

Paper Number: 2020_03

Evaluation of Corrosion Status in a Western Canadian Oil Transmission Pipeline

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Abstract

This paper evaluates the corrosion status of a Western Canadian oil transmission pipeline using 50 Key Performance Indicators (KPI). The risk score of the pipeline was approximately 40% whereas the integrity score was approximately 60%. Implementation of additional monitoring techniques will provide better monitoring of corrosion control strategies and will increase the integrity of the pipeline.

1. INTRODUCTION

According to Natural Resources Canada, the current pipeline inventory in the country is approximately 825,000 km of pipelines; of which approximately 100,000 km are transmission pipelines [1]. Transmission pipelines are used to move crude oil and natural gas across provincial or international borders [2]. Figure 1 shows the main pipelines carrying oil across Western Canada.

Canadian pipelines are regulated. The federal government regulates most of the large transmission pipelines (crossing provinces or countries) through the Canada Energy Regulator (CER), formerly National Energy Board (NEB). The pipelines within a province are regulated provincially.

Pipelines may suffer from internal and external corrosion. Canadian pipelines are externally protected with plant-applied coating which are applied under controlled conditions, but coatings on field welds are applied under variable and adverse conditions. Cathodic protection is a common mitigation technique used to reduce the corrosion rate of coated steel from pipelines [3, 4].

An analysis of the 46 ruptures occurred on the federally regulated pipelines from 1984 to 2003 showed that external corrosion (some leading to rupture) caused 48% [5]. Data analyzed by the NEB, from the 2000-2008 period, showed that 38% of pipelines failures are associated to stress corrosion cracking, while 25% of failures are associated to internal/external corrosion [6].

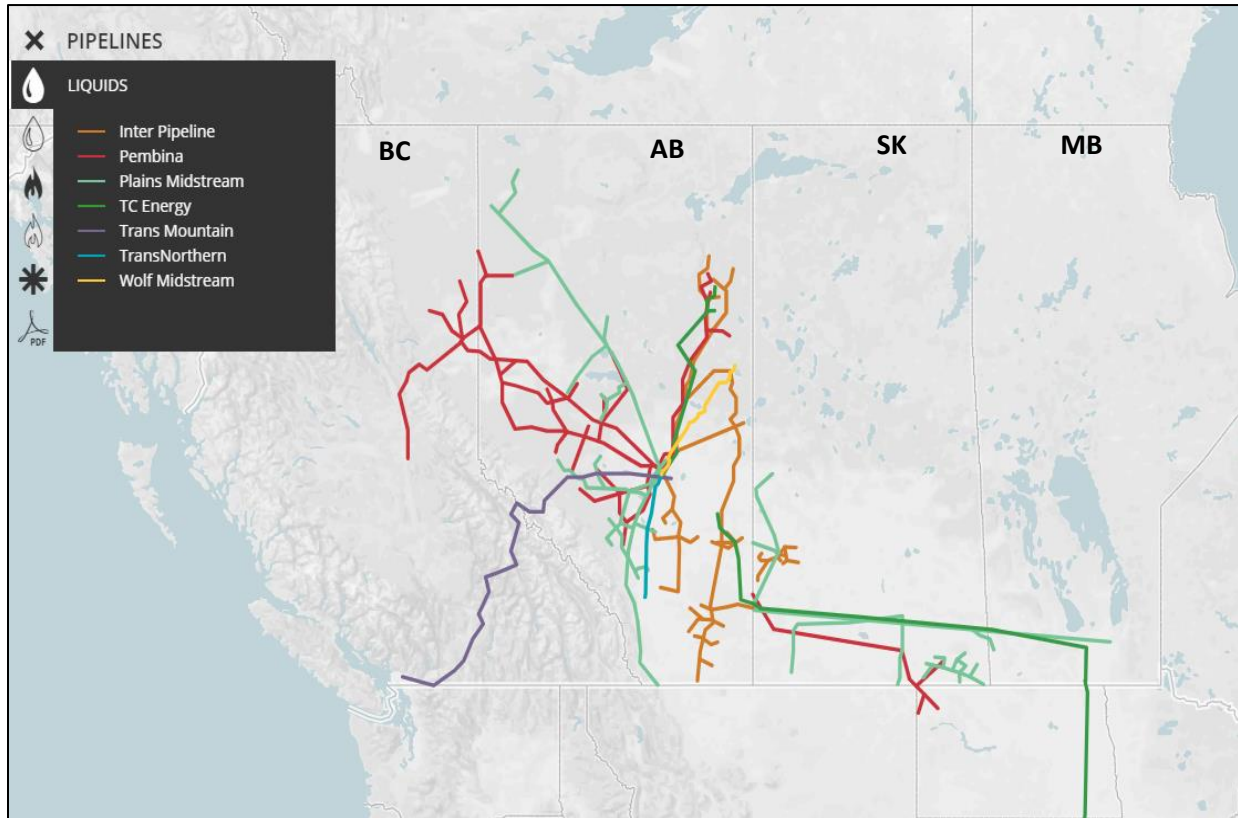


FIGURE 1. Oil pipelines across Western Canada [7]

