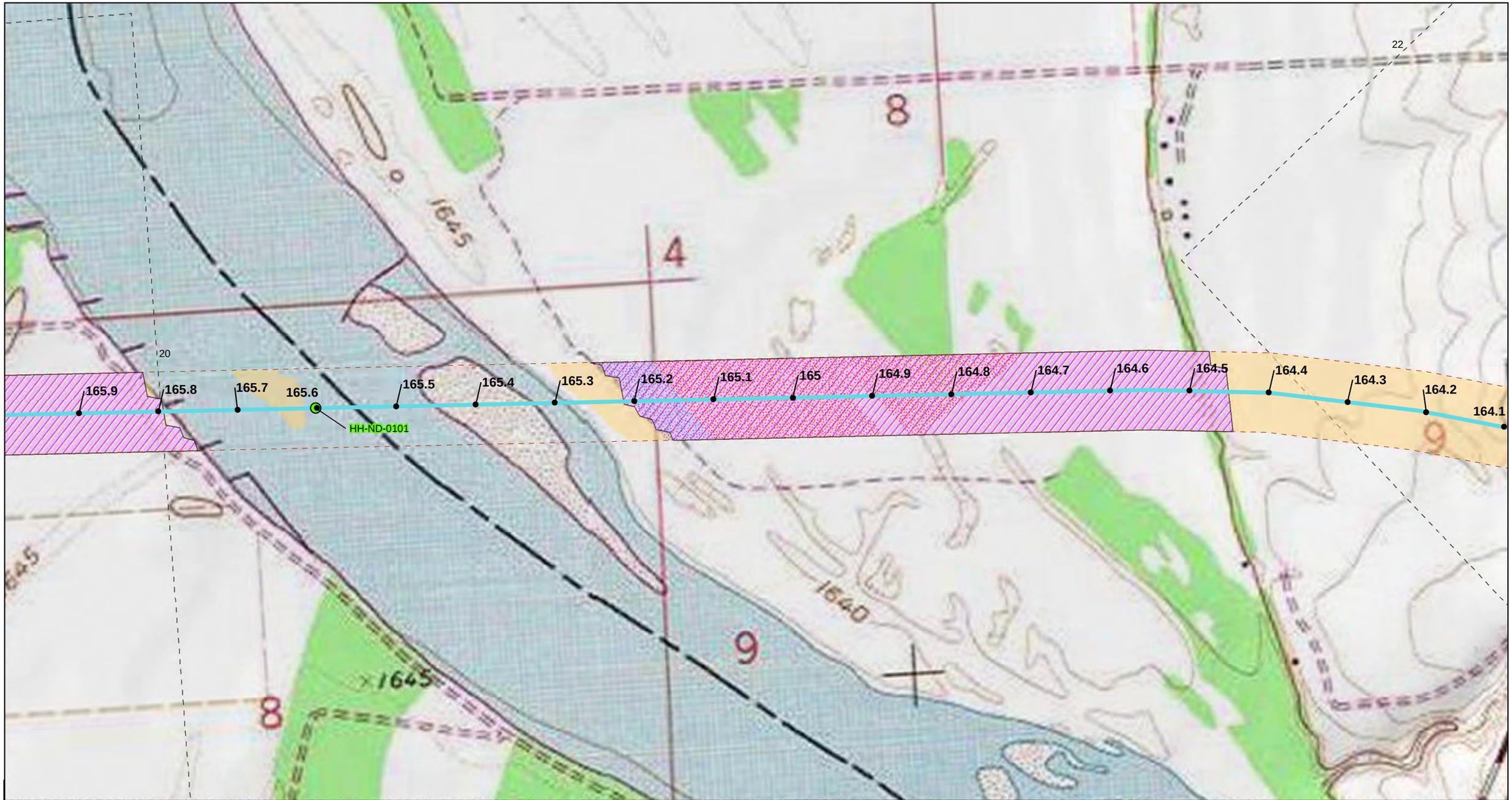

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-21

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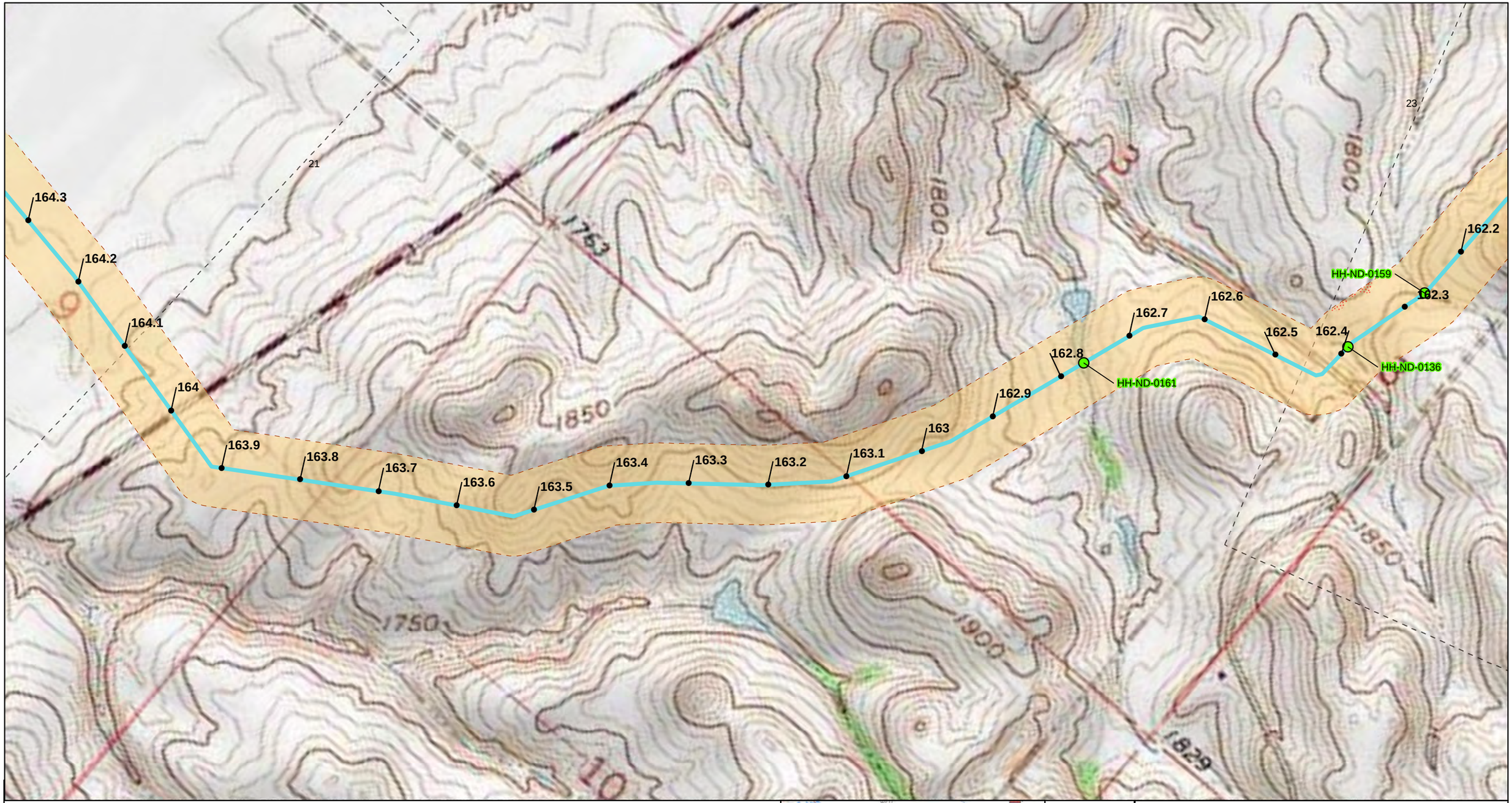

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
FROST ACTION CATEGORY
MEDIUM

NOTES:
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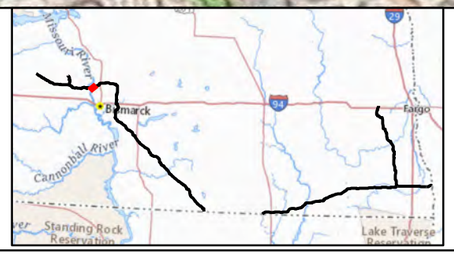

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-22

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
FROST ACTION CATEGORY
MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Summit Carbon Solutions - North Dakota
Phase I Assessment

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Figure **1-23**

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

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Summit Carbon Solutions - North Dakota
Phase I Assessment

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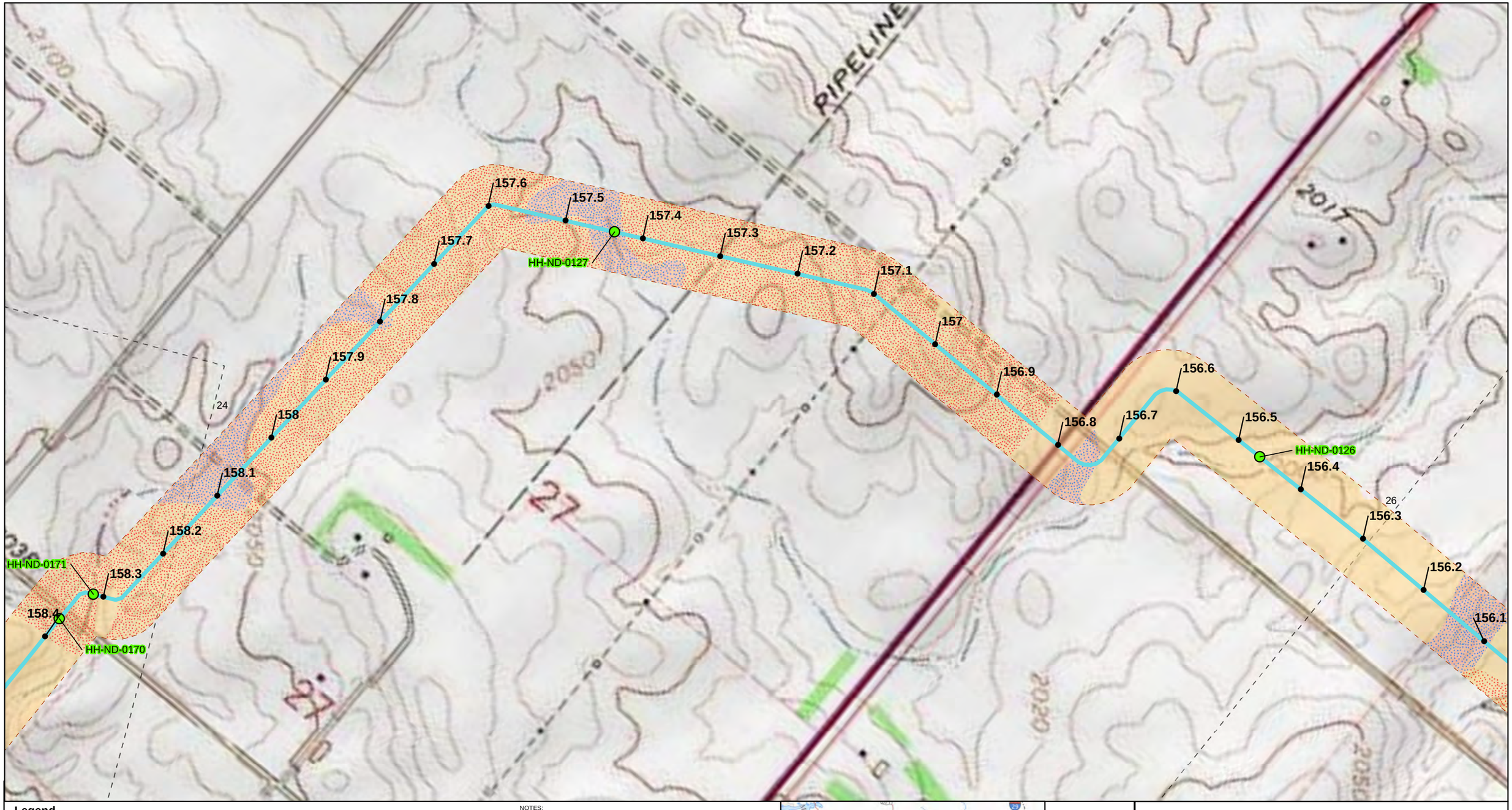

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-25

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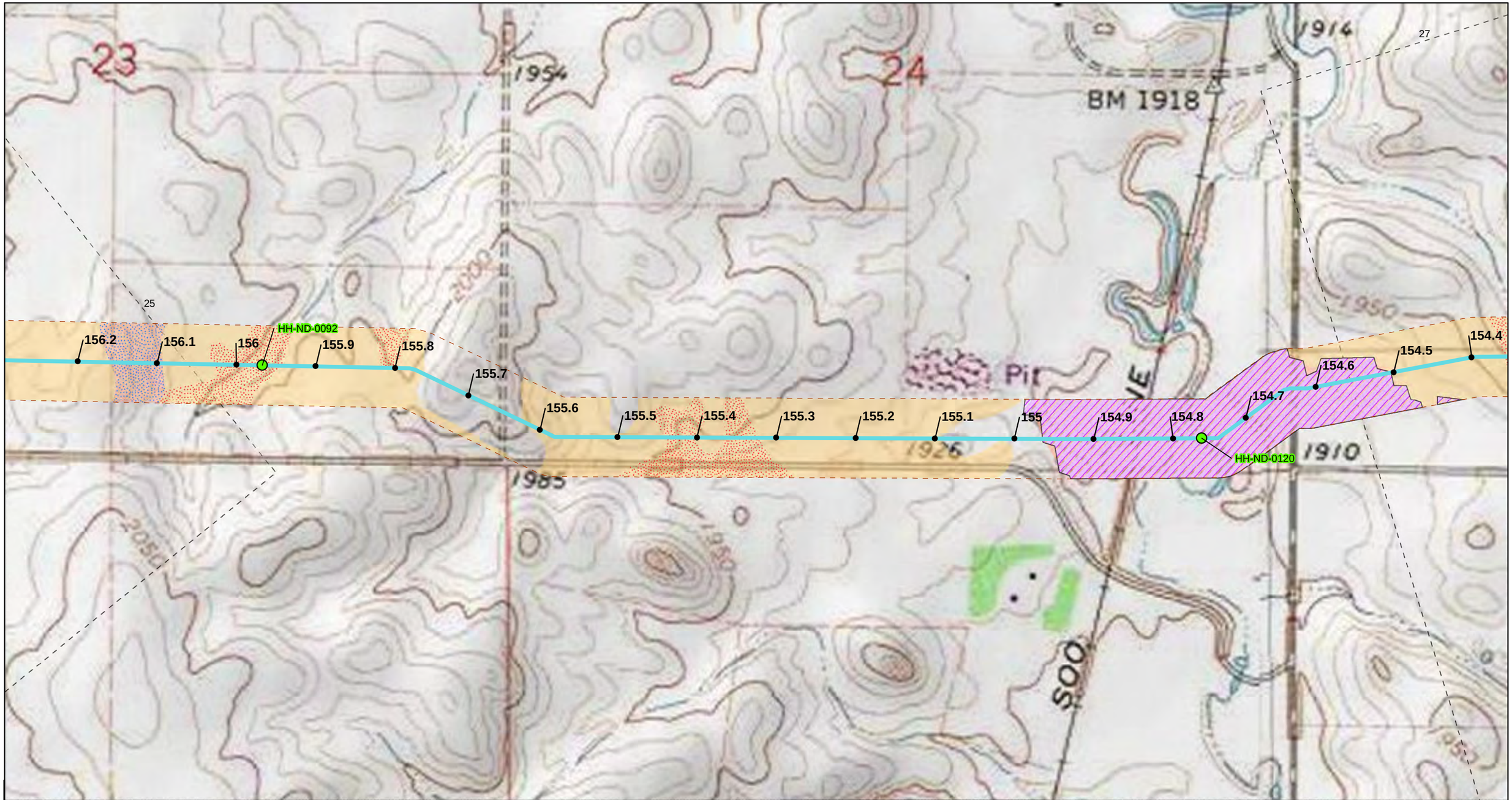

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY

- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-26

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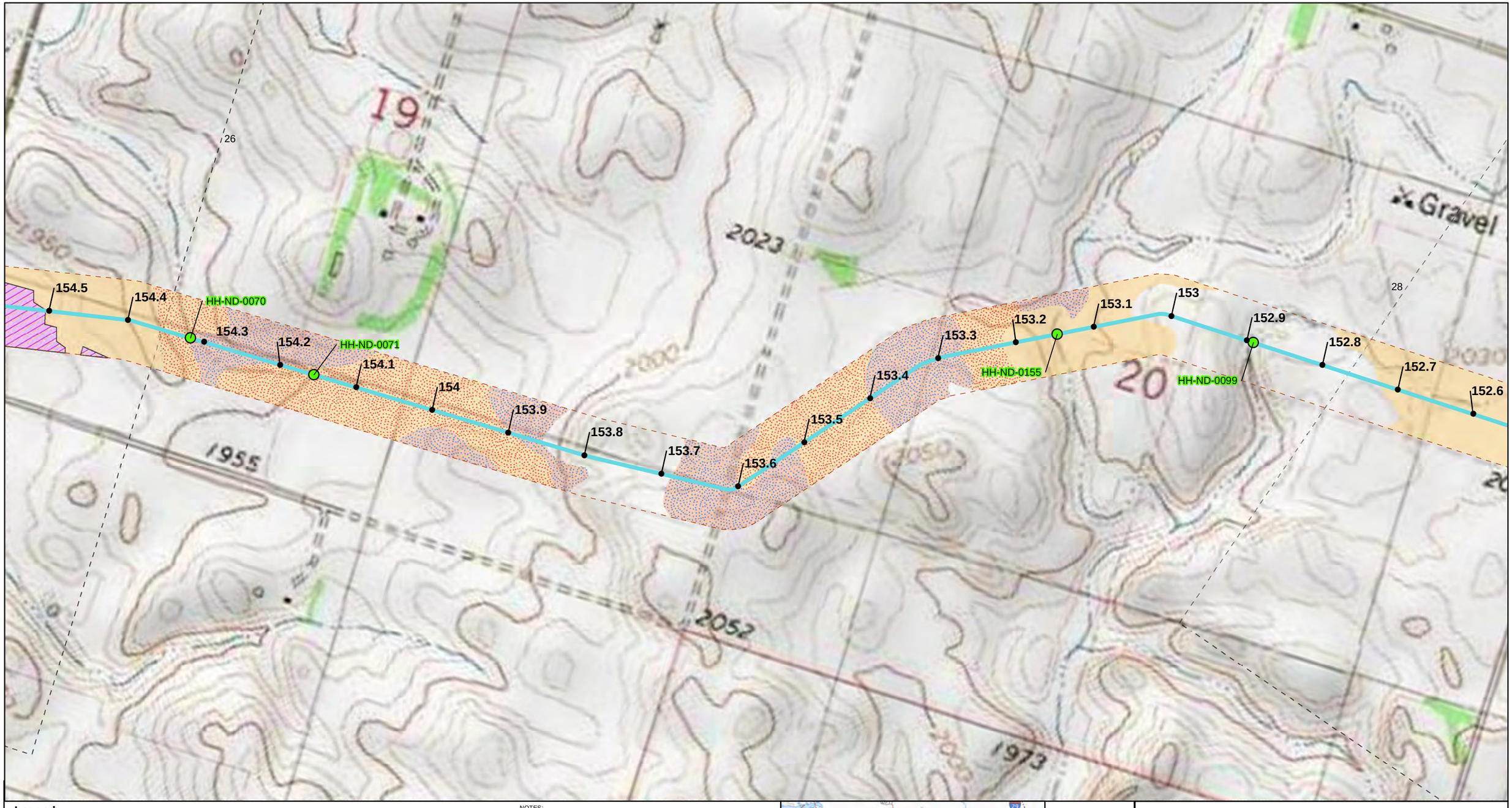

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY

- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
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TXG0450	January 2024	Figure 1-27

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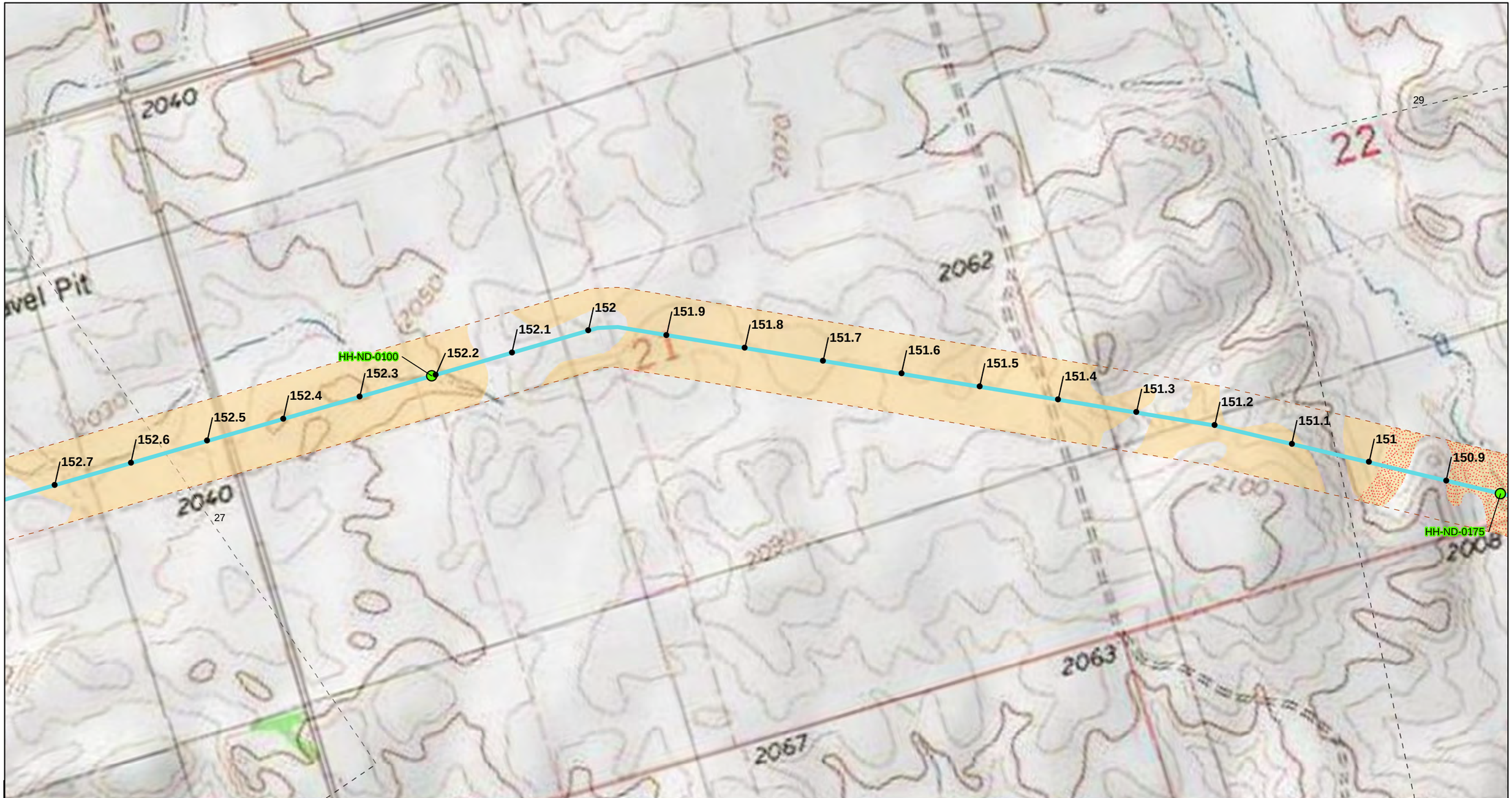

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- MEDIUM

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-28

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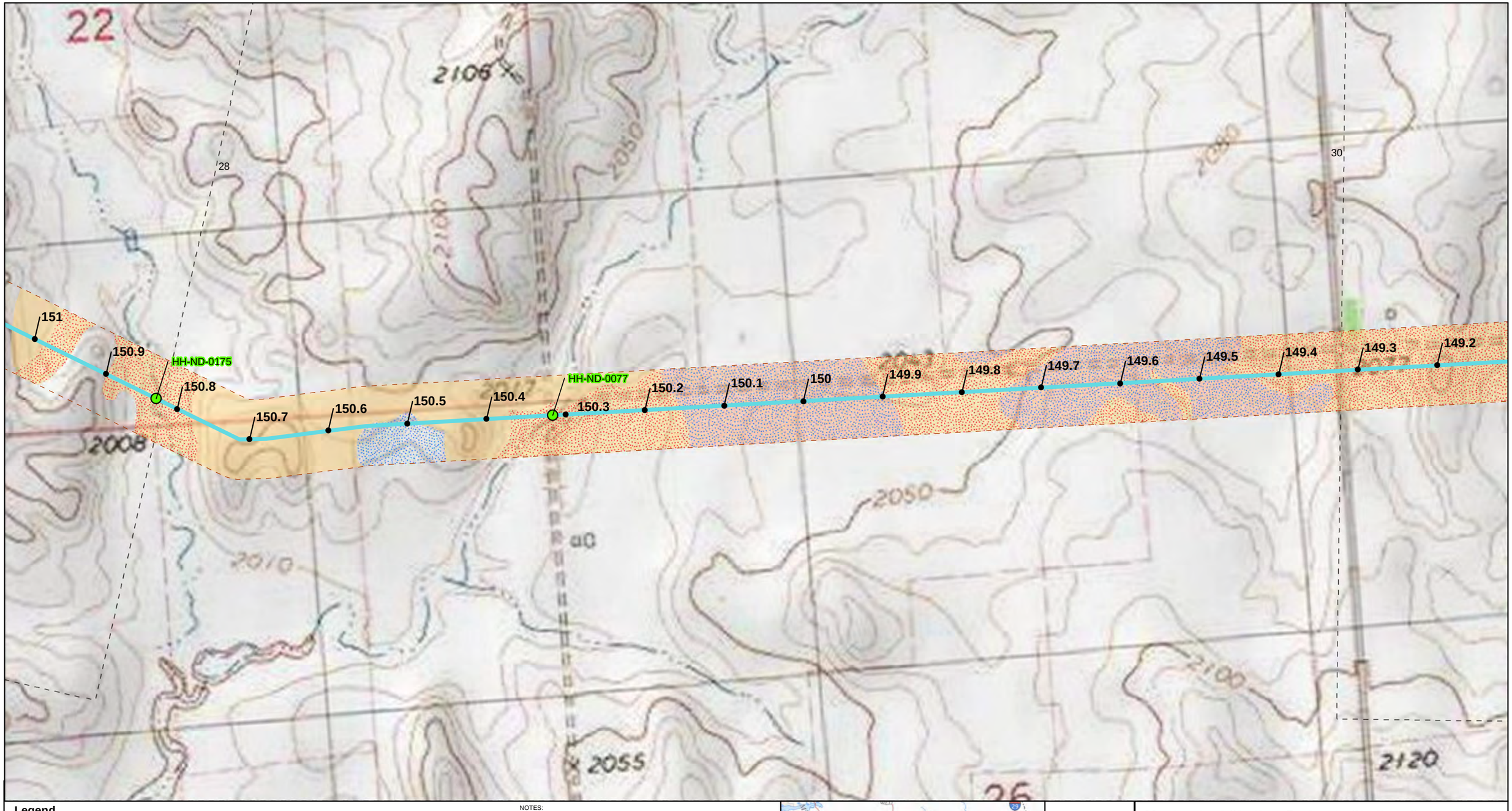

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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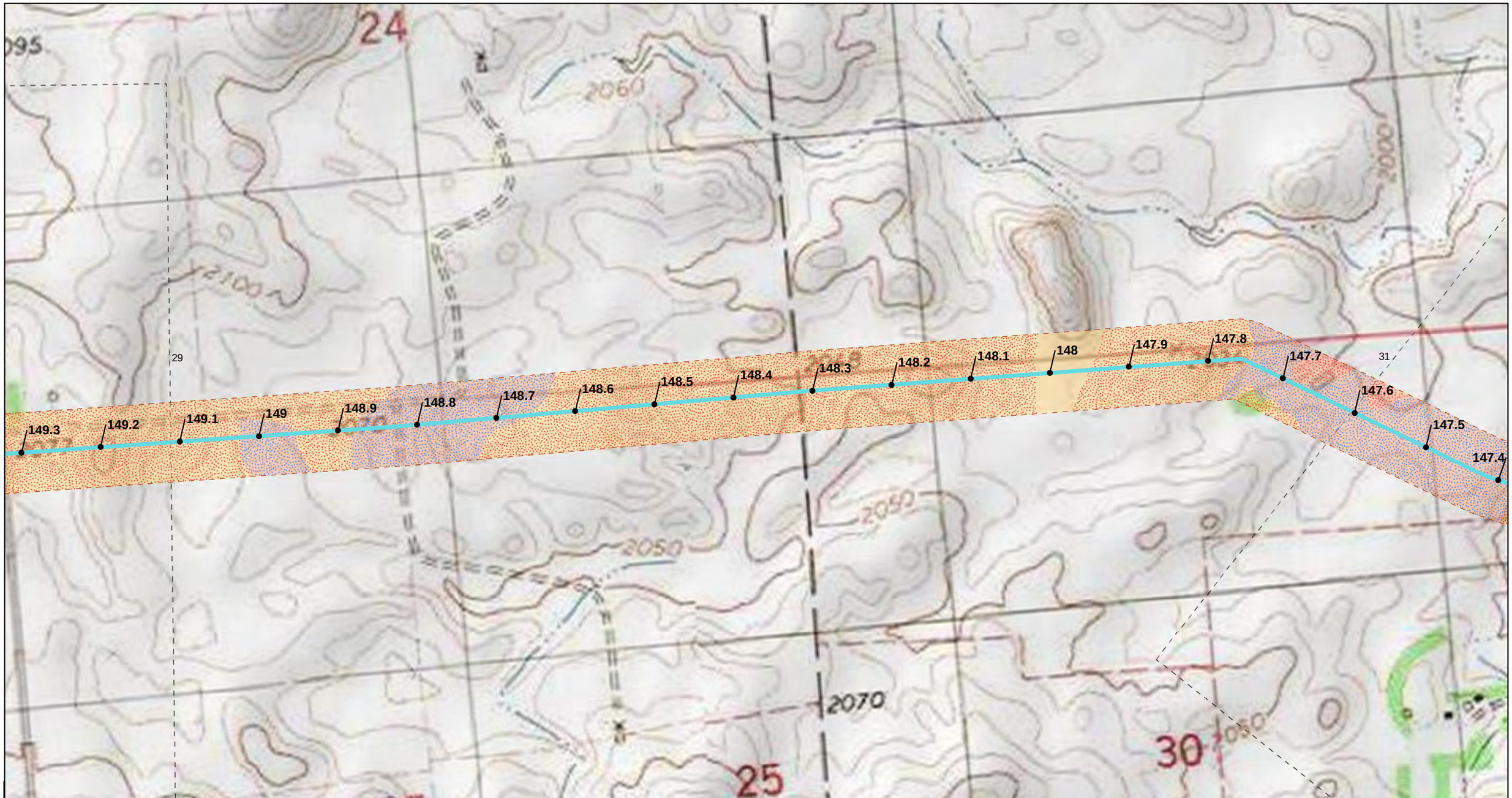

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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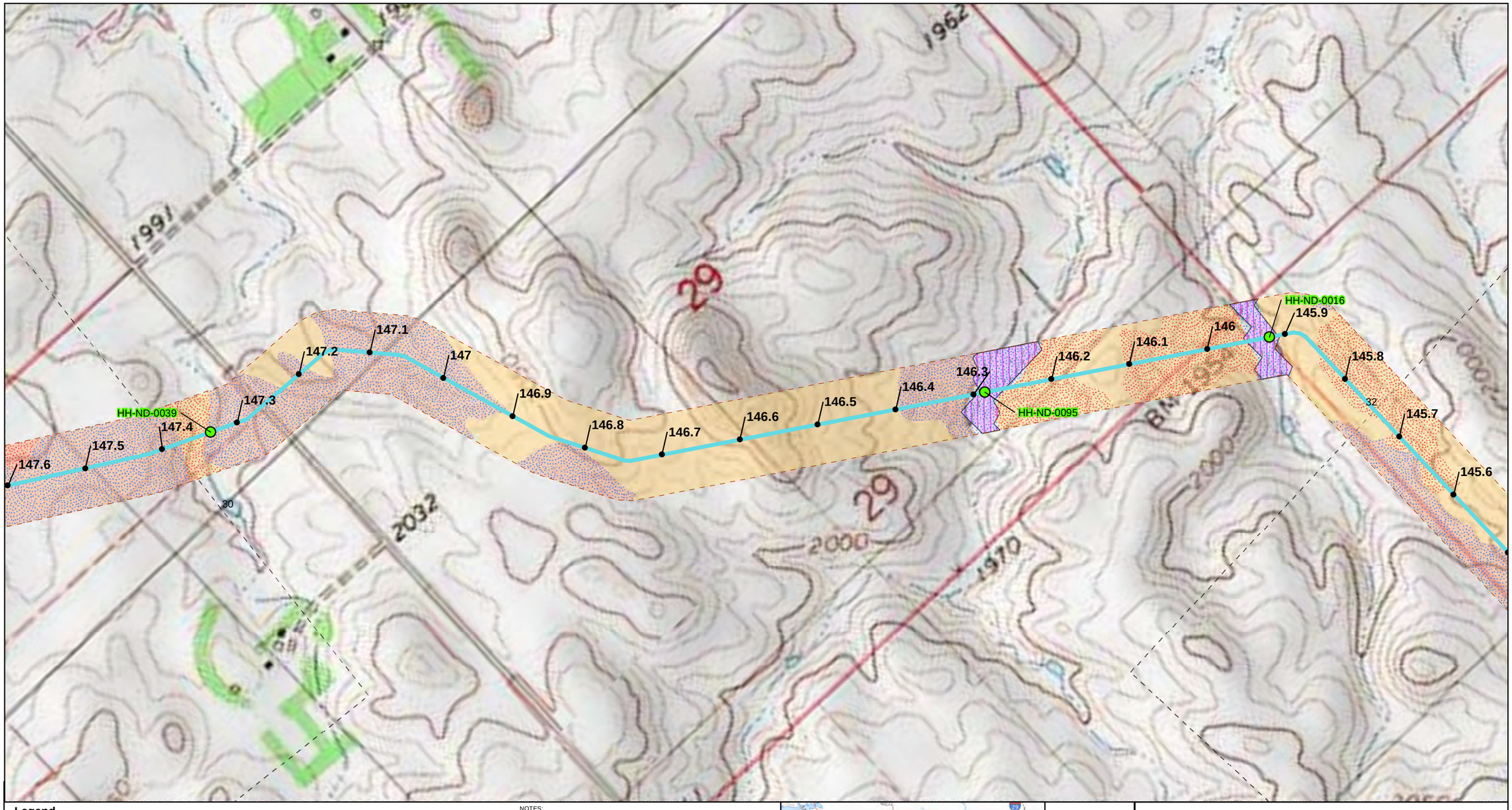

Legend

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- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY

- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

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Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-31

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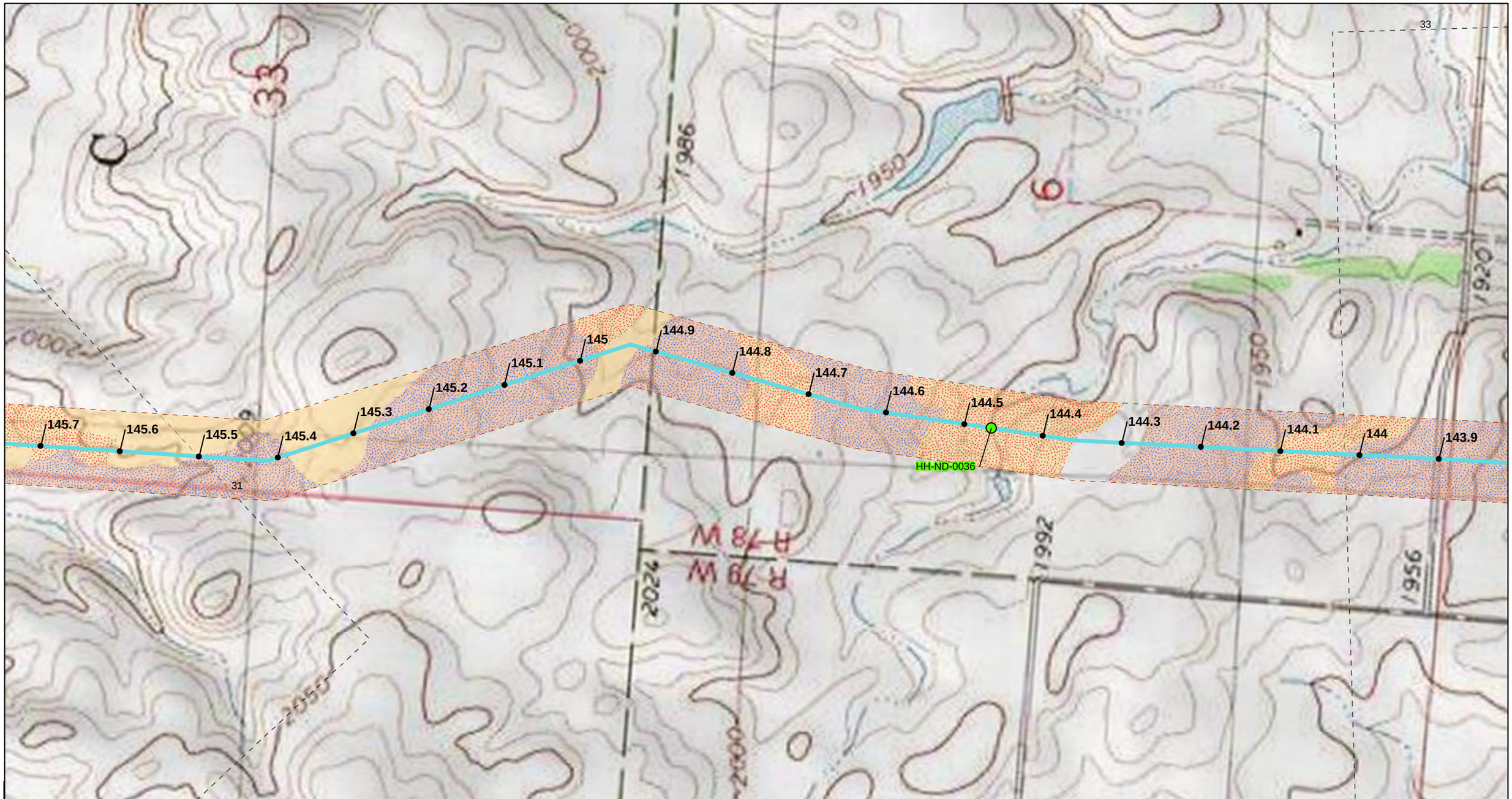

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- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

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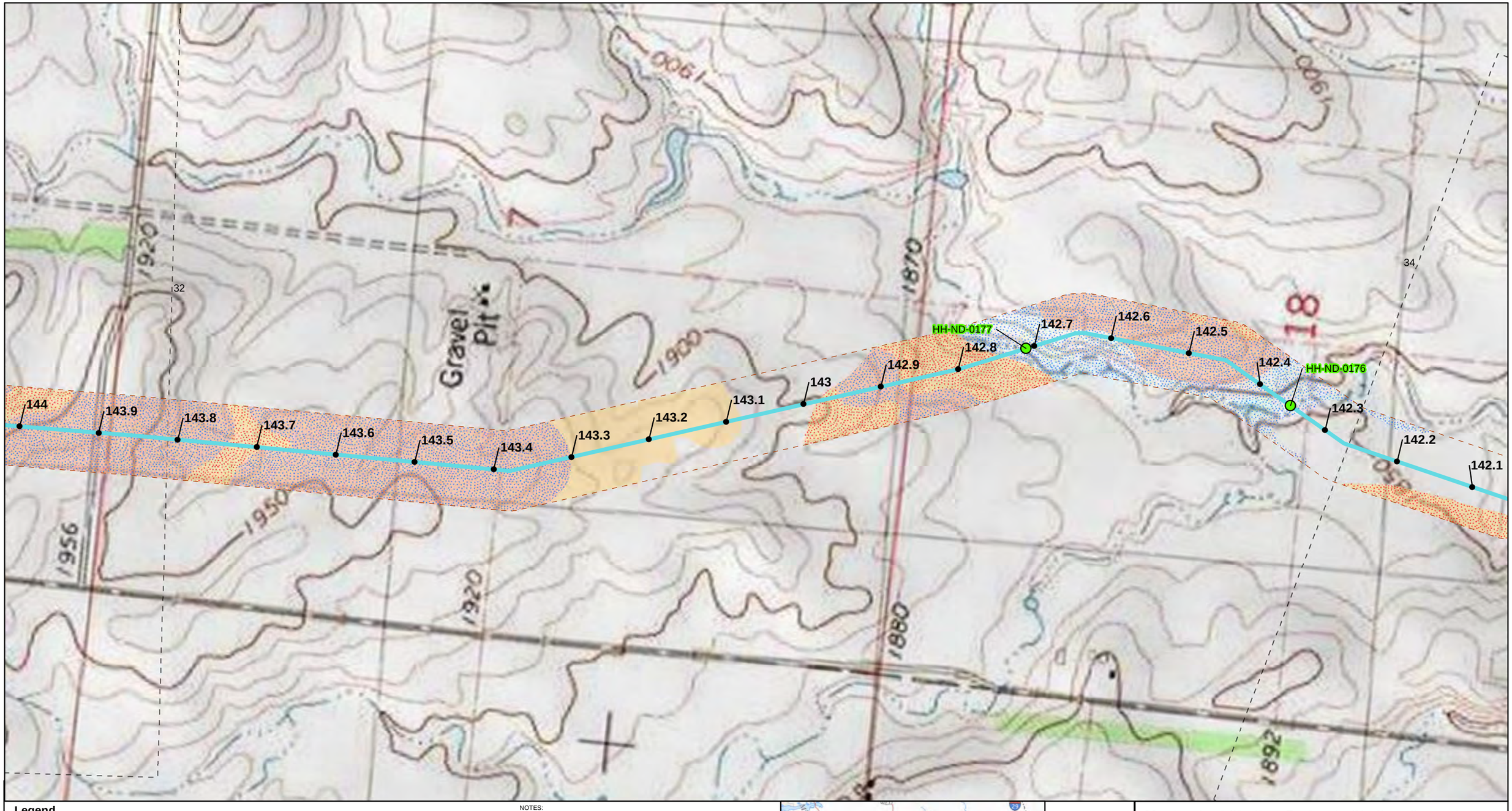

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- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
PIPELINE ALIGNMENTS RECEIVED 1/24/2024.
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-33

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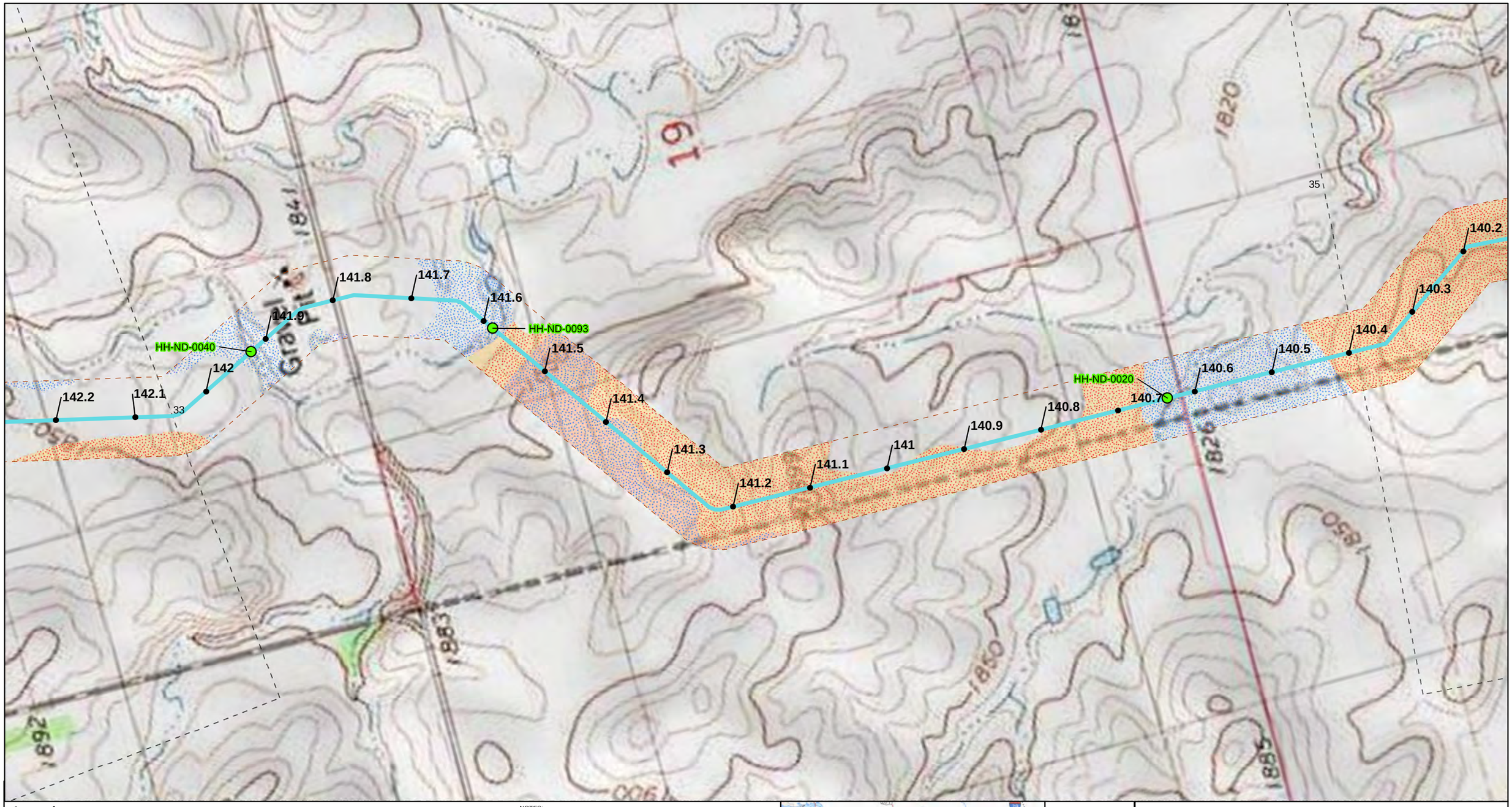

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024

Figure **1-34**

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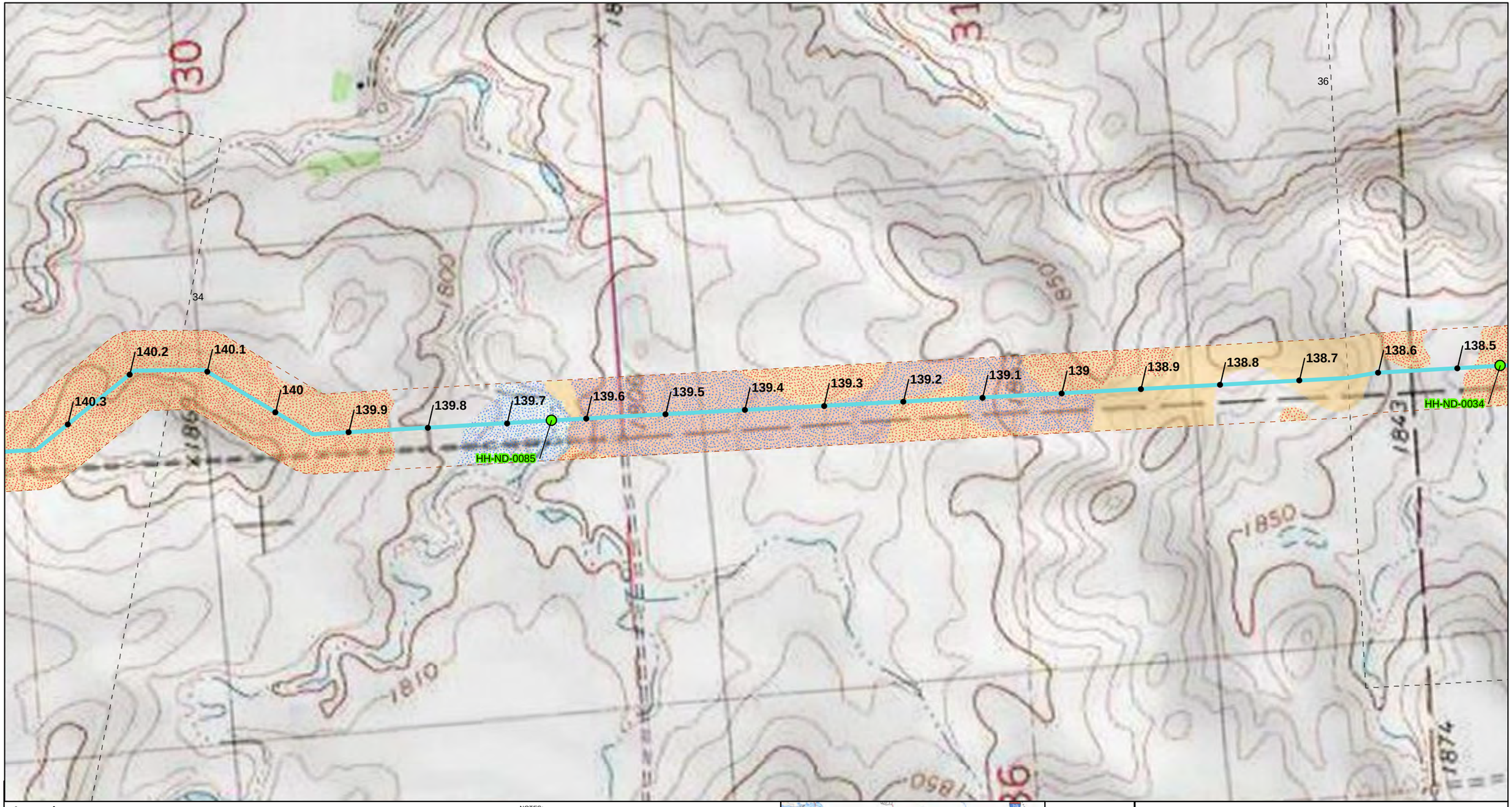

Legend

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- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-35

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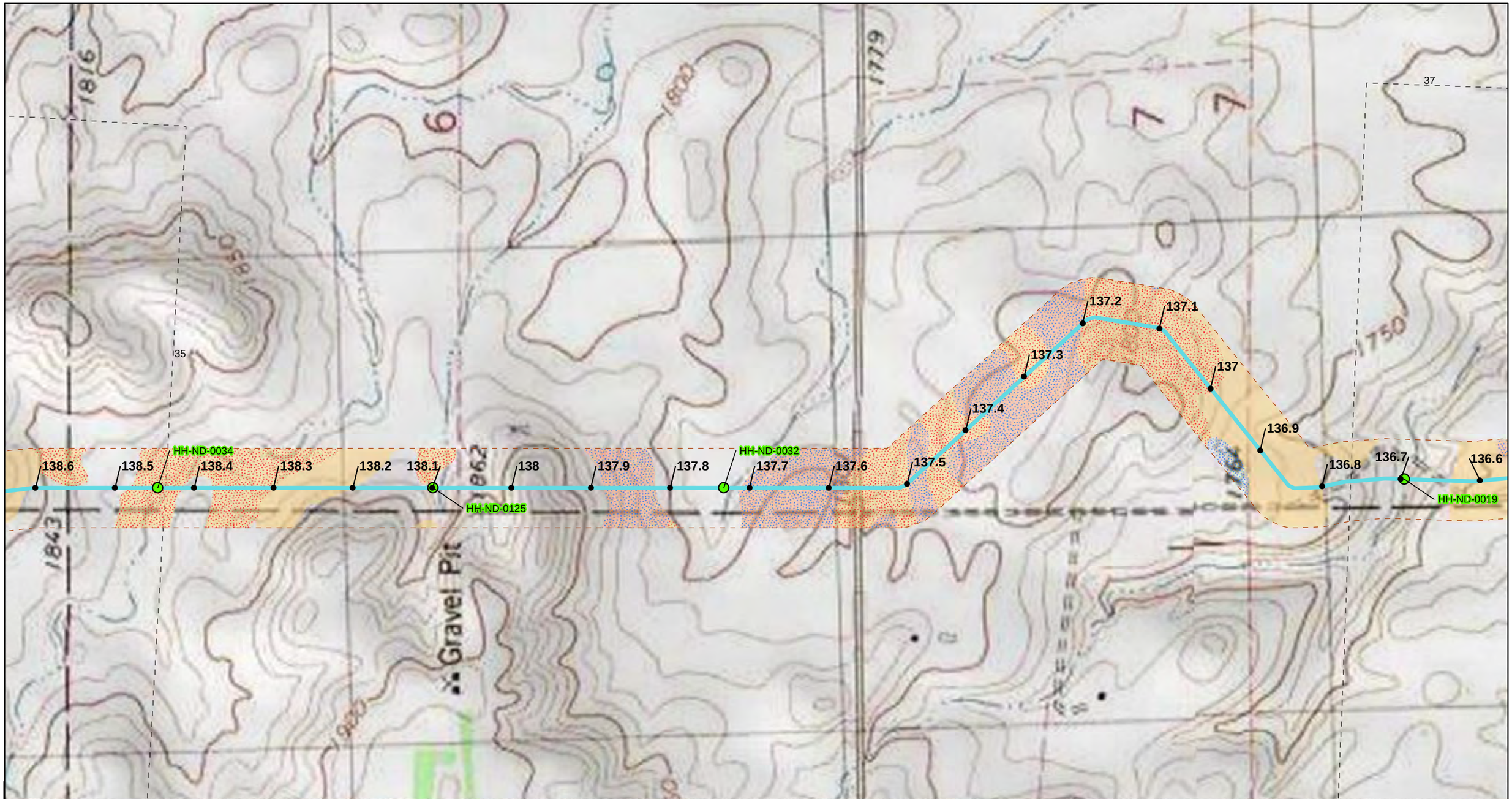

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-36

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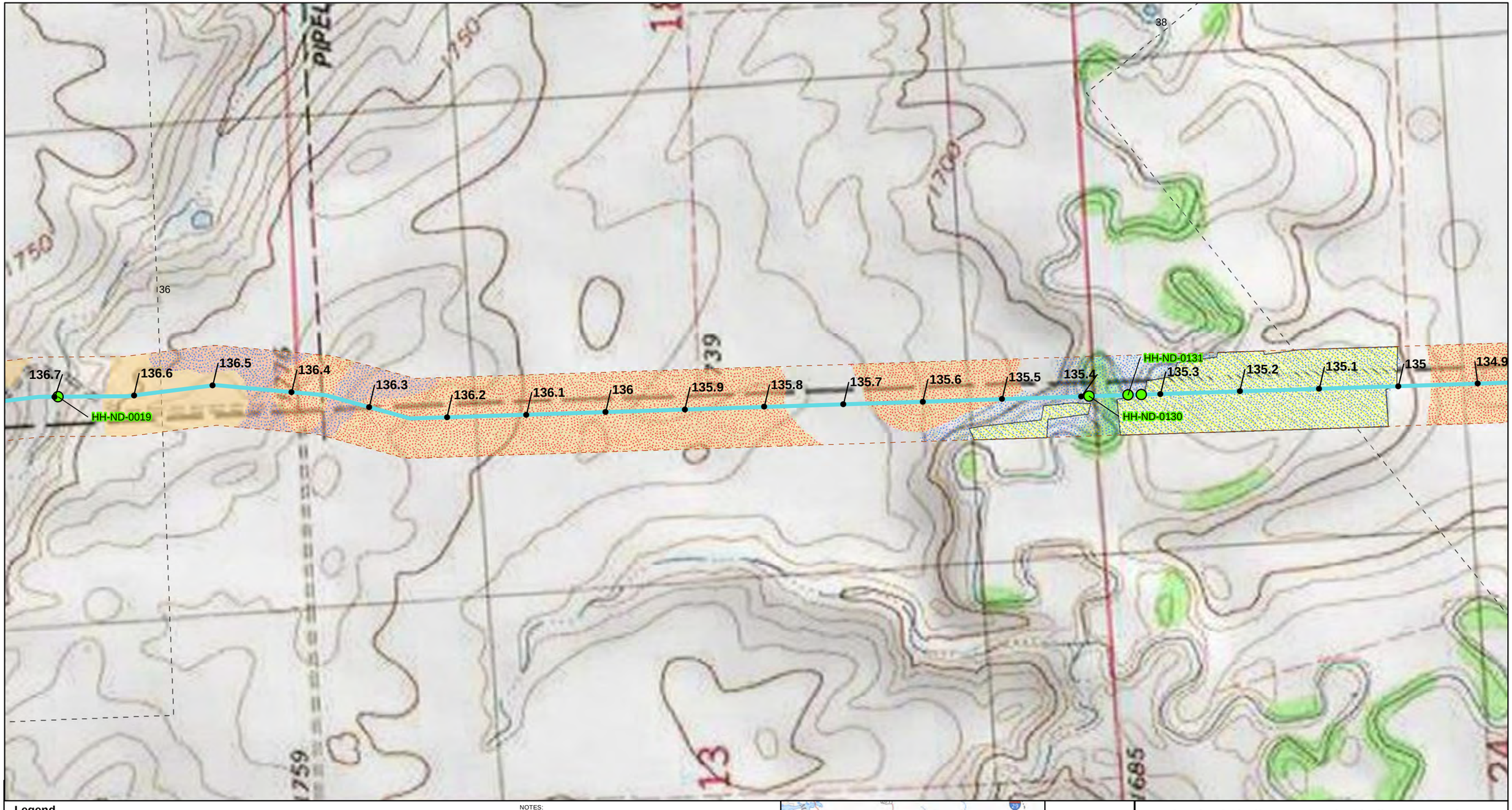

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY

- FLOODING FREQUENCY: RARE

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-37

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: RARE

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-38

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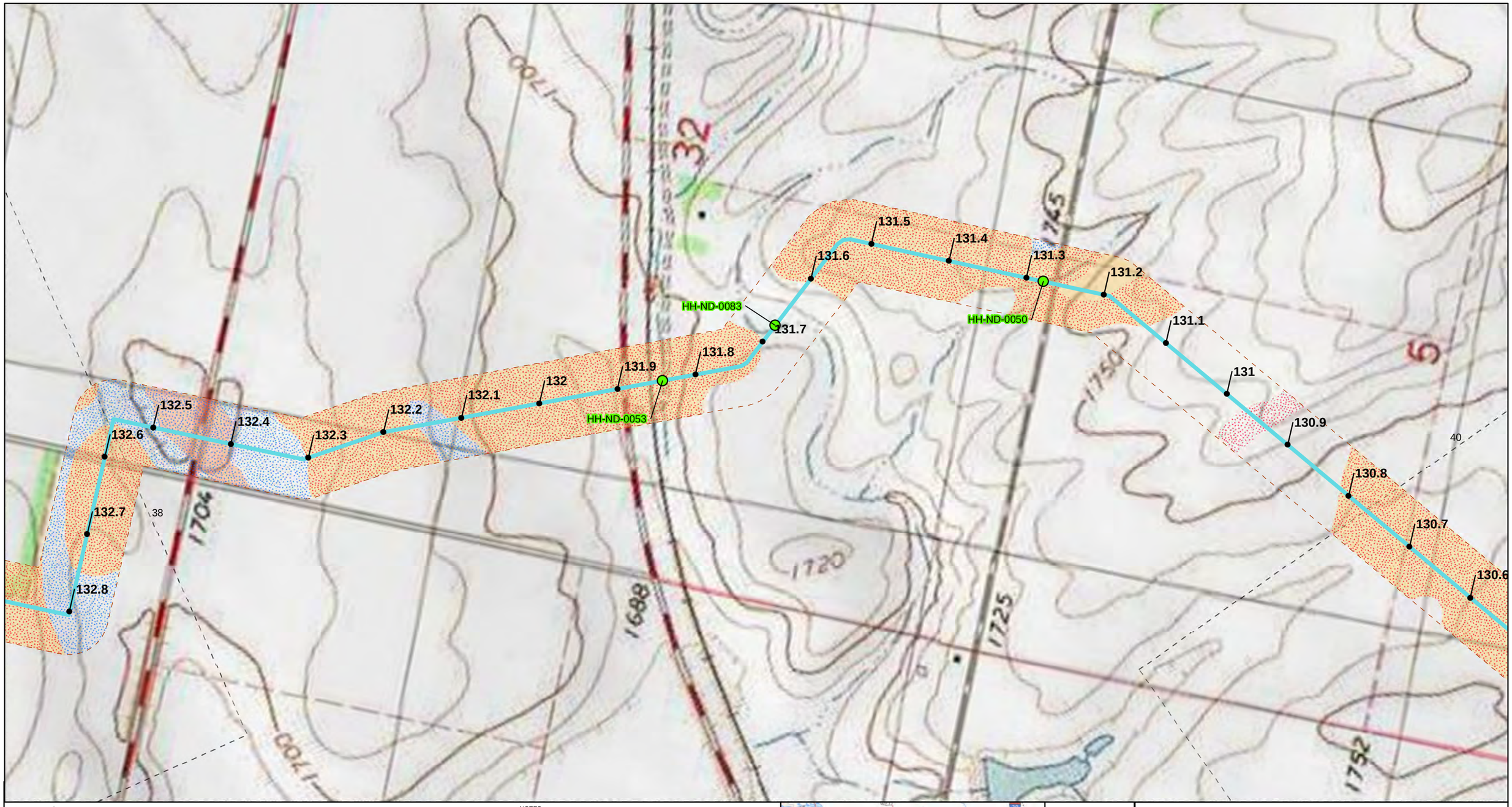

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-39

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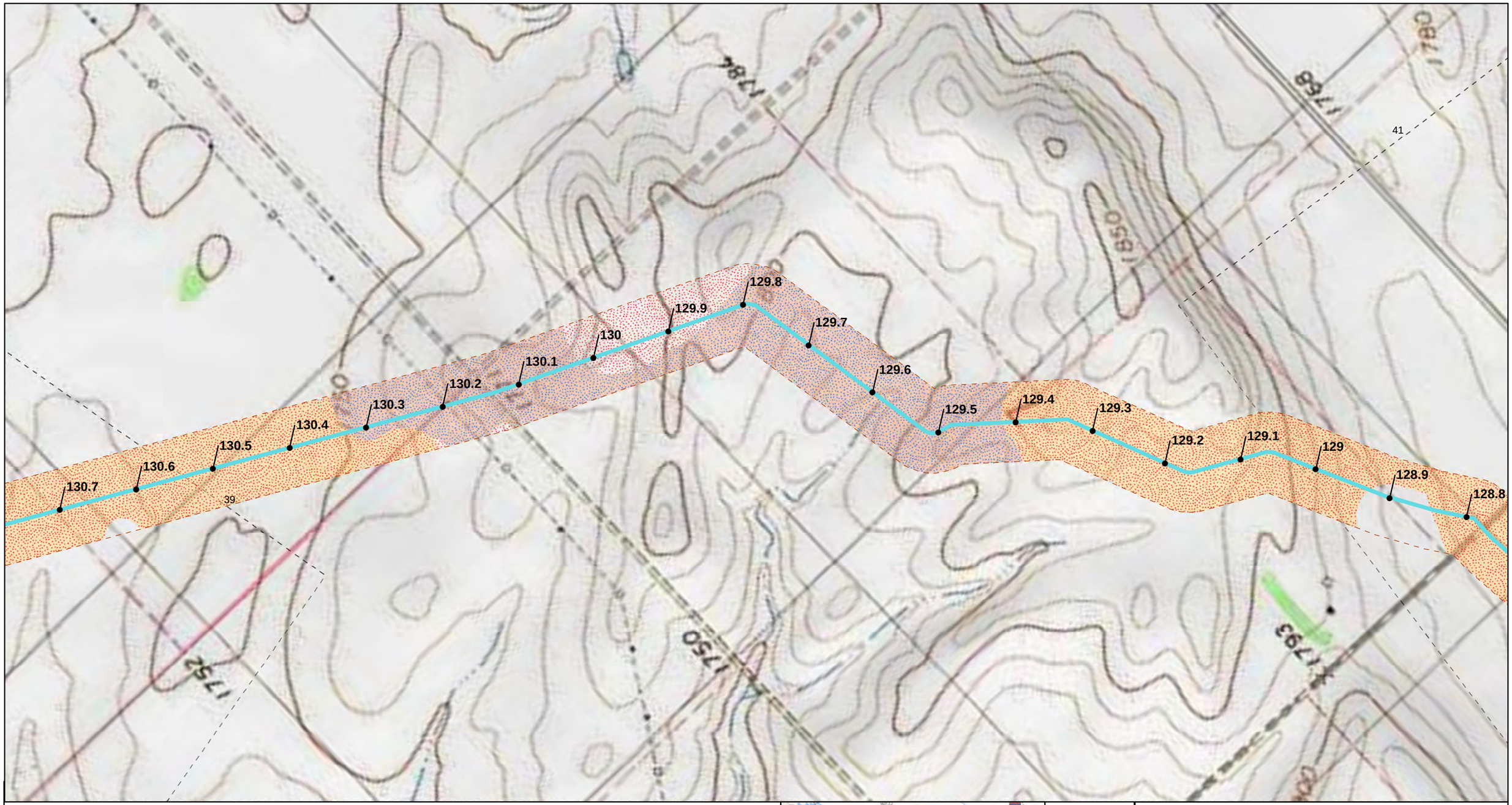

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-40

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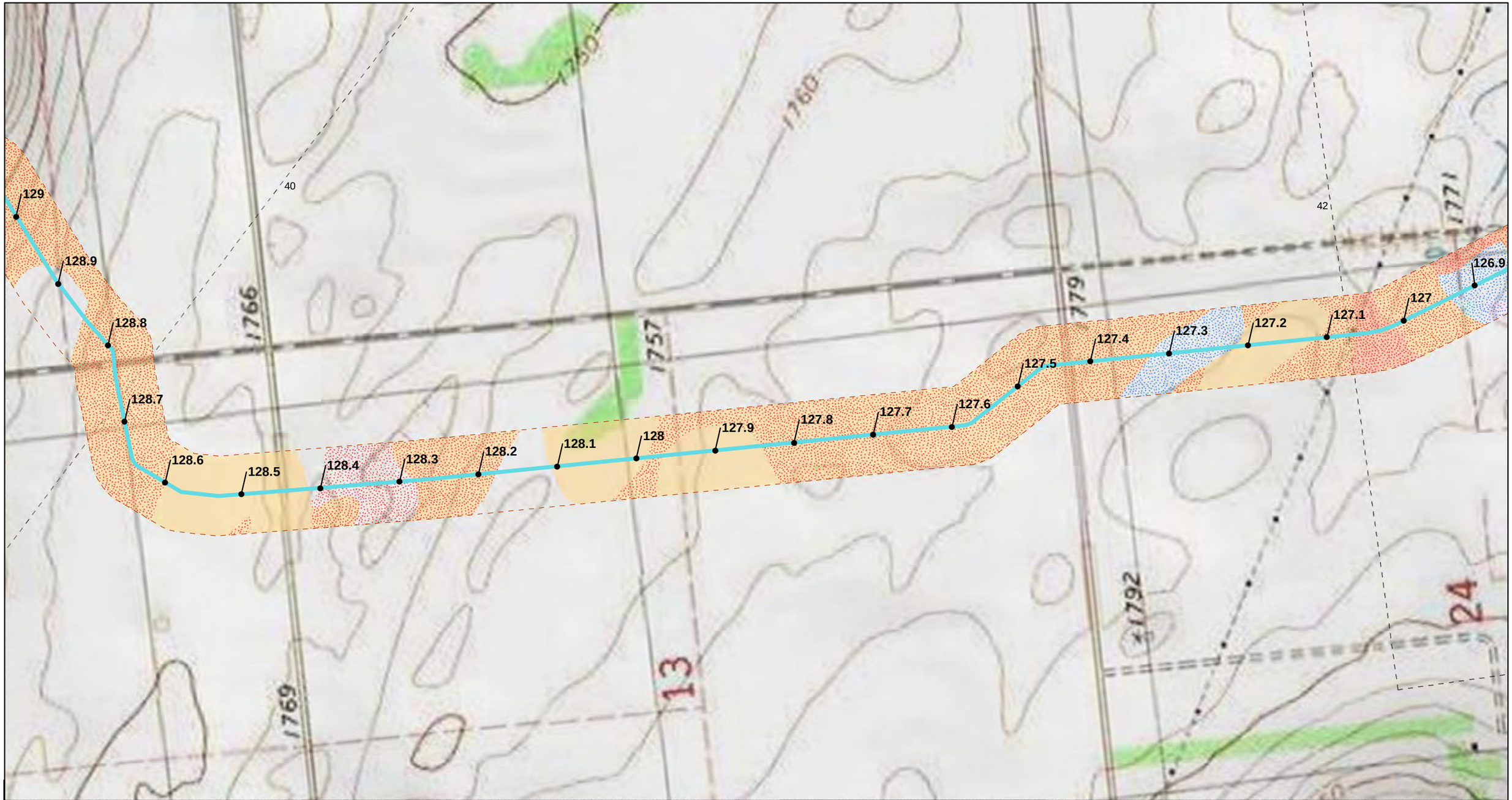

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-41

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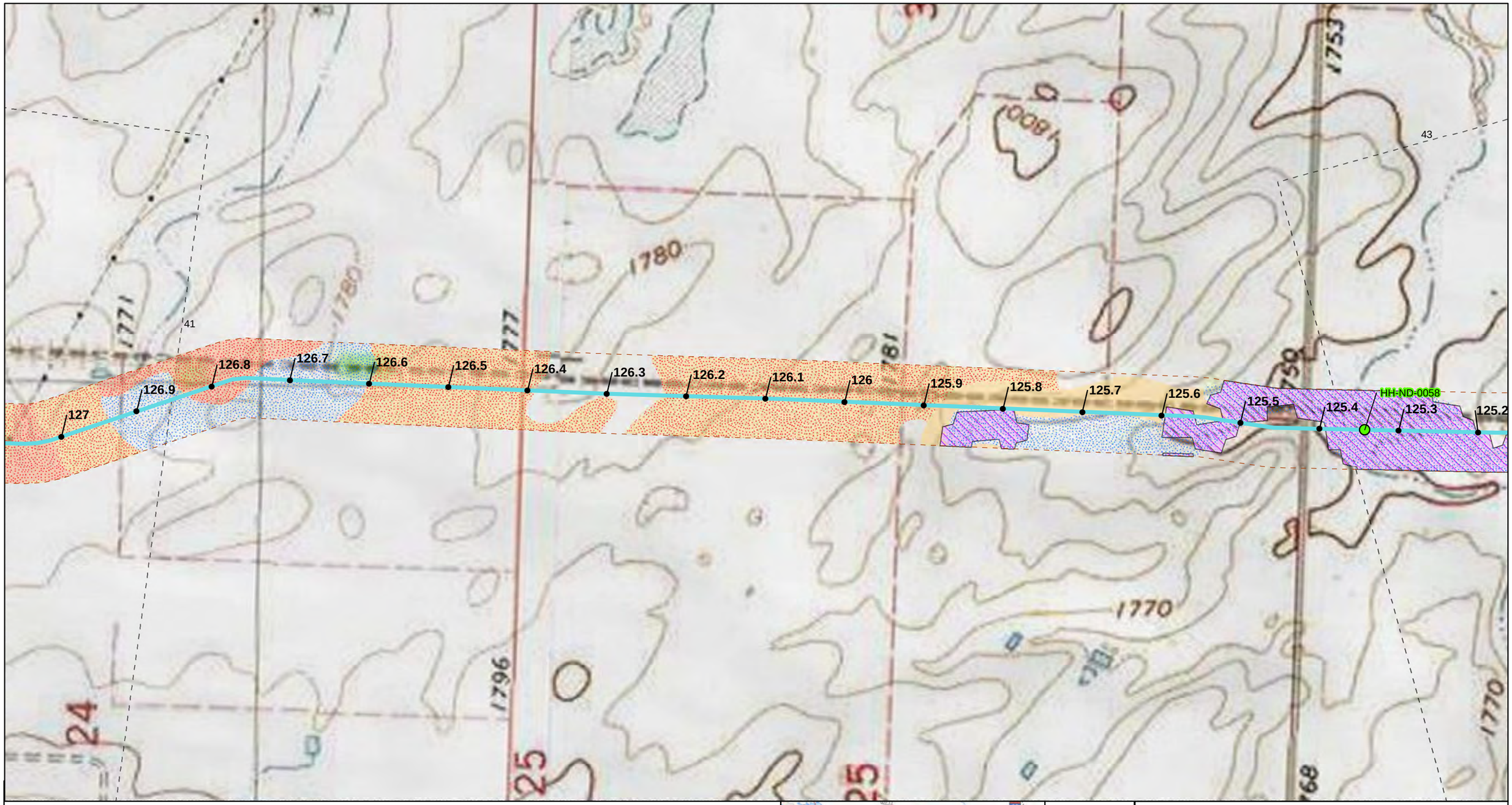

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY

- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-42

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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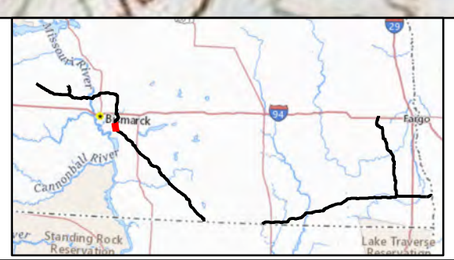

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-43

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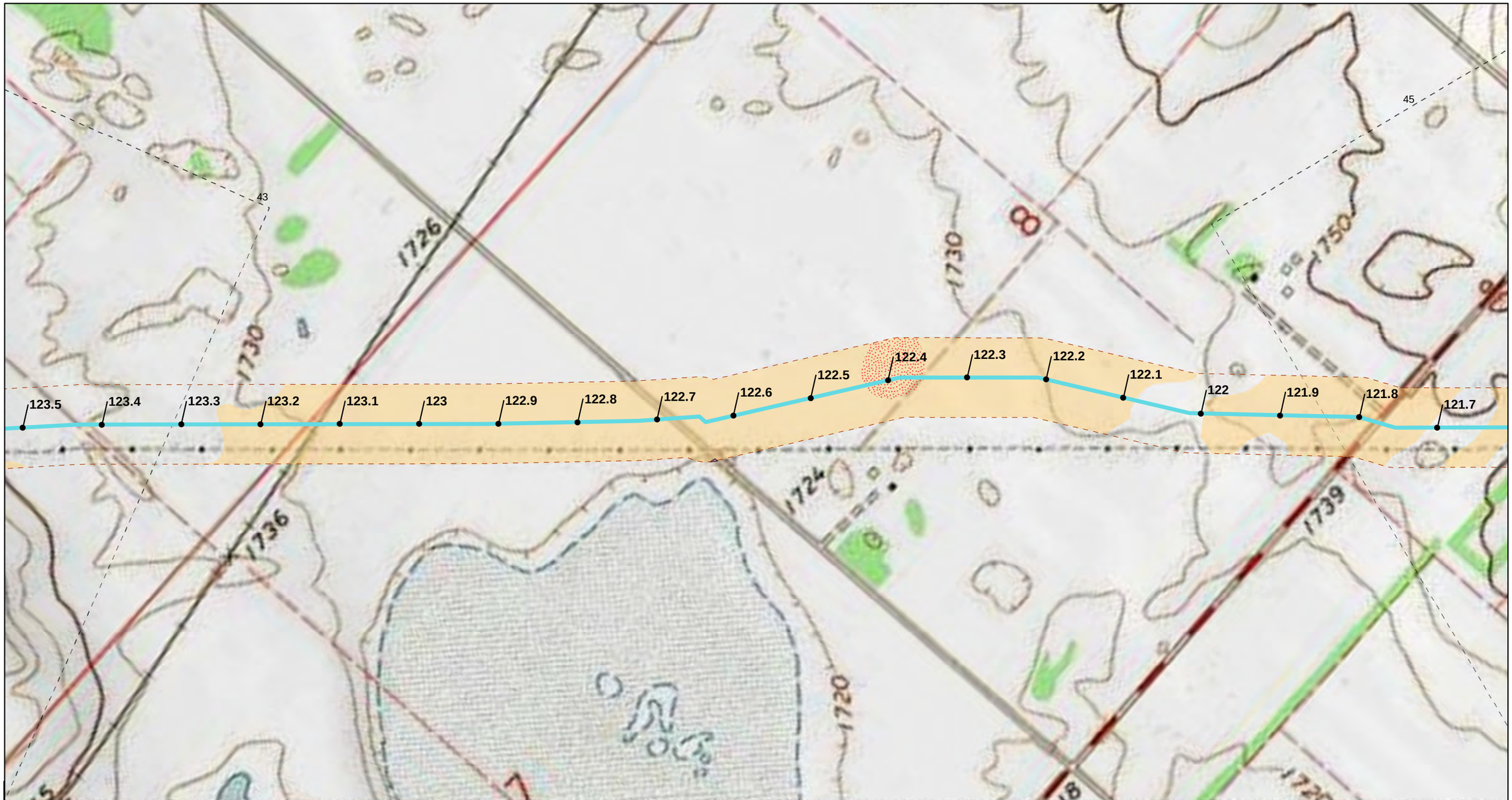

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- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

FLOODING FREQUENCY CATEGORY

- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY

- MEDIUM

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-44

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120.1
120
119.9
119.8

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
FROST ACTION CATEGORY
MEDIUM

NOTES:
PIPELINE ALIGNMENTS RECEIVED 1/24/2024.
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-45

