STRATEGY AND TECHNICAL CONSIDERATIONS OF AN UPSTREAM PIPELINE RISK ASSESSMENT PROCESS

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ABSTRACT

Managing pipeline integrity through a risk process has been adopted into the upstream pipeline industry. As a pipeline operator, Husky has learned many challenges in establishing and implementing an effective risk process for upstream pipeline integrity management.

We employ three levels of risk assessments in optimizing resources and technical expertise in pipeline integrity management. Level 1 prioritizes gathering systems for the next level of assessment. Level 2 is a thorough subject matter expert (SME) based assessment performed in collaboration with integrity groups and operation/maintenance representatives; it focuses on pipeline risk management and development of the mitigation action plan of higher risk pipelines. Level 3 targets pipelines that carry significant consequence of failure, or frequent failures of systematic mechanisms. Quantitative risk modeling techniques are often utilized in the Level 3 assessments.

Husky found that the key to manage pipeline integrity through a risk process is risk validation and the implementation of mitigation actions. The proposed risk mitigation actions shall be signed off by the responsible personnel and be implemented, closely followed-up and evaluated for the consistency and effectiveness of the implementations.

The strategy framework and technical considerations included in our risk process is presented in this paper.

INTRODUCTION

CSA Z662 (07) Oil and Gas Pipeline Systems[1] outlines in Clause 10.14 that operating companies shall develop and implement a pipeline integrity management program (IMP) that includes effective procedures for managing the integrity of their pipeline systems. The clause requires that methods be described for assessing current potential risks, identifying risk reduction approaches and corrective actions. Informative guidelines for developing a pipeline IMP and risk assessment process have been given in Annex N, B and H.

Annex N has adopted the risk assessment process as the key element for a pipeline IMP (see Figure N.1, Annex N). Although Annex N is not a mandatory guideline for the development of a pipeline IMP, Canadian pipeline regulatory agencies, such as ERCB[2] and BCOGC[3] have mandated that pipeline operating companies (or stake-holders) develop an IMP in accordance with Annex N requirements.

Similar to CSA Z662, two American standards have been established for liquid and gas pipelines' IMP respectively, of which the risk assessment approach is the key element of the process[4, 5]. In addition, US Pipeline and Hazardous Materials Safety Administration (PHMSA) has mandatory requirements of liquid or gas pipelines' IMP, in which a risk assessment process needs to be employed to identify pipeline segments that "could affect" High Consequence Areas (HCA's)[6, 7].

Husky has developed the Husky's Operational Integrity Management System (HOIMS)[8], in which risk assessment and management has been adopted as an essential element to achieve operational excellence. The element aims to provide essential decision-making information by performing comprehensive risk assessments.

To comply with HOIMS, the requirements of Canadian regulatory agencies and CSA Z662, Husky has developed its own Pipeline Integrity Management (PIM) program. The program has adopted risk assessment and management for planning and implementing preventive and mitigative integrity programs during operation and maintenance of pipelines.

Husky aligns with CSA Z662, Annex N requirements with three increasing levels of risk assessments, which looks into increased detail of risk analysis and control options. The framework of the process is depicted in the following section.

RISK ASSESSMENT PROCESS FRAMEWORK

The framework was developed to align with the IMP process diagram cited from CSA Z662, Annex N. The alignment is depicted in Figure 1.

Level 1 risk assessment process has been developed to fulfill the requirements of Annex N.10.1 through 10.3. The method includes the indexing of the safety and environmental hazards, and a review of system specific historical failures (as recommended by Annex B.5.2.3.2). It is to be noted that outside of the Level 1 risk assessment scope, Husky also conducts process HAZOP's for facility and major high risk pipelines on a regular basis to ensure pipeline safeguards and layers of protection are adequate in case of a pipeline failure.

The Level 1 risk ranking order is followed for scheduling detailed pipeline risk assessments using the Level 2: Pipeline Baseline Risk Assessment (PLBA) process for every Husky owned pipeline. Husky has adopted full implementation of the PLBA process to meet the Annex N.11 requirements. The pipelines in the scope of the PLBA will be evaluated for options of likelihood and consequence reduction methods, not limited to the methods listed in Annex N.12.