This paper evaluates corrosion characteristics of an oil transmission pipeline located in Western Canada using 50 Key Performance Indicators (KPI). The pipeline was constructed in January 2000 and for the purpose of writing this paper, the analysis was performed on how the pipeline’s corrosion would need to be managed from June 2020 until December 2025.

Table 1 presents the evaluation criteria on status of implementation of each KPI as well as the corresponding color code.

Table 1: Status of Implementation

Status of implementation	Score	Color Code
Analysis is not done		Grey
Not relevant	0	Blue
Accounted for adequately	1	Green
Accounted for inadequately	2	Yellowish Green
Accounted for inadequately	3	Yellow
Not adequately accounted for	4	Orange
Not adequately accounted for	5	Red

2. CONTEXT OF CORROSION CONTROL

KPI 1: Segmentation of Infrastructure

For the effects of corrosion management, a fixed superficial area would be considered. The superficial area of the pipeline considered in this paper is less than 1 km² (see equation 1), therefore a score of 1 was assigned for KPI 1 [8].

$$\begin{aligned} \text{Surface area} &= (2\pi r_{\text{inner}}L) + (2\pi r_{\text{outer}}L) \\ &= \frac{2\pi(893.98\text{mm})(161.5\text{km})}{2} + \frac{2\pi(914.4\text{mm})(161.5\text{km})}{2} = 0.91\text{km}^2 \quad \text{Eq. 1} \end{aligned}$$

KPI 2: Corrosion Risk

The internal corrosion mechanism and rate was simulated using the iFILMS™ software. The main findings were a high un-mitigated pitting corrosion rate (1.26mm/y), a small remaining wall thickness (3.91mm) and 0 years to fail. In this way, the risk of corrosion is high (KPI score 4) unless some repair/mitigation methods are implemented to extend the lifetime of the pipeline.

KPI 3: Location of Infrastructure

The transmission pipelines run through rich natural environments, across sensitive lands and close to populated cities [9]. Therefore, the consequence of a failure would be high and a score of 4 was assigned.

KPI 4: Quantification of risk

The overall risk (KPI 2 times KPI 3) for corrosion is high and the pipeline will fail if no mitigation techniques are implemented. In this way, a high score (4) was assigned.

KPI 5: Life of Infrastructure

The pipeline is going to be managed from June 2020 to December 2025. In this way, the remaining life of the pipeline is around 5 years. Therefore, a KPI score of 2 was assigned.

Table 2 summarizes the score assigned to KPIs 1 to 5.

TABLE 2: Summary of KPI for Corrosion Control Context

KPI	KPI Name	Score	Rationale for KPI Score
1	Segmentation of Infrastructure	1	Segmentation is quantitative, logic, and covers entire pipeline length
2	Corrosion Risk	4	Corrosion risk is high
3	Location of Infrastructure	4	Consequence of failure is high
4	Overall Corrosion Risk	4	Overall risk from corrosion is high
5	Remaining life of the Infrastructure	2	Life is between 5 to 10 years

3. INTERNAL CORROSION – MODEL

KPI 6: Materials of Construction

The pipeline was constructed using steel API 5L X70 (Initial pipe diameter was 914.40mm, initial wall thickness was 10.20mm) that can suffer corrosion when exposed to water and CO₂ if not protected, therefore a KPI score of 3 was assigned.

KPI 7: Corrosion Allowance

According to the iFILMS™ results, the un-mitigated corrosion rate is 1.26mm/y. Then, the un-mitigated corrosion rate times the anticipated lifetime (5 years) is more than the corrosion allowance or remaining wall thickness. In this way, mitigation is required.