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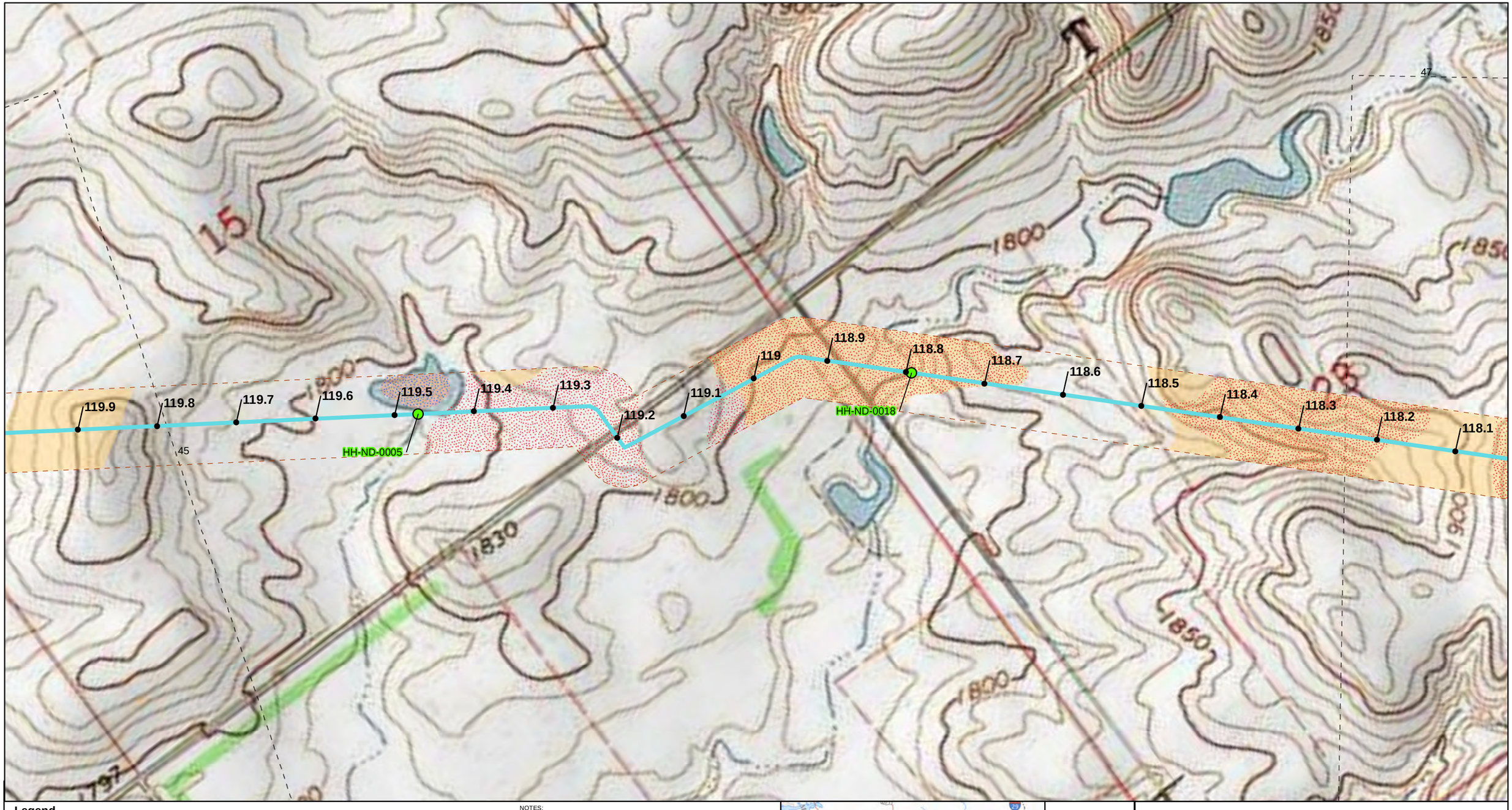

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
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- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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TXG0450	January 2024	Figure 1-46

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Legend

- REVISION 9 ROUTE MILEPOSTS
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- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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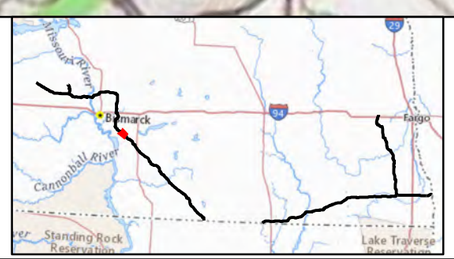

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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Figure **1-47**

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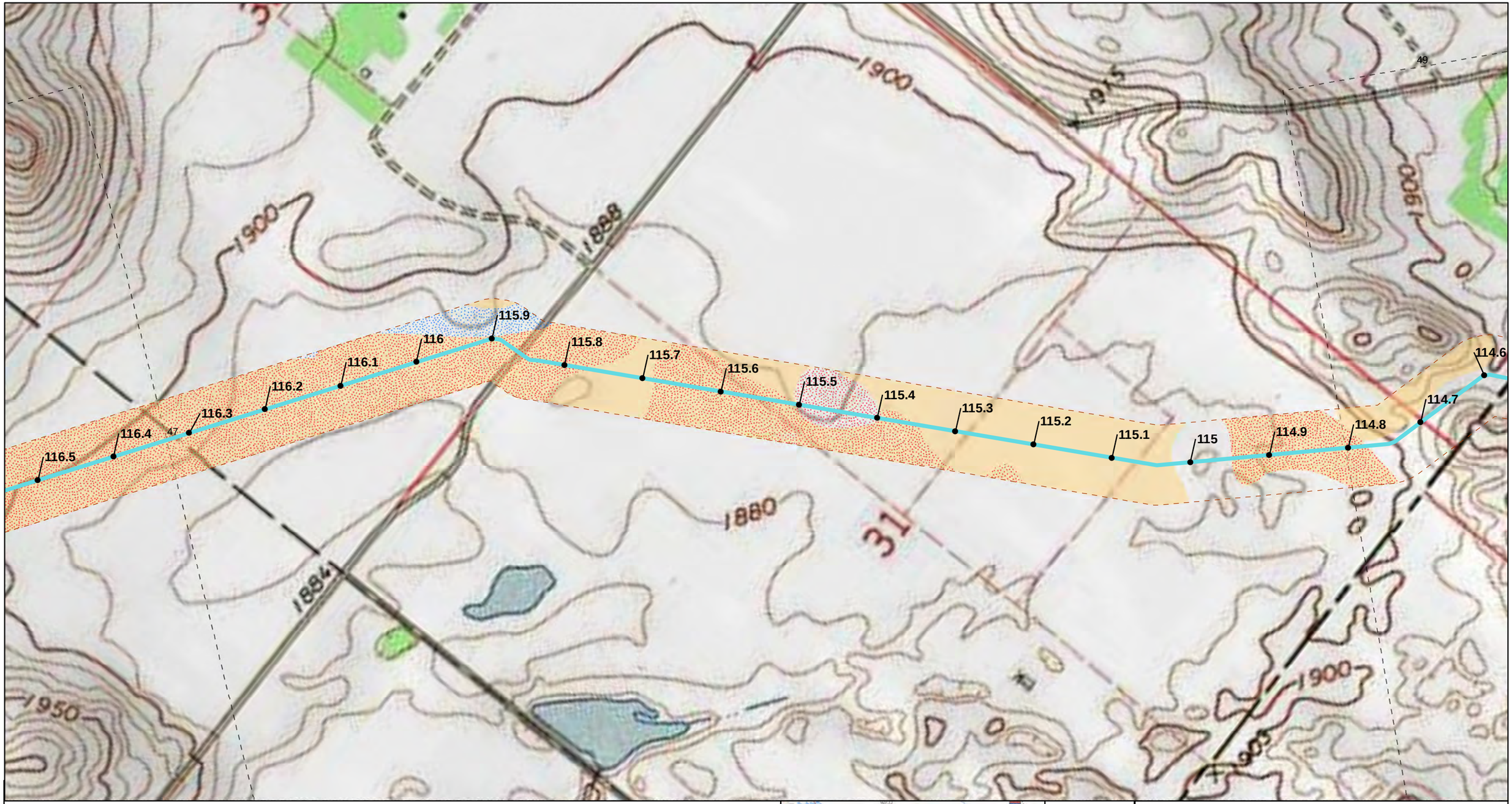

Legend

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- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
HIGHER: LEP >6
FROST ACTION CATEGORY
MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-48

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Legend

- REVISION 9 ROUTE MILEPOSTS
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- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-49

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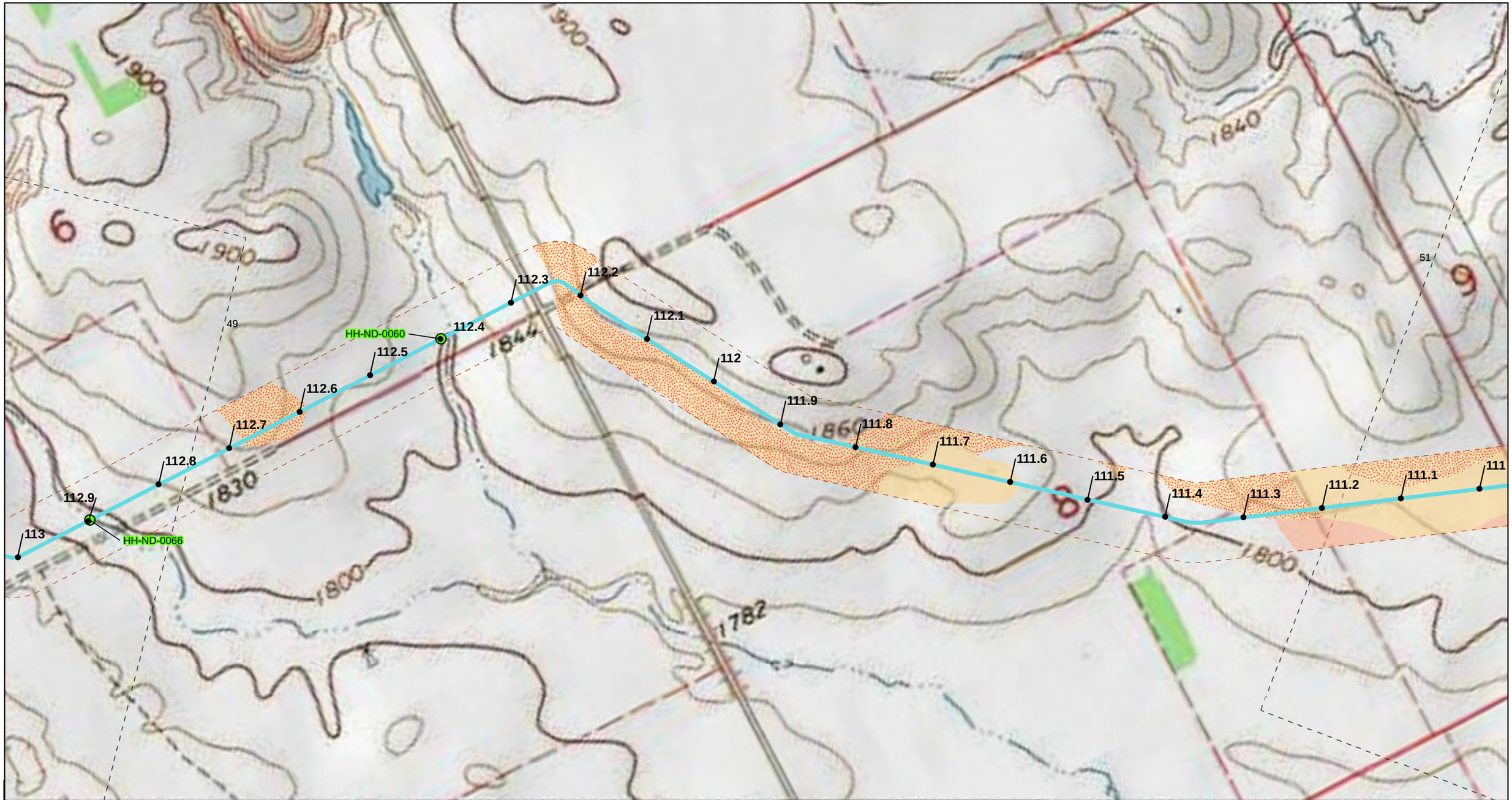

Legend

- REVISION 9 ROUTE MILEPOSTS
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- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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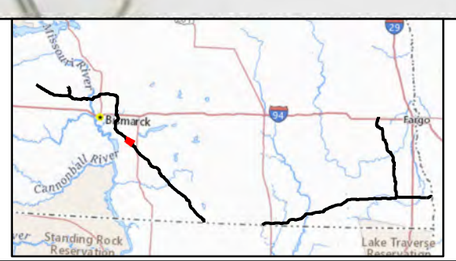

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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TXG0450	January 2024	Figure 1-50

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Legend

- REVISION 9 ROUTE MILEPOSTS
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- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY

- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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TXG0450	January 2024	Figure 1-51

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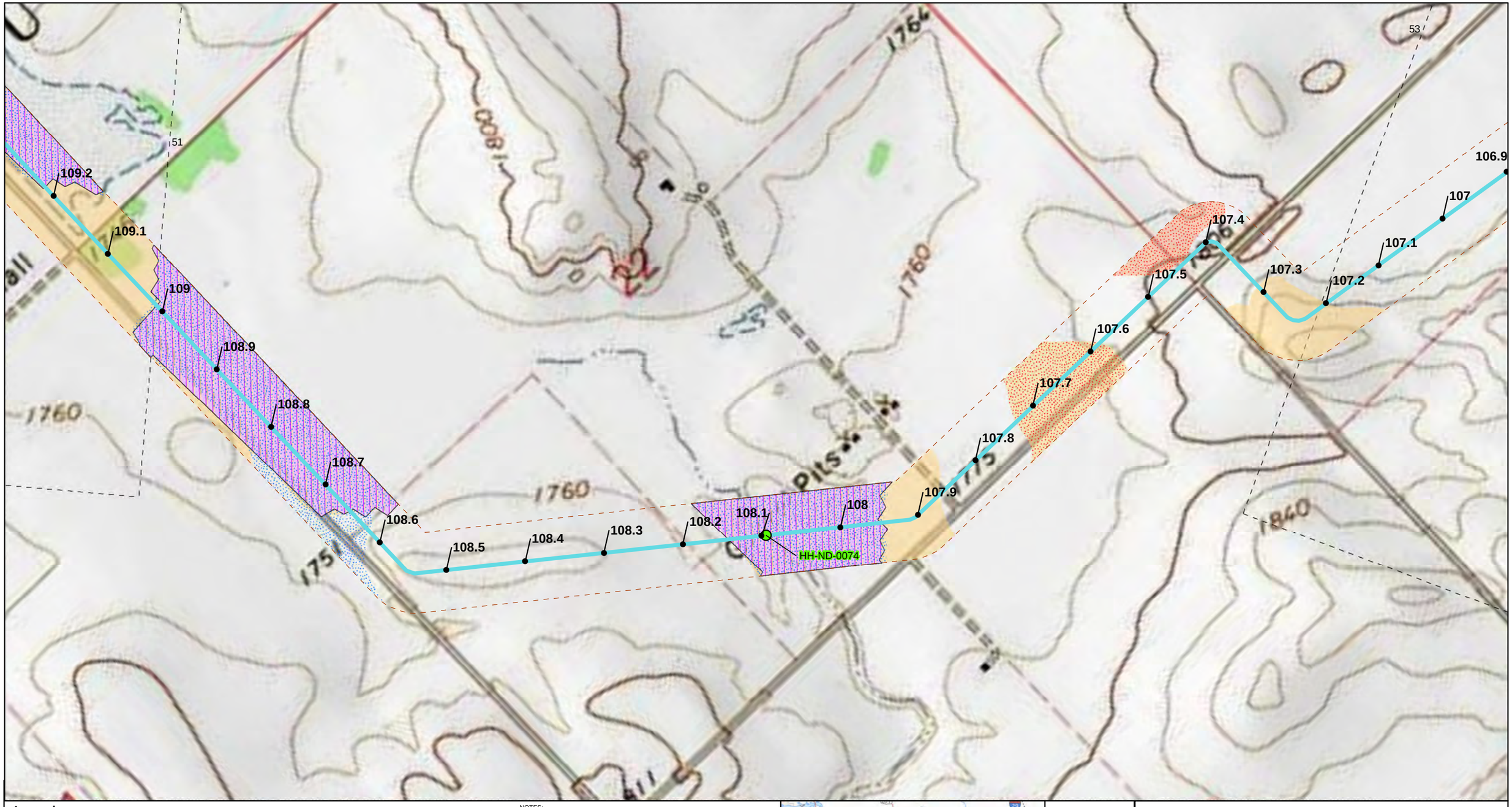

Legend

- REVISION 9 ROUTE MILEPOSTS
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- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY

- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES) SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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TXG0450	January 2024	Figure 1-52

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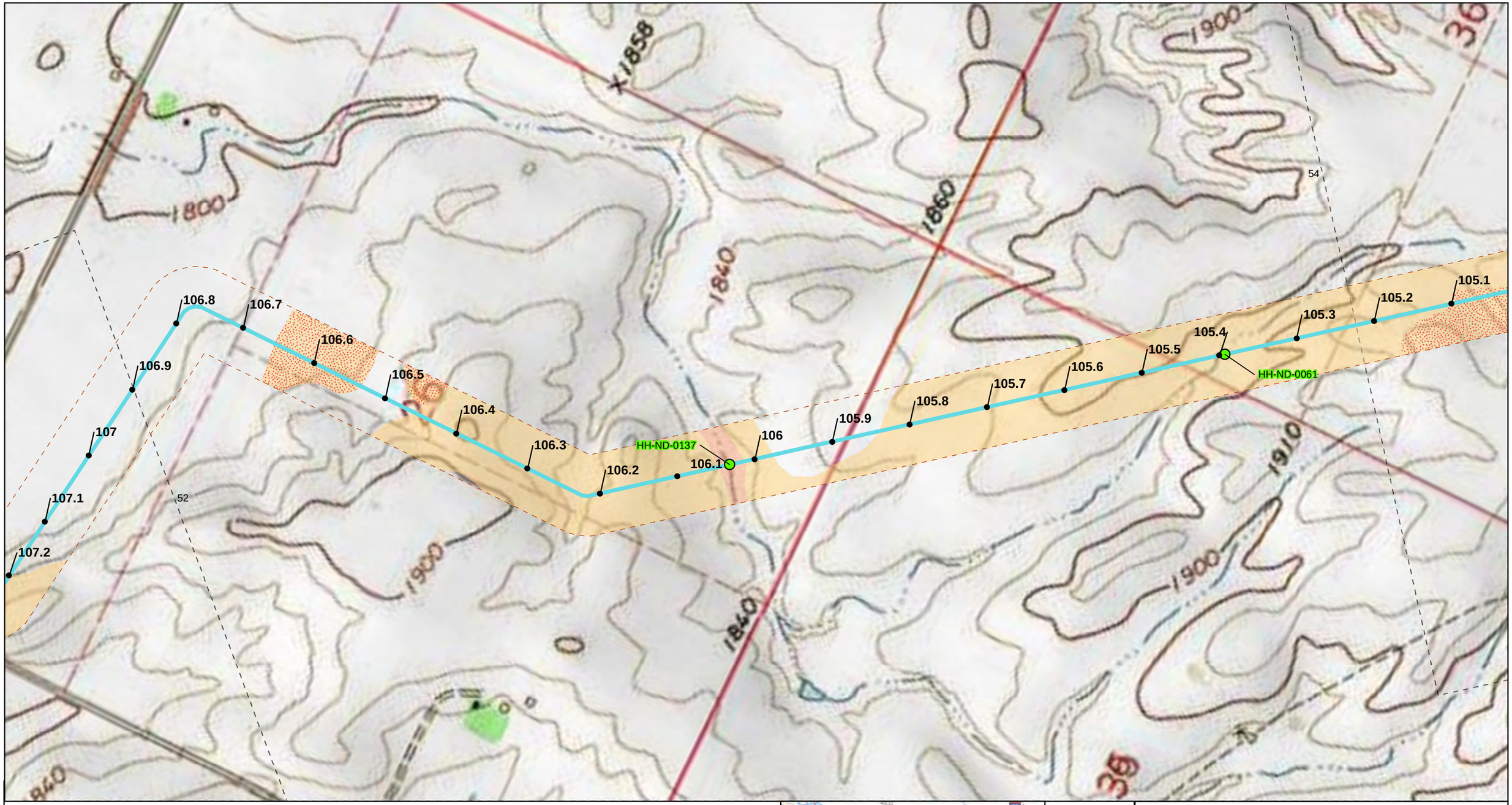

Legend

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- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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Phase I Assessment

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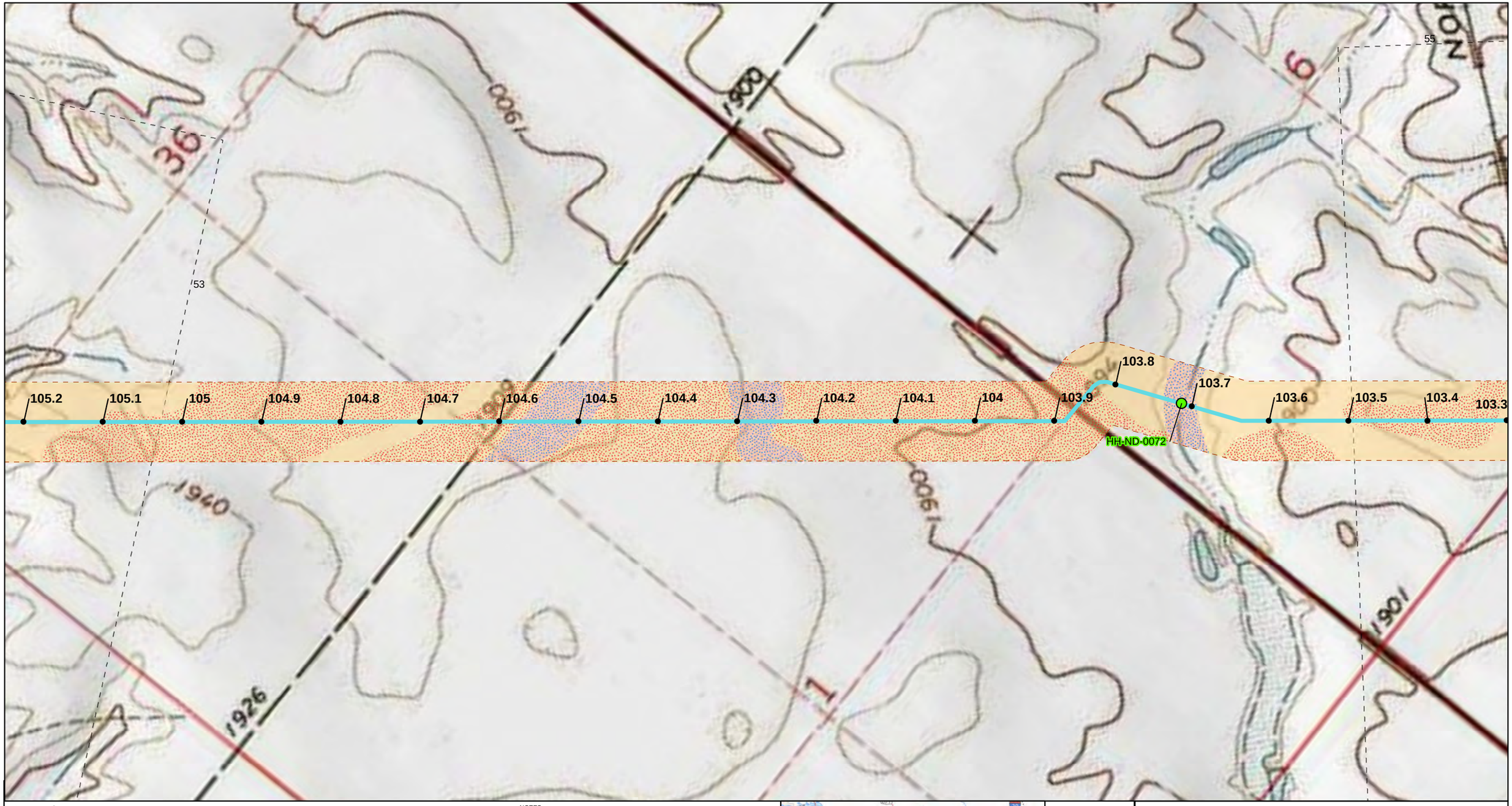

Legend

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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450 | January 2024

Figure **1-54**

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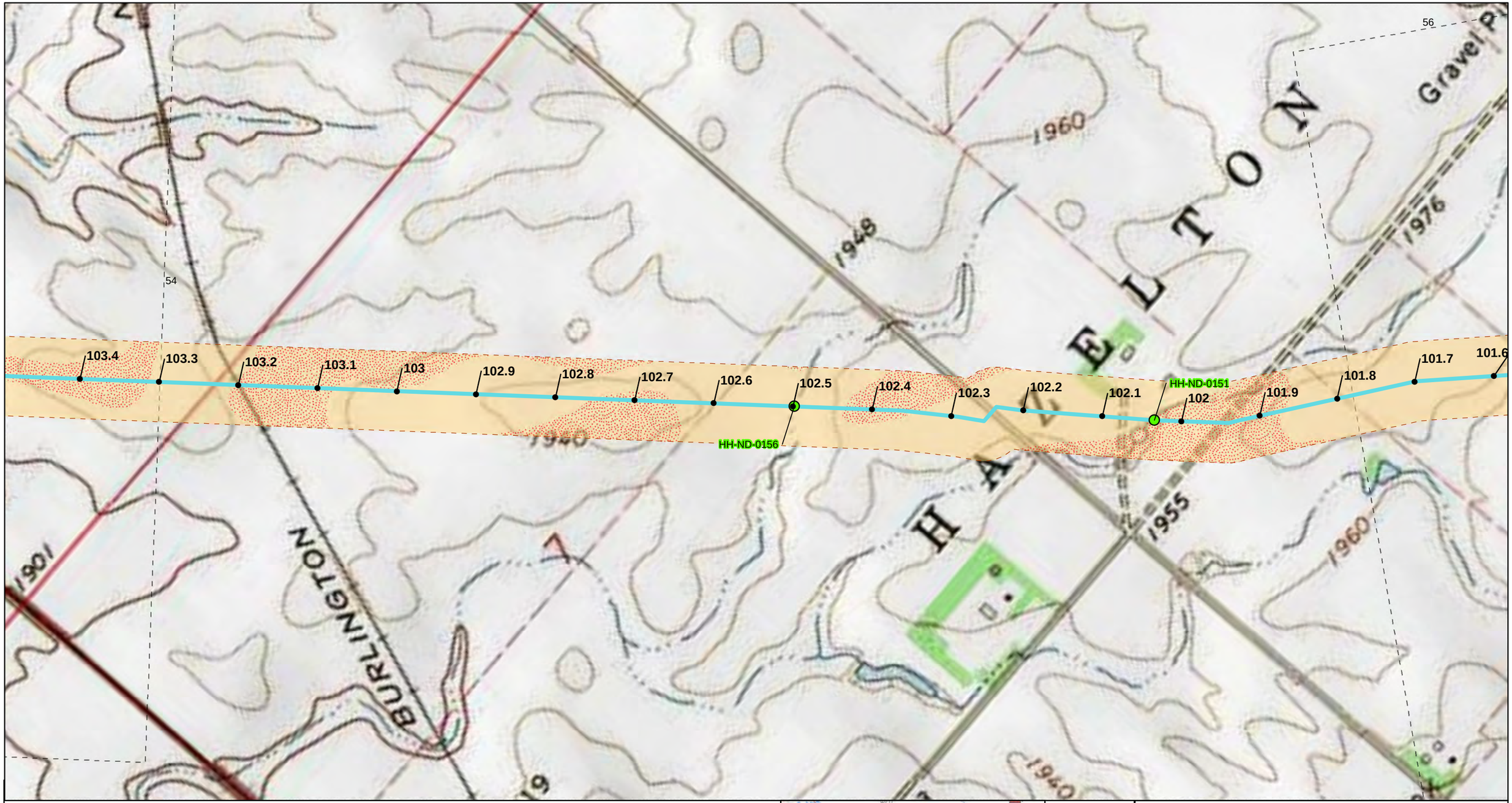

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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- MEDIUM

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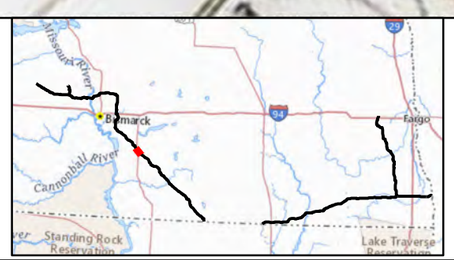

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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Phase I Assessment

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Figure **1-55**

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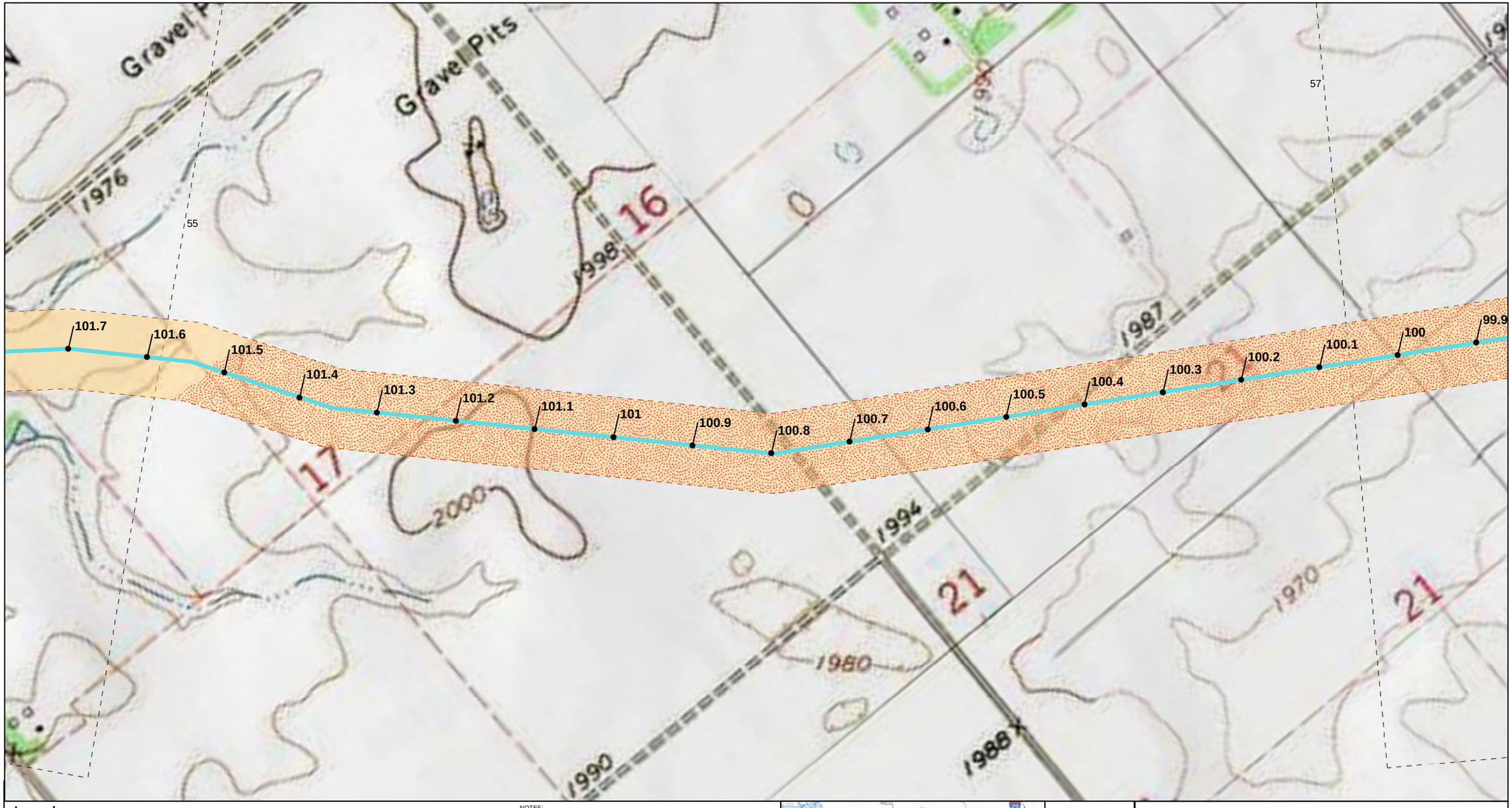

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- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- MEDIUM

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-56

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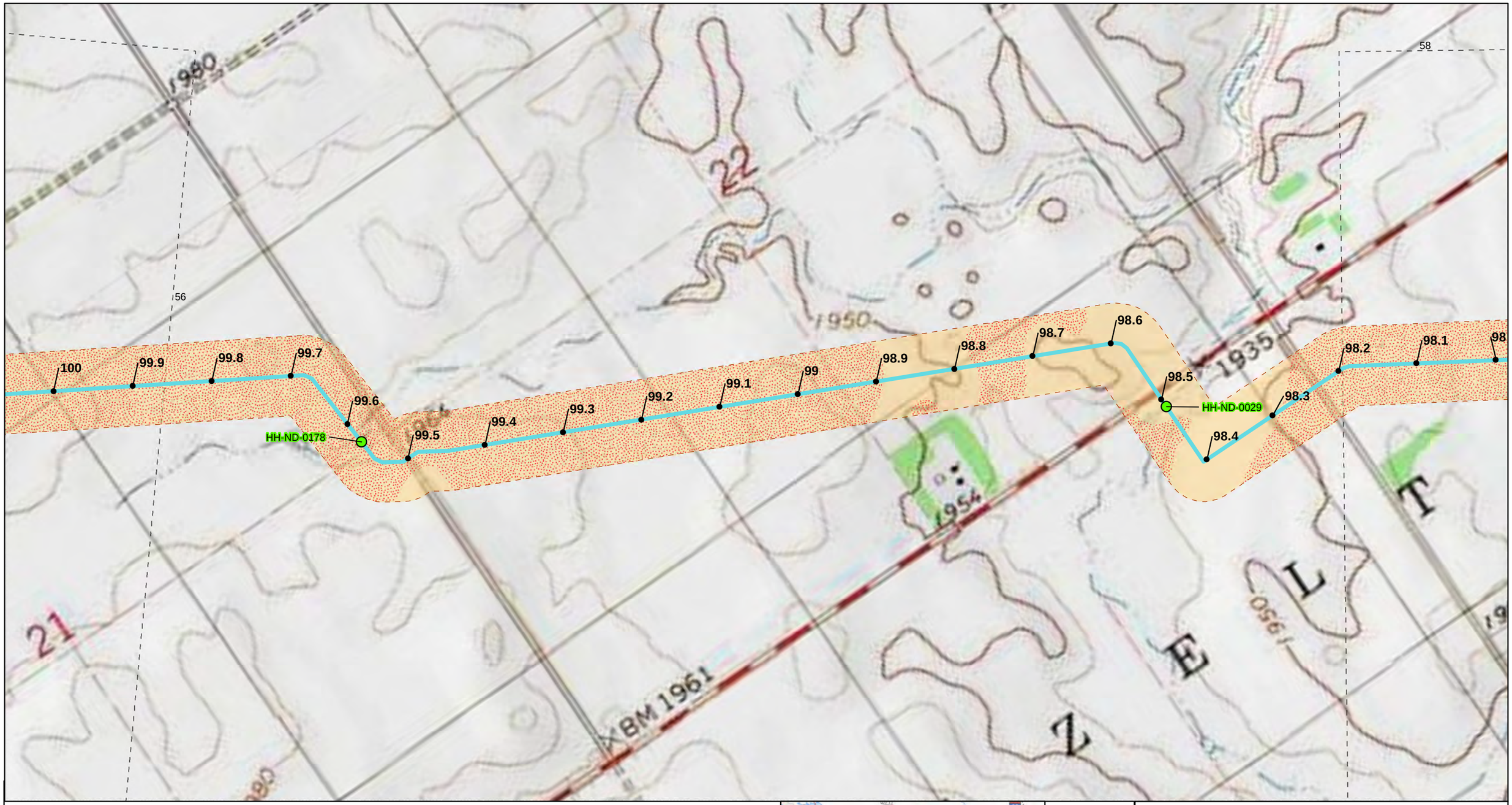

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
FROST ACTION CATEGORY
MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-57

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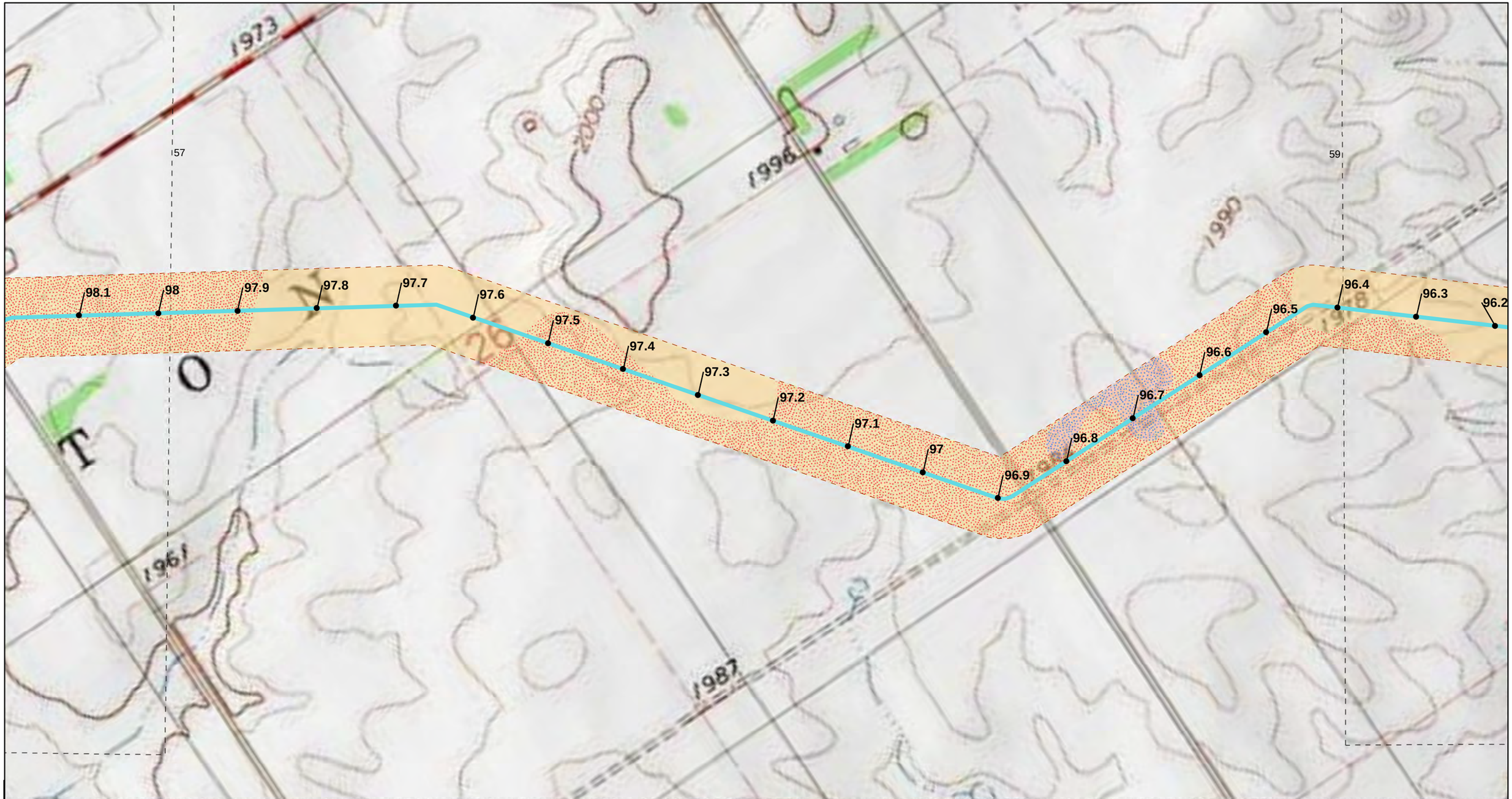

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-58

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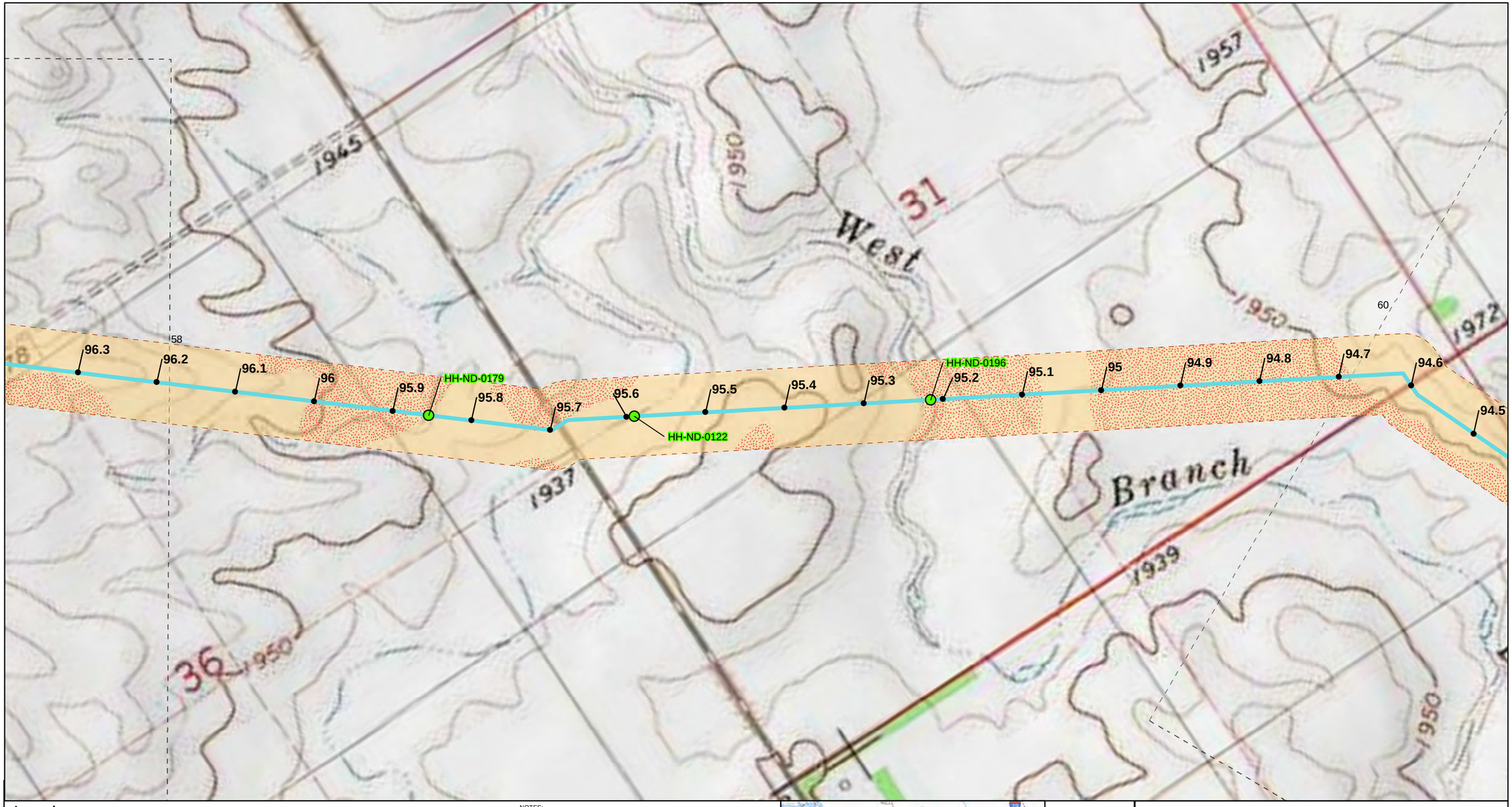

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
FROST ACTION CATEGORY
MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-59

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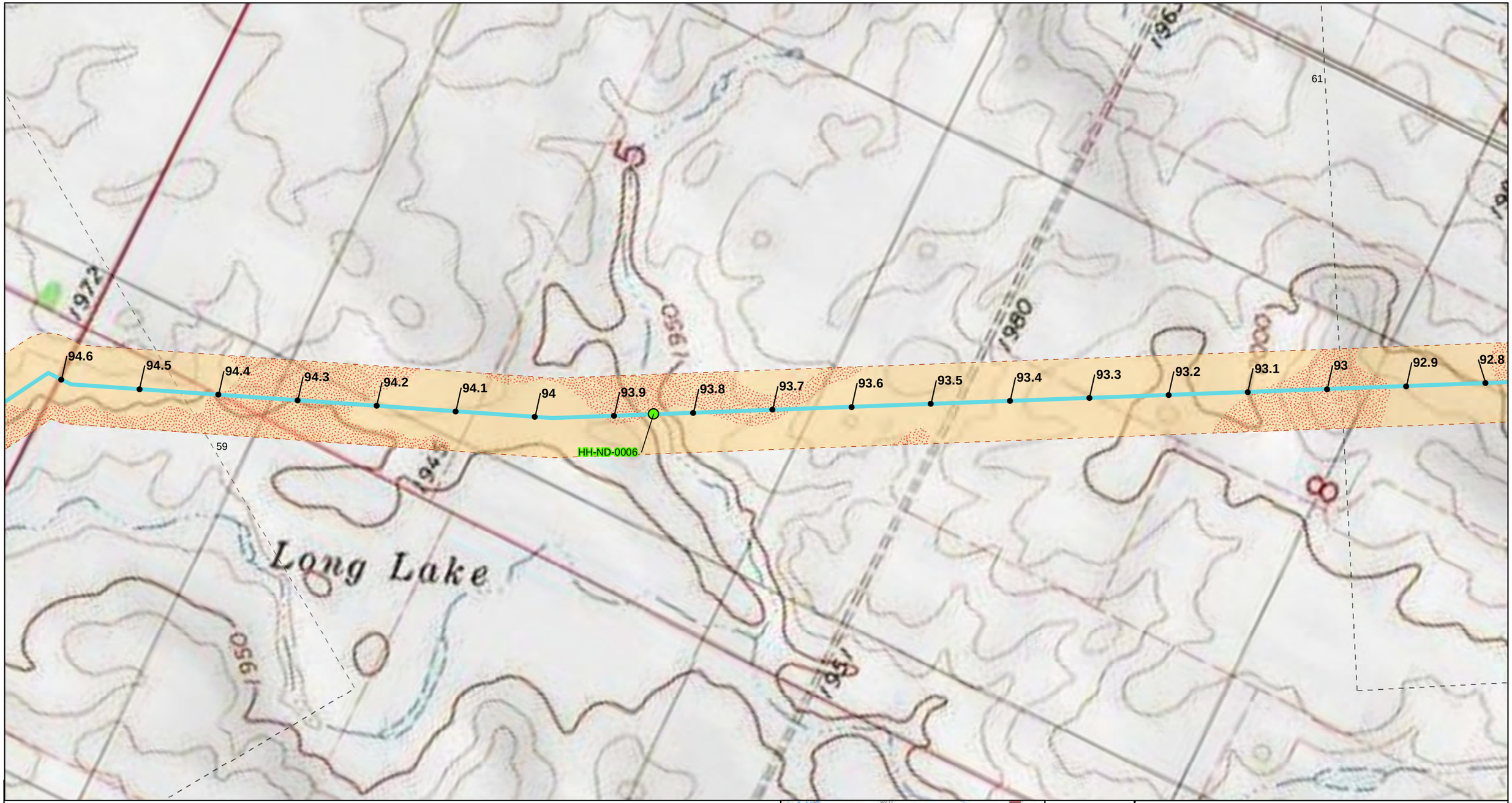

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
FROST ACTION CATEGORY
MEDIUM

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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-60

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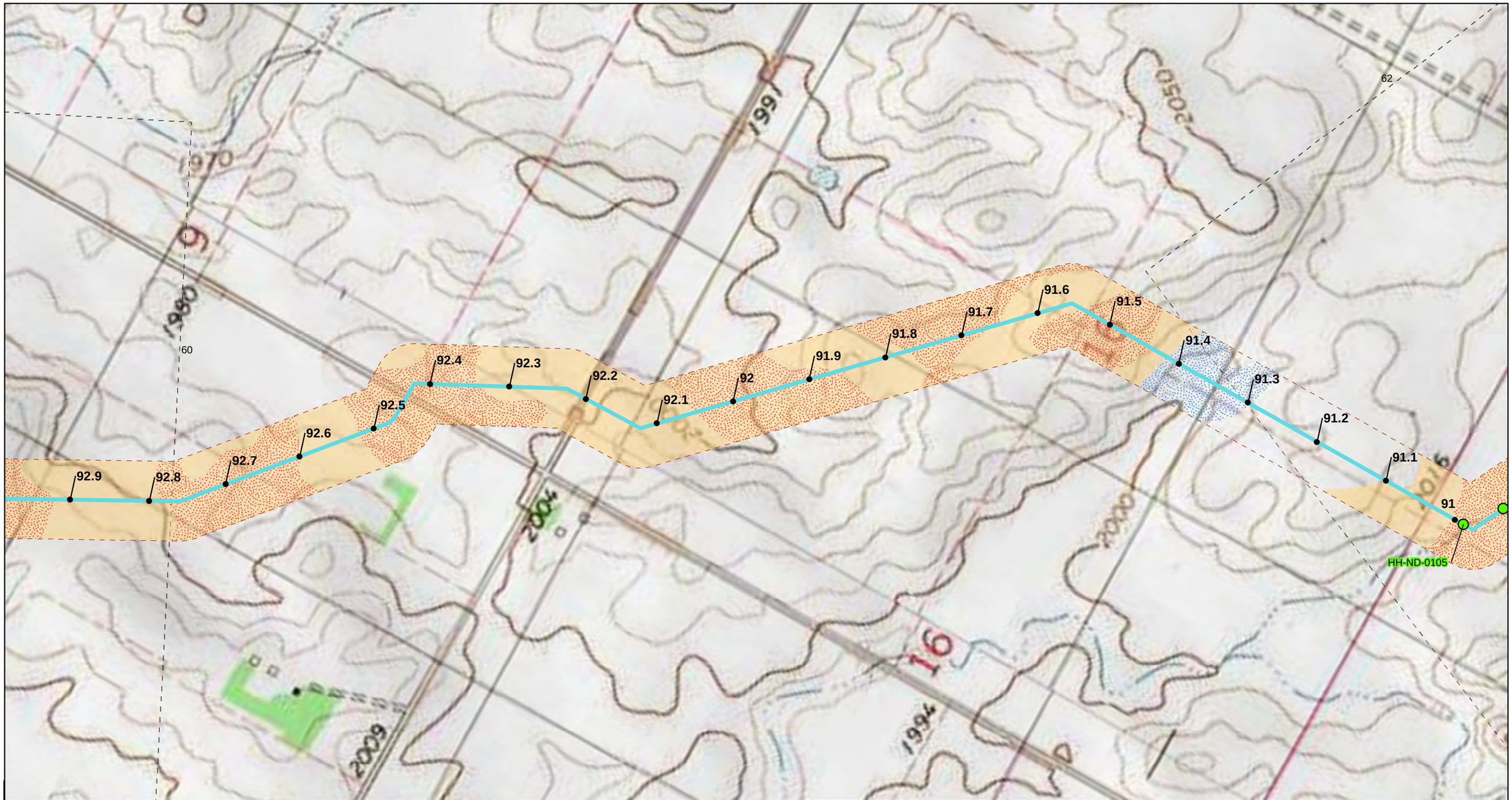

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-61

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Legend

- REVISION 9 ROUTE MILEPOSTS
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- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
HIGHER: LEP >6
FROST ACTION CATEGORY
MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
Phase I Assessment

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Figure **1-62**

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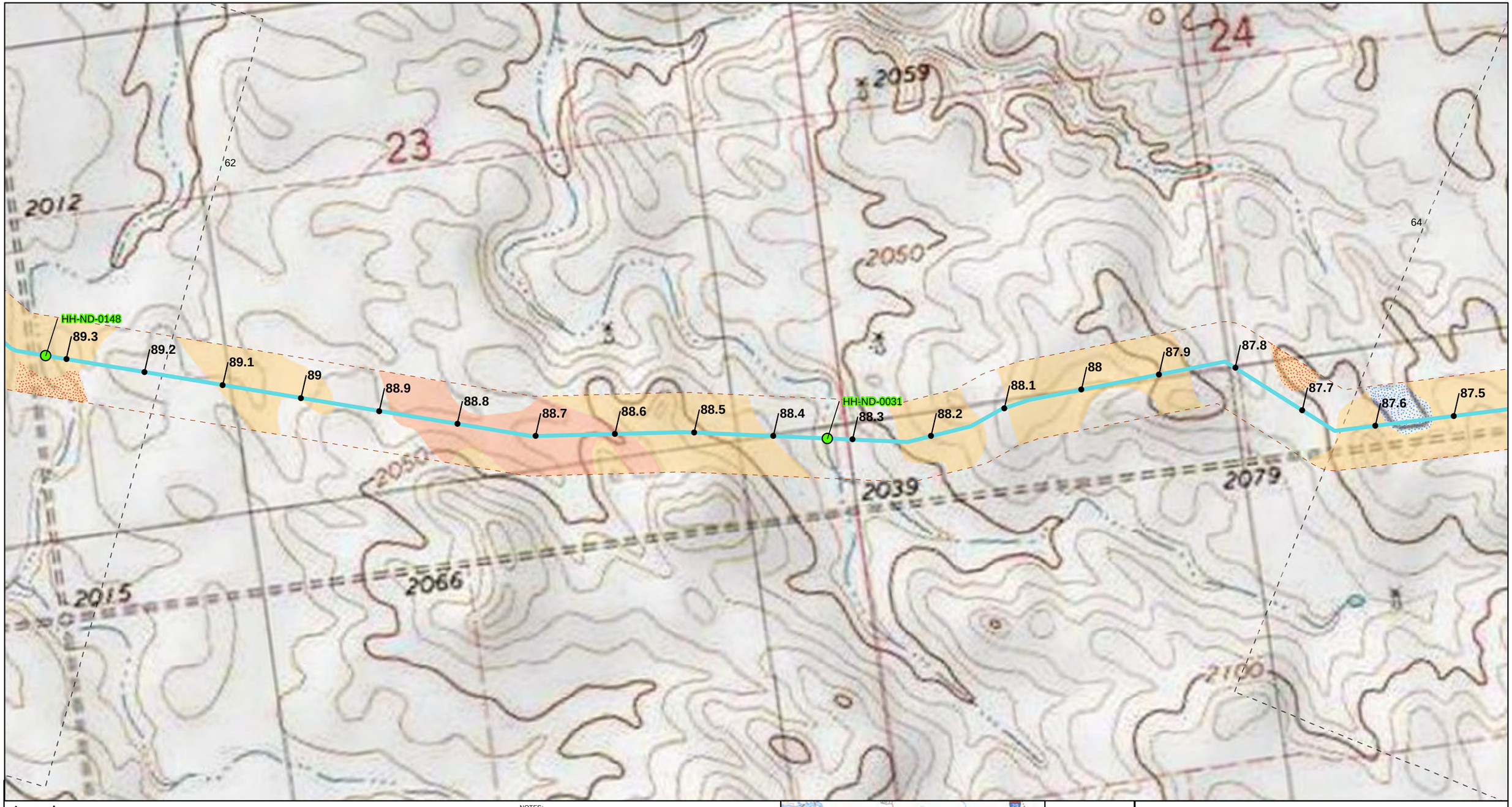

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
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TXG0450	January 2024	Figure 1-63

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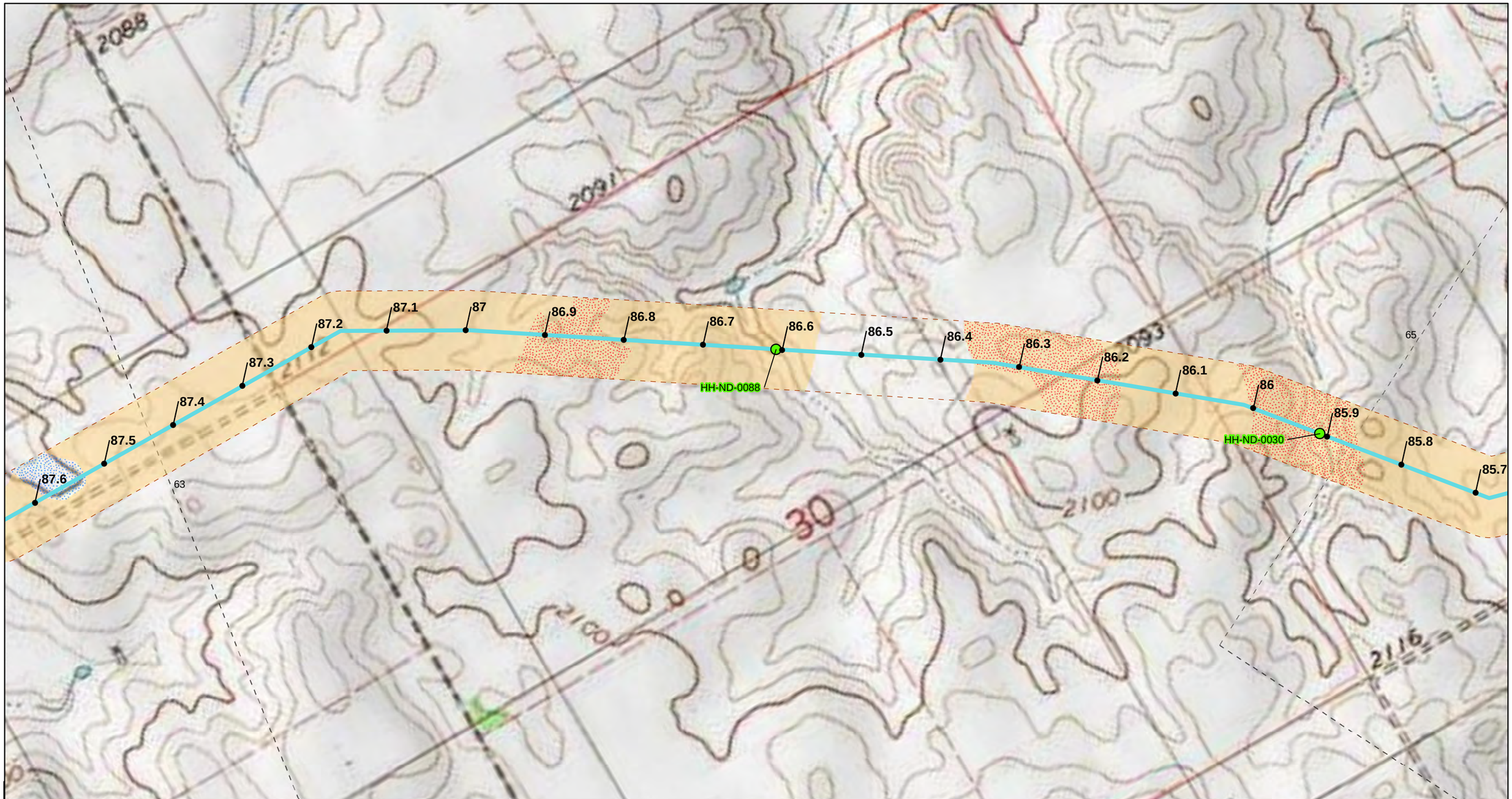

Legend

- REVISION 9 ROUTE MILEPOSTS
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- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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Figure **1-64**

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- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- MEDIUM

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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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Figure **1-65**

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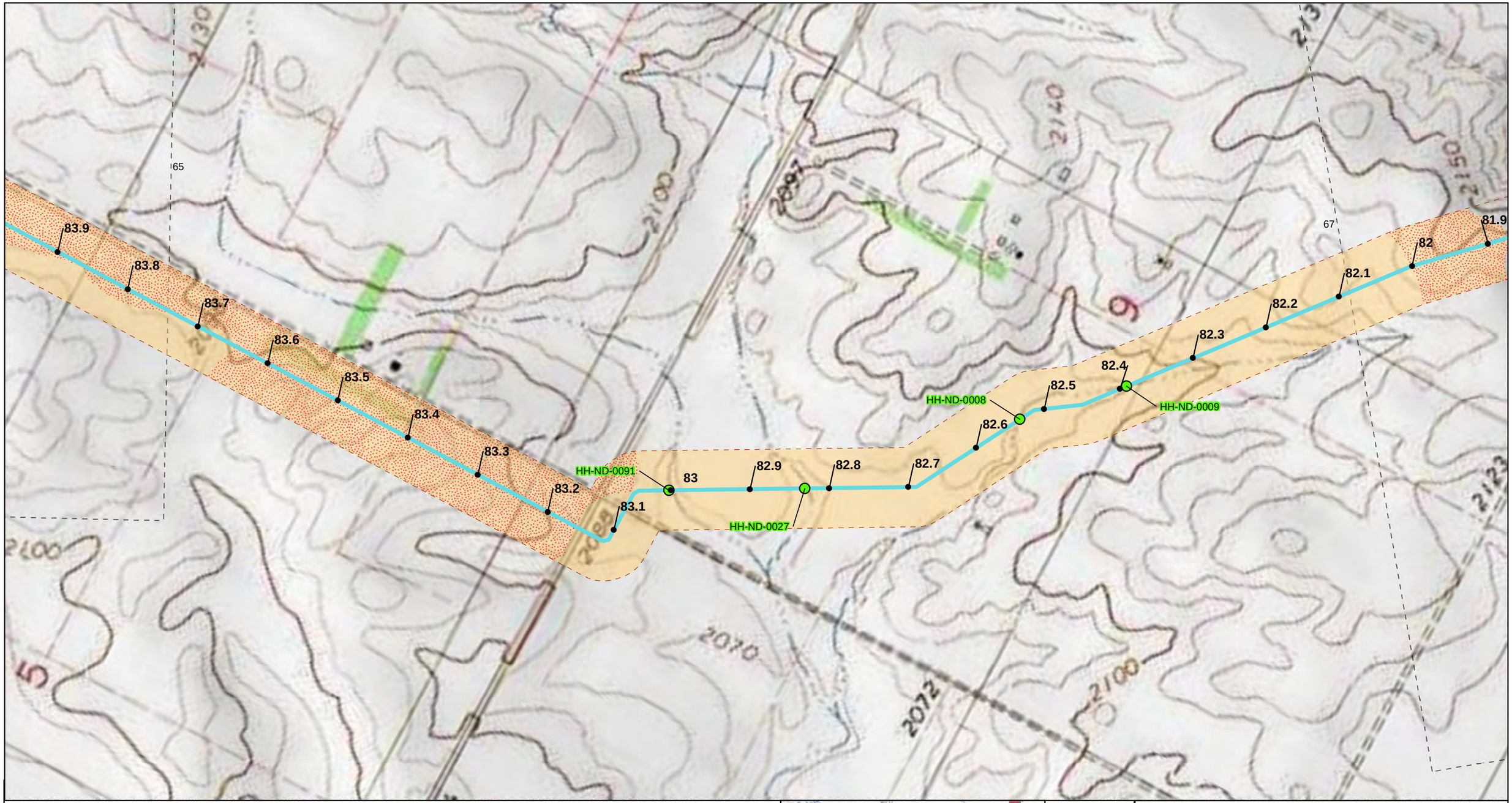

Legend

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- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
FROST ACTION CATEGORY
MEDIUM

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0 250 500 1,000 Feet

N

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Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-66

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Legend

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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
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0 250 500 1,000 Feet

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Summit Carbon Solutions - North Dakota
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TXG0450	January 2024	Figure 1-67

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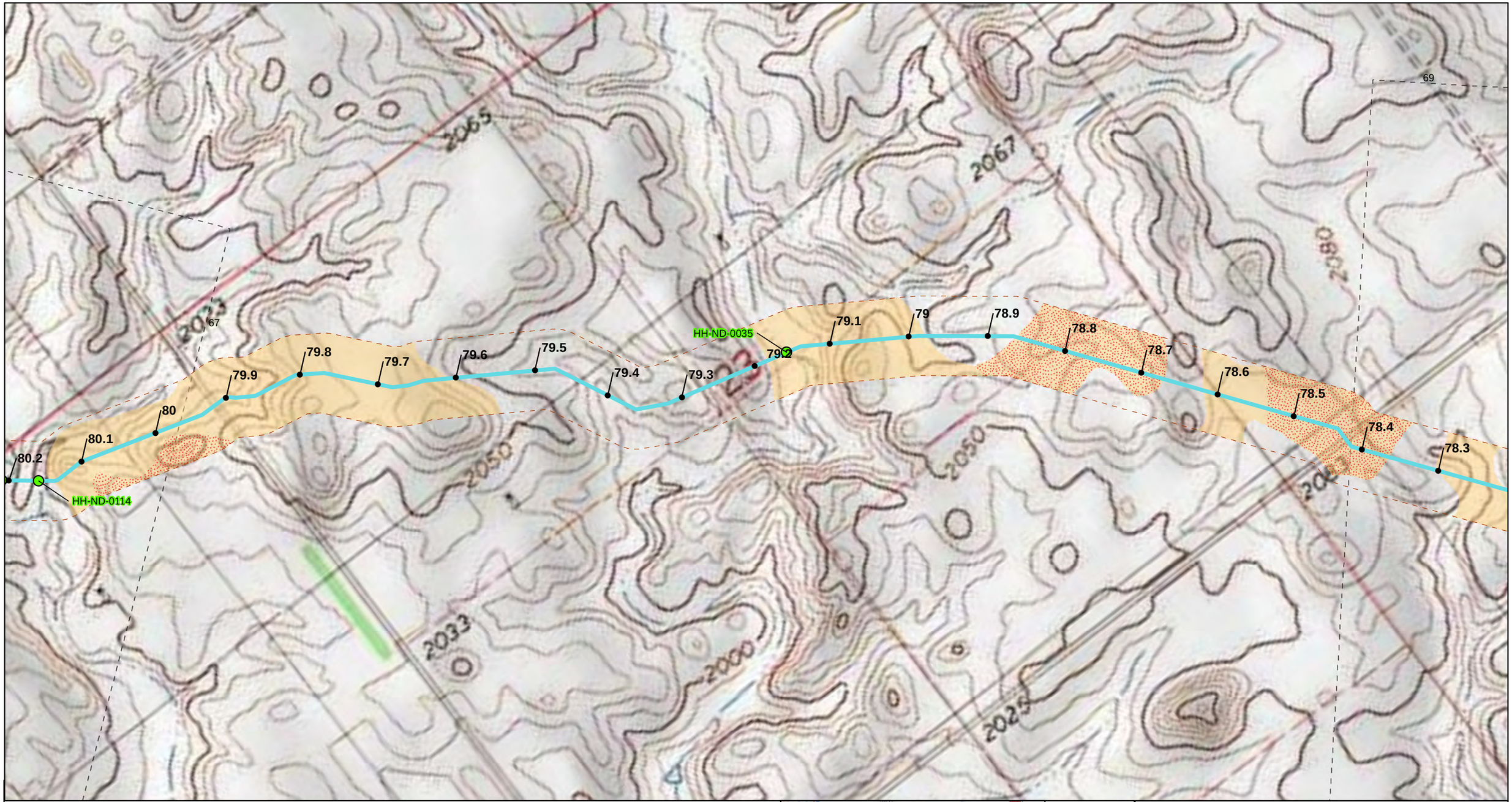

Legend

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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-68

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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- MEDIUM

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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-69

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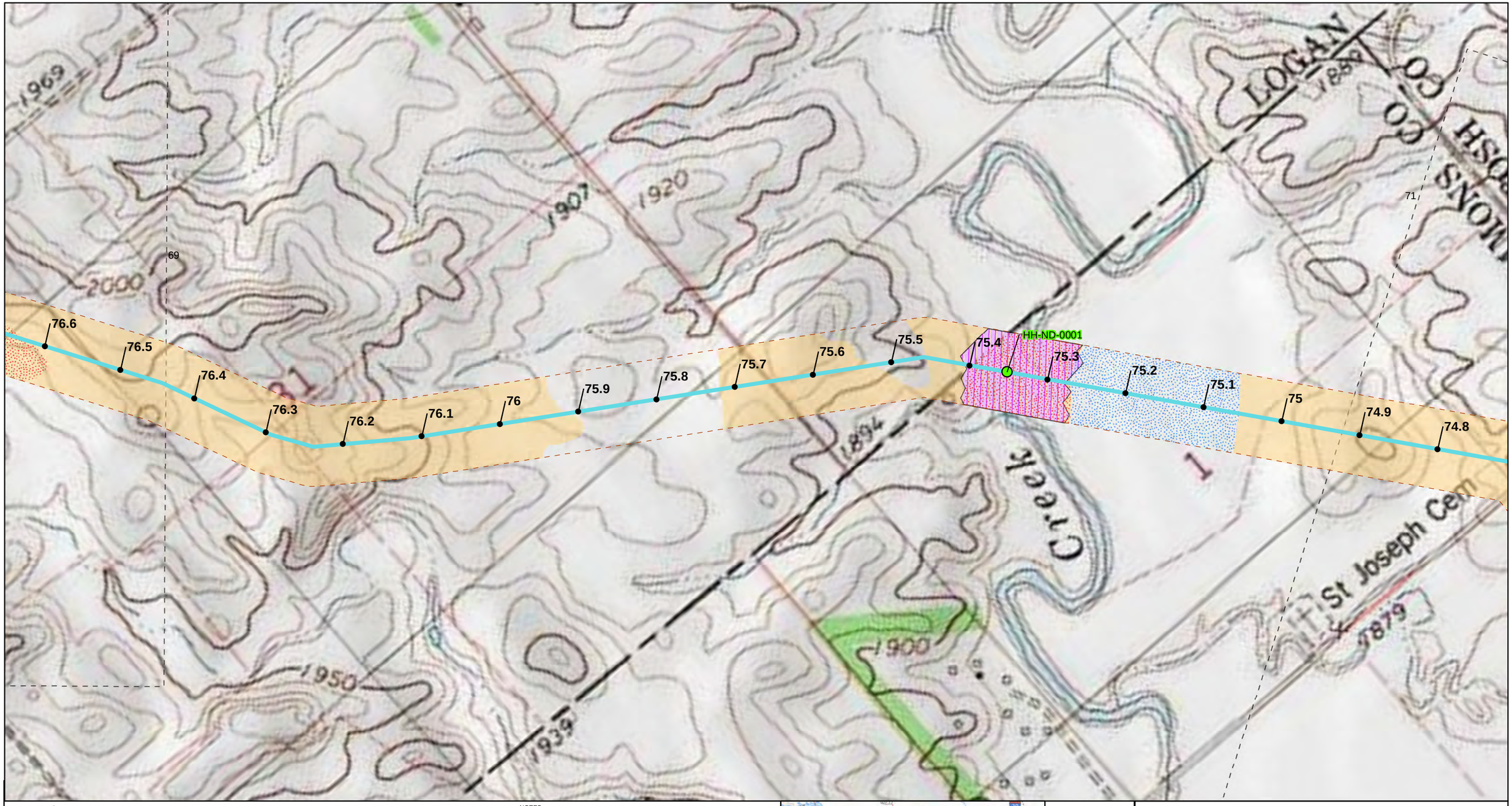

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-70

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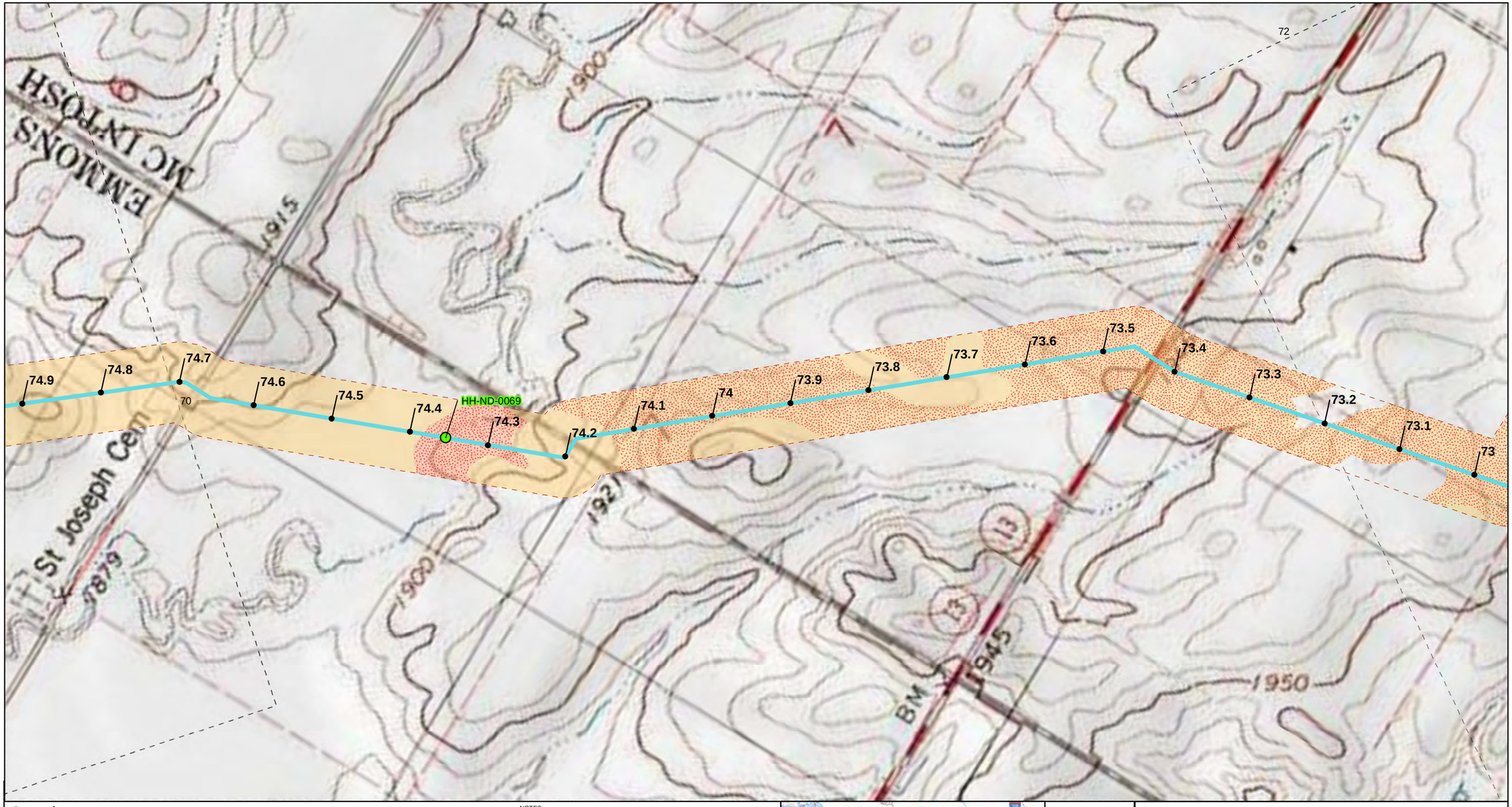

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- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-71

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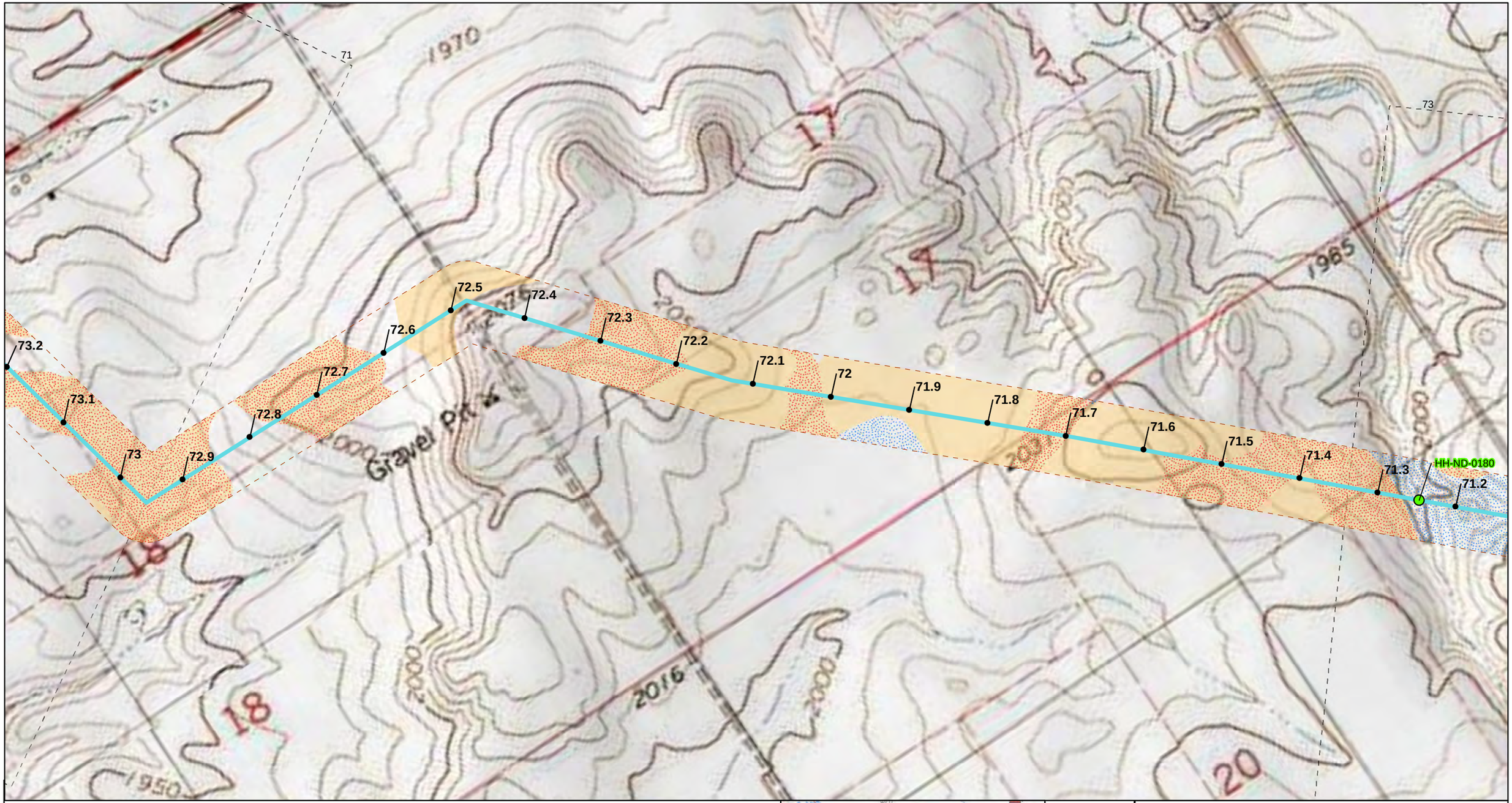