In the baseline process, Husky also identifies if there are pipelines within the system requires the next level of risk analysis due to the nature of the risk (Annex N.11.4), i.e., Level 3: High Risk Assessment (HRA).

The scope, techniques and frequency of the assessments for three levels of assessments are illustrated in the pyramid diagram outlined in Figure 2 and the associated tables below.

Scope

Level 1 RA	Evaluates hazard index of all ~30,000 Husky owned licenced pipeline segments
Level 2 RA (PLBA)	Evaluates likelihood and consequence of failure considering the likely failure mechanisms of every pipeline segment in a gathering or midstream system; Select options for risk mitigation
Level 3 RA (HRA)	Evaluates High Consequence Area (HCA), identify pipeline segments that “could affect” an HCA; and provide recommendations on pipeline risk monitoring and control

Techniques

Level 1 RA	Algorithm-based indexing method considering flammability, toxicity and environmental hazard of the product, and the vulnerability of people/environment exposed to a pipeline failure/spill
Level 2 RA (PLBA)	Risk matrix method using a three-step process: pre-assessment; subject matter expert risk assessment meeting; post-meeting assessment and follow-up.
Level 3 RA (HRA)	Identifies pipeline segments that “could affect” an HCA, and evaluates risk control and monitoring needs by Quantitative Risk Assessment (QRA) and other methods. Examples are load-resistance modeling; review of the Emergency Response Program (ERP) procedure; evaluation of the emergency blow-down and shut-down procedure by HAZOP or what-if analysis

Frequency of Assessment

Level 1 RA	Annual basis
Level 2 RA (PLBA)	20-40 gathering systems a year; each system is reassessed at maximum every 5 years
Level 3 RA (HRA)	As-required, from the recommendations of PLBA, Management of Change (MOC), engineering assessments and any other processes.

Detail and example illustration of each level of risk assessment processes are provided in the following sections.

LEVEL 1 RISK ASSESSMENT PROCESS

Objective

The objective of the process is to identify major hazards and to obtain relative safety or environmental consequence rankings amongst all Husky's pipelines and gathering systems.

Methodology

In the Level 1 risk assessment, the safety and environment hazard index for the individual pipelines are first calculated. The hazard indexes of the individual pipelines in the system are then summated into the system hazard index. This index number is further modified by the historical failure rate into the final hazard index of the system.

Safety Hazard Index

Major pipeline safety hazard is identified as the acute toxicity, flammability, and overpressure impact on people that could potentially be first-aid required, lost-time injury, disability, or fatalities.

A safety hazard is indexed from three factors: pipe factor, substance factor, and location (exposure) factor.

<u>Pipe factor</u> considers the potential impact radii[4] (PIR) and the total pipeline length between isolation points. The factor represents the energy of decompression stored in the pipe internal volume packed with the pressurized gas or high vapor pressure (HVP) substance in the event of loss of pressure containment.

<u>Substance factor</u> considers the toxicity, flammability, combustibility, and thermal radiation hazards of the substance.

<u>Location factor</u> considers that the pipelines could affect areas in proximity where there are permanent residential or commercial dwellings, recreational or traffic activities.

Environmental Hazard Index

Major environmental hazards are identified broadly as short term or long term effects to the environment. The effects impair water, air, soil, thus the living conditions of plants, wildlife, and people. The impact on people is shown as chronic health effects.

A potential environmental hazard concern is similarly indexed from three factors: Pipe factor, substance factor, and location (exposure) factor.

<u>Pipe factor</u> considers the pipe release rate and packed liquid volume between isolation points.

<u>Substance factor</u> considers if the spilled liquid substance can place prolonged negative impact on soil, surface and domestic portable water, and if it is difficult or expensive to recover.

<u>Location factor</u> considers if the significant or sensitive geographical and hydrographical areas are in proximity to the pipeline segment potential impact zones in the event of a failure.

Overall, the hazard index is the worst-case consequence index due to environmental or safety impacts.

Example Illustrations

The process is illustrated in a screen-shot in the area shown in Figure 3. In this case, the next level of risk assessment is implemented in accordance with the risk ranking order of System A to B and on to C, D, or E.

The Level 1 individual pipeline risk ranking is illustrated in a screen-shot for the area in Figure 4. In this figure the top 2.5% pipelines with highest safety or environment hazard indexes are identified in the area. These pipelines would receive highest priority of assessments by the next levels of risk assessment processes.

