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Improving the Quality of ECDA Indirect Inspection Data

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ABSTRACT

The quality of the indirect inspection data is a critical factor in conducting a successful ECDA. It is therefore essential to increase the accuracy of the field data collection, to improve the data processing and to effectively present the results. This paper describes several challenges faced during this continuous improvement process.

Techniques for obtaining accurate field data for assessing the risk of AC corrosion are reviewed.

Data processing considerations are presented in the context of a case of third-party damage. The implications for similar DCVG indications on the same line are discussed, and a mechanism for these “apparent” DCVG indications is presented.

A new format for displaying the data is also presented, allowing a better visual co-ordination between the indications and the site features, as well as allowing immediate assessment of the proposed locations for direct examinations in terms of access and other challenges.

Key words: External Corrosion Direct Assessment (ECDA), Close Interval Potential Survey (CIPS), Direct Current Voltage Gradient (DCVG), AC corrosion (ACC), DC interference, “apparent” DCVG indications.

INTRODUCTION

The quality of the indirect inspection data is a critical factor in conducting a successful ECDA. Decisions made based on false indications can result in high cost excavations at the wrong locations, while missed severe indications can result in an immediate threat to pipeline integrity.

It is therefore essential to increase the accuracy of the field data collection, to improve the data processing and to effectively present the results.

This paper describes several challenges faced during this continuous improvement process.

ASSESSING THE RISK OF AC CORROSION DURING THE ECDA PROCESS

An ECDA process was conducted in 2005 on a NPS8 gas pipeline in southern Ontario. The pipeline parallels HVAC power lines for almost its entire length. With increased awareness in the industry regarding the risk of AC corrosion, the standard ECDA procedure was extended to include AC corrosion (ACC) indications.

The soil resistivity was measured at the test posts using the 4-pin Wenner method. The survey results are shown in Table 1.

Table 1
Soil Resistivity Data

Chainage (m)	Soil Resistivity ρ_a (Ω-cm)			Notes
	@ 1.5 m	@ 3.0 m	@ 4.5 m	
0.0	8500	4600	4000	TB1
789.3	4300	4000	4000	TB2
1302.8	9290	13980	10920	TB3
2606.2	8800	14000	18000	TB5
3003.4	1450	2700	3750	TB6
4671.3	3350	3650	2300	TB8
5181.1	7600	3600	3200	TB9
5575.7	4500	2300	2800	TB10
6208.5	8600	8600	9200	TB11

AC induced voltages were measured to near earth at the test posts. The data were used in conjunction with the soil resistivity data to calculate the AC current density on a circular holiday having a critical surface area[(1)] of 1 cm^2:

$$i_{ac} = \frac{8 \times V_{ac}}{\pi \times d \times \rho} \tag{1}$$

where:
i_{ac} = Induced AC current density (A/m^2)
V_{ac} = Induced AC voltage (V)
d = Holiday diameter (m)
ρ = Soil resistivity (Ω-m)

[(1)] The risk of AC corrosion increases when the size of the holiday decreases, due to higher current density, however the risk of AC corrosion decreased when the size of the holiday was less than 1 cm^2 (i.e., 0.0113 m).

The AC induced voltages and the calculated AC current densities are shown in Table 2

Table 2
AC Induced Voltage and AC Current Densities

Chainage (m)	AC Voltage (V)	AC Current Density (A/m^2)	Notes
0.0	10.1	26.8	TB1
789.3	13.6	71.3	TB2
1302.8	10.2	24.7	TB3
2606.2	4.3	11.0	TB5
3003.4	1.6	24.9	TB6
4671.3	5.5	37.0	TB8
5181.1	9.4	27.8	TB9
5575.7	5	25.0	TB10
6208.5	4.9	12.9	TB11

According to literature[1], there is no risk of AC corrosion for AC current densities less than 20 A/m^2, AC corrosion is unpredictable for AC current densities between 20-100 A/m^2 and AC corrosion is to be expected for AC current densities greater than 100 A/m^2.

Subsequently, the identification criterion for ACC indications was conservatively set at 20 A/m^2 and the classification criteria were established as follows:

- Minor: AC current density less than or equal to 50 A/m^2
- Moderate: AC current density higher than 50 A/m2 and less than 100 A/m^2
- Severe: AC current density more than 100 A/m^2

The data from Table 2 were further analyzed considering the attenuation along the pipeline and it was estimated that under the worst case scenario (i.e. 1 cm^2 holidays), the pipe would display moderate ACC indications at minor or below-threshold DCVG indications from chainage 400.0 m to chainage 1200.0 m. From chainage 0.0 m to chainage 400.0 m and from chainage 1200.0 m to chainage 6000.0, the ACC indications were classified as minor.

In terms of prioritization, ACC indications in conjunction with moderate and severe DCVG indications were not prioritized, since the current densities were calculated on a 1 cm^2 holiday, while the bare area associated with moderate and severe DCVG indications is orders of magnitude larger. Severe ACC indications in conjunction with minor or below-threshold DCVG indications were prioritized as Immediate Action Required.

Ultimately, 11 indications were prioritized as “Scheduled Action Required”, all located in the same ECDA region, resulting in a total of only four direct examination digs.

