APA Group

Amadeus Gas Pipeline

Pipeline Licence 004

Cathodic Protection Survey 2014

Document Status				
Rev	**Comment**	**Author**	**Review**	**Approved**
A	Draft	BP	SP	

TABLE OF CONTENTS

1 INTRODUCTION

APA Group (NT) conducted a cathodic protection survey of the Amadeus Gas Pipeline (AGP) and its associated laterals and spur lines in 2014. The southern section, from Palm Valley to Newcastle Waters including the Mereenie, Tennant Creek and Elliott laterals, was completed between May and June. The Northern section, from Newcastle Waters to Channel Island including the Katherine lateral, was completed between July and September.

Past experience has shown that the AGP is subject to the influences of telluric activity. It is industry consensus that pipelines subjected to telluric activity are likely to lead to unreliable On/Off pipe to soil potential measurements. APA Group (NT) has a program of using data logging to quantify and evaluate the actual level of telluric influence and pipeline protection. The program allows for the full pipeline length to be evaluated.

2 BACKGROUND

The AGP was commissioned in 1986. The pipeline has an outer protective coating of SHAW yellow jacket with impressed current Cathodic Protection Units (CPU) and sacrificial anodes providing external corrosion mitigation.

Tennant Creek, Elliott, Katherine and Channel Island laterals are protected by the mainline cathodic protection system by being electrically bonded to the AGP mainline.

The AGP is over 1600 km in length, the mainline and laterals are constructed as follows:

- 1110 km 355.6 mm OD mainline from Palm Valley to Mataranka
- 402 km 323.9 mm OD mainline from Mataranka to Channel Island
- 116 km 273.1 mm OD spur line from Mereenie to Tylers Pass
- 23.7 km 114.3 mm OD lateral to Tennant Creek
- 3.8 km 60.3 mm OD lateral to Elliott (Pipeline License 10)
- 5.4 km 114.3 mm OD lateral to Katherine

The AGP (excluding Darwin City Gate to Channel Island) has 28 CPUs providing the protective cathodic current. It is electrically isolated at KP161, KP316.1, KP458.1, KP610.8, KP733.7, KP981.8 and KP1107.9, KP1242.7 and KP1377.6 with the Mereenie spur line electrically isolated from the mainline at KP45.7. A CP Schematic is shown in Appendix A. CP test points are spaced approximately every two kilometers. The pipework at all scraper and metering stations is electrically earthed for safety reasons. The stations are also electrically isolated from the mainline by insulating flanges or monolithic insulating joints.

Unless stated otherwise, all impressed current Cathodic Protection Units (CPUs) are set to control the pipe to soil potential such that the Off potential is at -1200mV, but the On potential is not more negative than -2000mV.

The mainline is protected from high transient voltages caused by lightning or fault conditions on power lines by explosion proof surge diverters installed across the insulating joints and via polarisation cells and earth beds in series with the mainline. Additionally, lightning protection is provided at each CPU.

In 2004, a number of CP upgrades were identified for the AGP. This study drove the CP Upgrade Stage 1 project which was completed in 2008. This project consisted of the installation of additional CPUs, additional resistance probes and a new anode bed at KP1506.

In 2009, a CP consultant (Geoff Cope and Associates) conducted a review on the AGP CP system. The main purpose of this review was to refine the scope of works for CP Upgrade Stage 2. This project came near to practical completion in 2013 and included the installation of nine new CPUs and seven new ground beds. Surge diverters were installed across all MIJ's and 46 new electrical resistance probes were installed. Some final commissioning works are still needed particularly to establish telemetry and SCADA interfacing at some sites. A study of the levels of AC voltage induced onto the AGP was completed as part of the CP Upgrade Stage 2 project. As a result the project will be extended to implement gradient rings and enclosed test point heads in locations where large levels of AC was measured and/or calculated on the pipeline.

3 PROTECTION CRITERIA

The relevant protection criteria are determined from the following standards:

- AS 2885.3 – 2012 "Pipelines-Gas and liquid petroleum, Part 3: Operation and maintenance"
- AS 2832.1 – 2004 "Corrosion protection of metals, Part 1: Pipes and cables", in particular sections 2.2.2.2, 2.2.4.2 and 2.2.2.6(b)

Sulphate-reducing bacteria are known to exist along the Darwin City Gate to Channel Island section of the pipeline. Along this section, the aim is to maintain a potential on all parts of the pipeline equal to, or more negative than, −950 mV with respect to a saturated $Cu/CuSO_4$ reference electrode. In accordance with the above standards, the protection criteria for all other pipeline sections is a pipe to soil potential equal to, or more negative than -850mV with respect to a saturated $Cu/CuSO_4$ reference electrode.

4 CP SURVEY TECHNIQUES

4.1 PIPE TO SOIL MEASUREMENTS

The pipe-to-soil potential readings were measured at CP test points located approximately every two kilometers. Surge diverters were disconnected to reduce current leakage during the survey. The results are presented in graphical format (On/Off potential vs. chainage) in Appendix B.

It should be noted that On/Off potentials at discrete test points do not necessarily attest to the protection between these test points.

Support frames at MLVs and blow downs are checked to determine whether these structures are appropriately isolated from the pipeline. Only instances of inadequate electrical isolation are referenced in this report.

Data loggers were placed at approximately 20 km intervals. The aim of the data loggers is to record the level and variation of pipe to soil potential for a period of approximately 20 hours. This is achieved by recording instantaneous readings at one second intervals. This data is plotted against magnetic activity from either the Alice Springs or Kakadu Geomagnetic Observatories to determine the influence of telluric activity. These results are presented in graphical format in Appendix C.

Standards state that in a nominal 20 hour test period, the potential of structures that are subject to telluric effects shall not be more positive than the protection criterion for more than 10% of the test period. Where possible, sections will be assessed to this criteria based on the results shown in Appendix C. References to “sufficient readings” refer to whether 20 hours worth of data was captured during the test period. If the number of readings did not make up to 20 hours, the number of valid readings is expressed in the tables as a percentage of 20 hours. For example if 15 hours of data were recorded, this would be stated as 75%.

The standing (continuous) AC voltage is measured where high voltage power lines are in the vicinity of the pipeline. These results are also shown in Appendix B.

4.2 RESISTANCE PROBES

The use of Electrical Resistance Probes (ERPs) is recognised in AS 2832.1 “Cathodic protection of metals, Part 1: Pipes and cables” as a means of demonstrating that the protection criteria has been met. ERPs are a useful guide to corrosion at a given location on the pipeline. If a probe is found to be corroding there is a good chance that the pipeline is also corroding at some locations, although the converse is not necessarily true.

On the AGP, ERPs are particularly important as the following conditions exist:

- Dry or very high resistivity soils where soil voltage gradient errors can be very high,
- The pipeline traverses soils of varying resistivity where a structure Off potential can give an optimistic evaluation of protection status,
- Significant variance in the seasonal conditions (soil moisture levels and resistivity) mean that spot samples are not truly representative of the protection during the entire year.

During a pipe to soil potential survey, a coating defect that dominates the potential reading is that with the lowest circuit resistance to the reference electrode. It is not necessarily the closest coating defect to the reference electrode, but is most likely the coating defect in the lowest resistivity environment. If this defect is in the lowest resistivity environment, it will also tend to be the most protected defect. This problem that occurs when taking pipe to soil potential surveys at fixed intervals is overcome with the use of ERPs.

The location of ERPs are shown in the CP schematic (Appendix A). Checks of ERPs are scheduled on a bi-monthly basis. The corrosion rate is determined in accordance with the manufacturer’s recommendations (Rohrback Cosaco Systems Inc. – Corrosometer Model MS 1500E). The annual corrosion rate was calculated for the period 1 January 2014 to 31 December 2014. The On/Off potential readings from the resistance probes are presented in graphical format in Appendix D. The corrosion rates for the resistance probes are presented in tabular format in Appendix E.

4.3 CPU AND GROUND BED CHECKS

The CPU power performance is evaluated on a bi-monthly basis. The CPU power output and battery voltage (for solar units) is also monitored remotely via the SCADA system for most stations. Detailed CPU and ground bed checks are performed during the annual CP survey. Only non-conformances with the CPU’s and ground beds are included in this report.

4.4 INTERFERENCE TESTING

There are two locations where foreign pipelines cross over APA pipelines*. Interference between the APA pipeline and foreign pipeline is tested in accordance with AS2832.1. According to this standard, interference is a specific form of stray current wherein cathodic protection current applied to a primary structure flows to a foreign structure which may cause corrosion of that structure by altering its potential. Interference may be detected by a change in the potential of the foreign structure when the system current is interrupted. As per AS2832.1-2004 section 8.3.3, foreign structures will be tested to ensure that the maximum allowed potential change is less than 20mV in the positive direction and less than 200mV in the negative direction.

*Note: A third foreign pipeline crossing was installed recently near Mereenie. This crossing will be included for testing in the 2015 CP survey.

5 PIPELINE ASSESSMENT

A summary of the annual CP survey results is provided in the appendices of this report, as shown in Table 1.

Table 1. Appendix contents.

Appendix	CP Survey Results
B	Pipe to Soil Potential Survey (On/Off) and AC Voltage Survey
C	Telluric Influence on Pipe to Soil Potential
D	Resistance Probe – Pipe to Soil Potential Results
E	Resistance Probe – Corrosion Rate Results

The interpretations regarding the performance of the CP system in Section 5 of this report are based on the results contained in Appendices B to E.

5.1 MAINLINE

5.1.1 Palm Valley to Tanami Road (KP-2.9 to KP161.0)

This section was surveyed on 1 May 2014. Spot pipe to soil potential readings met the protection criteria for this entire section, except for one unusually low reading at KP25. Protection levels are a slight improvement from 2013 between KP0 and KP80.

As per Table 2, data loggers at KP-2.9 and KP21 recorded Off potentials that failed the protection criteria for more than 10% of the logging period.

Table 2. Summary of Data Logger Readings, PVL-TMR

Logger Location (KP)	% of Readings Criteria not Met	Sufficient Readings	Level of Telluric Influence
-2.9	66	Yes	High
21.0	24	Yes	High
45.7	7	Yes	High
71.1	9	Yes	High
93.0	2	Yes	High
116.0	5	Yes	High
140.0	0	Yes	Moderate
161.0	0	Yes	Moderate

By comparing historic data for this section with this year's telluric activity, it is considered likely that geomagnetic activity would have had a moderate level of telluric influence on this section of pipeline. This is due to components of this section running in an east-west direction, as it is known that pipelines oriented in an east-west direction are more susceptible to telluric influence. The data logging results show consistently higher effects of tellurics compared to previous years.

The ERP pipe-to-soil potentials for this section were, in general, less negative than last year. Protection levels were marginal and failed in some locations against the protection criteria. Refer to Table 3 for a summary.

Table 3. Summary of ERP Pipe to Soil Potential Readings, PVL-TMR

ERP Location (KP)	Number of Measurements Taken	Number of measurements that did not meet protection criteria
-2.8	7	3
4.7	7	4
17.0	7	7
45.0	7	7
108.0	6	4
160.0	6	0

The corrosion rates for all probes on this section were < 5 µm per year (corrosion rate protection criteria met). Corrosion rates were zero for all but the ERP at KP4.7 which read 4.5 µm loss per year.

There is one foreign crossing on this section at KP13.0. The foreign structure had zero potential shift during the interruption of CP current on the AGP. This shows that the AGP CP was not affecting the foreign pipeline thus meeting the requirements of AS2832.1.

5.1.2 Tanami Road to Ti Tree (KP161.0 to KP316.1)

This section was surveyed on 6-7 May 2014. In early 2013, a new CPU was installed at Aileron (KP241.4). Protection levels improved in this area between 2012 and 2013, but these have since declined again in 2014. This section failed to meet the protection criteria at KP204.0, KP220.0, KP222.0, and numerous locations between KP242.0 and KP316.2 (Ti Tree).

As per Table 4, data loggers indicate several locations failed the protection criteria for more than 10% of the logging period. The number of readings below the protection criteria for KP216.0 is exaggerated below due to a likely logger / connection fault during testing. Data loggers indicate that tellurics have a low / moderate influence on pipe-to-soil potential readings.

Table 4. Summary of Data Logger Readings, TMR-TTR

Logger Location (KP)	% of Readings Criteria not Met	Sufficient Readings	Level of Telluric Influence
161.0	0	Yes	Low
176.0	0	Yes	Low
196.0	3	Yes	Low
216.0	63*	No (77%)	Moderate
241.4	7	Yes	Low
256.1	37	Yes	Moderate
276.1	8	Yes	Low
296.1	81	Yes	Low
316.1	16	Yes	Low

The ERP pipe-to-soil potentials for this section were less negative than last year. Many pipe to soil potential readings did not meet the protection criteria. Refer to Table 5 for a summary.

Table 5. Summary of ERP Pipe to Soil Potential Readings, TMR-TTR

ERP Location (KP)	Number of Measurements Taken	Number of measurements that did not meet protection criteria
162.0	6	0
210.0	7	6
241.4	7	3
242.0	5	2
268.1	7	3
316.0	7	7

The corrosion rates for all probes on this section were <5 µm per year (corrosion rate protection criteria met). Most ERP corrosion rates read 0µm per year.

5.1.3 Ti Tree to Wauchope (KP316.1 to KP458.1)

This section was surveyed on 28 May 2014. Spot pipe to soil potential readings deteriorated for the entire section between 2013 and 2014. The majority of the pipeline north of KP416 did not meet the protection criteria.

Table 6 indicates that KP434 and KP458.1 failed to meet the protection criteria for the majority of the logging period. Influence of tellurics was low / moderate.

Table 6. Summary of Data Logger Readings, TTR-WCH

Logger Location (KP)	% of Readings Criteria not Met	Sufficient Readings	Level of Telluric Influence
316.1	0	Yes	Low
334.0	0	Yes	Low
360.0	4	Yes	Low
410.0	Data Logger Error		
434.0	94	Yes	Moderate
458.1	44	Yes	Moderate

The consistently marginal protection levels in the vicinity of KP410 means it is likely that a new CPU will be required in this area in the near future.

Although four ERP pipe to soil potential readings did not meet the protection criteria at KP317, all readings only marginally failed the -850mV criteria. Refer to Table 7 for a summary of all readings.

Table 7. Summary of ERP Pipe to Soil Potential Readings, TTR-WCH

ERP Location (KP)	Number of Measurements Taken	Number of measurements that did not meet protection criteria
317.0	7	4
354.0	5	0
402.0	3	0
440.0	3	0
456.0	3	0

The corrosion rates for all probes on this section were < 5 µm per year and met the protection criteria.

5.1.4 Wauchope to Warrego (KP458.1 to KP610.8)

This section was surveyed on 4 June 2014. While the protection levels were a deterioration from 2013, the entire section met the protection criteria with the exception of KP482. The significant improvement between 2012 and 2013 can mostly be attributed to the new CPUs installed at Kelly Well and Wauchope.

As per table Table 8, the only logger location at which readings did not meet the protection criteria was at KP458.1. With this being the location of the Wauchope CPU, this is unusual. The level of telluric influence on this pipeline section is generally low.

Table 8. Summary of Data Logger Readings, WCH-WAR

Logger Location (KP)	% of Readings Criteria not Met	Sufficient Readings	Level of Telluric Influence
458.1	37	Yes	Moderate
484.0	0	Yes	Low
510.0	Data Logger Failure		
526.5	0	Yes	Low
544.0	0	Yes	Low
584.0	0	Yes	Low
610.8	0	Yes	Low

This section has five resistance probes, four of which were installed as part of the CP Stage 2 upgrade. Some readings were below the protection criteria (refer to Table 9).

Table 9. Summary of ERP Pipe to Soil Potential Readings, WCH-WAR

ERP Location (KP)	Number of Measurements Taken	Number of measurements that did not meet protection criteria
460.0	5	1
482.0	5	4
502.0	4	0
526.0	4	0
560.0	5	2
600.0	4	2

The corrosion rate for all ERPs in this section are <5 µm per year.

5.1.5 Warrego to Renner Springs (KP610.8 to KP733.7)

This section was surveyed on 12 June 2014. The pipeline was under protected at KP660 and KP664, plus between KP708.2 and Renner Springs. The protection criteria was met at all other test points. Protection levels overall were a degradation compared to 2013.

A summary of data logger readings are shown in Table 10. KP660 had 71% of readings failing to meet the protection criteria. KP640 was marginal, although before rounding this value was 9.7%. The telluric influence in this pipeline section is low / moderate.

Table 10. Summary of Data Logger Readings, WAR-RNS

Logger Location (KP)	% of Readings Criteria not Met	Sufficient Readings	Level of Telluric Influence
610.8	0	Yes	Low
640.0	10	Yes	Moderate
660.0	71	Yes	Moderate
684.1	6	Yes	Low
710.2	8	Yes	Low
733.7	4	Yes	Low

Five new ERP's have been installed on this section of pipeline as part of CP Upgrade Stage 2, however not many readings have been taken (refer to Table 11). The one reading at KP614.1 that failed the protection criteria only failed marginally.

Table 11. Summary of ERP Pipe to Soil Potential Readings, WAR-RNS

ERP Location (KP)	Number of Measurements Taken	Number of measurements that did not meet protection criteria
614.1	3	1
640.0	0	0
660.0	0	0
696.0	0	0
727.5	1	0

The corrosion rate for all ERPs in this section are <5 µm per year.

A very slight CP current leakage (40mV) was detected at the southern MLV support at Morphett creek in 2013. Testing this again in 2014 did not measure any leakage.

5.1.6 Renner Springs to Newcastle Waters (KP733.7 to KP850.8)

This section was surveyed on 18 June 2014. Spot pipe-to-soil potential readings met the protection criteria for all except for one spurious reading at KP759.8 and the section between KP809.3 and KP819.5. The small section between KP812.3 and KP815.4 could not be accessed due to wet ground conditions at the time. The Newcastle Waters Scraper station (KP844.4) continues to have poor protection levels. Investigations are underway to determine how this can be improved.

Protection levels in this region have been historically low south of the Newcastle Waters Scraper Station. Because of this, a new CPU at KP823 was installed in 2014. Effectiveness of this installation will be observed in the 2015 survey.

The Fergusson MLV indicated a potential shift on the MLV supports. Results were as follows:

- South: -1620 mV On / -1140 mV Off
- North: -1210 mV On / -1030 mV Off

These results are similar to the 2013 CP survey. A work order has been created to investigate this issue.

The Fergusson groundbed exhibited signs of deterioration between 2011 and 2013. As such, this groundbed was replaced in 2014. Effectiveness of this replacement will be seen in the 2015 survey.

Table 12 summarises the data logger readings in this section. KP844.4 failed to meet the protection criteria for all readings. This location is Newcastle Waters scraper station, and has been known to have inadequate CP readings, likely due to the rocky soil. KP816.4 failed to meet the protection criteria for 43% of the time, but was only marginally below the protection criteria. All other locations met the protection criteria for the entire logging period. KP780 and KP792 experienced a degree of data logger failure, but the readings that were taken were very consistent. There is a low level of telluric influence on this pipeline.

Table 12. Summary of Data Logger Readings, RNS-NCW

Logger Location (KP)	% of Readings Criteria not Met	Sufficient Readings	Level of Telluric Influence
733.7	0	Yes	Low
757.8	0	Yes	Low
780.0	0	No (89%)	Low
792.0	0	No (32%)	Low
816.4	43	Yes	Low
828.4	0	Yes	Moderate
844.4	100	Yes	Low
850.8	0	Yes	Low

Five new ERPs have been installed in this section as part of CP Upgrade Stage 2. One of these (KP850.8) is yet to be connected. Most of the readings failed to meet the protection criteria (refer to Table 13).

Table 13. Summary of ERP Pipe to Soil Potential Readings, RNS-NCW

ERP Location (KP)	Number of Measurements Taken	Number of measurements that did not meet protection criteria
739.5	1	1
757.8	1	1
791.6	1	1
824.4	1	0
851.0	Not yet connected	

The corrosion rate for all ERPs in this section are <5 µm per year.

5.1.7 Newcastle Waters to Daly Waters (KP850.8 to KP981.8)

This section was surveyed on 22-23 September 2014. Protection levels failed to meet the protection criteria at KP870 and between KP948.9 and Daly Waters. Protection levels are similar to 2013. 2013 levels improved significantly due to a new CPU at Front Sturt (KP889.8), and new groundbeds at Hayfield (KP912.4) and Newcastle Waters (KP850.8).

Protection levels deteriorate suddenly at KP948.9 and remain poor for the entire section to Daly Waters. These protection levels are similar to previous years. A consultant from Anode Engineering (Allan Sterling) was utilised to investigate this issue. After performing a desktop review and a site visit, he recommended taking the following actions to rule out common issues:

1. Undertake Swain clamp testing at Daly Waters to confirm effective electrical isolation by the MIJ,
2. Consider corrosion probes in the low area (KP949 to KP959) to confirm CP effectiveness,
3. Monitor the level of depolarisation by data logging at least 2 locations in the “low” section and then turning off the Daly Waters and Hayfield CP units,
4. Using Swain Clamps, measure current flow either side of the Daly Waters anchor block to determine if shorting to the reinforcing steel is significant,
5. Whenever the pipe is exposed, measure current flow magnitude and direction (Swain Clamp).

Refer to more detailed report of this investigation at Appendix F.

Recommendation 5 involves excavating the pipe near KP950, and having a swain clamp at the same time. An alternative to this recommendation is to measure current magnitude and direction at Type 4 test points on the AGP. These test points were placed every 10km at construction, and were designed specifically for this purpose.

Data logging of pipe to soil potentials and geomagnetic data indicate low levels of telluric activity in this pipeline section. Refer to Appendix C for graphs and to Table 14 for a summary. With the exception of the loggers at KP950.8 and KP969, the loggers indicate that protection levels are being met.

Table 14. Summary of Data Logger Readings, NCW-DLW

Logger Location (KP)	% of Readings Criteria not Met	Sufficient Readings	Level of Telluric Influence
850.8	0	Yes	Low
870.0	100	No (92%)	Low
890.0	0	No (99%)	Low
910.3	0	No (72%)	Low
936.8	0	No (96%)	Low
950.8	100	No (95%)	Low
969.0	96	No (99%)	Low
981.8	75	No (99%)	Low

With the consistently poor protection levels at KP870 and KP950, it is likely that new CPUs will need to be installed at these locations in the near future.

Seven new ERP’s have recently been installed in this section. Several readings in the northern part of the pipeline failed to meet the protection criteria. Refer to Table 15 for a summary of all readings.

Table 15. Summary of ERP Pipe to Soil Potential Readings, NCW-DLW

ERP Location (KP)	Number of Measurements Taken	Number of measurements that did not meet protection criteria
859.8	1	0
890.0	3	0
912.4	2	0
935.2	4	1
959.0	2	2
979.0	3	0

The ERP at KP912.4 had a corrosion rate of almost 100 µm/year. However, only two readings were taken, and one of these readings is likely to be an error. This will be monitored in 2015 to check. The corrosion rate for all other ERPs in this section are <5 µm per year.

5.1.8 Daly Waters to Mataranka (KP981.8 to KP1107.9)

Surveying between Daly Waters and Mataranka was conducted on 24 September 2014. Spot pipe to soil potential readings were similar to 2013 for this section. Spot readings failed to meet the protection criteria at about half of the test points.

Data logging of pipe to soil potentials and geomagnetic data indicate low to moderate levels telluric activity in this pipeline section. Refer to Appendix C for graphs, and to Table 16 for a summary. Results are similar to the 2012 data logging. It is likely that tellurics influenced the spot pipe to soil potential readings North of KP1040. The low pipe to soil potentials likely have the same root cause as the low pipe to soil potentials on the south side of Daly Waters Station.

It is likely that there will be a need to install a new CP site between KP1020 and KP1070 sometime over the next few years.

Table 16. Summary of Data Logger Readings, DLW-MAT

Logger Location (KP)	% of Readings Criteria not Met	Sufficient Readings	Level of Telluric Influence
981.8	99	Yes	Low
1000.0	84	Yes	Low
1020.0	0	Yes	Low
1040.0	6	Yes	Moderate
1060.0	39	Yes	Moderate
1080.0	25	Yes	Moderate
1100.0	9	Yes	Moderate
1107.9	27	Yes	Moderate

Refer to Table 17 below for a summary of ERP pipe to soil potential readings. Several readings failed to meet the protection criteria.

Table 17. Summary of ERP Pipe to Soil Potential Readings, DLW-MAT

ERP Location (KP)	Number of Measurements Taken	Number of measurements that did not meet protection criteria
982.5	3	1
990.0	0	0
1010.0	2	0
1053.0	4	2
1074.0	4	2
1106.0	4	0

The corrosion rates for all ERPs was < 5 µm/year.

5.1.9 Mataranka to Helling (KP1107.9 to KP1242.7)

This section was surveyed on 25 September 2014. Spot pipe to soil potential readings met the protection criteria for the entire section. Compared to 2013, protection levels were a slight improvement in the southern half of the section, and a slight deterioration in the northern half of the section.

Data logging of pipe to soil potentials and geomagnetic data indicate high levels of telluric activity for the section between KP1107 to KP1150.1. Refer to Appendix C for graphs, and to Table 18 for a summary, this can also be seen by the erratic On/Off readings in this region in Appendix B. This is similar to the 2012 data logging results. The pipeline changes to a more east-west orientation in the southern part of this region, which is typically more susceptible to tellurics. The high number of readings failing the protection criteria at KP1190.2 is likely due to a logger failure.

The CPU controller at Mataranka North was controlling the output voltage poorly in 2013. The control was greatly improved in the 2014 survey.

Table 18. Summary of Data Logger Readings, MAT-HEL

Logger Location (KP)	% of Readings Criteria not Met	Sufficient Readings	Level of Telluric Influence
1107.9	31	No (92%)	High
1130.1	32	No (95%)	High
1150.2	22	Yes	High
1170.2	0	Yes	Low
1190.2	23	No (24%)	Moderate
1210.2	0	Yes	Low
1230.0	0	Yes	Low
1242.7	0	Yes	Moderate

Five ERPs are located in this section, three of which were installed as part of CP Upgrade Stage 2. Several readings failed to meet the protection criteria. Refer to Table 19 for a summary.

Table 19. Summary of ERP Pipe to Soil Potential Readings, MAT-HEL

ERP Location (KP)	Number of Measurements Taken	Number of measurements that did not meet protection criteria
1108.1	4	3
1126.1	4	1
1160.2	3	1
1200.3	4	2
1240.0	5	0

All corrosion rate readings were < 5 µm/year.

5.1.10 Helling to Ban Ban Springs (KP1242.7 to KP1377.6)

This section was surveyed on 16 July 2014. The protection criteria was met for all of this section with the exception of KP1357 to KP1357.9, plus KP1367. The protection levels are similar compared to the last two years. Due to problems with interruption, data was not captured between Helling and KP1280.4.

Data logging of pipe to soil potentials and geomagnetic data indicate low levels of telluric activity in this pipeline section. Refer to Appendix C for graphs, and to Table 20 for a summary. Due to a problem with interruption, loggers in the southern part of this section failed. Recordings from KP1359.7 and KP1377.6 are misleading. Both of these locations suffered from either interruption or logger failures.

Table 20. Summary of Data Logger Readings, HEL-BBS

Logger Location (KP)	% of Readings Criteria not Met	Sufficient Readings	Level of Telluric Influence
1242.7	No data due to interrupter failure		
1259.9	No data due to interrupter failure		
1280.4	No data due to interrupter failure		
1299.6	No data due to interrupter failure		
1320.5	0	Yes	Low
1342.8	0	Yes	Low
1359.7	30	No (10%)	Low
1377.6	32	Yes	Low

Data logging of pipe to soil potentials and geomagnetic data indicate no significant levels of telluric activity. This is similar to the 2012 data logging results. It is unlikely that tellurics would have affected the spot pipe to soil potential readings.

The CP stage 2 upgrade project saw an additional four ERP's installed in this section. All Off potential readings met the protection criteria. Refer to Table 21 for a summary.

Table 21. Summary of ERP Pipe to Soil Potential Readings, HEL-BBS

ERP Location (KP)	Number of Measurements Taken	Number of measurements that did not meet protection criteria
1251.7	4	0
1280.4	3	0
1316.7	4	0
1338.9	4	0
1374.9	3	0

The corrosion rate for the probes was < 5 µm/year (corrosion rate protection criteria met).

5.1.11 Ban Ban Springs to Darwin City Gate (KP1377.6 to KP1498.9)

This section was surveyed on 23 July 2013. Spot pipe to soil potential readings did not meet the protection criteria at KP1446 and KP1472.8. The results are similar to 2013 survey results.

Low readings have been recorded at a number of locations over the last few years (KP1446, KP1458, KP1472.8, KP1478.4 and KP1482.1). These locations do not correspond to any known coating defects and are near the CPU located at KP1476.7. Previous investigations by CP consultants and northern operations have not been able to determine the cause. Protection in this area will continue to be monitored.

Data logging of pipe to soil potentials and geomagnetic data indicate only low levels of telluric activity in this pipeline section. Refer to Appendix C for graphs, and to Table 22 for a summary.

Table 22. Summary of Data Logger Readings, BBS-DCG

Logger Location (KP)	% of Readings Criteria not Met	Sufficient Readings	Level of Telluric Influence
1377.6	0	Yes	Low
1399.7	0	No (65%)	Low
1420.0	Data Logger Failure		
1460.6	0	Yes	Low
1476.7	0	Yes	Low
1498.9	0	Yes	Low

It is unlikely that tellurics would have affected the spot pipe to soil potential readings. This section met the protection criteria.

Six resistance probes are installed in this section. All Off potential readings met the protection criteria. Refer to Table 23 for a summary.

Table 23. Summary of ERP Pipe to Soil Potential Readings, BBS-DCG

ERP Location (KP)	Number of Measurements Taken	Number of measurements that did not meet protection criteria
1441.0	6	0
1472.8	6	0
1476.7	2	0
1478.4	6	0
1498.1	6	0
1498.9	6	0

The corrosion rate for the probes was < 5 µm/year (corrosion rate protection criteria met).

5.1.12 Darwin City Gate to Channel Island (KP1498.9 to KP1510.8)

This lateral was surveyed on 23 July 2014. This section has a protection criteria of --950 mV with respect to a saturated $Cu/CuSO_4$ reference electrode. Spot pipe to soil potential readings met the protection criteria for the entire lateral. This result is similar to the previous year. As the ground bed at KP1506 has failed, CP is applied to the Channel Island Spurline by cross bonding the MIJ at Darwin City Gate, providing CP from Townend Road. The sacrificial site at KP1506 has been completely disconnected.

Table 24. Summary of Data Logger Readings, DCG-CIMS

Logger Location (KP)	% of Readings Criteria not Met	Sufficient Readings	Level of Telluric Influence
1504.9	0	Yes	Low
1510.8	0	Yes	Low

No AC readings were taken in 2014. Readings will be taken in the 2015 survey.

Eight resistance probes are installed on this lateral. Only three out of 48 readings were measurements that did not meet the protection criteria. Refer to Table 25 for a summary.

Table 25. Summary of ERP Pipe to Soil Potential Readings, DCG-CIMS

ERP Location (KP)	Number of Measurements Taken	Number of measurements that did not meet protection criteria
1500.2	6	0
1501.1	6	0
1502.1	6	1
1503.1	6	2
1504.1	6	0
1504.9	6	0
1506.0	6	0
1510.8	6	0

All ERP’s showed the corrosion rate to be < 5 µm/year.

5.2 LATERAL AND SPUR LINE ASSESSMENT

The following laterals and spur pipelines were surveyed as along with the mainline.

5.2.1 Mereenie to Tylers Pass Spur Line (KP0.0 to KP115.3)

This spur line was surveyed on 14 May 2014. Spot pipe to soil potential readings met the protection criteria for the entire spur line. Results are similar to previous years.

A summary of data logger readings are shown below in Table 26. It is likely a logger failure occurred at KP41.1. The level of telluric influence on this pipeline is low.

Table 26. Summary of Data Logger Readings, Mereenie Spur

Logger Location (KP)	% of Readings Criteria not Met	Sufficient Readings	Level of Telluric Influence
0	0	Yes	Low
19.6	0	Yes	Low
41.1	0	No (60%)	Low
61.3	0	Yes	Low
81.3	0	Yes	Low
101.2	0	Yes	Low
115.3	0	Yes	Low

Five ERPs were installed in this section in 2012 as part of the CP Stage 2 upgrade. The ERP at KP27.3 has failed to meet protection criteria since its installation and a work order has been created to inspect this test point. For the other ERPs, three readings failed to meet the protection criteria. Refer to Table 27.

Table 27. Summary of ERP Pipe to Soil Potential Readings, MER-TYP

ERP Location (KP)	Number of Measurements Taken	Number of measurements that did not meet protection criteria
3.6	7	0
27.3	7	6
53.2	7	2
81.3	7	1
113.0	7	0

There is a foreign crossing on this section at KP2.3. No potential difference was measured on the foreign pipeline when the CP was interrupted on the Mereenie spur, showing that the foreign pipeline was unaffected by the AGP CP. A new foreign crossing was installed on this pipeline in 2014, located close to the Mereenie Meter Station. Testing of this location will take place during the 2015 CP survey.

5.2.2 Tennant Creek Lateral (KP0.0 to KP23.7)

This lateral was surveyed on 4 June 2014. Spot pipe to soil potential readings met the protection criteria for the entire lateral. Results are similar to the 2013 survey. This lateral is bonded to the Mainline between Wauchope and Warrego at KP577. Protection levels improved between 2012 and 2013 due to the new CPU at Kelly Well.

A summary of data logger readings are shown below in Table 28. The one logger placed at KP23.7 (the Tennant Creek Meter Station) failed to meet the protection criteria for 37% of readings. Due to the east / west orientation of the lateral, the level of telluric influence is moderate.

Table 28. Summary of Data Logger Readings, Tennant Creek Lateral

Logger Location (KP)	% of Readings Criteria not Met	Sufficient Readings	Level of Telluric Influence
23.7	37	Yes	Moderate

One ERP was installed on this lateral as part of CP upgrade stage 2. One reading failed to meet the protection criteria. Refer to Table 29.

Table 29. Summary of ERP Pipe to Soil Potential Readings, TCK Lateral

ERP Location (KP)	Number of Measurements Taken	Number of measurements that did not meet protection criteria
19.2	4	1

5.2.3 Elliott Lateral (KP0.0 to KP3.8)

This lateral was surveyed on 18 June 2014. Results on this lateral were similar to the 2013 results, and all spot readings met the protection criteria. Improvements observed between 2012 and 2013 are likely due to the new Newcastle Waters CPU.

One data logger was placed on this short lateral (refer to Table 30). The level of telluric influence on this east / west lateral is moderate.

Table 30. Summary of Data Logger Readings, Elliott Lateral

Logger Location (KP)	% of Readings Criteria not Met	Sufficient Readings	Level of Telluric Influence
3.0	7	Yes	Moderate

There are no ERPs located on this short lateral.

5.2.4 Katherine Lateral (KP0.0 to KP5.4)

This lateral was surveyed on 26 September 2014. Spot pipe to soil potential readings met the protection criteria for the entire lateral. These results are similar to 2013.

AC readings were logged at five different locations on the pipeline. Each location showed high AC readings at about 19:48. According to SCADA, this correlates with when gas supply at Katherine Meter Station reduces, implying this is related to when the power station turned off. AC voltages were consistently less than 5V (protection criteria met).

There are no ERPs located on this short lateral.

6 WORK LIST

Tasks completed in 2014 are shown below in Table 31.

Actions arising from the 2014 CP survey for the AGP mainline and associated laterals and spur lines is summarised in Table 32.

Incomplete tasks carried over from previous surveys are shown in Table 33.

Table 31. Tasks Completed in 2014.

Work Order	Section	Task	Responsibility	Date Complete	Comments
33686	REN - NCW	Augment CP system to improve protection between KP808 and KP824	Engineering	September 2014	New CP unit installed at Lake Woods (KP823). CP is working, but yet to be fully commissioned in SCADA.
33686	REN - NCW	Replace Ground Bed at Fergusson	Engineering	September 2014	
NTY-193345	WCH-WAR	Repair insulation at the Kelly Well MLV Pipe support	Southern Operations	12/5/2014	
NTY-193351	RNS-NCW	Confirm the presence of isolating material in the blowdown support at Newcastle Waters SS.	Southern Operations	7/1/2014	
NA	WAR-RNS	Monitor Morphett Creek MLV supports for leakage in the 2014 CP survey.	Engineering / Southern Operations	NA	No potential shift observed in 2014 survey.
NTY-204222	HEL-BBS	Increase set point on CPU at BBS South side	Northern Operations	25/7/2014	
NA	NT	Develop CP survey policy and data validation procedure. Provide training and have operations implement new procedures	Engineering	NA	
NTY-77985	N/A	Update CP survey policy 430 to ensure the appropriate data is collected at each location	Engineering	2014	

Table 32. Actions from 2014 CP Survey.

Work Order	Section	Task	Responsibility	Date Work Order Created	Comments
		Investigate the poor protection levels at Newcastle Waters Scraper Station	Southern Operations		
	TMR-RNS	Check all CPUs are operating correctly between Tanami Road and Renner Springs	Southern Operations		
NTY-262512	MER-TYP	Investigate the poor off potential measured by Mereenie ERP KP27	Southern Operations	04/02/15	Related to WO NTY-207096
NTY-262523	Daly Waters SS	Undertake Swain Clamp testing at Daly Waters	Central Operations	04/02/15	Recommendation from Anode Engineering report
NTY-262524	NCW-DLW	Monitor depolarisation between KP950 and Daly Waters to check at least 100mV drop	Central Operations	04/02/15	Recommendation from Anode Engineering report
NTY-262526	NCW-DLW	Measure current magnitude and direction near KP950 using Type 4 Test Points.	Central Operations	04/02/15	Recommendation from Anode Engineering report
		Develop a procedure for current testing of Type 4 Test Points	Engineering		Related to WO NTY-262526
NTY-262528	Daly Waters SS	Measure current flow either side of the Daly Waters anchor block to determine if shorting to the reinforcing steel is significant.	Engineering / Central Operations	04/02/15	Recommendation from Anode Engineering report
	NCW-DLW	Install a new CP site near KP870	Engineering		

Table 33. Incomplete Tasks from Previous Surveys.

Work Order	Section	Task	Responsibility	Date Work Order Created	Date Due	Comments
NTY-122651	RNS-NCW	Investigate the leakage from the support pipework at the Fergusson MLV	Southern Operations	25/06/2012		
NA	DLW	Investigate Low off potentials North and South of Daly Waters	Central Ops			A consultant investigated this issue in late 2014. Actions and investigations arising from this will be implemented in 2015.
NTY-207096	MER-TYP	Inspect and repair ERP at KP27.3	Southern Ops	01/04/2014		

7 CONCLUSIONS AND RECOMMENDATIONS

The 2014 AGP CP survey was consistent with 2013 results in the northern end of the pipeline, but protection levels at the southern end of the pipeline have reduced. In particular, a reduction in protection levels was seen in the following sections.

- KP230 – KP316 (Tanami Road to Ti Tree section)
- KP316 – KP458 (Ti Tree to Wauchope)
- KP458 – KP610 (Wauchope to Warrego)
- KP610 – KP733 (Warrego to Renner Springs)

Although deterioration was observed in these sections between 2013 and 2014, it should be noted that most of these sections experienced a significant improvement in protection levels between 2012 and 2013 with various augmentations from CP Upgrade Stage 2.

Spot pipe to soil potentials did not meet the protection criteria for 15% of test points measured. This compares to 11% in 2013, 21% in 2012 and 8%[1] in 2011.

In 2013, most loggers did not capture data in the southern area due to either operator error or equipment failure. This issue was rectified in 2014. Telluric activity may have affected the spot pipe to soil potential measurements at several locations, particularly those in an east-west orientation.

It is likely that there will be need to install a new CP sites near KP870 and KP1020 in the future. APA will prioritise the KP870 site, but will also acquire land for the new site at KP1020 in this process.

Testing should be performed south of Daly Waters to determine the cause of the poor protection levels in this area. If no improvements can be made, consideration should be given to installing a new CP unit near KP950.

Although CP units installed for CP Upgrade Stage 2 are operational, priority should be given to completing commissioning to allow data to be transmitted

Where resistance probe measurements were taken, the corrosion rates were all found to be insignificant (< 5 µm/year).

---

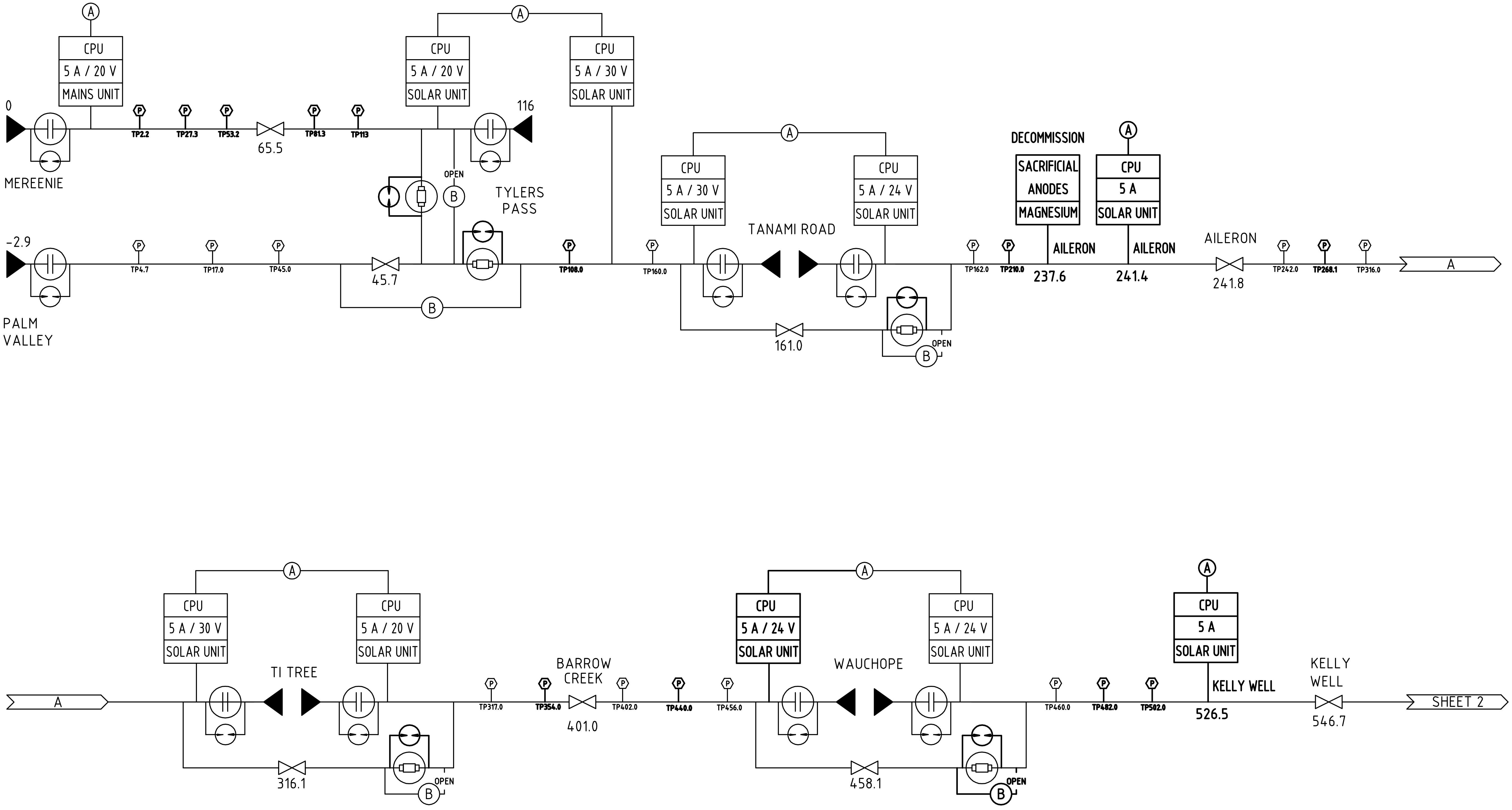
[1] These statistics are a percentage of Test Points at which On/Off values were recorded. Many test points in the Lake Woods area in did not meet the protection criteria in 2010 and 2012 but could not be accessed in 2011, slightly skewing the 2011 results.

Appendix A

Amadeus Basin to Darwin Natural Gas Pipeline

Cathodic Protection Schematic

Mainline - Drawing Number AD0000-8001 revision 6



NOTES:
1. CHAINAGES CORRESPOND TO CP TEST POINTS, NOT ALIGNMENT SHEET CHAINAGE.
2. CP UPGRADE STAGE 2 INDICATED BY HEAVY LINEWEIGHT.

LEGEND

⊣▭⊢	MONOLITHIC INSULATED JOINT	Ⓟ	RESISTANCE PROBE	⏚	EARTHING
⊣⊢	INSULATED FLANGE	⊖	SURGE DIVERTER	Ⓑ	BOND
⊡	POLARISATION CELL	⋈	MAIN LINE VALVE		
Ⓐ	ANODE BED	▶	PIG TRAP		

REV	REVISION DESCRIPTION	DATE	DRN.	CKD.	APP.	REFERENCE DRAWINGS	DRG.NO.
6	UPDATED FOR CP UPGRADE STAGE 2 PROJECT	20/10/12	ML				

NOTES:

APA Group

This drawing is confidential and the information and details contained in it are and remain the property of APA Group.
© Copyright in this drawing is owned by APA Group

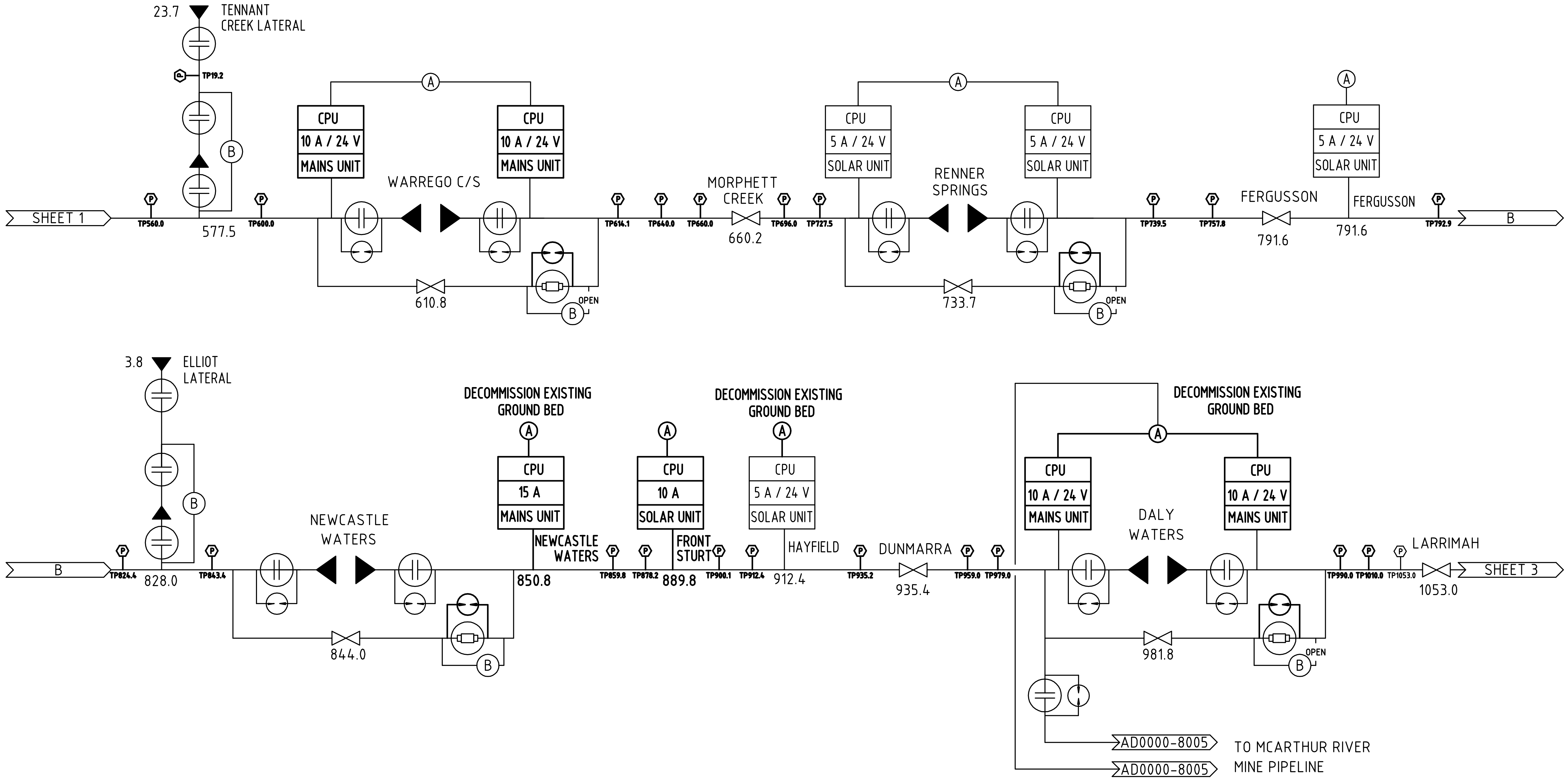
SHEET NO.	1	SCALE	NTS
LEVEL DATUM		FILENAME	
FIELD BOOK		DATE	
		DRAWN	
		CHECKED	
DESIGN ENGINEER ML		APPROVING ENGINEER	

PROJECT
AMADEUS GAS PIPELINE

TITLE
CP SCHEMATIC
SHEET 1

PROJECT NO.	DRAWING NO.	REV
	AD0000-8001	6

A3



LEGEND

	MONOLITHIC INSULATED JOINT	Ⓟ	RESISTANCE PROBE	⏚	EARTHING
	INSULATED FLANGE		SURGE DIVERTER	Ⓑ	BOND
	POLARISATION CELL		MAIN LINE VALVE		
Ⓐ	ANODE BED	▶	PIG TRAP		

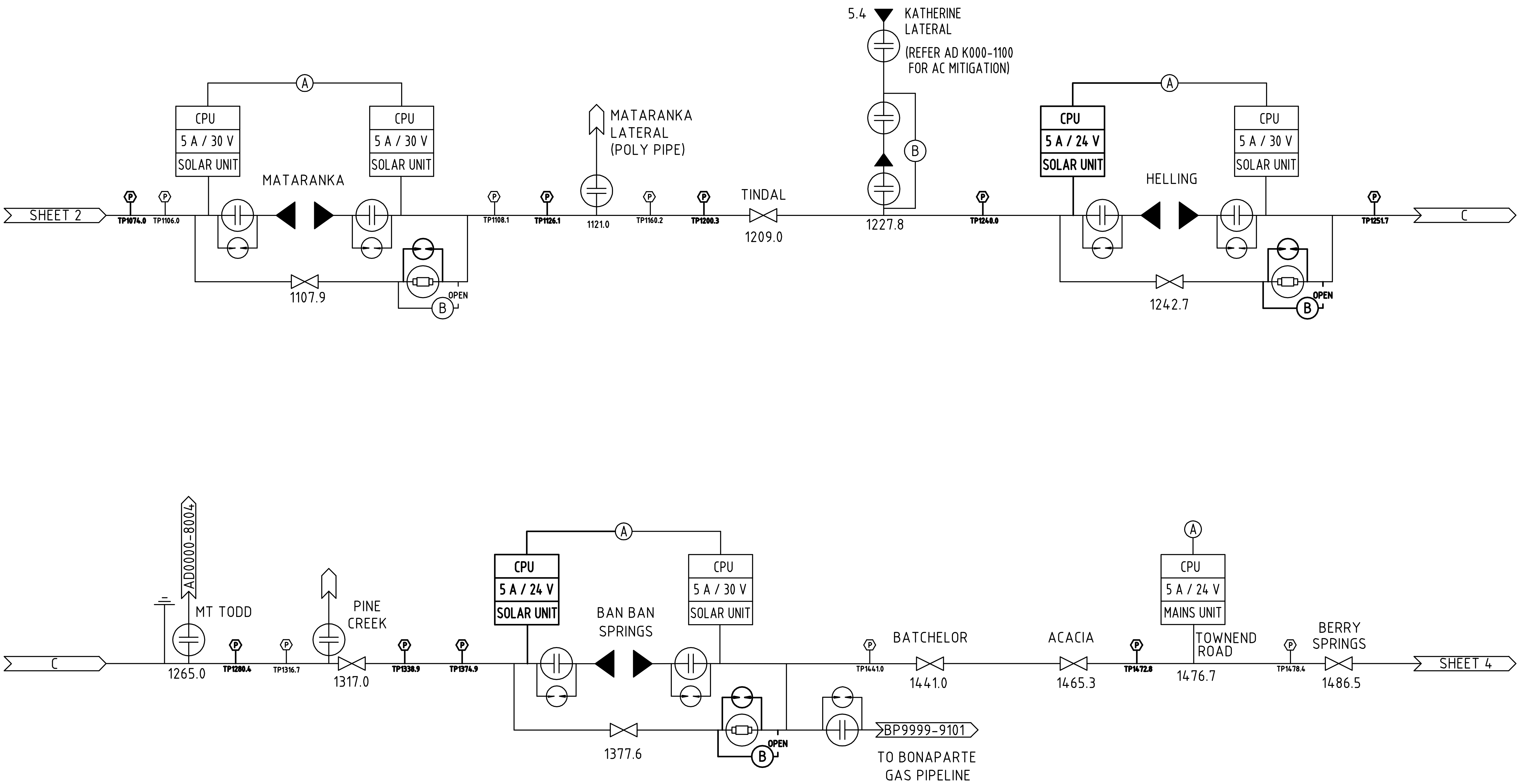
NOTES:
1. CHAINAGES CORRESPOND TO CP TEST POINTS, NOT ALIGNMENT SHEET CHAINAGE.
2. CP UPGRADE STAGE 2 INDICATED BY HEAVY LINEWEIGHT.

6	UPDATED FOR CP UPGRADE STAGE 2 PROJECT	20/10/12	ML				
REV	REVISION DESCRIPTION	DATE	DRN.	CKD.	APP.	REFERENCE DRAWINGS	DRG.NO.

NOTES:

APA Group

SHEET NO. 2
LEVEL DATUM
FIELD BOOK
DESIGN ENGINEER ML
SCALE NTS
FILENAME
DATE
DRAWN
CHECKED
APPROVING ENGINEER
PROJECT AMADEUS GAS PIPELINE
TITLE CP SCHEMATIC SHEET 2
PROJECT NO.
DRAWING NO. AD0000-8001
REV 6
A3



LEGEND

	MONOLITHIC INSULATED JOINT	Ⓟ	RESISTANCE PROBE	⏚	EARTHING
	INSULATED FLANGE		SURGE DIVERTER	Ⓑ	BOND
	POLARISATION CELL	⋈	MAIN LINE VALVE		
Ⓐ	ANODE BED	▶	PIG TRAP		

NOTES:
1. CHAINAGES CORRESPOND TO CP TEST POINTS, NOT ALIGNMENT SHEET CHAINAGE.
2. CP UPGRADE STAGE 2 INDICATED BY HEAVY LINEWEIGHT.

REV	REVISION DESCRIPTION	DATE	DRN.	CKD.	APP.	REFERENCE DRAWINGS	DRG.NO.
6	UPDATED FOR CP UPGRADE STAGE 2 PROJECT	20/10/12	ML				

NOTES:

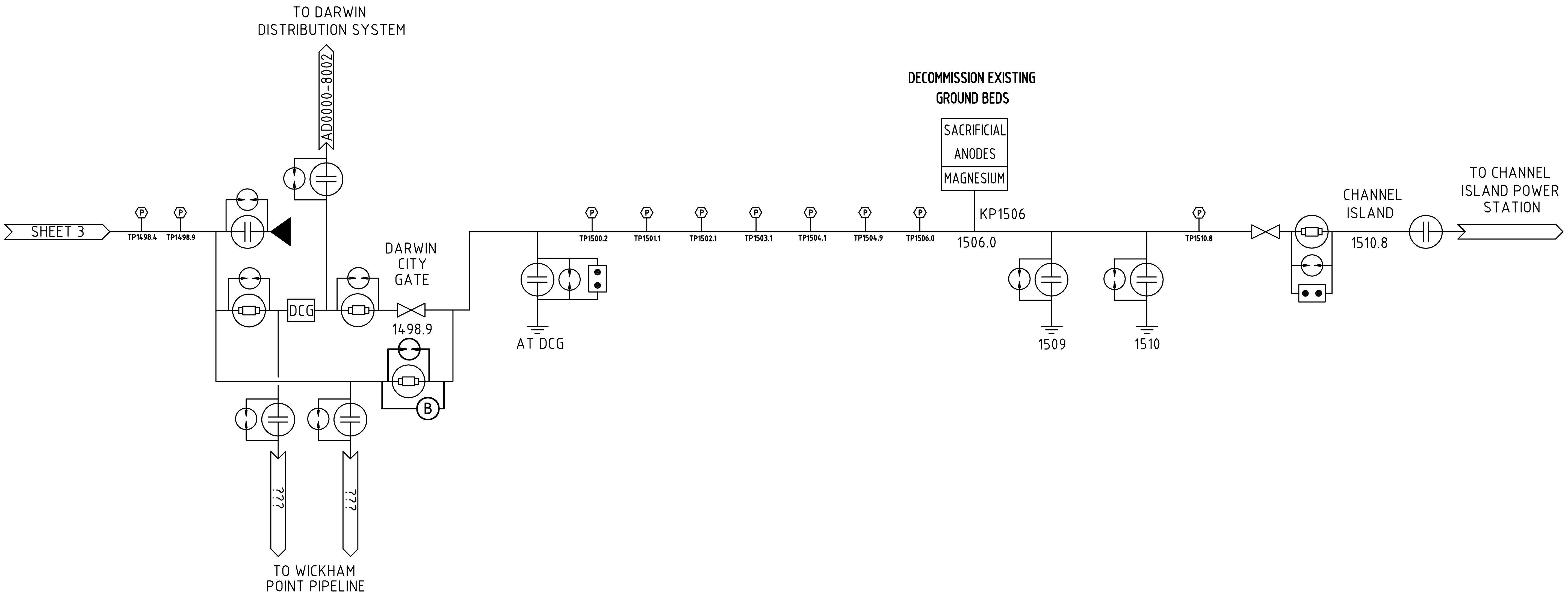
APA Group

SHEET NO. 3
SCALE NTS
LEVEL DATUM
FILENAME
FIELD BOOK
DATE
DRAWN
CHECKED
DESIGN ENGINEER ML
APPROVING ENGINEER

PROJECT AMADEUS GAS PIPELINE
TITLE CP SCHEMATIC
SHEET 3

PROJECT NO.
DRAWING NO. AD0000-8001
REV 6

A3



LEGEND

—⊡—	MONOLITHIC INSULATED JOINT	Ⓟ	RESISTANCE PROBE	⏚	EARTHING
—⦶—	INSULATED FLANGE	⊖	SURGE DIVERTER	Ⓑ	BOND
—[••]—	POLARISATION CELL	—⋈—	MAIN LINE VALVE		
Ⓐ	ANODE BED	▶	PIG TRAP		

NOTES:
1. CHAINAGES CORRESPOND TO CP TEST POINTS, NOT ALIGNMENT SHEET CHAINAGE.
2. CP UPGRADE STAGE 2 INDICATED BY HEAVY LINEWEIGHT.

6	UPDATED FOR CP UPGRADE STAGE 2 PROJECT	20/10/12	ML				
REV	REVISION DESCRIPTION	DATE	DRN.	CKD.	APP.	REFERENCE DRAWINGS	DRG.NO.

NOTES:

APA Group

SHEET NO. 4	SCALE NTS
LEVEL DATUM	FILENAME
FIELD BOOK	DATE
	DRAWN
	CHECKED
DESIGN ENGINEER ML	APPROVING ENGINEER

PROJECT
AMADEUS GAS PIPELINE

TITLE
CP SCHEMATIC
SHEET 4

PROJECT NO.	DRAWING NO.	REV
	AD0000-8001	6

A3

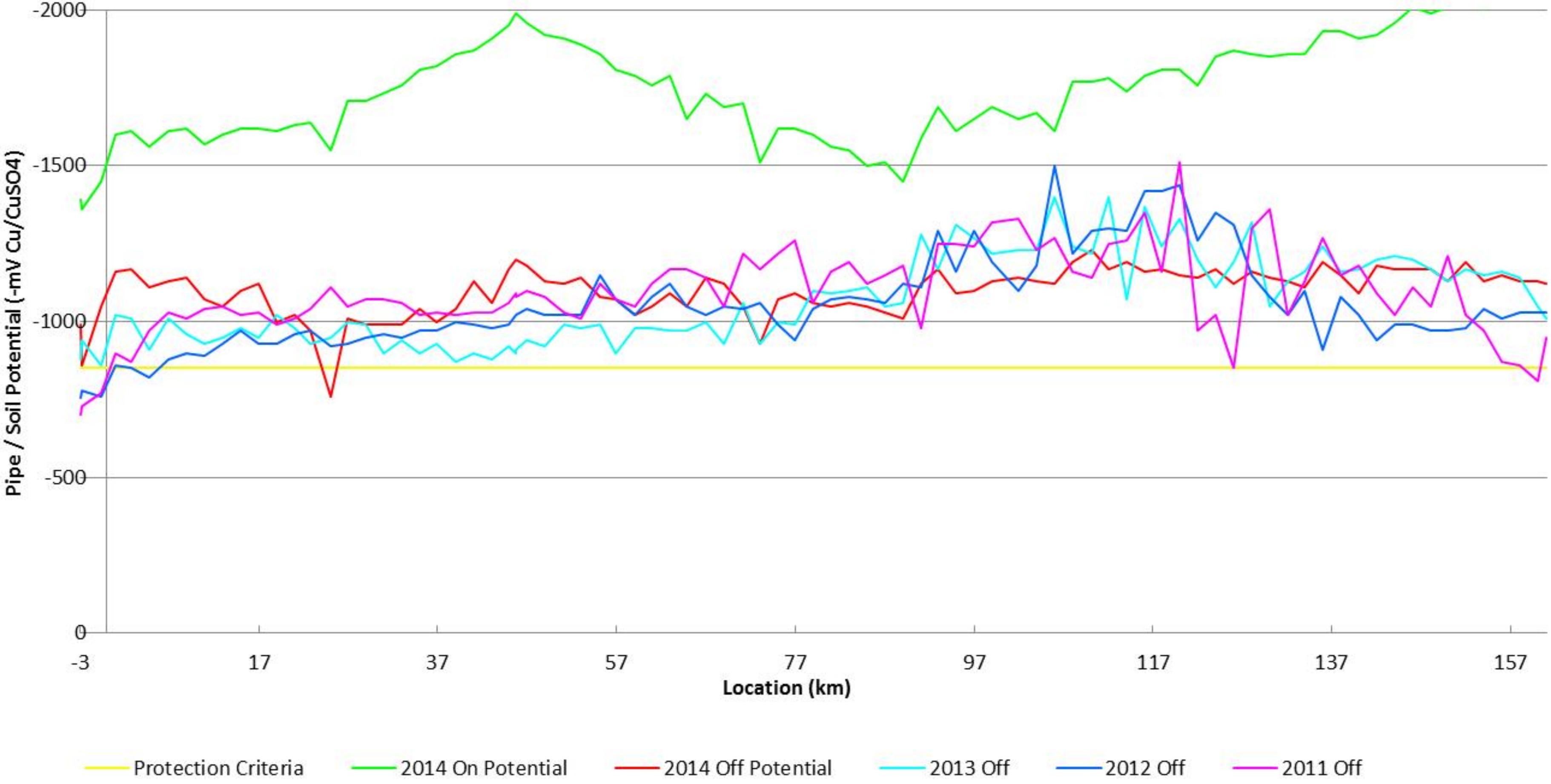
Appendix B

Amadeus Basin to Darwin Natural Gas Pipeline

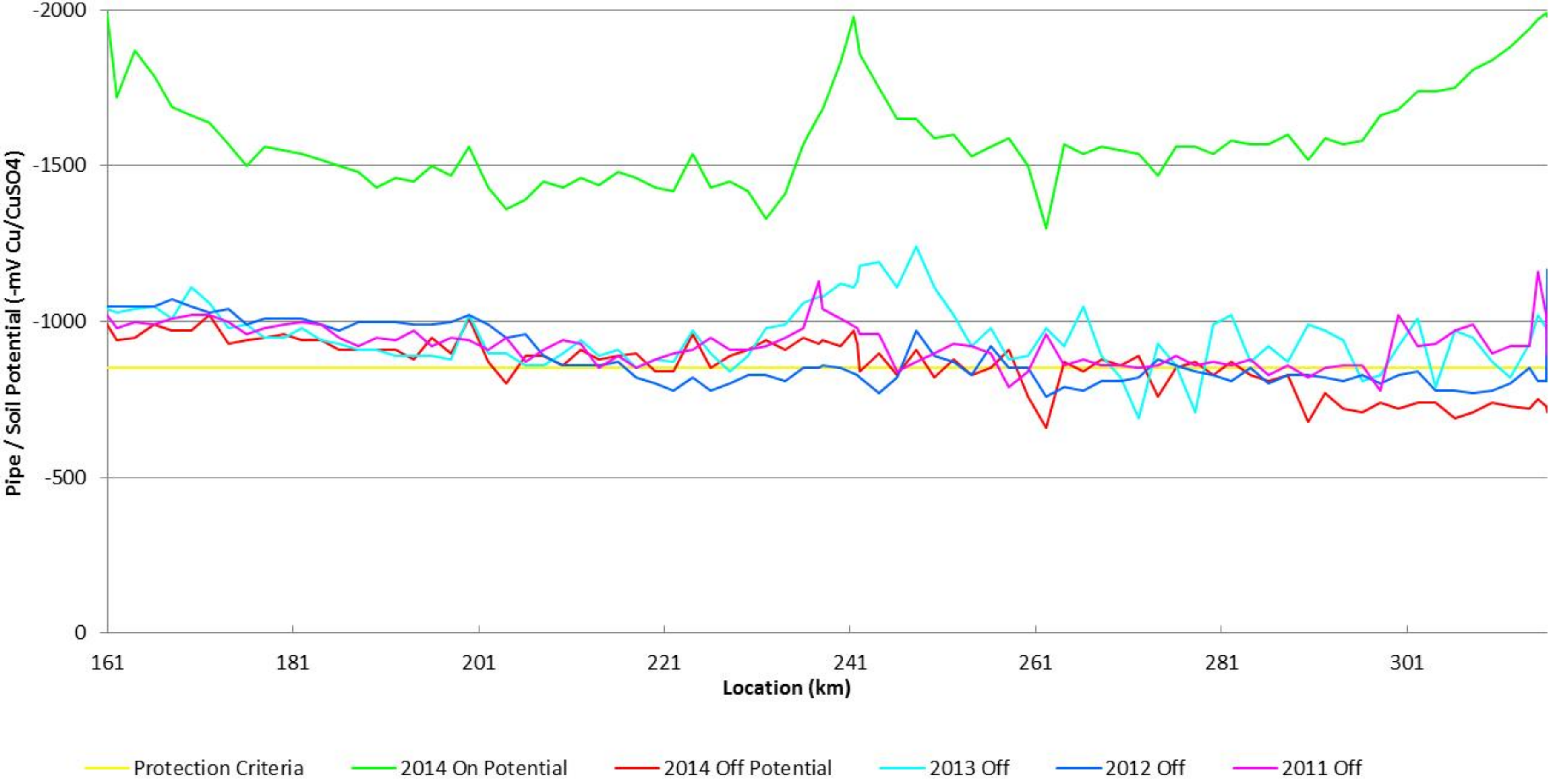
Pipe to Soil Potential Survey (On/Off)

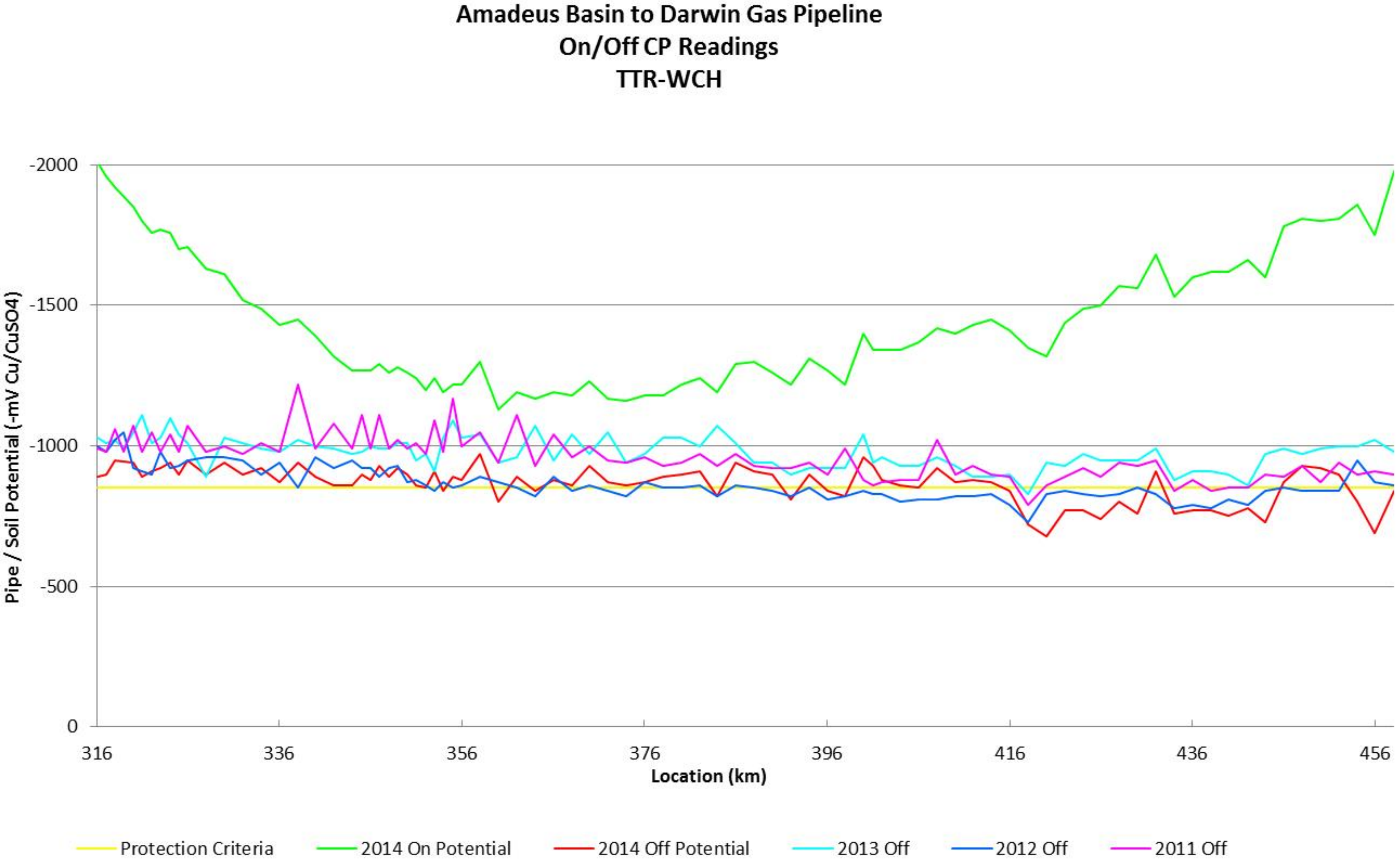
AC Standing Pipe to Soil Potentials

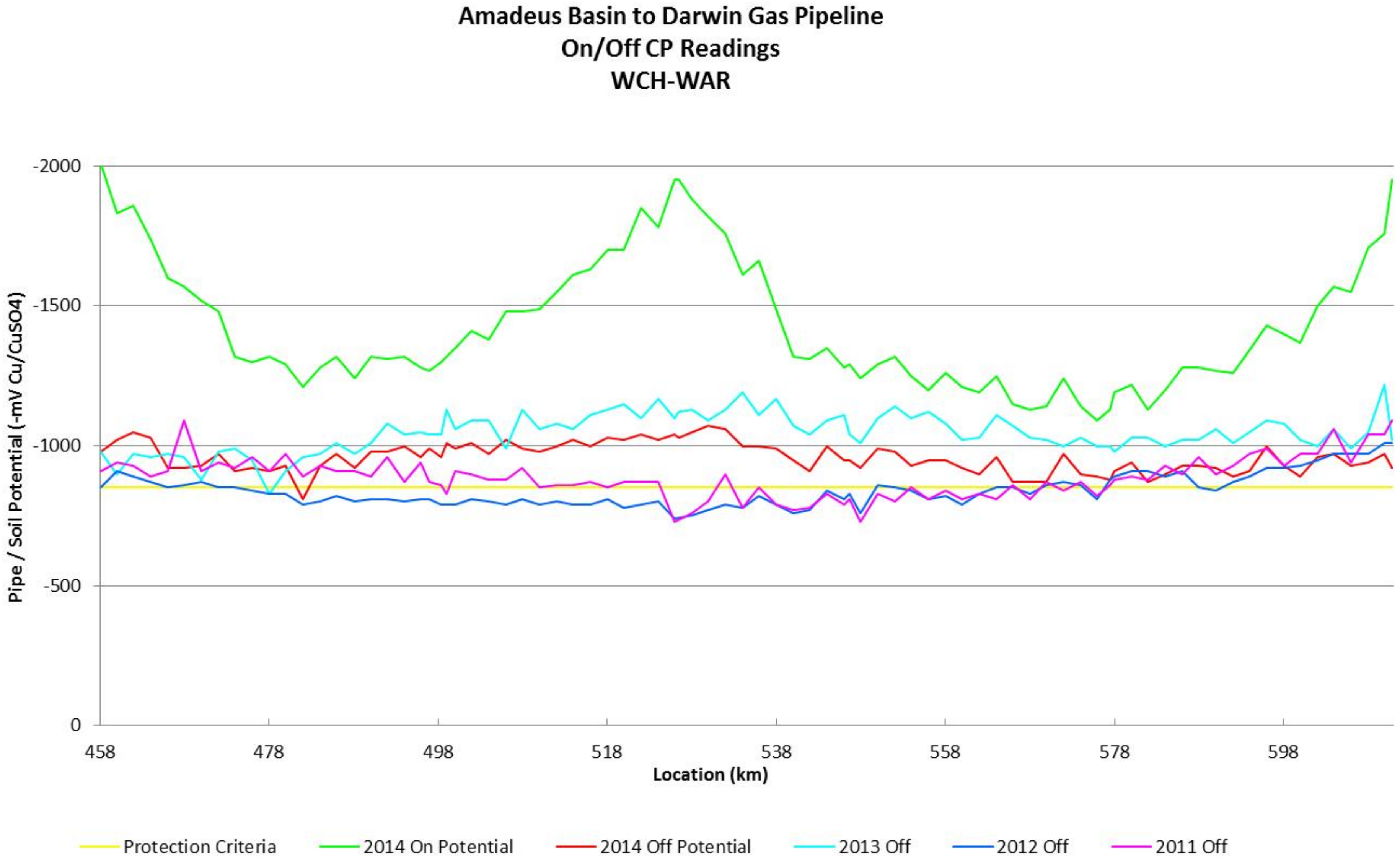
Amadeus Basin to Darwin Gas Pipeline
On/Off CP Readings
PVL-TMR

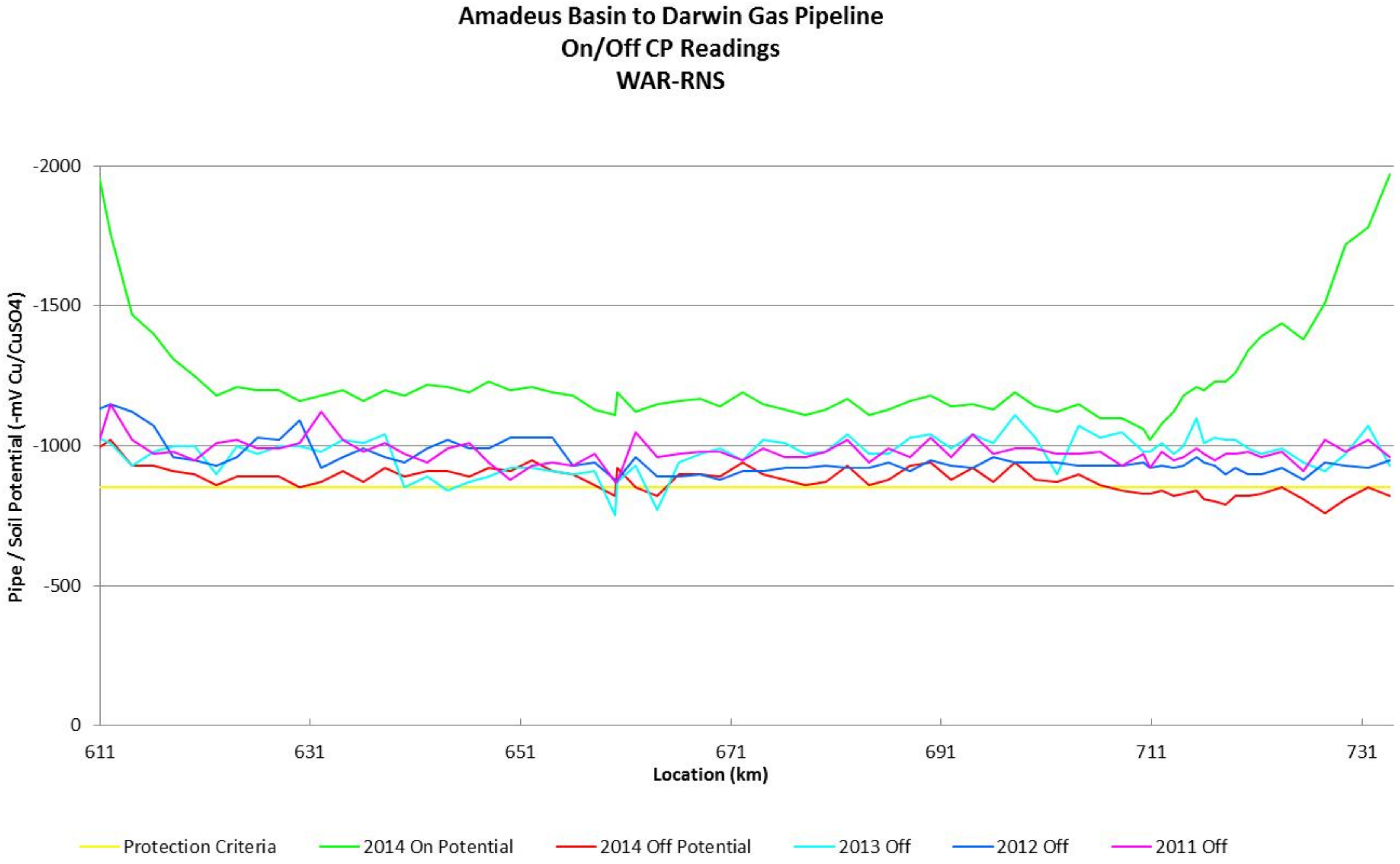


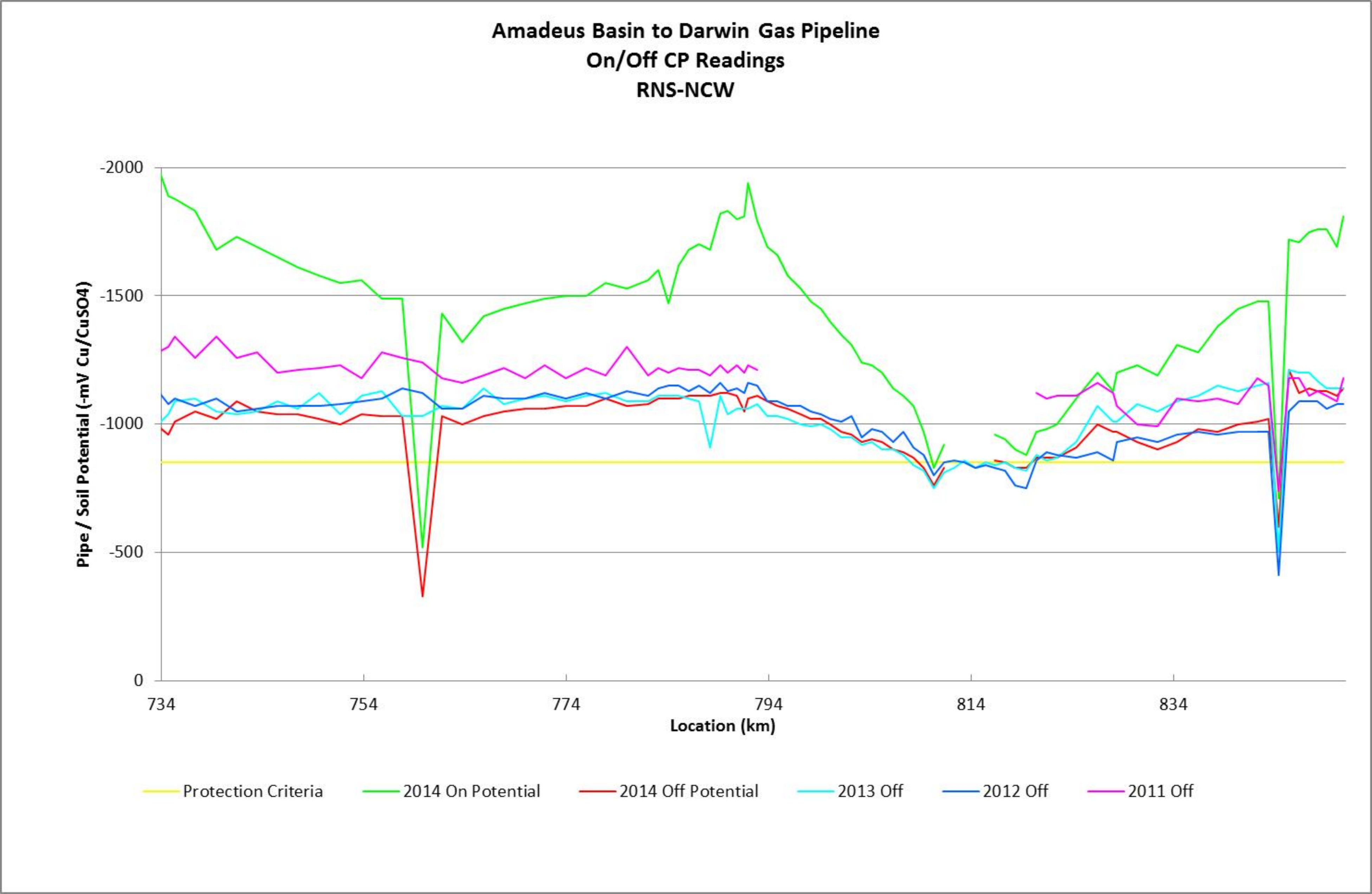
Amadeus Basin to Darwin Gas Pipeline
On/Off CP Readings
TMR-TTR

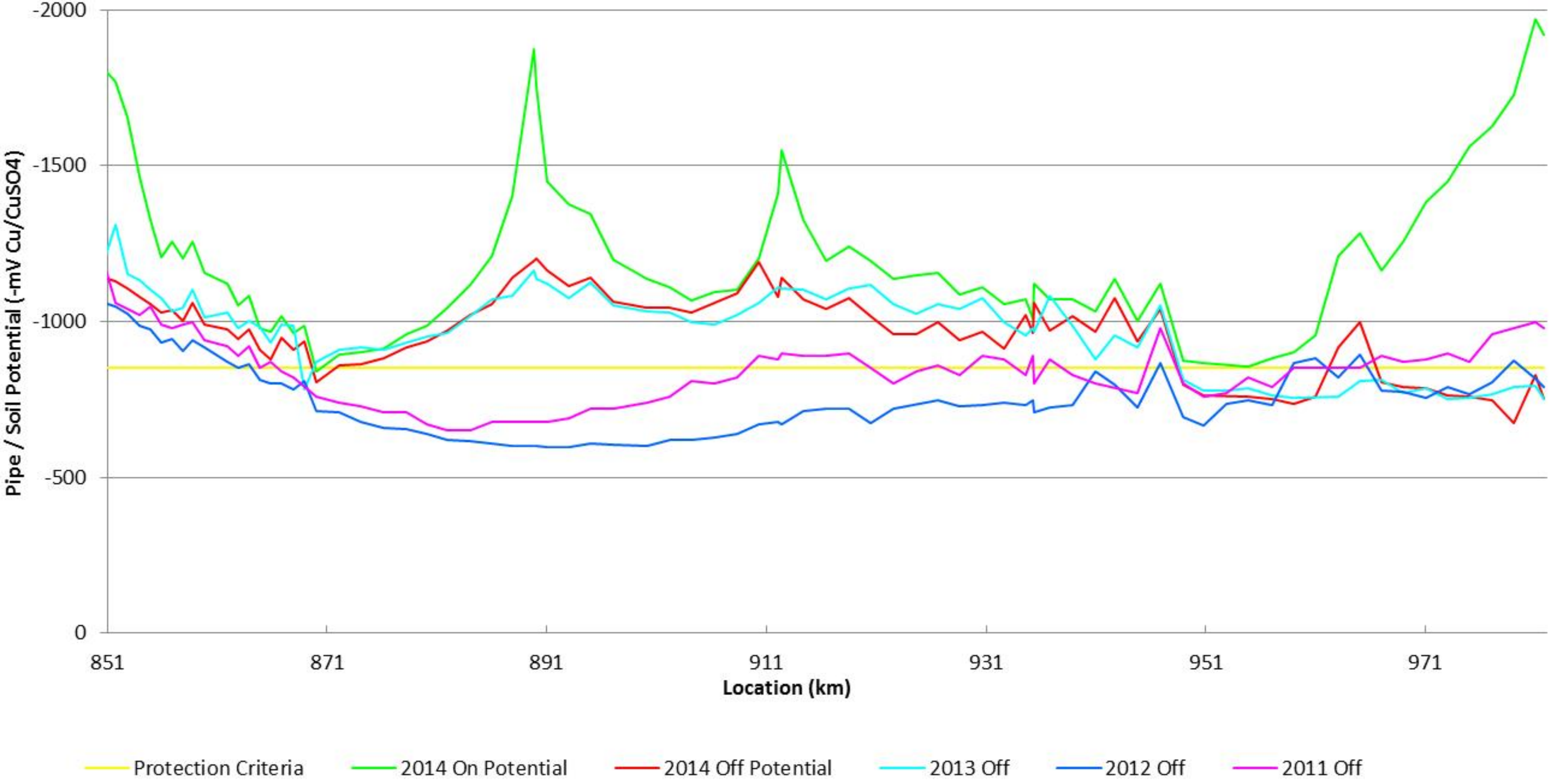



Amadeus Basin to Darwin Gas Pipeline
On/Off CP Readings
TTR-WCH
Pipe / Soil Potential (-mV Cu/CuSO4)
-2000
-1500
-1000
-500
0
316
336
356
376
396
416
436
456
Location (km)
Protection Criteria
2014 On Potential
2014 Off Potential
2013 Off
2012 Off
2011 Off


Amadeus Basin to Darwin Gas Pipeline
On/Off CP Readings
WCH-WAR
Pipe / Soil Potential (-mV Cu/CuSO4)
-2000
-1500
-1000
-500
0
458
478
498
518
538
558
578
598
Location (km)
Protection Criteria
2014 On Potential
2014 Off Potential
2013 Off
2012 Off
2011 Off

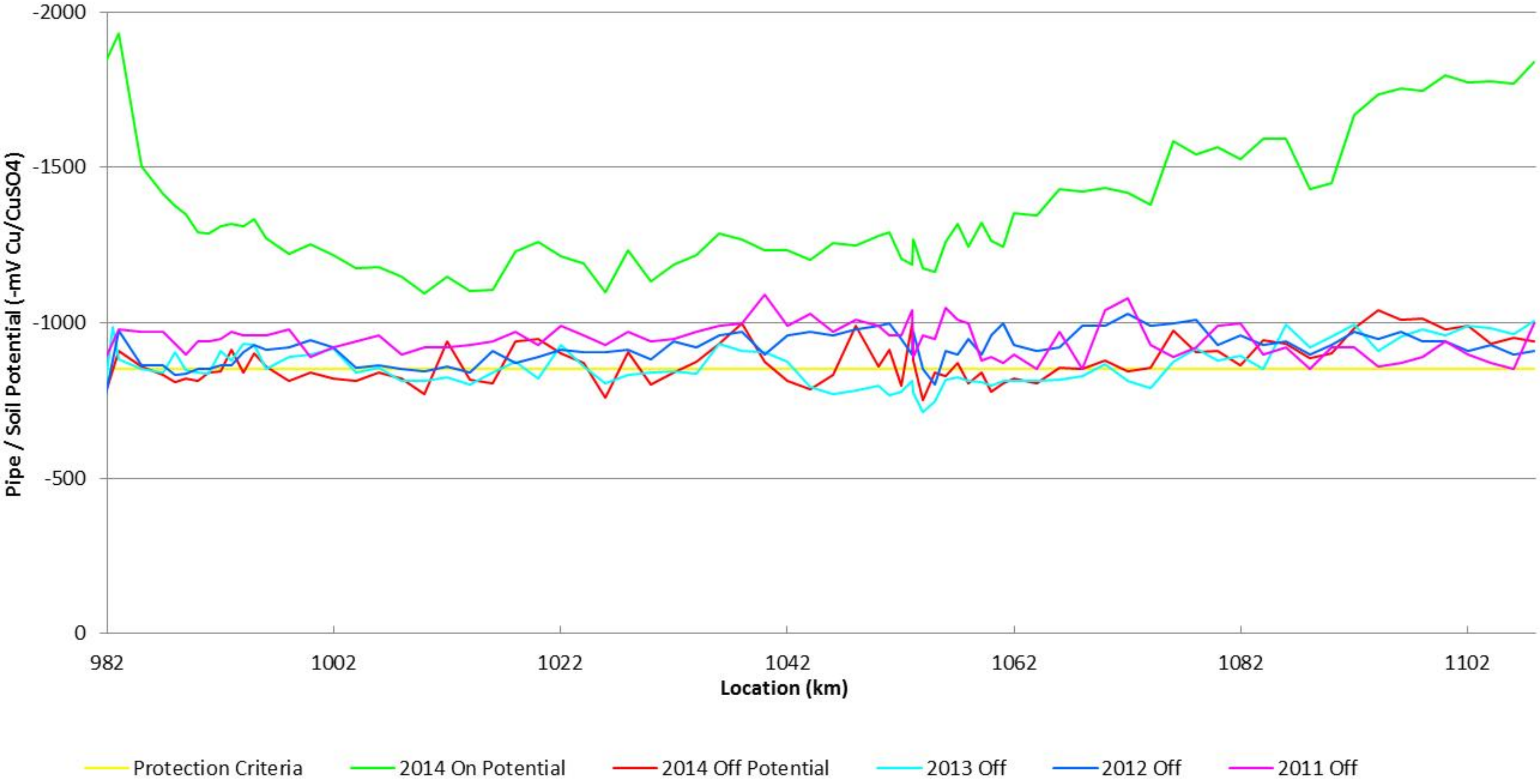

Amadeus Basin to Darwin Gas Pipeline
On/Off CP Readings
WAR-RNS
Pipe / Soil Potential (-mV Cu/CuSO4)
-2000
-1500
-1000
-500
0
611
631
651
671
691
711
731
Location (km)
Protection Criteria
2014 On Potential
2014 Off Potential
2013 Off
2012 Off
2011 Off

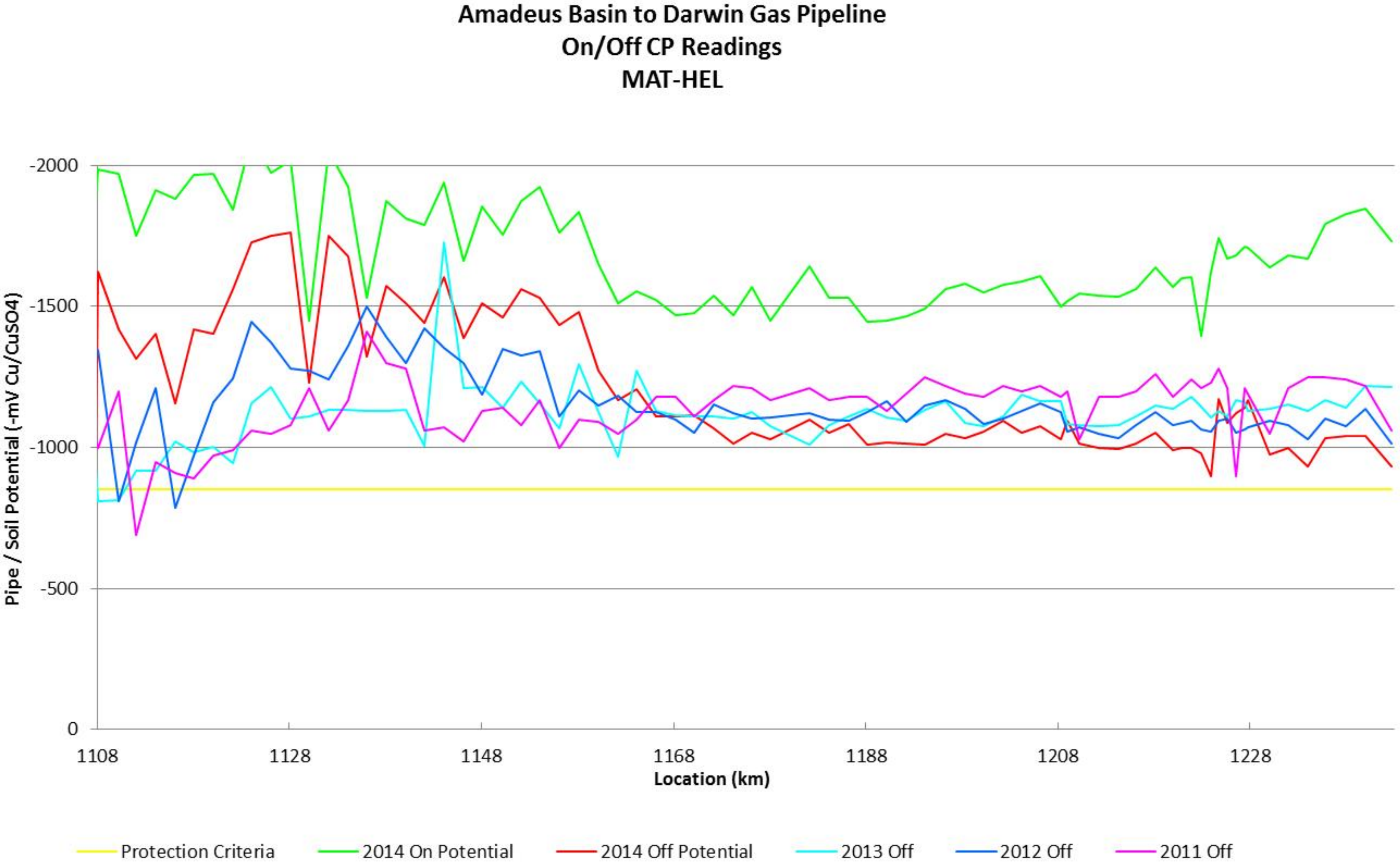

Amadeus Basin to Darwin Gas Pipeline
On/Off CP Readings
RNS-NCW
-2000
-1500
-1000
-500
0
Pipe / Soil Potential (-mV Cu/CuSO4)
734
754
774
794
814
834
Location (km)
Protection Criteria
2014 On Potential
2014 Off Potential
2013 Off
2012 Off
2011 Off

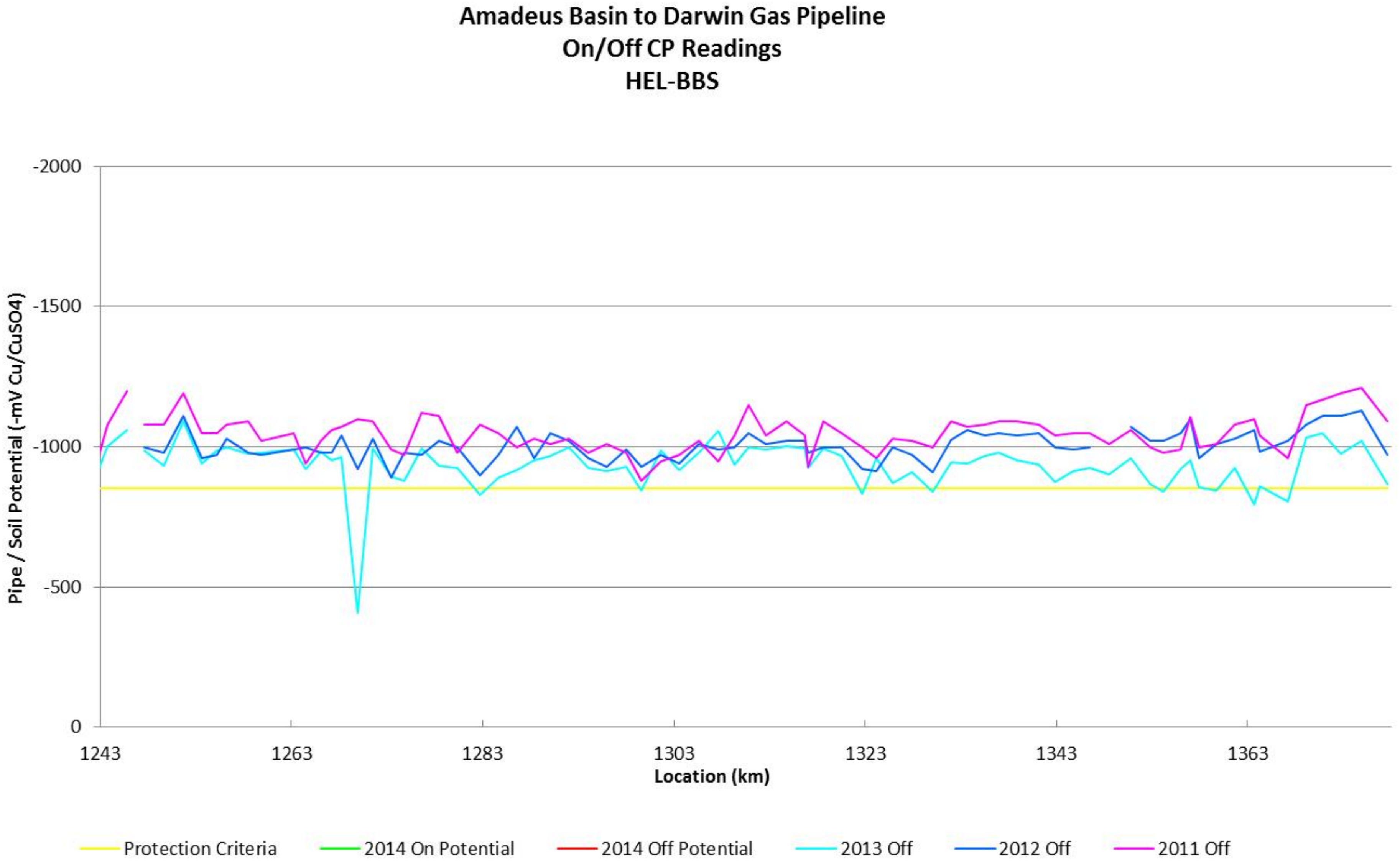


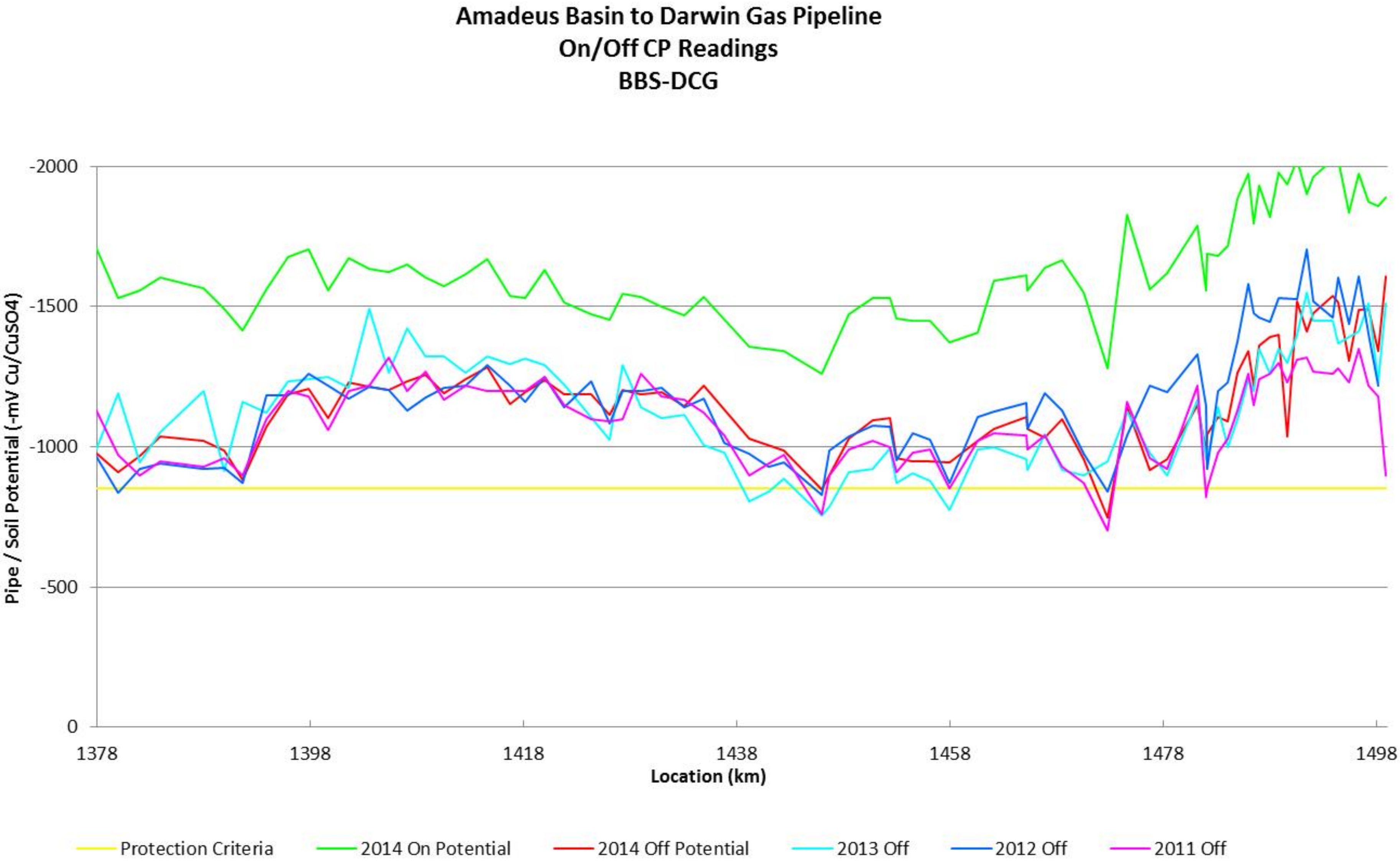
Amadeus Basin to Darwin Gas Pipeline
On/Off CP Readings
NCW-DLW

