Risk Assessment
Cavern 45 Re-drill

Pembina Infrastructure and Logistics LP
Pembina Corunna Terminal

April 20, 2016

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Executive Summary

On April 20th 2016, a "What If" process hazard analysis was performed by a multidisciplinary team of employees of Pembina Pipelines Infrastructure and Logistics LP. to assess all the potential hazards involved in the entire life cycle of the Cavern 45 Re-drill project. This assessment was completed as it is both a Pembina Pipelines internal requirement and a requirement as outlined in CSA Z341.2-14 (Section 7.1).

Cavern 45 is an underground salt storage cavern originally mined by Dow Chemicals. It is presently out of service. The proposed project is to drill two new well bores into this cavern and utilize the cavern for the storage of propane.

The assessment focused on 3 major aspects of the re-drill project; Geological issues, Drilling and Workover Activities (including abandonment) and Operations. Each of these sections involve their own unique set of hazards to consider. The Geological Issues section discusses geological risks as per section 7.3 of CSA Z341.2-14 as well as risks involving Neighbouring Activities as per section 7.2 of CSA Z341.2-14.

Over the course of the hazard assessment session 112 potential hazards were identified, analyzed and risk ranked using the Pembina Risk Matrix. Any hazards that were deemed unacceptable were assigned and action to reduce the risk to an acceptable level.

By the end of the session the group was comfortable that the risks had received the appropriate level of consideration and were properly mitigated.

Introduction

Cavern 45 is a salt storage cavern that is owned by Pembina Pipelines Infrastructure and Logistics LP. Pembina is in the planning stages of a project to drill two new entries into this cavern (and abandon the existing entry) to bring this cavern back into service as a propane storage cavern.

As part of Pembina's internal standards as well as the standards set out by CSA Z341.2-14 (Section 7.1) a risk assessment is required to be performed prior to any work starting in order to properly analyze the hazards involved in this project. A "What If" risk assessment was chosen as the risk assessment tool for its abilities to assess a wide range of hazards consistently.

On April 20, 2016 the "What If" Assessment was completed by a diverse team of subject matter experts. Hazards were identified, risk ranked using the Pembina Corporate Risk Assessment Matrix, and discussed.

The results of the "What If" can be found in the "What If" Assessment section of this document.

"What If" Team Profile

Team Member	Job Title	Attendance
Pat Mahoney	Operations Foreman	Full
Scott Morris, C.E.T.	Cavern Specialist	Full
Mike Mousseau	Instrumentation Technician	Full
Chad Severs, P.Eng.	Project Engineer	Full
Ian Shaw	Operations Day Lead	Full
Alex Strachan P.Eng. (Facilitator)	Plant Engineer	Full
Steve Vandenheuvel	Maintenance Foreman	Full

Facility Information

Facility History

The Pembina Corunna Terminal is Located on Highway 40 in St Clair Township, Ontario, Canada, east of the town of Corunna, Ontario. The property extends on both sides of the highway between Lasalle Line and Petrolia Line/Hill Street. The extent of the property is shown in Figure 1.