The same basic approach was successfully applied for the next 10 years, with no missed AC corrosion pitting and one direct examination finding minor pitting attributed to AC corrosion at a minor ACC indication.

Although the technical approach remained the same, the techniques in obtaining and processing the data have gradually improved. Initially, the AC current density was calculated using the apparent resistivity measured at pipe depth. Today, the soil resistivity data at possible ACC indications are processed using the appropriate software to obtain the resistivities per layer. As more soil resistivities become available from AC mitigation, cathodic protection and other ECDA projects, the limits of the areas affected by ACC indications were more precisely defined, including the limits of each classification category.

Waveforms collected as part of the influence testing were analyzed to obtain the 60 Hz component, providing a better assessment of the variation of the induced voltages with the powerline loading. More recently, the survey procedure was modified to use 24-hour recording of the AC voltage at each test post instead of just measuring an instant value.

Despite these improvements, there are limits in the accuracy of an ACC assessment based on data collected during the indirect inspections. Both the AC and DC current density depend on the spread resistance (i.e., the actual resistance of the holiday), which may be different by orders of magnitude from the calculated resistance based on the holiday diameter and the measured soil resistivity. Usually, the spread resistance is higher due to the calcareous deposit formed at the holiday on a well cathodically protected pipeline, but in extremely rare occasions it could be significantly lower. Furthermore, new research indicates a threshold of 30 A/m^2 for AC current density instead of 20 A/m^2. This threshold increases significantly when the DC current density is maintained below 1 A/m^2.

These limitations typically result in a conservative approach, with minimum increase in the number of digs. However, any ACC indications in areas prone to low spread resistance, such as swamps, ditches exposed to deicing salts, etc.) require special attention, including installation of AC coupons to validate the assessment.

It is expected that the introduction on a larger scale of AC coupons, allowing to actually record both the AC and DC current densities, as well as the use of ER probes would allow to better assess the risk of AC corrosion. However, despite all the improvements, the line is not guaranteed to be “safe” from AC corrosion, as it would be for conventional indications.

DEALING WITH “APPARENT” DCVG INDICATIONS

A lateral DCVG survey was conducted in 2007 on a NPS8 gas pipeline in southern Ontario, as part of the ECDA program. The pipeline parallels a distribution powerline along part of its route.

The line displayed only one DCVG indication at chainage 9216.8 m (18.6%IR), as shown in Figure 1.