Several scenarios were analyzed with iFILMS™ and the corrosion rate was estimated for different mitigation techniques: corrosion inhibitor (99% availability), corrosion inhibitor (99% effectiveness), batch inhibitor, pigging, and internal coating. Based on the remaining wall thickness (3.91mm) and the anticipated lifetime, a “maximum” corrosion rate was calculated (0.78mm/y), and a safety factor of 0.5 was applied. Then, all the mitigation techniques with a pitting corrosion rate over 4mm/y were eliminated as possible candidates, and only 2 viable mitigation methods remain. Both methods include annual cleaning pigging and the installation of an internal coating as soon as possible, for an 85% reduction of the corrosion rate (Figure 2). The rate reduction can be extended to 95% when the proposed mitigation method is combined with monthly batch inhibitor. But in order to reduce costs, this method was discarded as an option.

In this way, the use of an internal coating plus annual pigging gives the best option for mitigating the corrosion of the pipeline. The mitigated corrosion rate (0.20 mm/y) times the anticipated life is less than the corrosion allowance, and therefore a KPI score of 2 was assigned.

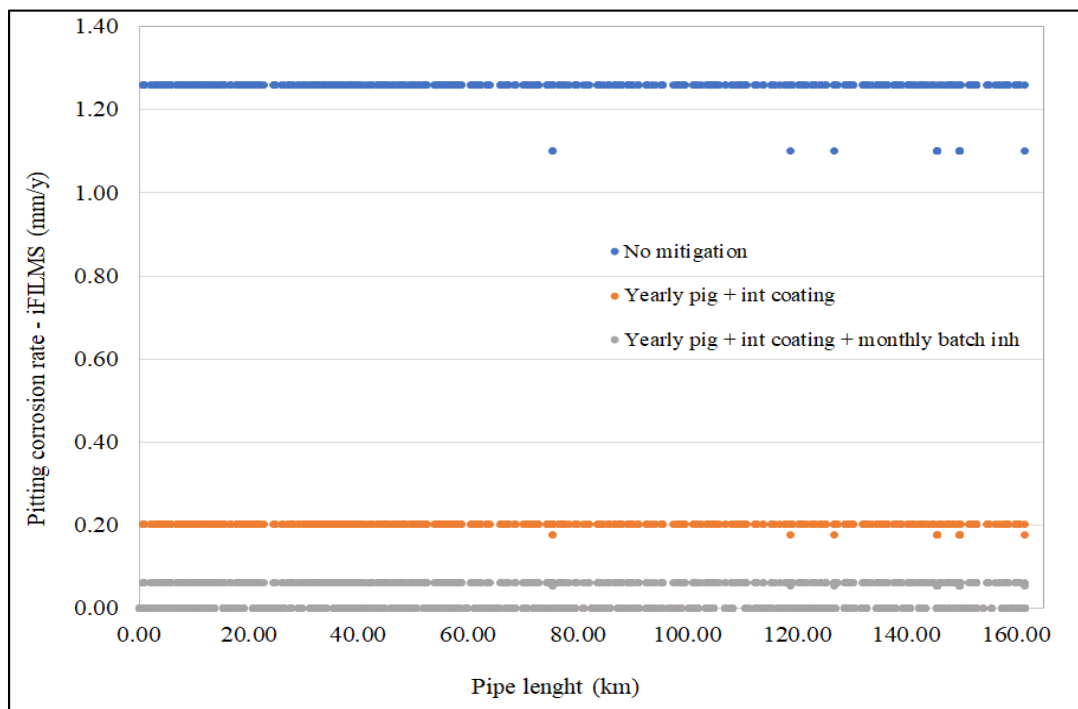


FIGURE 2. Best conditions – iFILMS™ scenarios

KPI 8: Normal operating conditions

Operating conditions are expected to be within the range established for the entire duration of the project. Therefore, the KPI score of 1 was assigned.

KPI 9: Upset Conditions in the Upstream Segment on the Current Sector

Because adequate information was not available a high-risk score of 5 was assigned for this KPI.

KPI 10: Upset Conditions in the Current Sector on the Downstream Sector

Because adequate information was not available a high-risk score of 5 was assigned for this KPI.

KPI 11: Mechanism of Corrosion

The corrosion mechanism affecting the pipeline was established using iFILMS™. Top of line corrosion, microbiologically influenced corrosion (MIC), and under deposit corrosion can occur in critical areas of the pipeline. These critical areas correspond to a change in the inclination of the pipeline and the possibility of having bubble flow. In non-critical areas, there is stratified flow and the un-mitigated corrosion rate is 0mm/y. A low KPI score of 1 was assigned as the corrosion mechanisms are considered and determined.