Amadeus Basin to Darwin Gas Pipeline
On/Off CP Readings
DLW-MAT

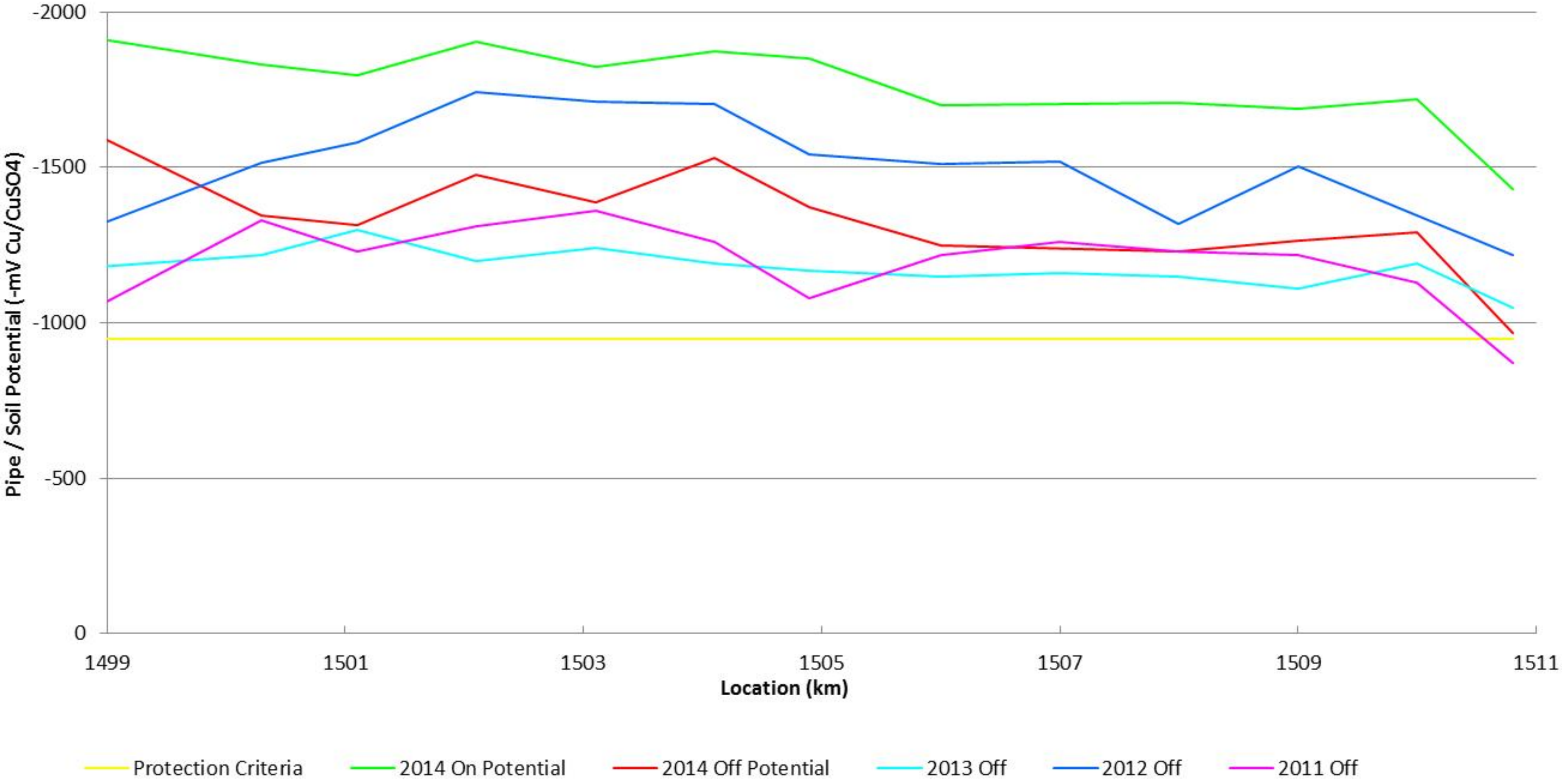


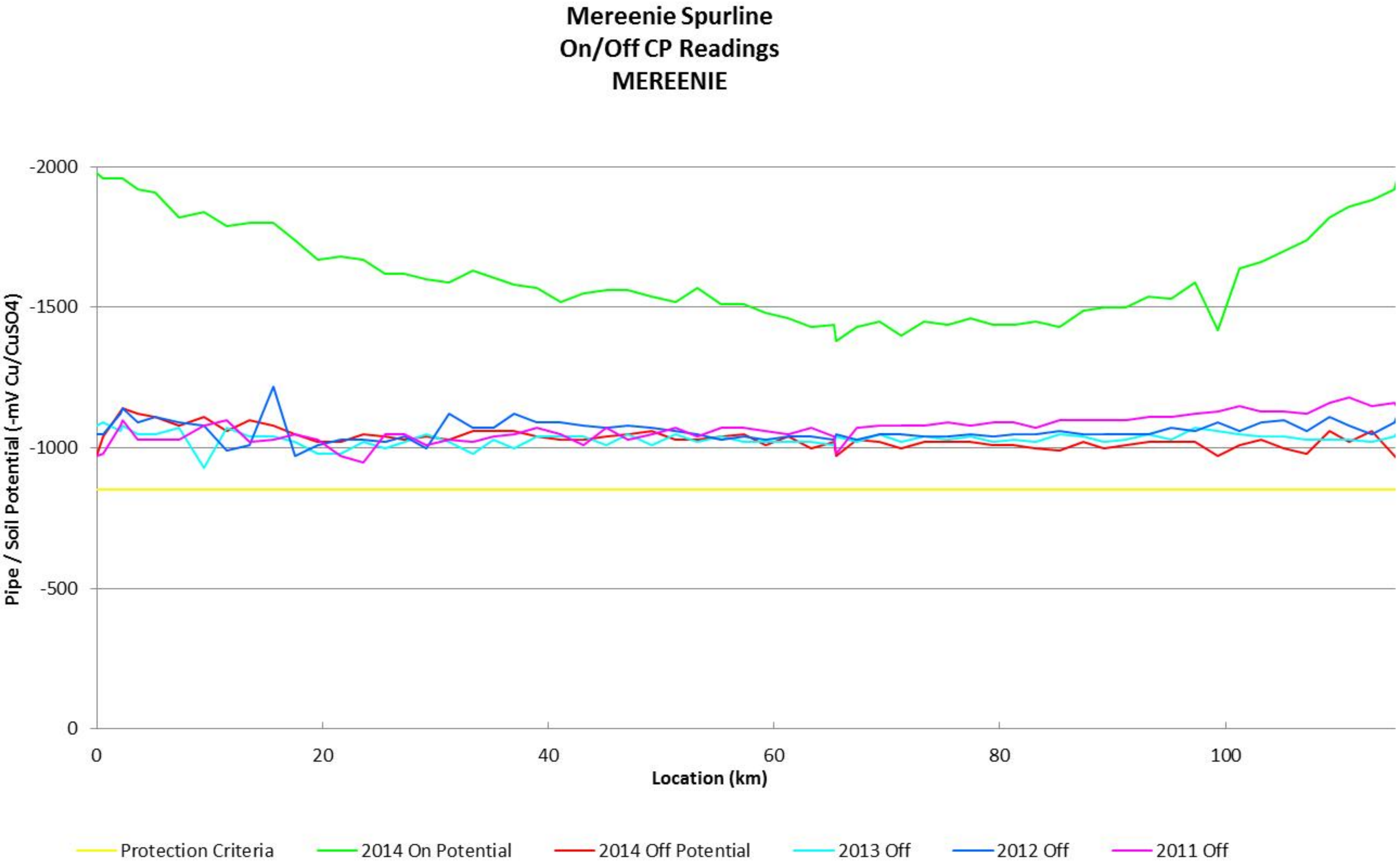

Amadeus Basin to Darwin Gas Pipeline
On/Off CP Readings
MAT-HEL
Pipe / Soil Potential (-mV Cu/CuSO4)
-2000
-1500
-1000
-500
0
1108
1128
1148
1168
1188
1208
1228
Location (km)
Protection Criteria
2014 On Potential
2014 Off Potential
2013 Off
2012 Off
2011 Off

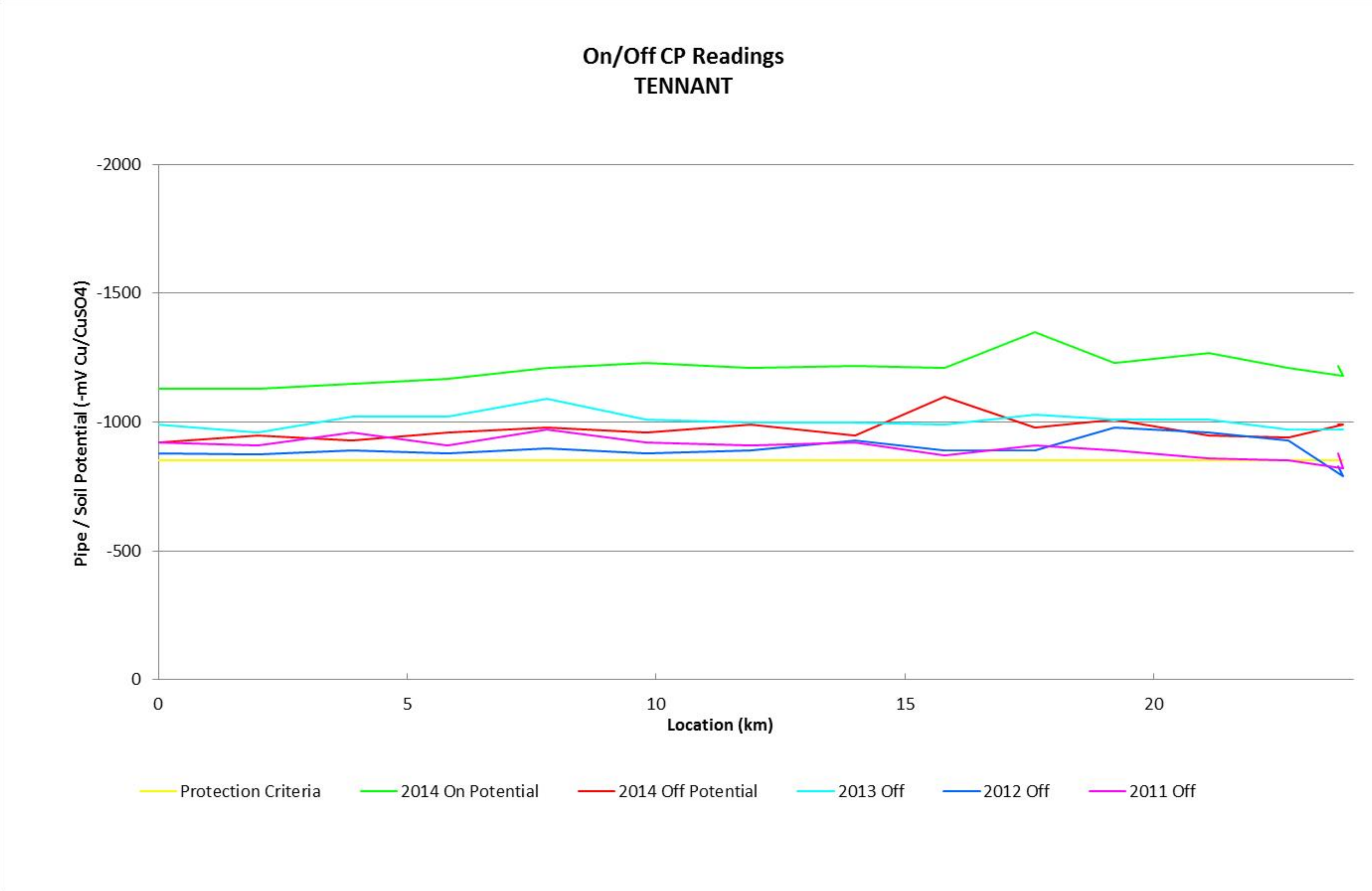

Amadeus Basin to Darwin Gas Pipeline
On/Off CP Readings
HEL-BBS
Pipe / Soil Potential (-mV Cu/CuSO4)
-2000
-1500
-1000
-500
0
1243
1263
1283
1303
1323
1343
1363
Location (km)
Protection Criteria
2014 On Potential
2014 Off Potential
2013 Off
2012 Off
2011 Off


Amadeus Basin to Darwin Gas Pipeline
On/Off CP Readings
BBS-DCG
Pipe / Soil Potential (-mV Cu/CuSO4)
-2000
-1500
-1000
-500
0
1378
1398
1418
1438
1458
1478
1498
Location (km)
Protection Criteria
2014 On Potential
2014 Off Potential
2013 Off
2012 Off
2011 Off

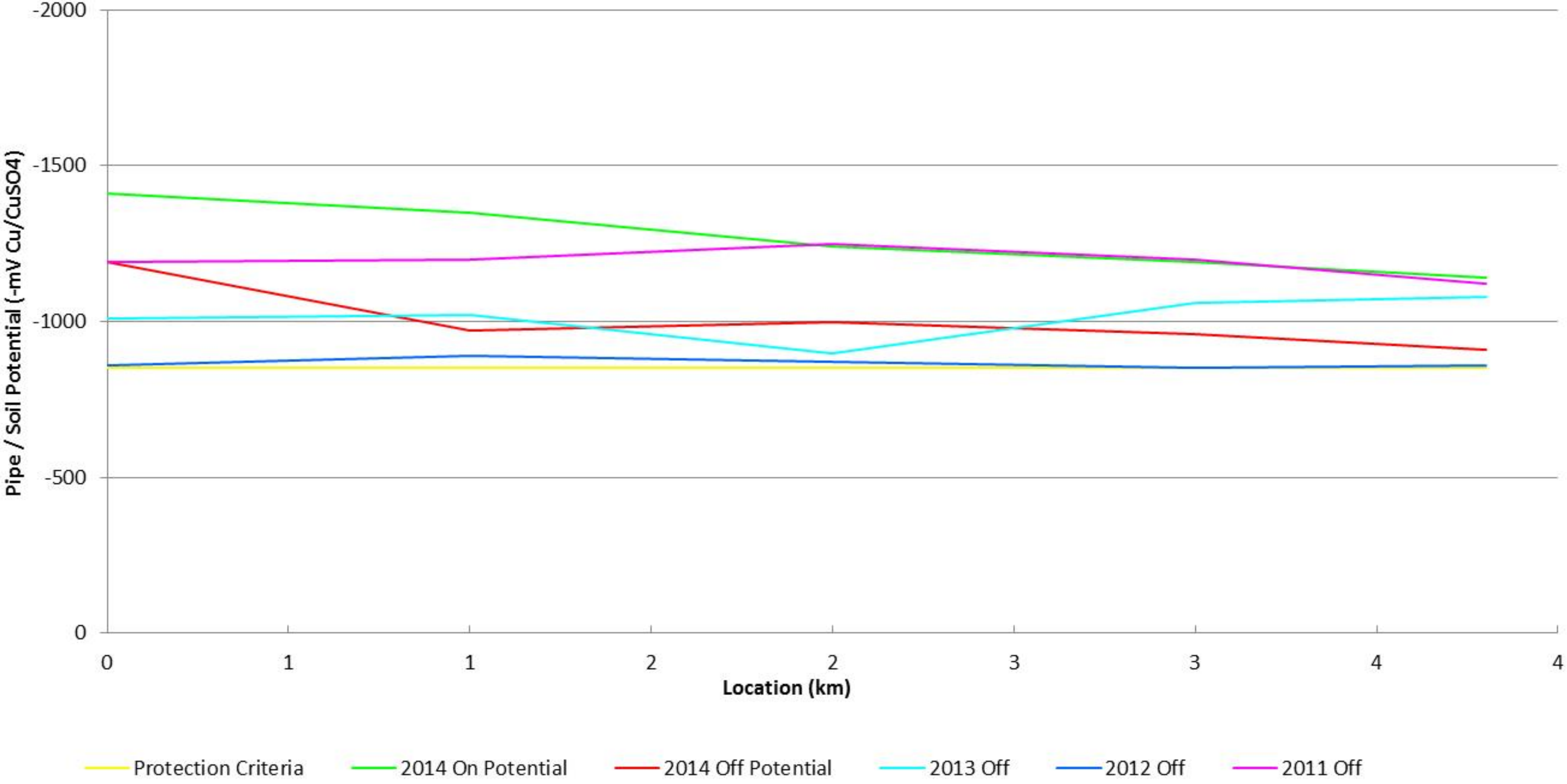
Amadeus Basin to Darwin Gas Pipeline
On/Off CP Readings
DCG-CIM

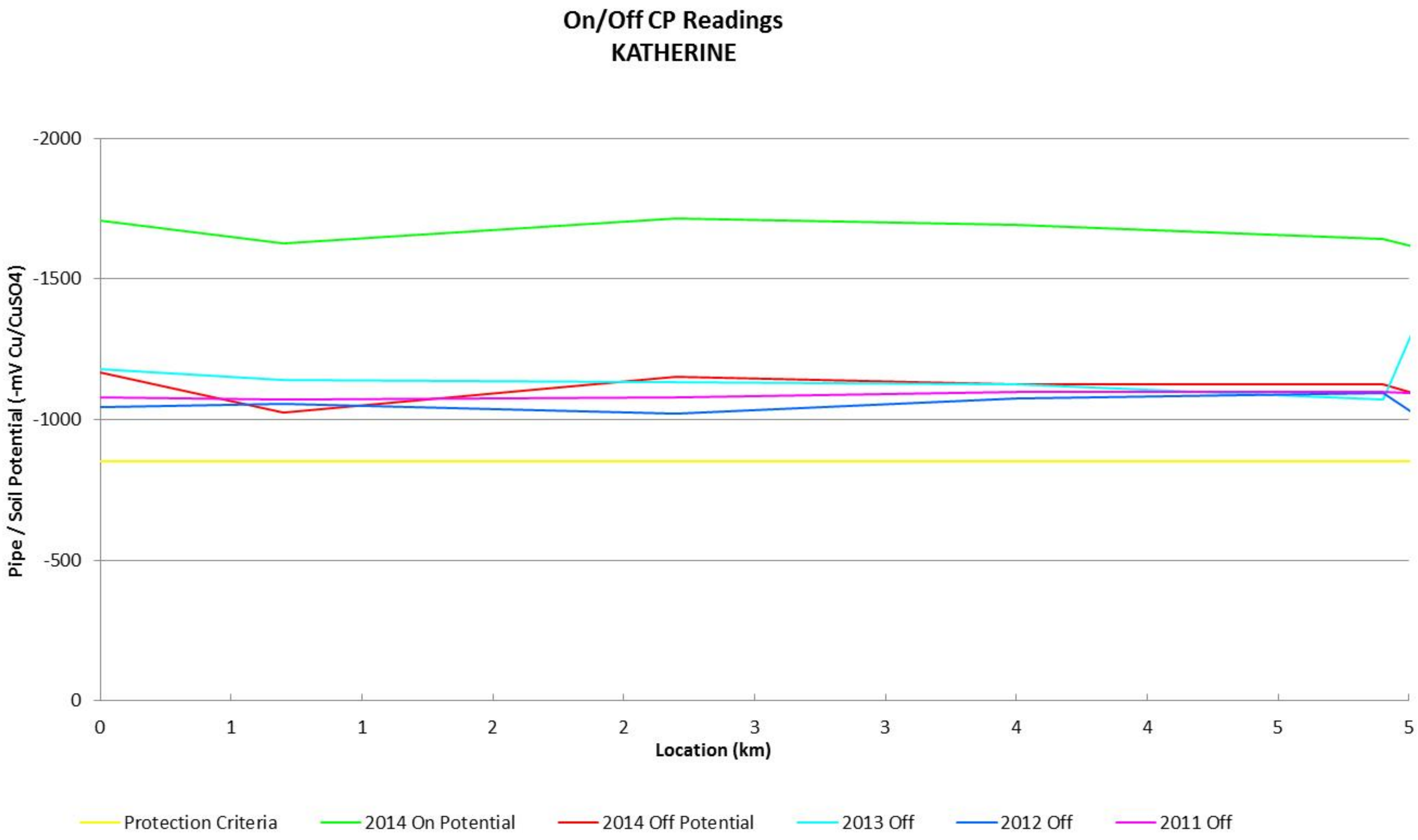


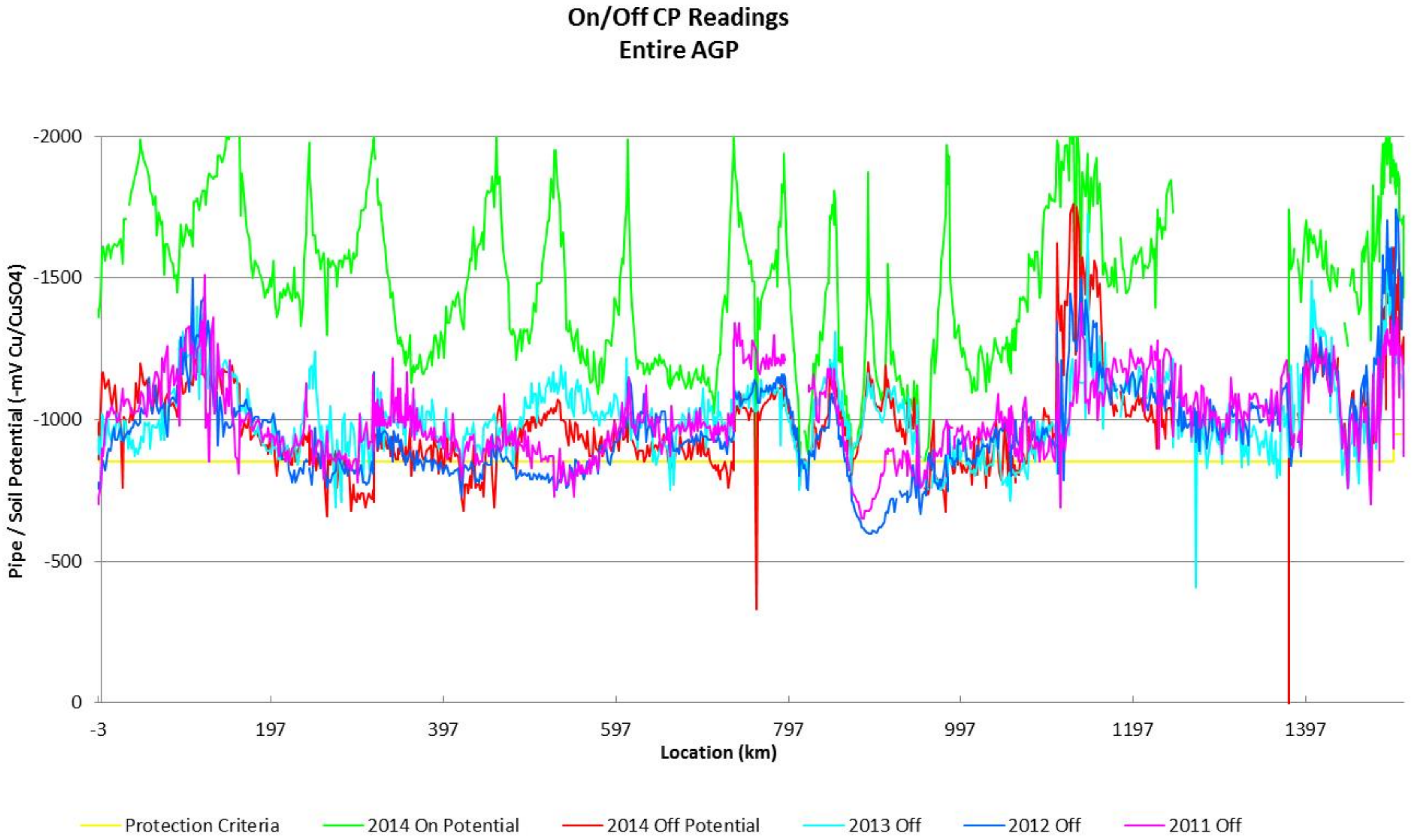

Mereenie Spurline
On/Off CP Readings
MEREENIE
Pipe / Soil Potential (-mV Cu/CuSO4)
-2000
-1500
-1000
-500
0
0
20
40
60
80
100
Location (km)
Protection Criteria
2014 On Potential
2014 Off Potential
2013 Off
2012 Off
2011 Off


On/Off CP Readings
TENNANT
Pipe / Soil Potential (-mV Cu/CuSO4)
-2000
-1500
-1000
-500
0
0
5
10
15
20
Location (km)
Protection Criteria
2014 On Potential
2014 Off Potential
2013 Off
2012 Off
2011 Off

Elliott Lateral
On/Off CP Readings
ELLIOT



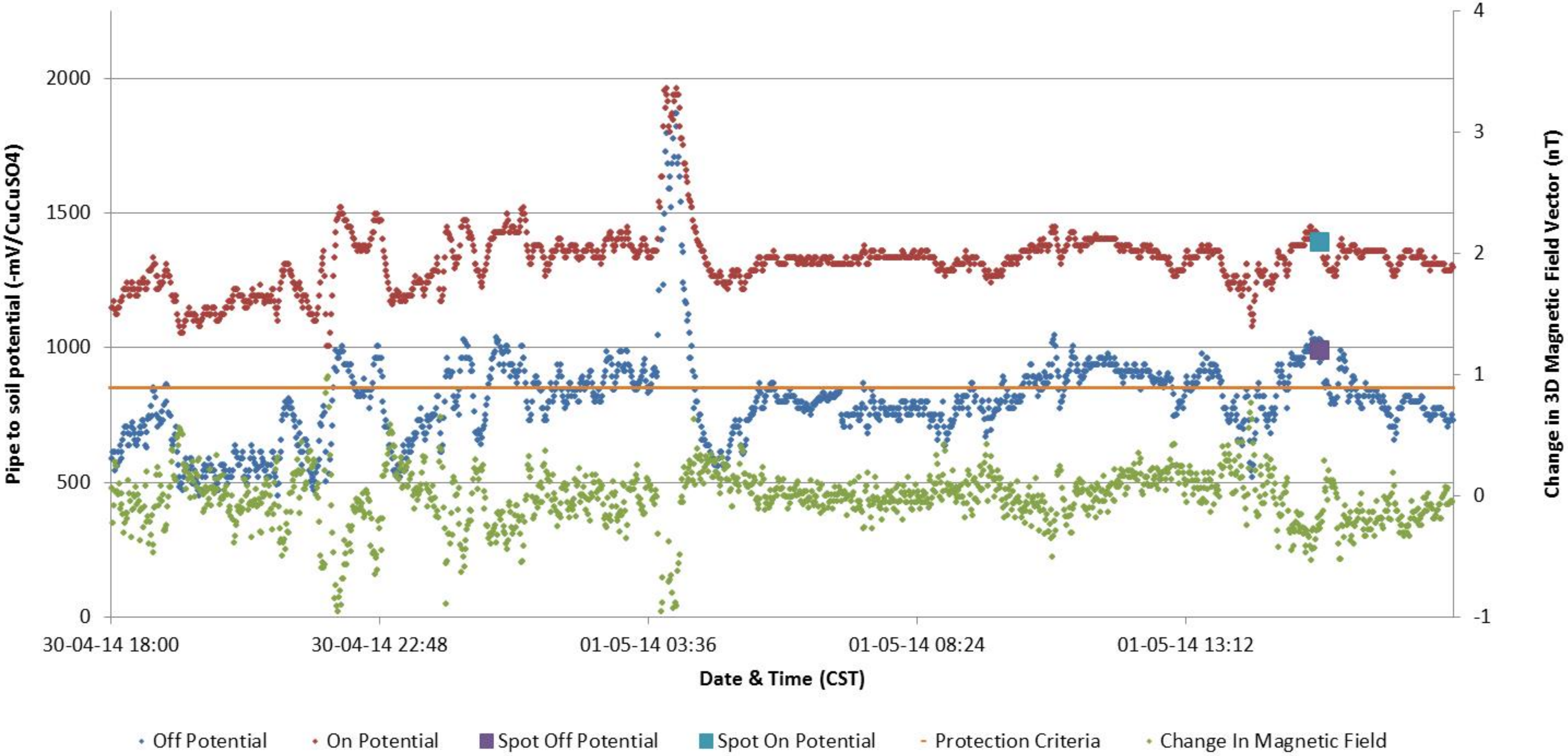

On/Off CP Readings
KATHERINE
Pipe / Soil Potential (-mV Cu/CuSO4)
-2000
-1500
-1000
-500
0
0
1
1
2
2
3
3
4
4
5
5
Location (km)
Protection Criteria
2014 On Potential
2014 Off Potential
2013 Off
2012 Off
2011 Off


On/Off CP Readings
Entire AGP
Pipe / Soil Potential (-mV Cu/CuSO4)
-2000
-1500
-1000
-500
0
-3
197
397
597
797
997
1197
1397
Location (km)
Protection Criteria
2014 On Potential
2014 Off Potential
2013 Off
2012 Off
2011 Off

Appendix C

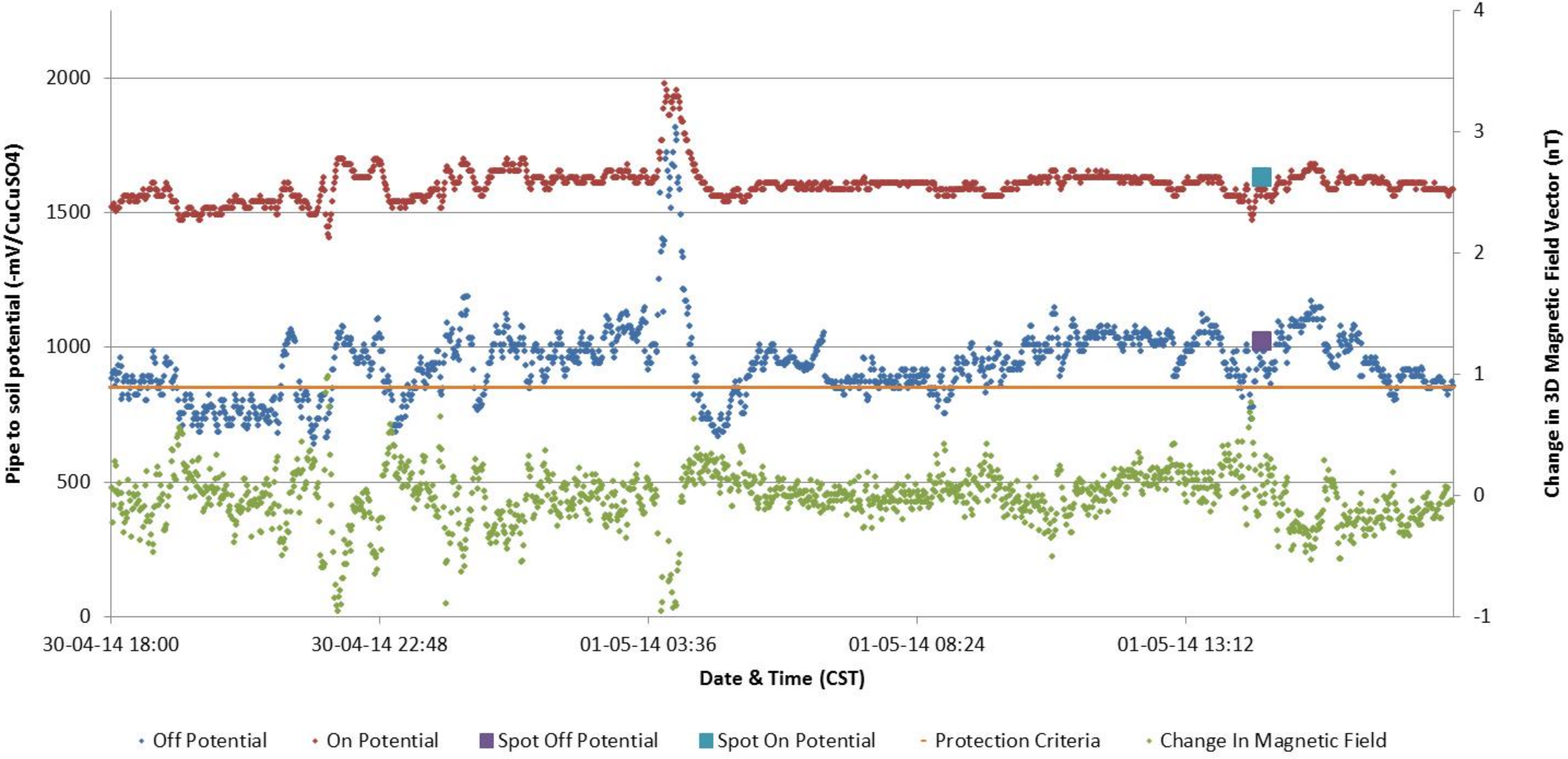
Amadeus Basin to Darwin Natural Gas Pipeline

Telluric Influence on Pipe to Soil Potential



Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 2.9 PVL-TMR

Time Below Protection Criteria 66%

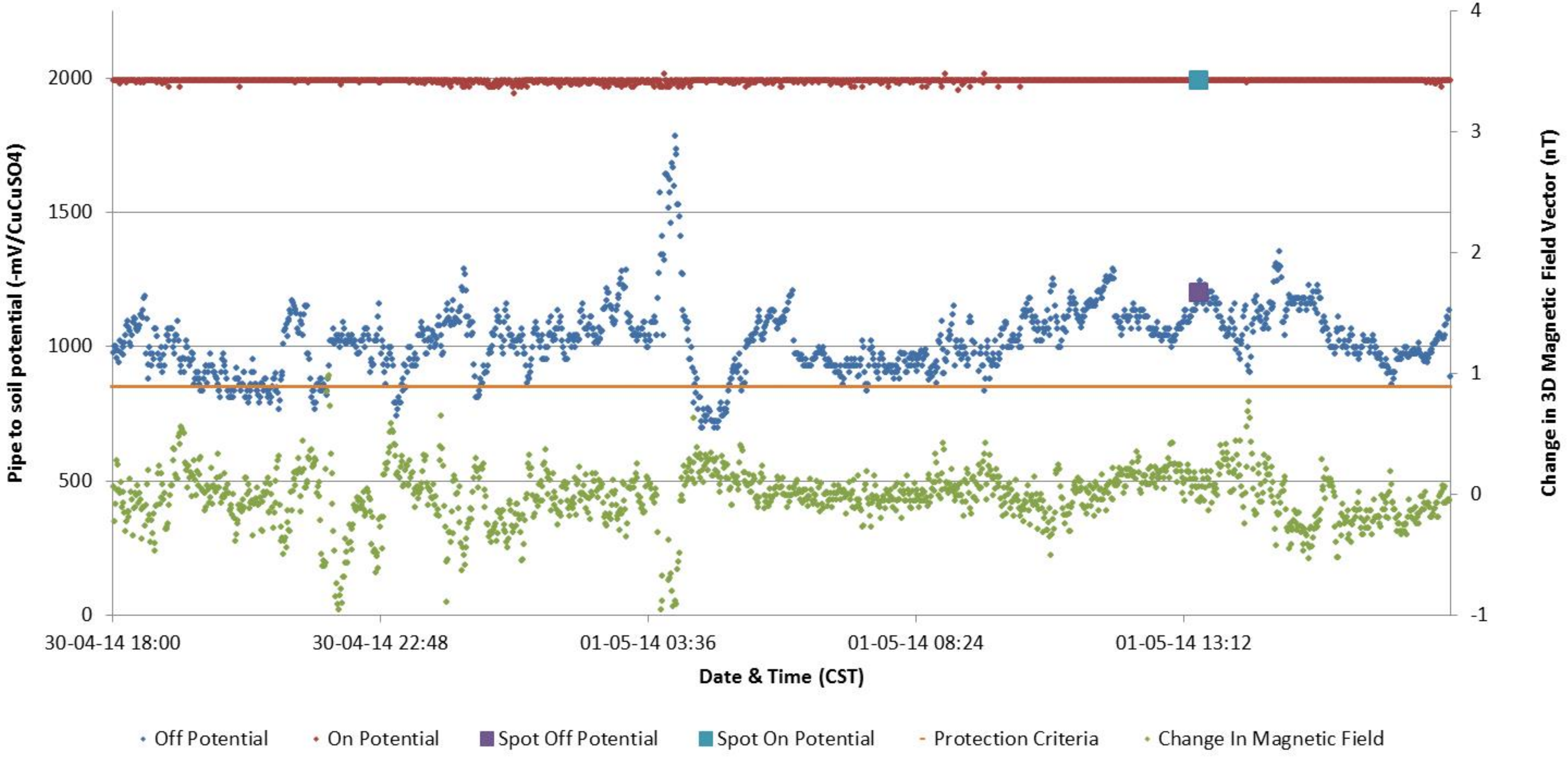


Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 21 PVL-TMR

Time Below Protection Criteria 24%

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 45.7 PVL-TMR

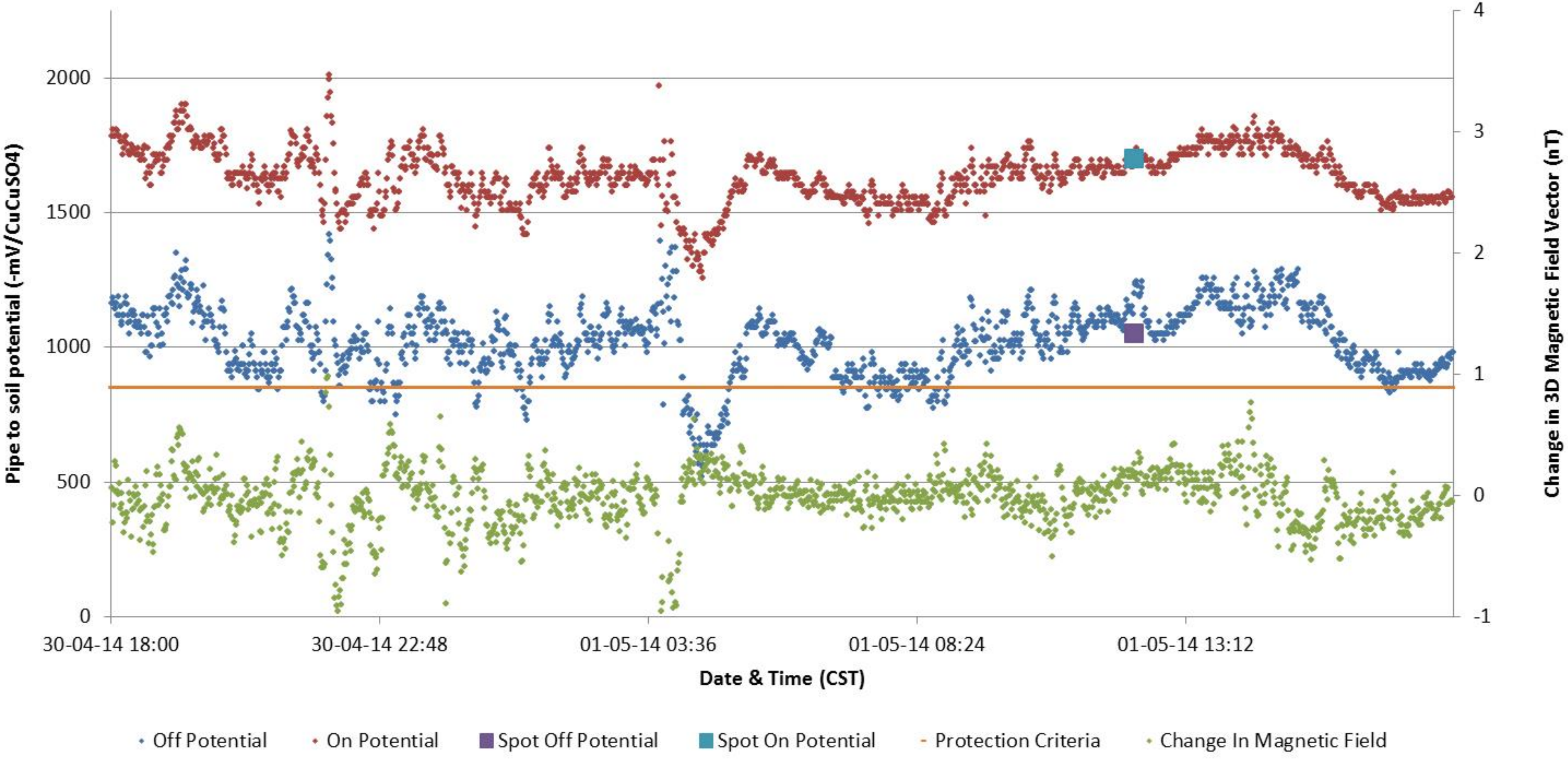
Time Below Protection Criteria 7%



Effect of Telluric Activity on Pipe to Soil Potential

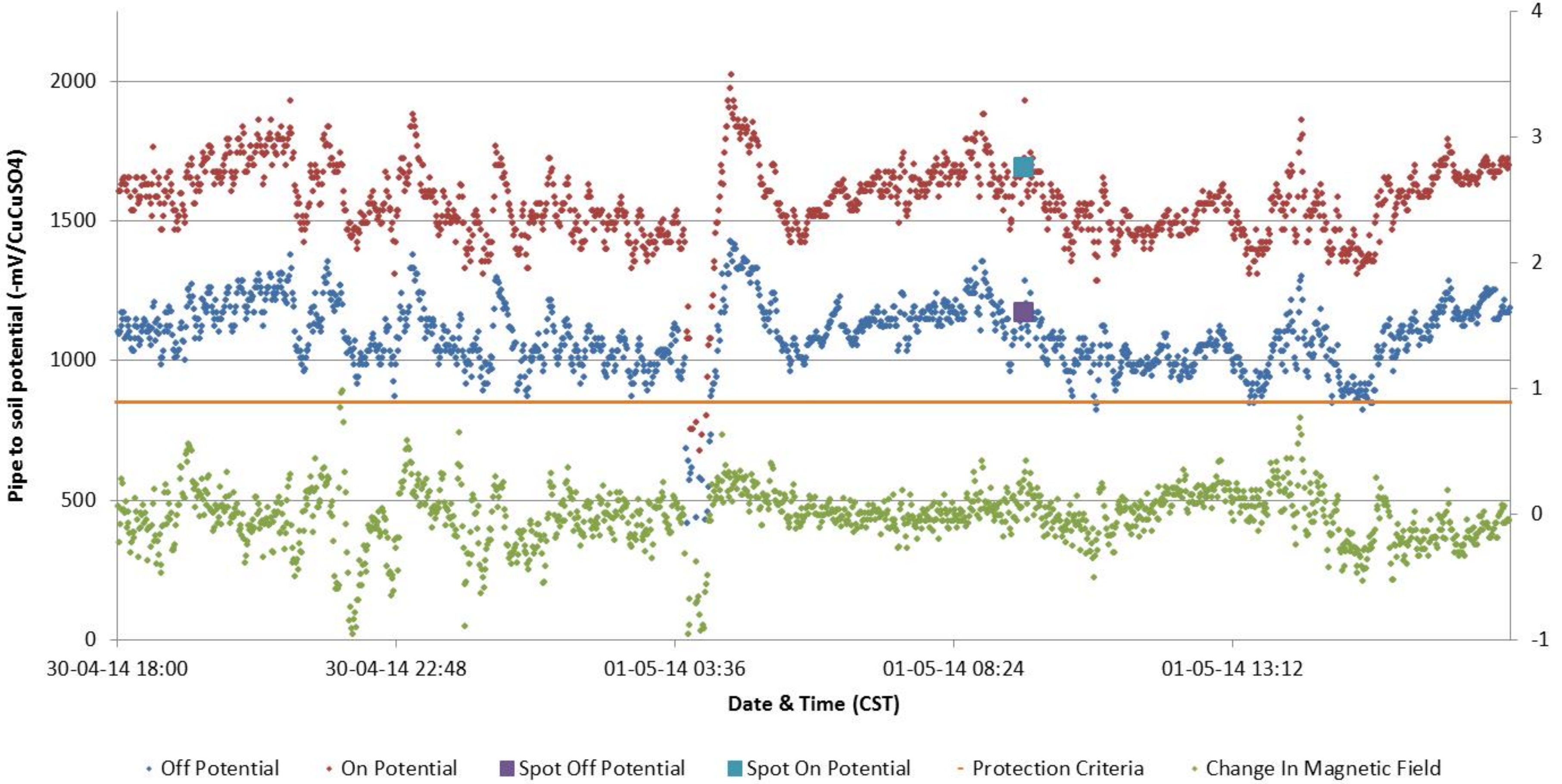
Amadeus Gas Pipeline KP 71.1 PVL-TMR

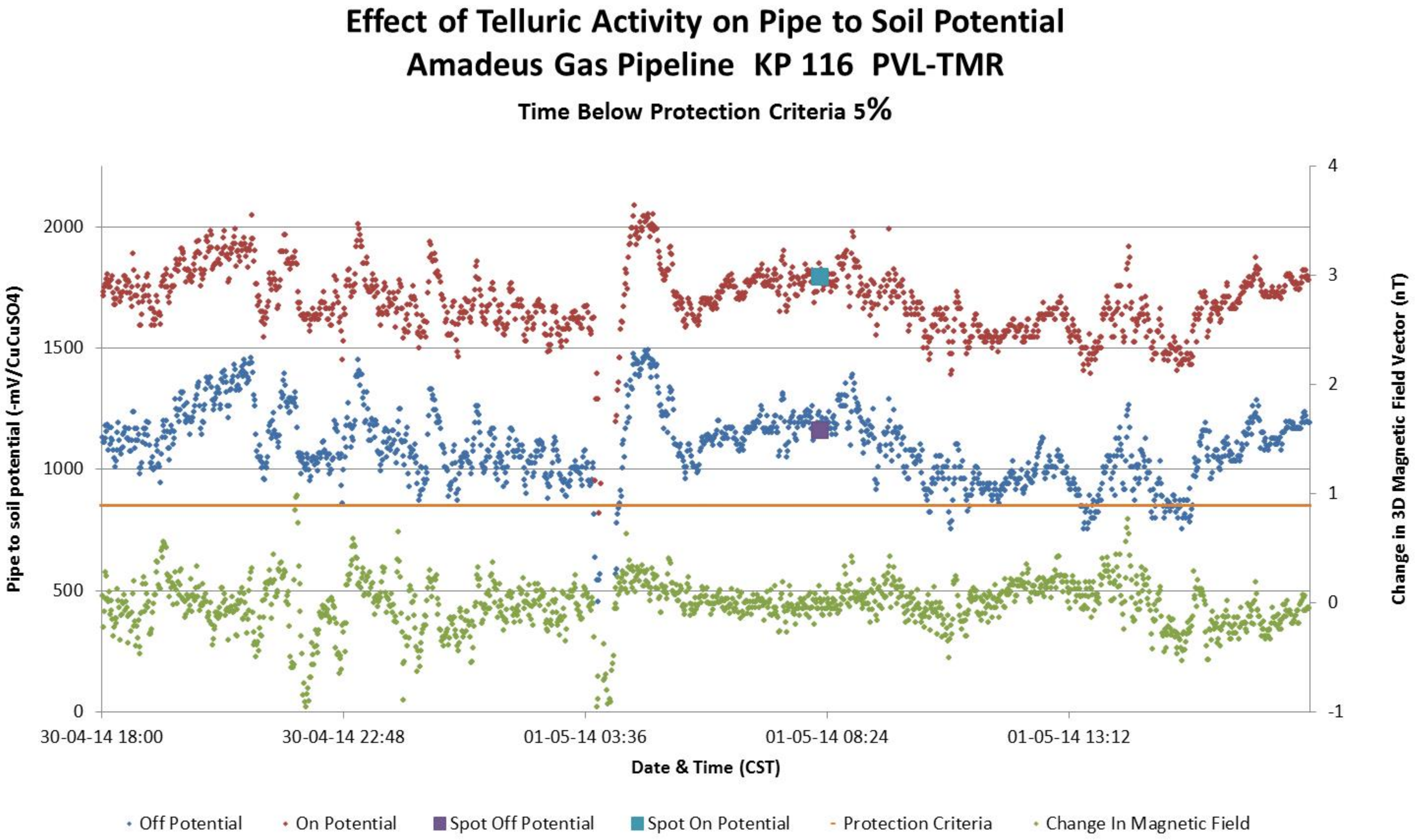
Time Below Protection Criteria 9%



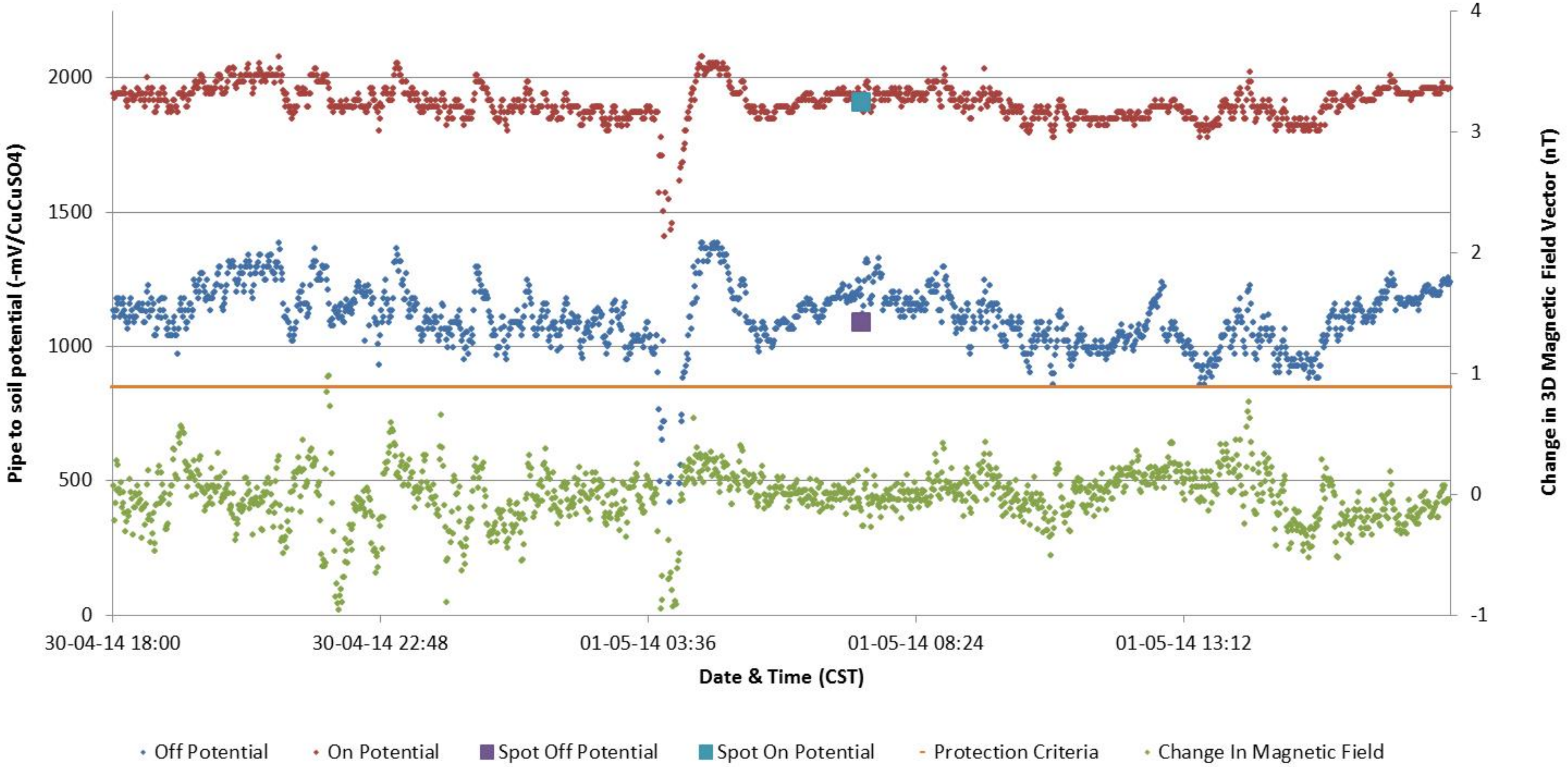
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 93 PVL-TMR

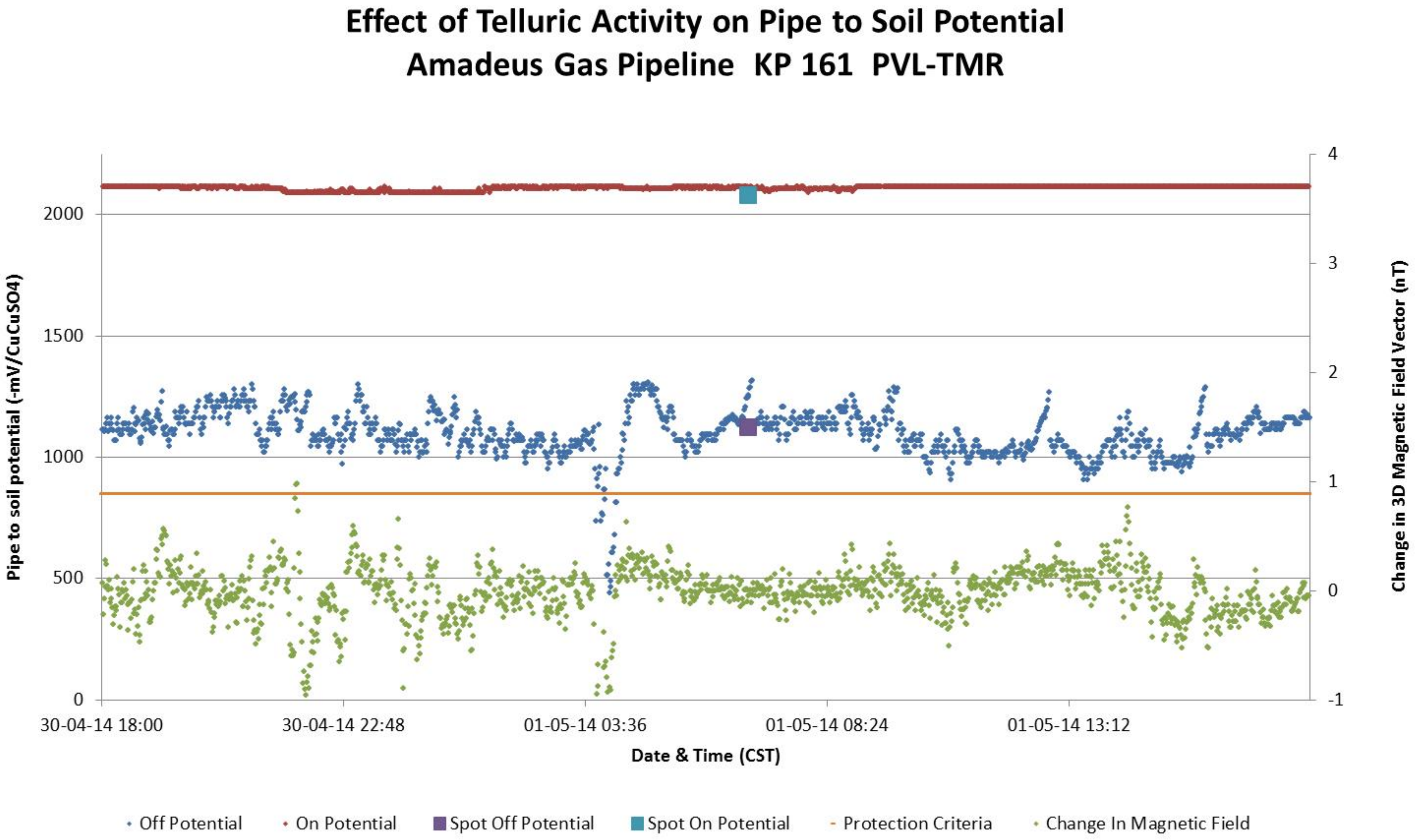
Time Below Protection Criteria 2%

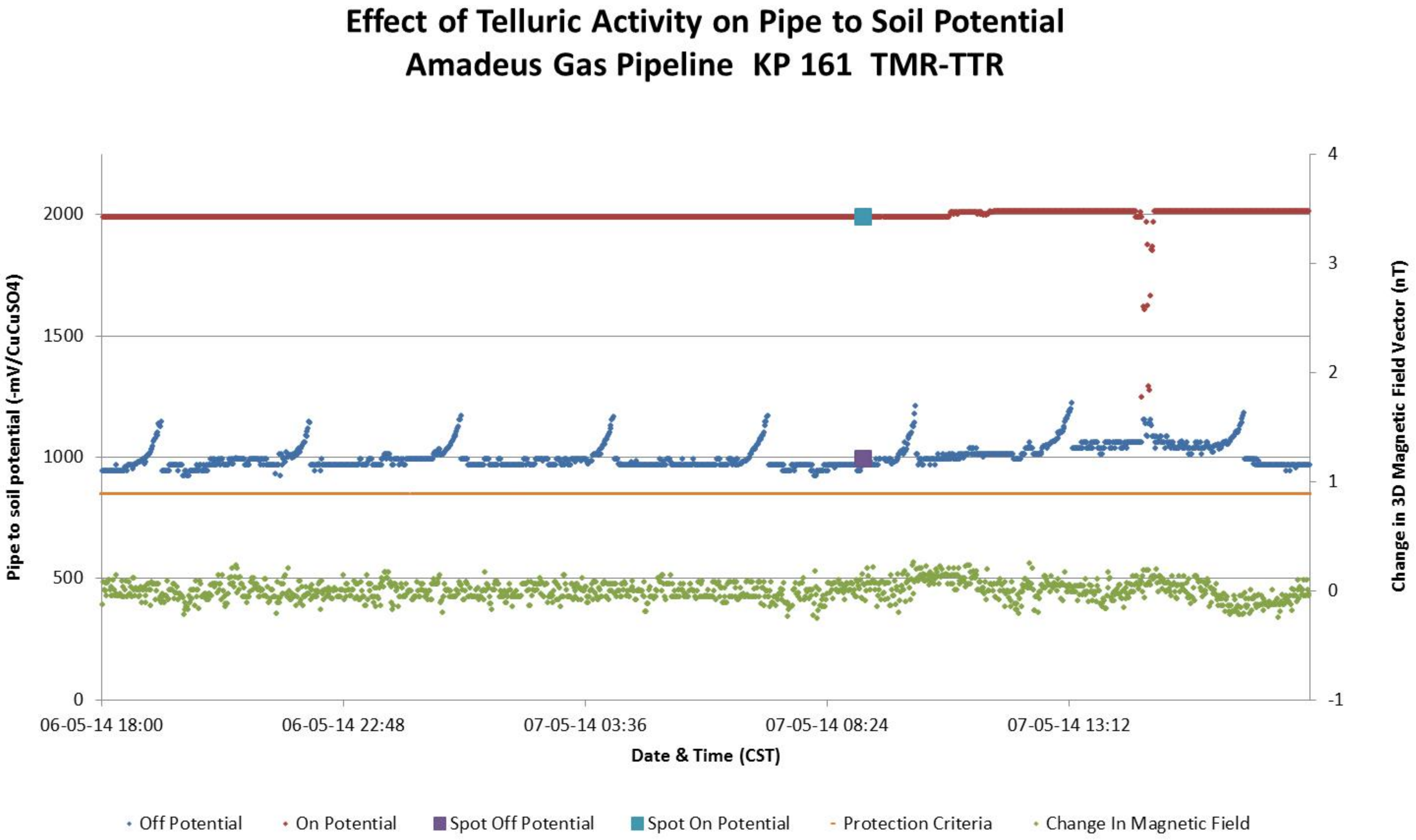



Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 116 PVL-TMR
Time Below Protection Criteria 5%
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
30-04-14 18:00
30-04-14 22:48
01-05-14 03:36
01-05-14 08:24
01-05-14 13:12
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field

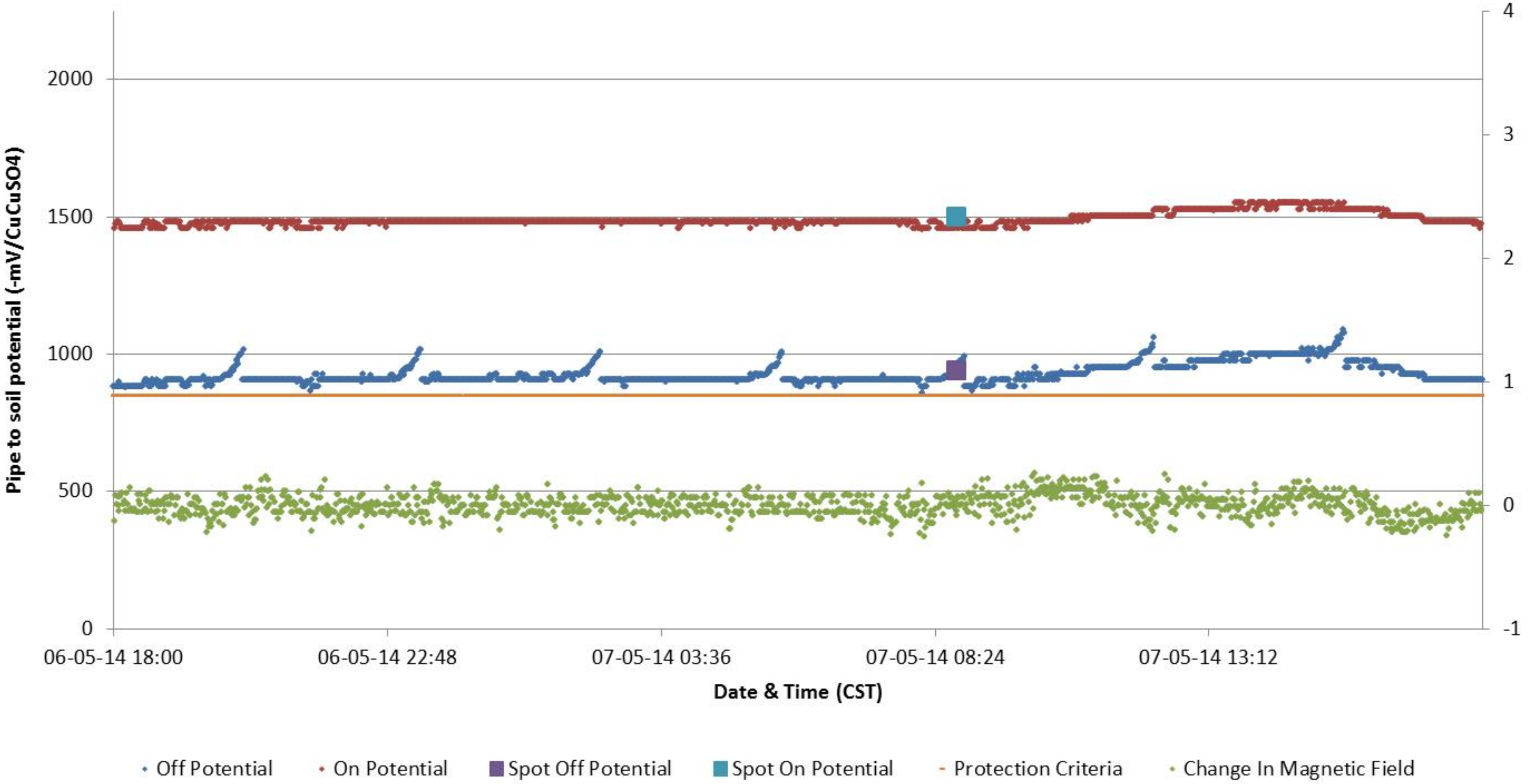
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 140 PVL-TMR



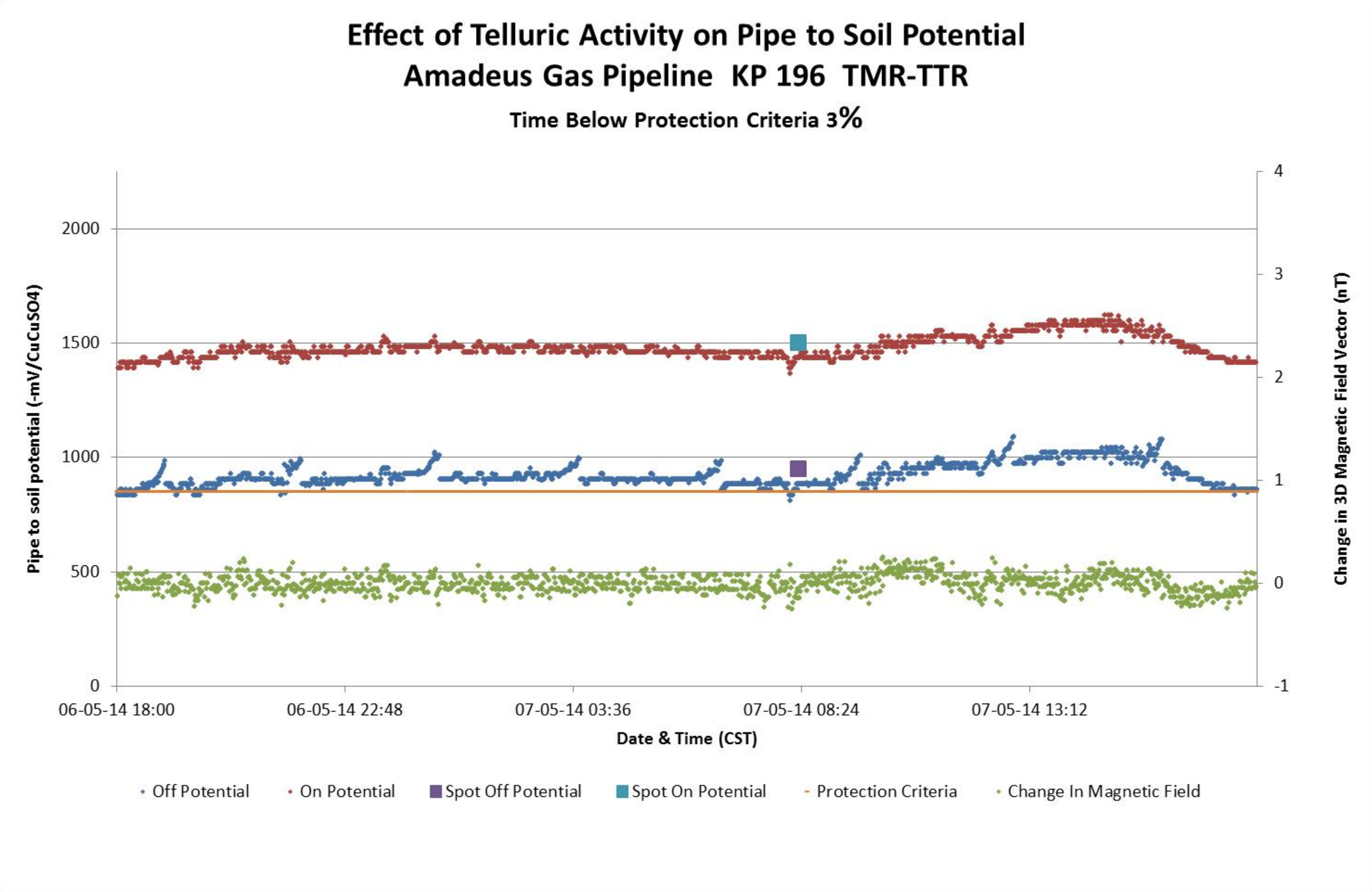

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 161 PVL-TMR
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
30-04-14 18:00
30-04-14 22:48
01-05-14 03:36
01-05-14 08:24
01-05-14 13:12
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field

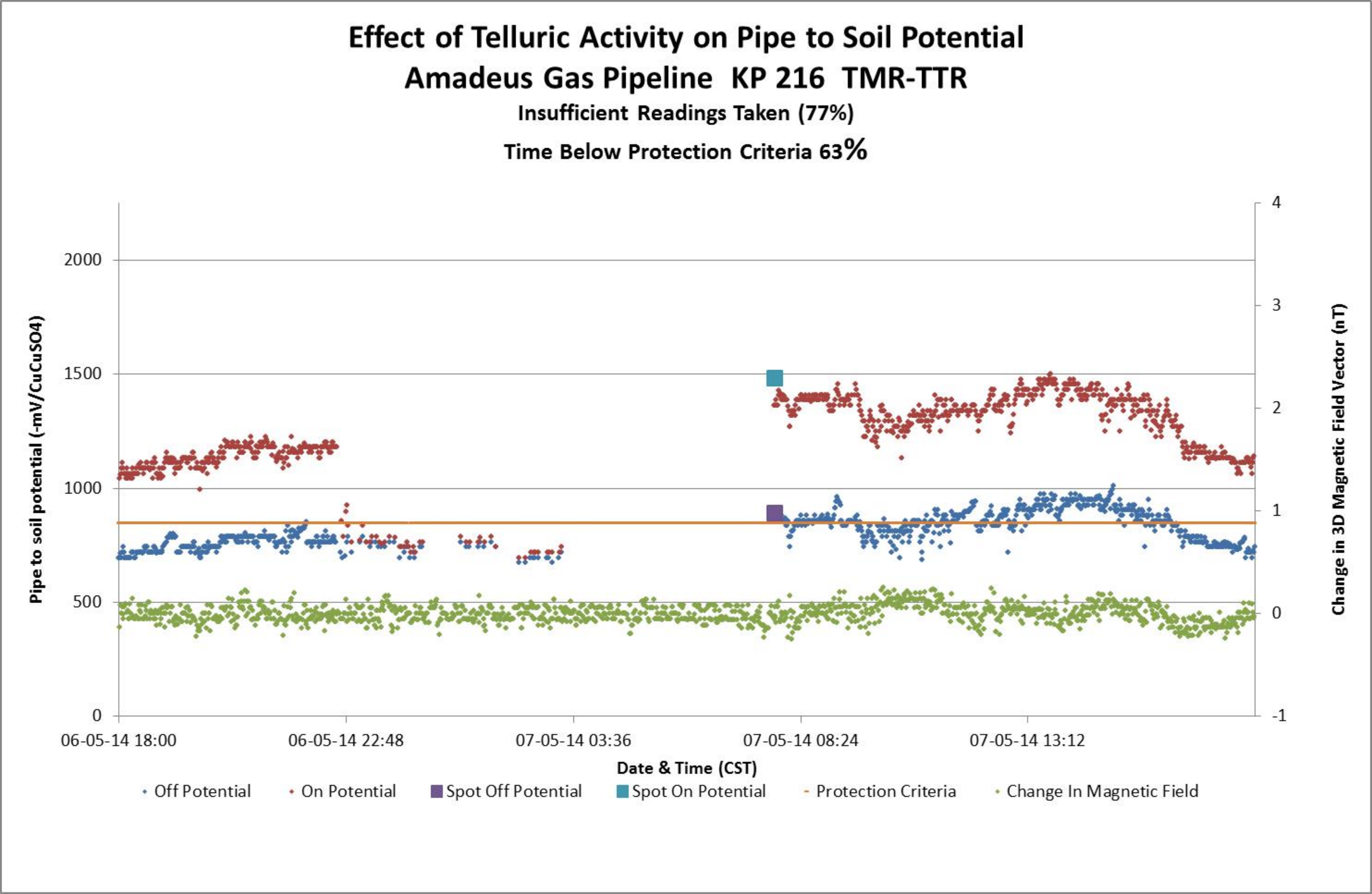


Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 161 TMR-TTR



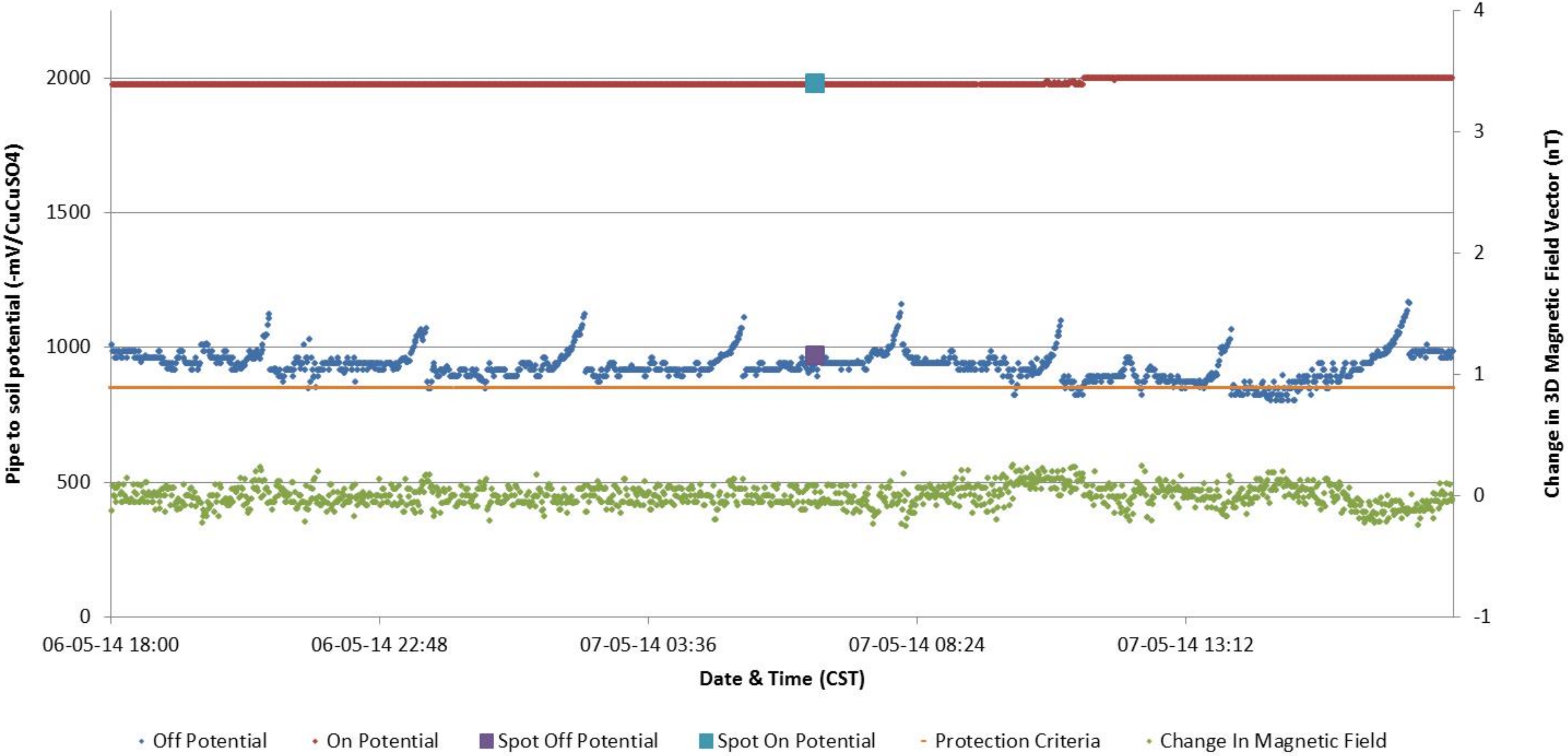
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 176 TMR-TTR


Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 196 TMR-TTR
Time Below Protection Criteria 3%
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
06-05-14 18:00
06-05-14 22:48
07-05-14 03:36
07-05-14 08:24
07-05-14 13:12
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field


Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 216 TMR-TTR
Insufficient Readings Taken (77%)
Time Below Protection Criteria 63%
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
06-05-14 18:00
06-05-14 22:48
07-05-14 03:36
07-05-14 08:24
07-05-14 13:12
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field

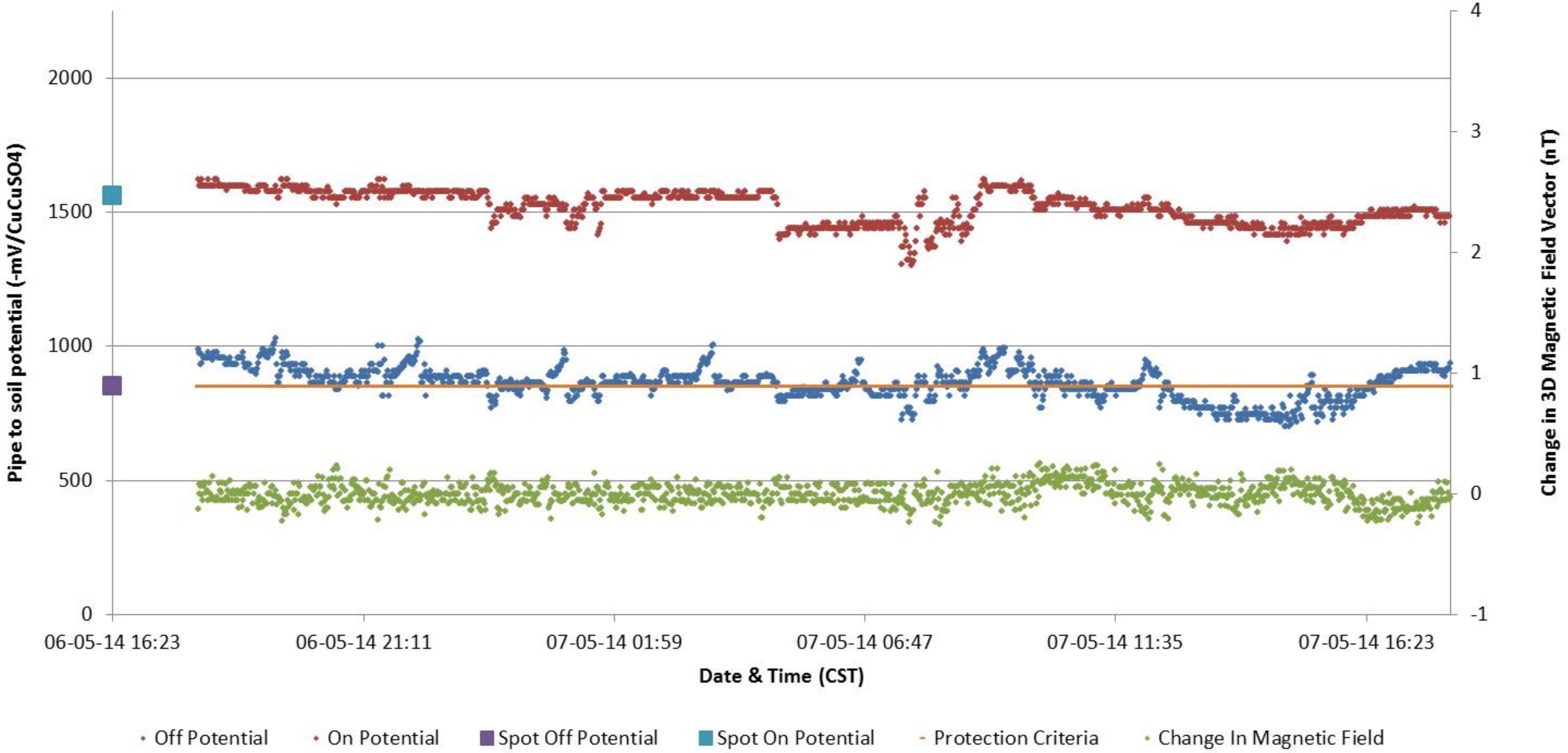
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 241.4 TMR-TTR

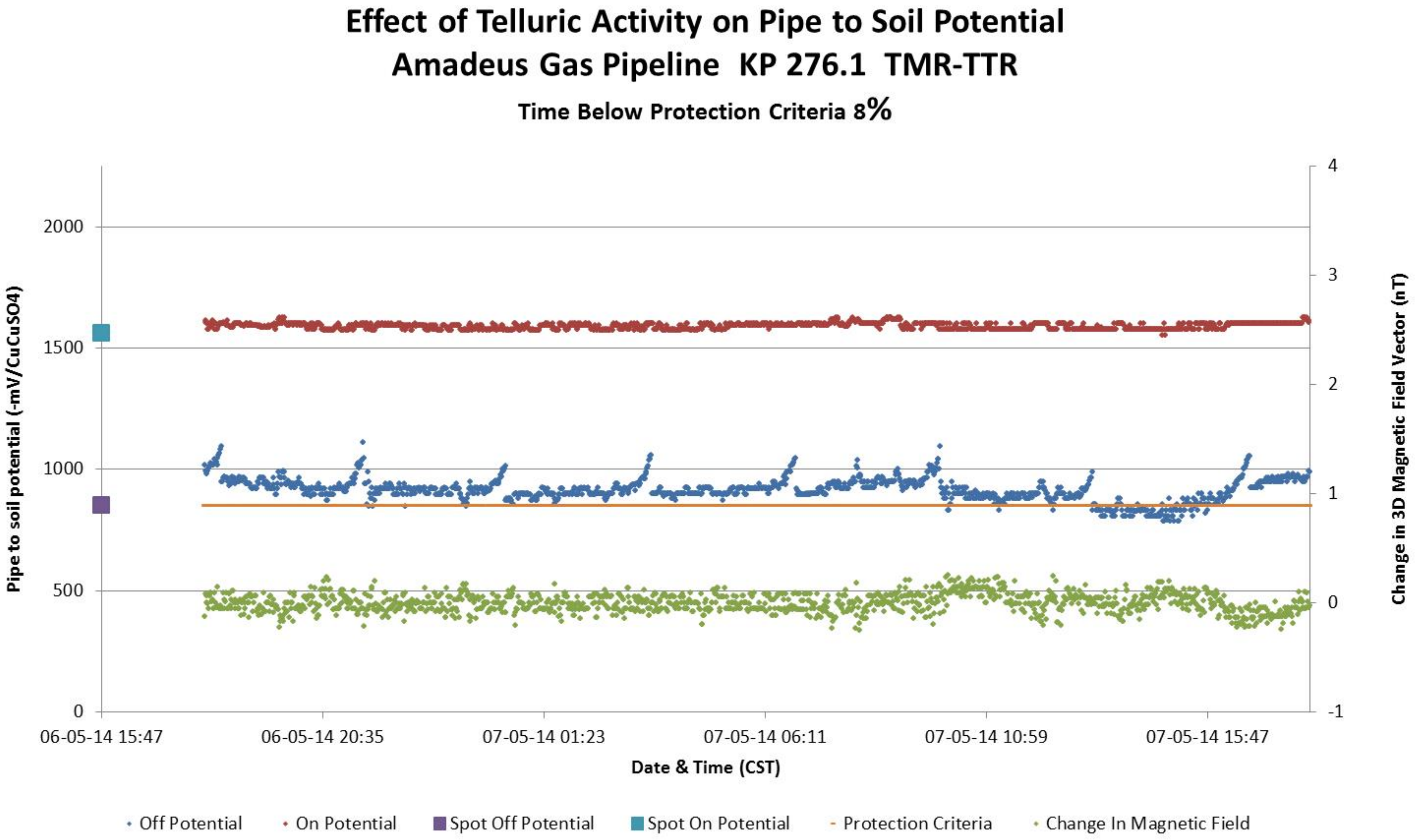
Time Below Protection Criteria 7%



Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 256.1 TMR-TTR

Time Below Protection Criteria 37%

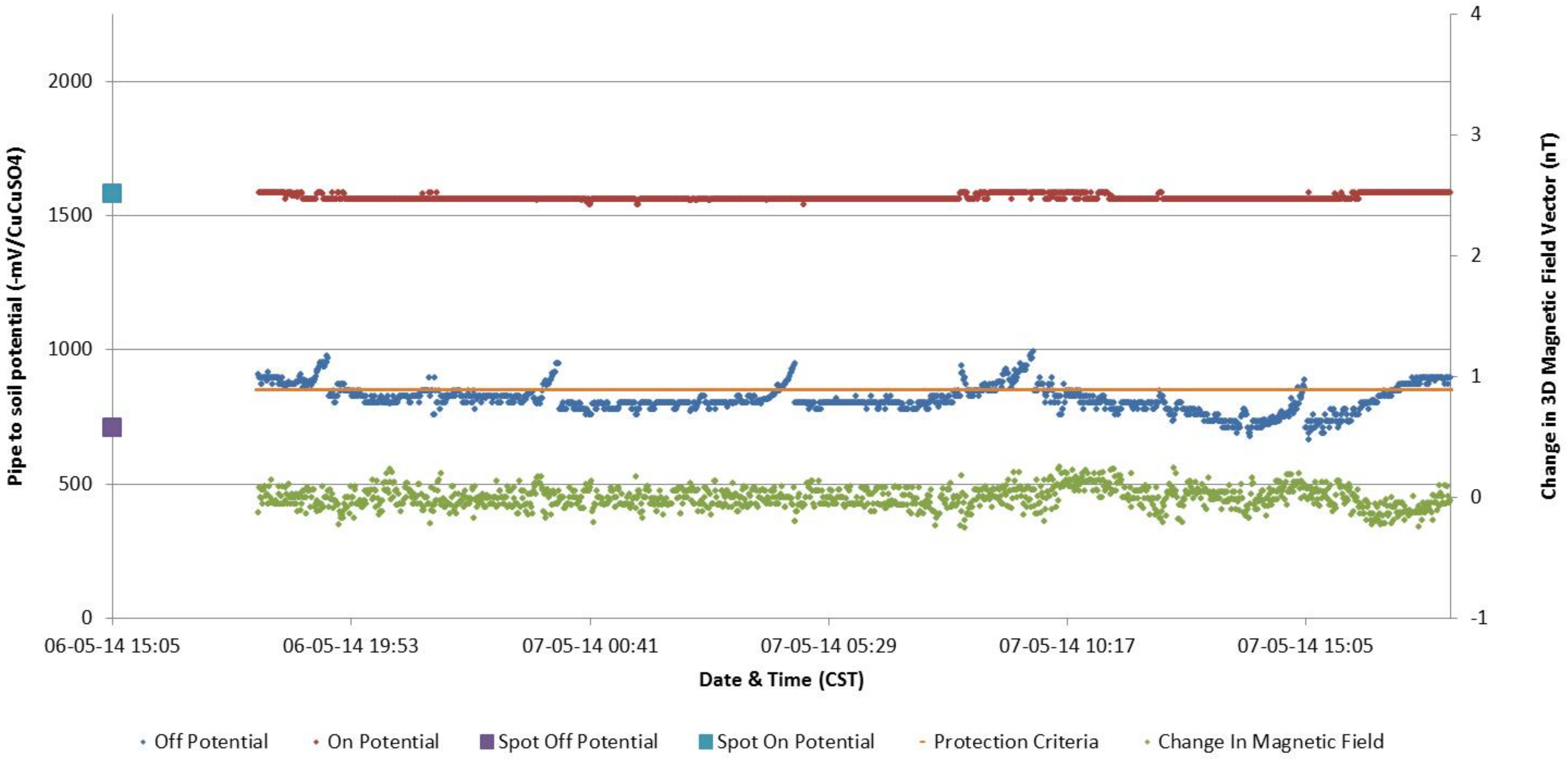




Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 276.1 TMR-TTR
Time Below Protection Criteria 8%
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
06-05-14 15:47
06-05-14 20:35
07-05-14 01:23
07-05-14 06:11
07-05-14 10:59
07-05-14 15:47
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field

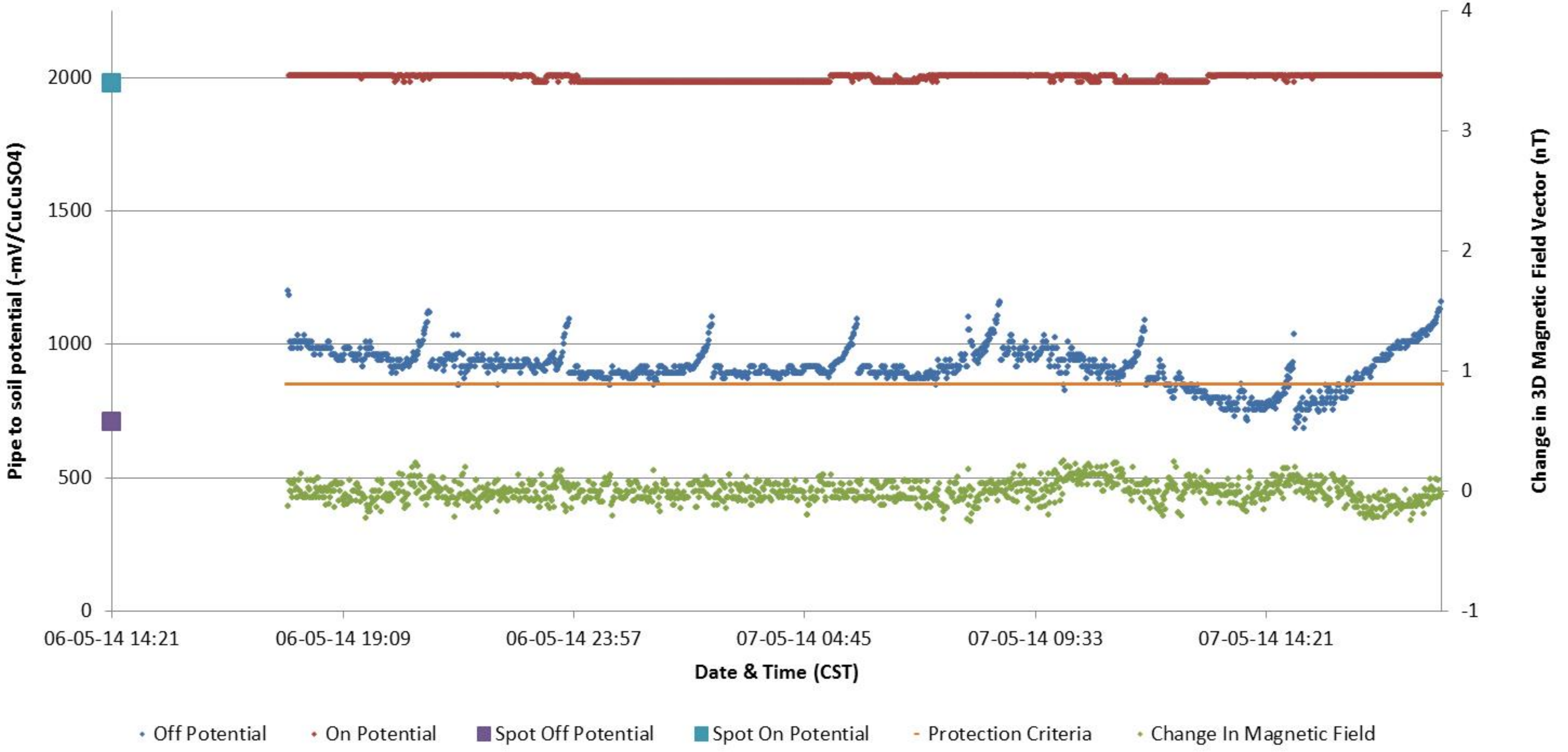
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 296.1 TMR-TTR

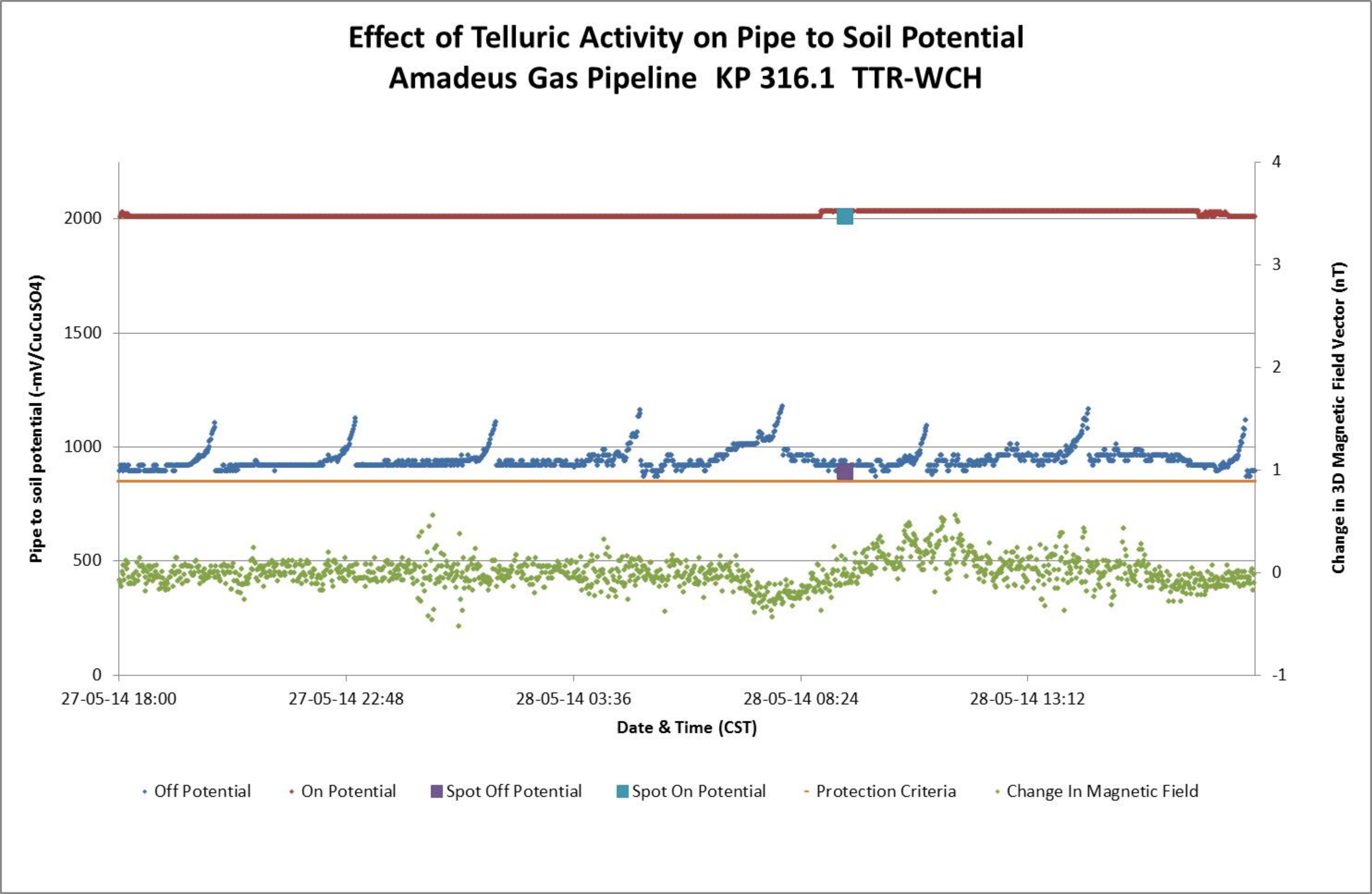
Time Below Protection Criteria 81%

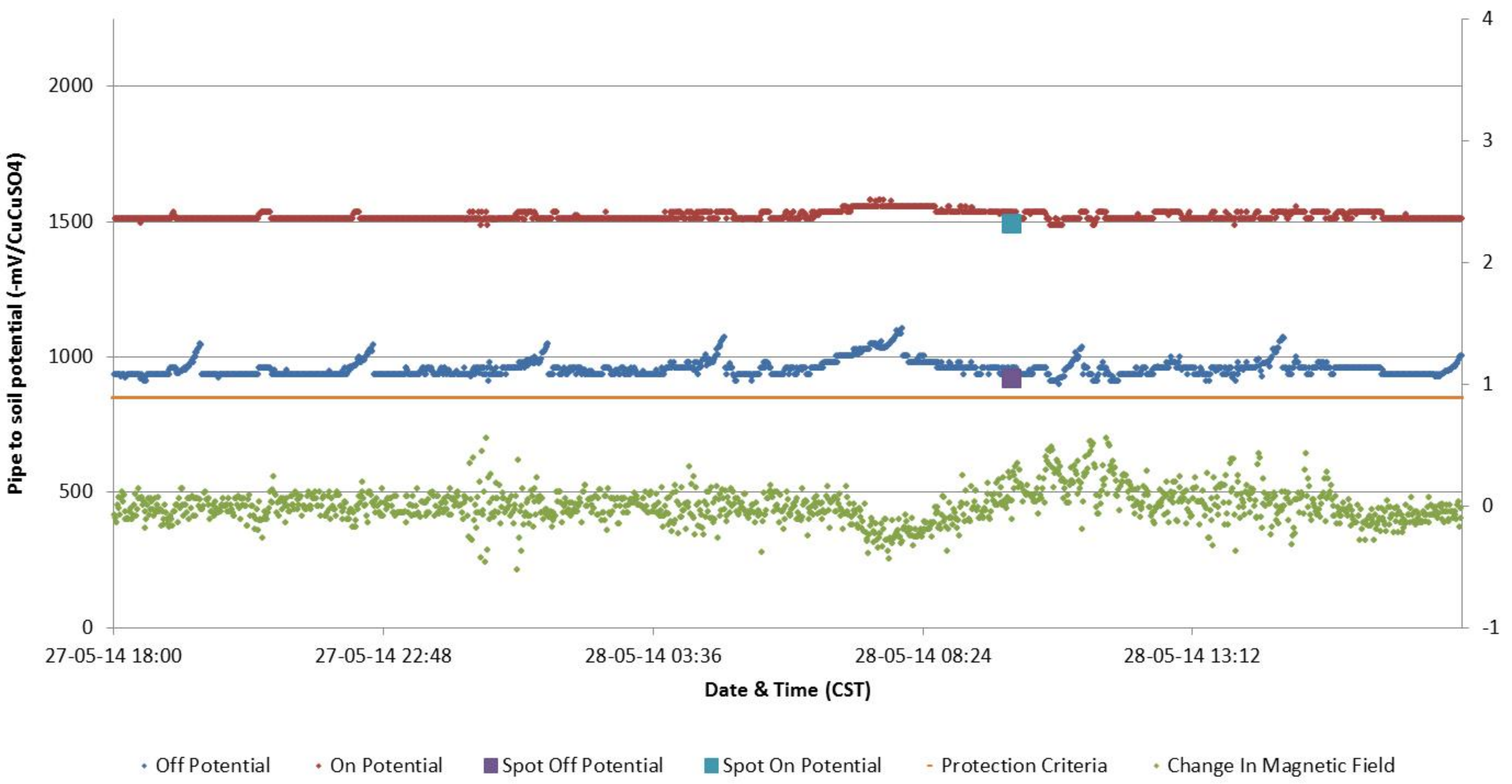


Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 316.1 TMR-TTR

Time Below Protection Criteria 16%



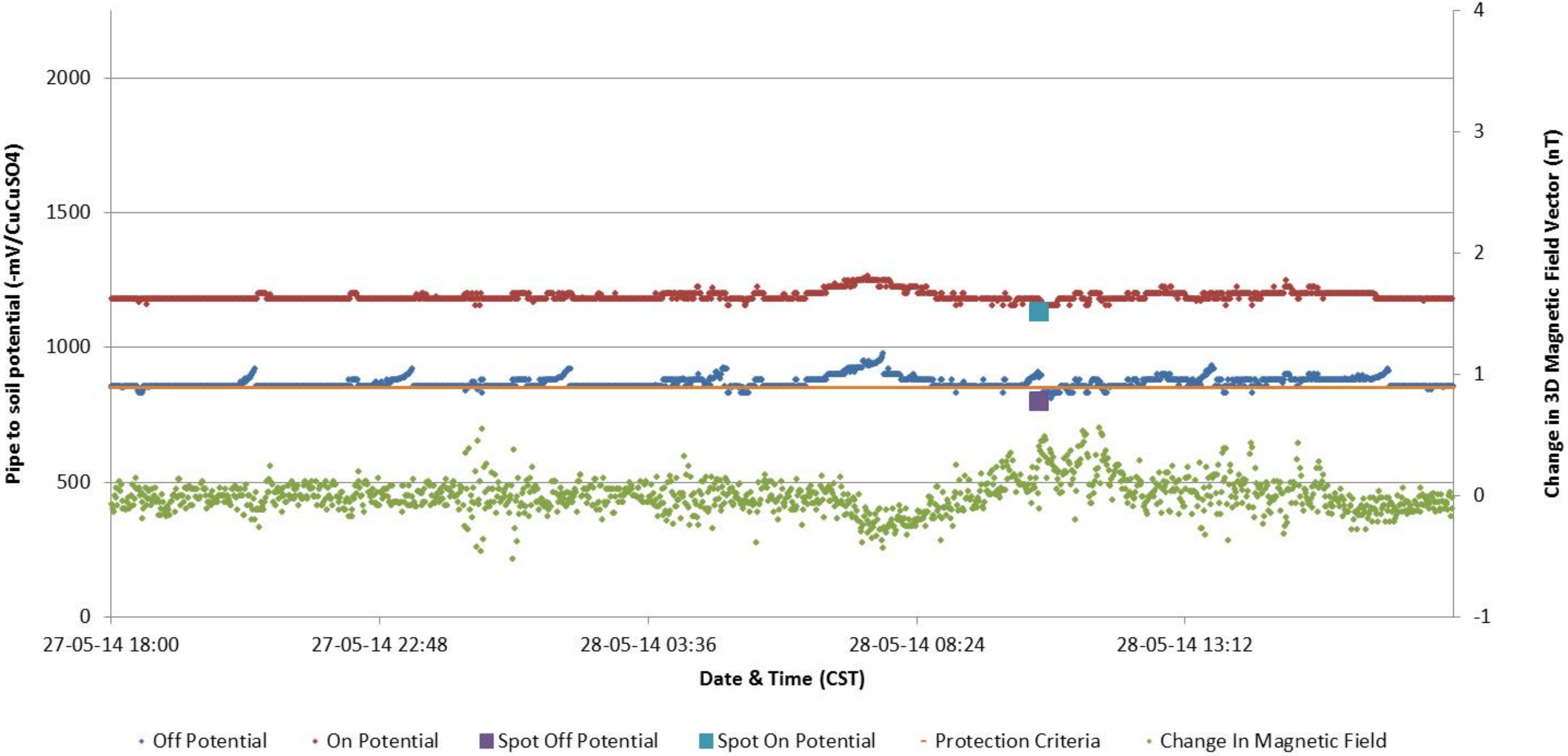

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 316.1 TTR-WCH
Pipe to soil potential (-mV/CuCuSO4)
0
500
1000
1500
2000
Change in 3D Magnetic Field Vector (nT)
-1
0
1
2
3
4
27-05-14 18:00
27-05-14 22:48
28-05-14 03:36
28-05-14 08:24
28-05-14 13:12
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field