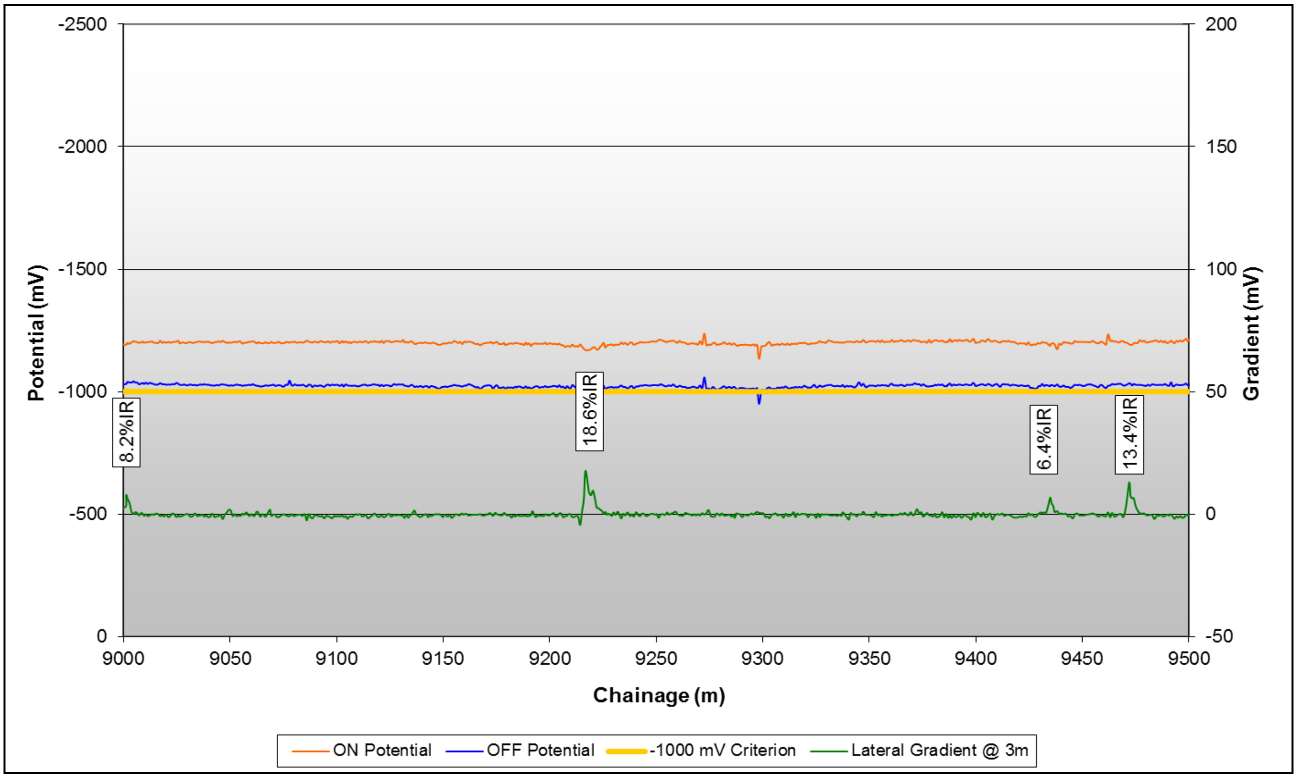

Figure 1: Ch. 8769 0 m to 9000 0 m. CIPS/DCVG Survey Results

Five more DCVG indications were classified as below-threshold and reported in conjunction with minor ACC indications. All coating defects are plotted in terms of %IR and severity limits in Figure 2.

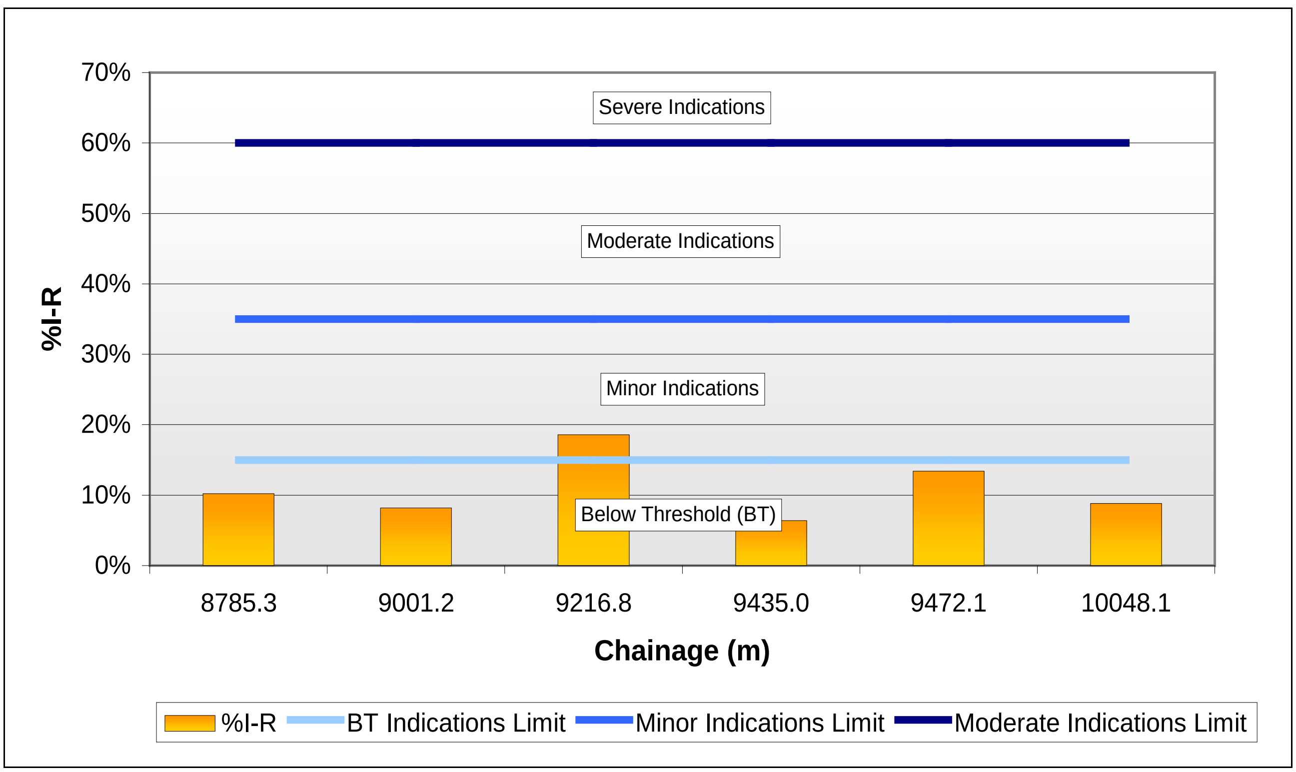

Figure 2: %IR Severity Index for Coating Defects

All the indications were prioritized as “Suitable for Monitoring” and with no indications prioritized as “Immediate Action Required” or “Scheduled Action Required”, a minimum of four direct examinations (DE) were selected, according to Paragraphs 5.3.1.1 and 6.7.2.1 of NACE Standard SP0502-2010[2].

During a first attempt to conduct the direct examinations, the digs could not be completed because the direct examination sites were located at hydro poles. Finally, the direct examinations were performed after three hydro poles were relocated.

Third-party damage was found at the location of the direct examination site #3 (chainage 10048.1 m). The factory applied coating had been damaged by an auger during the installation of the hydro pole, causing severe abrasion extending to the metal surface and resulting in three extensive holidays, as shown in Figures 3 to 5.

Figure 3: DE#3. Third-Party Coating Damage. Holiday #1

Figure 4: DE#3. Third-Party Coating Damage. Holiday #2

Figure 5: DE#3. Third-Party Coating Damage. Holiday #3

Except for the third-party damage, the coating at all dig sites was found in good condition, with superficial defects and no bare metal exposed to soil, as shown in Figure 6.