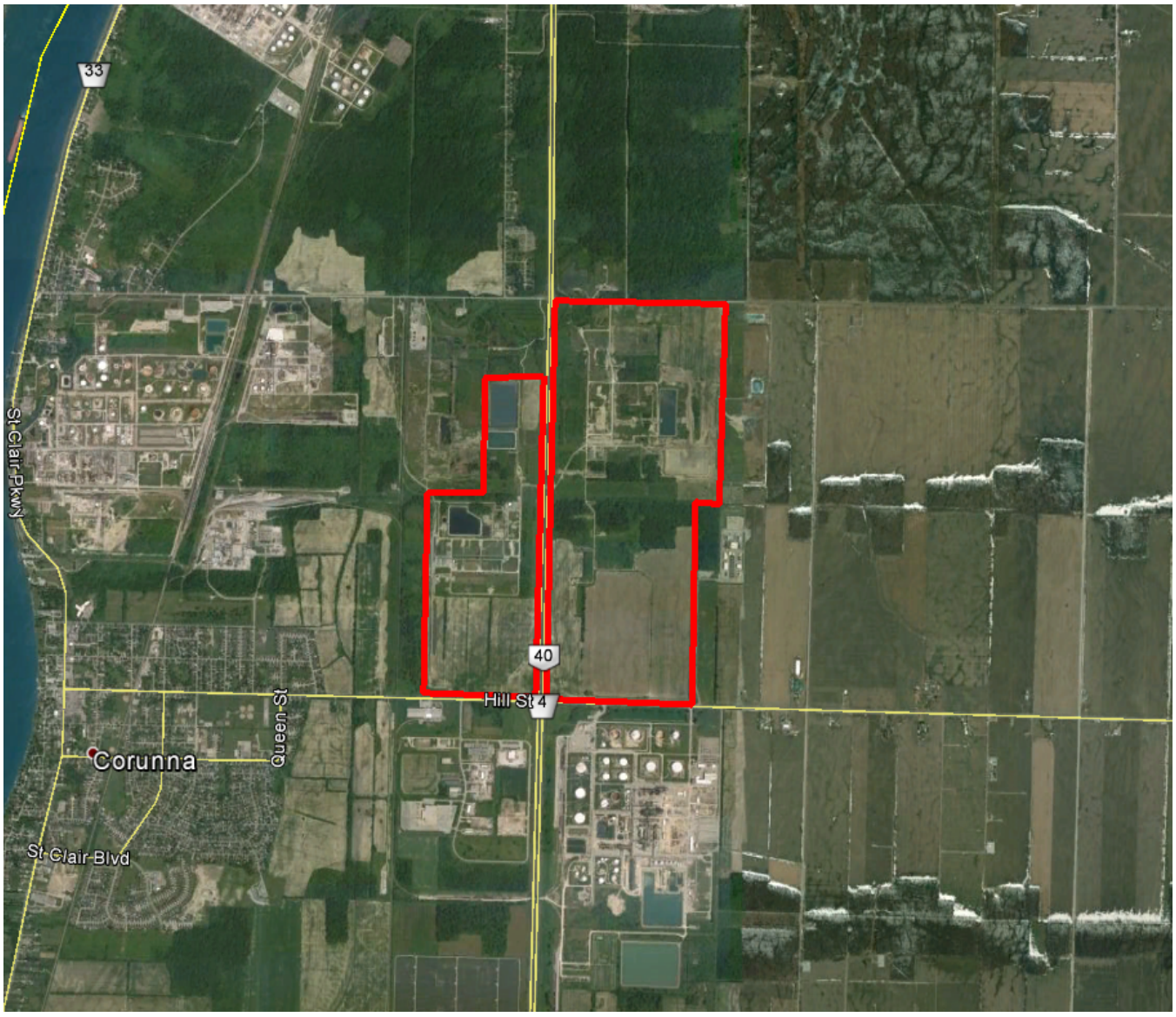


Figure 1: Overview of Pembina Corunna Terminal Boundaries

What is currently known as the Pembina Corunna Terminal was originally owned by Dow Chemicals Canada ULC. Dow operated a salt solution mining operation. This operation resulted in the mining of more than 20 Salt Caverns. Dow then used some of the Salt caverns for storage of various hydrocarbons and chemicals used by their processing plant in Sarnia, Ontario. Salt mining operations were suspended in 1993. Provident Energy purchased the facility from Dow in 2010 and converted the facility into a natural gas liquids storage site. Pembina Pipelines acquired Provident In 2012 and has since expanded the NGL storage operation.

Current Operations Description

Pembina Pipelines Infrastructure and Logistics LP. is the owner and operator of the Pembina Corunna Terminal. The Facility is a 24 hour manned plant for the import, export and underground storage of natural gas liquids. Currently, Pembina maintains and operates 9 storage caverns. Three of these caverns are currently in ethane service, three in propane service, two in refinery grade butane service and one in iso-butane service.

