BIPOLE III TRANSMISSION PROJECT
Soil Productivity Monitoring for Agricultural Lands- 2015 and 2016

Prepared for :

Manitoba Hydro

Submitted by:

Stantec

Bipole III Transmission Project
Soil Productivity Monitoring for Agricultural Lands – 2015 and 2016

Final Report

Prepared for:
Manitoba Hydro
820 Taylor Avenue
Winnipeg, MB R3M 3T1

Prepared by:
Stantec Consulting Ltd.
500-311 Portage Avenue
Winnipeg, MB R3B 0B9

111420045

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Prepared by 
(signature)

Grant Wiseman, M.Sc.

Reviewed by 
(signature)

David Whetter, M.Sc., P.Ag.

Approval to transmit: 
(signature)

George Kroupa, RFT

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1.0 INTRODUCTION

Manitoba Hydro retained Stantec Consulting Ltd. (Stantec) to conduct monitoring of soil productivity along the portion of the Bipole III Transmission Project (the "Project") under agricultural crop production. This report represents the first annual report on this monitoring and includes monitoring information on pre-construction baseline conditions and construction phase conditions along some portions of the Project.

In Agro-Manitoba, primarily in the southern portion of the Project, the productivity of soils for arable agriculture is valued by agricultural producers as a primary source of income. Agricultural production is also of general benefit to society. Soil productivity, as quantified by the agricultural capability of soils in rural Manitoba, could be affected primarily due to the use of heavy equipment and vehicles, disturbance of surface materials during grading, excavation of foundations, and removal of vegetation. Construction activities may adversely affect soil capability and productivity through physical, chemical and biological effects to the soil. These direct effects on soil properties are typically manifested in and can be assessed using vegetation productivity. Therefore, a vegetation productivity indicator can often be used as an effective proxy for soil productivity and can be used as an effective screening tool to assess the effectiveness of prescribed mitigation in the maintenance and reclamation of soil productivity following construction activities.

The soil productivity monitoring program is founded largely on the use of the Normalized Difference Vegetation Index (NDVI) calculated from remotely-sensed data collected through satellite imagery and evaluating the difference between NDVI values on the right of way (RoW) and adjacent, comparable off RoW areas.

1.1 OBJECTIVE

The objective of the monitoring program is to monitor crop performance in agricultural portions of the Project rights-of-way as a key indicator of soil productivity. Monitoring is to be conducted for one year prior to construction, an assumed two year construction period and for two years following construction. Applicable Project components include N4, C1, C2, S1, and S2 (**Map1-1**), with portions of these components under crop production included in the monitoring program.

A three-tiered approach to monitor and assess soil productivity is being undertaken. This approach relies primarily on desktop-based activities, namely remote sensing of vegetative productivity using Normalized Difference Vegetation Index (NDVI), and, supplemented with field assessments post-construction, if warranted (**Figure 1-1**).

The monitoring activities being undertaken are outlined in **Table 1-1**.

MAP 1-1 - Project Area

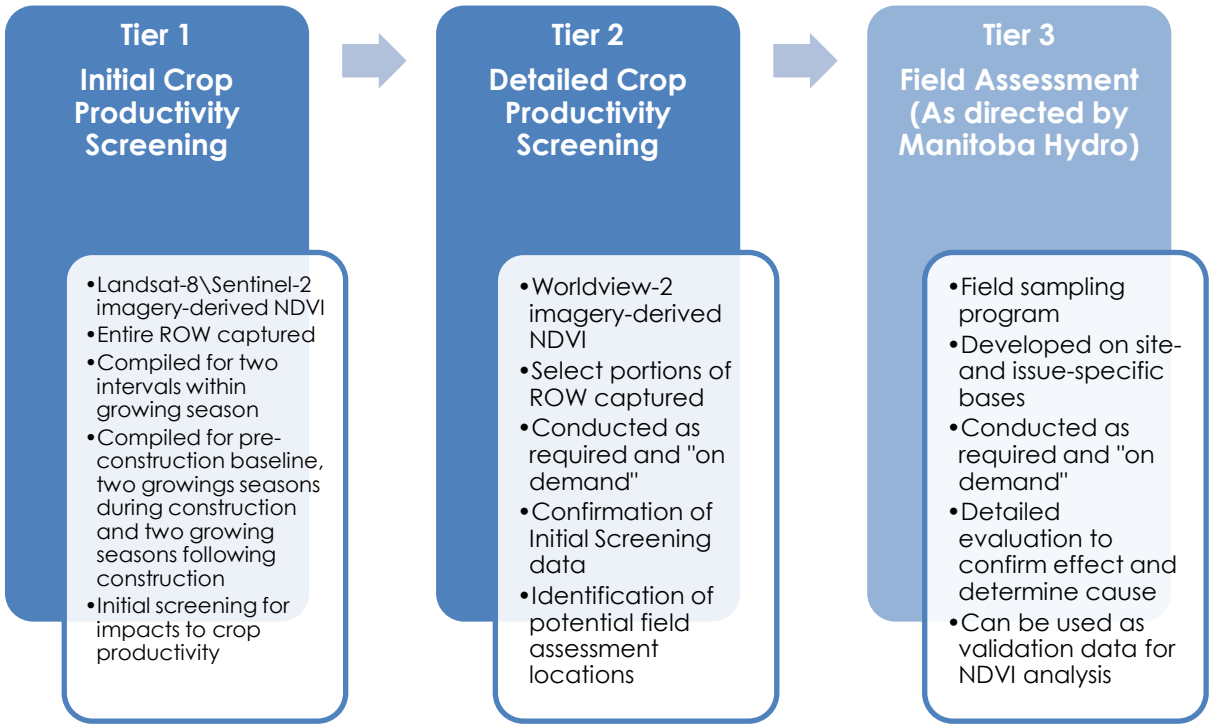


Figure 1-1 Key Aspects of a Proposed Three-Tiered Soil Productivity Monitoring and Assessment Approach for Bipole III Transmission Project

Table 1-1 Monitoring Activities

Phase	Task Description	Parameters	Duration	Frequency	Timing	Measurable Indicator(s)
Tier 1 Pre-construction phase (baseline)	Map crop productivity and crop type along ROW, access roads, and other temporary project footprints , plus a non-disturbed buffer area	Crop performance	One year prior to construction (pre-construction baseline) for all segments (N4, C1, C2, S1 and S2). Actual calendar year will align with construction schedule.	Semi-annually	Summer	NDVI
Tier 1 Construction phase	Map crop productivity and crop type along ROW, access roads, and other temporary project footprints , plus a non-disturbed buffer area, using Landsat-8 or Sentinel-2 imagery	Crop performance	Year 1 and Year 2 of construction phase. Actual calendar years will align with construction schedule.	Semi-annually	Summer	NDVI
Tier 2 and Tier 3 Post-construction phase (if required)	Map crop productivity at targeted locations and crop type along ROW, access roads, and other temporary project footprints, plus a non-disturbed buffer area, using Worldview-2 imagery. Field assessments at targeted locations to determine soil and crop productivity on-ROW and off-ROW where differences were determined using NDVI analysis.	Crop performance; Soil conditions	Year 3 and Year 4 (two years following construction). Actual calendar years will align with construction schedule.	Semi-annually	Summer	NDVI and/or specific field assessment measurements for soil and crop conditions

2.0 METHODOLOGY

The methods used to conduct the soil productivity monitoring program are outlined below.

2.1 IMAGE ACQUISITION

For 2015 and 2016 monitoring seasons, imagery was collected from Landsat-8 (2015 and 2016) and Sentinel-2 (2016 only) satellites to support the Tier 1 Initial Productivity Screening. The Landsat-8 and Sentinel-2 sensors provide an ideal radiometric and spatial resolution to capture crop conditions across a landscape in a cost effective manner.

Landsat-8 (Operational Land Imager) OLI collects multispectral data in eight channels ranging from 433 um to 2,300 um including Blue (450-453 um), Green (525-600 um), Red (630-680 um) and Near Infrared (NIR) (845-885) wavelengths at 30 meter spatial resolution. Landsat-8 data was acquired to fully cover the Bipole III RoW from sections N4 to S2 in 2015 and 2016. The OLI sensors is affected by atmospheric interference such as clouds, fog, rain or smoke and requires cloud free conditions to collect surface spectral reflectance information. The Landsat-8 satellite has a repeat coverage cycle of 16 days and has a 30% overlap swath width at mid-latitudes such as the Project location. Satellite image acquisition for the Bipole III RoW required multiple orbital paths due to the sheer size of the extent. Due to cloud cover, a long repeat coverage period and a high level of orbital overlap, each Landsat-8 image mosaic is unique in timing, orbital paths and number of images required to cover the RoW. Landsat-8 imagery was collected where cloud free data was available (**Table 2-1**). Due to high cloud contamination in 2015, only one Landsat-8 mosaic was achievable.

In early 2016, Sentinel-2A satellite imagery became freely available to the public. Similar to Landsat-8, Sentinel-2 has the same Blue (465-520 um), Green (540-575 um), Red (650-685 um) and Near Infrared (NIR) (800-915) wavelengths but at 10 meter resolution instead of 30 meters. Sentinel-2 also has a 10 day revisit period (verses 16 days for Landsat-8), which will be improved to a 5 day revisit period in 2017. Sentinel-2 imagery is subject to the same atmospheric constraints as Landsat-8 and therefore also required multiple orbital tracks over varying dates to collect a single imagery mosaic for sections N4 to S2 in 2016 (**Table 2-1**).

Table 2-1 Image Acquisition Dates for 2015 and 2016 – Landsat-8 OLI and Sentinel-2A

Landsat-8 OLI		Sentinel-2A
Summer 2015	**Summer 2016**	**Summer 2016**
Jul. 7, 2015	Jun. 21, 2016	May 17, 2016
Jul. 21, 2015	Jun. 30, 2016	Jun. 14, 2016

Table 2-1 Image Acquisition Dates for 2015 and 2016 – Landsat-8 OLI and Sentinel-2A

Landsat-8 OLI		Sentinel-2A
Summer 2015	**Summer 2016**	**Summer 2016**
July 30, 2015	Jul. 16, 2016	Jun. 20, 2016
Aug. 1, 2015	Jul. 18, 2016	Jul. 30, 2016
	Jul. 25, 2016	Aug. 2, 2016
	Aug. 10, 2016	

Tier 2 Detailed Crop Productivity Screening using WorldView-2 imagery is planned for post-construction years and was not collected during 2015 and 2016.