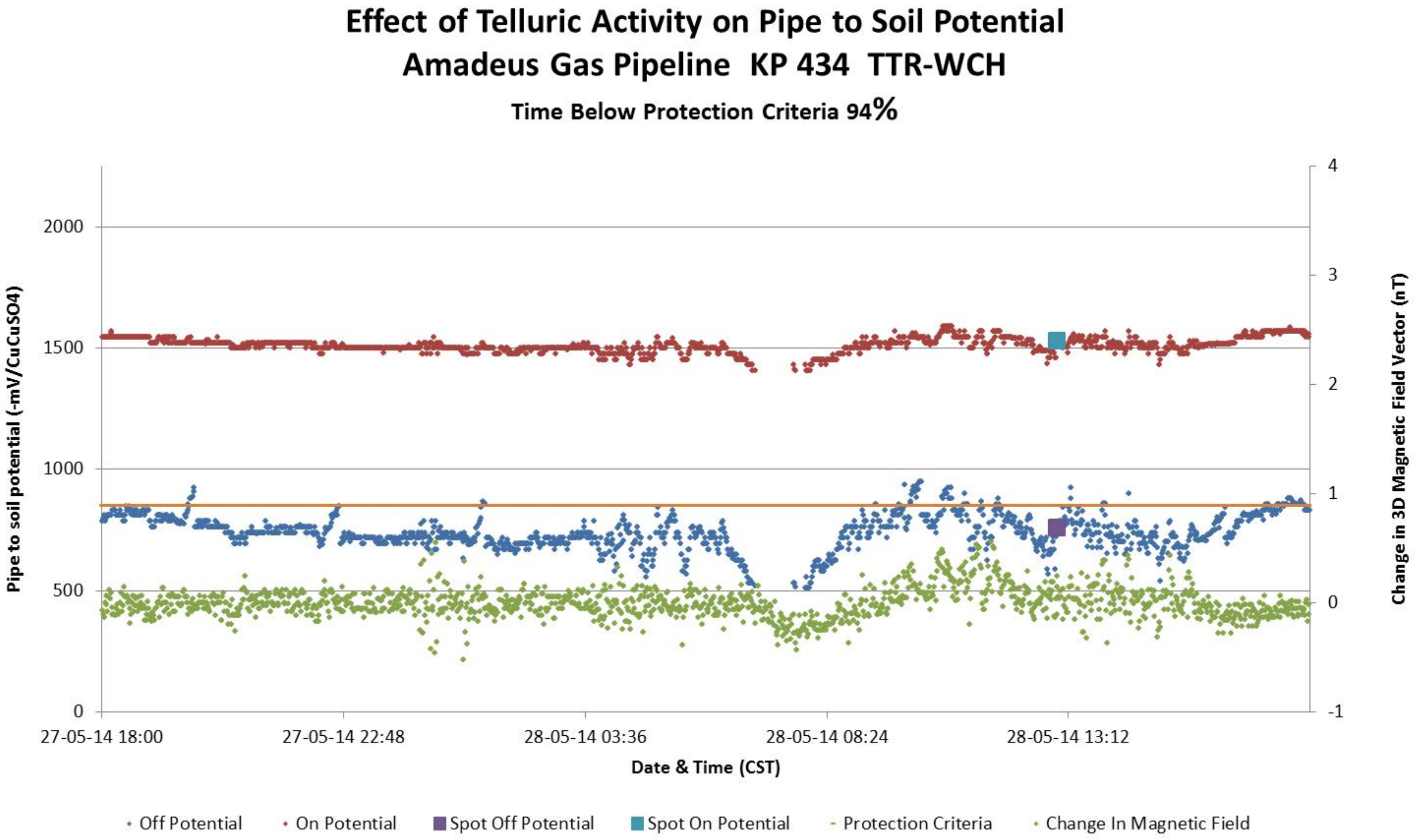


Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 334 TTR-WCH

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 360 TTR-WCH

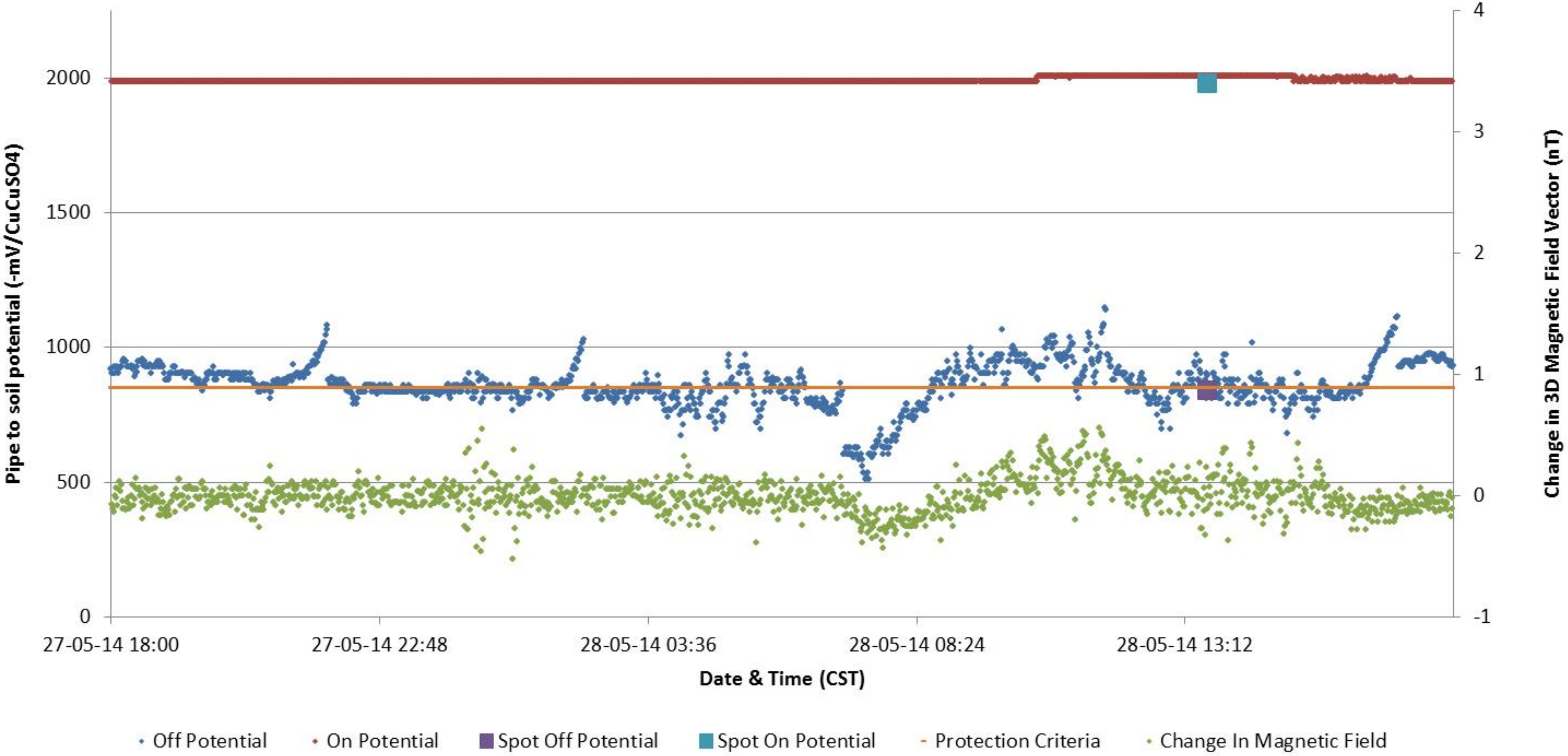
Time Below Protection Criteria 4%

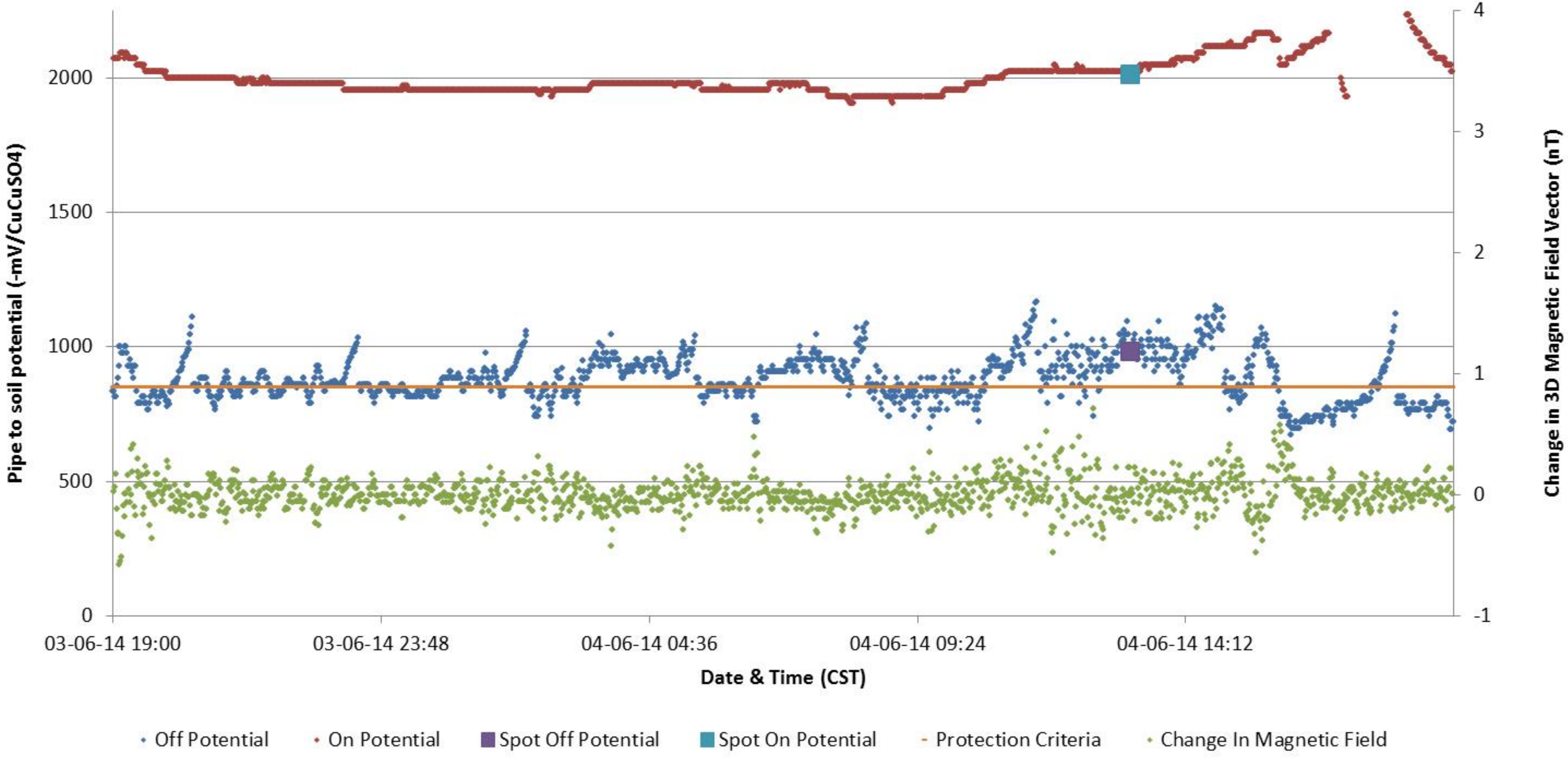



Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 434 TTR-WCH
Time Below Protection Criteria 94%
Pipe to soil potential (-mV/CuCuSO4)
0
500
1000
1500
2000
Change in 3D Magnetic Field Vector (nT)
-1
0
1
2
3
4
27-05-14 18:00
27-05-14 22:48
28-05-14 03:36
28-05-14 08:24
28-05-14 13:12
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 458.1 TTR-WCH

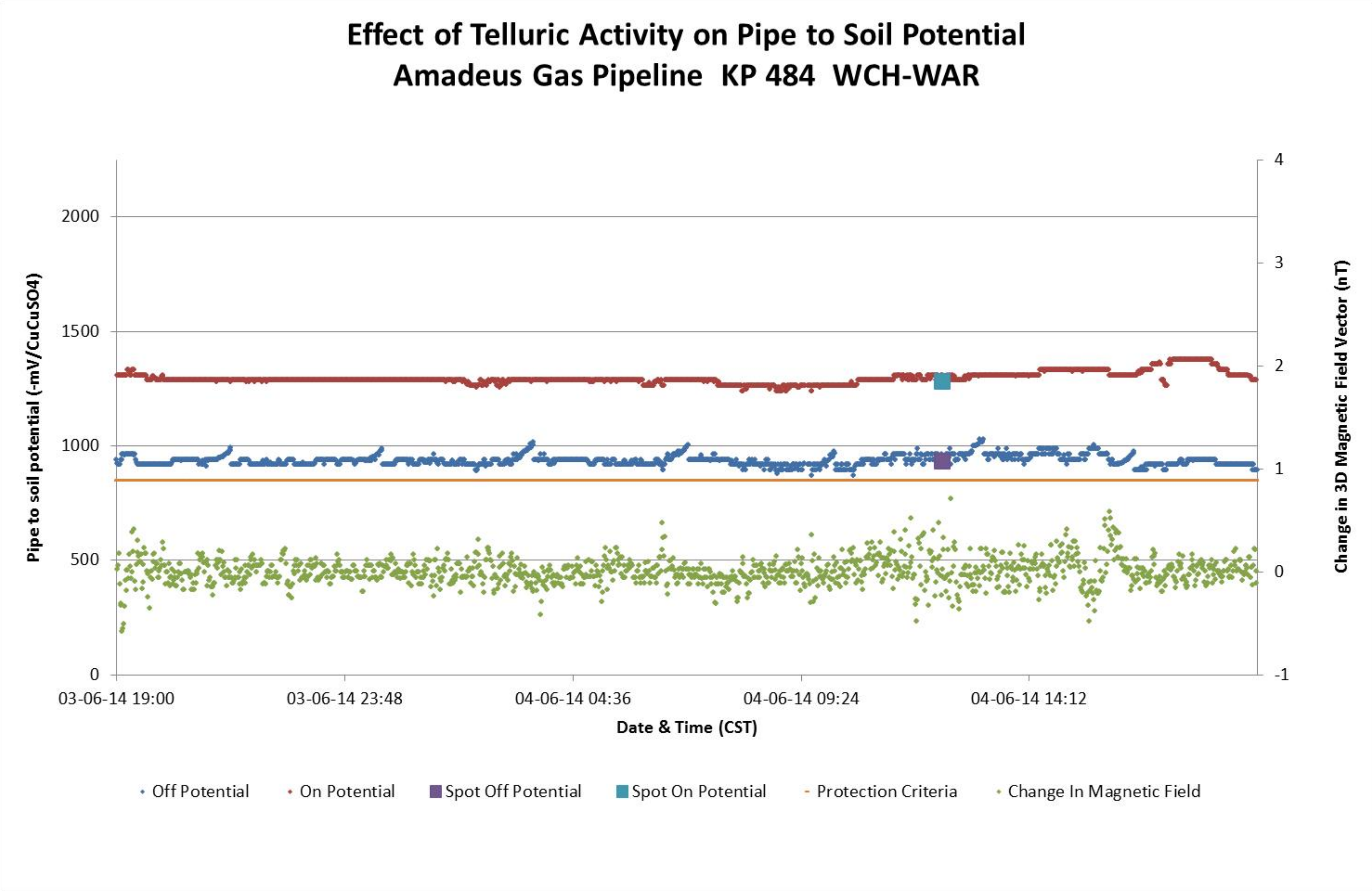
Time Below Protection Criteria 44%

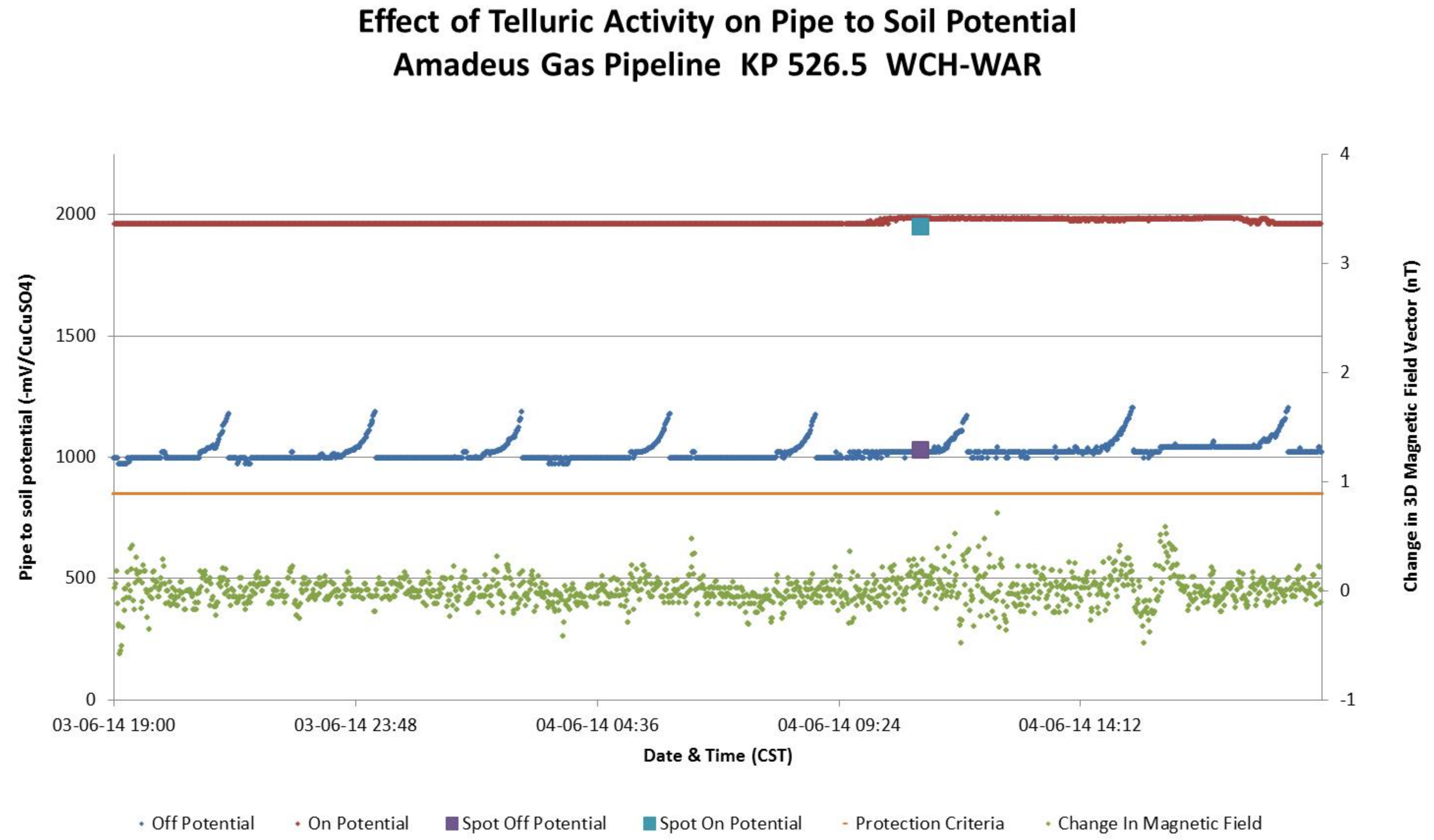




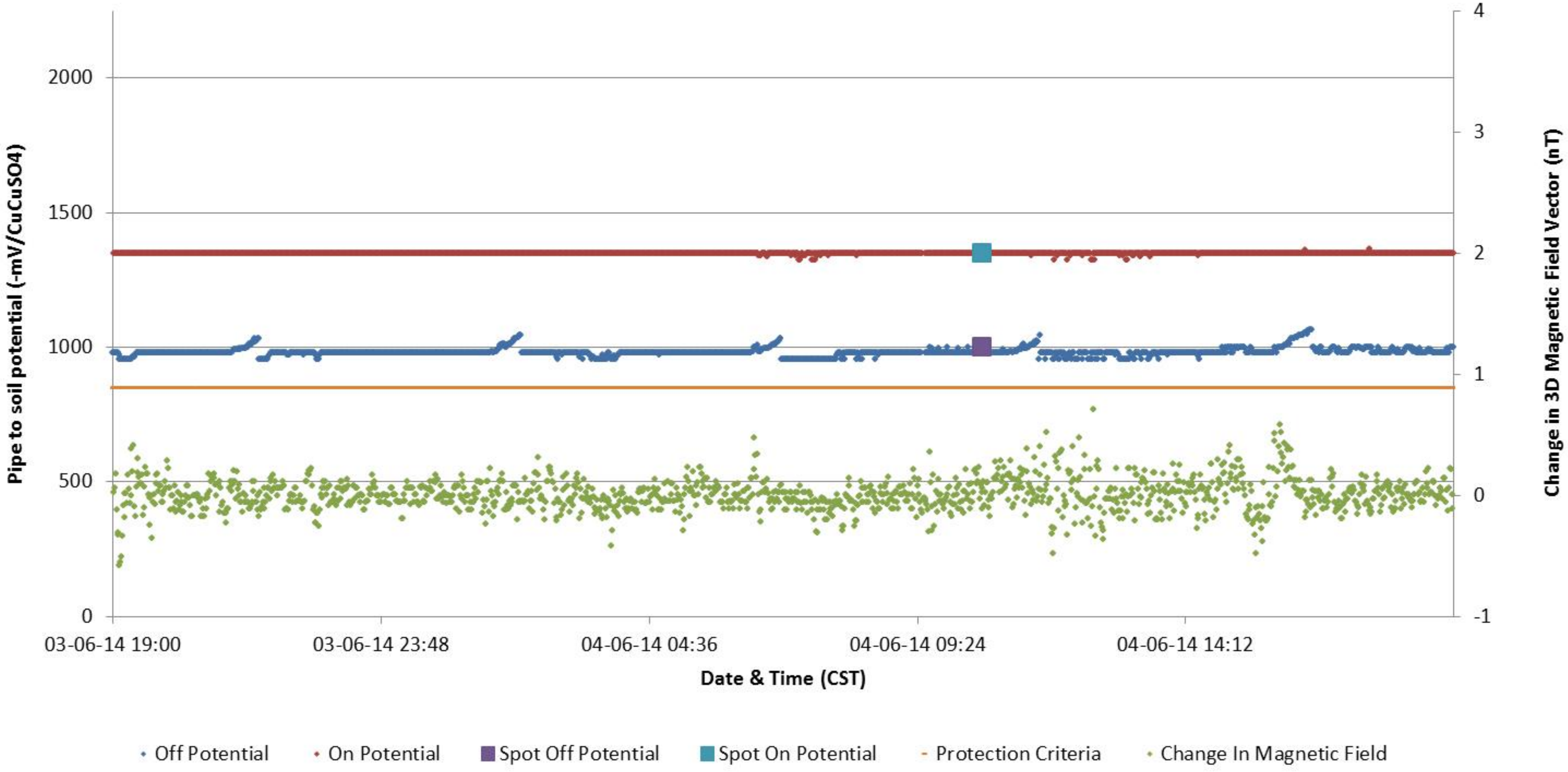
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 458.1 WCH-WAR

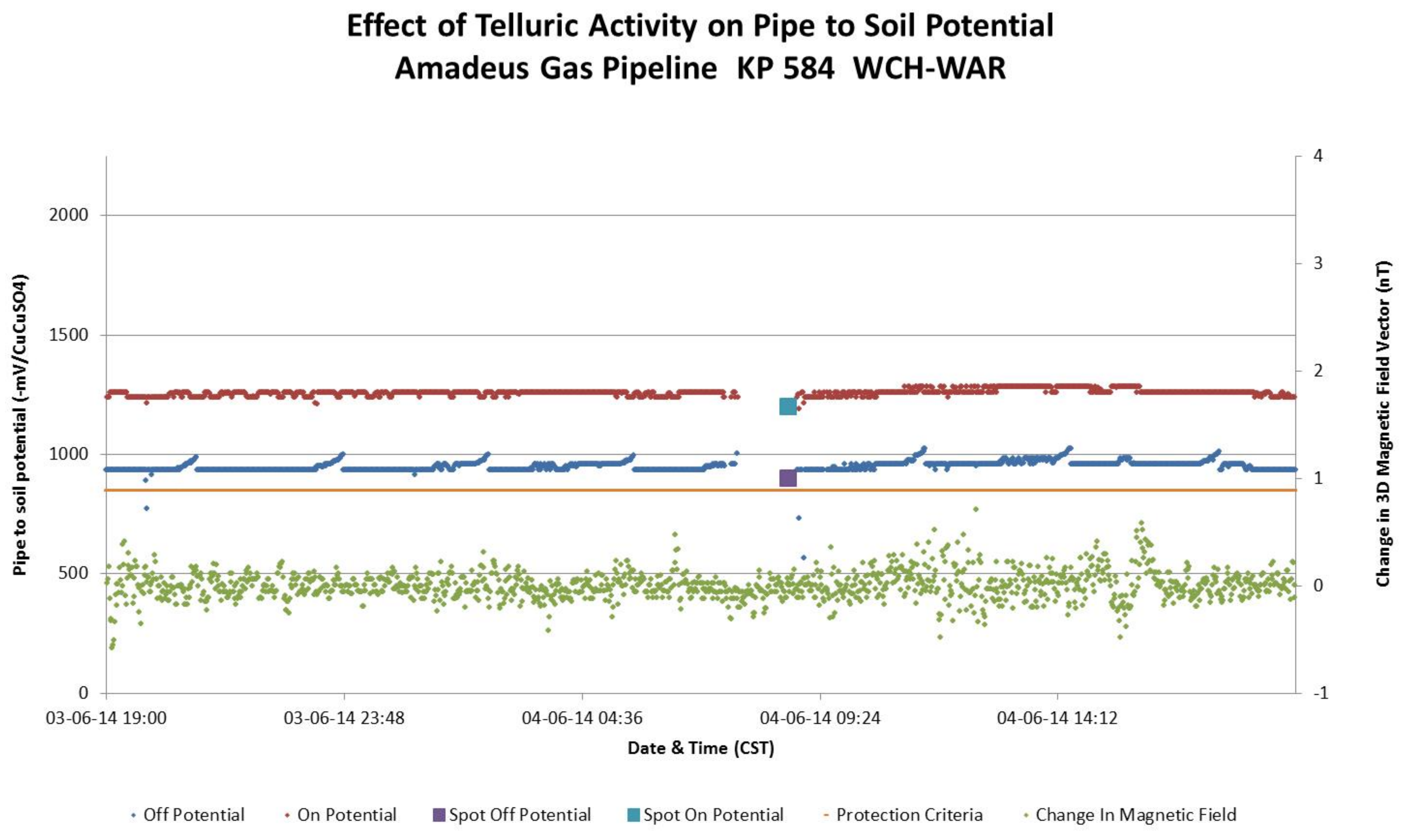
Time Below Protection Criteria 37%


Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 484 WCH-WAR
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
03-06-14 19:00
03-06-14 23:48
04-06-14 04:36
04-06-14 09:24
04-06-14 14:12
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field

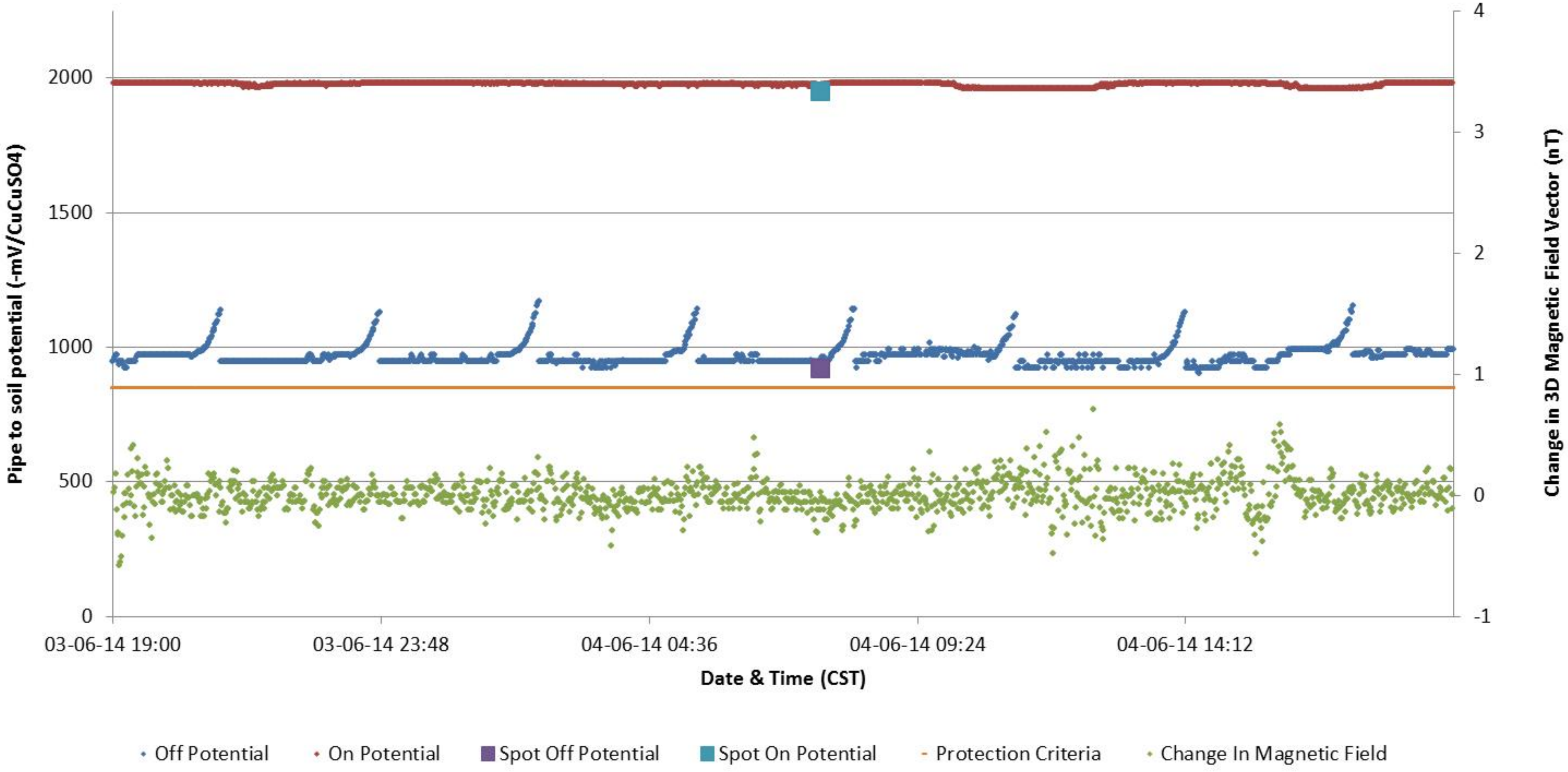

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 526.5 WCH-WAR
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
03-06-14 19:00
03-06-14 23:48
04-06-14 04:36
04-06-14 09:24
04-06-14 14:12
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 544 WCH-WAR

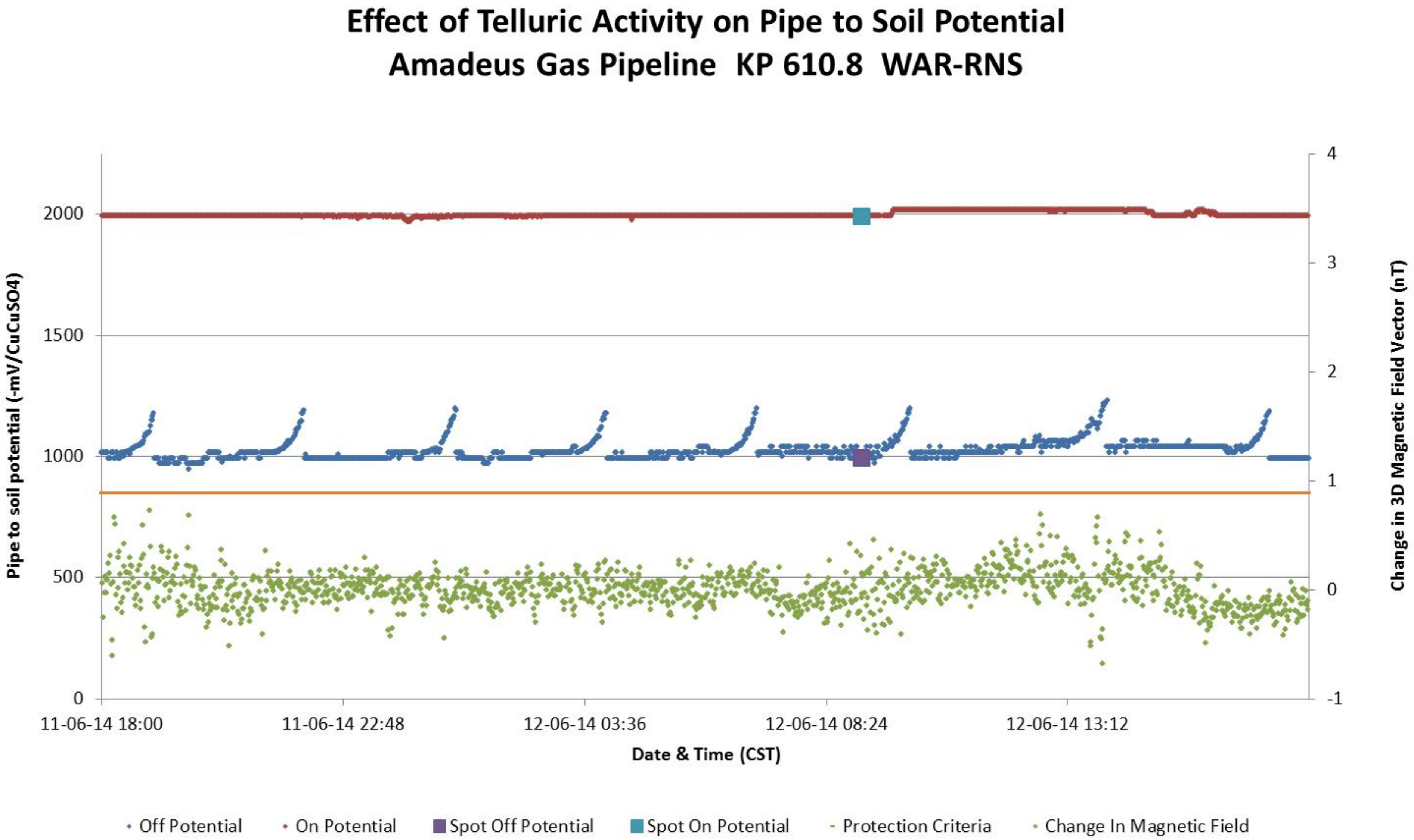




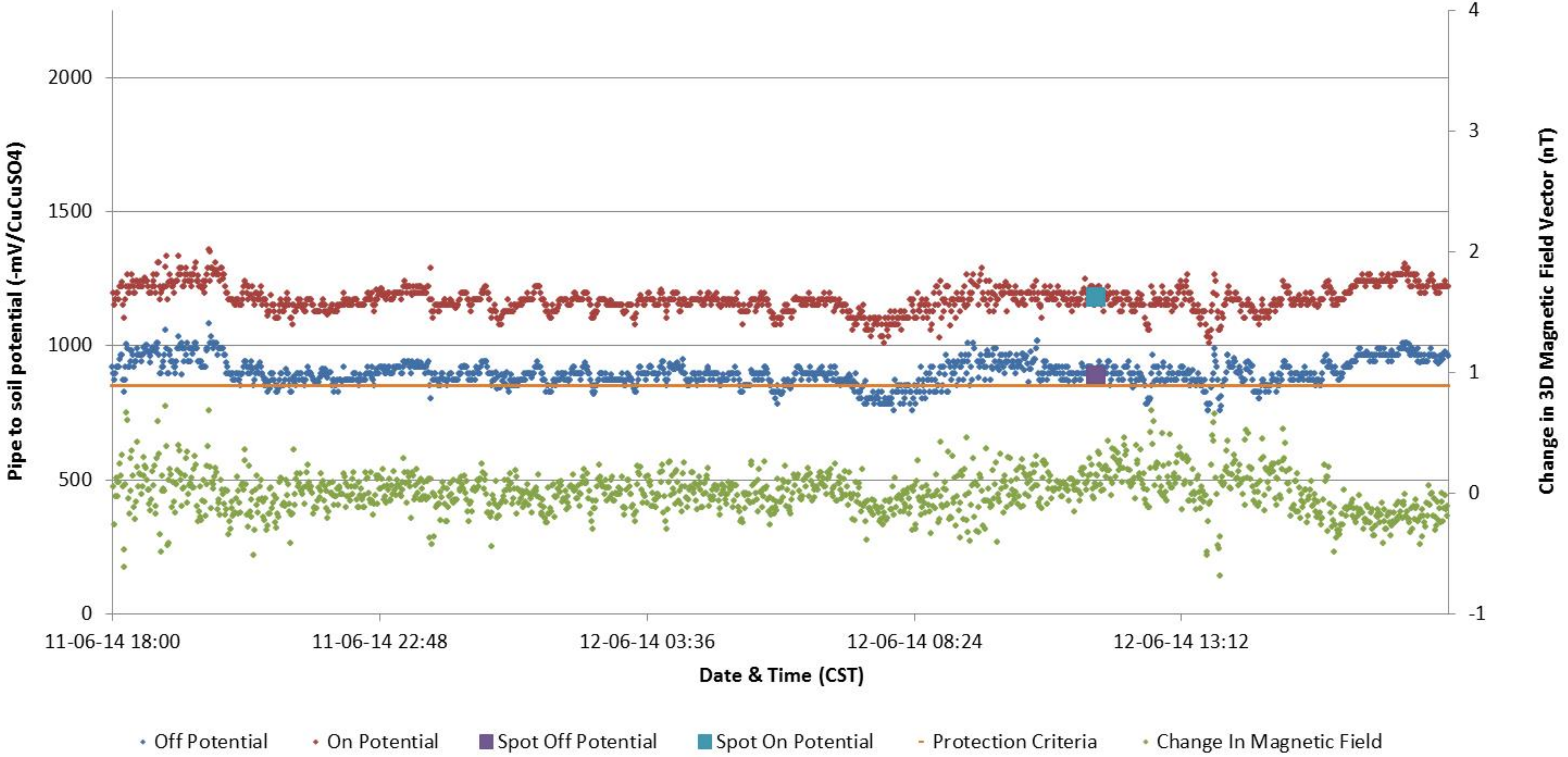
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 584 WCH-WAR



Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 610.8 WCH-WAR



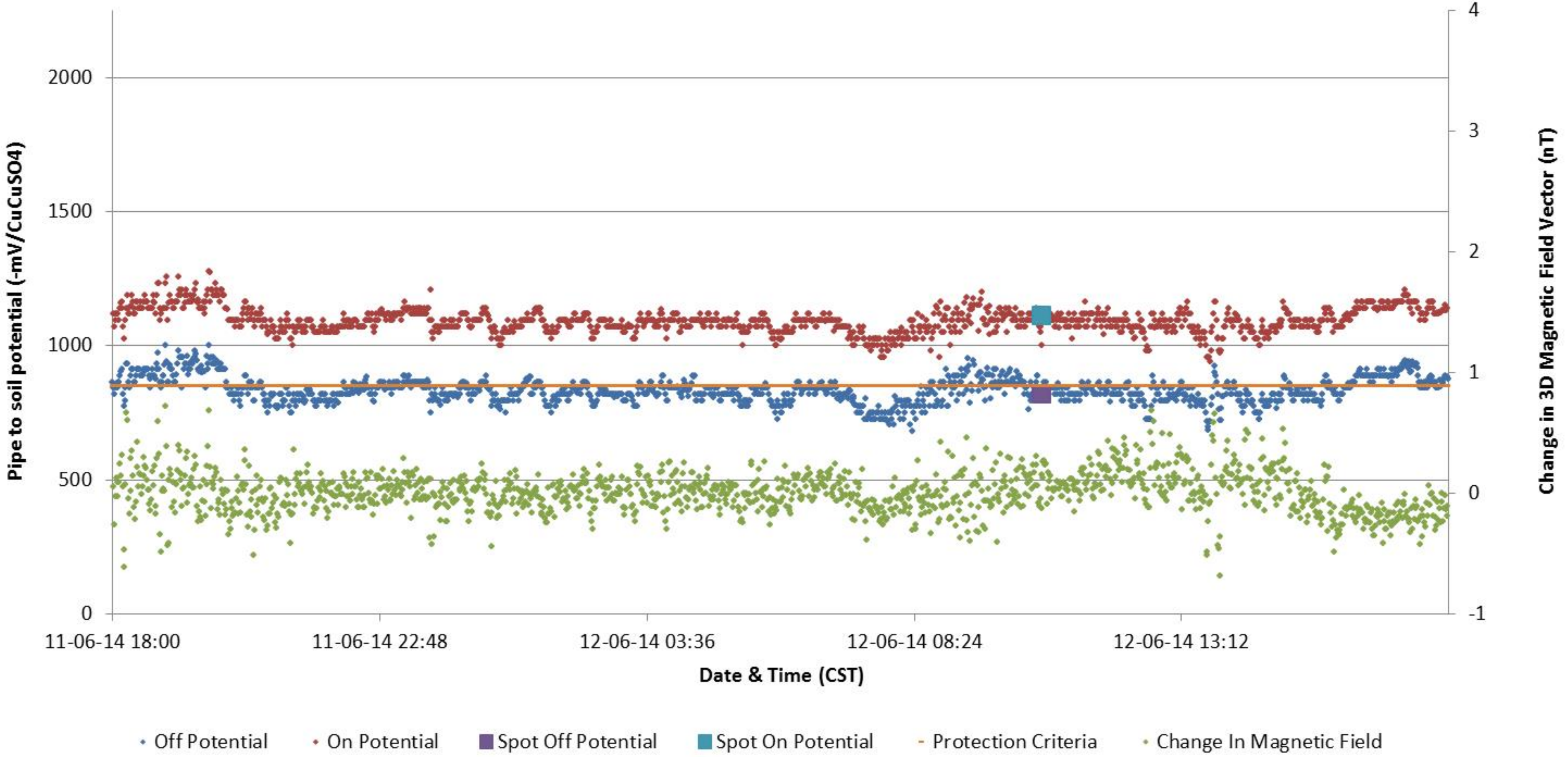
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 610.8 WAR-RNS



Effect of Telluric Activity on Pipe to Soil Potential

Amadeus Gas Pipeline KP 640 WAR-RNS

Time Below Protection Criteria 10%



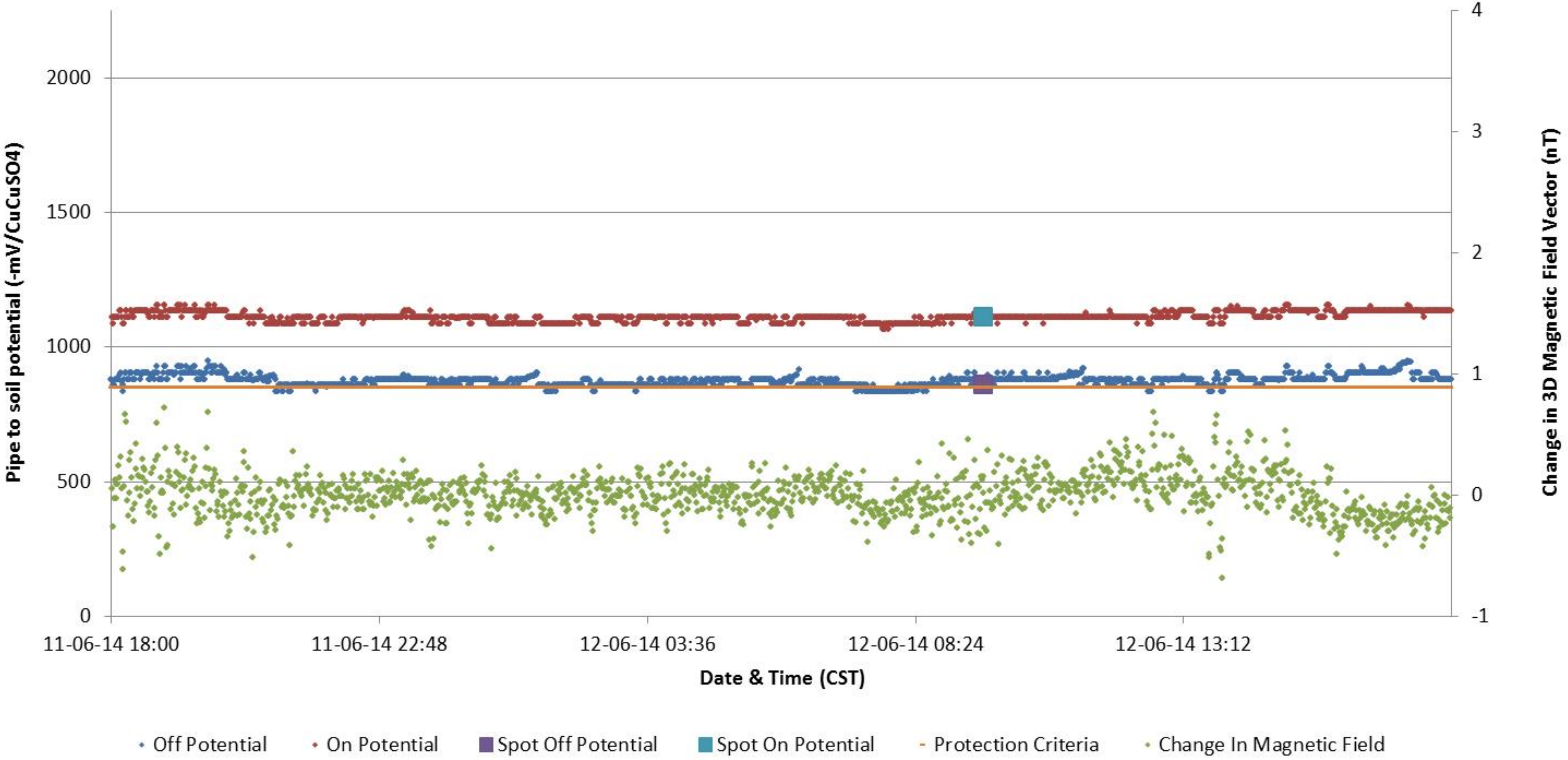
Effect of Telluric Activity on Pipe to Soil Potential

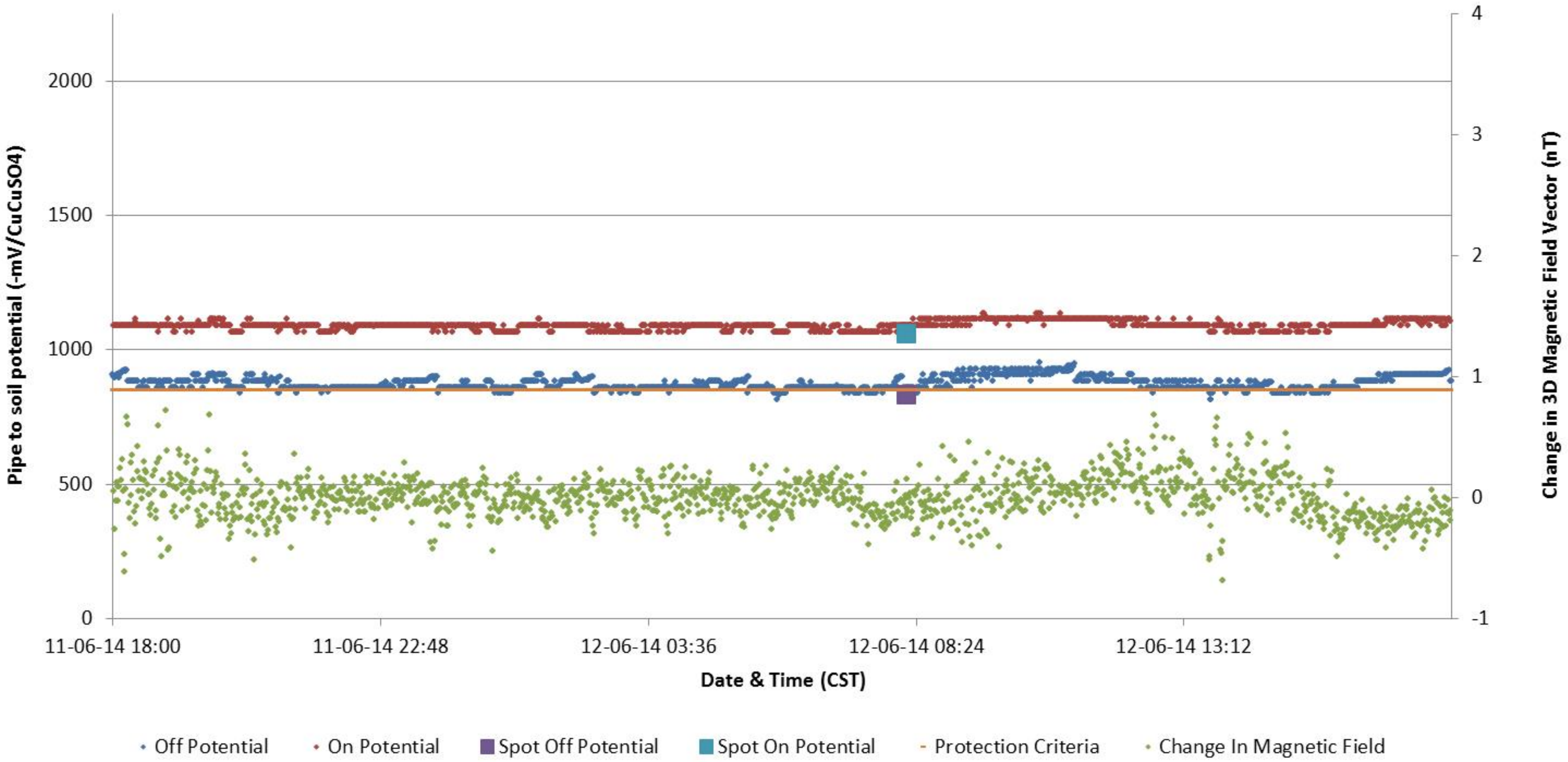
Amadeus Gas Pipeline KP 660 WAR-RNS

Time Below Protection Criteria 71%

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 684.1 WAR-RNS

Time Below Protection Criteria 6%

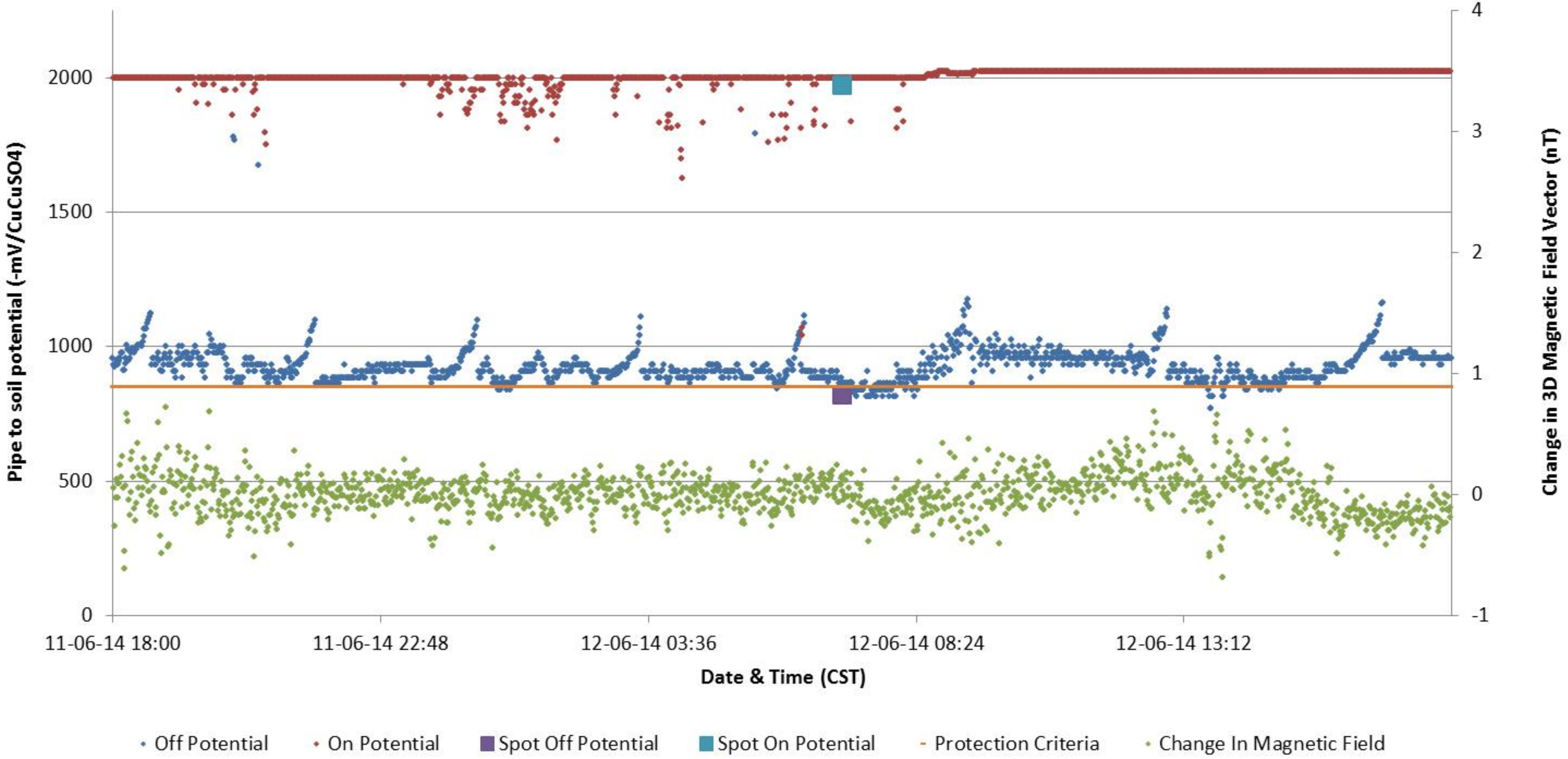




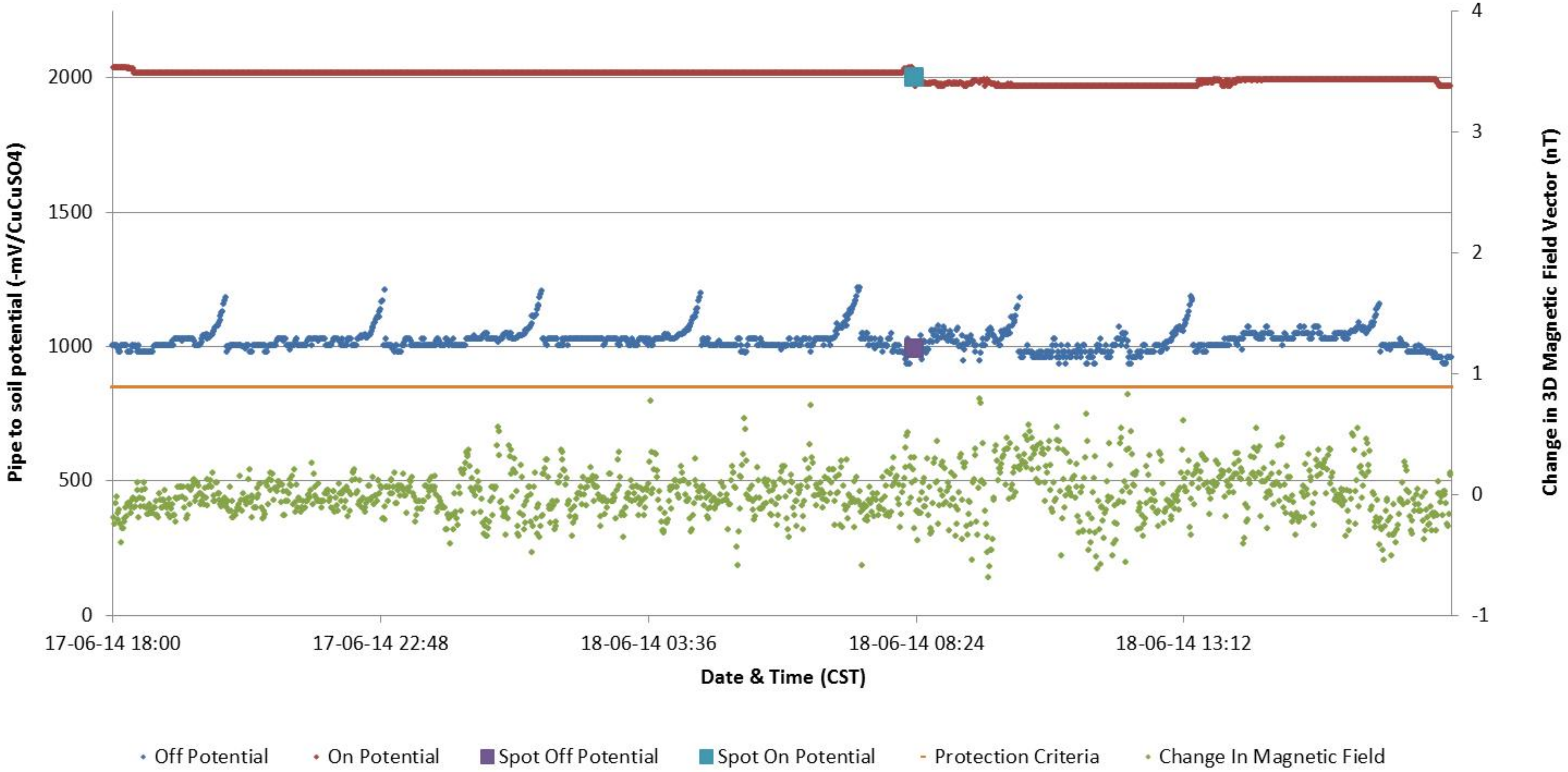
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 710.2 WAR-RNS
Time Below Protection Criteria 8%

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 733.7 WAR-RNS

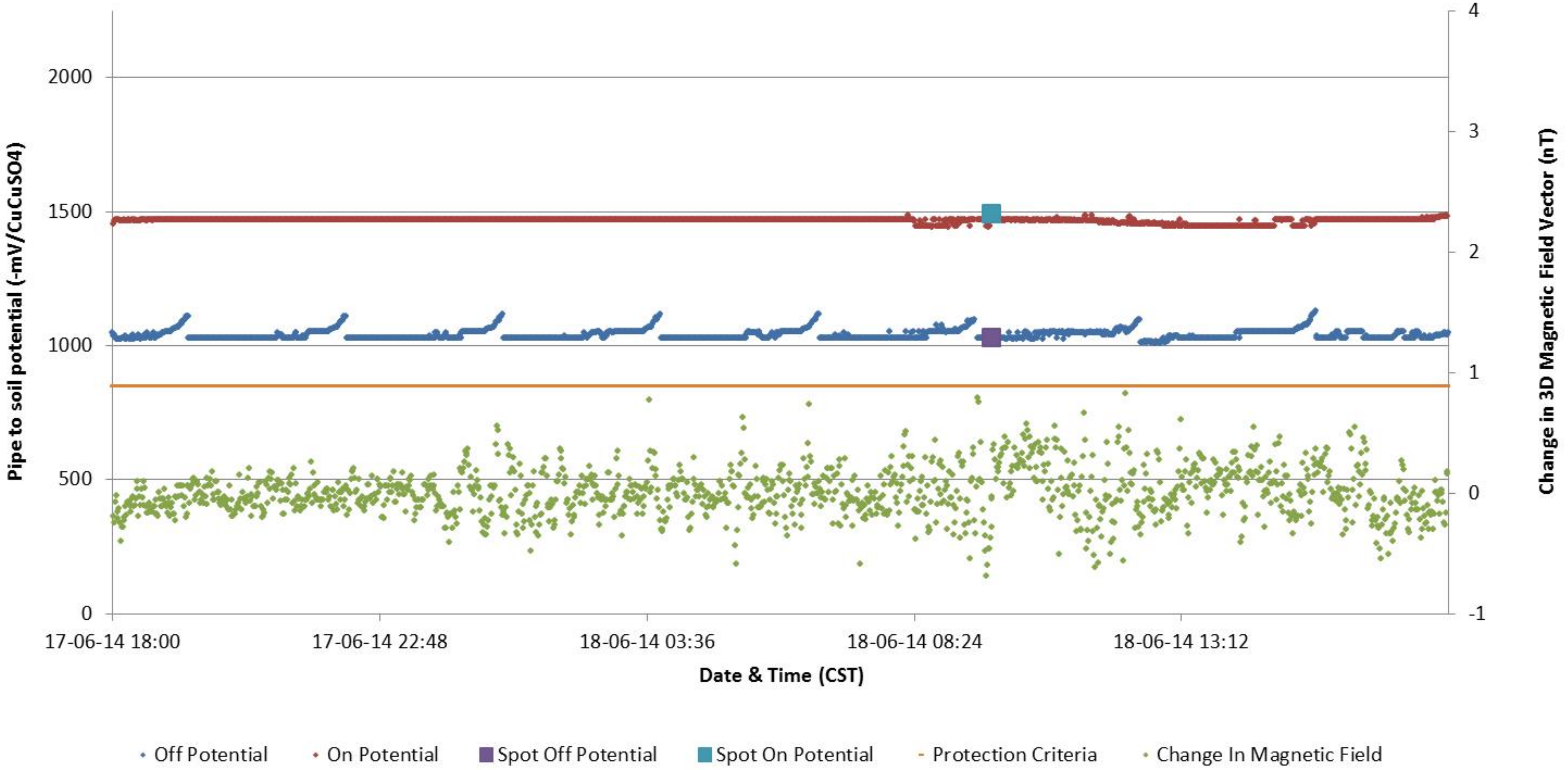
Time Below Protection Criteria 4%

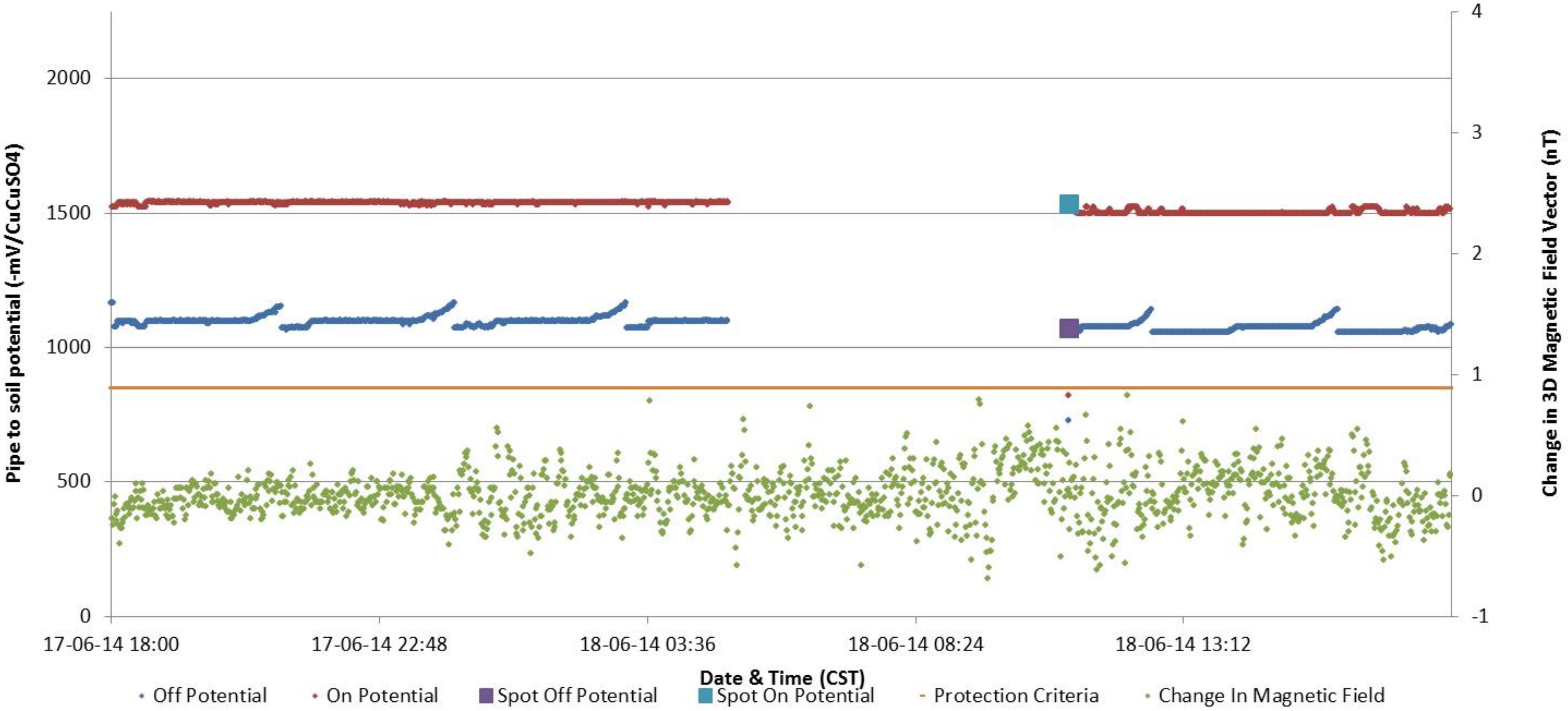


Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 733.7 RNS-NCW



Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 757.8 RNS-NCW





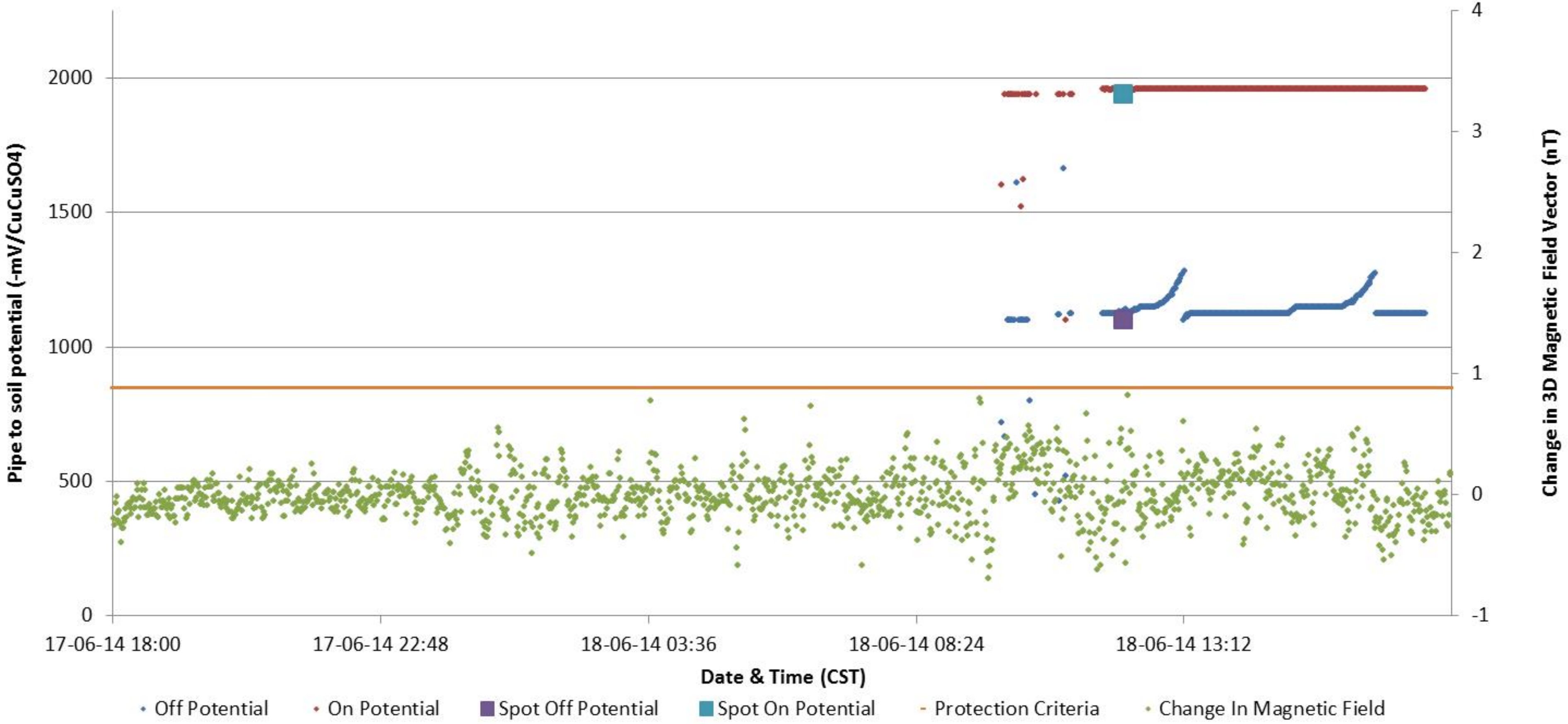
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 780 RNS-NCW

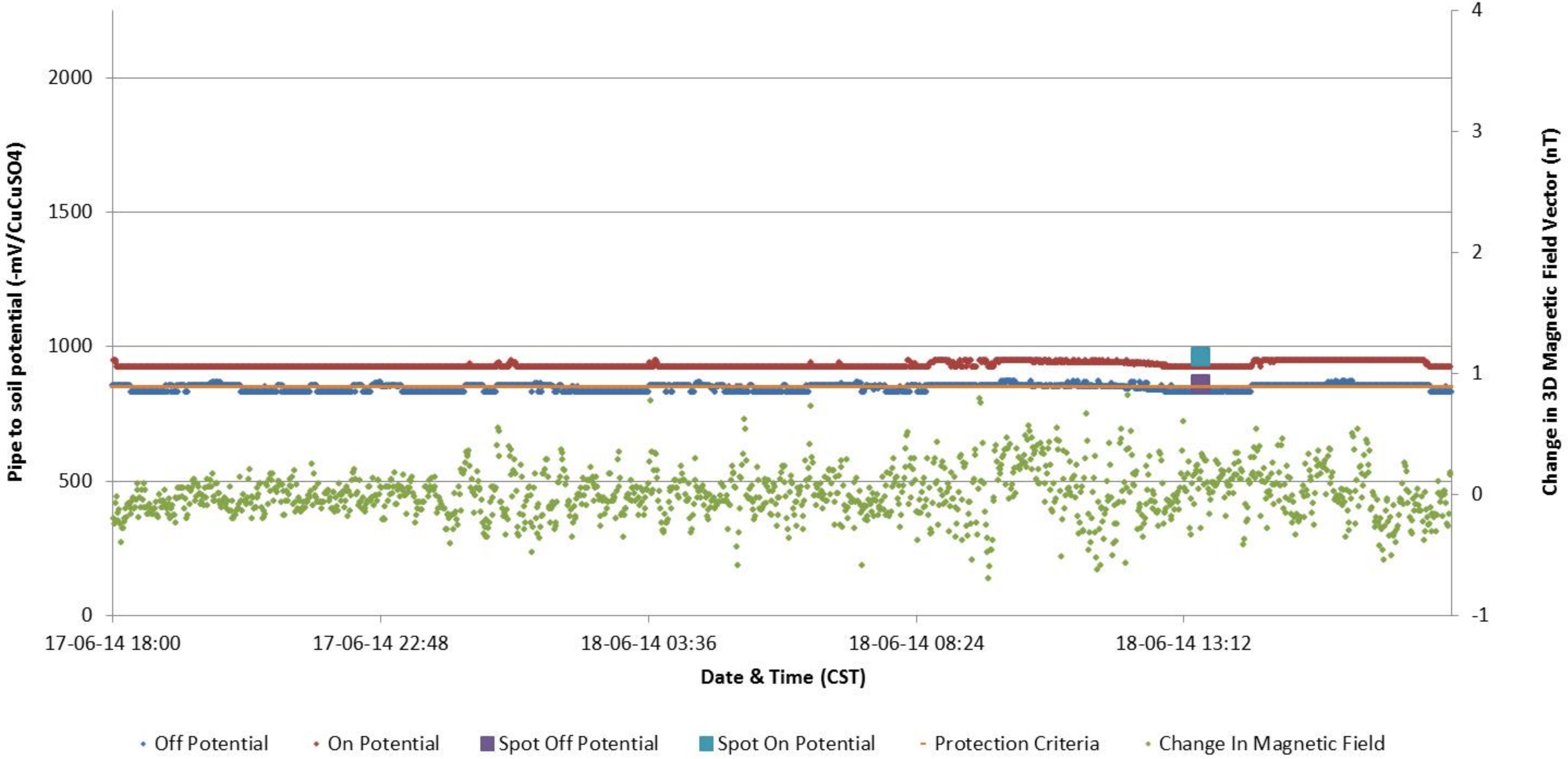
Insufficient Readings Taken (89%)

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 792 RNS-NCW

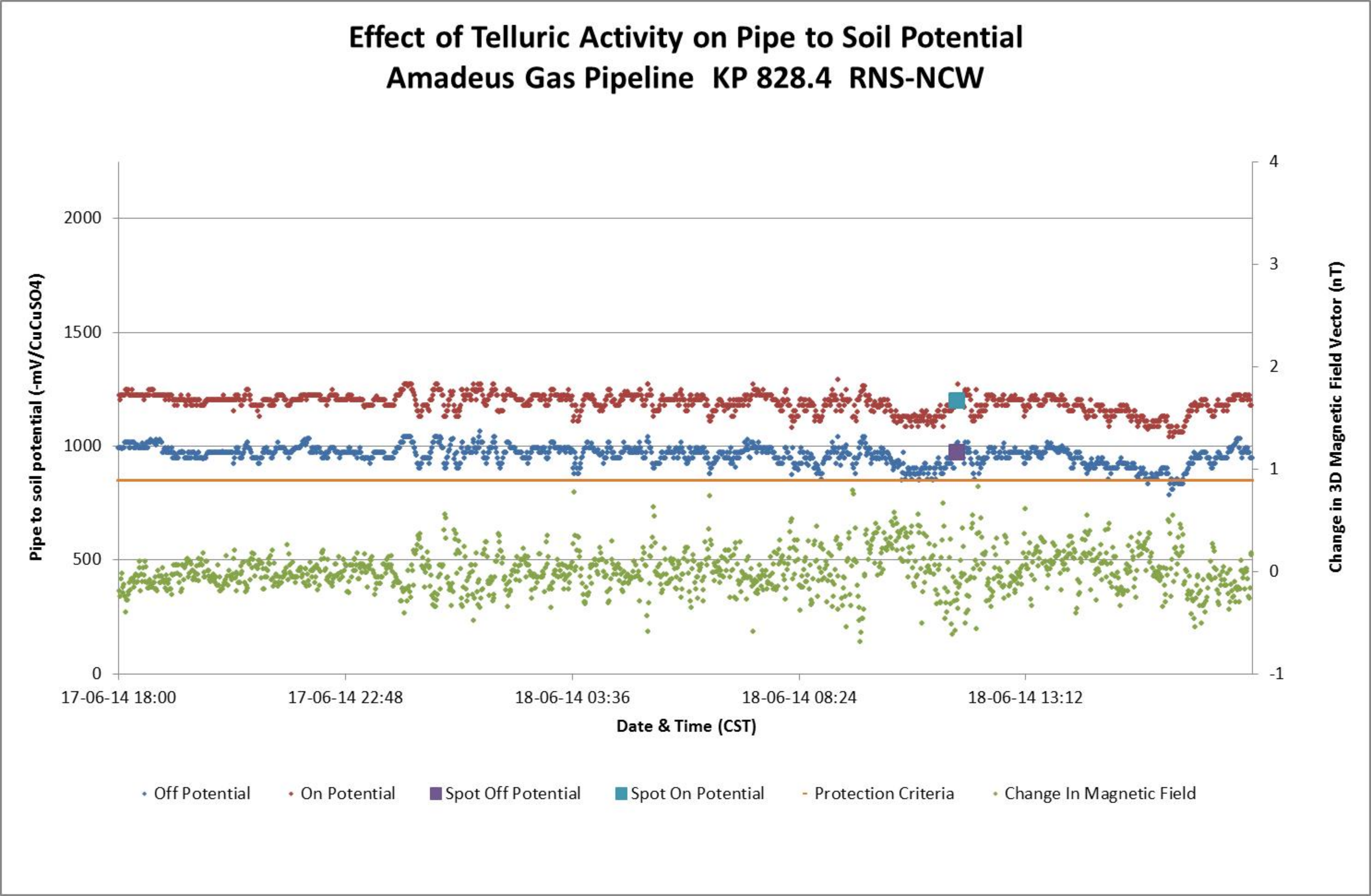
Insufficient Readings Taken (31%)

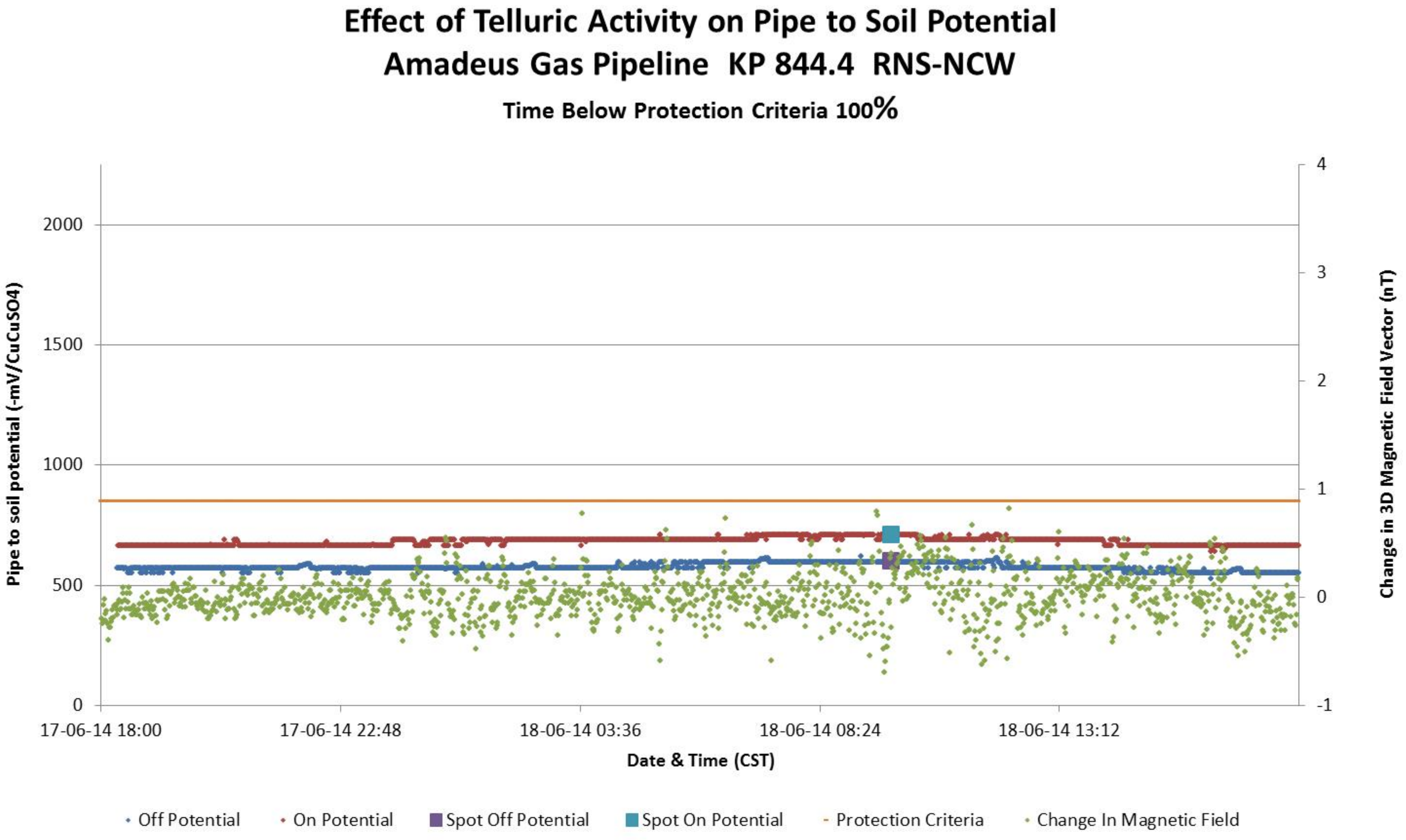
Time Below Protection Criteria 2%

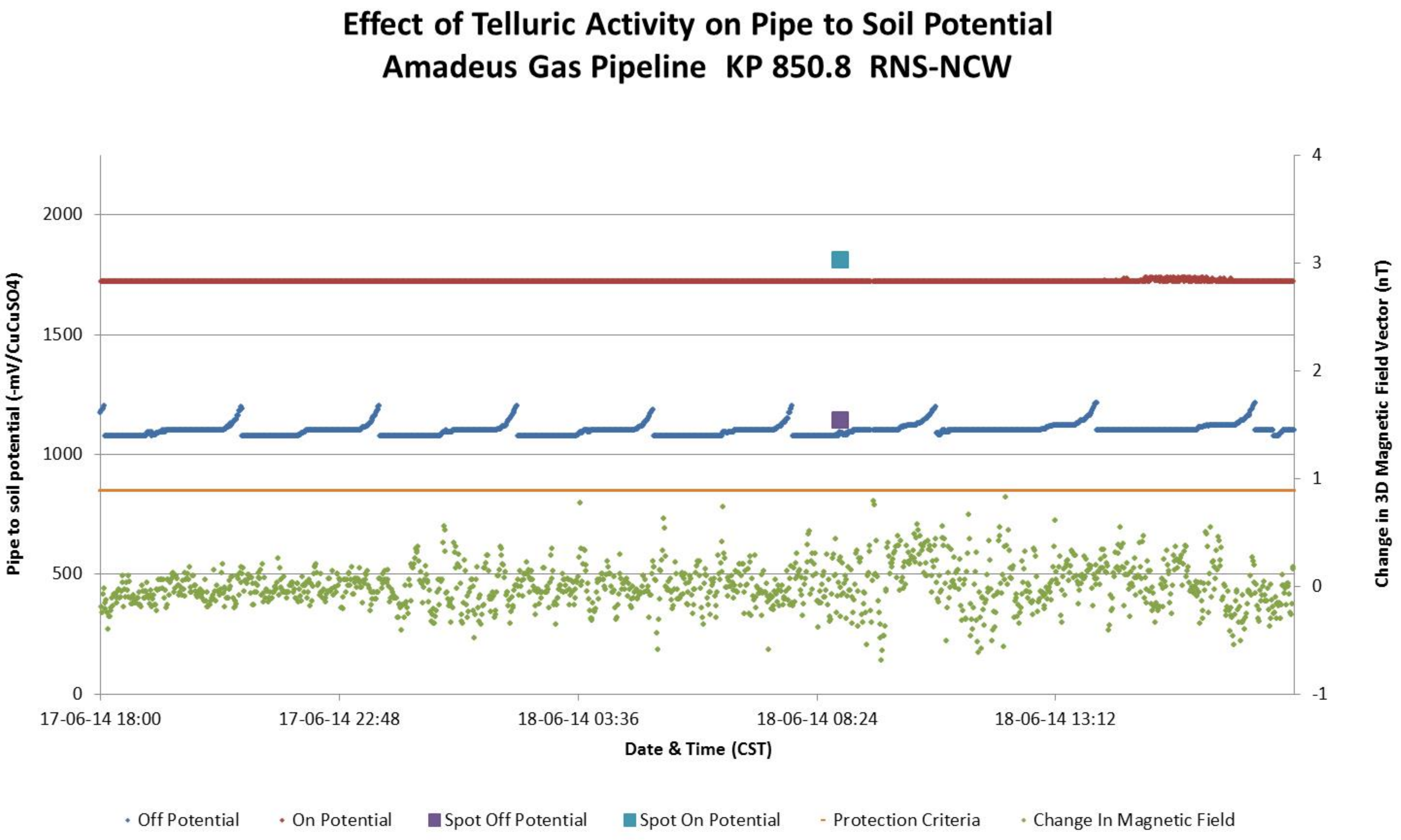




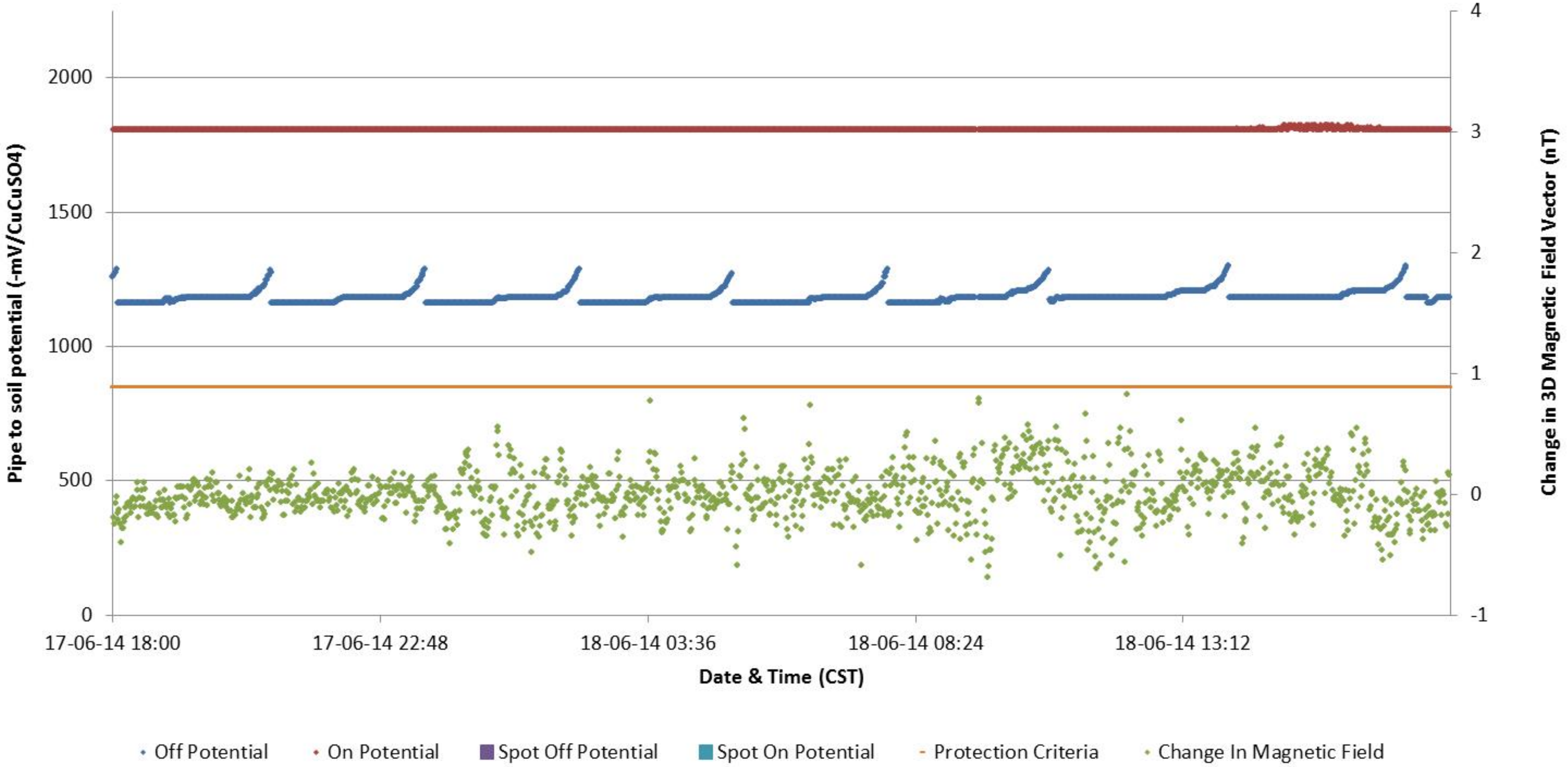
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 816.4 RNS-NCW
Time Below Protection Criteria 43%


Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 828.4 RNS-NCW
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
17-06-14 18:00
17-06-14 22:48
18-06-14 03:36
18-06-14 08:24
18-06-14 13:12
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field


Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 844.4 RNS-NCW
Time Below Protection Criteria 100%
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
17-06-14 18:00
17-06-14 22:48
18-06-14 03:36
18-06-14 08:24
18-06-14 13:12
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field



Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 850.8 RNS-NCW

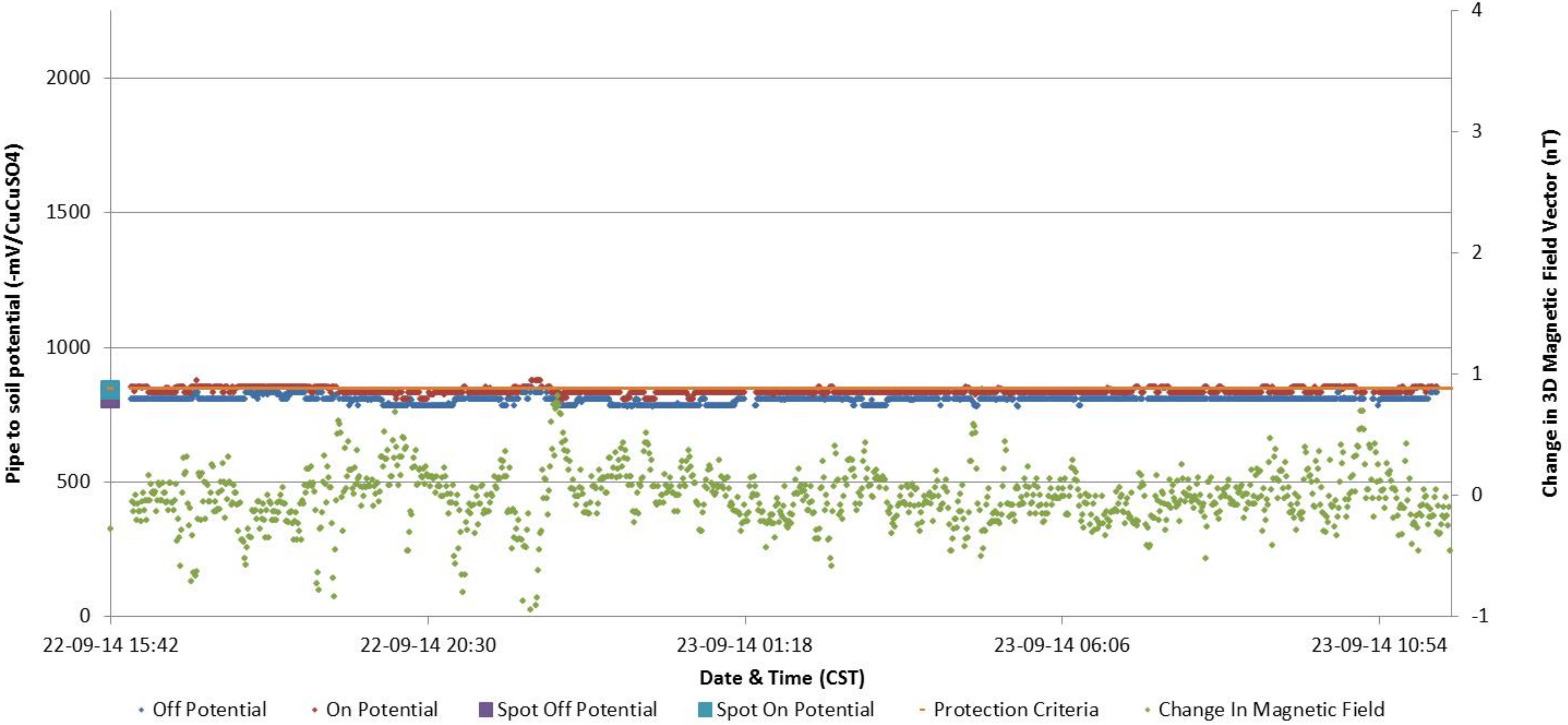

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 850.8 NCW-DLW

Effect of Telluric Activity on Pipe to Soil Potential

Amadeus Gas Pipeline KP 870 NCW-DLW

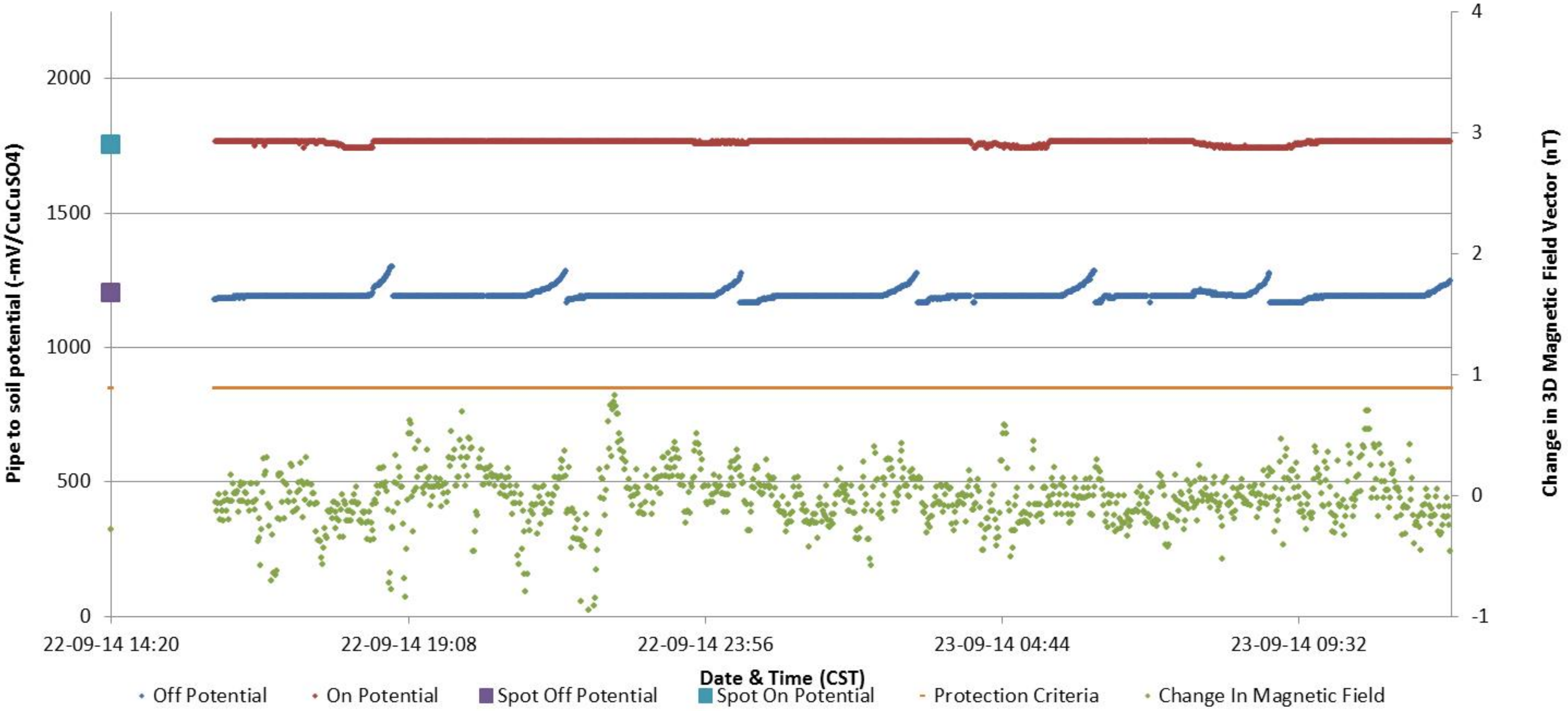
Insufficient Readings Taken (92%)

Time Below Protection Criteria 100%



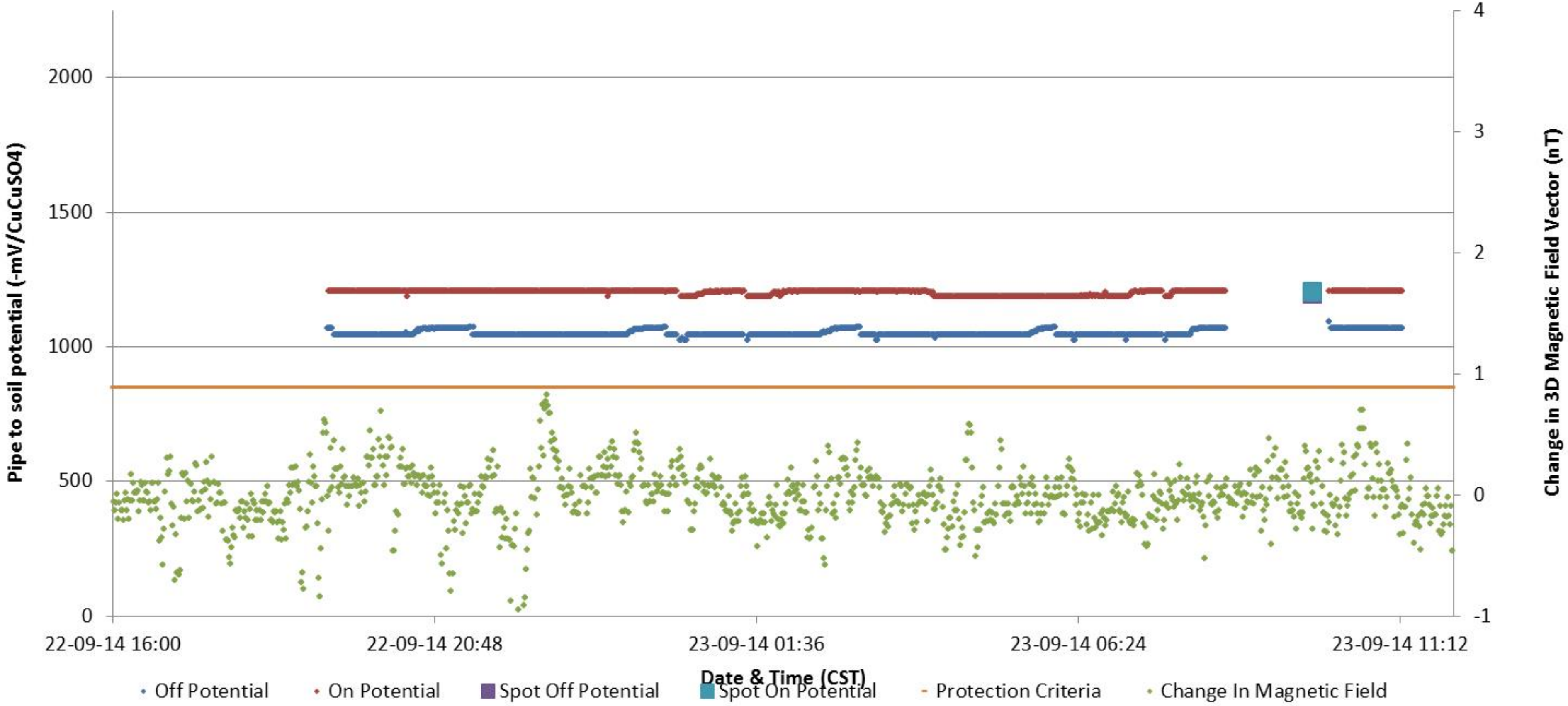
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 890 NCW-DLW

Insufficient Readings Taken (99%)



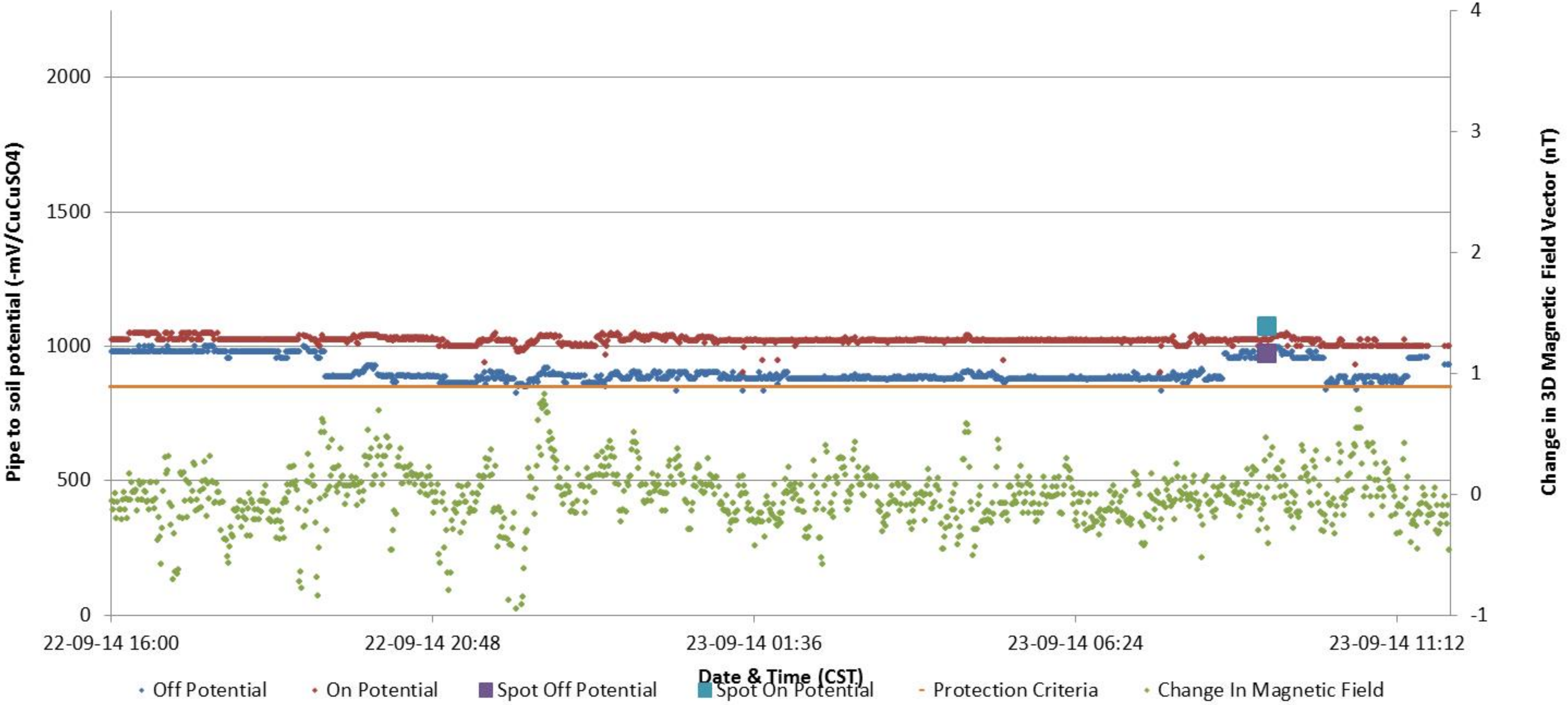
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 910.3 NCW-DLW

Insufficient Readings Taken (72%)



Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 936.8 NCW-DLW

Insufficient Readings Taken (96%)

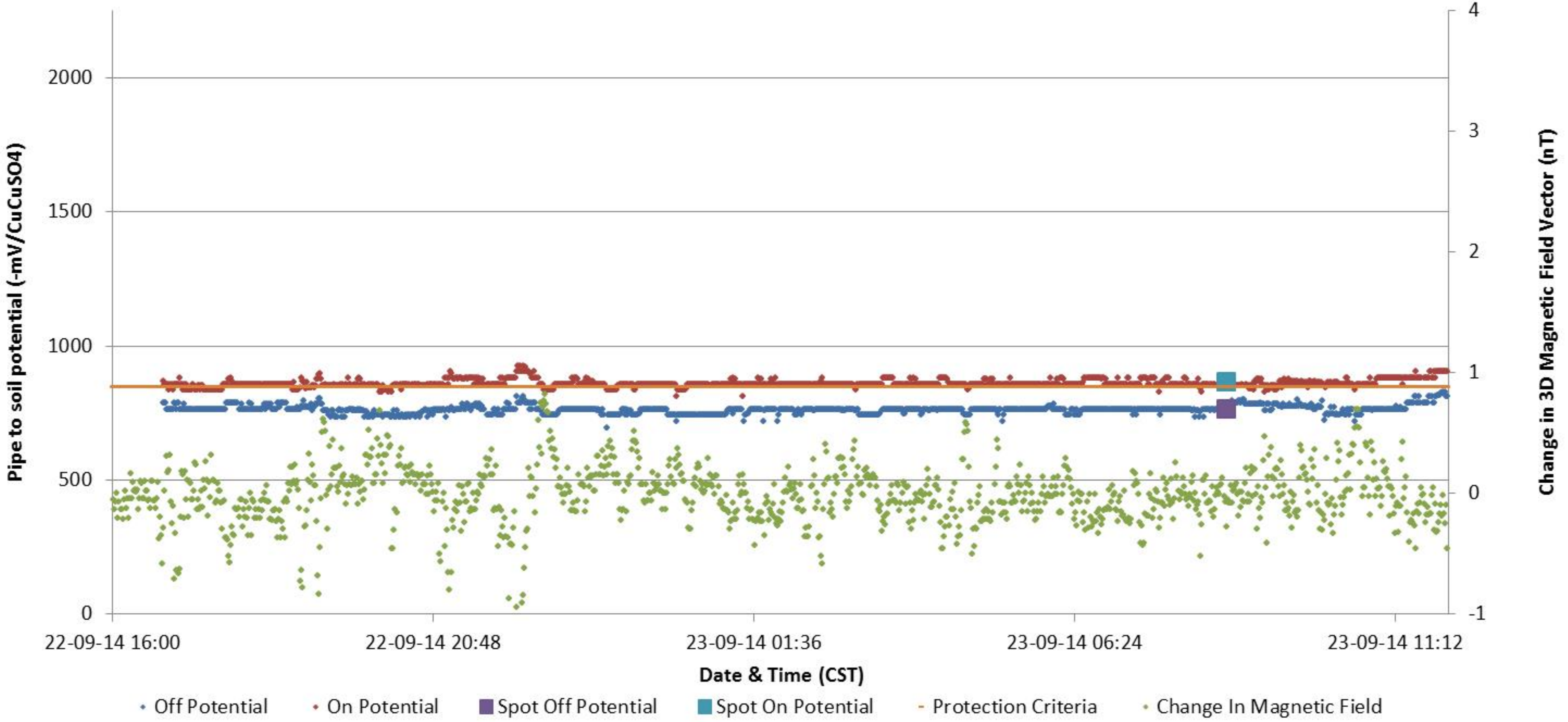


Effect of Telluric Activity on Pipe to Soil Potential

Amadeus Gas Pipeline KP 950.8 NCW-DLW

Insufficient Readings Taken (95%)