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-72

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-73

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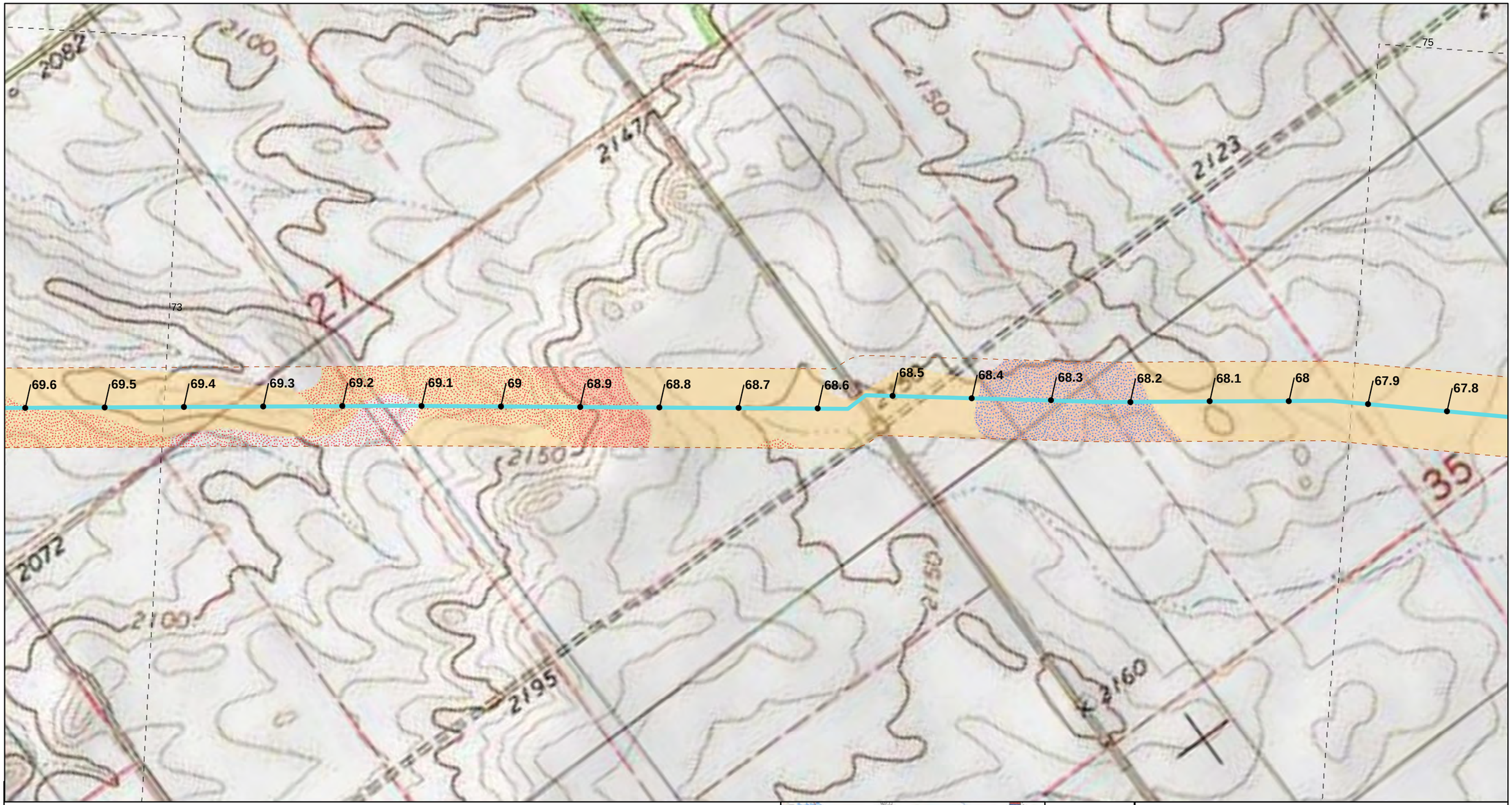

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-74

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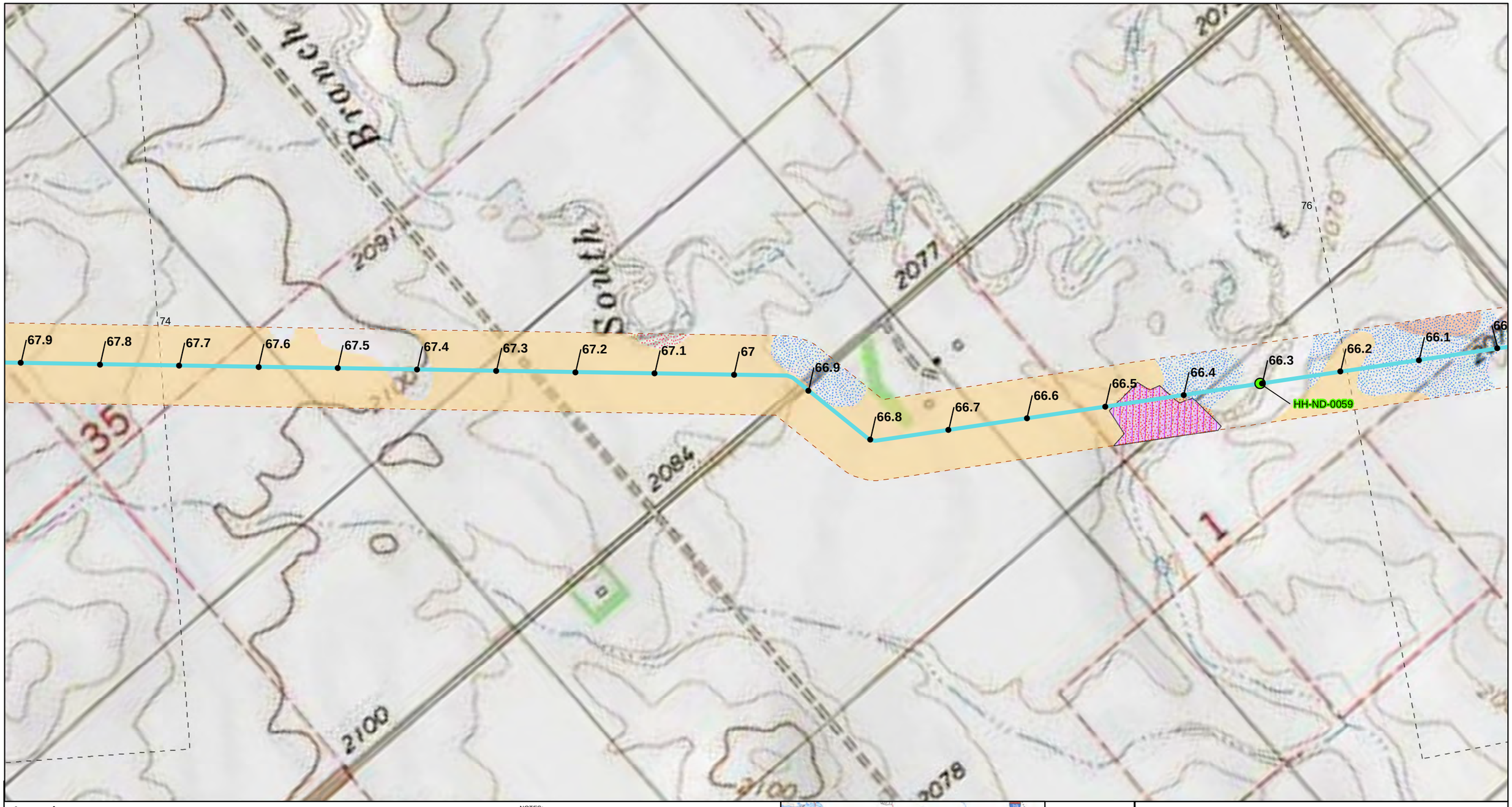

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
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- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY

- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-75

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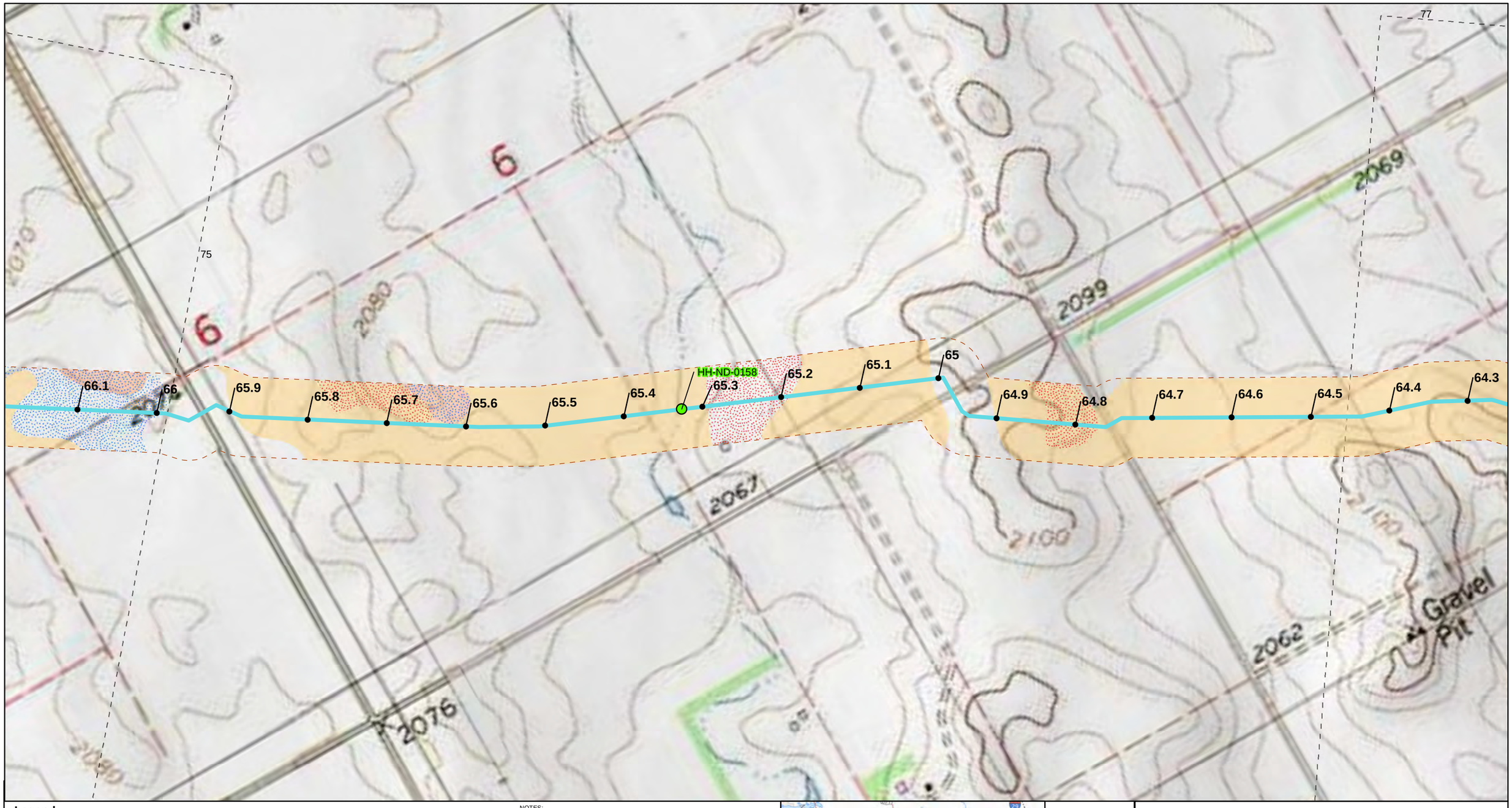

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-76

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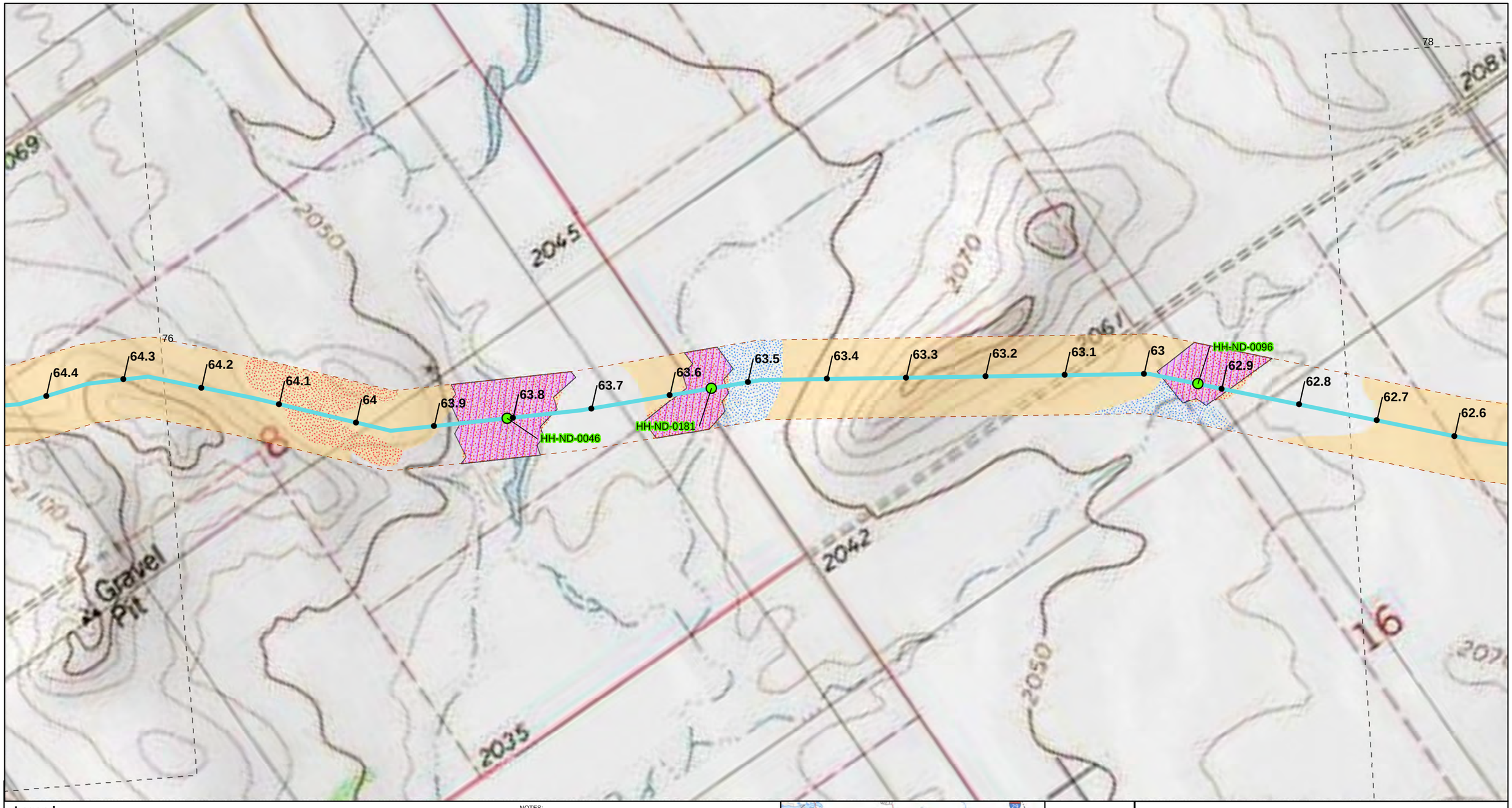

Legend

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- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
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- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-77

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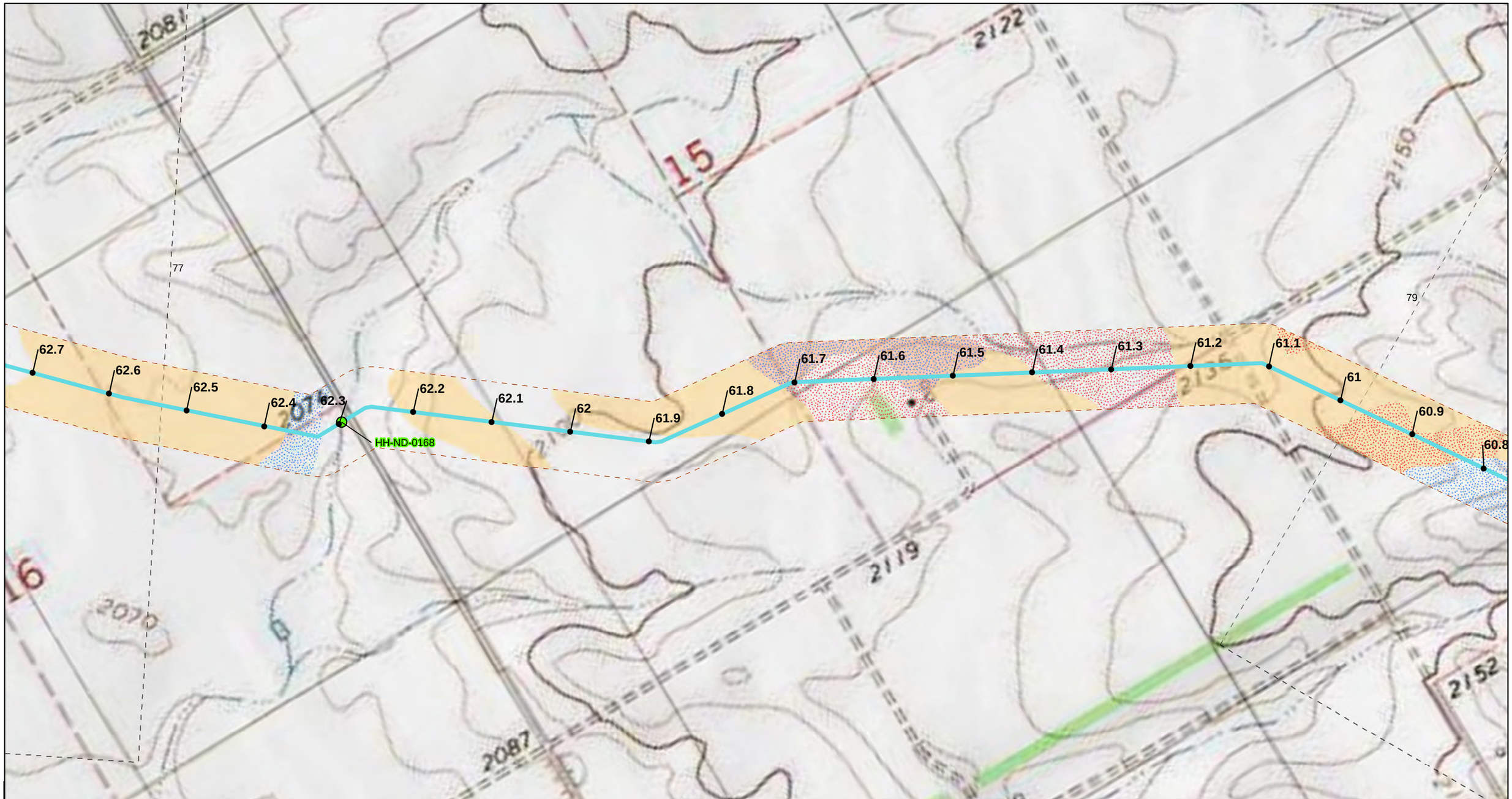

Legend

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FLOODING FREQUENCY CATEGORY

- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-78

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Legend

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- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
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- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

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FROST ACTION CATEGORY

- HIGHER
- MEDIUM

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
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Figure **1-79**

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R72W
R71W
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Legend

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EXPANSIVE SOILS (LEP VALUES)
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FROST ACTION CATEGORY
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Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-80

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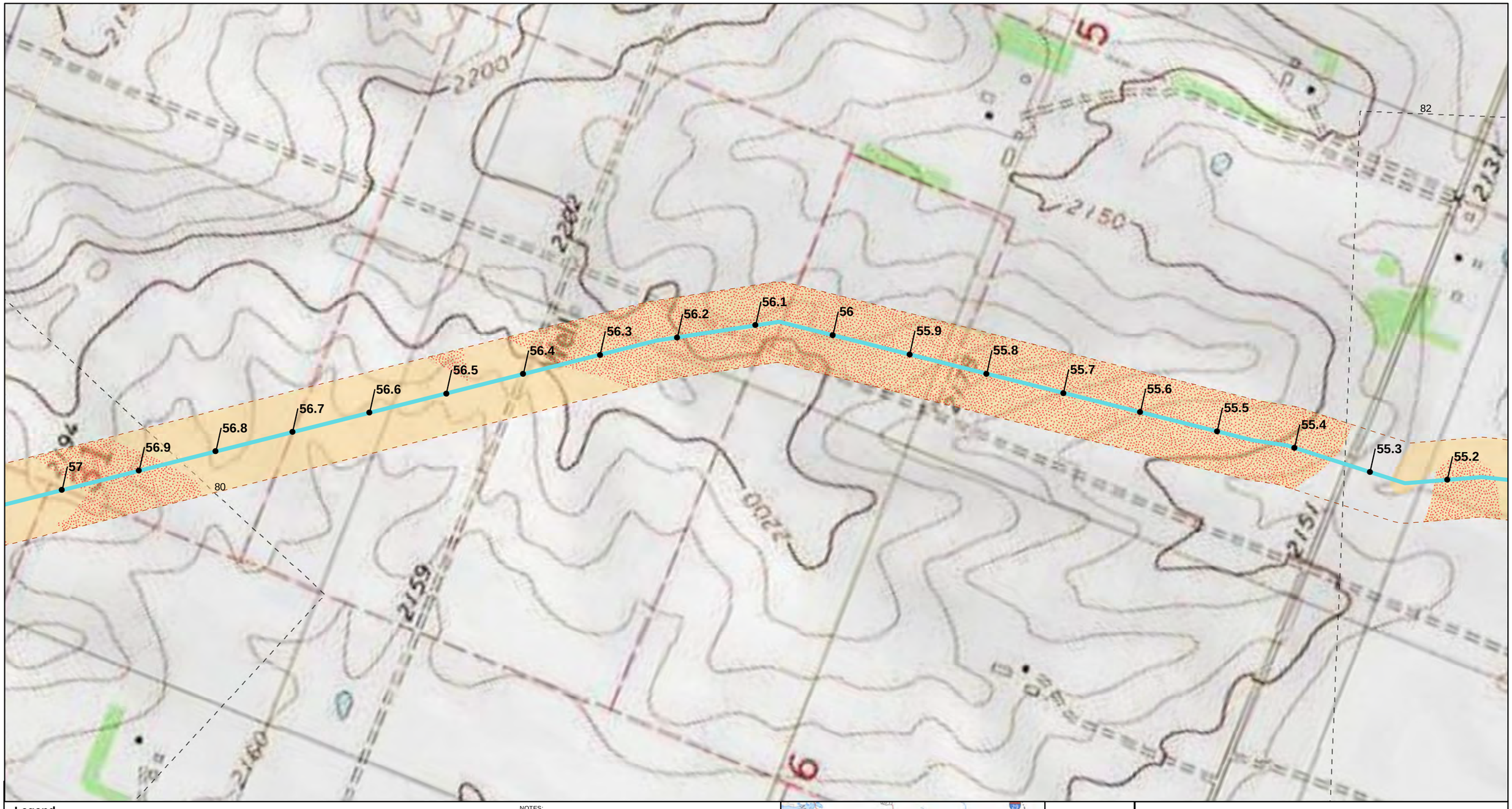

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-81

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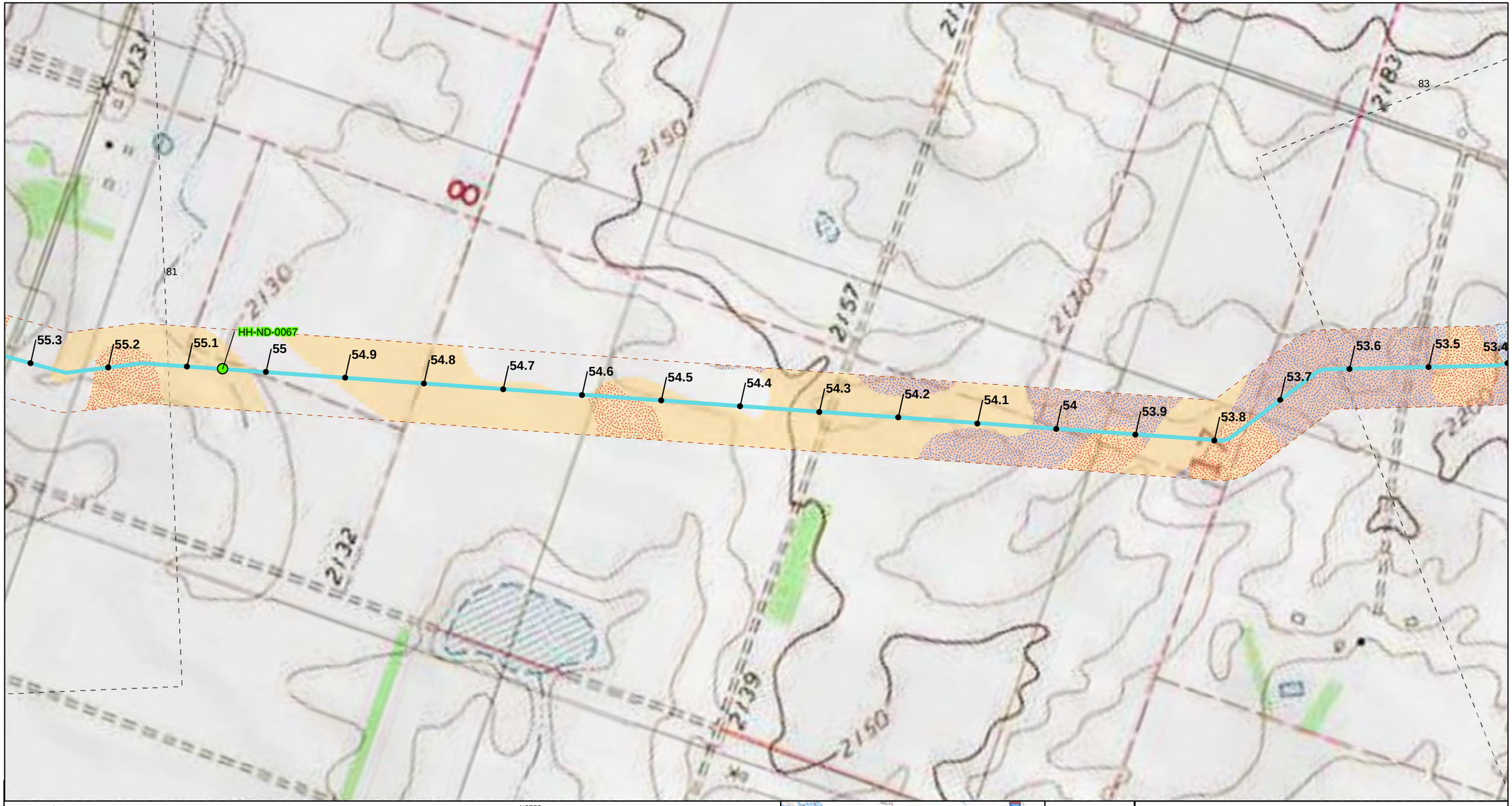

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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Phase I Assessment

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TXG0450	January 2024	Figure 1-82

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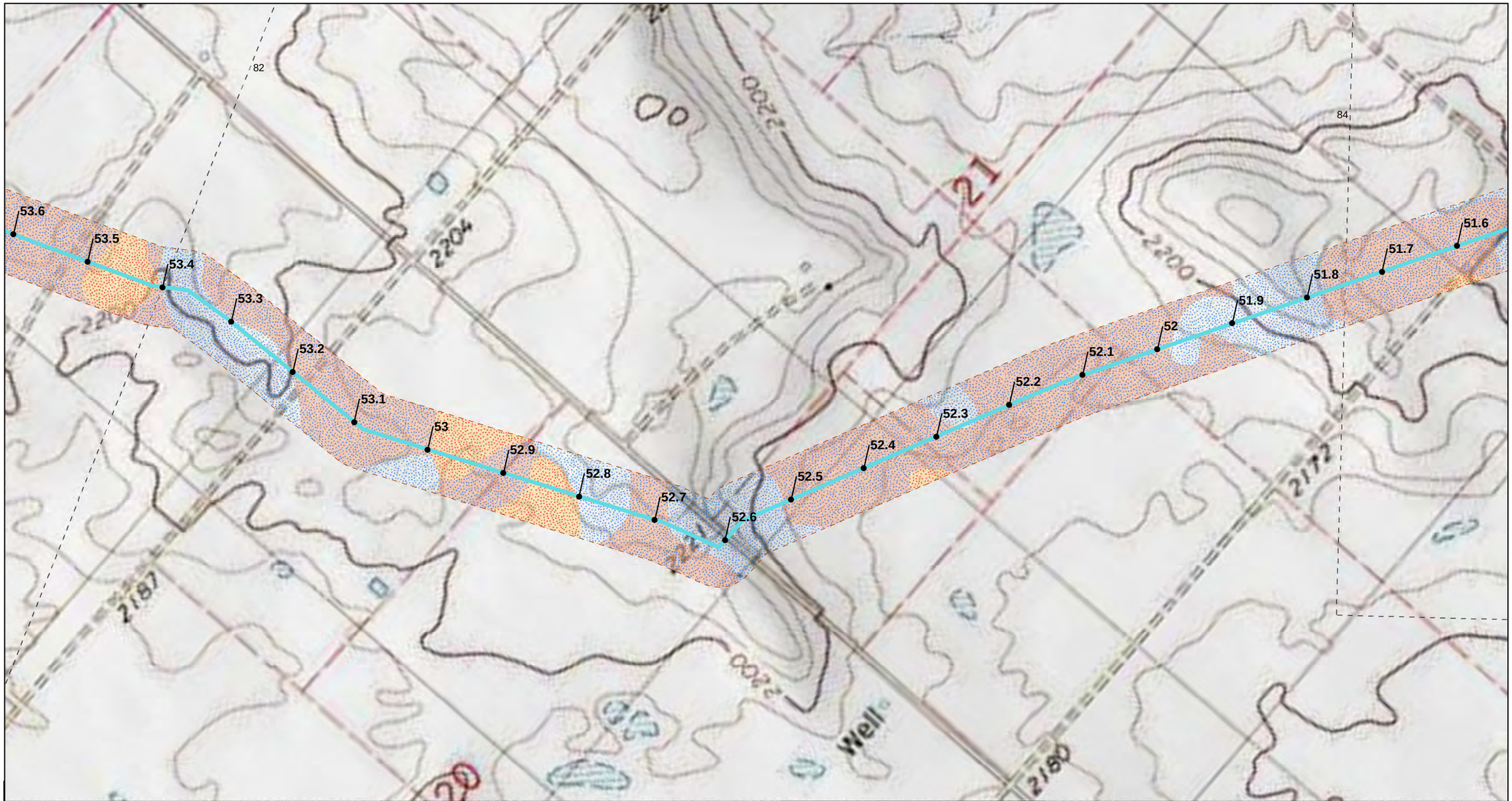

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- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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Figure **1-83**

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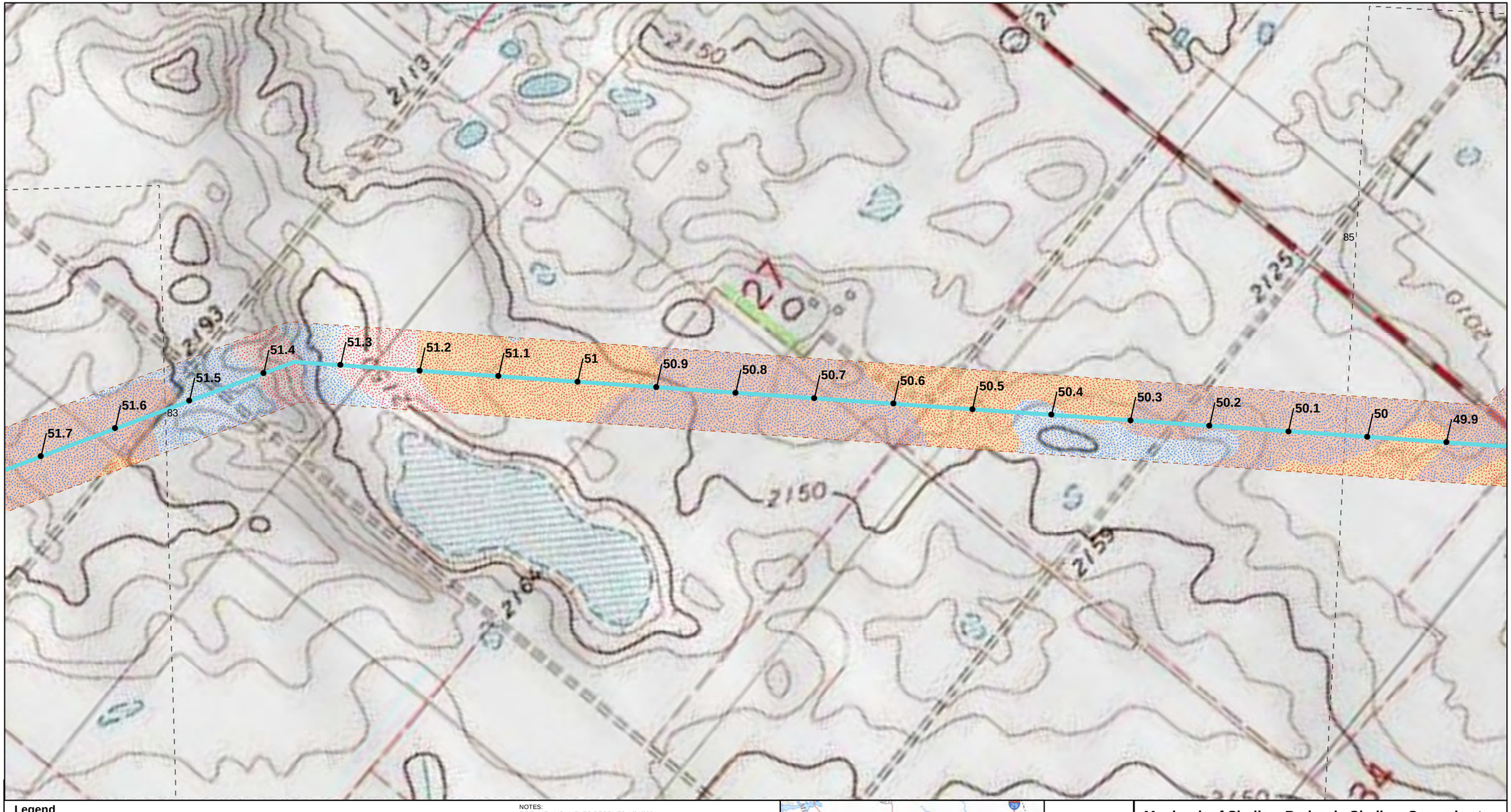

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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Figure **1-84**

TXG0450 | January 2024

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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Phase I Assessment

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TXG0450	January 2024	Figure 1-85

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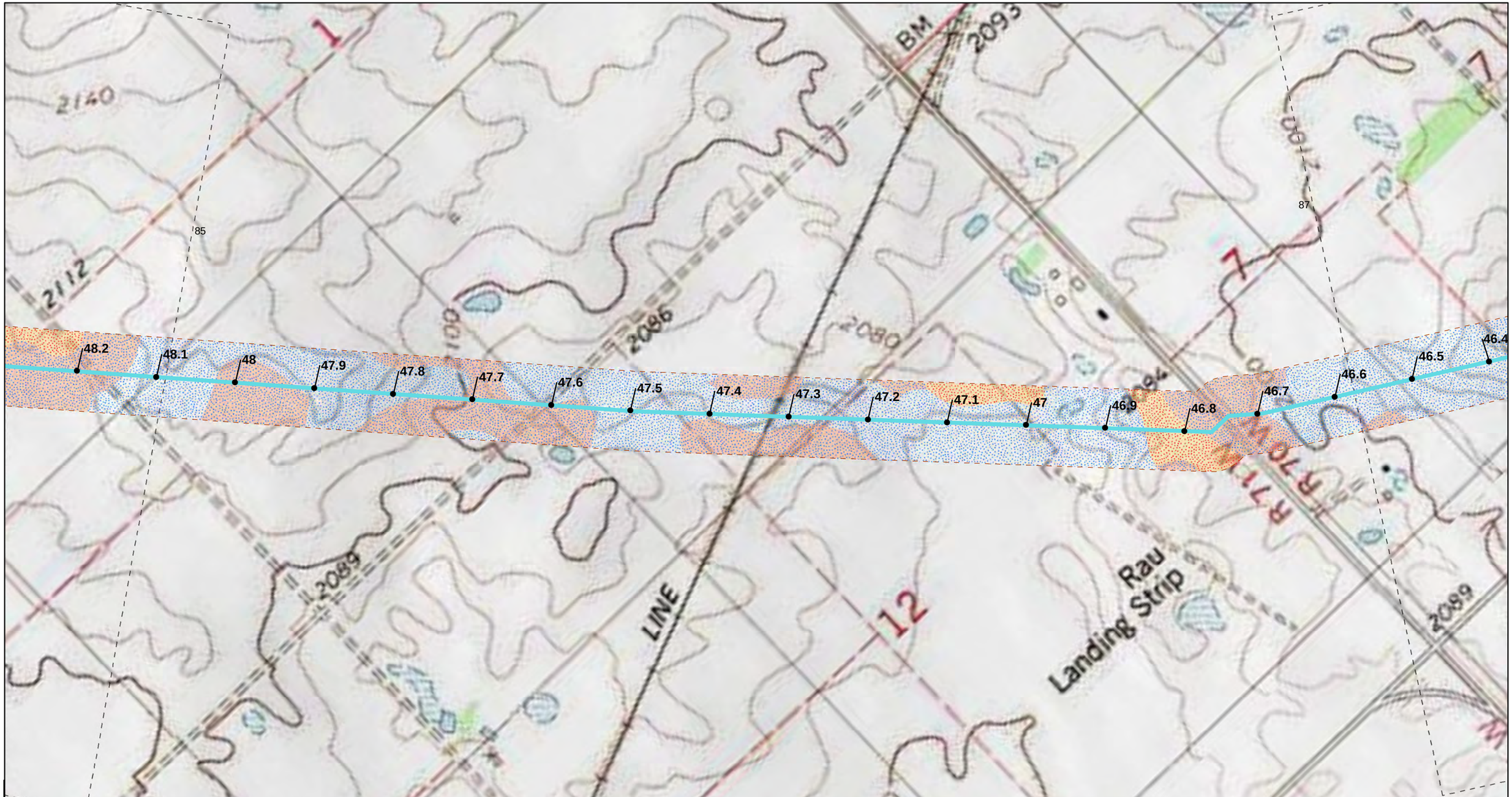

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-86

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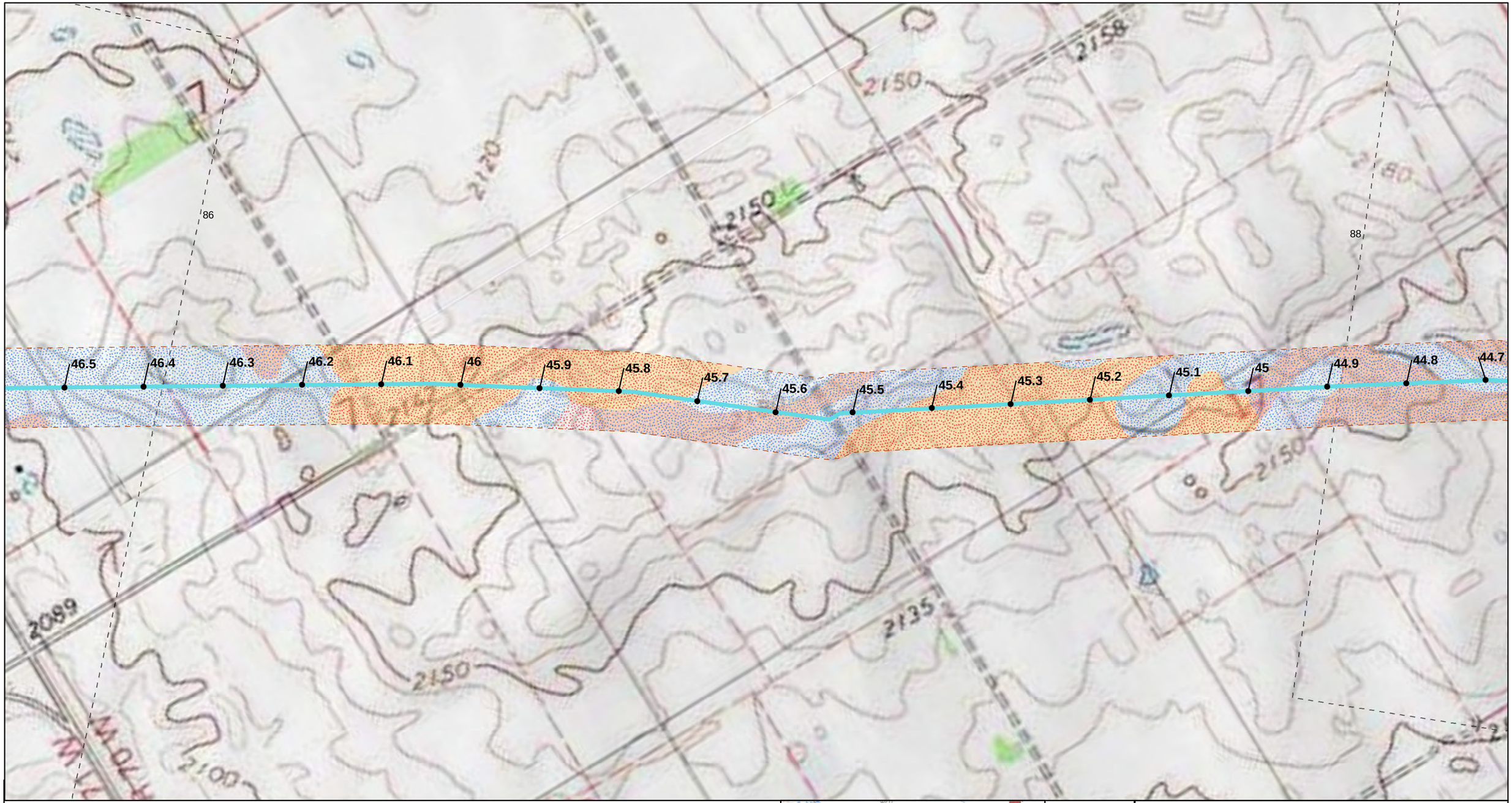

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Phase I Assessment

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TXG0450	January 2024	Figure 1-87

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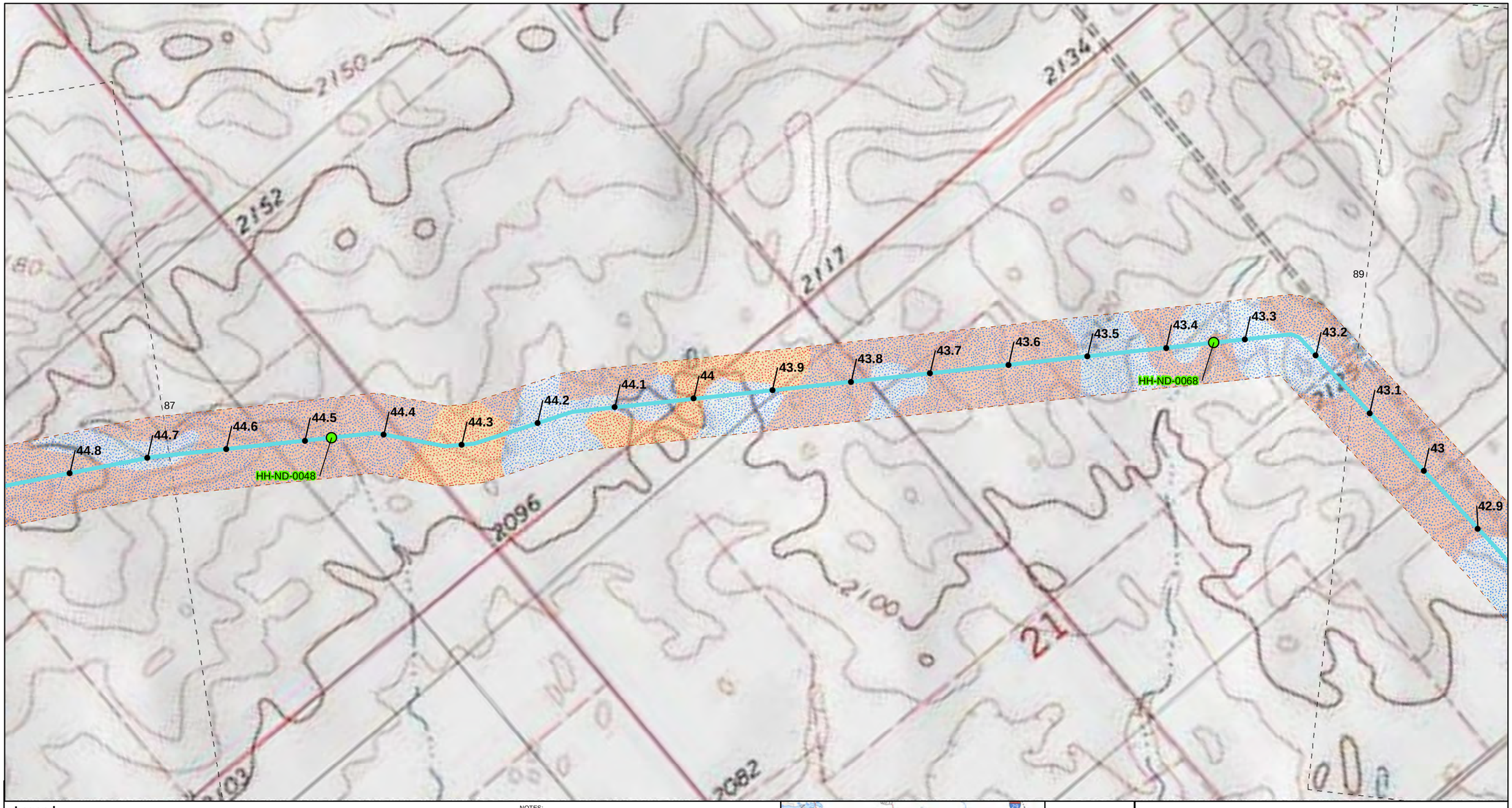

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9
- MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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TXG0450	January 2024	Figure 1-88

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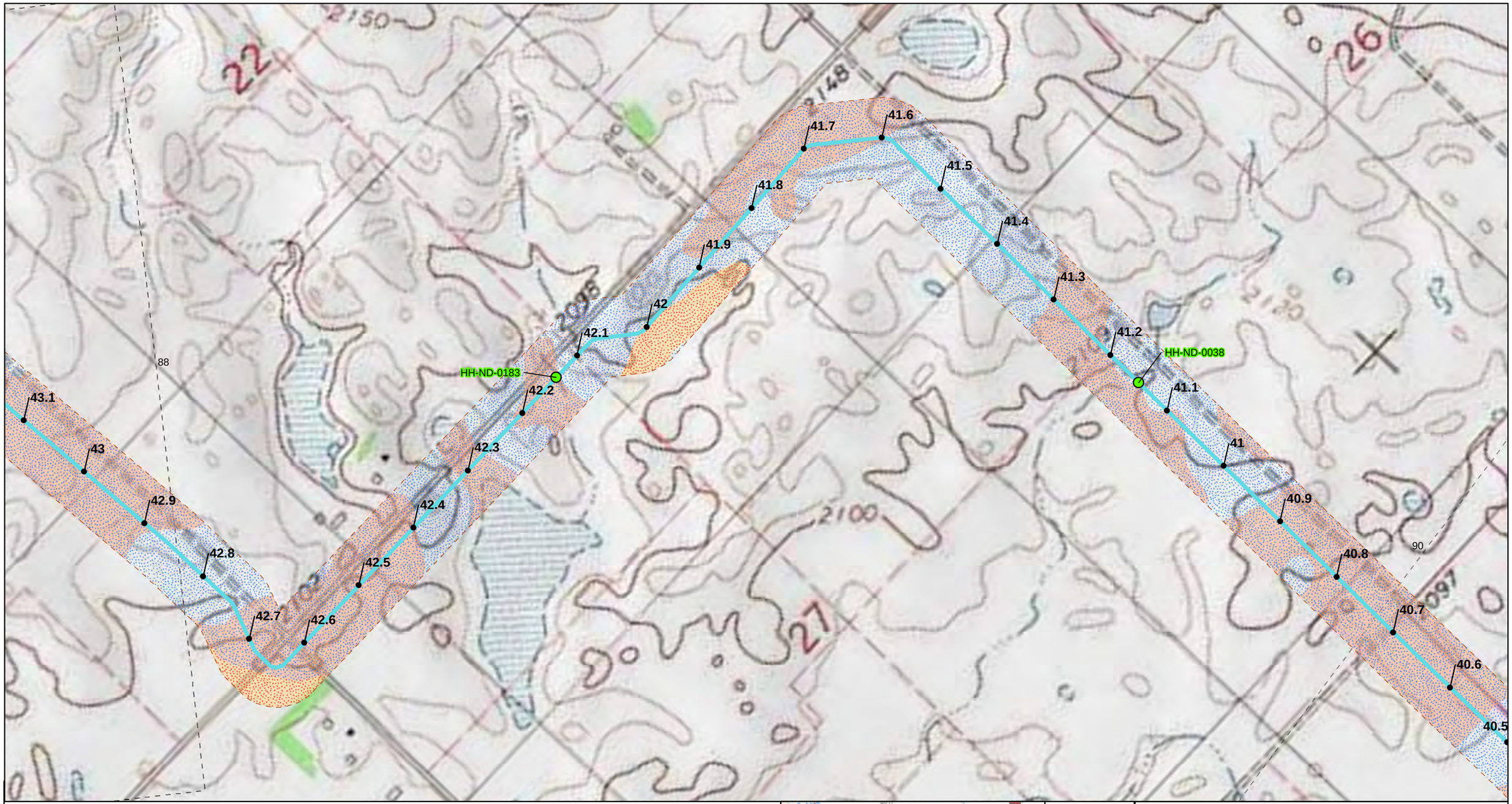

Legend

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- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
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Legend

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- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

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0 250 500 1,000 Feet

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Summit Carbon Solutions - North Dakota
Phase I Assessment

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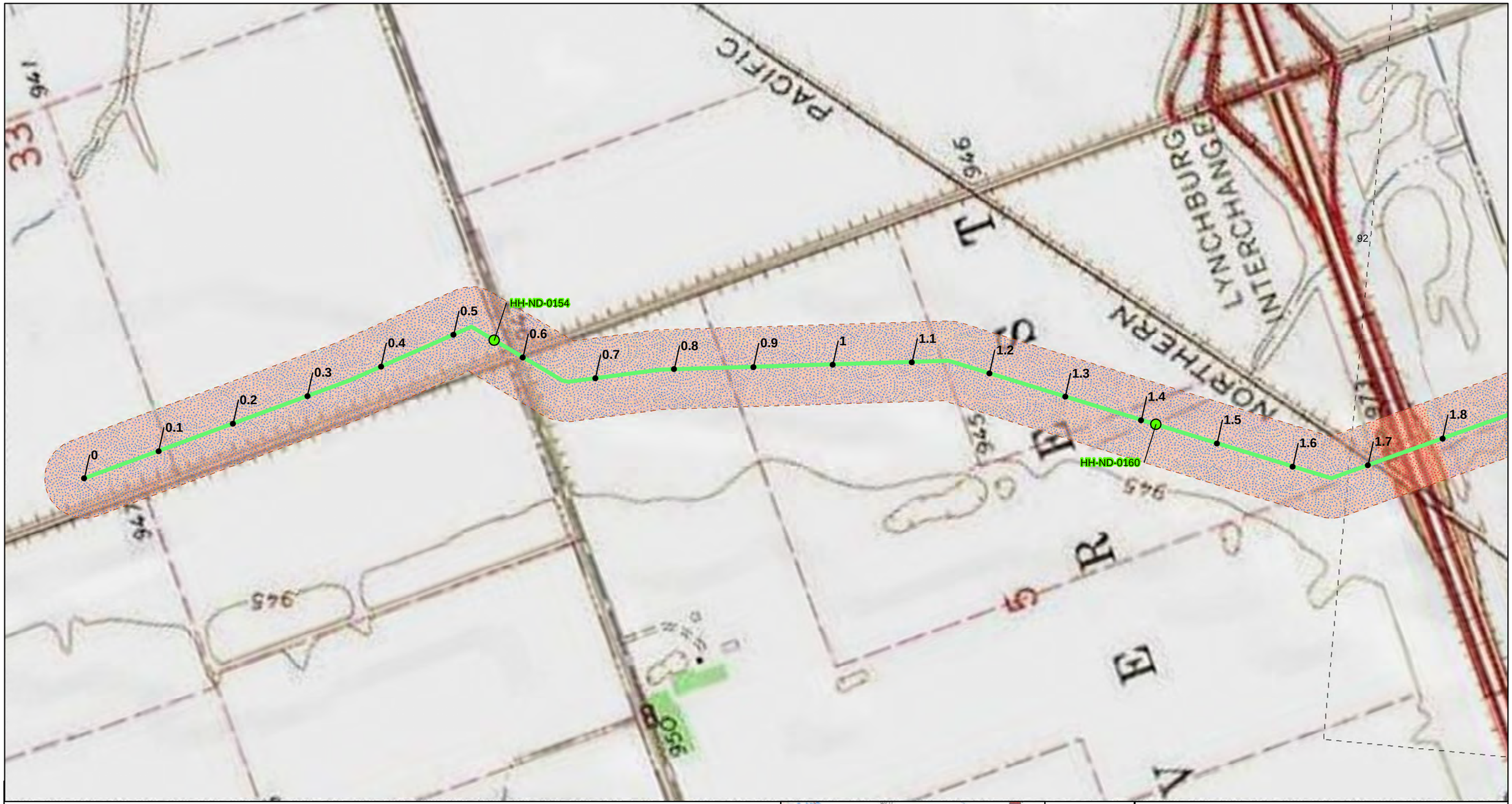

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-324
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER

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0 250 500 1,000 Feet

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Summit Carbon Solutions - North Dakota
Phase I Assessment

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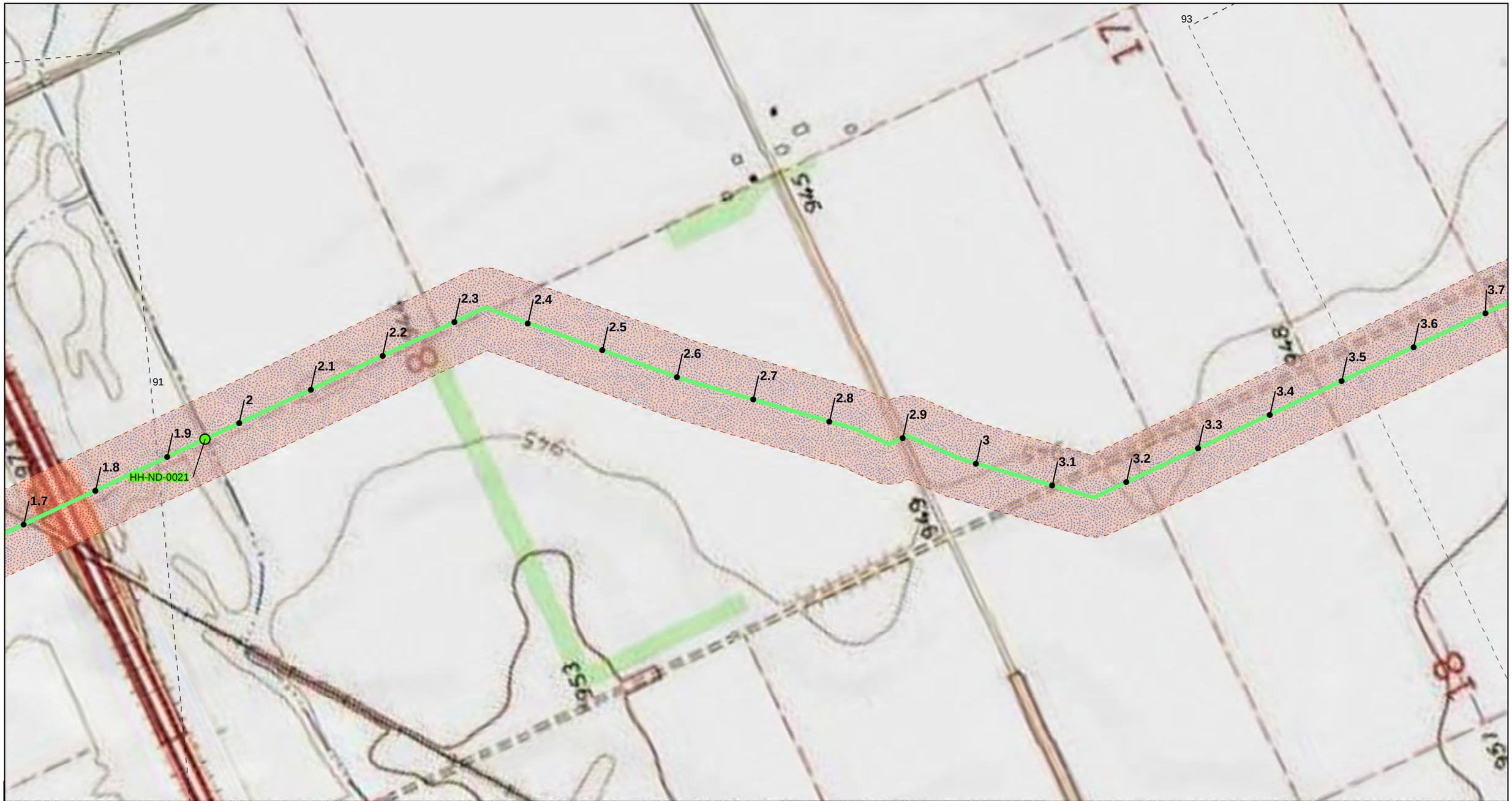

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-324
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER

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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-324
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: RARE

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-93

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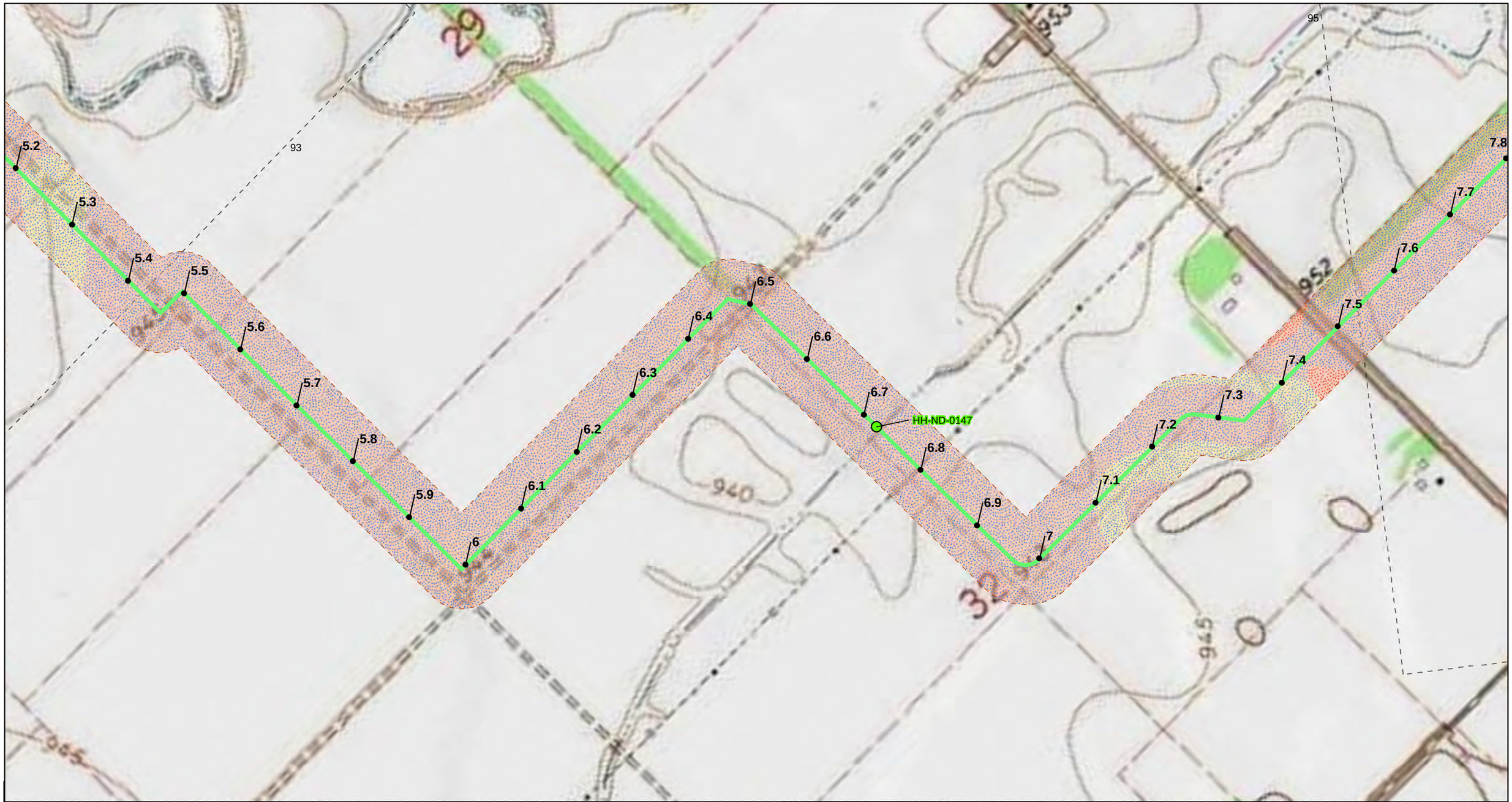

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-324
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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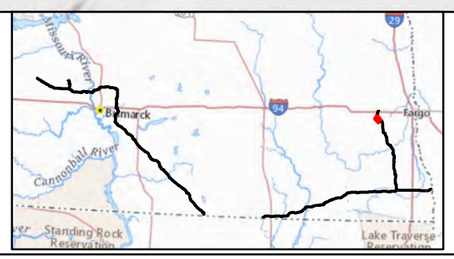

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Summit Carbon Solutions - North Dakota
Phase I Assessment

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Figure **1-94**

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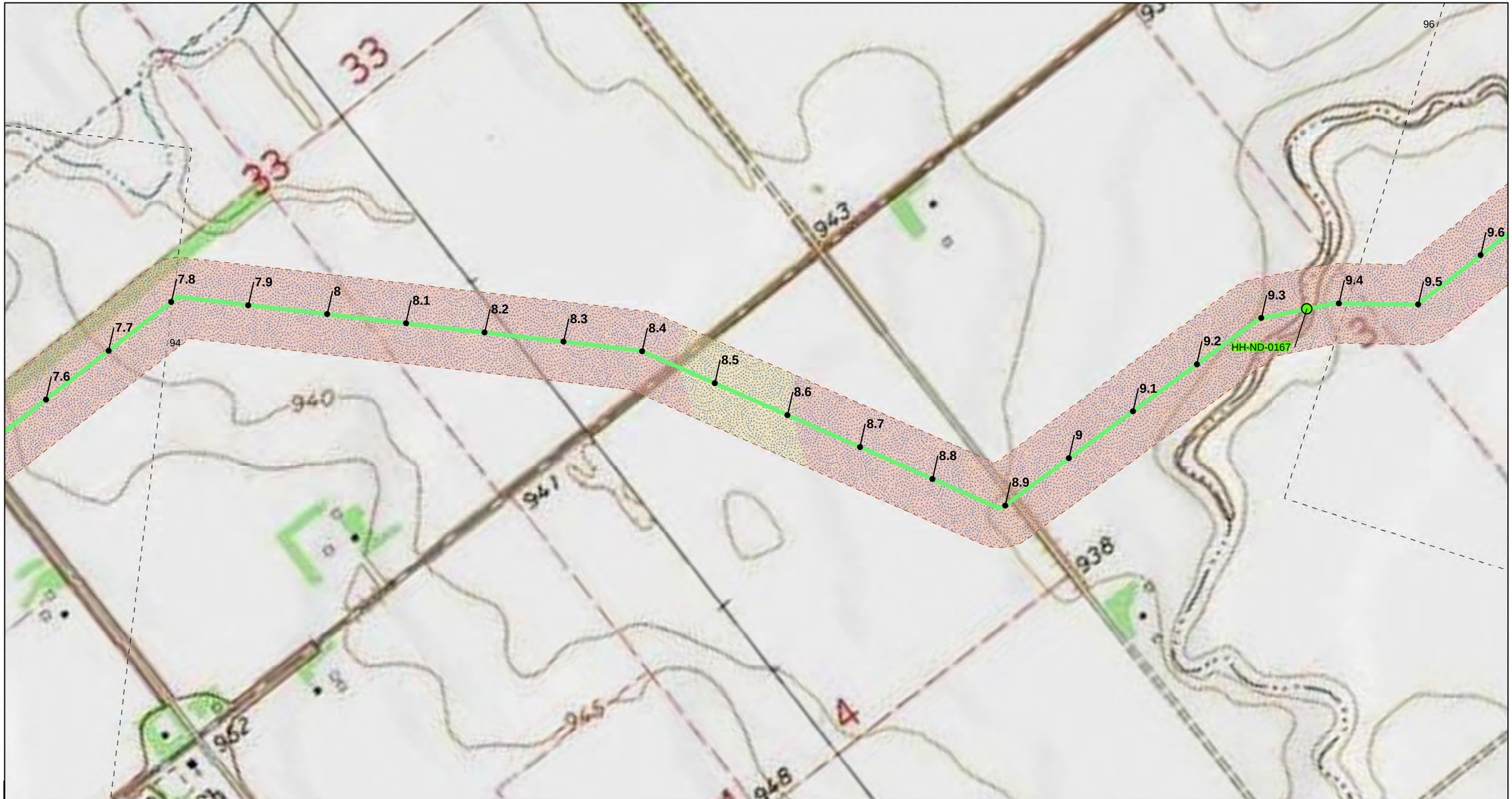

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- REVISION 9 ROUTE MILEPOSTS
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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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Summit Carbon Solutions - North Dakota
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Figure **1-95**

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Legend

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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
HIGHER: LEP >6
FROST ACTION CATEGORY
HIGHER

NOTES:
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Summit Carbon Solutions - North Dakota
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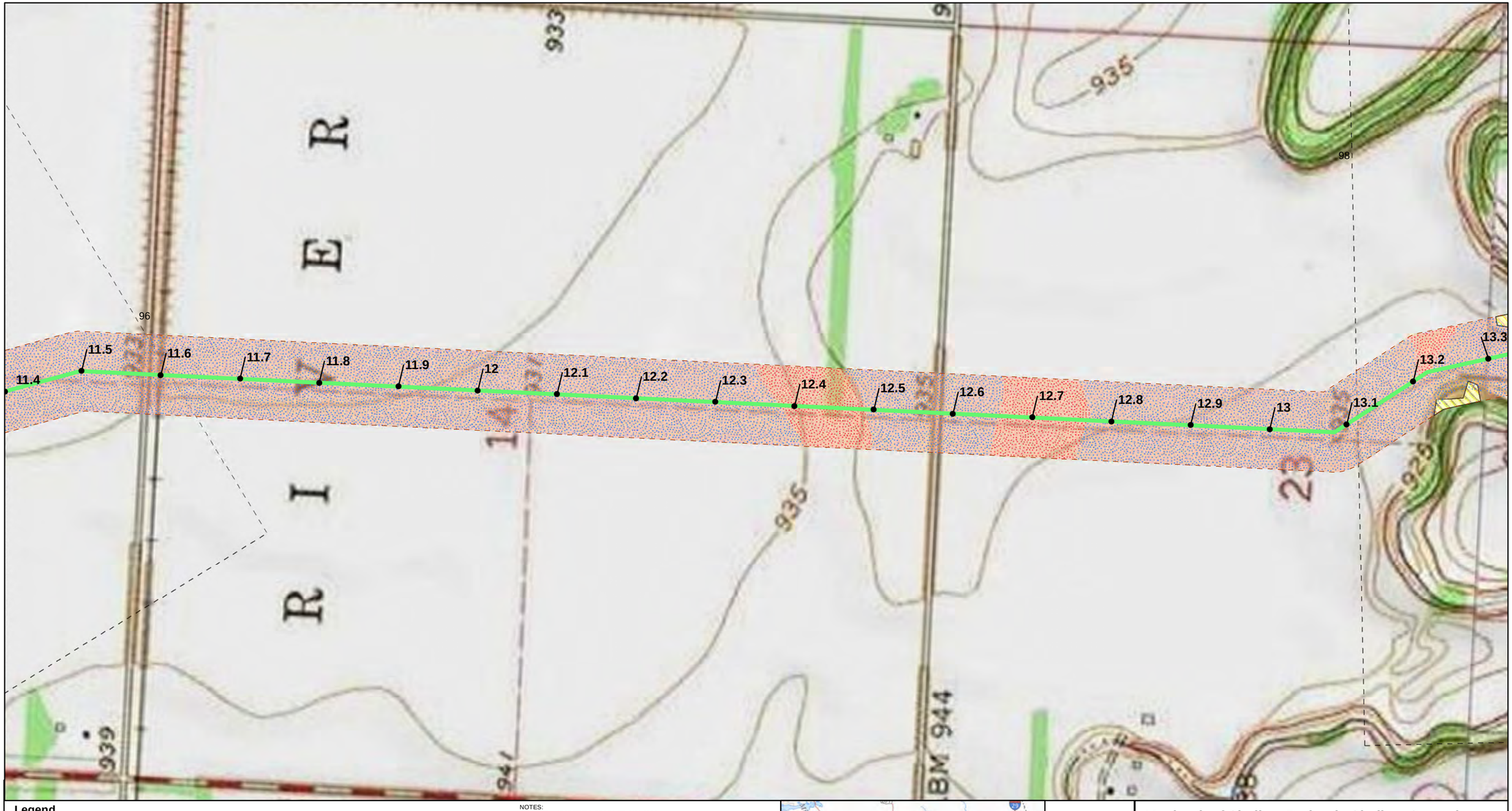

Legend

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FLOODING FREQUENCY CATEGORY

- FLOODING FREQUENCY: RARE

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER

NOTES:
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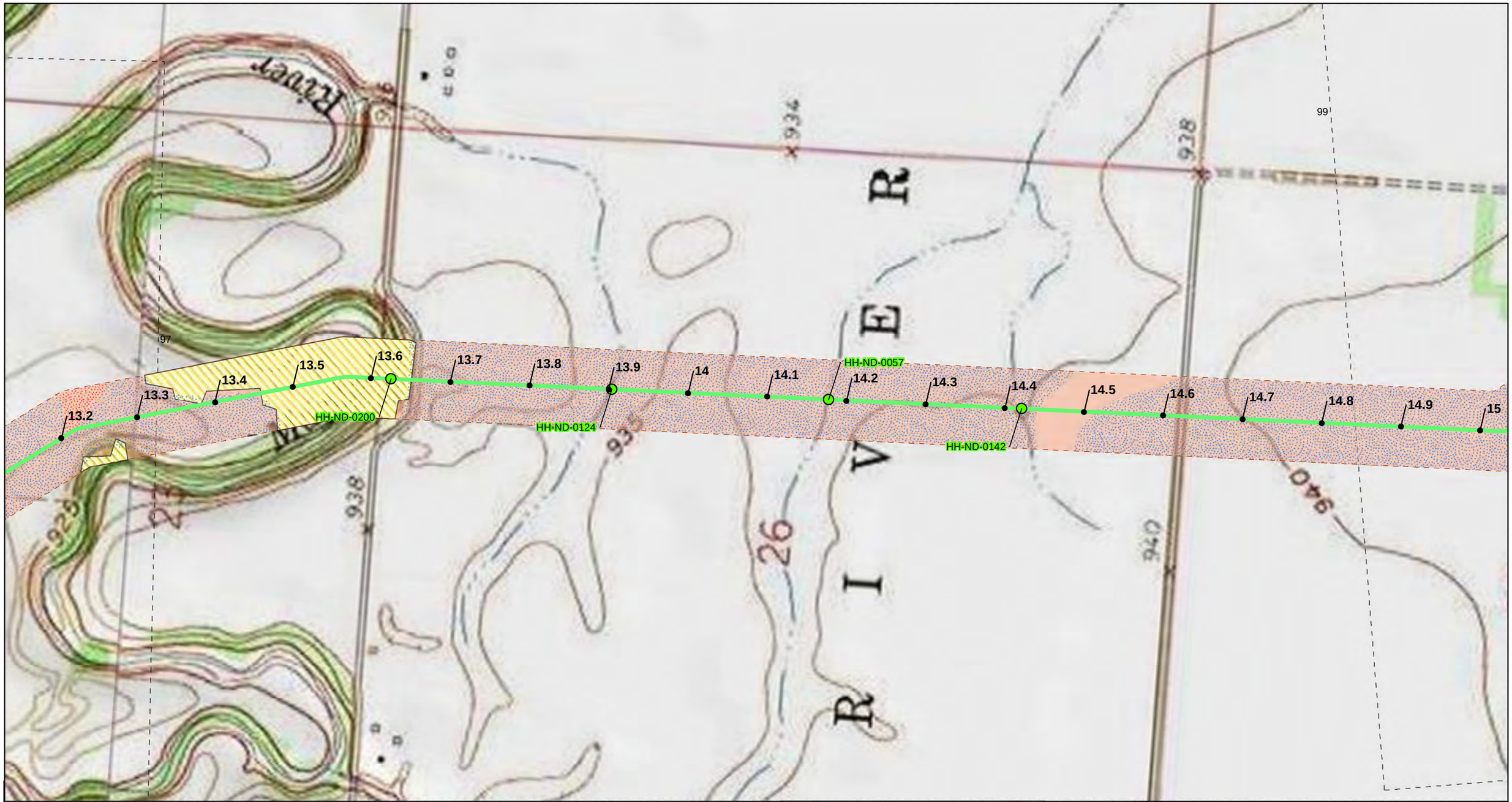

Legend

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FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: RARE

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER

NOTES:
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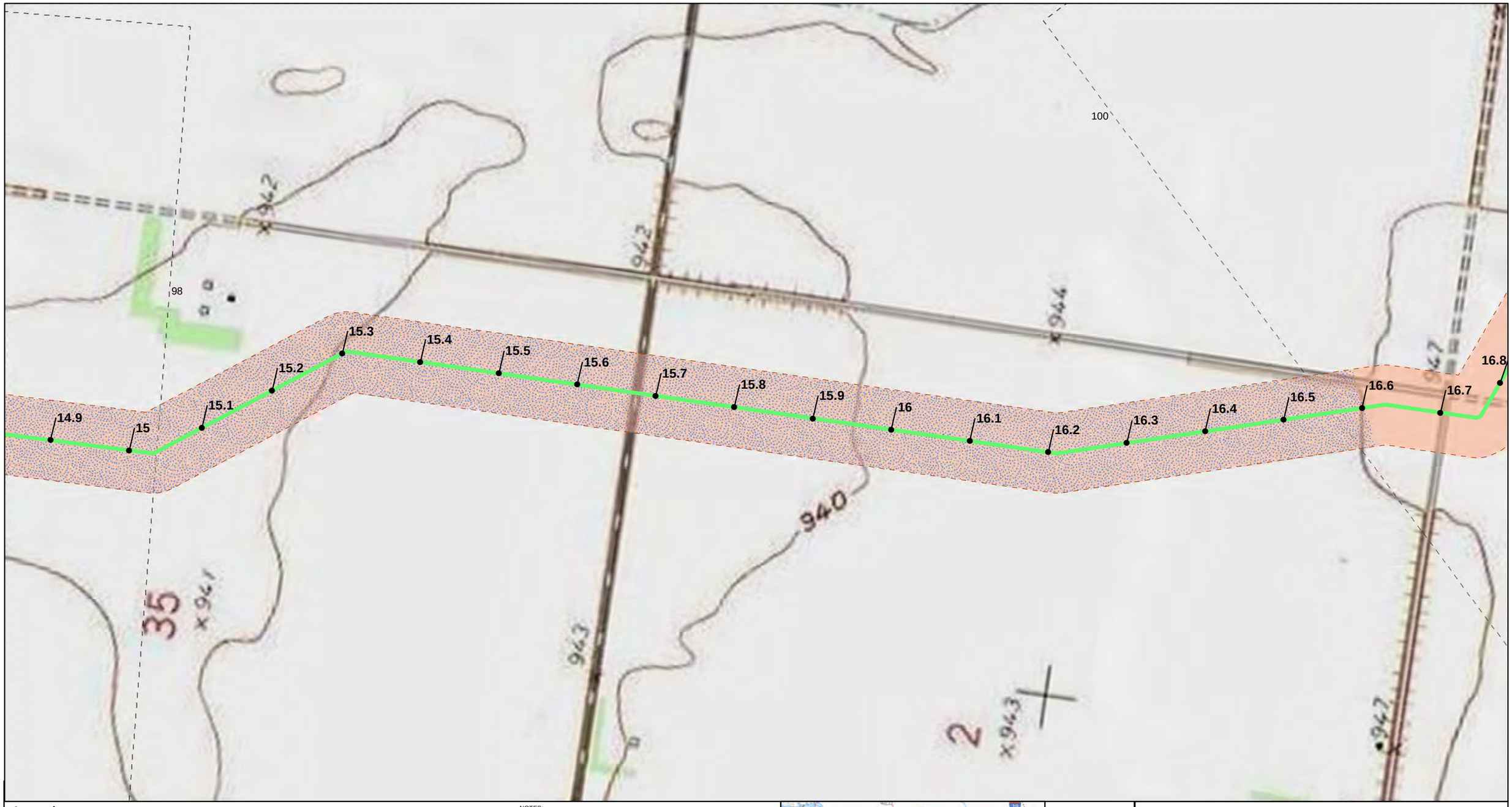

Legend

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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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Legend

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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
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- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER

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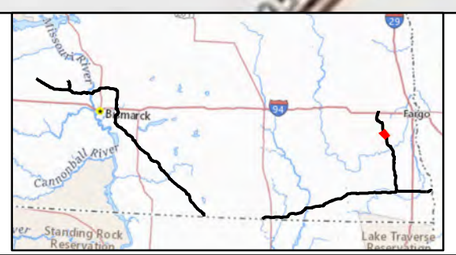

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Legend

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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
HIGHER: LEP >6
FROST ACTION CATEGORY
HIGHER

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Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450 | January 2024

Figure
1-101

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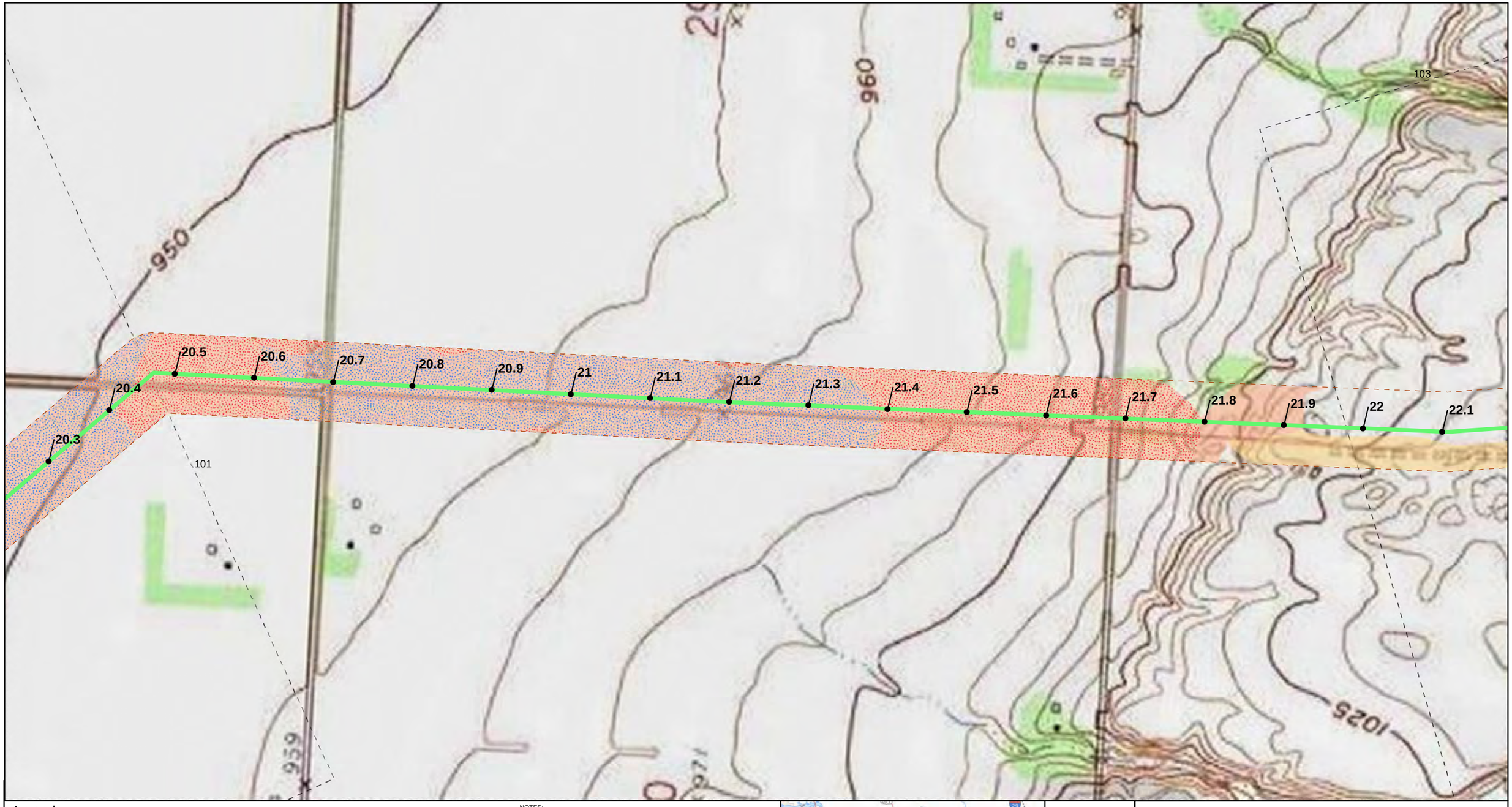

