SUMMIT
CARBON
SOLUTIONS

Risk Assessment

Report to the South Dakota Public Utilities Commission

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1 Overview

1.1 Intent

The purpose of this document is to summarize Summit Carbon Solutions' ("Summit") risk assessment for its proposed carbon dioxide pipeline system in South Dakota. Completing a risk assessment allows Summit to proactively identify potential hazards and risks, which facilitates implementation of preventative and mitigative measures to improve overall safety. Improved safety can be accomplished through a variety of measures to reduce the likelihood of failure as well as the potential consequences of failure.

Risk assessment is a key component of the Pipeline and Hazardous Materials Safety Administration's (PHMSA) Integrity Management (IM) program regulation, intended to drive decision-making aimed at protecting the pipeline and its human and environmental surroundings. The purpose of a pipeline risk assessment is to provide a comprehensive evaluation of the probability and consequences of a pipeline failure. As set out in more detail below, federal regulations require, at a minimum, Summit to apply its IM program to any segment that could affect a High Consequence Area (HCA) (roughly 8% of the route in South Dakota). Summit has committed to exceed these regulations by applying its IM program to the entirety of its pipeline system, including the approximately 698 miles in South Dakota.

1.2 Background

Risk is commonly defined as the product of the probability of an event occurring and the resulting consequence of that event. Summit's risk assessment utilizes a process known as Dynamic Segmentation which analyzes the pipeline system in tens of thousands of smaller segments allowing for assessment of the unique and varying aspects of the system.

Summit utilizes a state-of-the-art program that produces estimates of risk based on each pipeline segment's characteristics and surroundings. For example, the risk profile of a pipeline segment under a road is different than the risk profile of a pipeline segment in an agricultural field, and Summit's approach accounts for these differences. In fact, the risk assessment utilizes over 200 different inputs and over 200 unique algorithms to produce risk estimates.

Risk estimates are re-generated periodically during the pre-construction/design phase, during construction, and after the pipeline is operational. Summit is continuously collecting additional information to improve its designs, construction plans, materials, and techniques. By taking this approach, Summit is able to ensure that risks are identified and mitigated as part of Summit's on-going risk management decision making.

1.3 Regulatory Requirements

While PHMSA regulations do not specify the type of risk assessment methodology that must be used, PHMSA has come to expect increasingly sophisticated approaches to risk[1]. PHMSA has noted that more robust quantitative assessments, such as the Summit methodology, are best able to achieve the objectives of IM.

The output of a risk assessment is used to help direct key risk management elements of the operator's IM program, allowing the pipeline operator to deploy its resources most efficiently along a pipeline based on risk. Specifically, the regulation requires a pipeline operator to use the results of their risk assessment to drive the related IM processes of:

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[1] https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2020-03/Pipeline-Risk-Modeling-Technical-Information-Document-02-01-2020-Final_0.pdf

1. Setting baseline and reassessment schedules (195.452(e)). This is to ensure the operator timely and appropriately assesses pipeline integrity.
2. Undertaking a continual process of evaluation and assessment to maintain integrity (195.452(j)), including annual verification of the risk factors used to identify high consequence areas (195.452(j)(2)). This requirement ensures that the operator regularly updates its risk assessment.
3. Identifying and implementing actions to enhance public safety and environmental protection, or so-called Preventative and Mitigative Measures (PMM) (195.452(i)). This is to confirm that, where risks might be higher, additional risk reduction measures are implemented.

1.4 Risk Context

There are approximately 5,500 miles of carbon dioxide pipelines under PHMSA jurisdiction. Since reporting began, there has never been a fatality associated with a carbon dioxide pipeline. The lone injury reported in the past 20 years (PHMSA, 2024) involved a pipeline contractor and was avoidable.

PHMSA also regulates approximately 230,000 miles of hazardous liquid pipelines. Since 2010, there have been ten incidents involving fatalities. This results in a longer-term average of ~0.71 incidents involving fatalities per year from all of the hazardous liquid pipeline miles in the United States combined. Of these ten incidents, seven were due to someone striking and damaging the pipeline (PHMSA, 2024). This historical data helps demonstrate that the probability of a release affecting the health and safety to members of the public from any hazardous liquid pipeline is extremely low

Recent historical data (2010-Present) indicates that any section of a PHMSA-regulated carbon dioxide pipeline has a statistical failure[2] rate of about 0.0005 failures per mile-year which translates to a incident less than once every 2,000 years. While this is a very low incident rate, the new Summit pipeline system, as discussed below, has been assessed to be lower than 0.0003 per mile-year – a failure less than once every 3,300 years. Comparing the Summit system to United States hazardous liquid pipeline historical risk levels – from 0.0005 to 0.001 reportable failures per mile-year – shows that the Summit system will have even lower failure potential, as much as 3X lower.