2.2 IMAGE PROCESSING

All satellite imagery was atmospherically corrected using PCI Geomatica 2016 – ATCOR software. Top of atmosphere (TOA) reflectance values were used to convert raw pixel values to spectral reflectance signatures using the radiometric calibration coefficients from the OLI and Sentinel-2 sensors. Haze removal was performed as part of the atmospheric correction allowing for precise vegetation measurements. ATCOR successfully normalized solar illumination conditions at different time periods allowing for accurate change detection analysis for 2015, 2016 and future project years. Individual images were clipped and mosaicked together creating continuous coverages of agricultural land use areas of N4-S2 for 2015 and 2016.

2.3 NORMALIZED DIFFERENCE VEGETATION INDEX

Landsat-8 and Sentinel-2 imagery was processed to quantify agricultural crop health by implementing the NDVI formula. NDVI is a measure of vegetative vigor or plant health using the Red and NIR channels of the electromagnetic spectrum. NIR energy is highly reflected by healthy vegetation while Red wavelengths are highly absorbed by vibrant vegetation (**Figure 2-1**). This relationship is not as strong in stressed vegetation and is non-existent in dead vegetation. This unique vegetative property, provides detail on vegetation health and is amplified in the NDVI formula;

(NIR – RED) / (NIR + RED) = NDVI

NDVI values range from 1 (healthy vegetation) to -1 (non-vegetation). Results of the NDVI formula can vary from one landscape to another but typically areas of water, sand, or infrastructure show very low NDVI values (for example, -0.5 or less). Bare soil usually scores near 0.0 on the NDVI scale range. Sparse vegetation such as shrubs and grasslands or senescing crops may result in moderate NDVI values (approximately 0.1 to 0.4). High NDVI values

(approximately 0.5 to 0.9) correspond to dense vegetation such as that found in temperate and tropical forests or crops at their peak growth stage.

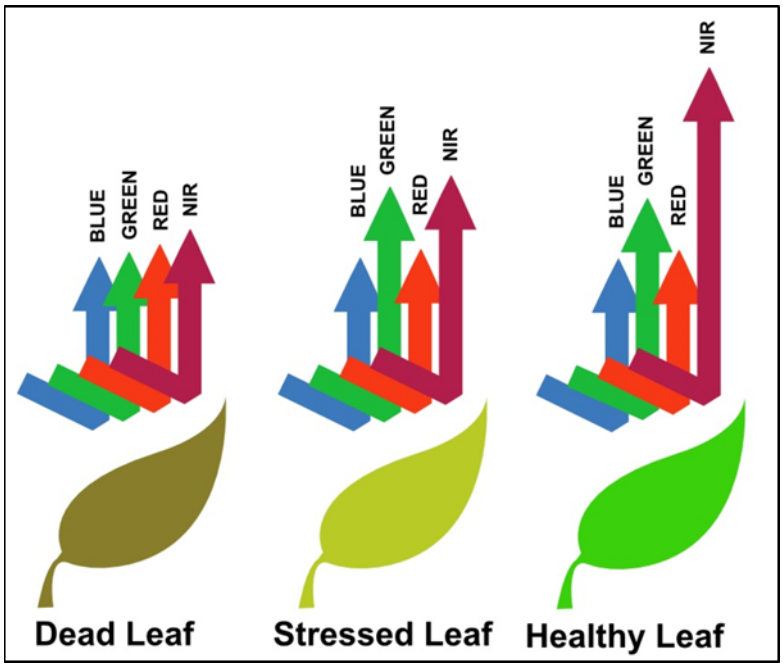


Figure 2-1 Spectral Reflectance Amount Variations for Blue, Green, Red and NIR Energy of Dead, Stressed and Healthy Crops Leaves

2.4 DATA ANALYSIS

2.4.1 On RoW and Off RoW Study Areas

In order to analyze data and evaluate for potential effects to crop productivity on the RoW from construction activities, "On RoW" and "Off RoW" study areas were established. The On RoW area consists of a 66 m wide corridor centered on the Bipole III route centreline. The 66 m wide RoW was then buffered by 66 m on both sides to create the Off RoW study areas (**Figure 2-2**). The creation of these areas for sections N4-S2 (752 km in length) allows for the comparison of NDVI values in areas likely to be disturbed by construction (i.e., On RoW) and adjacent, comparable areas not disturbed by construction (i.e., Off RoW).

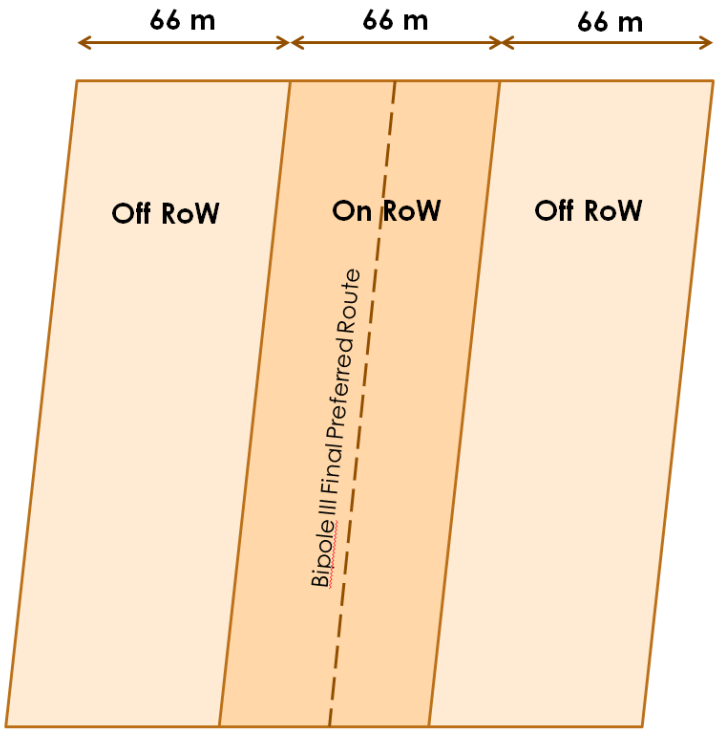


Figure 2-2 Conceptual Drawing of On Row and Off RoW Study Area Corridors

2.4.2 Agricultural Study Area Definition

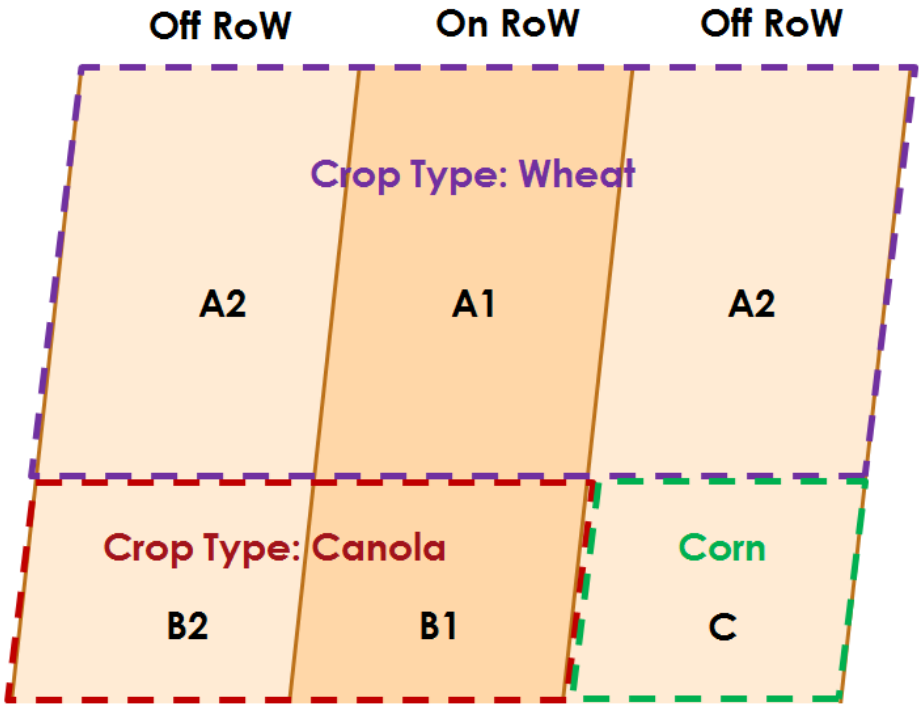
2.4.2.1 Agricultural Crop Type

The corridor study areas were clipped using the Agriculture and Agri-Food Canada 2015 land use/land cover data (AAFC Agricultural LU/LC) to isolate areas under agricultural crop production and define the agricultural study areas for the monitoring program. The NDVI analysis was completed for the entire agricultural study areas and sub-divided by section (five sections consisting of N4, C1, C2, S1 and S2) and by each segment within sections (84 segments).

Some basic statistical analysis was conducted on segmentized NDVI change data, including identifying outliers using quartile analysis, specifically the identification of median (Q2), lower quartile (Q1), upper quartile (Q3) and interquartile ranges (IQR) for 2015 and 2016 data. Outliers were identified where differences between On RoW values and Off RoW values were found to be greater than Q3 + 1.5(IQR) or lower than Q1 – 1.5(IQR).

Agricultural crop type data were used in the analysis to determine similar Off RoW areas for On RoW areas being evaluated. The location and orientation of the RoW in some cases such that Off RoW areas on either side of the RoW may be in a different field management unit with a

different crop being grown in a given monitoring year. Therefore, using crop types allows for the elimination of Off RoW areas not under production of the same crop type as the On RoW area of interest. Where the On RoW corridor crop type matches both Off RoW corridor crop types, both Off RoW polygons are retained for NDVI analysis. Where the On RoW corridor crop type only matches one Off RoW corridor crop type, only the matching Off RoW polygon is retained for NDVI analysis and the non-matching Off RoW corridor polygon is eliminated (**Figure 2-3**).



Area A1 is compared against A2 areas to determine the NDVI difference based on the crop type wheat (purple). Area B1 is compared against B2 area to determine the NDVI difference based on the crop type canola (maroon). Area C under crop type corn (green) is eliminated from the analysis.