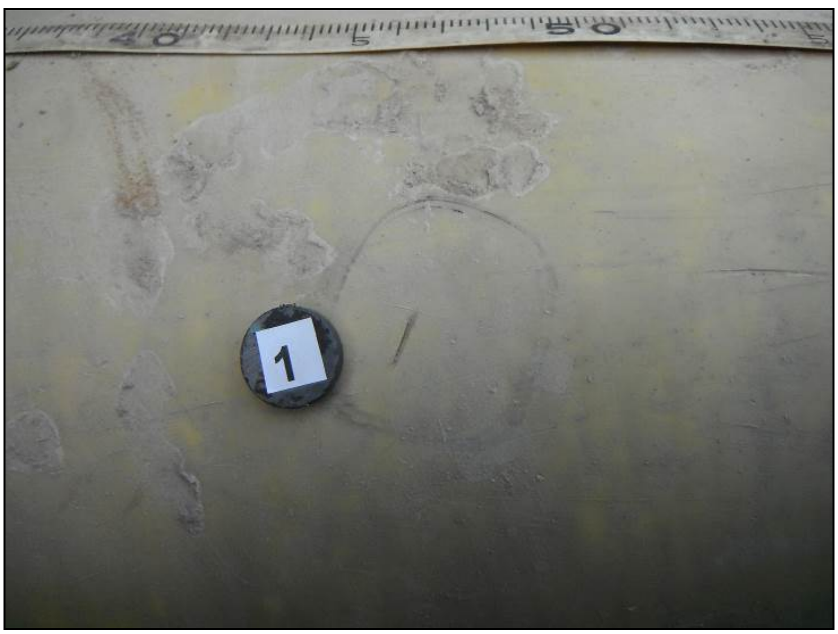

Figure 6: Sample of Superficial Defect at DE#2

However, the lateral gradient profiles at DE#1 and DE#2 clearly indicate holidays with 18.6%IR and 8.8%IR, respectively.

In order to explain the reason for these “apparent” DCVG indications, both the survey data and the direct examination information were revisited to detect any possible anomaly.

A buried grounding rod at a hydro pole was identified in one of the photographs showing the open excavation, as shown in Figure 7. Note that this hydro pole had been relocated prior to this excavation.

Figure 7: DE#2 Open Trench. Looking South. Buried Grounding Rod

The grounding rods were interconnected via the fourth wire of the hydro line, as seen in Figure 8.