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[2] The words accident, incident, and failure are used interchangeably in this report. Accordingly, the frequency of failure estimate contemplates all incidents that meet the definition of a reportable accident under federal regulations, including those that are very minor and fully contained on the operator's property. Under 49 CFR 195.50 an accident report must be filed for each failure in a pipeline system in which there is a release of carbon dioxide transported resulting in any of the following:

a. Explosion or fire not intentionally set by the operator.
b. Release of 5 gallons or more of carbon dioxide, except that no report is required for a release of less than 5 barrels resulting from a pipeline maintenance activity if the release is:
    1. Not otherwise reportable under th[e regulation];
    2. Not one described in [49 CFR part] 195.52(a)(4);
    3. Confined to company property or pipeline right-of-way; and
    4. Cleaned up promptly;
c. Death of any person;
d. Personal injury necessitating hospitalization;
e. Estimated property damage, including cost of clean-up and recovery, value of lost product, and damage to the property of the operator or others, or both, exceeding $50,000.

2 Pipeline Failure Probability Analysis

This chapter focuses on the first component of risk: the probability of a release occurring.

2.1 Threat Assessment

The first step in Summit's failure probability analysis is a threat assessment. The primary objective of the threat assessment is to review the attributes for all potential threats to a pipeline system considering the design, materials, construction methods, and operational variables for the pipeline system. The threat assessment forms the basis of a subsequent analysis to provide quantitative estimates of the likelihood of failure for all pipeline segments.

The first step of the threat assessment is identification of potential threat. In this analysis, threats were divided into seven failure categories:

1. Third-party damage
2. Incorrect operations
3. Sabotage
4. Geohazards
5. External corrosion
6. Internal corrosion
7. Cracking

These seven categories capture the potential failure mechanisms relevant to Summit's pipeline system.

Table 2.1-1 outlines a summary of some of the major potential threats and associated controls, or protective measures, identified through the threat assessment process:

Category	Example Threats	Examples of Protective Measures
Third-party Damage	Excavations, agricultural activities, vehicle impacts, falling objects, and other excessive external loads	One-call system, pipeline markers, patrol frequency, depth of cover
Incorrect Operations	Surge potential, thermal pressure events, misalignment of valves, incorrect installation	Operating procedures and training programs, SCADA system, Process Hazard Analysis
Sabotage	Accessibility and threat level	Site security, patrols, surveillance
Geohazards	Natural forces, ground movements, flooding, seismic, lateral migration and scour of rivers	Geohazard analysis, aerial patrols, in-line-inspection tools, material specifications
External Corrosion	Interference potentials, soil corrosivity, external coating damage, AC induced corrosion	Fusion-bonded epoxy coating, cathodic protection system, overline surveys, AC interference mitigation, QAQC measures during pipe coating and installation, direct current voltage gradient quality check during pipeline installation, operational procedures for testing cathodic

		protection system effectiveness, in-line-inspection tools
Internal Corrosion	Product stream composition, contaminants, and erosional velocities	Dehydration system, moisture and other gas quality analyzers, corrosion probe monitoring, in-line-inspection tools
Cracking	Cyclic fatigue, environmental assisted cracking, vibrations	Material specifications, routine inspection, SCADA systems, in-line-inspection tools

2.2 Threat Potential Summary

The basis for the frequency of failure (FoF) model is to examine each failure mechanism in three parts:

1. Exposure: Estimate each component's unmitigated exposure from each threat, recognizing the two types of exposure.
    a. Degradation rate from time-dependent failure mechanisms
    b. Event rate from time-independent failure mechanisms
2. Mitigation: Estimate effect of each mitigation measure for each component's threats
    a. Identify all mitigation measures
    b. Rate effectiveness of each
    c. Combine and apply estimates to appropriate exposures
3. Resistance: Estimate each component's resistance to failure from each mitigate exposure
    a. Theorize amount of resistance available in the absence of defects
    b. Estimate the role of possible defects present in each component, considering rates of defect emergence and age and accuracy of all inspections and integrity assessments

FoF estimates for each of the seven threat potentials are first evaluated independently. This analysis is broken out between time dependent mechanisms (corrosion and cracking) and time independent mechanisms (third-party damage, incorrect operations, sabotage, and geohazards).