Time Below Protection Criteria 100%

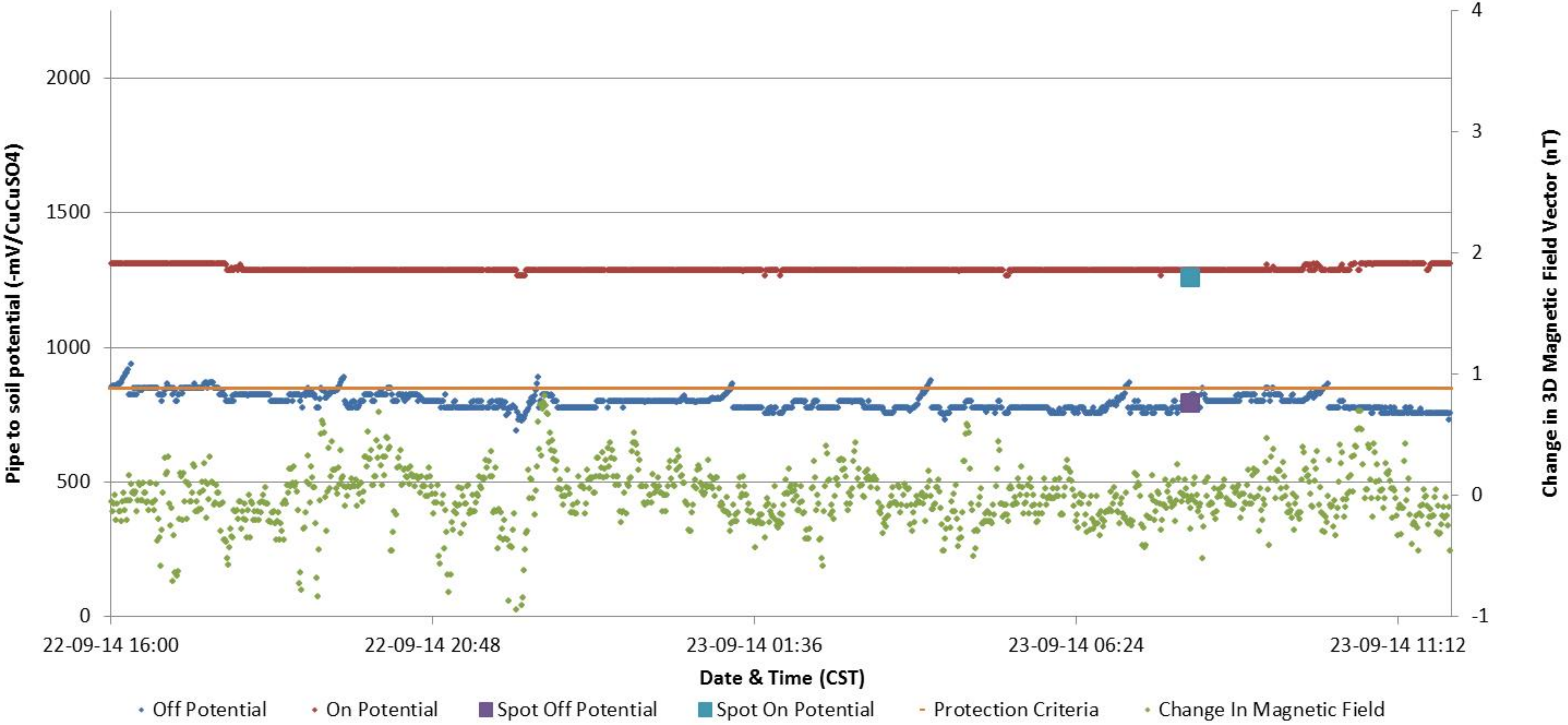


Effect of Telluric Activity on Pipe to Soil Potential

Amadeus Gas Pipeline KP 969 NCW-DLW

Insufficient Readings Taken (99%)

Time Below Protection Criteria 96%

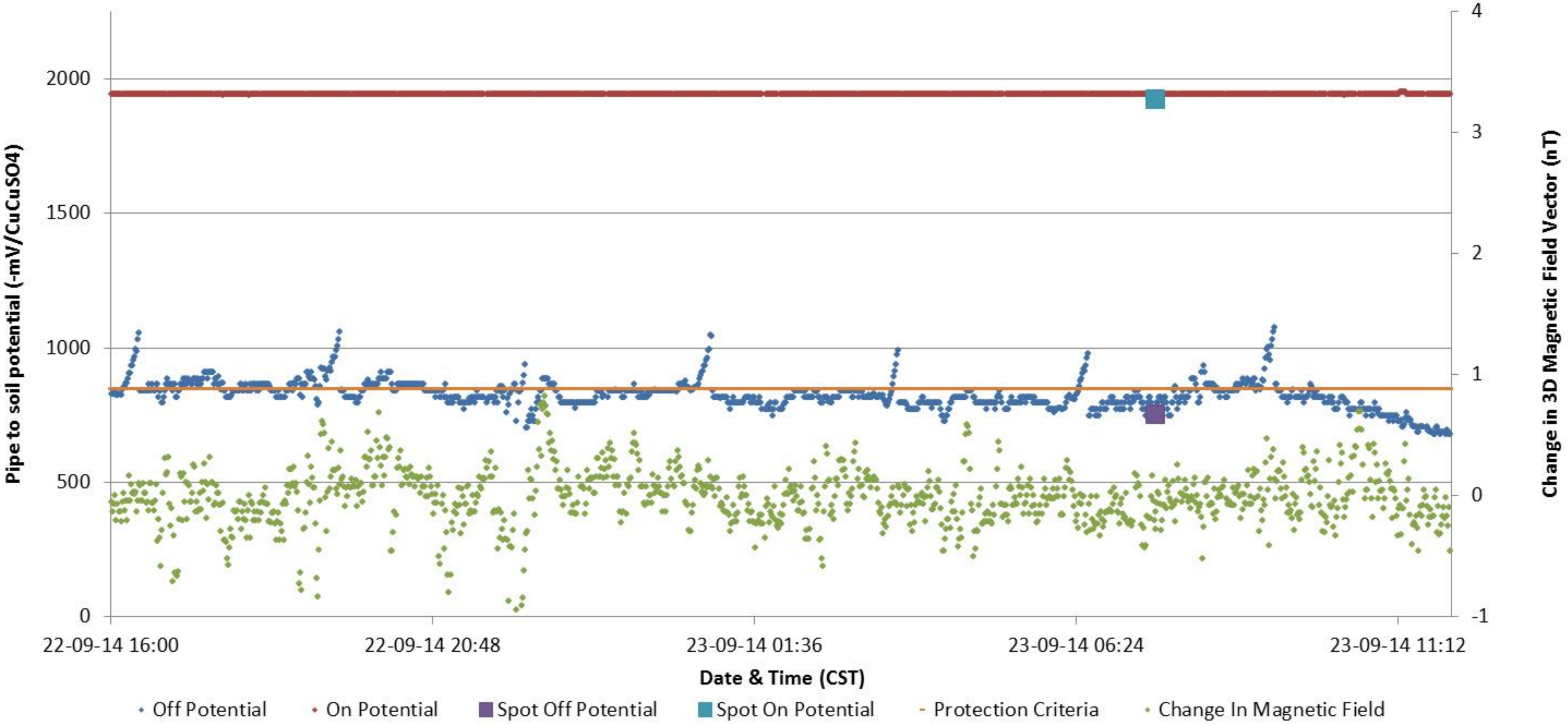


Effect of Telluric Activity on Pipe to Soil Potential

Amadeus Gas Pipeline KP 981.8 NCW-DLW

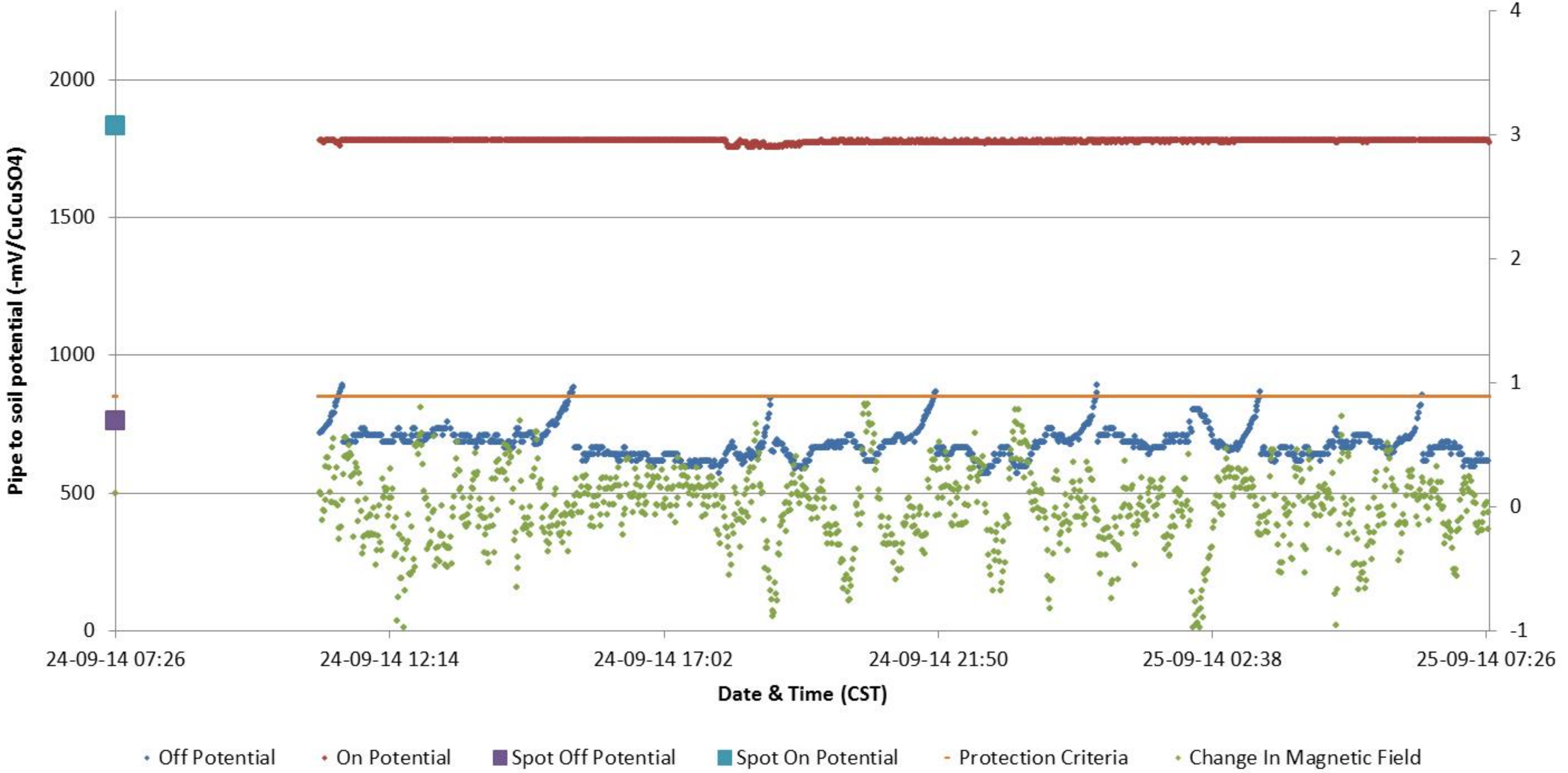
Insufficient Readings Taken (99%)

Time Below Protection Criteria 75%



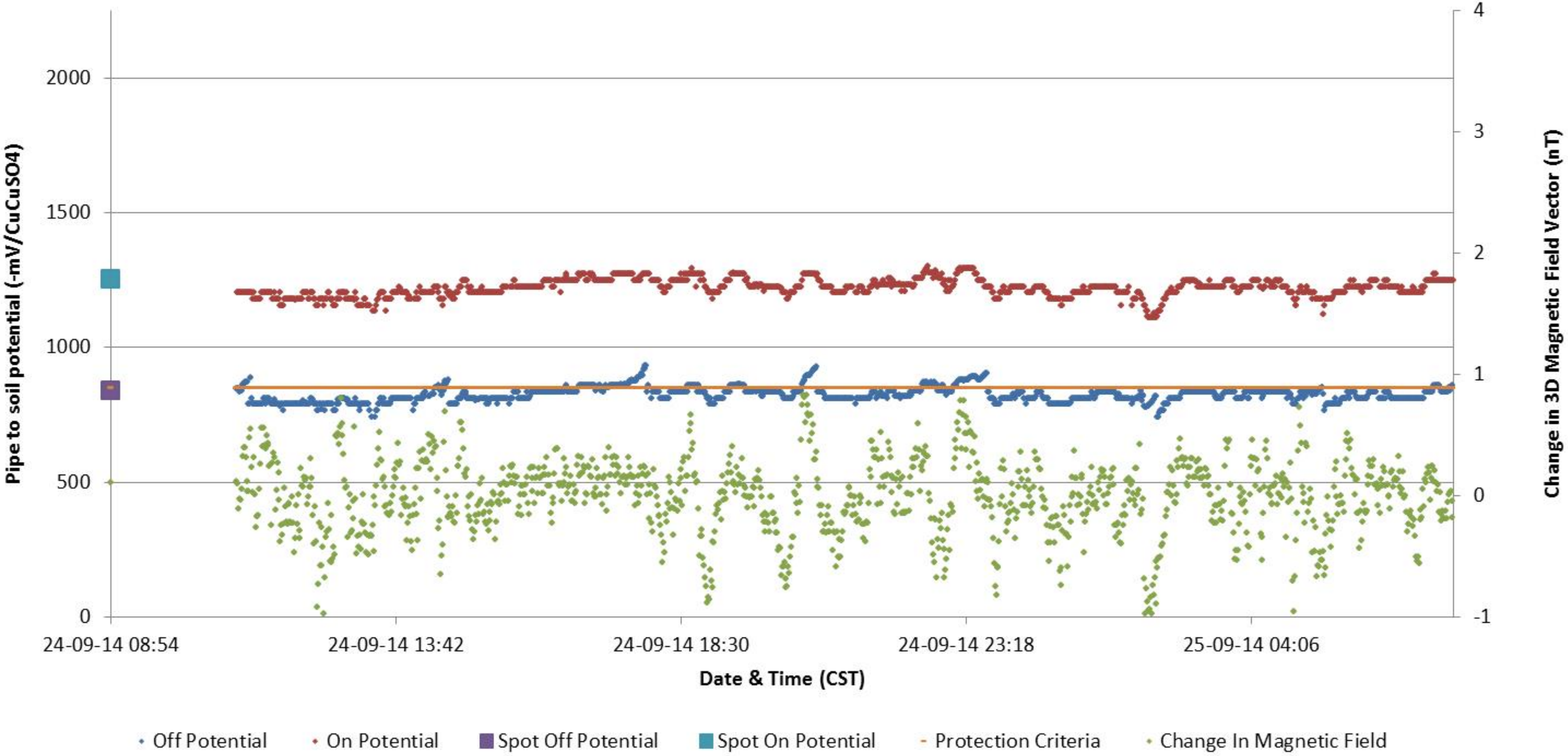
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 981.8 DLW-MAT

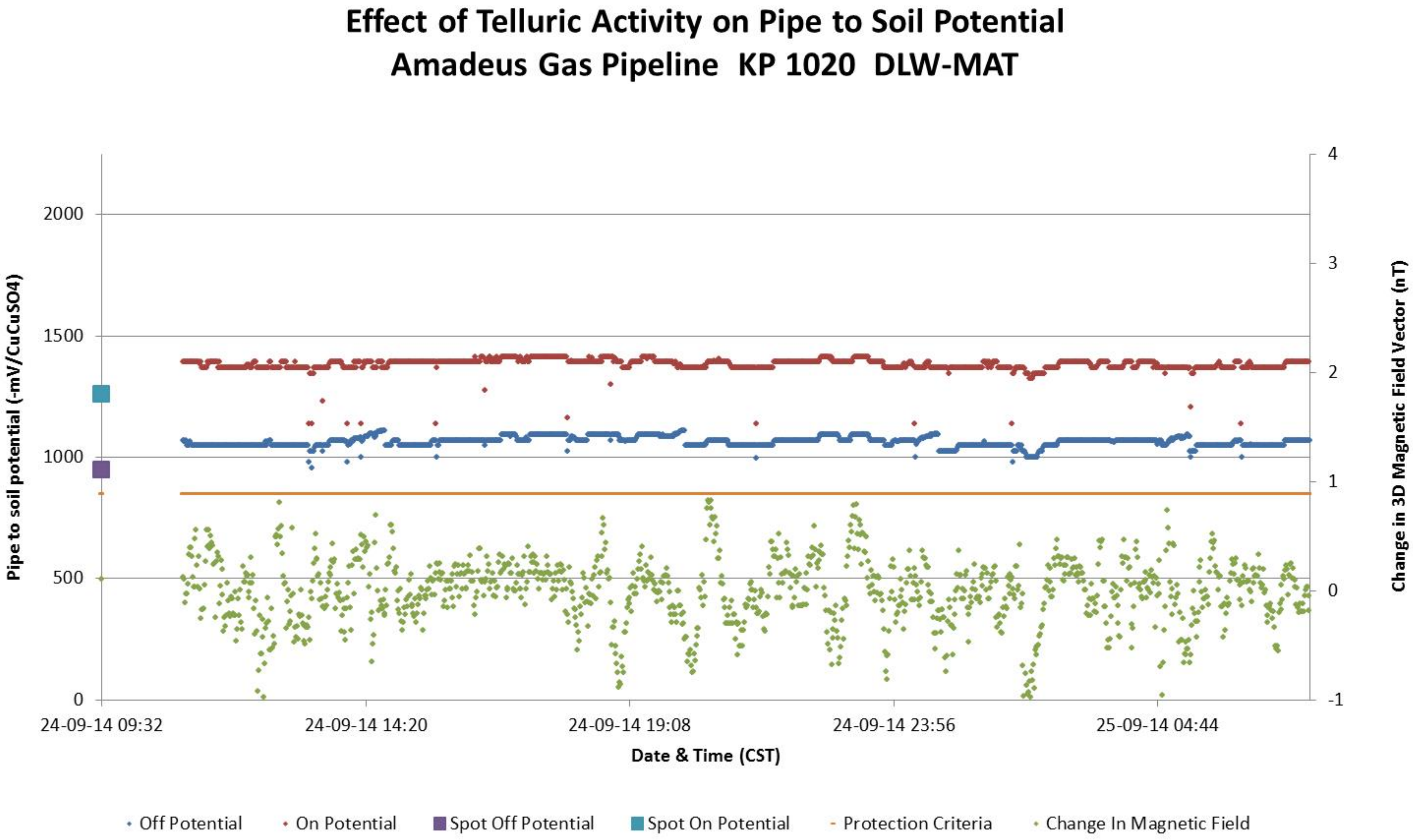
Time Below Protection Criteria 99%

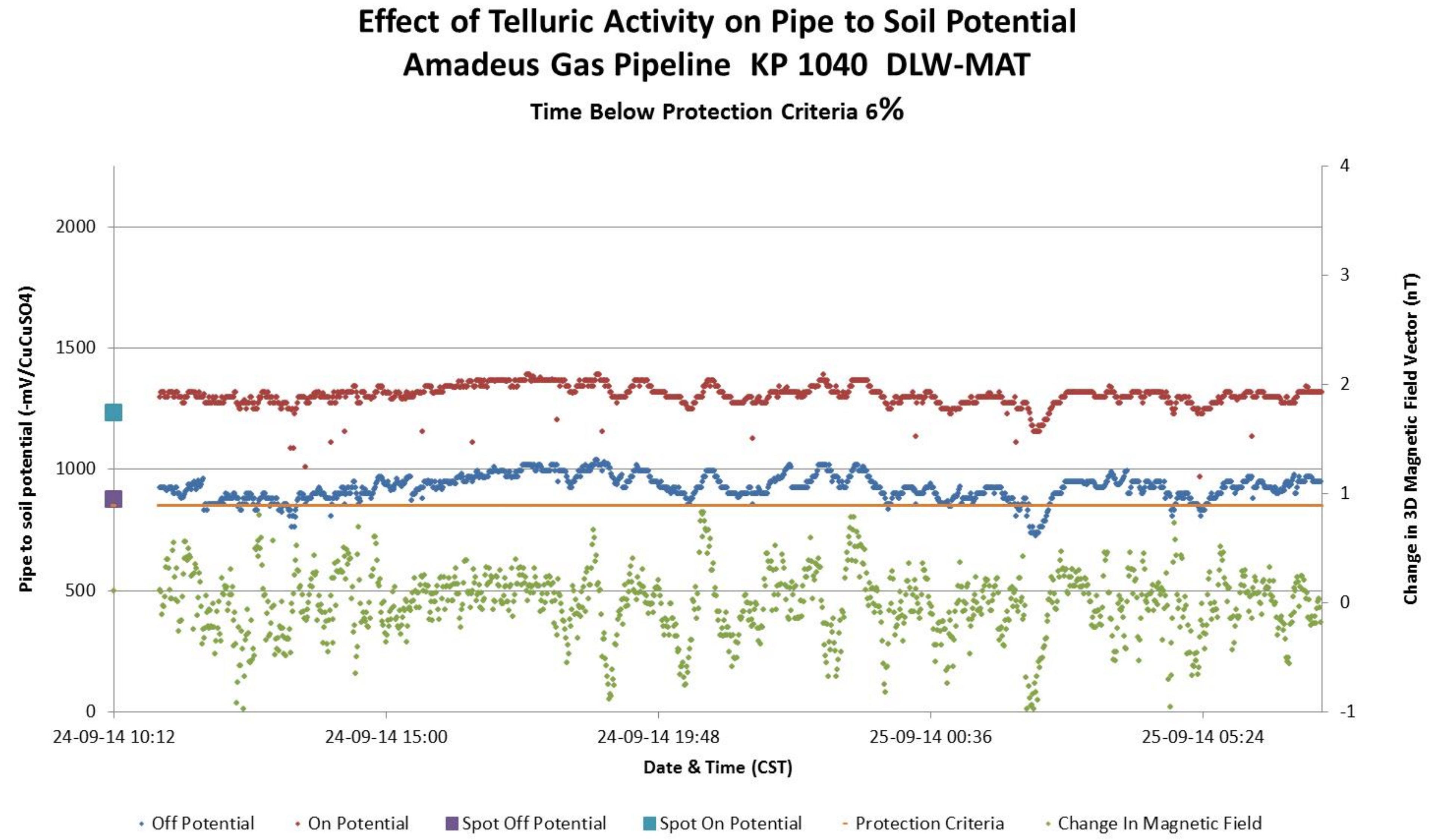


Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1000 DLW-MAT

Time Below Protection Criteria 84%

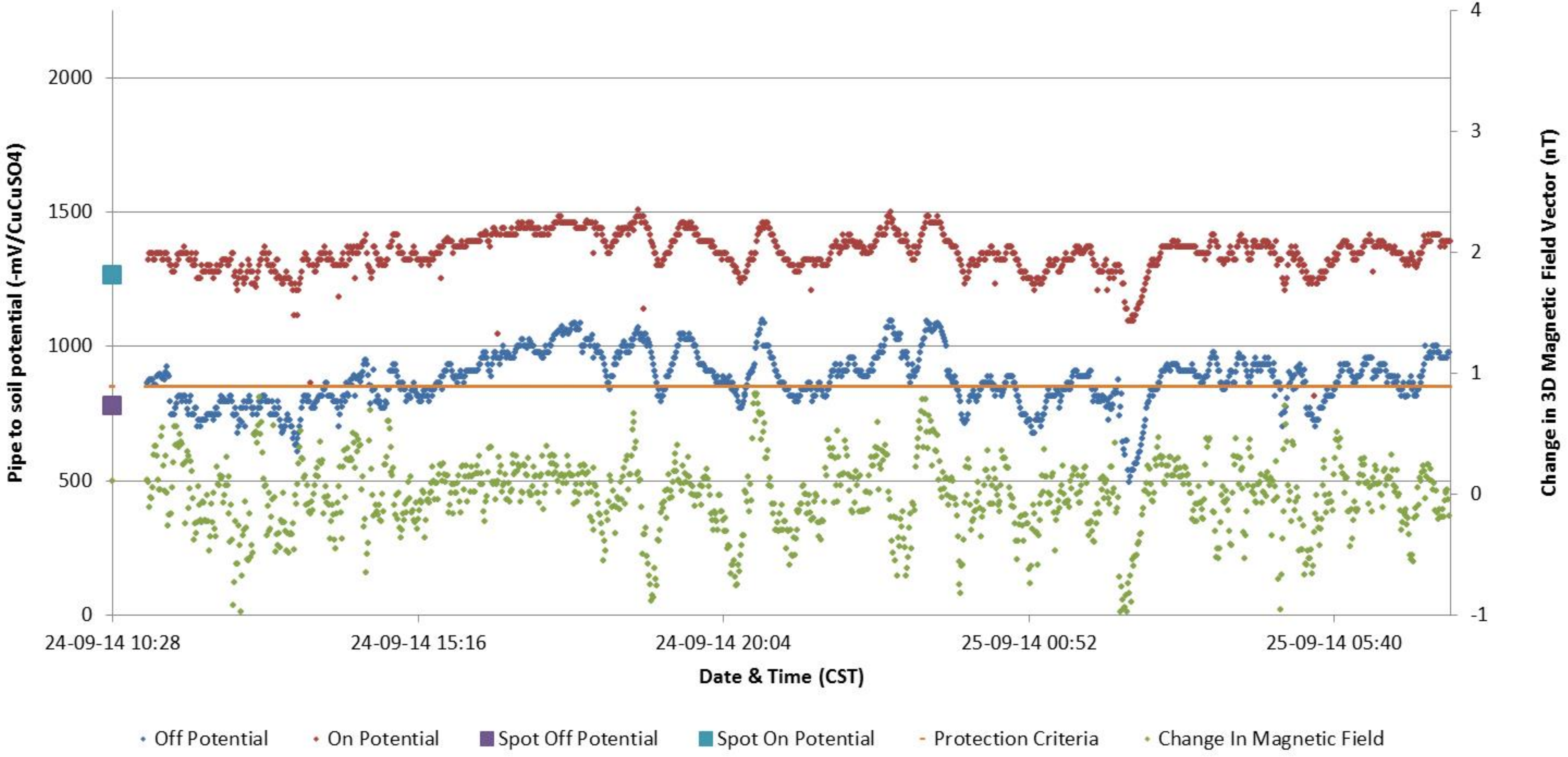


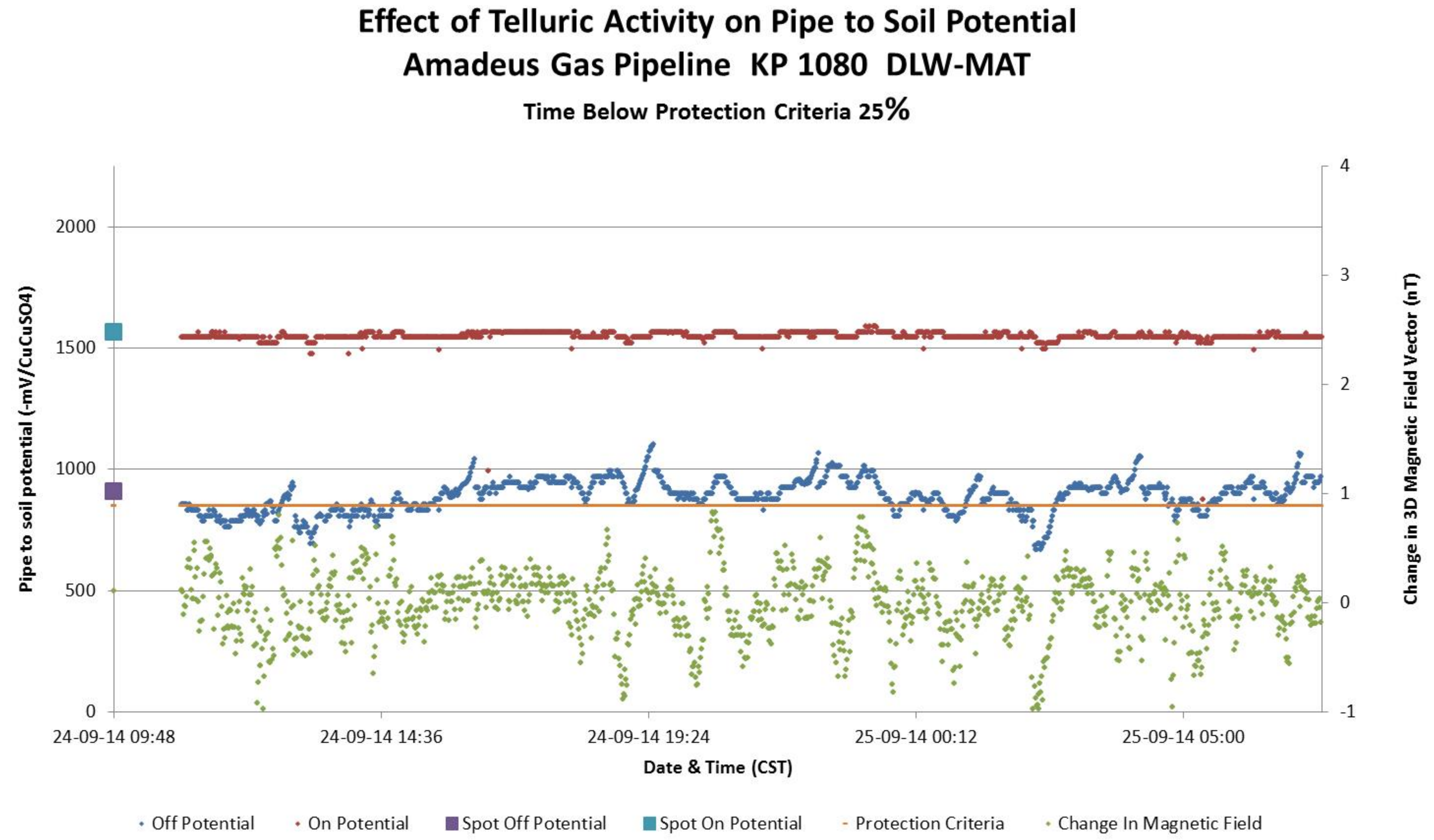

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1020 DLW-MAT
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
24-09-14 09:32
24-09-14 14:20
24-09-14 19:08
24-09-14 23:56
25-09-14 04:44
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field

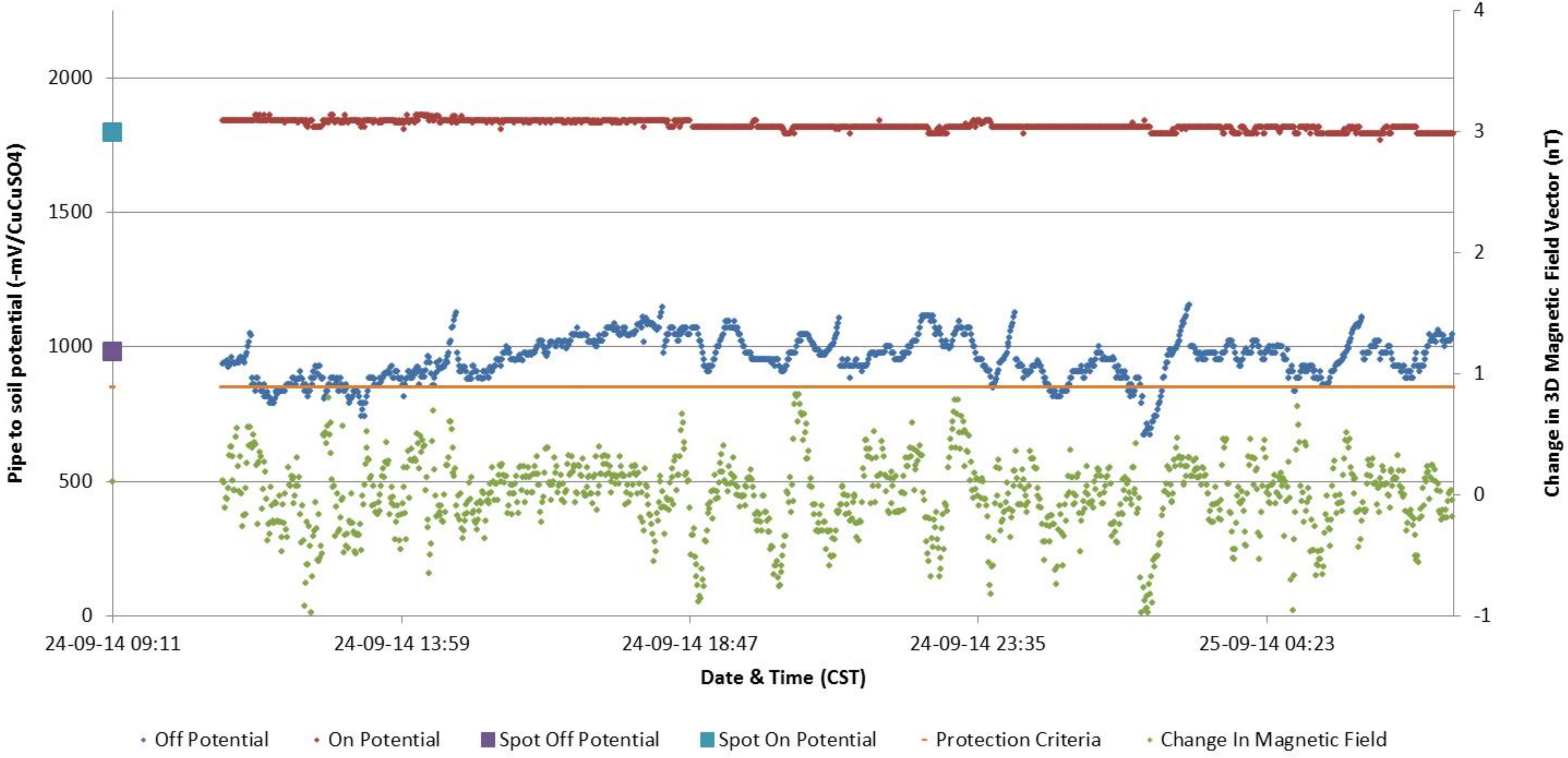

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1040 DLW-MAT
Time Below Protection Criteria 6%
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
24-09-14 10:12
24-09-14 15:00
24-09-14 19:48
25-09-14 00:36
25-09-14 05:24
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1060 DLW-MAT

Time Below Protection Criteria 39%




Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1080 DLW-MAT
Time Below Protection Criteria 25%
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
24-09-14 09:48
24-09-14 14:36
24-09-14 19:24
25-09-14 00:12
25-09-14 05:00
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field

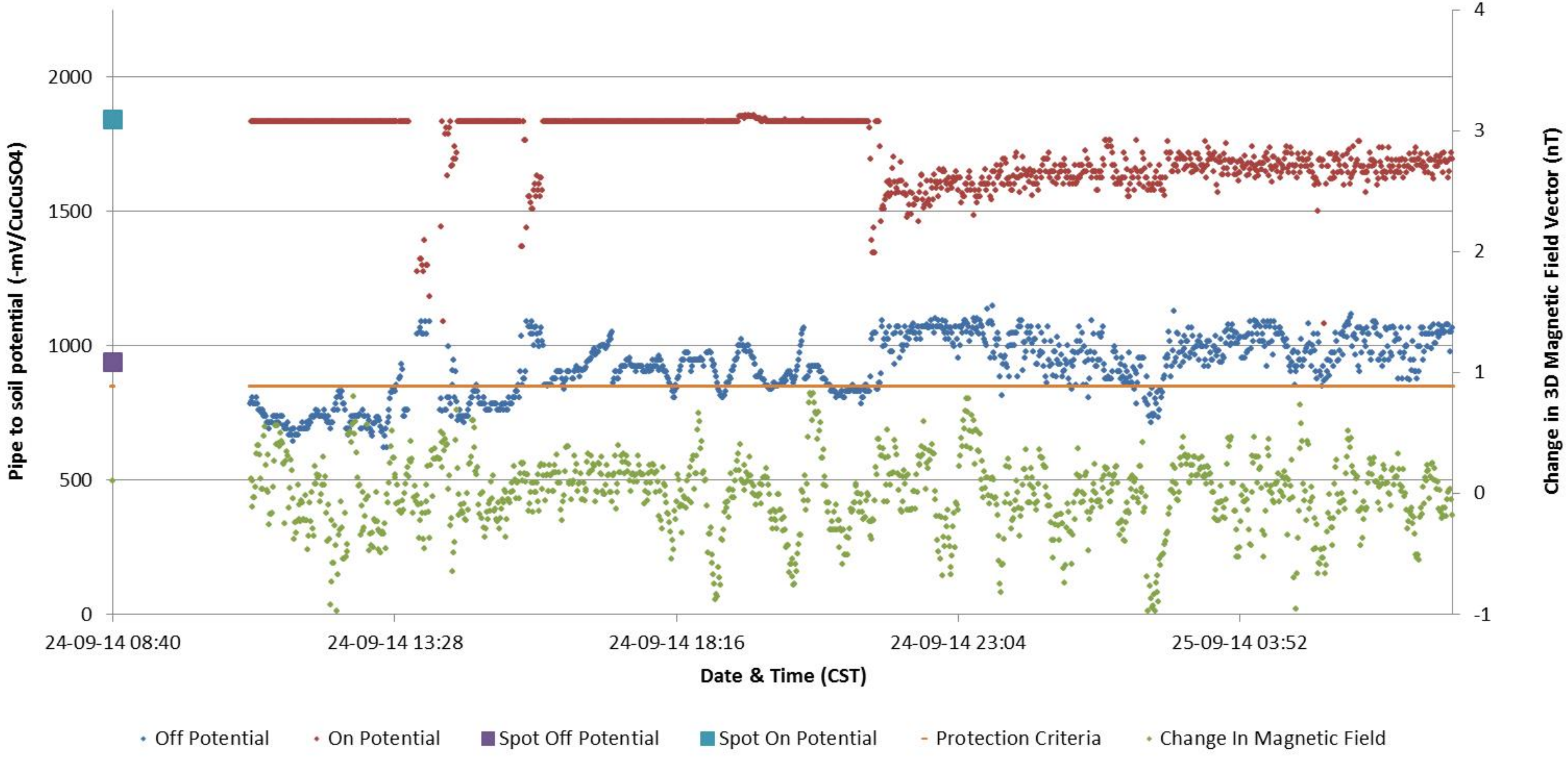

Effect of Telluric Activity on Pipe to Soil Potential

Amadeus Gas Pipeline KP 1100 DLW-MAT

Time Below Protection Criteria 9%

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1107.9 DLW-MAT

Time Below Protection Criteria 27%

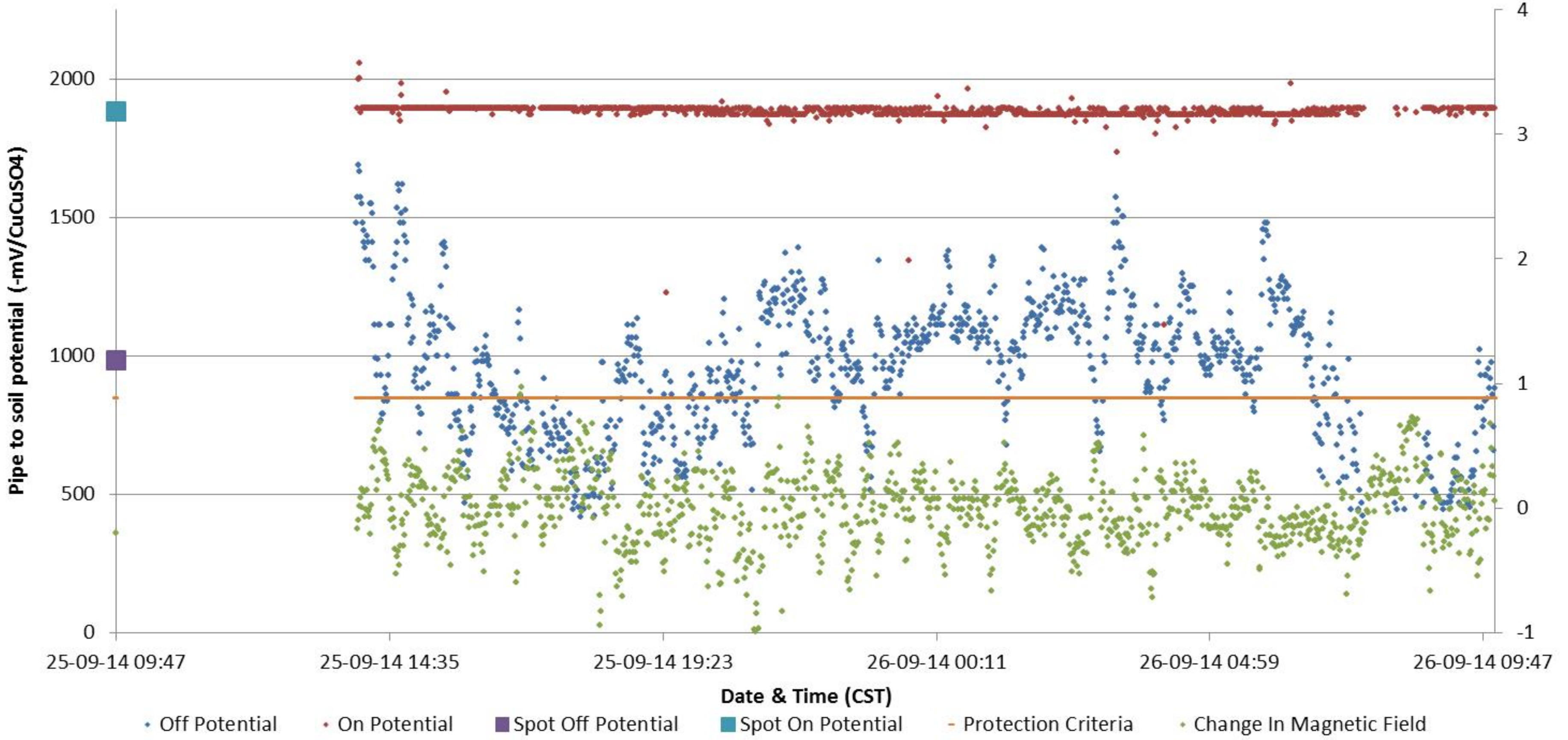


Effect of Telluric Activity on Pipe to Soil Potential

Amadeus Gas Pipeline KP 1107.9 MAT-HEL

Insufficient Readings Taken (92%)

Time Below Protection Criteria 31%

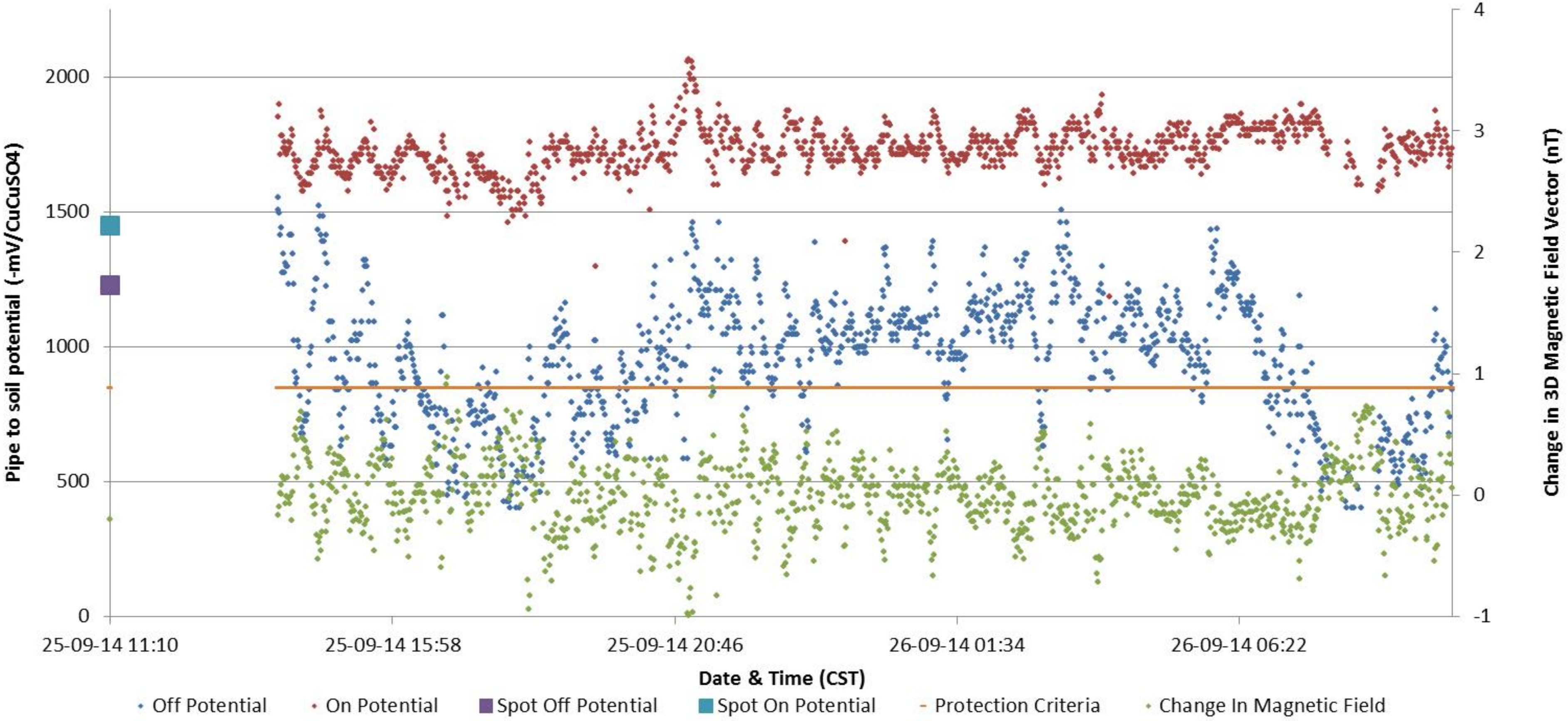


Effect of Telluric Activity on Pipe to Soil Potential

Amadeus Gas Pipeline KP 1130.1 MAT-HEL

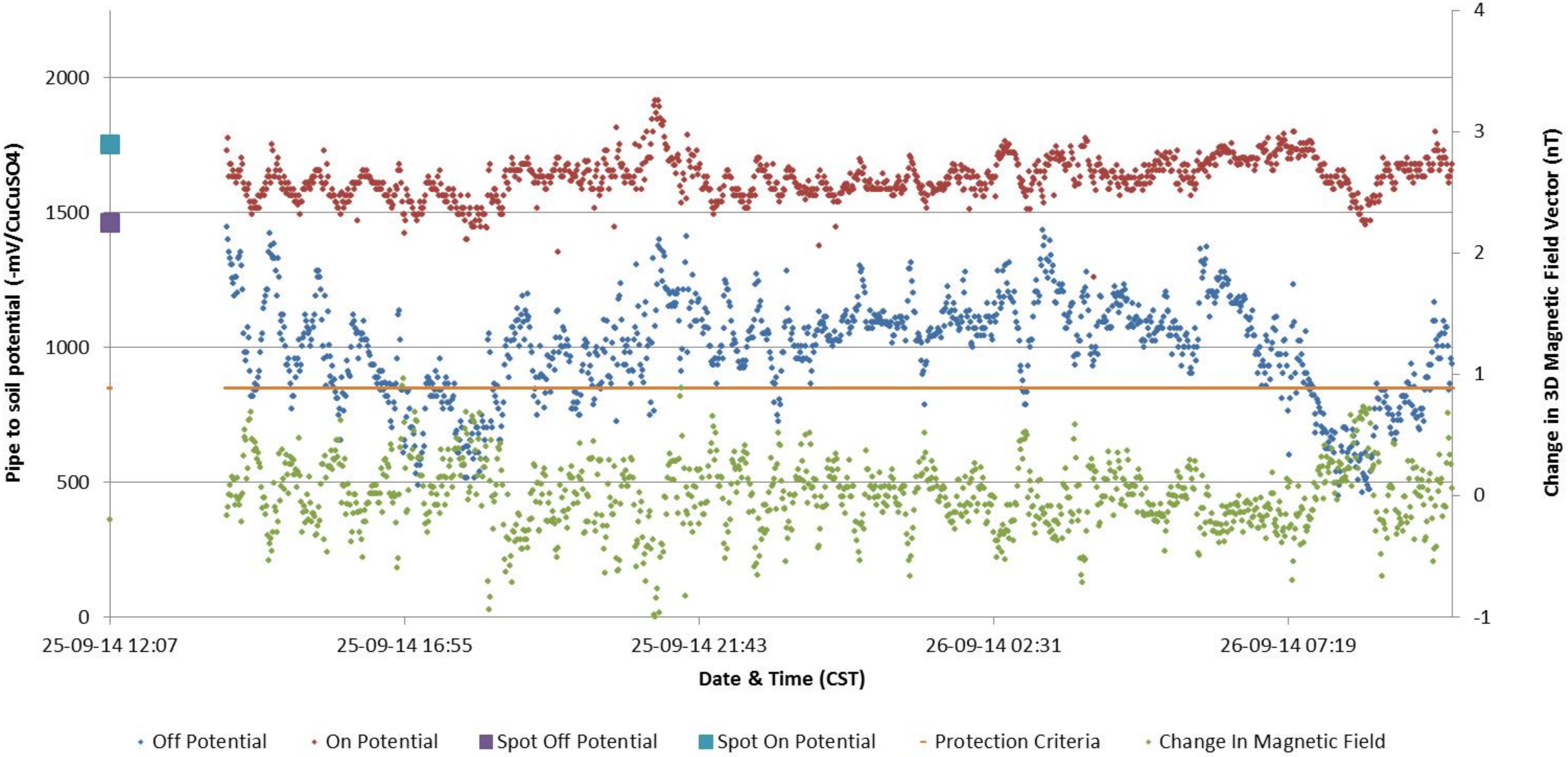
Insufficient Readings Taken (95%)

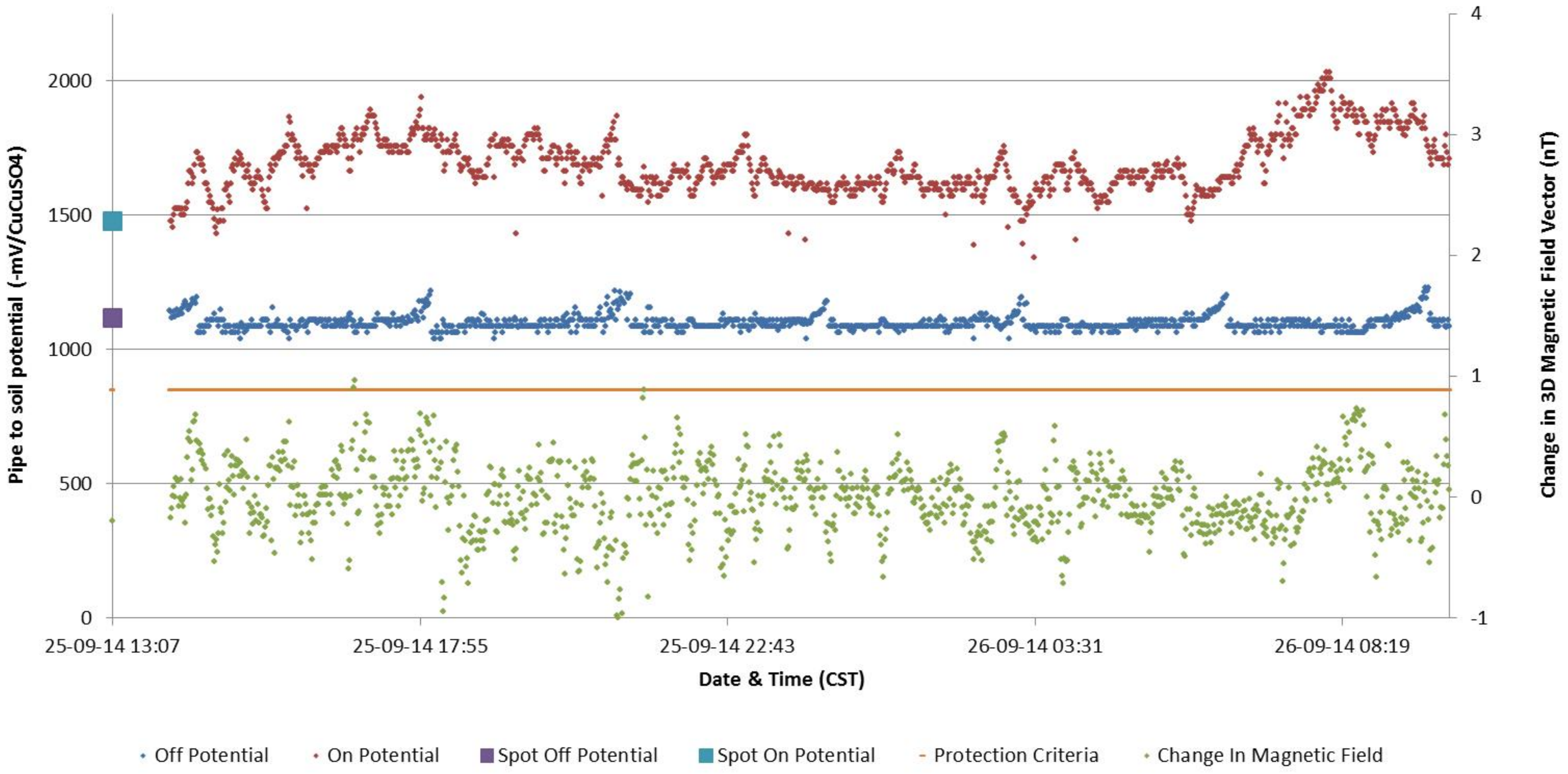
Time Below Protection Criteria 32%



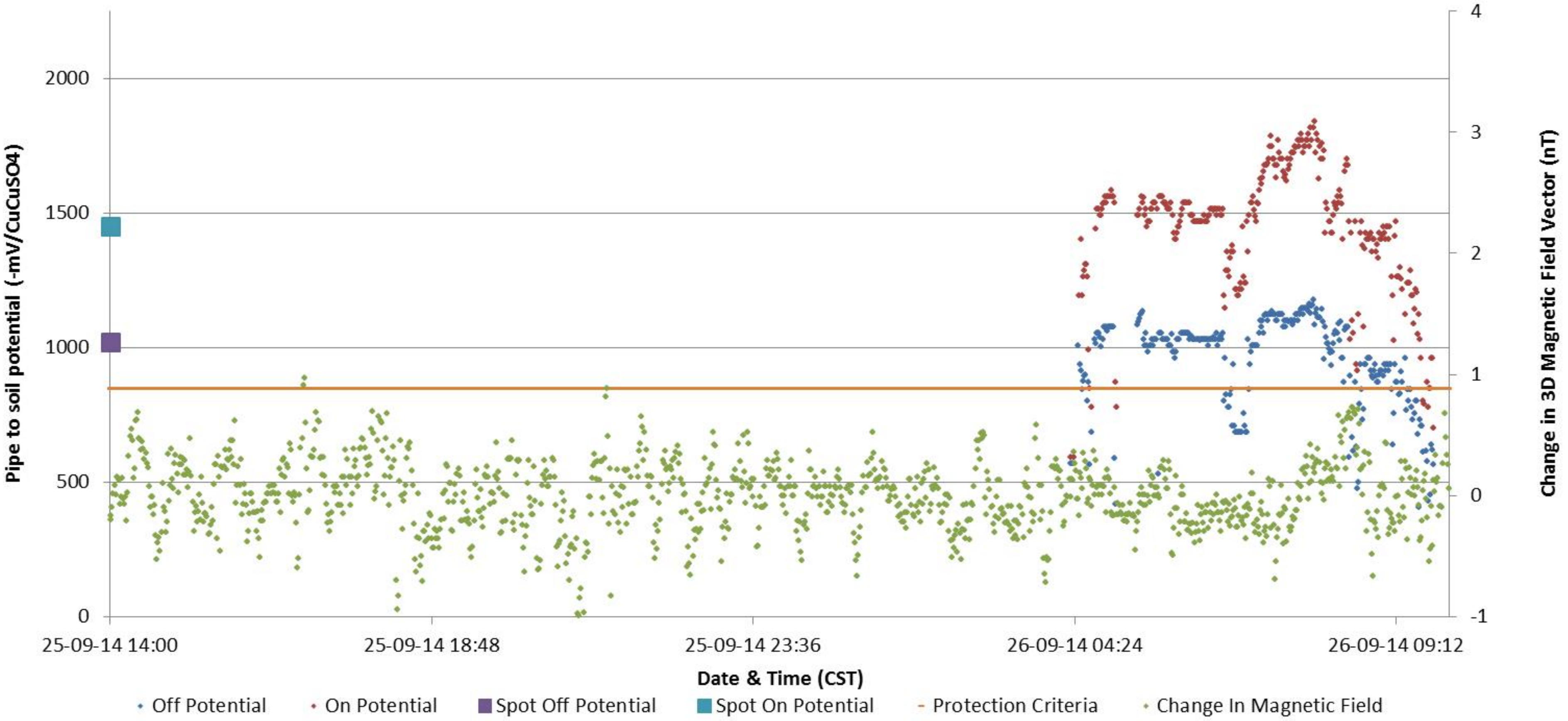
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1150.2 MAT-HEL

Time Below Protection Criteria 22%





Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1170.2 MAT-HEL



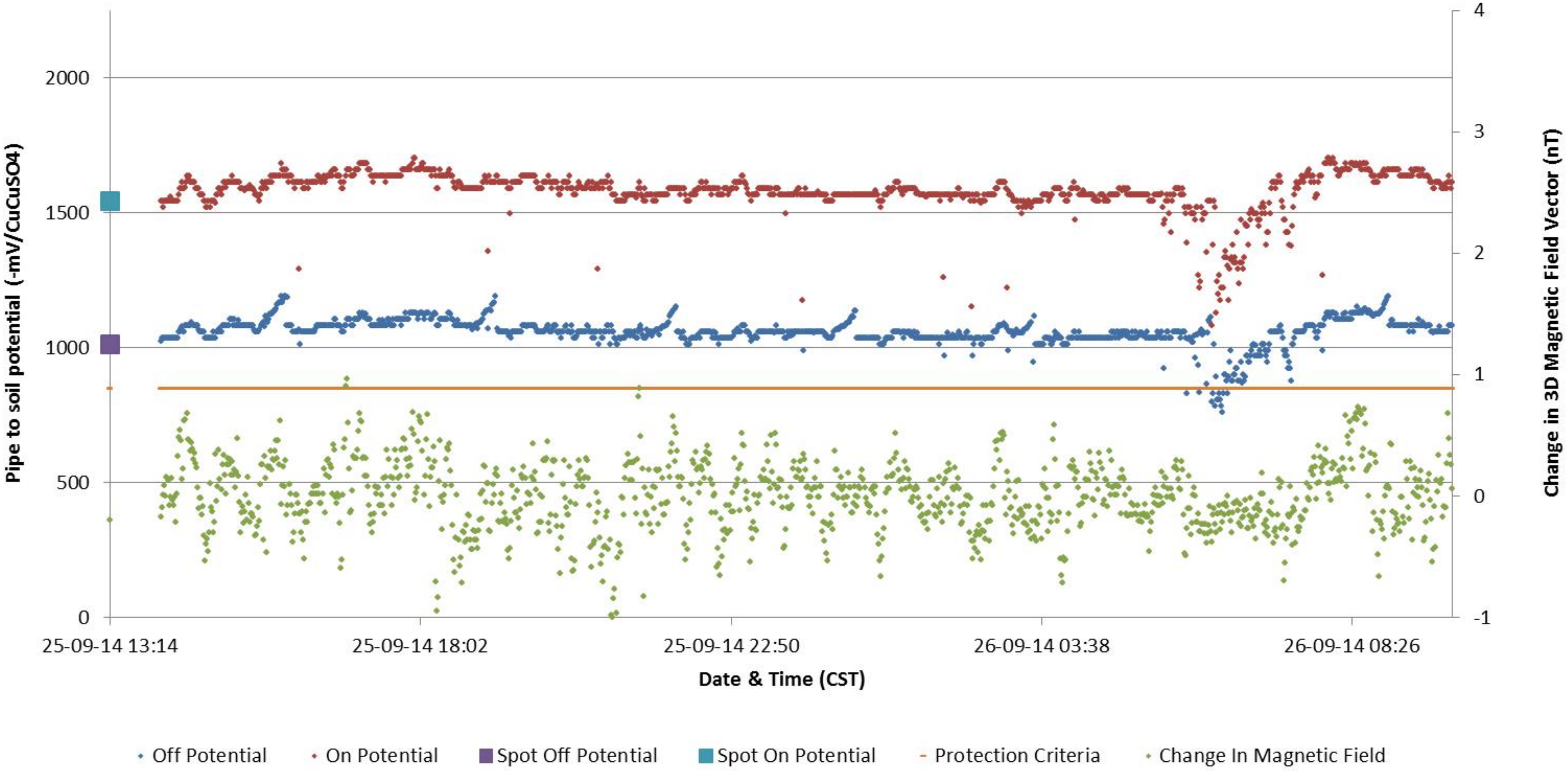
Effect of Telluric Activity on Pipe to Soil Potential

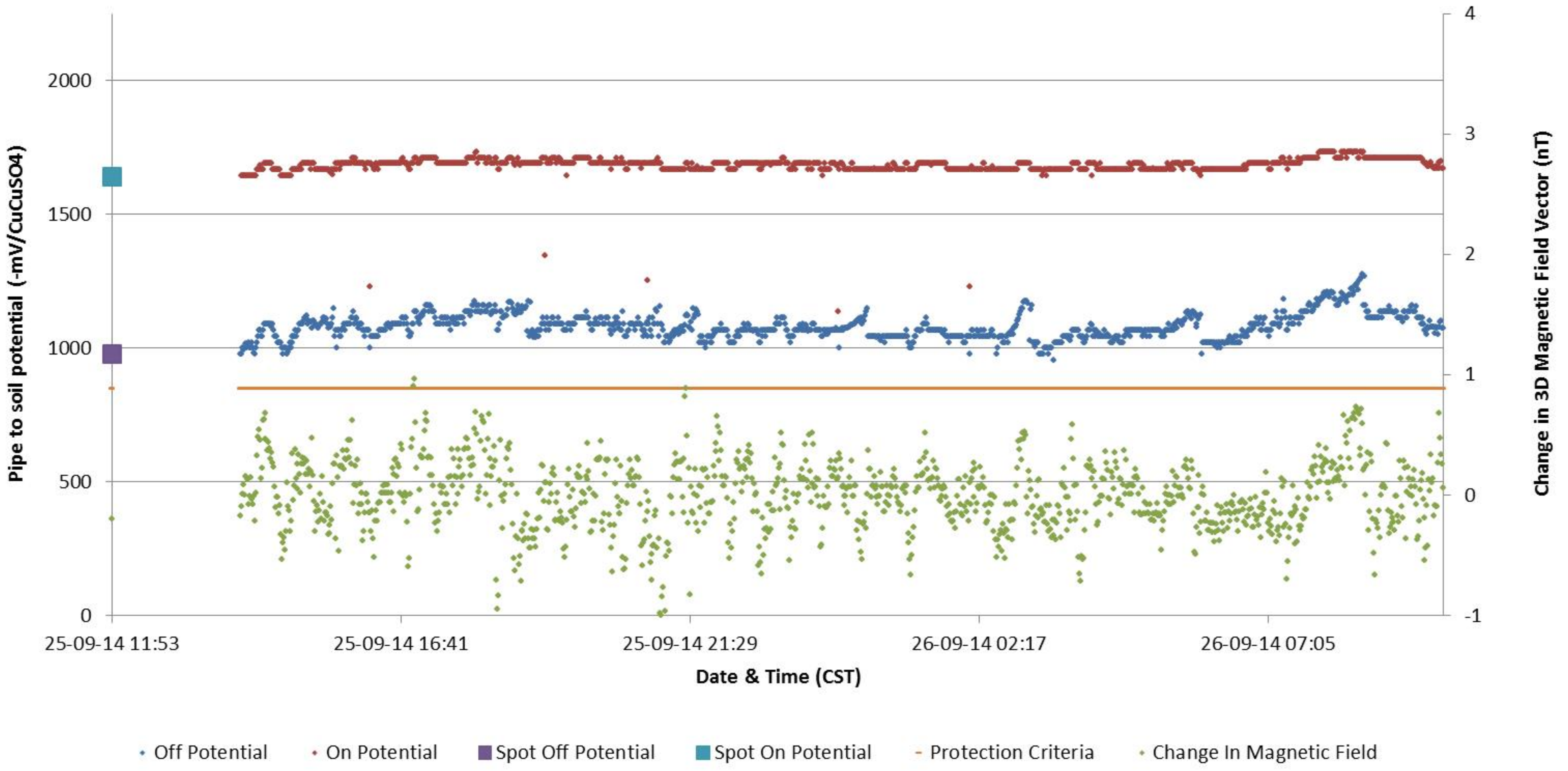
Amadeus Gas Pipeline KP 1190.2 MAT-HEL

Insufficient Readings Taken (24%)

Time Below Protection Criteria 23%

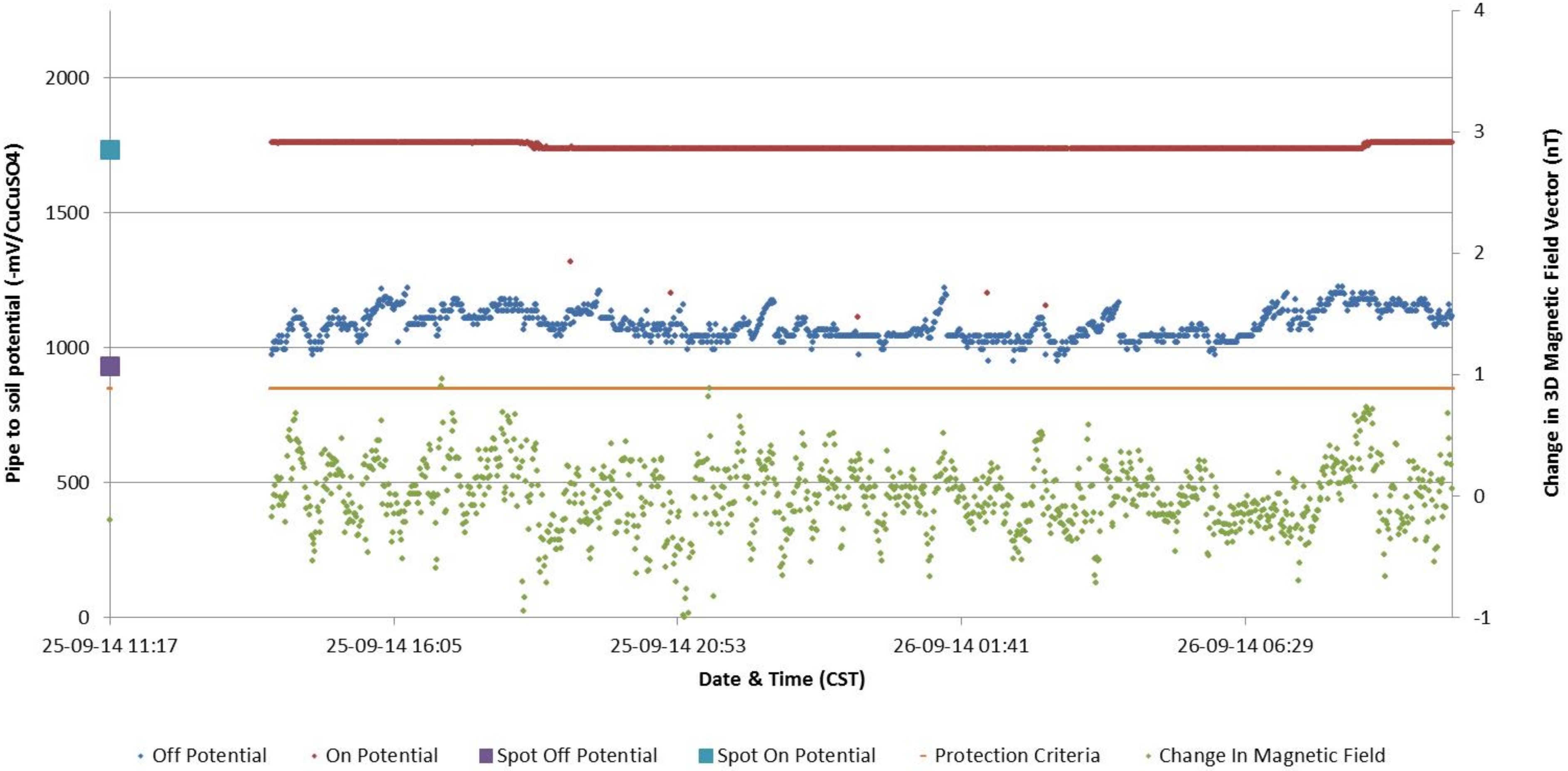
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1210.2 MAT-HEL

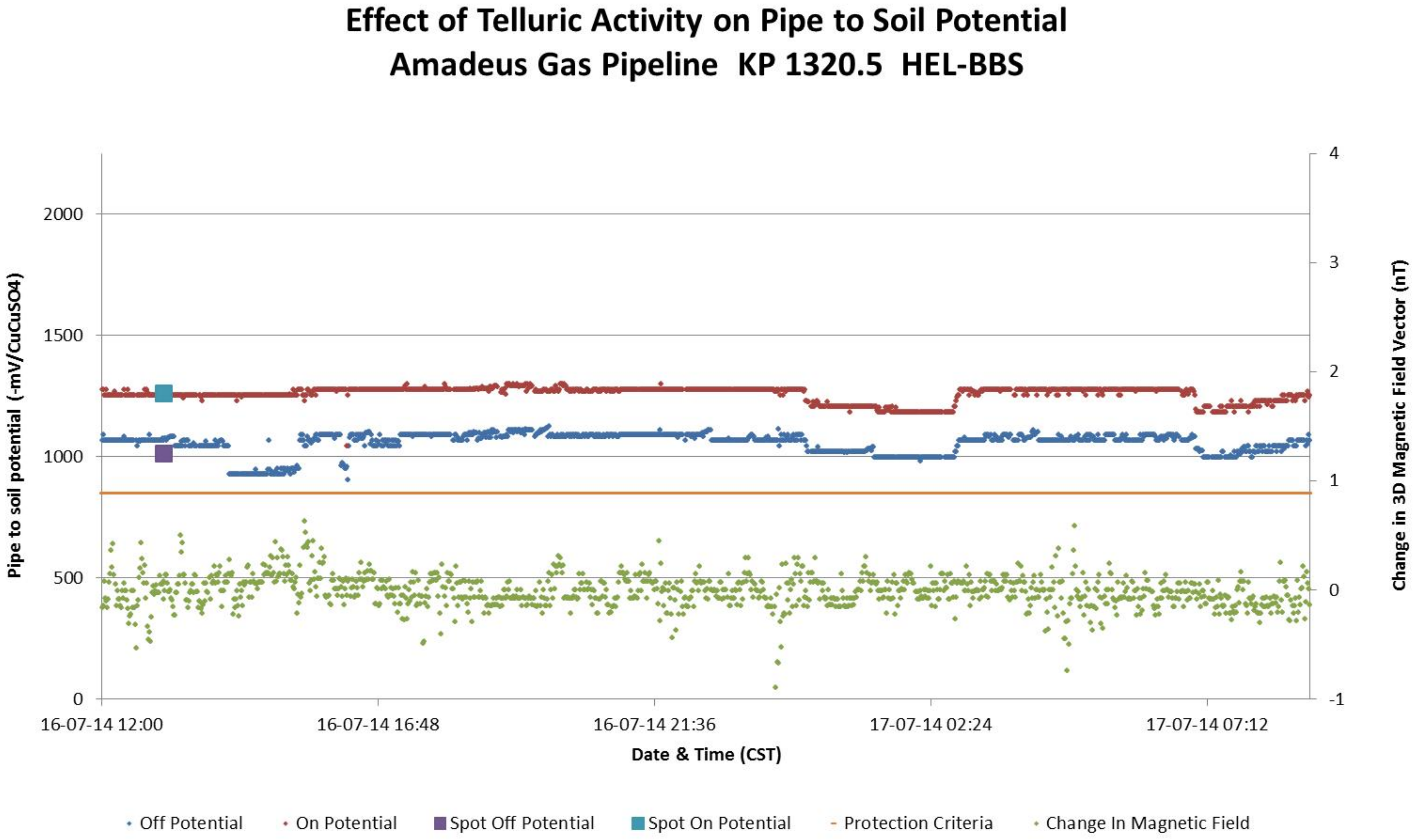




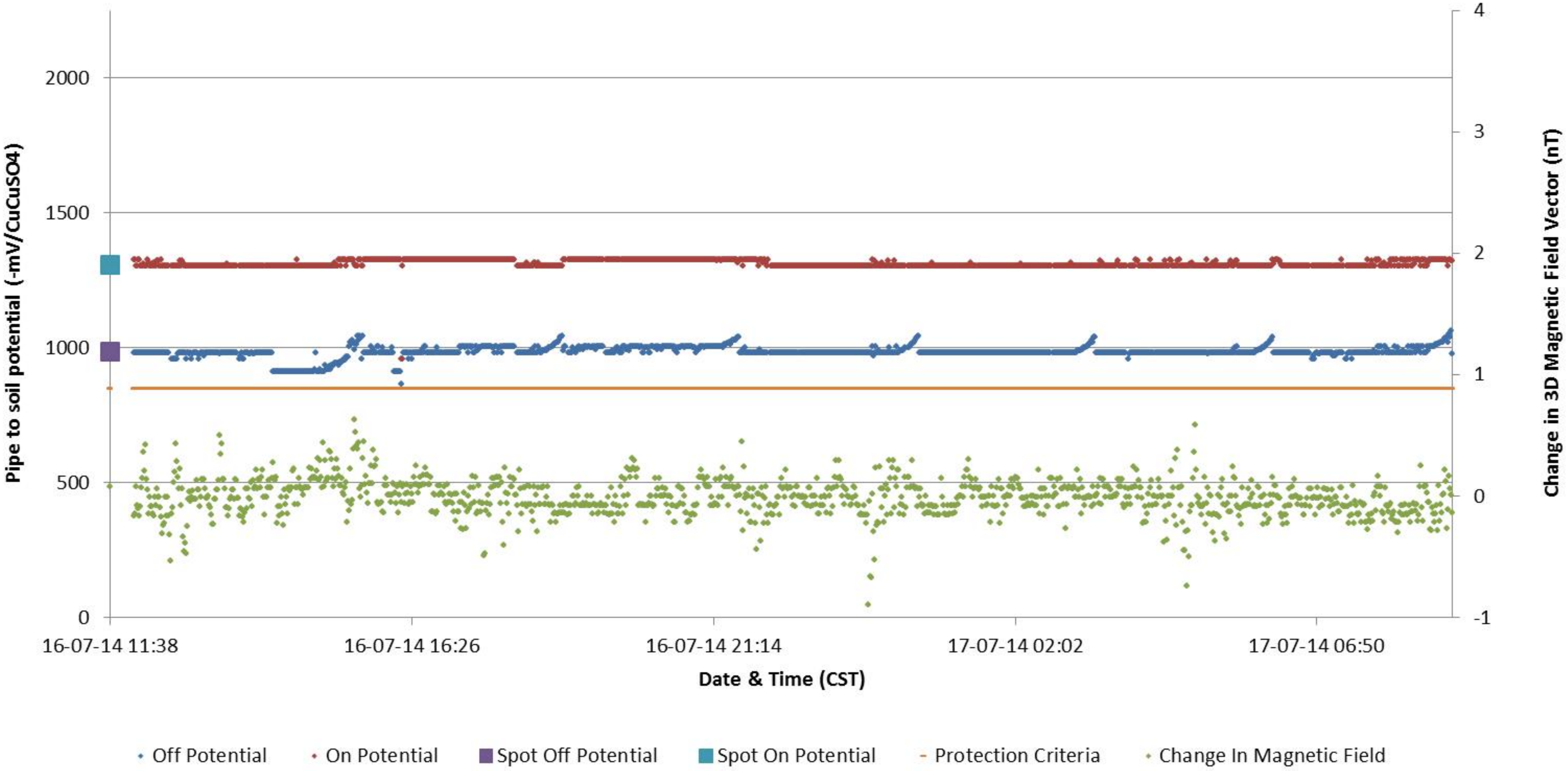
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1230 MAT-HEL

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1242.7 MAT-HEL




Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1320.5 HEL-BBS
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
16-07-14 12:00
16-07-14 16:48
16-07-14 21:36
17-07-14 02:24
17-07-14 07:12
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1342.8 HEL-BBS

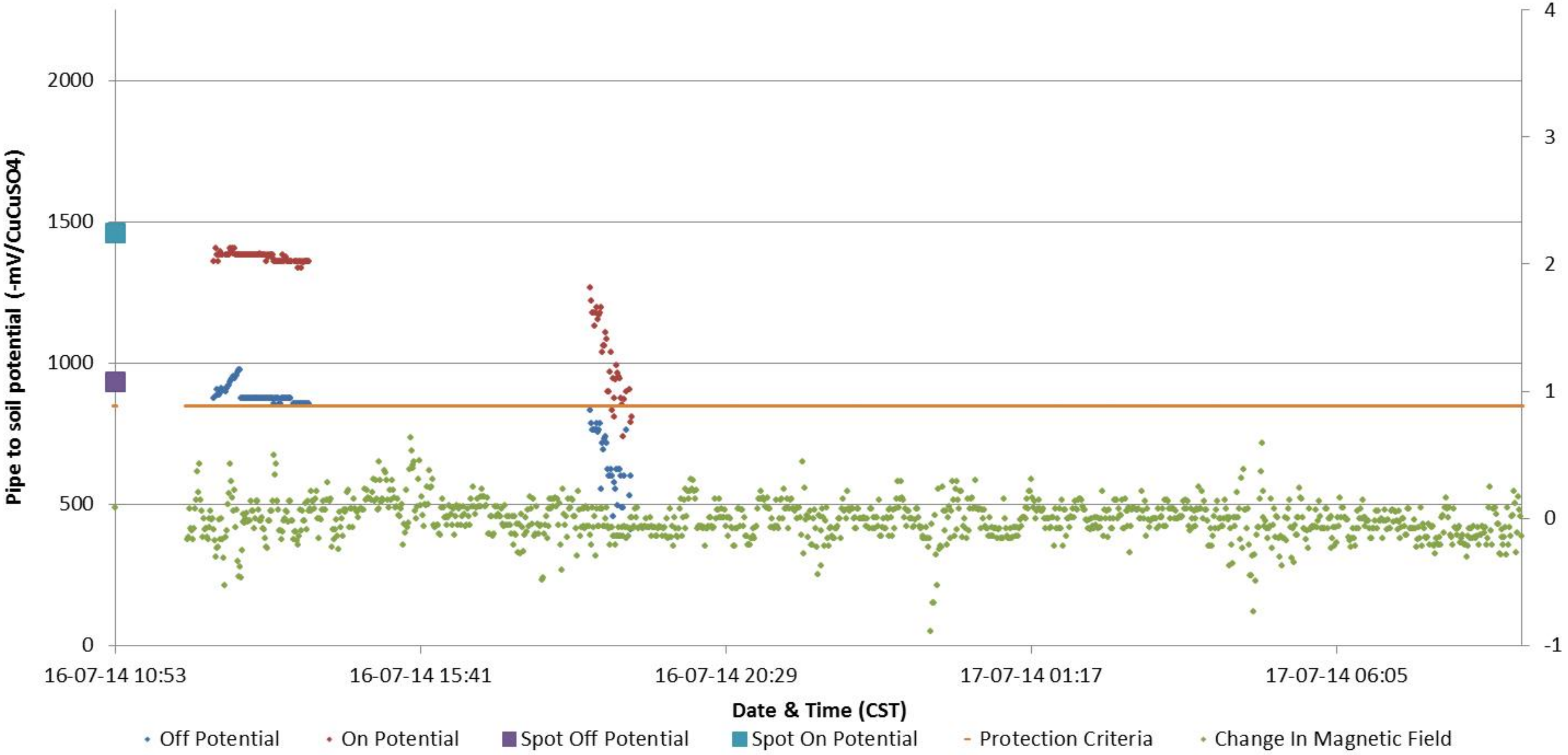


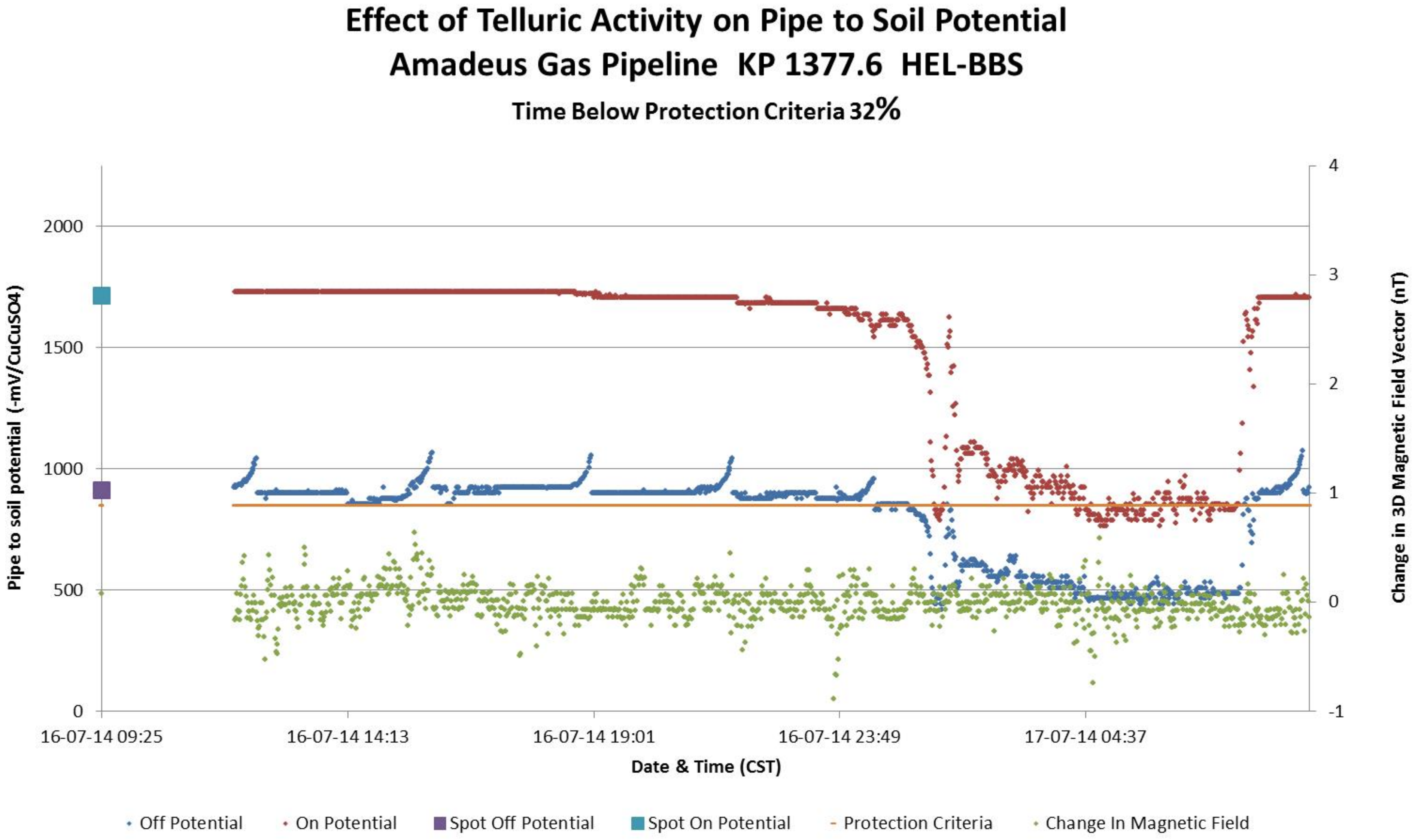
Effect of Telluric Activity on Pipe to Soil Potential

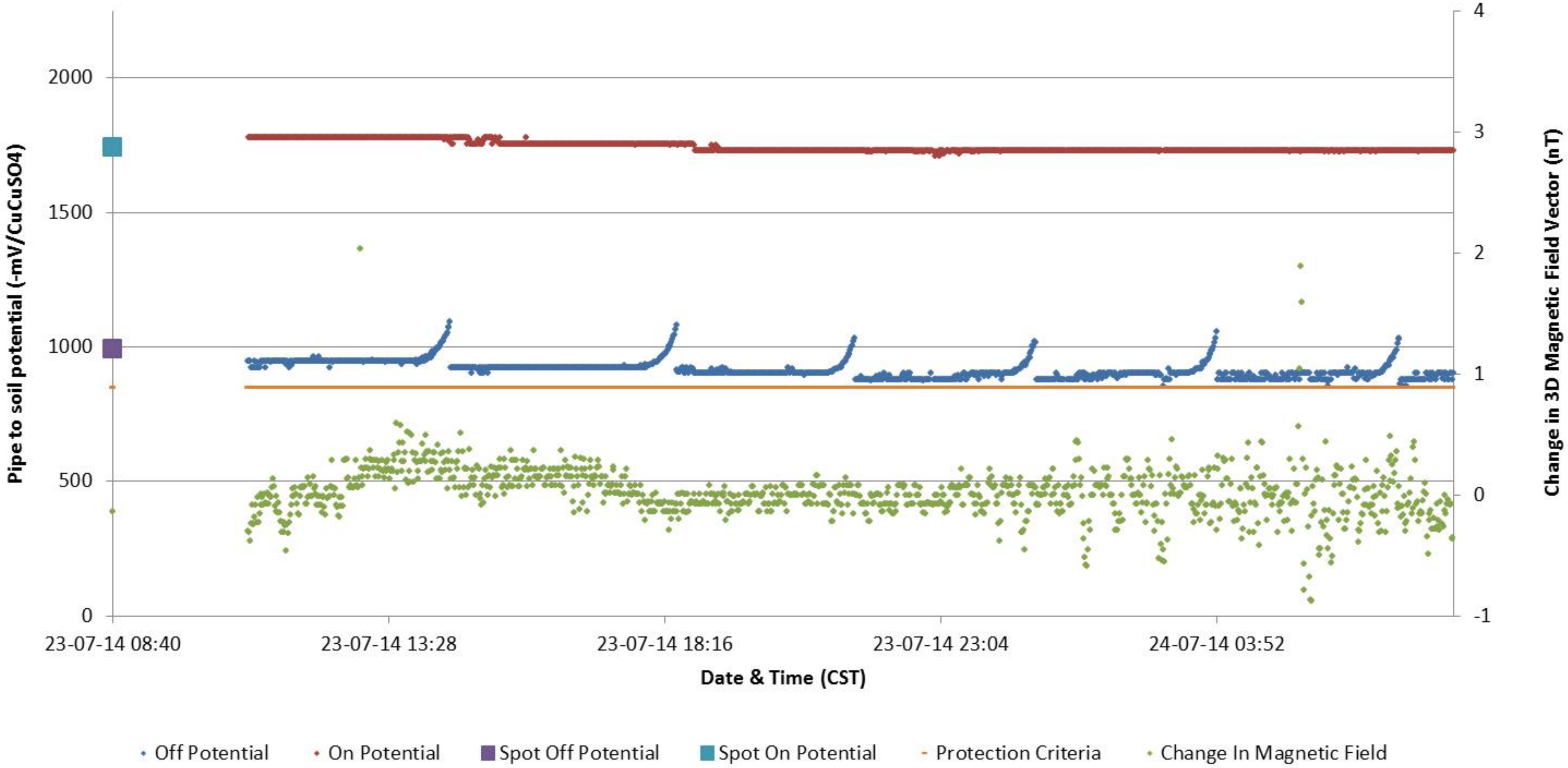
Amadeus Gas Pipeline KP 1359.7 HEL-BBS

Insufficient Readings Taken (10%)

Time Below Protection Criteria 30%



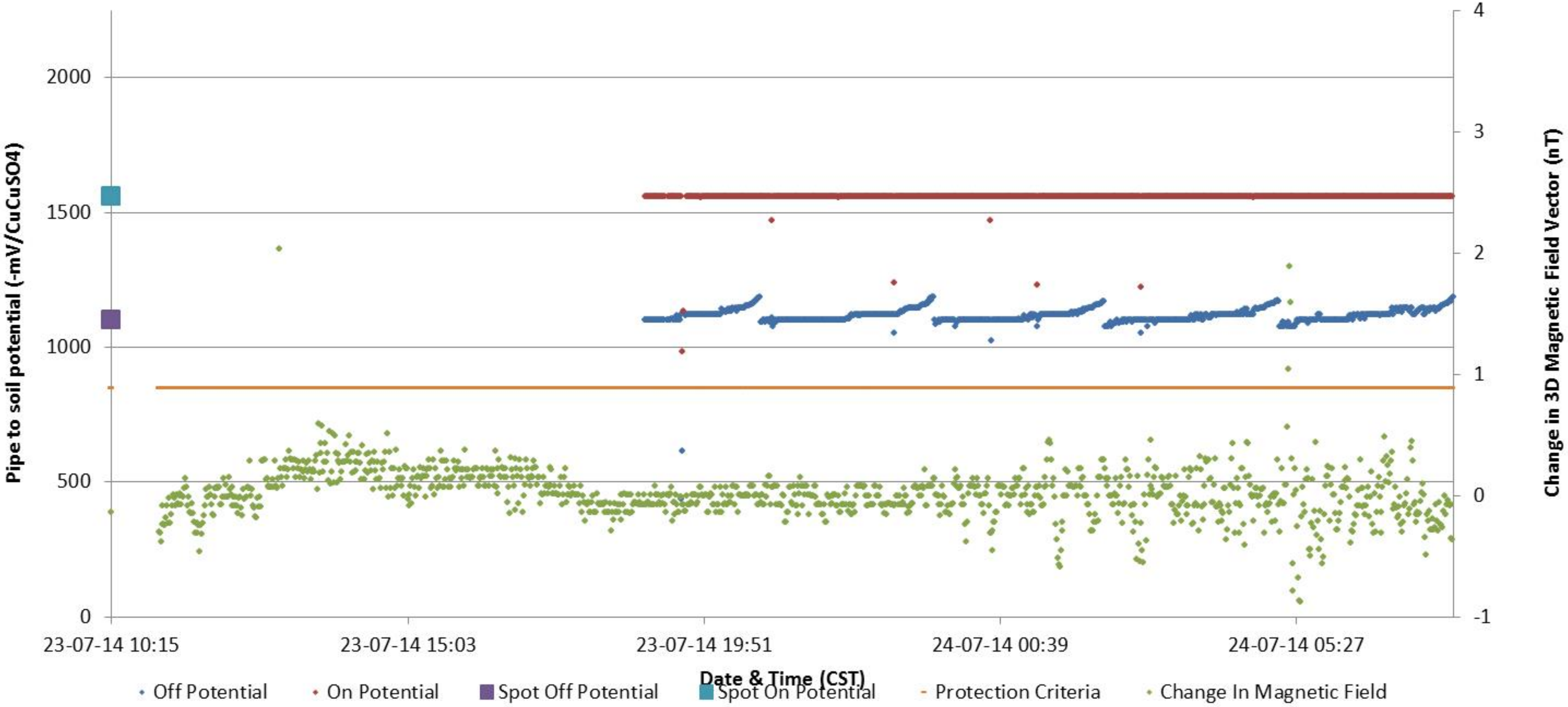

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1377.6 HEL-BBS
Time Below Protection Criteria 32%
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
16-07-14 09:25
16-07-14 14:13
16-07-14 19:01
16-07-14 23:49
17-07-14 04:37
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field



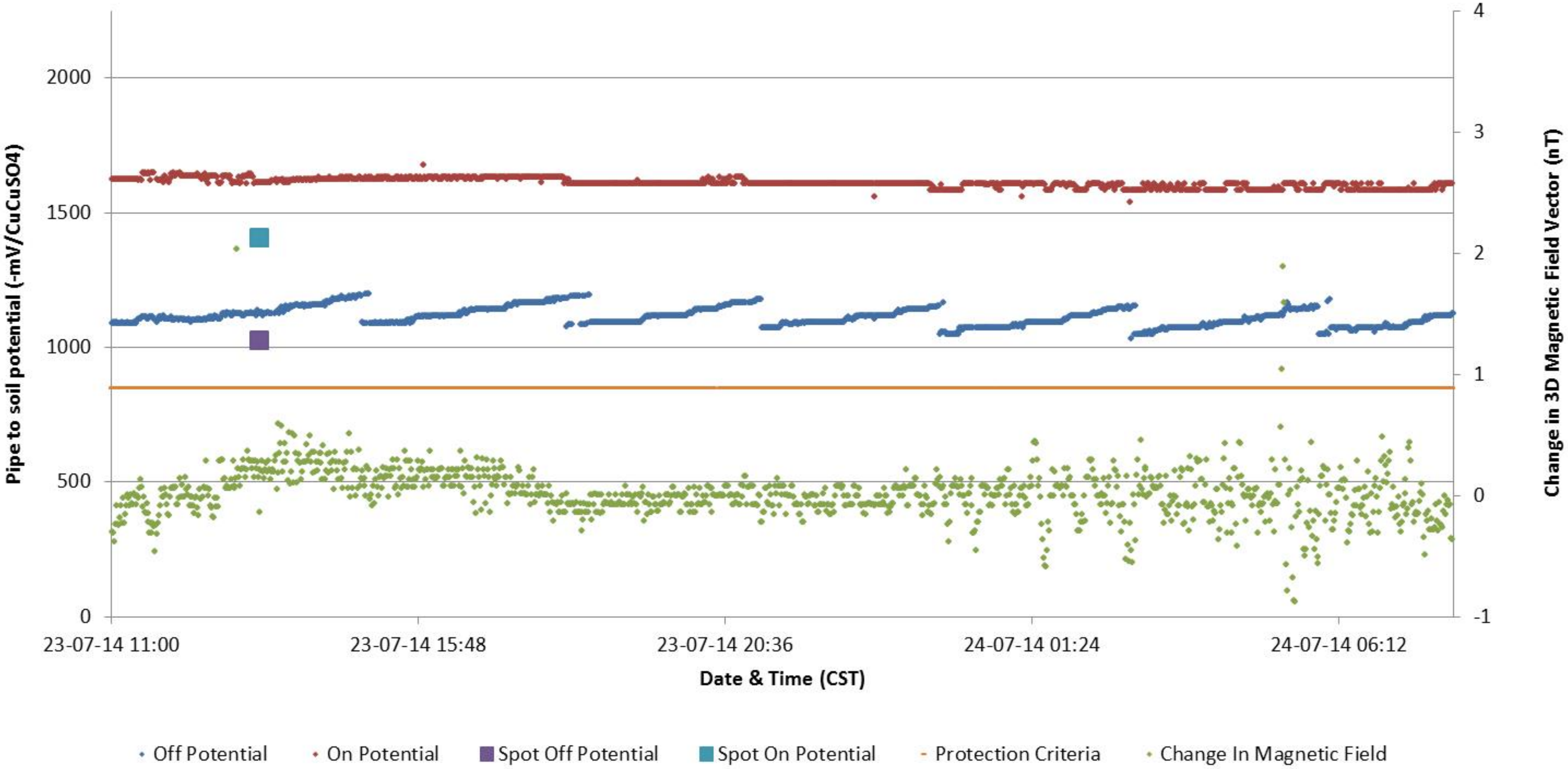
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1377.6 BBS-DCG

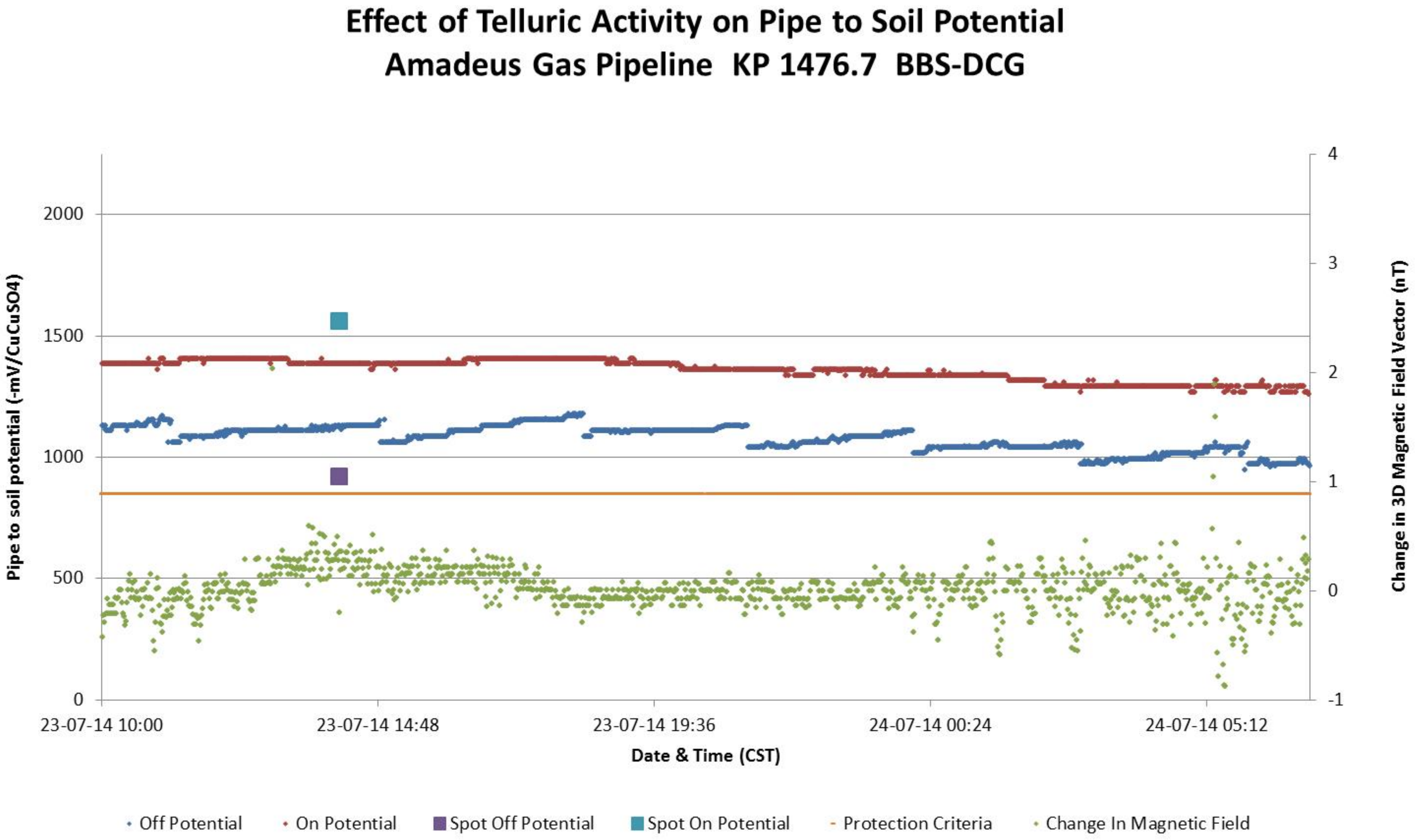
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1399.7 BBS-DCG

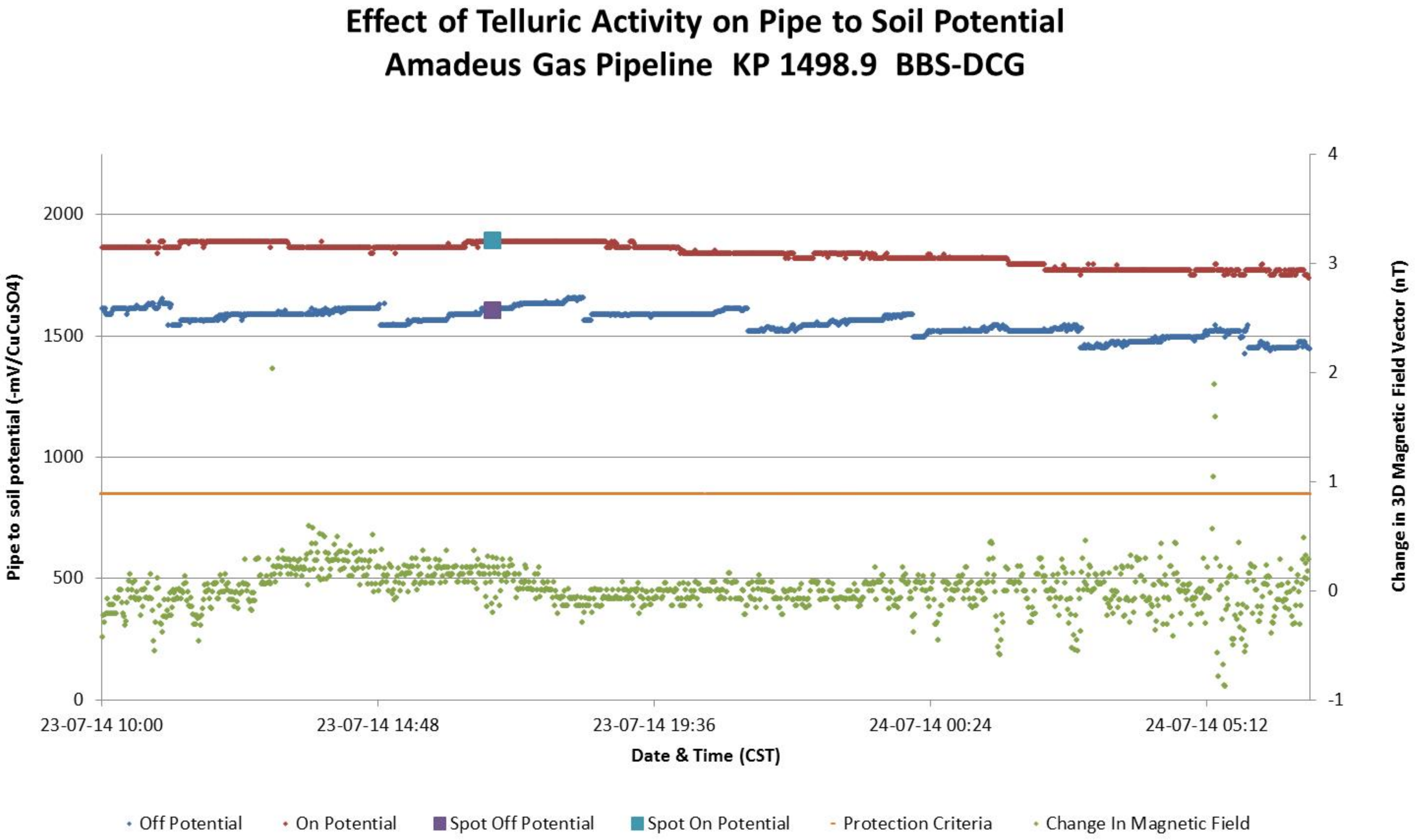
Insufficient Readings Taken (65%)