Legend

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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
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FROST ACTION CATEGORY
- HIGHER
- MEDIUM

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Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-102

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Legend

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- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
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Legend

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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
FROST ACTION CATEGORY
HIGHER
MEDIUM

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Legend

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EXPANSIVE SOILS (LEP VALUES)
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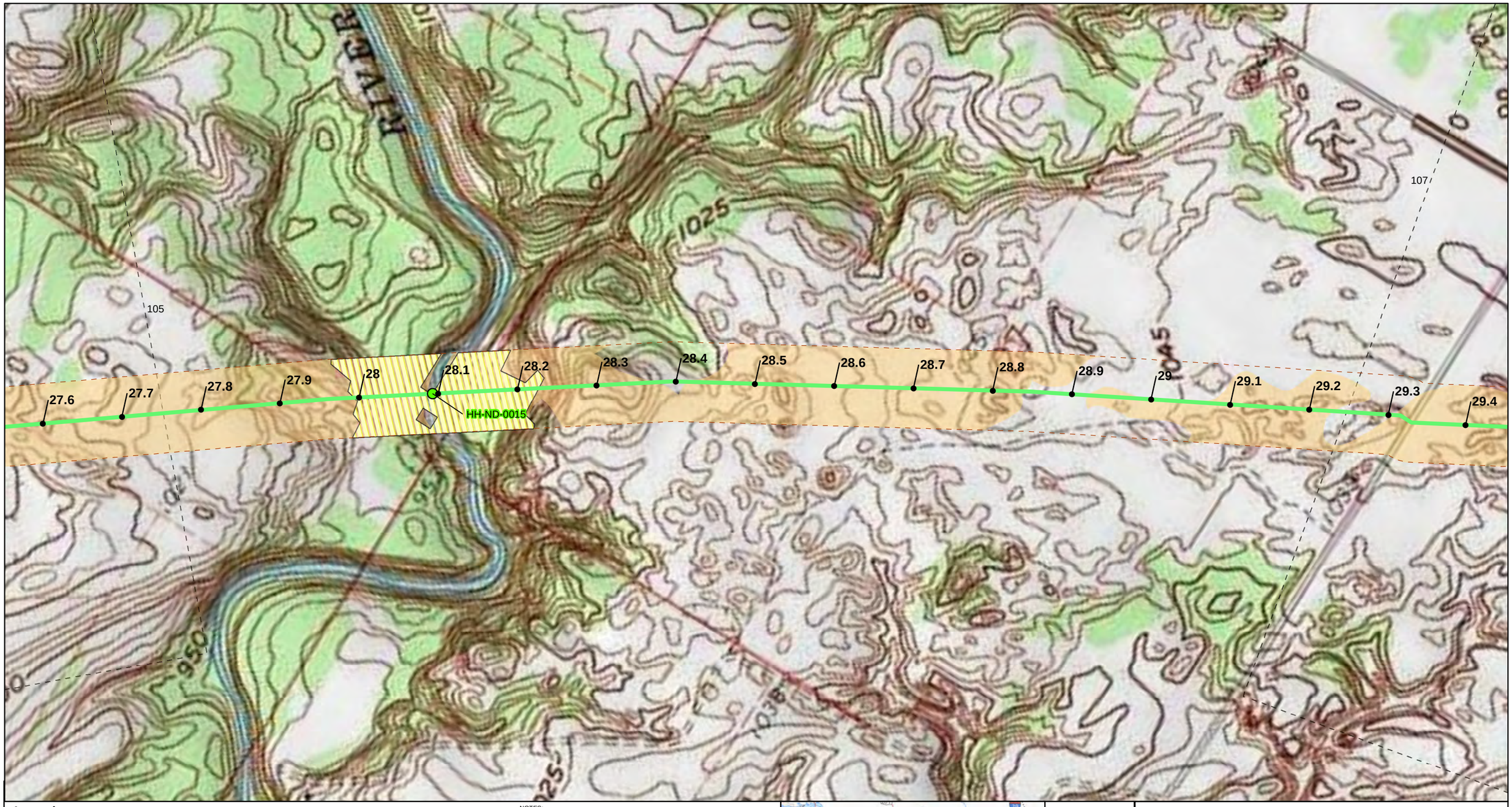

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- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: RARE
- EXPANSIVE SOILS (LEP VALUES)
- SHRINK/SWELL POTENTIAL
  - LOWER: LEP <3
- FROST ACTION CATEGORY
  - HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-106

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-324
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-107

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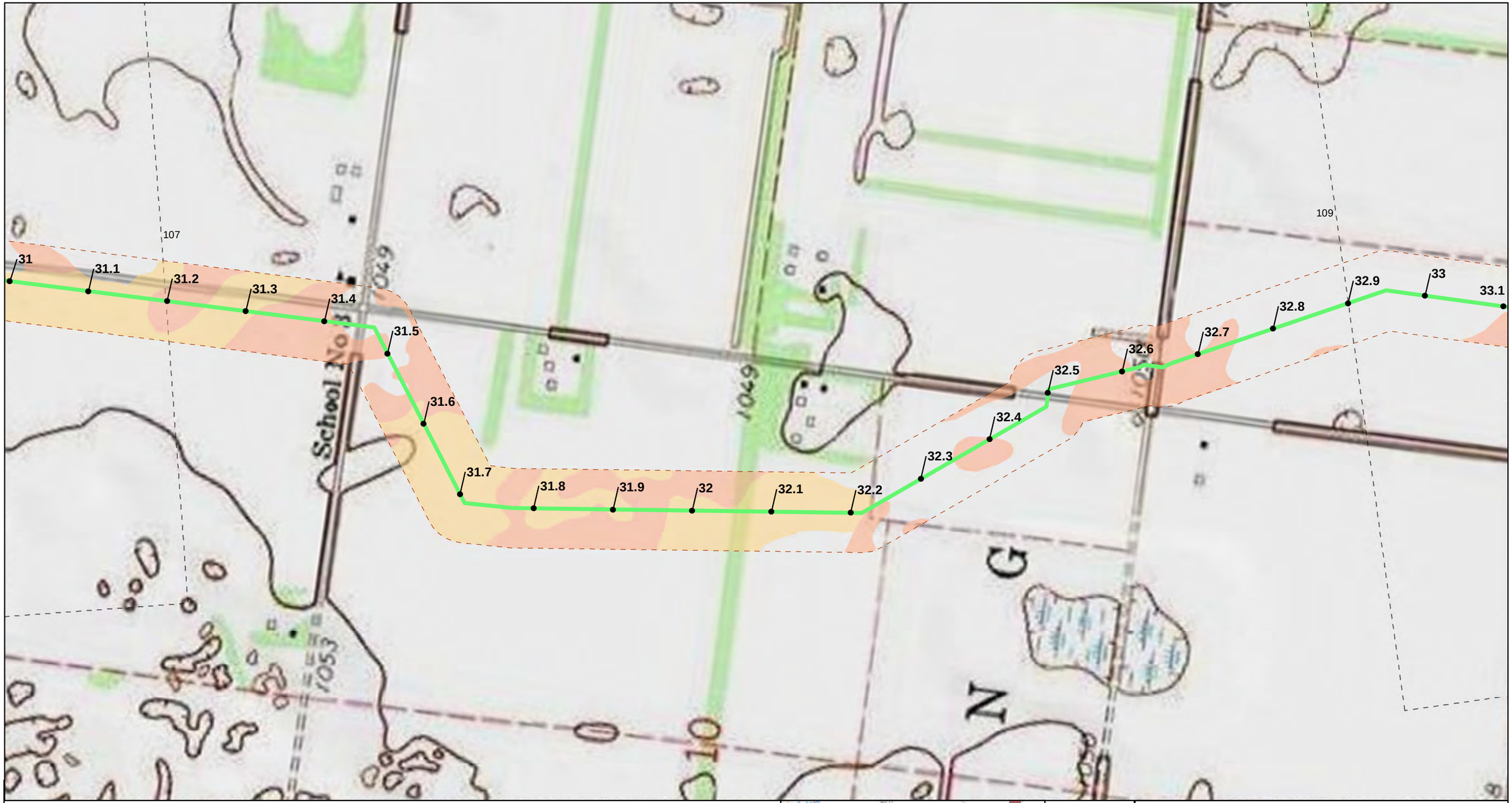

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-324
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-108

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-324
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-109

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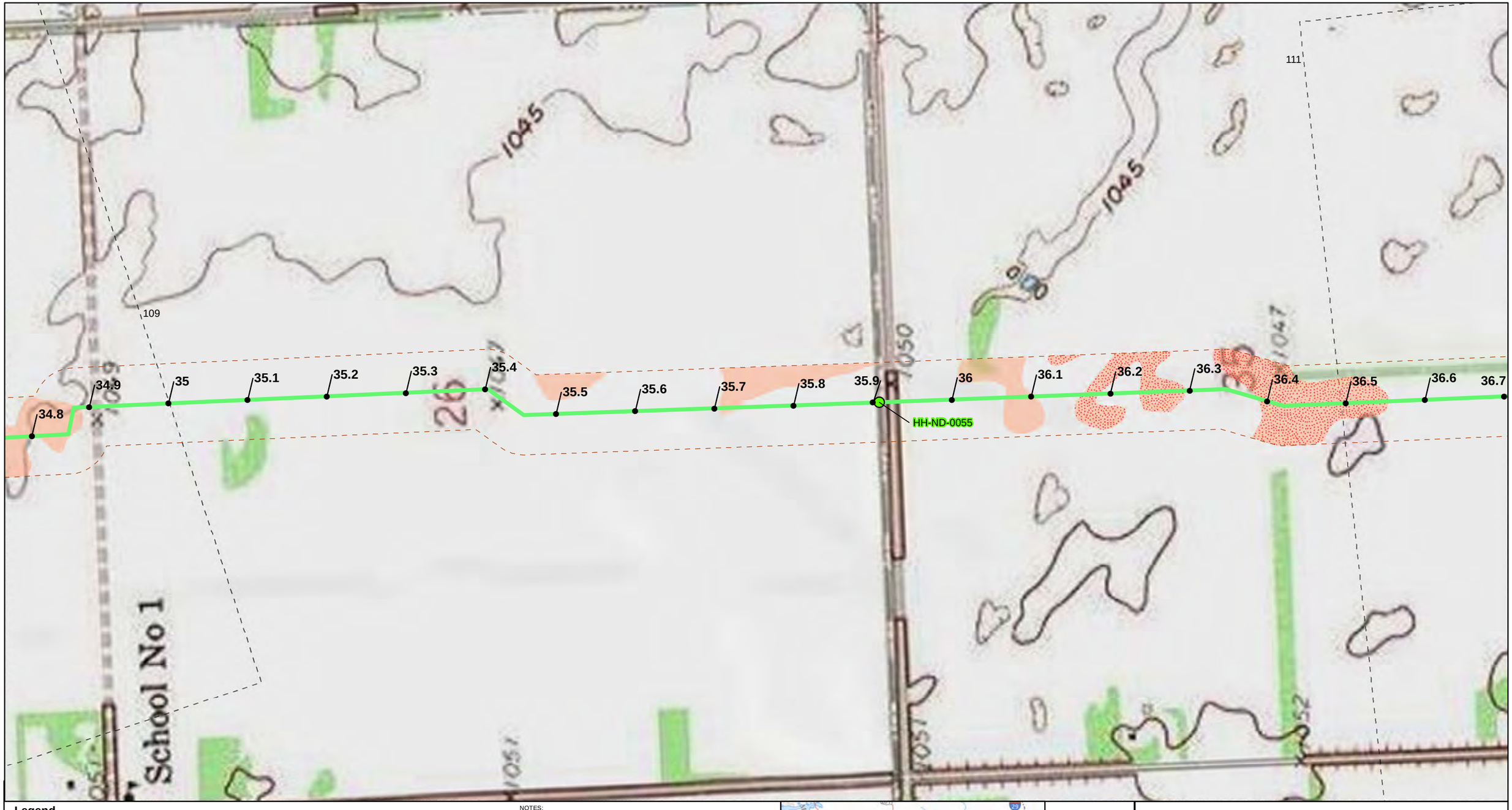

Legend

- REVISION 9 ROUTE MILEPOSTS
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- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-110

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-324
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- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
FROST ACTION CATEGORY
HIGHER

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-111

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Legend

- REVISION 9 ROUTE MILEPOSTS
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- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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Legend

- REVISION 9 ROUTE MILEPOSTS
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- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
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Figure
1-113

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-324
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
FROST ACTION CATEGORY
HIGHER

NOTES:
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0 250 500 1,000 Feet

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Summit Carbon Solutions - North Dakota
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Figure
1-114

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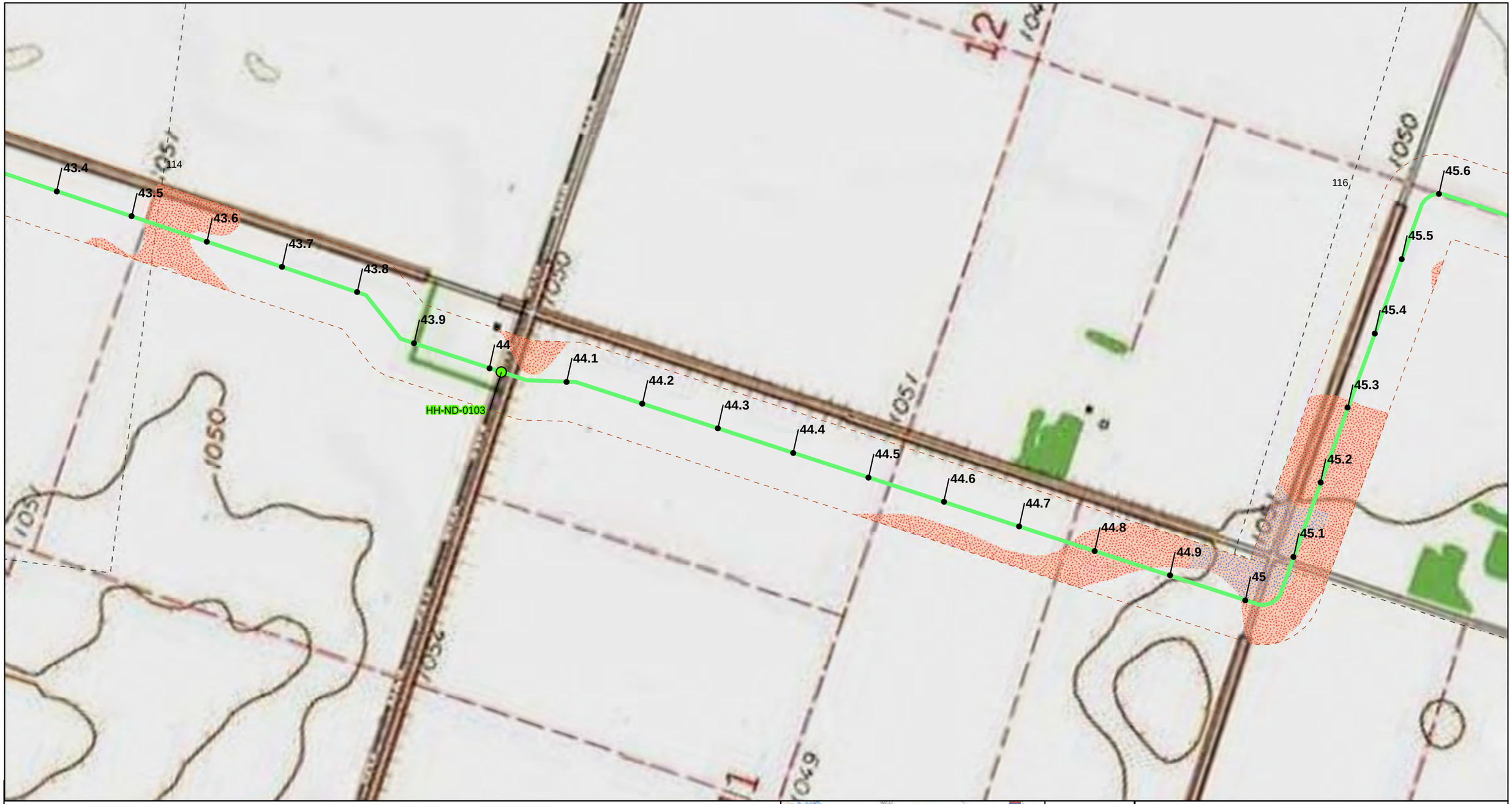

Legend

- REVISION 9 ROUTE MILEPOSTS
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- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
HIGHER: LEP >6
FROST ACTION CATEGORY
HIGHER

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
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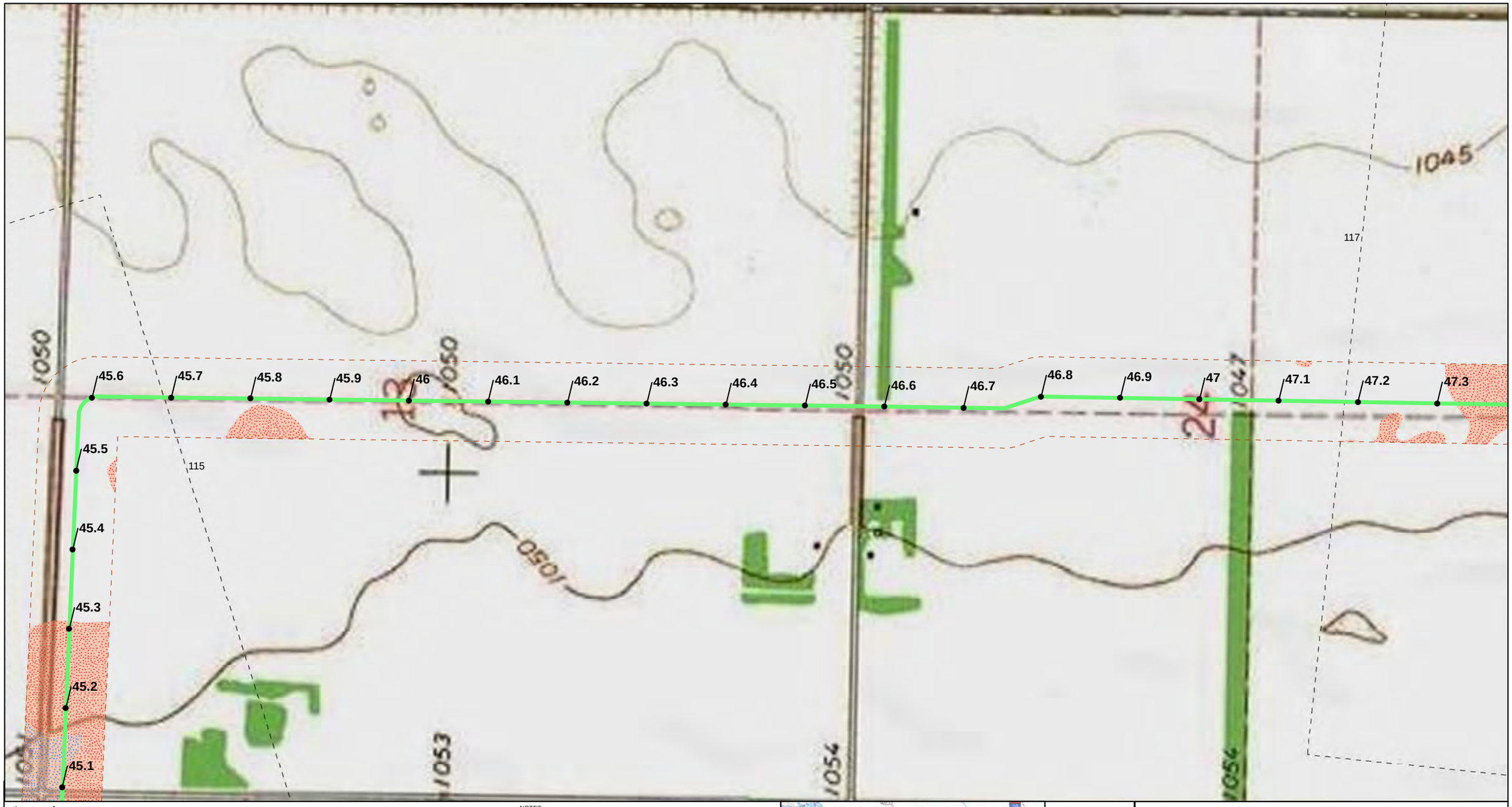

Legend

- REVISION 9 ROUTE MILEPOSTS
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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-116

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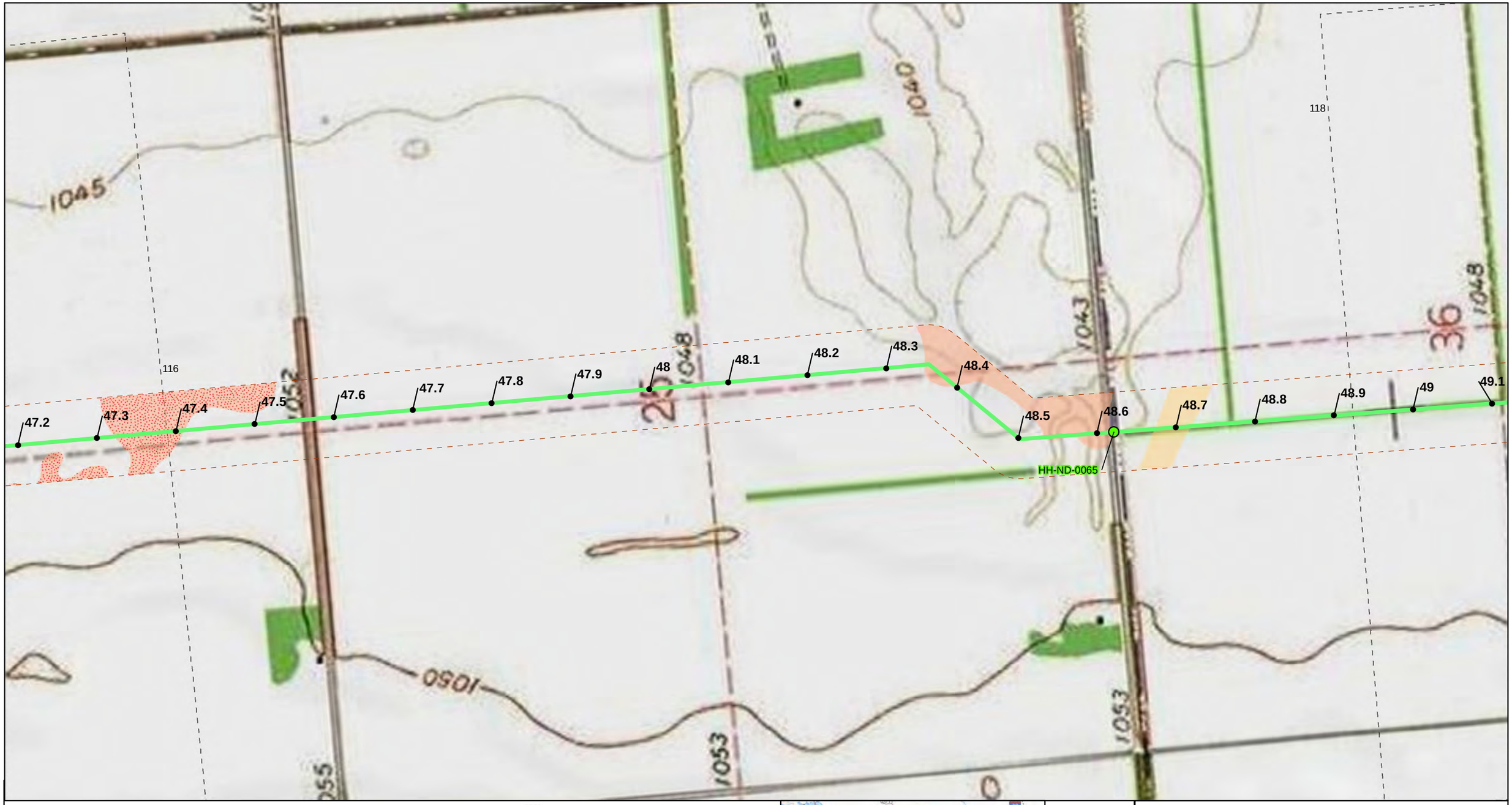

Legend

- REVISION 9 ROUTE MILEPOSTS
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- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

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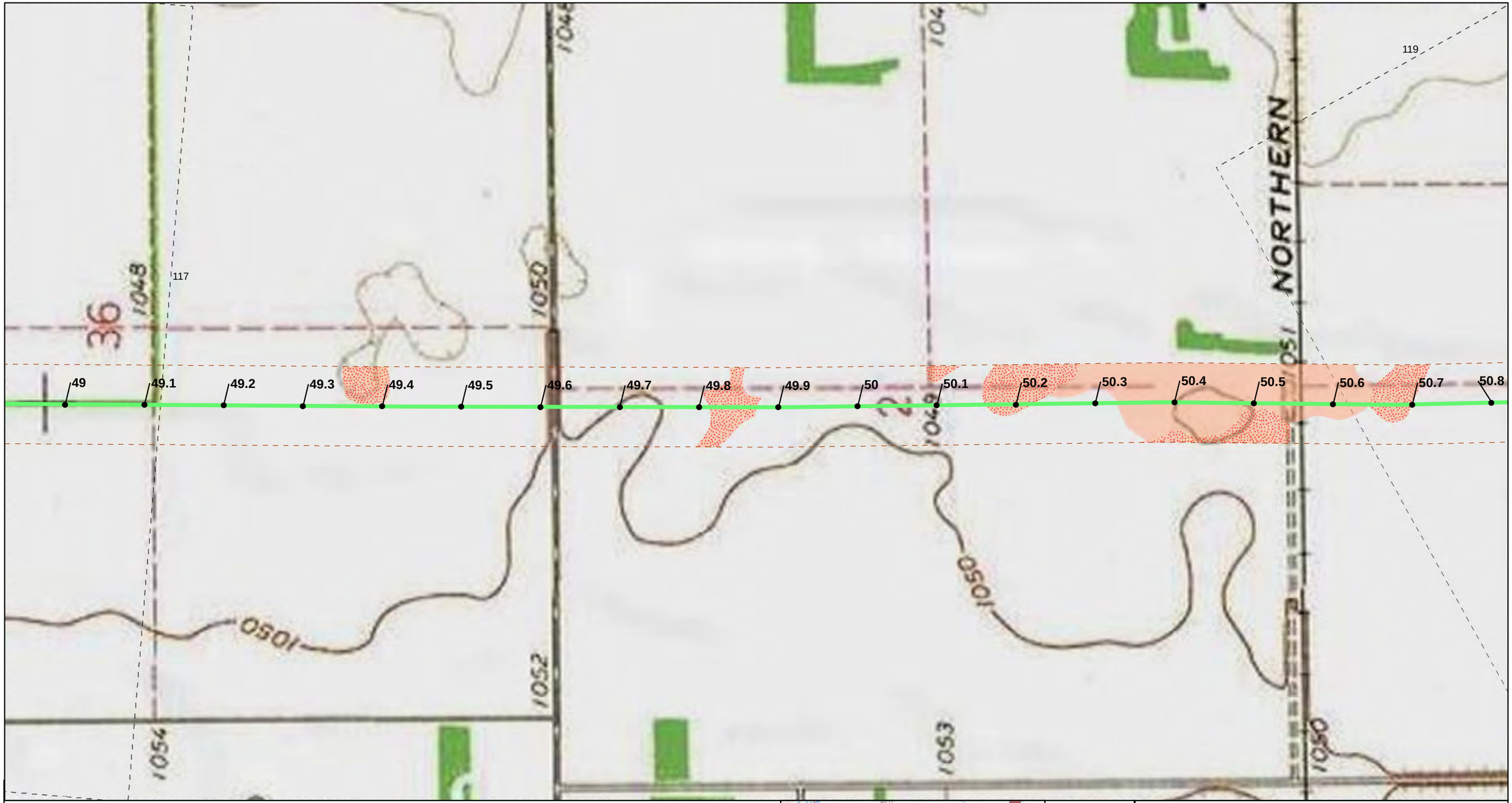

Legend

- REVISION 9 ROUTE MILEPOSTS
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- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER

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Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

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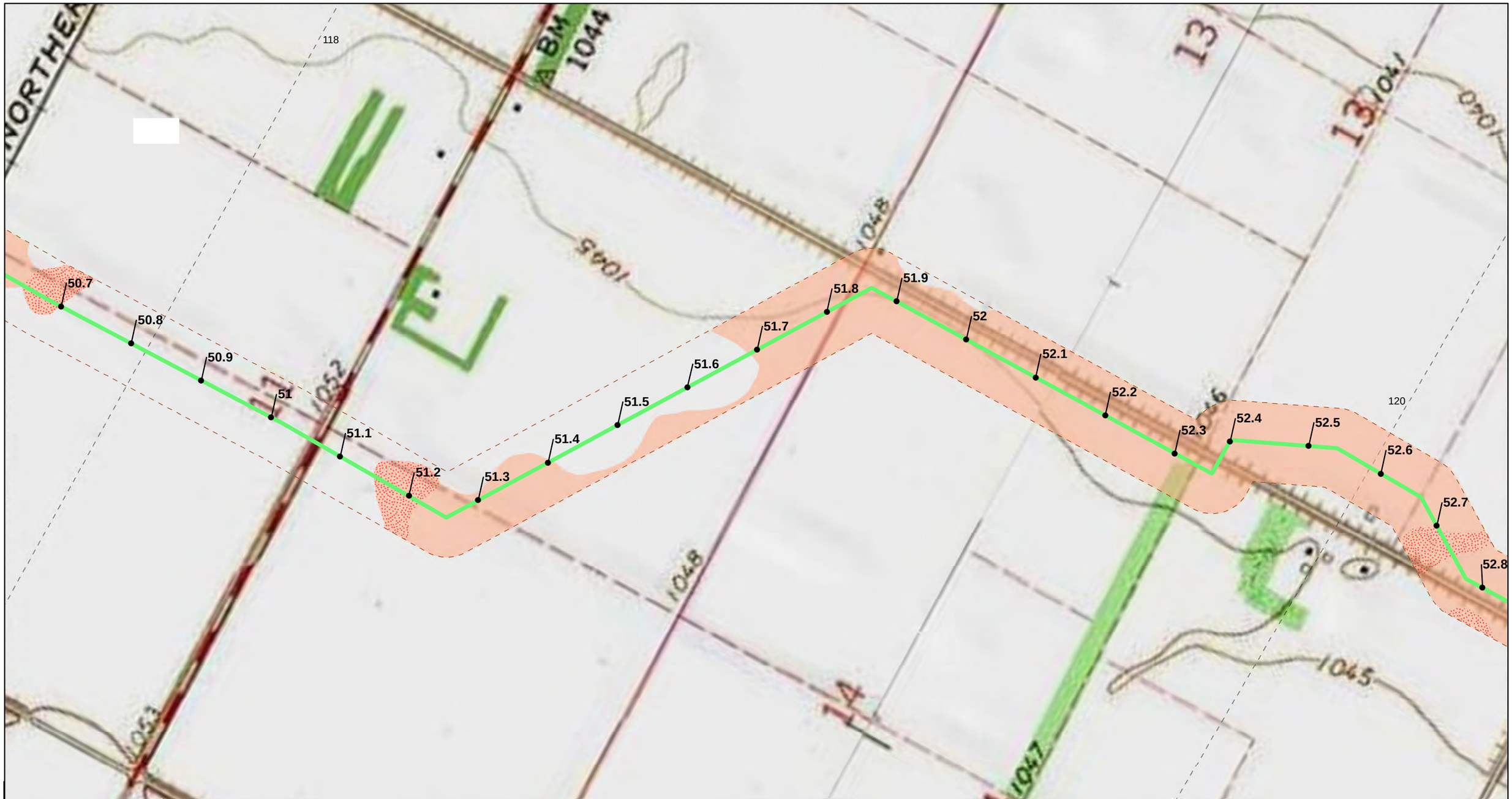

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-324
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-119

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-324
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
PIPELINE ALIGNMENTS RECEIVED 1/24/2024.
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0 250 500 1,000 Feet

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-120

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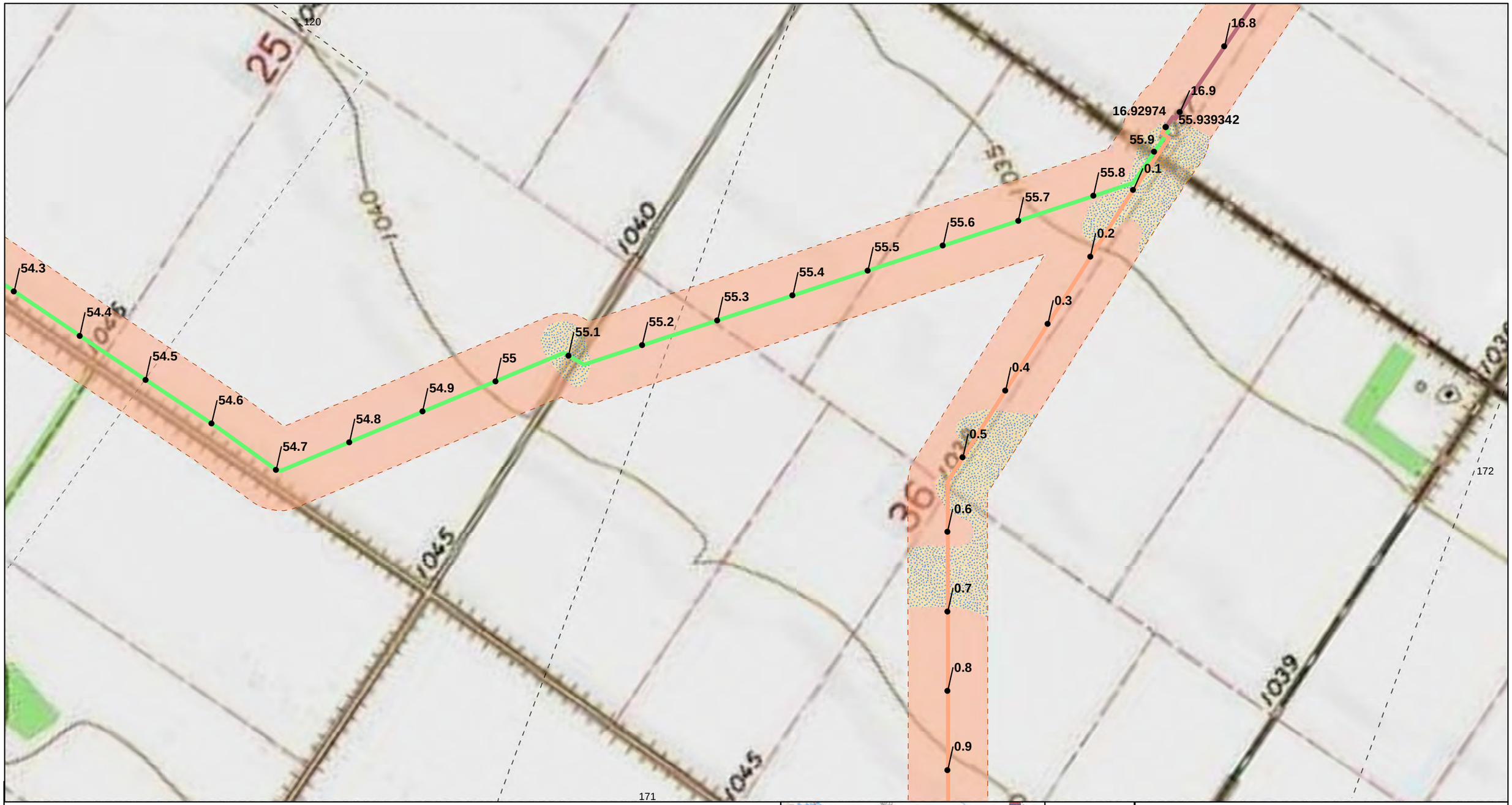

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-323
- NDL-324
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-121

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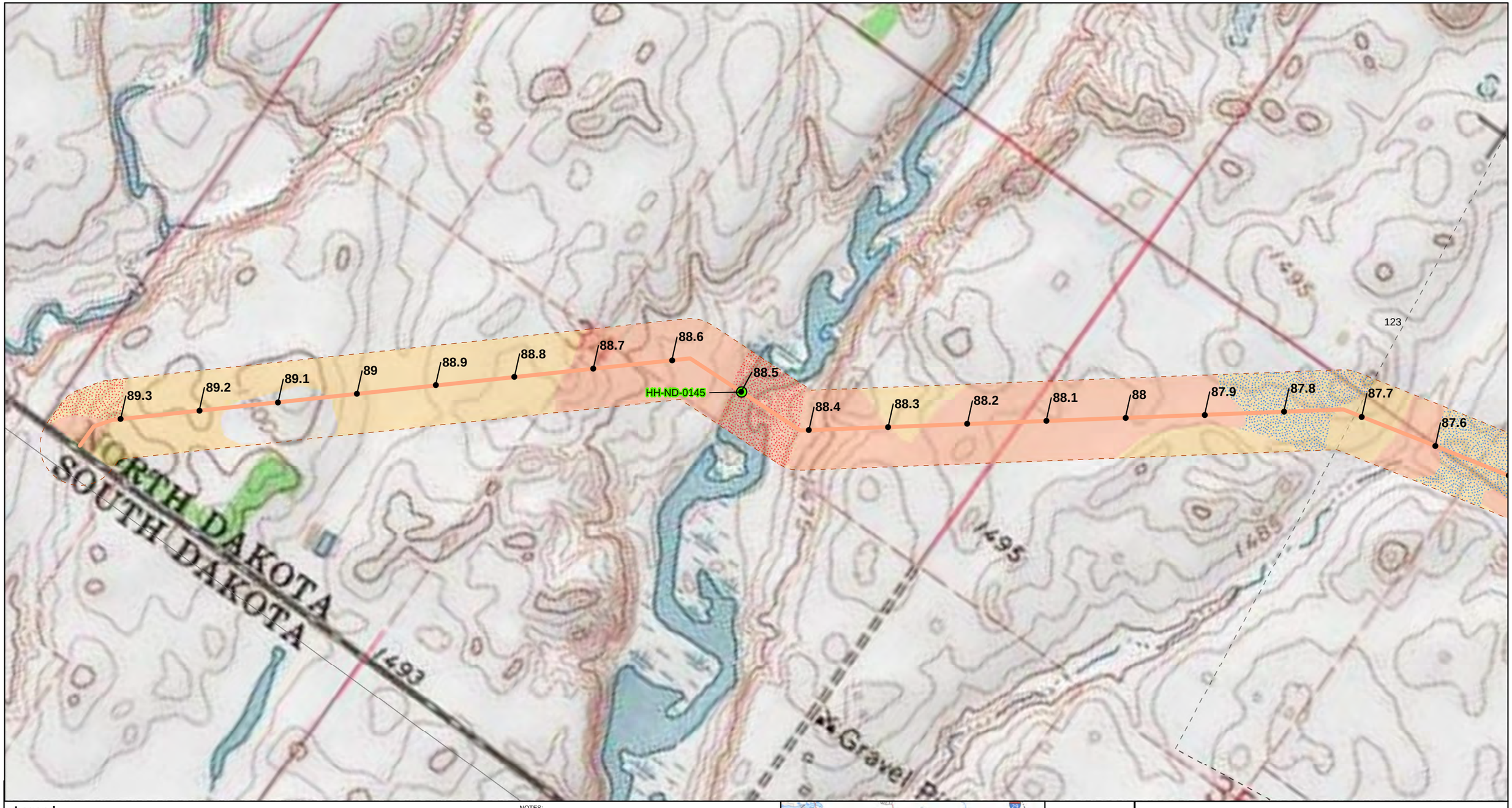

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-122

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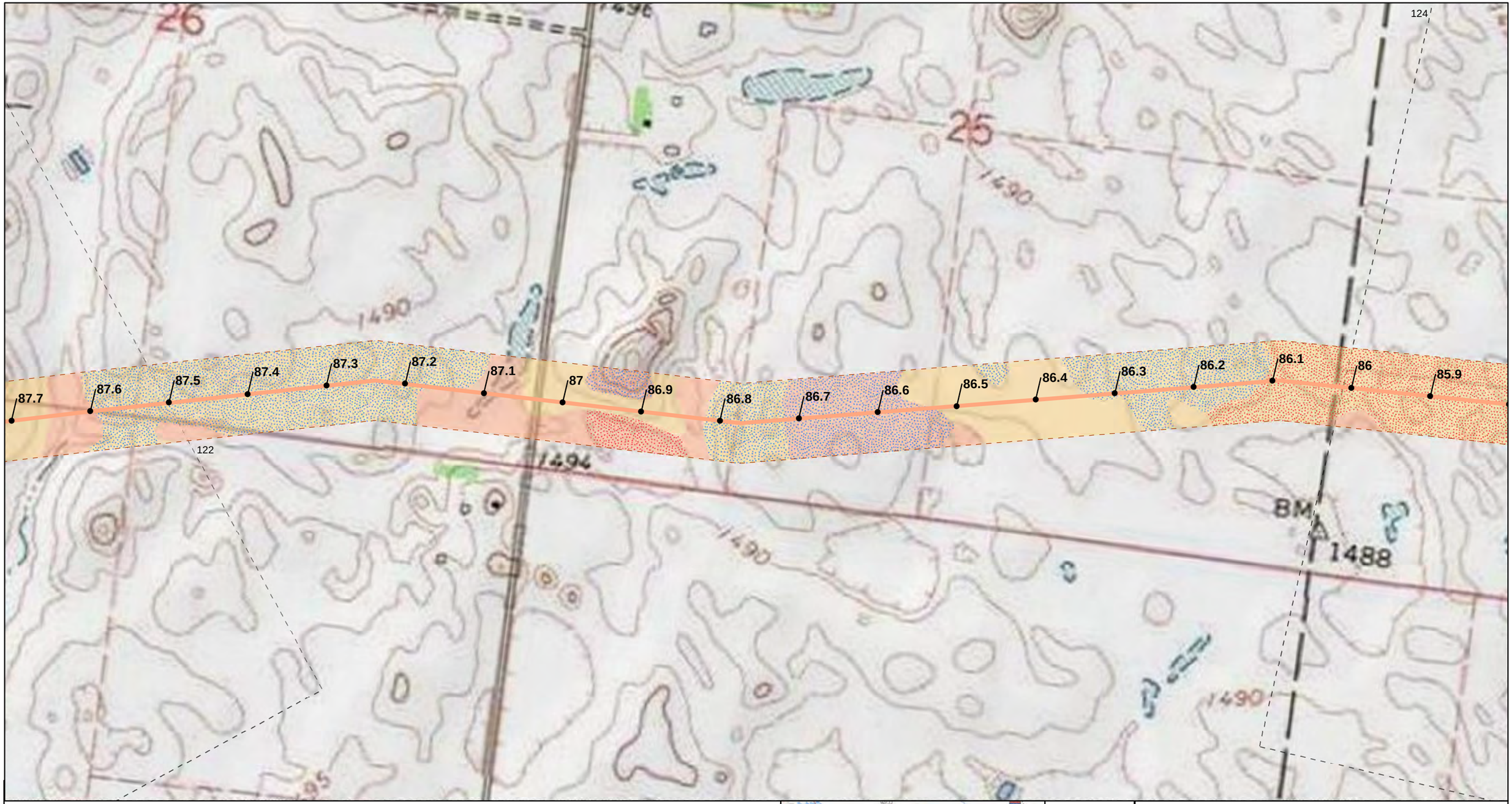

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-123

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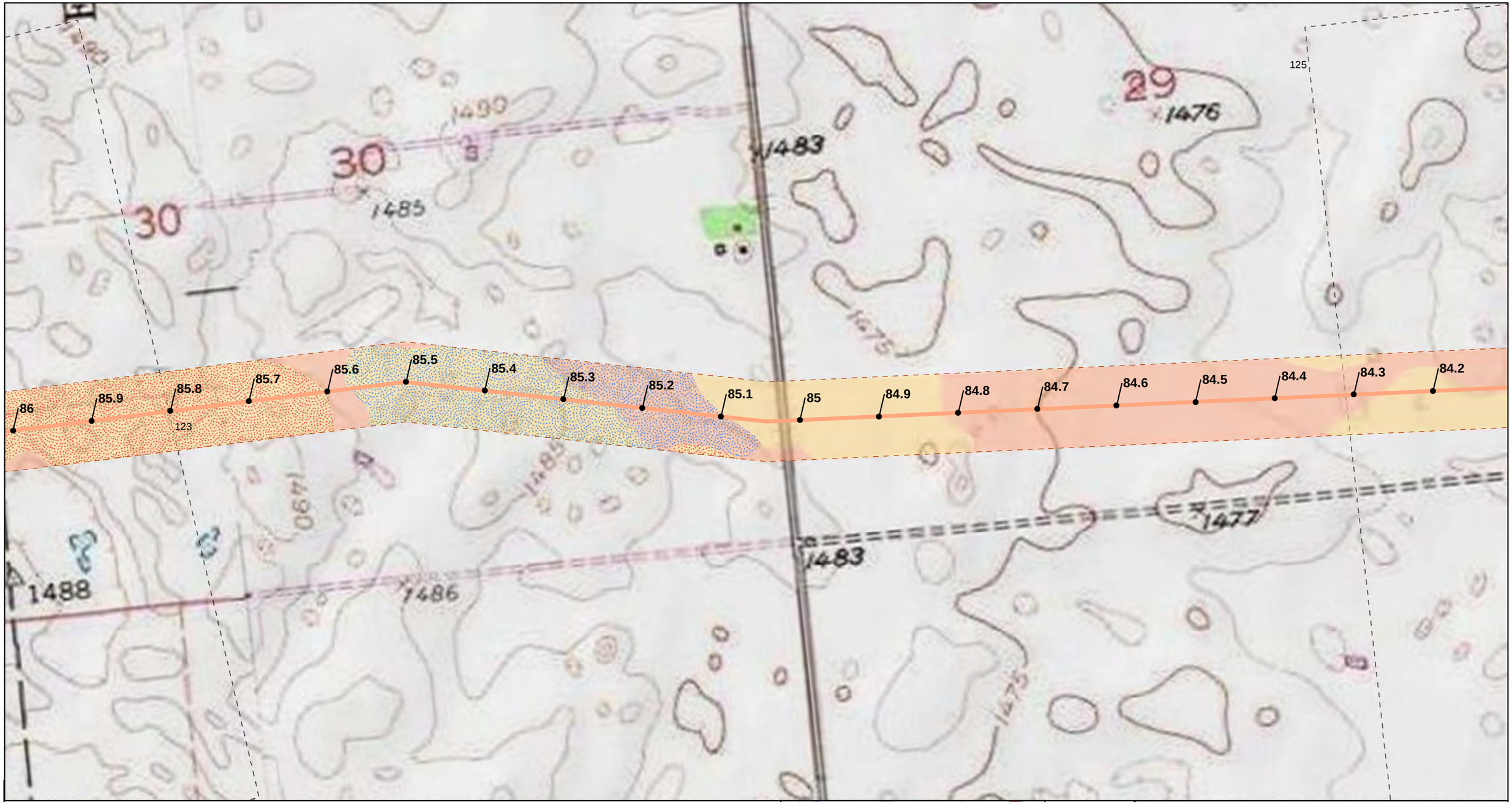

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-124

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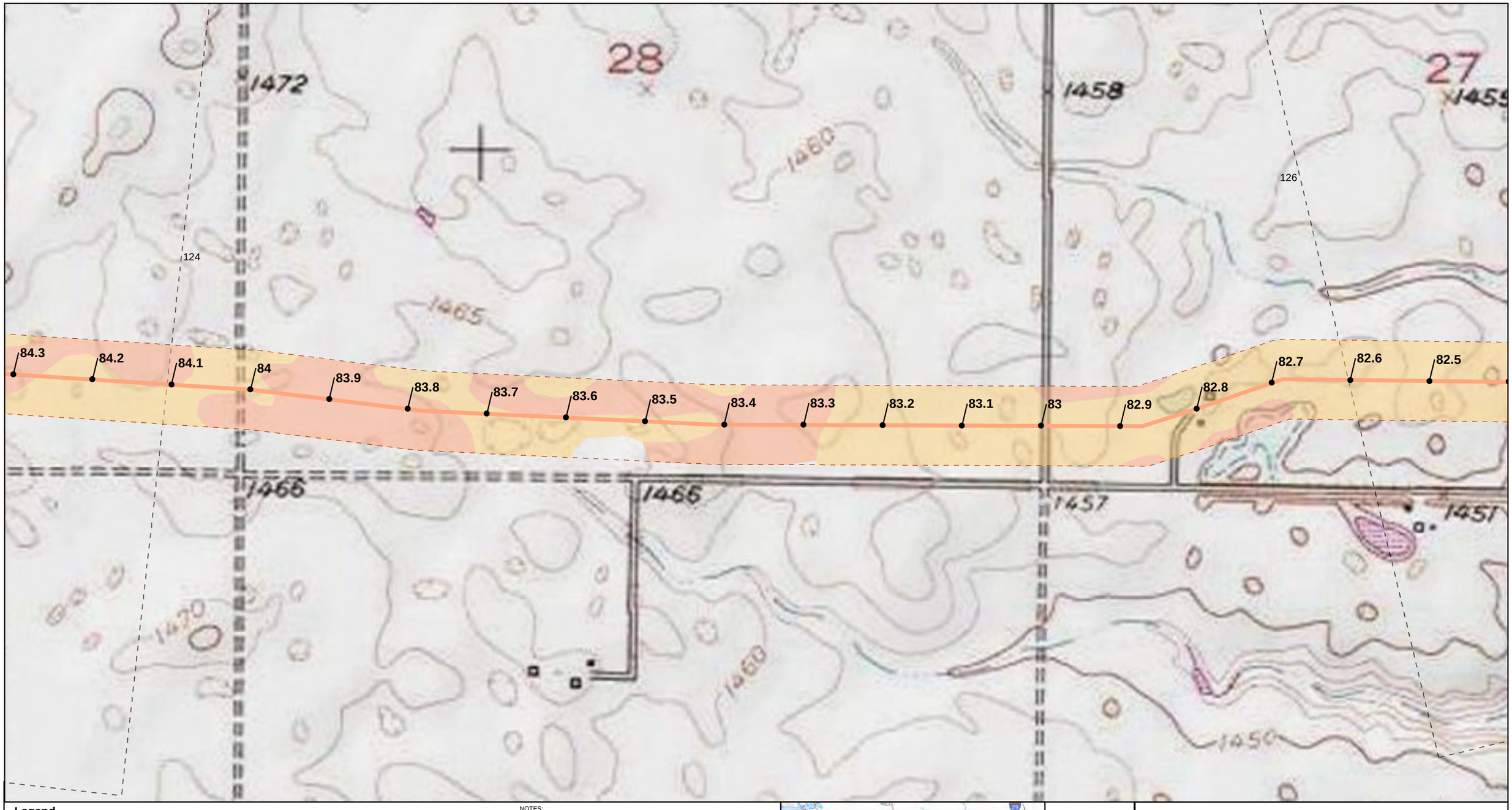

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-125

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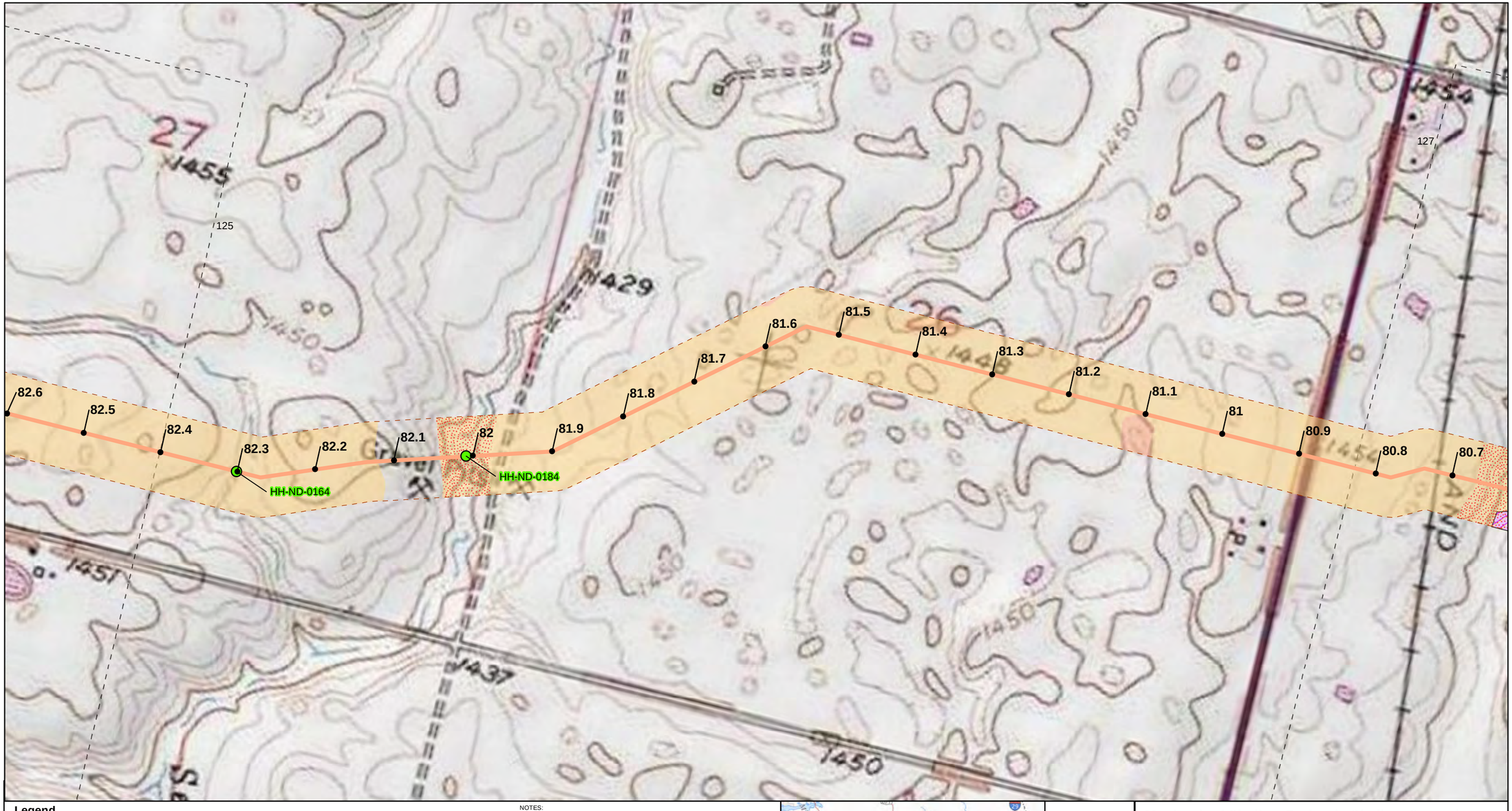

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-126

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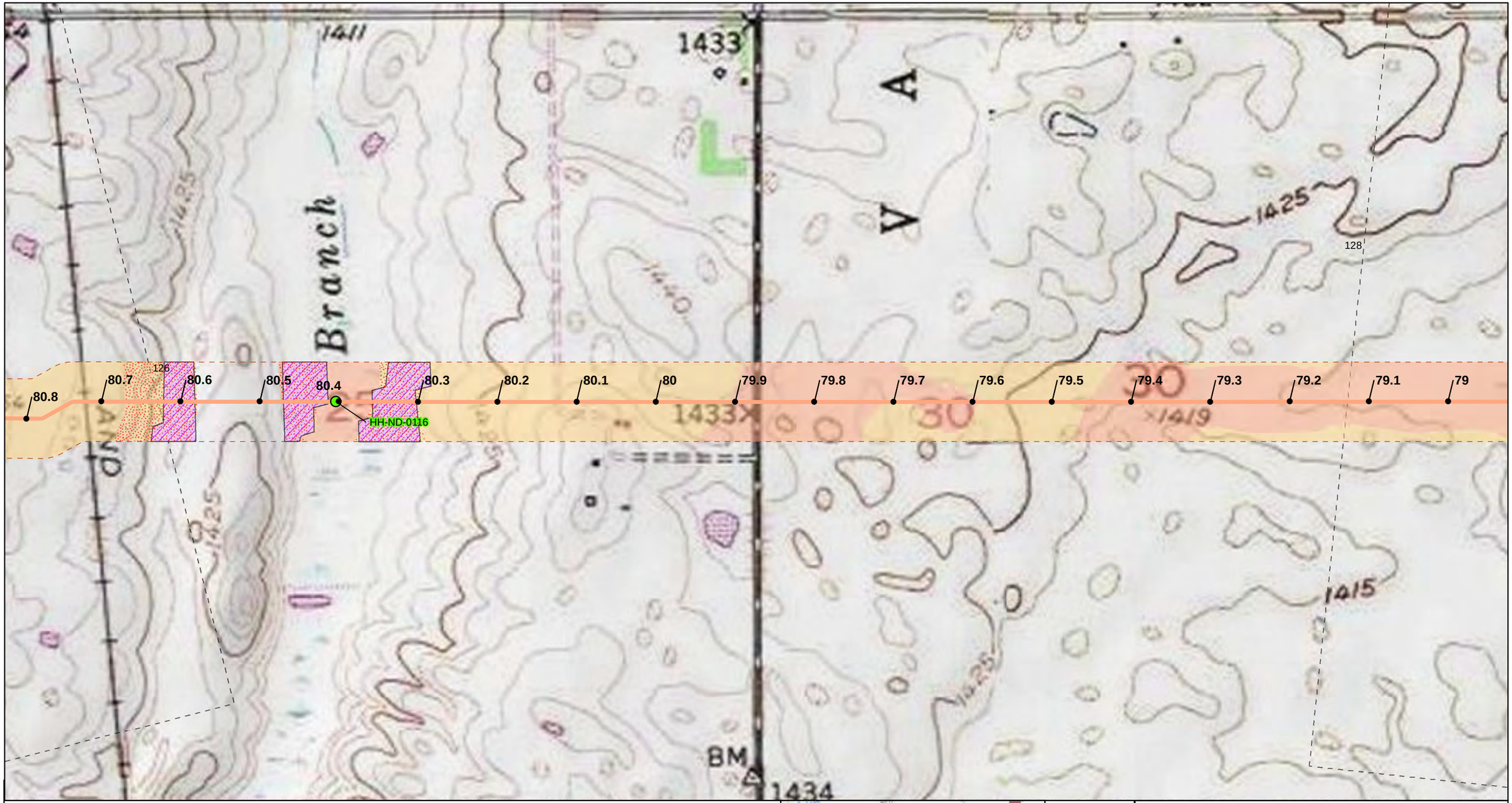

Legend

- REVISION 9 ROUTE MILEPOSTS
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- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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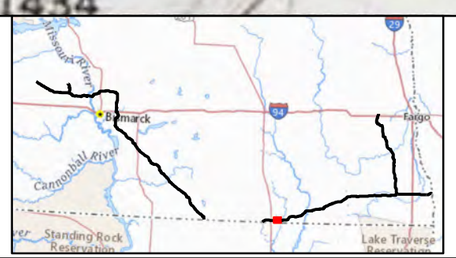

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-127

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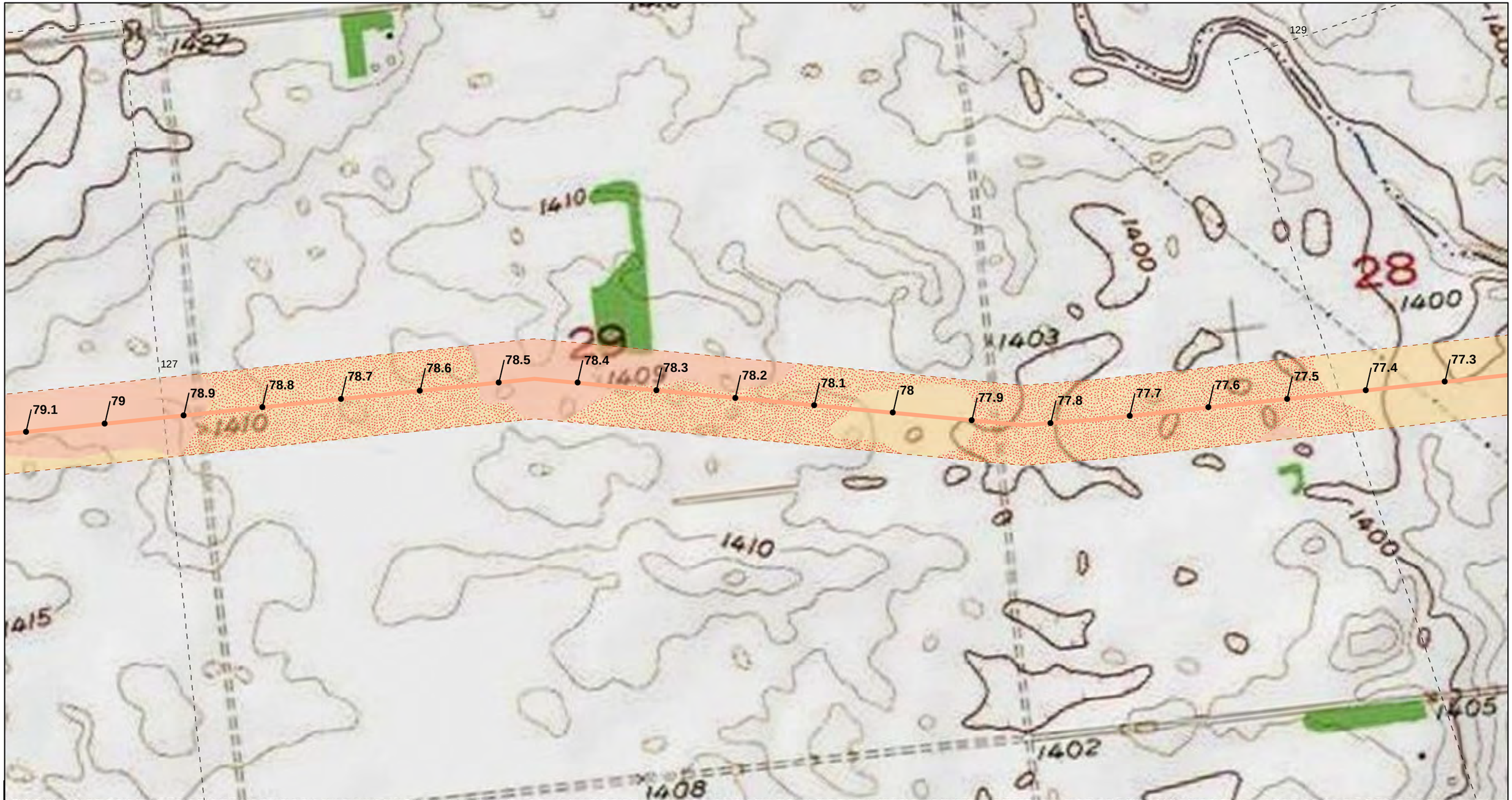

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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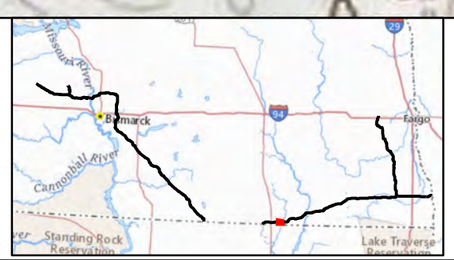

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-128

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-129

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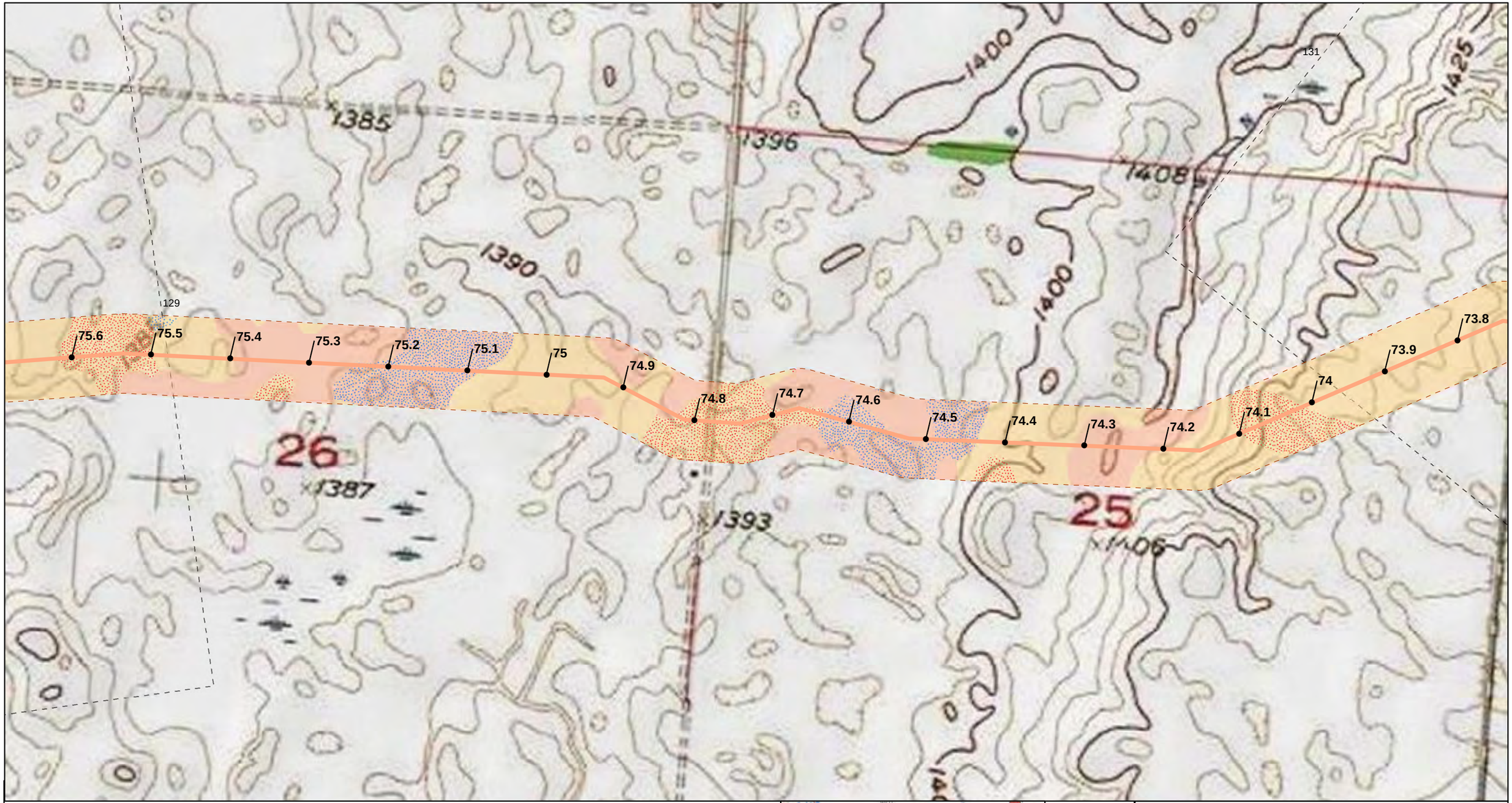

Legend

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- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
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FROST ACTION CATEGORY
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- MEDIUM

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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-130

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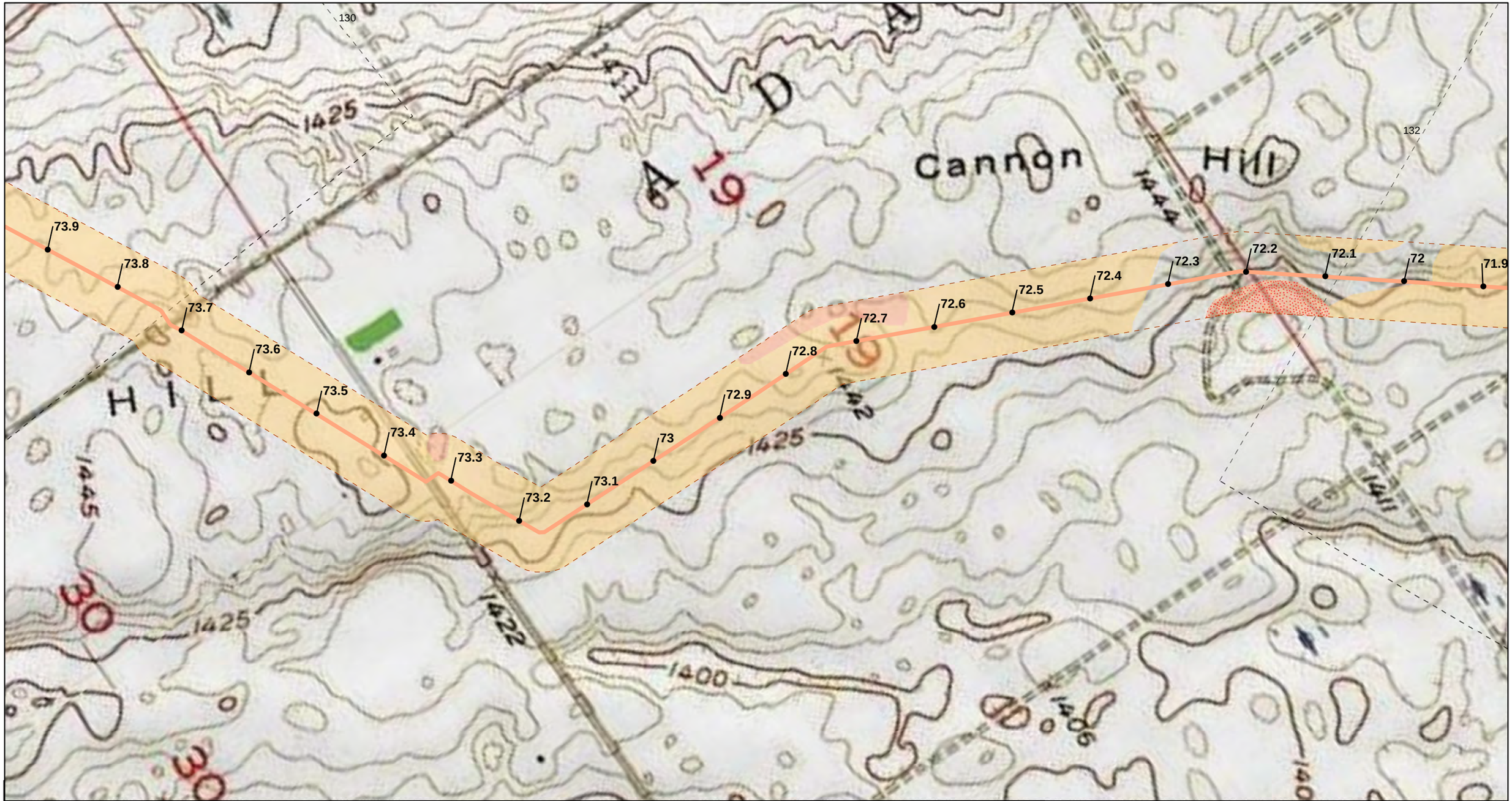

Legend

- REVISION 9 ROUTE MILEPOSTS
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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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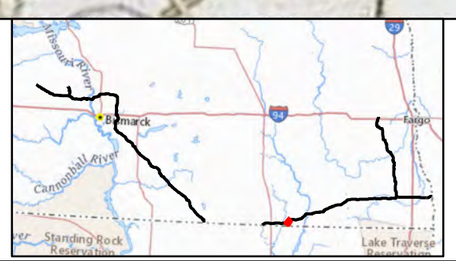

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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Phase I Assessment

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TXG0450	January 2024	Figure 1-131

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Legend

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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
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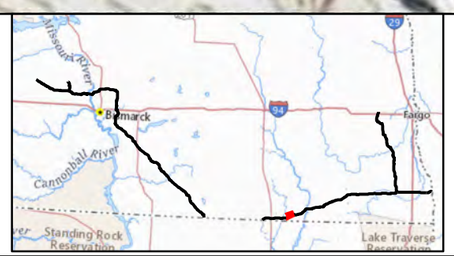

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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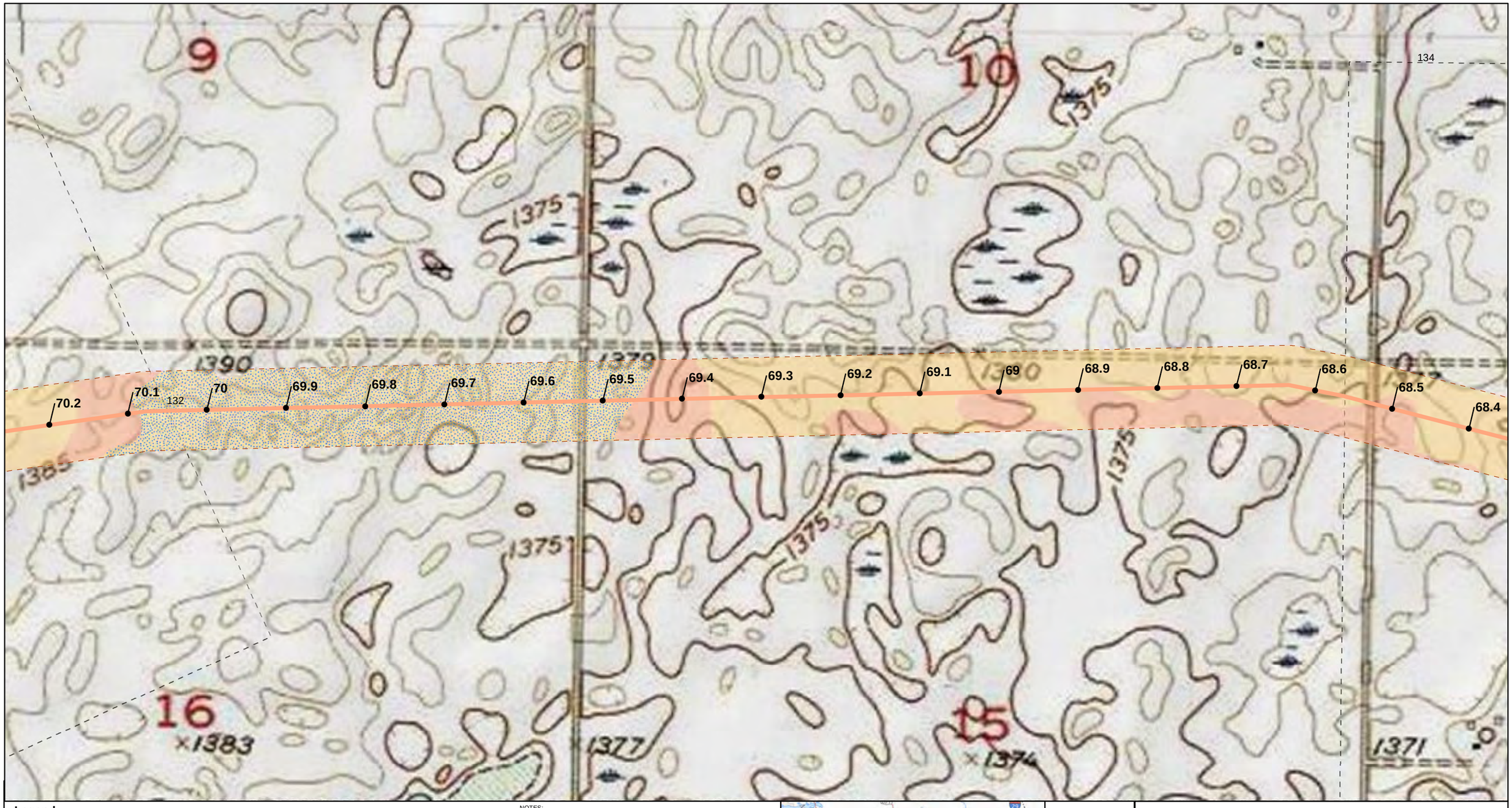

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EXPANSIVE SOILS (LEP VALUES)
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TXG0450	January 2024	Figure 1-133

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Legend

- REVISION 9 ROUTE MILEPOSTS
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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
FROST ACTION CATEGORY
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MEDIUM

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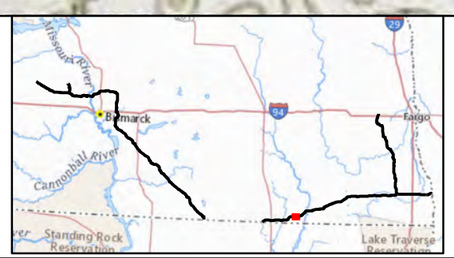

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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Figure **1-134**