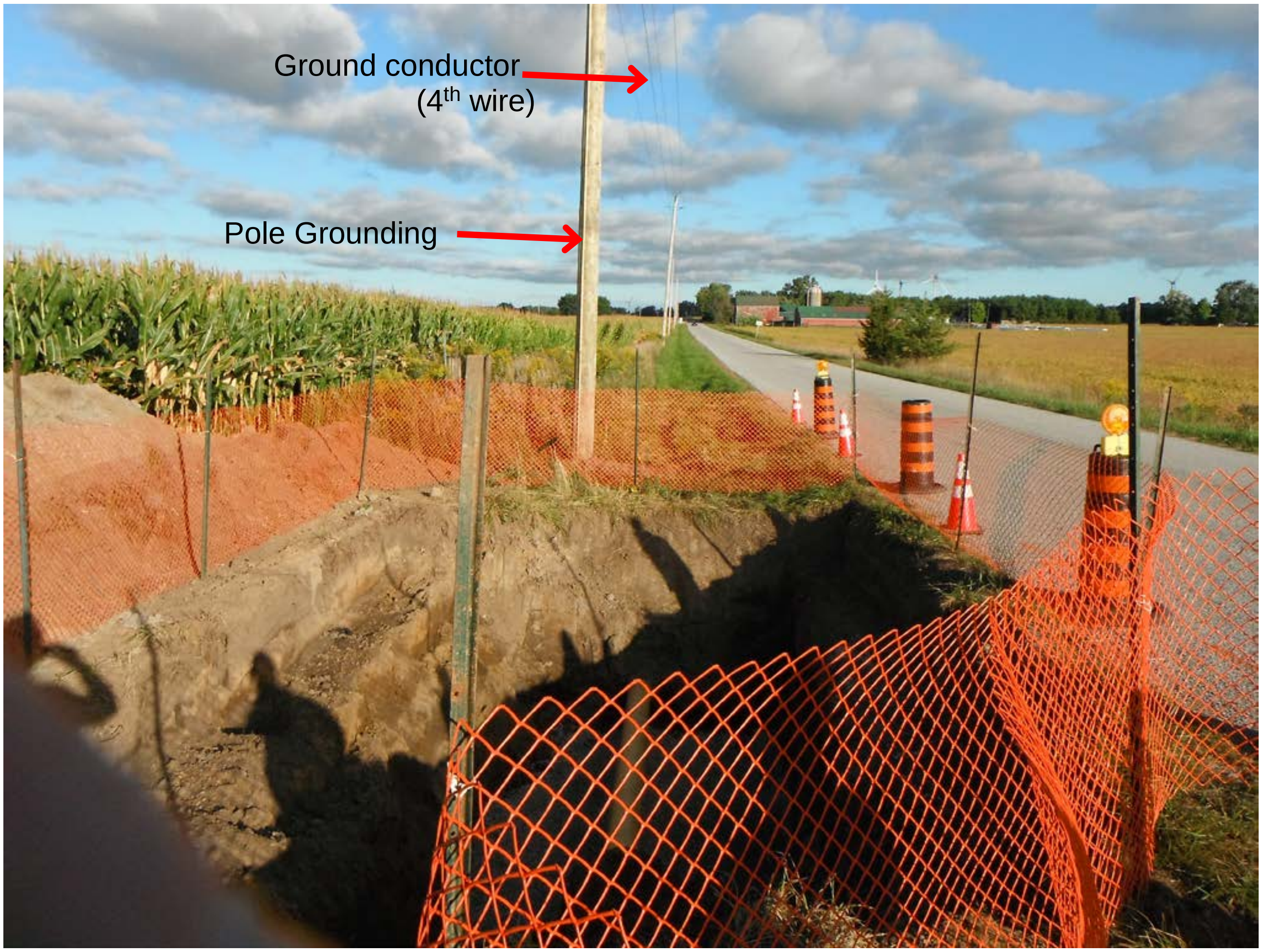

Figure 8: DE#1 Open Trench. Looking North. Powerline Ground Conductor and Pole Grounding

Based on this additional information, the “apparent” DCVG indications were attributed to DC interference on the grounding rods. Cathodic protection currents were picked up by grounding rods close to the groundbeds, travelled via the ground conductors and were discharged at grounded poles located in the immediate proximity of the pipeline. This interpretation was confirmed by the fact that all the hydro poles with grounding (e.g. at transformers), and no other hydro poles, exhibited this behavior.

IMPROVING THE PRESENTATION OF INDIRECT INSPECTIONS RESULTS

A clear and efficient presentation of the indirect inspection results is an essential factor in data analysis and ultimately in selecting the most appropriate locations for direct examinations.

Just plotting the aligned CIPS and DCVG data on the same graph helps identifying and validating indications. For example, a drop in the ON potential in conjunction with an increase in the lateral gradient would always point to a coating holiday, as shown in Figure 9, reproduced from a previous presentation[3].