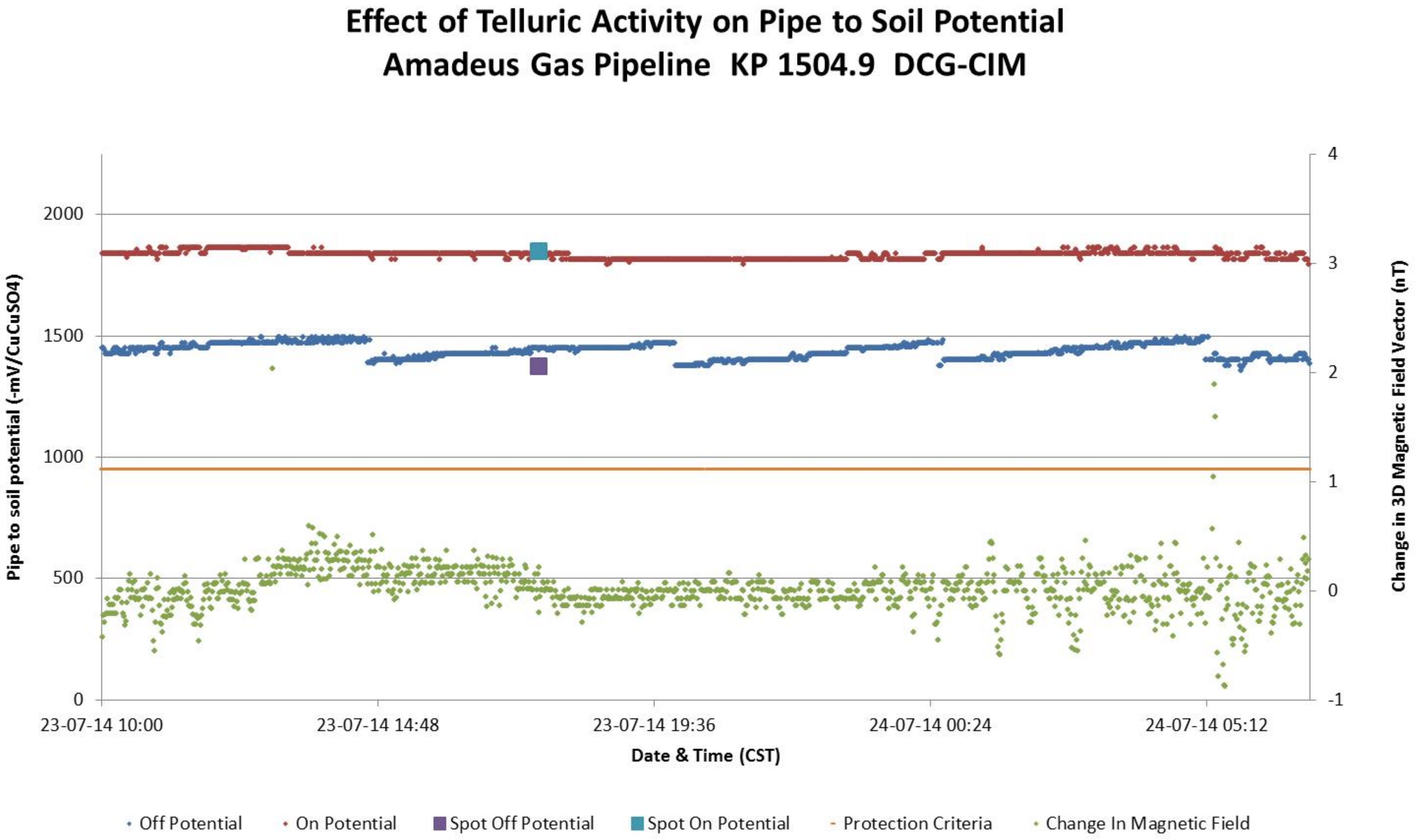
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1460.6 BBS-DCG

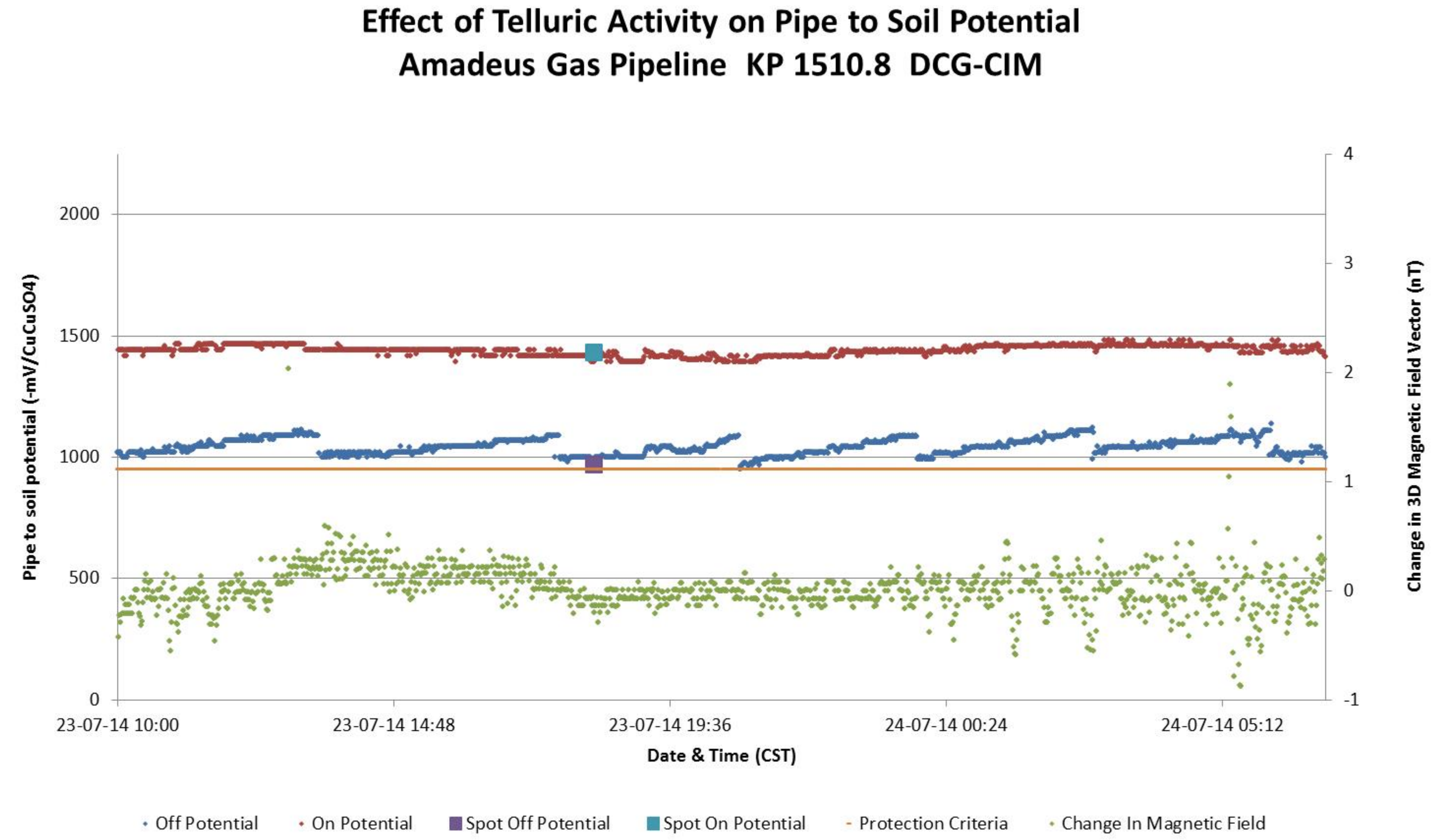


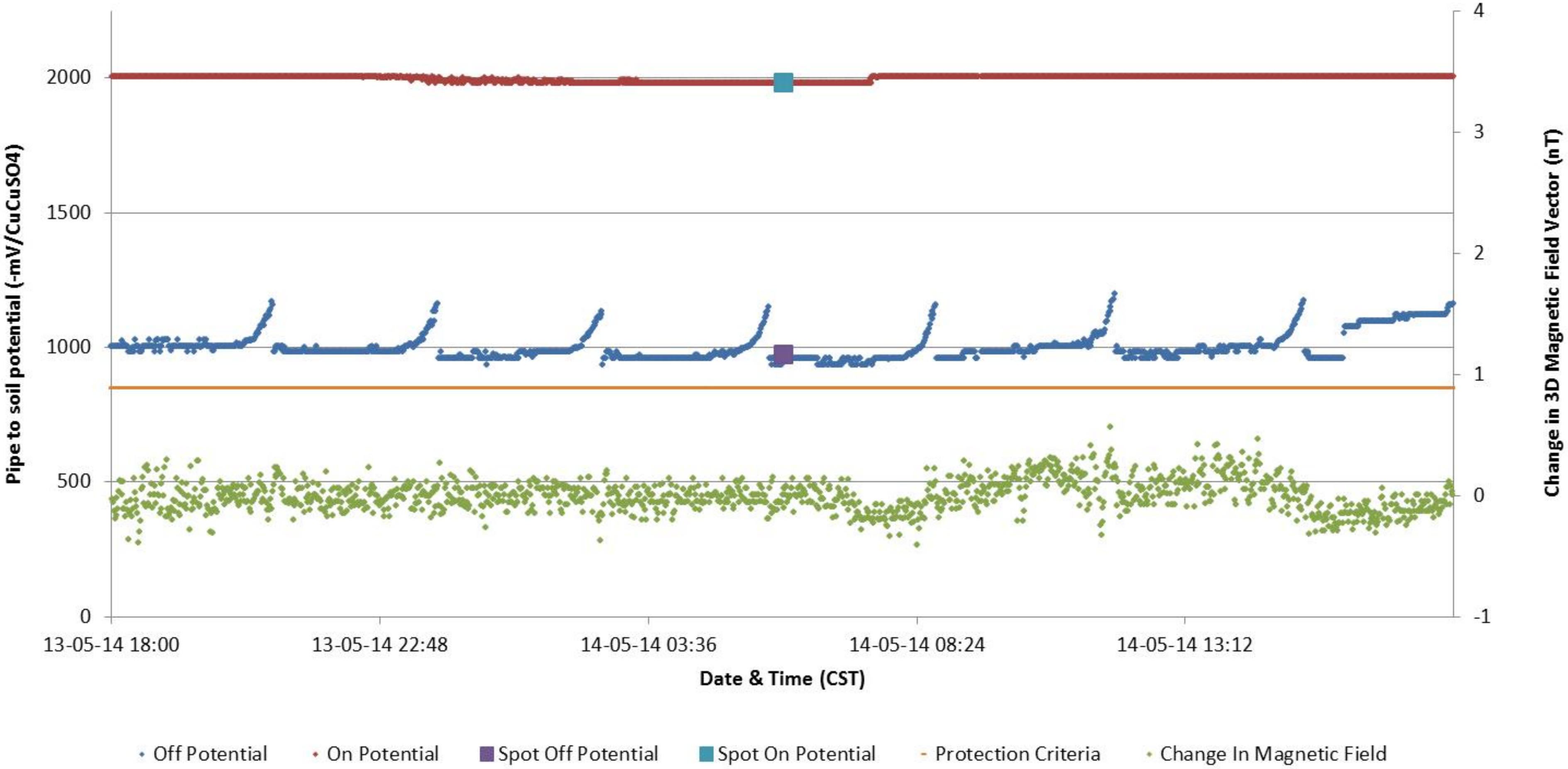

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1476.7 BBS-DCG
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
23-07-14 10:00
23-07-14 14:48
23-07-14 19:36
24-07-14 00:24
24-07-14 05:12
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field



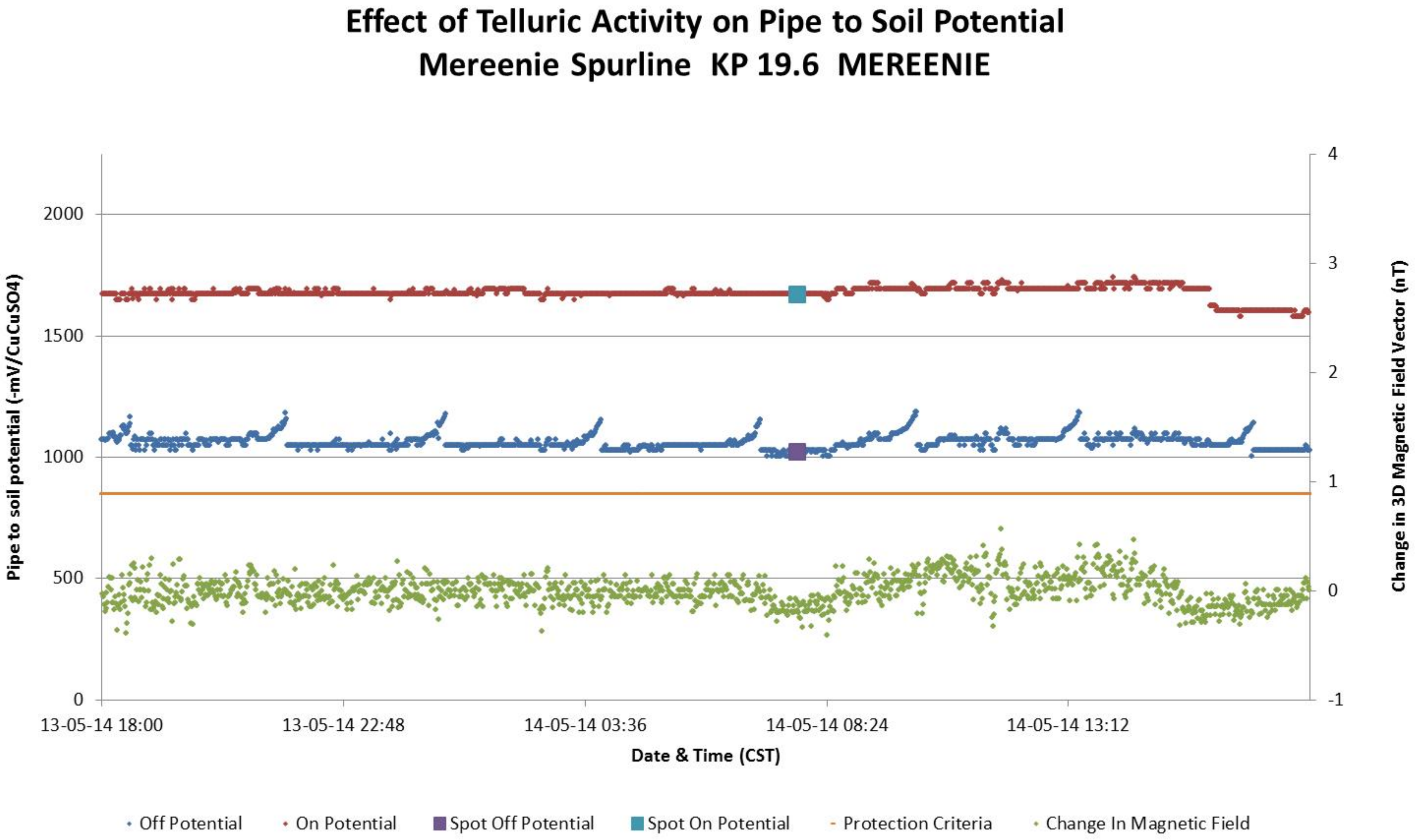
Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1498.9 BBS-DCG


Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1504.9 DCG-CIM
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
23-07-14 10:00
23-07-14 14:48
23-07-14 19:36
24-07-14 00:24
24-07-14 05:12
Date & Time (CST)
Off Potential
On Potential
Spot Off Potential
Spot On Potential
Protection Criteria
Change In Magnetic Field

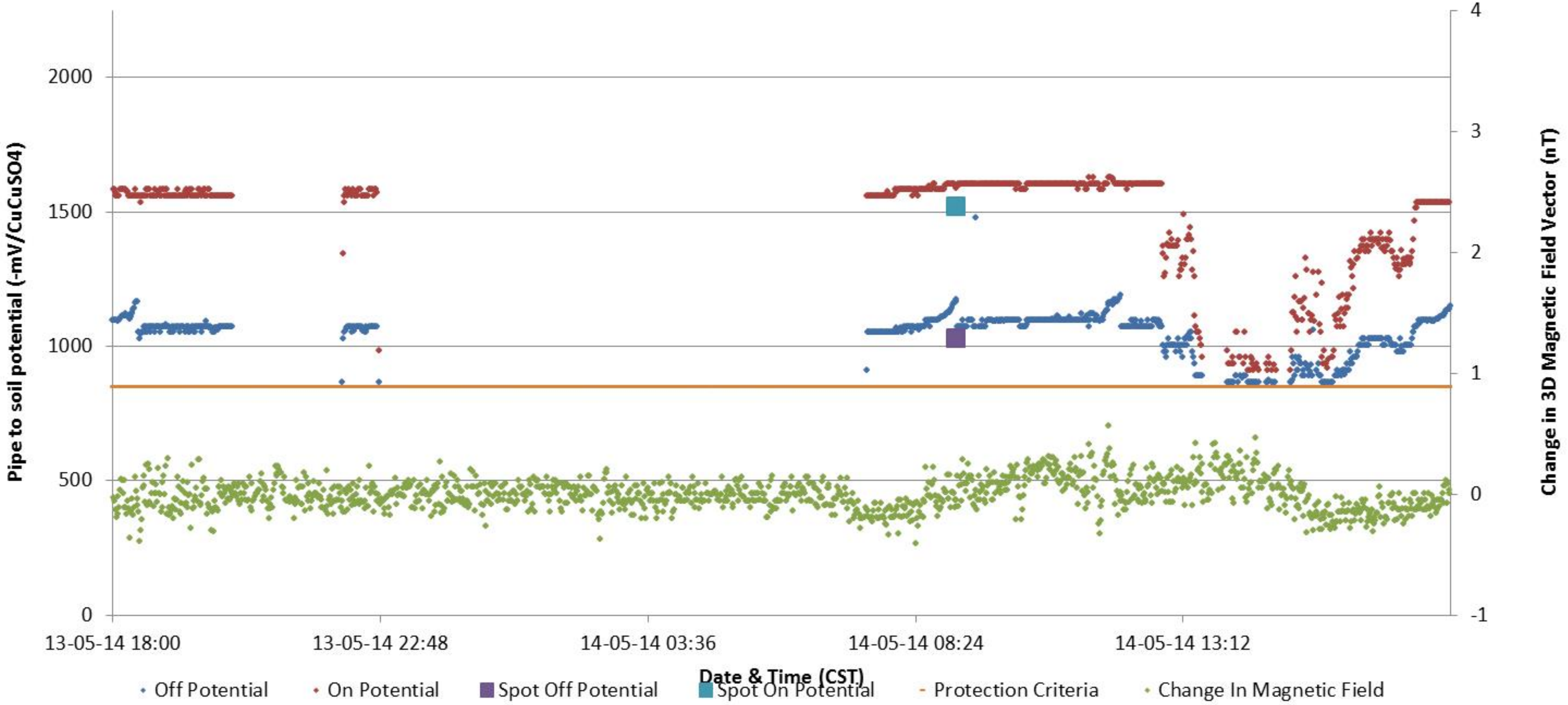

Effect of Telluric Activity on Pipe to Soil Potential
Amadeus Gas Pipeline KP 1510.8 DCG-CIM
Pipe to soil potential (-mV/CuCuSO4)
2000
1500
1000
500
0
Change in 3D Magnetic Field Vector (nT)
4
3
2
1
0
-1
23-07-14 10:00
23-07-14 14:48
23-07-14 19:36
24-07-14 00:24
24-07-14 05:12
Date & Time (CST)
◆ Off Potential
◆ On Potential
■ Spot Off Potential
■ Spot On Potential
- Protection Criteria
◆ Change In Magnetic Field



Effect of Telluric Activity on Pipe to Soil Potential
Mereenie Spurline KP 0.0 MEREENIE



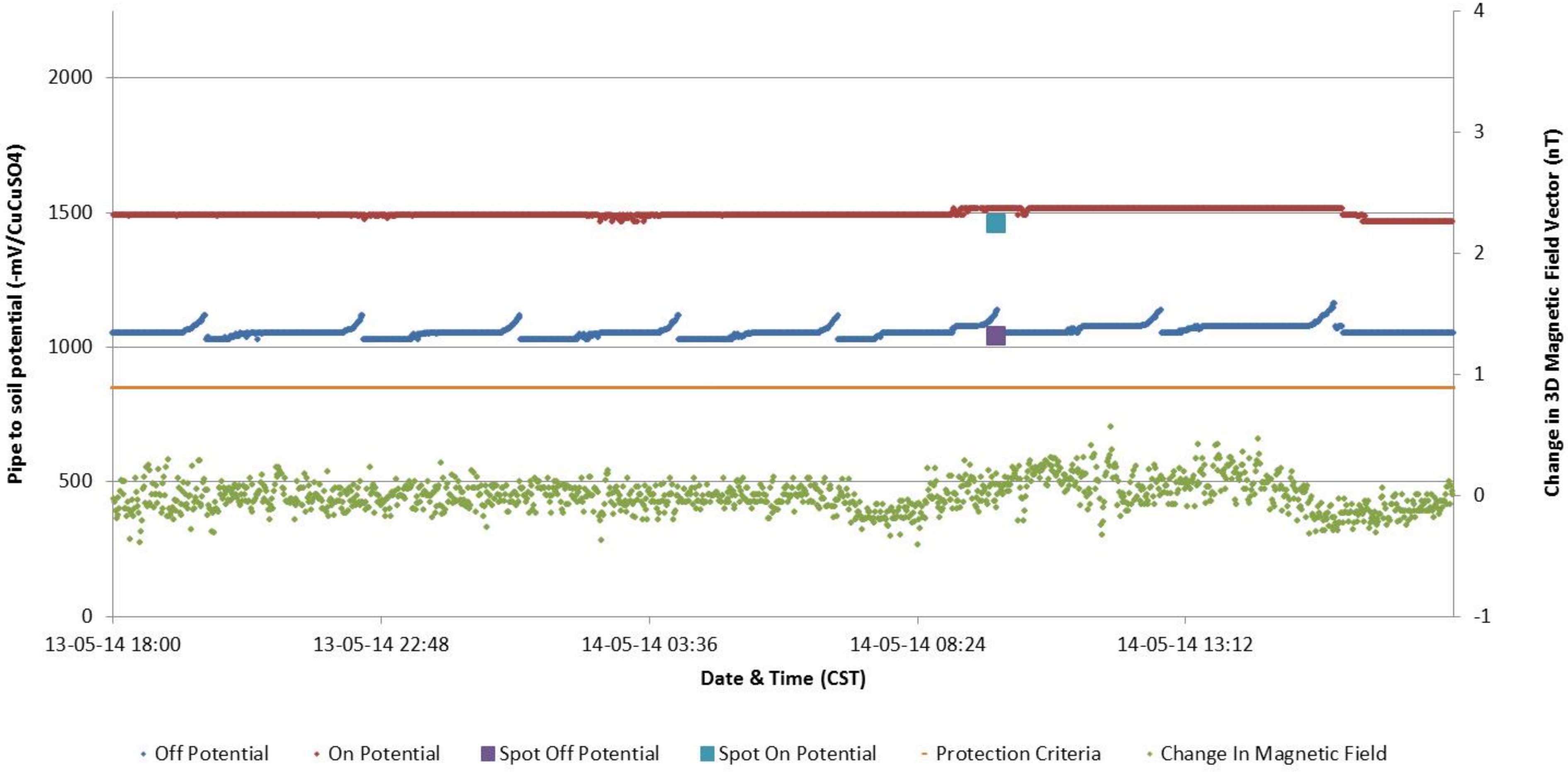
Effect of Telluric Activity on Pipe to Soil Potential
Mereenie Spurline KP 19.6 MEREENIE



Effect of Telluric Activity on Pipe to Soil Potential

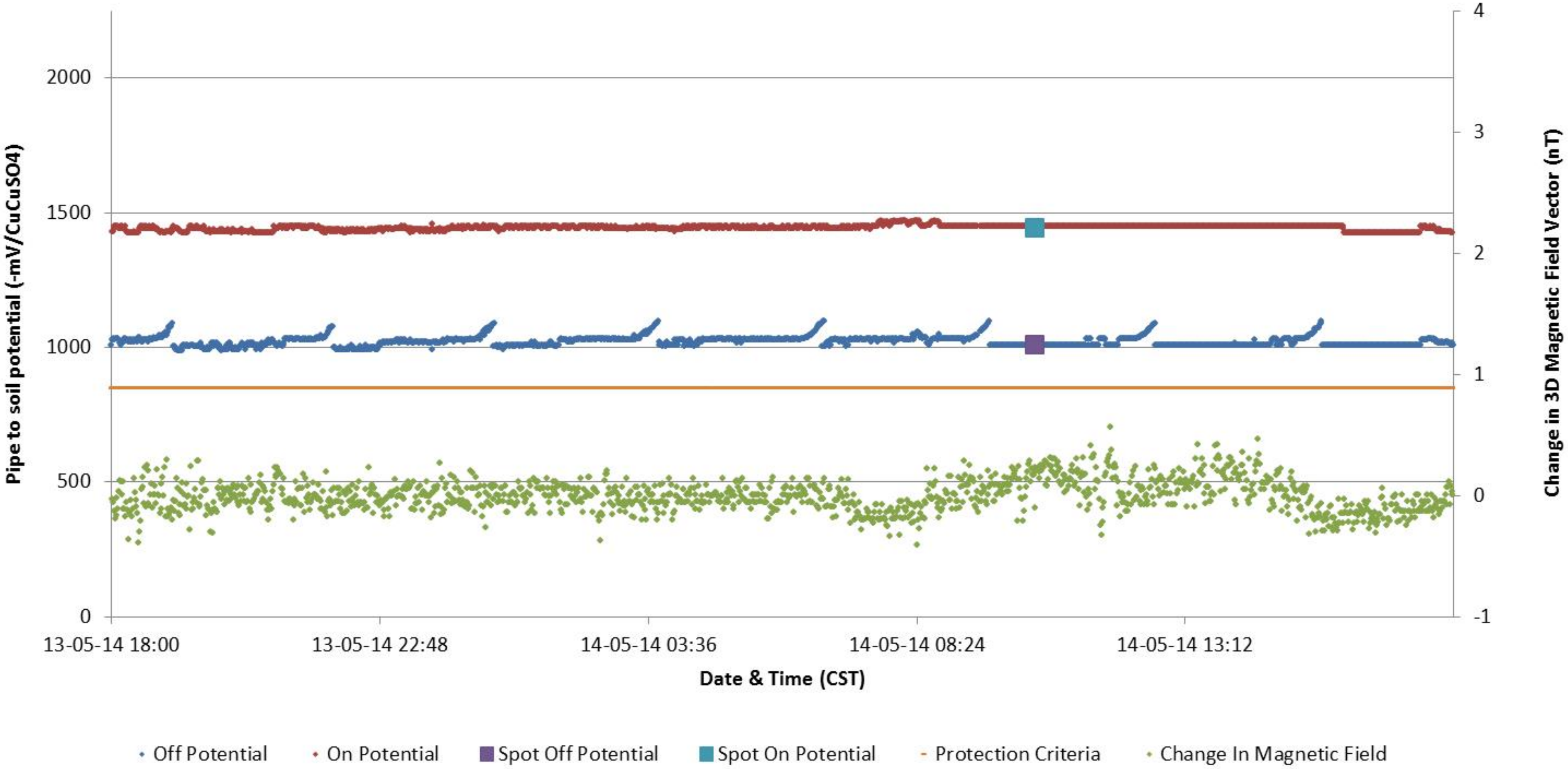
Mereenie Spurline KP 41.1 MEREENIE

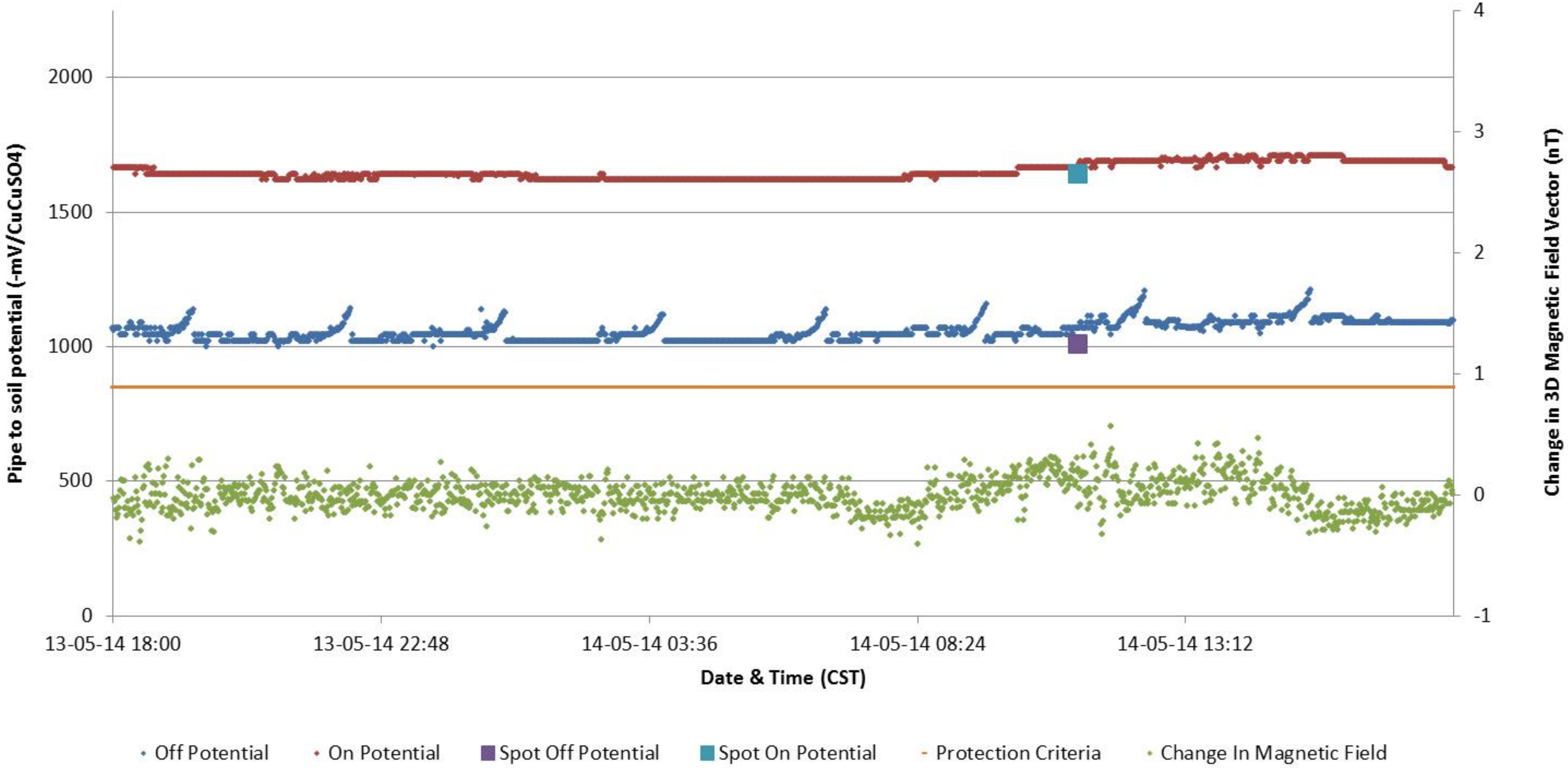
Insufficient Readings Taken (60%)

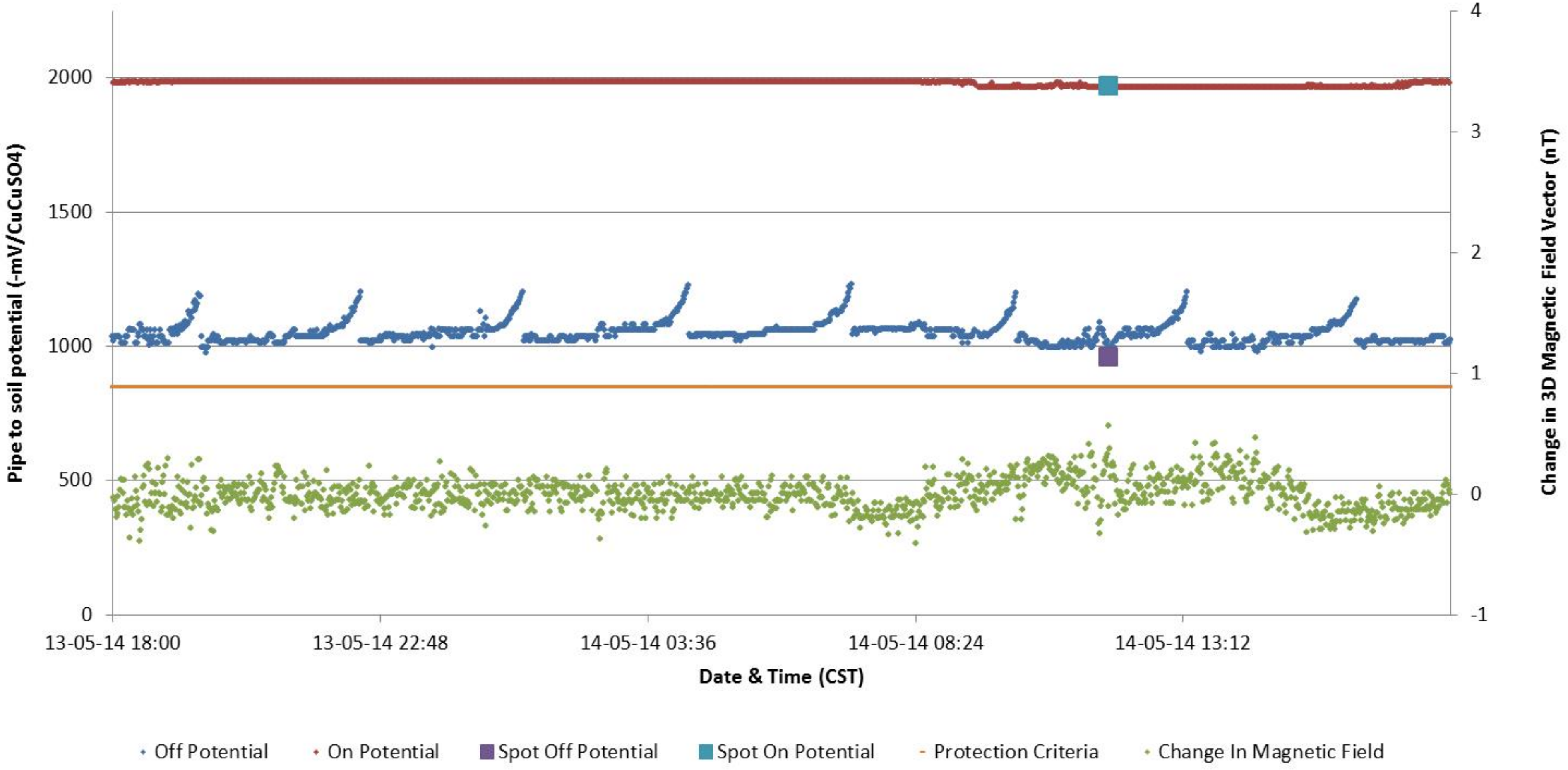


Effect of Telluric Activity on Pipe to Soil Potential
Mereenie Spurline KP 61.3 MEREENIE

Effect of Telluric Activity on Pipe to Soil Potential
Mereenie Spurline KP 81.3 MEREENIE



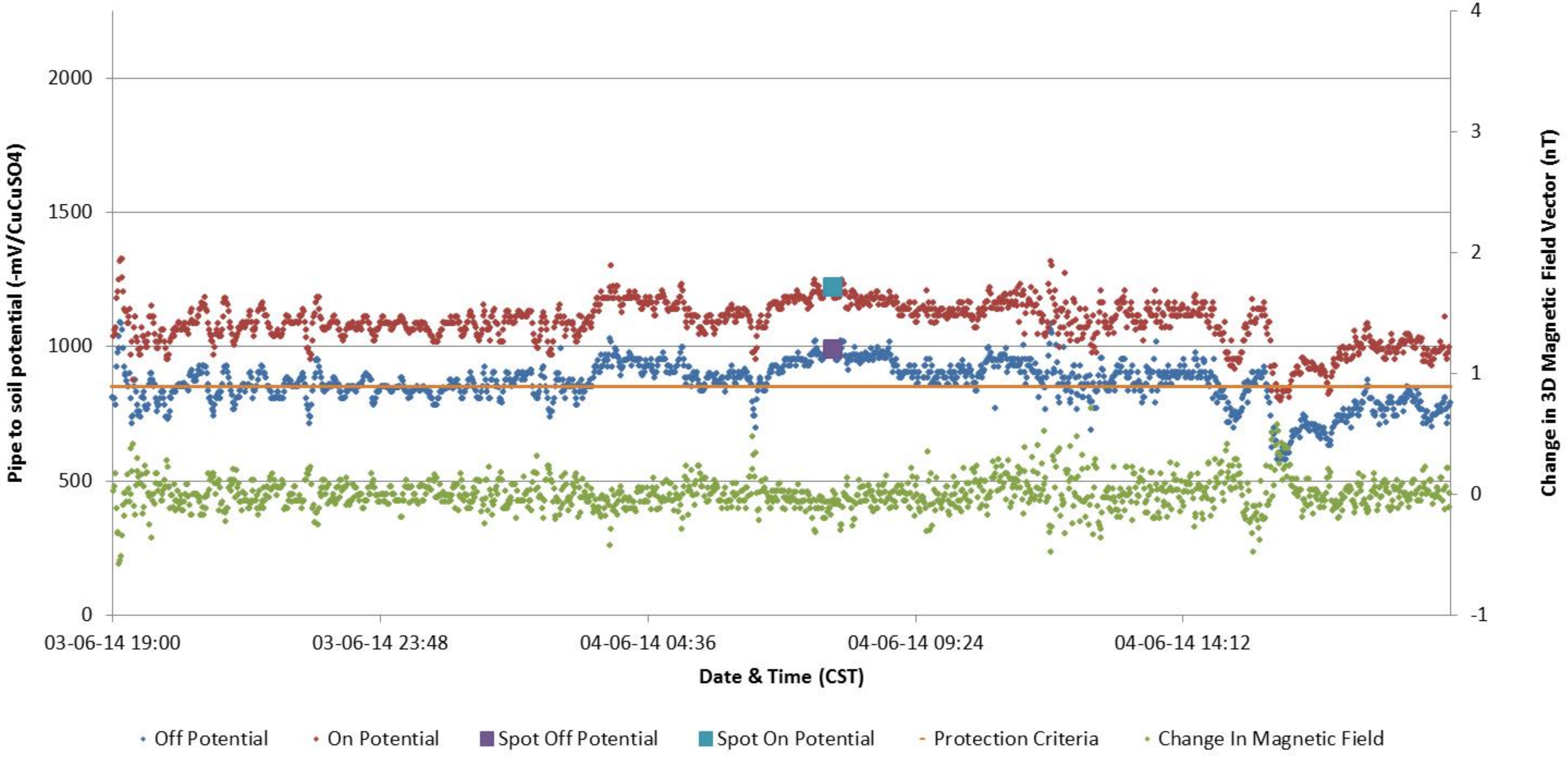

Effect of Telluric Activity on Pipe to Soil Potential
Mereenie Spurline KP 101.2 MEREENIE



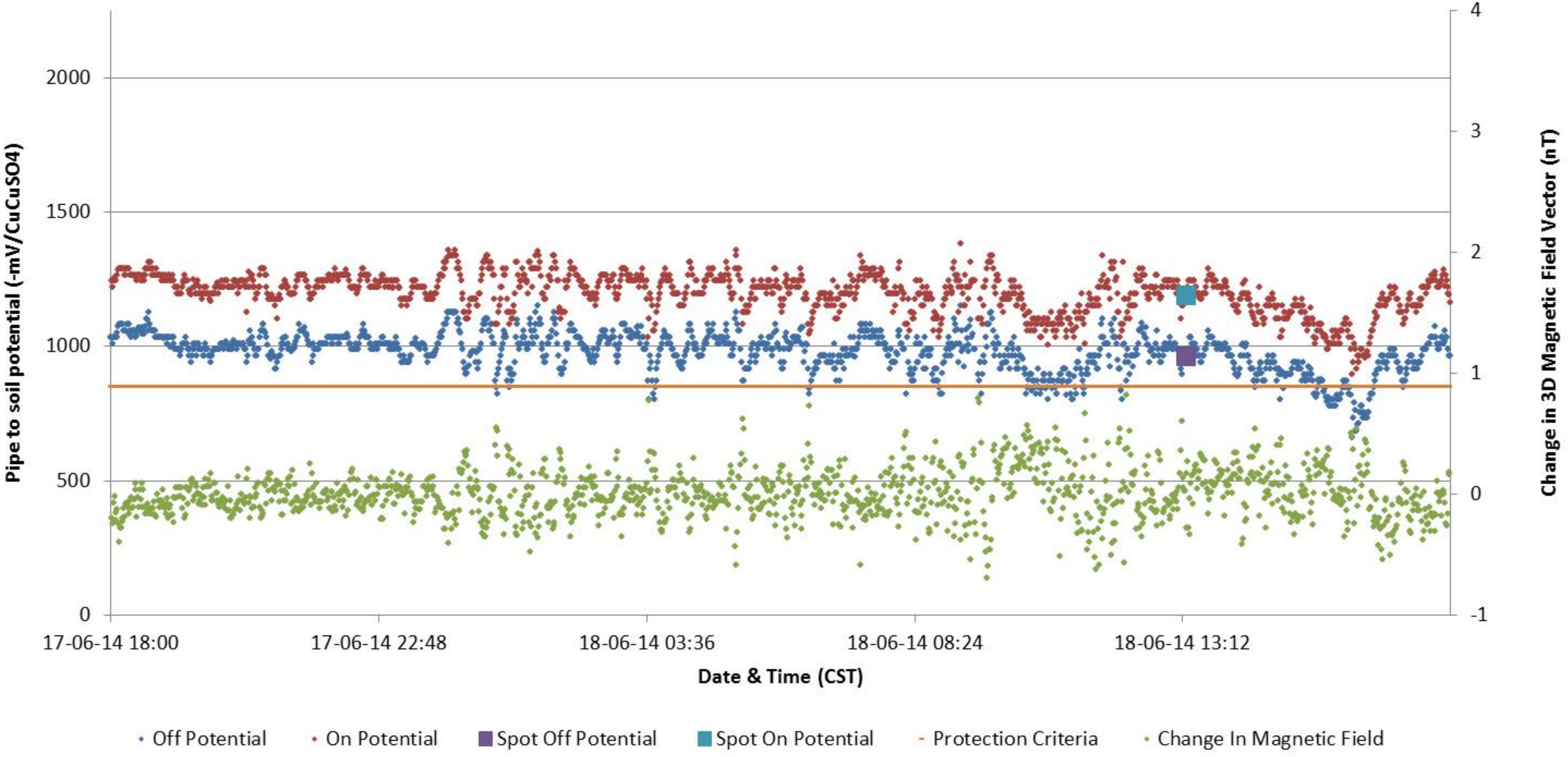
Effect of Telluric Activity on Pipe to Soil Potential
Mereenie Spurline KP 115.3 MEREENIE

Effect of Telluric Activity on Pipe to Soil Potential
Tennant Creek Lateral KP 23.7 TENNANT

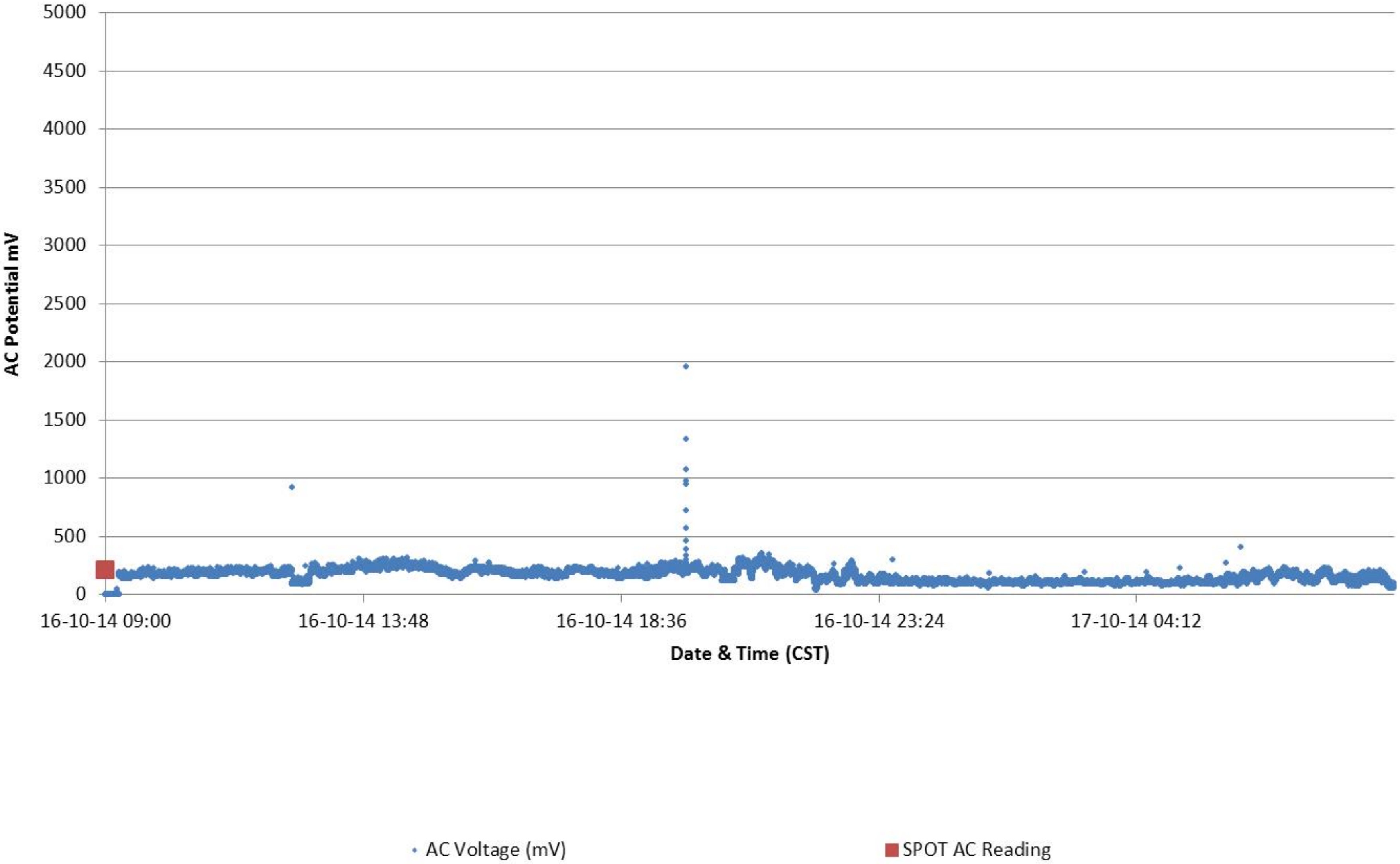
Time Below Protection Criteria 37%



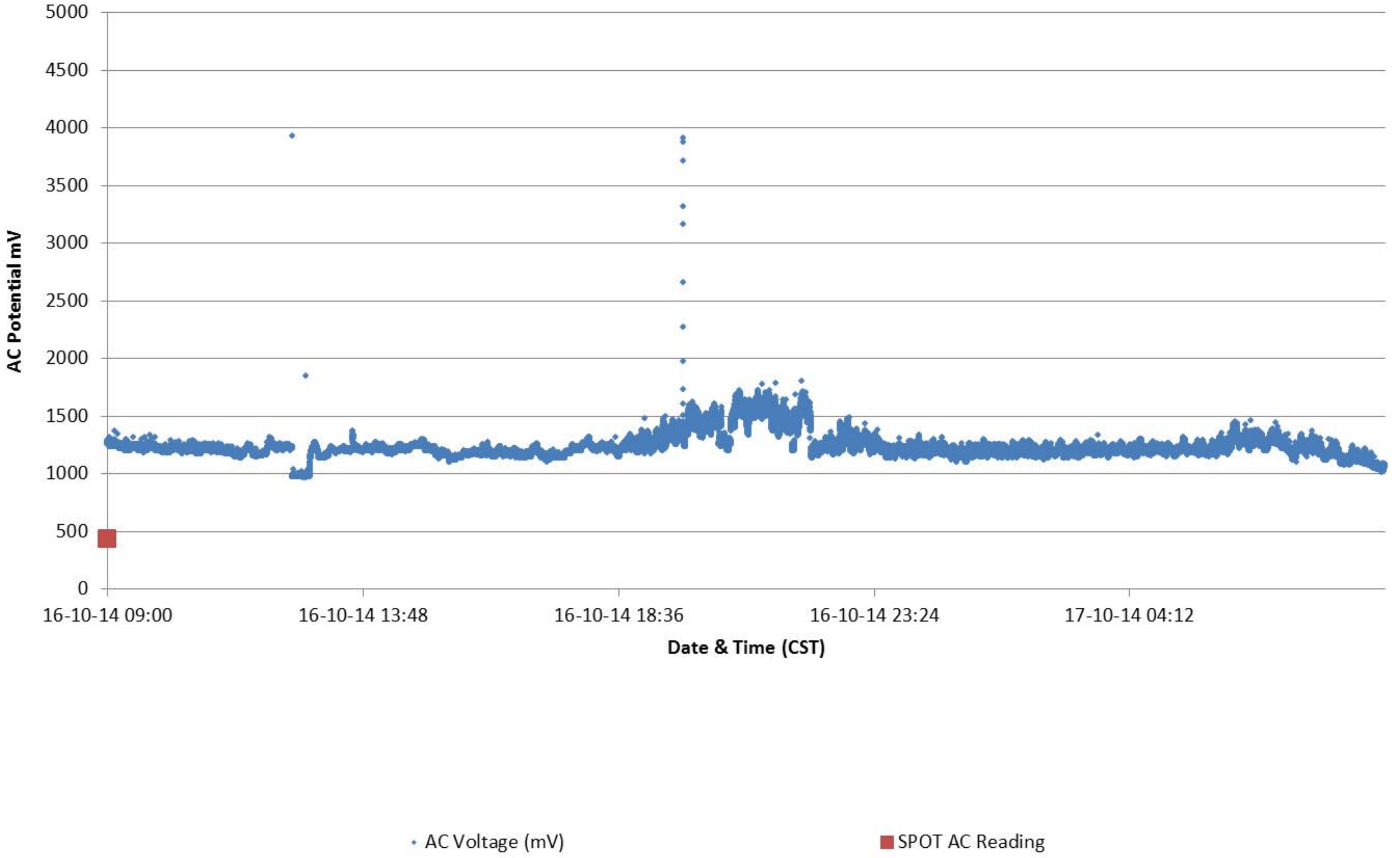
Effect of Telluric Activity on Pipe to Soil Potential
Elliott Lateral KP 3 ELLIOTT
Time Below Protection Criteria 7%

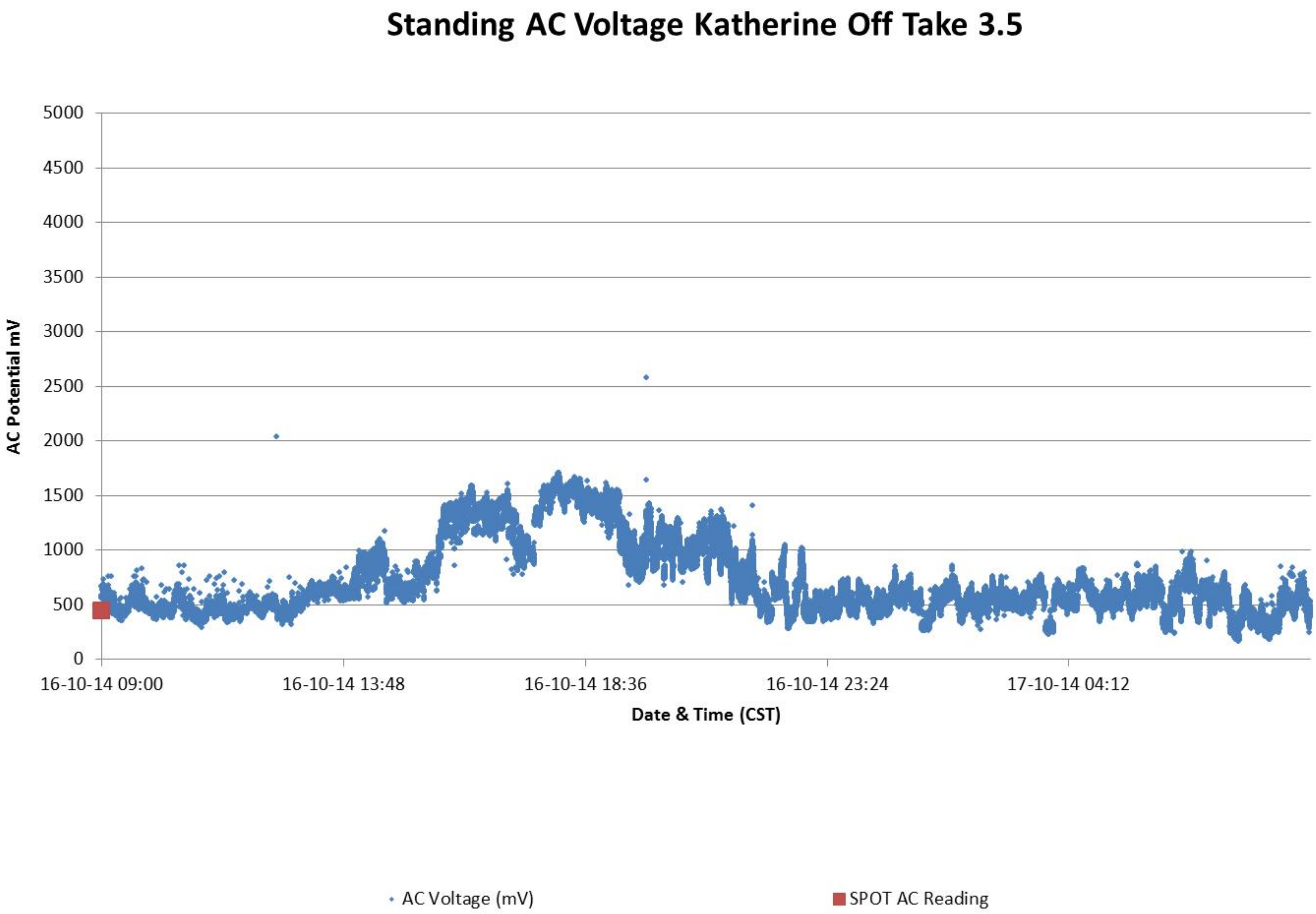


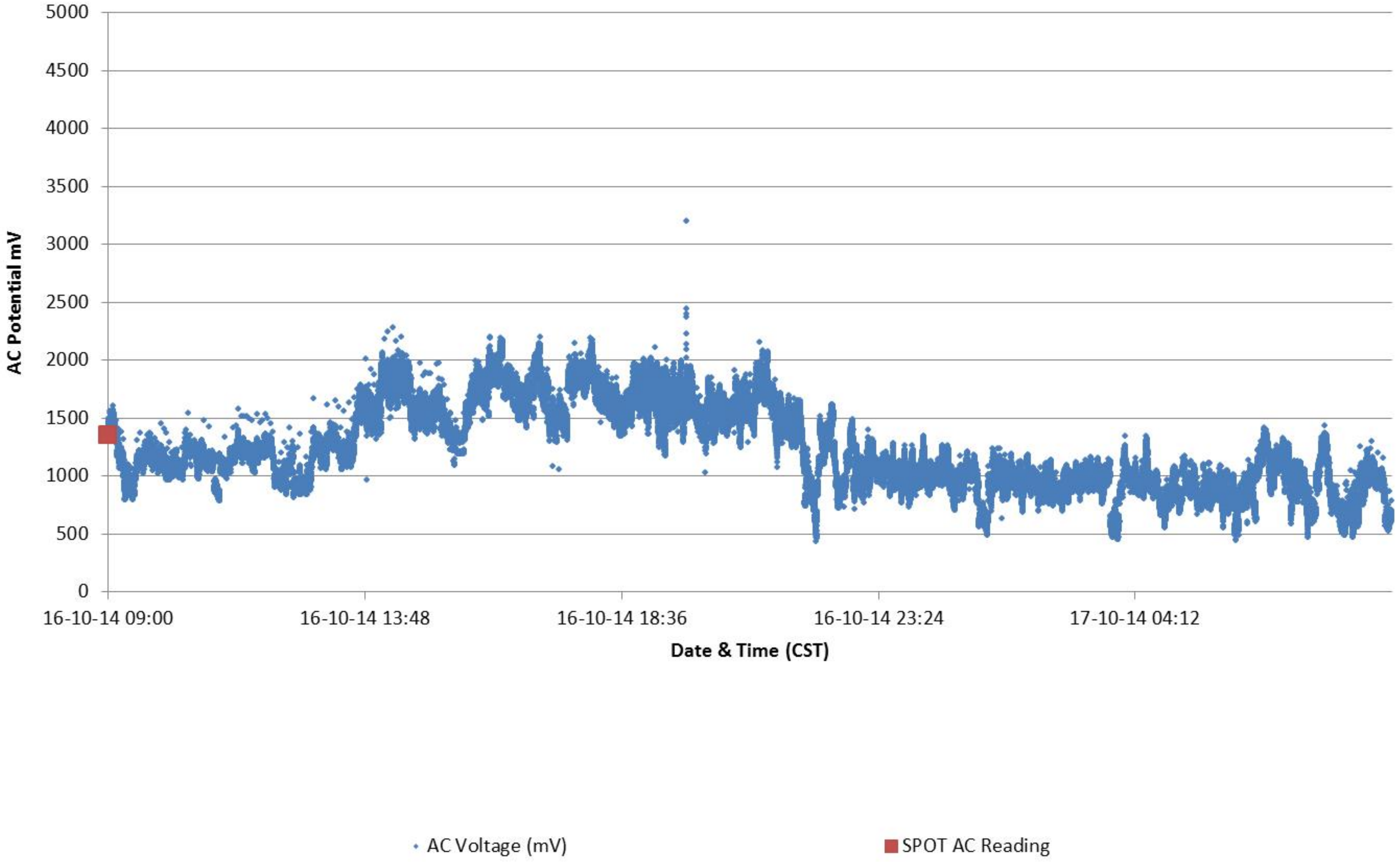
Standing AC Voltage Katherine Off Take 0.7



Standing AC Voltage Katherine Off Take 2.2

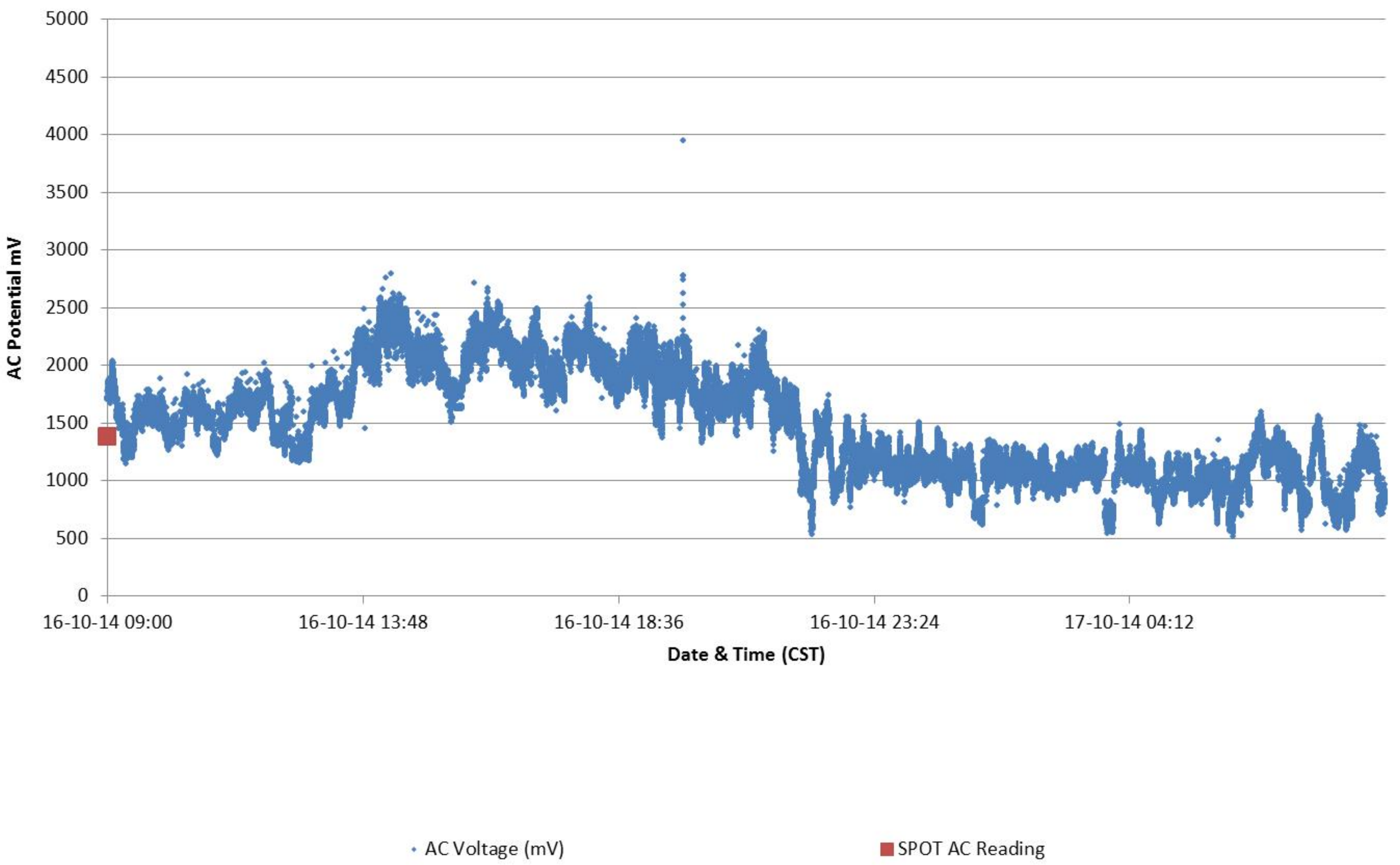



Standing AC Voltage Katherine Off Take 3.5



Standing AC Voltage Katherine Off Take 4.9

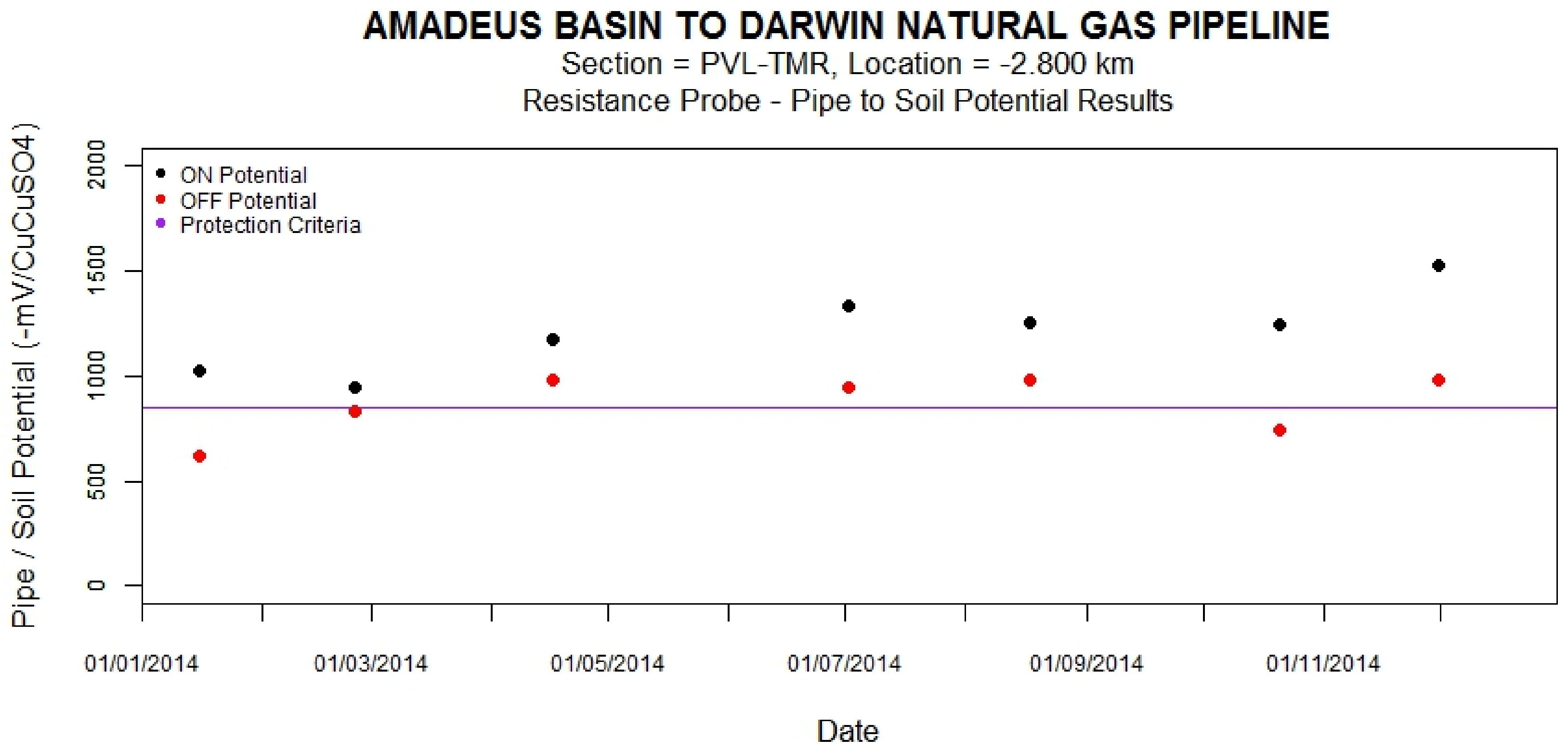
Standing AC Voltage Katherine Off Take 5.1

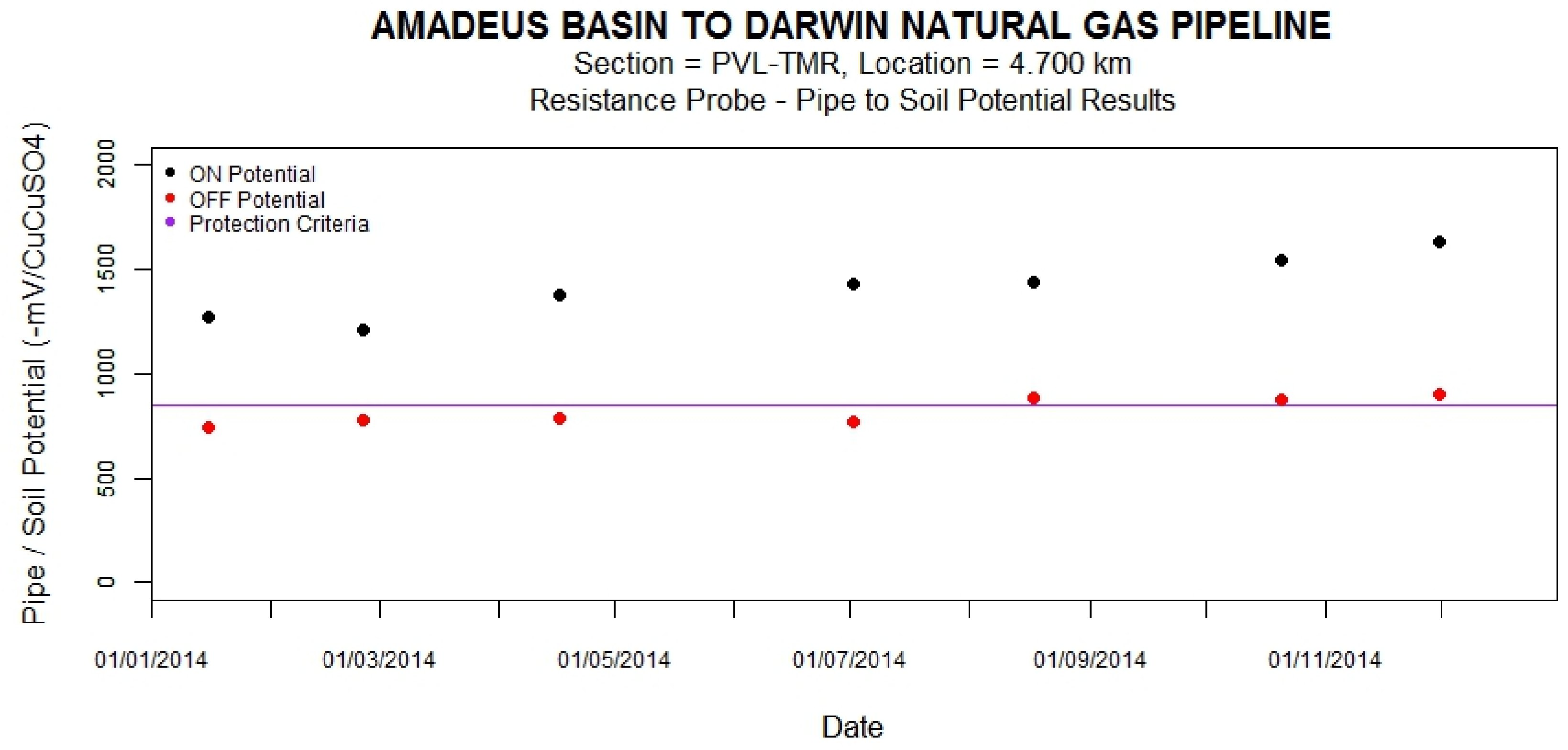


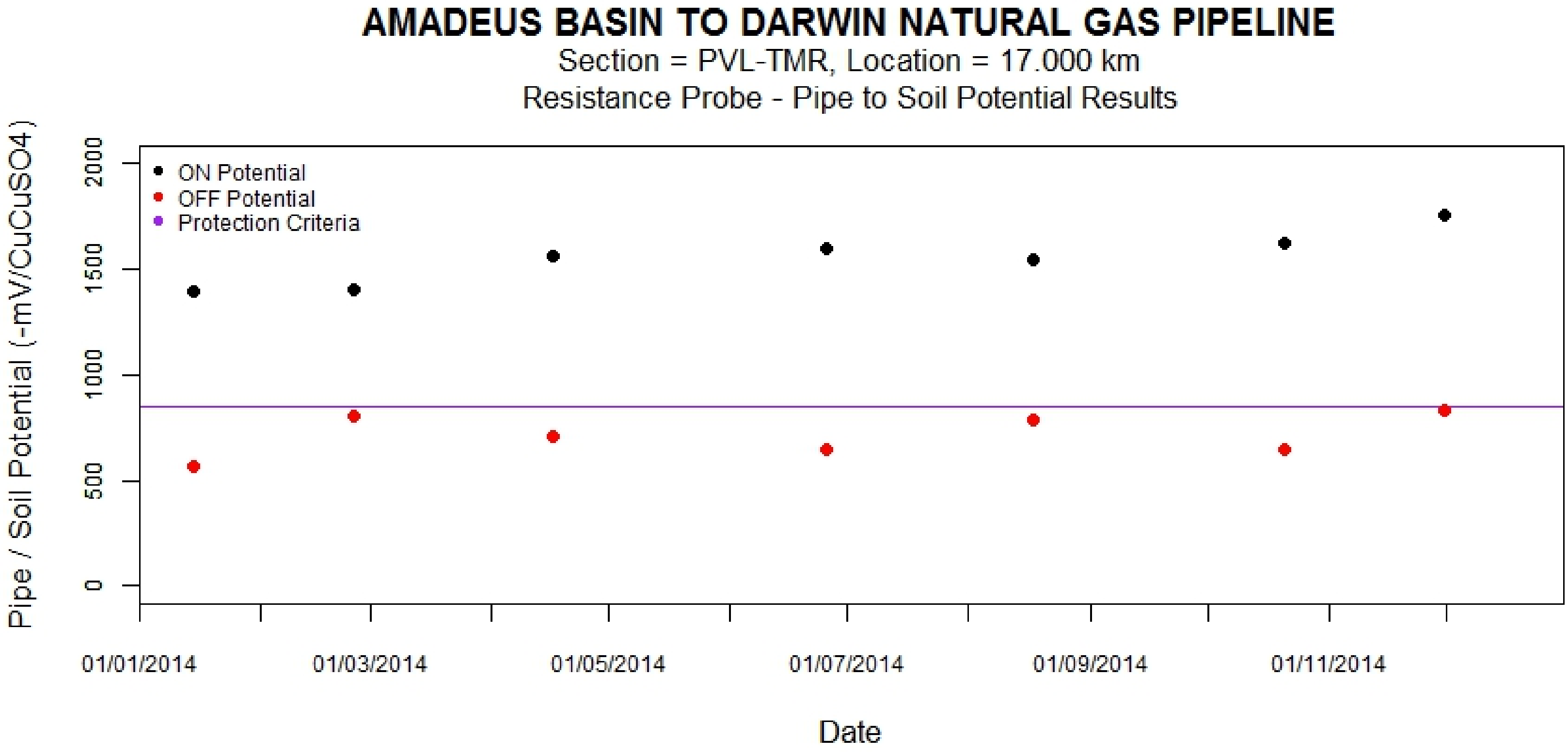
Appendix D

Amadeus Basin to Darwin Natural Gas Pipeline

Resistance Probe – Pipe to Soil Potential Results


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = PVL-TMR, Location = -2.800 km
Resistance Probe - Pipe to Soil Potential Results
ON Potential
OFF Potential
Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

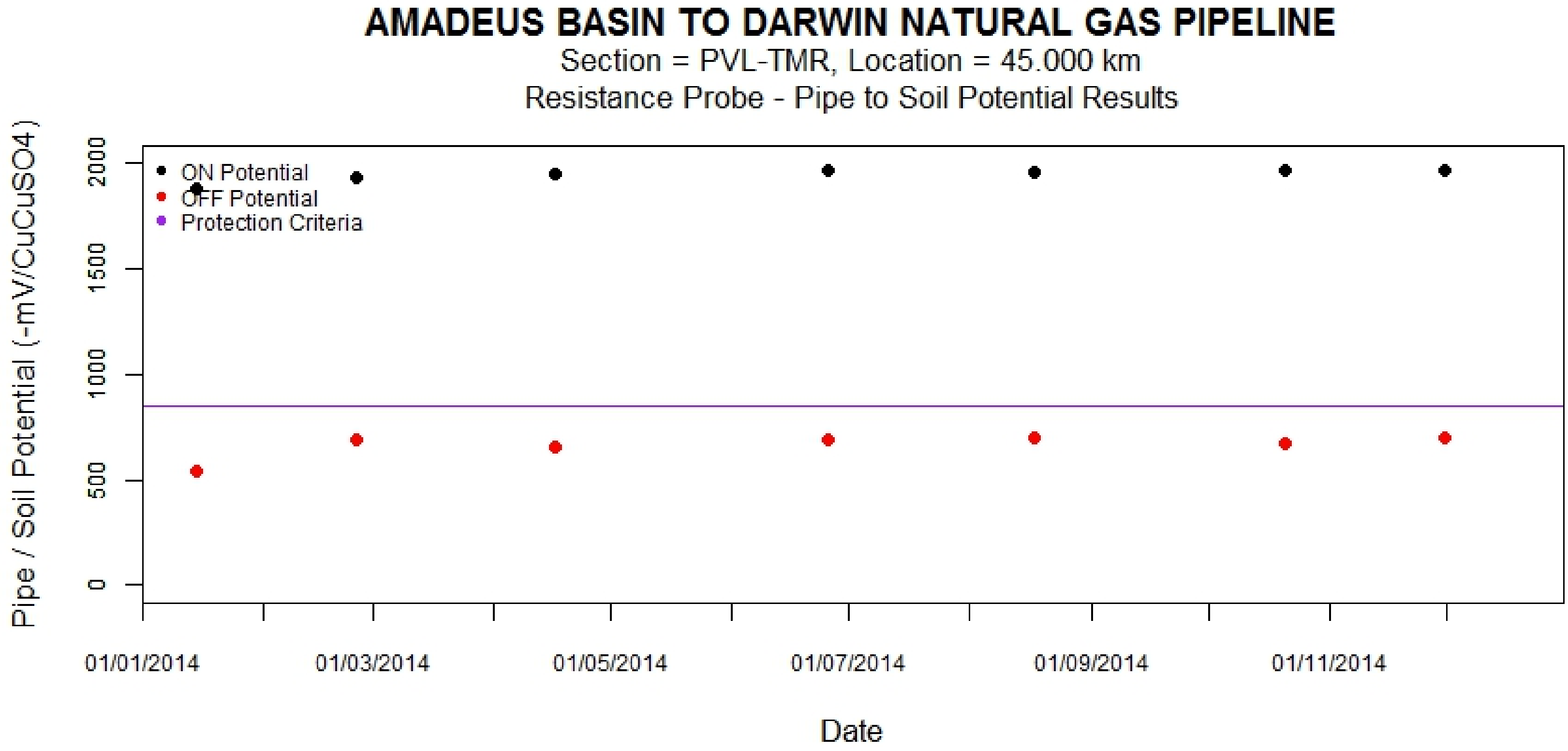

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = PVL-TMR, Location = 4.700 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date



AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = PVL-TMR, Location = 17.000 km

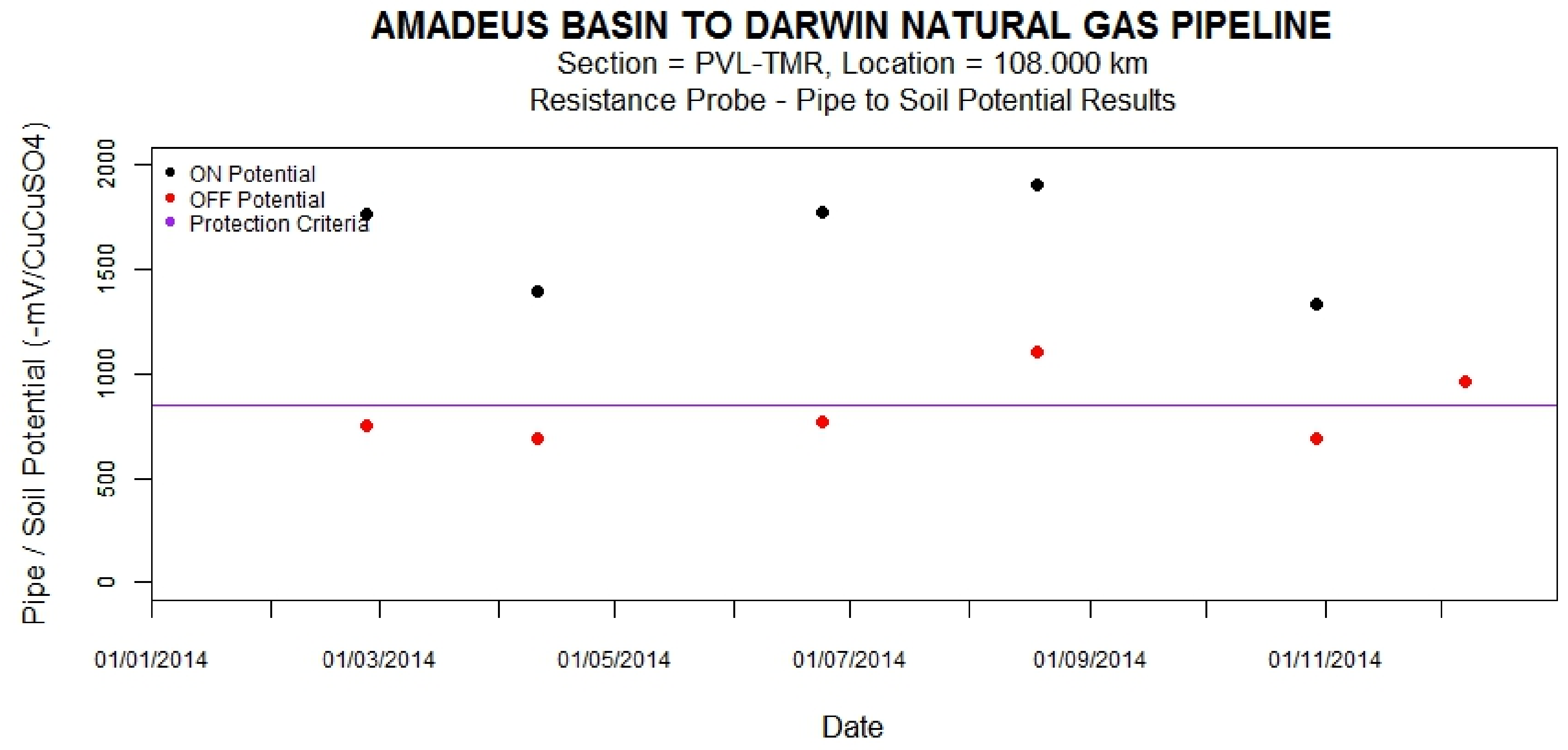
Resistance Probe - Pipe to Soil Potential Results

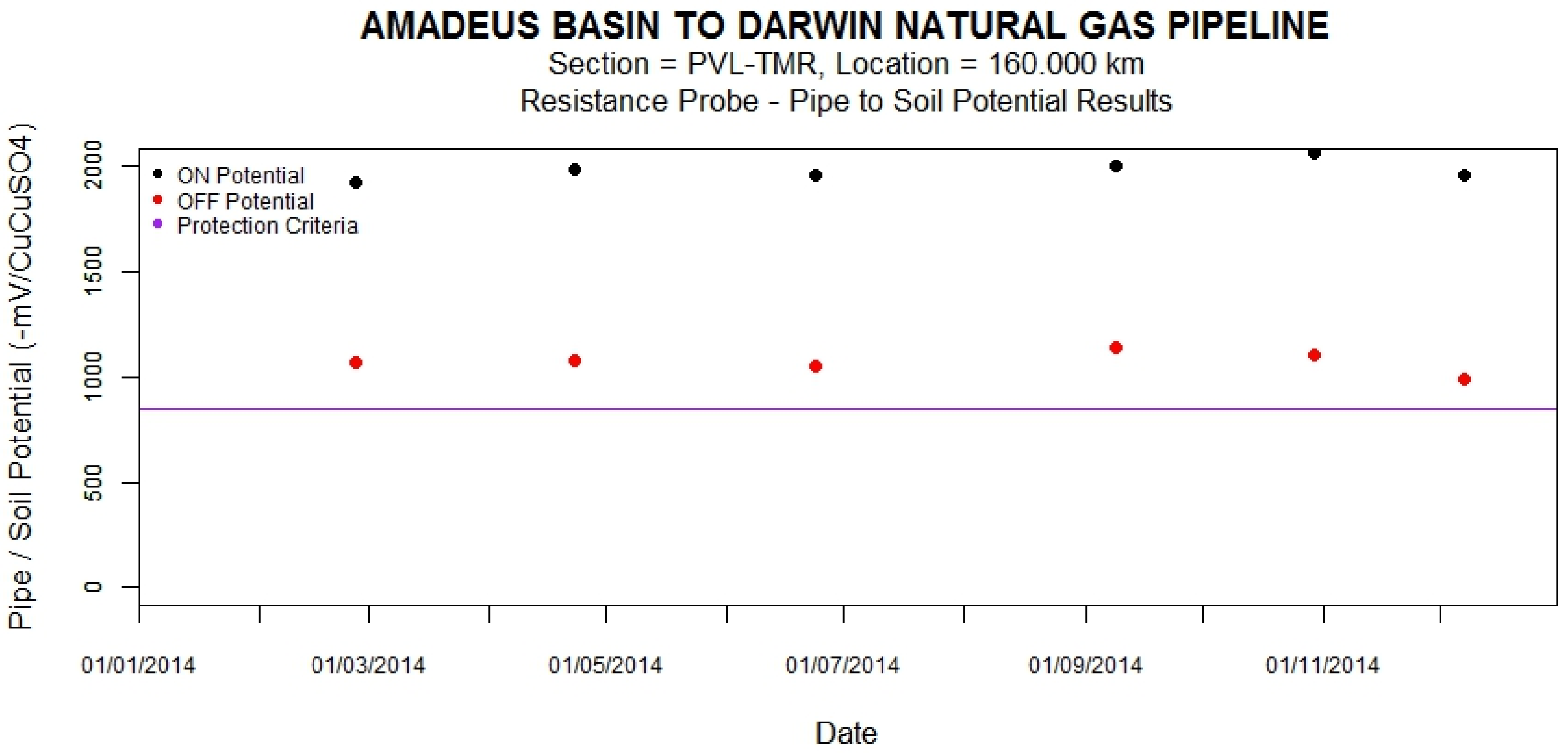


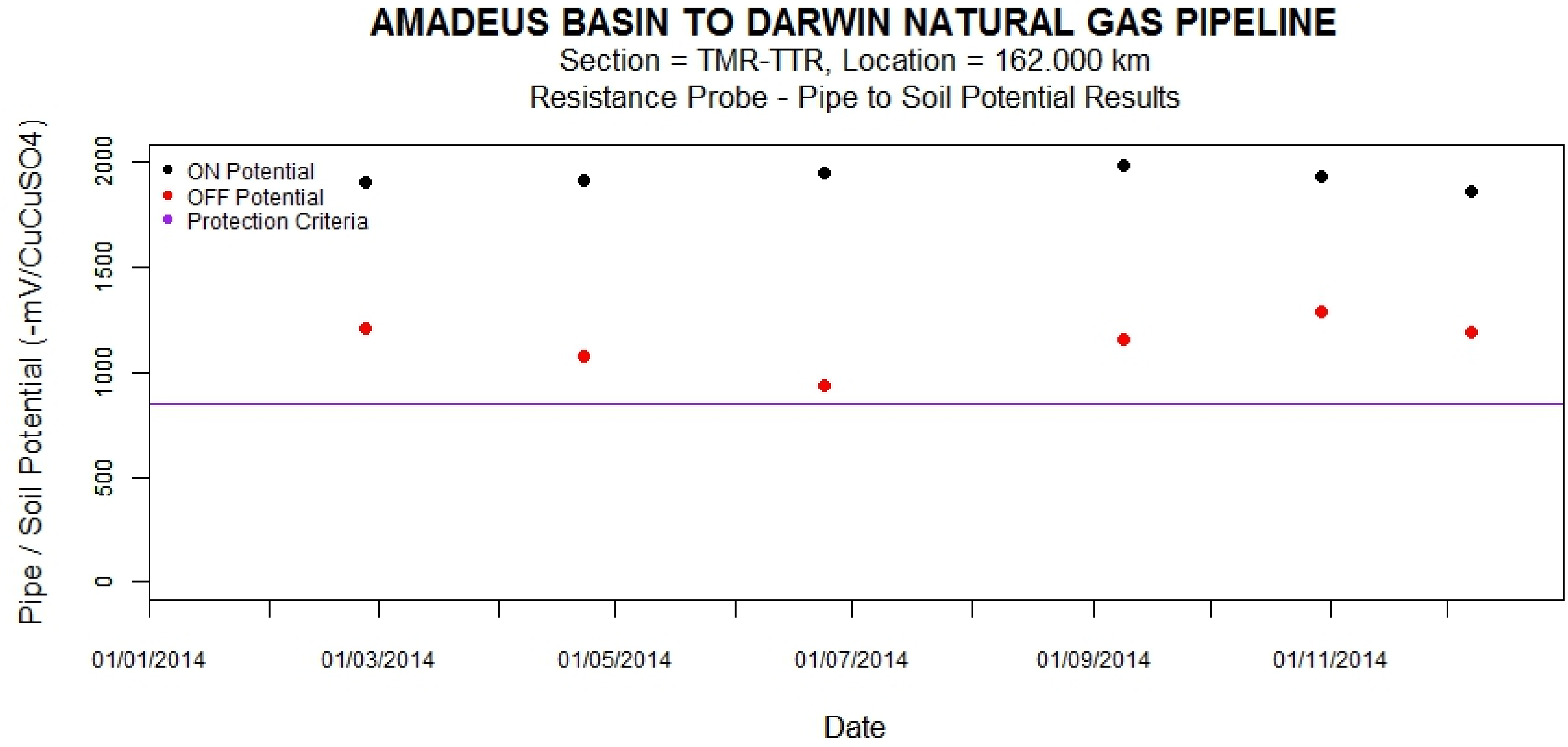
AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

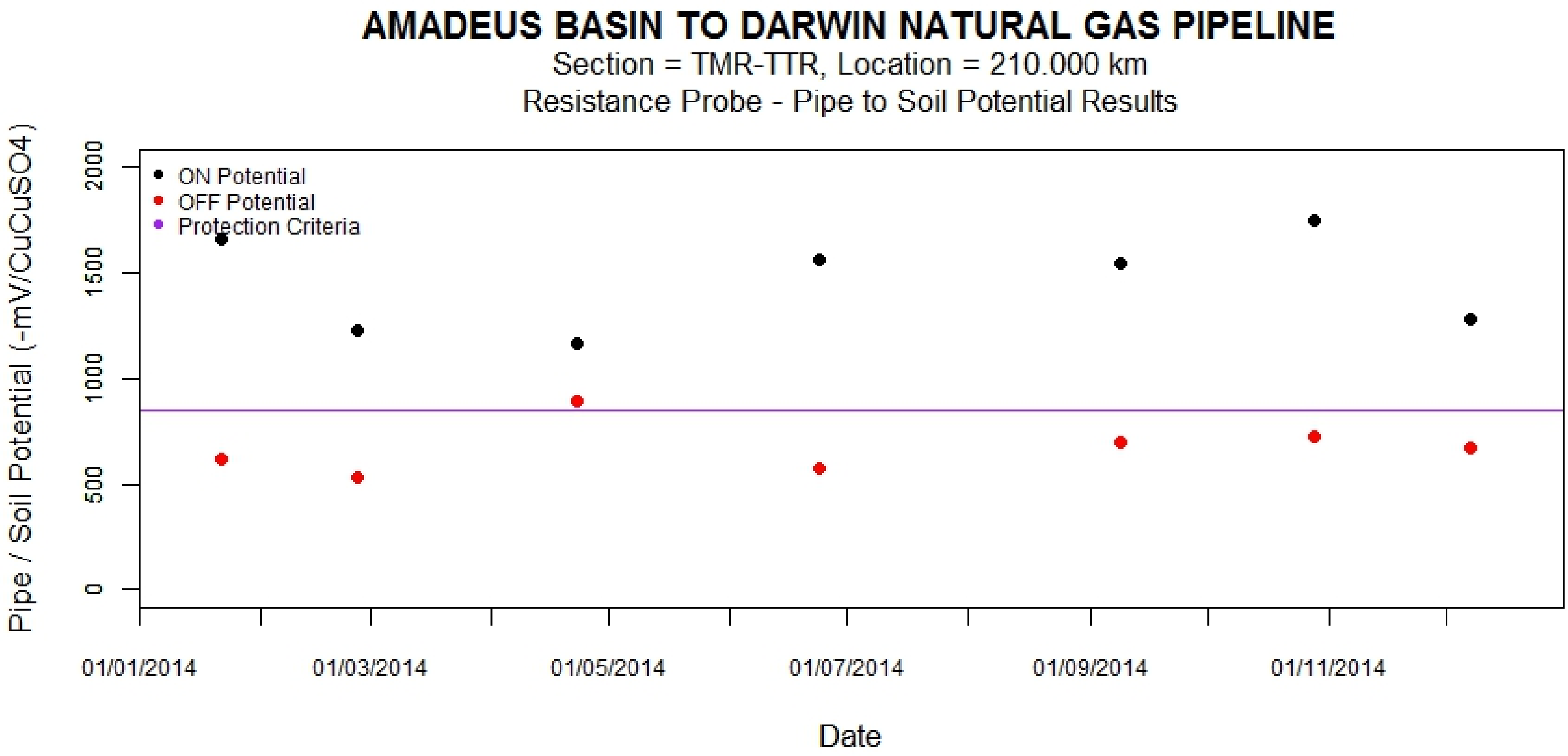
Section = PVL-TMR, Location = 45.000 km

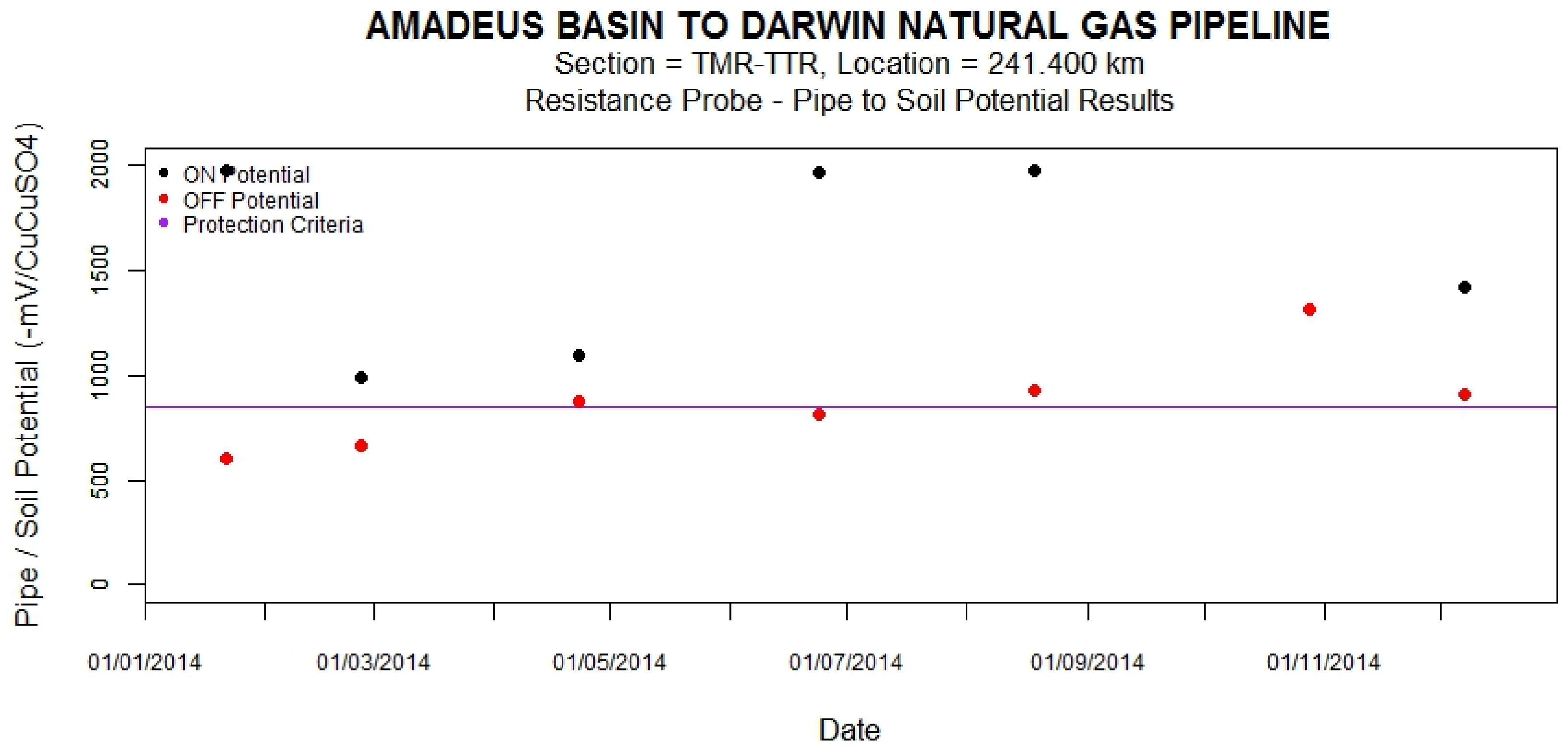
Resistance Probe - Pipe to Soil Potential Results

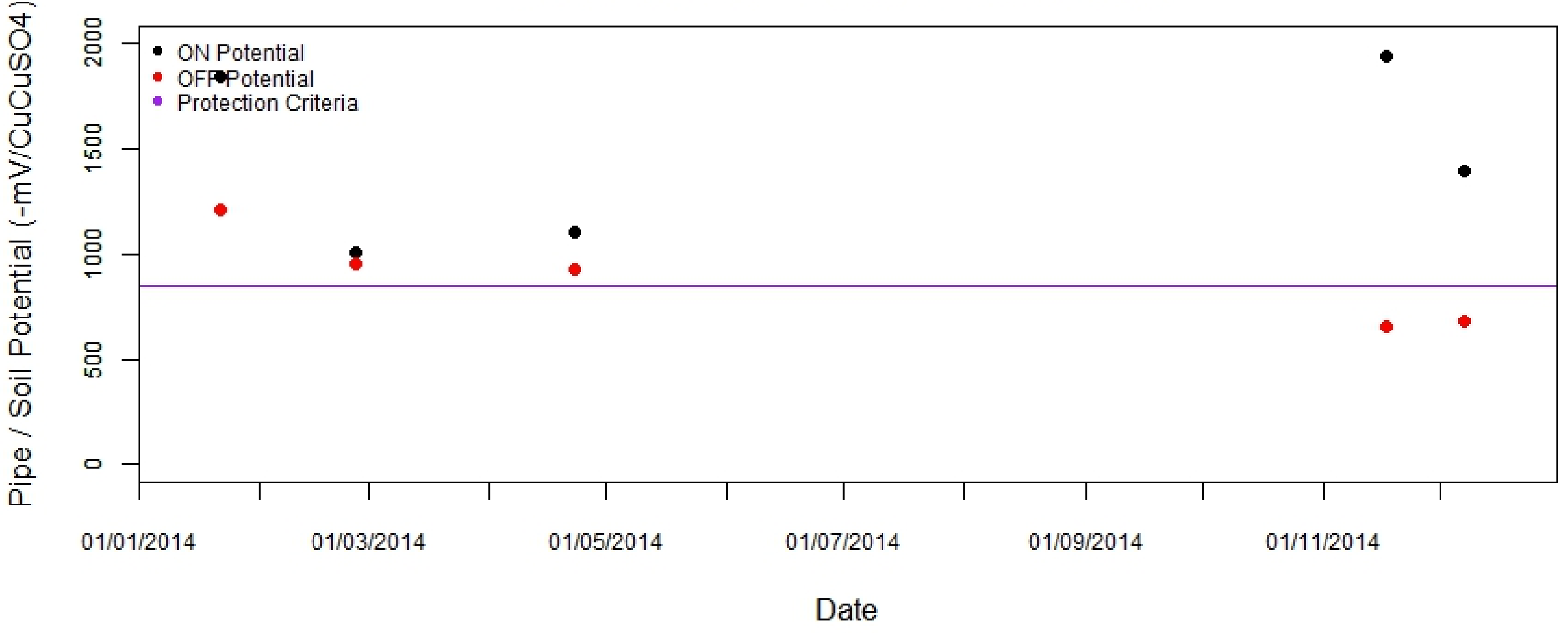

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = PVL-TMR, Location = 108.000 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = PVL-TMR, Location = 160.000 km
Resistance Probe - Pipe to Soil Potential Results
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
ON Potential
OFF Potential
Protection Criteria
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = TMR-TTR, Location = 162.000 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = TMR-TTR, Location = 210.000 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
2000
1500
1000
500
0
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = TMR-TTR, Location = 241.400 km
Resistance Probe - Pipe to Soil Potential Results
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
● ON Potential
● OFF Potential
● Protection Criteria
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date



AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

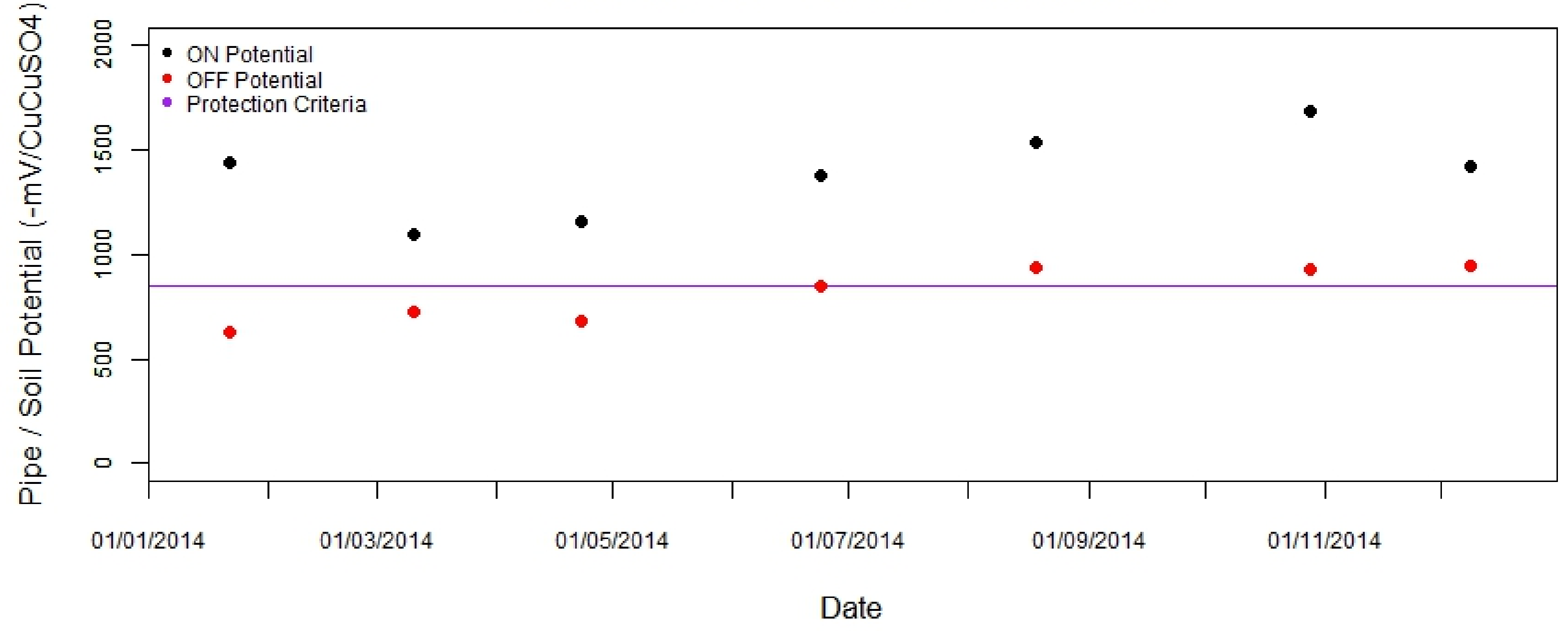
Section = TMR-TTR, Location = 242.000 km