KPI 12: Maximum Corrosion Rate

As stated before, the maximum corrosion rate is based on iFILMS. Therefore, a low KPI score of 1 was assigned.

KPI 14: Installation of Proper Accessories

The selected corrosion control practices were assumed to be supervised by a corrosion professional to ensure the proper installation of accessories (pig launcher, pig receiver, rectifier, corrosion monitoring coupons and probes). Therefore, a low KPI score of 1 was assigned.

KPI 39: Internal Corrosion Rate after Maintenance Activities

Based on the information received from the instructor of the course, the pitting corrosion rate after maintenance of the pipeline is 0.06mm/y in critical areas (lower than before maintenance), thus a low KPI score of 1 was assigned.

KPI 40: Percentage Difference Between Internal Corrosion Rate Before and After Maintenance Activities

Based on the information received from the instructor of the course, the corrosion rate is reduced in 90% after maintenance. Therefore, a low KPI score of 1 was assigned.

Table 3 summarizes the KPIs associated with the internal corrosion model.

TABLE 3. Summary of KPI for Internal Corrosion Model

KPI	KPI Name	Score	Rationale for KPI Score
6	Material of Construction – Internal	3	Material selection not based on corrosion consideration, but the material is compatible in the environment with appropriate corrosion control measures
7	Corrosion Allowance	2	Corrosion allowance is slightly more than mitigated corrosion rate times anticipated life
8	Normal Operating Conditions	1	Operating conditions within the range established for the entire duration of the project
9	Upset Conditions in the Upstream Segment	5	Potential influence of upset conditions upstream is not understood and no communication plan is in place to obtain information on upset conditions
10	Upset Conditions	5	Potential influence of upset conditions on downstream is not understood and no communication plan is in place to obtain information on upset conditions
11	Corrosion Damage Mechanisms	1	All corrosion damage mechanisms are considered and most prominent ones determined
12	Maximum Internal Corrosion Rate	1	Maximum corrosion rate is based on all corrosion damage mechanisms (CDM)
14	Installation of Accessories	1	Corrosion professionals are involved during construction and the accessories for implementing mitigation, monitoring, and maintenance activities are properly installed
15	Commissioning	1	Infrastructure is properly hydrotested and the water used in the hydrotest properly is completely removed, baseline conditions (e.g., inline inspection, CP current demand) are established to ensure that the corrosion rate is and will remain at the predicted rate, and all data from the design stage are collected and properly stored in the database for future use
39	Internal Corrosion Rate after Maintenance	1	Corrosion rate after the maintenance activities is lower than the corrosion rate before maintenance activities
40	Percentage Difference in Internal Corrosion Rate Before and After	1	Corrosion rate before the maintenance activities is within 10% of the corrosion rate established in KPI 27.

4. INTERNAL CORROSION – MITIGATION

KPI 16: Mitigation to Control Internal Corrosion

The use of mitigation strategies to control corrosion is required. After analyzing different scenarios with iFILMS™, the use of an internal coating plus annual pigging gives the best option for mitigating the corrosion of the pipeline. Therefore, the KPI score of 3 was assigned.

KPI 17: Mitigation Strategies to Control Internal Corrosion

The mitigation strategies were selected based on the operations of the pipeline and a KPI score of 3 was assigned.

KPI 18: Mitigated Internal Corrosion Rate

The mitigated internal corrosion rate is based on the assumption that the mitigation practices will keep the corrosion rate low, as established in KPI 12 and KPI 17. Therefore a KPI score of 1 was assigned.

KPI 19: Effectiveness of the Internal Corrosion Mitigation Strategy

It is assumed that the mitigation strategy is available and effective 100% of the time (internal coating), which is reinforced by yearly pigging to avoid the formation of deposits and minimize MIC. Therefore a KPI score of 1 was assigned.

Table 4 summarizes KPIs 16 to 19.

TABLE 4. Summary of KPI for Internal Corrosion - Mitigation

KPI	KPI Name	Score	Rationale for KPI Score
16	Internal Corrosion Mitigation	3	Yes. Based on some analysis performed at the conceptual and design stages
17	Types of Internal Corrosion Mitigation Strategies	3	Mitigation strategy is standardized by trial and error method under the operating conditions and is proven to be effective
18	Targeted Mitigated Internal Corrosion Rate	1	Mitigated corrosion rate is based on baseline corrosion rate (established as per KPIs 12 and 17) and efficiency of mitigation strategy
19	Internal Corrosion Mitigation Strategy Effectiveness	1	Mitigation practices are implemented (e.g., corrosion inhibitor is available) slightly more than 99% of the time

5. INTERNAL CORROSION – MONITORING

KPI 24: Internal Corrosion Monitoring Techniques

It is proposed the use of smart pig (UT) with capability to monitor both internal and external corrosion. Additionally, the use of coupons to monitor internal corrosion of the pipeline is recommended [10]. Therefore, a low KPI score of 1 was assigned.