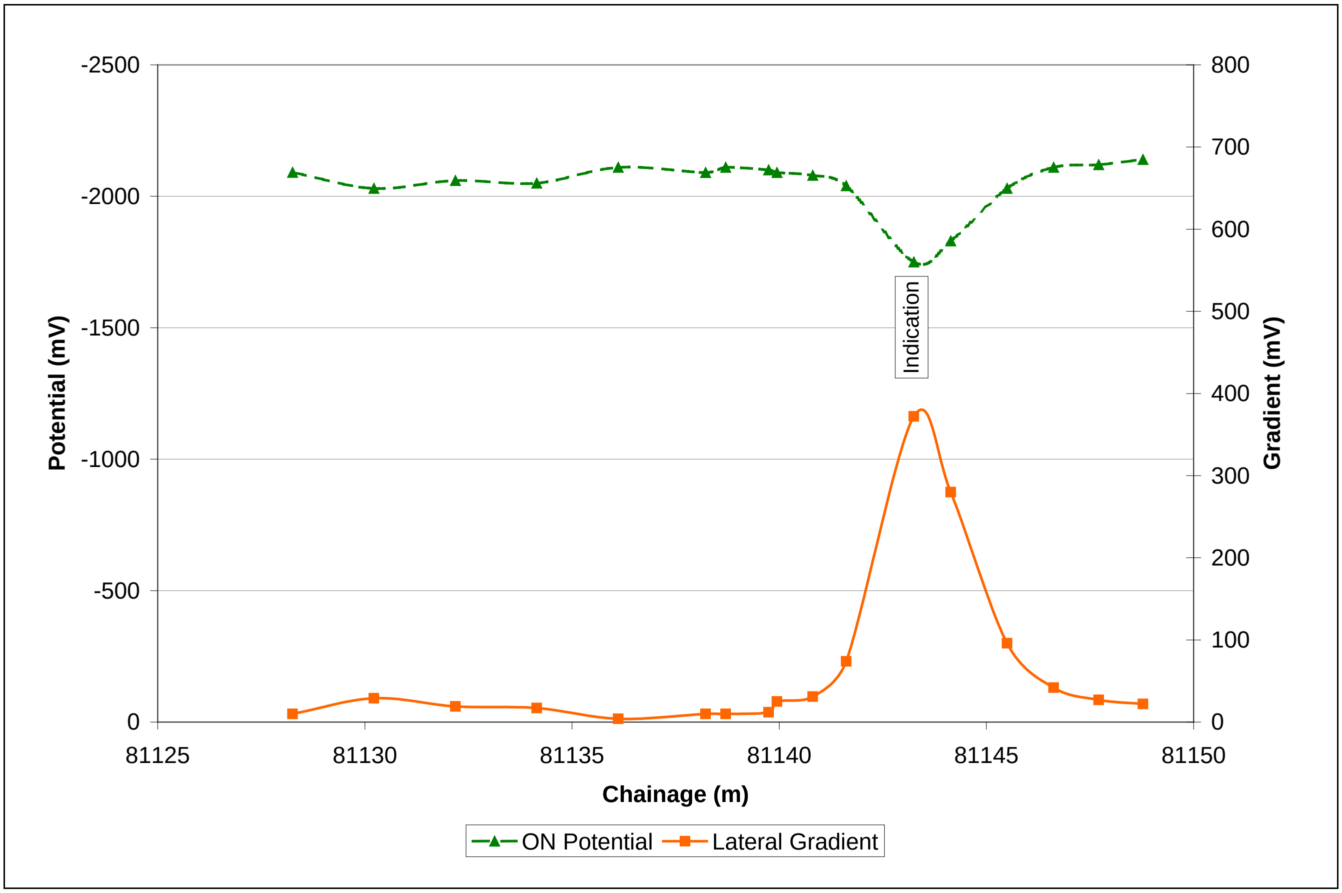

Figure 9: NPS16 Pipeline. 2004 CIPS/DCVG Integrated Survey Data

Similarly, an increase in the OFF potential in conjunction with an increase in the lateral gradient (see Figure 10) typically indicates a magnesium anode, but it also may be result of a holiday discharging equalization current, as discussed in a previous paper[4].

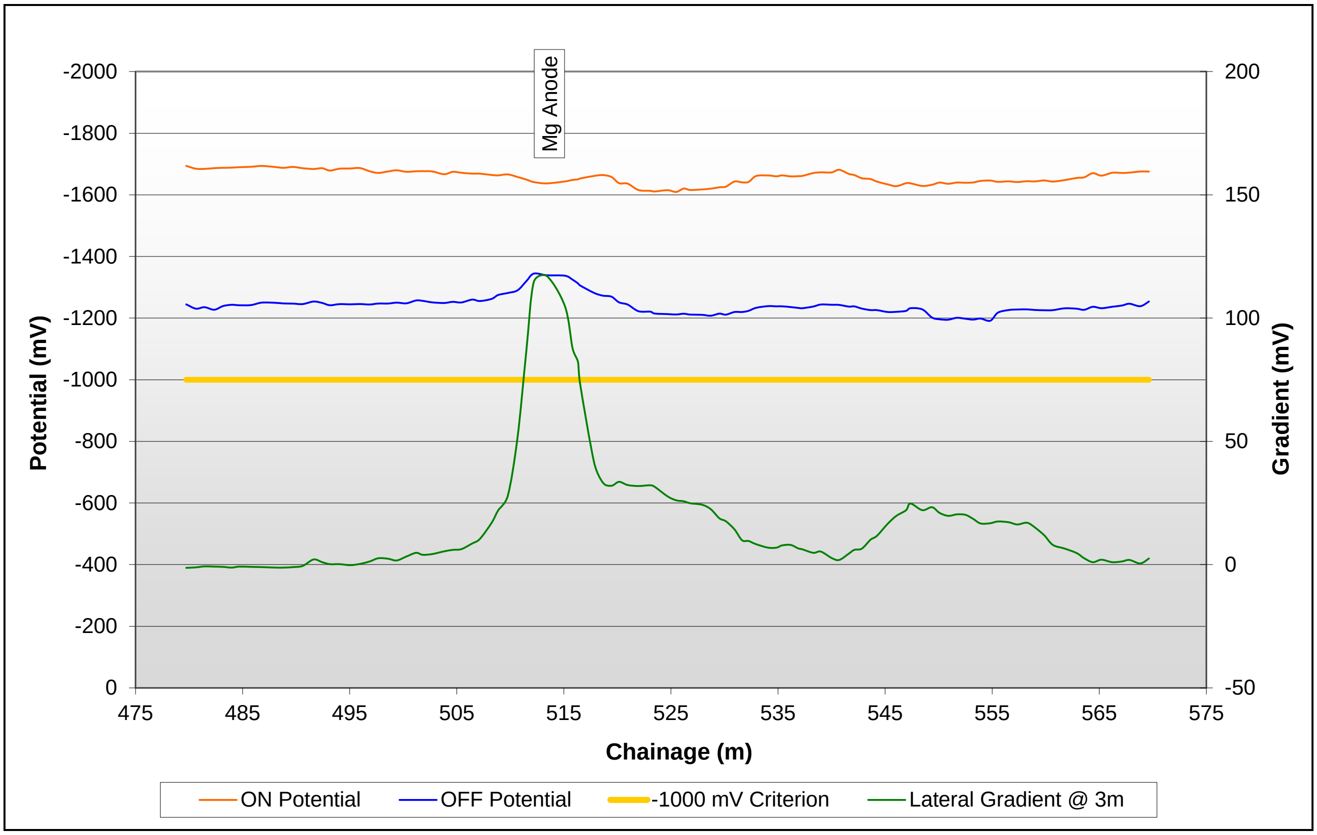

Figure 10: Typical Profile of an Active Magnesium Anode

Although plotting CIPS and DCVG data on the same graph facilitates data analysis, it provides only a limited amount of useful information. The exact location of the indication, the type of terrain, the presence of other features, as well as the access for direct examinations cannot be represented in a simple graph display.