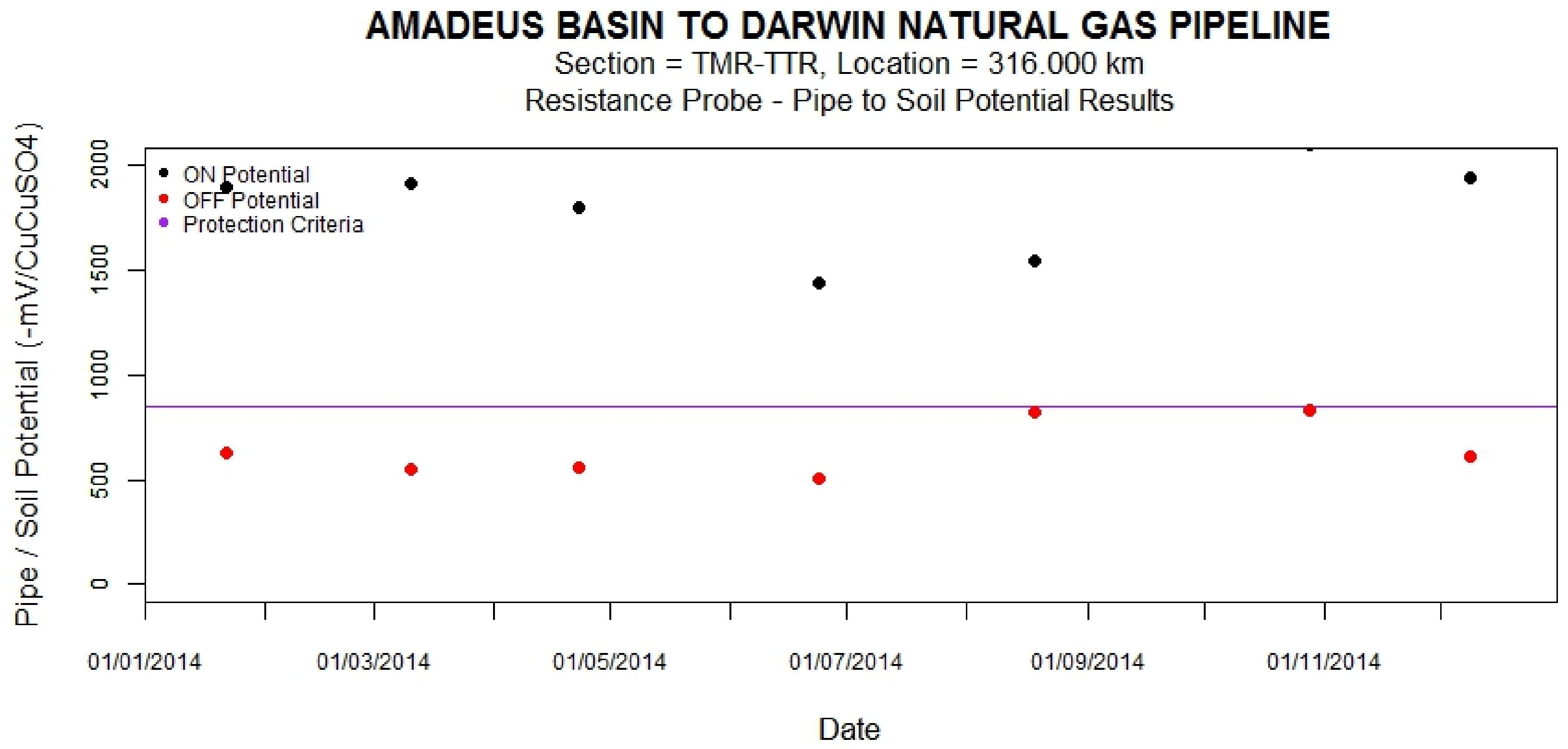
Resistance Probe - Pipe to Soil Potential Results

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = TMR-TTR, Location = 268.100 km

Resistance Probe - Pipe to Soil Potential Results

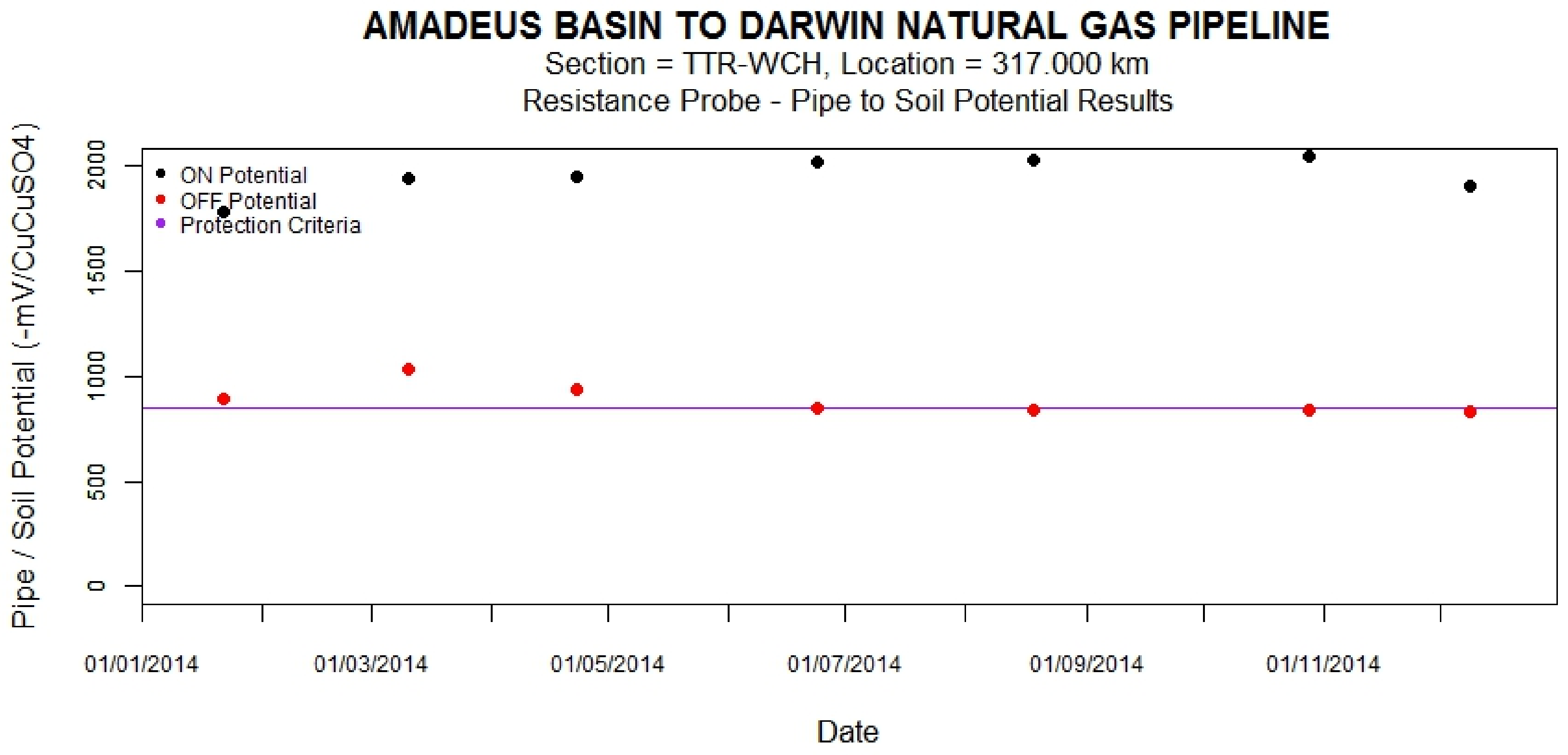




AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = TMR-TTR, Location = 316.000 km

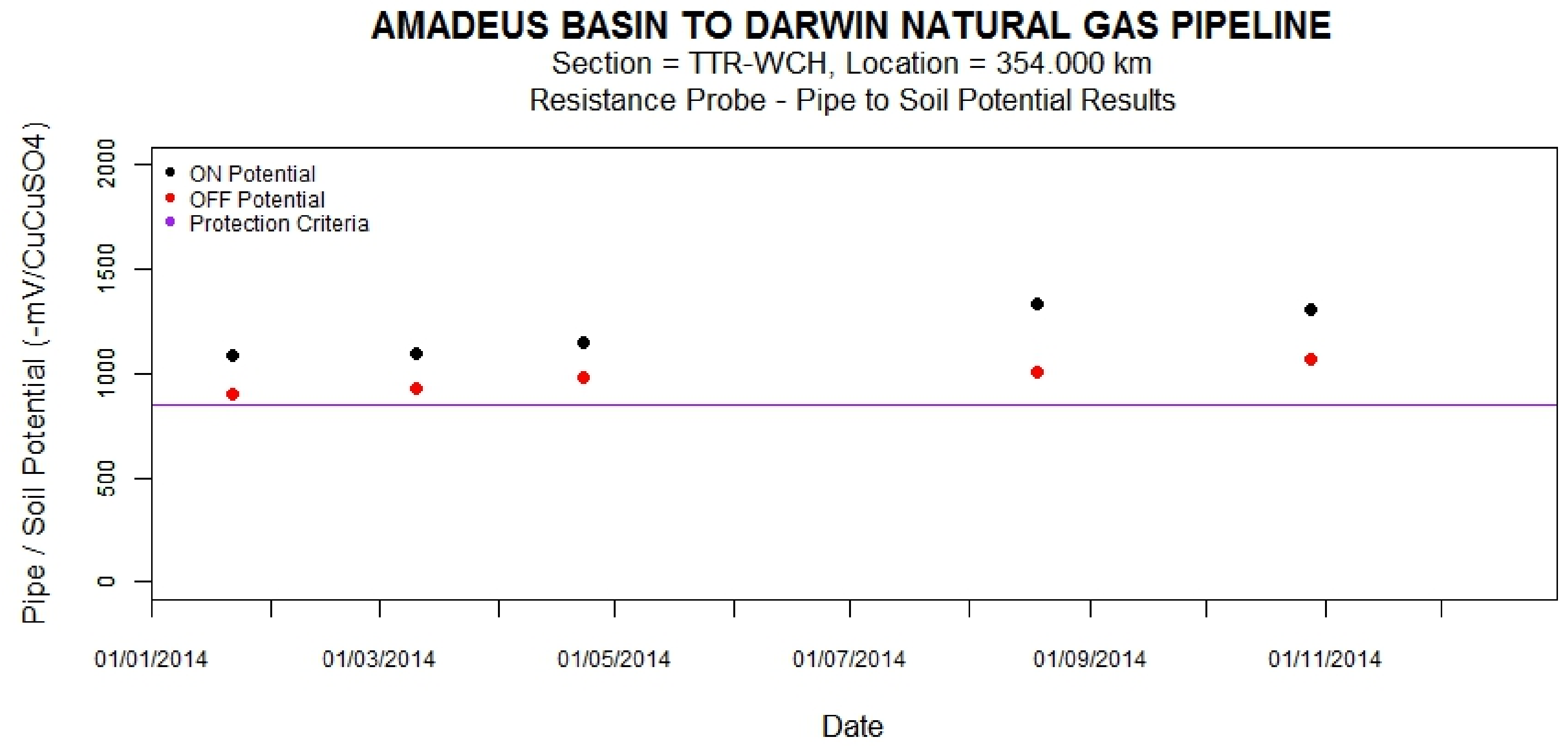
Resistance Probe - Pipe to Soil Potential Results

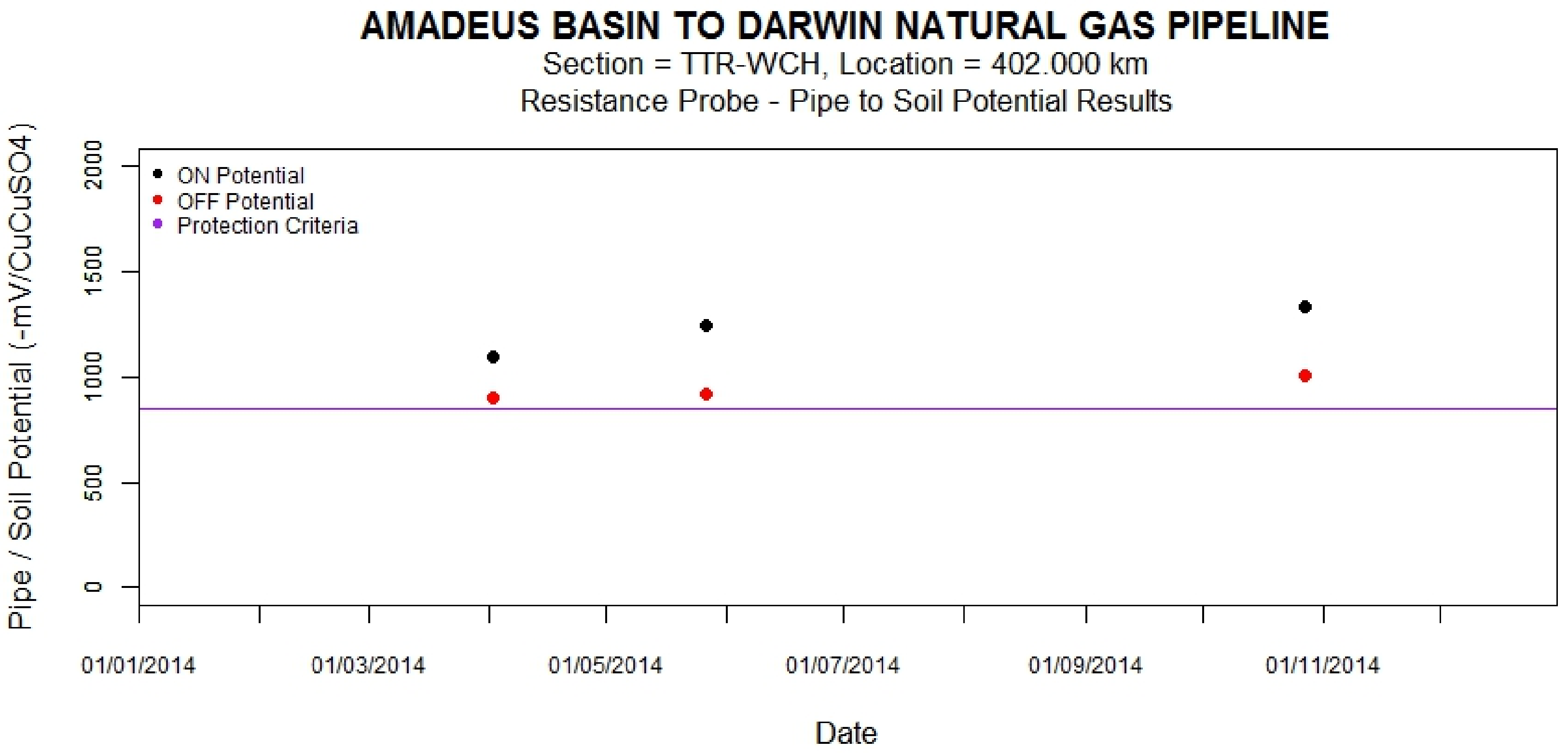


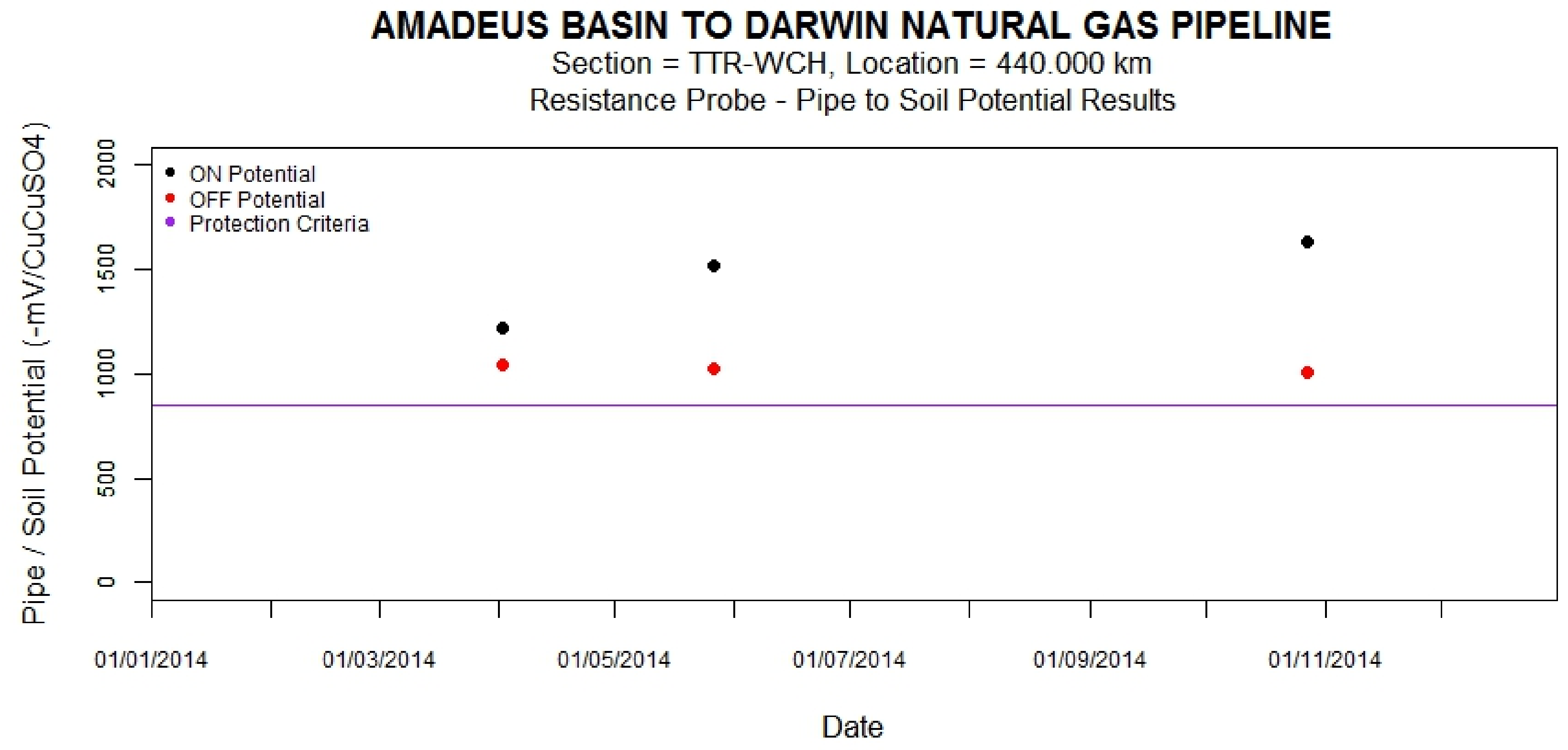
AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = TTR-WCH, Location = 317.000 km

Resistance Probe - Pipe to Soil Potential Results


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = TTR-WCH, Location = 354.000 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

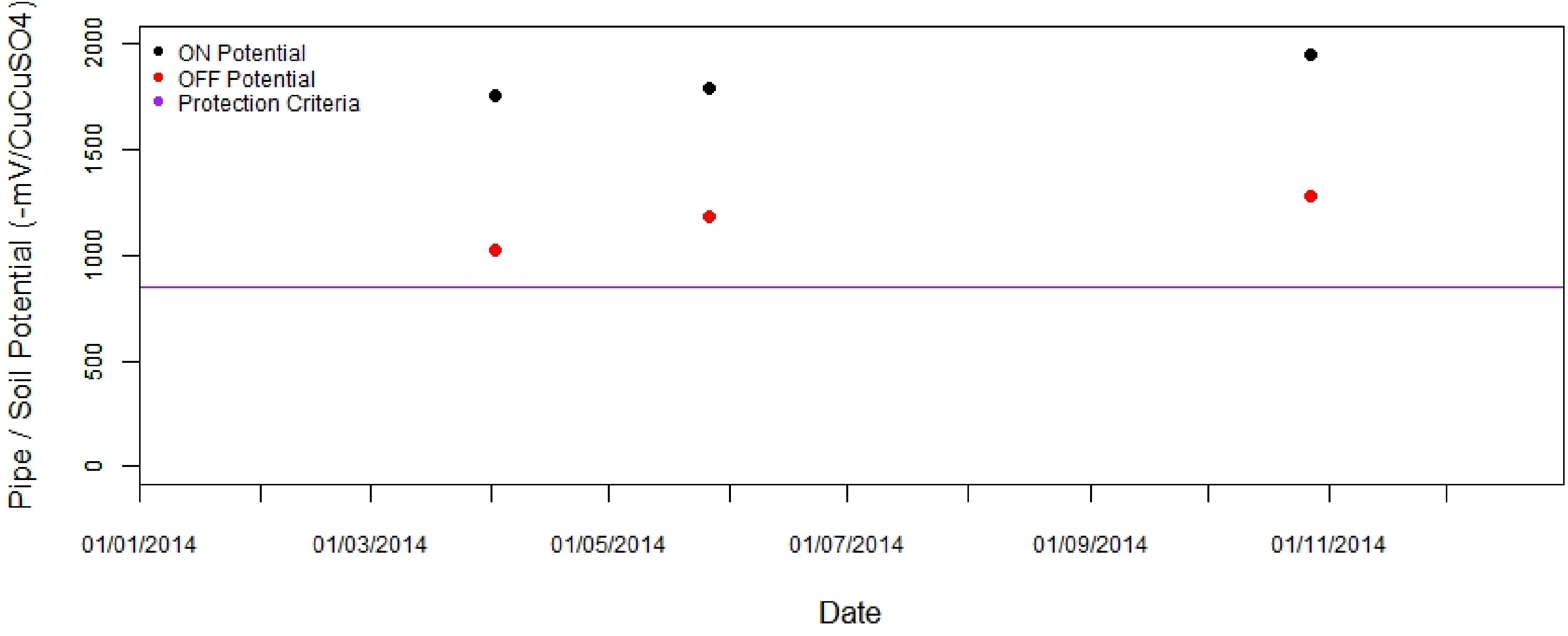

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = TTR-WCH, Location = 402.000 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = TTR-WCH, Location = 440.000 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = TTR-WCH, Location = 456.000 km

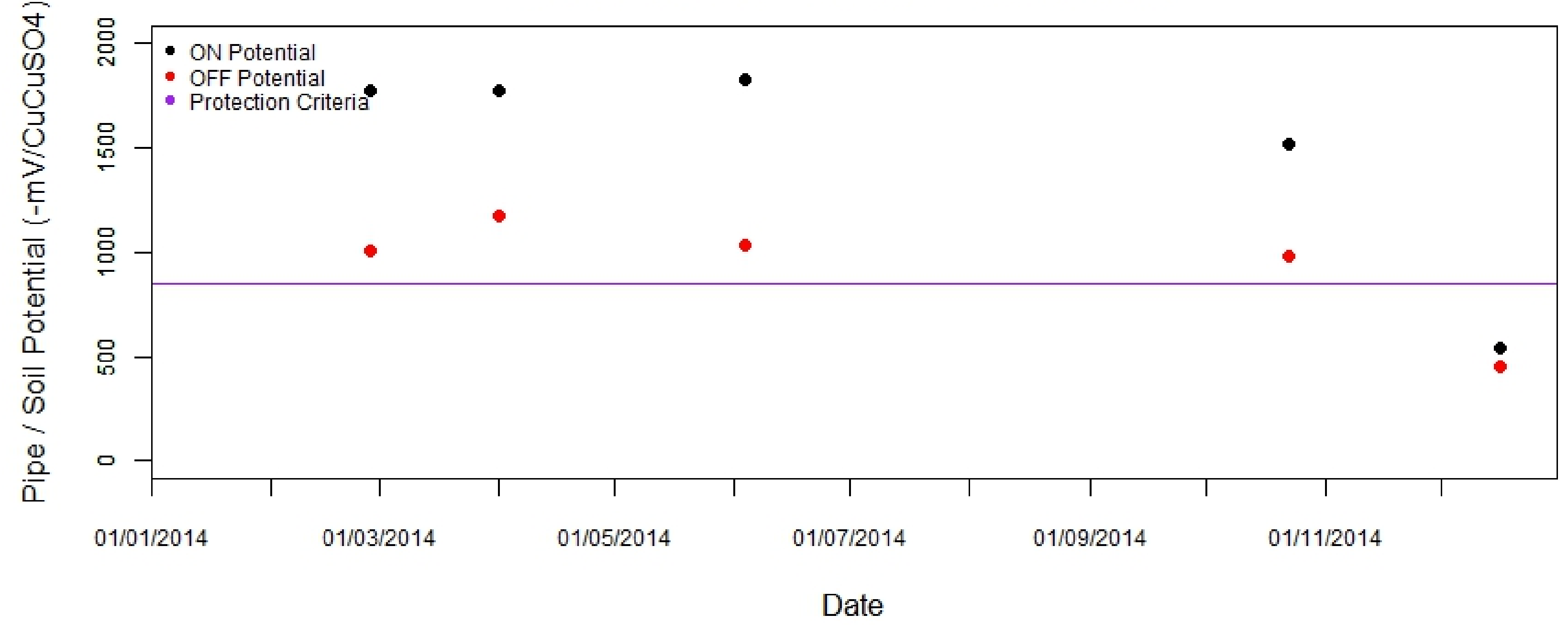
Resistance Probe - Pipe to Soil Potential Results

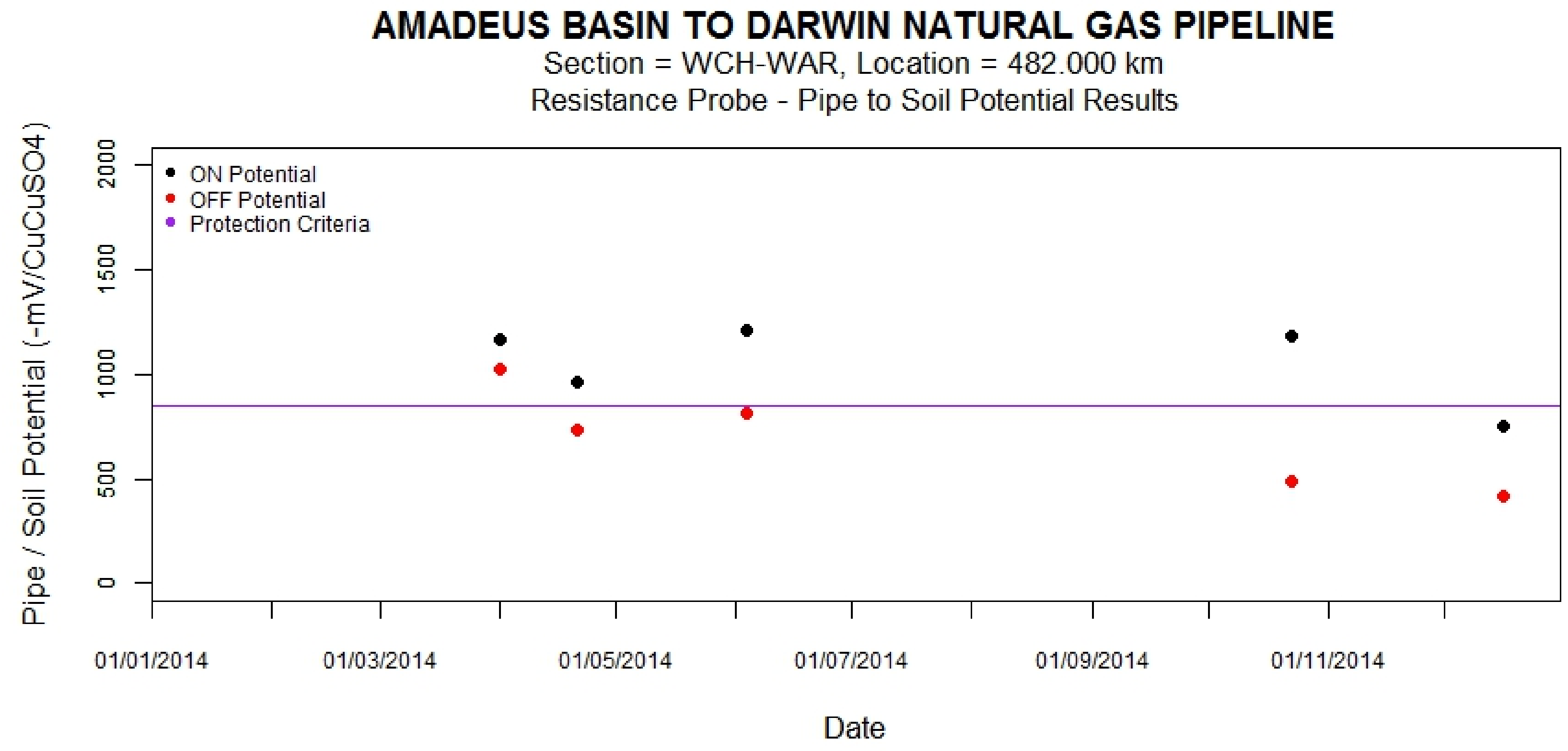


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = WCH-WAR, Location = 460.000 km

Resistance Probe - Pipe to Soil Potential Results

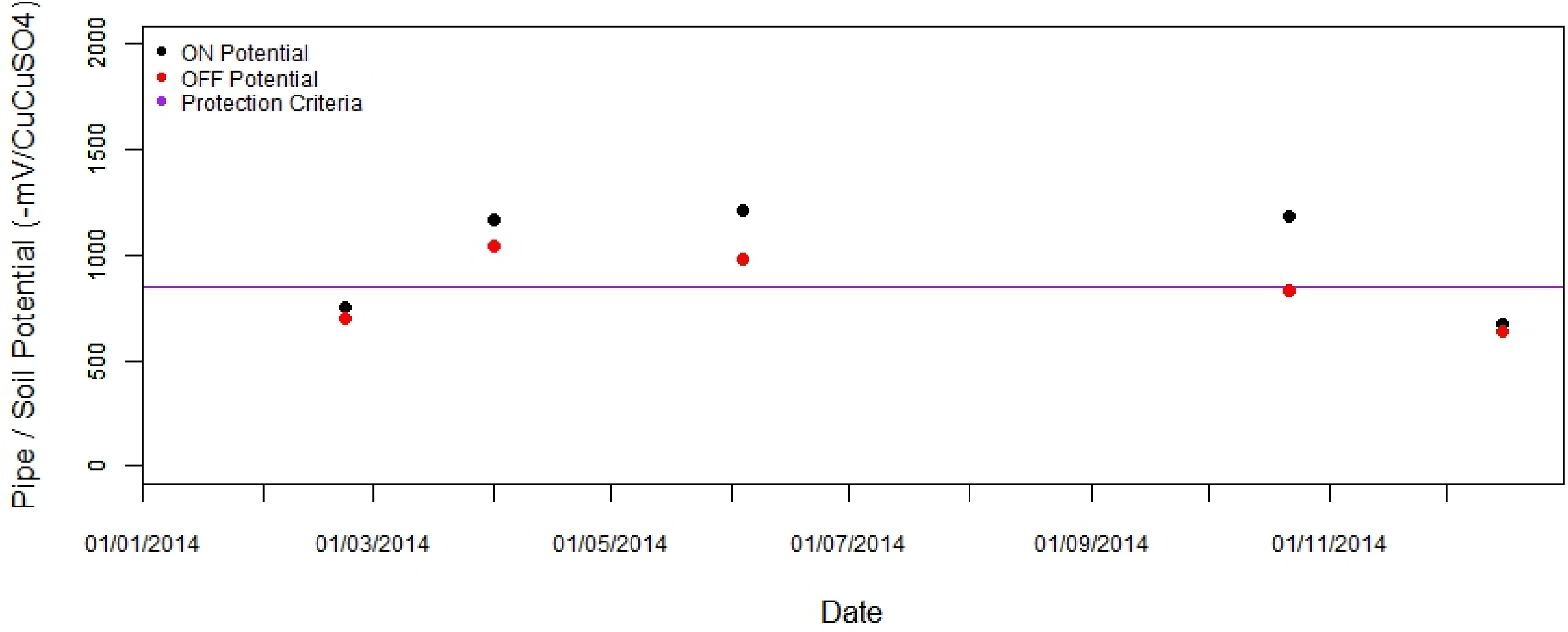


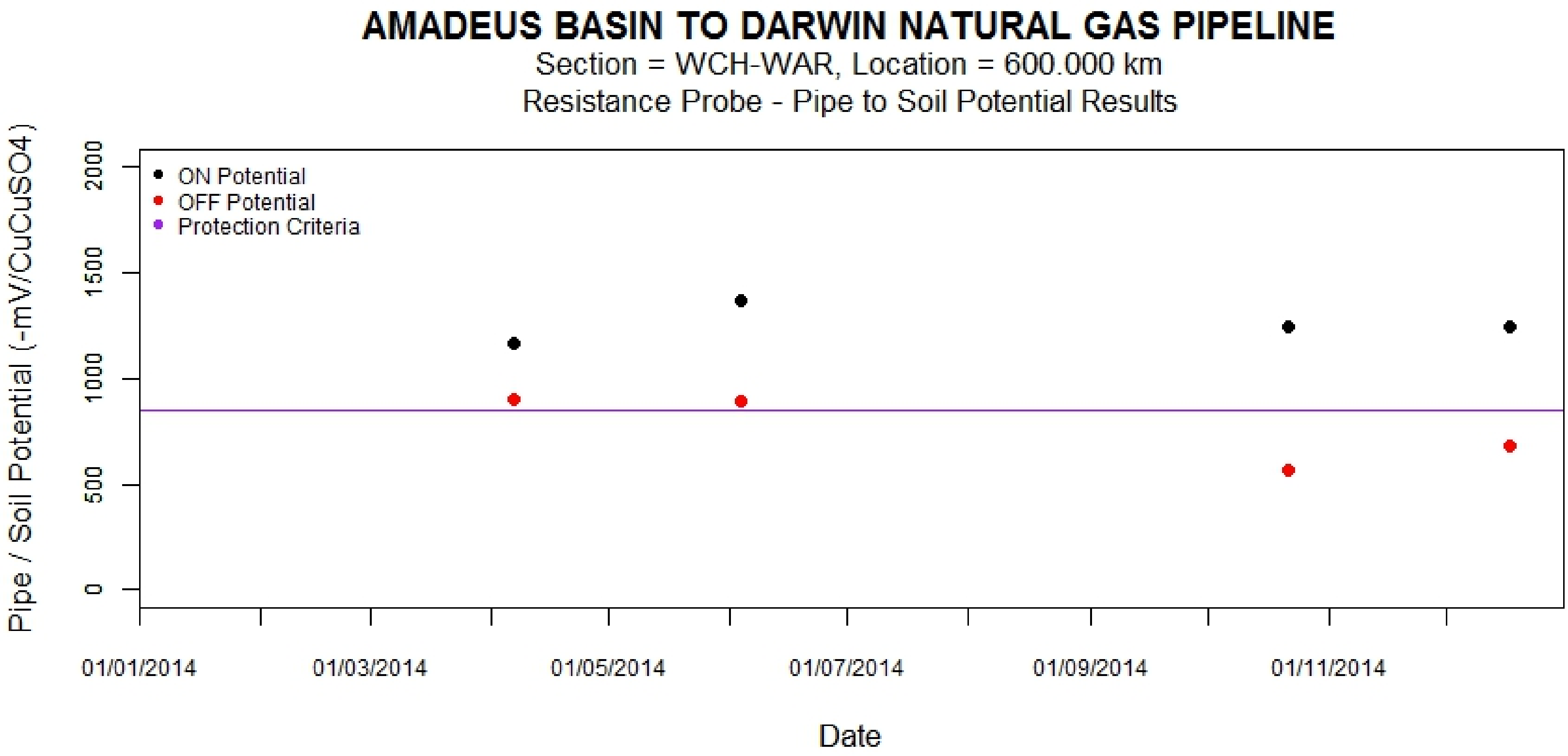

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = WCH-WAR, Location = 482.000 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

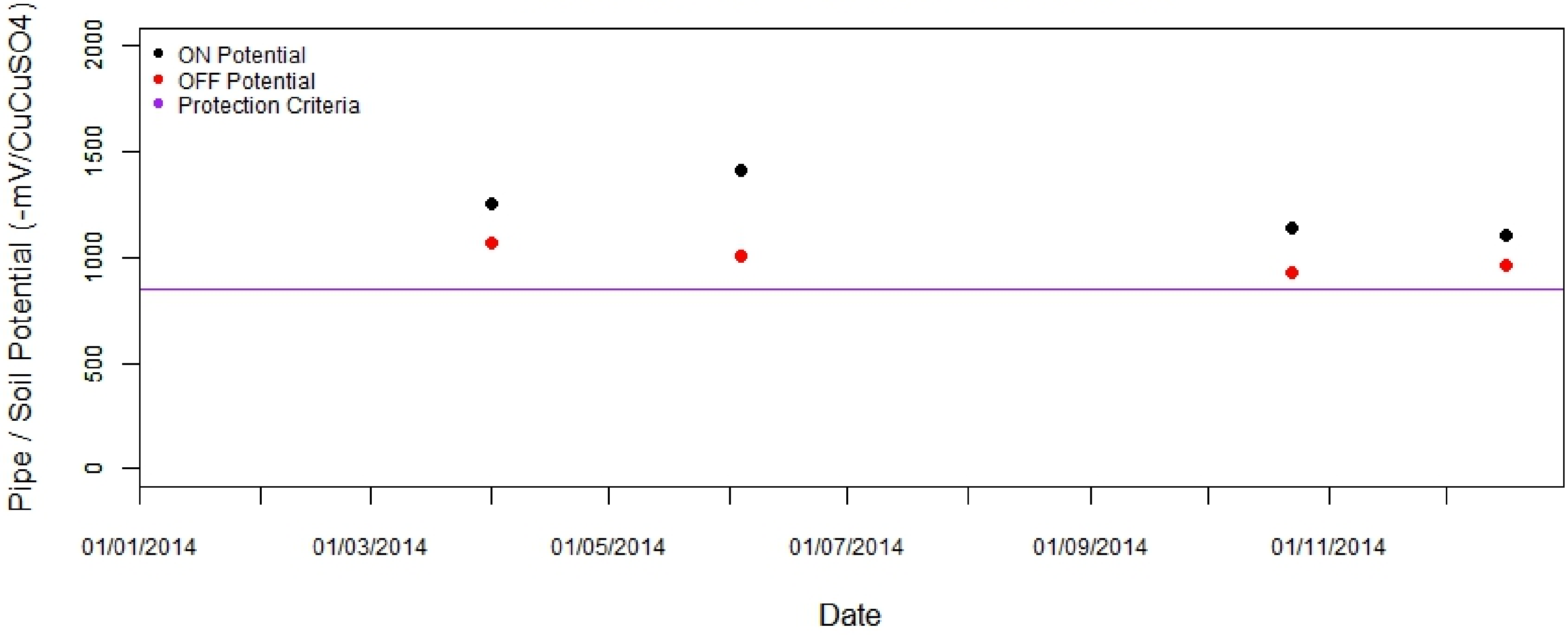
AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = WCH-WAR, Location = 560.000 km

Resistance Probe - Pipe to Soil Potential Results



AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = WCH-WAR, Location = 600.000 km
Resistance Probe - Pipe to Soil Potential Results
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
ON Potential
OFF Potential
Protection Criteria
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

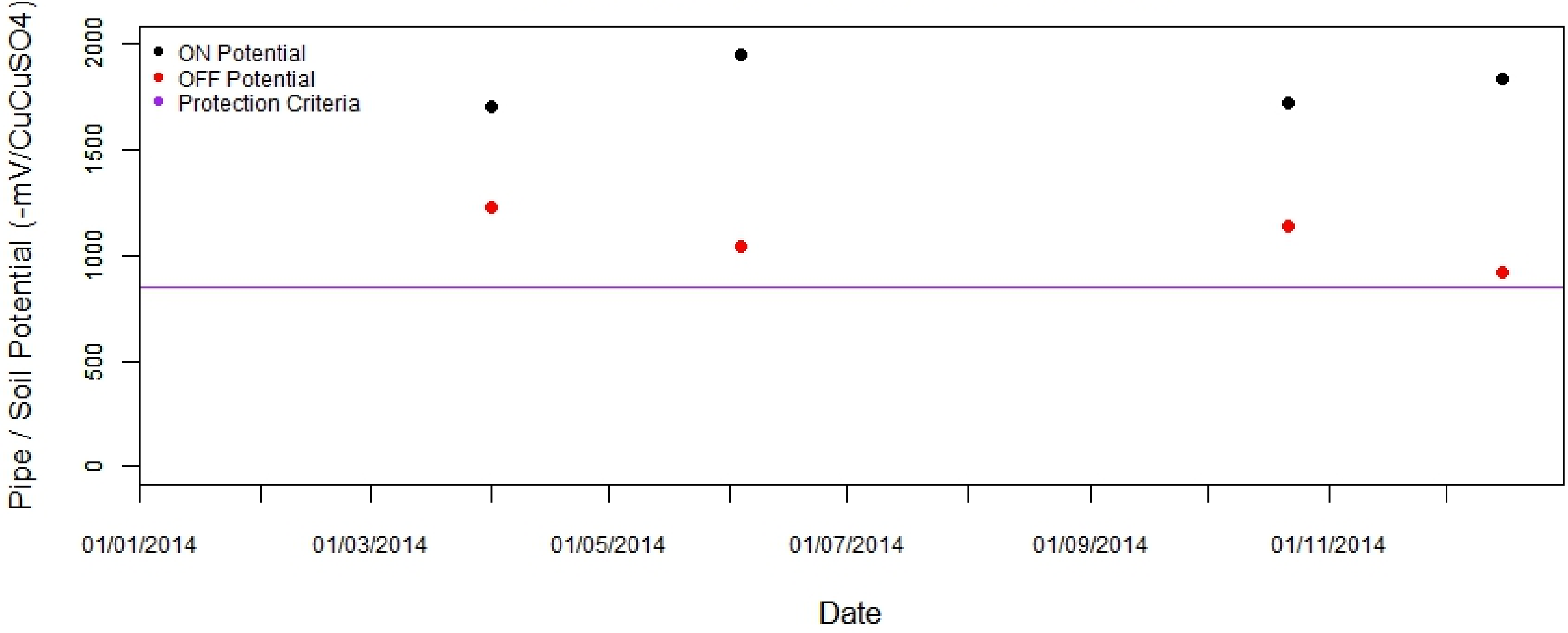


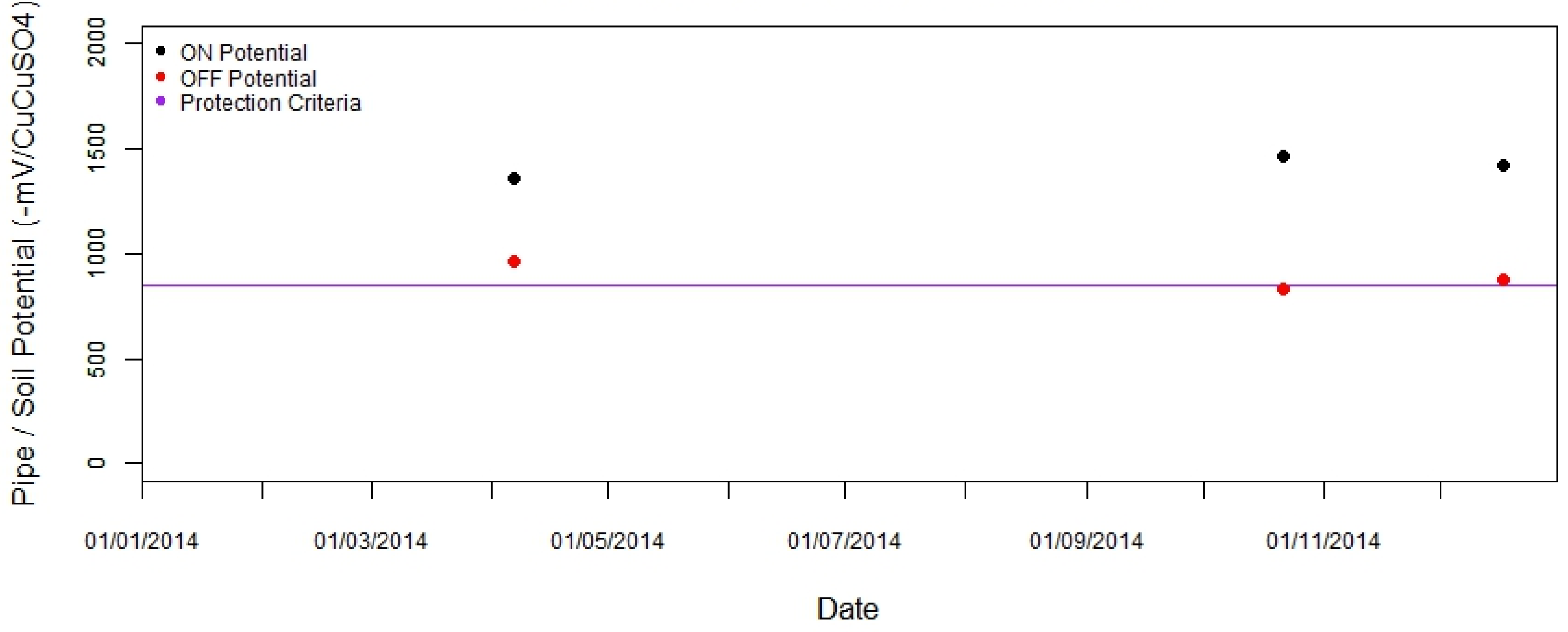
AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = WCH-WAR, Location = 502.000 km
Resistance Probe - Pipe to Soil Potential Results

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = WCH-WAR, Location = 526.000 km

Resistance Probe - Pipe to Soil Potential Results

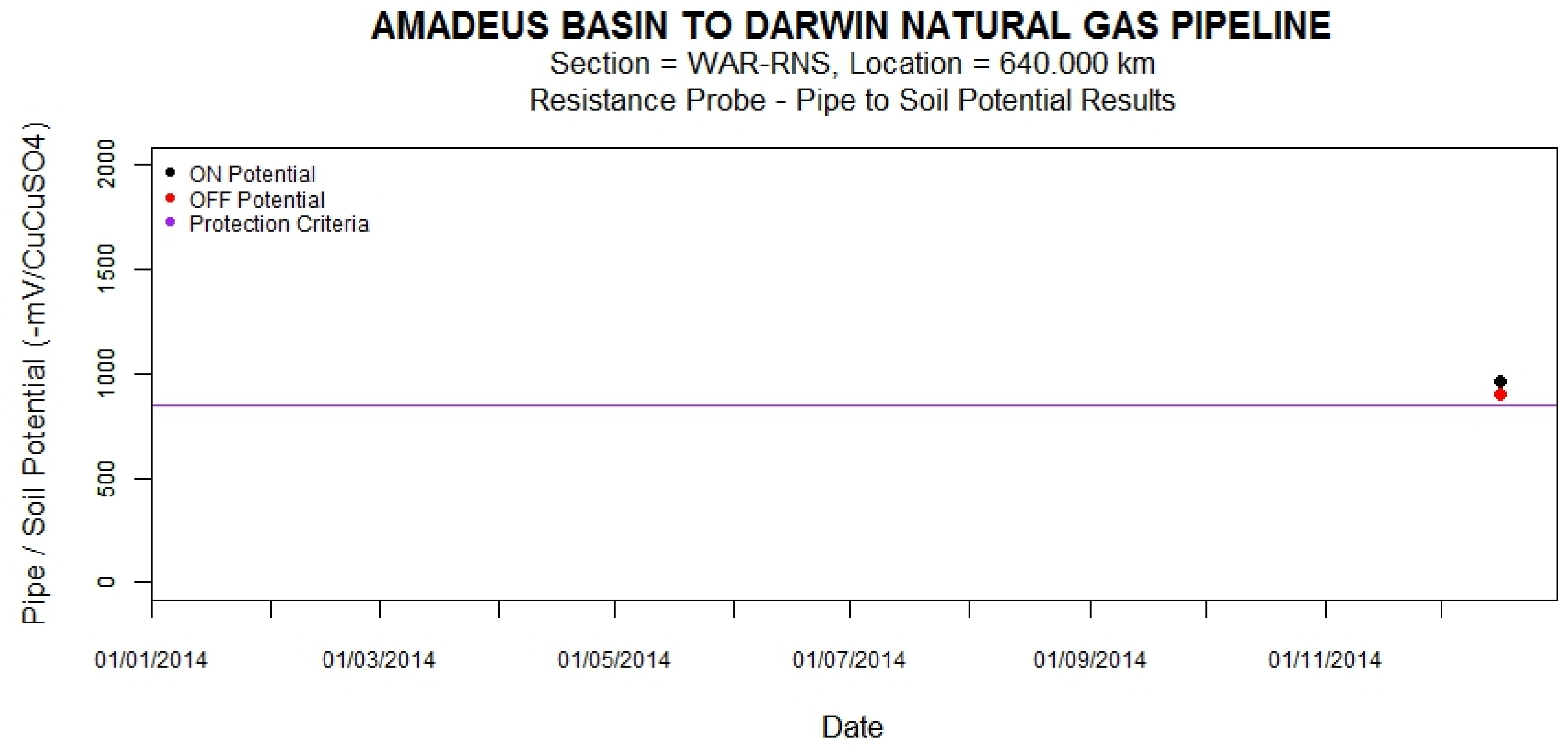




AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = WAR-RNS, Location = 614.100 km

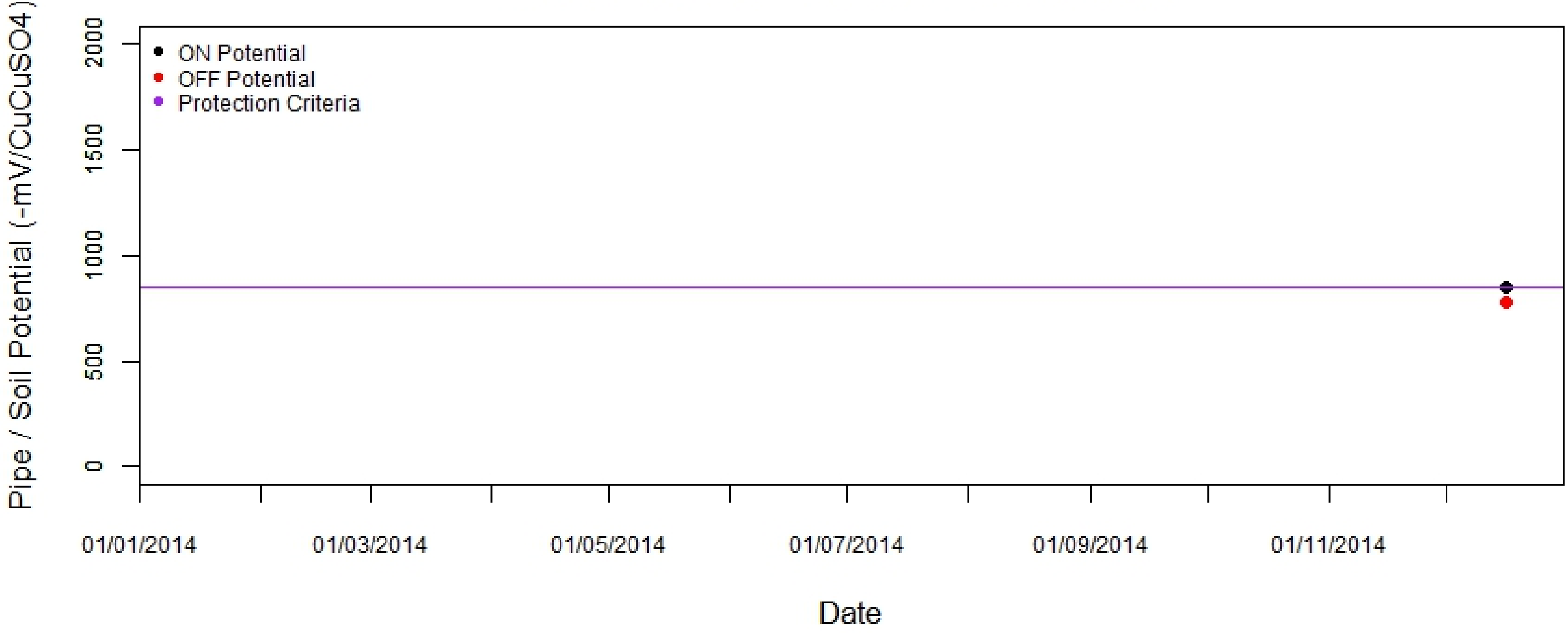
Resistance Probe - Pipe to Soil Potential Results

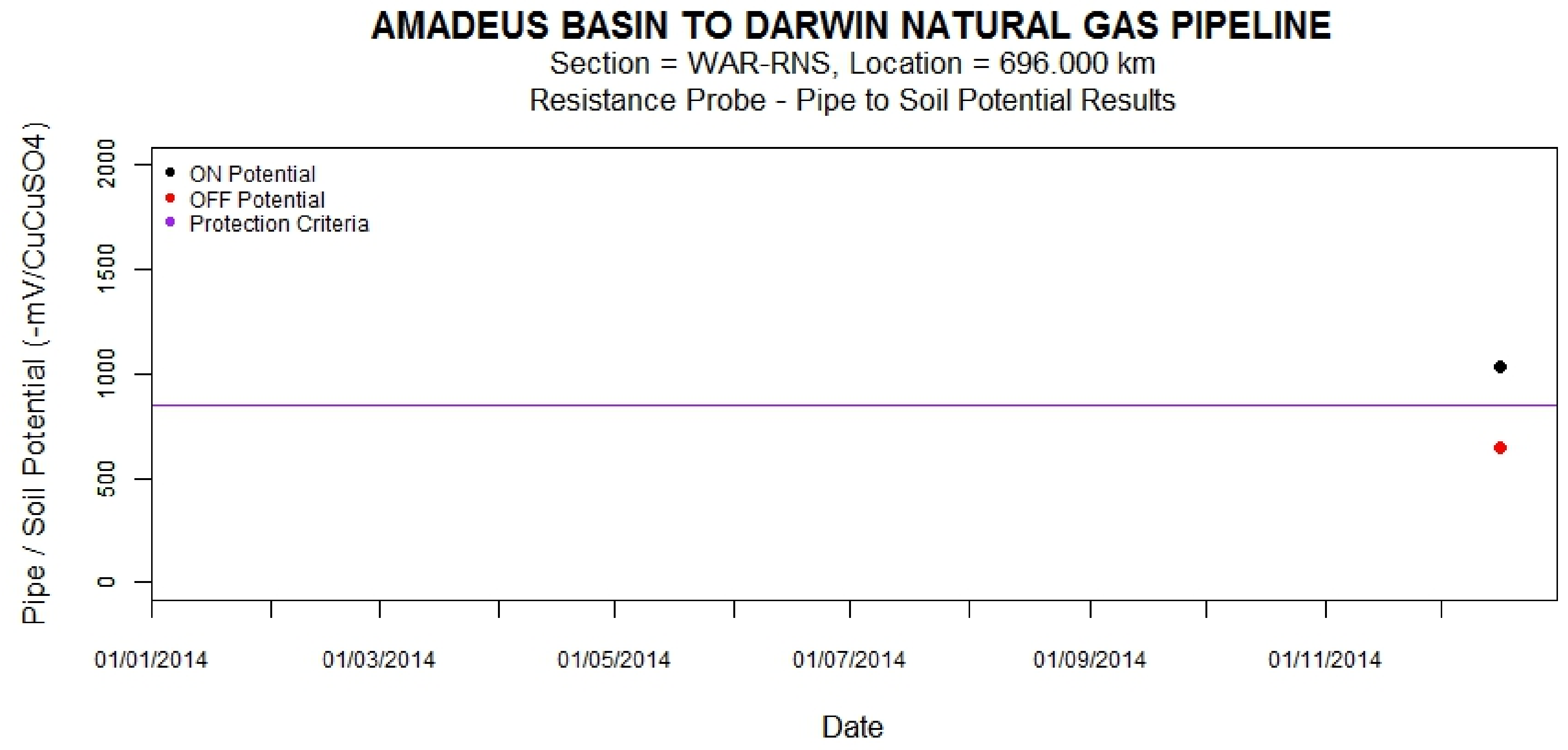
AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = WAR-RNS, Location = 640.000 km
Resistance Probe - Pipe to Soil Potential Results
ON Potential
OFF Potential
Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = WAR-RNS, Location = 660.000 km

Resistance Probe - Pipe to Soil Potential Results

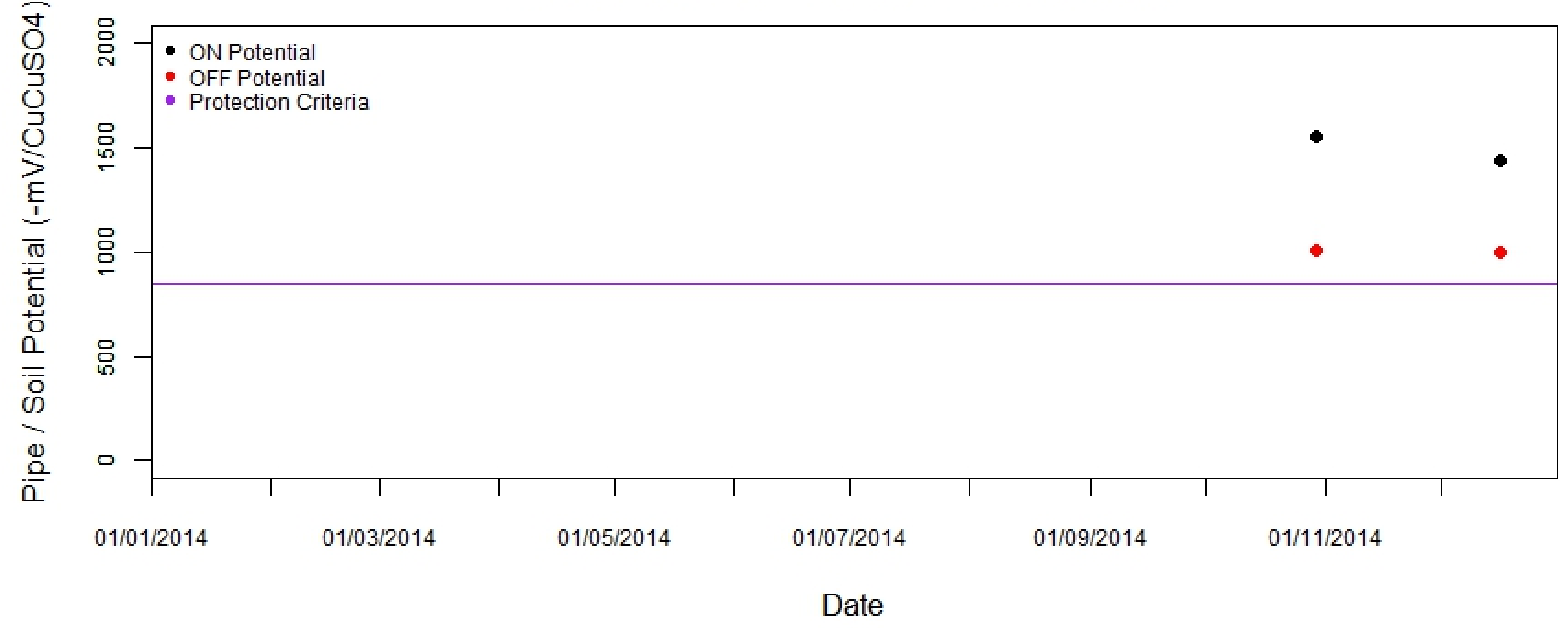




AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = WAR-RNS, Location = 696.000 km

Resistance Probe - Pipe to Soil Potential Results



AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

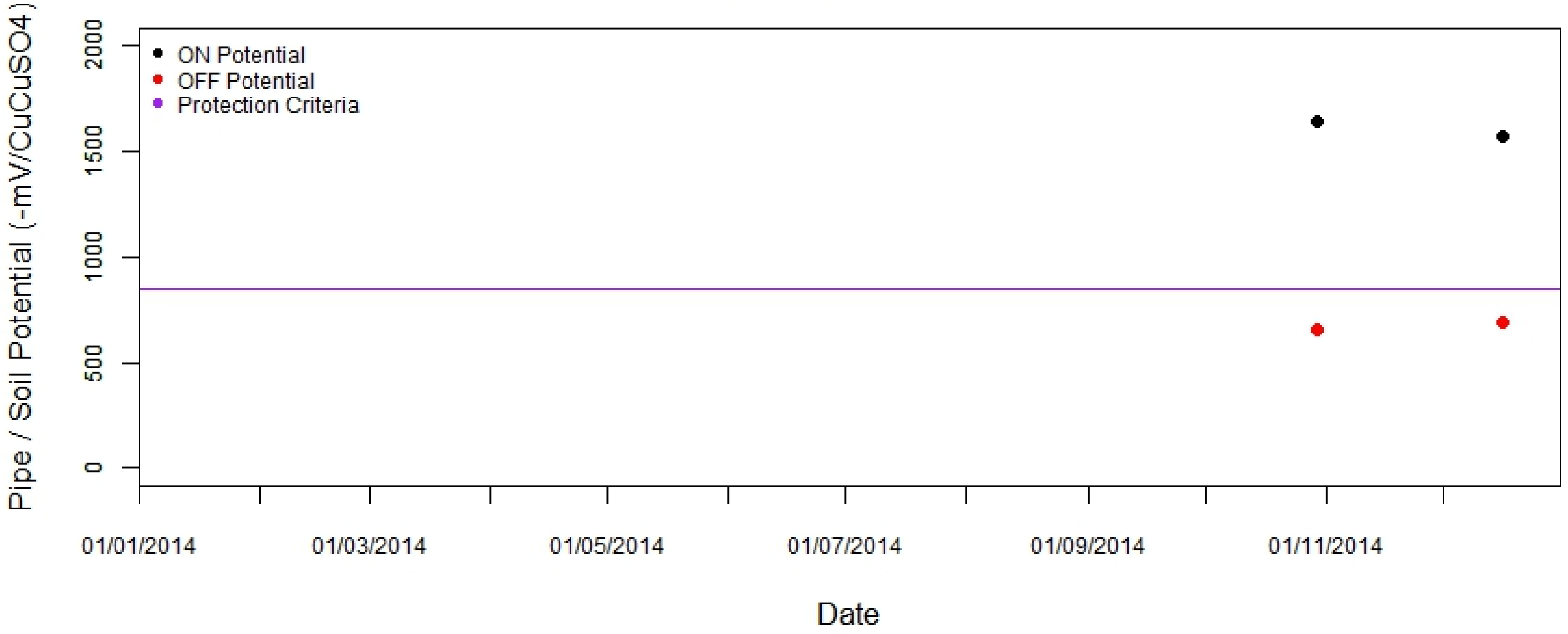
Section = WAR-RNS, Location = 727.500 km

Resistance Probe - Pipe to Soil Potential Results

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = RNS-NCW, Location = 739.500 km

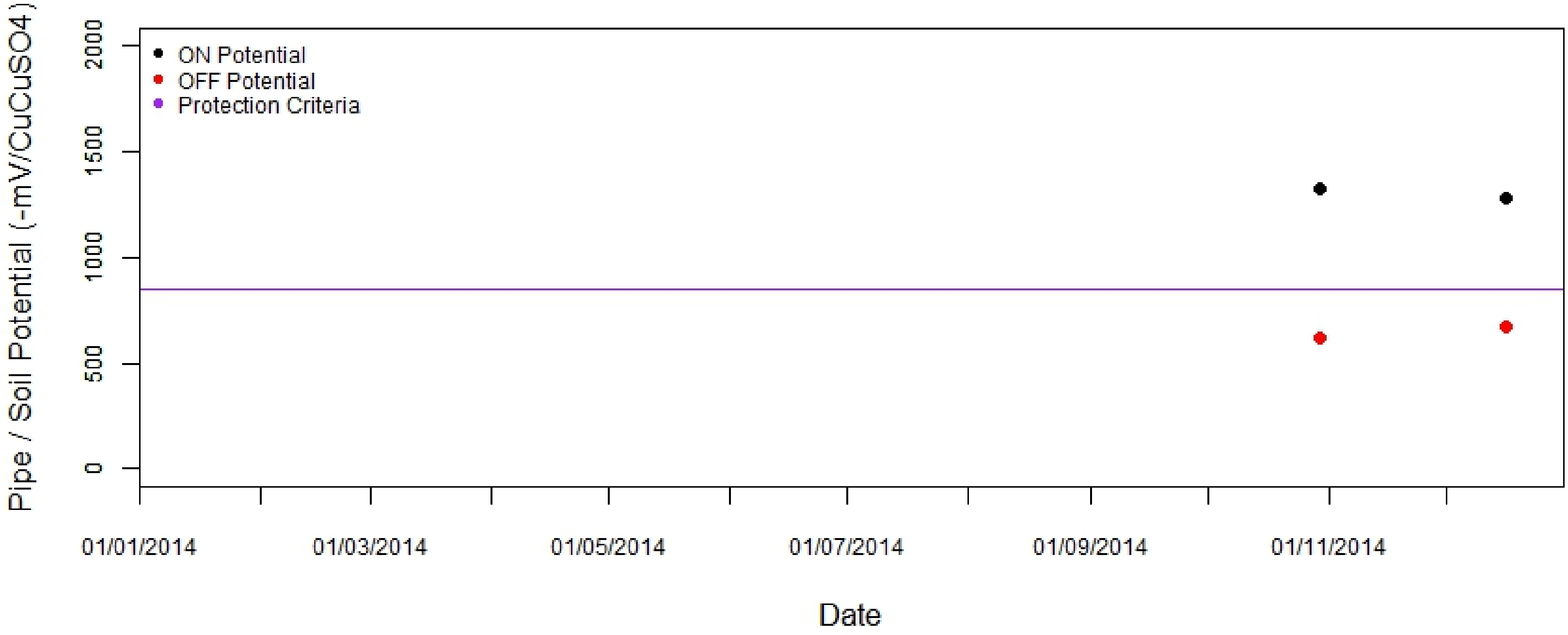
Resistance Probe - Pipe to Soil Potential Results



AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = RNS-NCW, Location = 757.800 km

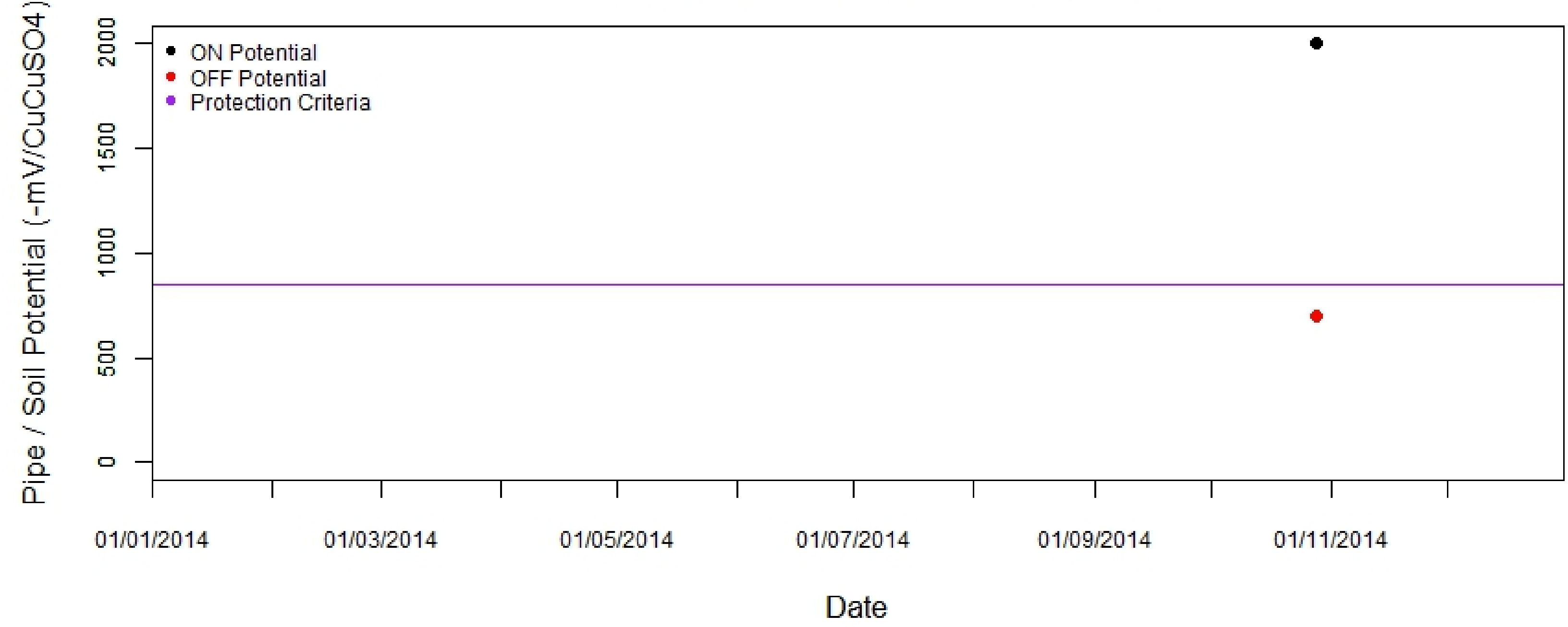
Resistance Probe - Pipe to Soil Potential Results

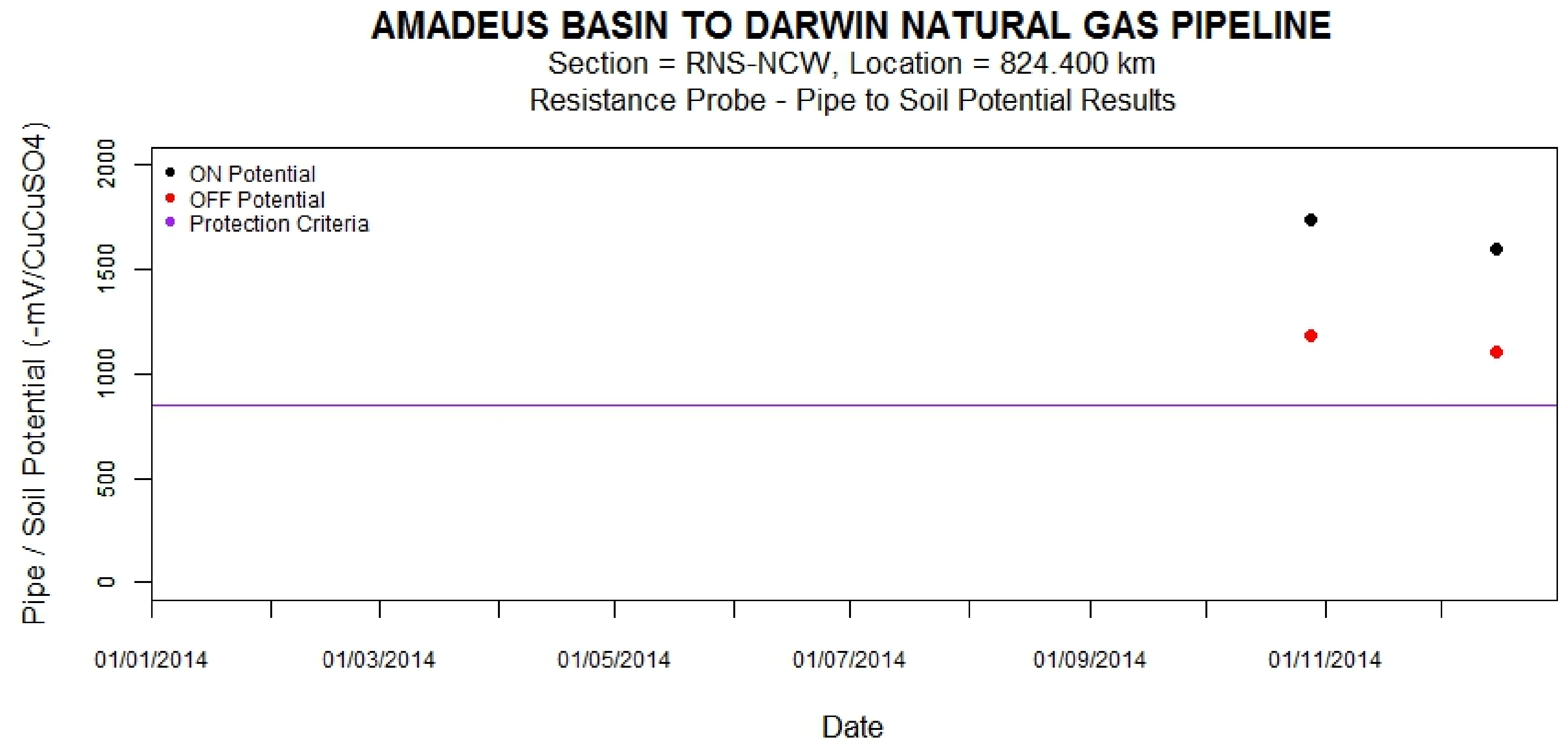


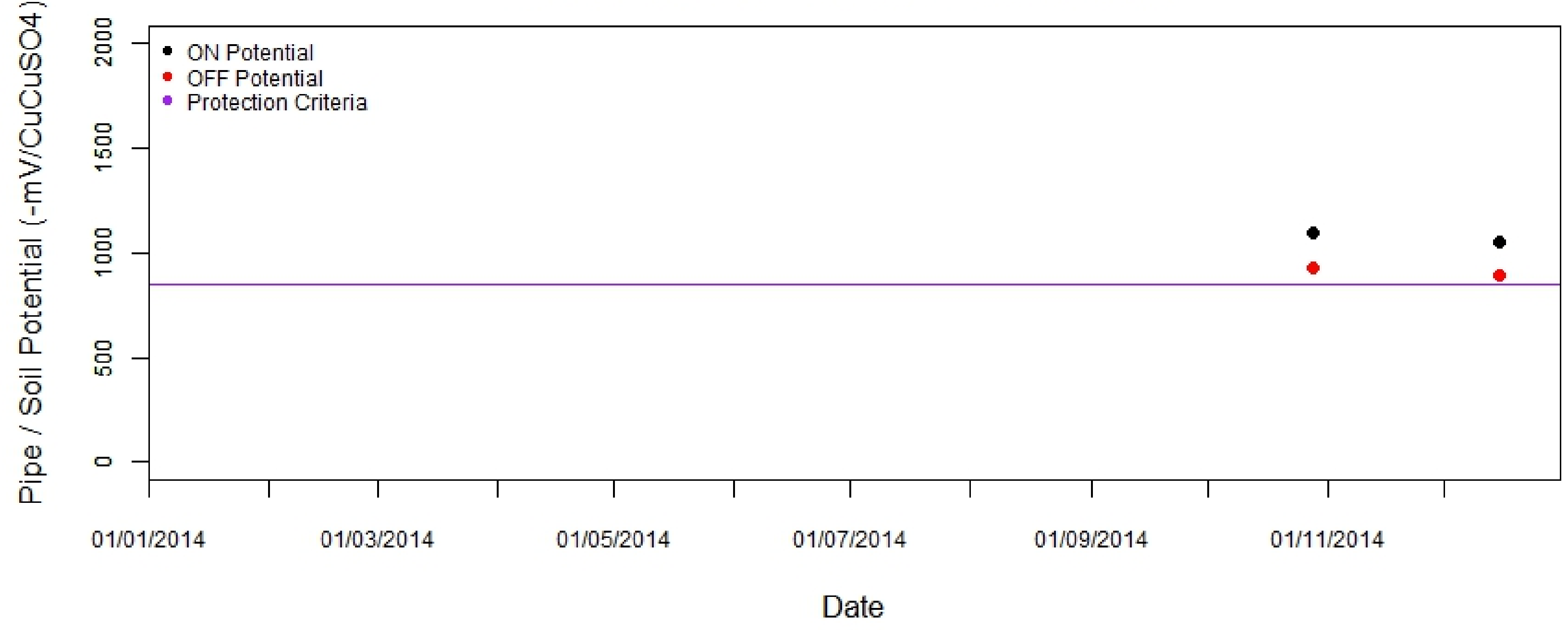
AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = RNS-NCW, Location = 791.600 km

Resistance Probe - Pipe to Soil Potential Results




AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = RNS-NCW, Location = 824.400 km
Resistance Probe - Pipe to Soil Potential Results
Pipe / Soil Potential (-mV/CuCuSO4)
2000
1500
1000
500
0
● ON Potential
● OFF Potential
● Protection Criteria
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date



AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

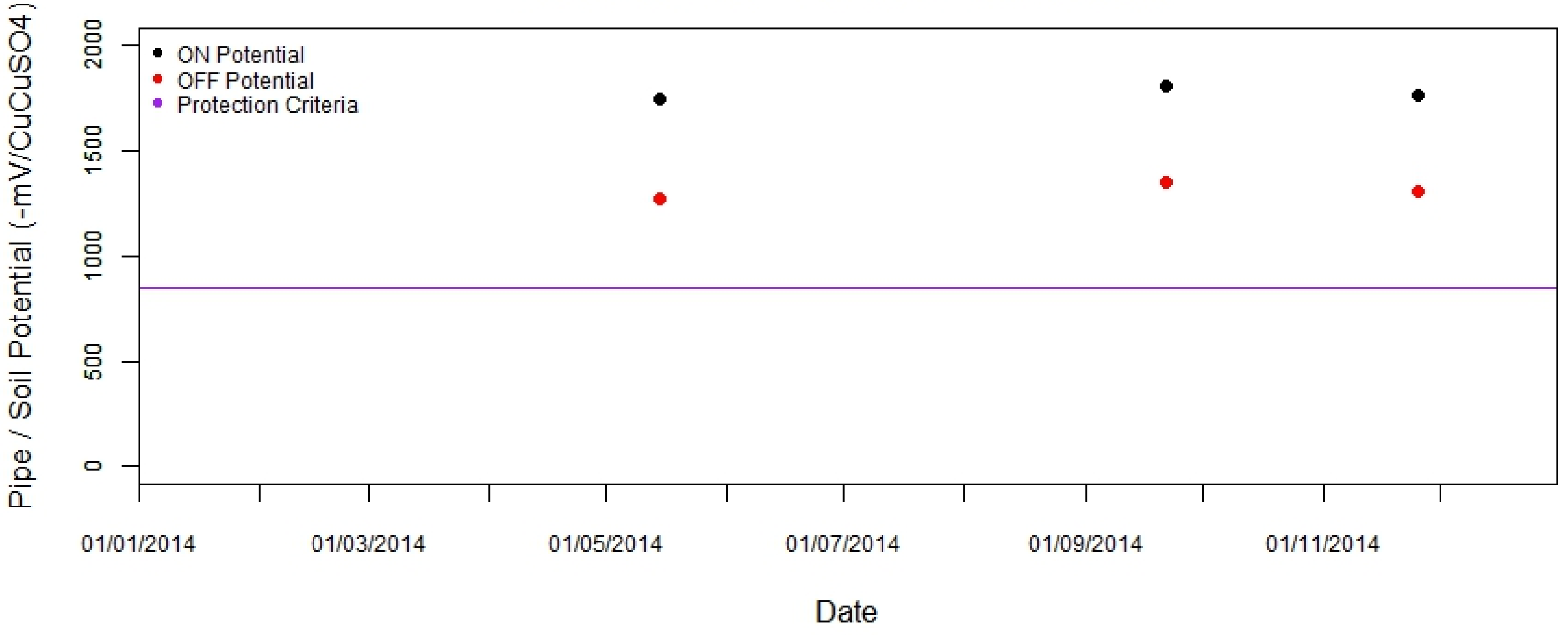
Section = NCW-DLW, Location = 859.800 km

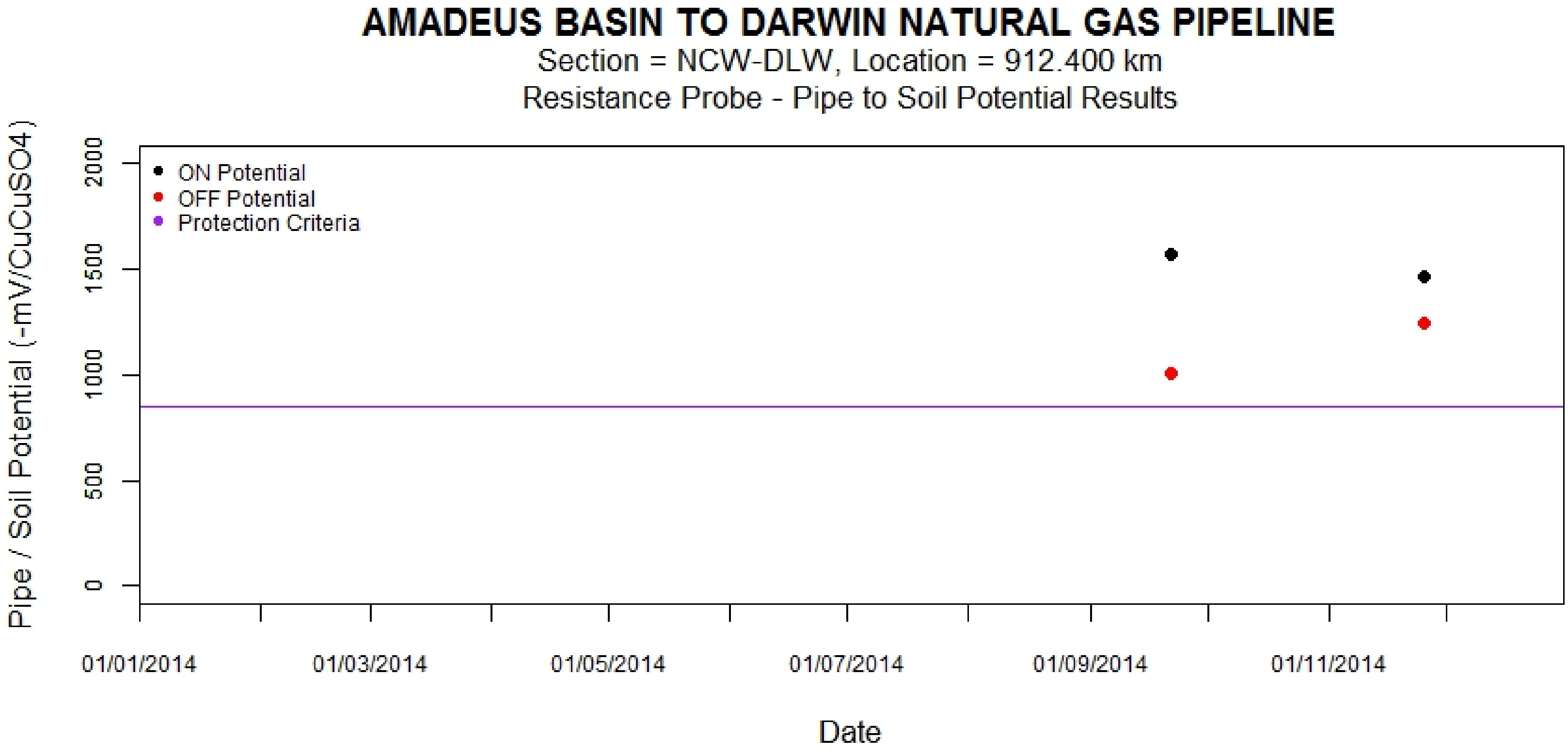
Resistance Probe - Pipe to Soil Potential Results

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = NCW-DLW, Location = 890.000 km

Resistance Probe - Pipe to Soil Potential Results





AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

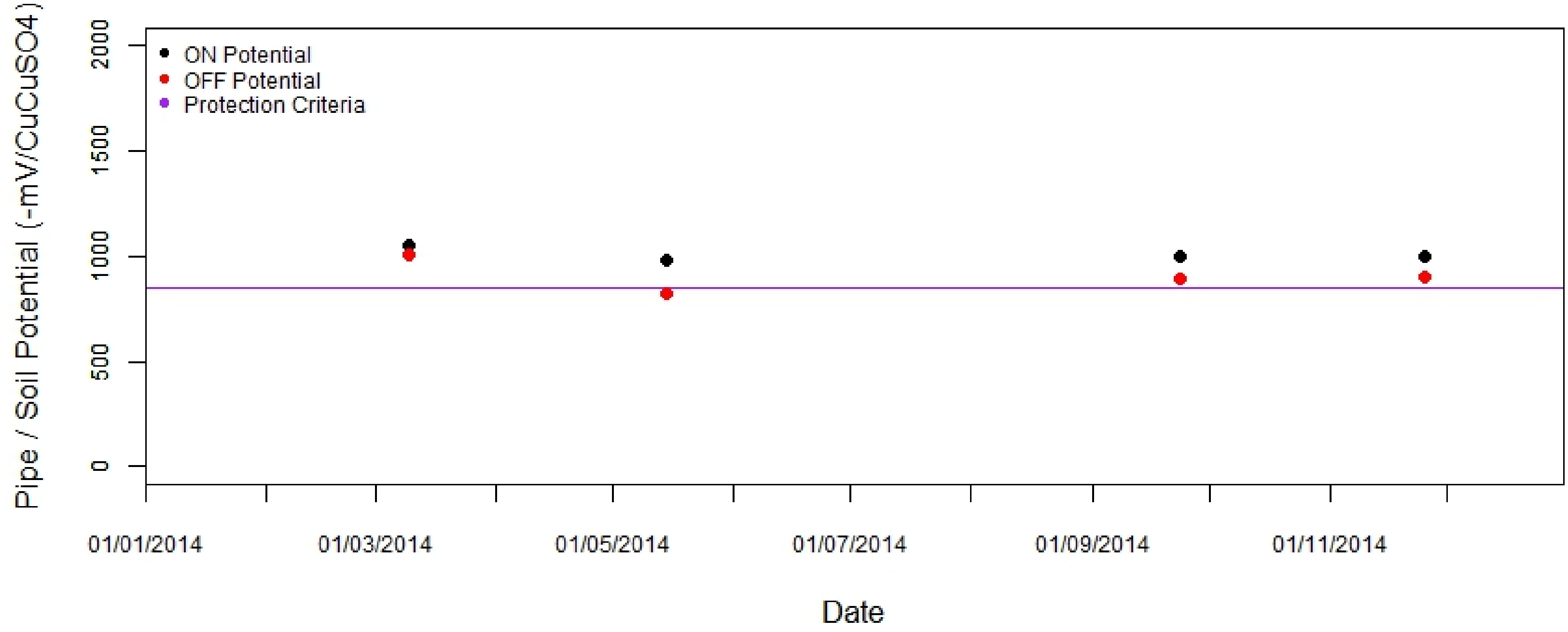
Section = NCW-DLW, Location = 912.400 km

Resistance Probe - Pipe to Soil Potential Results

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = NCW-DLW, Location = 935.200 km

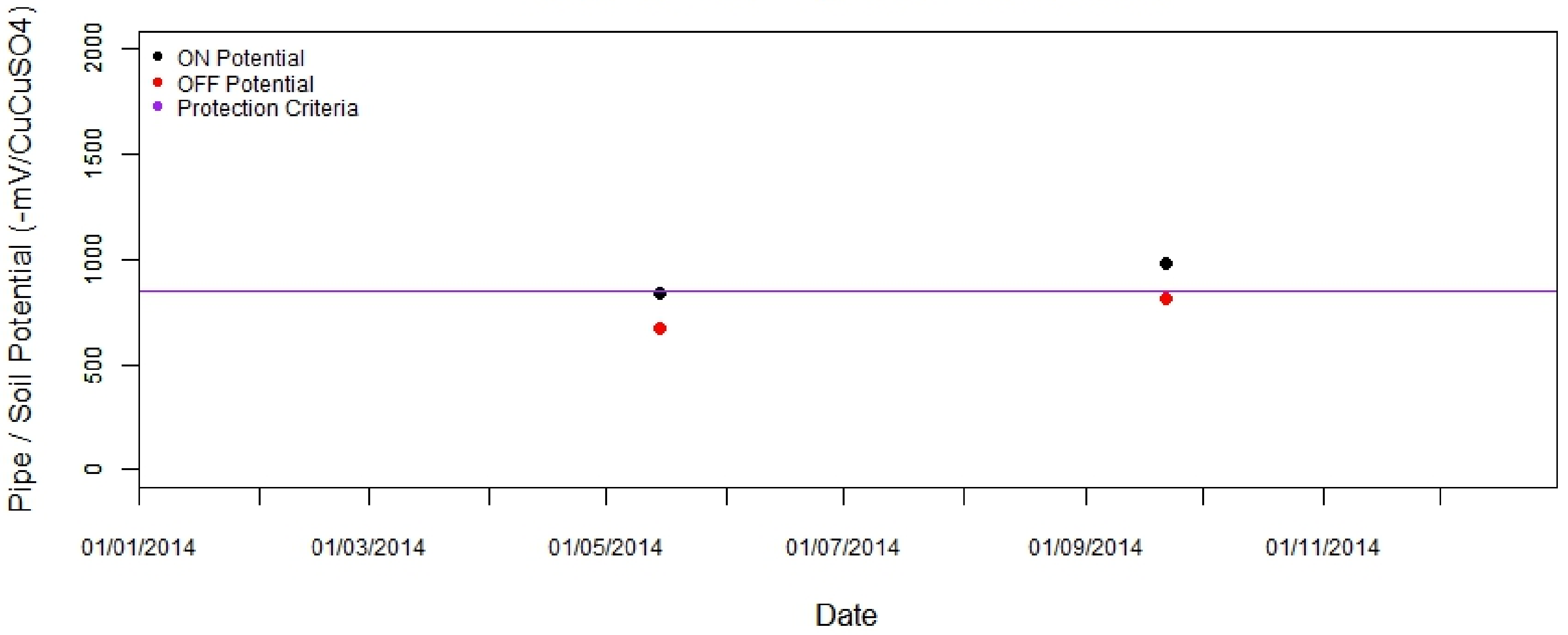
Resistance Probe - Pipe to Soil Potential Results

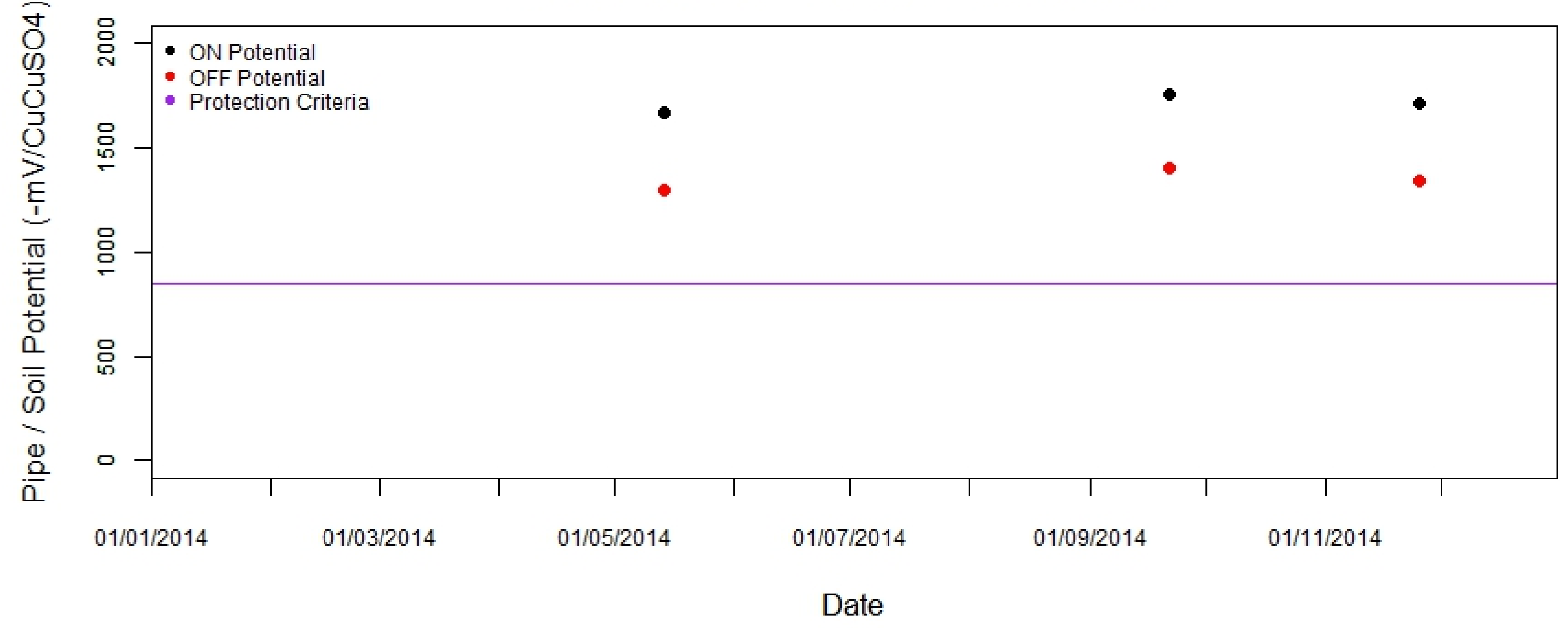


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = NCW-DLW, Location = 959.000 km

Resistance Probe - Pipe to Soil Potential Results

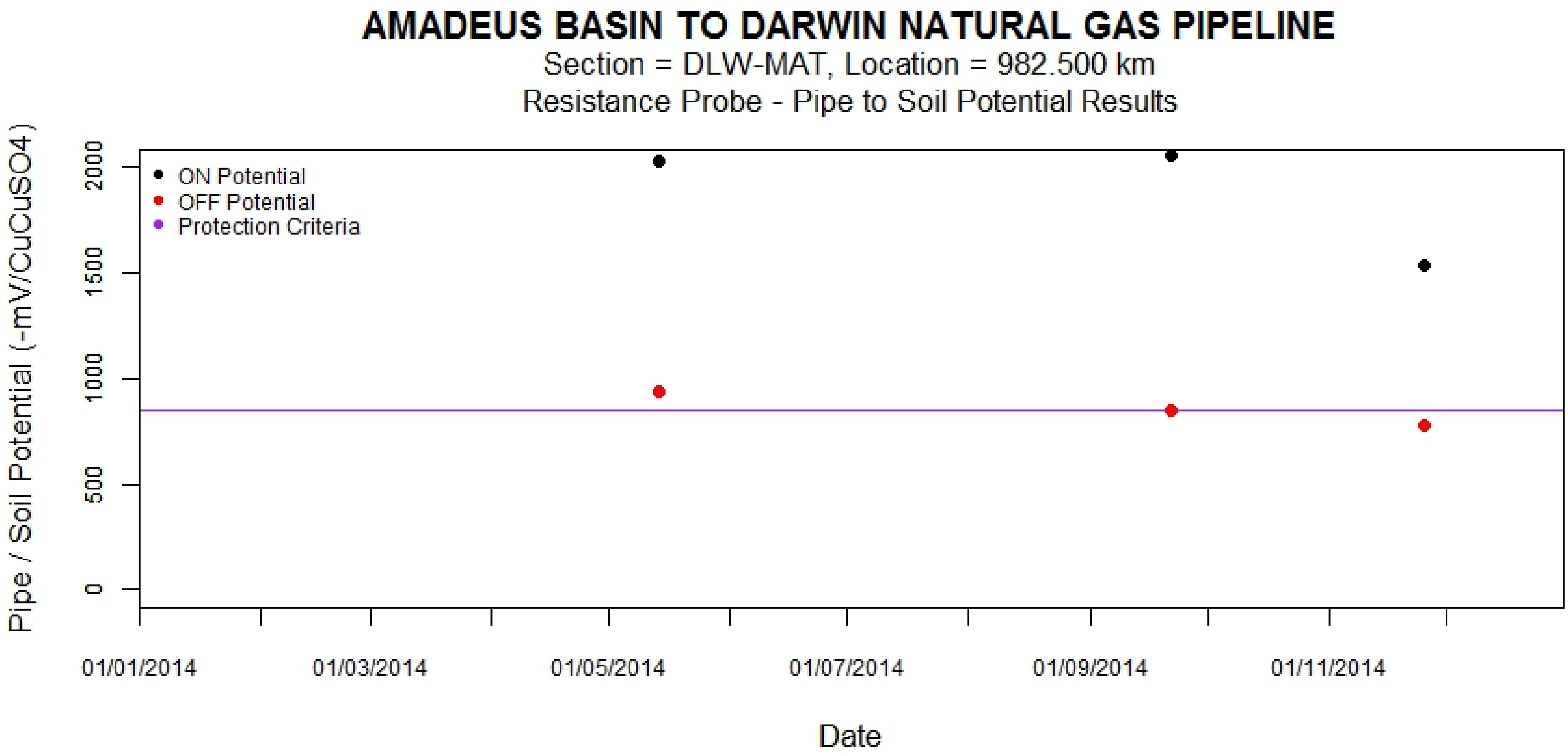




AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = NCW-DLW, Location = 979.000 km

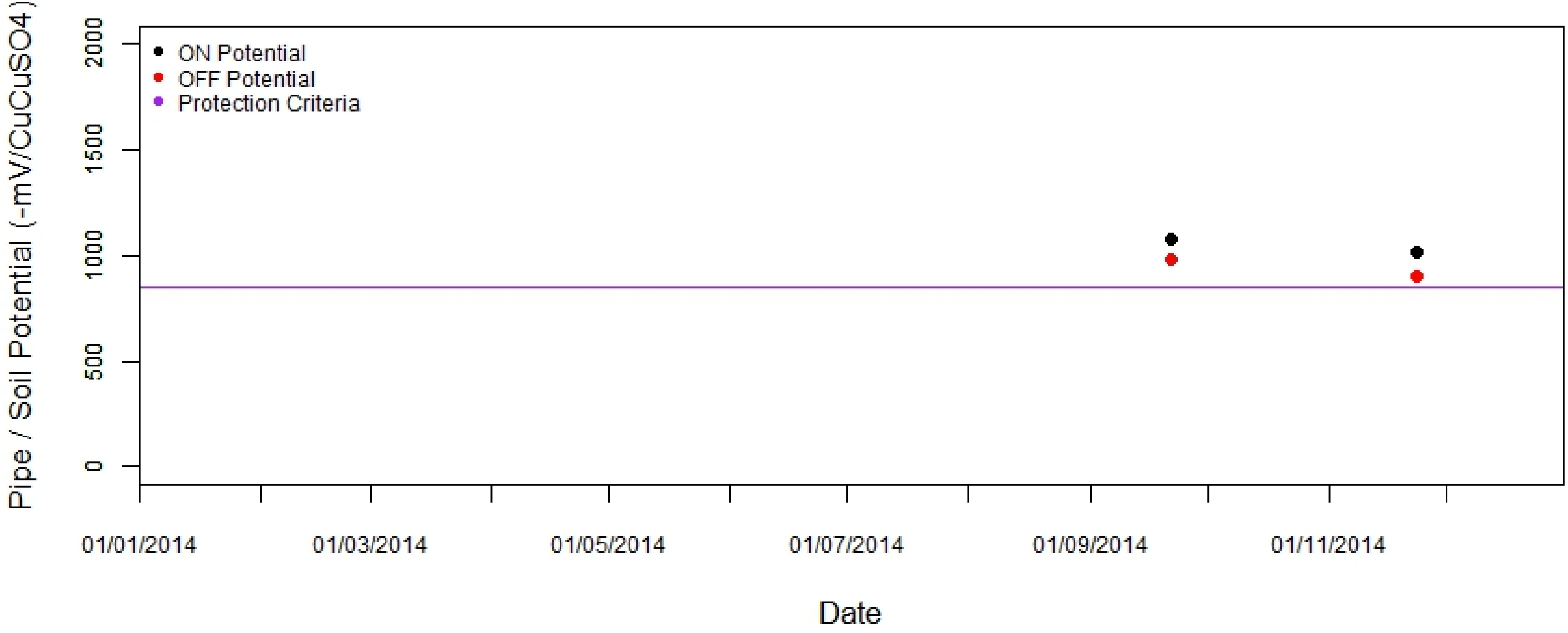
Resistance Probe - Pipe to Soil Potential Results

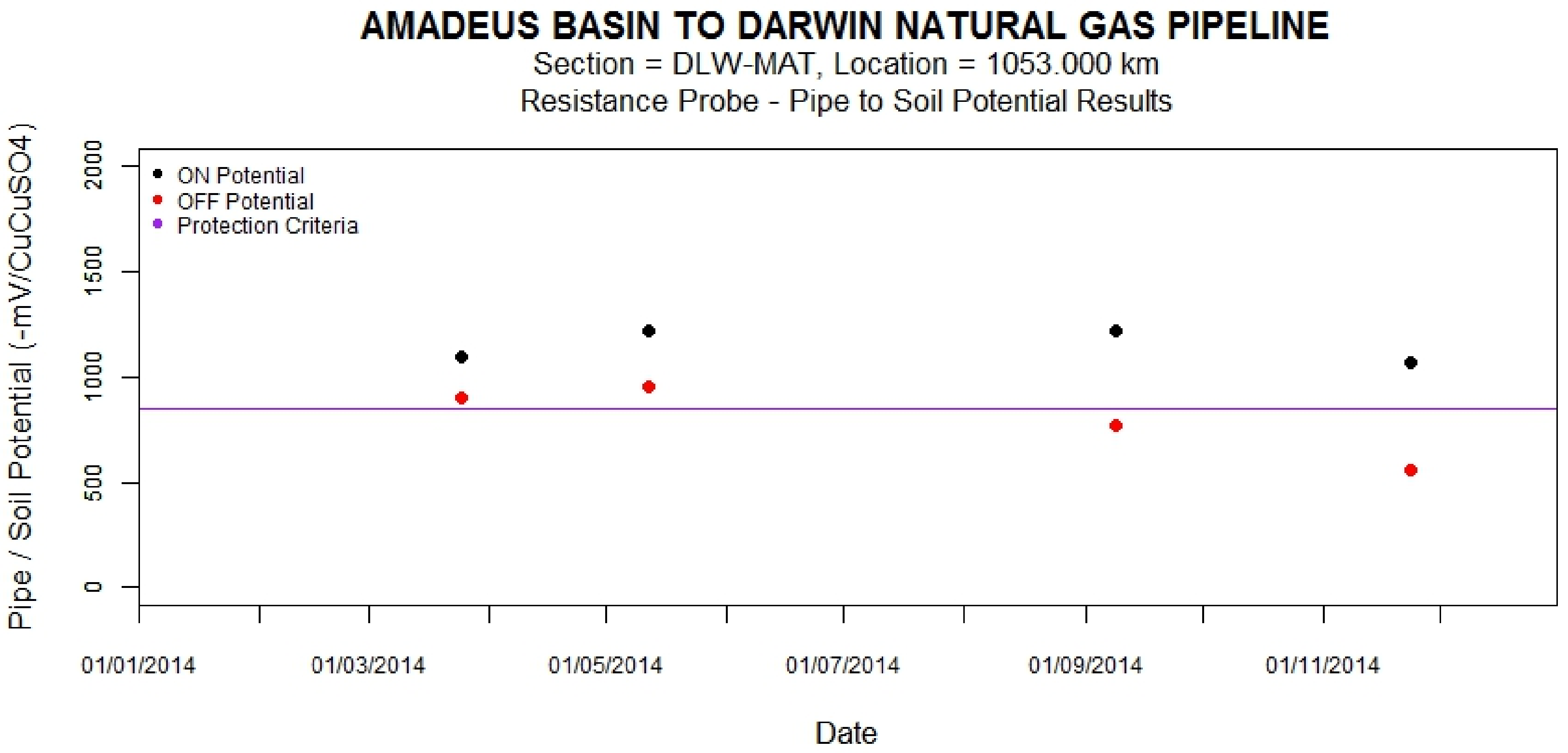

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = DLW-MAT, Location = 982.500 km
Resistance Probe - Pipe to Soil Potential Results
Pipe / Soil Potential (-mV/CuCuSO4)
2000
1500
1000
500
0
● ON Potential
● OFF Potential
● Protection Criteria
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