Opportunities for Improvement

To enhance the resolution and accuracy of the Level 1 Risk Assessment, the data-driven model will include more detailed consequence analysis considering the geospatial distribution of the chloride levels of the produced water in producing wells in addition to the location and well screening depth of the portable water wells. The work will also include analysis of pipeline system isolation points and connectivity for sour gas pipelines, and any liquid pipelines.

LEVEL 2: BASELINE RISK ASSESSMENT PROCESS

Objective

The objective of the process is to comply with CSA Z662 Annex N.11, and to ensure a systematic and consistent risk assessment approach is followed for pipelines in every gathering system.

Methodology

A PLBA process for a particular system of pipelines follows the steps below.

In the data gathering step, pipeline connectivity and flow calculations are performed for complex systems. Once the pipelines, producing wells or other facilities are connected, the corporate Production Volume Record (PVR) information is then used to perform flow calculations in the pipelines, as well total shut-in days for the last 2-5 years span. The process helps identifying high internal corrosion risk pipelines, deadlegs, pipeline licencing information inconsistencies, etc.

The actual risk assessment consists of three steps, pre-assessment, subject matter expert (SME) assessment meeting, and post-assessment.

The purpose of pre-assessment step is to identify potentially high risk lines and representative lines for the SME risk assessment meeting. The tasks include: create verification list for data verifications, identify major threats (damage mechanisms) to the system, perform risk screening through review of the maintenance records, past direct and indirect assessment records. Based on the information collected, the risk facilitator selects potential high risk lines for assessment. The facilitator also groups lines by product substance, pipe material, internal protection method, or gathering lateral so that the representative lines of the group can be evaluated through the SME meeting.

The risk assessment follows the risk matrix method, as the company's risk tolerability can be readily built into the company's risk matrix. The most important goal of the SME risk assessment meeting is to evaluate if the lines bear high risks and to select options for confirmation of the risk or to reduce risk according to the pipeline IMP risk matrix.

The matrix is described in Figure 7. A risk-matrix guideline and an assessment procedure document have been developed to facilitate risk assessments.

Husky evaluates both unmitigated and mitigated likelihood and consequences of failures. The "unmitigated" likelihood of failure is determined when a failure happens without any methods to prevent or mitigate an integrity threat. "Unmitigated" consequence of failure assumes consequence of a failure without any functioning safeguards such as PSV, ESD, or any other isolation devices. In contrast, the "mitigated" risk takes into account of all the active mitigation methods on integrity threats, all functioning safeguards, Standard Operating Procedures (SOP's), and Emergency Response Procedures (ERP's) in responding to a pipeline failure. The effectiveness of any of these risk mitigations is verified by direct or indirect inspection and monitoring.

Post-assessment step includes the prioritization of the action items for management sign-off and schedule implementations. To ensure the pipeline IMP is effective through a PLBA process, the identified risk needs to be validated, and the risk level should be reduced to "Low" through actions.

Opportunities for Improvement

To increase the transparency of the SME type of risk assessment, depending on whether the system is sour, non-sour, liquid, or gas, risk factors which are essential for each type of system will be documented. There will also be development to include more quantitative assessment techniques into the process, especially in terms of the safety and environment consequence assessments.

HIGH RISK ASSESSMENT PROCESS

This process is applied to pipelines that show significantly higher risk than the rest of the pipelines or systems. Many of these pose high public or occupational hazard. These are, for example, acid gas injection lines that carry high level of H_2S and CO_2, or large size liquid flow-lines crossing a major river. The high risk pipelines could also include pipelines specific to a material that has had frequent failures, for example, fiberglass pipelines.

These pipelines are handled by detailed investigations, using techniques not limited to the following:

- HAZOP
- Root-cause analysis
- Event tree or fault tree analysis
- Quantitative Risk Assessment (QRA)
- Emergency Response Procedure (ERP) review

- What-if analysis
- Load-resistance modeling
- Multi-disciplinary review

Example studies are given below.

Acid Gas Line Risk Assessment

An acid gas pipeline is quantitatively evaluated by the outflow release model and the vapor cloud dispersion model using Phast™ [9]. The lethality due to H_2S toxicity and flammable effects (i.e., fireball and jet fire thermal radiations and explosion overpressure effects) were analyzed. Failure Likelihood is estimated, employing the ERCB statistics of sour gas pipeline ruptures, the functionality of the pipeline's SCADA leak detection, ESD isolation mechanism, the SOPs, safety protection, and training levels of the plant operational.