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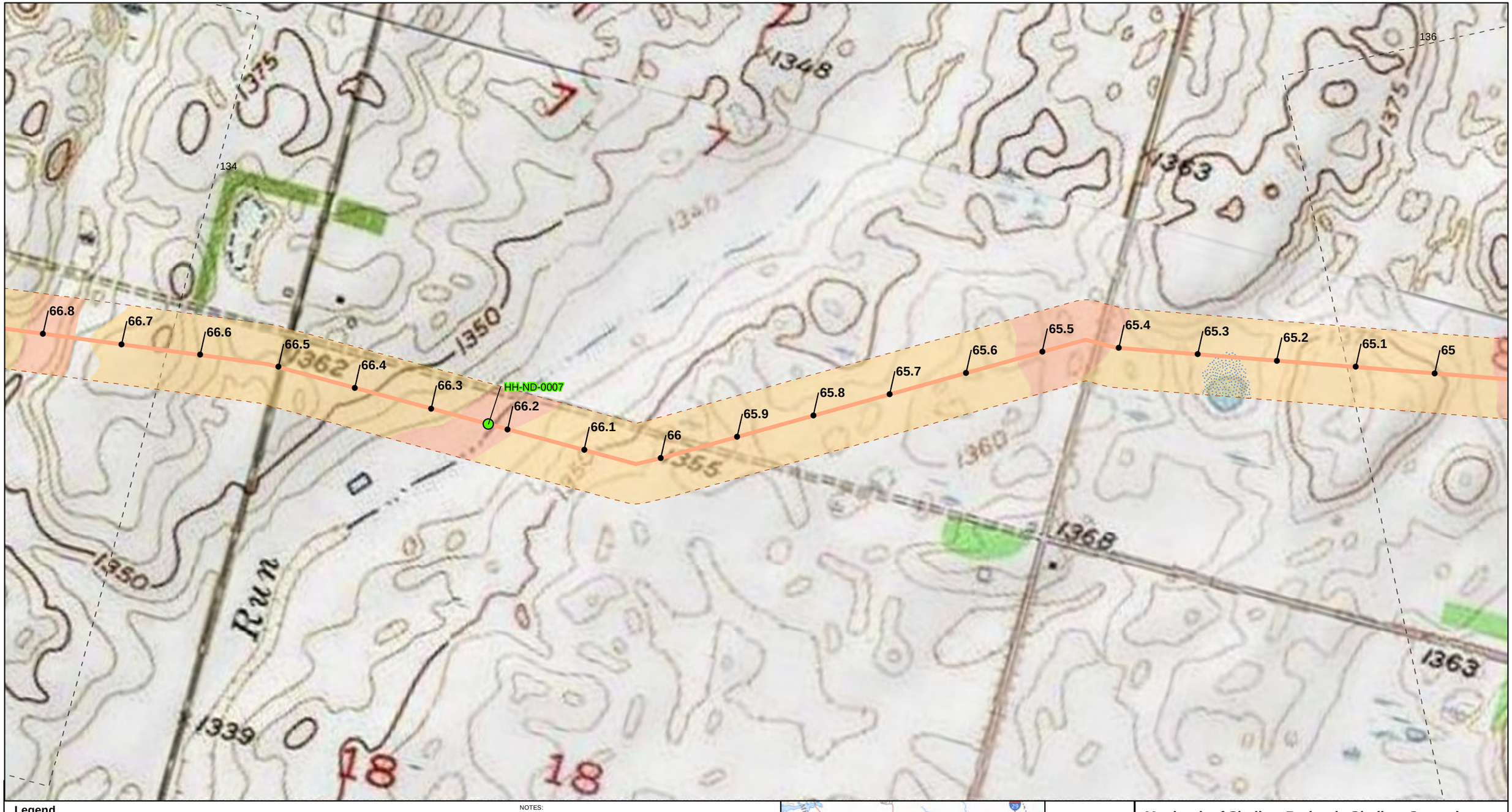

Legend

- REVISION 9 ROUTE MILEPOSTS
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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
HIGHER: LEP >6
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
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Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
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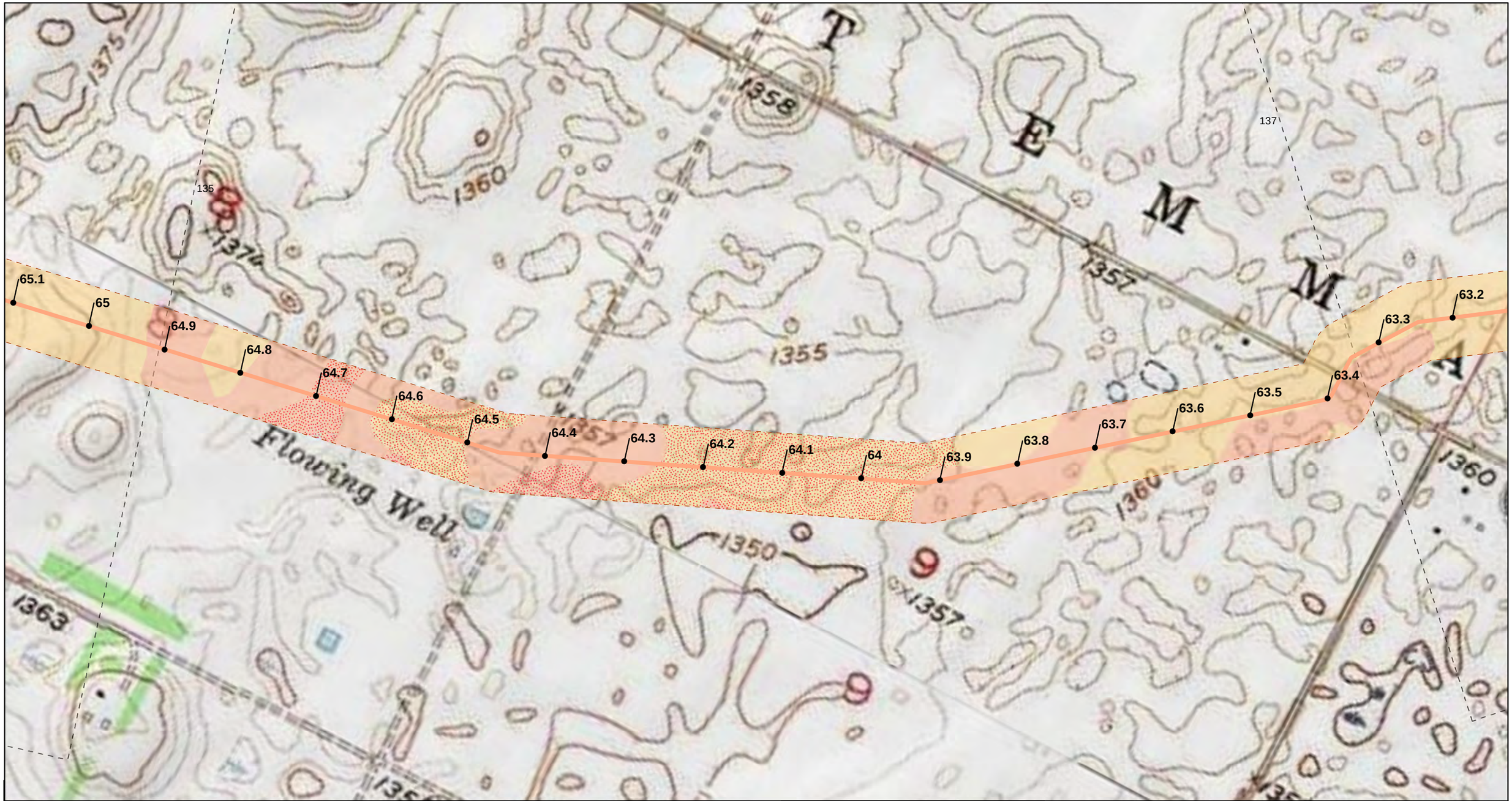

Legend

- REVISION 9 ROUTE MILEPOSTS
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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
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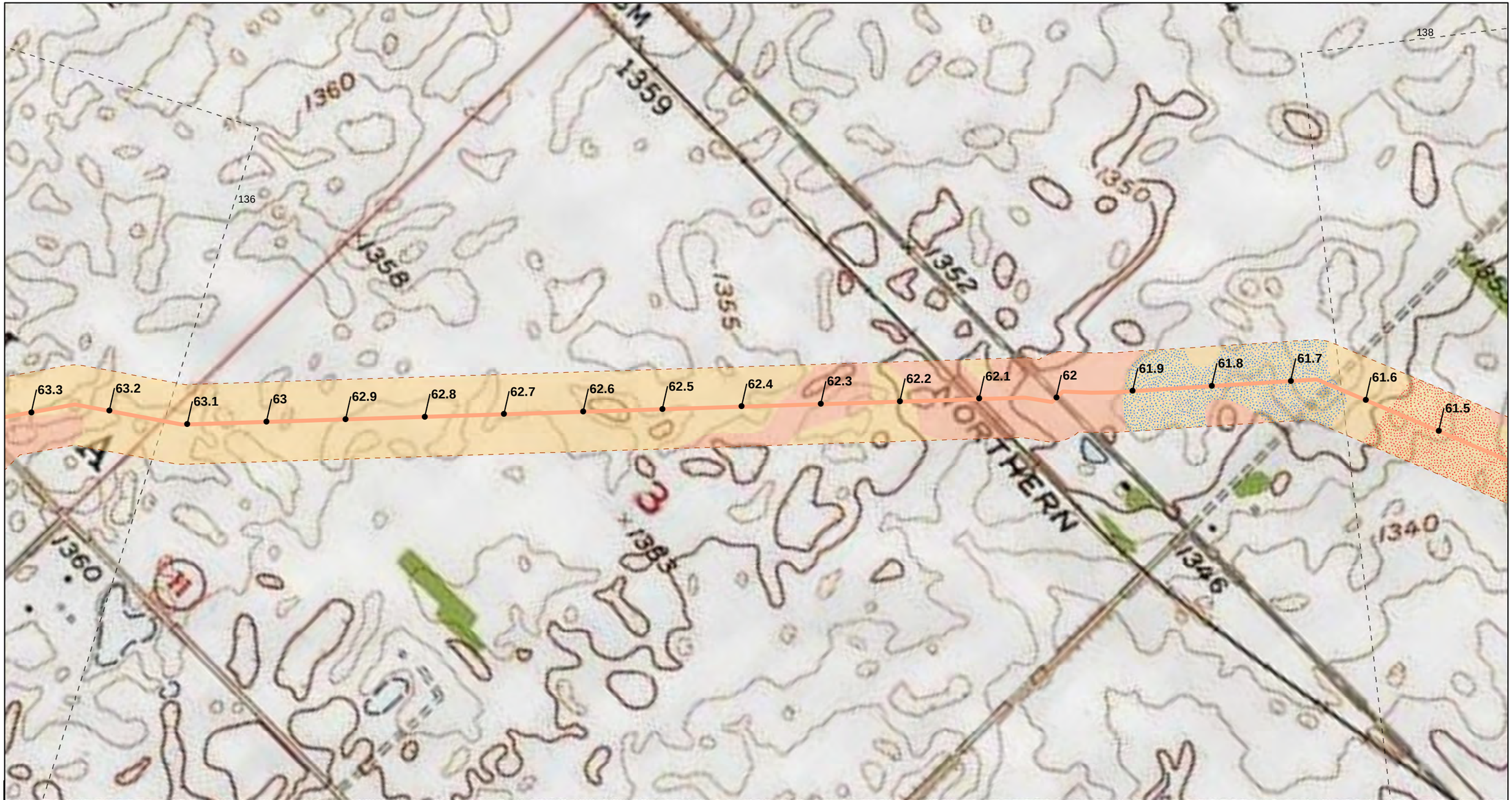

Legend

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EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
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FROST ACTION CATEGORY
- HIGHER
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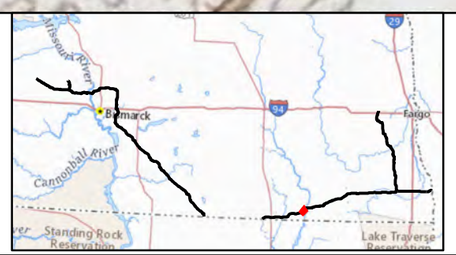

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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Figure **1-137**

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- REVISION 9 ROUTE MILEPOSTS
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EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- MEDIUM
- HIGHER

NOTES:
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0 250 500 1,000 Feet

N

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Summit Carbon Solutions - North Dakota
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Figure **1-138**

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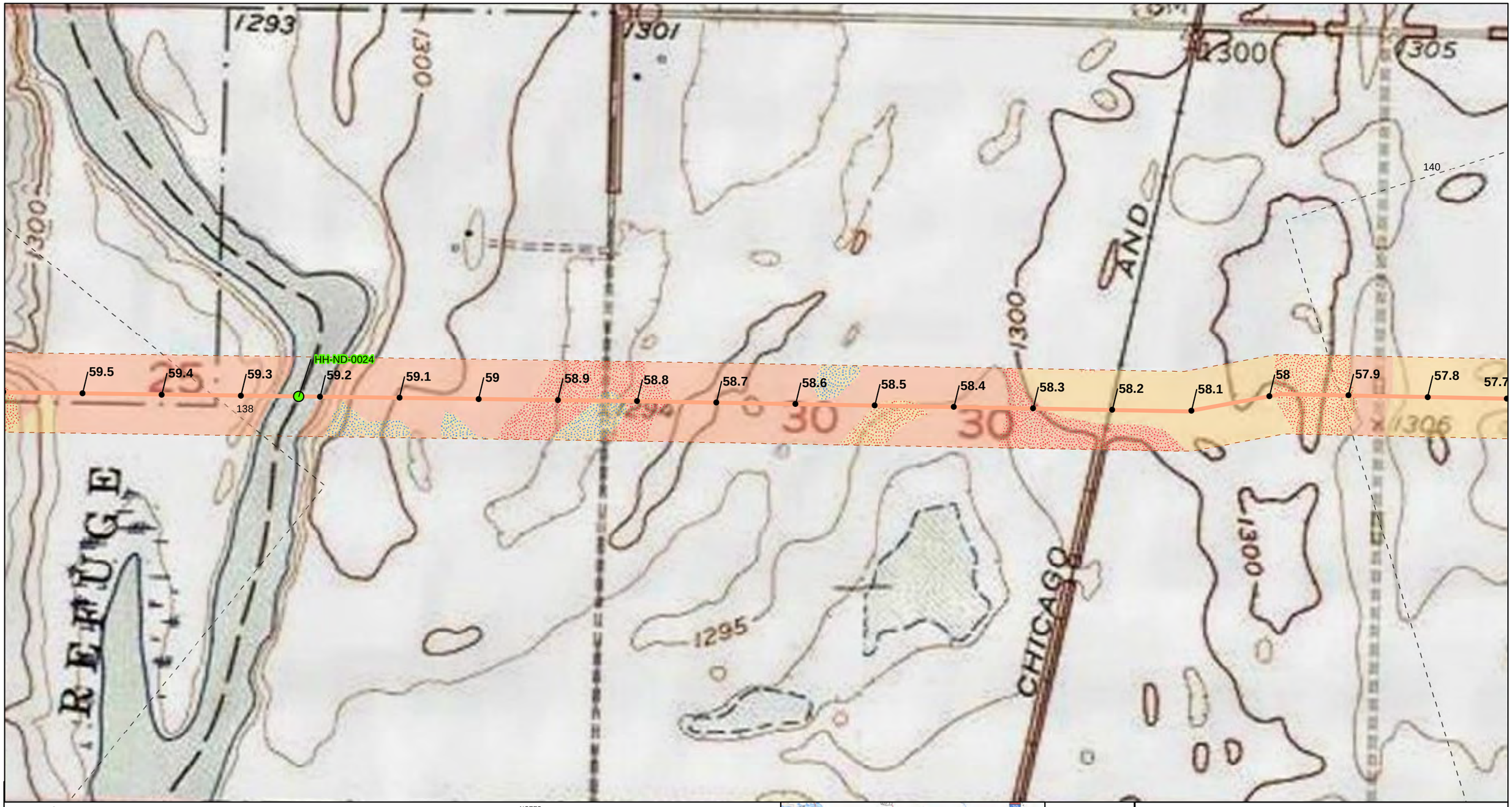

Legend

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- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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Summit Carbon Solutions - North Dakota
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Figure
1-140

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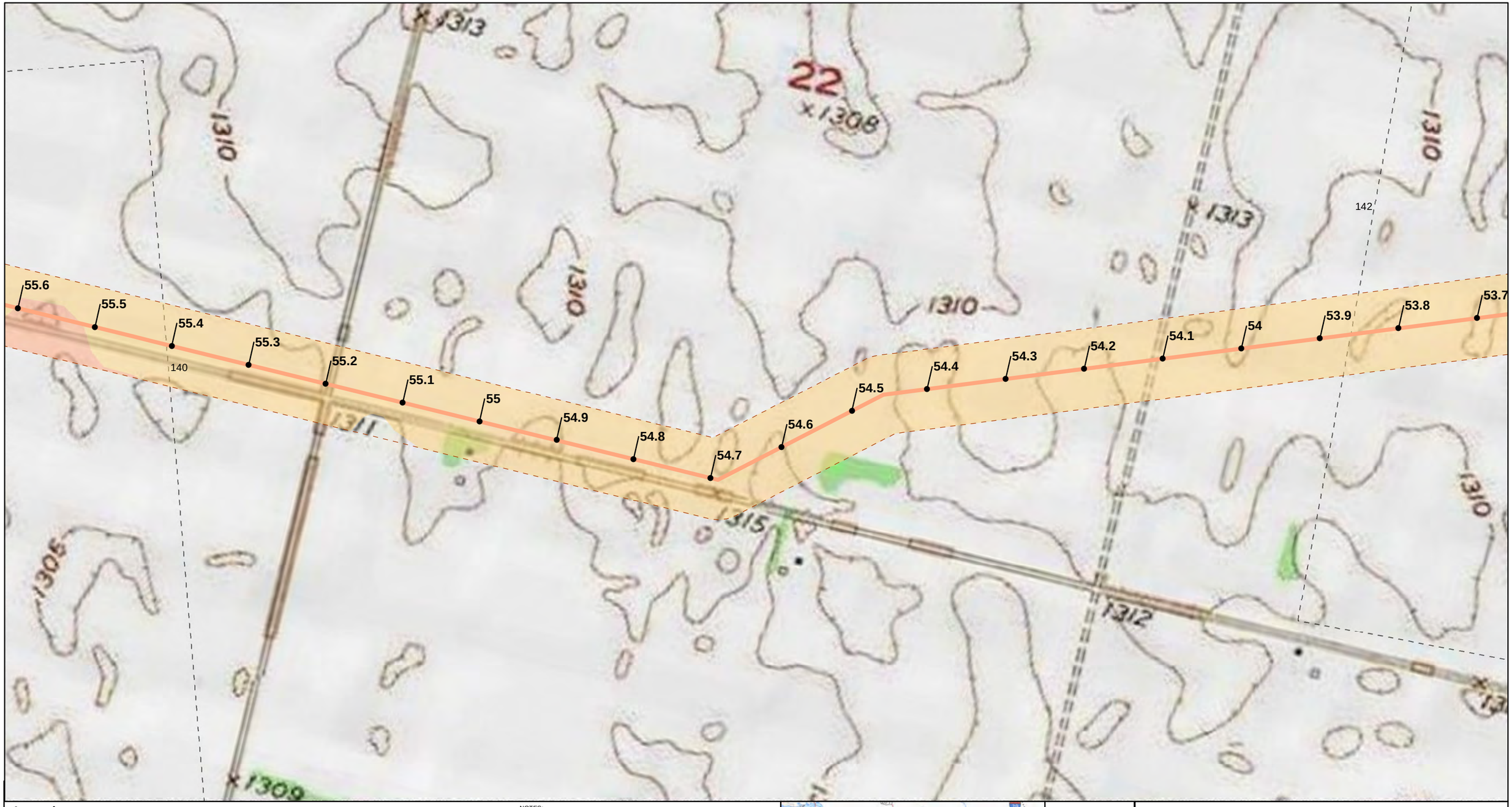

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
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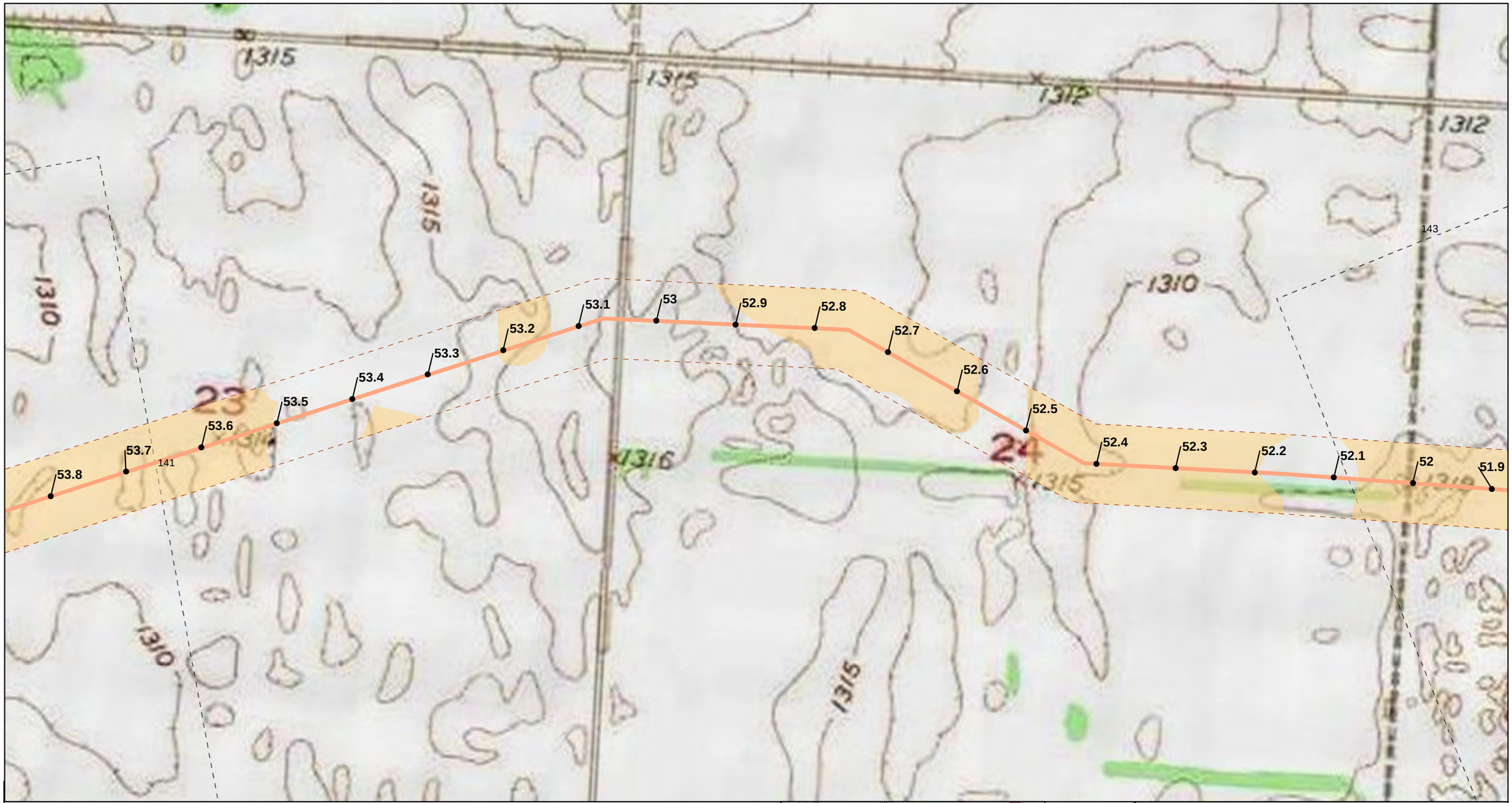

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
PIPELINE ALIGNMENTS RECEIVED 1/24/2024.
LINEAR EXTENSIBILITY PERCENT (LEP) AND FROST ACTION FROM NRCS SOILS DATA.
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0 250 500 1,000 Feet

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-143

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Legend

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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

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Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024

Figure
1-144

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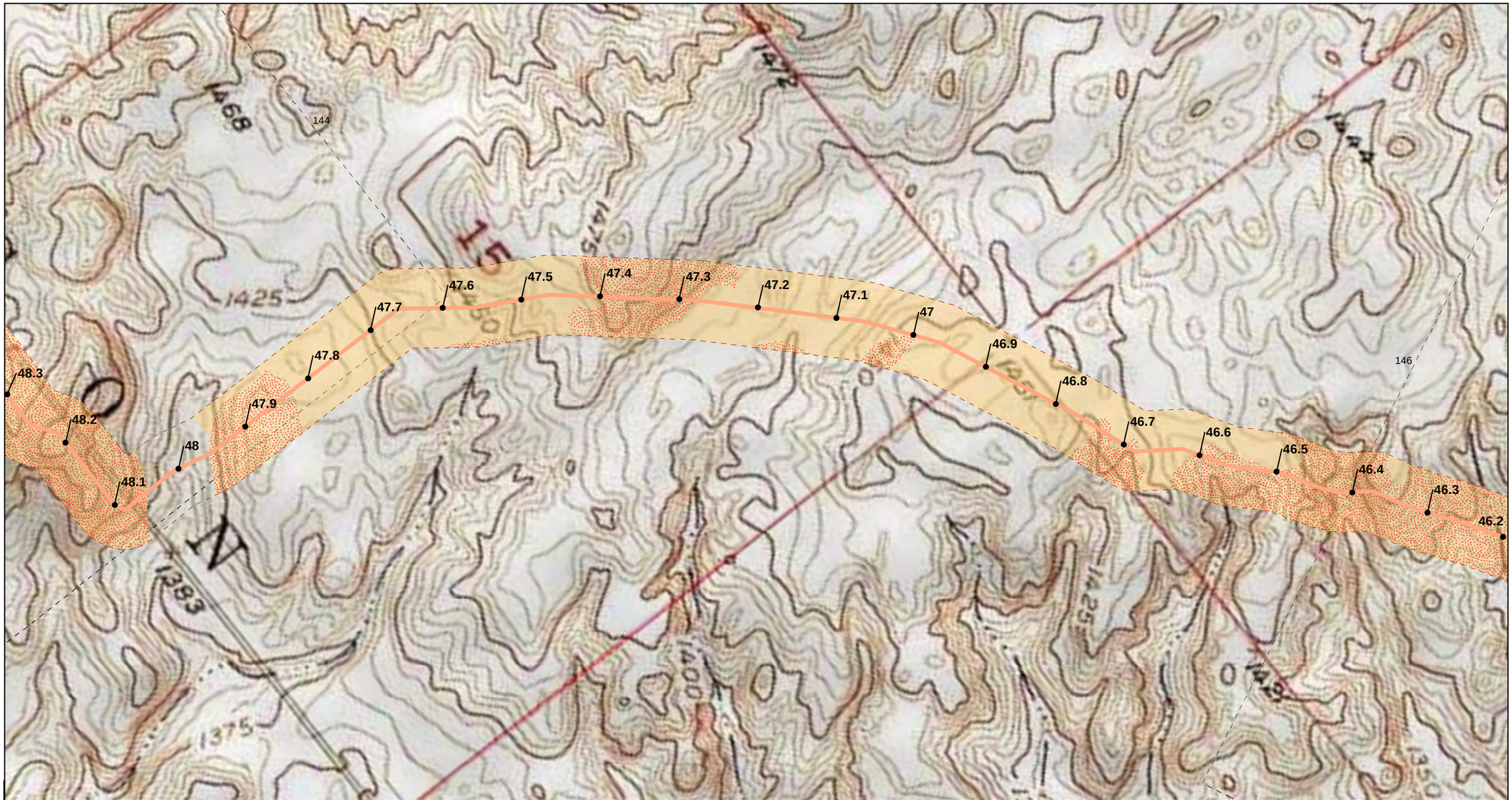

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- REVISION 9 ROUTE MILEPOSTS
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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
FROST ACTION CATEGORY
MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Phase I Assessment

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Figure **1-145**

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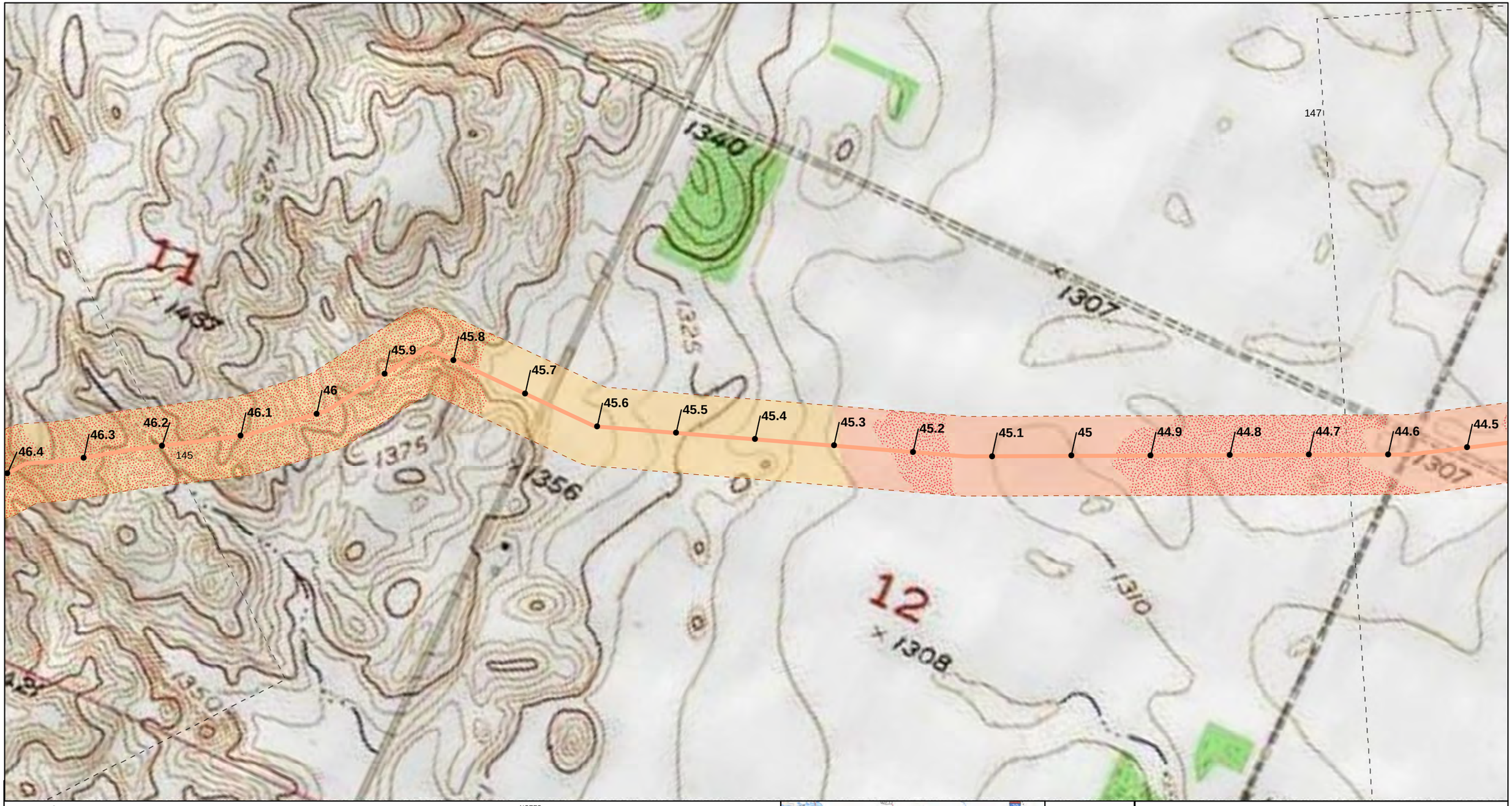

Legend

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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

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TXG0450	January 2024	Figure 1-146

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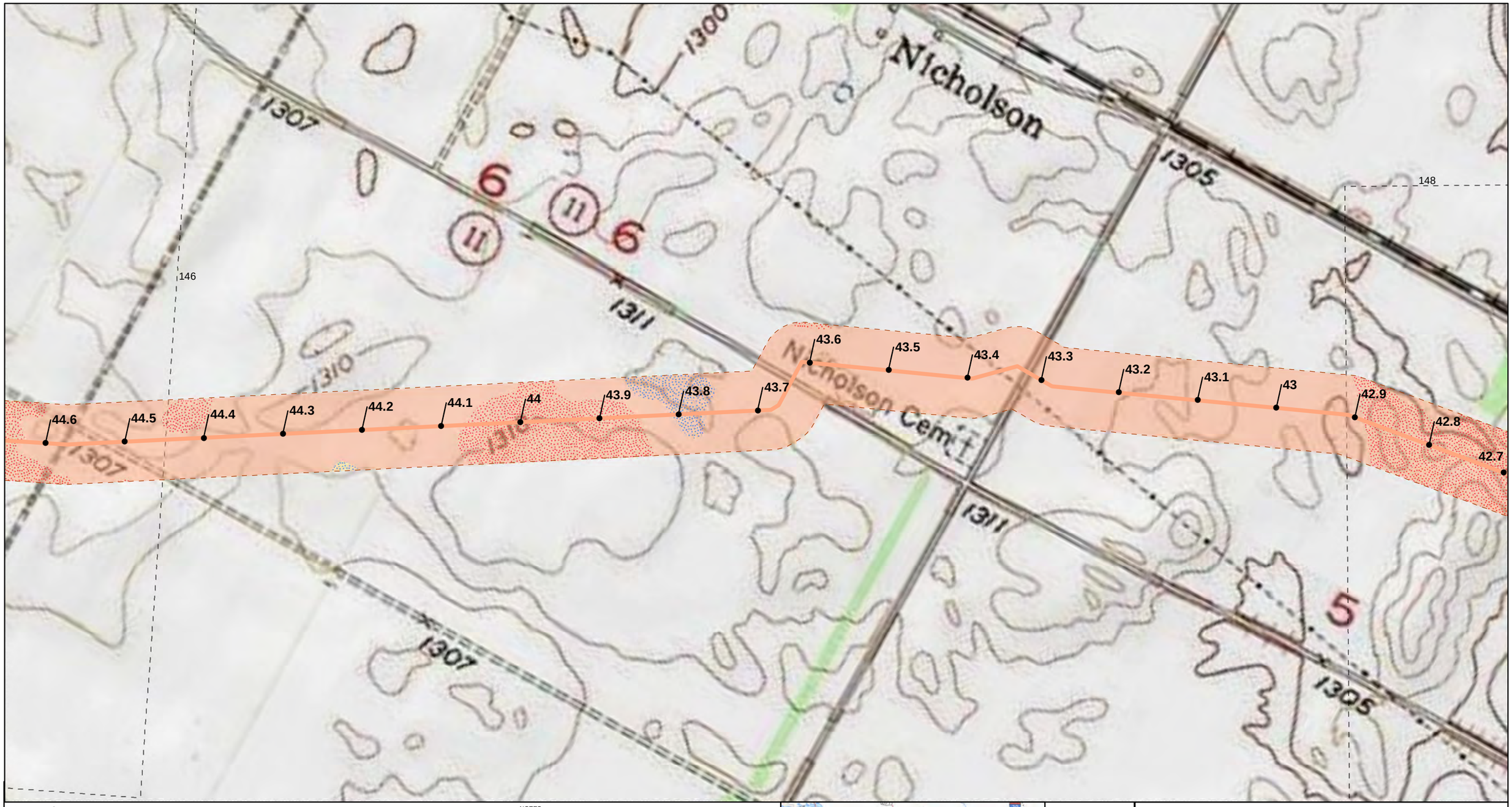

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

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Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-147

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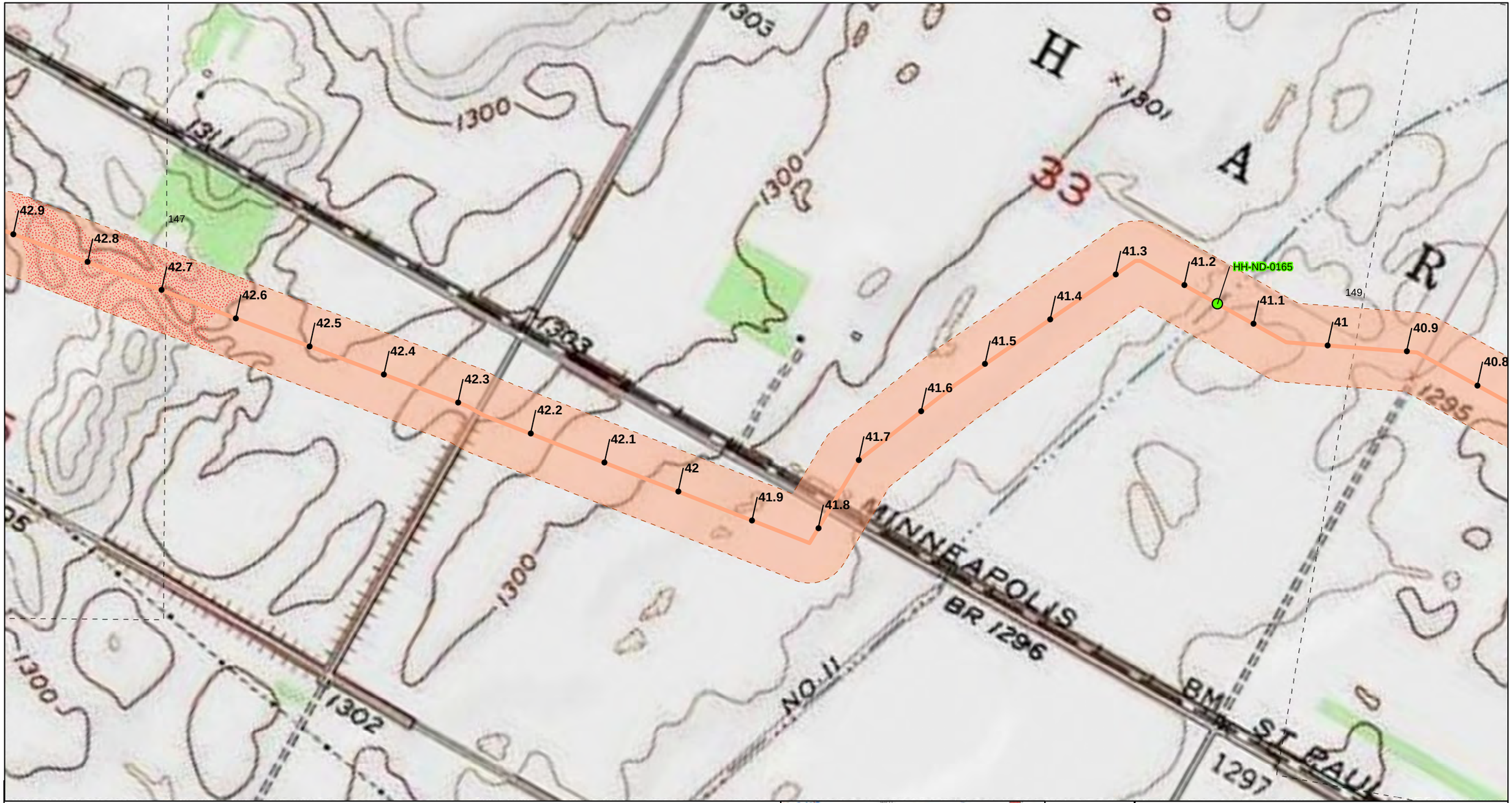

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER

NOTES:
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0 250 500 1,000 Feet

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Summit Carbon Solutions - North Dakota
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TXG0450	January 2024	Figure 1-148

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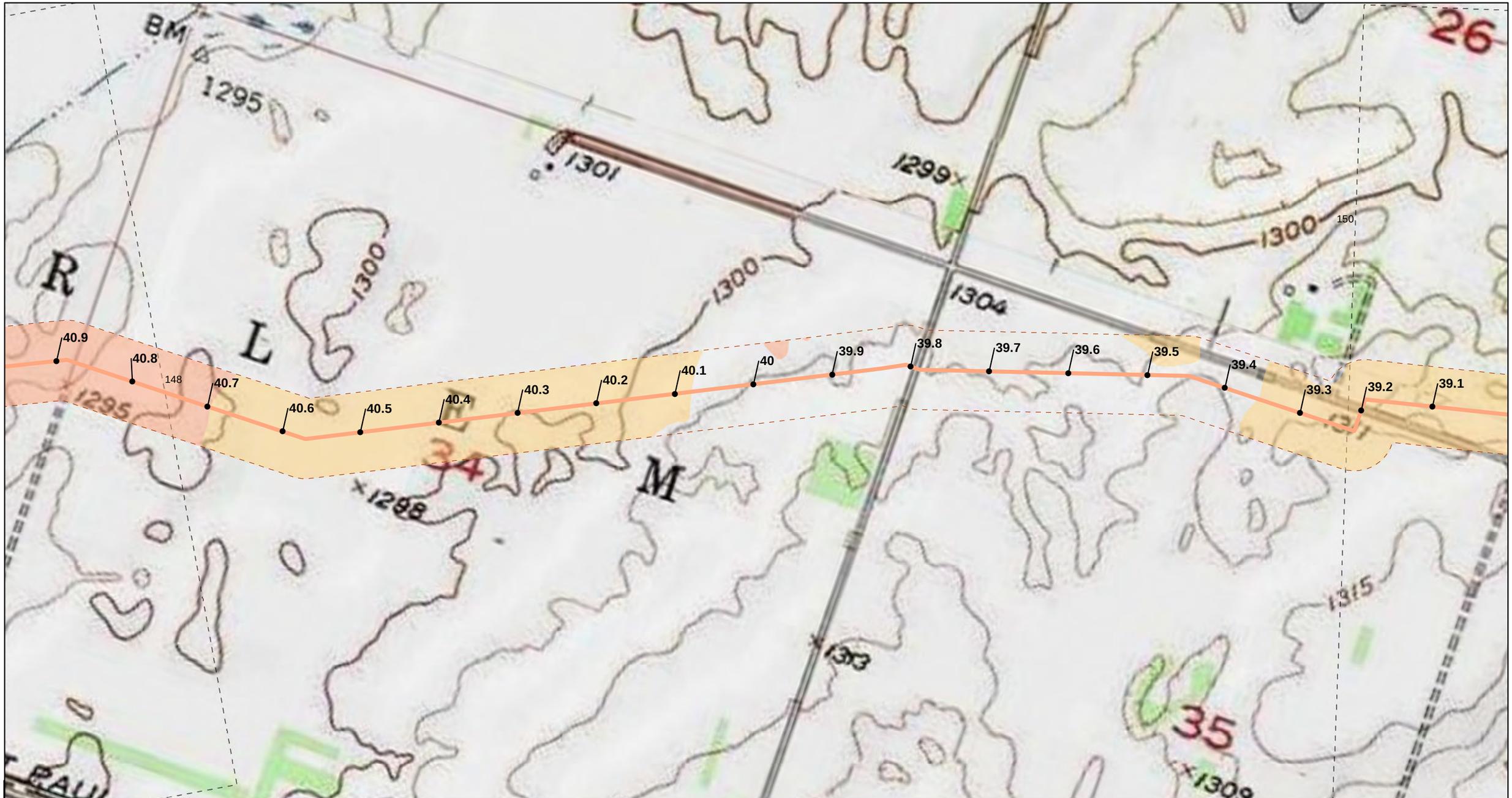

Legend

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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

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Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

Figure **1-149**

TXG0450 | January 2024

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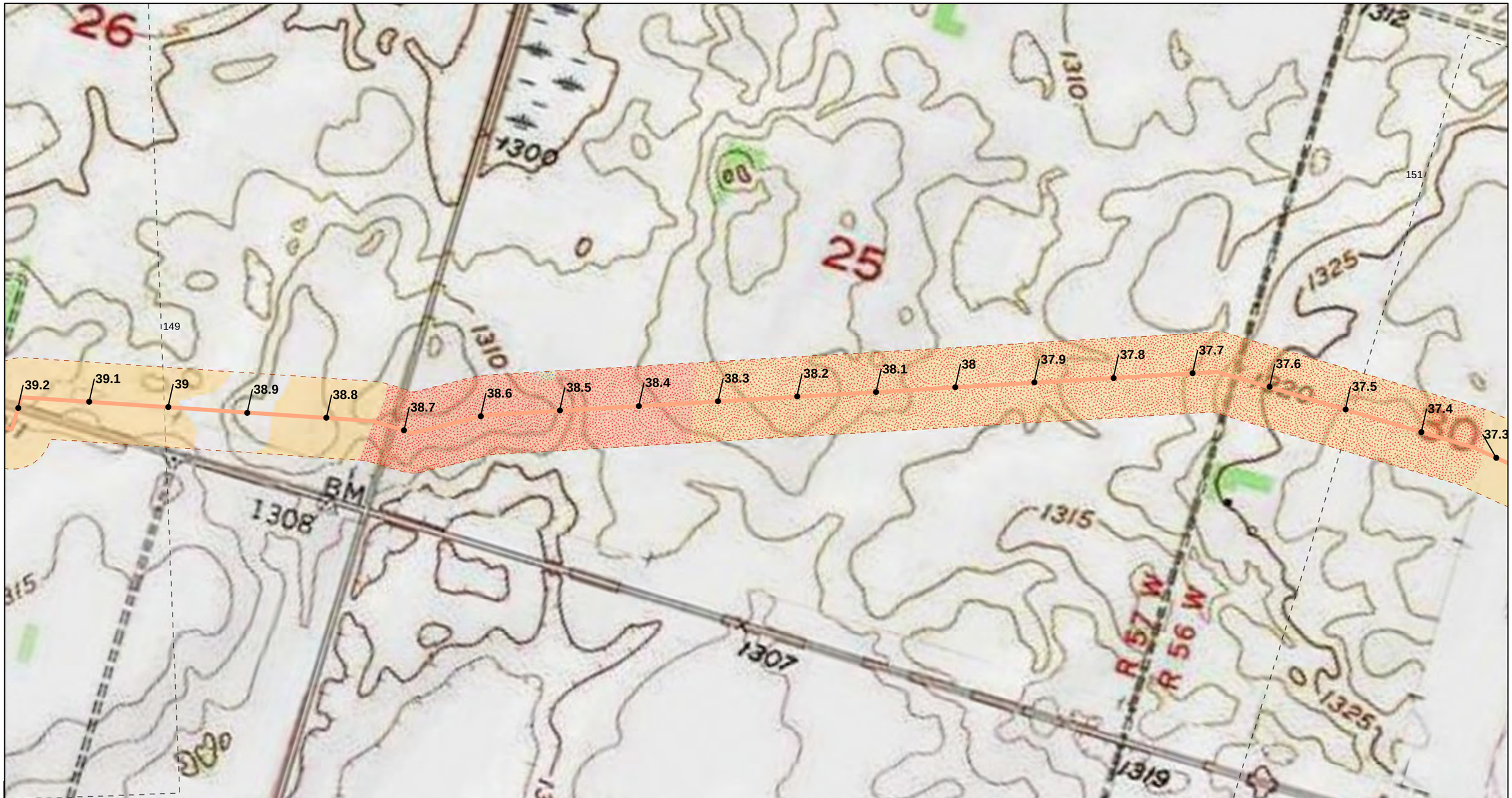

Legend

- REVISION 9 ROUTE MILEPOSTS
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- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- MEDIUM
- HIGHER

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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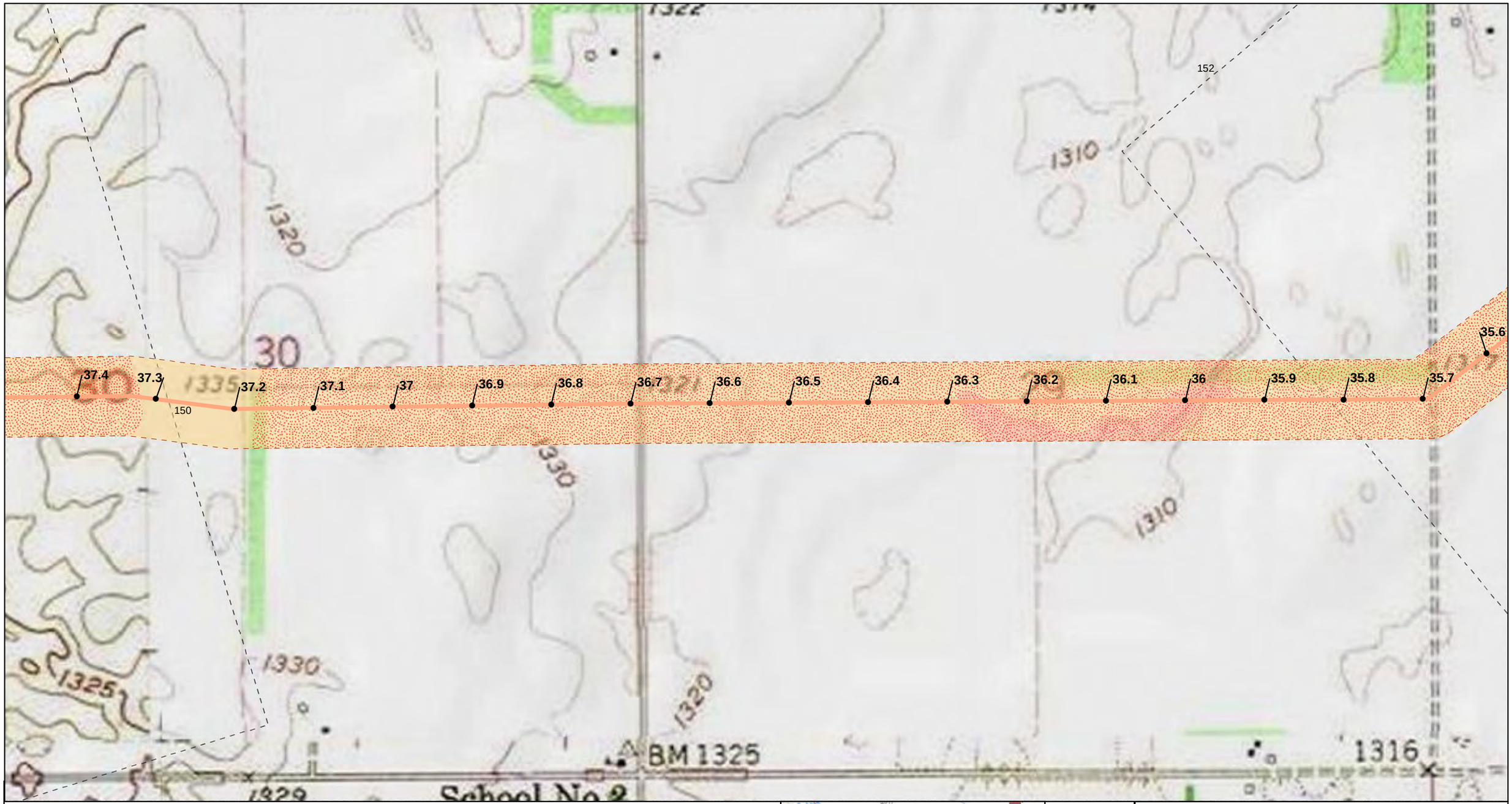

Legend

- REVISION 9 ROUTE MILEPOSTS
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- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

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Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-151

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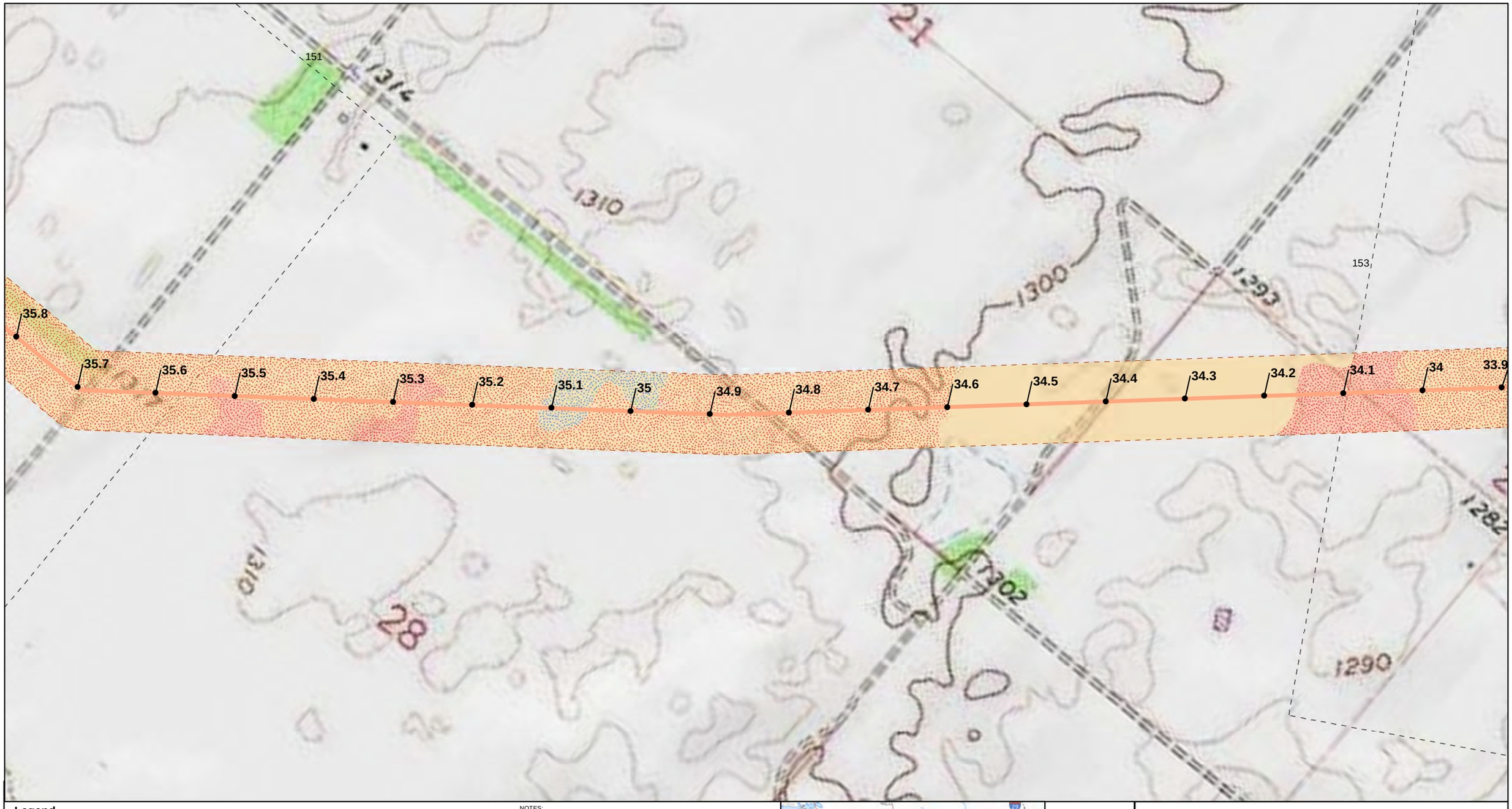

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-152

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

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0 250 500 1,000 Feet

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-153

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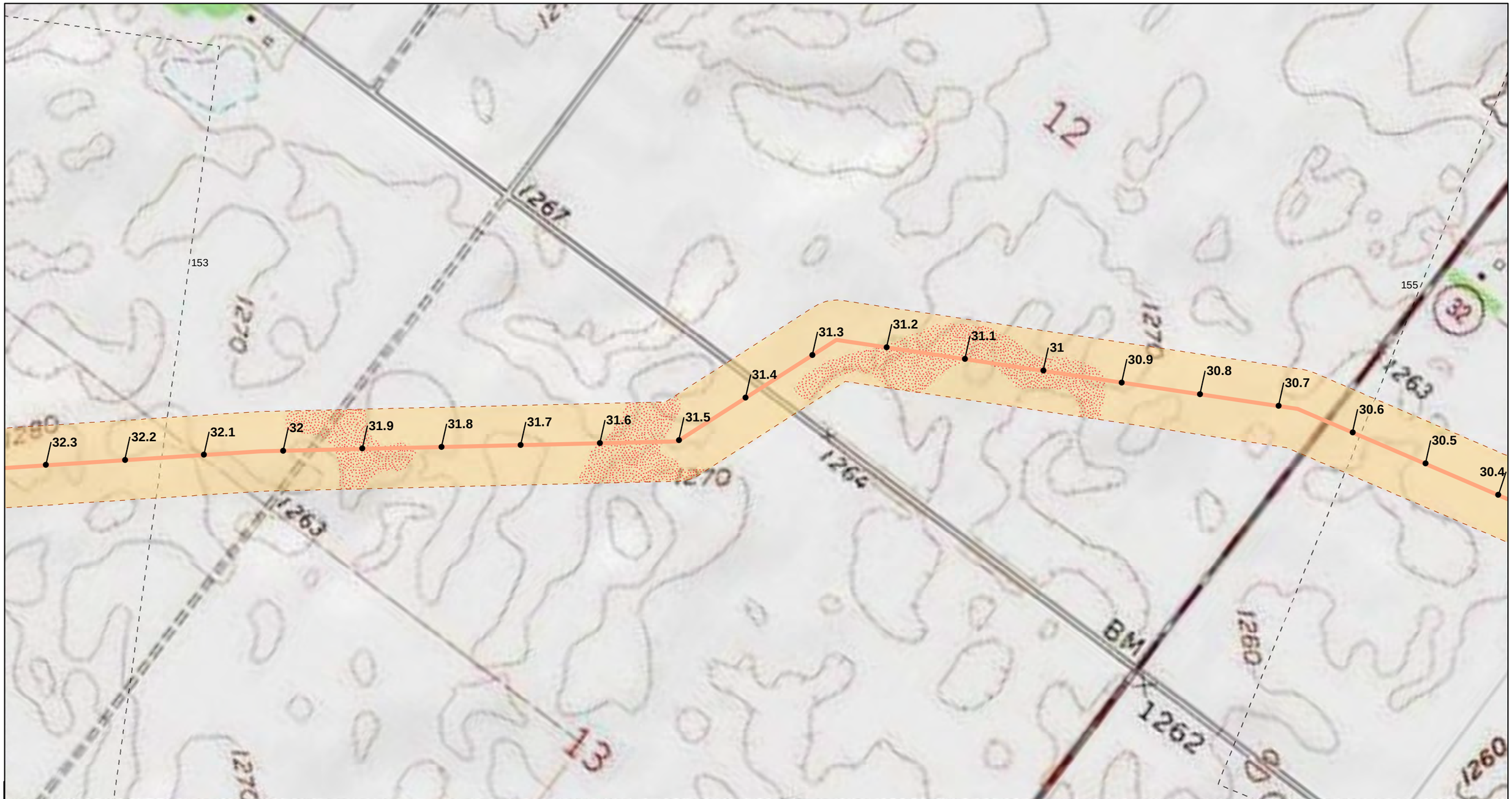

Legend

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- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- MEDIUM

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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

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Legend

- REVISION 9 ROUTE MILEPOSTS
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- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
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EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- MEDIUM

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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-155

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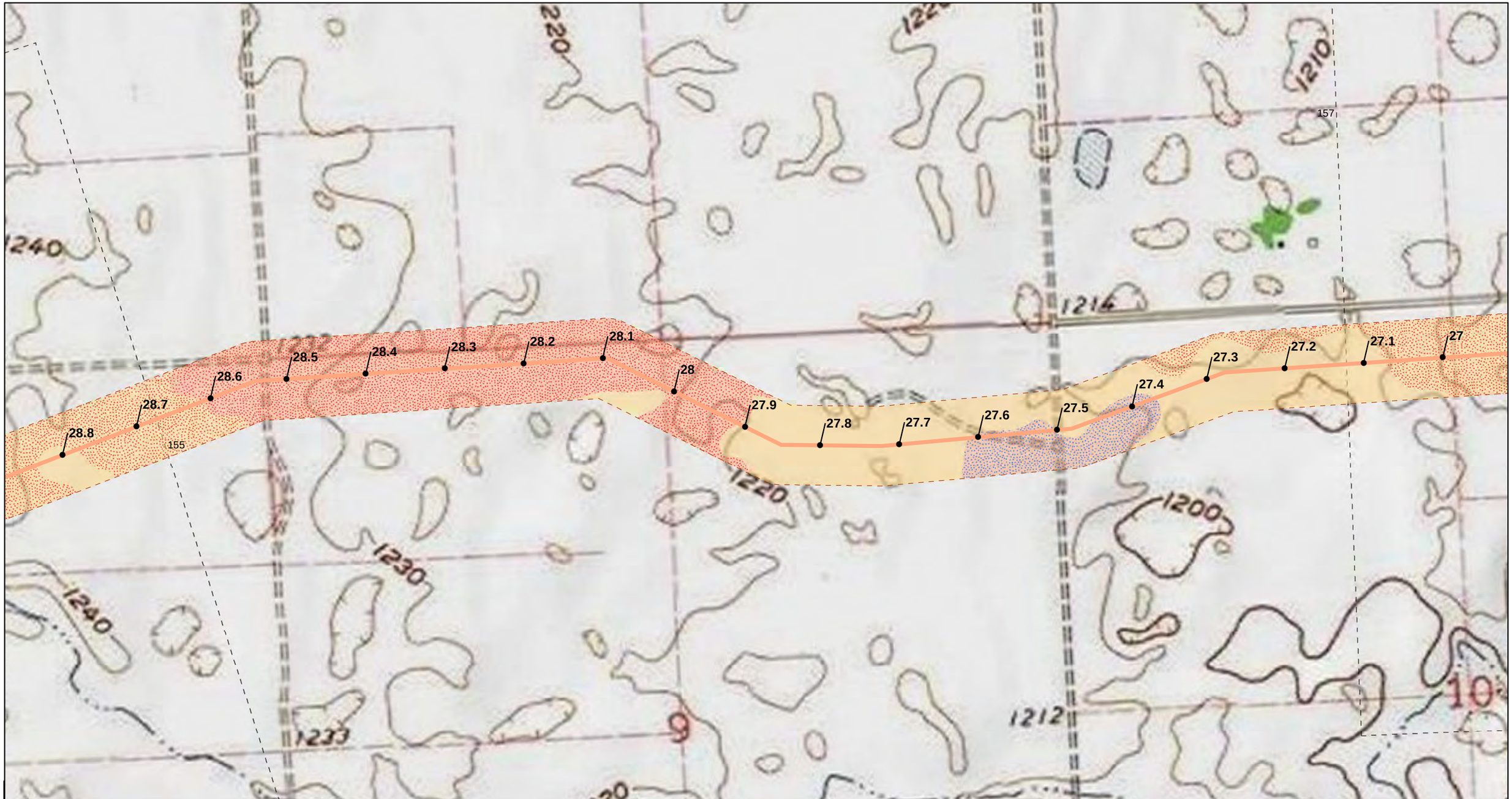

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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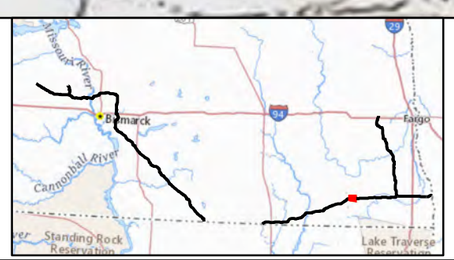

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024

Figure **1-156**

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-157

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-158

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-159

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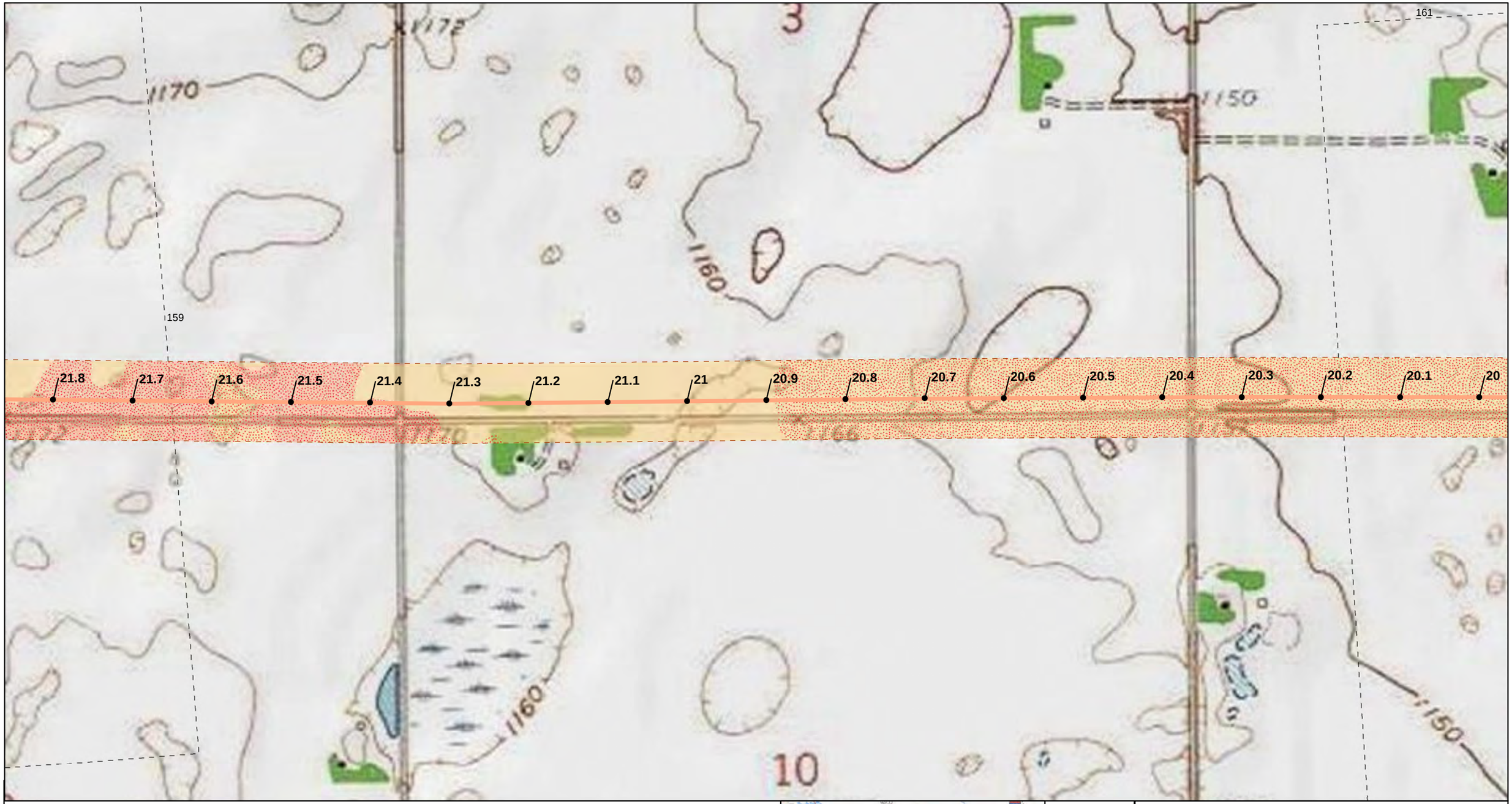

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
MEDIUM: LEP 3-6
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
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Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-160

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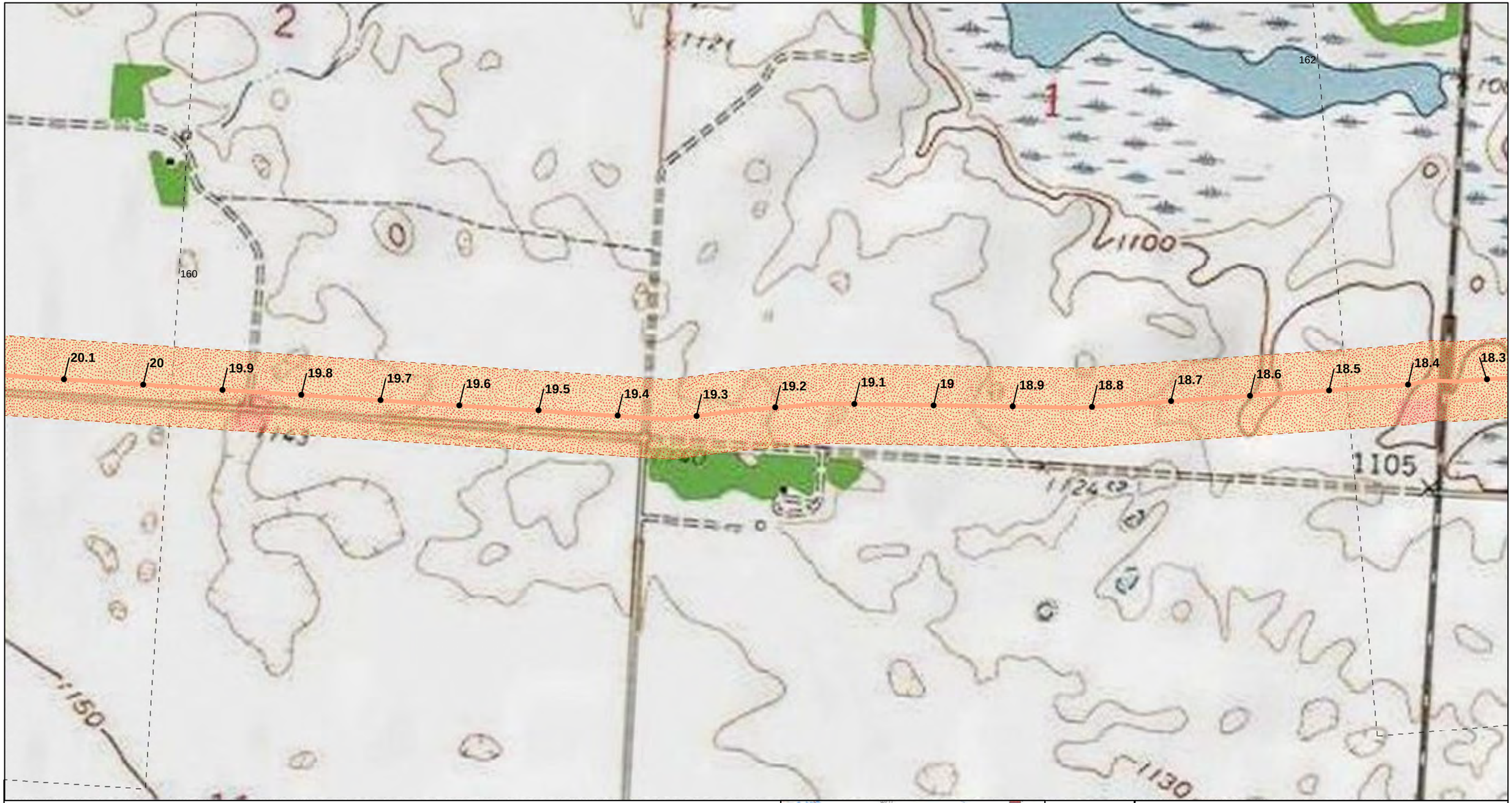

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-161

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-162

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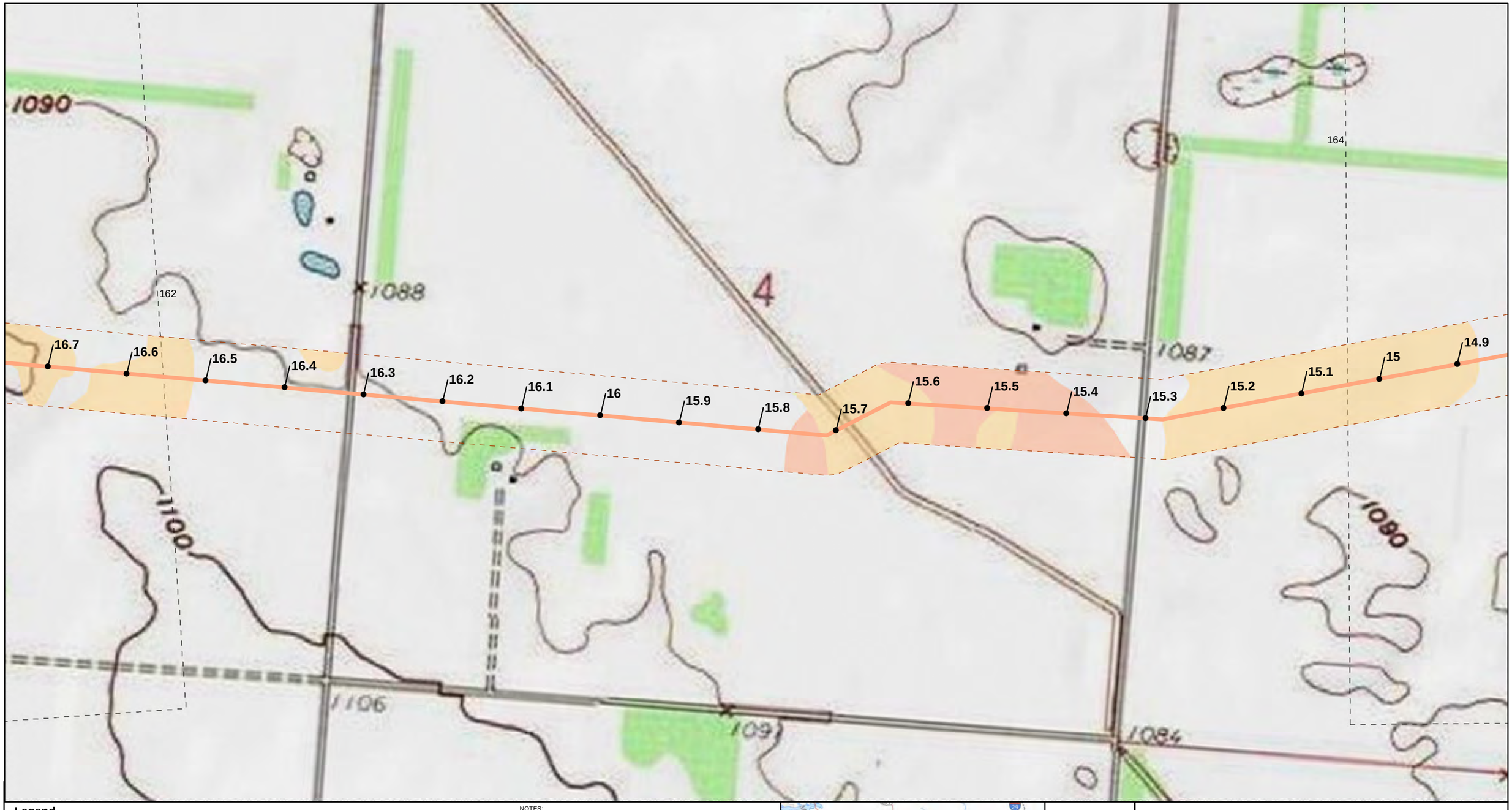

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-163

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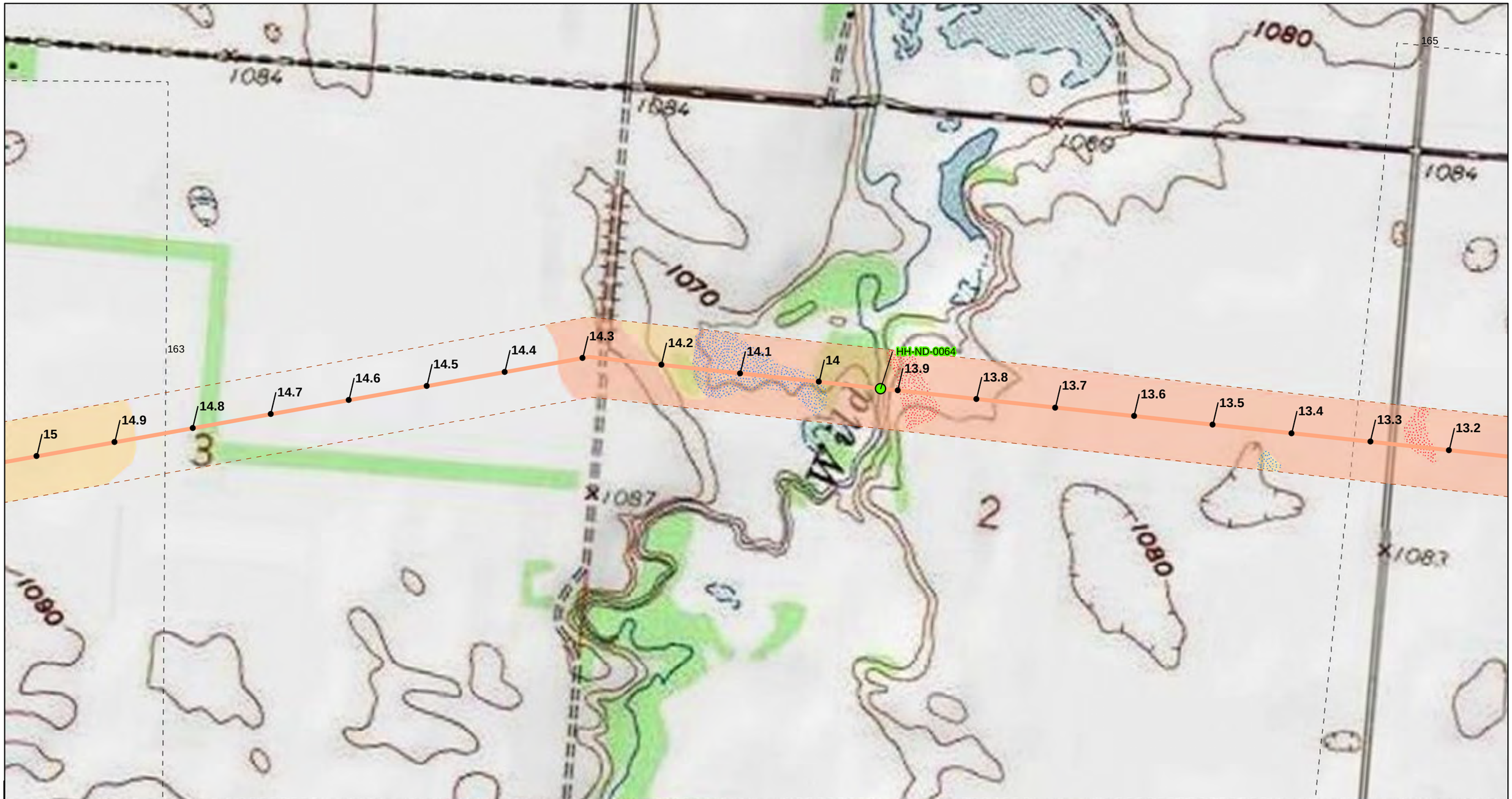