Figure 2-3 Conceptual Drawing of Use of Crop Type to Determine Off RoW Areas for Comparison

AAAFC LU/LC classes of the clipped corridors by 2015 crop type are presented in **Table 2-2**. The 2016 AAFC LU/LC data was not available at the time of this report and is expected to be available by spring 2017. Therefore, only the 2015 NDVI coverage was analyzed by crop type in this report. The AAFC LU/LC data indicates the agricultural study area in 2015 was largely

comprised of grasslands and pasture/forage production, oilseed production (predominantly canola and soybeans) and cereals (predominantly wheat).

Table 2-2 Area by Crop Type within RoW (On RoW) in 2015

AAFC Crop Type	Hectares	Percent
Barley	32.7	1.50%
Canola / Rapeseed	351.6	16.15%
Corn	127.8	5.87%
Fallow	10.8	0.50%
Grassland	528.2	24.26%
Oats	25.8	1.18%
Pasture / Forages	258.8	11.89%
Potatoes	0.6	0.03%
Rye	1.1	0.05%
Soybeans	342.5	15.73%
Spring Wheat	60.5	2.78%
Sunflower	12.2	0.56%
Wheat	424.7	19.51%
Total	**2177.3**	**100%**
Source: 2015 AAFC Annual Crop Inventory		

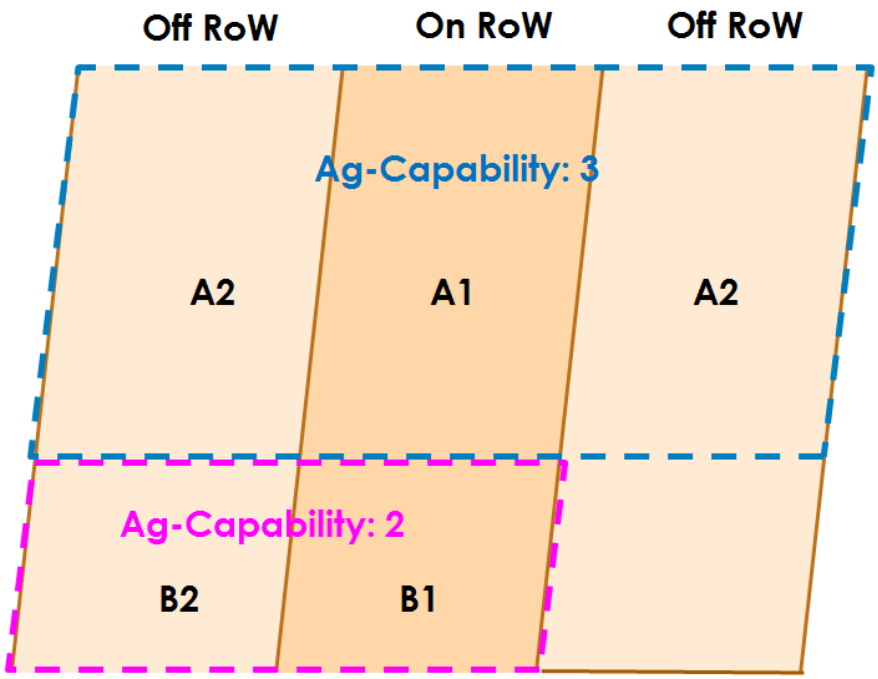
2.4.2.2 Agricultural Capability

Agricultural capability provides a hierarchical measure of the capability of the land to support agricultural crop production and was used as a foundational element in the environmental assessment for the Project. Therefore, NDVI values were also examined by agricultural capability classes by defining agricultural capability polygons within the agricultural study areas. Similar to the method described above for crop types, NDVI values for On RoW areas were compared against adjacent Off RoW areas of the same agricultural capability (**Figure 3-3**). The seven agricultural capability classes are presented in **Table 2-3**.

Table 2-3 Ag-capability Classes and Description Based on the AAFC Land Capability Method

Class	Description
1	Soils in this class have no significant limitations in use for crops.
2	Soils in this class have moderate limitations that restrict the range of crops or require moderate conservation practices.
3	Soils in this class have moderately severe limitations that restrict the range of crops or require special conservation practices.
4	Soils in this class have severe limitations that restrict the range of crops or require special conservation practices.
5	Soils in this class gave very severe limitations that restrict their capability in producing perennial forage crops, and improvement practices are feasible.
6	Soils in this class are capable only of producing perennial forage crops, and improvement practices are not feasible.
Organic	Organic Soils (not placed in capability classes).

Source: http://sis.agr.gc.ca/cansis/nsdb/cli/classdesc.html



Area A1 is compared against A2 areas to determine the NDVI difference based on the agricultural capability Class 3 (blue). Area B1 is compared against B2 area to determine the NDVI difference based on the agricultural capability Class 2 (pink).

Figure 3-4 Conceptual Drawing of Use of Agricultural Capability to Determine Off RoW Areas for Comparison

2.5 VISUAL ASSESSMENT

A manual visual review of the entire RoW was conducted for 2015 and 2016 NDVI data to identify visual evidence of construction effects along the agricultural RoW. This was completed due to a absence of reliable spatial data on construction progress that could be used to direct targeted data reviews and the anticipated lack of change detection at the relatively coarse scales of the entire agricultural RoW, Project section or Project segment within section. Different types of visual disturbances were identified including 1) construction around tower footprints, 2) linear disturbances along centreline and between towers, and 3) other disturbances (e.g., larger areas suggesting marshalling yards/laydown areas).

3.0 RESULTS

Results are presented below for NDVI evaluation by section and segment, by agricultural crop type and by agricultural capability class. Additionally, some findings from "hot spot" analysis are presented.

Tabular based results are complemented with map books of the change detection or differences between On RoW and Off RoW values along the entire length of the agricultural RoW for the 2016 Sentinel-2 NDVI data. These maps are presented in **Appendix B** as follows: **Map Series 4-100** (N4), **Map Series 4-200** (C1), **4-300** (C2), **4-400** (S1), and **4-500** (S2).

3.1 NDVI BY PROJECT SECTION AND SEGMENT

The NDVI comparative analysis for the entire agricultural study area in N4 to S2 for 2015 and 2016 coverages revealed minimal NDVI differences when On RoW was compared to Off RoW (**Tables 3-1 and 3-2**). As a reminder, NDVI output values have an absolute range from +1 to -1. NDVI differences within the entire agricultural study area of -0.010, 0.001 and -0.010 for 2015 (Landsat-8), 2016 (Landsat-8) and 2016 (Sentinel-2), respectively, were considered negligible. This was not unexpected due to the minimal amount of construction that has occurred in agricultural areas by the end of 2016, and the small proportion of the RoW that was disturbed in agricultural fields where construction has occurred.

Table 3-1 Comparison of NDVI for Entire Agricultural Study Area for 2015

Entire Agricultural RoW	Landsat-8 2015 Summer			
	On	Off	Difference	Percent
N4 to S2	0.667	0.677	-0.010	-0.48%

Table 3-2 Comparison of NDVI for Entire Agricultural Study Area for 2016

Entire Agricultural RoW	Landsat-8 - 2016 Summer				Sentinel-2 2016 Summer			
	On	Off	Difference	Percent	On	Off	Difference	Percent
N4 to S2	0.673	0.672	0.001	0.05%	0.511	0.521	-0.010	-0.48%

When analyzing the NDVI coverages by Project section, similar, generally negligible change results were found in 2015 and 2016 (**Table 3-3 and 3-4**). The Landsat-8 - 2016 Summer NDVI image sections N4 and S1 showed a negligible increase in On RoW NDVI values compared with Off RoW values, while the other sections showed negligible decrease in values, suggesting random variability in data. The Sentinel-2 2016 Summer NDVI data indicated all negative

differences between On RoW and Off RoW. Section C2 showed the greatest change with a decrease in On RoW values verses Off RoW vales of -0.053 (**Table 3-4**), suggesting this section may be showing the greatest effect in productivity as a result of construction.

Table 3-3 Comparison of NDVI by Project Section for 2015

Agricultural RoW Section	Landsat-8 2015 Summer			
	On	Off	Difference	Percent
N4	0.381	0.386	-0.005	-0.23%
C1	0.348	0.353	-0.005	-0.24%
C2	0.674	0.701	-0.027	-1.34%
S1	0.769	0.775	-0.007	-0.34%
S2	0.750	0.761	-0.011	-0.57%

Table 3-4 Comparison of NDVI by Project Section for 2016

Agricultural RoW Section	Landsat-8 – 2016 Summer				Sentinel-2 – 2016 Summer			
	On	Off	Difference	Percent	On	Off	Difference	Percent
N4	0.411	0.399	0.013	0.63%	0.287	0.296	-0.009	-0.44%
C1	0.360	0.365	-0.005	-0.25%	0.524	0.543	-0.020	-0.98%
C2	0.639	0.649	-0.010	-0.48%	0.524	0.577	-0.053	-2.66%
S1	0.747	0.740	0.008	0.39%	0.544	0.544	-0.001	-0.04%
S2	0.800	0.806	-0.005	-0.26%	0.517	0.520	-0.003	-0.17%

When NDVI coverages were evaluated by section segment, minimal positive and negative NDVI change values greater/less than +/-5% are found throughout the dataset from 2015 (**Appendix A, Table A-1**) and 2016 (**Appendix A, Table A-2**). Of the 168 segments from the Landsat-8 2015 and 2016 NDVI coverages, zero segments had a NDVI change greater/less than +/-5%. Of the 84 segments from the Sentinel-2 2016 coverage, three segments had a NDVI change greater than +/-5%.

Based on quartile analysis of segmentized NDVI data, outliers were identified as follows:

- 2015 – 3 negative outliers (C2-07, S2-25, S2-35) and 2 positive outliers (S2-04, S2-05)
- 2016 (Landsat-8) – 4 negative outliers (C1-01, S1-10, S2-21, S2-35) and 7 positive outliers (N4-09, N4-16, C2-01, S1-08, S2-07, S2-25, S2-39)
- 2016 (Sentinel-2) – 5 negative outliers (N4-10, C2-07, C2-08, S1-10, S2-23, N4-16) and 1 positive outlier (N4-16)

Monitoring year 2015 had the fewest identified outliers and close to the same number of negative and positive outliers – this suggests a relatively normal distribution which is to be expected as in 2015 there was little construction disturbance on agricultural portions of the Project.