Natural Gas Liquids are imported into the Corunna terminal via a number of pipelines as well as a 16 spot rail rack. The imported product is injected into the underground caverns.

The Corunna Terminal has 5 brine ponds in operation to hold brine that is displaced when product is put into a storage cavern. To extract product, brine is pumped into the caverns to displace the hydrocarbon liquid.

The hydrocarbon liquid is then dried using either a Molecular Sieve Dehydration unit (ethane) or Calcium Chloride Dryers (propane and butane) before being exported via pipeline, rail or in the case of propane, a 2 spot truck loading rack.

Cavern 45

Cavern 45 was one of many wells solution mined by Dow Chemicals Canada ULC. It is located on the East side of the Pembina Corunna Terminal (see Figure 2).

Figure 2: Location of Cavern 45

Cavern 45 is currently a single entry cavern. Dow utilized this cavern for storage of diesel fuel to assist with the solution mining of other caverns in the area. The diesel was removed and the cavern has been inactive since the early 1990s.

Based on the most recent Sonar Report completed in 2007 by Sonarwire, Cavern 45 has a capacity of 267,275 cubic meters. The cavern begins at a depth of 601 m below surface and extends to 646 m below surface.

The proposed project is to drill two new entries into the cavern. After completion of the two new well bores, the existing well will be abandoned.

"What If" Analysis Background

"What If" Methodology

What If analysis is a creative, brainstorming methodology for examining a process, operation, or facility. This qualitative technique identifies design faults, potential hazards, and operating problems – depending on the team's experience – by asking "What if …" questions for hazards. Examples of such a question might be;

- What if a leak occurs?
- What if the feed material is directed to the wrong storage tank?
- What if a fire occurs?
- What if the product is changed for low vapour product to a high vapour product?

The What If team then assesses each question or scenario, one at a time, for the consequences of the postulated or hypothetical event and, depending on what

safeguards are present or planned for installation, decides upon recommendations for preventing or mitigating such an occurrence if it were to occur.

Projects, systems, sub-systems, study areas or nodes are noted on the relevant documents, diagrams and drawings, such as process flow sheets and diagrams (PFD) or P&IDs, and are reviewed by the PHA Team composed of a diverse group of subject matter experts (SME). Credible worst case consequences are summarized in a few words to be used in the What If review as possible scenarios.

Steps in a "What If":

1. Divide the facility or unit into systems and subsystems, i.e. study areas, that perform common functions, much like the approach taken for Guide Word HAZOP for the designation of color highlighted nodes.
2. Postulate potential problems or possible failures by asking questions, such as "What if …?" or "Is it possible for … to occur?" or "Has … been considered?"
3. For each question asked in step 2, record and identity the expected consequences in the absence of safeguards.
4. For each question asked in step 2, also record all safeguards present, or planned that may prevent the occurrence of the hazard or mitigate the consequences in the unlikely event of occurrence.
5. For each consequences identified within step 3, estimate the likelihood of the event actually occurring with all safeguards in place and functioning normally as per the corporate PHA Risk Assessment Matrix.
6. For each of the risks identified in step 5, propose any recommendations or actions required, on a nonprescriptive basis, to prevent the occurrence of the hazard or

mitigate the consequences should it occur within the boundaries of ALARP (as low as reasonably practicable).

Risk Assessment Matrix

A Risk Assessment Matrix (RAM) is a two dimensional matrix that is used during a risk assessment to define the various levels of risk as the function, or combination, of the severity of a credible worst case consequence, in the absence of safeguards, and the likelihood of the consequence occurring with safeguards in place.