A pipeline Hazard Identification and Risk Assessment was conducted to evaluate all time dependent, stable and random integrity threats from pipeline design, construction practices to operation and maintenance. An integrity plan was established that include dew-point monitoring and control for the dehydration program, corrosion inhibitor program, FSM corrosion defect monitoring, scheduled in-line-inspection and UT inspection, ROW surveillance, CP survey and monitoring.

Fiberglass Pipelines

A risk assessment was conducted using a load-resistance methodology. Major threat and resistance-to-failure attributes were identified. The significance of each threat and resistance attribute, such as type and grade of pipe, and construction methods, (i.e., joining method, backfill method, riser connection method, etc) were analyzed based on the failure statistical correlations. The assessment concluded that the most significant threat is a construction activity interfering with the existing fiberglass pipe zone embedment. On the other hand, the most important resistance attribute to a failure is that pipelines, especially at tie-in points, need appropriate bedding, backfill, and compaction. This represents most resistance to ground settlement, frost-heaving, thaw-unstable soil, or pipe movement due to residual stress or thermal and pressure shocks.

Technical analysis to identify risk mitigation options was followed, with the support of fiberglass pipe supplier and distributors. To reduce the risk of continuing fiberglass pipeline failures, a civil-engineering backfill review process was adopted for approval of any backfills and a general pipeline tie-in/repair procedure checklist was developed to improve the workmanship quality. Proactive mitigation options were also investigated to prevent failures on high-risk fiberglass pipelines.

CONCLUSION

Husky developed and adopted three levels of risk assessment processes in its Pipeline Integrity Management (PIM) program. The process framework was established to meet the requirements of its own Operation and Integrity Management System, and CSA-Z662, Annex N. Techniques employed in each level of assessment has also been effective in allocating resources to prioritize systems or pipelines for risk assessments and risk/integrity management.

It was found that to make the risk assessment processes effective in managing pipeline integrity, risk validation and mitigation actions proposed shall be signed off by the responsible personnel and be implemented, closely followed up, and evaluated for the consistency and effectiveness of the implementations.

REFERENCES

1. CSA Z662-07 Oil and Gas Pipeline Systems. Canadian Standard Association, 2007

2. Directive 041- Adoption of CSA Z662-03 Annex N, as Mandatory. Energy Resources Conservation Board, ERCB, July 2006

3. Information Letter #OGC 06-12-Adoption of CSA Z662-03 Annex N Guideline for Integrity Management Programs. BC Oil and Gas Commission, Aug 2006

4. Managing System Integrity of Gas Pipelines, ASME B31.8S-2004. the American Society of Mechanical Engineers, 2004

5. Managing System Integrity for Hazardous Liquid Pipelines, API Standard 1160, 1st Edition. American Petroleum Institute, Nov 2001

6. Code of Federal Regulations (CFR) Part 192 – Transportation of Natural and other Gas by Pipelines: Minimum Federal Safety Standards, March 2009