A simplified calculation for frequency of failure for time independent threats is shown below:

$FoF_{Time\text{-}Indep}$ = *[unmitigated exposure frequency] * (1-[threat reduction])*

Where [threat reduction] is a function of mitigation and resistance

A simplified calculation for frequency of failure for time dependent threats is shown below:

$FoF_{Time\text{-}Dep} = 1/[\text{time to failure}]$

Where [time to failure] = (available pipe wall) / [wall loss rate) x (1-mitigation)]

After the FoF estimates have been generated for the seven threat potentials, they can be combined to give an overall failure probability per segment:

$FoF_{Overall} = 1-[(1-FoF_{third\text{-}party}) \times (1-FoF_{geohazard}) \times (1-FoF_{cracking}) \times (1-FoF\ldots)]$

2.3 Quantitative FoF Analysis

Summarized estimates of FoF analysis for each individual segment are listed below:

Segment	Length (miles)	Frequency of Failure (incidents per mile-year)
IAL-510	2.616	0.00049
NDM-106	27.817	0.00020
NDT-211	30.404	0.00025
SDL-320	81.508	0.00019
SDL-335	0.438	0.00073
SDL-513	32.693	0.00049
SDL-514	51.905	0.00031
SDL-515	25.931	0.00054
SDM-104A	0.098	0.00021
SDM-104B	125.492	0.00012
SDM-105A	27.244	0.00021
SDM-105B	86.534	0.00018
SDT-206	14.492	0.00059
SDT-207	23.784	0.00056
SDT-208	51.948	0.00031
SDT-209	12.652	0.00052
SDT-210	13.189	0.00051
SDT-212	18.105	0.00057
SDT-409	7.918	0.00059
SDT-410	42.436	0.00038
SDT-411	20.547	0.00058

Summit’s risk assessment estimates an average frequency of PHMSA reportable failures of 0.0003 incidents per mile-year, which equates to roughly once every 3,300 years for a mile of pipeline. In the unlikely event of a failure, the consequence potential can vary dramatically with the vast majority of historical carbon dioxide incidents being very minor and fully contained on the operator’s property. Further discussion on the consequence of failure is discussed below.

3 Pipeline Failure Consequence Probability Analysis

This section focuses on the second component of risk: the potential consequence of a release.

3.1 Consequence Assessment

The primary objective of the consequence assessment is to fully understand and quantify potential consequences in the unlikely event of a pipeline failure. The consequence assessment forms the basis of a subsequent analysis to provide quantitative estimates for the cost of failure for all pipeline segments.

Consequence potentials that were examined:

1. Potential Receptor Damage
    - Human populations
    - Environmentally sensitive areas
        - Wildlife
        - Terrestrial
    - Drinking water
    - Navigable waterways
2. Repair costs
3. Service interruption
4. Other indirect

Table 3.1-1 outlines a summary of some of the major potential impacts:

Category	Potential Impact
Human populations	When released in large quantities, carbon dioxide can physically displace the other components of ambient air and reduce the amount of available oxygen, potentially resulting in temporary adverse effects, or in the worst-case asphyxiation. Dispersion modeling results can be overlaid with population data to identify areas that have the potential for effects.
Environmentally Sensitive Areas - Wildlife	When released in large quantities, carbon dioxide can physically displace the other components of ambient air and reduce the amount of available oxygen, potentially resulting in temporary adverse effects, or in the worst-case asphyxiation. Dispersion modeling results can be overlaid with ecologically sensitive data to identify intersects.
Environmentally Sensitive Areas - Terrestrial	It is highly unlikely that damages would occur due to a carbon dioxide release. Effects to terrestrial ESA's would either be the result of a release that progressed for a long period of time (weeks or months), or would be limited in spatial extent to the area of the failure (feet to tens of feet) based on ground disturbance. Dispersion-based hazards can be overlaid on terrestrial ESA to identify sensitive areas with the potential for effects.
Drinking Water	It is highly unlikely that damages would occur due to a carbon dioxide release. Effects to drinking water would require a release for a long period of time (weeks or months). Nonetheless, sensitive areas are identified and overlaid with potential dispersion-based hazards.
Navigable Waterways	It is highly unlikely that damages would occur due to a carbon dioxide release. Nonetheless, sensitive areas are identified and overlaid with potential dispersion-based hazards.