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- MEDIUM
- HIGHER

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-164

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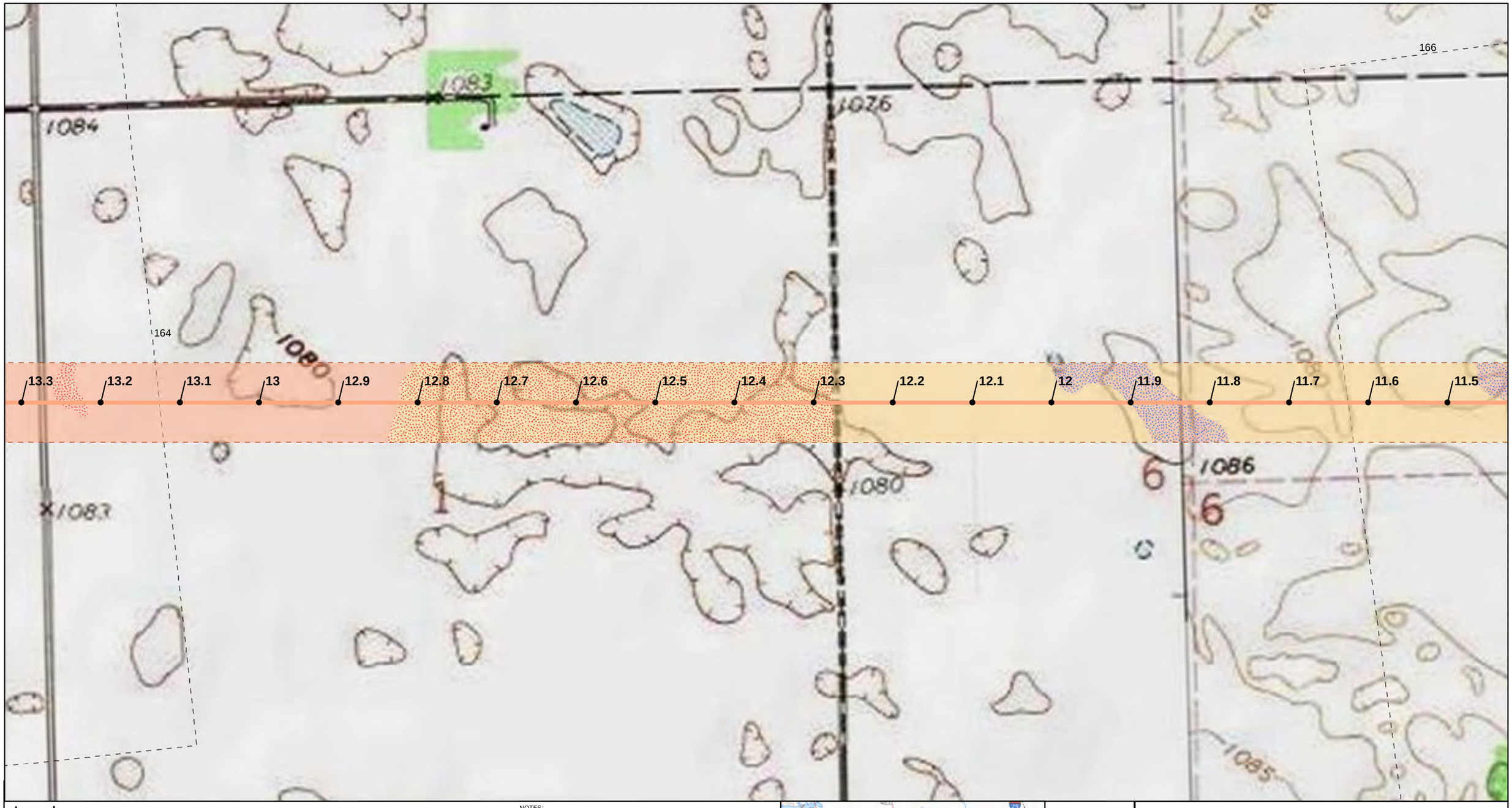

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

Figure **1-165**

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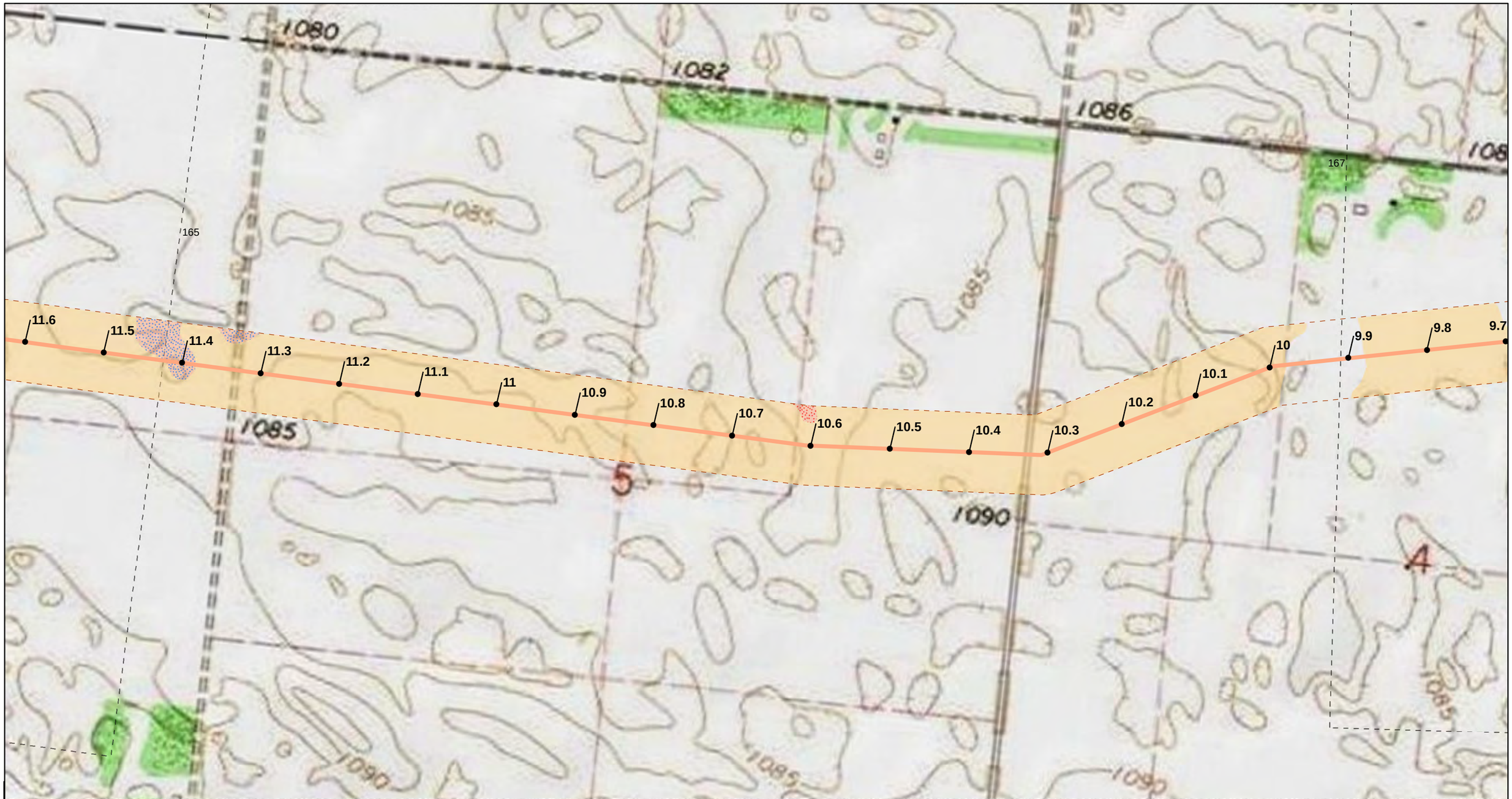

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024

Figure
1-166

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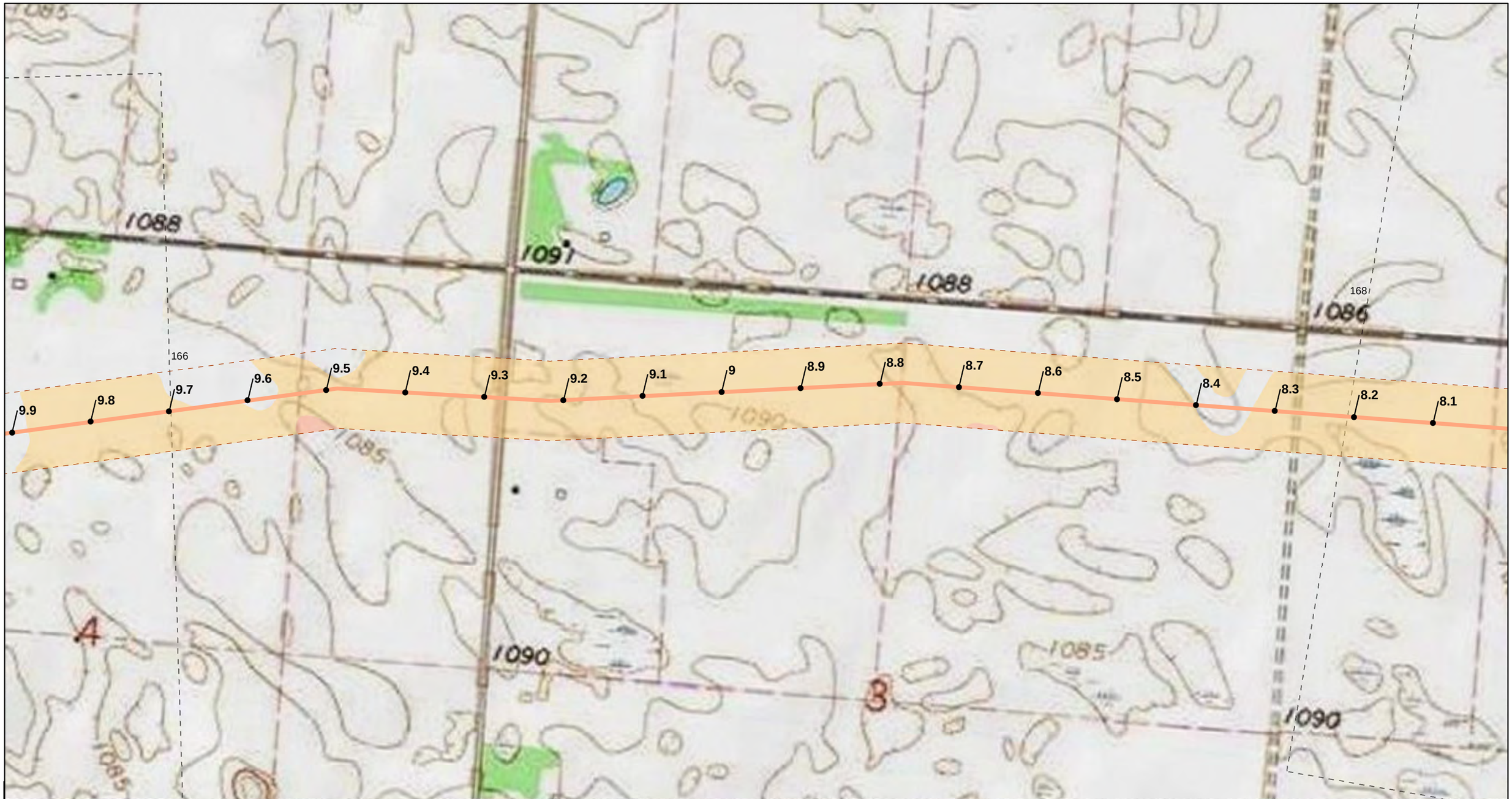

Legend

- REVISION 9 ROUTE MILEPOSTS
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- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

Figure **1-167**

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-168

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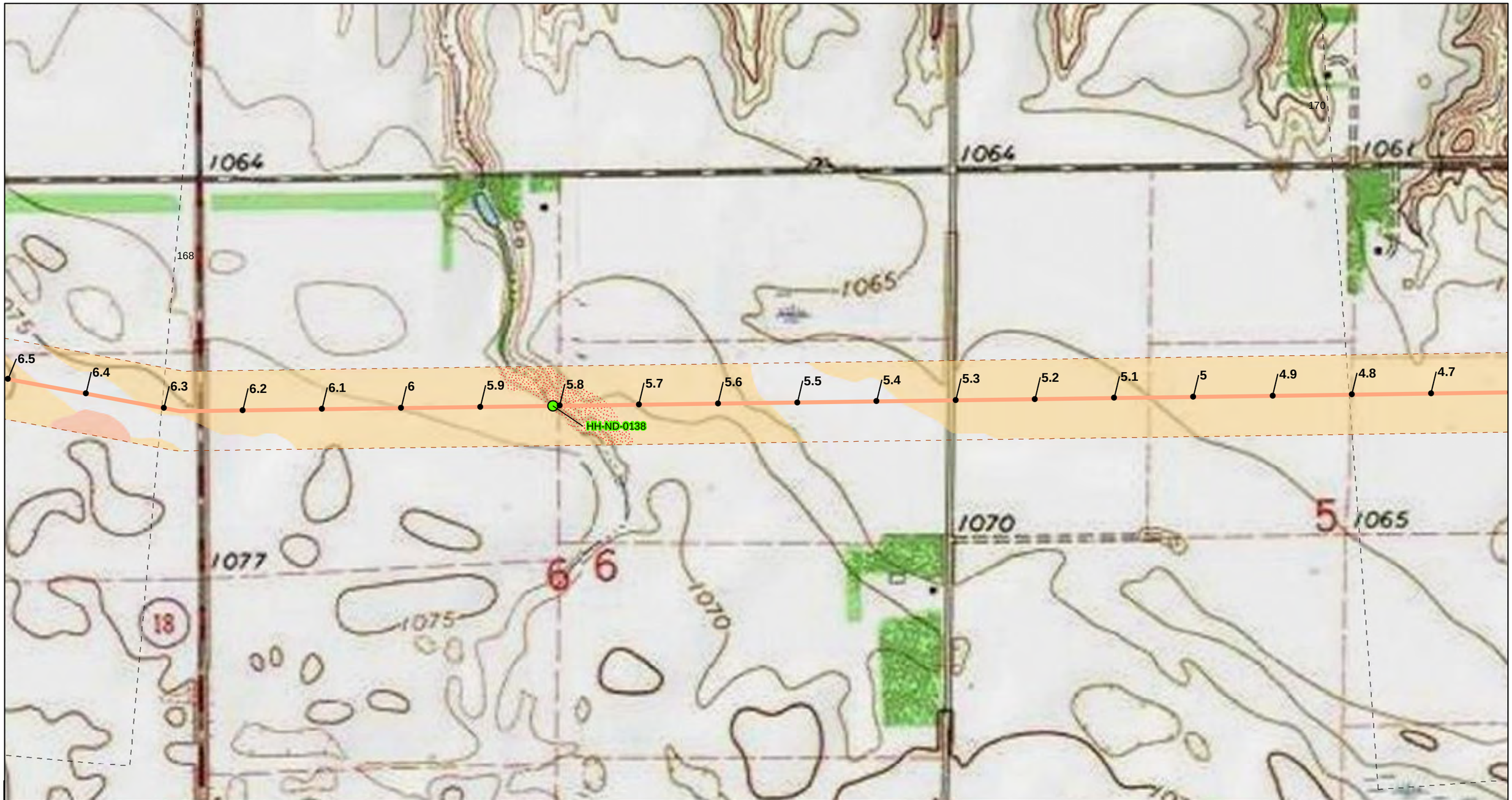

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

Figure **1-169**

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Legend

- REVISION 9 ROUTE MILEPOSTS
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- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: RARE

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024

Figure **1-170**

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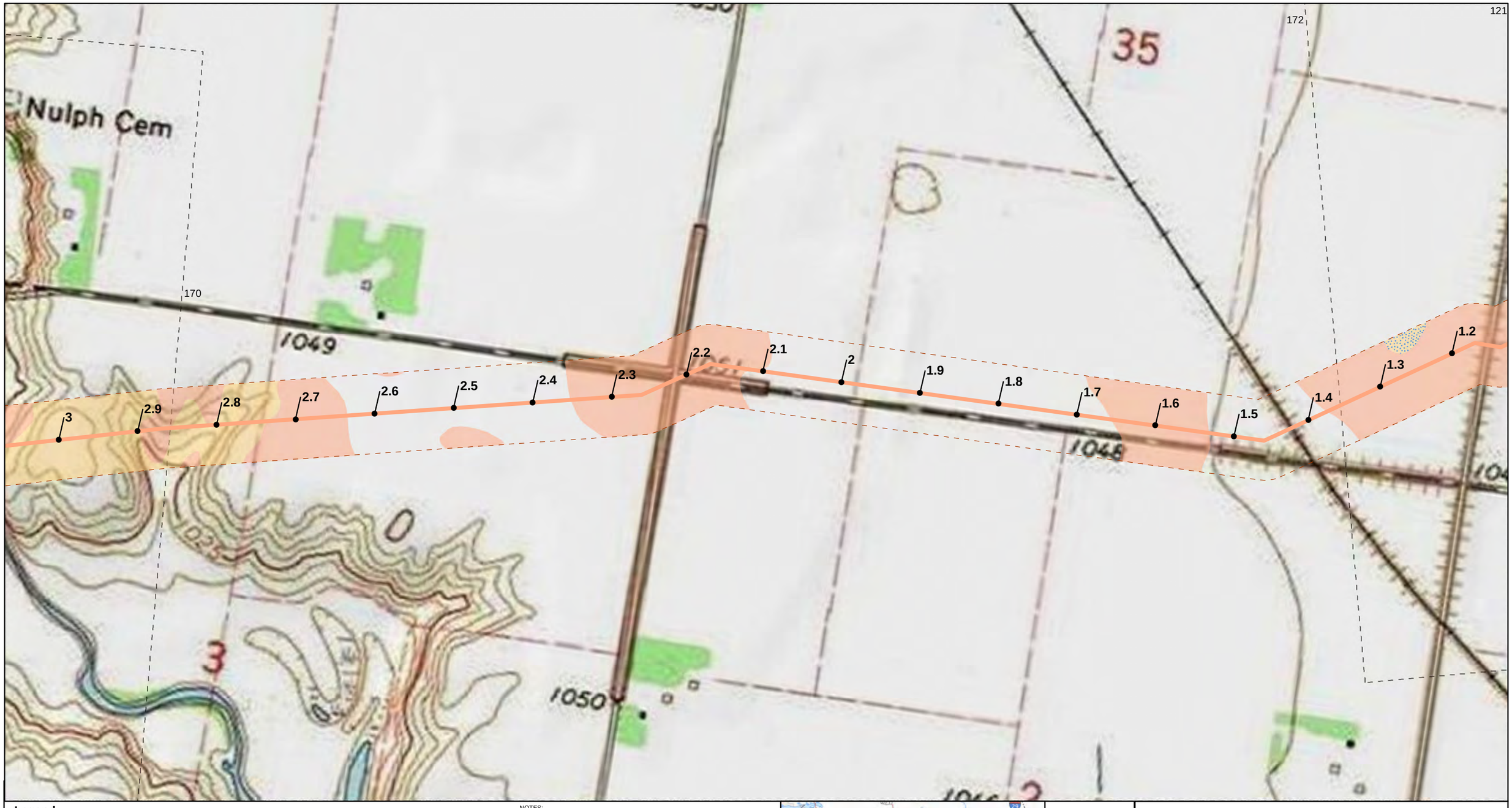

Legend

- REVISION 9 ROUTE MILEPOSTS
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- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
HIGHER: LEP >6
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

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TXG0450	January 2024	Figure 1-171

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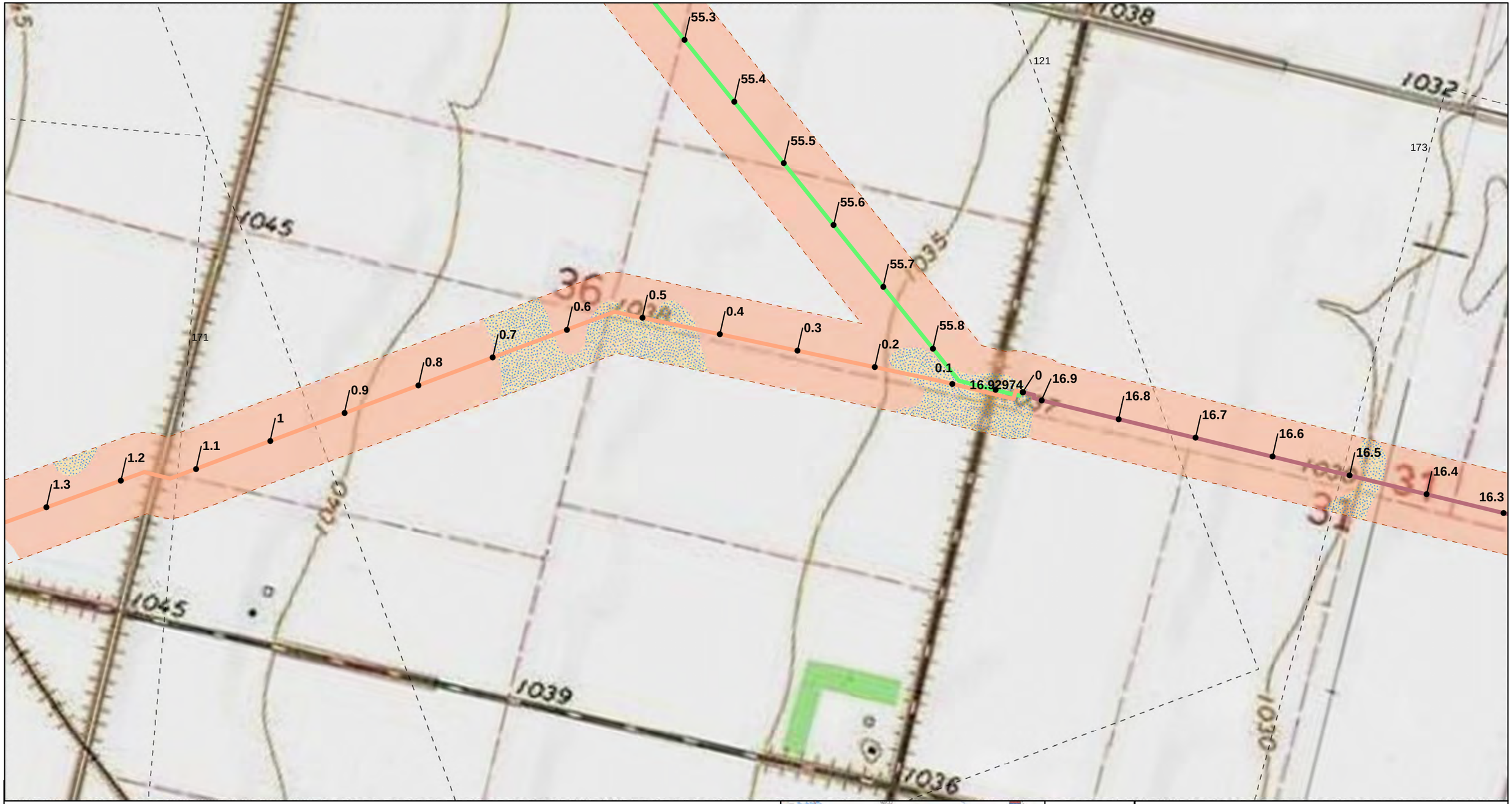

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-323
- NDL-324
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

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Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-172

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-323
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- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
LOWER: LEP <3
HIGHER: LEP >6
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
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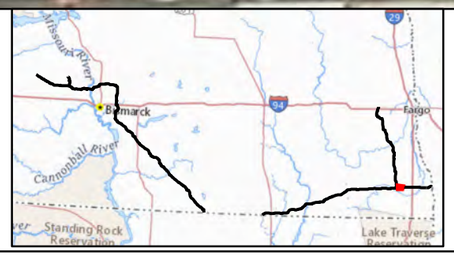

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Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-173

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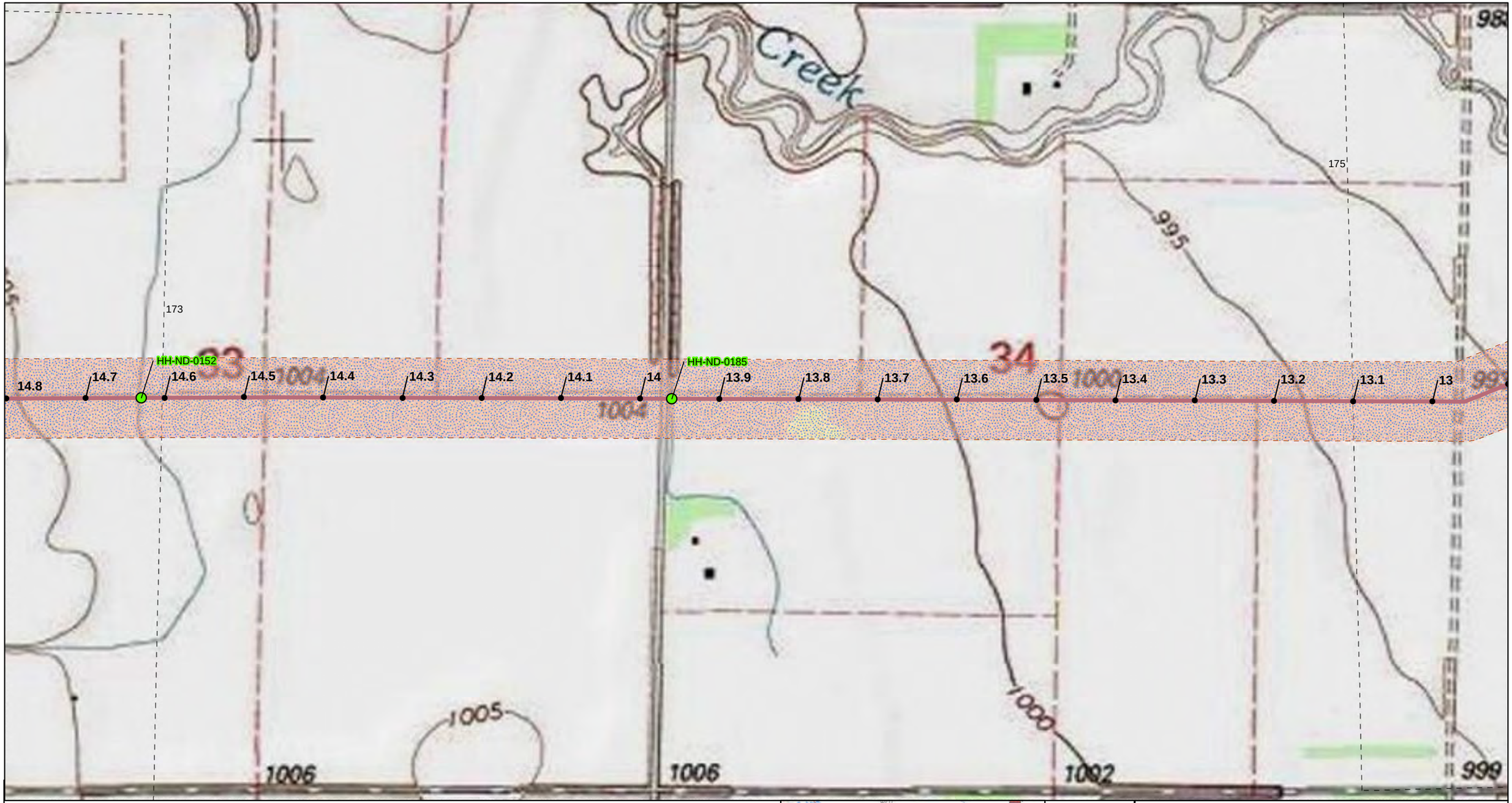

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-323
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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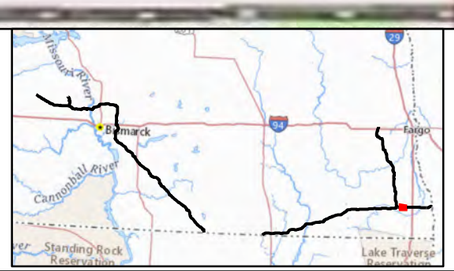

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
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TXG0450	January 2024	Figure 1-174

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-323
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: RARE

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER

NOTES:
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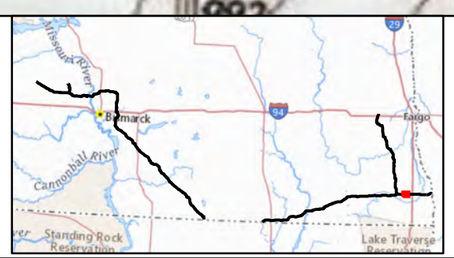

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-175

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-323
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- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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Figure **1-176**

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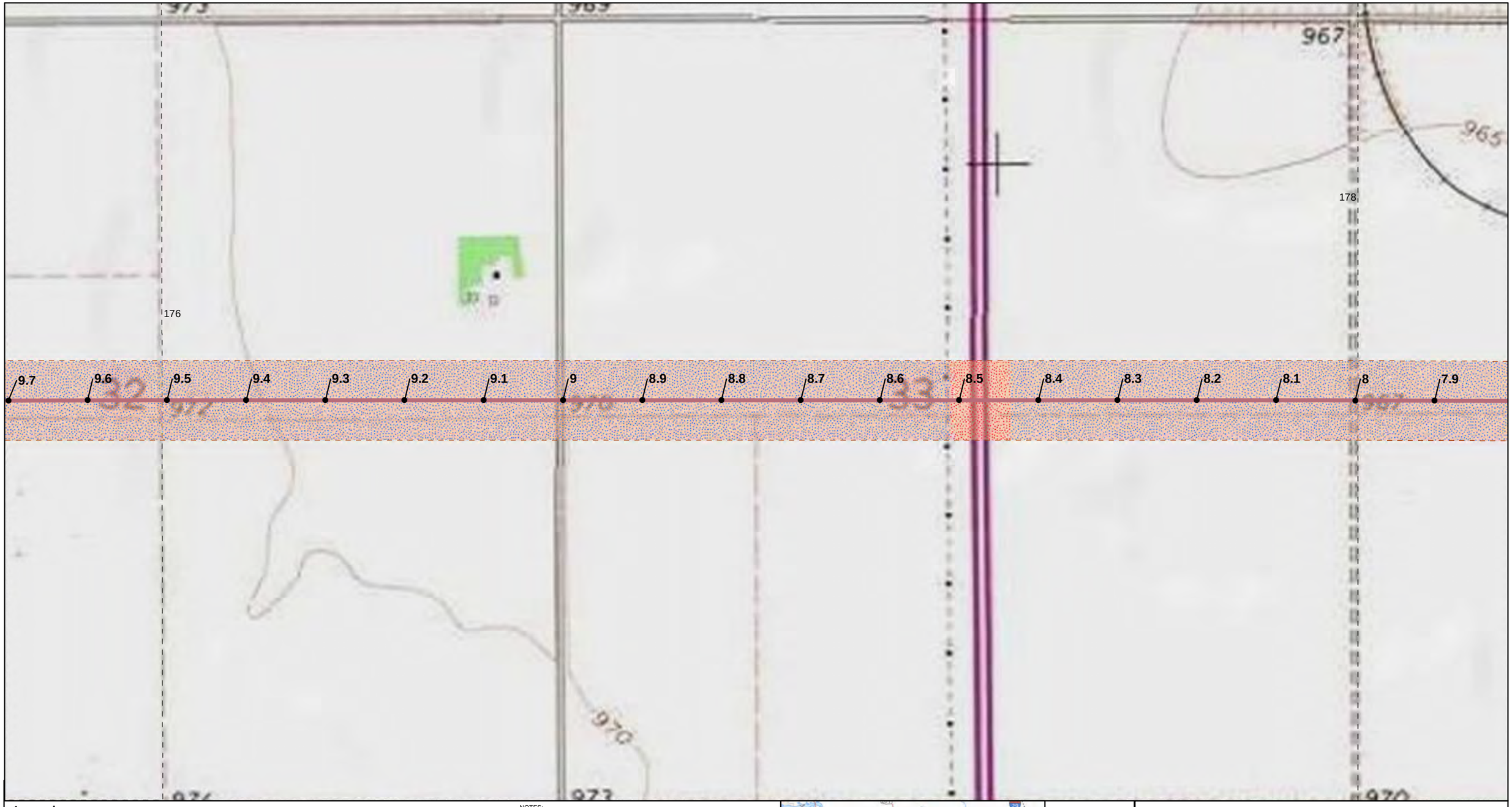

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-323
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER

NOTES:
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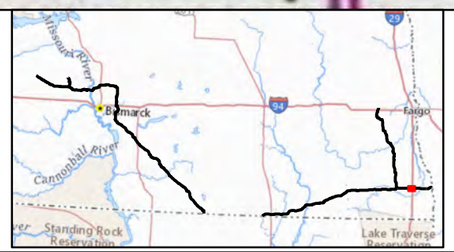

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-177

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-323
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
HIGHER: LEP >6
FROST ACTION CATEGORY
HIGHER

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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Figure
1-178

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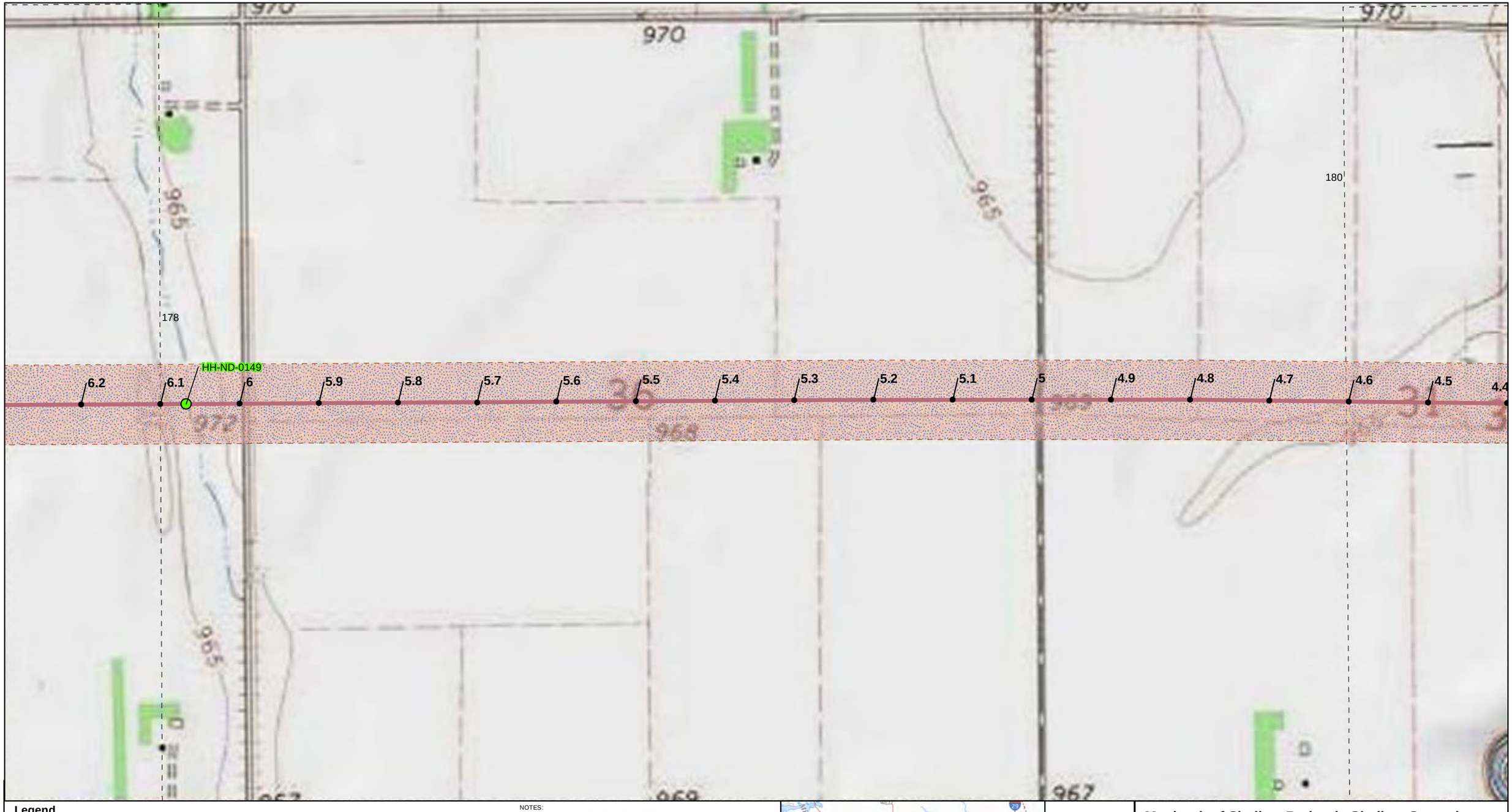

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-323
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
HIGHER: LEP >6
FROST ACTION CATEGORY
HIGHER

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450	January 2024	Figure 1-179

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Legend

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- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: RARE

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-180

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Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-323
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
PIPELINE ALIGNMENTS RECEIVED 1/24/2024.
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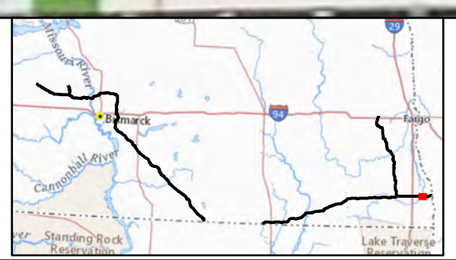

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Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-181

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Legend

- REVISION 9 ROUTE MILEPOSTS
- MNL-321
- NDL-323
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM
- HIGHER

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

Figure **1-182**

TXG0450 | January 2024

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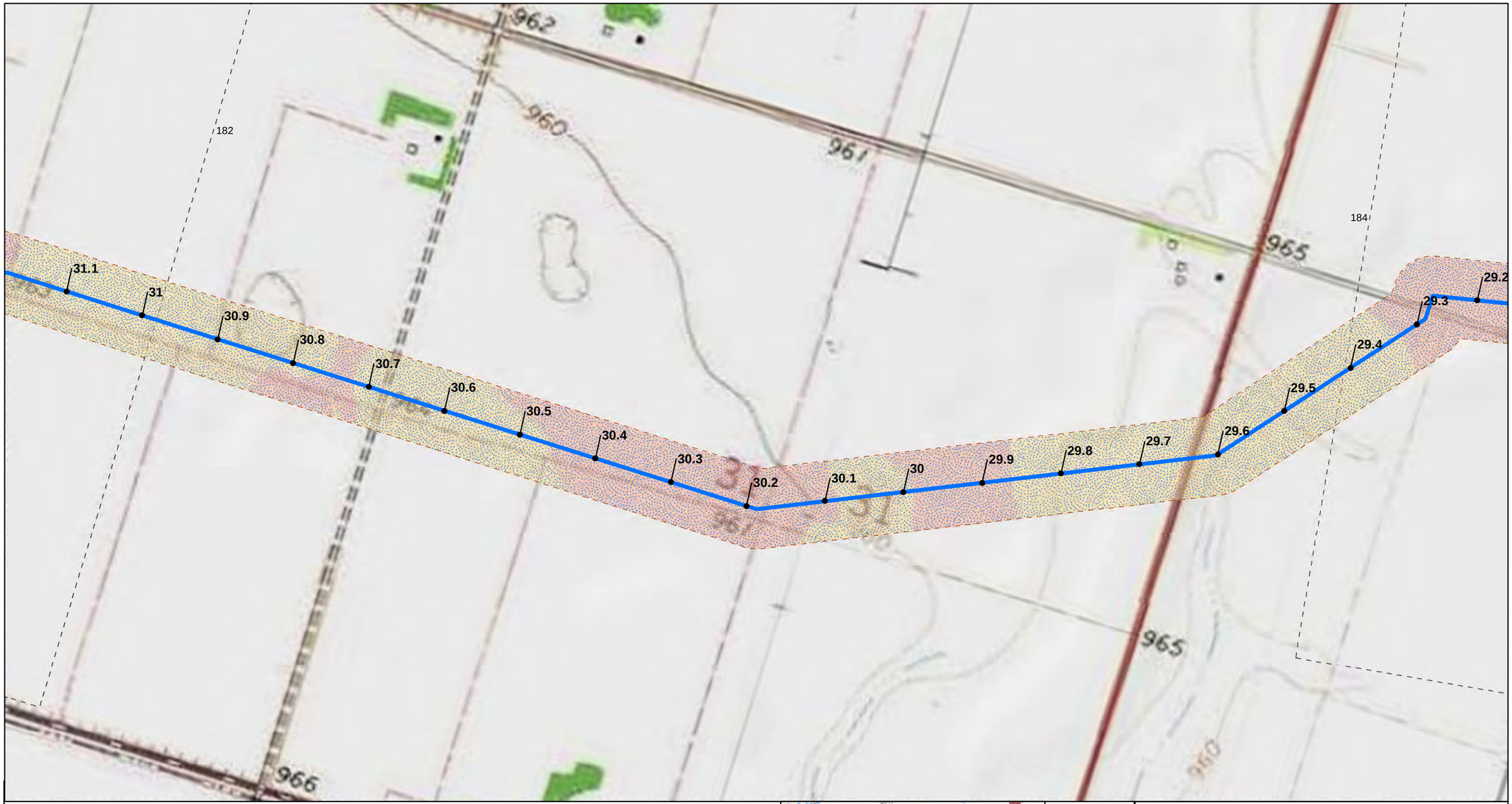

Legend

- REVISION 9 ROUTE MILEPOSTS
- MNL-321
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
HIGHER: LEP >6
FROST ACTION CATEGORY
HIGHER
MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-183

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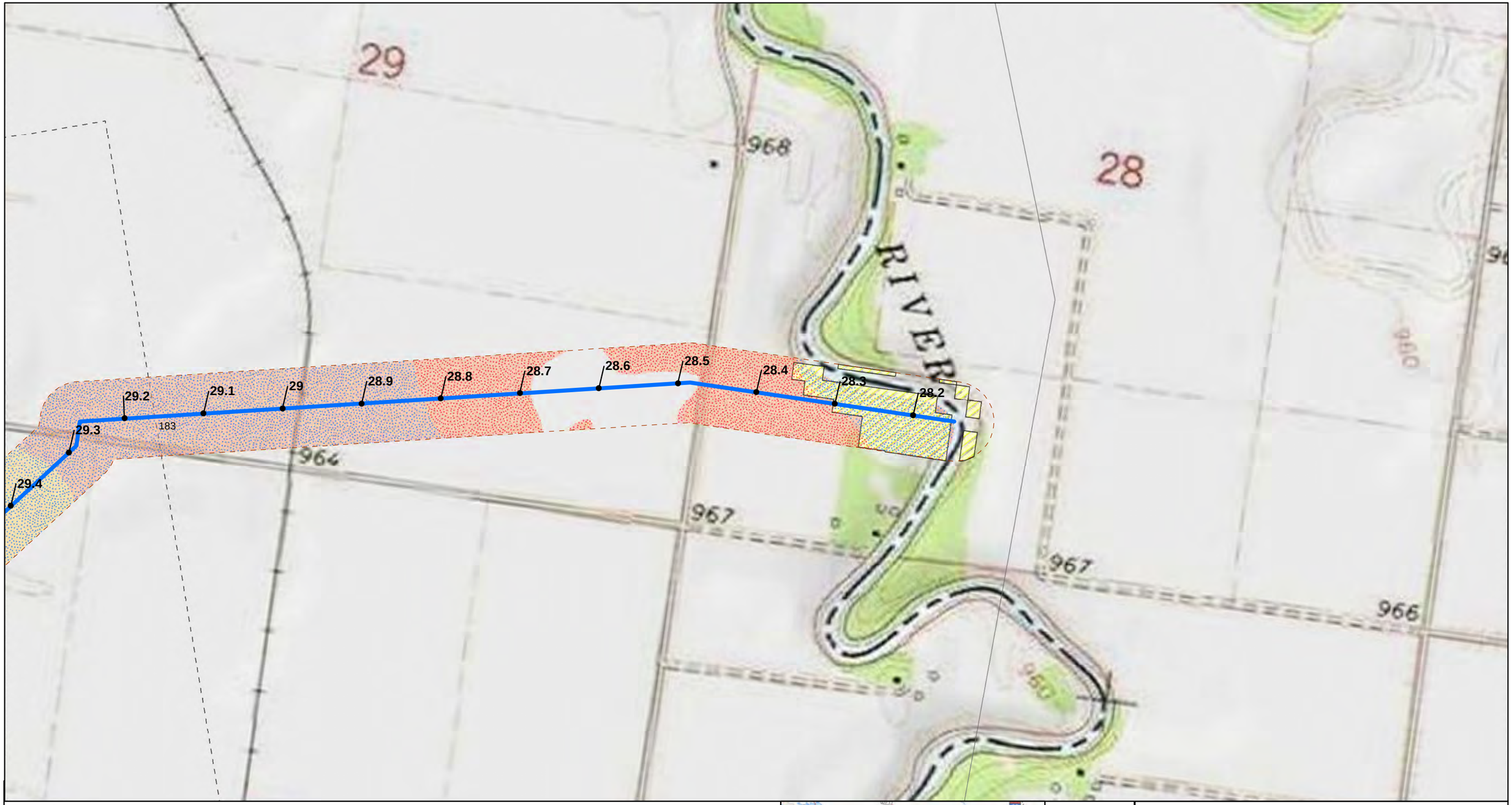

Legend

- REVISION 9 ROUTE MILEPOSTS
- MNL-321
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: RARE

EXPANSIVE SOILS (LEP VALUES)
- MEDIUM

SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards
Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-184

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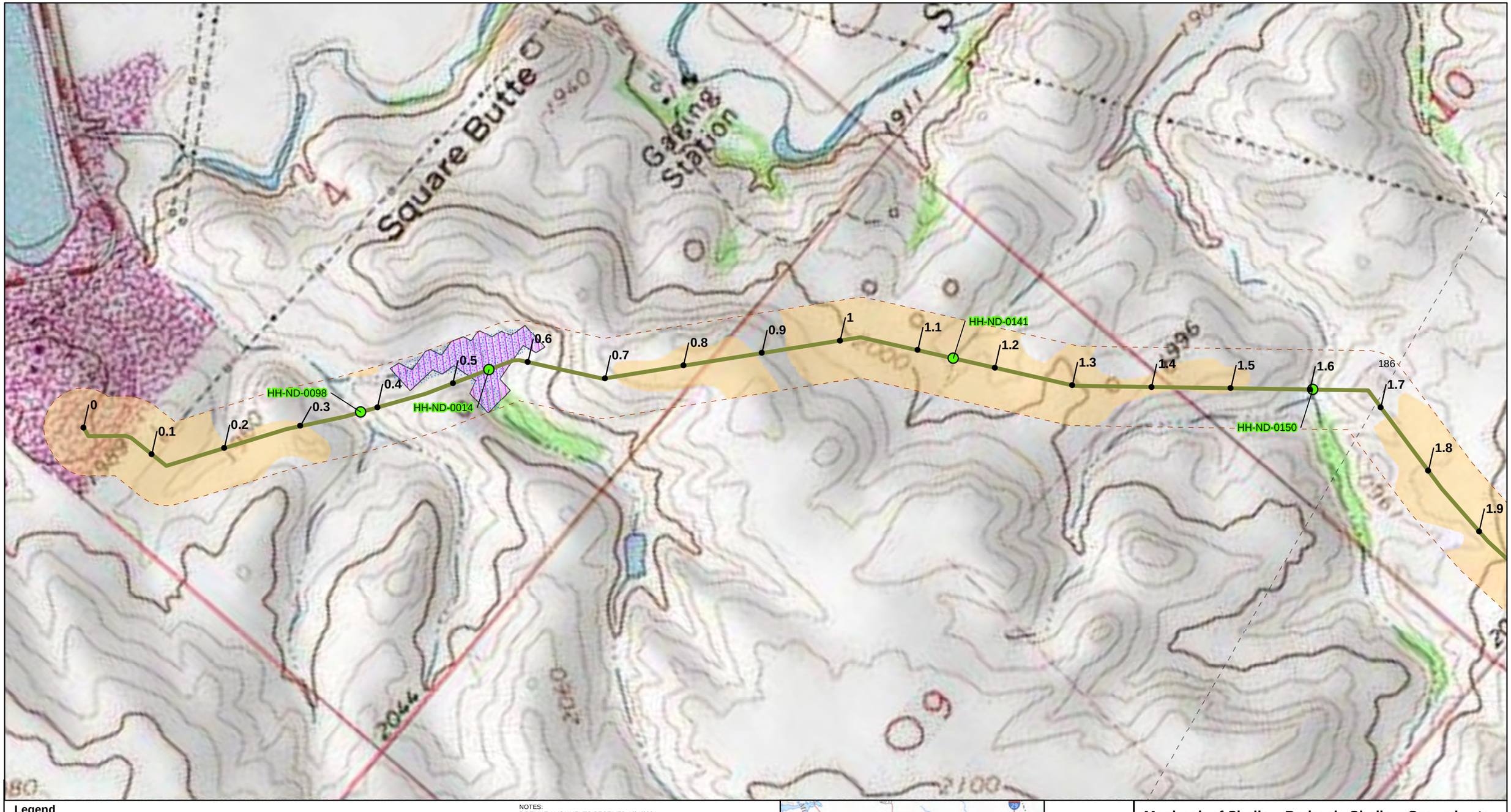

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-328
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- HIGHER: LEP >6

FROST ACTION CATEGORY
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-185

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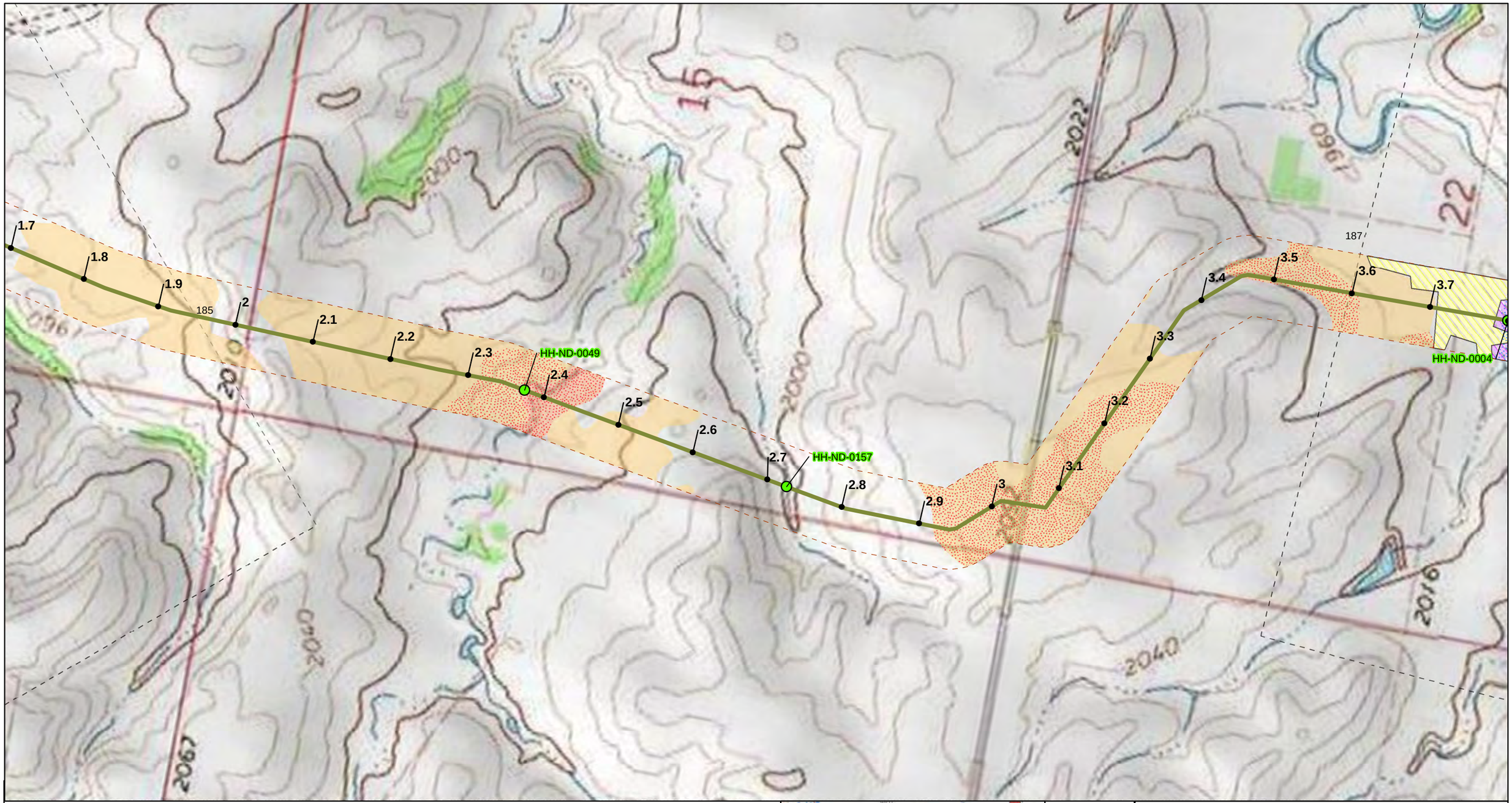

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-328
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY

- FLOODING FREQUENCY: OCCASIONAL
- FLOODING FREQUENCY: RARE

EXPANSIVE SOILS (LEP VALUES)

SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

Figure **1-186**

TXG0450 | January 2024

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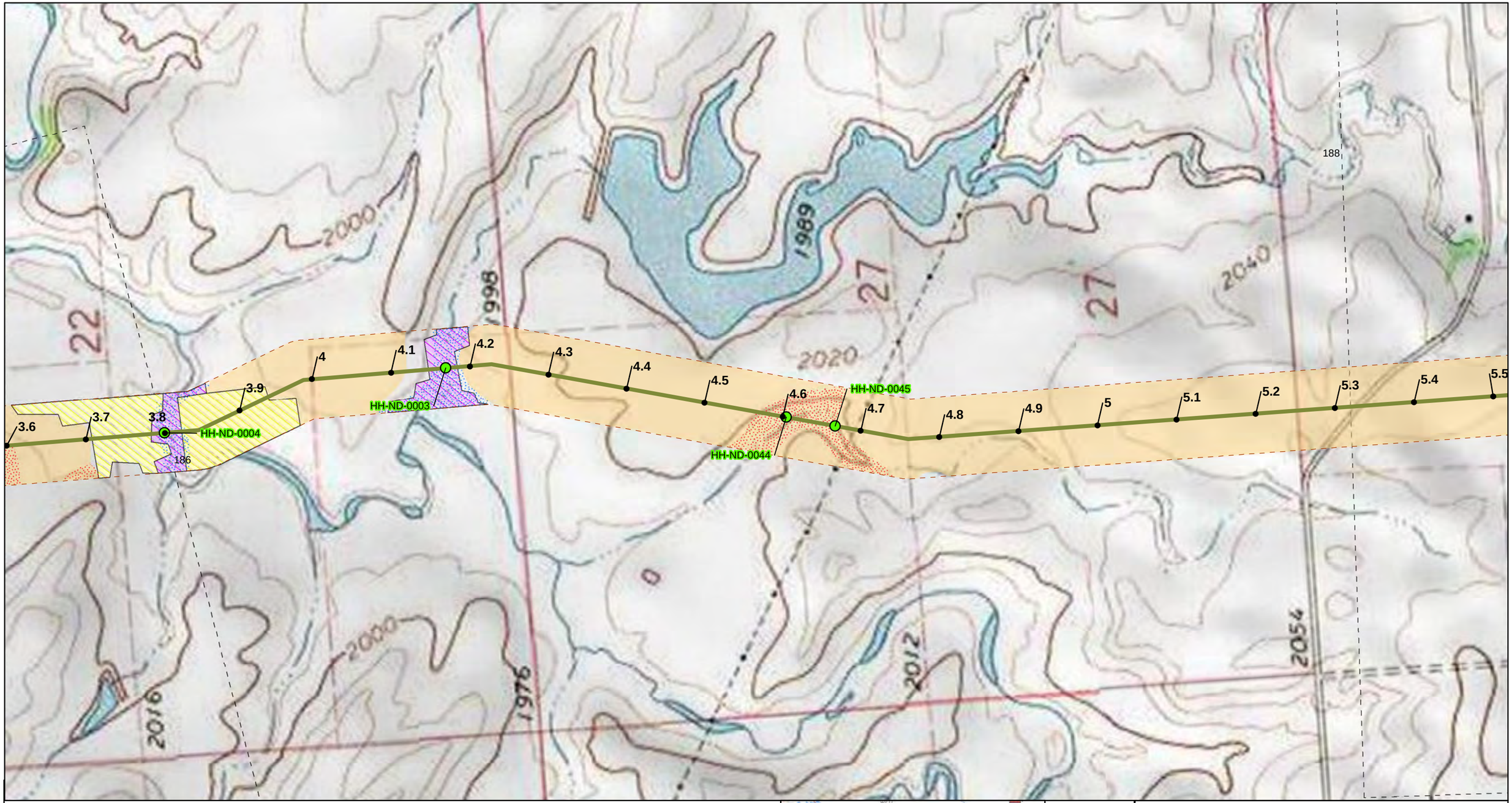

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-328
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY

- FLOODING FREQUENCY: OCCASIONAL
- FLOODING FREQUENCY: RARE

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL

- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY

- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 1-187

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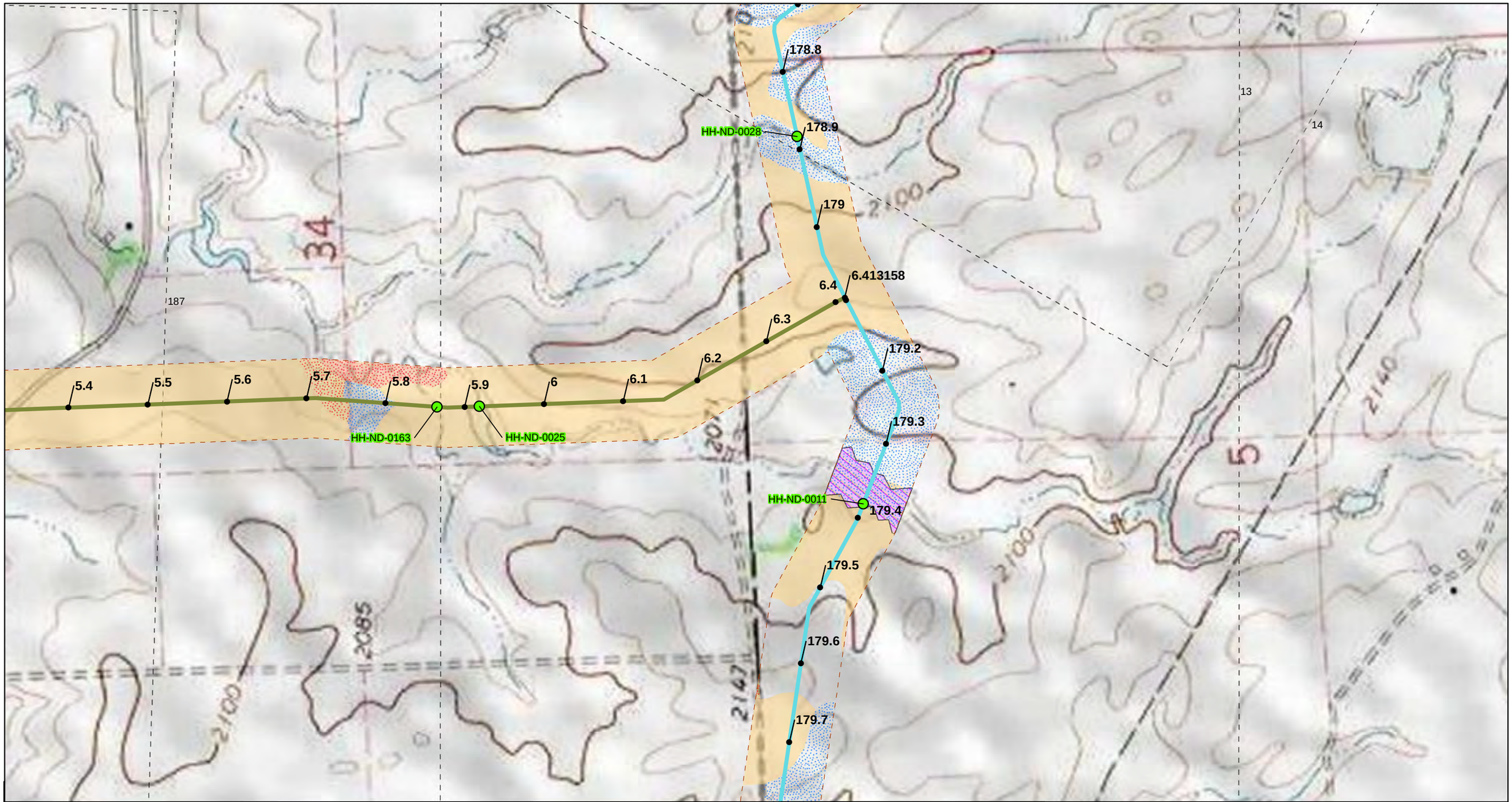

Legend

- REVISION 9 ROUTE MILEPOSTS
- NDL-328
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX
- WATERBODY CROSSING

FLOODING FREQUENCY CATEGORY
- FLOODING FREQUENCY: OCCASIONAL

EXPANSIVE SOILS (LEP VALUES)
SHRINK/SWELL POTENTIAL
- LOWER: LEP <3
- MEDIUM: LEP 3-6
- HIGHER: LEP >6

FROST ACTION CATEGORY
- HIGHER
- MEDIUM

NOTES:
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0 250 500 1,000 Feet

N

Mapbook of Shallow Bedrock, Shallow Groundwater, Expansive Soils, Frost Action, Flooding Frequency, and Hydrotechnical Hazards

Summit Carbon Solutions - North Dakota
Phase I Assessment

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TXG0450 | January 2024

Figure **1-188**

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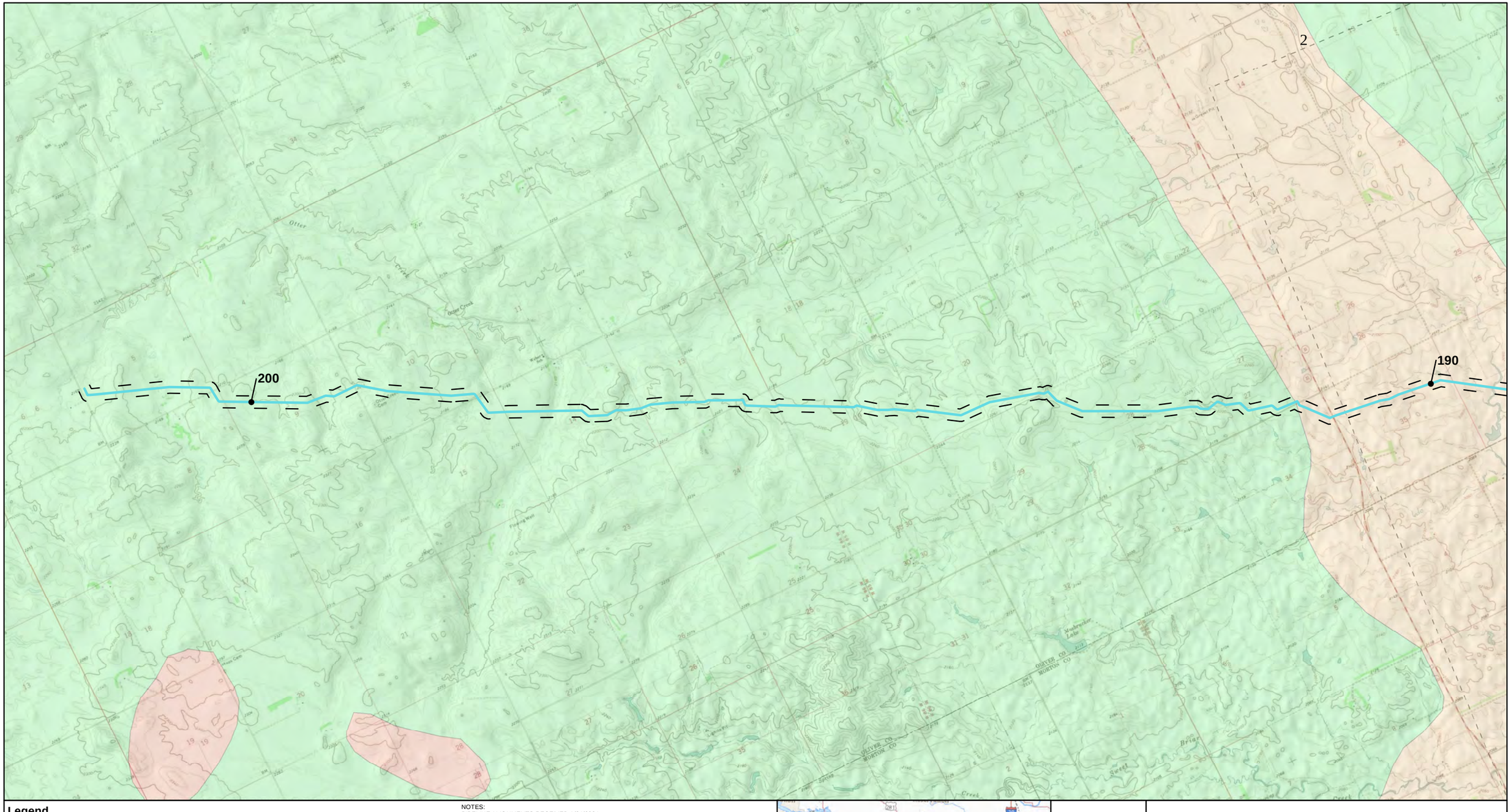

Legend

GEOLOGIC UNIT (SGMC USGS 2017)
- TB - BULLION CREEK FORMATION
- TG
- TS - SENTINEL BUTTE FORMATION

REVISION 9 ROUTE MILEPOSTS

NDM-106

NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)

MAPBOOK INDEX

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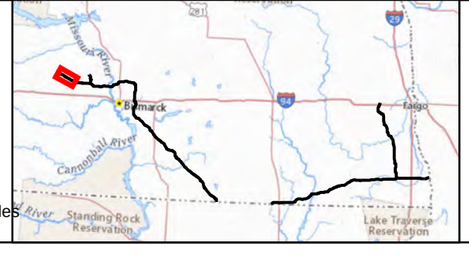

Mapbook of Surficial Geology

Summit Carbon Solutions - Bismarck Reroute - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450 | January 2024

Figure 2-1

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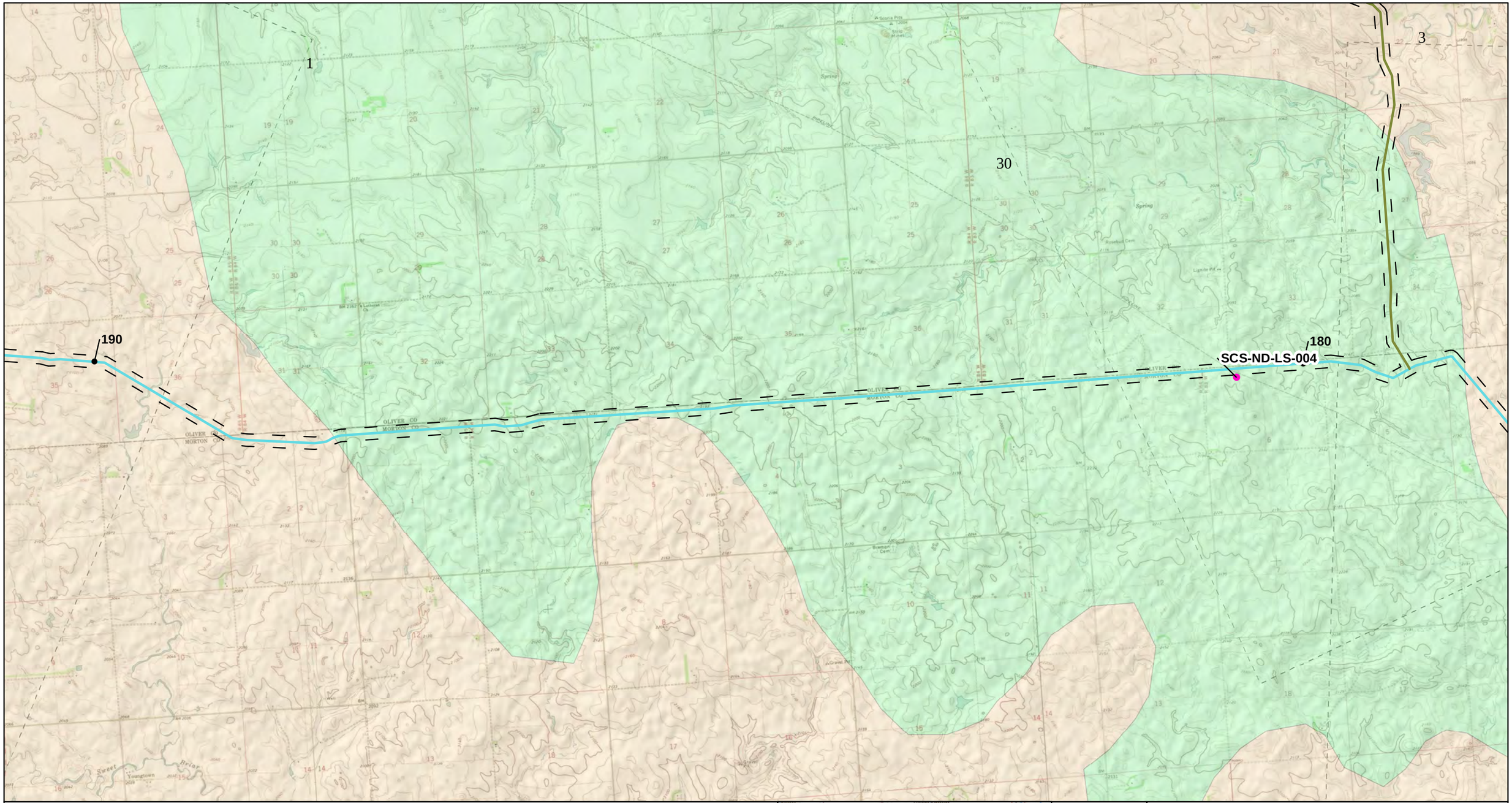

Legend

HAZARD CLASS
- CLASS B

GEOLOGIC UNIT (SGMC USGS 2017)
- TB - BULLION CREEK FORMATION
- TS - SENTINEL BUTTE FORMATION

- REVISION 9 ROUTE MILEPOSTS
- NDL-328
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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0 0.5 1 2 Miles

Mapbook of Surficial Geology

Summit Carbon Solutions - Bismarck Reroute - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 2-2

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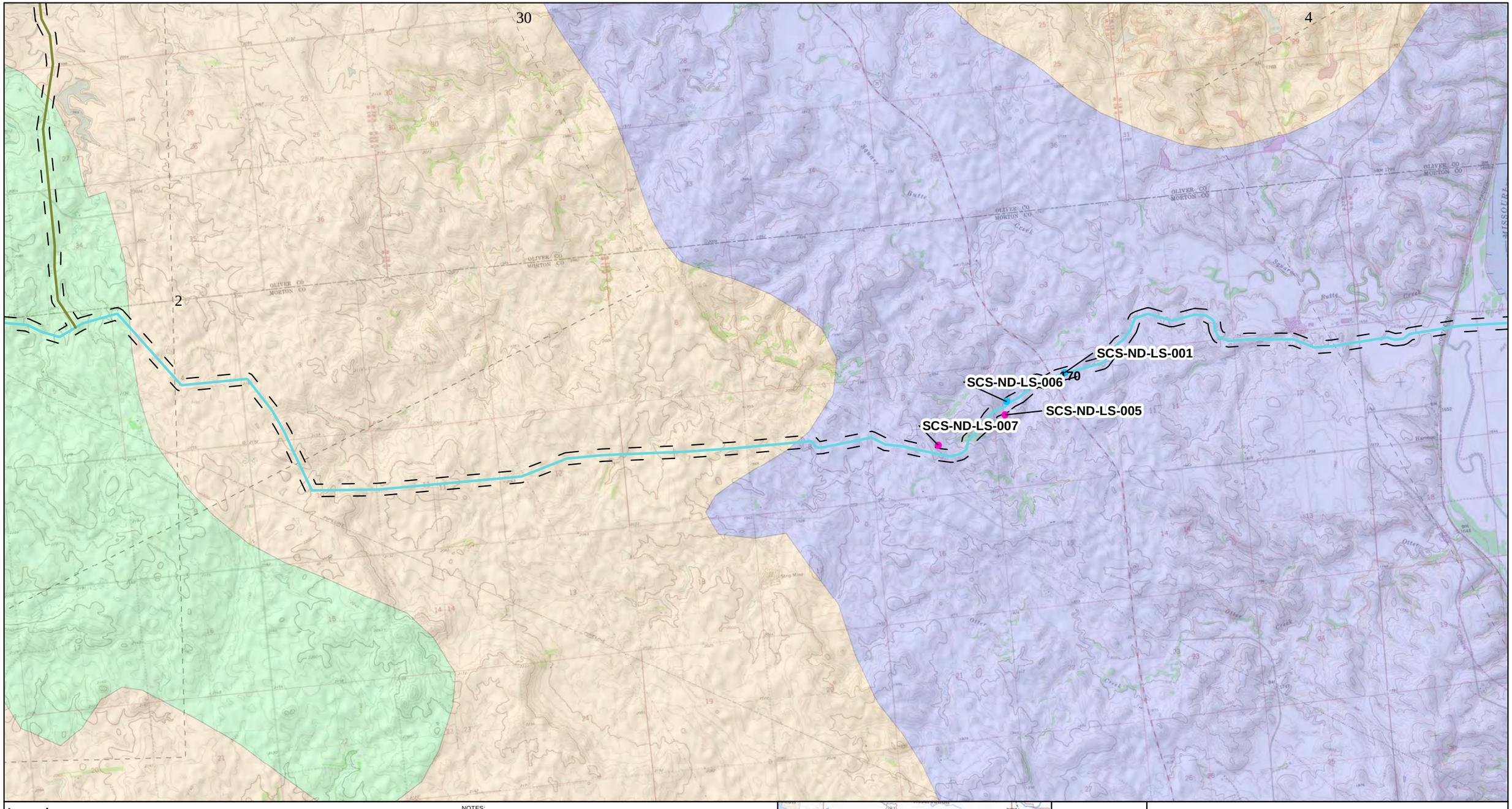

Legend

HAZARD CLASS
- CLASS A
- CLASS B

GEOLOGIC UNIT (SGMC USGS 2017)
- TB - BULLION CREEK FORMATION
- TC - CANNONBALL FORMATION
- TS - SENTINEL BUTTE FORMATION

- REVISION 9 ROUTE MILEPOSTS
- NDL-328
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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0 0.5 1 2 Miles

Mapbook of Surficial Geology

Summit Carbon Solutions - Bismarck Reroute - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 2-3

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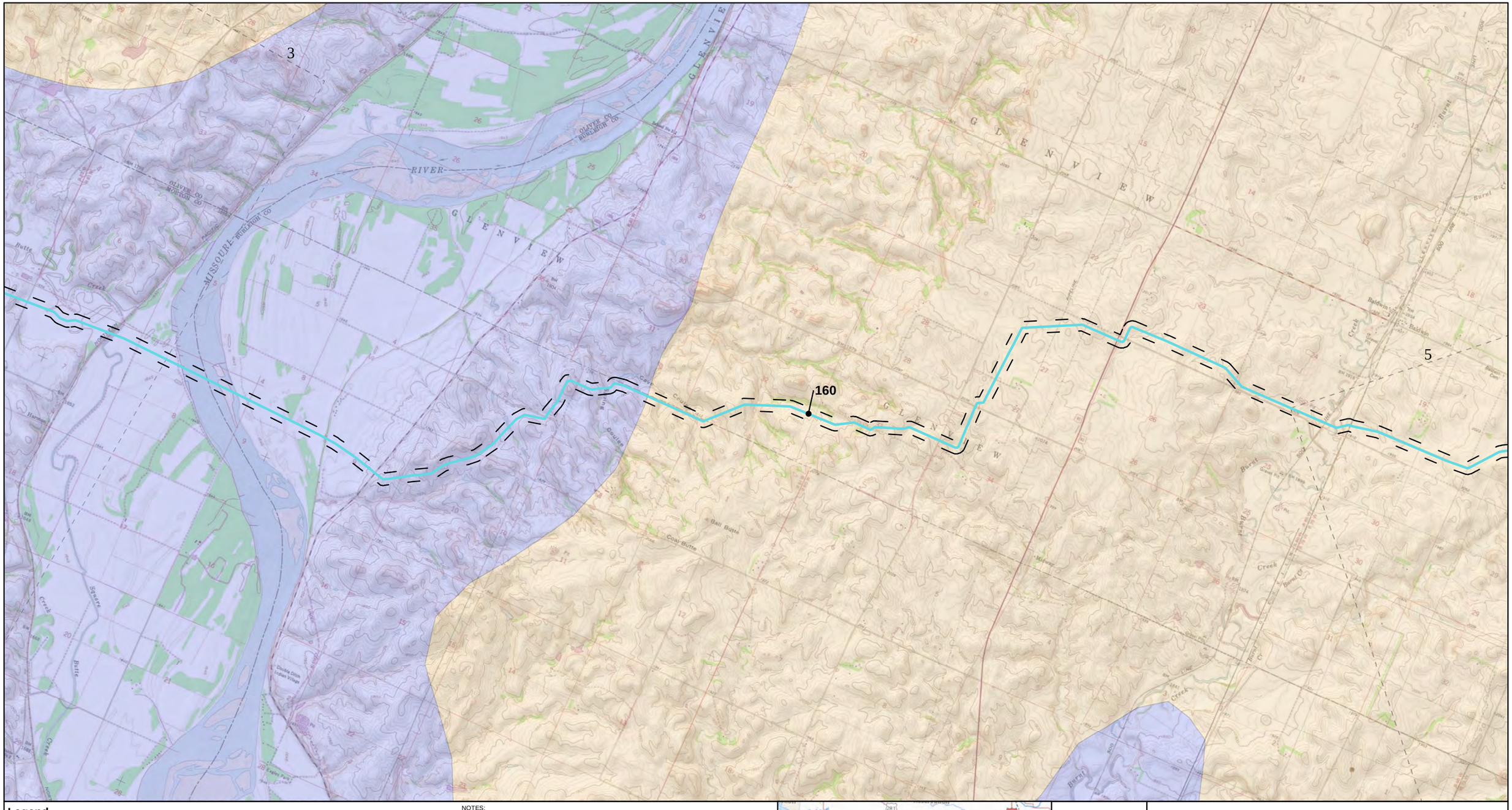

Legend

GEOLOGIC UNIT (SGMC USGS 2017)
- TB - BULLION CREEK FORMATION
- TC - CANNONBALL FORMATION

REVISION 9 ROUTE MILEPOSTS

NDM-106

NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)

MAPBOOK INDEX

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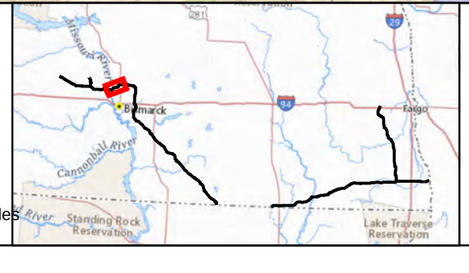

Mapbook of Surficial Geology

Summit Carbon Solutions - Bismarck Reroute - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450	January 2024