7. Code of Federal Regulations (CFR) Part 195 – Transportation of Hazardous Liquids by Pipeline CFR, 195, April 2009

8. Husky Operational Integrity Management System (HOIMS Confidential Document), Husky Energy Inc., 2007

9. Process Hazard Analysis Software Tool v6.51(PHAST), Det Norske Veritas (DNV), 2006

FIGURES AND TABLES

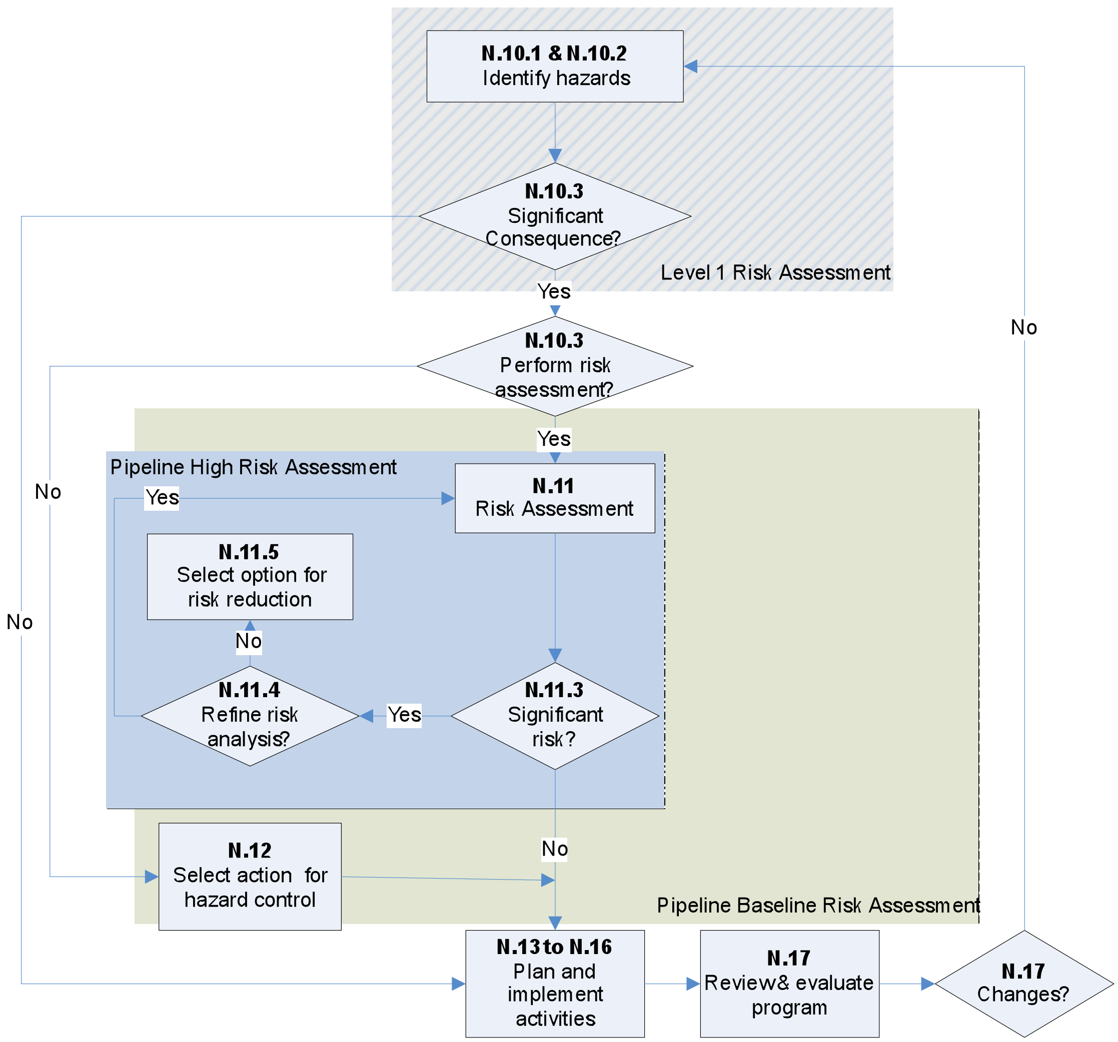

Figure 1 Alignment of Husky's Onshore Pipeline Risk Assessment Process with CSA Z662, Annex N Requirements