Repair Costs	Cost of any repairs required to return the pipeline to service.
Service Interruption	In the event of a failure, Summit may have to temporarily suspend services until a repair is complete.
Other Indirect	Damage to corporate reputation, increased regulatory oversight, legal costs, etc.

3.2 Consequence Potential Summary

The potential impact of a pipeline incident depends on two conditions: (1) the product and (2) the surroundings. The consequence of failure estimates are stated in monetary terms in order to fully understand risk in a quantitative, and not subjective, manner. Using this quantitative approach is also helpful in understanding the potential range of consequences.

The process can be generalized into the five steps below:

1. Estimate possible threshold distances and associated probabilities.
2. Produce zones based on those distances.
3. Associate damage states with each distance zone.
4. Characterize receptors within each zone.
5. Combine the results from the previous steps into a potential loss value for each consequence of failure scenario.

The product of four variables essentially determines the magnitude of the consequence of failure (CoF):

CoF = PH x RQ x D x R

Where PH = product hazard (toxicity, flammability, etc.)

RQ = release quantity

D = dispersion

R = receptors (all things that could be damaged by contact with the release)

Each CoF scenario has an associated probability of occurrence, produces a certain hazard zone, and contains certain numbers and types of receptors with associated damage potential values. Multiplying these values together and then summing the results for each hazard zone produces the CoF estimate for the pipeline segment.

Summit utilizes data published by the United Kingdom Health and Safety Executive (UKHSE) to establish the basis for product hazard. Although considered conservative, UKHSE provides data to make probabilistic determinations based on concentration and duration of exposure, further described in Summit's Dispersion Analysis.

Data for both release quantity and dispersion were produced utilizing CANARY and integrated into the risk assessment. This is further described in Summit's Dispersion Analysis.

Receptors utilize a variety of data sets like those published by the National Pipeline Mapping System as well as the United States Census Bureau.

3.3 Quantitative CoF Analysis

Summarized estimates of CoF analysis for each individual segment are listed below:

Segment	Length (miles)	Consequence of Failure (Dollars per incident)
IAL-510	2.616	7,000
NDM-106	27.817	19,566
NDT-211	30.404	8,937
SDL-320	81.508	7,000
SDL-335	0.438	7,000
SDL-513	32.693	7,000
SDL-514	51.905	7,000
SDL-515	25.931	7,000
SDM-104A	0.098	16,900
SDM-104B	125.492	20,751
SDM-105A	27.244	19,888
SDM-105B	86.534	21,670
SDT-206	14.492	7,117
SDT-207	23.784	7,000
SDT-208	51.948	7,406
SDT-209	12.652	7,000
SDT-210	13.189	7,149
SDT-212	18.105	7,000
SDT-409	7.918	7,000
SDT-410	42.436	7,000
SDT-411	20.547	7,000

Summit's risk assessment estimates that a pipeline incident would cost on average around $9,900, with an unlikely (<99.9% chance) value of over $600,000. These values align with historical data for accidental carbon dioxide releases that occurred from 2010 to present. 85% of historical carbon dioxide releases cost less than $67,675 with the median being $12,025 (PHMSA 2024). Moreover, monetary costs related to carbon dioxide pipelines were orders of magnitude lower than those of other pipeline types. (A. Duguid et al. 2022).

4 Conclusion

Summit takes a holistic approach to risk management that meets or exceeds all applicable regulations. Summit will continuously evaluate and improve upon safety through the life of the project, from design through operations. Summit's analysis of that portion of its pipeline proposed for South Dakota will have an extremely low likelihood of failure and that the average consequence of such a failure is quite moderate.

Summit's pipeline system in South Dakota, which will be constructed with state-of-the-art materials and construction techniques within a safety-dominated culture, is expected to have much lower failure frequencies – lower than 0.0003 per mile-year – than hazardous liquid pipelines under PHMSA regulations – as much as 3X lower – and lower failure frequencies than other PHMSA-regulated carbon dioxide pipelines too, While Summit will seek to achieve a failure-free record, the average consequence of an accidental release ranges is around $9,900.

5 References

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