The RAM is simplified tool showing a two dimensional arrangement of many different cells linking likelihood of the consequence occurring, across the horizontal axis with the perceived severity of the linked consequence depicted on the vertical access. Each cell within the matrix is a combination of consequence severity and likelihood of occurrence of the consequence. Each cell is also coded with a colour depicting the relative risk level. A two dimensional matrix is used to increase the visibility of risks and assist in management decision making by showing different relative risk levels for operational and residual risks with new or improved safeguarding.

Please note however that some problems can occur with the use of a risk matrix in a qualitative review as a team can assign identical ratings to quantitatively very different risks due to “range compression” within an order of magnitude; likewise the team can also assume that on a 5 x 5 matrix that a consequence of 5 and likelihood of 3 is the same relative risk as a consequence of 3 and a likelihood of 5, which is not the case. Use of risk matrices can also result in a team mistakenly assigning higher qualitative ratings to quantitatively smaller risks. Issues like these are often overcome with matrix calibration,

the use of a diverse group of subject matter experts and the comparison with known past events similar to the ones under review.

How to use a risk assessment matrix:

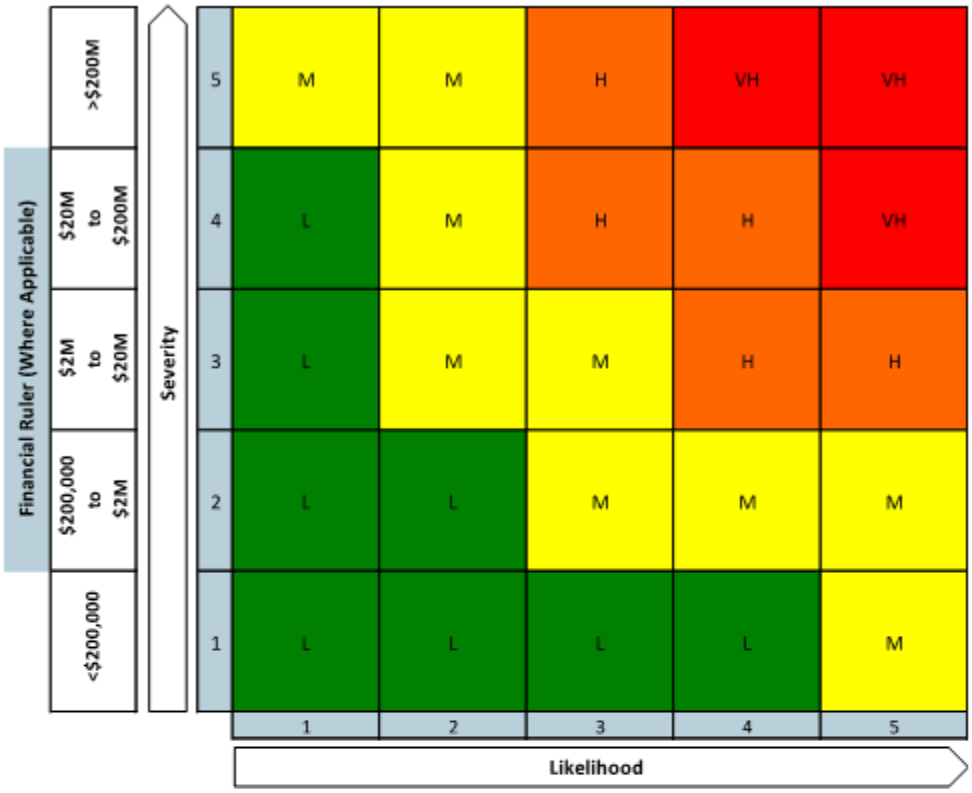
Tables for both consequence and likelihood are meant to aid in the qualitative approach for determining and assigning the relative scores for both consequence severity and likelihood on an order of magnitude (OoM) basis by the PHA team composed of a diverse group of subject matter experts with at least one experienced and knowledgeable worker (operator) present.

Risk is estimated for each cause – consequence scenario under review as the combination of the credible worst case consequence, in the absence of safeguards, and the likelihood of the final outcome of the initiating event going forward to the final outcome of concern.