There were mixed results in 2016 when outliers where evaluated for the Landsat-8 and Sentinel-2 datasets. That there were more positive outliers, suggesting more segments had higher productivity On RoW than Off RoW, perhaps indicates limitations in the scale or pixel size (30 m) of this data. Review of outliers in the Sentinel-2 dataset yielded results that appear more reasonable with a higher number of negative outliers. This suggests that data is confirming that some segments have reduced productivity On RoW compared with similar Off RoW areas which would be expected during the construction phase.

3.2 NDVI BY CROP TYPE

Nearly all crop types show a similar marginal decrease in NDVI value along the RoW for 2015 (**Table 3-5**). Barley had the largest NDVI decrease at -2.75%, however barley was found to occupy a small portion of the agricultural study area (1.5%). Results for the 2016 NDVI coverages will be completed when AAFC has completed the 2016 LU/LC classification for Manitoba. In future analyses, crop type data will provide additional value when monitoring post-construction change recovery.

Table 3-5 NDVI Change Detection Results for each AAFC Crop Type in 2015

AAFC Crop Type	2015 Summer			
	On	Off	Difference	Percent
Grassland	0.6287	0.6498	-0.0211	-1.06%
Pasture / Forages	0.6173	0.6377	-0.0203	-1.02%
Fallow	0.6733	0.6840	-0.0107	-0.53%
Barley	0.6469	0.7019	-0.0550	-2.75%
Oats	0.6332	0.6595	-0.0263	-1.31%
Rye	0.8280	0.8059	0.0221	1.10%
Wheat	0.7239	0.7272	-0.0034	-0.17%
Spring Wheat	0.3352	0.3356	-0.0004	-0.02%
Corn	0.7502	0.7486	0.0017	0.08%
Canola / Rapeseed	0.6541	0.6713	-0.0171	-0.86%
Sunflower	0.7095	0.7559	-0.0464	-2.32%
Soybeans	0.7348	0.7725	-0.0378	-1.89%
Potatoes	0.9352	0.9446	-0.0095	-0.47%

3.3 NDVI BY AGRICULTURAL CAPABILITY

No obvious NDVI value change pattern emerged when segmenting the RoW by agricultural capability classes (**Tables 3-6 and 3-7**). Of note, agricultural capability Class 5 showed the largest drop in relative On RoW to Off RoW NDVI change (-2.18%) in the Sentinel-2 2016 NDVI mosaic. Section C2 was found to have had the highest amount of NDVI change and is entirely comprised of agricultural fields with either an agricultural capability rating of Class 4 or 5. In future analyses, agricultural capability data will provide additional value when monitoring post-construction change recovery.

Table 3-6 NDVI Change Detection Results by Agricultural Capability Classes in 2015

Agricultural Capability Class	Landsat-8 2015 Summer			
	On	Off	Difference	Percent
1	0.679	0.665	0.014	0.68%
2	0.705	0.725	-0.020	-1.02%
3	0.716	0.726	-0.011	-0.53%
4	0.572	0.595	-0.023	-1.15%
5	0.556	0.593	-0.036	-1.82%
6	0.574	0.584	-0.010	-0.49%
Organic	0.458	0.463	-0.005	-0.25%

Table 3-7 NDVI Change Detection Results for Agricultural Capability Classes for 2016

Agricultural Capability Class	Landsat-8 – 2016 Summer				Sentinel-2 – 2016 Summer			
	On	Off	Difference	Percent	On	Off	Difference	Percent
1	0.704	0.708	-0.005	-0.23%	0.537	0.553	-0.016	-0.81%
2	0.713	0.710	0.003	0.17%	0.553	0.553	0.000	0.02%
3	0.724	0.725	0.000	-0.02%	0.509	0.511	-0.002	-0.10%
4	0.598	0.603	-0.005	-0.26%	0.519	0.537	-0.018	-0.92%
5	0.597	0.596	0.001	0.05%	0.471	0.515	-0.044	-2.18%
6	0.541	0.543	-0.003	-0.14%	0.440	0.454	-0.013	-0.67%
Organic	0.444	0.443	0.001	0.03%	0.460	0.465	-0.004	-0.22%

3.4 VISUAL ASSESSMENT

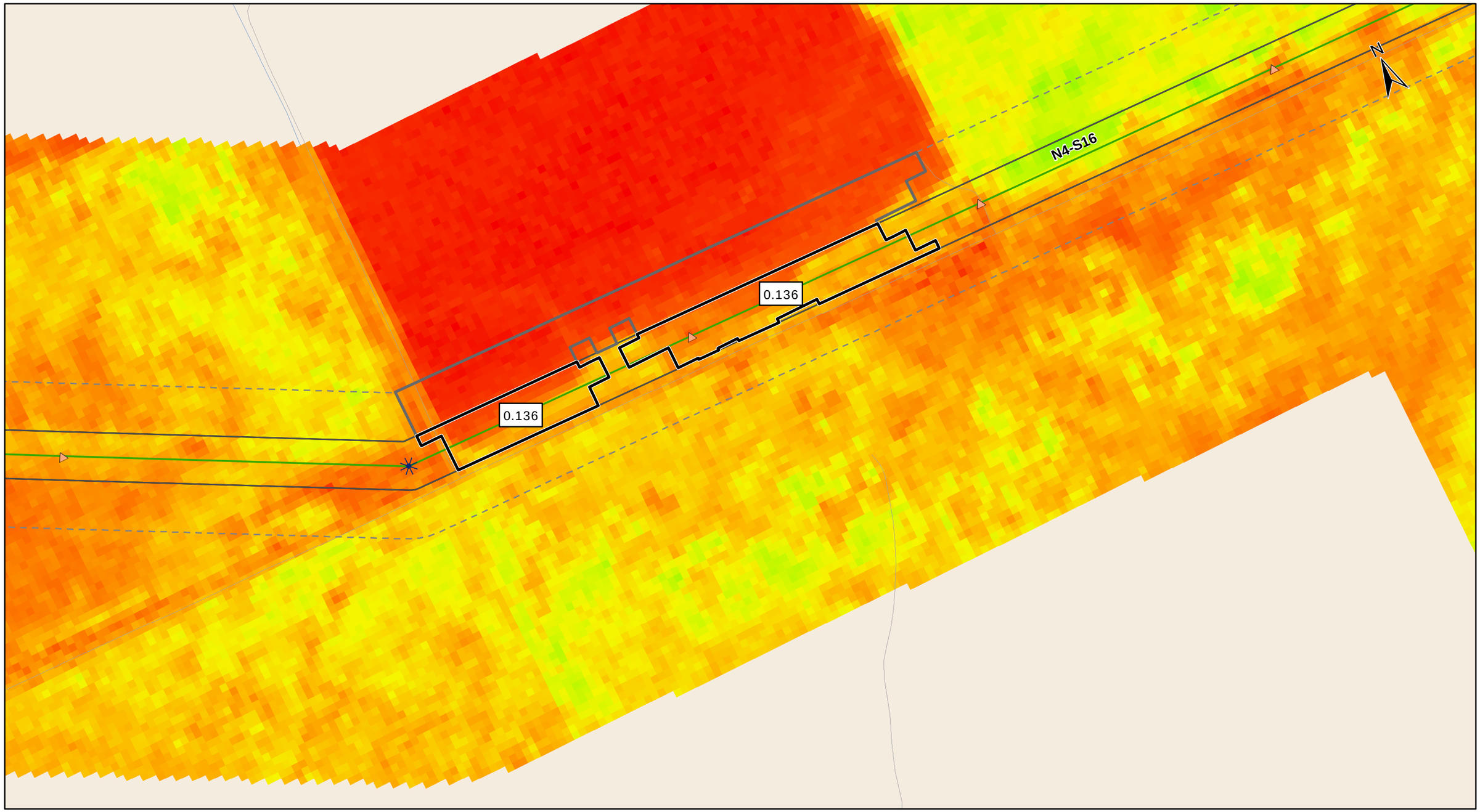
A preliminary visual assessment resulted in some interesting observations in select segments.

Segment N4-16 was found to have increased NDVI values On RoW compared with Off RoW. This segment saw an NDVI increase of 0.136 or +6.8% when 2016 Sentinel-2 data was evaluated (**Map 4-1**), and was the only segment identified as a positive outlier. This is a short segment with a small amount of identified agricultural crop production and the Off RoW polygons appear to be under different management (e.g., bare soil/tilled field) relative to On RoW appears to have some relatively poor vegetative growth, which likely explains the positive difference.

Segments C2- S7 and C2-S8 had decreases of -0.127 and -0.224 or -6.35% and -11.2%, respectively (**Maps 4-2 and 4-3**), the largest % decreases of all segments. The On RoW area within C2- S7 shows reduced NDVI values relative to Off RoW areas along portions of the segment (e.g., between tower nos. 5192 and 5193) and appears construction related, while a portion of the segment (i.e., polygon centered on tower 5194) appears to be influenced by some "natural" variability (likely a wetland area along the southern portion of the polygon). Similarly, segment C2-S8 appears to be affected by both the natural landscape and potentially construction activities.

Some other interesting observations confirming construction activities resulting in decreased NDVI values on RoW relative to adjacent Off RoW areas are noted in section S2. In S2-S10 the portion of the RoW in Section NE 7-7-1-E (between tower nos. 7097 and 7098) indicates reduced NDVI values over the entire RoW area (**Map 4-4**) with a difference of -0.143 or -7.3%. This entire RoW difference pattern suggests different management along the RoW relative to adjacent areas (potentially un-seeded RoW or a mowed perennial crop).

Segment S2-S35 had a minimal decrease in NDVI value of -0.02 or -1.0% but shows obvious reduced NDVI in areas where tower foundations have been installed, including disturbed areas around tower footprints and along the RoW centerline (i.e., between tower nos. 7273 and 7274; Map 4-5). Similarly, in segment S2-S40, which had a decrease in NDVI -0.025 or -1.2%, construction activities have had an obvious effect on NDVI values around tower footprints and between towers along the RoW centreline.



Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN, Stantec Consulting
Date Created: November 14, 2016

0 62.5 125 250
Metres

1:5,000

NDVI

Summer 2016

High : 1

Low : -1

NDVI Change Detection Analysis

- On ROW Polygons Used in NDVI Change Detection Analysis
- Off ROW Polygons Used in NDVI Change Detection Analysis
- ## Change in NDVI Between On and Off ROW Polygons

Project Infrastructure

- BPIII Final Preferred Route
- 66m ROW
- 66m Buffer of ROW
- Towers (Preliminary)
- Angle Towers (Preliminary)

Landbase

- Local Road
- Watercourse

Bipole III Transmission Project

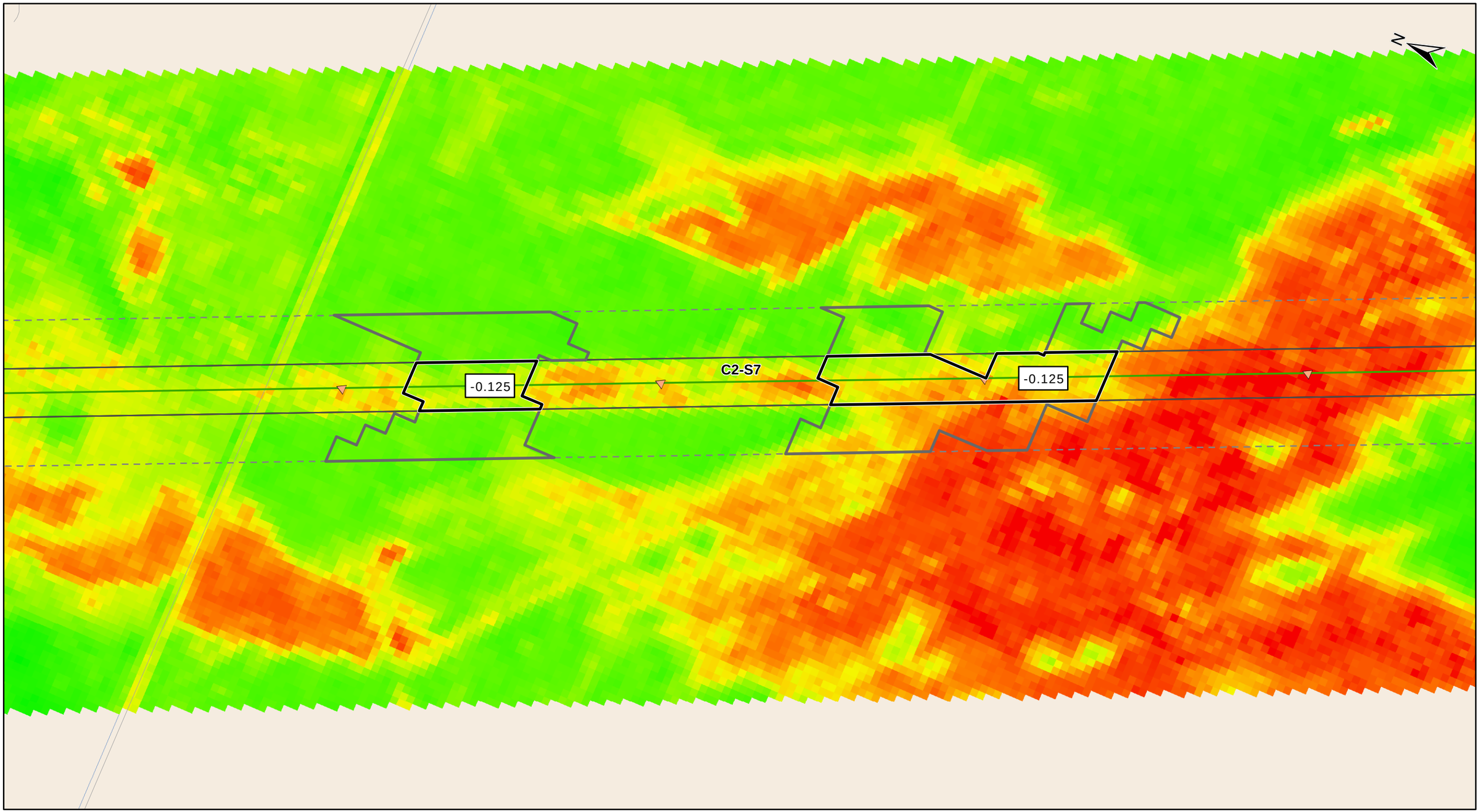
NDVI Change Detection at Section N4 - Segment S16 (N4-S16)

Summer 2016

DRAFT

Map 4-1

DOCUMENT PATH: G:_GIS_PROJECT_FOLDER\00_HYDRO\1114200451\ARCMAP\SOIL PRODUCTIVITY\BPIII_NDVI_N4_SITE_N4S16.MXD



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN, Stantec Consulting
Date Created: November 14, 2016

0 62.5 125 250
Metres

1:5,000

NDVI
Summer 2016
High : 1
Low : -1

NDVI Change Detection Analysis
- On ROW Polygons Used in NDVI Change Detection Analysis
- Off ROW Polygons Used in NDVI Change Detection Analysis
- ## Change in NDVI Between On and Off ROW Polygons

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW
- 66m Buffer of ROW
- Towers (Preliminary)

Landbase
- Local Road
- Watercourse

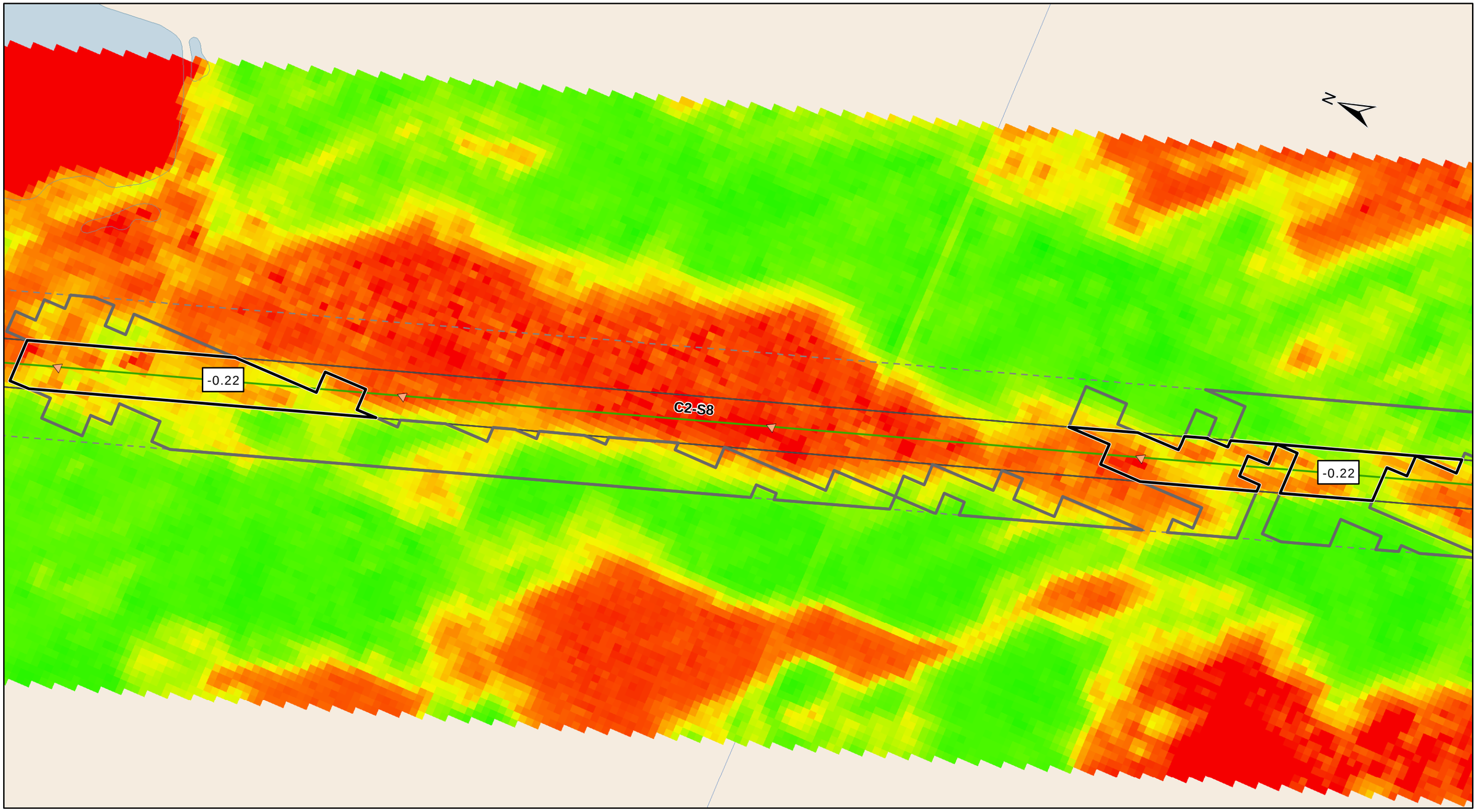
Bipole III Transmission Project

NDVI Change Detection at Section C2 - Segment S7 (C2-S7)

Summer 2016

DRAFT

Map 4-2



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN, Stantec Consulting
Date Created: November 14, 2016

0 62.5 125 250
Metres

1:5,000

NDVI
Summer 2016
High : 1
Low : -1

NDVI Change Detection Analysis
- On ROW Polygons Used in NDVI Change Detection Analysis
- Off ROW Polygons Used in NDVI Change Detection Analysis
- ## Change in NDVI Between On and Off ROW Polygons

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW
- 66m Buffer of ROW
- Towers (Preliminary)