Subsequently, a new form of indirect inspections data presentation was introduced as part of the continuous improvement of the ECDA process.

In the new format, aligned CIPS and DCVG data, as well as the pipe elevation, are displayed on aerial maps, similar to pipeline alignment sheets, as shown in Figure 11.

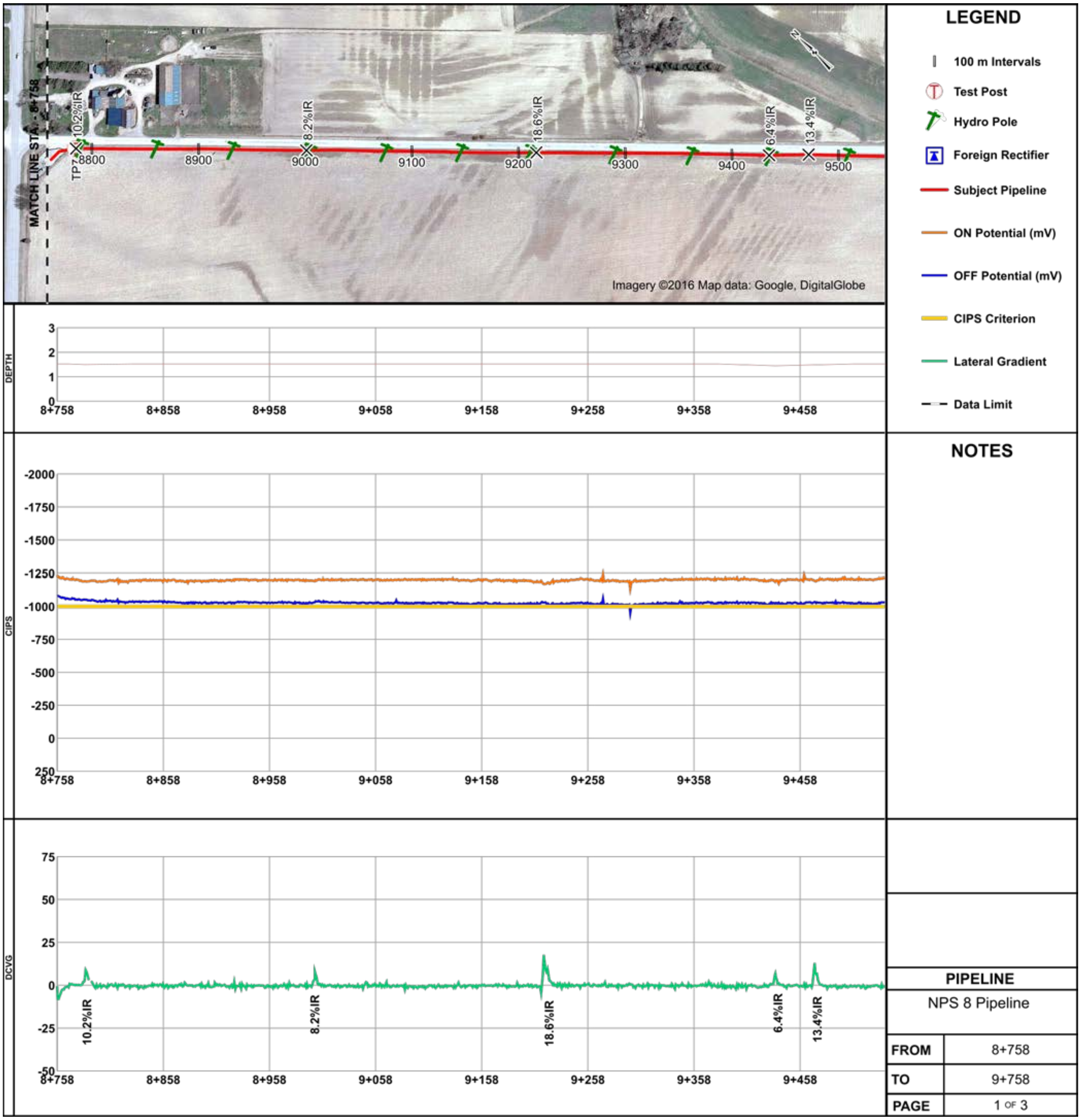

Figure 11: Ch. 8758 0 m to 9758 0 m. CIPS/DCVG Survey Results (New Format)

For comparison, Figure 11 displays the same survey data resulting in “apparent” DCVG indications as Figure 1. However, now the Hydro poles may be easily identified at the indication locations, as well as the road crossings, the type of terrain, the elevation, and the risks associated with excavating at the poles for direct examinations. The impressed current foreign rectifier responsible for the DC interference on the powerline grounding rods appears in the last graph (see Figure 12).