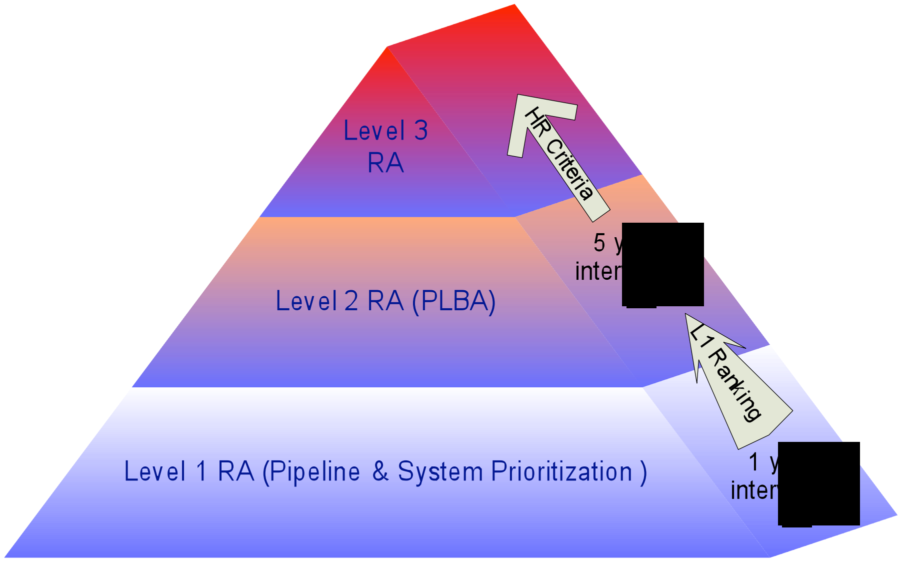

Figure 2 Pyramid Structure of Husky's Onshore Pipeline Risk Assessment Process

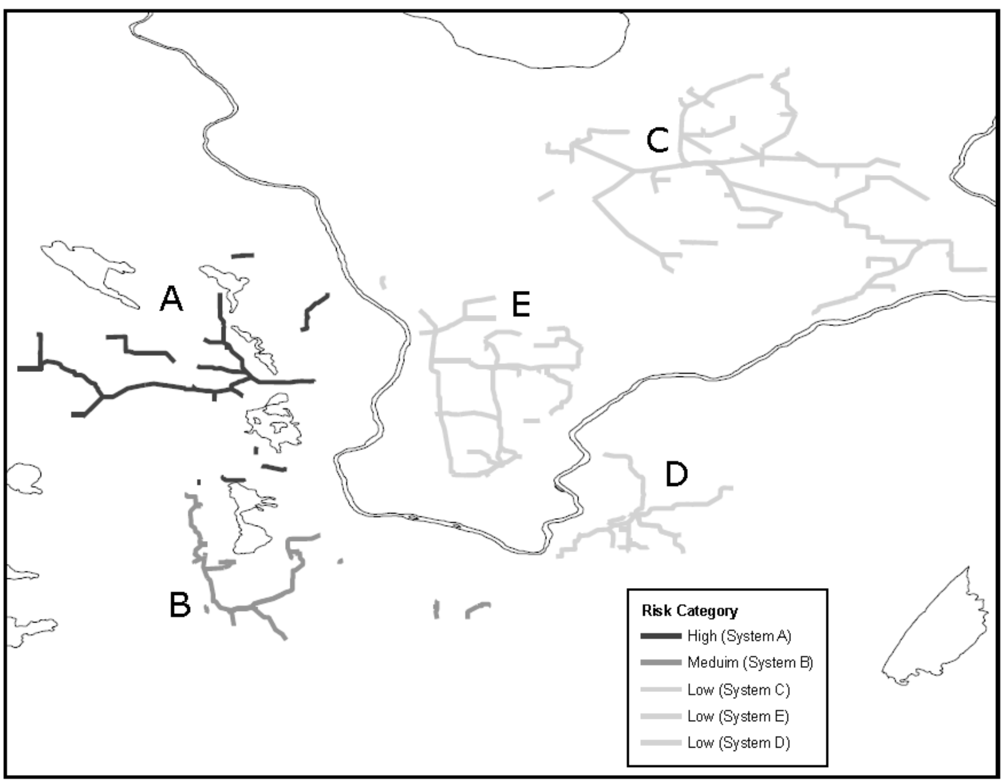

Figure 3 Conceptual Illustrations of High Risk Gathering Systems through Level 1 Risk Assessment