Landbase
- Waterbody
- Watercourse

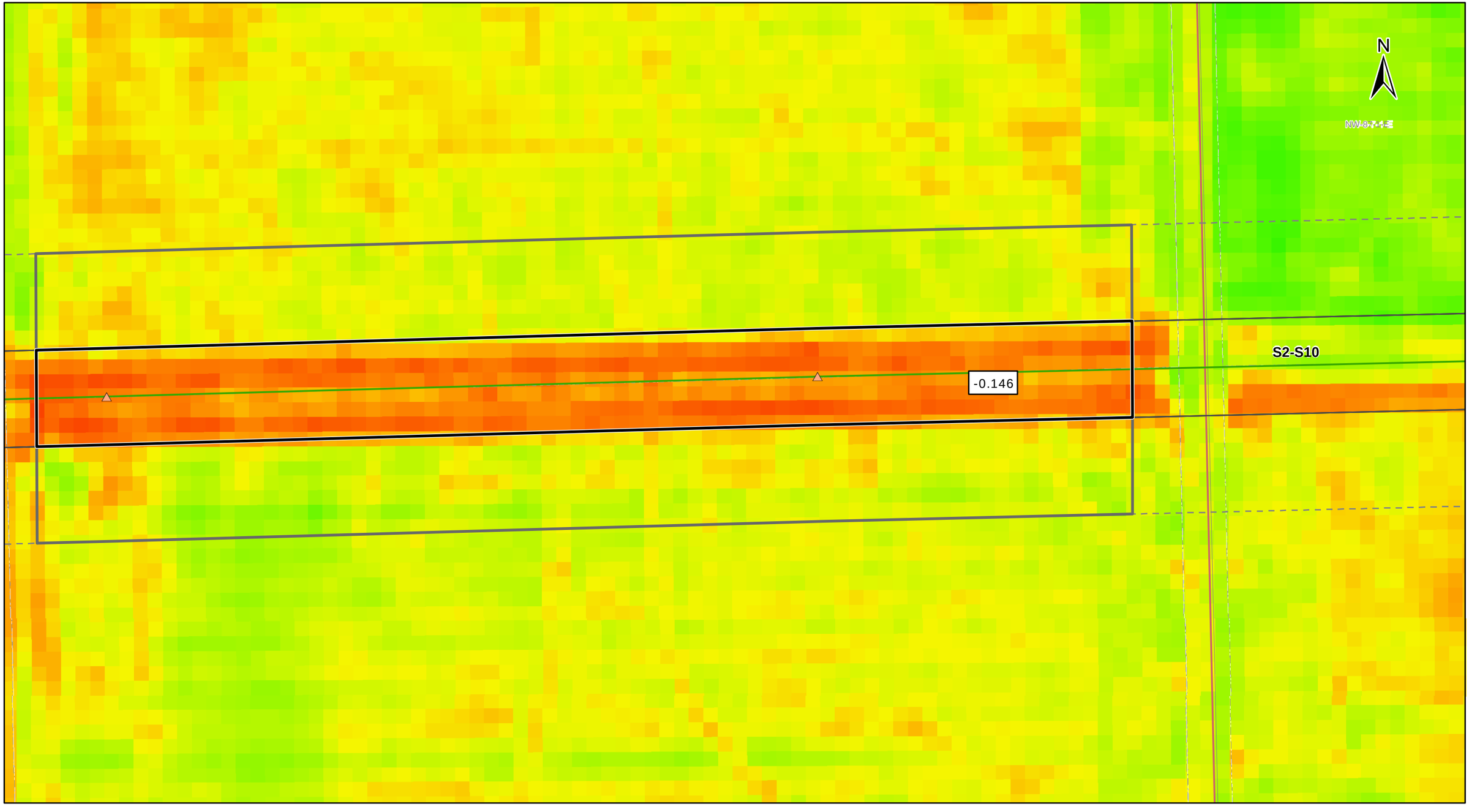
Bipole III Transmission Project

NDVI Change Detection at Section C2 - Segment S8 (C2-S8)

Summer 2016

DRAFT

Map 4-3



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN, Stantec Consulting
Date Created: November 15, 2016

0 30 60 120
Metres
1:2,500

NDVI
Summer 2016
High : 1
Low : -1

NDVI Change Detection Analysis
- On ROW Polygons Used in NDVI Change Detection Analysis
- Off ROW Polygons Used in NDVI Change Detection Analysis
- ## Change in NDVI Between On and Off ROW Polygons

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW
- 66m Buffer of ROW
- Towers (Preliminary)

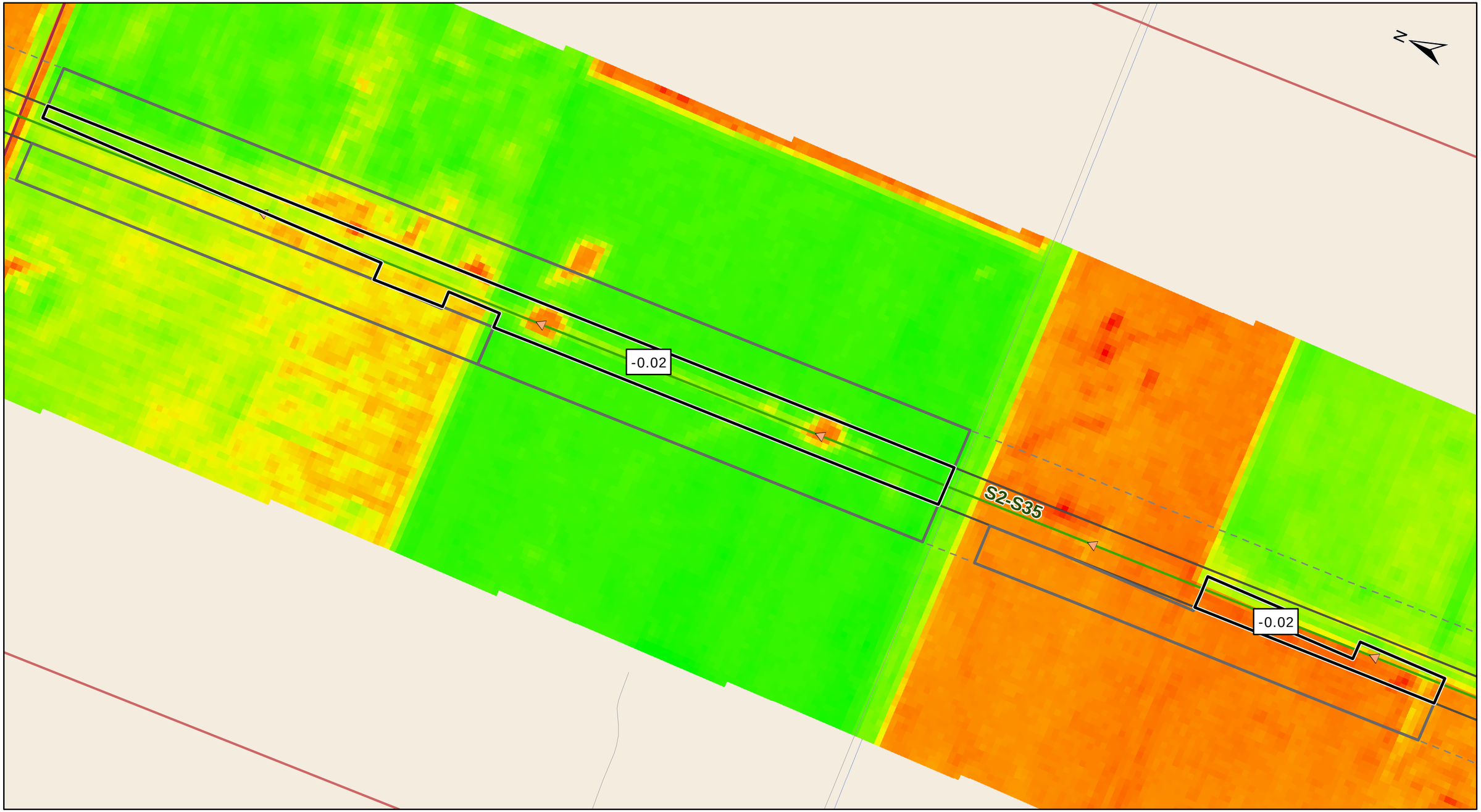
Landbase
- Major Road
- Parcel Fabric

Bipole III Transmission Project

NDVI Change Detection at Section S2 - Segment S10 (S2-S10) Summer 2016

DRAFT

Map 4-4



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN, Stantec Consulting
Date Created: November 14, 2016

0 70 140 280
Metres

1:6,000

NDVI
Summer 2016
High : 1
Low : -1

NDVI Change Detection Analysis
- On ROW Polygons Used in NDVI Change Detection Analysis
- Off ROW Polygons Used in NDVI Change Detection Analysis
- ## Change in NDVI Between On and Off ROW Polygons

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW
- 66m Buffer of ROW
- Towers (Preliminary)
- Proposed Access Route

Landbase
- Highway
- Major Road
- Local Road
- Watercourse

Bipole III Transmission Project

NDVI Change Detection at Section S2 - Segment S2 (S2-S35)