KPI 25: Number of probes to monitor internal corrosion

The number of probes is considered to be covering most of the critical areas. Therefore, a KPI score of 3 was assigned.

KPI 26: Internal Corrosion Rates

The corrosion rate from the monitoring technique was not available by the time this report was produced, so this activity was not analyzed.

KPI 27: Accuracy of Internal Corrosion Monitoring Techniques

This activity was not analyzed.

KPI 32: Frequency of Inspection

This activity was not analyzed.

KPI 33: Percentage difference between internal corrosion rates from monitoring and inspection techniques

This activity was not analyzed.

Table 5 summarizes the KPIs 24 and 25. KPIs 26, 27, 32 and 33 were not analyzed and are not shown in the table.

TABLE 5 Summary of KPI for Internal Corrosion - Monitoring

KPI	KPI Name	Score	Rationale for KPI Score
24	Internal Corrosion Monitoring Techniques	1	Two or slightly more complimentary techniques that are proven to be effective in monitoring the corrosion damage mechanism occurring in the segment are used
25	Number of Internal Corrosion Monitoring	3	Number of working probes just enough to cover most critical areas

6. EXTERNAL CORROSION – MITIGATION**KPI 20: Selection of Mitigation to control external corrosion**

The pipeline analyzed in this paper was protected with FBE external coating and liquid epoxy applied over girth welds. The pipeline was analyzed with the software Expedition™ to determine the main corrosion mechanism and remaining lifetime. The main findings are that the corrosion rate is low (0.11mm/y) which gives over 30 years of service. The main corrosion damage is weld zone corrosion and the main coating damage modes includes blistering, disbondment, and dissolution. In this way, controlling the damage of the coating is a key factor to control corrosion, and adding cathodic protection would protect the steel substrate in the event that the coating is damaged or degraded. Therefore, the KPI score assigned was 2.

KPI 21: Implementation of Mitigation strategies to control external corrosion

Cathodic protection is a common mitigation technique used to reduce the corrosion rate of coated steel from pipelines. When design adequately, it has high effectiveness. But coating disbondment must be monitored as it reduces the cathodic protection effectiveness [10, 11]. Therefore, the KPI score assigned was 3.

KPI 22: Mitigated external corrosion rate, target

The mitigated corrosion rate was evaluated using Expedition. Effectiveness of the mitigation strategy was assumed. Therefore, a low KPI score of 1 was assigned.

KPI 23: Effectiveness of external corrosion mitigation strategy

It is assumed that the mitigation strategy is going to be available more than 99% of the time, thus a low KPI score of 1 was assigned.

Table 6 summarizes KPIs scores 20 to 23.

TABLE 6 Summary of KPI for External Corrosion - Mitigation

KPI	KPI Name	Score	Rationale for KPI Score
20	External Corrosion – Mitigation	2	Yes. Based on the analysis performed at the conceptual and design stages
21	Types of External Mitigation strategies	3	Mitigation strategy is standardized by trial and error method under the operating conditions and is proven to be effective
22	Targeted Mitigated Corrosion Rate	1	Mitigated corrosion rate is based on baseline corrosion rate (established as per KPIs 12 and 17) and efficiency of mitigation strategy
23	External Mitigation Strategy Effectiveness	1	Mitigation practices are implemented (e.g., Cathodic protection is available) slightly more than 99% of the time

7. EXTERNAL CORROSION – MODEL

KPI 6 EC (External corrosion): Material of Construction

The use of a coated steel for the construction of pipelines is based on external corrosion consideration, then a low KPI score of 1 was assigned.

KPI 7 EC: Corrosion Allowance

According to the scenarios analyzed using Expedition, the corrosion allowance of the coated pipeline (without cathodic protection) is more than the corrosion rate times the anticipated life of the pipeline, which gives more than 30 years of remaining life. In this case, the cathodic protection is used to protect the substrate in case of coating damage. Therefore, the KPI score assigned was 1.

KPI 9 EC: Upset conditions in the upstream segment

See KPI 9 (Internal corrosion).