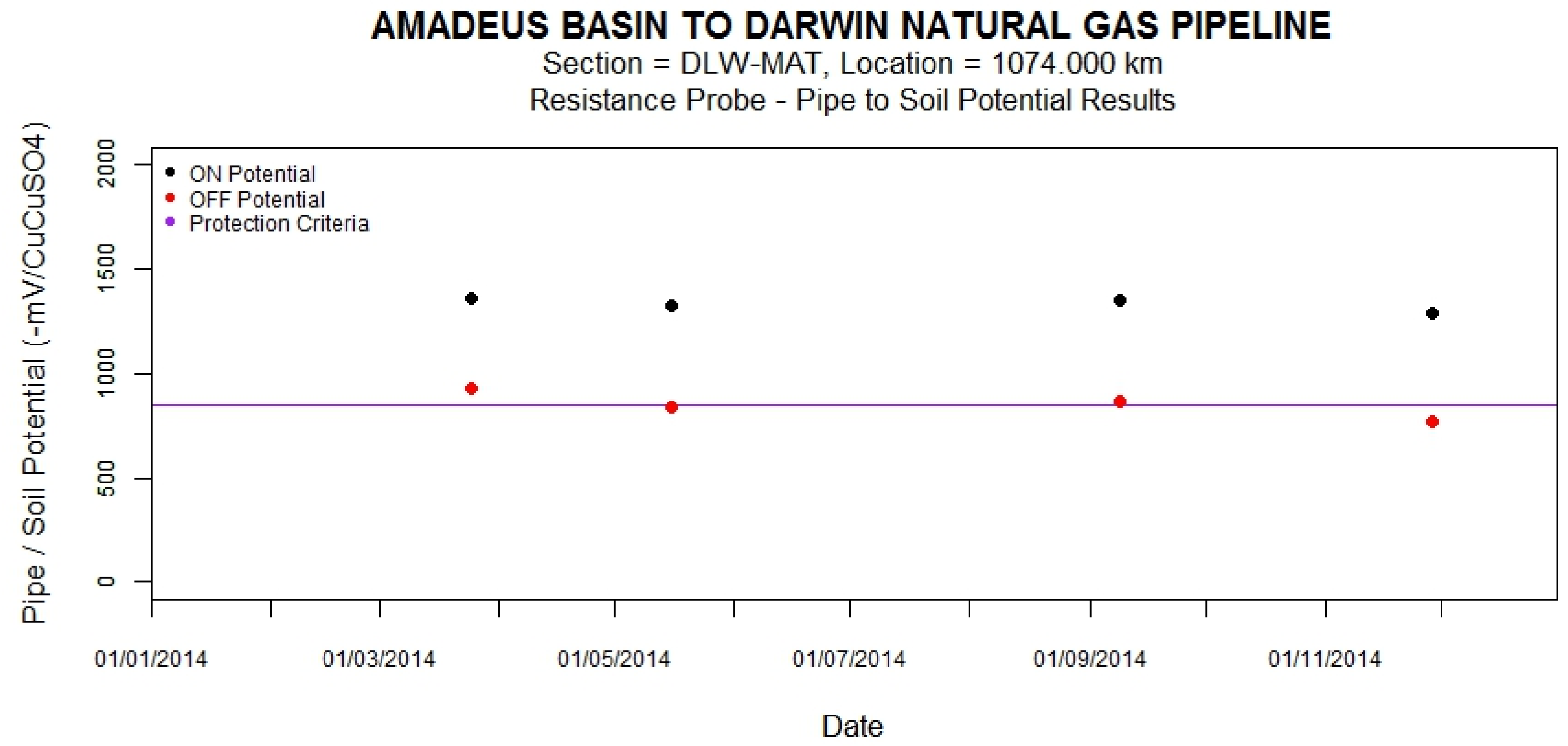
AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

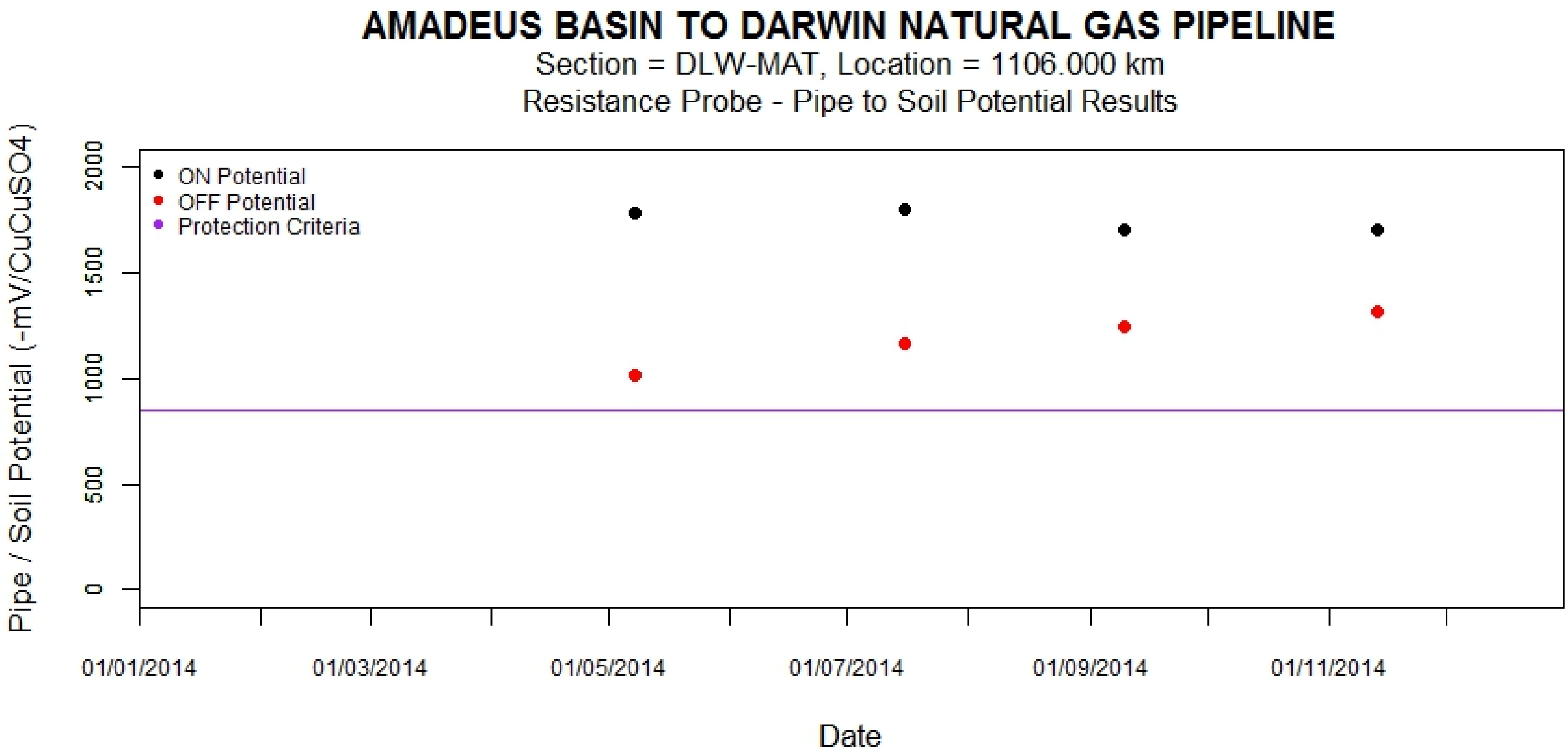
Section = DLW-MAT, Location = 1010.000 km

Resistance Probe - Pipe to Soil Potential Results




AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = DLW-MAT, Location = 1053.000 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

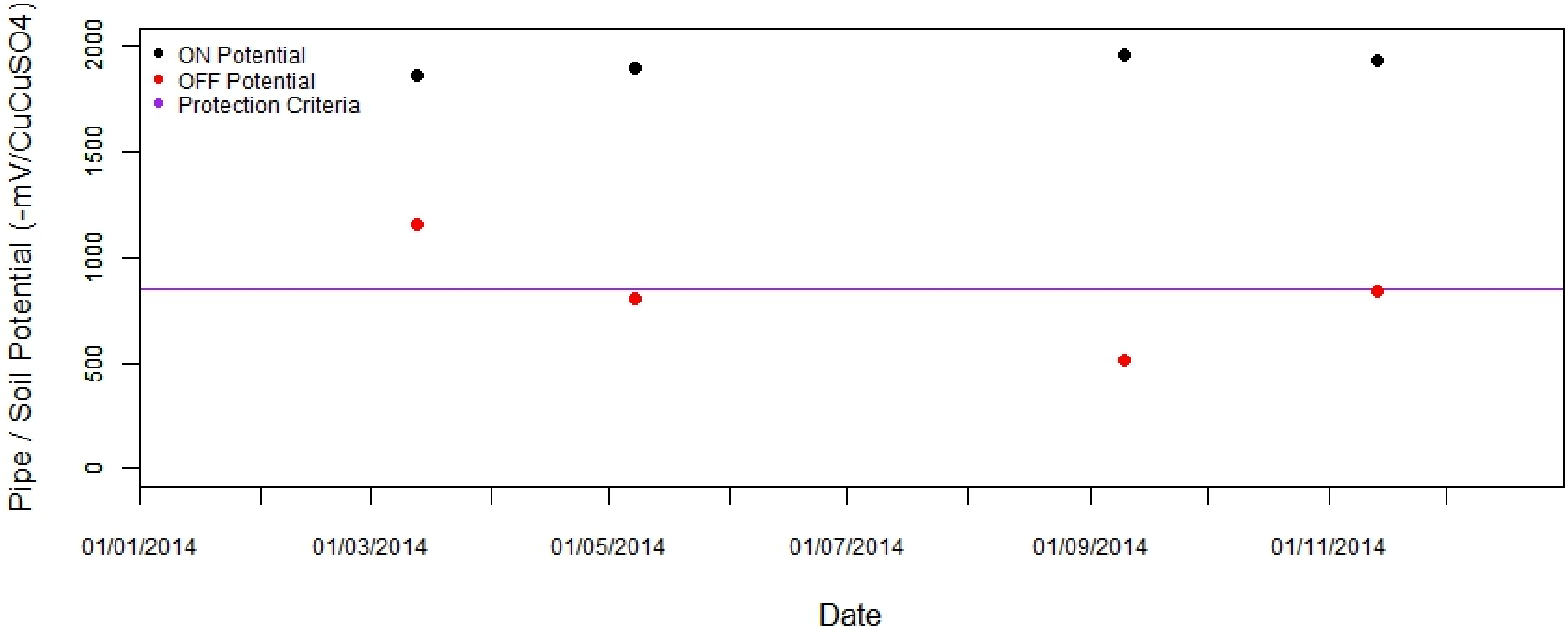

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = DLW-MAT, Location = 1074.000 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
2000
1500
1000
500
0
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

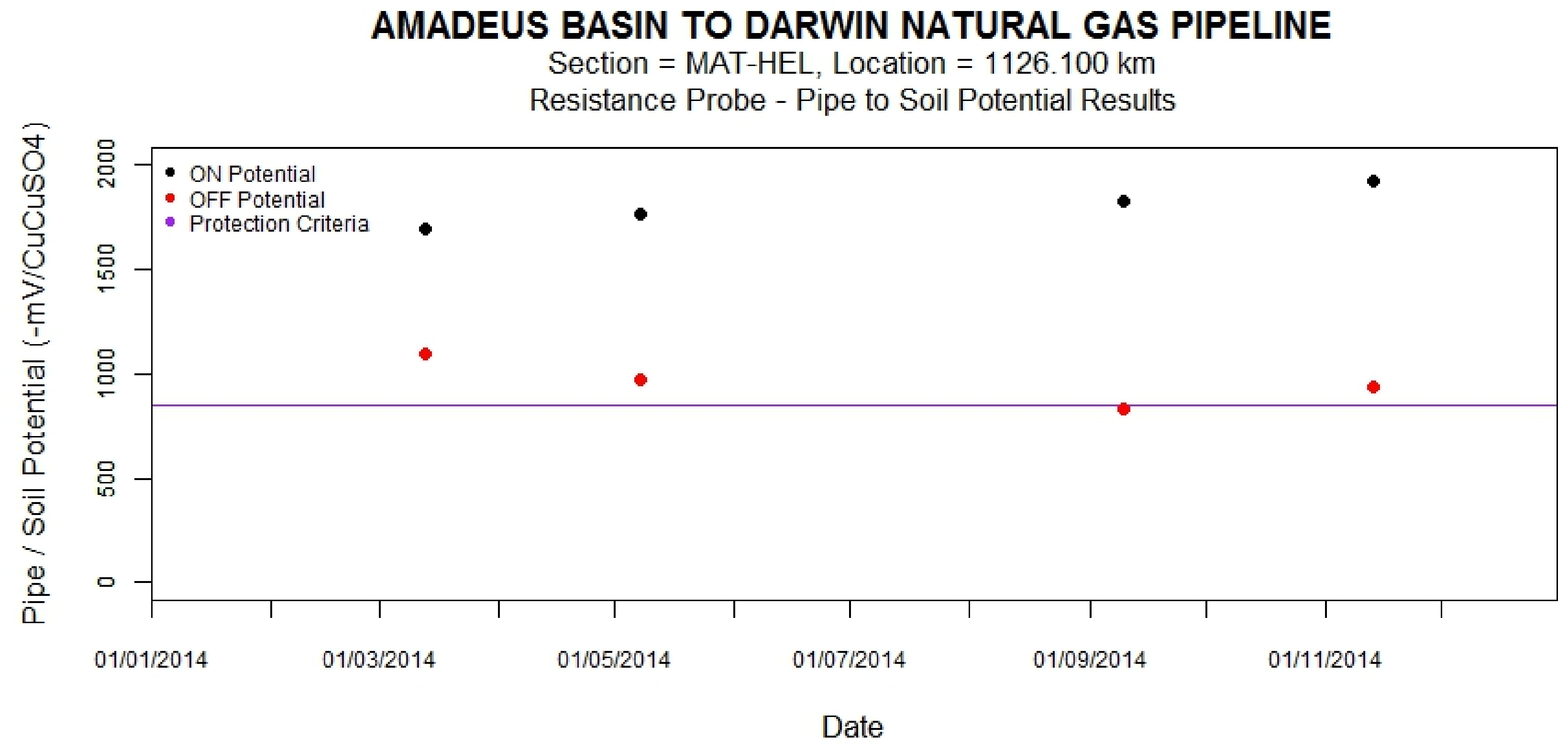

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = DLW-MAT, Location = 1106.000 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = MAT-HEL, Location = 1108.100 km

Resistance Probe - Pipe to Soil Potential Results





AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

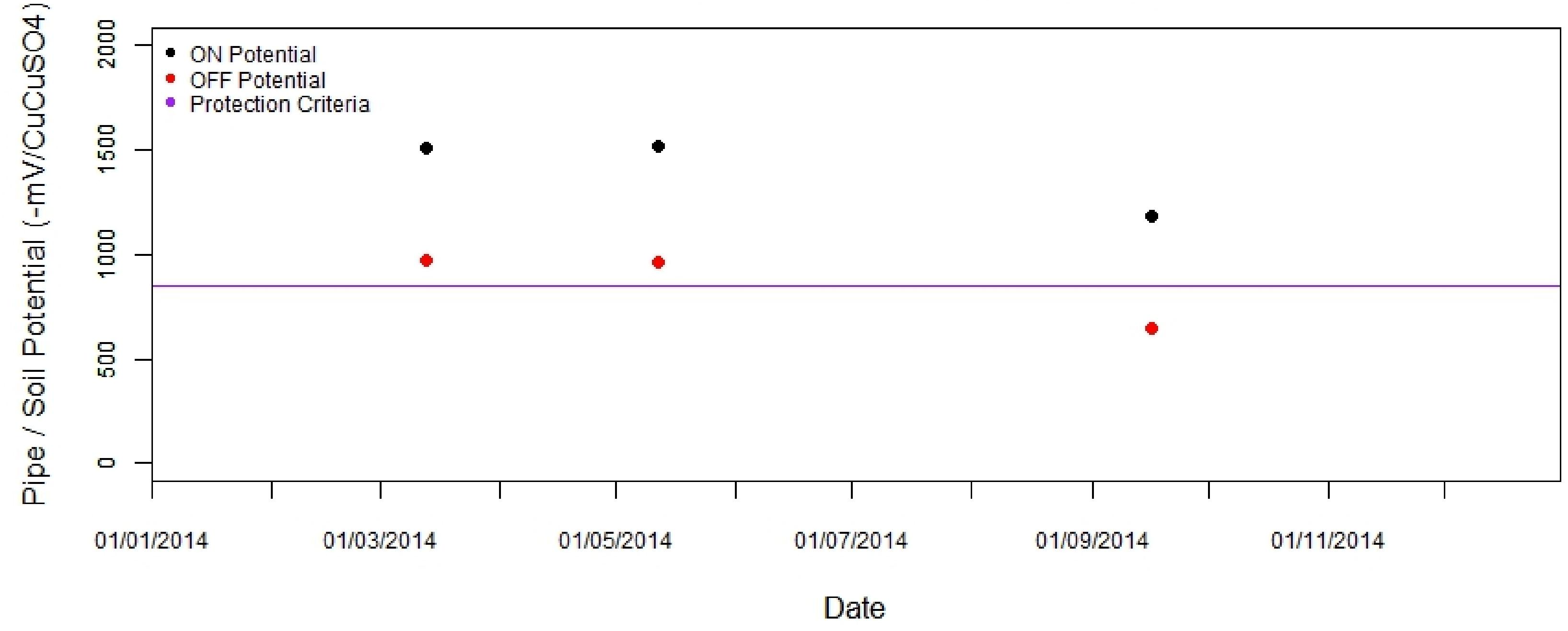
Section = MAT-HEL, Location = 1126.100 km

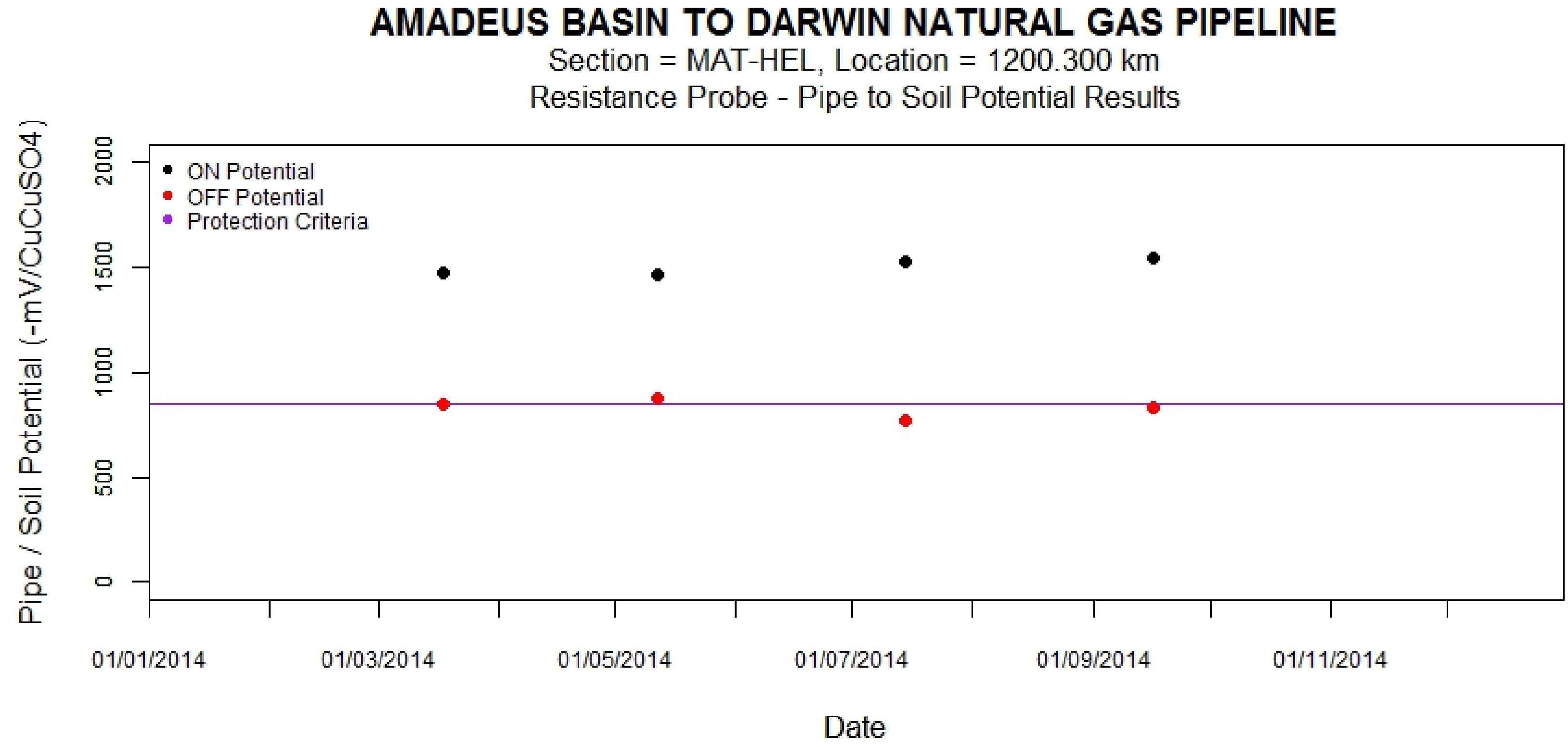
Resistance Probe - Pipe to Soil Potential Results

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = MAT-HEL, Location = 1160.200 km

Resistance Probe - Pipe to Soil Potential Results

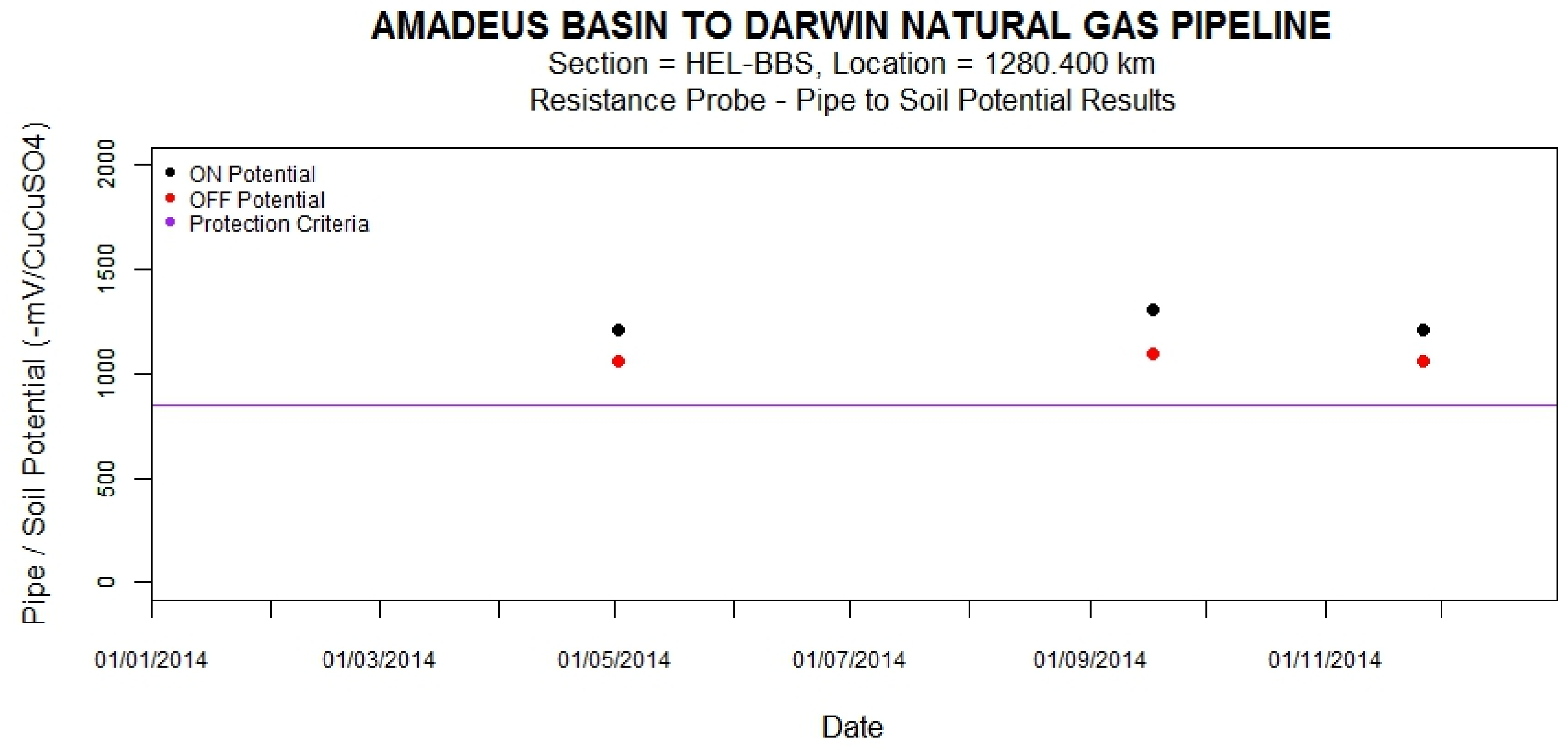




AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = MAT-HEL, Location = 1200.300 km

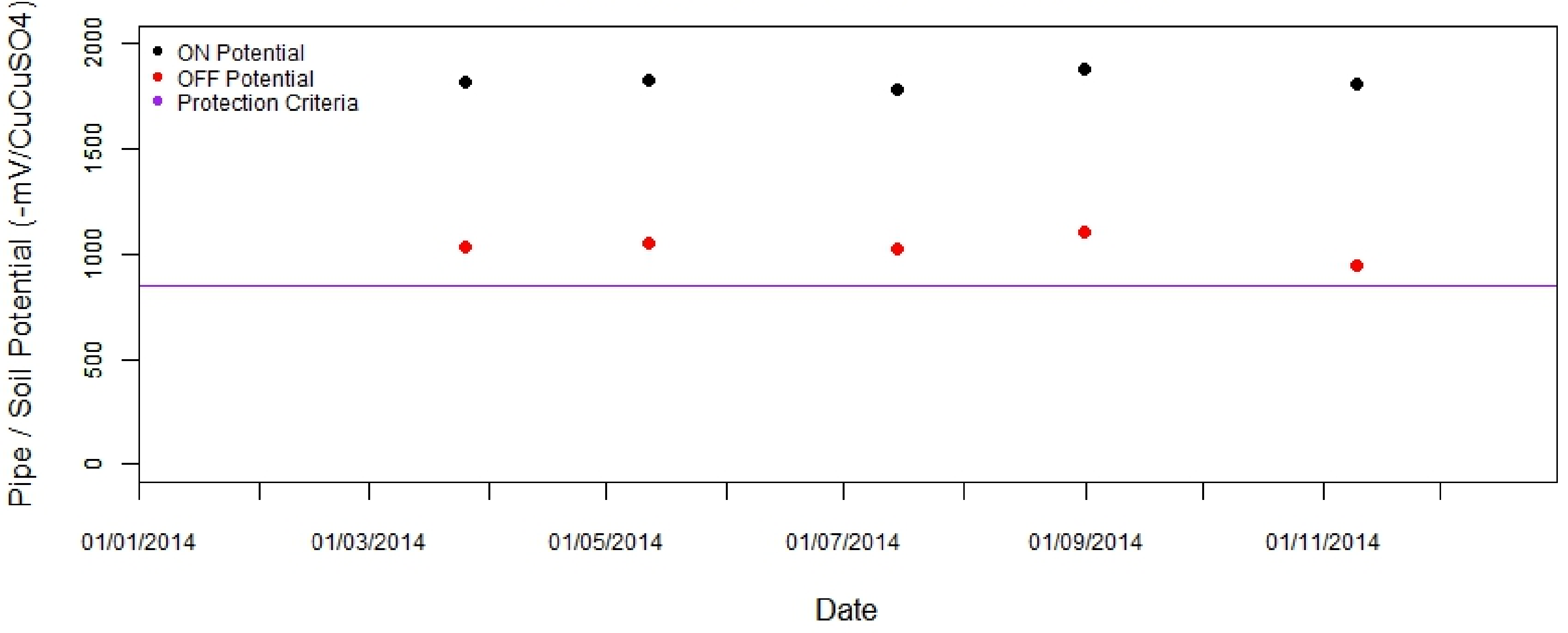
Resistance Probe - Pipe to Soil Potential Results


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = HEL-BBS, Location = 1280.400 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = MAT-HEL, Location = 1240.000 km

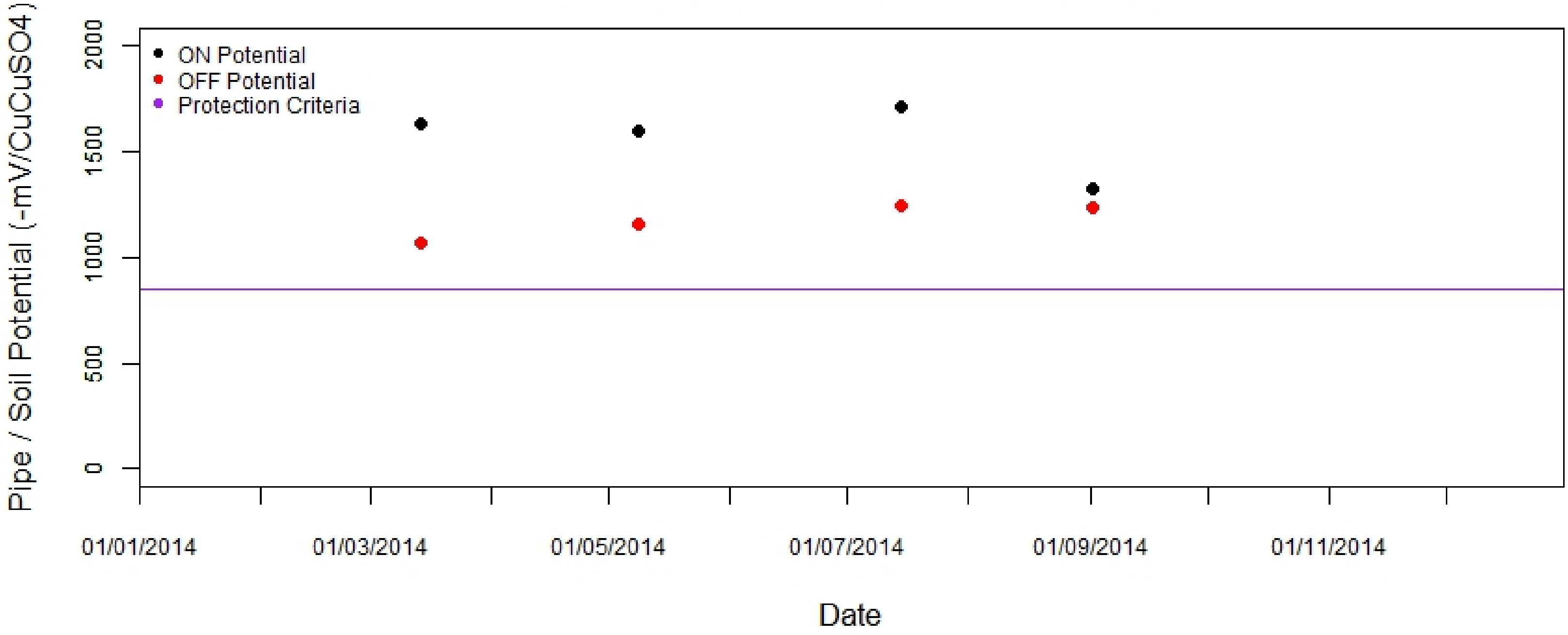
Resistance Probe - Pipe to Soil Potential Results

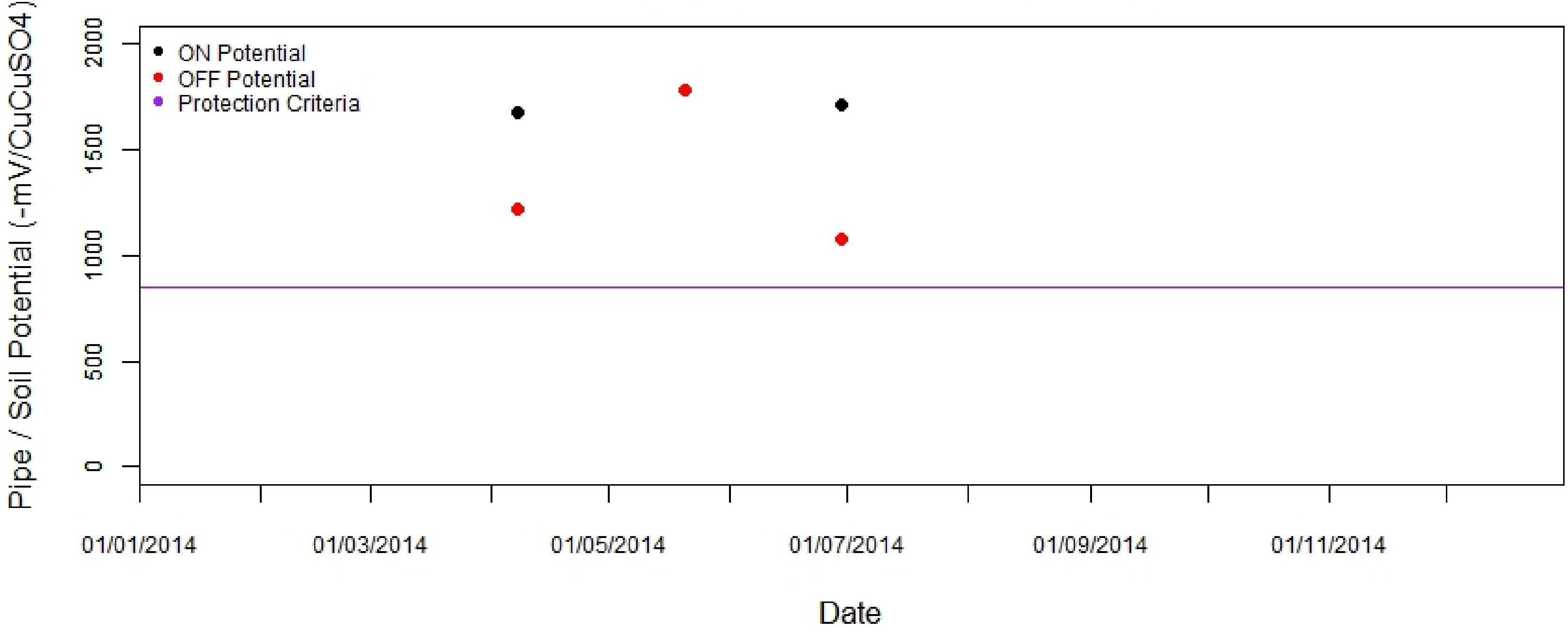


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = HEL-BBS, Location = 1251.700 km

Resistance Probe - Pipe to Soil Potential Results

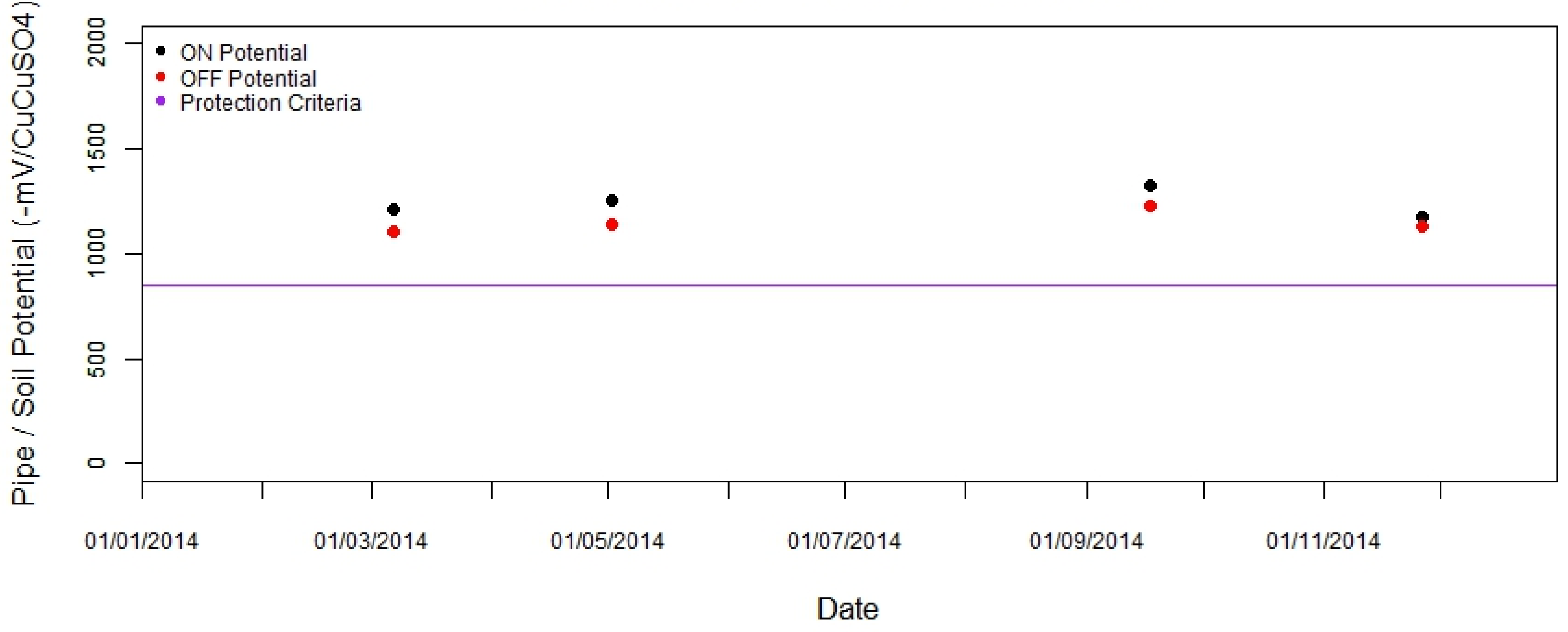




AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = HEL-BBS, Location = 1374.900 km

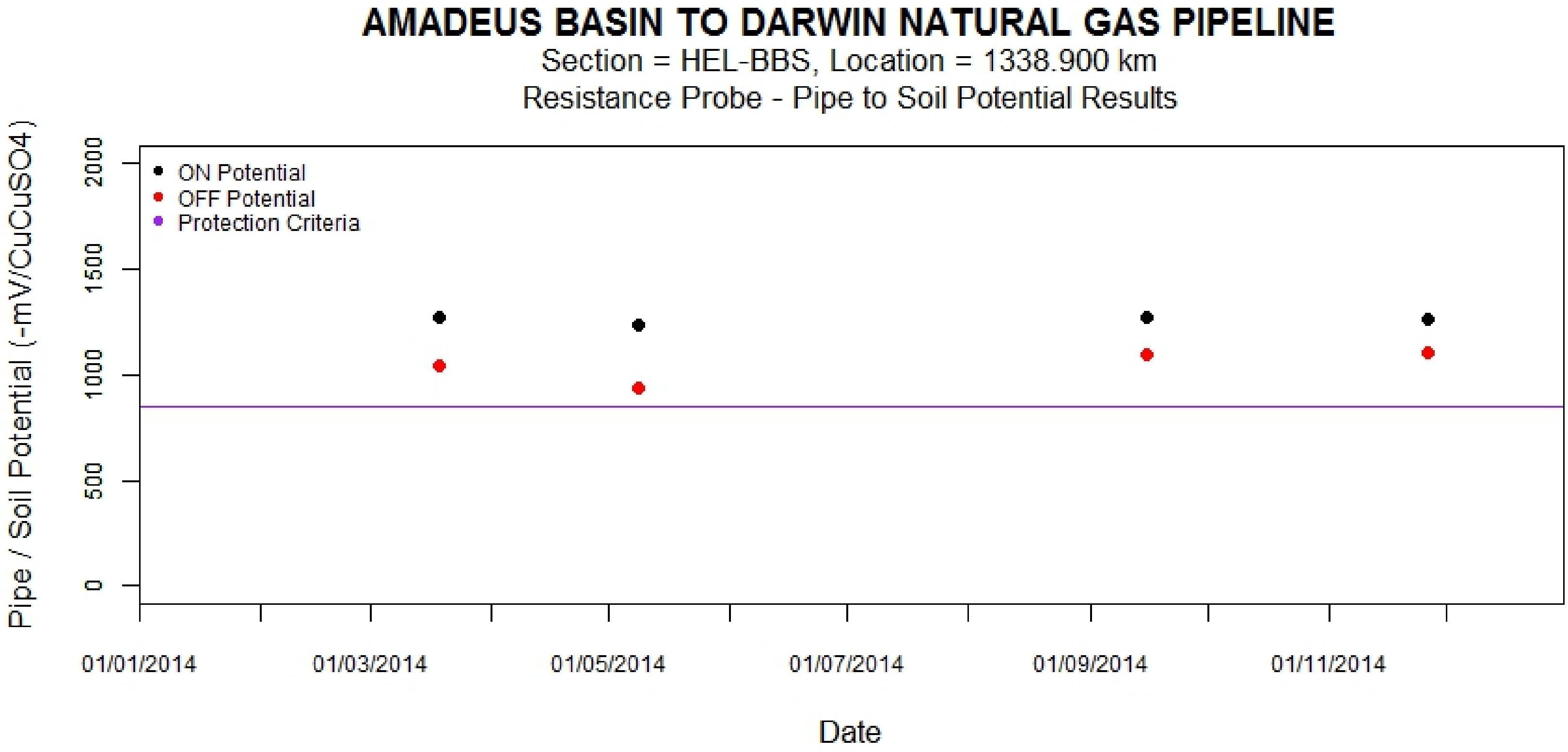
Resistance Probe - Pipe to Soil Potential Results



AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = HEL-BBS, Location = 1316.700 km

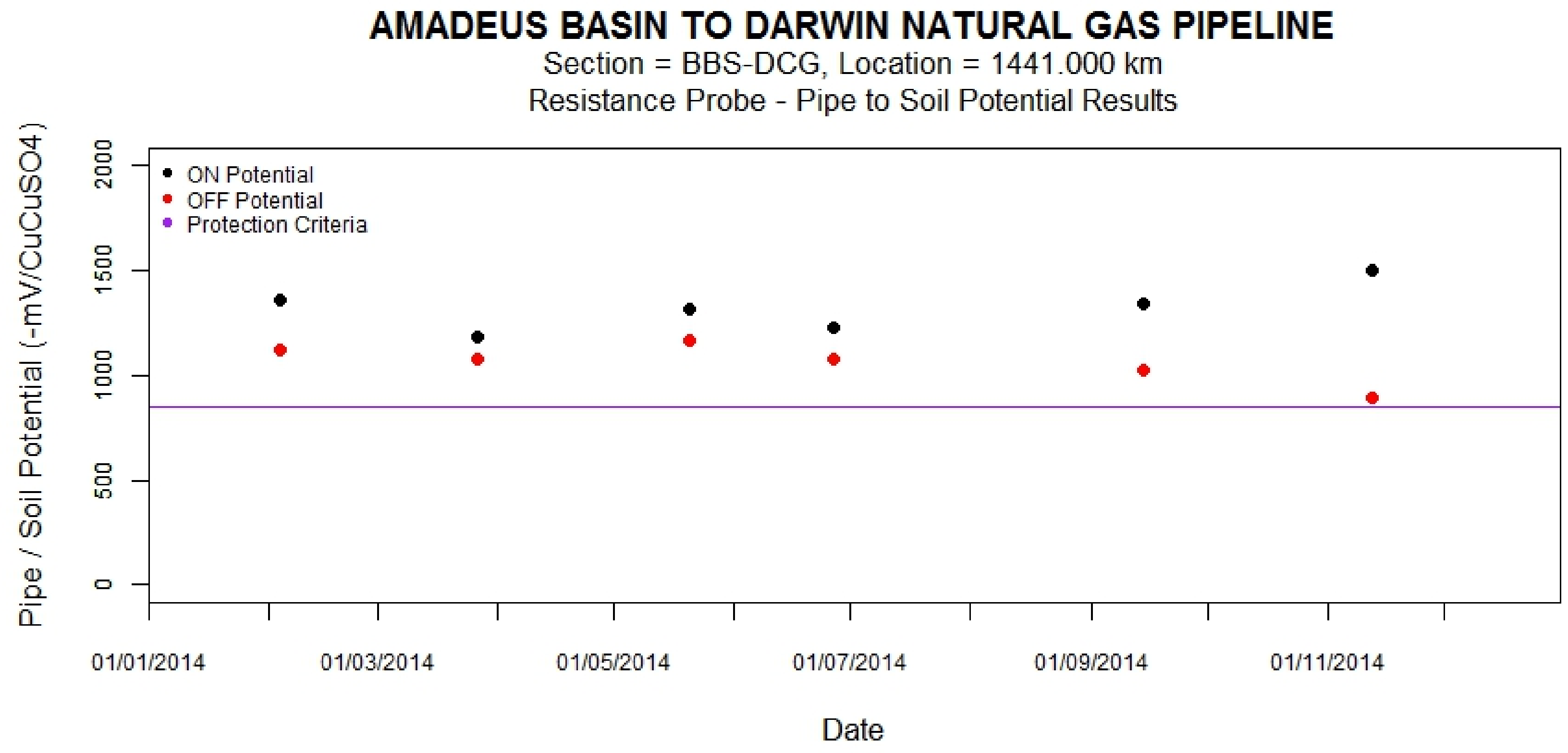
Resistance Probe - Pipe to Soil Potential Results



AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = HEL-BBS, Location = 1338.900 km

Resistance Probe - Pipe to Soil Potential Results

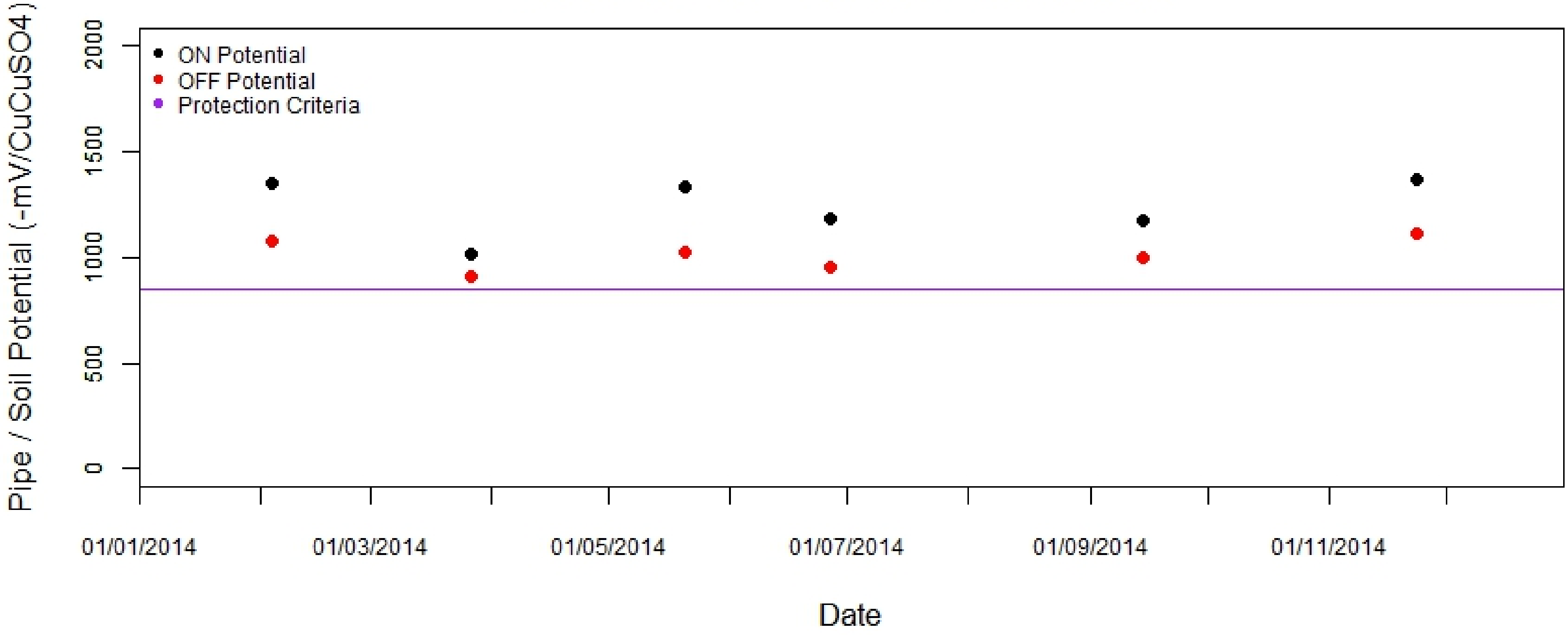


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = BBS-DCG, Location = 1441.000 km
Resistance Probe - Pipe to Soil Potential Results

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = BBS-DCG, Location = 1472.800 km

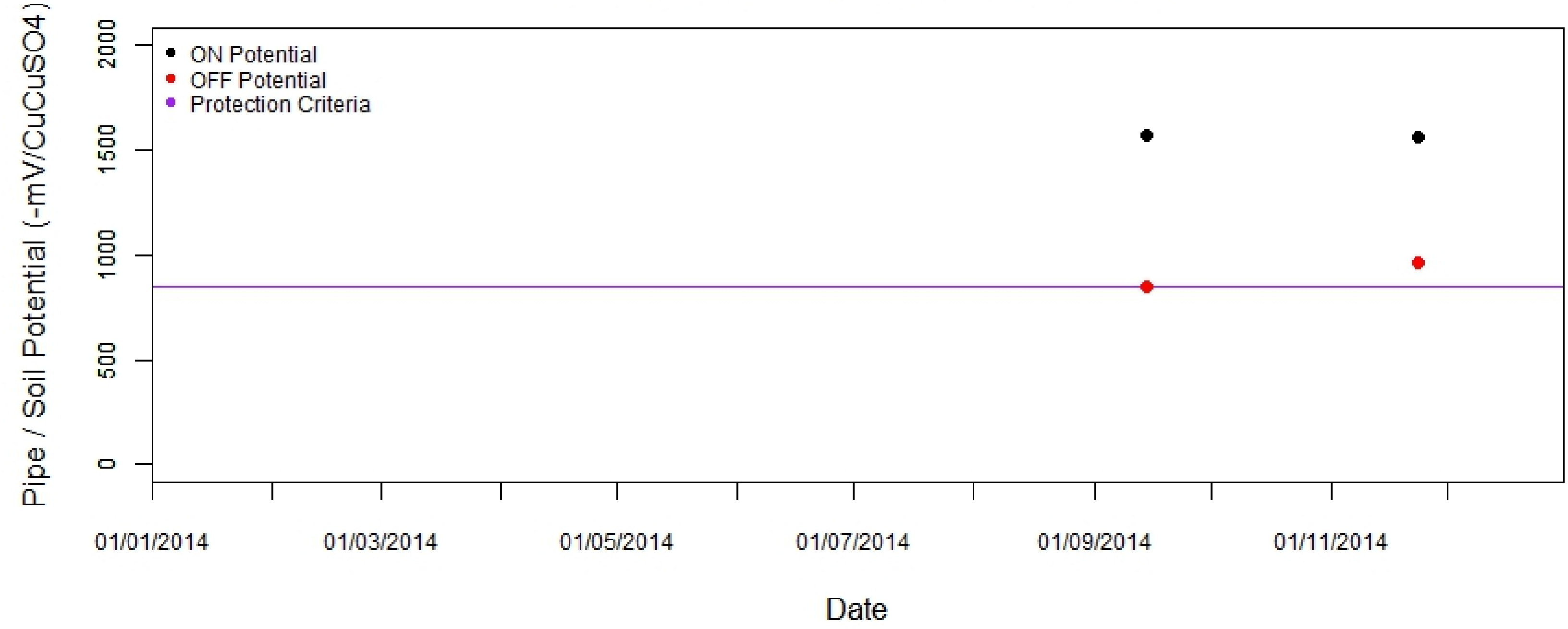
Resistance Probe - Pipe to Soil Potential Results

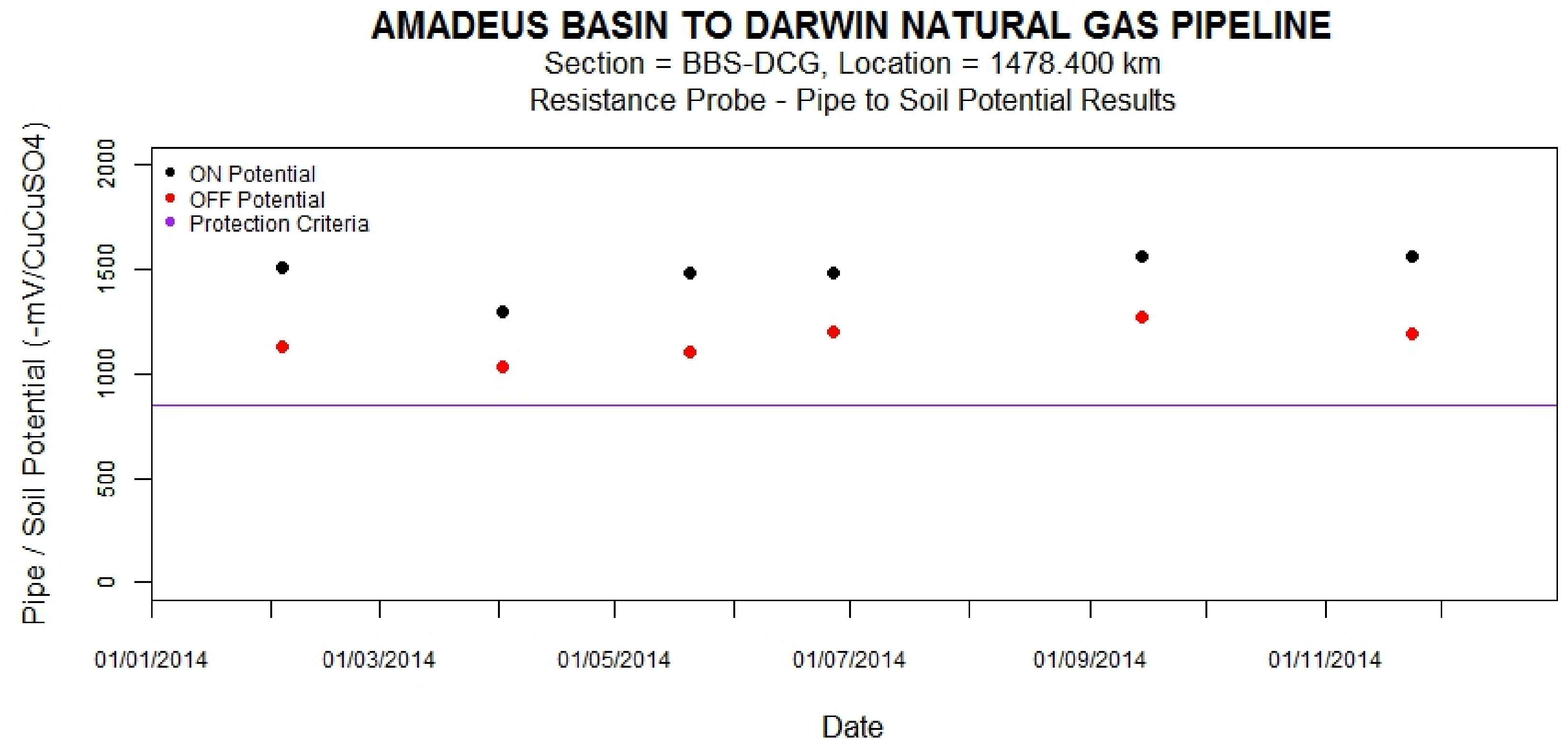


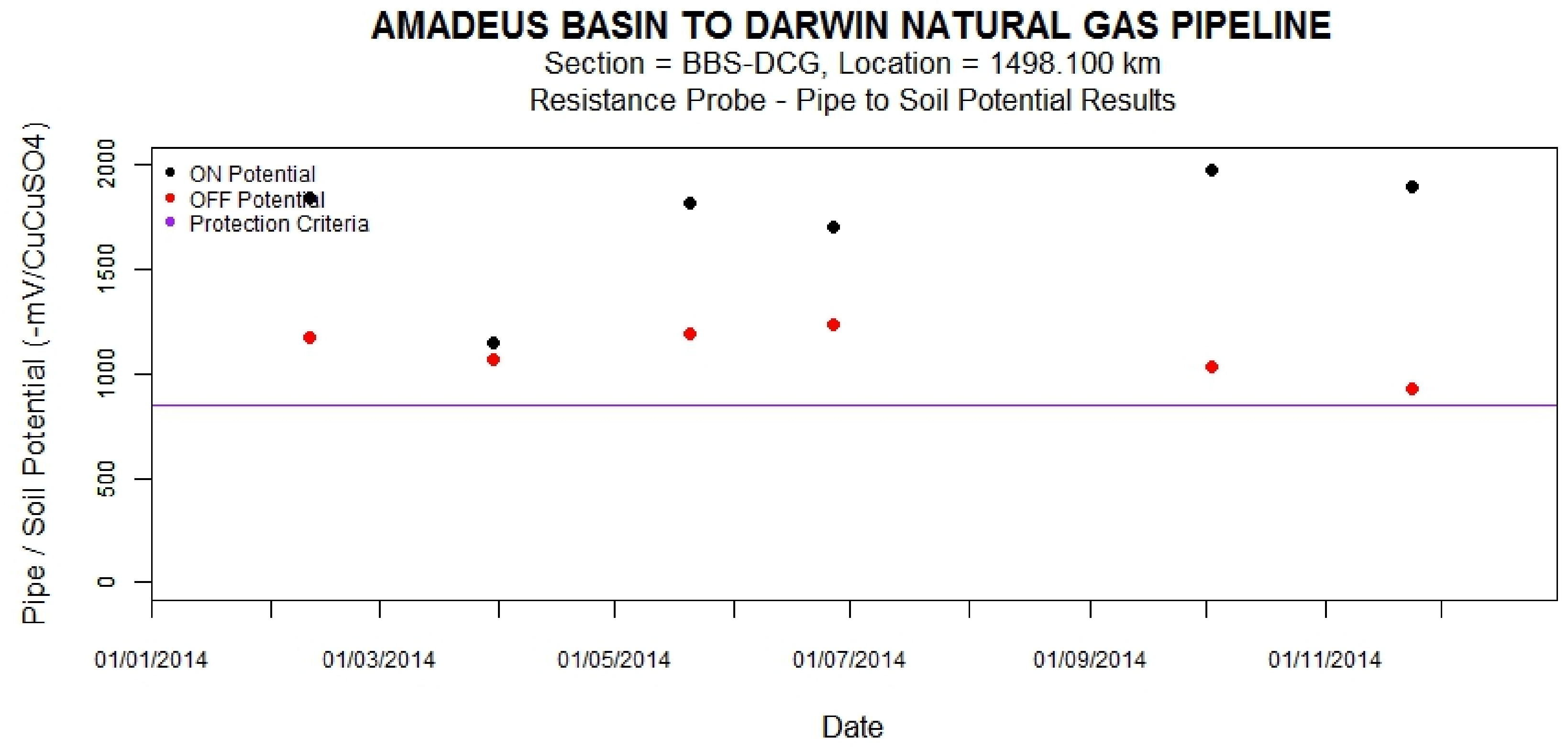
AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

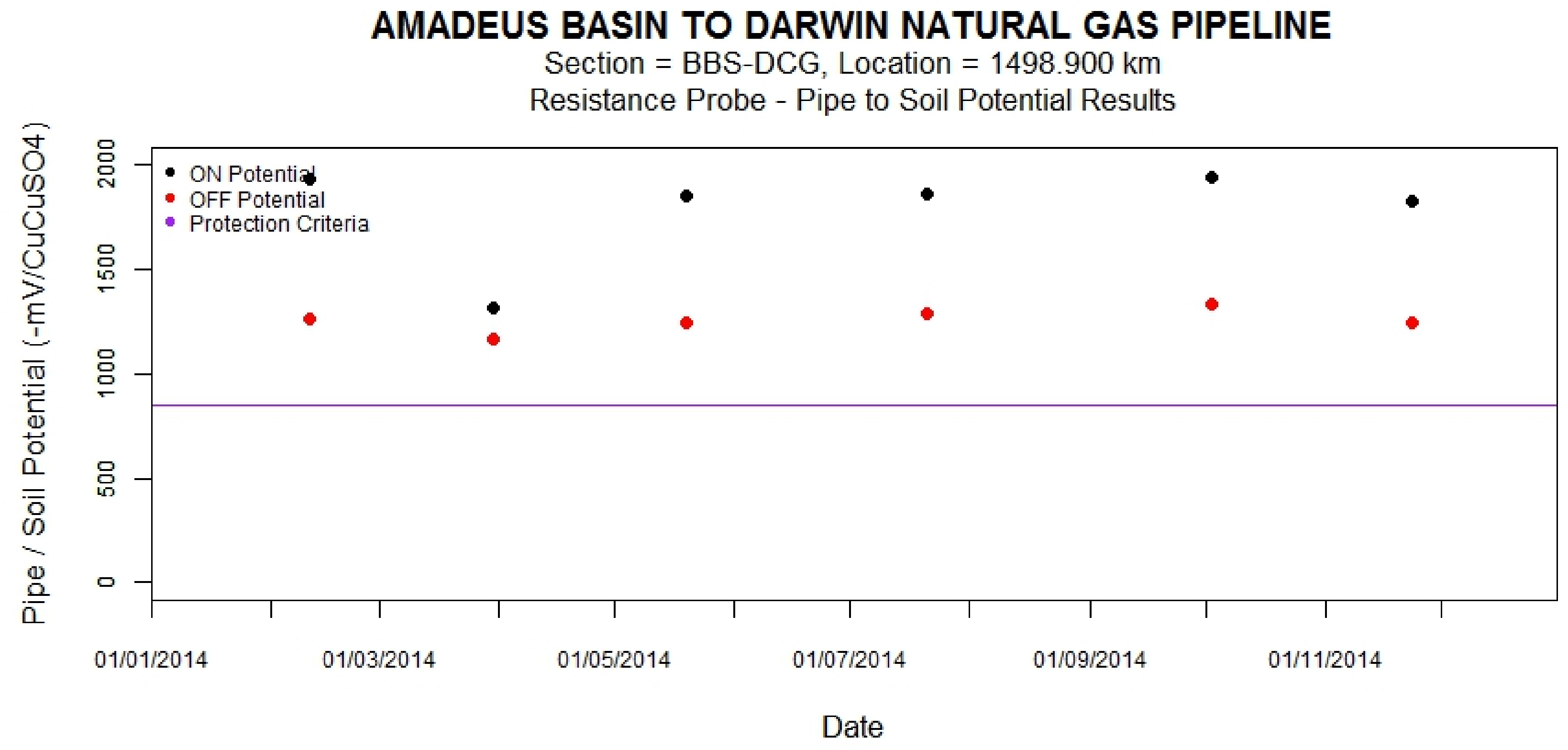
Section = BBS-DCG, Location = 1476.700 km

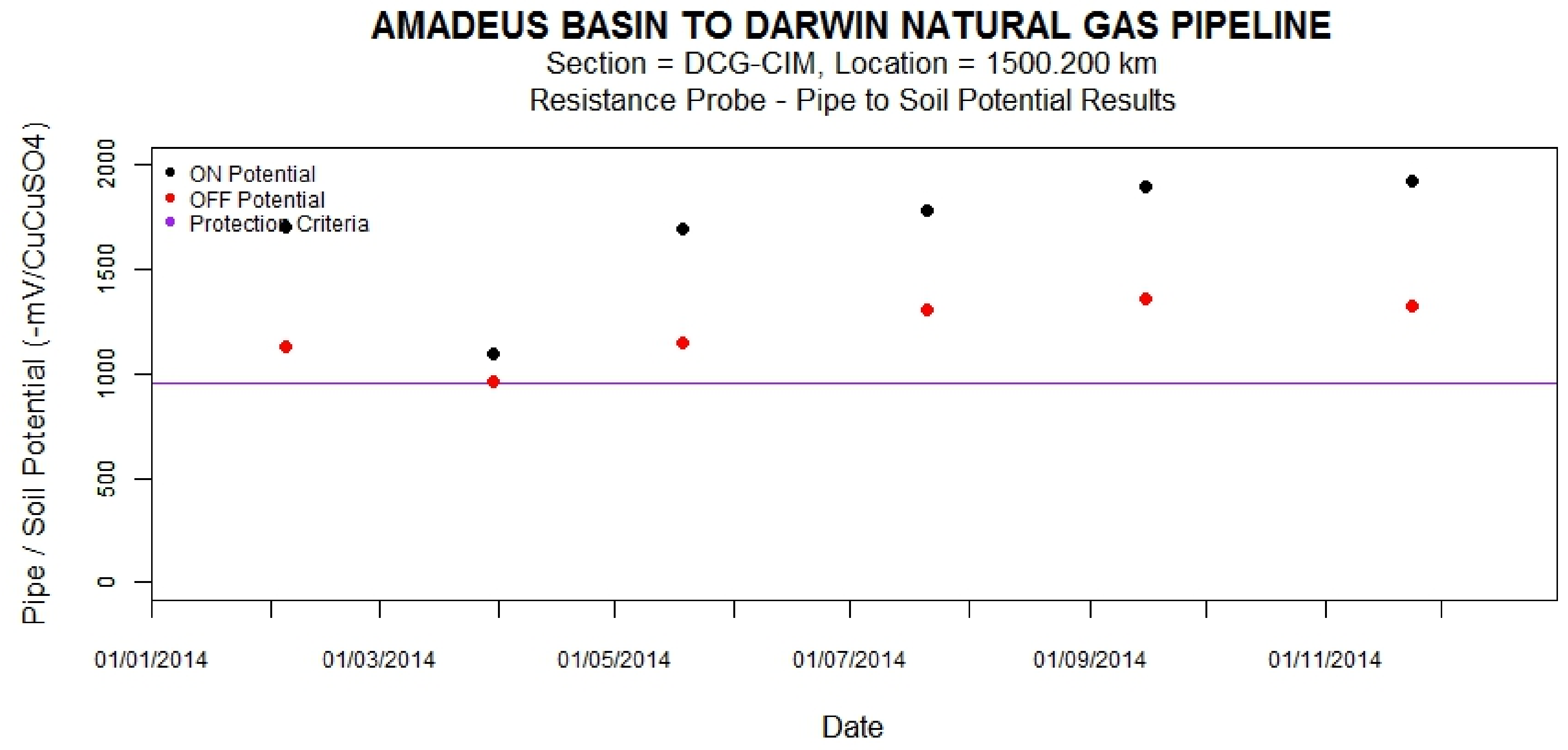
Resistance Probe - Pipe to Soil Potential Results




AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = BBS-DCG, Location = 1478.400 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = BBS-DCG, Location = 1498.100 km
Resistance Probe - Pipe to Soil Potential Results
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
ON Potential
OFF Potential
Protection Criteria
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

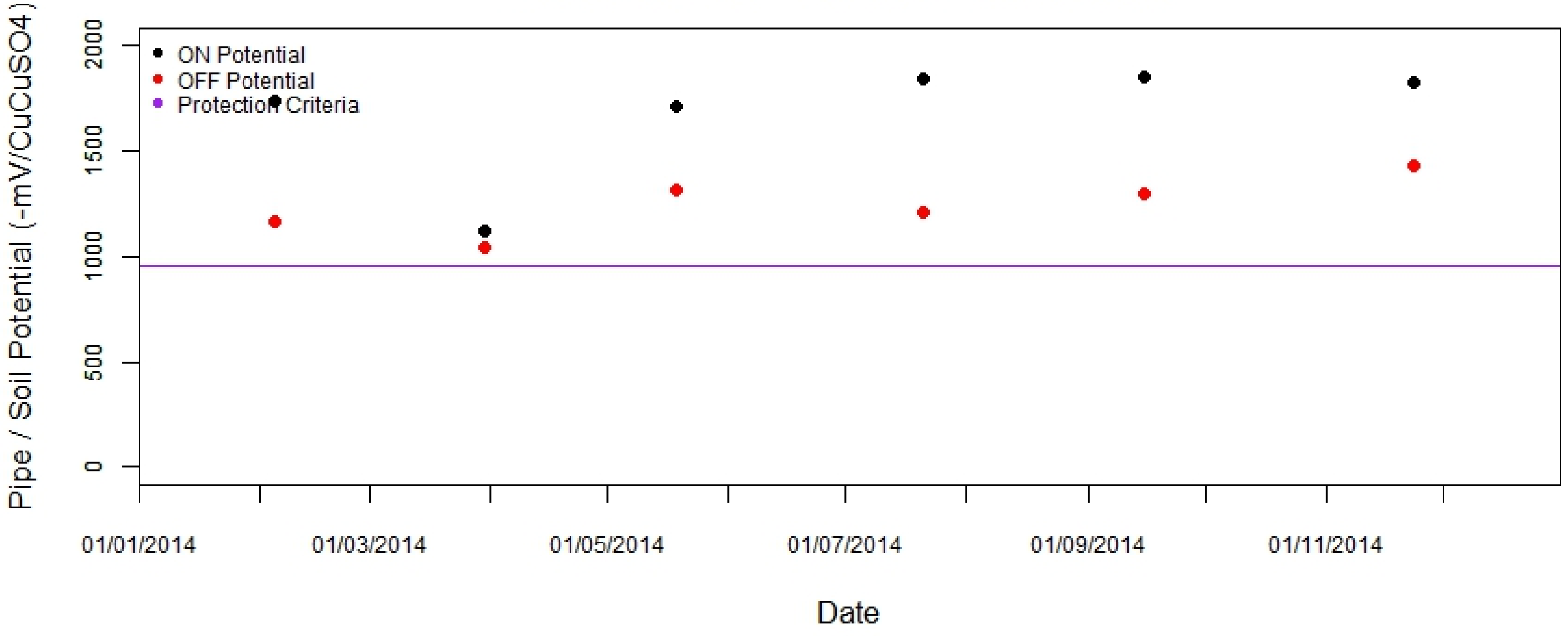
AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = BBS-DCG, Location = 1498.900 km
Resistance Probe - Pipe to Soil Potential Results
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
ON Potential
OFF Potential
Protection Criteria
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

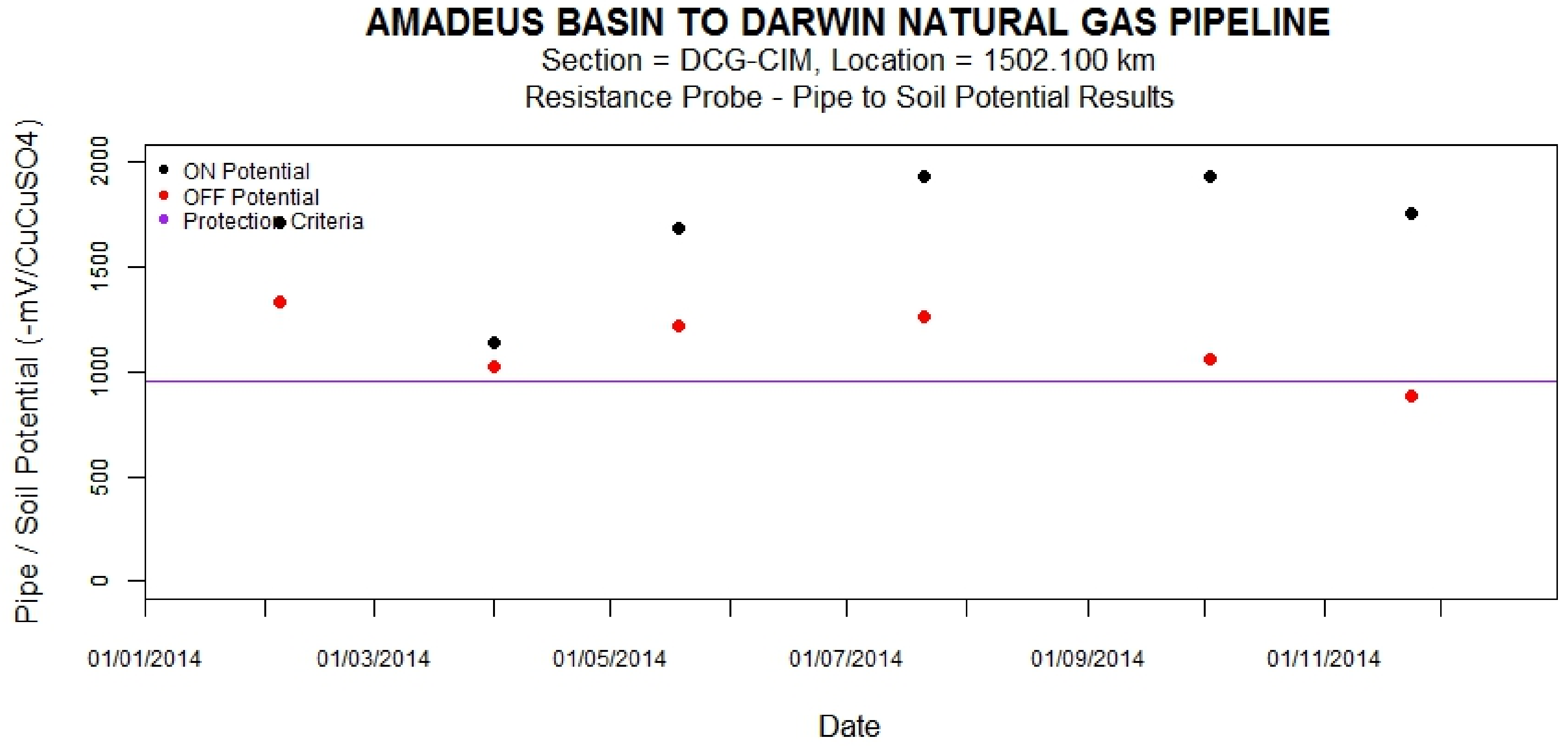

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = DCG-CIM, Location = 1500.200 km
Resistance Probe - Pipe to Soil Potential Results
Pipe / Soil Potential (-mV/CuCuSO4)
2000
1500
1000
500
0
ON Potential
OFF Potential
Protection Criteria
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = DCG-CIM, Location = 1501.100 km

Resistance Probe - Pipe to Soil Potential Results

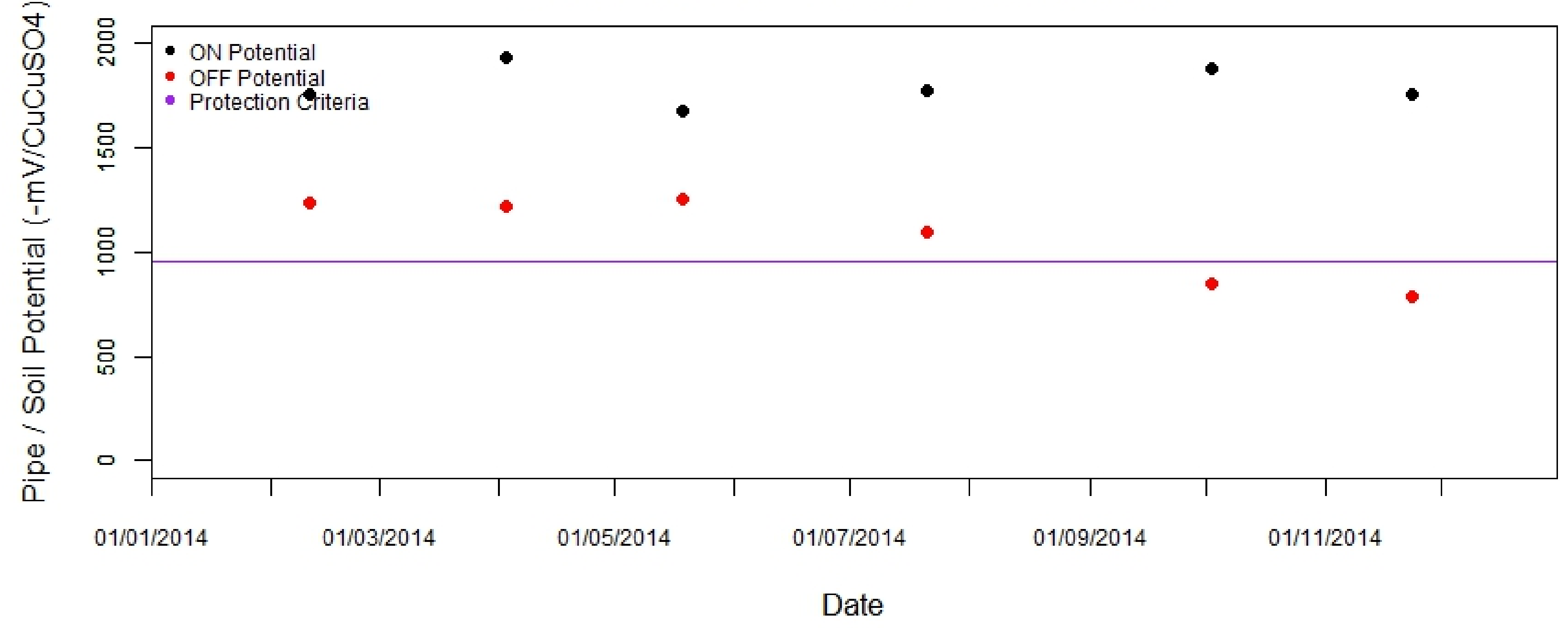




AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = DCG-CIM, Location = 1502.100 km

Resistance Probe - Pipe to Soil Potential Results



AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

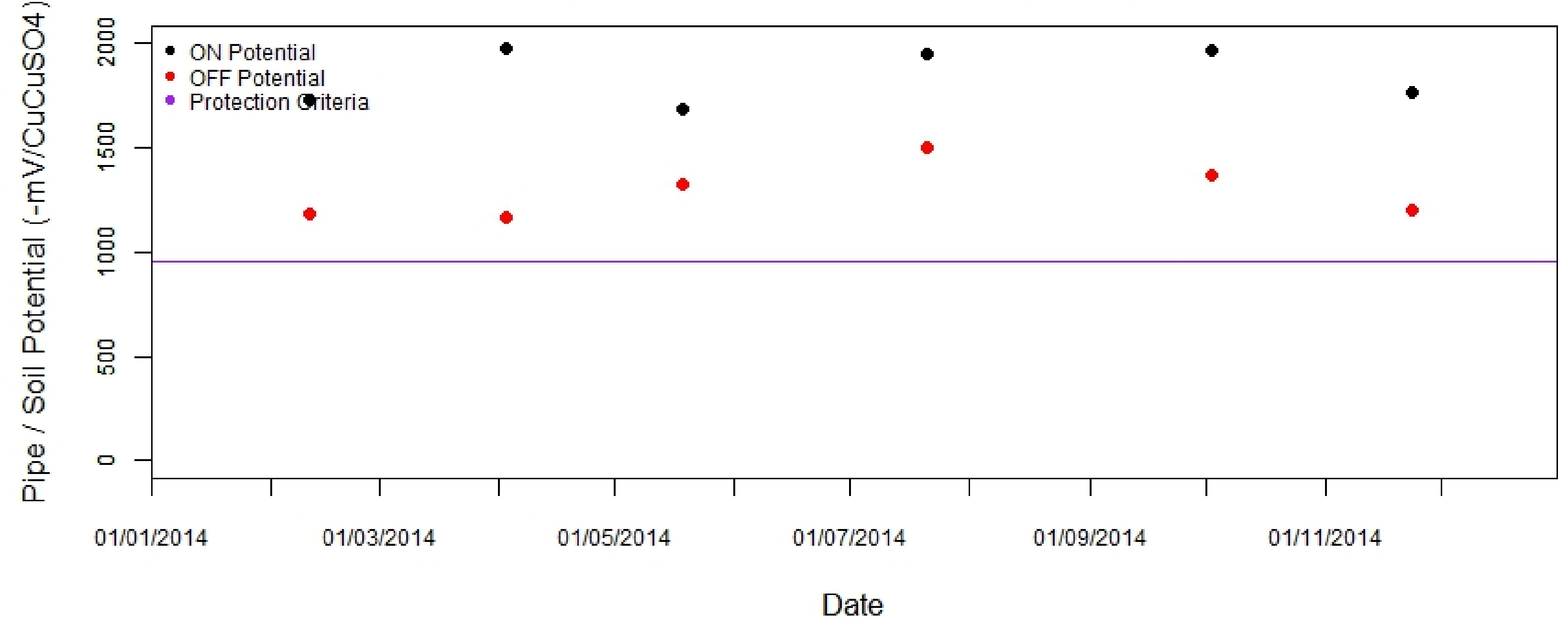
Section = DCG-CIM, Location = 1503.100 km

Resistance Probe - Pipe to Soil Potential Results

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = DCG-CIM, Location = 1504.100 km

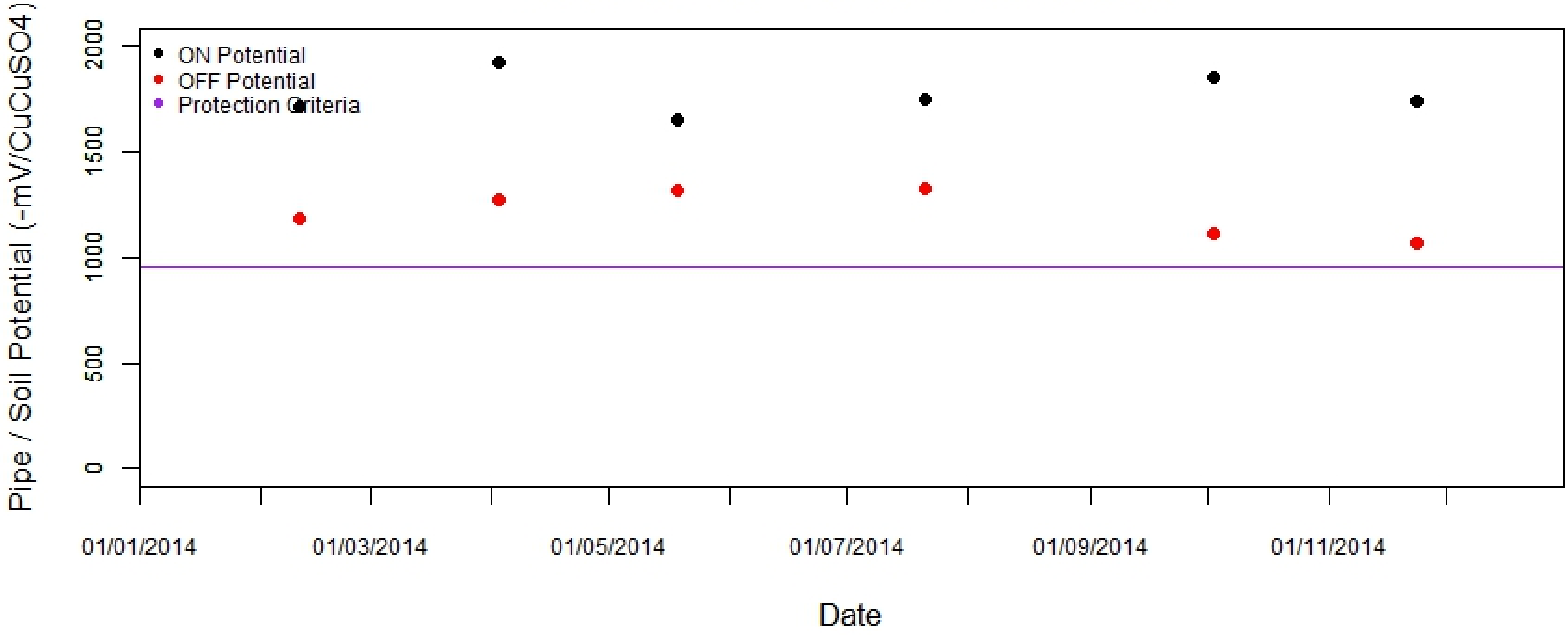
Resistance Probe - Pipe to Soil Potential Results

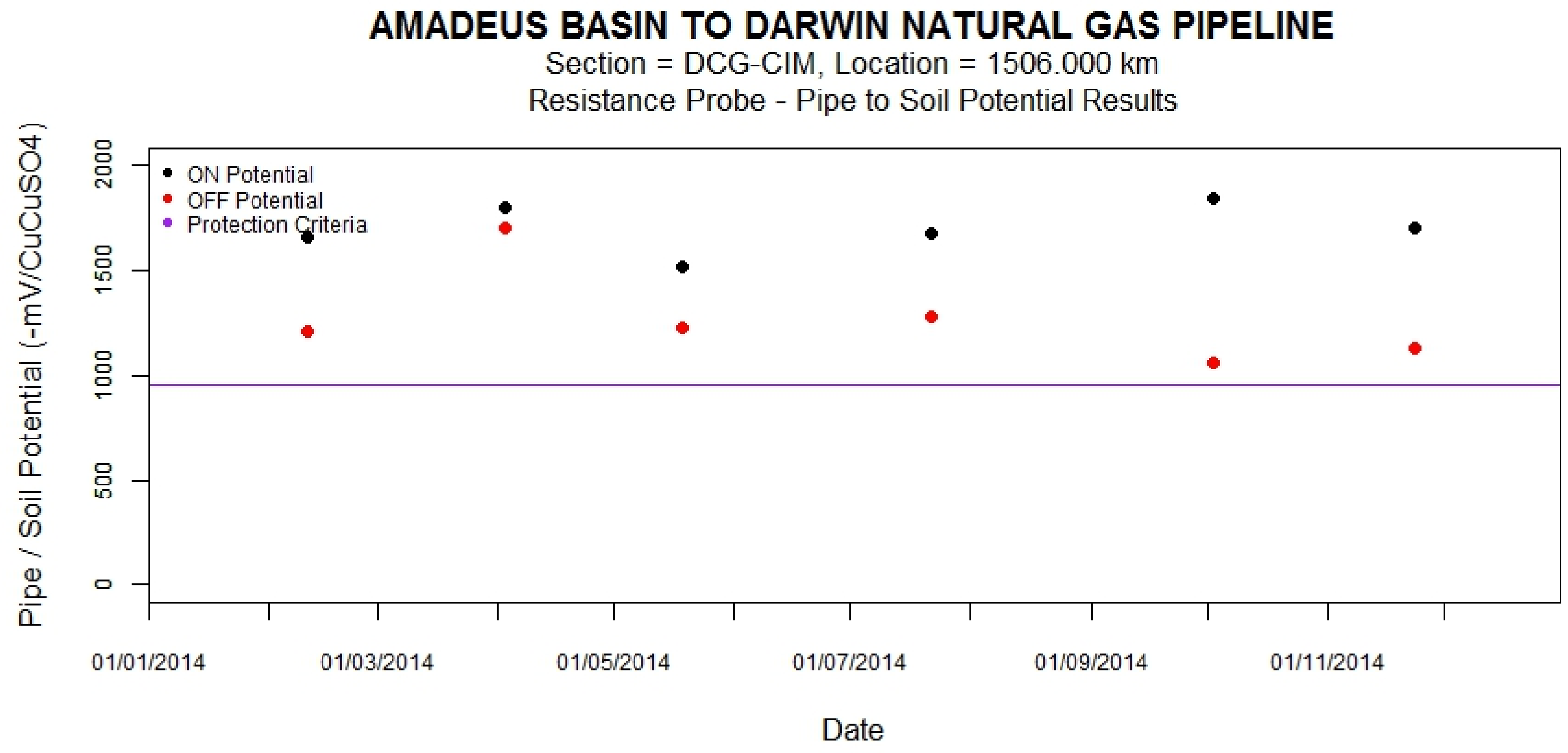


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = DCG-CIM, Location = 1504.900 km

Resistance Probe - Pipe to Soil Potential Results

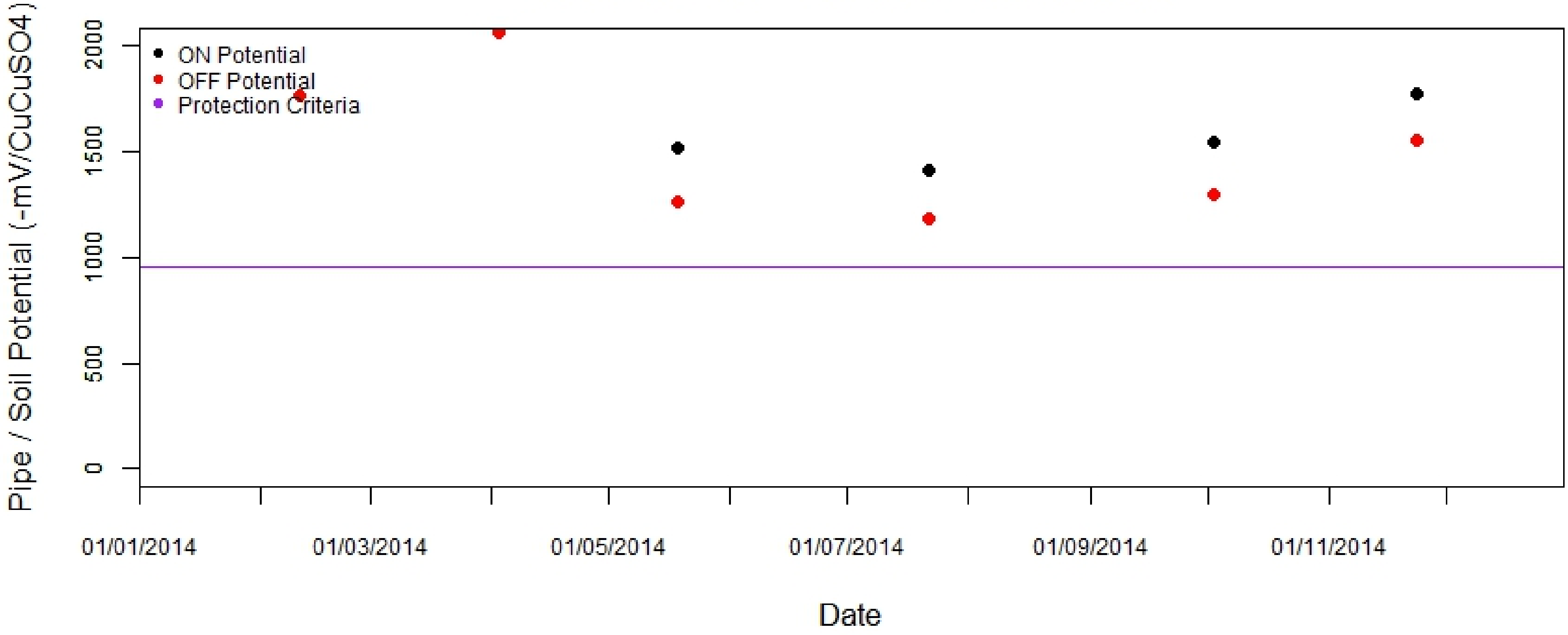


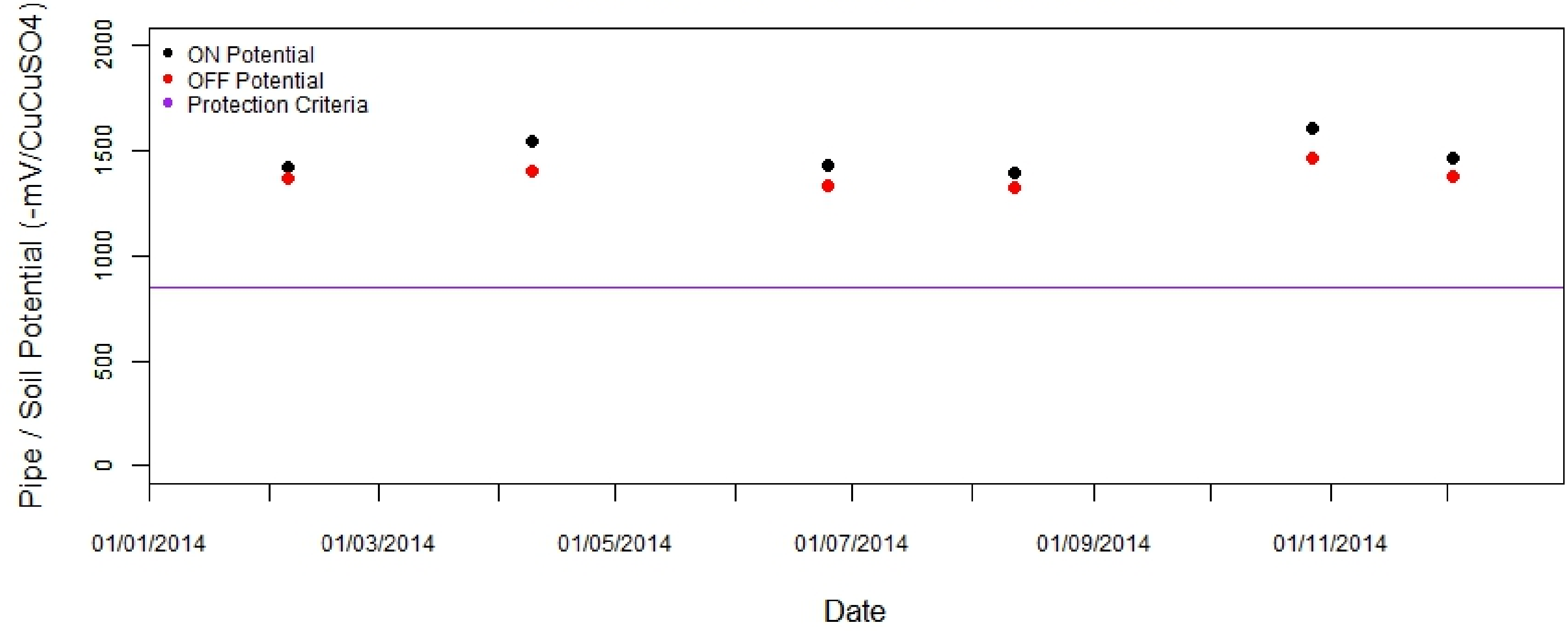

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = DCG-CIM, Location = 1506.000 km
Resistance Probe - Pipe to Soil Potential Results
Pipe / Soil Potential (-mV/CuCuSO4)
2000
1500
1000
500
0
● ON Potential
● OFF Potential
● Protection Criteria
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = DCG-CIM, Location = 1510.800 km

Resistance Probe - Pipe to Soil Potential Results

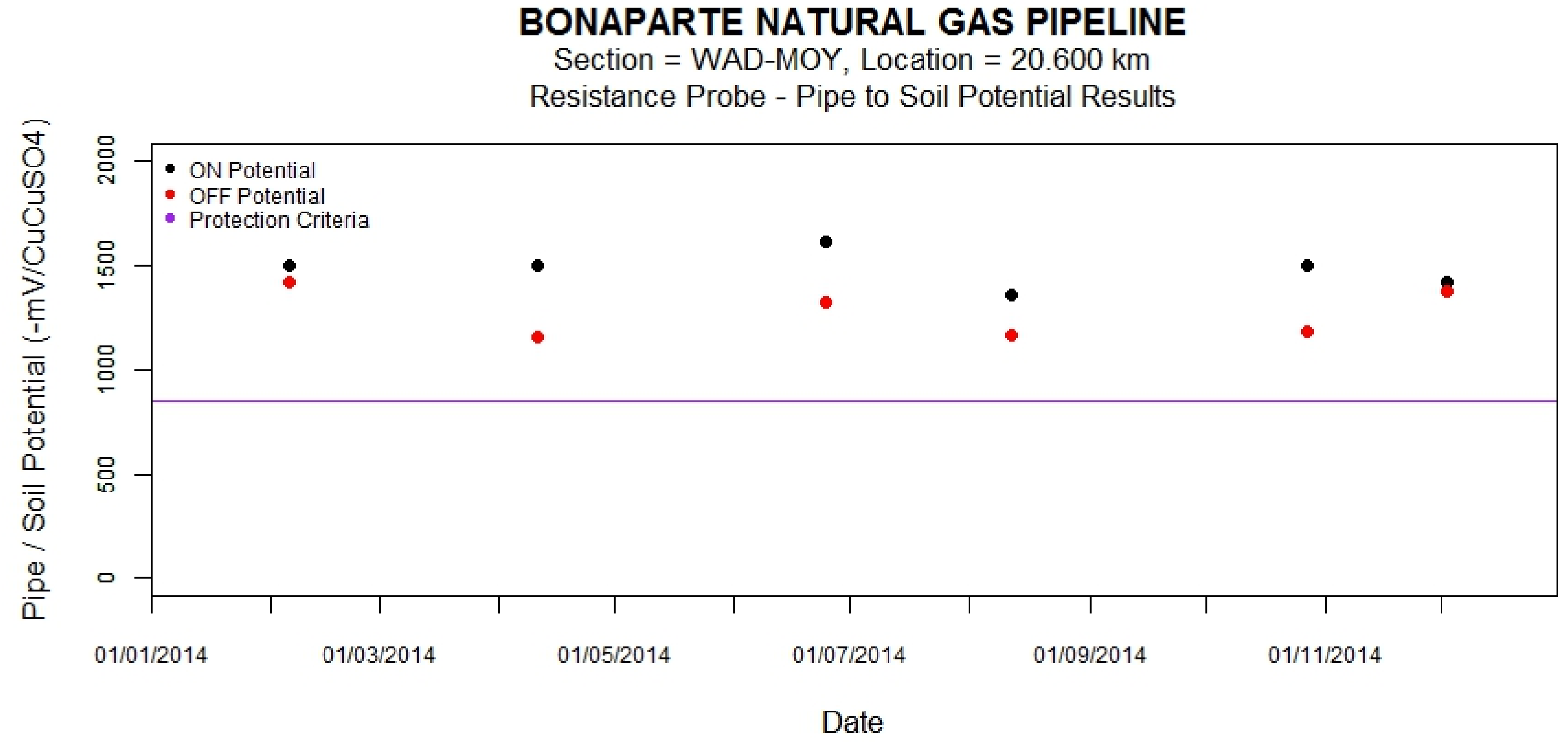




BONAPARTE NATURAL GAS PIPELINE

Section = WAD-MOY, Location = 0.000 km

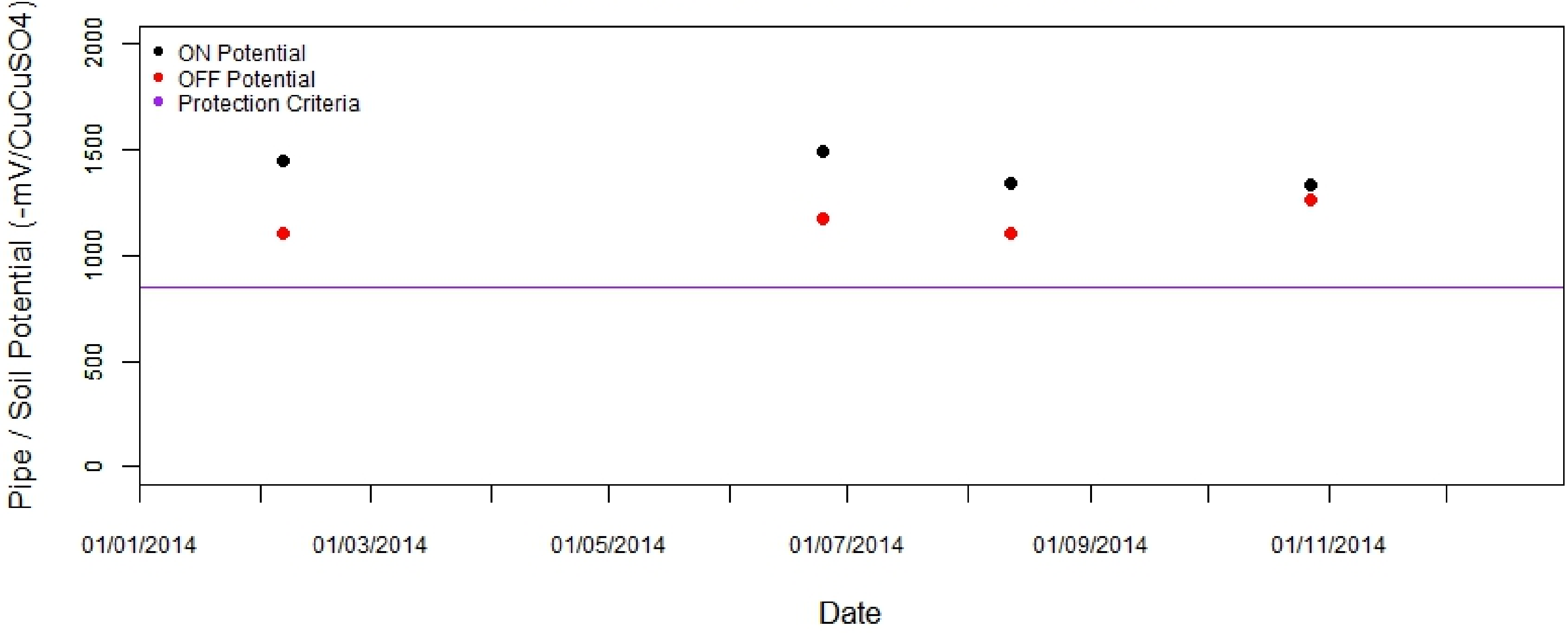
Resistance Probe - Pipe to Soil Potential Results

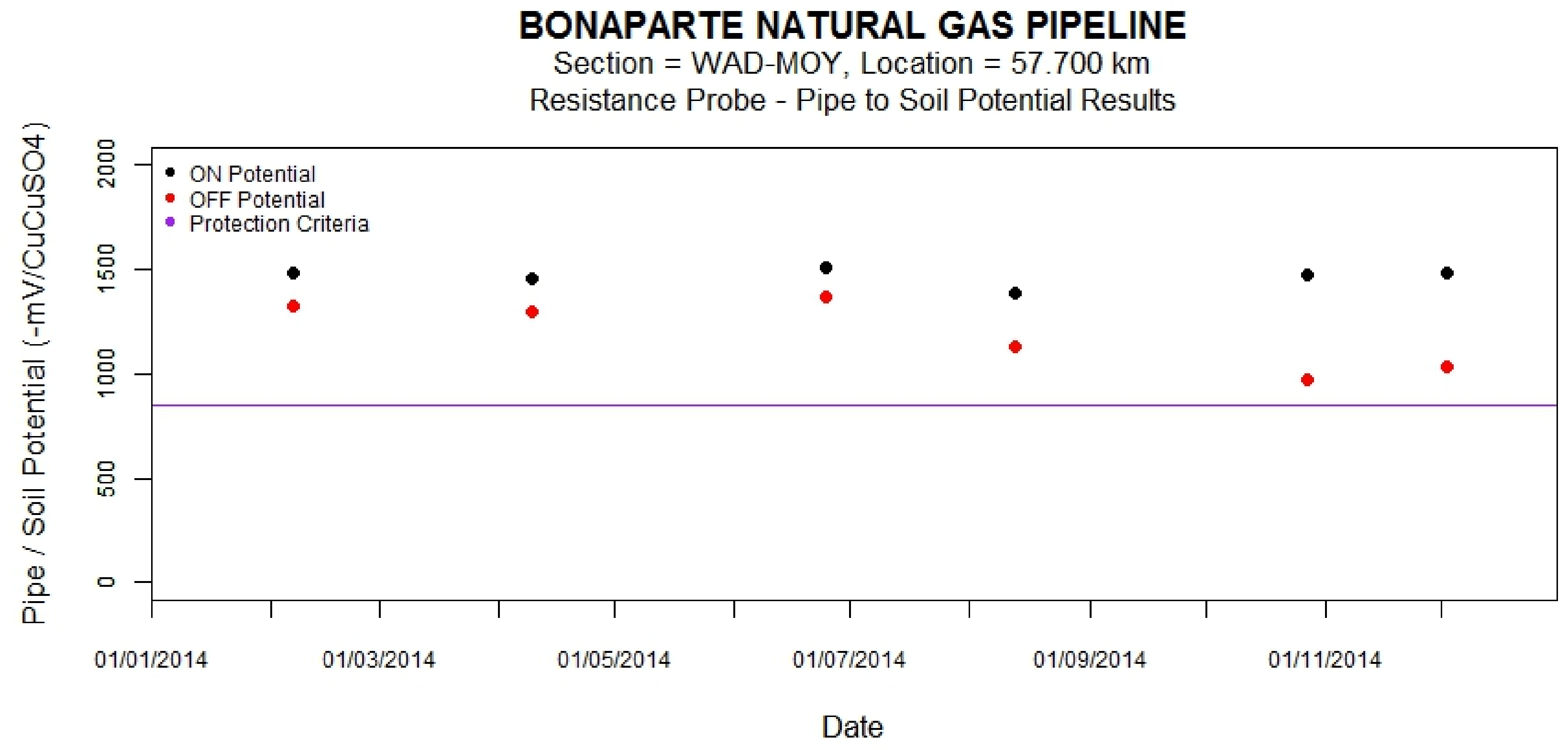

BONAPARTE NATURAL GAS PIPELINE
Section = WAD-MOY, Location = 20.600 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