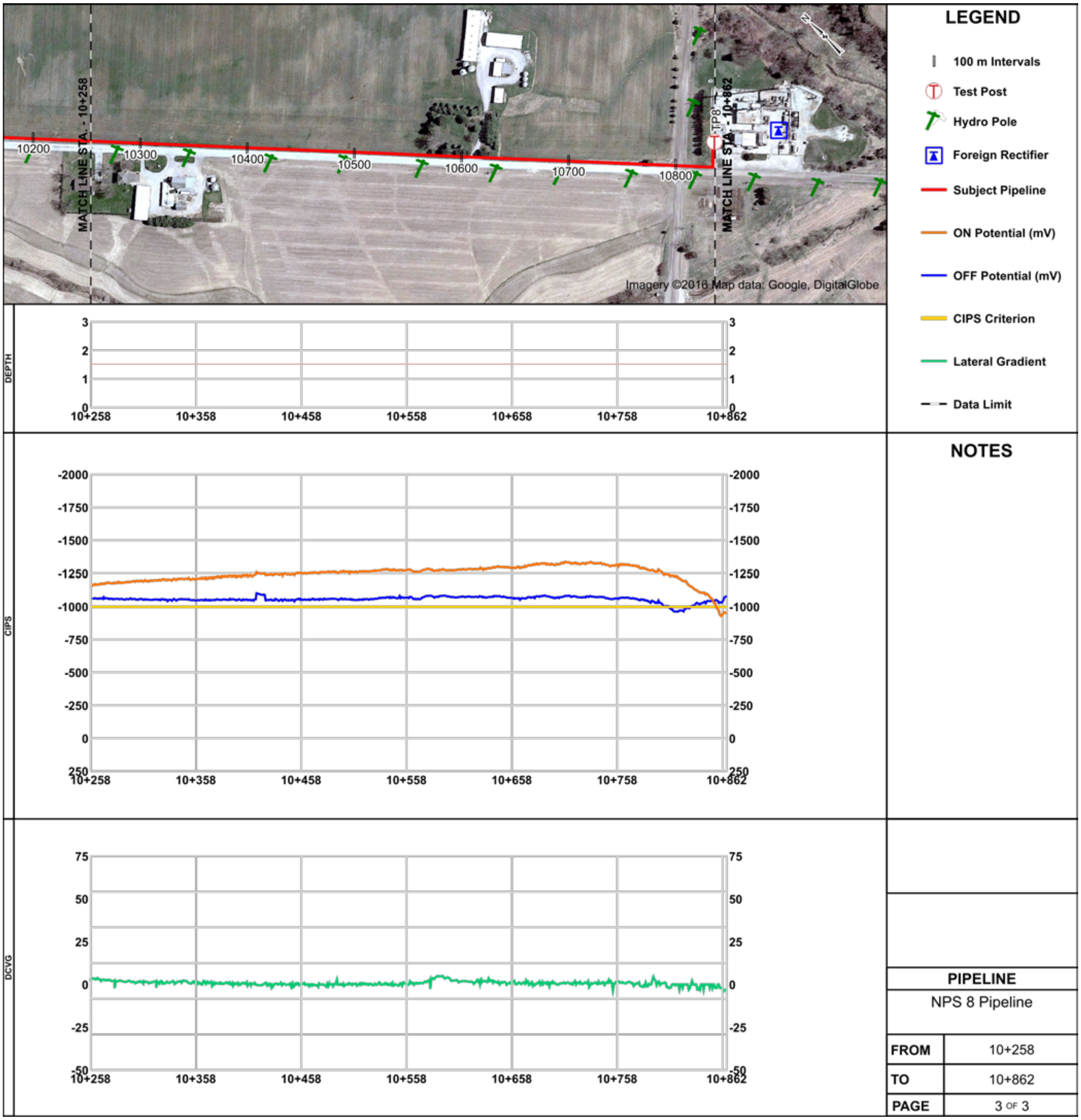

Figure 12: Ch. 10258 0 m to 10862 0 m. CIPS/DCVG Survey Results (New Format)

It is expected that the new format will be further improved and will become an important tool in both the analysis and presentation of the indirect inspection data.

CONCLUSIONS

Three challenges related to continuous improvement of the ECDA process were presented in this paper.

The first challenge was to address the risk of AC corrosion based on the limited amount of data obtained from the indirect inspections. An assessment method based on calculated AC current densities using measured soil resistivities and recorded AC voltages at test stations was successfully used for more than 10 years and continues to be improved. It is important to emphasize that despite the excellent record and the continuous improvement, there are limits in the accuracy of a field-based ACC assessment.

The second challenge was addressing "apparent" DCVG indications, clearly displayed on the integrated CIPS/DCVG survey graph but that cannot be identified during the direct examinations. An in-depth review of all the available survey and direct examination information, attributed the lateral gradients at the "apparent" DCVG indications to were attributed to DC interference on the grounding rods. Cathodic protection currents were picked up by grounding rods close to the groundbeds, travelled via the ground conductors and were discharged at grounded poles located in the immediate proximity of the pipeline.

The third challenge was related to improving the presentation of the indirect inspection data. In the new format, aligned CIPS and DCVG data, as well as the pipe elevation, are displayed on aerial maps, similar to pipeline alignment sheets. Additional information such as exact location of the indication, the type of terrain, the presence of other features, as well as the access for direct examinations is clearly displayed in conjunction with the regular CIPS and DCVG graphs.

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