KPI 10 EC: Upset conditions in the downstream segment

See KPI 10 (Internal corrosion).

KPI 11 EC: Mechanisms of corrosion

According to the Expedition™ results, the main corrosion damage is weld-zone corrosion and the main coating damage modes includes blistering, disbondment, and dissolution. The probability of corrosion is low. Therefore, the a low KPI score of 1 was assigned.

KPI 13: Maximum corrosion rate (External surfaces)

The maximum corrosion rate (0.11mm/y, over 30 years of remaining lifetime) is based on simulations done using Expedition, therefore a low KPI score of 1 was assigned.

KPI 14 EC: Installation of proper accessories

See KPI 14 (Internal corrosion)

KPI 41: External corrosion rate after maintenance activities

According to the information received, the corrosion rate after maintenance is similar to the unmitigated corrosion rate. Therefore, a KPI score of 2 was assigned.

KPI 42: Percentage difference between external corrosion rate before and after maintenance activity

According to the information received, the corrosion rate after maintenance was within 10% before maintenance. Therefore, a KPI score of 1 was assigned.

Table 7 summarizes the KPIs 6, 7, 9 to 11, 13, 14, 41 and 42.

TABLE 7 Summary of KPI for External Corrosion - Model

KPI	KPI Name	Score	Rationale for KPI Score
6	Material of Construction – External	1	Material selected solely based on corrosion consideration
7	Corrosion Allowance	1	Corrosion allowance is slightly more than corrosion rate times anticipated life
9	Upset Conditions in the Upstream Segment	5	Potential influence of upset conditions upstream is not understood and no communication plan is in place to obtain information on upset conditions
10	Upset Conditions	5	Potential influence of upset conditions on downstream is not understood and no communication plan is in place to obtain information on upset conditions
11	Corrosion Damage Mechanisms	1	All corrosion damage mechanisms are considered and most prominent ones determined
13	Maximum External Corrosion Rate	1	Maximum corrosion rate is based on model, laboratory experiment, simulation, or documented lar field experience
14	Installation of Accessories	1	Corrosion professionals are involved during construction and the accessories for implementing mitigation, monitoring, and maintenance activities are properly installed
41	External Corrosion Rate after Maintenance	2	Corrosion rate after the maintenance activities is same as that before maintenance activities
42	Percentage Difference in External Corrosion Rate Before and After	1	Corrosion rate before the maintenance activities is within 10% of the corrosion rate established in KPI 31

8. EXTERNAL CORROSION – MONITORING

KPI 28: External corrosion monitoring techniques

It is proposed the use of smart pig (UT) with capability to monitor both internal and external corrosion [12]. But no additional method for monitoring the external technique is in use. Therefore, a KPI score of 3 was assigned.

KPI 29: Number of probes to monitor external corrosion

This activity was not analyzed.

KPI 30: External corrosion rate from monitoring technique

The corrosion rate from the monitoring technique was not available by the time this paper was produced, so this activity was not analyzed.

KPI 31: Accuracy of external corrosion monitoring techniques

This activity was not analyzed.

KPI 32 EC: Frequency of inspection

This activity was not analyzed.

KPI 34: Comparison between Inspection and Monitoring for External Corrosion

This activity was not analyzed.

Table 8 summarizes the KPIs applied for the external corrosion monitoring. KPIs 29 to 32 and 34 were not analyzed.

TABLE 8 Summary of KPI for External Corrosion - Monitoring

KPI	KPI Name	Score	Rationale for KPI Score
28	External Corrosion Monitoring Techniques	3	Only one type of monitoring technique that is proven to be effective in monitoring the corrosion type occurring in the segment is used

9. MEASUREMENT

KPI 35: Measurement data availability

Not all measurement data required for deciding corrosion conditions of the segment are available, and a high KPI score of 5 was assigned (Table 9).

KPI 36: Validity and utilization of measured data

This activity was not analyzed.

TABLE 9 Summary of KPI for Measurement

KPI	KPI Name	Score	Rationale for KPI Score
35	Measurement Data	5	5-No measurement data required for deciding corrosion conditions of the segment are available

10. MAINTENANCE

KPI 8: Normal operating conditions

It is assumed that the operating conditions are within the range established for the entire duration of time analyzed in this paper. Therefore, a low KPI score of 1 was assigned.

KPI 15: Commissioning

It is assumed that the infrastructure was properly hydrotested and the water used was completely removed. Therefore, a low KPI score of 1 was assigned to this activity.