Figure **2-4**

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Legend

GEOLOGIC UNIT (SGMC USGS 2017)
- KH - HELLS CREEK FORMATION
- TB - BULLION CREEK FORMATION
- TC - CANNONBALL FORMATION
- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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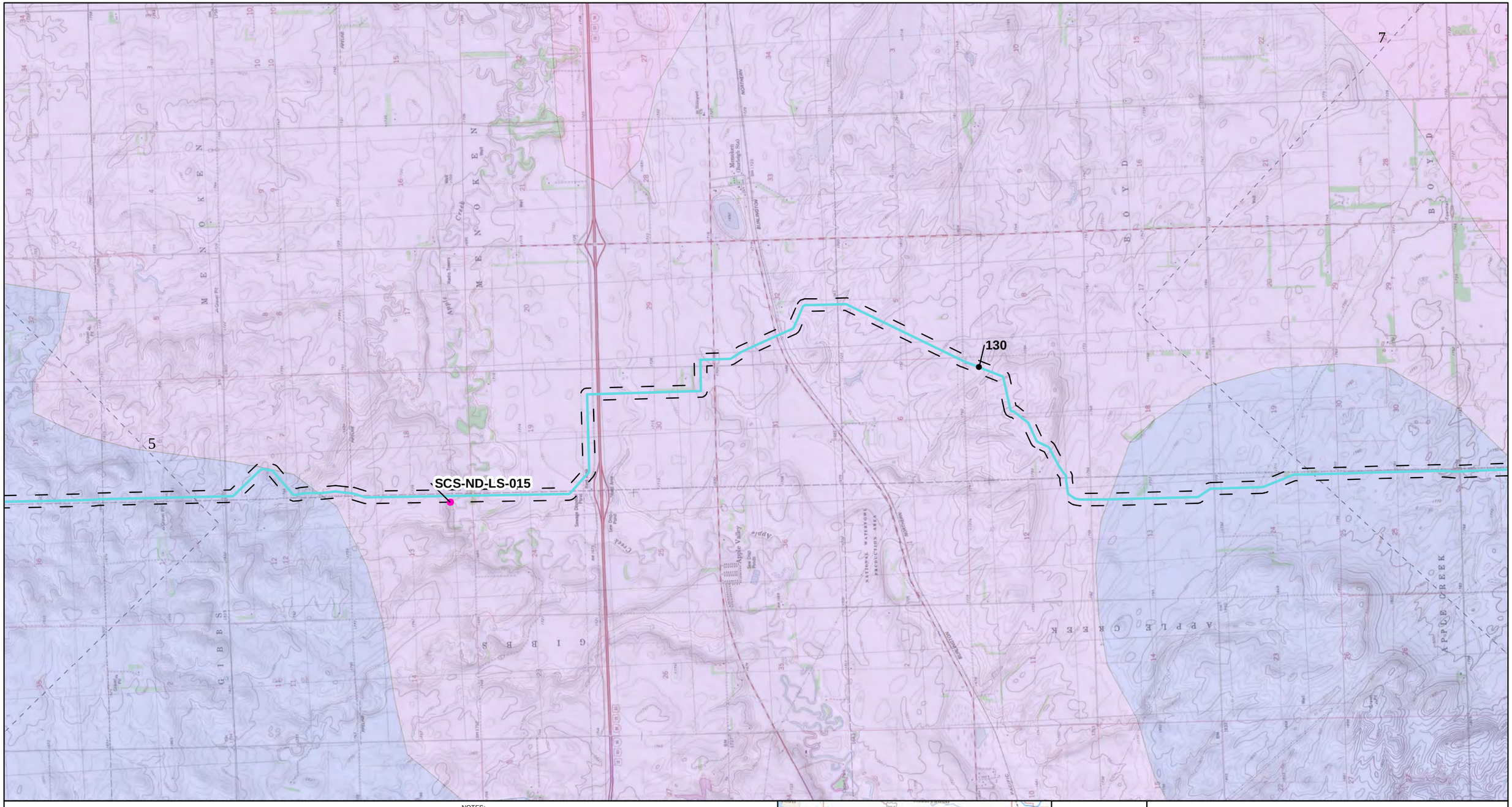
Geosyntec consultants

TXG0450	January 2024

Figure **2-5**



Legend

HAZARD CLASS
- CLASS B

GEOLOGIC UNIT (SGMC USGS 2017)
- KF - FOX HILLS FORMATION
- KH - HELLS CREEK FORMATION
- TC - CANNONBALL FORMATION
- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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Phase I Assessment

Geosyntec consultants

TXG0450	January 2024	Figure 2-6

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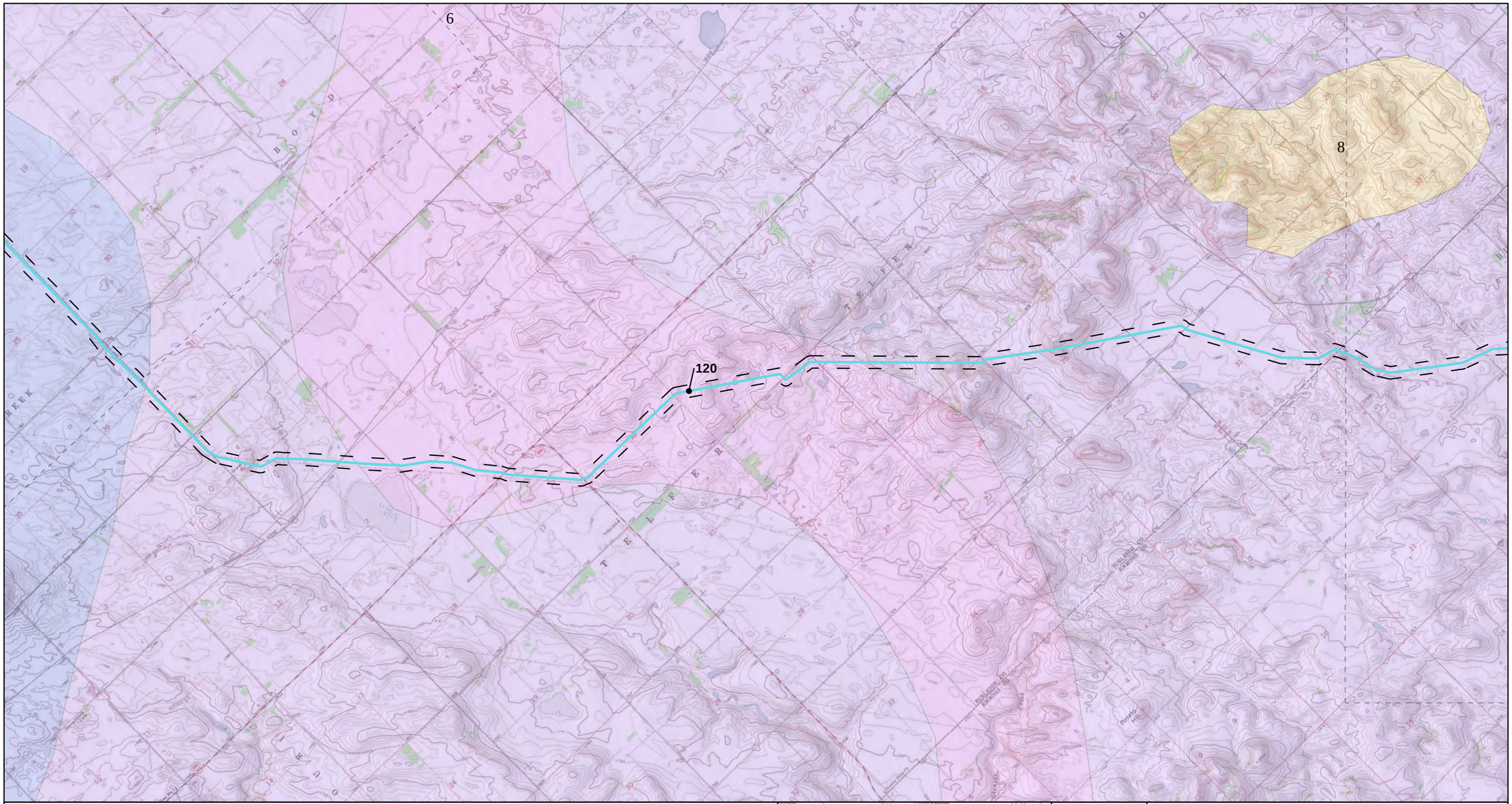

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GEOLOGIC UNIT (SGMC USGS 2017)
- KF - FOX HILLS FORMATION
- KH - HELLS CREEK FORMATION
- TB - BULLION CREEK FORMATION
- TC - CANNONBALL FORMATION

REVISION 9 ROUTE MILEPOSTS

NDM-106

NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)

MAPBOOK INDEX

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Figure **2-7**

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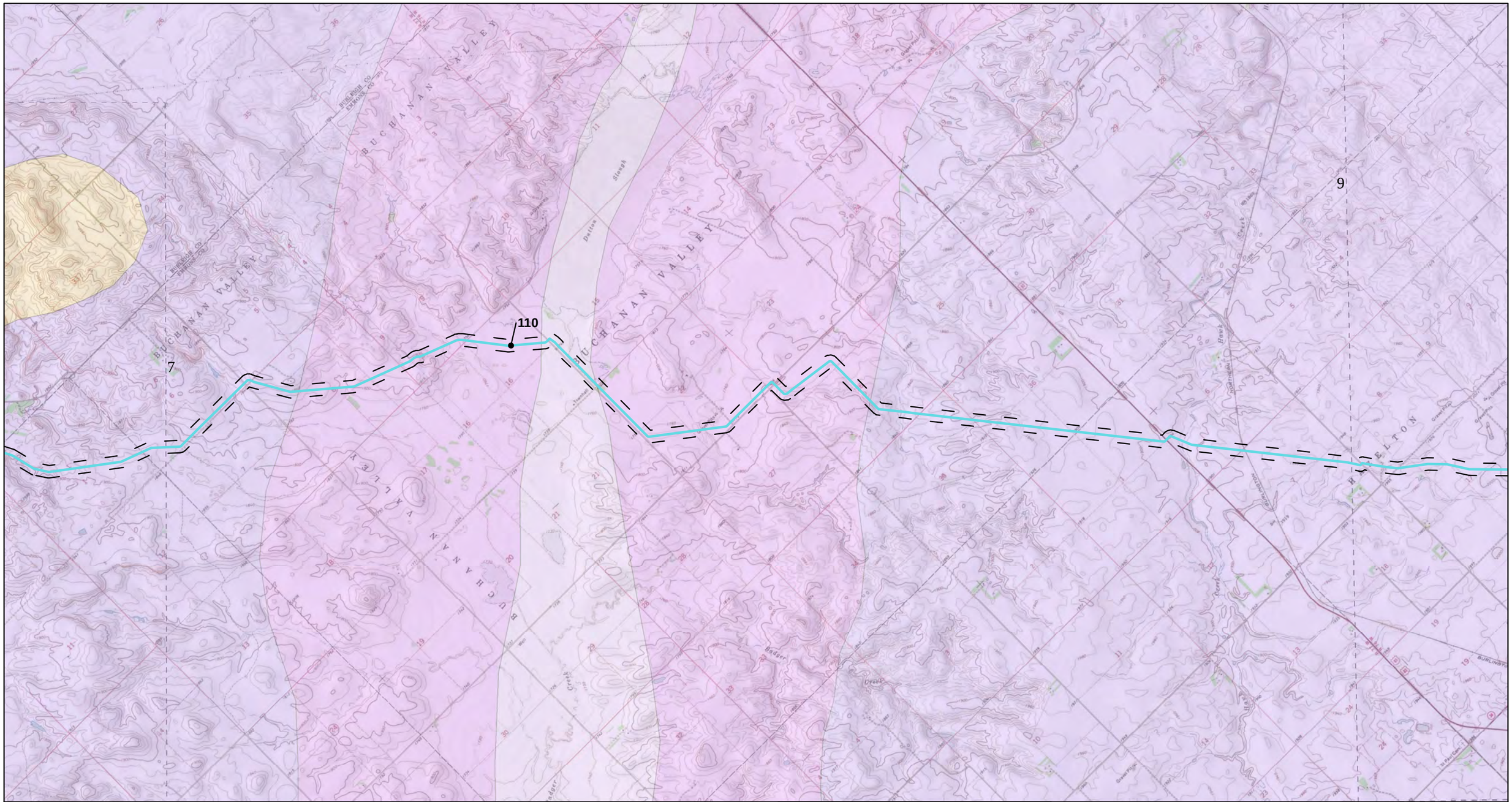

Legend

GEOLOGIC UNIT (SGMC USGS 2017)
- KF - FOX HILLS FORMATION
- KH - HELLS CREEK FORMATION
- KP - PIERRE FORMATION
- TB - BULLION CREEK FORMATION

REVISION 9 ROUTE MILEPOSTS

NDM-106

NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)

MAPBOOK INDEX

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TXG0450	January 2024

Figure **2-8**

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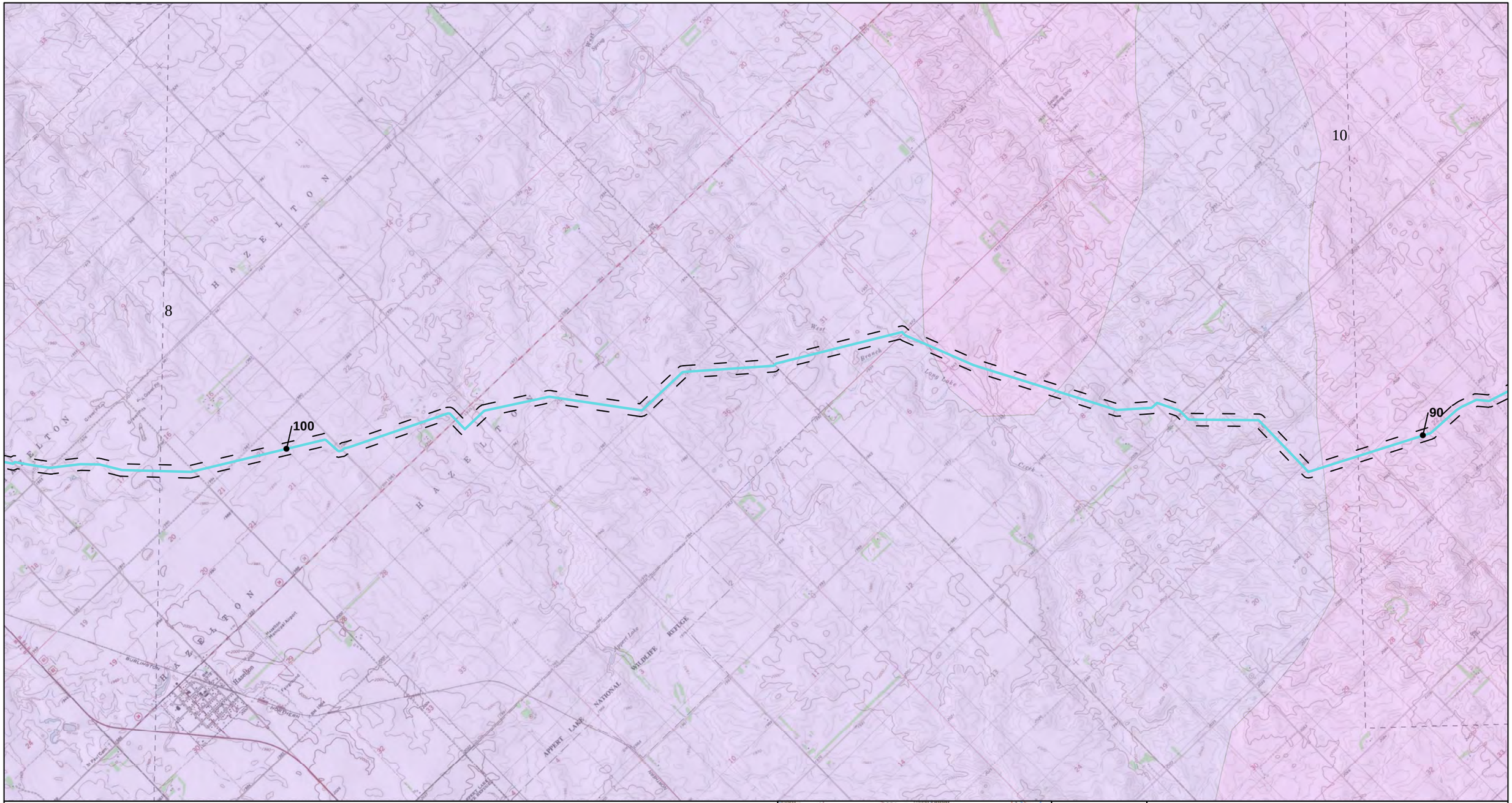

Legend

GEOLOGIC UNIT (SGMC USGS 2017)

- KF - FOX HILLS FORMATION
- KH - HELLS CREEK FORMATION
- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
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Figure **2-9**

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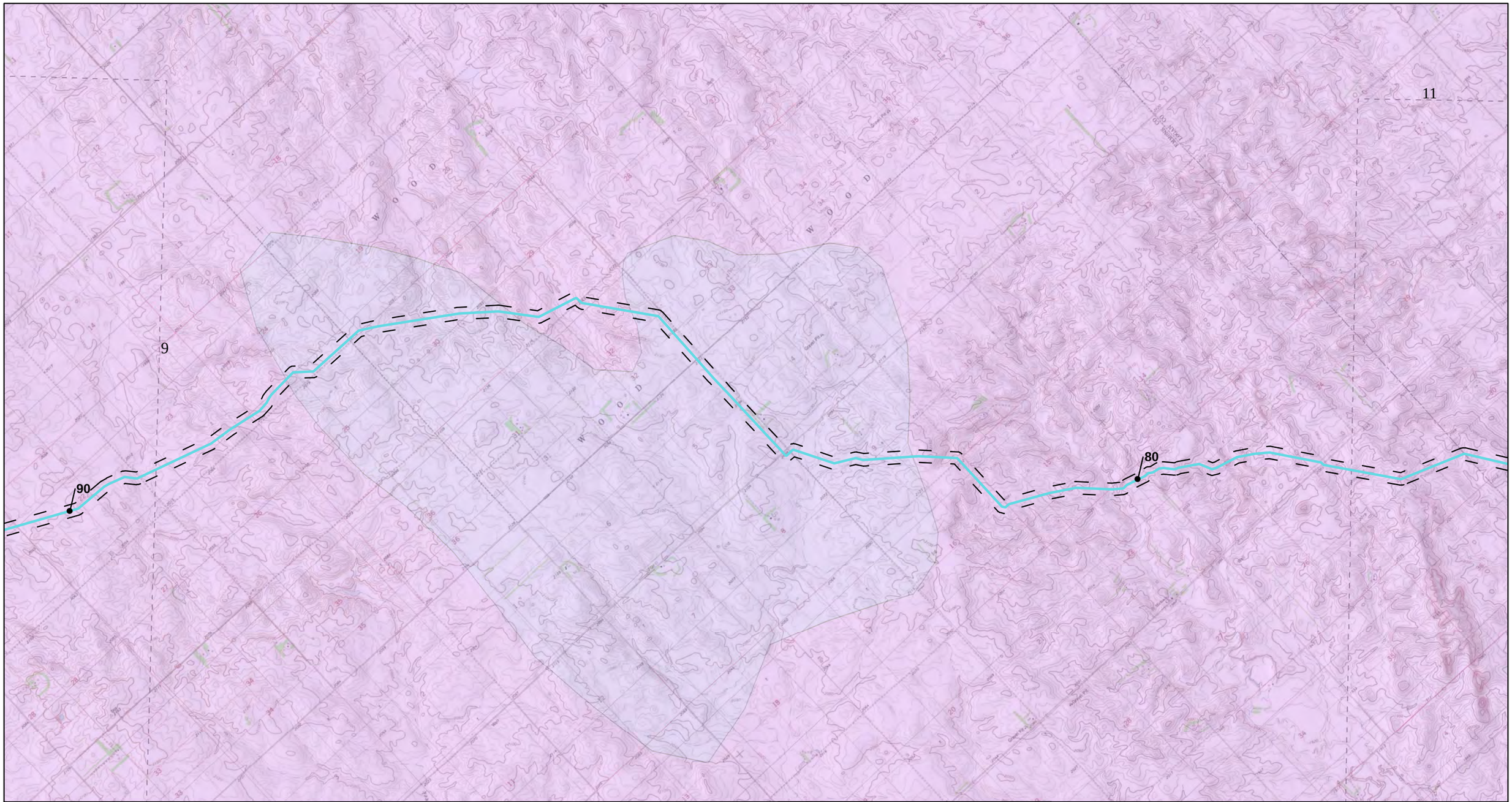

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GEOLOGIC UNIT (SGMC USGS 2017)
- KF - FOX HILLS FORMATION
- KH - HELLS CREEK FORMATION

REVISION 9 ROUTE MILEPOSTS

NDM-106

NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)

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Figure **2-10**

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Legend

GEOLOGIC UNIT (SGMC USGS 2017)
- KF - FOX HILLS FORMATION
- KP - PIERRE FORMATION
- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
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Figure **2-11**

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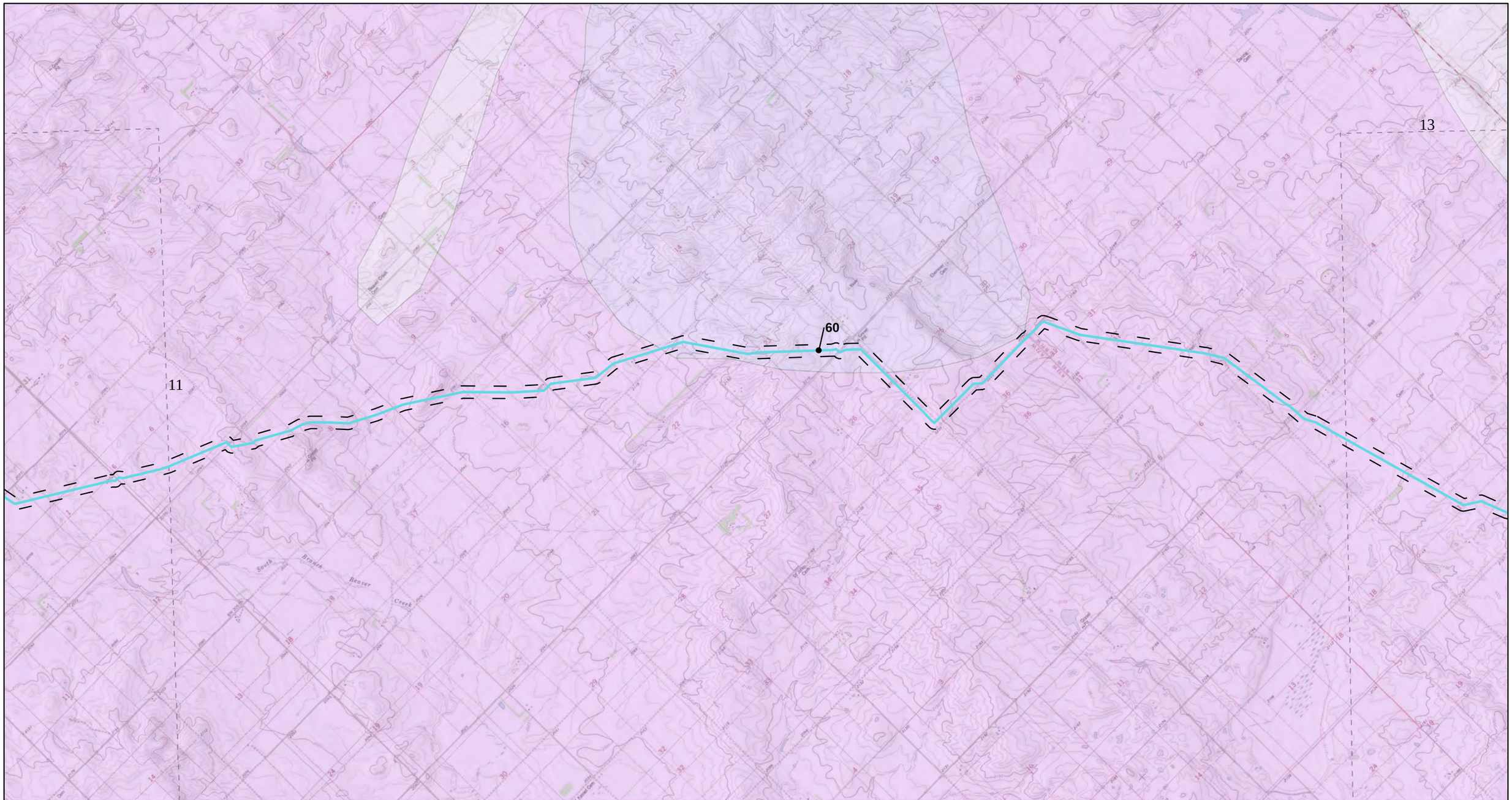

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GEOLOGIC UNIT (SGMC USGS 2017)
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- KH - HELLS CREEK FORMATION
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- REVISION 9 ROUTE MILEPOSTS
- NDM-106
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Figure **2-12**

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Legend

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- KF - FOX HILLS FORMATION
- KP - PIERRE FORMATION
- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)

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Figure **2-13**

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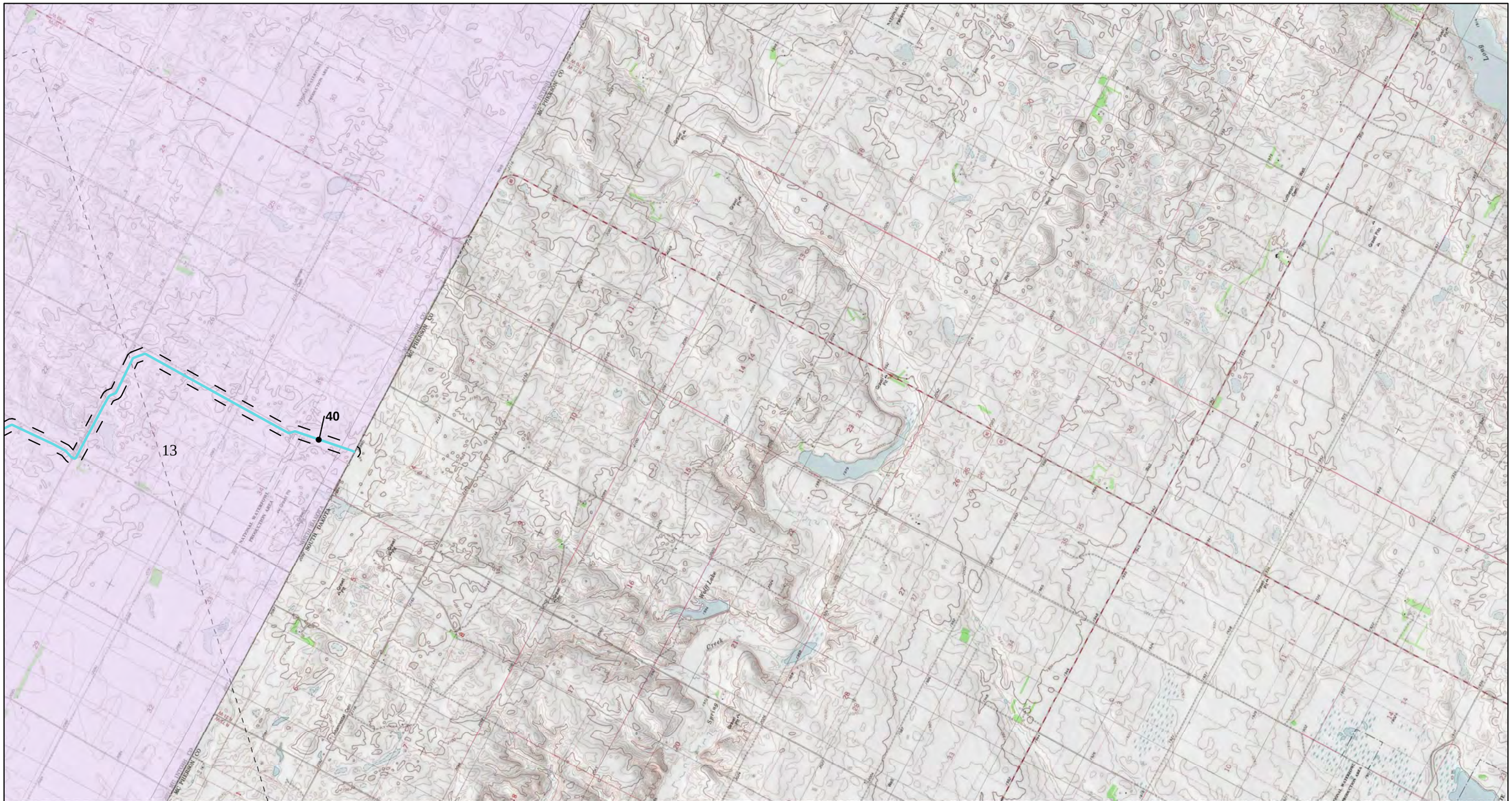

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GEOLOGIC UNIT (SGMC USGS 2017)
- KP - PIERRE FORMATION
- REVISION 9 ROUTE MILEPOSTS
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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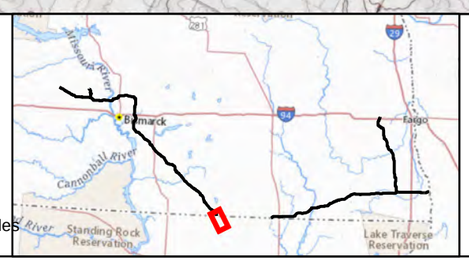

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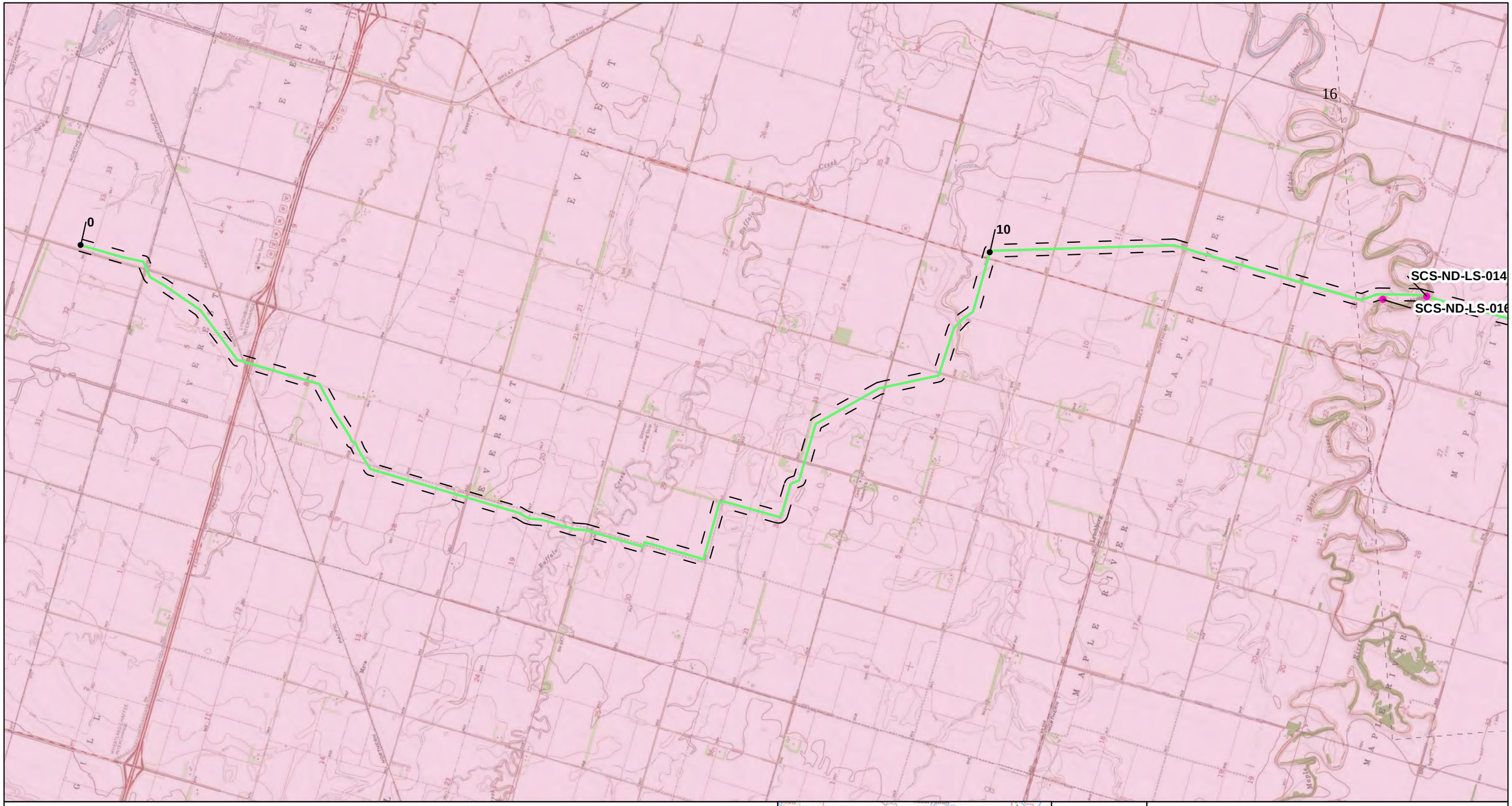

Legend

HAZARD CLASS
- CLASS B

GEOLOGIC UNIT (SGMC USGS 2017)
- KBS - BEILE FOURCHE-SKULL CREEK, UNDIVIDED
- REVISION 9 ROUTE MILEPOSTS
- NDL-324
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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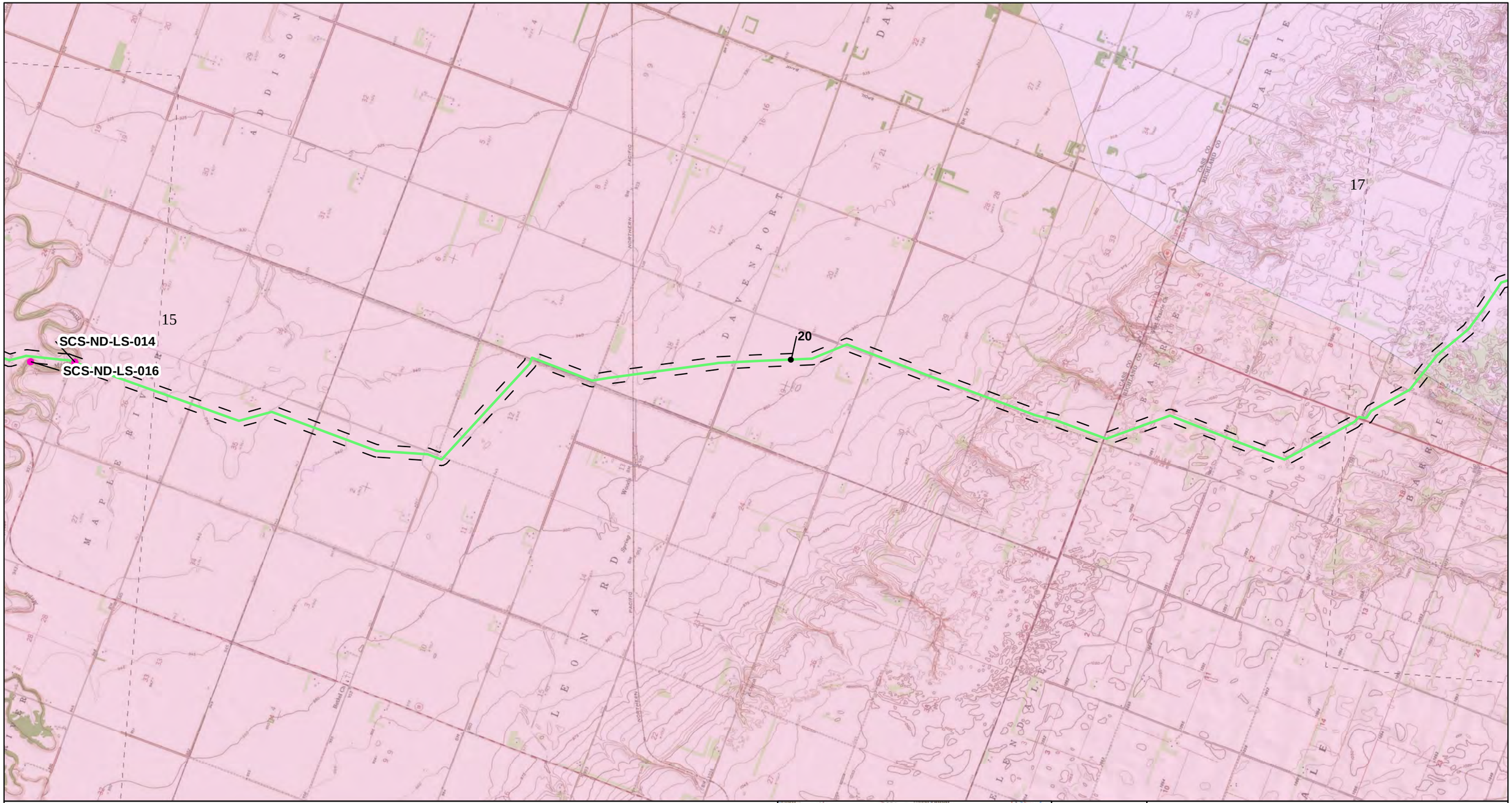

Legend

HAZARD CLASS
- CLASS B

GEOLOGIC UNIT (SGMC USGS 2017)
- KBS - BEILE FOURCHE-SKULL CREEK, UNDIVIDED
- PCA - PRE CAMBRIAN ROCKS
- REVISION 9 ROUTE MILEPOSTS
- NDL-324
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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Phase I Assessment

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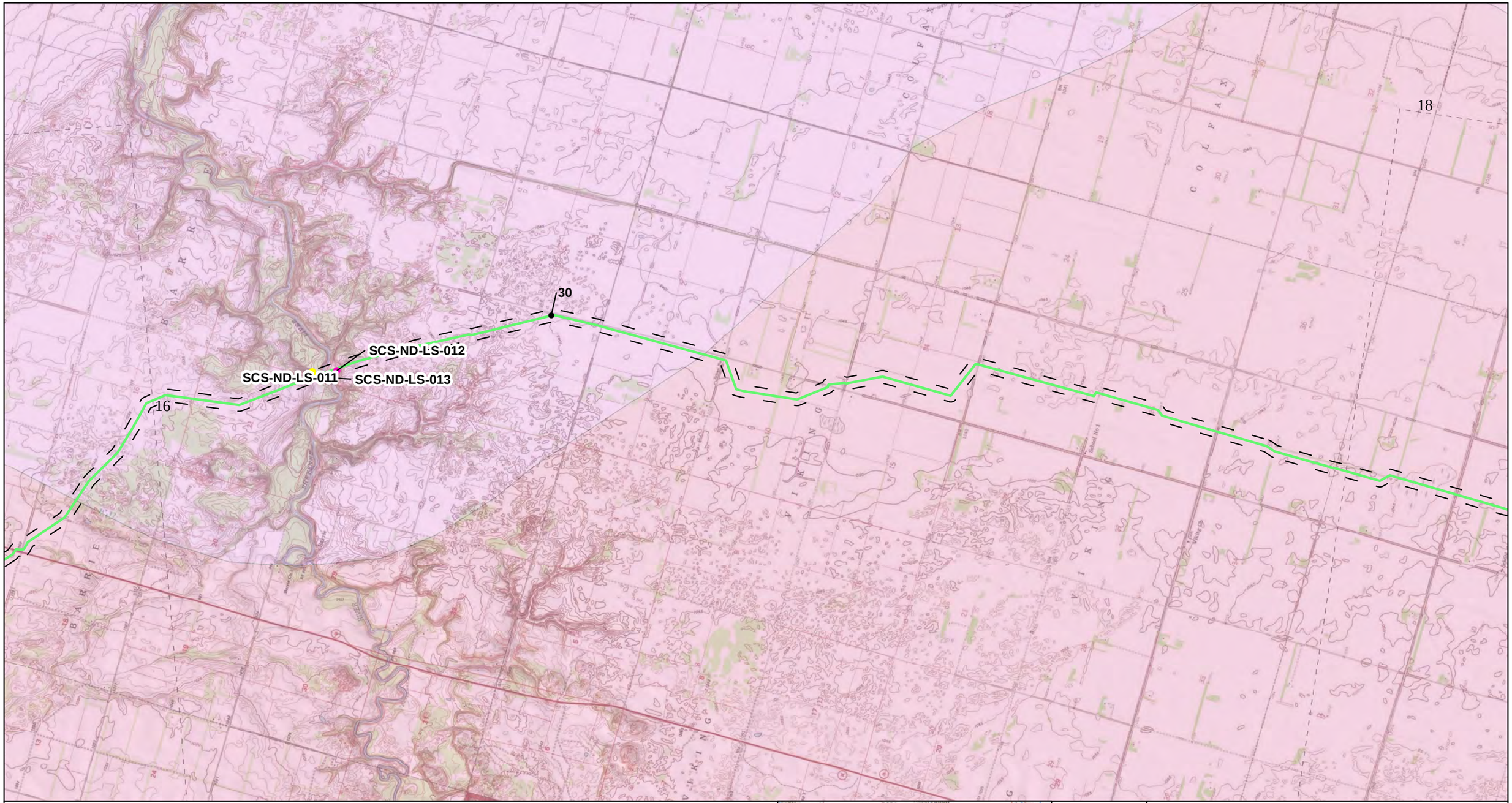

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HAZARD CLASS
- CLASS B
- N/A

GEOLOGIC UNIT (SGMC USGS 2017)
- KBS - BEILE FOURCHE-SKULL CREEK, UNDIVIDED
- PCA - PRE CAMBRIAN ROCKS

- REVISION 9 ROUTE MILEPOSTS
- NDL-324
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
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Mapbook of Surficial Geology

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Phase I Assessment

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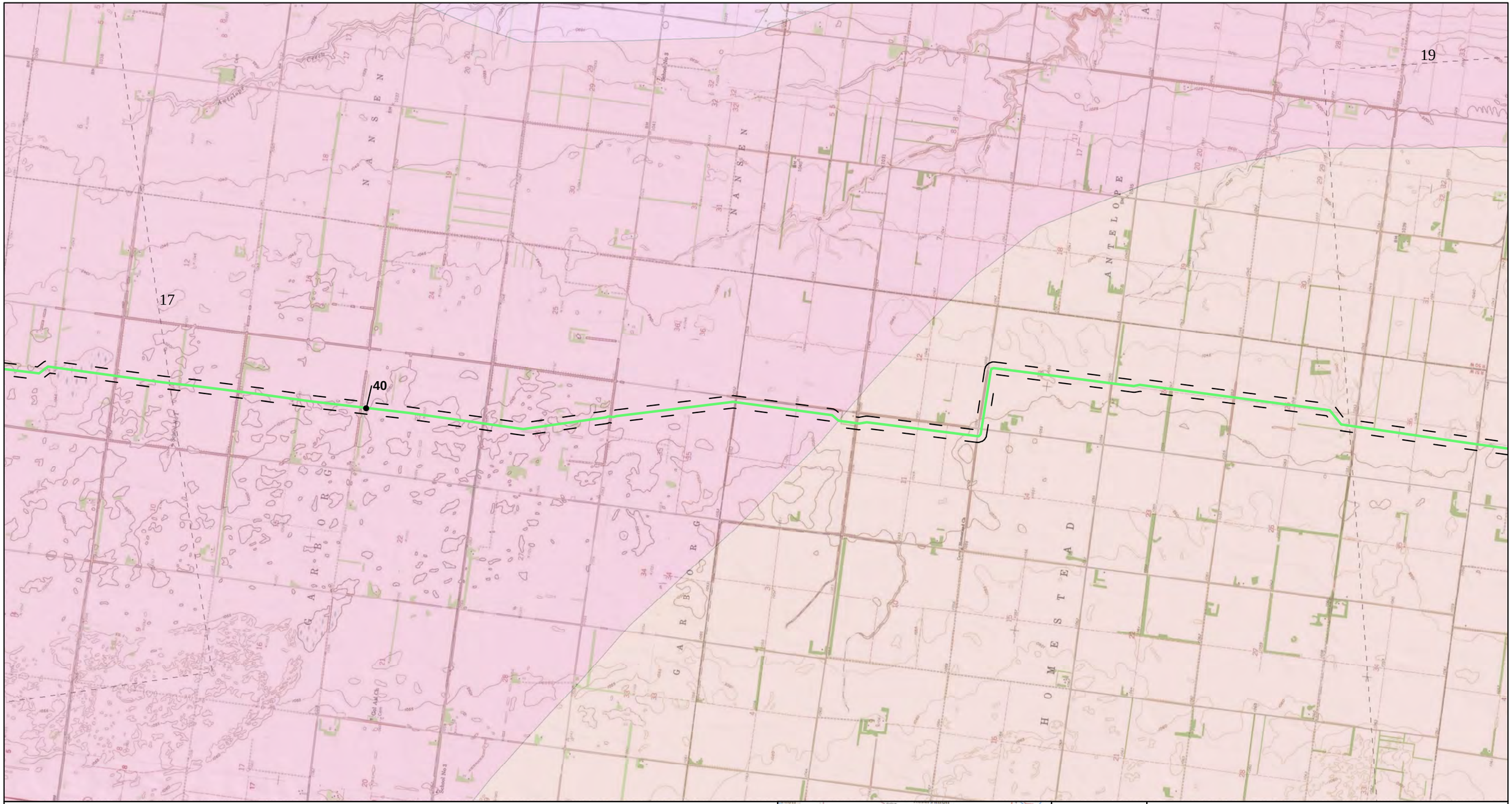
Figure **2-17**



Legend

GEOLOGIC UNIT (SGMC USGS 2017)
- KBS - BEILE FOURCHE-SKULL CREEK, UNDIVIDED
- KG - GREENHORN FORMATION
- KI - INYAN KARA FORMATION
- PCA - PRE CAMBRIAN ROCKS
- REVISION 9 ROUTE MILEPOSTS
- NDL-324
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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TXG0450	January 2024	Figure 2-18

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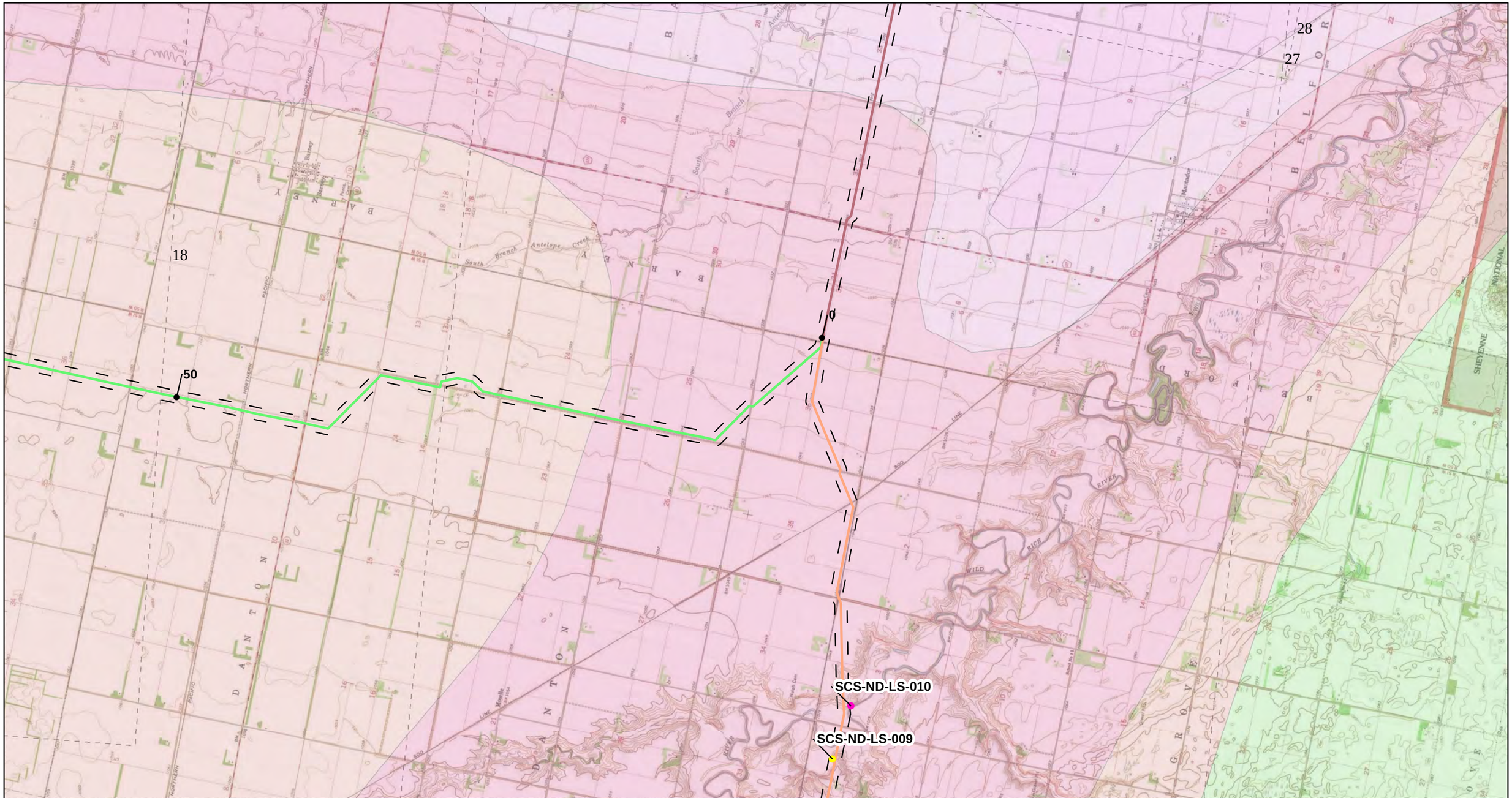

Legend

HAZARD CLASS
- CLASS B
- N/A

GEOLOGIC UNIT (SGMC USGS 2017)
- KBS - BEILE FOURCHE-SKULL CREEK, UNDIVIDED
- KC - CARLILE FORMATION
- KG - GREENHORN FORMATION
- KI - INYAN KARA FORMATION
- PCA - PRE CAMBRIAN ROCKS
- REVISION 9 ROUTE MILEPOSTS
- NDL-323
- NDL-324
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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Figure **2-19**

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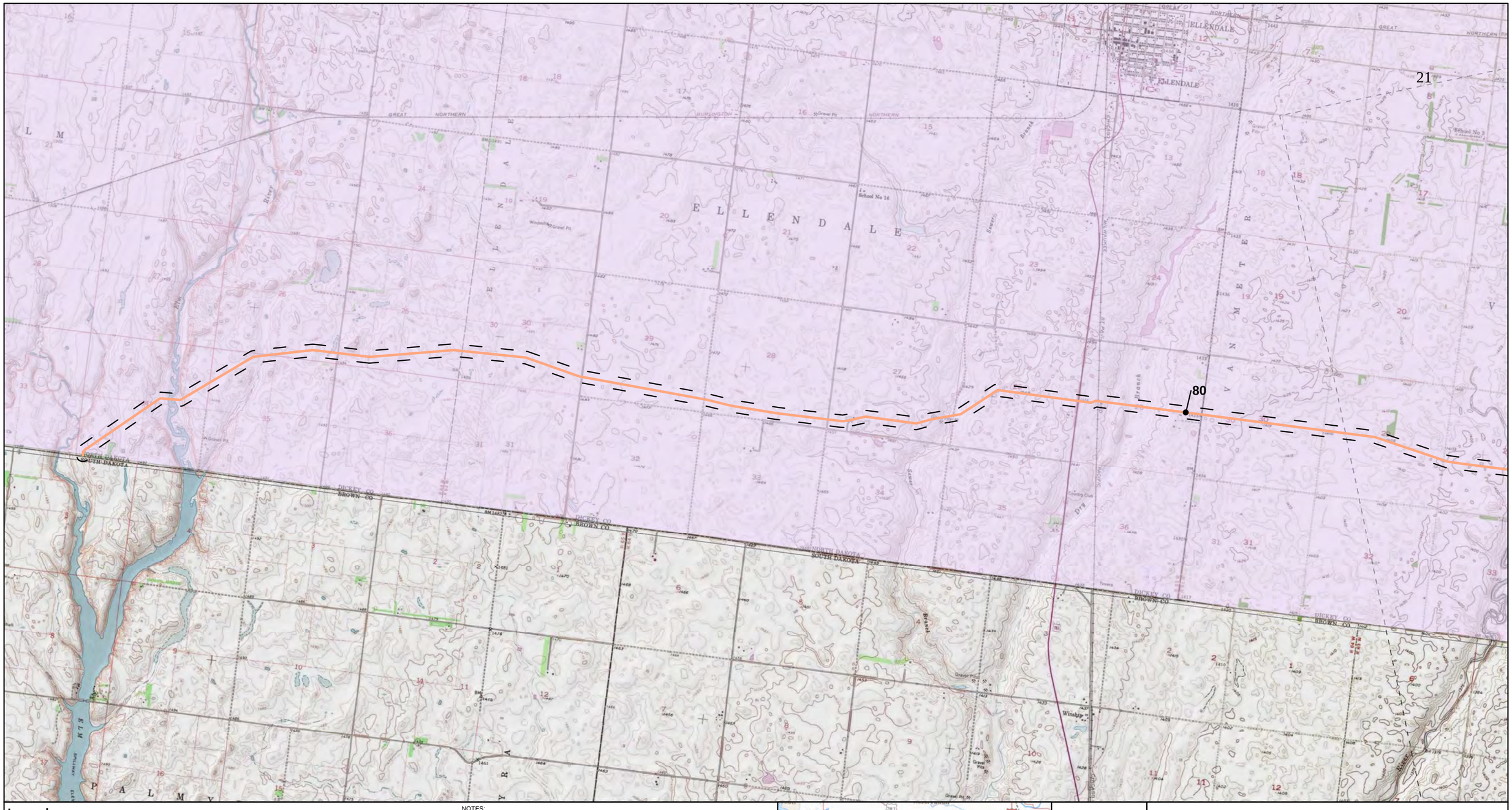

Legend

GEOLOGIC UNIT (SGMC USGS 2017)
- KP - PIERRE FORMATION
- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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TXG0450	January 2024	Figure 2-20

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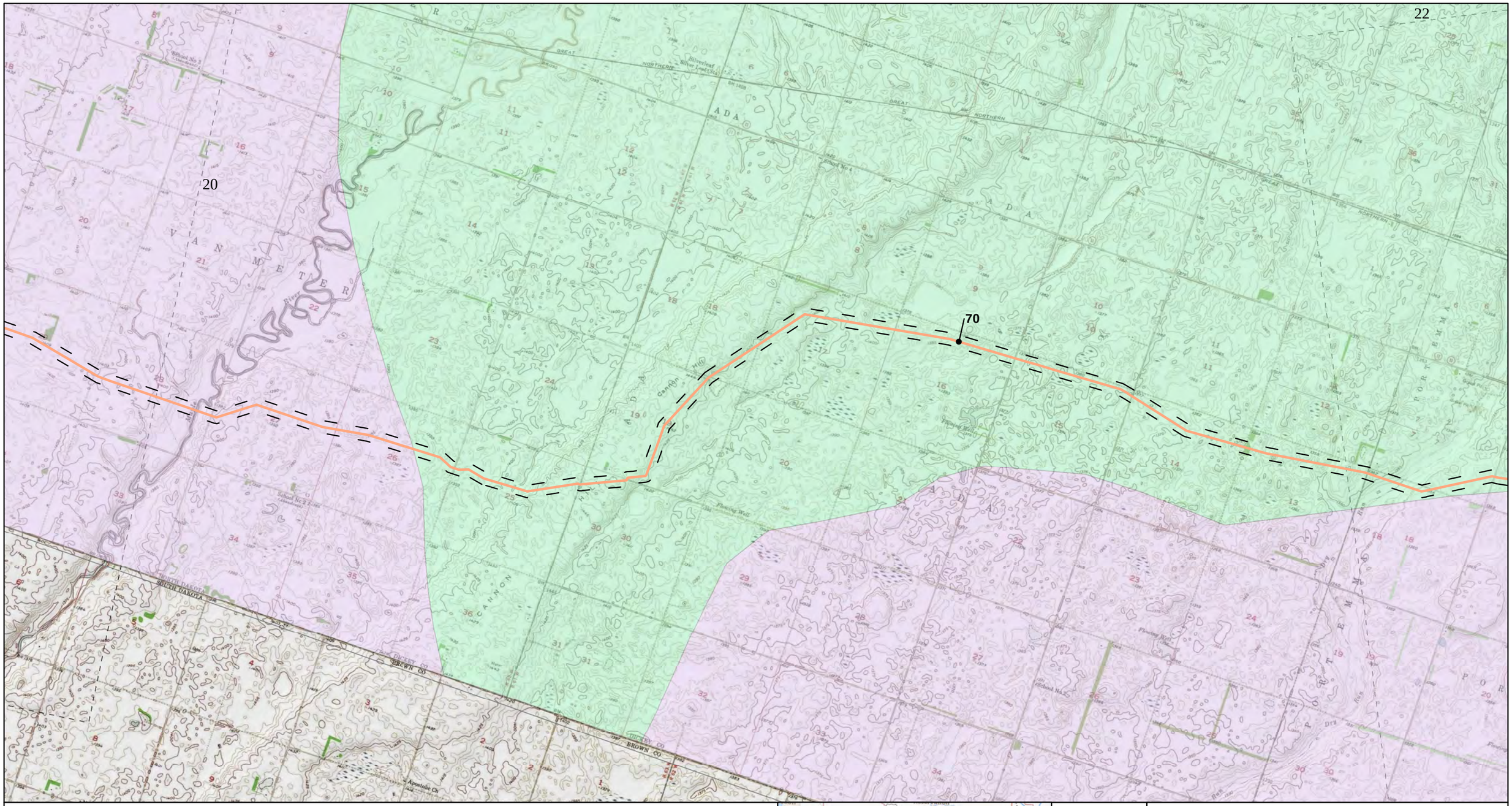

Legend

GEOLOGIC UNIT (SGMC USGS 2017)

- KN - NIOBRARA AND CARLILE FORMATIONS, UNDIVIDED
- KP - PIERRE FORMATION
- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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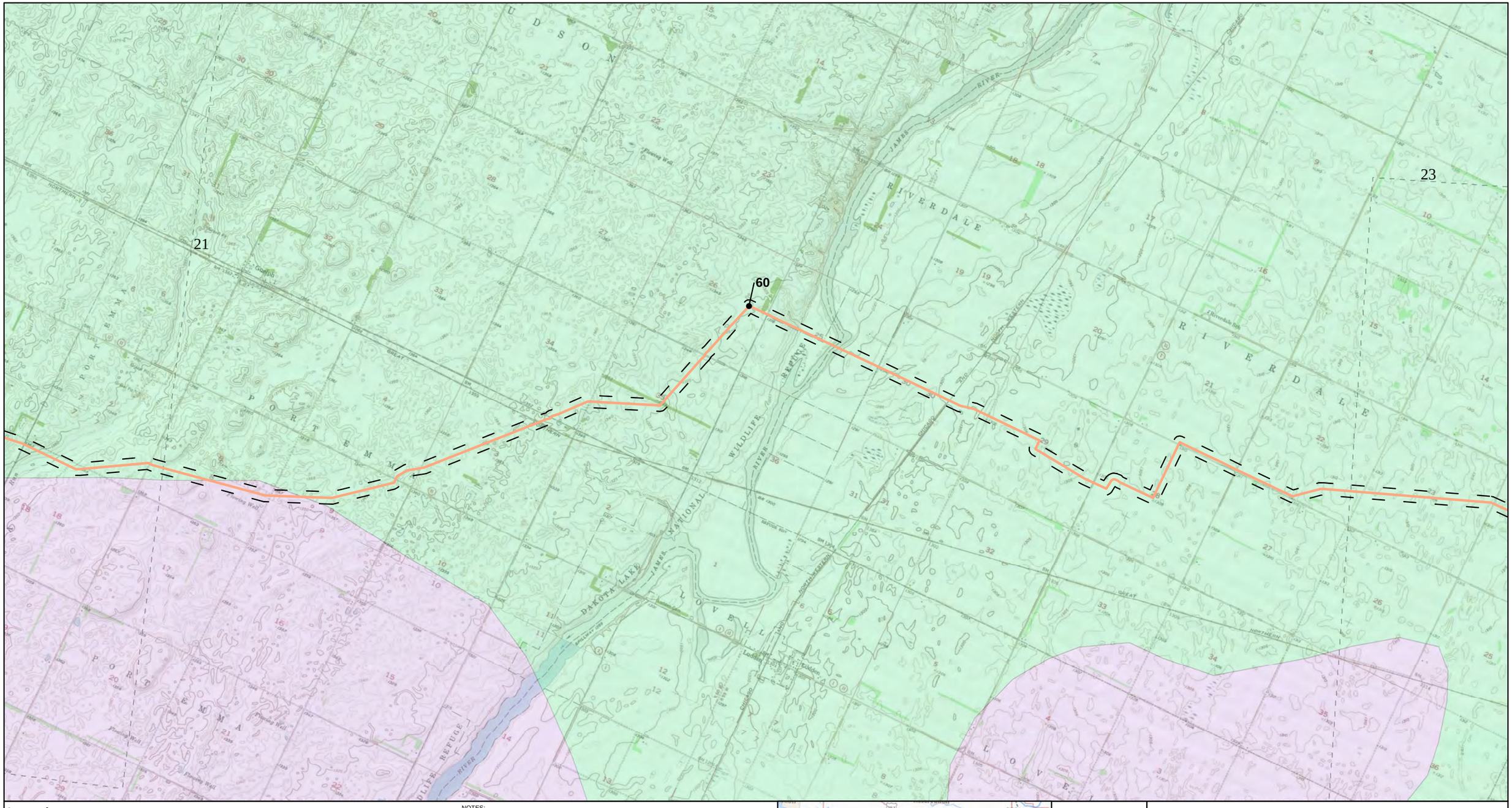

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GEOLOGIC UNIT (SGMC USGS 2017)

- KN - NIOBRARA AND CARLILE FORMATIONS, UNDIVIDED
- KP - PIERRE FORMATION
- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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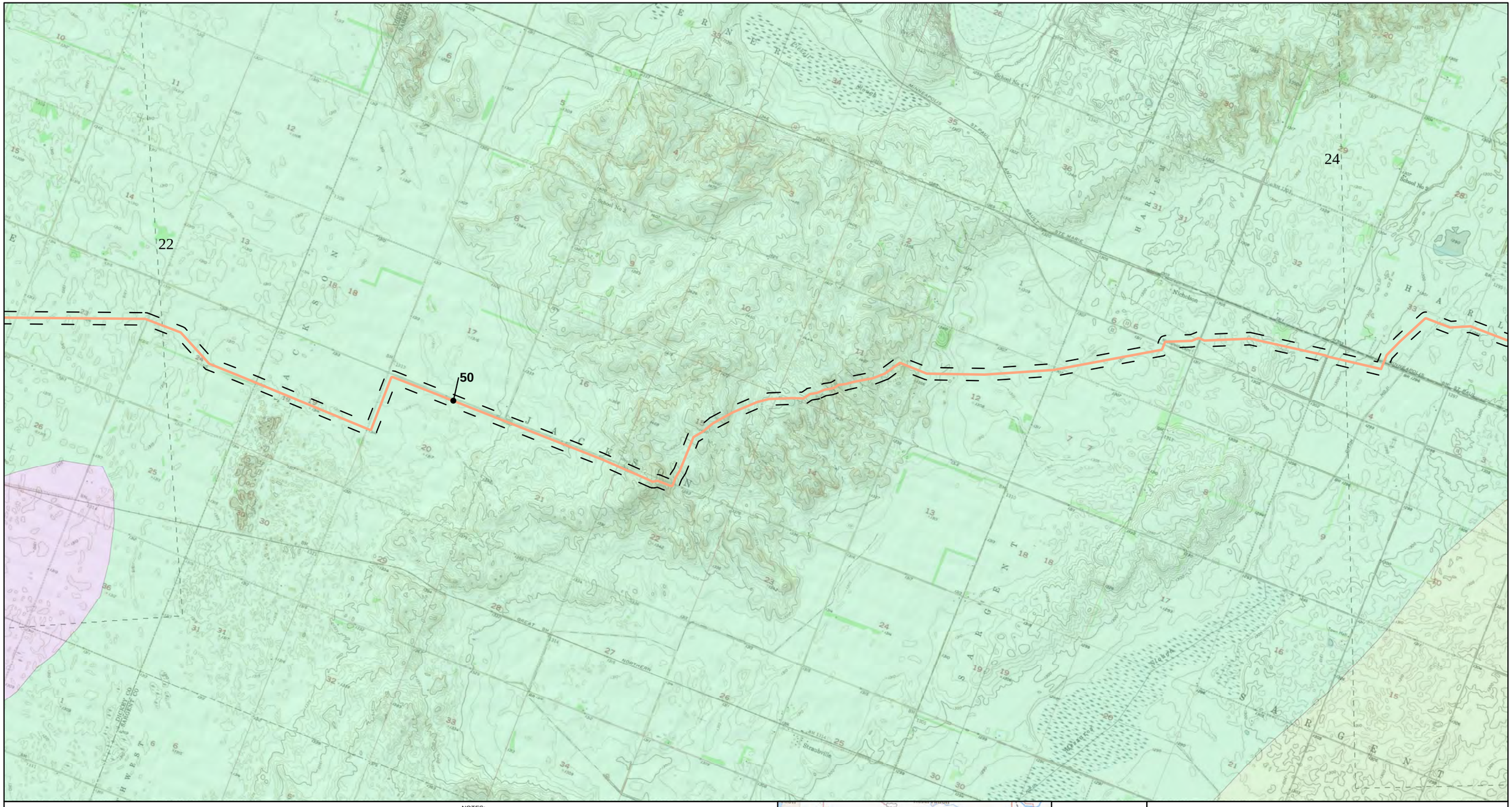

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GEOLOGIC UNIT (SGMC USGS 2017)
- KC - CARLILE FORMATION
- KN - NIOBRARA AND CARLILE FORMATIONS, UNDIVIDED
- KP - PIERRE FORMATION
- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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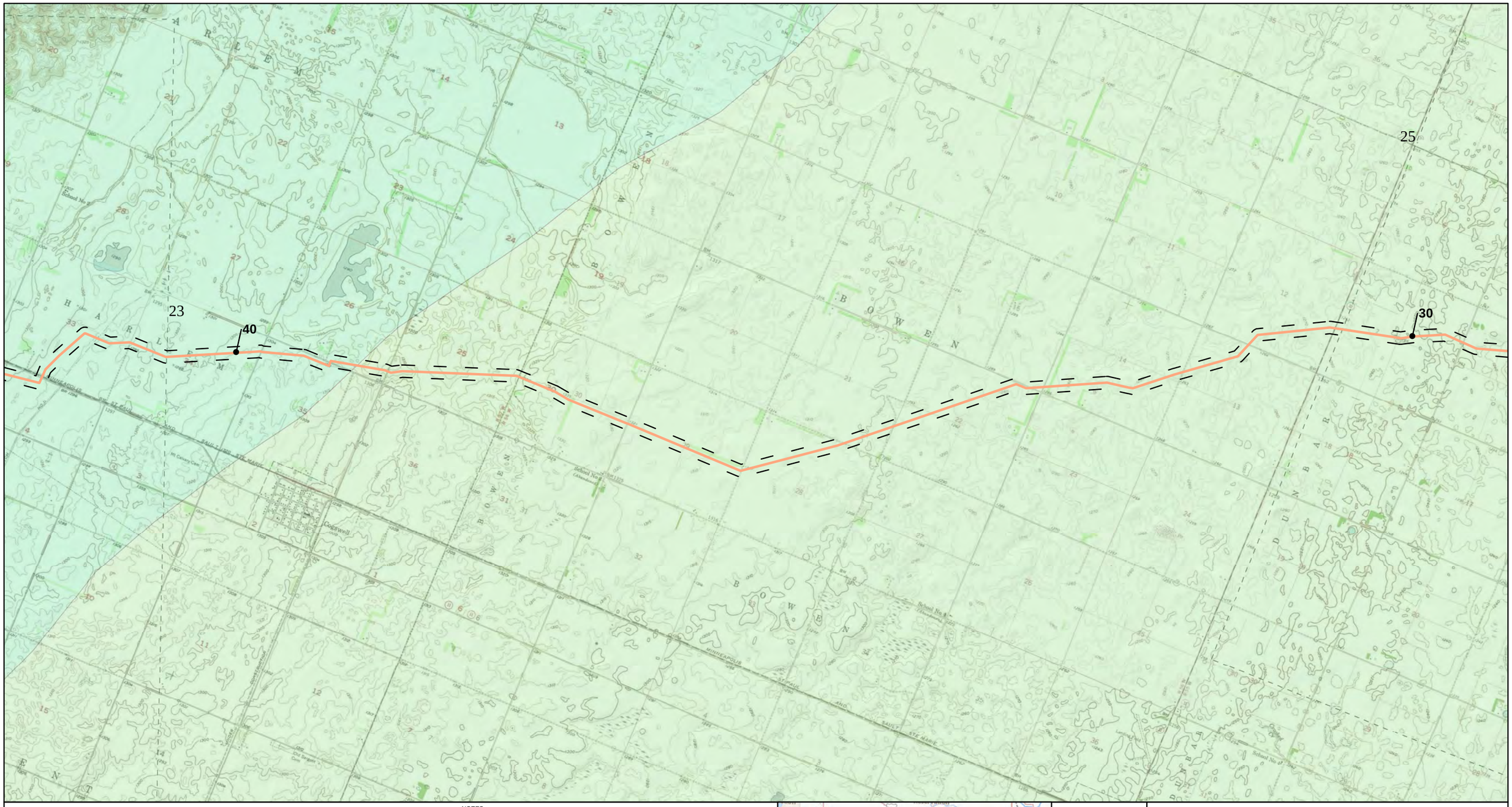

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GEOLOGIC UNIT (SGMC USGS 2017)
- KC - CARLILE FORMATION
- KN - NIOBRARA AND CARLILE FORMATIONS, UNDIVIDED
- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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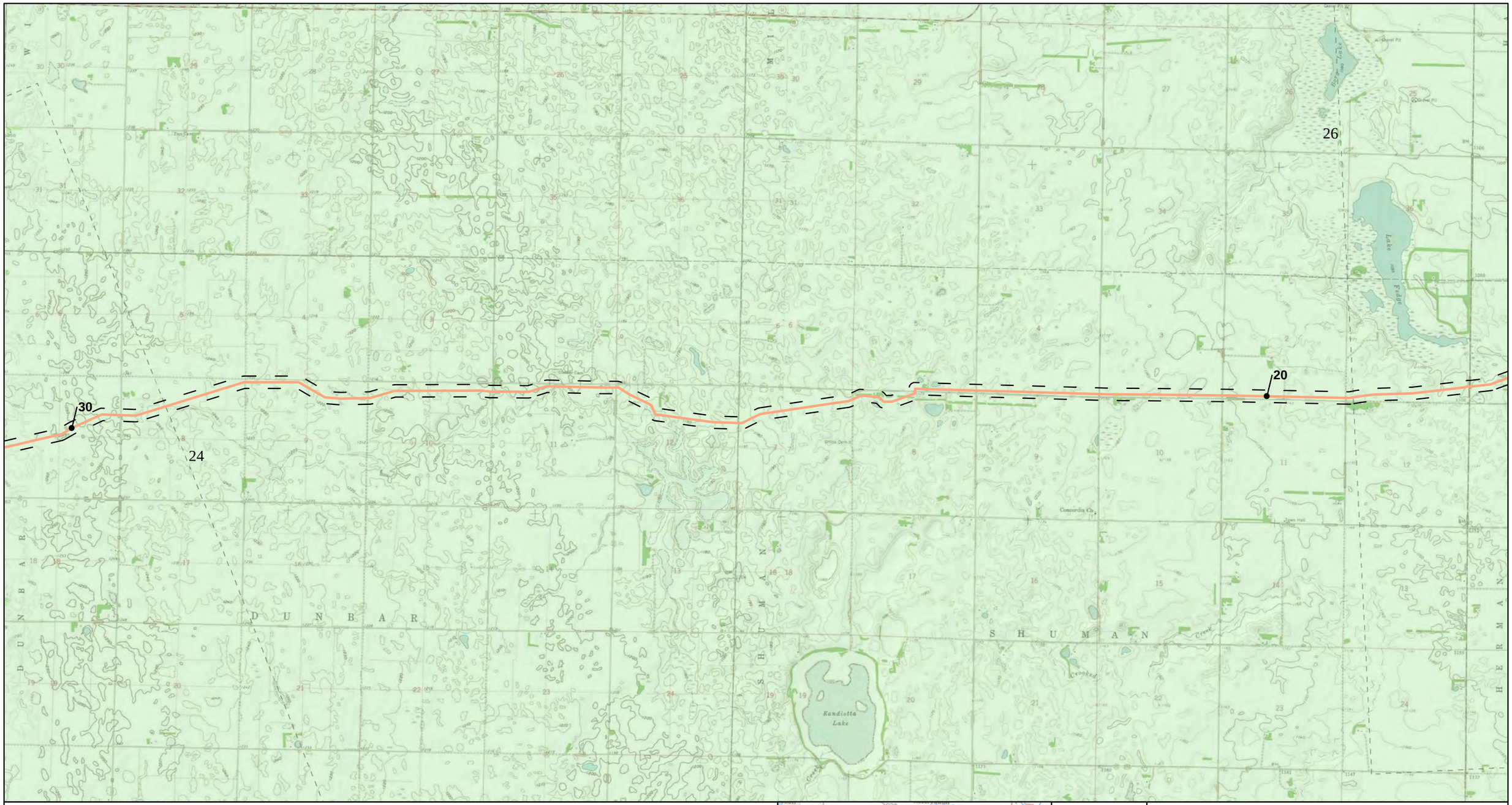

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GEOLOGIC UNIT (SGMC USGS 2017)
KC - CARLILE FORMATION
REVISION 9 ROUTE MILEPOSTS
NDT-211
NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
MAPBOOK INDEX

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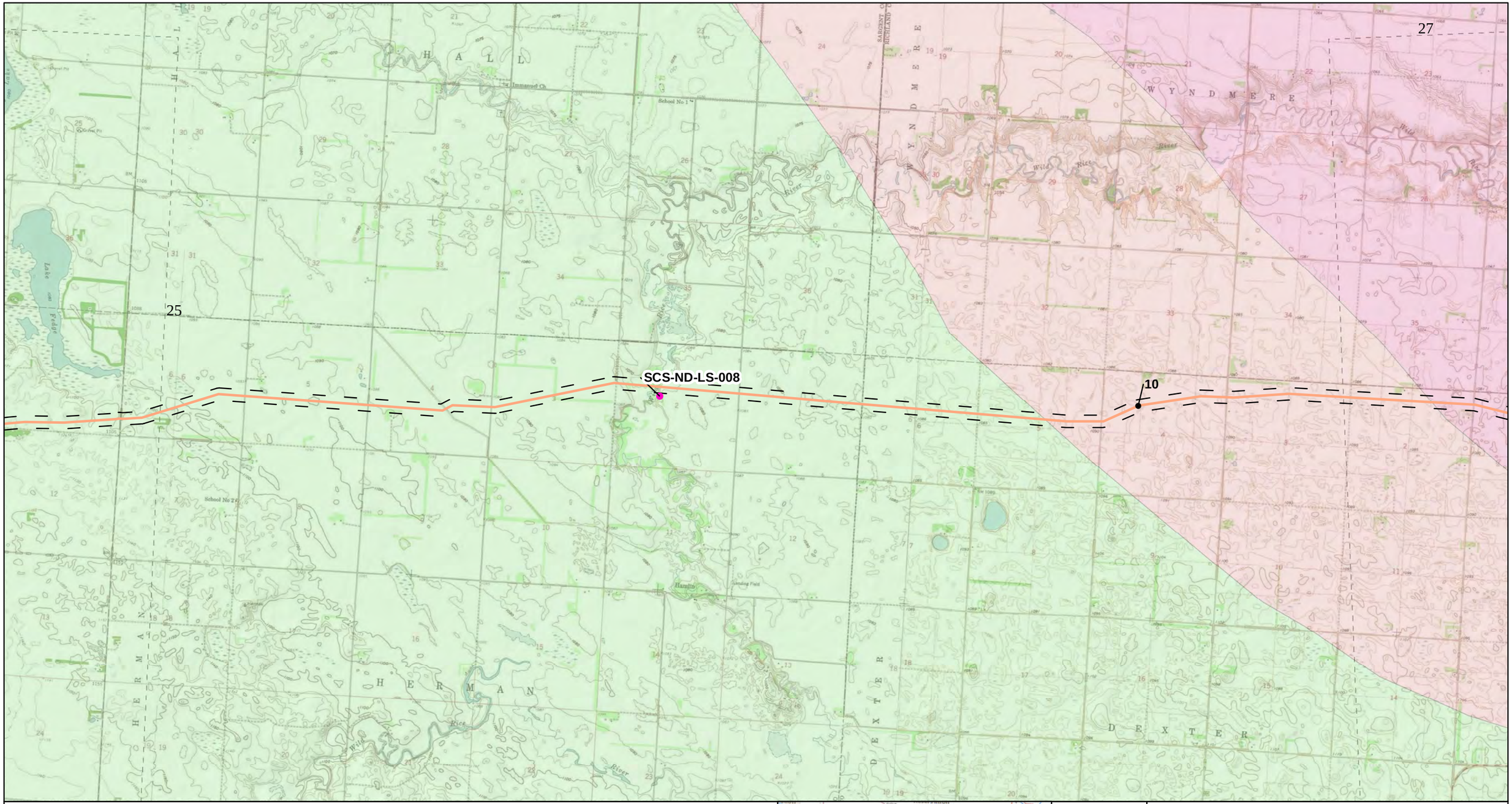

Legend

HAZARD CLASS
- CLASS B

GEOLOGIC UNIT (SGMC USGS 2017)
- KBS - BEILE FOURCHE-SKULL CREEK, UNDIVIDED
- KC - CARLILE FORMATION
- KG - GREENHORN FORMATION

- REVISION 9 ROUTE MILEPOSTS
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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Figure **2-26**

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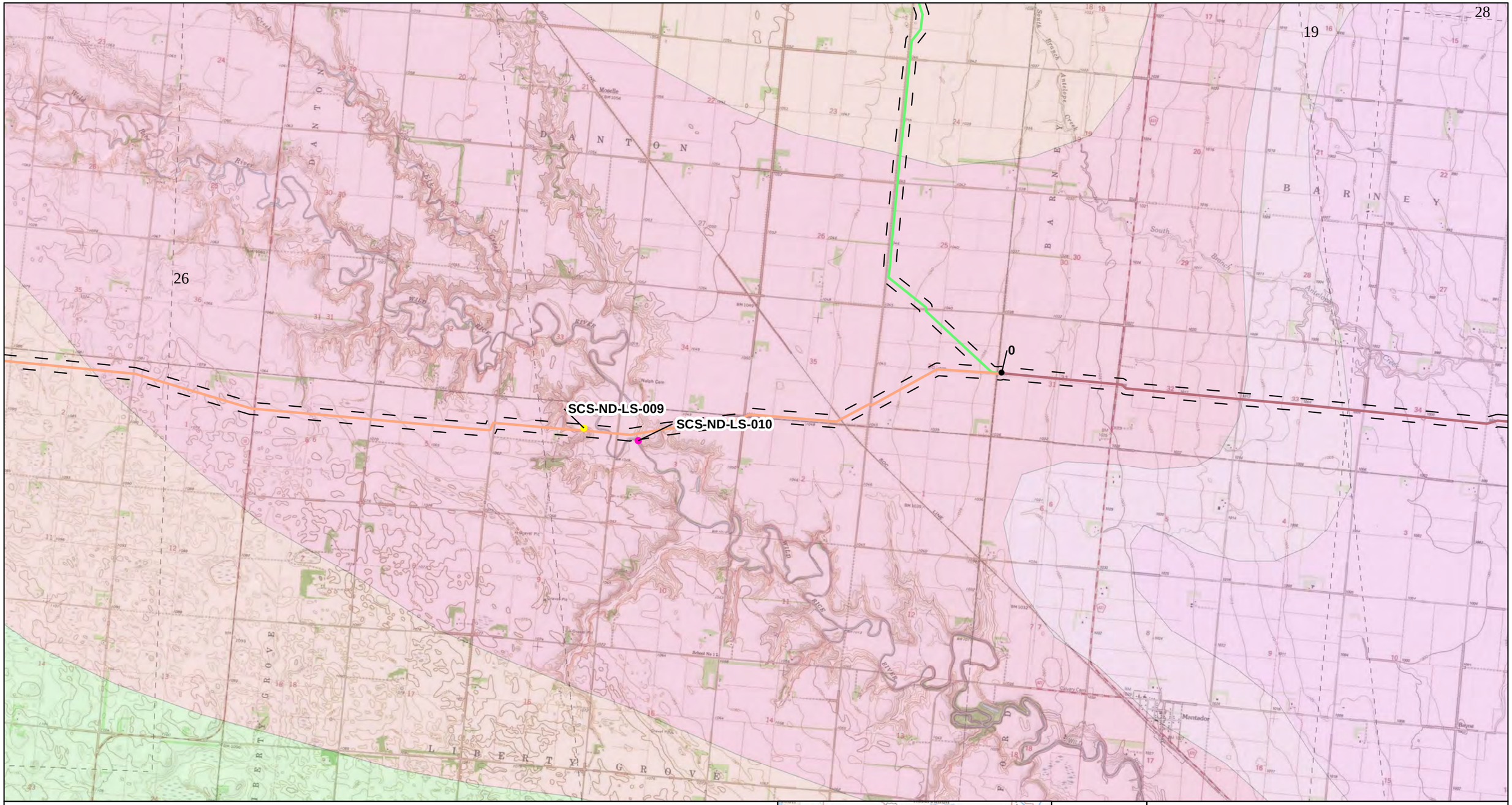