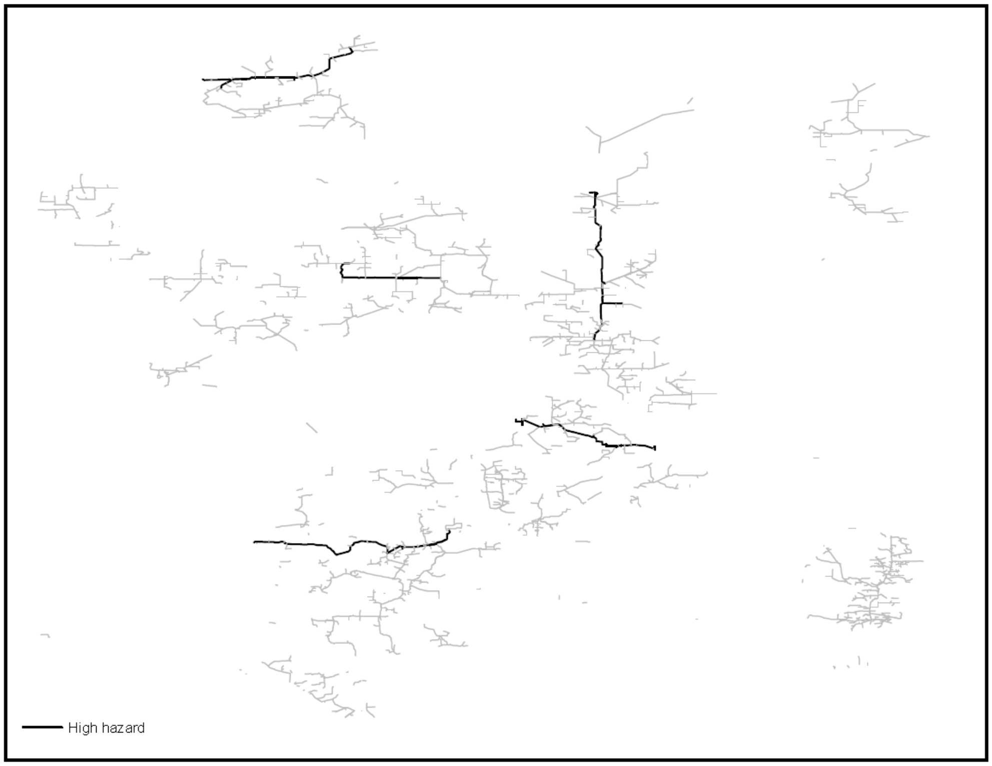

Figure 4 Conceptual Illustrations of High Hazard Index Pipelines through Level 1 Risk Assessment