BONAPARTE NATURAL GAS PIPELINE

Section = WAD-MOY, Location = 38.300 km

Resistance Probe - Pipe to Soil Potential Results

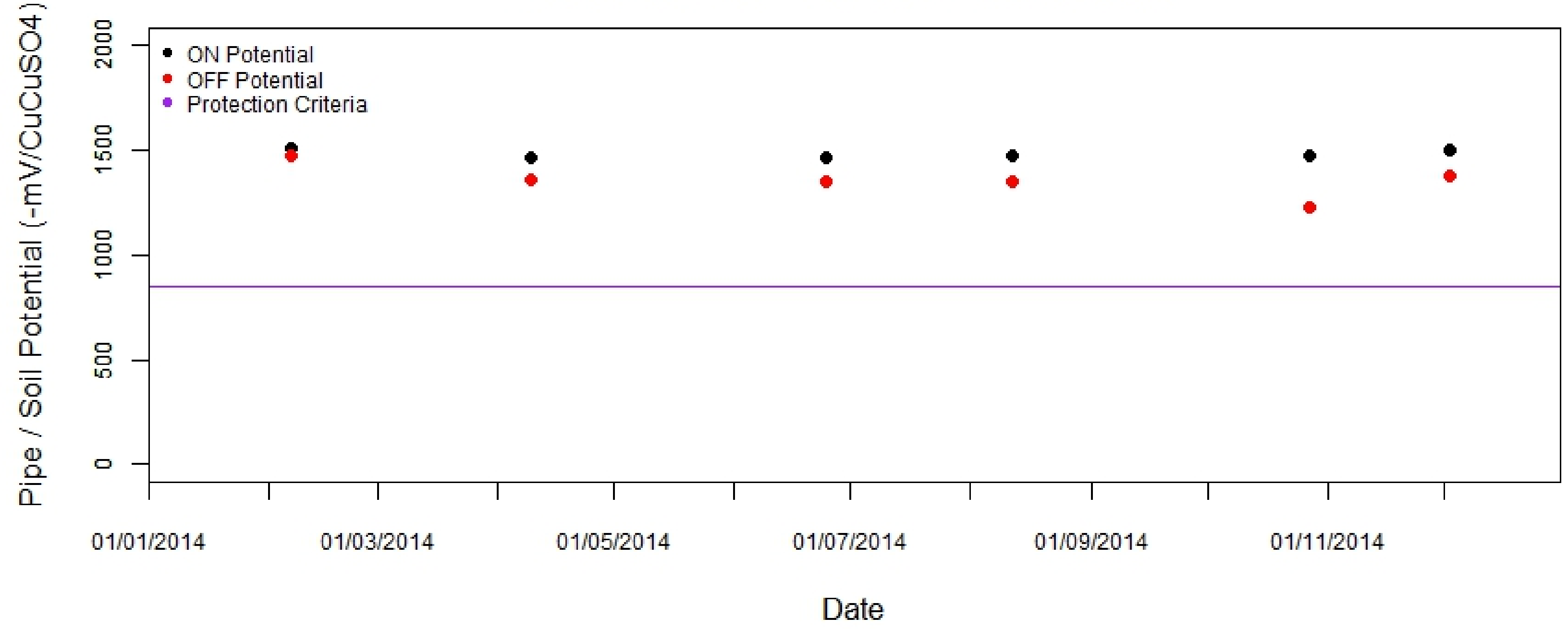




BONAPARTE NATURAL GAS PIPELINE

Section = WAD-MOY, Location = 57.700 km

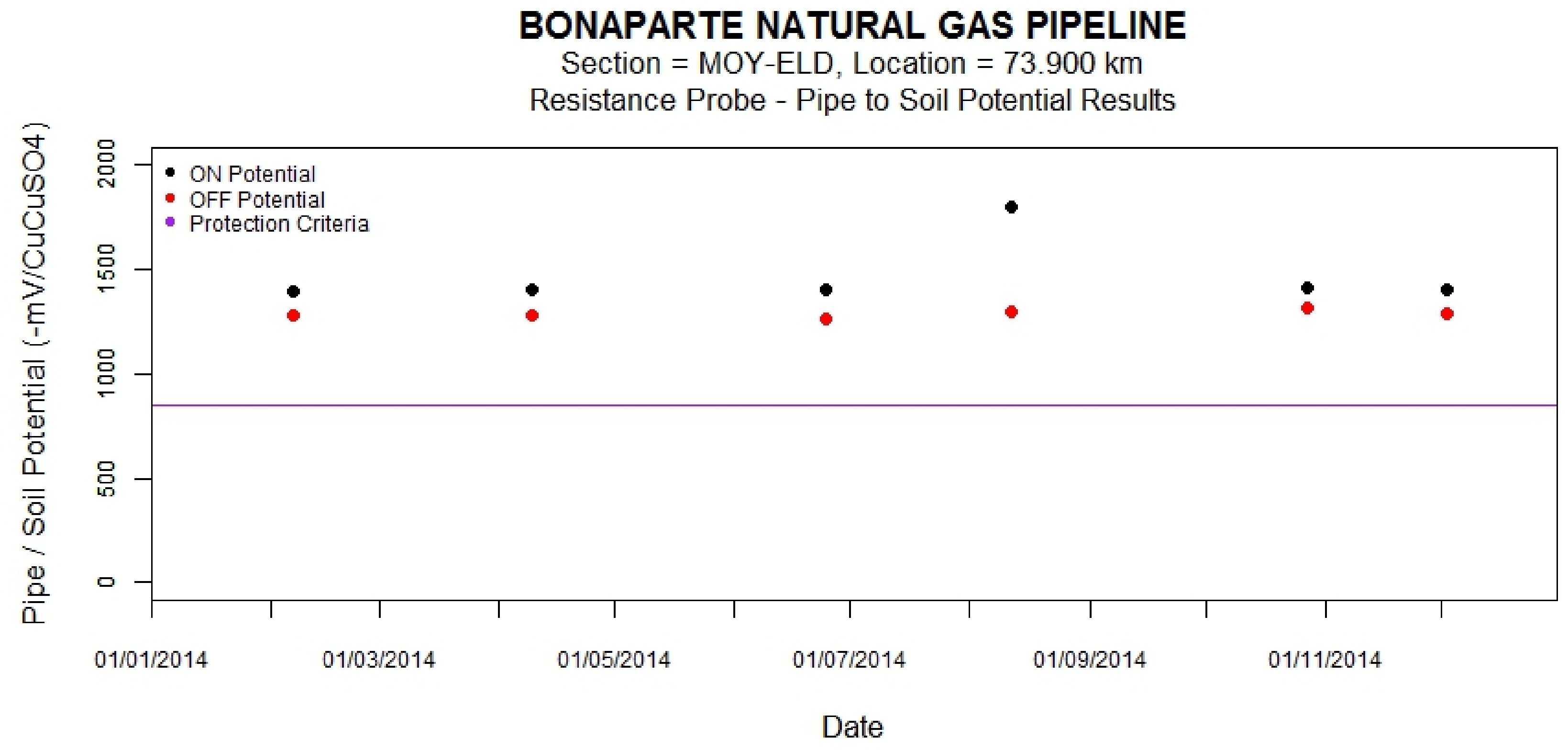
Resistance Probe - Pipe to Soil Potential Results

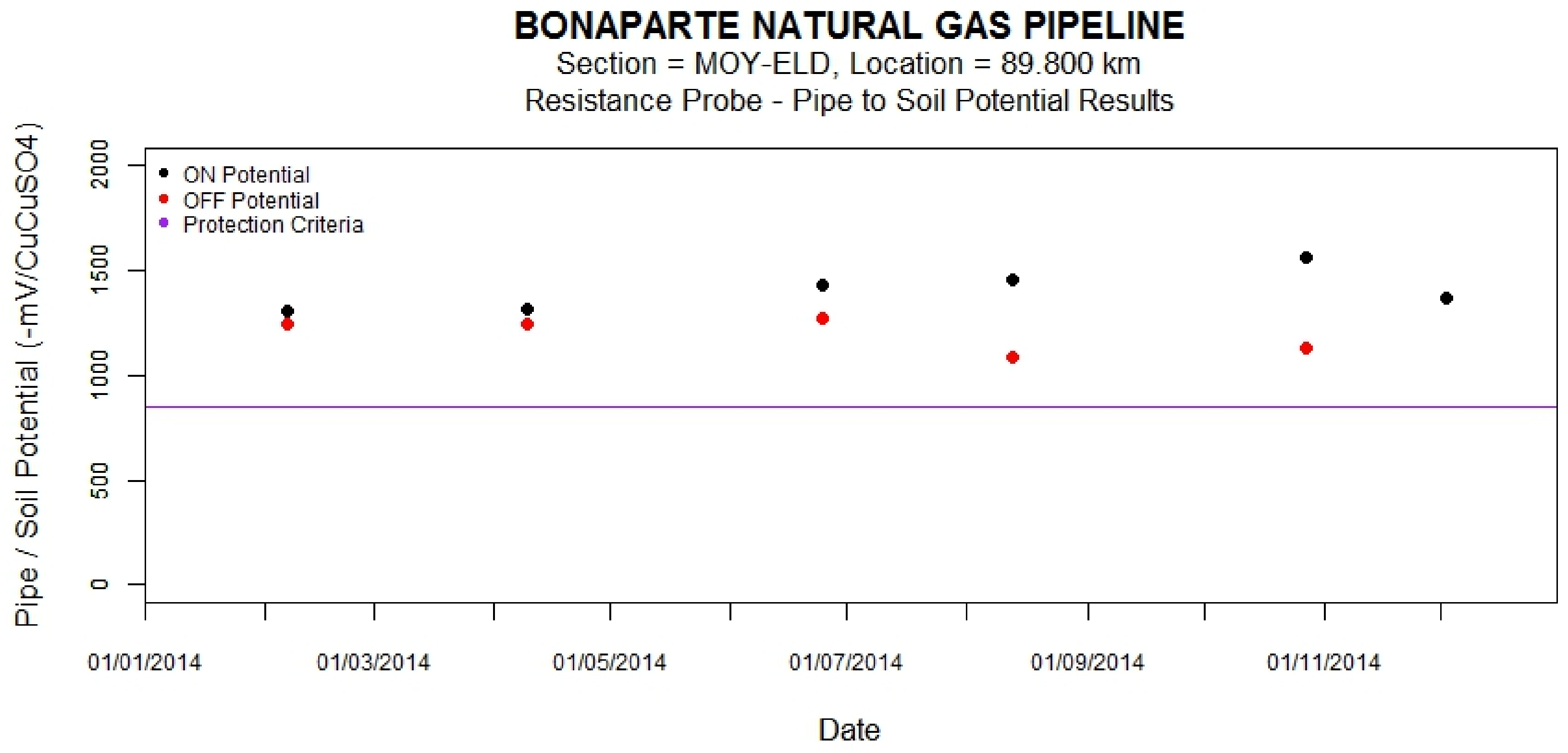


BONAPARTE NATURAL GAS PIPELINE

Section = WAD-MOY, Location = 73.900 km

Resistance Probe - Pipe to Soil Potential Results


BONAPARTE NATURAL GAS PIPELINE
Section = MOY-ELD, Location = 73.900 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date



BONAPARTE NATURAL GAS PIPELINE

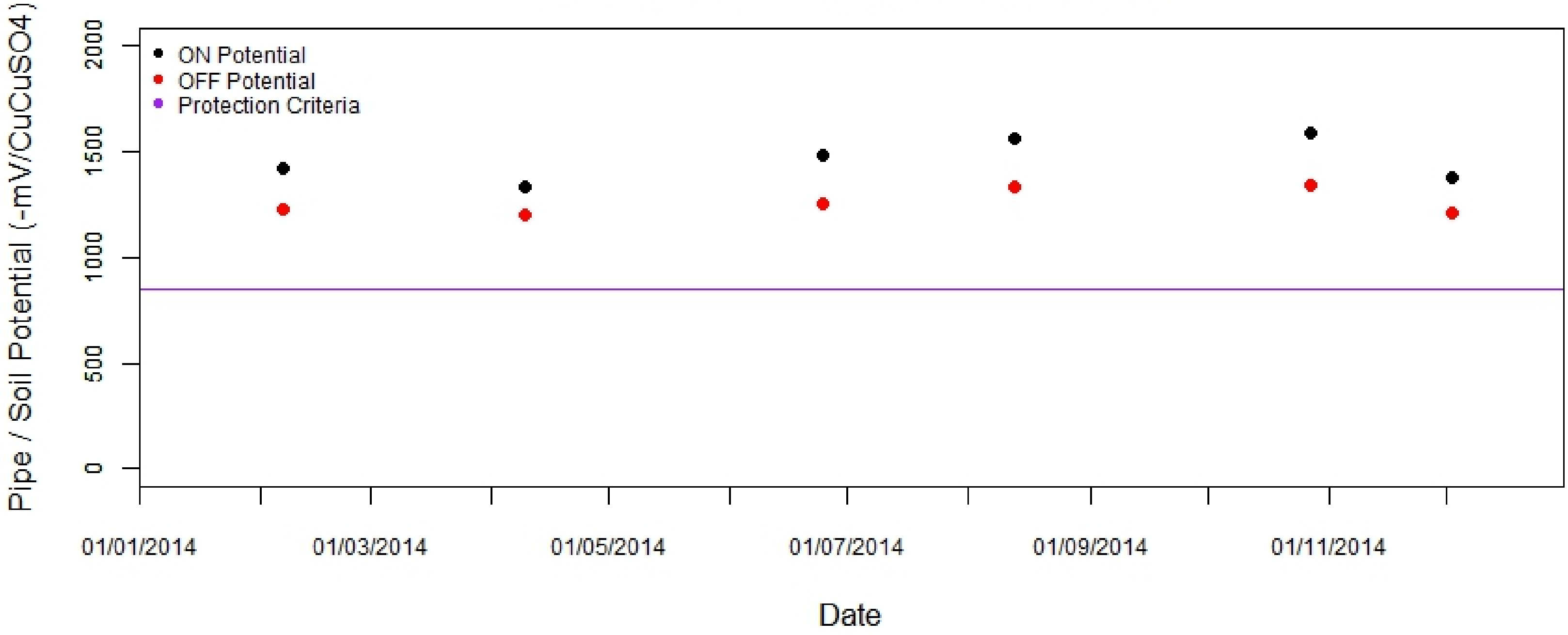
Section = MOY-ELD, Location = 89.800 km

Resistance Probe - Pipe to Soil Potential Results

BONAPARTE NATURAL GAS PIPELINE

Section = MOY-ELD, Location = 106.400 km

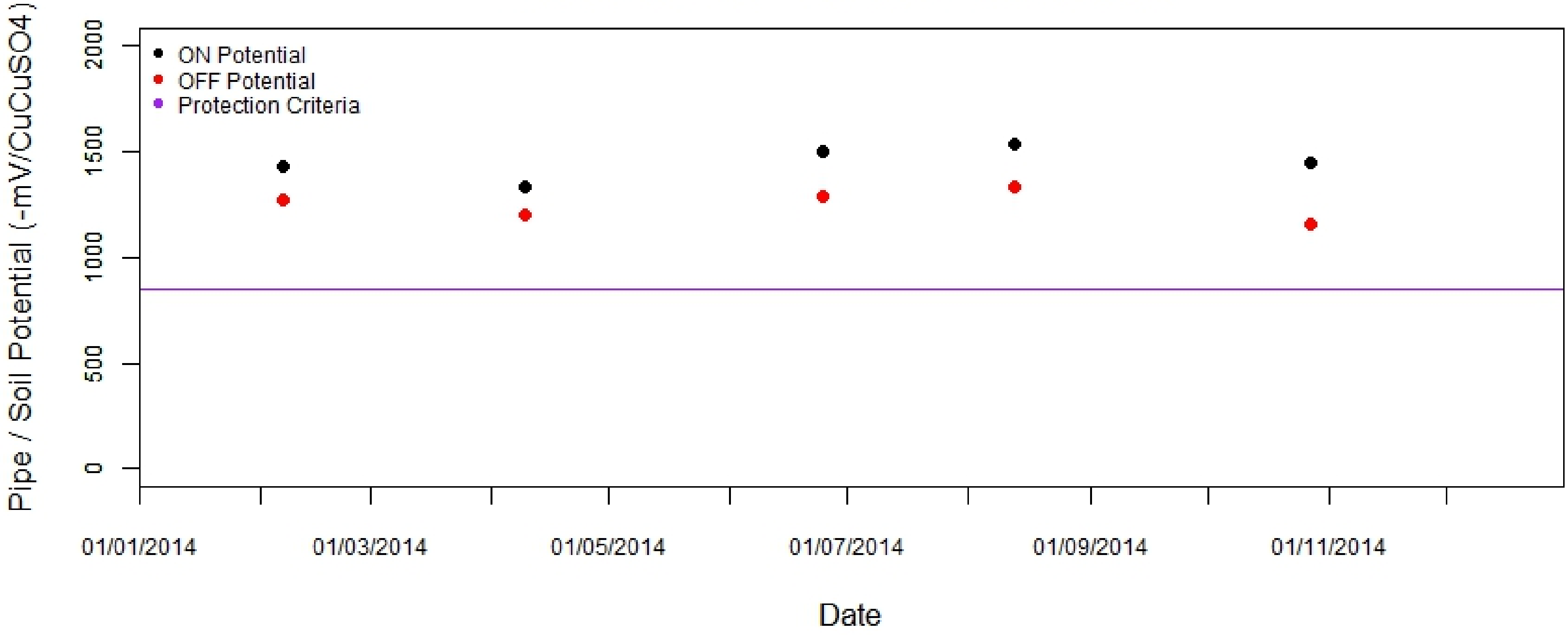
Resistance Probe - Pipe to Soil Potential Results

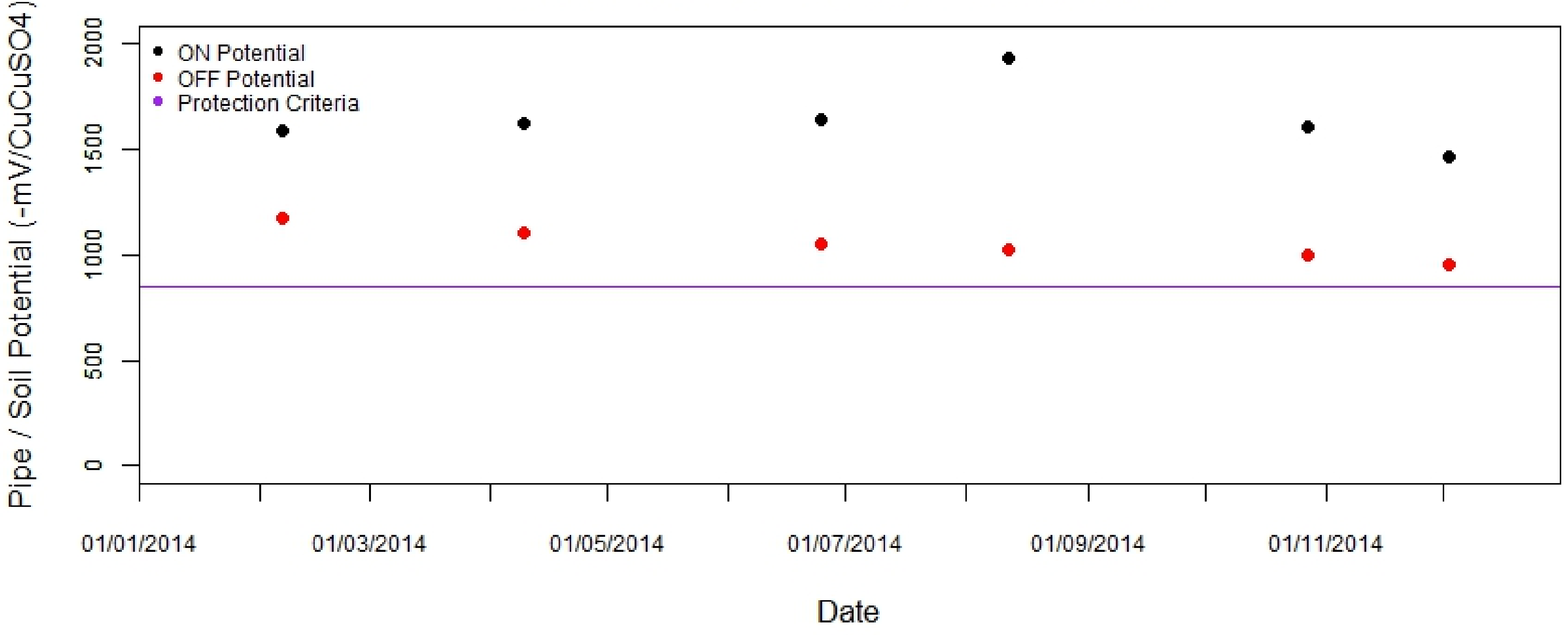


BONAPARTE NATURAL GAS PIPELINE

Section = MOY-ELD, Location = 129.800 km

Resistance Probe - Pipe to Soil Potential Results

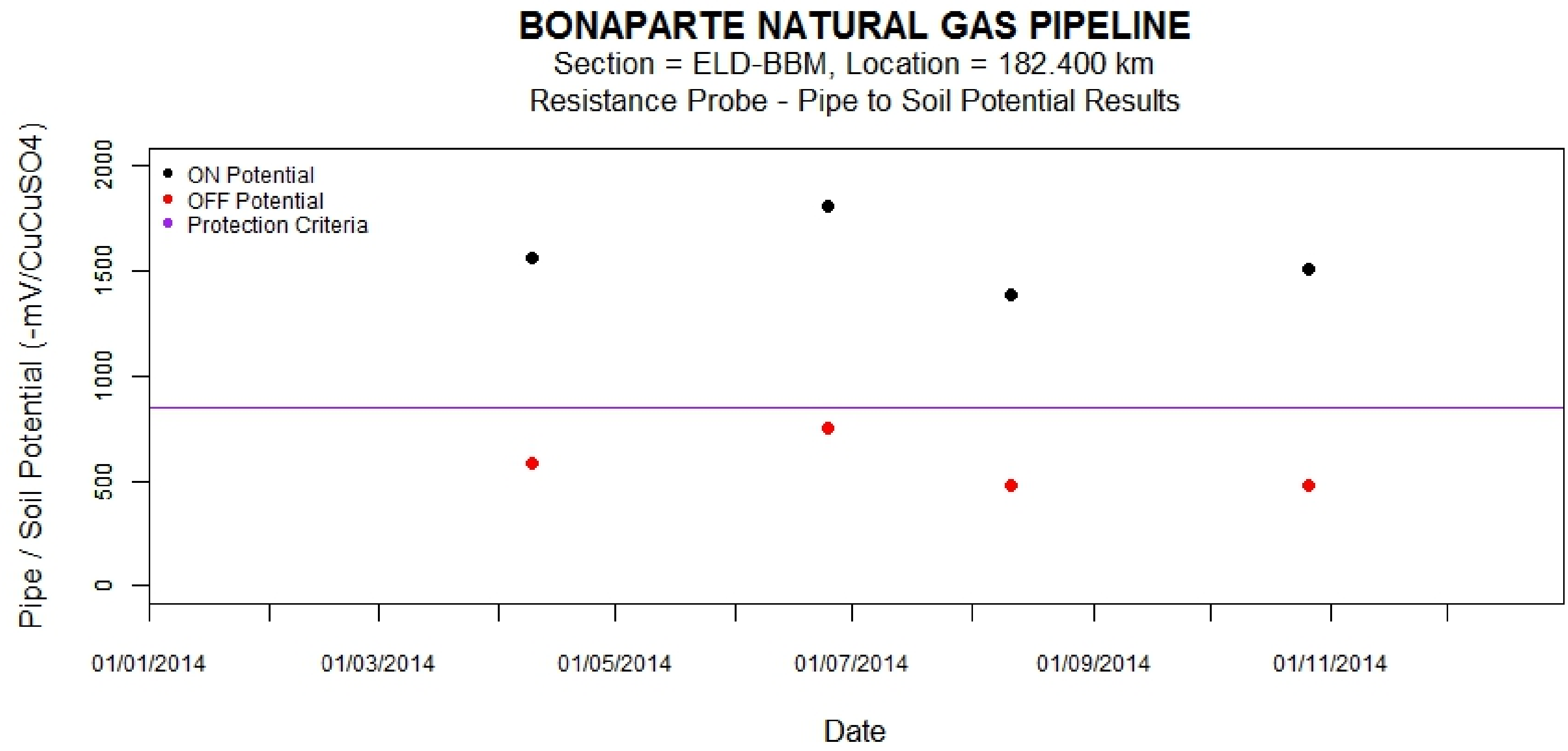




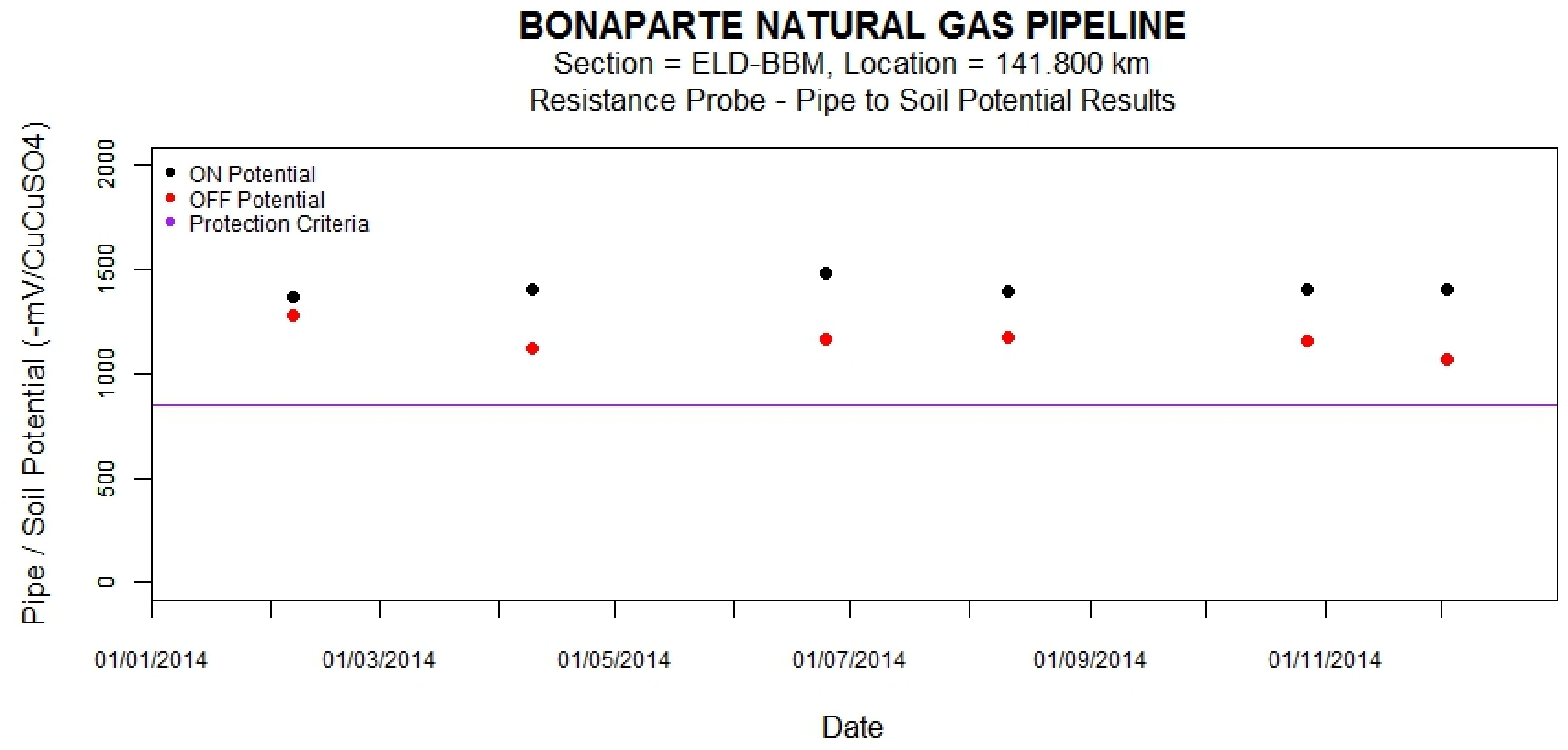
BONAPARTE NATURAL GAS PIPELINE

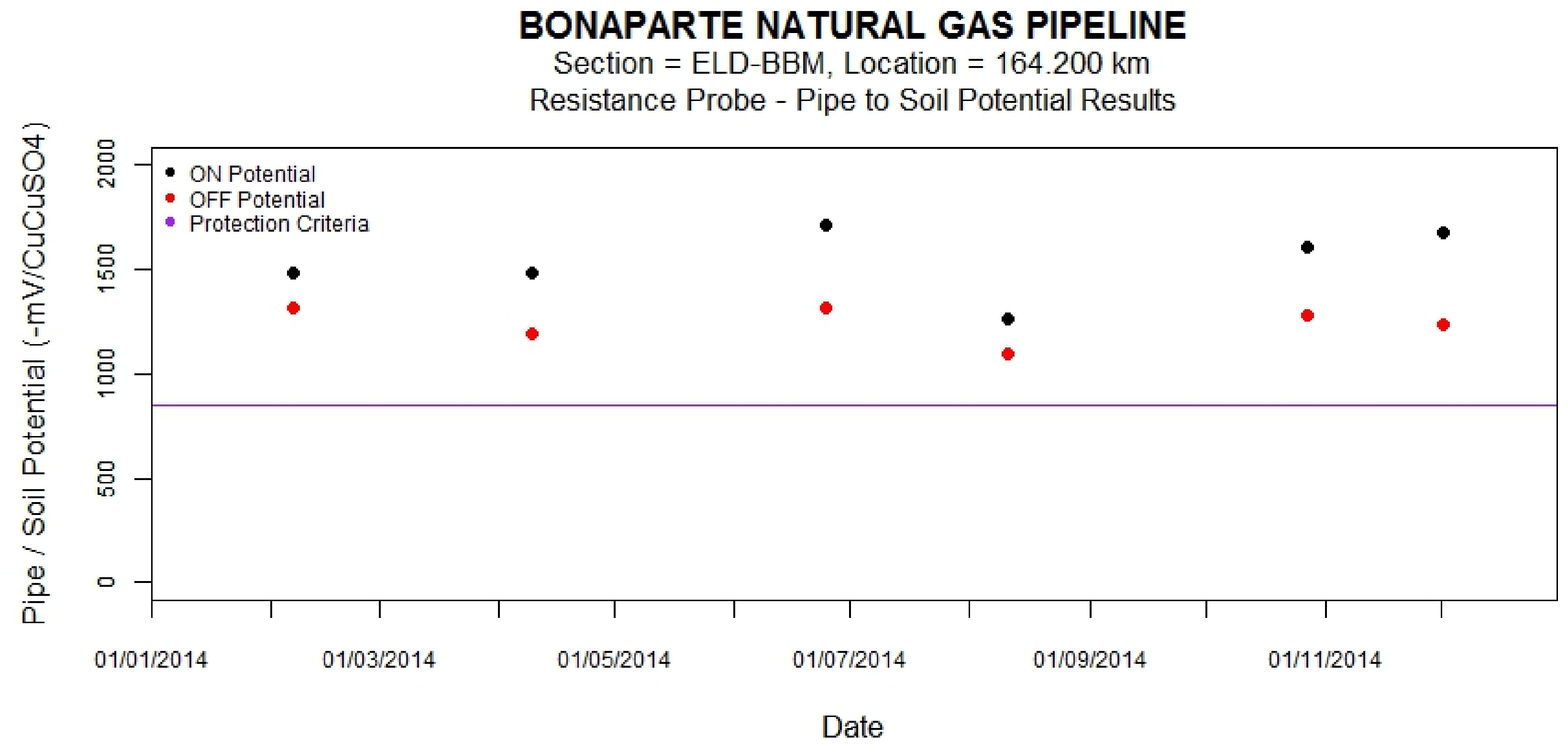
Section = MOY-ELD, Location = 141.800 km

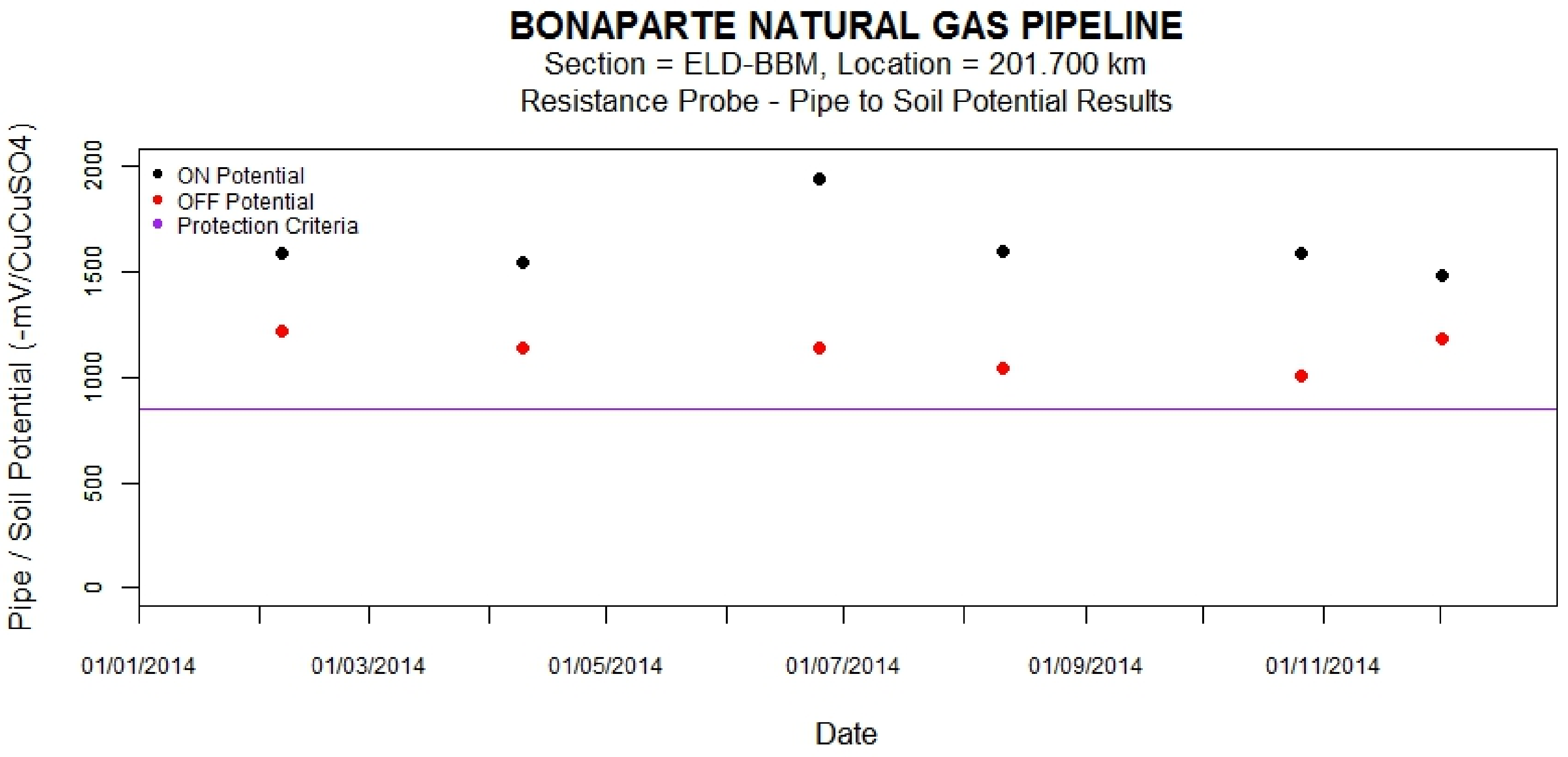
Resistance Probe - Pipe to Soil Potential Results

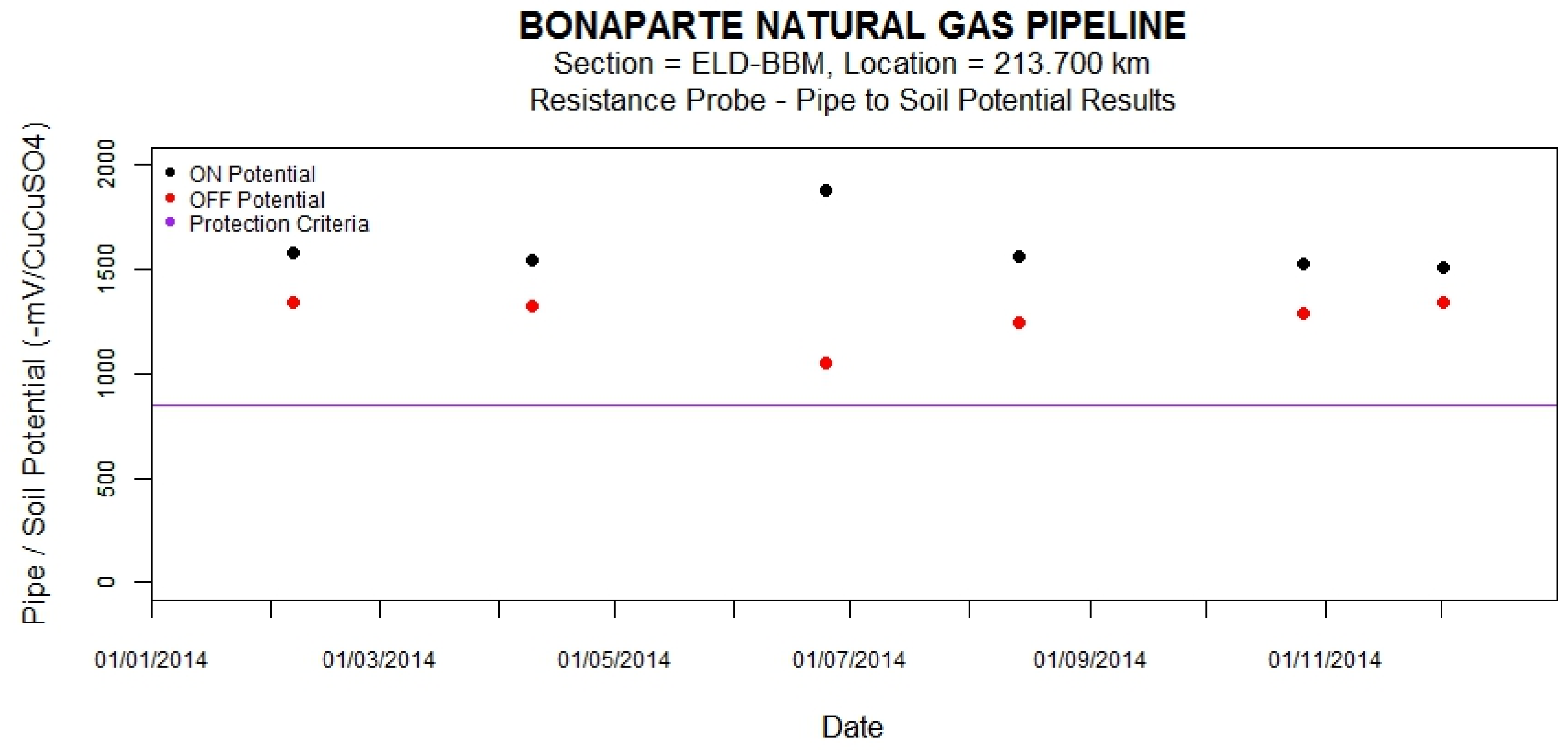


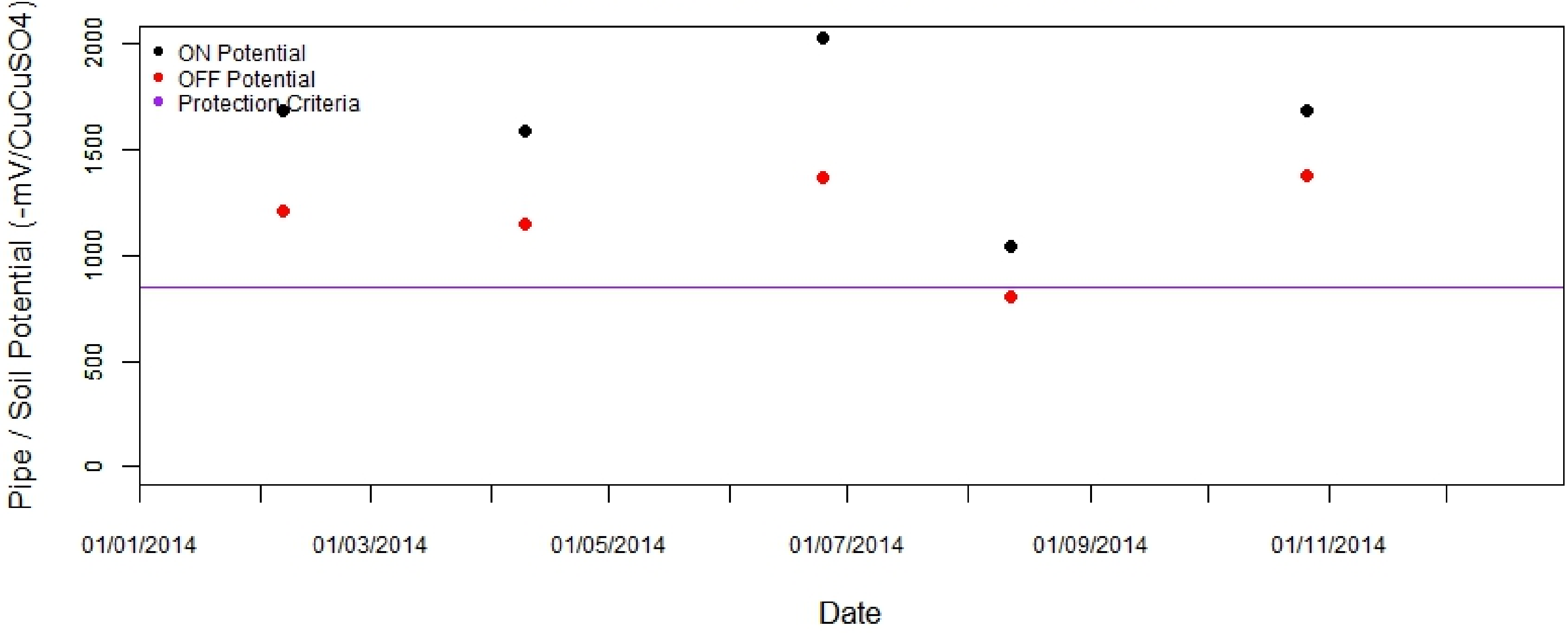
BONAPARTE NATURAL GAS PIPELINE
Section = ELD-BBM, Location = 182.400 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date


BONAPARTE NATURAL GAS PIPELINE
Section = ELD-BBM, Location = 141.800 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date


BONAPARTE NATURAL GAS PIPELINE
Section = ELD-BBM, Location = 164.200 km
Resistance Probe - Pipe to Soil Potential Results
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
● ON Potential
● OFF Potential
● Protection Criteria
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

BONAPARTE NATURAL GAS PIPELINE
Section = ELD-BBM, Location = 201.700 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

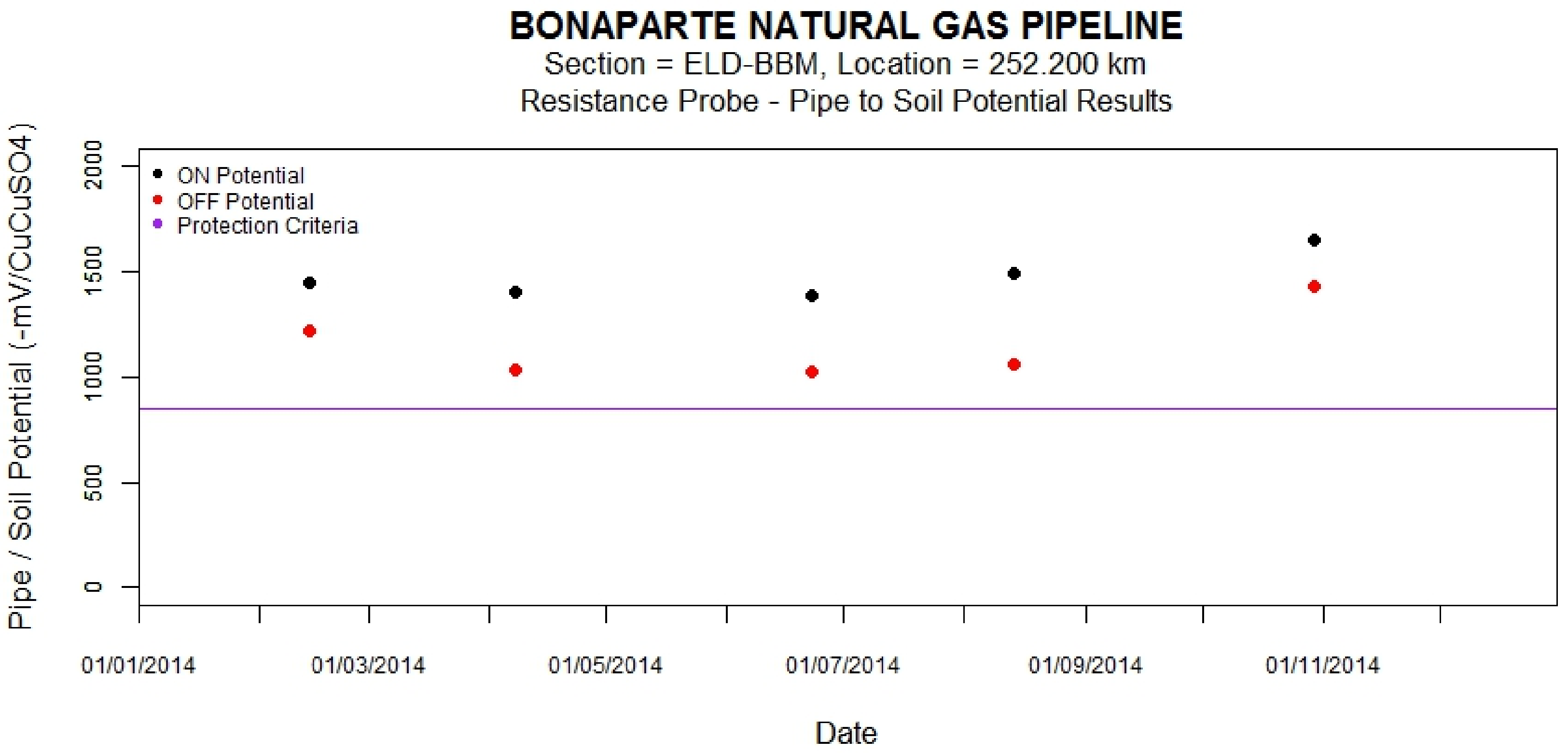

BONAPARTE NATURAL GAS PIPELINE
Section = ELD-BBM, Location = 213.700 km
Resistance Probe - Pipe to Soil Potential Results
Pipe / Soil Potential (-mV/CuCuSO4)
2000
1500
1000
500
0
● ON Potential
● OFF Potential
● Protection Criteria
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date



BONAPARTE NATURAL GAS PIPELINE

Section = ELD-BBM, Location = 232.300 km

Resistance Probe - Pipe to Soil Potential Results

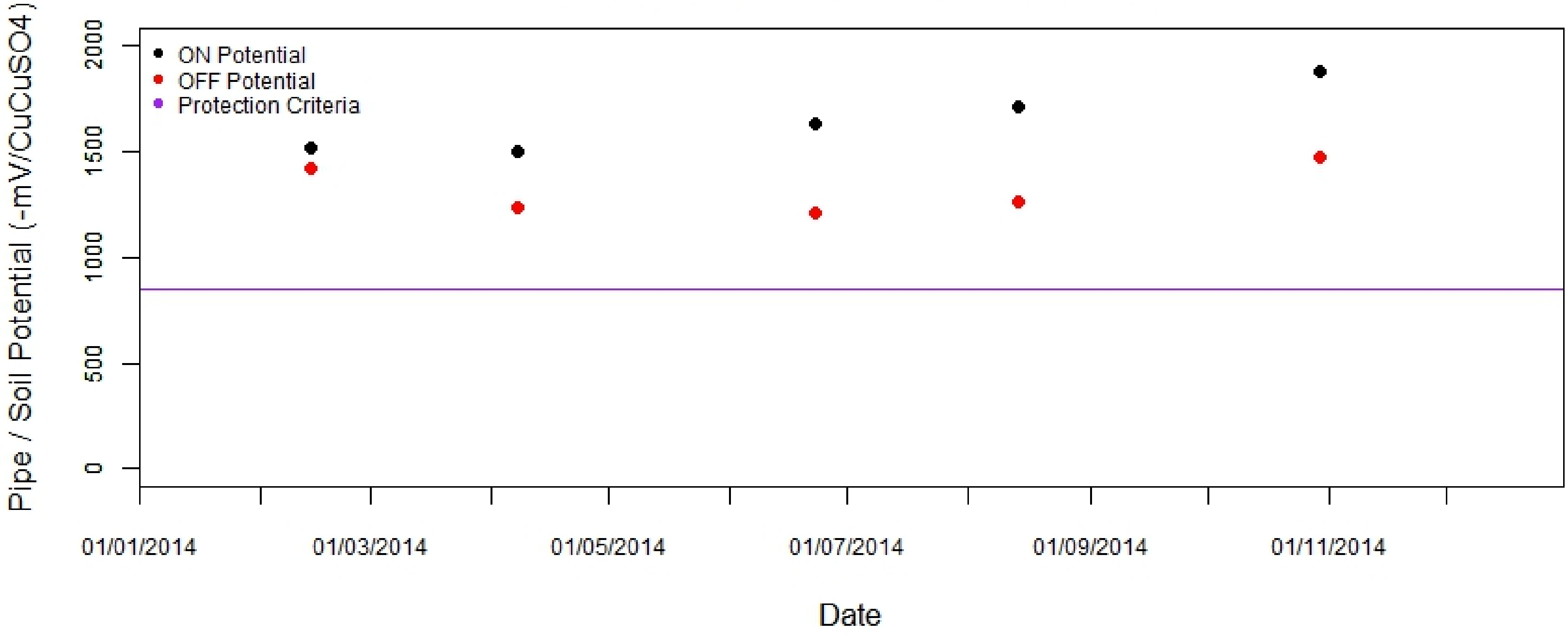


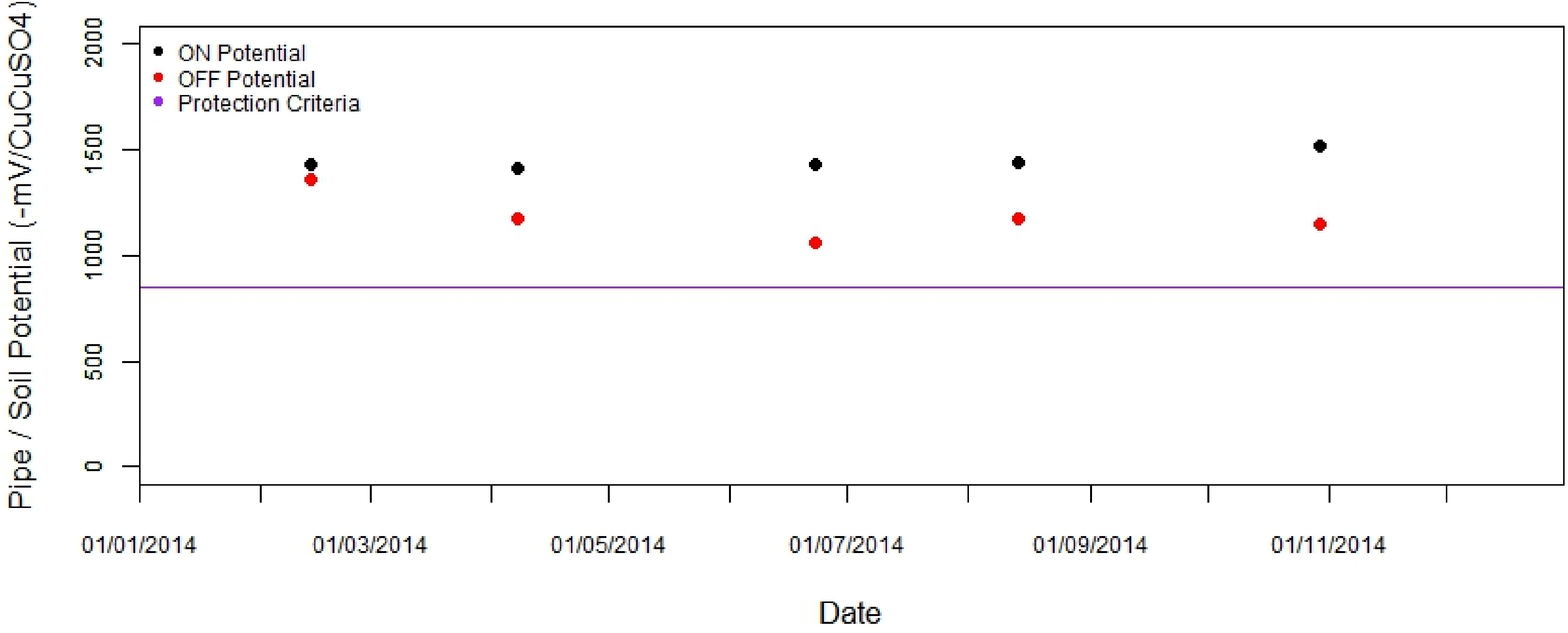
BONAPARTE NATURAL GAS PIPELINE
Section = ELD-BBM, Location = 252.200 km
Resistance Probe - Pipe to Soil Potential Results

BONAPARTE NATURAL GAS PIPELINE

Section = ELD-BBM, Location = 267.100 km

Resistance Probe - Pipe to Soil Potential Results

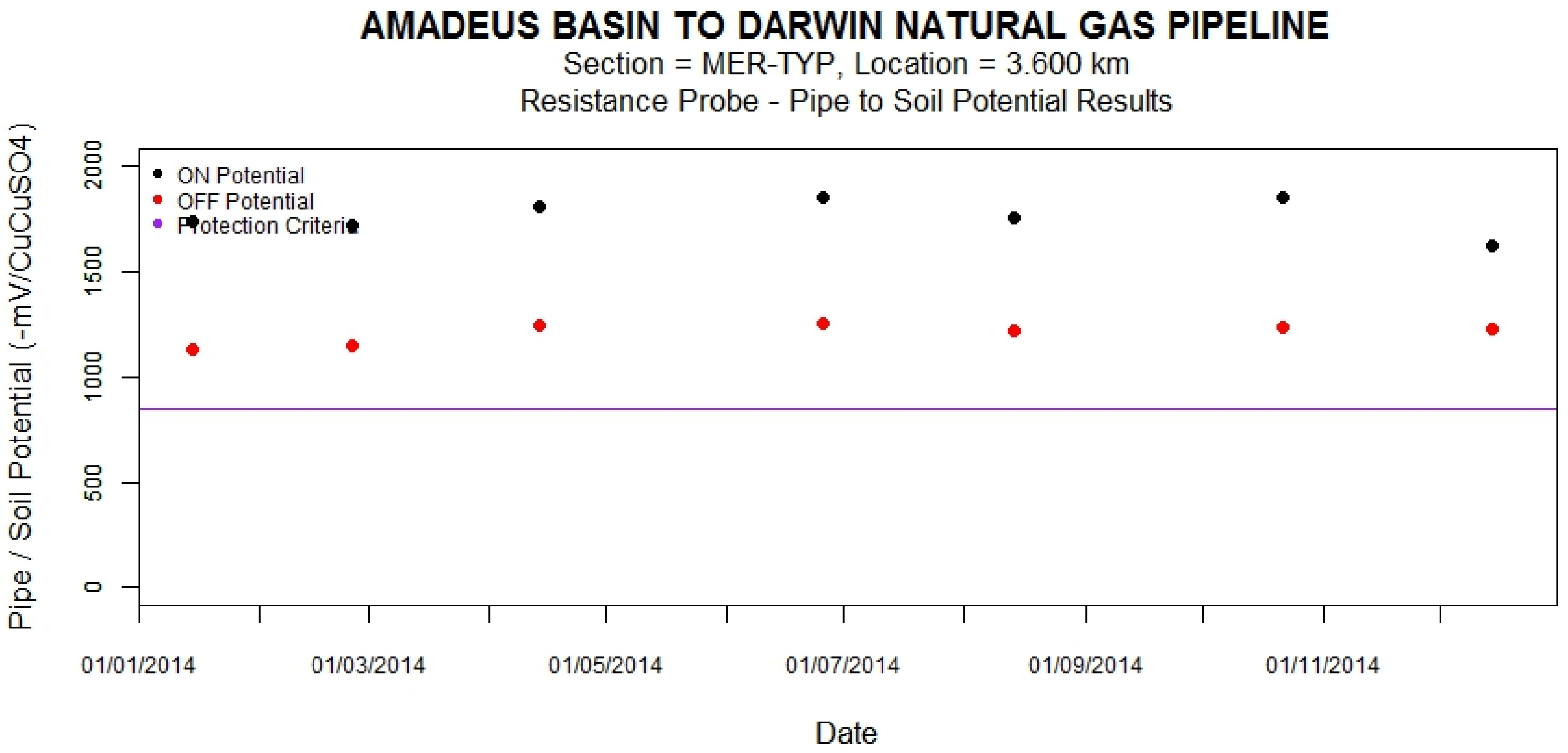


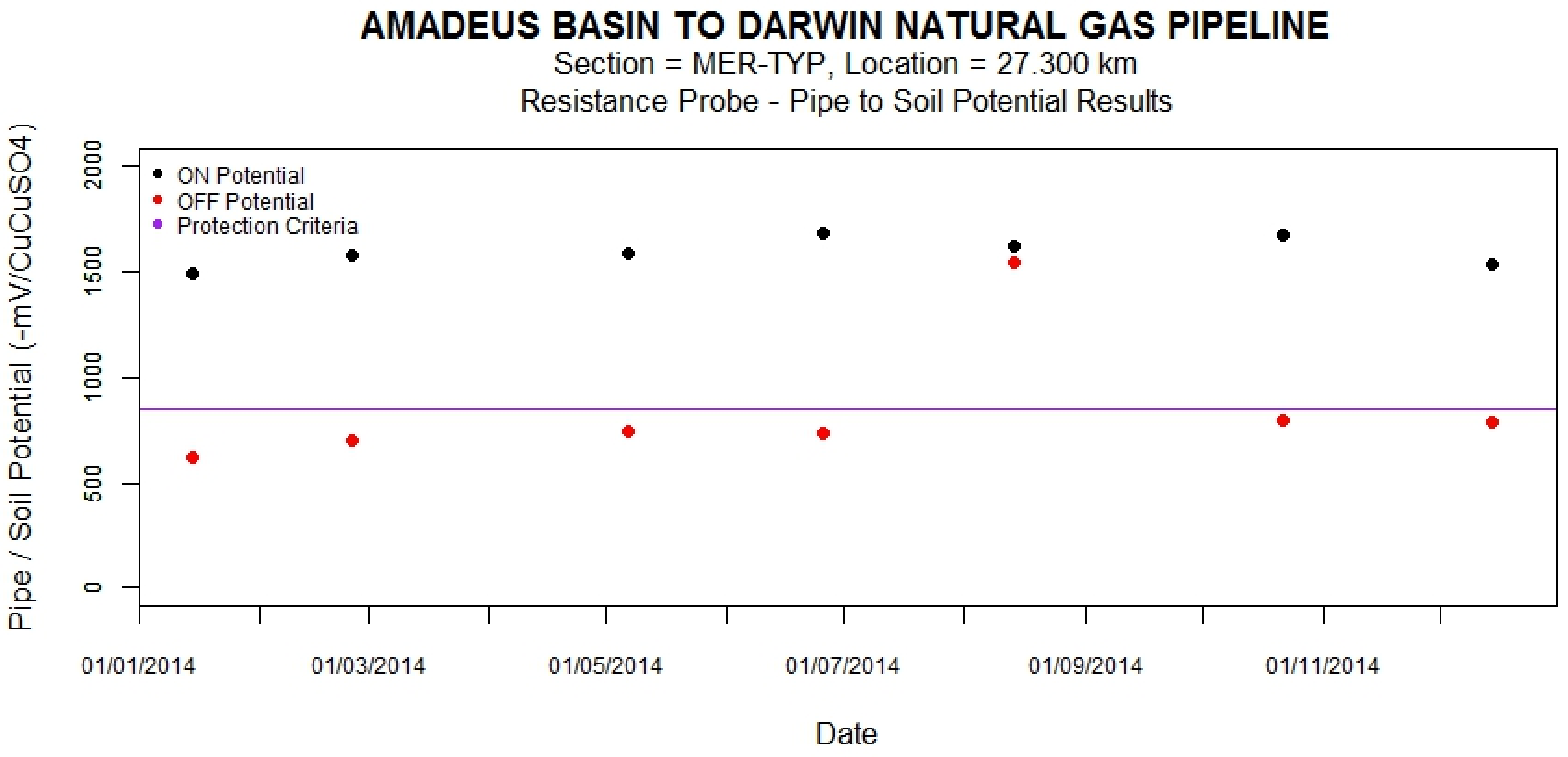


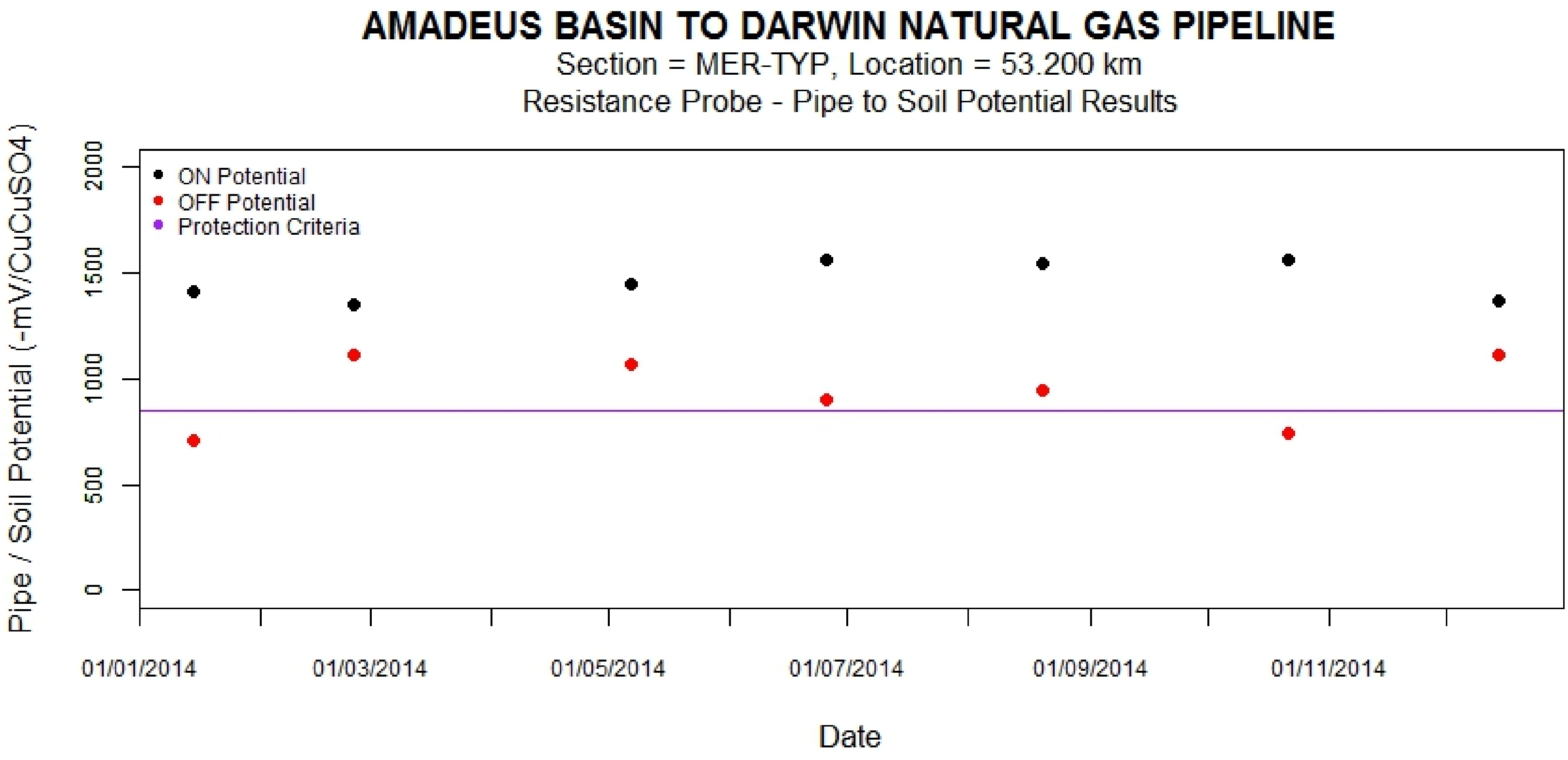
BONAPARTE NATURAL GAS PIPELINE

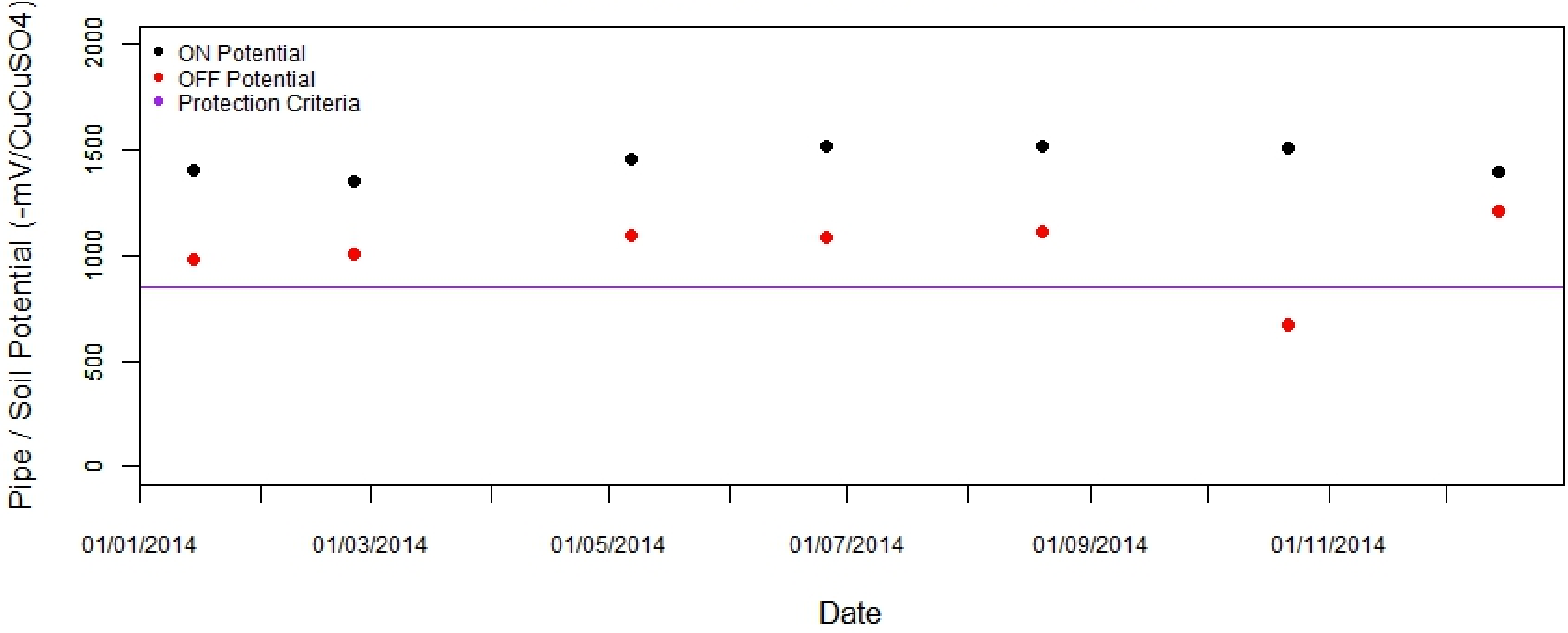
Section = ELD-BBM, Location = 286.600 km

Resistance Probe - Pipe to Soil Potential Results


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = MER-TYP, Location = 3.600 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteri
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = MER-TYP, Location = 27.300 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

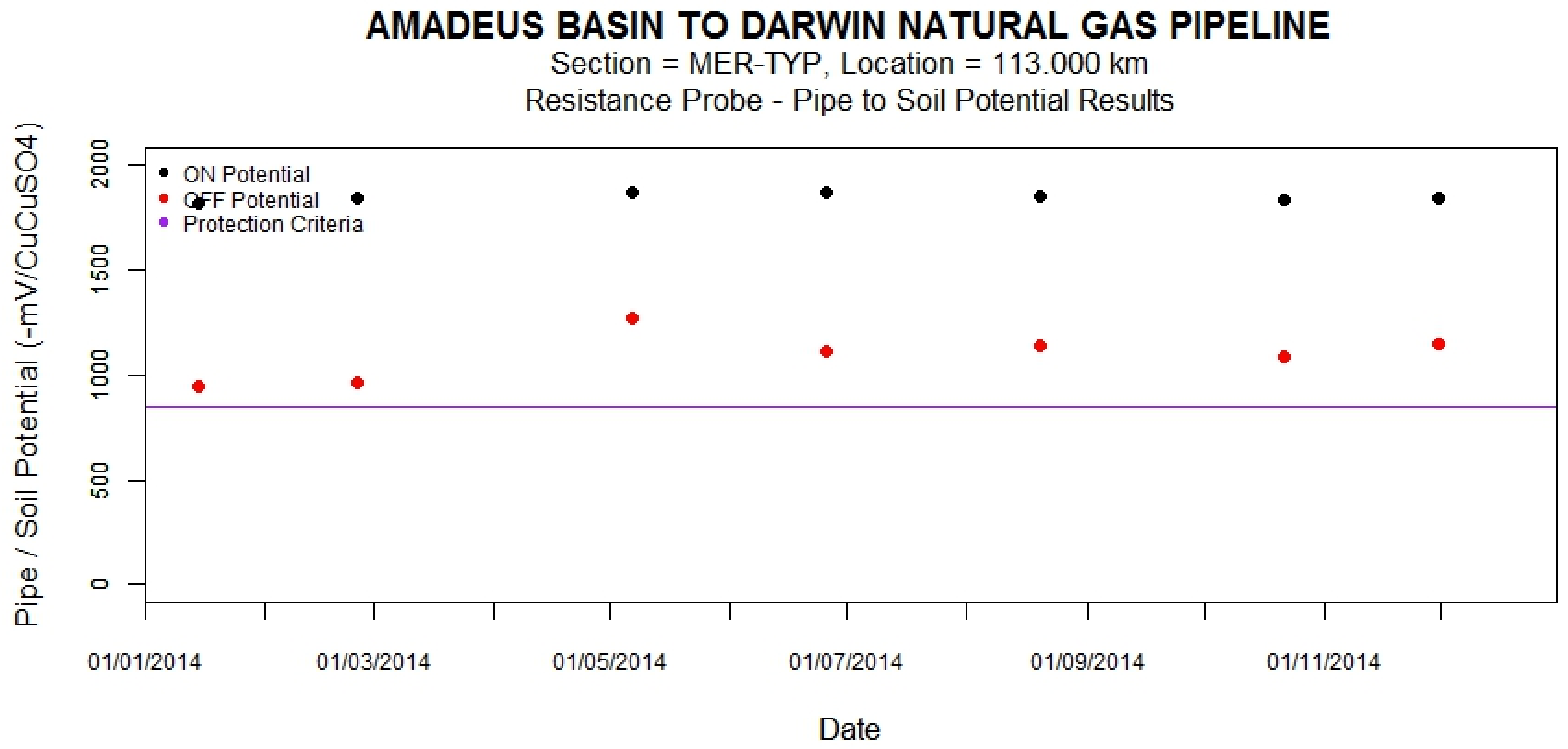

AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = MER-TYP, Location = 53.200 km
Resistance Probe - Pipe to Soil Potential Results
● ON Potential
● OFF Potential
● Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
2000
1500
1000
500
0
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date



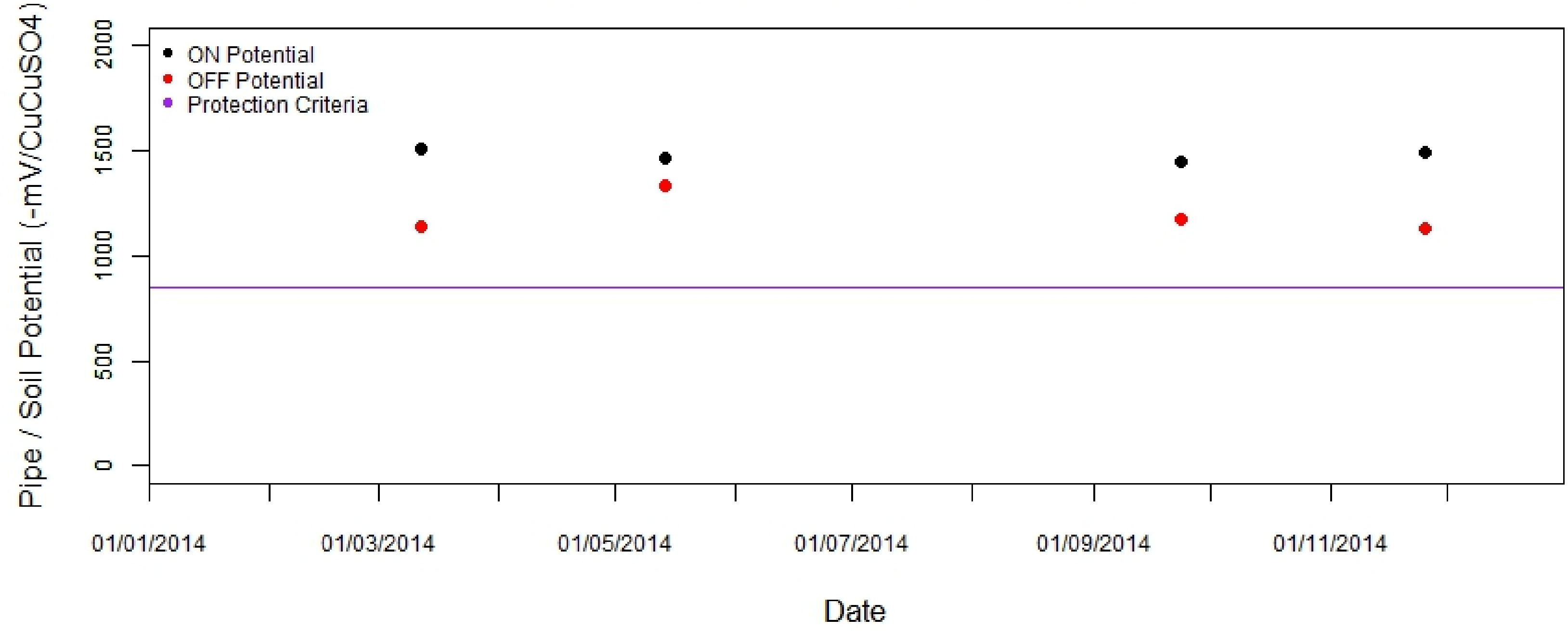
AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE

Section = MER-TYP, Location = 81.300 km

Resistance Probe - Pipe to Soil Potential Results



AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = MER-TYP, Location = 113.000 km
Resistance Probe - Pipe to Soil Potential Results



DALY WATERS TO MACARTHUR RIVER MINE NATURAL GAS PIPELINE

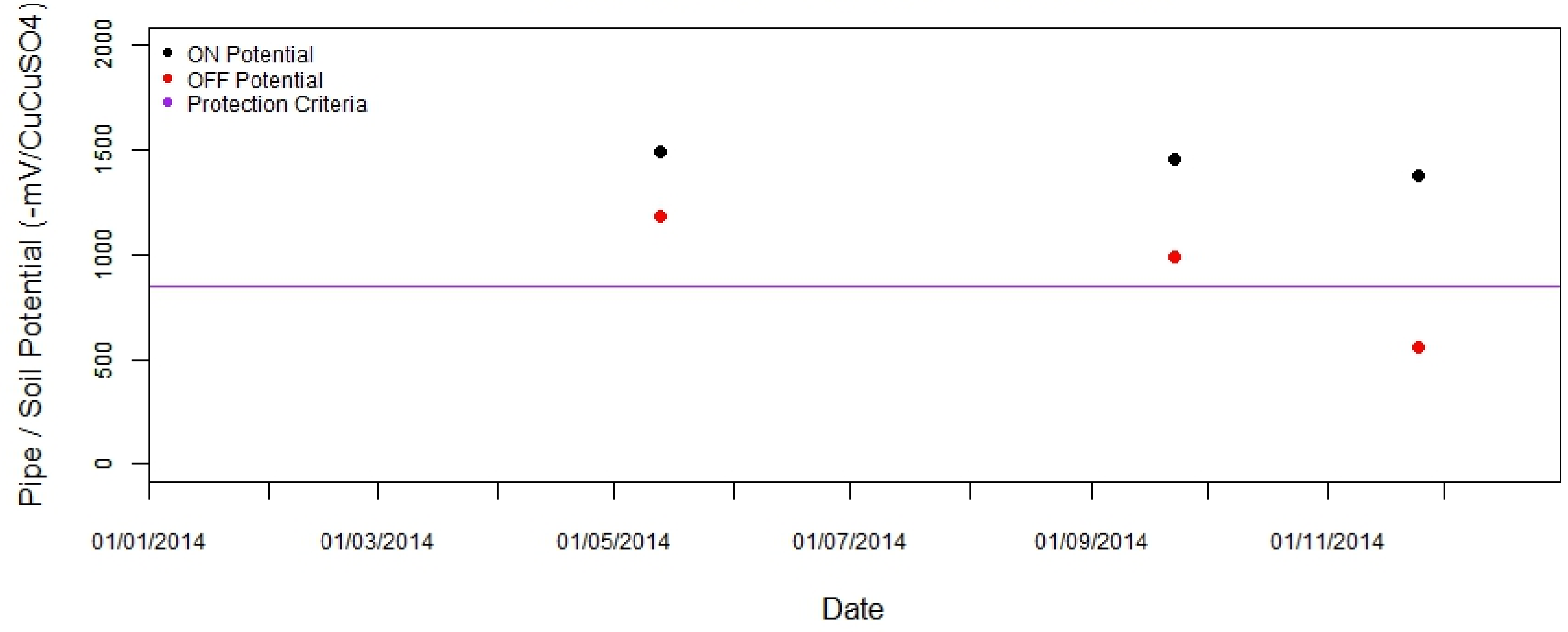
Section = DLW-TAN, Location = 0.000 km

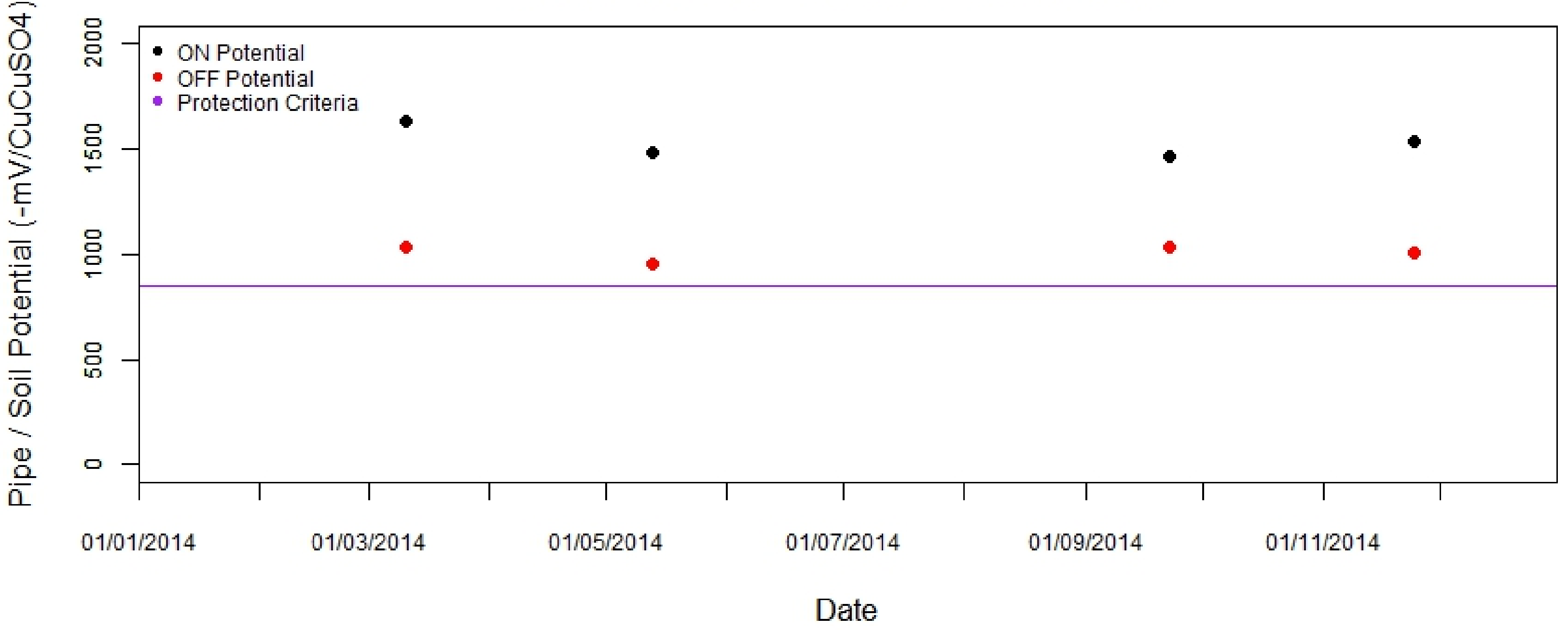
Resistance Probe - Pipe to Soil Potential Results

DALY WATERS TO MACARTHUR RIVER MINE NATURAL GAS PIPELINE

Section = DLW-TAN, Location = 87.400 km

Resistance Probe - Pipe to Soil Potential Results





DALY WATERS TO MACARTHUR RIVER MINE NATURAL GAS PIPELINE

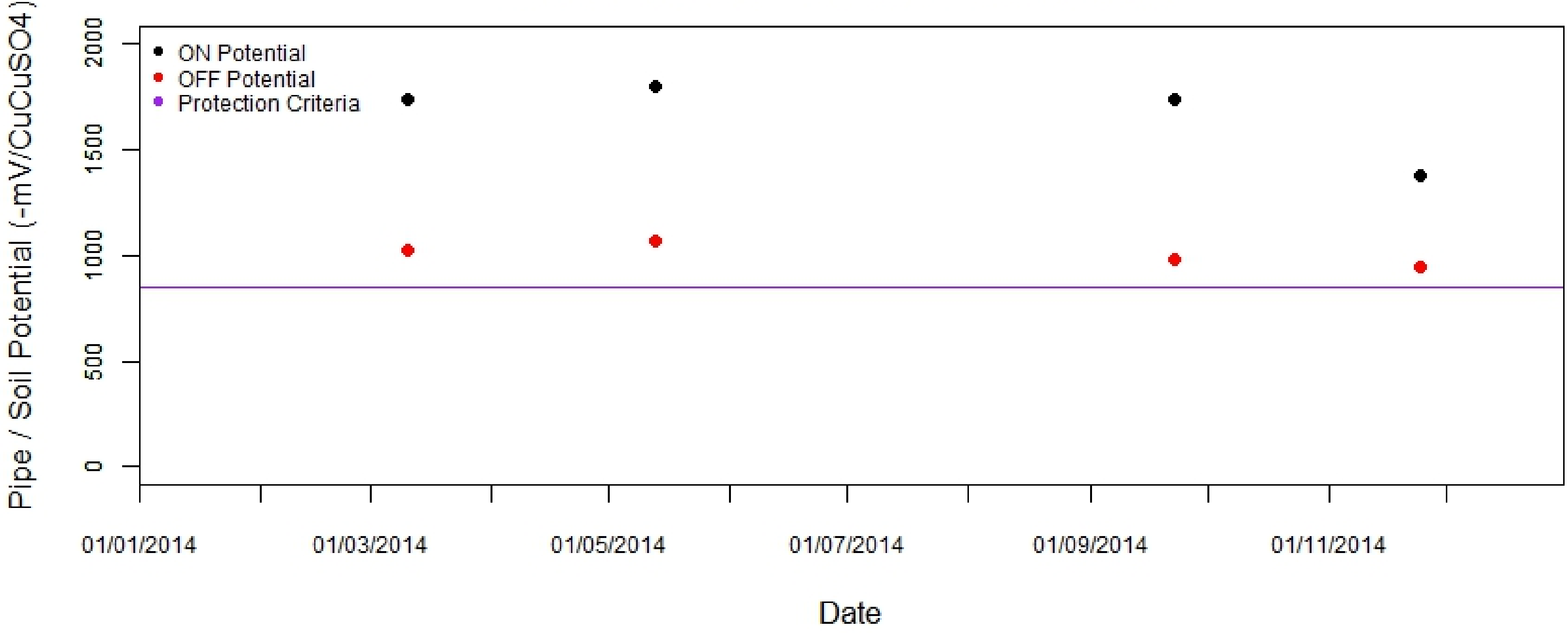
Section = DLW-TAN, Location = 157.500US km

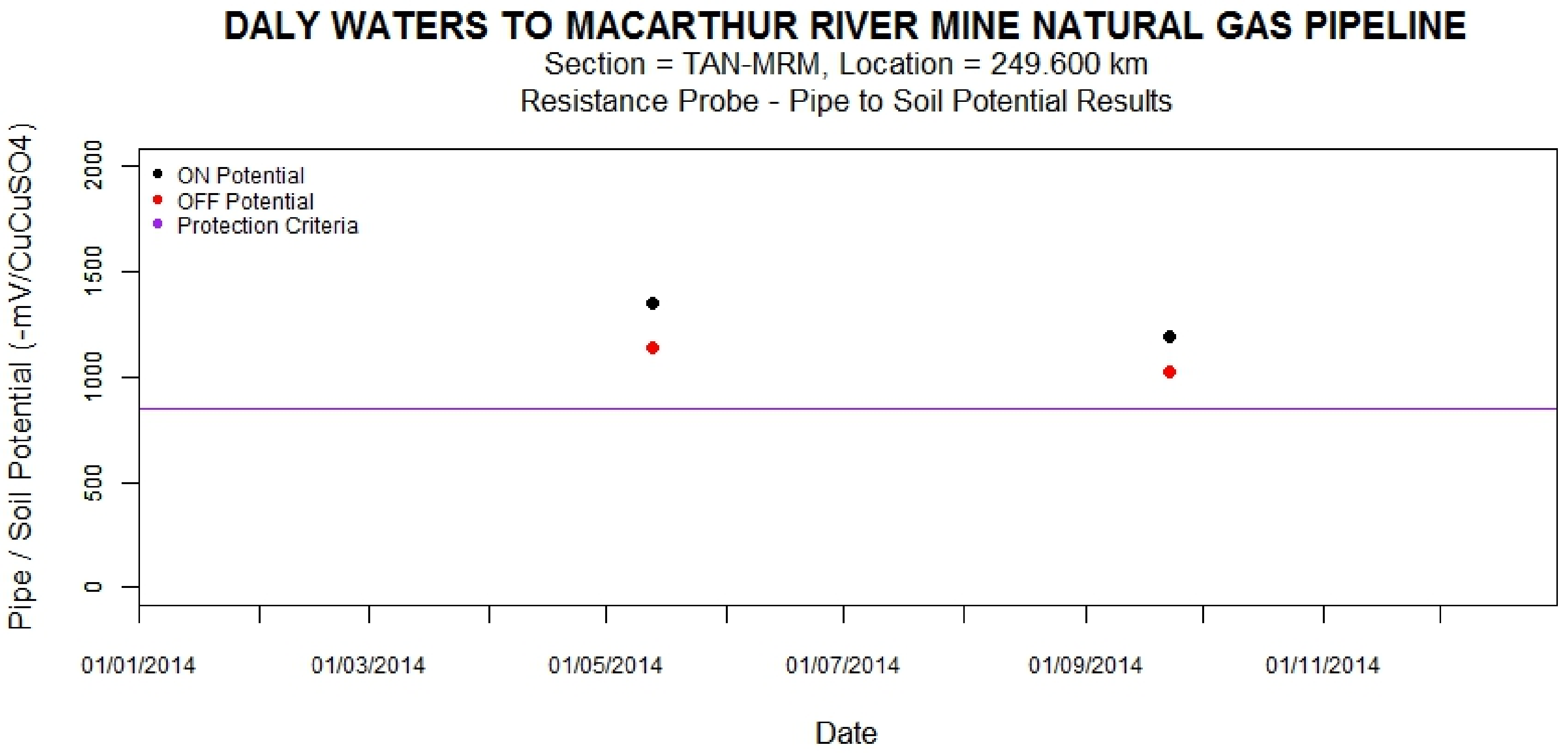
Resistance Probe - Pipe to Soil Potential Results

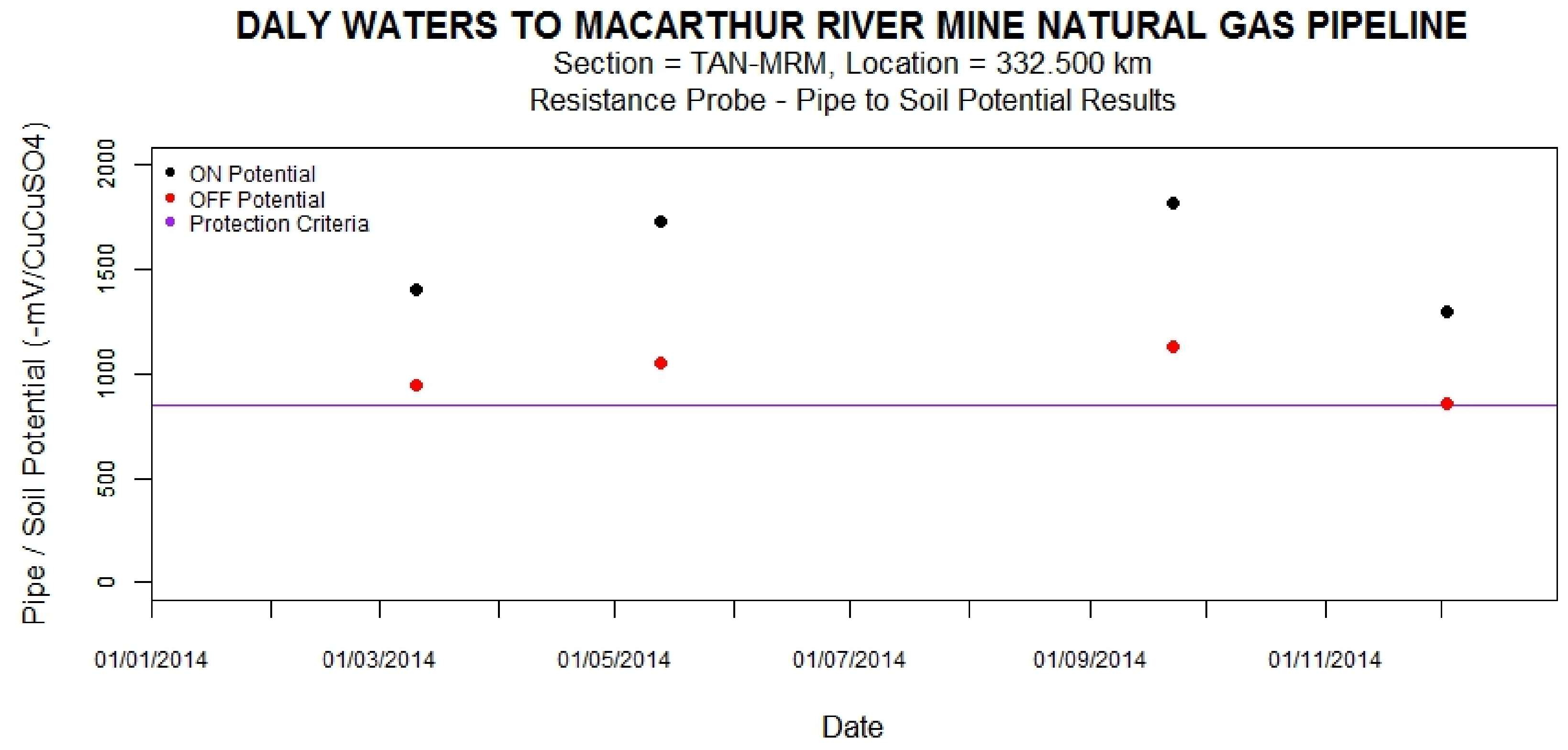
DALY WATERS TO MACARTHUR RIVER MINE NATURAL GAS PIPELINE

Section = TAN-MRM, Location = 157.500DS km

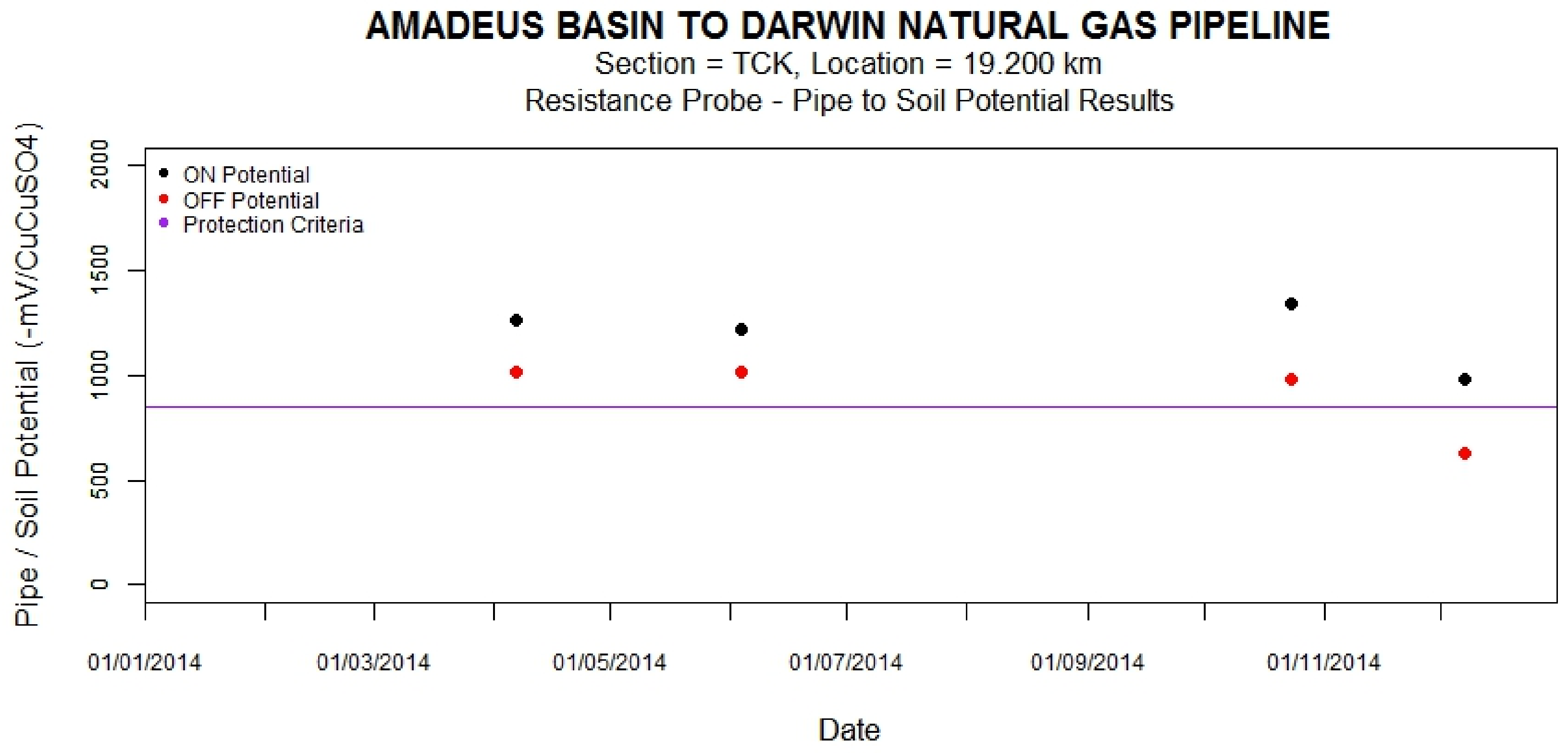
Resistance Probe - Pipe to Soil Potential Results




DALY WATERS TO MACARTHUR RIVER MINE NATURAL GAS PIPELINE
Section = TAN-MRM, Location = 249.600 km
Resistance Probe - Pipe to Soil Potential Results
ON Potential
OFF Potential
Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
0
500
1000
1500
2000
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date



DALY WATERS TO MACARTHUR RIVER MINE NATURAL GAS PIPELINE
Section = TAN-MRM, Location = 332.500 km
Resistance Probe - Pipe to Soil Potential Results


AMADEUS BASIN TO DARWIN NATURAL GAS PIPELINE
Section = TCK, Location = 19.200 km
Resistance Probe - Pipe to Soil Potential Results
ON Potential
OFF Potential
Protection Criteria
Pipe / Soil Potential (-mV/CuCuSO4)
2000
1500
1000
500
0
01/01/2014
01/03/2014
01/05/2014
01/07/2014
01/09/2014
01/11/2014
Date

Appendix E

Amadeus Basin to Darwin Natural Gas Pipeline

Resistance Probe – Corrosion Rate Results

Resistance Probe – Corrosion Rate Results

Section	Location (km)	Corrosion rate (micrometers per year)
PVL-TMR	-2.8	<5
PVL-TMR	4.7	<5
PVL-TMR	17.0	<5
PVL-TMR	45.0	<5
PVL-TMR	108.0	<5
PVL-TMR	160.0	<5
TMR-TTR	162.0	<5
TMR-TTR	210.0	<5
TMR-TTR	241.4	<5
TMR-TTR	242.0	<5
TMR-TTR	268.1	<5
TMR-TTR	316.0	<5
TTR-WCH	317.0	<5
TTR-WCH	354.0	<5
TTR-WCH	402.0	<5
TTR-WCH	440.0	<5
TTR-WCH	456.0	<5
WCH-WAR	460.0	<5
WCH-WAR	482.0	<5
WCH-WAR	502.0	<5
WCH-WAR	560.0	<5
WCH-WAR	600.0	<5
WAR-RNS	614.1	<5
WAR-RNS	640.0	Insufficient readings
WAR-RNS	660.0	Insufficient readings
WAR-RNS	696.0	Insufficient readings
WAR-RNS	727.5	<5
RNS-NCW	739.5	<5
RNS-NCW	757.8	<5
RNS-NCW	791.6	<5
RNS-NCW	824.4	<5
RNS-NCW	850.8	Insufficient readings
NCW-DLW	859.8	<5
NCW-DLW	890.0	<5
NCW-DLW	912.0	>5*
NCW-DLW	935.2	<5
NCW-DLW	959.0	<5
NCW-DLW	979.0	<5
DLW-MAT	990.0	<5
DLW-MAT	1010.0	<5
DLW-MAT	1053.0	<5
DLW-MAT	1106.0	<5
MAT-HEL	1108.1	<5
MAT-HEL	1126.1	<5
MAT-HEL	1160.2	<5
MAT-HEL	1200.3	<5
MAT-HEL	1240.0	<5
HEL-BBS	1251.7	>5*
HEL-BBS	1280.4	<5
HEL-BBS	1316.7	<5
HEL-BBS	1338.9	<5
HEL-BBS	1374.9	<5
BBS-DCG	1441.0	<5
BBS-DCG	1472.8	<5
BBS-DCG	1478.4	<5
BBS-DCG	1498.1	<5
BBS-DCG	1498.9	<5
DCG-CIM	1500.2	<5
DCG-CIM	1501.1	<5
DCG-CIM	1502.1	<5
DCG-CIM	1503.1	<5
DCG-CIM	1504.1	<5
DCG-CIM	1504.9	>5*
DCG-CIM	1510.8	<5
MER-TYP	3.6	<5

Section	Location (km)	Corrosion rate (micrometers per year)
MER-TYP	27.3	<5
MER-TYP	53.2	<5
MER-TYP	81.3	<5
MER-TYP	113.0	<5
TCK	19.2	<5

*Note: these values are considered to be caused by spurious readings

Appendix F

Amadeus Basin to Darwin Natural Gas Pipeline

Review of Protection Levels in the Vicinity of Daly Waters

Conducted by Allan Sterling, Anode Engineering

ANODE ENGINEERING
engineering@anodeengineering.com
www.anodeengineering.com

19th December, 2014

Ref: P4232-04_001_Rev0

APA Group – NT Gas
Attention: Mr Ben Parkin

RE: Amadeus Gas Pipeline – Cathodic Protection – Hayfield to Daly Waters

Dear Ben,

Anode Engineering travelled to Daly Waters to review cathodic protection on the Amadeus Gas Pipeline (AGP) between Hayfield and Daly Waters. Cathodic protection (CP) levels along parts of this section were very low and there was some concern the pipeline may be freely corroding. Of most concern was the section from KP 949 to KP 959.

At the time of inspection both CP units at Daly Waters and Hayfield had been offline for some time. Consequently cathodic protection levels were very low, so only "on" potentials were reviewed following repairs to the CP units.

It is clear CP potentials are lower (more positive) in this section compared to sections either side. It also apparent instant off potentials south of Daly Waters are also very low.

The following actions are recommended to rule out common issues that may well explain the area of "low" potentials:

1. Undertake Swain clamp testing at Daly Waters to confirm effective electrical isolation by the MIJ (switching the CP system will assist with confirmation of the current source).
2. Consider corrosion probes in the low area (KP 949 to KP 959) to confirm CP effectiveness.
3. Monitor the level of depolarisation by data logging at least 2 locations in the "low" section and then turning off the Daly Waters and Hayfield CP units.
4. Using Swain Clamps, measure current flow either side of the Daly Waters anchor block to determine if shorting to the reinforcing steel is significant.
5. Whenever the pipe is exposed, measure current flow magnitude and direction (Swain Clamp). Results will assist with determination of areas of high current demand and therefore ideal locations for future CP systems.

Item 1 will check for internal short across the MIJ (the surge diverter should be disconnected to remove this as a possible current path).

Item 2 will confirm if the pipe is protected, if protection levels are good then the focus can be on coating repair as this is a very serious issue.

Item 3 will again provide a guide as to whether cathodic protection is effective in this area. Aim is to confirm at least 100 mV of depolarisation to satisfy the criteria in AS 2832.1. If the pipeline is still well protected the focus would be to direct funding towards coating repairs as this is much more critical because of the possible shielding.

Anode Engineering Pty Ltd
Head Office Brisbane
PO Box 4444 | 30 Chetwynd St
Loganholme, QLD 4129, Australia

Toll Free: 1800 446 400
Phone: 07 3801 5521
Fax: 07 3801 5523
ABN: 67 184 998 742

Items 4 & 5 will assist in future planning, particularly if the anchor block is shown to be a major defect, measures can be taken to minimise current flow as the pipeline should be protected by the concrete.

The CP units at Hayfield and Daly waters aim to protect the section from KP 912 to KP 982. This means they need to protect ~ 35 km of pipeline each. On the basis of both units putting in ~ 2 Amps (Hayfield is also protecting to the south), the attenuation calculations (attached) indicate that the CP units will only protect ~ 23 km of pipe (uniform current density assumed). This correlates with site observations where the low potentials start ~ 22 km south of Daly Waters. The calculations however, do not explain the sudden change in potentials. The "low" area starts ~ 37 km north of Hayfield, which may be explained by significant repairs completed south of the "low" section.

In the medium term it is likely that a CP system will be required in this area, however the testing suggested above will clarify the urgency for installation.

If you have any questions regarding the comments above, do not hesitate to contact me.

Yours Faithfully,

Allan Sterling
Principal Engineer
Anode Engineering Pty Ltd
Phone: 07 3801 5521 | Mobile: 0488 788 355
allansterling@anodeengineering.com