Legend

HAZARD CLASS
- CLASS B
- N/A

GEOLOGIC UNIT (SGMC USGS 2017)
- KBS - BEILE FOURCHE-SKULL CREEK, UNDIVIDED
- KC - CARLILE FORMATION
- KG - GREENHORN FORMATION
- KI - INYAN KARA FORMATION
- PCA - PRE CAMBRIAN ROCKS
- REVISION 9 ROUTE MILEPOSTS
- NDL-323
- NDL-324
- NDT-211
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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Figure **2-27**

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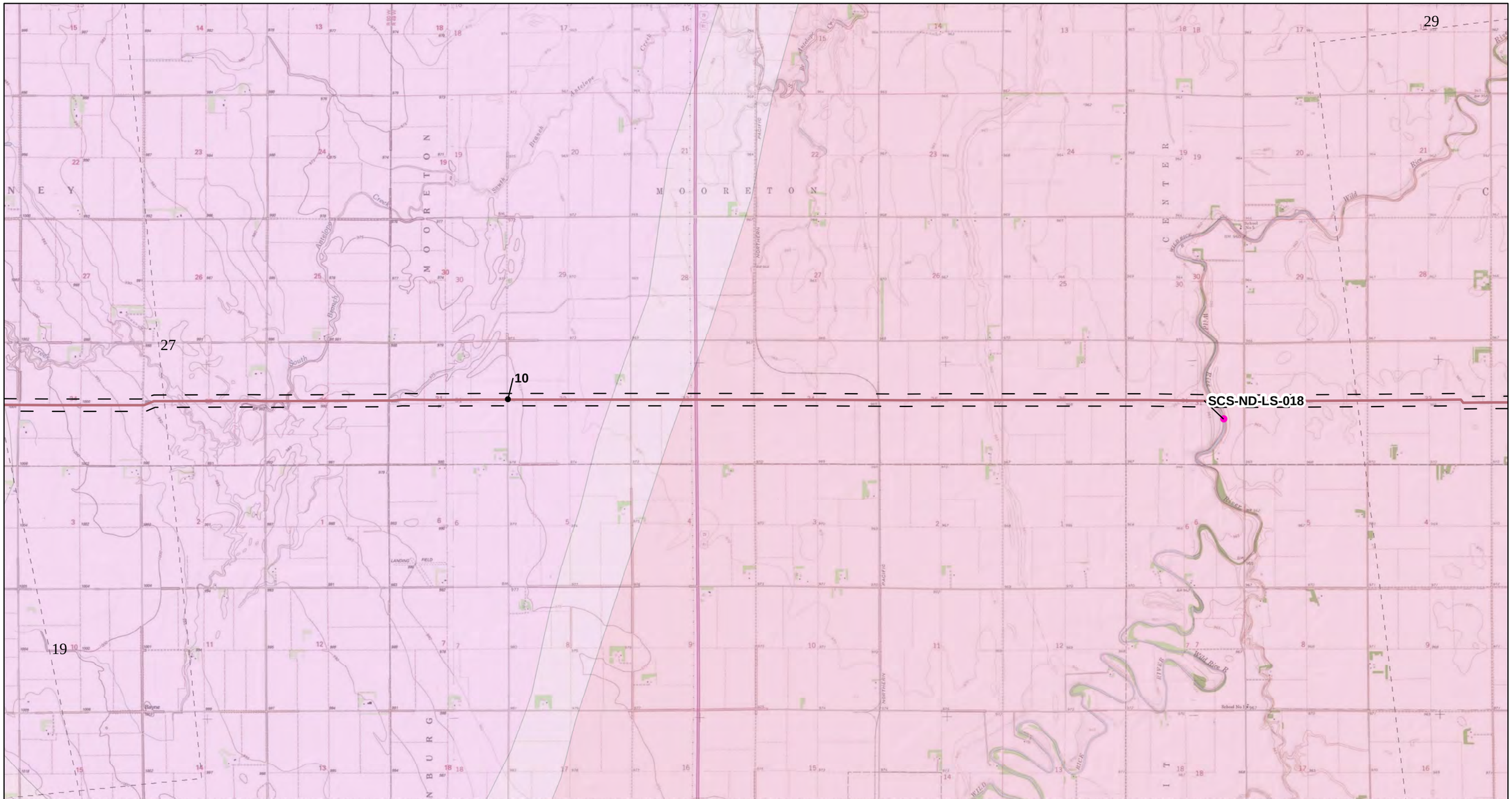

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HAZARD CLASS
- CLASS B

GEOLOGIC UNIT (SGMC USGS 2017)
- KBS - BEILE FOURCHE-SKULL CREEK, UNDIVIDED
- KI - INYAN KARA FORMATION
- PCA - PRE CAMBRIAN ROCKS

- REVISION 9 ROUTE MILEPOSTS
- NDL-323
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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Phase I Assessment

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Figure **2-28**

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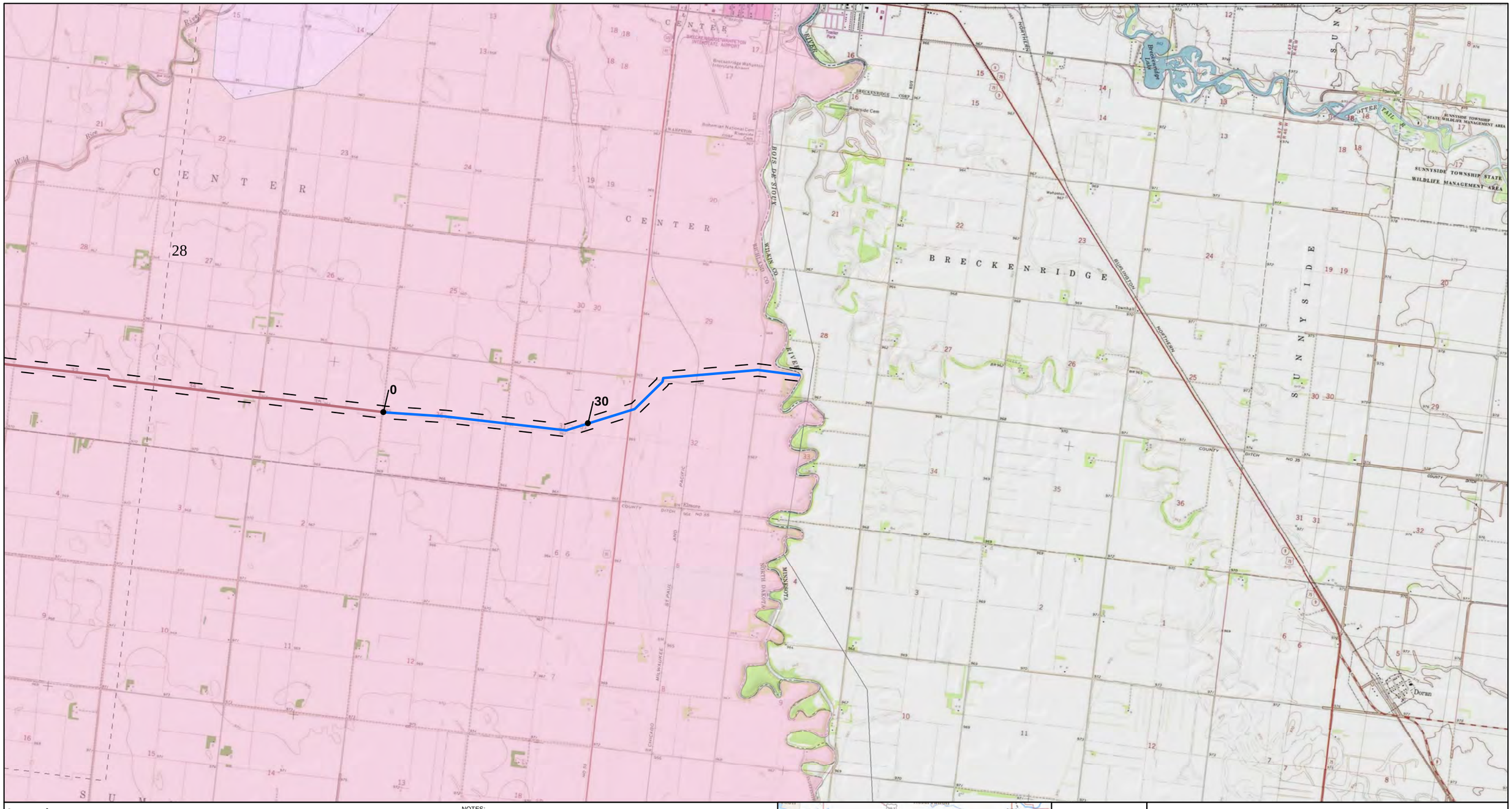

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GEOLOGIC UNIT (SGMC USGS 2017)

- KBS - BEILE FOURCHE-SKULL CREEK, UNDIVIDED
- PCA - PRE CAMBRIAN ROCKS
- REVISION 9 ROUTE MILEPOSTS
- MNL-321
- NDL-323
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

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SCS-ND-LS-003
SCS-ND-LS-017
SCS-ND-LS-002
0
3
2
180
SCS-ND-LS-004
Nelson Lake
Square Butte Creek
Square Butte
Hagel Creek
Burnt Creek
Spring Creek
Oliver Co
Morton Co

Legend

HAZARD CLASS
- CLASS B

GEOLOGIC UNIT (SGMC USGS 2017)
- TB - BULLION CREEK FORMATION
- TC - CANNONBALL FORMATION
- TS - SENTINEL BUTTE FORMATION
- REVISION 9 ROUTE MILEPOSTS
- NDL-328
- NDM-106
- NORTH DAKOTA REVISION 9 MAPPING CORRIDOR (250 FT)
- MAPBOOK INDEX

NOTES:
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LINEAR EXTENSIBILITY PERCENT (LEP) AND FROST ACTION FROM NRCS SOILS DATA.
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0 0.5 1 2 Miles

Mapbook of Surficial Geology

Summit Carbon Solutions - Bismarck Reroute - North Dakota
Phase I Assessment

Geosyntec consultants

TXG0450 | January 2024

Figure **2-30**

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APPENDIX A

SUMMARY TABLES

January 30, 2024

Table A-1. Surficial Geology Along the Proposed Pipeline

Geologic Unit1	Map Label[1]	Description[1]	Total (miles)	Percentage of Pipeline
Fox Hills Formation	Kf	Olive-brown sand, shale, and sandstone; marine shoreline and offshore sediment; as thick as 120 meters (400 feet).	39.8	12.6%
Hell Creek Formation	Kh	Gray sand, silt, clay, and sandstone; river sediment; as thick as 150 meters (500 feet).	36.0	11.4%
Niobrara and Carlile Formations, Undivided	Kn	Niobrara Formation: light-brown to dark-gray calcareous shale; offshore marine sediment; maximun outcrop thickness is 45 meters (150 feet). Carlile Formation: dark-gray shale; marine offshore sediment; maximum outcrop thickness is 30 meters (100 feet).	33.4	10.6%
Pierre Formation	Kp	Dark-gray shale; marine offshore sediment; maximum outcrop thickness is a few hundred meters.	26.7	8.5%
Bullion Creek Formation	Tb	Yellow-brown silt, sand, clay, sandstone, and lignite; river, lake, and swamp sediment; as thick as 200 meters (600 feet).	29.7	9.4%
Cannonball Formation	Tc	Olive-brown sand, shale, and sandstone; marine shoreline and offshore sediment; as thick as 120 meters (400 feet).	20.0	6.3%
Sentinel Butte Formation	Ts	Gray-brown silt, sand, clay, sandstone, and lignite; river, lake, and swamp sediment; as thick as 200 meters (600 feet).	20.9	6.6%
Beile Fourche-Skull Creek, Undivided	Kbs	Belle Fourche Formation (as described in Kb). Mowry Formation: medium- to dark-gray shale; marine offshore sediment; as thick as 55 metres (180 feet). Newcastle Formation: light-gray, fine- to medium-grained sandstone; marine shoreline and offshore sediment; as thick as 45 metres (150 feet). Skull Creek Formation: medium-gray to dark-gray shale; marine offshore sediment; as thick as 40 metres (140 feet).	58.6	18.6%
Carlile Formation	Kc	Dark-gray shale; marine offshore sediment; as thick as 120 metres (400 feet).	26.6	8.4%
Greenhorn Formation	Kg	Dark-gray calcareous shale; marine offshore sediment; as thick as 45 metres (150 feet).	12.3	3.9%
Inyan Kara Formation	Ki	Light-gray, fine to coarse sandstone and gray shale; river, lake, and nearshore marine sediment; as thick as 135 metres (450 feet).	1.4	0.4%
Pre Cambrian Rocks	pCA	Greenschists and amphibolites; banded iron formation; stretched pebble conglomerates; metabasalt; serpentinite; felsic tuff; mylonite; intermediate felsic plutonic rocks; migmatite; layered gneiss.	10.0	3.2%
		Total	**315.2**	**100.0%**

1 - Geologic Unit, Map Label, and Description derived from the SGMC USGS 2017.

Table A-2. Conditions Along the Proposed Pipeline

Condition[1]	Category	Total (Miles)	Percentage of Pipeline
Depth to Bedrock	<5 ft	**51.7**	**16%**
	>5 ft	**0.0**	**0%**
	Unknown	**263.5**	**84%**
	Total	**315.2**	**100%**
Depth to Water Table	<6 ft	**191.8**	**61%**
	>6 ft	**0.0**	**0%**
	Unknown	**123.4**	**39%**
	Total	**315.2**	**100%**
Flooding Frequency	None	**307.0**	**97%**
	Rare	**2.0**	**1%**
	Occasional	**4.2**	**1%**
	Frequent	**2.0**	**1%**
	Total	**315.2**	**100%**
Frost Action Potential (Frost Heave)	Unknown	**18.3**	**6%**
	Lower	**50.3**	**16%**
	Medium	**165.3**	**52%**
	Higher	**81.3**	**26%**
	Total	**315.2**	**100%**
Expansive Soils Potential (Shrink/Swell)	Unknown	**29.6**	**9%**
	Lower (LEP <3)	**152.7**	**48%**
	Medium (LEP 3-6)	**64.0**	**20%**
	Higher (LEP >6)	**68.9**	**22%**
	Total	**315.2**	**100%**

1 - All Condition data were determined from the USDA NRCS Soils Data.

Table A-3. Detailed Summary of Landslide Results

Hazard ID	Feature Type	Landslide Category	Pipeline System	Approx. Milepost (MP)	Approx. Distance to Proposed Pipeline (ft)	Identification Source	Ground Recon	Latitude	Longitude
SCS-ND-LS-001	Landslide	Class A	NDM-106	MP 169.9	18	Geosyntec	Yes	46.963243	-101.015889
SCS-ND-LS-002	Landslide	Class B	NDL-328	MP 0.8	200	NDGS: Areas of Landslides, Nelson Lake Quadrangle (2023)	Yes	47.055061	-101.201156
SCS-ND-LS-003	Landslide	Class B	NDL-328	MP 0.8	220	NDGS: Areas of Landslides, Nelson Lake Quadrangle (2023)	Yes	47.054509	-101.200499
SCS-ND-LS-004	Possible Landslide	Class B	NDM-106	MP 180.6	115	NDGS: Areas of Landslides, Crown Butte NW Quadrangle (2023)	-	46.980038	-101.213426
SCS-ND-LS-005	Possible Landslide	Class B	NDM-106	MP 170.5	215	NDGS: Areas of Landslides, Crown Butte Quadrangle (2023)	-	46.959003	-101.026768
SCS-ND-LS-006	Possible Landslide	Class A	NDM-106	MP 170.4	25	NDGS: Areas of Landslides, Crown Butte Quadrangle (2023)	-	46.960533	-101.026298
SCS-ND-LS-007	Landslide	Class B	NDM-106	MP 171.2	175	NDGS: Areas of Landslides, Crown Butte Quadrangle (2023)	Yes	46.956217	-101.038639
SCS-ND-LS-008	Possible Landslide	Class A	NDT-211	MP 13.9	40	NDGS: Areas of Landslides, Hamlin Quadrangle (2023)	-	46.189277	-97.293509
SCS-ND-LS-009	Not a Landslide	N/A	NDT-211	MP 3.5	20	NDGS: Areas of Landslides, Moselle Quadrangle (2023)	Yes	46.192685	-97.079606
SCS-ND-LS-010	Possible Landslide	Class B	NDT-211	MP 3.1	160	NDGS: Areas of Landslides, Moselle Quadrangle (2023)	-	46.191822	-97.070177
SCS-ND-LS-011	Not a Landslide	N/A	NDL-324	MP 28	105	NDGS: Areas of Landslides, Barrie Quadrangle (2022)	Yes	46.574703	-97.094300
SCS-ND-LS-012	Landslide	Class B	NDL-324	MP 28.2	0	NDGS: Areas of Landslides, Barrie Quadrangle (2022)	Yes	46.571985	-97.093025
SCS-ND-LS-013	Not a Landslide	N/A	NDL-324	MP 28	0	NDGS: Areas of Landslides, Barrie Quadrangle (2022)	Yes	46.574393	-97.095031
SCS-ND-LS-014	Landslide	Class B	NDL-324	MP 13.6	0	NDGS: Areas of Landslides, Leonard Quadrangle (2022)	Yes	46.745432	-97.206598
SCS-ND-LS-015	Landslide	Class B	NDM-106	MP 135.6	85	NDGS: Areas of Landslides, Menoken Quadrangle (2021)	Yes	46.854825	-100.584402
SCS-ND-LS-016	Landslide	Class B	NDL-324	MP 13.3	120	NDGS: Areas of Landslides, Leonard Quadrangle (2022)	Yes	46.750278	-97.209239
SCS-ND-LS-017	Possible Landslide	Class B	NDL-328	MP 0.6	110	NDGS: Areas of Landslides, Nelson Lake Quadrangle (2023)	-	47.056945	-101.203400
SCS-ND-LS-018	Possible Landslide	Class B	NDL-323	MP 4.2	230	NDGS: Areas of Landslides, Fairmount NW Quadrangle (2020)	-	46.201305	-96.744781

Table A-4. Landslide Site Descriptions and Applicable Mitigation Strategies

Hazard ID	Landslide Category	Site Description	Mitigation Strategy
SCS-ND-LS-001	Class A	Feature delineated by Geosyntec. Based on the July 11, 2023 ground reconnaissance, a shallow landslide was observed on a west facing slope approximately 18 feet north of the proposed NDM-106 pipeline centerline. The landslide was relatively small and measured approximately 70 feet long by 25 feet wide. The direction of ground movement was west and axial relative to the orientation of the proposed pipeline centerline. The headscarp measured approximately 2 feet high, the left and right lateral flanks measured approximately 2 ft high, and the toe measured approximately 1-foot high. The landslide appeared to be inactive (>10 years old) based on the condition of the morphology observed and exhibited in historical aerial imagery. The landslide was estimated to be 1-2 feet deep based on the observed size of the landslide features and topography. At the time of the site visit, the landslide was uniformly vegetated with mixed grass up to 2 feet tall except where recent cattle activity had exposed bare soil within and around the landslide. The slope gradient along the proposed pipeline centerline was generally moderate and increased from west to east.	No action required beyond standard best management practices (BMPs). The landslide appears to be shallow and features within the construction limits of disturbance would be removed during pipeline construction.
SCS-ND-LS-002	Class B	Feature delineated by the NDGS. Based on the July 11, 2023 ground reconnaissance, the landform observed at SCS-ND-LS-002 appeared consistent with a dormant landslide on a northeast facing slope. The landslide boundary mapped by the NDGS was approximately 250 feet long and 450 feet wide. The direction of landslide movement was northeast and perpendicular relative to the proposed pipeline centerline. The mapped and observed landslide headscarp intersected the proposed pipeline centerline over an approximate length of 130 feet and was less than 1 foot high while appearing to be highly weathered, rounded, and subdued. Downslope of the proposed pipeline centerline, the landslide body exhibited rounded and subdued hummocks less than 1 foot high while lateral flanks were indistinct. The rounded and subdued landslide toe was 2 to 3 feet high. No sharp or fresh landslide features were identified. The inferred landslide depth was estimated to be less than 4 feet based on the size and condition of the landslide features observed. At the time of the visit the feature was uniformly vegetated with mixed grasses and wooded shrubs less than 4 ft high.	Avoid landslide: The landslide is approximately 200 ft from the proposed pipeline and is located outside of planned workspaces. The landslide is not anticipated to be disturbed by pipeline construction.
SCS-ND-LS-003	Class B	Feature delineated by the NDGS. Based on the July 11, 2023 ground reconnaissance, the landform observed at SCS-ND-LS-003 appeared consistent with a recently active landslide on a northeast facing slope. The landslide boundary mapped by the NDGS was approximately 135 ft long and 250 ft wide. The direction of landslide movement was northeast and perpendicular relative to the proposed pipeline centerline. The mapped and observed landslide headscarp was less than 1 foot high while appearing to be highly weathered, rounded, and subdued. A series of distinct internal scarps approximately 2 to 3 feet high were observed within the mapped landslide boundary. The condition of the observed internal scarps suggests this area of the slope may have experienced localized ground movement in the past 10 years. The mapped landslide toe was 2 to 3 feet high and appeared rounded and subdued. The inferred landslide depth was estimated to be less than 4 feet based on the size and condition of the landslide features observed.	Avoid landslide: The landslide is approximately 220 ft from the proposed pipeline and is located outside of planned workspaces. The landslide is not anticipated to be disturbed by pipeline construction.
SCS-ND-LS-004	Class B	Feature delineated by the NDGS. Based on remote sensing review, this landform appears to occur on a gentle slope within a farm field. LiDAR data and aerial imagery exhibit poor evidence of landslide morphology. Additionally, aerial imagery suggests there has been no disruption of farming activity in the past few decades, suggesting this landform is either not landslide related, or the landslide features are shallow, subtle, and healed. Based on historic aerial imagery, the condition of the morphology does not appear to have changed since at least the 1950s (earliest imagery readily available).	Avoid landslide: The mapped landslide is approximately 115 ft from the proposed pipeline and is located outside of planned workspaces. The mapped landslide is not anticipated to be disturbed by pipeline construction.
SCS-ND-LS-005	Class B	Feature delineated by the NDGS. Based on remote sensing review, this landform appears to consist of lobed material at the base of a steep slope. Although the morphology of the deposits appears consistent with a landslide toe, no discernible corresponding headscarp features are observed and landslide origin is questionable. Based on historic aerial imagery, the condition of the morphology does not appear to have changed since at least the 1950s (earliest imagery readily available).	Avoid landslide: The mapped landslide is approximately 215 ft from the proposed pipeline and is located outside of planned workspaces. The mapped landslide is not anticipated to be disturbed by pipeline construction.
SCS-ND-LS-006	Class A	Feature delineated by the NDGS. Based on remote sensing review, this landform appears consistent with landslide morphology although it may also be related to erosion. The mapped landslide toe appears to be very subtle to indistinct based on LiDAR data and the mapped headscarp is irregular and consists of a series of arcuate slope breaks that, individually, appear consistent with soil erosion. No internal features are exhibited within the mapped body and the slope appears to be relatively smooth and uniformly vegetated with grass downslope of the mapped headscarp. The morphology, if landslide related, appears shallow (less than 3 feet deep) based on the interpreted height of the mapped features. Based on historic aerial imagery, the condition of the morphology does not appear to have changed since at least the 1950s (earliest imagery readily available).	No action required beyond standard best management practices (BMPs). The mapped landslide appears to be shallow and features near the edge of the construction limits of disturbance appear likely to be removed if intercepted during pipeline construction. Note: If deep cuts are required at the toe of the slope then temporary support measures may be considered to maintain slope stability until slope restoration.
SCS-ND-LS-007	Class B	Feature delineated by the NDGS. Based on the July 11, 2023 ground reconnaissance, the landform observed at SCS-ND-LS-007 appeared consistent with a recently active landslide on a northeast facing slope. The landslide boundary mapped by the NDGS was approximately 260 feet long and 515 feet wide; however, the observed landslide morphology was approximately 60 feet long and 230 feet wide. The direction of landslide movement was east and oblique relative to the proposed pipeline centerline. The distinct landslide headscarp was 1 to 2 feet high and the distinct landslide toe was 1 to 2 feet high. The condition of the observed features and their visibility in recent aerial imagery suggests this area of the slope likely experienced localized ground movement in the past 10 to 15 years. The inferred landslide depth was estimated to be less than 3 feet based on the based on the size and condition of the landslide features observed. Although the boundary mapped by the NDGS is located within 250 feet of the proposed pipeline, the observed landslide morphology is approximately 320 feet from the proposed pipeline.	Avoid landslide: The mapped landslide boundary is approximately 175 ft from the proposed pipeline and the observed landslide features are approximately 350 ft from the proposed pipeline. The mapped landslide is located outside of planned workspaces and is not anticipated to be disturbed by pipeline construction.

Table A-4. Landslide Site Descriptions and Applicable Mitigation Strategies

Hazard ID	Landslide Category	Site Description	Mitigation Strategy
SCS-ND-LS-008	Class B	Feature delineated by the NDGS. Based on remote sensing review, this landform appears to occur on a gentle to moderately steep slope on the eastern bank of the Wild Rice River. LiDAR data and aerial imagery exhibit poor evidence of landslide morphology and the slope nearest to the proposed pipeline appears to be relatively smooth except where traversed by multiple cattle trails. Based on historic aerial imagery, the condition of the morphology does not appear to have changed since at least the 1980s (earliest imagery readily available).	Avoid landslide: The mapped landslide is approximately 40 ft from the proposed pipeline and is outside of planned workspaces. Additionally, a proposed HDD crossing for the Wild Rice River is planned for this location; therefore, the mapped landslide would be avoided by the pipeline due to distance and HDD construction beneath the river.
SCS-ND-LS-009	N/A	Feature delineated by the NDGS. Based on the July 13, 2023 ground reconnaissance, the landform observed at SCS-ND-LS-009 did not appear to be consistent with landslide morphology and no discernible landslide features were identified at the time of evaluation. The landform mapped by the NDGS consisted of a gentle natural slope above a wetland area. The slope was densely vegetated with trees and shrubs and was generally smooth except where it was traversed by deer trails. Downslope of the mapped area, cattails and ponded water were observed in the wetland area. It is possible that the combination of dense vegetation and presence of deer trails may be reasons why this landform was mapped as a possible landslide by the NDGS.	The landform does not appear to be landslide related. No actions required beyond standard best management practices (BMPs).
SCS-ND-LS-010	Class B	Feature delineated by the NDGS. Based on remote sensing review, this narrow landform occurs along the outer bend of the Wild Rice River and appears consistent with erosion and localized shallow bank slumping. The features appear unlikely to retrogress much beyond the narrow margins of the riverbank. Based on historic aerial imagery, the morphology first becomes evident in 2010 imagery and does not appear to have noticeably changed since 2010.	Avoid landslide: The mapped landslide is approximately 160 ft from the proposed pipeline and is located outside of planned workspaces. The mapped landslide is not anticipated to be disturbed by pipeline construction.
SCS-ND-LS-011	N/A	Feature delineated by the NDGS. Based on the July 14, 2023 ground reconnaissance, the landform observed at SCS-ND-LS-011 did not appear to be consistent with landslide morphology and no discernible landslide features were identified at the time of evaluation. The landform mapped by the NDGS appeared as a generally smooth and gradual slope with some bare soil exposed by erosion along a natural slope break that corresponds with the upper boundary mapped by the NDGS. A mound of material observed at the mapped toe boundary appeared to be related to differential weathering of underlying materials. It is possible that the combination of the natural slope break and mound may be reasons for this landform to be mapped as a landslide by the NDGS.	The landform does not appear to be landslide related. A proposed HDD crossing for the Sheyenne River is planned for this location. Based on Geosyntec's review of the proposed HDD site plan and profile, including the proposed entry and exit points, the features observed at this location would be avoided due to distance and HDD construction beneath the river.
SCS-ND-LS-012	Class B	Feature delineated by the NDGS. Based on the July 14, 2023 ground reconnaissance, the landform observed at SCS-ND-LS-012 appeared consistent with dormant landslide morphology on a northwest-facing slope. The landslide boundary mapped by the NDGS was approximately 460 feet long and 1100 feet wide. The direction of landslide movement is northwest and axial relative to the proposed pipeline centerline. The observed landslide features were generally distinct but rounded with no discernible evidence of recent movement. The slope corresponding with the mapped headscarp was 10 to12 feet high in the vicinity of the proposed pipeline centerline. Observed hummocks downslope of the mapped headscarp were rounded and approximately 4 feet high. The mapped landslide toe was up to 6 feet high and appeared to be modified or truncated by fluvial processes related to the Sheyenne River. West of the proposed pipeline centerline, a rounded headscarp up to 15 feet high and a rounded internal toe up to 10 feet high were observed with backward leaning trees up to 24 inches in diameter situated on the internal landslide body. The vegetation along the proposed pipeline centerline mostly consisted of grass up to 2 feet high with occasional deciduous trees. The inferred landslide depth was estimated to be 20 to 30 feet deep in the vicinity of the proposed pipeline centerline based on the size and condition of observed landslide features.	Avoid landslide: A proposed HDD crossing for the Sheyenne River is planned for this location. Based on Geosyntec's review of the proposed HDD site plan and profile, including the proposed entry and exit points, the landslide morphology observed at this location would be avoided by the proposed pipeline as a result of HDD construction beneath the landslide.
SCS-ND-LS-013	N/A	Feature delineated by the NDGS. Based on the July 14, 2023 ground reconnaissance, the landform observed at SCS-ND-LS-013 did not appear to be consistent with landslide morphology and no discernible landslide features were identified at the time of evaluation. The landform mapped by the NDGS appeared as a generally smooth and gradual slope with some bare soil exposed by erosion along a natural slope break that corresponds with the upper boundary mapped by the NDGS. A mound of material observed at the mapped toe boundary appeared to be related to differential weathering of underlying materials. It is possible that the combination of the natural slope break and mound may be reasons for this landform to be mapped as a landslide by the NDGS.	The landform does not appear to be landslide related. A proposed HDD crossing for the Sheyenne River is planned for this location. Based on Geosyntec's review of the proposed HDD site plan and profile, including the proposed entry and exit points, the features observed at this location would be avoided by the proposed pipeline as a result of HDD construction beneath the landform.
SCS-ND-LS-014	Class B	Feature delineated by the NDGS. Based on the July 13, 2023 ground reconnaissance, the landform observed at SCS-ND-LS-014 appeared to be related to a series of inactive, localized bank slumps located along an outer meander bend of the Maple River. The curved landslide boundary mapped by the NDGS was approximately 130 feet long by 1,350 feet wide and encompasses multiple localized banks slumps. The proposed pipeline centerline crosses the mapped landslide boundary near the apex of the meander bend. The direction of landslide movement is north and axial relative to the proposed pipeline centerline. A possible headscarp of a localized bank slump crossed by the proposed pipeline centerline measured approximately 3 feet high and may have been exaggerated by a berm along a dirt road to the south. The lateral flanks corresponding with the possible headscarp were indistinct, but a questionable toe feature downslope of the possible headscarp measured approximately 2 feet high. The landslide morphology observed appeared to be rounded and subdued. The inferred depth of the landslide was estimated to be less than 4 feet deep based on the observed size and condition of landslide features and the topography of the riverbank. At the time of the site visit, the landslide was vegetated with mixed grass up to 4 feet tall and deciduous trees and shrubs.	Avoid landslide: A proposed HDD crossing for the Maple River is planned for this location. Based on Geosyntec's review of the proposed HDD site plan and profile, including the proposed entry and exit points, the landslide observed at this location would be avoided by the proposed pipeline as a result of HDD construction beneath the landslide.

Table A-4. Landslide Site Descriptions and Applicable Mitigation Strategies

Hazard ID	Landslide Category	Site Description	Mitigation Strategy
SCS-ND-LS-015	Class B	Feature delineated by the NDGS. Based on the July 13, 2023 ground reconnaissance, the landform observed at SCS-ND-LS-015 appeared to be a recently active landslide located on a west-facing slope at the outer meander bend of a stream. The curved landslide boundary mapped by the NDGS measured approximately 200 feet long by 430 feet wide. The landslide is located approximately 85 feet west of the proposed pipeline centerline at its nearest approach. The direction of landslide movement was west-southwest and oblique relative to the proposed pipeline centerline. The landslide headscarp was approximately 5 to 6 feet high and the right and left lateral flanks were 4 to 5 feet high. The landslide toe appeared to encroach into the stream bed. The landslide morphology appeared to be distinct and sharp along the southern portion of the mapped feature and rounded and subdued along the northern portion of the mapped feature, suggesting the southern features are relatively younger than the northern features. Based on aerial imagery and the observed morphology, the landslide appears to be 10 to 15 years old. The inferred landslide depth was estimated to be 6 to 10 feet deep based on the observed size and condition of the landslide features and topography of the streambank. At the time of the site visit, the landslide and the area in the vicinity of the proposed pipeline was uniformly vegetated with mixed grasses up to 2 feet high. The slope gradient along the proposed pipeline centerline was generally low to flat. Based on the topography observed, the landslide appears unlikely to retrogress across the path of the proposed pipeline centerline.	Avoid landslide: The landslide is approximately 85 ft from the proposed pipeline and is located outside of planned workspaces. The landslide is not anticipated to be disturbed by pipeline construction.
SCS-ND-LS-016	Class B	Feature delineated by the NDGS. Based on the July 14, 2023 ground reconnaissance, landform observed at SCS-ND-LS-016 appeared to be related to multiple, inactive bank slumps located along the outer meander bend of the Maple River. The curved landslide boundary mapped by the NDGS was approximately 130 feet long by 630 feet wide. The mapped headscarp is located approximately 120 feet from the proposed pipeline centerline. The direction of landslide movement is west-southwest and perpendicular relative to the proposed pipeline centerline. The observed headscarp and toe features nearest to the proposed pipeline centerline appeared rounded and subdued and measured approximately 3 feet high. The inferred depths of the bank slumps were estimated to be less than 4 feet based on the size and condition of the observed landslide features and topography of the riverbank. At the time of the site visit, the area in the vicinity of the proposed pipeline was a cultivated soybean farm field and the mapped bank slumps were vegetated with mixed grasses up to 4 feet high and undisturbed deciduous trees up to 12 inches in diameter. Dense vegetation may have obscured more recent landslide features at the time of the site assessment. Based on the topography observed, the bank slumps at SCS-ND-LS-016 appear unlikely to expand across the path of the proposed pipeline centerline.	Avoid landslide: The mapped landslide is approximately 120 ft from the proposed pipeline and is located outside of planned workspaces. The mapped landslide is not anticipated to be disturbed by pipeline construction.
SCS-ND-LS-017	Class B	Feature delineated by the NDGS. Based on remote sensing review, this landform appears to consist of at least two coalescing landslides on a west facing slope. The NDGS mapped boundary is 110 ft from the proposed pipeline location and appears to include erosion areas while the nearest well defined landslide morphology visible is approximately 200 ft from the proposed pipeline location. Based on historic aerial imagery, the condition of the morphology does not appear to have changed significantly since at least the 1950s (earliest imagery readily available).	Avoid landslide: The mapped landslide is approximately 110 ft from the proposed pipeline and is located outside of planned workspaces. The mapped landslide is not anticipated to be disturbed by pipeline construction.
SCS-ND-LS-018	Class B	Feature delineated by the NDGS. Based on remote sensing review, this landform appears to consist of multiple localized bank slumps along the eastern bank of the Wild Rice River. The features appear unlikely to retrogress much beyond the narrow margins of the riverbank. Based on historic aerial imagery, the Wild Rice River channel does not appear to have changed significantly since at least the 1960s (earliest imagery readily available).	Avoid landslide: The mapped landslide is approximately 230 ft from the proposed pipeline and is located outside of planned workspaces. The mapped landslide is not anticipated to be disturbed by pipeline construction.

Table A-5. Summary of Waterbody Crossings

Hazard ID	Historic Feature ID	Historic GEO ID	Latitude	Longitude	County	State	Route	Mile Post*	Identified Date	Identified By	Identified Source	Stream Name	Hydrographic Category	Stream Type	Stream Order	Crossing Method
HH-ND-0001			46.282516	-99.89103	Emmons	North Dakota	NDM-106	75.4	1/26/2024	Geosyntec	USGS NHD	Beaver Creek		Artificial Path	5	Open Cut
HH-ND-0002			46.605739	-100.369087	Emmons	North Dakota	NDM-106	110.5	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0003			47.011514	-101.18339	Oliver	North Dakota	NDL-328	4.2	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	3	Open Cut
HH-ND-0004			47.016713	-101.184606	Oliver	North Dakota	NDL-328	3.8	1/26/2024	Geosyntec	USGS NHD		Perennial	Stream/River	4	Open Cut
HH-ND-0005			46.680302	-100.510237	Burleigh	North Dakota	NDM-106	119.5	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0006			46.448387	-100.143258	Emmons	North Dakota	NDM-106	93.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0007			45.993293	-98.250799	Dickey	North Dakota	NDT-211	66.2	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0008			46.349878	-99.99398	Emmons	North Dakota	NDM-106	82.5	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0009			46.348451	-99.991869	Emmons	North Dakota	NDM-106	82.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0010			46.984793	-101.39452	Oliver	North Dakota	NDM-106	189.2	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0011			46.979491	-101.189335	Morton	North Dakota	NDM-106	179.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0013			46.398357	-97.060761	Richland	North Dakota	NDL-324	40.9	1/26/2024	Geosyntec	USGS NHD			Canal/Ditch		Open Cut
HH-ND-0014			47.056597	-101.204859	Oliver	North Dakota	NDL-328	0.5	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0015	S2006RI001	ND-03	46.573398	-97.09402	Richland	North Dakota	NDL-324	28.1	1/26/2024	Geosyntec	USGS NHD	Sheyenne River		Artificial Path	6	HDD
HH-ND-0016			46.996506	-100.580079	Burleigh	North Dakota	NDM-106	145.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0017			46.967879	-101.003682	Morton	North Dakota	NDM-106	169.2	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0018			46.675505	-100.49911	Burleigh	North Dakota	NDM-106	118.8	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0019			46.871144	-100.582022	Burleigh	North Dakota	NDM-106	136.7	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0020			46.924777	-100.581349	Burleigh	North Dakota	NDM-106	140.6	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0021			46.872919	-97.274019	Cass	North Dakota	NDL-324	2	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0022			46.958619	-101.089242	Morton	North Dakota	NDM-106	173.7	1/26/2024	Geosyntec	USGS NHD	Otter Creek	Intermittent	Stream/River	2	Open Cut
HH-ND-0023			46.958864	-101.097578	Morton	North Dakota	NDM-106	174.1	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0024	S_2_DI_013_DT	ND-07	46.04483	-98.140252	Dickey	North Dakota	NDT-211	59.2	1/26/2024	Geosyntec	USGS NHD	James River		Artificial Path	6	HDD
HH-ND-0025			46.986433	-101.186395	Oliver	North Dakota	NDL-328	5.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0026			46.992387	-101.426443	Oliver	North Dakota	NDM-106	190.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0027			46.352728	-99.998282	Emmons	North Dakota	NDM-106	82.8	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0028			46.980474	-101.179486	Morton	North Dakota	NDM-106	178.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0029			46.487292	-100.214295	Emmons	North Dakota	NDM-106	98.5	1/26/2024	Geosyntec	USGS NHD			Artificial Path	3	Open Cut
HH-ND-0030			46.389634	-100.020109	Emmons	North Dakota	NDM-106	85.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0031			46.401328	-100.064827	Emmons	North Dakota	NDM-106	88.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0032			46.883567	-100.582052	Burleigh	North Dakota	NDM-106	137.7	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0033			46.958174	-101.068074	Morton	North Dakota	NDM-106	172.7	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0034			46.8939	-100.581882	Burleigh	North Dakota	NDM-106	138.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0035			46.319662	-99.946225	Emmons	North Dakota	NDM-106	79.2	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	3	Open Cut
HH-ND-0036			46.97628	-100.577037	Burleigh	North Dakota	NDM-106	144.5	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0037			46.326501	-99.96473	Emmons	North Dakota	NDM-106	80.2	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	3	Open Cut
HH-ND-0038			45.961014	-99.421865	McIntosh	North Dakota	NDM-106	41.2	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0039			47.008358	-100.60253	Burleigh	North Dakota	NDM-106	147.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0040			46.940706	-100.573833	Burleigh	North Dakota	NDM-106	141.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	3	Open Cut
HH-ND-0041			46.980806	-101.261792	Morton	North Dakota	NDM-106	182.8	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0042			46.958276	-101.077832	Morton	North Dakota	NDM-106	173.1	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0043			46.958214	-101.074752	Morton	North Dakota	NDM-106	173	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0044			47.005373	-101.185322	Oliver	North Dakota	NDL-328	4.6	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0045			47.004497	-101.185644	Oliver	North Dakota	NDL-328	4.7	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0046			46.177933	-99.715696	McIntosh	North Dakota	NDM-106	63.8	1/26/2024	Geosyntec	USGS NHD			Artificial Path	4	Open Cut
HH-ND-0047			46.988252	-101.401914	Oliver	North Dakota	NDM-106	189.6	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0048			45.987175	-99.463984	McIntosh	North Dakota	NDM-106	44.5	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0049			47.034108	-101.191286	Oliver	North Dakota	NDL-328	2.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0050			46.808875	-100.55282	Burleigh	North Dakota	NDM-106	131.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0051			46.980998	-101.22967	Morton	North Dakota	NDM-106	181.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0052			45.956853	-98.446868	Dickey	North Dakota	NDT-211	77	1/26/2024	Geosyntec	USGS NHD	Maple River		Artificial Path	6	Open Cut
HH-ND-0053			46.815298	-100.557496	Burleigh	North Dakota	NDM-106	131.8	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0054			46.98707	-101.399387	Oliver	North Dakota	NDM-106	189.5	1/26/2024	Geosyntec	USGS NHD			Artificial Path	4	Open Cut
HH-ND-0055			46.470915	-97.061844	Richland	North Dakota	NDL-324	35.9	1/26/2024	Geosyntec	USGS NHD			Canal/Ditch	1	Open Cut
HH-ND-0056			46.331569	-99.973941	Emmons	North Dakota	NDM-106	80.8	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0057			46.737379	-97.206411	Cass	North Dakota	NDL-324	14.2	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut

Table A-5. Summary of Waterbody Crossings

Hazard ID	Historic Feature ID	Historic GEO ID	Latitude	Longitude	County	State	Route	Mile Post*	Identified Date	Identified By	Identified Source	Stream Name	Hydrographic Category	Stream Type	Stream Order	Crossing Method
HH-ND-0058			46.735287	-100.585007	Burleigh	North Dakota	NDM-106	125.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0059			46.196447	-99.758949	McIntosh	North Dakota	NDM-106	66.3	1/26/2024	Geosyntec	USGS NHD	South Branch Beaver Creek	Intermittent	Stream/River	3	Open Cut
HH-ND-0060			46.619338	-100.4008	Emmons	North Dakota	NDM-106	112.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0061			46.555234	-100.314098	Emmons	North Dakota	NDM-106	105.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0062			46.386097	-100.011881	Emmons	North Dakota	NDM-106	85.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0063			46.980874	-101.250108	Morton	North Dakota	NDM-106	182.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0064	S2006SA022	ND-06	46.190325	-97.293796	Sargent	North Dakota	NDT-211	13.9	1/26/2024	Geosyntec	USGS NHD	Wild Rice River	Perennial	Stream/River	5	HDD
HH-ND-0065			46.296693	-97.041868	Richland	North Dakota	NDL-324	48.6	1/26/2024	Geosyntec	USGS NHD			Canal/Ditch		Open Cut
HH-ND-0066			46.619369	-100.411281	Emmons	North Dakota	NDM-106	112.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0067			46.096531	-99.60324	McIntosh	North Dakota	NDM-106	55.1	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0068			45.978147	-99.444646	McIntosh	North Dakota	NDM-106	43.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0069			46.270535	-99.879989	Emmons	North Dakota	NDM-106	74.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	3	Open Cut
HH-ND-0070			47.014033	-100.743079	Burleigh	North Dakota	NDM-106	154.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0071			47.014082	-100.739646	Burleigh	North Dakota	NDM-106	154.2	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0072			46.536685	-100.292139	Emmons	North Dakota	NDM-106	103.7	1/26/2024	Geosyntec	USGS NHD	Hawk Creek	Intermittent	Stream/River	3	Open Cut
HH-ND-0073			46.982995	-100.853247	Burleigh	North Dakota	NDM-106	161	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0074			46.577409	-100.348422	Emmons	North Dakota	NDM-106	108.1	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0075			46.203957	-96.886371	Richland	North Dakota	NDL-323	11	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0076			46.229832	-99.819749	McIntosh	North Dakota	NDM-106	70.1	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0077			47.011459	-100.664518	Burleigh	North Dakota	NDM-106	150.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0078			46.981161	-101.203957	Morton	North Dakota	NDM-106	180.1	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0079			46.302916	-99.921186	Emmons	North Dakota	NDM-106	77.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0080			46.441949	-97.060979	Richland	North Dakota	NDL-324	37.9	1/26/2024	Geosyntec	USGS NHD	Antelope Creek		Canal/Ditch		Open Cut
HH-ND-0081			46.981185	-101.198265	Morton	North Dakota	NDM-106	179.8	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0082			46.307494	-99.93094	Emmons	North Dakota	NDM-106	78	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0083			46.813499	-100.555439	Burleigh	North Dakota	NDM-106	131.7	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0084			46.980551	-101.326622	Morton	North Dakota	NDM-106	185.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0085			46.911242	-100.581608	Burleigh	North Dakota	NDM-106	139.6	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	3	Open Cut
HH-ND-0086			45.950239	-99.422074	McIntosh	North Dakota	NDM-106	40.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0087			46.981035	-101.221913	Morton	North Dakota	NDM-106	180.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0088			46.395914	-100.031453	Emmons	North Dakota	NDM-106	86.6	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0089			46.958154	-101.061734	Morton	North Dakota	NDM-106	172.4	1/26/2024	Geosyntec	USGS NHD	Otter Creek	Intermittent	Stream/River	2	Open Cut
HH-ND-0090			46.987343	-100.843675	Burleigh	North Dakota	NDM-106	160.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0091			46.354896	-100.00003	Emmons	North Dakota	NDM-106	83	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0092			47.013621	-100.77708	Burleigh	North Dakota	NDM-106	156	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0093			46.936337	-100.574891	Burleigh	North Dakota	NDM-106	141.6	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	3	Open Cut
HH-ND-0094			46.964118	-100.94938	Morton	North Dakota	NDM-106	166.4	1/26/2024	Geosyntec	USGS NHD	Square Butte Creek		Artificial Path	5	Open Cut
HH-ND-0095			46.999296	-100.586647	Burleigh	North Dakota	NDM-106	146.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0096			46.171318	-99.700192	McIntosh	North Dakota	NDM-106	62.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0097			46.963366	-100.967583	Morton	North Dakota	NDM-106	167.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0098			47.05787	-101.207958	Oliver	North Dakota	NDL-328	0.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0099			47.01986	-100.716025	Burleigh	North Dakota	NDM-106	152.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0100			47.019809	-100.701503	Burleigh	North Dakota	NDM-106	152.2	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0101	S2004MO017	ND-04	46.963801	-100.932612	Morton	North Dakota	NDM-106	165.6	1/26/2024	Geosyntec	USGS NHD	Missouri River		Artificial Path	10	HDD
HH-ND-0102			46.964679	-100.978964	Morton	North Dakota	NDM-106	167.8	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0103			46.355007	-97.05239	Richland	North Dakota	NDL-324	44	1/26/2024	Geosyntec	USGS NHD			Canal/Ditch	2	Open Cut
HH-ND-0104			46.980113	-101.379337	Morton	North Dakota	NDM-106	188.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0105			46.413896	-100.116257	Emmons	North Dakota	NDM-106	91	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0106			46.413399	-100.115376	Emmons	North Dakota	NDM-106	90.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0107			46.413294	-100.115071	Emmons	North Dakota	NDM-106	90.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0108			46.411442	-100.109697	Emmons	North Dakota	NDM-106	90.6	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0109			46.999843	-101.443914	Oliver	North Dakota	NDM-106	191.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0110			46.998961	-101.440594	Oliver	North Dakota	NDM-106	191.7	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0111			46.998732	-101.439643	Oliver	North Dakota	NDM-106	191.7	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0112			46.998064	-101.43904	Oliver	North Dakota	NDM-106	191.6	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut

Table A-5. Summary of Waterbody Crossings

Hazard ID	Historic Feature ID	Historic GEO ID	Latitude	Longitude	County	State	Route	Mile Post*	Identified Date	Identified By	Identified Source	Stream Name	Hydrographic Category	Stream Type	Stream Order	Crossing Method
HH-ND-0113			46.997325	-101.438031	Oliver	North Dakota	NDM-106	191.6	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0114			46.326087	-99.963964	Emmons	North Dakota	NDM-106	80.2	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0115			46.135247	-99.648886	McIntosh	North Dakota	NDM-106	59.2	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0116			45.959121	-98.517506	Dickey	North Dakota	NDT-211	80.4	1/26/2024	Geosyntec	USGS NHD	Dry Branch		Artificial Path	2	Open Cut
HH-ND-0117			46.965978	-101.006396	Morton	North Dakota	NDM-106	169.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0118			46.965515	-101.007112	Morton	North Dakota	NDM-106	169.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0119			46.963632	-101.011833	Morton	North Dakota	NDM-106	169.7	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-012			46.833569	-100.566795	Burleigh	North Dakota	NDM-106	133.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0120			47.012474	-100.751998	Burleigh	North Dakota	NDM-106	154.8	1/26/2024	Geosyntec	USGS NHD	Burnt Creek		Artificial Path	4	Open Cut
HH-ND-0121			47.048789	-101.586678	Oliver	North Dakota	NDM-106	199.8	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0122			46.465655	-100.16702	Emmons	North Dakota	NDM-106	95.6	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	3	Open Cut
HH-ND-0123			47.029367	-101.531008	Oliver	North Dakota	NDM-106	196.7	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0124			46.741338	-97.206548	Cass	North Dakota	NDL-324	13.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0125			46.888874	-100.581965	Burleigh	North Dakota	NDM-106	138.1	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0126			47.013617	-100.787626	Burleigh	North Dakota	NDM-106	156.5	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0127			47.00927	-100.804708	Burleigh	North Dakota	NDM-106	157.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0128			46.181518	-97.538686	Sargent	North Dakota	NDT-211	26	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0129			46.958308	-101.105052	Morton	North Dakota	NDM-106	174.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0130		ND-09	46.85235	-100.583385	Burleigh	North Dakota	NDM-106	135.4	1/26/2024	Geosyntec	USGS NHD	Apple Creek	Perennial	Stream/River	5	HDD
HH-ND-0131		ND-09	46.851638	-100.583403	Burleigh	North Dakota	NDM-106	135.3	1/26/2024	Geosyntec	USGS NHD	Apple Creek	Perennial	Stream/River	5	HDD
HH-ND-0132		ND-09	46.851398	-100.583409	Burleigh	North Dakota	NDM-106	135.3	1/26/2024	Geosyntec	USGS NHD	Apple Creek	Perennial	Stream/River	5	HDD
HH-ND-0133	S2007RI012	ND-05	46.192387	-97.074878	Richland	North Dakota	NDT-211	3.3	1/26/2024	Geosyntec	USGS NHD	Wild Rice River		Artificial Path	5	HDD
HH-ND-0134			46.695543	-97.178552	Cass	North Dakota	NDL-324	17.8	1/26/2024	Geosyntec	USGS NHD			Canal/Ditch	1	Open Cut
HH-ND-0135			47.033705	-101.545533	Oliver	North Dakota	NDM-106	197.4	1/26/2024	Geosyntec	USGS NHD	Otter Creek	Intermittent	Stream/River	2	Open Cut
HH-ND-0136			46.976468	-100.875999	Burleigh	North Dakota	NDM-106	162.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0137			46.562484	-100.322457	Emmons	North Dakota	NDM-106	106	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0138			46.191176	-97.126047	Richland	North Dakota	NDT-211	5.8	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0139			46.386382	-100.013388	Emmons	North Dakota	NDM-106	85.5	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0140			47.047208	-101.579996	Oliver	North Dakota	NDM-106	199.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0141			47.050304	-101.196546	Oliver	North Dakota	NDL-328	1.1	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0142			46.73385	-97.206289	Cass	North Dakota	NDL-324	14.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0143			47.038234	-101.555965	Oliver	North Dakota	NDM-106	198.1	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0144			46.962604	-101.020507	Morton	North Dakota	NDM-106	170.1	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0145	S2015DI024	ND-08	45.946344	-98.679361	Dickey	North Dakota	NDT-211	88.5	1/26/2024	Geosyntec	USGS NHD	Elm River		Artificial Path	5	HDD
HH-ND-0146			47.056665	-101.604428	Oliver	North Dakota	NDM-106	200.8	1/26/2024	Geosyntec	USGS NHD			Artificial Path	2	Open Cut
HH-ND-0147			46.814729	-97.27385	Cass	North Dakota	NDL-324	6.7	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0148			46.404725	-100.084992	Emmons	North Dakota	NDM-106	89.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0149			46.20376	-96.784031	Richland	North Dakota	NDL-323	6.1	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0150			47.044956	-101.190919	Oliver	North Dakota	NDL-328	1.6	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0151			46.517599	-100.27075	Emmons	North Dakota	NDM-106	102	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0152			46.203557	-96.962454	Richland	North Dakota	NDL-323	14.6	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0153			46.203925	-96.90325	Richland	North Dakota	NDL-323	11.8	1/26/2024	Geosyntec	USGS NHD	South Branch Antelope Creek	Intermittent	Stream/River	2	Open Cut
HH-ND-0154			46.890791	-97.262954	Cass	North Dakota	NDL-324	0.6	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	3	Open Cut
HH-ND-0155			47.018918	-100.721082	Burleigh	North Dakota	NDM-106	153.1	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0156			46.52275	-100.276679	Emmons	North Dakota	NDM-106	102.5	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0157			47.029087	-101.192528	Oliver	North Dakota	NDL-328	2.7	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0158			46.189438	-99.741532	McIntosh	North Dakota	NDM-106	65.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0159			46.978117	-100.875345	Burleigh	North Dakota	NDM-106	162.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0160			46.879962	-97.271067	Cass	North Dakota	NDL-324	1.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0161			46.973149	-100.881128	Burleigh	North Dakota	NDM-106	162.8	1/26/2024	Geosyntec	USGS NHD			Artificial Path	1	Open Cut
HH-ND-0162			46.957854	-101.050405	Morton	North Dakota	NDM-106	171.8	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0163			46.987206	-101.18637	Oliver	North Dakota	NDL-328	5.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0164			45.954034	-98.554666	Dickey	North Dakota	NDT-211	82.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0165			46.116424	-97.825473	Sargent	North Dakota	NDT-211	41.2	1/26/2024	Geosyntec	USGS NHD			Canal/Ditch	1	Open Cut
HH-ND-0166			46.971778	-101.162319	Morton	North Dakota	NDM-106	177.8	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut

Table A-5. Summary of Waterbody Crossings

Hazard ID	Historic Feature ID	Historic GEO ID	Latitude	Longitude	County	State	Route	Mile Post*	Identified Date	Identified By	Identified Source	Stream Name	Hydrographic Category	Stream Type	Stream Order	Crossing Method
HH-ND-0167			46.797236	-97.233255	Cass	North Dakota	NDL-324	9.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	3	Open Cut
HH-ND-0168			46.165257	-99.690522	McIntosh	North Dakota	NDM-106	62.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0169			46.981767	-100.869095	Burleigh	North Dakota	NDM-106	161.8	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0170			46.997372	-100.809538	Burleigh	North Dakota	NDM-106	158.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0171			46.998112	-100.809259	Burleigh	North Dakota	NDM-106	158.3	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0172			47.018427	-101.49862	Oliver	North Dakota	NDM-106	194.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0173			46.98054	-101.31931	Morton	North Dakota	NDM-106	185.5	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0174			46.956996	-101.032485	Morton	North Dakota	NDM-106	170.8	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0175			47.012232	-100.675045	Burleigh	North Dakota	NDM-106	150.8	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	2	Open Cut
HH-ND-0176			46.946512	-100.573056	Burleigh	North Dakota	NDM-106	142.4	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	3	Open Cut
HH-ND-0177			46.95142	-100.572258	Burleigh	North Dakota	NDM-106	142.7	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	3	Open Cut
HH-ND-0178			46.495006	-100.232433	Emmons	North Dakota	NDM-106	99.6	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0179			46.467729	-100.171554	Emmons	North Dakota	NDM-106	95.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0180			46.240776	-99.838399	McIntosh	North Dakota	NDM-106	71.2	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0181			46.176276	-99.710819	McIntosh	North Dakota	NDM-106	63.5	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0182			46.144621	-99.652546	McIntosh	North Dakota	NDM-106	59.9	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0183			45.968806	-99.432273	McIntosh	North Dakota	NDM-106	42.1	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0184			45.955286	-98.548915	Dickey	North Dakota	NDT-211	82	1/26/2024	Geosyntec	USGS NHD	Sewer Branch	Intermittent	Stream/River	3	Open Cut
HH-ND-0185			46.203536	-96.948485	Richland	North Dakota	NDL-323	14	1/26/2024	Geosyntec	USGS NHD		Intermittent	Stream/River	1	Open Cut
HH-ND-0186			46.203944	-96.921582	Richland	North Dakota	NDL-323	12.7	1/26/2024	Geosyntec	USGS NHD	South Branch Antelope Creek	Intermittent	Stream/River	2	Open Cut
HH-ND-0196			46.462945	-100.160224	Emmons	North Dakota	NDM-106	95.2	1/26/2024	Geosyntec	USGS NHD	West Branch Long Lake Creek	Intermittent	Stream/River	4	Open Cut
HH-ND-0200	S_2_CA_042_DT	ND-02	46.745374	-97.206687	Cass	North Dakota	NDL-324	13.6	1/26/2024	Geosyntec	USGS NHD	Maple River	Perennial	Stream/River	5	HDD
HH-ND-0210			46.834864	-97.285611	Cass	North Dakota	NDL-324	4.8	1/26/2024	Geosyntec	USGS NHD	Buffalo Creek	Intermittent	Stream/River	4	Open Cut
HH-ND-0211			46.83413	-97.285621	Cass	North Dakota	NDL-324	4.9	1/26/2024	Geosyntec	USGS NHD	Buffalo Creek	Intermittent	Stream/River	4	Open Cut
HH-ND-0212			46.83186	-97.285185	Cass	North Dakota	NDL-324	5	1/26/2024	Geosyntec	USGS NHD	Buffalo Creek	Intermittent	Stream/River	4	Open Cut
HH-ND-0214	S2006RI017	ND-01	46.203506	-96.746573	Richland	North Dakota	NDL-323	4.3	1/26/2024	Geosyntec	USGS NHD	Wild Rice River		Artificial Path	5	HDD

Note:
*Approximate nearest Mile Post Marker generated by Geosyntec.

APPENDIX B

OVERVIEW OF CONDITIONS AND HAZARDS WITH CLASSIFICATION CRITERIA (AS APPLICABLE)

APPENDIX B – OVERVIEW OF CONDITIONS AND HAZARDS WITH CLASSIFICATION CRITERIA (AS APPLICABLE)

1. CONDITIONS ALONG THE PROPOSED PIPELINE

1.1. Frost Heave

Frost heave occurs when saturated soil is subject to freezing (e.g., during the winter season) and subsequently thaws out (e.g., during the summer season); it typically occurs only near the ground surface. Frost heave results from the formation of segregated ice crystals and ice lenses in the soil and the subsequent loss of soil strength when the ground thaws. Frost heave can cause an initially level trench-bottom profile to become uneven, causing upheaval buckling. Upheaval buckling is a well-known phenomenon in buried pipelines that can lead to upward movements of a pipeline; it is caused by the interaction between the longitudinal compressive force present during operation and overbend irregularities in the profile (Palmer and Williams 2003; Nixon and Vebo 2005; Oswell et al. 2005). Frost heave is dependent on freezing temperatures, soil moisture, and susceptible soils. Within the U.S., frost heave processes typically occur within the upper 10 feet of soil, being shallowest (or non-existent) in southern regions that experience short, mild winters and deepest in northern regions that experience longer, colder winters (Bilotta et al. 2015).

To assess the frost heave hazard potential to the pipeline, the highest value for *potential frost action class* from the United States Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS 2023) soil data was used for each soil unit along the proposed pipeline alignment. . Potential frost action is a rating of the susceptibility of the soil to upward or lateral movement by the formation of segregated ice lenses. It rates the potential for frost heave and the subsequent loss of soil strength when the ground thaws. The frost action designation in the NRCS data is estimated for the whole soil column to the depth of frost penetration, the depth to bedrock, or to a depth of 6.6 feet (2 meters), whichever is shallowest. Areas where frost action was identified by NRCS as *None* were assumed to represent areas with no or negligible frost heave potential. The maximum depth of frost penetration estimated for a 100-year return air-freezing index (based on data from 1981-2010) (Bilotta et al. 2015) show frost depths are greater than 5 feet below ground surface across the entire project area. Therefore, the potential frost action class designation within the NRCS data was used to categorize soils as having low, medium, and high frost action potential as follows:

- **Higher Frost Action Potential**: Areas where potential frost action class is rated as *Highly Susceptible* from NRCS data.
- **Medium Frost Action Potential**: Areas where potential frost action class is rated as *Susceptible* from NRCS data.
- **Low Frost Action Potential**: Areas where potential frost action class is rated as *Rarely Susceptible* from NRCS data.

1.2. Shrink/Swell Potential

Some types of clay-rich soils can undergo volume changes when moisture content decreases (i.e., shrink) or increases (i.e., swell). Significant shrinking and/or swelling of soils can impart stresses from differential settlement and/or heave, respectively, that can damage vulnerable infrastructure including buildings, roads, and buried pipelines. To assess the shrink/swell potential of soils, we compiled soils data from the USDA-NRCS (2023) and used the highest value for *linear extensibility percent* that is assigned to each soil unit to classify the soils within the project area. Linear extensibility percent (LEP) represents the potential for a soil to undergo volume changes in response to wetting or drying. The classifications listed below are based on the low, moderate, and high shrink/swell classifications assigned by the NRCS in their National Soil Survey Handbook (NSSH) (USDA-NRCS 2022).

- **Higher Shrink/Swell Potential**: LEP value is greater than 6
- **Medium Shrink/Swell Potential**: LEP value is between 3 and 6
- **Lower Shrink/Swell Potential**: LEP value is lower than 6

2. GEOHAZARDS ALONG THE PROPOSED PIPELINE

2.1. Unstable Slope Hazards (Landslides)

A landslide is the "movement of a mass of rock, debris, or earth down a slope" and encompasses geologic processes such as debris or mud flows, rotational slides (slumps), translational slides, earth flows, rockfalls, or debris slides (Cruden 1991; Cruden and Varnes 1996). Landslide hazards can potentially pose a serious threat to pipeline integrity because the nature and magnitude of ground movement can impose differential loading on pipelines that may ultimately exceed pipe strength capacity (INGAA 2016). Landslides can damage pipelines by shearing or bending the pipe along the lateral limits or failure planes of the landslide, by compressing and tensioning the pipe during downslope movement of soil and rock, by undercutting and exposing the pipe (in the event that material flows out from underneath the pipeline), or by physically impacting the pipe in the event of a rapid debris flow or rockfall.

Geosyntec developed landslide categories to provide guidance on an appropriate level of construction response for each landslide. Our landslide categories are provided in the table below.

Landslide Categories

Category	Recommended Response	Definition and Recommended Action
Class A	None Required	Landslides that do not appear to pose a challenge to pipeline constructability nor appear to pose a threat to pipeline integrity such that no mitigative action is required beyond implementation of standard best management practices (BMPs). Typically, Class A landslides would be partially or wholly removed by standard construction practices within the construction limits of disturbance (LOD).
Class B	Avoidance	Landslides that appear unlikely to pose a challenge to pipeline construction and appear unlikely to pose a threat to pipeline integrity if the landslide can be avoided either by circumvention around the landslide or via trenchless pipeline installation (i.e., HDD) beneath the landslide. Typically, avoidance of Class B landslides appears feasible due to apparent allowable workspace tolerances or due to proposed HDD installations planned for river crossings that coincide with the landslide. If a Class B landslide cannot be avoided, then Class C mitigative actions should apply.
Class C	Mitigation	Landslides that appear likely to be disturbed and/or impacted by pipeline construction activities such that landslide activity may be more likely to occur as a result of pipeline construction. Depending on the conditions encountered during construction, mitigative measures may be warranted to maintain or improve drainage and slope stability such as trench breakers, subsurface drains, water bars, etc.

2.2. Seismic Hazards

2.2.1. Strong Ground Shaking

Strong ground shaking from large earthquakes can potentially strain and damage pipelines because of lateral and vertical ground movements, or accelerations from seismic wave propagation (O'Rourke and Liu 1999, 2012). The potential hazard from earthquake wave propagation is commonly measured by the ground shaking parameter of peak horizontal ground acceleration (PGA), expressed as a percentage of the Earth's gravitational acceleration (g). Earthquake strong ground shaking may also trigger liquefaction and lateral spreading of saturated soil, as well as landslides.

Empirical correlations of potential damage related to ground motions indicate that light damage to engineered surface structures generally occurs in the acceleration range of 0.09 g to 0.18 g; moderate damage occurs in the acceleration range of about 0.18 g to 0.34 g; and moderate to severe damage occurs at accelerations from 0.34 g to 1.24+ g (e.g., Wald et al. 1999). These PGA thresholds correspond with seismic hazard mapping developed by the United States Geological Survey (USGS) for ground motions having a 10-percent probability of exceedance in 50 years, which represents a return period of 475 years (Rukstales and Petersen 2019; Petersen et al. 2021).

With these correlations, we conservatively selected the hazard classification criteria listed below to highlight areas where corresponding PGA values suggest there may be elevated potential for earthquake shaking to affect a pipeline.

Seismic ground shaking potential threat categories are as follows:

- **Higher Ground Shaking Potential**: Areas where PGA is greater than 0.34 g
- **Medium Ground Shaking Potential**: Areas where PGA is 0.18 g to 0.34 g
- **Lower Ground Shaking Potential**: Areas where PGA is less than 0.18 g

2.2.2. Soil Liquefaction

Liquefaction involves the transformation of a granular material from a solid to a liquefied state because of increased pore-water pressure and reduced effective stress (Youd et al. 2001). Seismic liquefaction typically occurs when loose to moderately dense granular soils with poor drainage such as silty sands, or sands and gravels containing seams of impermeable sediment, are saturated during strong ground shaking events (Youd et al. 2001). Liquefaction of soils involving a pipeline can potentially result in pipe strain or rupture from settlement, heave (buoyancy), and/or lateral displacements when liquefaction occurs on sloping ground. Mass movements, including permanent ground deformation may also develop because of lateral spreading, which occurs when liquefied ground cannot support even shallow slope gradients such that liquefied material flows downslope (O'Rourke and Liu 1999, 2012).

Areas that we interpret to be frequently or permanently saturated near the ground surface (e.g., groundwater less than 5 feet below ground surface) that are interpreted to contain relatively young (i.e., Holocene) alluvium, lacustrine (i.e., lakebed) deposits, or similar, that appear to consist of loose to moderately dense granular soils are assumed to have liquefaction potential if subjected to strong ground shaking. We qualitatively identified areas where these conditions appear to be present, then correlated these potential liquefaction areas with seismic hazard mapping for a return period of 475 years (Rukstales and Petersen 2019; Petersen et al. 2021) to classify their liquefaction threat potential.

Liquefaction threat categories are as follows:

- **Higher Liquefaction Potential**: Potential liquefaction conditions present in areas where PGA is greater than 0.34 g.
- **Medium Liquefaction Potential**: Potential liquefaction conditions present in areas where PGA is 0.18 g to 0.34 g.
- **Lower Liquefaction Potential**: Potential liquefaction conditions present in areas where PGA is less than 0.18 g.

2.2.3. Surface Fault Rupture

Surface fault rupture from earthquakes causes permanent ground deformation that induces tensile and compressional forces on pipelines, which have resulted in many pipeline breaks (e.g., rupture, buckling) from fault movement during past earthquakes (O'Rourke and Liu 1999, 2012).

Based on review of the USGS Quaternary Fault and Fold Database (USGS 2020), no surface fault rupture hazards were identified during this assessment. Therefore, no potential threat classification criteria were applied for surface fault rupture hazards.

2.3. Ground Subsidence Hazards

2.3.1. Karst

Karst generally refers to topography and features that typically form as a result of dissolution of carbonate rocks such as limestone and dolomite. Common karst features observed in karst topography include sinkholes, ridgetop ponds, caves, disappearing streams (i.e., sinks), and reappearing streams (i.e., springs) that are often interrelated through complex subsurface drainage networks. Karst processes that mainly result in potential hazards to pipelines involve the formation of sinkholes. Three types of sinkholes commonly form from karst processes (after Tihansky 1999):

Dissolution: A process by which surface drainage dissolves carbonate bedrock from the surface-down, forming shallow depressions that may fill with sediment or ponded water. Dissolution sinkholes develop very slowly and typically have little impact on human activity.

Cover-subsidence: A process by which overlying granular sediments settle or erode into cavities formed by dissolution of the carbonate bedrock below, causing gradual down-warping at the surface. Cover-subsidence sinkholes may develop over months or years and can cause damage to surface facilities.

Cover-collapse: A process that results in abrupt formation of sinkholes that can cause catastrophic damage to surface facilities. Cover-collapse sinkholes form when an underground cavity expands upward due to gradual dissolution and erosion until the overlying materials fail suddenly and collapse into the cavity within minutes or hours.

Although dissolution sinkholes typically have little impact on human activity, they are often indistinguishable from the more hazardous cover-subsidence and cover-collapse sinkholes based on surface expression alone. Therefore, we assume that all possible sinkholes or potentially hazardous karst features identified in the vicinity of a pipeline alignment are either the result of, or are indicative of, ongoing cover-subsidence or cover-collapse processes.

No karst terrain or individual karst features were identified during this assessment. Therefore, areas mapped as being underlain by carbonate bedrock (Weary and Doctor 2014) (e.g., limestone, dolomite) are considered to pose low karst hazard potential. No other potential threat classification criteria were applied for karst subsidence.

2.3.2. Fluid Withdrawal

Subsidence from fluid withdrawal can cause permanent ground deformation that may stress pipelines and ultimately lead to pipe rupture. Noticeable or measurable fluid withdrawal subsidence occurs through withdrawal and drawdown of underground fluids in combination with geologic conditions favorable to subsidence (Poland 1984). Typically, fluid withdrawal subsidence occurs when the volume of fluids being removed from a subsurface aquifer is greater than the volume of fluids recharging the aquifer, and when soil or bedrock within the aquifer is compressible (Galloway et al. 1999).

In most cases, fluid withdrawal subsidence occurs slowly over a large area, with little differential movement within the subsiding areas. In some instances, scarps, fissures, and/or sinkholes may form in response to differential movement within subsiding areas, or from rapid surface subsidence or collapse (e.g., Paine et al. 2009, 2012).

No fluid withdrawal subsidence areas or related features were identified during this assessment. Therefore, no potential threat classification criteria were applied for fluid withdrawal subsidence hazards.

2.3.3. Underground Mining

Collapse or subsidence of underground voids left by underground mining can produce sinkholes like those produced by karst. These sinkholes can result from collapse of overlying overburden into a mine or mine related feature (such as air shafts), or the gradual or sudden collapse of the mine itself.

No mapped underground mine areas and no related subsidence features were identified along the proposed pipelines during this assessment. Therefore, no potential threat classification criteria were applied for underground mine subsidence hazards.

2.4. Hydrotechnical Hazards

Hydrotechnical impacts at pipeline stream crossings are typically caused by channel changes and bed and bank material movement. Undesirable channel changes include vertical movement, lateral movement, and complete channel relocation (i.e., vertical and/or lateral instabilities). Vertical movement can result from scour, degradation, and aggradation. Lateral movement can occur due to bank erosion, and complete channel relocation can occur from avulsion and meander cutoffs. An exposed and unsupported pipeline span within a waterbody is vulnerable to fatigue due to vortex-induced vibration (VIV), and localized scour around an exposed pipeline can further increase the unsupported length of the pipeline. Other damages to an exposed pipeline can be caused by impacts from debris, which may dent, puncture, or rupture the pipeline, damage pipeline coating, and increase hydrodynamic drag forces on the pipeline.

Geosyntec developed a hazard classification rating system that qualitatively categorized the potential hydrotechnical threat for the pipeline crossing as either low, medium, or high and conducted a hydrotechnical review of crossings. The rating system was based on a combination of factors including the following:

- Stream Morphology at crossing including sinuosity, meander belt width, bankfull width.
- Crossing orientation (e.g. perpendicular crossing, oblique crossing, parallel encroachment) and length within active channel.
- Proposed installation method (HDD or open cut) and preliminary crossing design, if available. If HDD was proposed, Geosyntec reviewed the preliminary HDD plan and profile drawings to evaluate the proposed burial depth and lateral extents of the HDD relative to the waterbody crossing and hydrotechnical risks.
- Engineering/scientific judgement based on experience with similar type projects, pipeline construction, and principals of fluvial geomorphology and hydrology.

The hazards classifications were defined as follows:

- **Low Hazard** = Low likelihood for pipeline to be exposed due to hydrotechnical hazards within design life of project (assumed to be 50-years).
- **Moderate Hazard** = Moderate likelihood for pipeline to be exposed due to hydrotechnical hazards within design life of project.
- **High Hazard** = High likelihood for pipeline to be exposed due to hydrotechnical hazards within design life of project.

The hazards classifications defined for each crossing were based on the below assumptions.

Classification Assumptions:

- Pipeline would be installed using the techniques identified by SCS in the information provided to Geosyntec.
- For crossings identified as HDD installations, the proposed extents of the HDD would match those provided in the preliminary HDD plan and profile drawings.
- For crossings identified as open cut, the top of pipe would have a minimum depth of cover of 5-feet beneath the channel thalweg and the sag bends would be set back 15-feet from top of bank.
- HDD profile drawings show an accurate representation of channel bottom and proposed depth of cover for HDD crossings.
- Crossings that did not have an installation method identified were assumed to be open-cut installations.
- River and creek crossings will be integrated into a pipeline system integrity management monitoring program to monitor potential changes in hydrologic and conditions.

Note that if the installation method is modified, or the preliminary HDD layout changes, the relative hazard rating for the crossing may change. Additionally, the HDD crossings were evaluated with respect to potential hydrotechnical hazards and not evaluated based on potential geotechnical or constructability risks associated with the HDD installation.

2.5. Meteorological Hazards

2.5.1. Tornadoes

Although tornadoes do not typically pose a significant threat to buried pipelines, they can pose a threat to surface structures associated with pipelines. Geosyntec assessed tornado hazards by utilizing mapping performed by the National Oceanic and Atmospheric Administration's (NOAA's) National Severe Storms Laboratory (NSSL) (2015). The NSSL has prepared a tornado probability map based on historical data from 1986 to 2015. The probability of a tornado occurring is expressed in terms of *tornado days per decade* which is the number of days an Enhanced Fujita (EF) scale of EF2, or greater tornado is expected to occur within 25 miles of a given point in an average decade. Areas mapped with more than 2.0 tornado days per decade are areas where tornadoes are historically most likely to occur in a given decade; areas mapped as having between 0.5 and 2.0 tornado days per decade are areas where tornadoes are historically less likely to occur but are still areas where tornadoes can be expected; and areas with less than 0.5 tornado days per decade are areas where tornadoes are considered unlikely to occur.

Geosyntec assigned tornado threat categories as follows:

- **Higher Tornado Hazard Potential**: More than 2.0 tornado days per decade
- **Medium Tornado Hazard Potential**: Between 0.5 and 2.0 tornado days per decade
- **Lower Tornado Hazard Potential**: Less than 0.5 tornado days per decade

2.5.2. Lightning Strikes

Lightning strikes are natural forces that can damage pipelines and related infrastructure. For example, in April 2023, lightning struck a pipeline compressor station in Corinth, Mississippi which caused the natural gas product to ignite and catch fire (e.g., Associated Press 2023). Gesoyntec assessed lightning hazards by utilizing a map generated by Vaisala (2019) that shows cloud-to-ground lightning incidence in the continental U.S. Vaisala, a private company, maintains a U.S. National Lightning Detection Network used by NOAA and the National Weather Service (NWS). The map is based on data collected between 2009 and 2018 and shows the average cloud-to-ground lightning incidence per square kilometer per year. Geosyntec digitized information from Vaisala (2019) into a generalized map and assigned lightning strike threat categories as follows:

- **Higher Lightning Strike Potential**: Areas with more than 4 lightning strikes per square kilometer per year
- **Medium Lightning Strike Potential**: Areas with 1 to 4 lightning strikes per square kilometer per year

- **Lower Lightning Strike Potential**: Areas with 0 to 1 lightning strikes per square kilometer per year

2.5.3. Hurricanes

We assessed the potential for hurricanes to affect the project area by reviewing national hurricane risk index mapping from the Federal Emergency Management Agency (FEMA 2023). FEMA's national hurricane risk index rankings represent a region's relative risk from hurricanes when compared to the rest of the U.S., based on the NOAA National Hurricane Center's database of Atlantic hurricanes between 1851 and 2022.

FEMA's national hurricane risk index ranks the entire project area as *Not Applicable*, indicating that there is no threat from hurricanes based on historic data. Therefore, no potential threat classification criteria were applied for hurricane hazards.

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