Summer 2016

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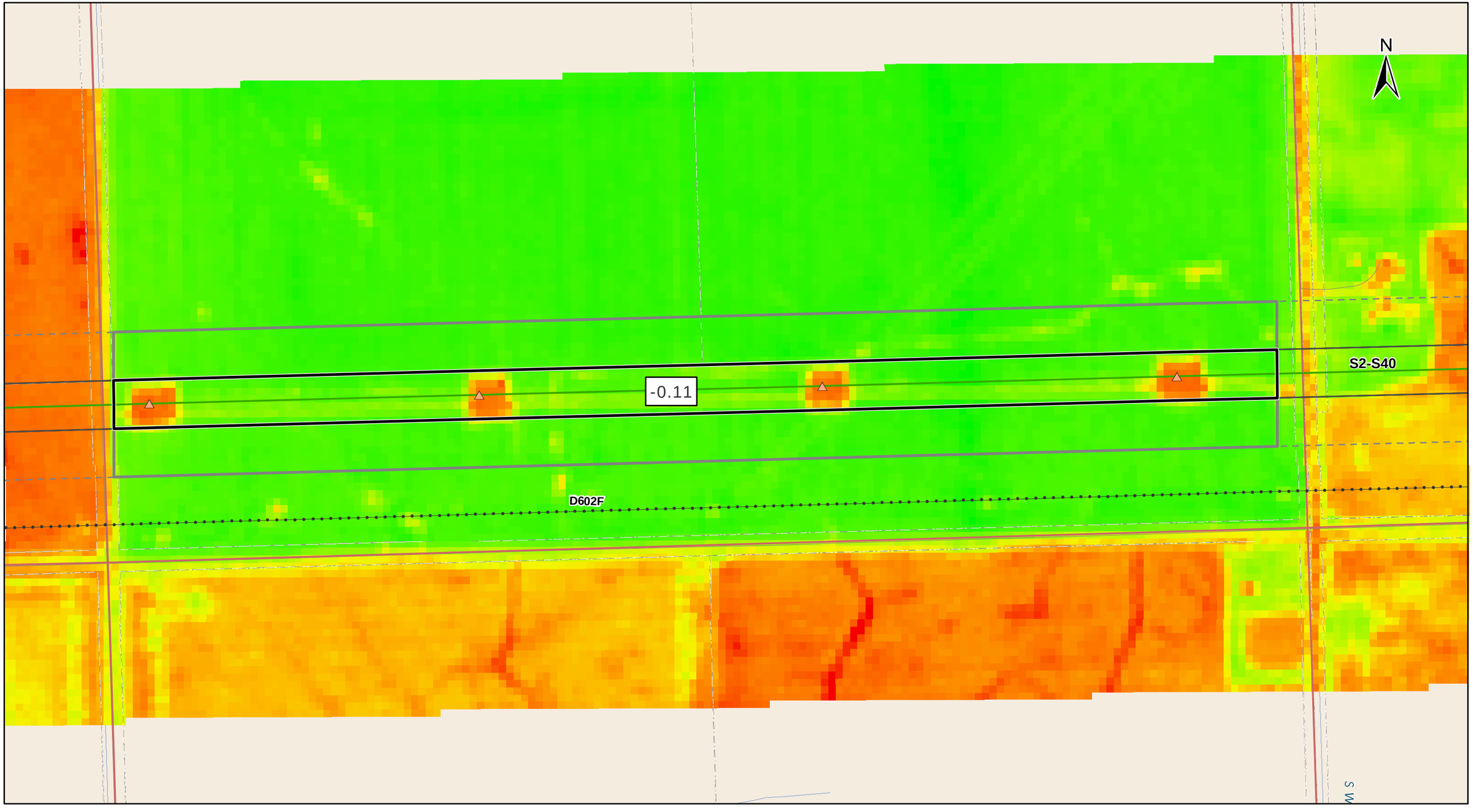

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, ProvMB, NRCAN, Stantec Consulting
Date Created: November 15, 2016

0 62.5 125 250
Metres
1:5,000

NDVI
Summer 2016
High : 1
Low : -1

NDVI Change Detection Analysis
- On ROW Polygons Used in NDVI Change Detection Analysis
- Off ROW Polygons Used in NDVI Change Detection Analysis
- ## Change in NDVI Between On and Off ROW Polygons

Project Infrastructure
- BPIII Final Preferred Route
- 66m ROW
- 66m Buffer of ROW
- Towers (Preliminary)

Landbase
- Major Road
- Transmission Line
- Parcel Fabric
- Watercourse

Bipole III Transmission Project

NDVI Change Detection at Section S2 - Segment S40 (S2-S40) Summer 2016

DRAFT

Map 4-6

4.0 CONCLUSIONS

The NDVI On RoW and Off RoW analysis demonstrated there has been minimal effect on NDVI values across the agricultural study area from 2015 to 2016, including when analyzing NDVI values by crop type in 2015 and by agricultural capability classes in 2015 and 2016. The NDVI analysis did determine negative outliers (or decrease in NDVI values) in 5 section segments (N4-S10, C2-S7, C2-S8, S1-S10 and S2-S23). Visual assessment was found to be effective in confirming land cover patterns in some instances where changes were detected and confirmed effects to NDVI values resulting from tower construction and construction activities/traffic between tower locations in 2016 in some fields (e.g., within S2-10, S2-S35 and S2-S40). The relative On RoW and Off RoW NDVI change detection methodology appears to be effectively identifying and delineating agricultural fields where soil productivity may be affected by construction activities. The Sentinel-2 data that became available in 2016 shows improvement in the ability to detect changes over the coarser scale Landsat-8 data.

5.0 RECOMMENDATIONS

The following recommendations are made to continue to improve the soil productivity monitoring program in subsequent years:

- In order to capture the effects of transmission tower construction on soil productivity, Stantec recommends analyzing the NDVI values of buffered tower locations and comparable agricultural field areas immediately adjacent to towers.
- Stantec will continue to analyze NDVI values on an entire RoW width basis to capture the construction effects to the entire RoW, as seen in S2-S10 (**Map 4-4**)
- To improve the ability to determine typical construction effects between towers, it is recommended that a narrower width be evaluated (e.g., 20 m) that would better isolate the typical areas where effects are occurring between towers. The newly available Sentinel-2 imagery is better able to evaluate a narrower width and effects of dilution from non-affected areas within the RoW would be reduced.

5.1 DATA NEEDS

The following data would assist Stantec in determining timing of construction across the project confirming baseline and construction years to support monitoring data analysis:

- Tower foundation location/footprint shapefiles or coordinates.
- Spatial files on key construction activity timelines, for example when major activities that may cause soil disturbance (geotechnical drilling, tower foundation installation, stringing) were undertaken by segment.
- NDVI analysis for 2017 will be conducted solely using Sentinel-2 satellite imagery with its 10 meter resolution.
- Sentinel-2B imagery will be available for the 2017 growing season reducing the repeat coverage period from 10 days to 5 days increasing the likelihood of cloud free imagery acquisition.

6.0 REFERENCES

AAFC, 2013. Overview of Classification Methodology for Determining Land Capability For Agriculture, Agriculture and Agri-Food Canada. May 31, 2013. http://sis.agr.gc.ca/cansis/nsdb/cli/classdesc.html.

Appendix A TABLES

Table A-1 Bipole III On/Off RoW Agricultural Extent NDVI Comparative Analysis by Section Segment for 2015

Bipole III Segment	L-8 2015 Summer			
	On	Off	Difference	Percent
N4-S08	0.427	0.445	-0.018	-0.88%
N4-S09	0.361	0.373	-0.013	-0.63%
N4-S10	0.309	0.322	-0.013	-0.65%
N4-S15	0.415	0.415	0.000	0.01%
N4-S16	0.467	0.434	0.033	1.66%
N4-S17	0.338	0.332	0.006	0.31%
N4-S19	0.404	0.410	-0.007	-0.33%
N4-S20	0.373	0.384	-0.012	-0.58%
N4-S21	0.329	0.323	0.006	0.31%
N4-S23	0.364	0.365	-0.001	-0.05%
N4-S24	0.503	0.502	0.002	0.08%
N4-S25	0.382	0.382	0.000	-0.01%
C1-S01	0.224	0.214	0.010	0.49%
C1-S02	0.204	0.203	0.001	0.04%
C1-S06	0.322	0.302	0.019	0.96%
C1-S07	0.128	0.136	-0.008	-0.39%
C1-S08	0.685	0.684	0.001	0.05%
C1-S09	0.653	0.643	0.010	0.49%
C1-S10	0.601	0.612	-0.012	-0.58%
C1-S11	0.523	0.530	-0.008	-0.38%
C1-S12	0.558	0.565	-0.007	-0.33%
C2-S1	0.681	0.715	-0.034	-1.70%
C2-S2	0.691	0.679	0.012	0.61%
C2-S3	0.630	0.662	-0.031	-1.57%
C2-S4	0.721	0.738	-0.017	-0.83%
C2-S5	0.792	0.823	-0.031	-1.56%
C2-S6	0.685	0.736	-0.052	-2.59%
C2-S7	0.746	0.817	-0.071	-3.54%
C2-S8	0.767	0.788	-0.021	-1.04%
C2-S9	0.639	0.653	-0.014	-0.68%
S1-01	0.710	0.726	-0.016	-0.80%
S1-02	0.854	0.840	0.014	0.68%
S1-03	0.736	0.766	-0.029	-1.47%
S1-04	0.645	0.647	-0.002	-0.12%
S1-05	0.759	0.737	0.022	1.12%
S1-06	0.836	0.839	-0.004	-0.18%

Table A-1 Bipole III On/Off RoW Agricultural Extent NDVI Comparative Analysis by Section Segment for 2015

Bipole III Segment	L-8 2015 Summer			
	On	Off	Difference	Percent
S1-07	0.767	0.810	-0.043	-2.15%
S1-08	0.769	0.798	-0.029	-1.47%
S1-09	0.855	0.848	0.008	0.38%
S1-S10	0.822	0.857	-0.035	-1.74%
S1-S14	0.935	0.936	-0.001	-0.06%
S1-S15	0.751	0.703	0.047	2.35%
S1-S16	0.794	0.823	-0.030	-1.48%
S1-S17	0.797	0.813	-0.016	-0.81%
S1-S18	0.827	0.829	-0.002	-0.09%
S1-S19	0.745	0.770	-0.025	-1.27%
S1-S20	0.893	0.876	0.017	0.83%
S1-S21	0.783	0.761	0.023	1.13%
S1-S22	0.784	0.795	-0.011	-0.56%
S1-S24	0.775	0.779	-0.004	-0.19%
S2-S01	0.768	0.794	-0.025	-1.25%
S2-S02	0.719	0.721	-0.002	-0.12%
S2-S03	0.796	0.802	-0.006	-0.30%
S2-S04	0.614	0.532	0.082	4.10%
S2-S05	0.754	0.691	0.064	3.18%
S2-S06	0.825	0.812	0.013	0.64%
S2-S07	0.881	0.873	0.008	0.39%
S2-S08	0.588	0.572	0.017	0.83%
S2-S09	0.777	0.816	-0.039	-1.95%
S2-S10	0.749	0.722	0.027	1.35%
S2-S12	0.644	0.630	0.015	0.74%
S2-S13	0.567	0.562	0.006	0.28%
S2-S15	0.582	0.570	0.012	0.59%
S2-S16	0.844	0.850	-0.006	-0.29%
S2-S18	0.928	0.932	-0.004	-0.21%
S2-S19	0.818	0.823	-0.005	-0.24%
S2-S21	0.778	0.760	0.018	0.90%
S2-S22	0.676	0.684	-0.008	-0.41%
S2-S23	0.916	0.922	-0.005	-0.27%
S2-S25	0.741	0.818	-0.077	-3.87%
S2-S26	0.818	0.851	-0.033	-1.66%
S2-S28	0.656	0.699	-0.043	-2.14%

Table A-1 Bipole III On/Off RoW Agricultural Extent NDVI Comparative Analysis by Section Segment for 2015