KPI 37: Procedures for establishing the maintenance schedule

The pipeline requires immediate maintenance in order to reduce the internal corrosion rate and extend the life of the pipeline. According to iFILMS™ scenarios, the pipeline failure is imminent if the maintenance is not executed. Therefore, KPI score of 3 was assigned.

KPI 38: Maintenance activities

Adequate and planned maintenance activities are considered. Therefore, KPI score of 1 was assigned.

KPI 43: Workforce – capacity, skills, education, and training

Corrosion control activities are supervised by trained personnel. Moreover, the pipeline analyzed in this report is based on Canada. In Canada, engineers must be registered a professional association and continuing professional development program (CPD) is required for all Professional and In-Training Members. Therefore, training programs are mandatory, and the ability of the personnel to perform specific tasks is ensured. Therefore, KPI score of 1 was assigned.

KPI 44: Workforce – experience, knowledge, and quality

Due to requirements of the professional associations of engineers in Canada, Engineer-in-Training members cannot work un-supervised in critical projects. In this way, experienced key personnel should be in supervision functions and are considered in this paper. Therefore, KPI score of 1 was assigned.

KPI 45: Data management – Data to database

Data collection and information technology (IT) as an integral part of corrosion management is being considered in this report. Therefore, KPI score of 1 was assigned.

KPI 46: Data management – Data from database

Regular analysis and verification of the data is considered in this paper. Therefore, KPI score of 1 was assigned.

Table 10 summarizes KPIs 8, 15, 37, 38, and 43 to 46.

TABLE 10 Summary of KPI for Maintenance

KPI	KPI Name	Score	Rationale for KPI Score
8	Normal Operating Conditions	1	Operating conditions within the range established for the entire duration of the project
15	Commissioning	1	Infrastructure is properly hydrotested and the water used in the hydrotest properly is completely removed, baseline conditions (e.g., inline inspection, CP current demand) are established to ensure that the corrosion rate is and will remain at the predicted rate, and all data from the design stage are collected and properly stored in the database for future use
37	Procedures for Establishing Maintenance Schedule	3	When the risk moves from ALARP to high risk stage, i.e., when conditions indicate that failure is imminent if the maintenance is not executed
43	Workforce – Capacity, Skills, Education, and Training	1	The number of workers is enough to carry out the work and all personnel involved have proper education and formal training to carry out the task
45	Data to Database	1	Data from different activities, measurements are automatically and systematically transferred to the database with no or minimal human intervention
38	Maintenance Activities	1	The work is carried out as per planned maintenance activities with all teams delivering their services as per schedule
44	Workforce – Experience, Knowledge, and Quality	1	All personnel involved have at least five years of experience and knowledge in similar work
46	Data from Database	1	Data is properly verified, systematically stored, and proactively passed onto appropriate persons or appropriate persons can retrieve the data in the format required

11. MANAGEMENT

KPI 47: Internal communication strategy

Bi-weekly internal communications for topics related to corrosion control are being considered. Therefore, KPI score of 1 was assigned.

KPI 48: External Communication Strategy

Some external communications with external parties are considered. Therefore, KPI score of 2 was assigned.

KPI 49: Corrosion management review for continuous improvement

Revision of the KPIs every 2 years to improve corrosion control. Therefore, KPI score of 2 was assigned.

KPI 50: Failure frequency

Less than 5 failures and some due to corrosion but none in high consequence area. But, this KPI can be adjusted during the KPI revision. Therefore, KPI score of 2 was assigned.

Table 11 summarizes KPIs 47 to 50.

TABLE 11 Summary of KPI for Management

KPI	KPI Name	Score	Rationale for KPI Score
47	Internal Communication Strategies	1	Internal communication strategy between all parties (including corrosion team, integrity team, subordinates, upper management, suppliers and service providers, workers, and regulators) is established, practiced, and documented
48	External Communication Strategies	2	External communication strategy and communication person(s) with many entities is established, communication with others is only on adhoc basis
49	Review for Continued Improvement	2	The corrosion control activities are reviewed between every 2 to 5 years
50	Failure Frequency	2	Less than 5 failures and some due to corrosion but none in high consequence area

12. SUMMARY OF THE STATUS OF KPIS AND STATUS OF INFRASTRUCTURE

The status of the analyzed infrastructure and the application of the fifty KPIs considered in this paper are summarized in figure 3. This figure was produced using the STEM_Risk_Pipeline™ software. The risk for the pipeline is close to 40% meaning that maintenance is required to extend the lifetime of the pipeline. A monitoring plan is also recommended in order to verify the effectiveness of the mitigation techniques and have a better control of the operating conditions.