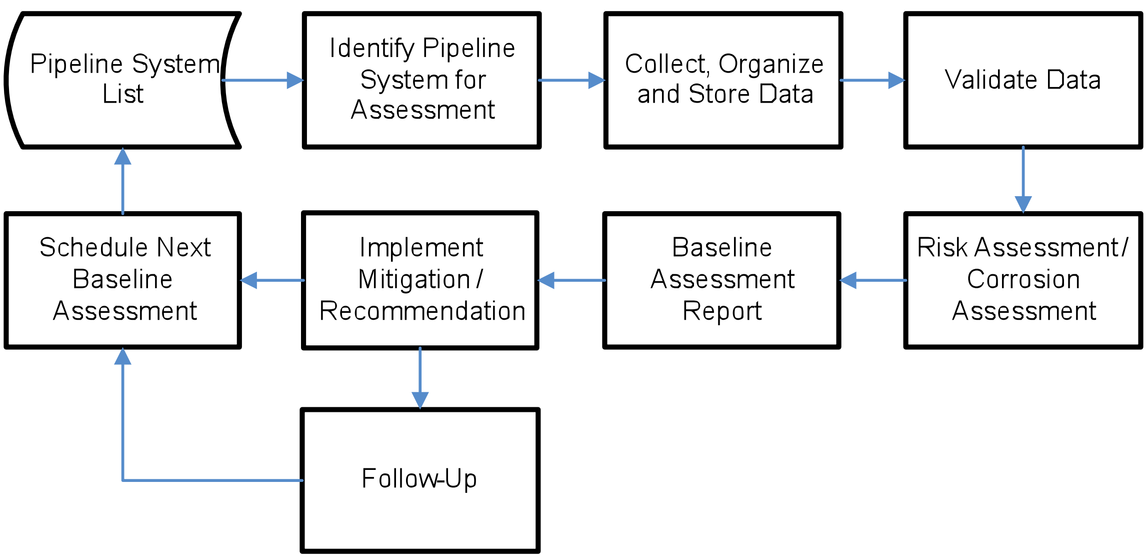

Figure 5 Flow Chart of the Baseline Assessment Process

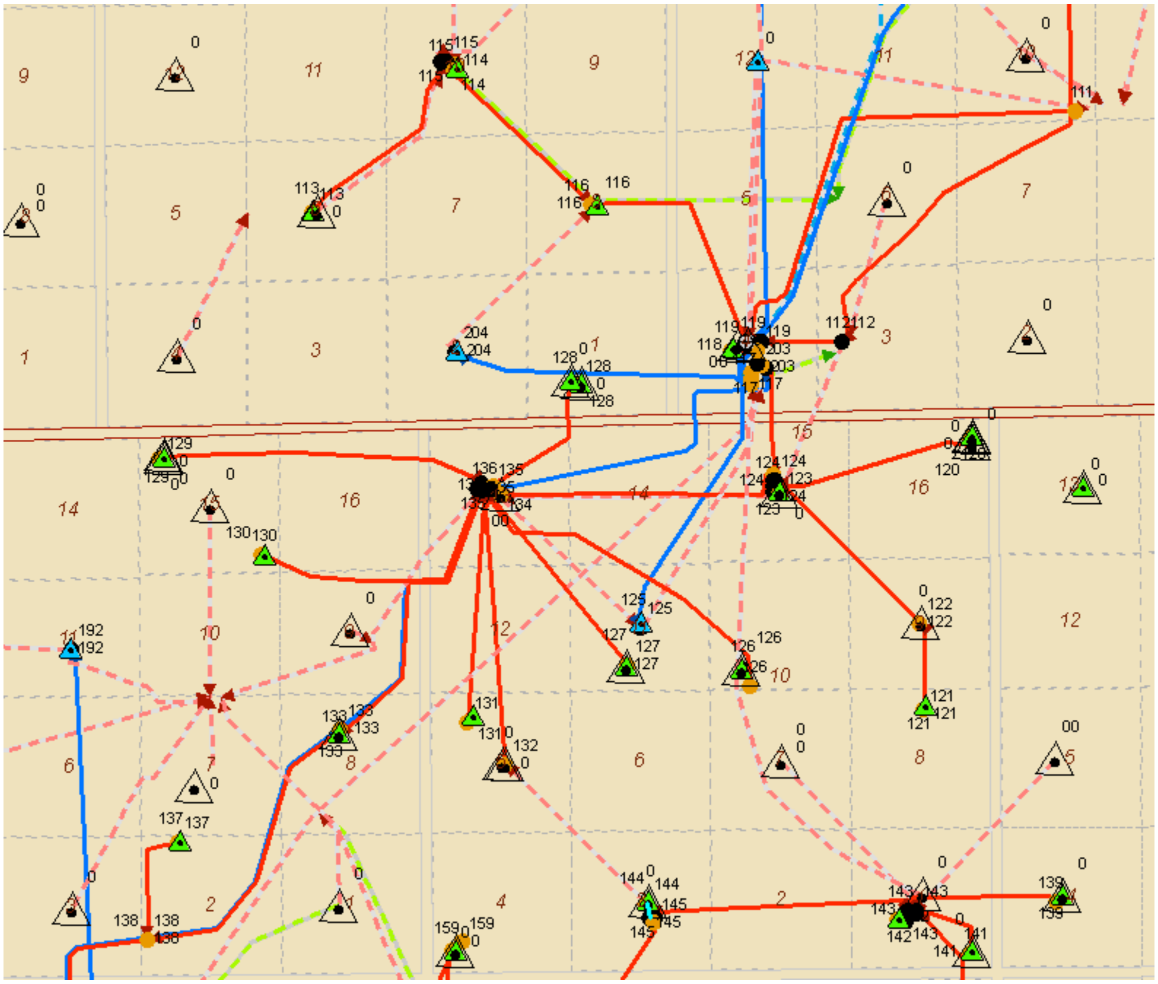

Figure 6 Example Connectivity Analysis of Pipelines in a Gathering System

Risk Ranking		Likelihood Ranking				
		A	B	C	D	E
Consequence Ranking	5	5	10	15	20	25
	4	4*	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
	0	0	0	0	0	0

Risk Category	Priority Action Setting	Timeline
Unacceptable	Immediate action must be taken to prevent or mitigate the risk	Immediate
High	Approved action plan to mitigate or prevent risk from happening must be in place within 3 months	3 months
Medium	Approved action plan to mitigate or prevent risk from happening must be in place within 12 months	12 months
Low	No immediate action required	None required

Figure 7 Pipeline IMP Risk Matrix Model of the PLBA Process