Bipole III Segment	L-8 2015 Summer			
	On	Off	Difference	Percent
S2-S29	0.765	0.777	-0.013	-0.63%
S2-S30	0.652	0.652	0.000	0.02%
S2-S31	0.784	0.780	0.004	0.18%
S2-S32	0.773	0.762	0.011	0.54%
S2-S34	0.404	0.400	0.004	0.21%
S2-S35	0.754	0.831	-0.077	-3.85%
S2-S36	0.845	0.875	-0.030	-1.51%
S2-S37	0.735	0.778	-0.043	-2.14%
S2-S38	0.833	0.810	0.023	1.15%
S2-S39	0.778	0.771	0.007	0.33%
S2-S40	0.773	0.775	-0.002	-0.09%
S2-S41	0.806	0.795	0.011	0.53%

Table A-2 Bipole III On/Off RoW Agricultural Extent NDVI Comparative Analysis by Section Segment for 2016

Bipole III Segment	L-8 2016 Summer				S-2 2016 Summer			
	On	Off	Difference	Percent	On	Off	Difference	Percent
N4-S08	0.432	0.445	-0.013	-0.66%	0.244	0.289	-0.045	-2.23%
N4-S09	0.433	0.390	0.044	2.19%	0.339	0.352	-0.013	-0.66%
N4-S10	0.396	0.381	0.015	0.75%	0.264	0.349	-0.085	-4.25%
N4-S15	0.495	0.488	0.007	0.37%	0.296	0.317	-0.021	-1.05%
N4-S16	0.478	0.418	0.060	2.99%	0.286	0.150	0.136	6.81%
N4-S17	0.509	0.509	0.000	-0.01%	0.192	0.216	-0.024	-1.20%
N4-S19	0.454	0.447	0.007	0.37%	0.257	0.255	0.002	0.12%
N4-S20	0.436	0.437	-0.001	-0.05%	0.312	0.351	-0.039	-1.94%
N4-S21	0.346	0.354	-0.008	-0.41%	0.253	0.249	0.004	0.20%
N4-S23	0.279	0.252	0.027	1.34%	0.305	0.273	0.032	1.61%
N4-S24	0.296	0.277	0.019	0.95%	0.298	0.246	0.052	2.61%
N4-S25	0.424	0.430	-0.007	-0.33%	0.680	0.693	-0.012	-0.62%
C1-S01	0.370	0.414	-0.045	-2.24%	0.723	0.738	-0.014	-0.72%
C1-S02	0.396	0.395	0.000	0.01%	0.501	0.509	-0.007	-0.37%
C1-S06	0.476	0.471	0.006	0.29%	0.628	0.633	-0.006	-0.28%
C1-S07	0.321	0.335	-0.014	-0.71%	0.518	0.543	-0.025	-1.27%
C1-S08	0.401	0.404	-0.003	-0.16%	0.587	0.599	-0.013	-0.63%
C1-S09	0.444	0.438	0.006	0.32%	0.620	0.650	-0.030	-1.52%
C1-S10	0.364	0.361	0.003	0.14%	0.556	0.549	0.006	0.31%
C1-S11	0.331	0.326	0.005	0.27%	0.515	0.527	-0.012	-0.59%
C1-S12	0.371	0.371	-0.001	-0.03%	0.504	0.531	-0.027	-1.36%
C2-S1	0.482	0.423	0.060	2.98%	0.670	0.695	-0.025	-1.24%
C2-S2	0.313	0.301	0.011	0.57%	0.363	0.386	-0.023	-1.15%
C2-S3	0.341	0.357	-0.016	-0.78%	0.572	0.623	-0.051	-2.54%
C2-S4	0.380	0.410	-0.030	-1.50%	0.584	0.607	-0.023	-1.15%
C2-S5	0.821	0.804	0.017	0.85%	0.620	0.632	-0.012	-0.61%
C2-S6	0.774	0.772	0.002	0.10%	0.558	0.583	-0.025	-1.24%
C2-S7	0.806	0.827	-0.021	-1.06%	0.507	0.634	-0.127	-6.34%
C2-S8	0.738	0.776	-0.038	-1.90%	0.388	0.612	-0.224	-11.21%
C2-S9	0.763	0.775	-0.012	-0.58%	0.530	0.564	-0.034	-1.70%
S1-01	0.796	0.797	0.000	-0.01%	0.535	0.553	-0.018	-0.91%
S1-02	0.849	0.845	0.004	0.22%	0.707	0.711	-0.004	-0.22%
S1-03	0.531	0.533	-0.002	-0.10%	0.649	0.653	-0.004	-0.18%
S1-04	0.716	0.720	-0.003	-0.17%	0.483	0.491	-0.008	-0.38%
S1-05	0.721	0.689	0.032	1.59%	0.631	0.620	0.012	0.59%
S1-06	0.792	0.771	0.021	1.06%	0.507	0.510	-0.003	-0.14%

Table A-2 Bipole III On/Off RoW Agricultural Extent NDVI Comparative Analysis by Section Segment for 2016

Bipole III Segment	L-8 2016 Summer				S-2 2016 Summer			
	On	Off	Difference	Percent	On	Off	Difference	Percent
S1-07	0.746	0.728	0.019	0.93%	0.573	0.565	0.008	0.41%
S1-08	0.625	0.576	0.049	2.45%	0.566	0.619	-0.053	-2.63%
S1-09	0.641	0.639	0.002	0.10%	0.656	0.668	-0.012	-0.59%
S1-S10	0.782	0.882	-0.099	-4.97%	0.354	0.437	-0.083	-4.14%
S1-S14	0.951	0.942	0.009	0.45%	0.347	0.346	0.000	0.02%
S1-S15	0.762	0.753	0.009	0.43%	0.562	0.564	-0.002	-0.08%
S1-S16	0.793	0.804	-0.011	-0.55%	0.515	0.517	-0.002	-0.08%
S1-S17	0.826	0.825	0.001	0.05%	0.686	0.652	0.034	1.69%
S1-S18	0.725	0.764	-0.039	-1.93%	0.661	0.682	-0.021	-1.05%
S1-S19	0.794	0.761	0.032	1.62%	0.449	0.449	0.001	0.03%
S1-S20	0.818	0.810	0.008	0.39%	0.534	0.544	-0.010	-0.49%
S1-S21	0.835	0.839	-0.004	-0.20%	0.502	0.518	-0.016	-0.81%
S1-S22	0.809	0.814	-0.006	-0.28%	0.426	0.416	0.010	0.49%
S1-S24	0.814	0.806	0.008	0.38%	0.460	0.430	0.029	1.47%
S2-S01	0.906	0.908	-0.002	-0.08%	0.713	0.703	0.010	0.49%
S2-S02	0.778	0.794	-0.016	-0.79%	0.378	0.379	-0.001	-0.05%
S2-S03	0.772	0.774	-0.002	-0.09%	0.499	0.513	-0.014	-0.71%
S2-S04	0.767	0.736	0.031	1.54%	0.564	0.545	0.020	0.98%
S2-S05	0.758	0.743	0.014	0.71%	0.676	0.625	0.052	2.60%
S2-S06	0.764	0.763	0.001	0.04%	0.388	0.390	-0.002	-0.09%
S2-S07	0.762	0.717	0.045	2.27%	0.422	0.412	0.009	0.47%
S2-S08	0.852	0.848	0.004	0.21%	0.376	0.360	0.016	0.78%
S2-S09	0.790	0.821	-0.030	-1.51%	0.459	0.438	0.021	1.05%
S2-S10	0.827	0.859	-0.032	-1.61%	0.454	0.446	0.008	0.42%
S2-S12	0.871	0.876	-0.005	-0.27%	0.287	0.284	0.002	0.12%
S2-S13	0.920	0.910	0.010	0.51%	0.320	0.288	0.032	1.59%
S2-S15	0.919	0.919	-0.001	-0.04%	0.302	0.306	-0.004	-0.19%
S2-S16	0.832	0.822	0.010	0.52%	0.546	0.534	0.012	0.61%
S2-S18	0.911	0.909	0.002	0.10%	0.416	0.402	0.014	0.70%
S2-S19	0.878	0.905	-0.026	-1.32%	0.512	0.479	0.033	1.66%
S2-S21	0.826	0.879	-0.052	-2.62%	0.359	0.372	-0.013	-0.64%
S2-S22	0.845	0.847	-0.002	-0.11%	0.544	0.533	0.011	0.55%
S2-S23	0.698	0.704	-0.006	-0.32%	0.477	0.553	-0.077	-3.84%
S2-S25	0.845	0.792	0.052	2.61%	0.683	0.692	-0.009	-0.46%
S2-S26	0.788	0.804	-0.016	-0.80%	0.811	0.807	0.004	0.19%
S2-S28	0.741	0.727	0.015	0.73%	0.572	0.584	-0.012	-0.60%

Table A-2 Bipole III On/Off RoW Agricultural Extent NDVI Comparative Analysis by Section Segment for 2016

Bipole III Segment	L-8 2016 Summer				S-2 2016 Summer			
	On	Off	Difference	Percent	On	Off	Difference	Percent
S2-S29	0.787	0.786	0.000	0.02%	0.692	0.696	-0.004	-0.18%
S2-S30	0.645	0.611	0.034	1.71%	0.817	0.841	-0.024	-1.18%
S2-S31	0.856	0.855	0.001	0.03%	0.566	0.571	-0.006	-0.28%
S2-S32	0.833	0.830	0.004	0.19%	0.558	0.557	0.001	0.04%
S2-S34	0.882	0.886	-0.004	-0.22%	0.485	0.508	-0.023	-1.16%
S2-S35	0.785	0.797	-0.012	-0.59%	0.541	0.566	-0.025	-1.25%
S2-S36	0.754	0.757	-0.003	-0.17%	0.543	0.561	-0.019	-0.93%
S2-S37	0.747	0.778	-0.031	-1.57%	0.552	0.591	-0.039	-1.97%
S2-S38	0.538	0.591	-0.053	-2.63%	0.236	0.244	-0.007	-0.37%
S2-S39	0.808	0.750	0.058	2.92%	0.358	0.345	0.014	0.68%
S2-S40	0.752	0.766	-0.014	-0.71%	0.466	0.491	-0.025	-1.23%
S2-S41	0.802	0.824	-0.022	-1.10%	0.210	0.219	-0.009	-0.45%

Appendix B MAPS

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Available in accessible formats upon request