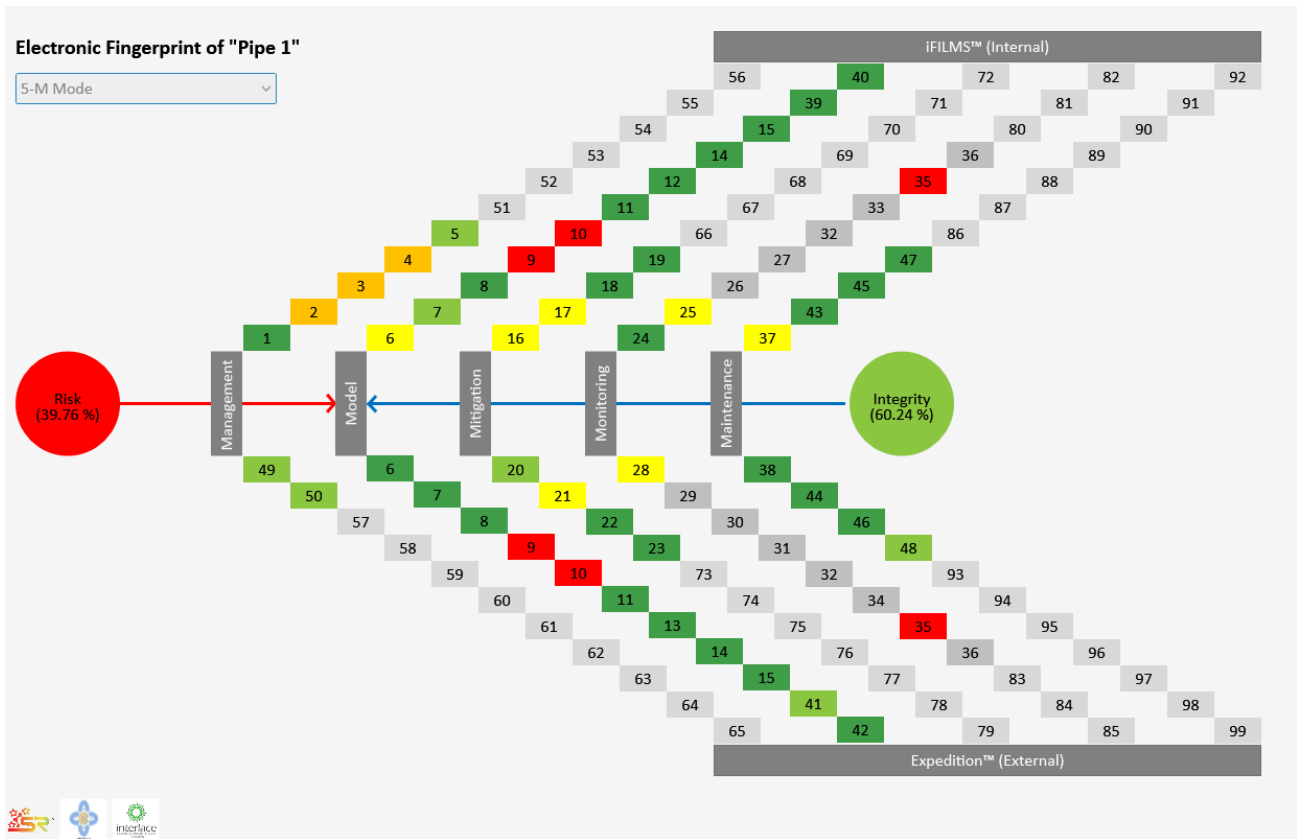


FIGURE 3 Summary of the status of KPIs for the analyzed pipeline

13. ADDITIONAL RECOMMENDATIONS

Based on the summary of the KPIs, more emphasis should be put in monitoring the corrosion rate after maintenance in order to determine the effectiveness of the applied mitigation techniques.

14. CONCLUSIONS

Based on the summary of the KPIs, 27 KPI are adequately implemented, and the corrosion risk is close to 40%. In order to decrease the corrosion risk, the effect of the upstream segment should be taken into account. Documenting and reporting the incidents causing deviation from the predicted normal operations of the pipeline will increase the integrity of the analyzed system. Implementing adequate monitoring techniques will also increase the integrity of the pipeline and would allow to take measurements when abnormal values are obtained.

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