Final outcome takes into account all planned or existing safeguards being in place and acting normally.

Once the risk has been estimated by the team, with agreement in the results by the worker representative, it is mapped onto the PHA Risk Assessment Matrix.

Pembina Risk Assessment Matrix



RESIDUAL RISK RANKING

Residual Risk	Description
Very High	- Immediate action for risk reduction is required. - Confirmation of credible consequence and appropriate likelihood. - Additional safeguards required after confirmation of high scores for both consequence and likelihood. - LOPA recommended if consequence deemed credible worst case.
High	- Action for risk reduction is required as soon as reasonably practicable. - Confirmation of credible consequence and appropriate likelihood. - An additional safeguard may be required after confirmation of consequence and likelihood. - LOPA recommended if consequence deemed credible worst case.
Medium	- Action for risk reduction will be considered with cost/scheduling factors. - No mitigation required where controls can be verified as functional. - ALARP (as Low as Reasonably Practicable).
Low	- Mitigation measures may be justified. - Acceptable level of risk if a management plan is in place.

Figure 3: Pembina Risk Assessment Matrix

The following tables show the qualitative assessment guidelines for both severity and likelihood that comprise the risk estimation calculation.

Severity

Severity Score	Descriptor	Health & Safety	Environmental and Regulatory	Financial	Operational	Reputation
5	Catastrophic/ Extreme	Multiple loss of life and/or serious long-term health implications as a result of the company's actions.	Major long term widespread environmental incident; or significant long term mitigation required; or significant risk to "Social Licence to Operate".	Equipment damage or production costs greater than $200,000,000.	Major production outage with lengthy response time & extensive damage.	Sustained major negative press coverage or analyst reports; or national coverage for sustained periods; or stakeholders begin to lose faith and some withdraw support.
4	Major	Single loss of life and/or some long-term health implications as a result of the company's actions .	Long term environmental damage; or offsite release with significant pollution/contamination; or possibility of revocation of regulatory licence.	Equipment damage or production costs between $20,000,000 & $200,000,000.	A critical event with a long recovery period which stretches plans to the limit and requires significant management effort to endure; or major failure, quickly controlled; or major damage.	Long-term negative media focus and/or sustained concerns raised by more than one key stakeholder; or prolonged area attention/difficult to resolve.
3	Moderate	Lost time injury and/or significant health effects.	Onsite release outside designed containment; or impact extends beyond property line and noticeable odours and/or visible emissions migrating beyond property boundary resulting in potential complaint from neighbouring property ; or significant cleanup efforts required; or a non-compliance incident resulting in enforcement.	Equipment damage or production costs between $2,000,000 & $20,000,000.	A significant event which can be managed through existing processes; or a major failure, quickly controlled with minor damage.	Medium-term negative media focus; or short term credibility concern, quickly resolved; or brief area attention.
2	Minor	Reportable incident and/or minor injuries.	Onsite release within designed containment; or minor cleanup efforts required ; or incident reportable to regulator.	Equipment damage or production costs between $200,000 & $2,000,000.	Impact of event requires actions that can be managed through existing processes; or a minor failure, quickly controlled, loss.	Short-term negative media focus; or negative analyst reports/press and employees disgruntled; or isolated incidents/resolvable.
1	Insignificant	Non-reportable incident; or incident with no injuries.	Controlled or minor non-reportable release.	Equipment damage or production costs less than $200,000.	Impact of event can be absorbed through normal activity; or minor incident.	Minimal impact on public; or no media attention.

Likelihood

Likelihood Score	Descriptor	Description	Frequency
5	Almost Certain	Frequent repeat occurrences in unit.	$f \geq 1/yr$
4	Likely	Common occurrence in unit.	$1/yr < f \geq 1/10\,yr$
3	Possible	Occasional occurrence in company.	$1/10\,yr < f \geq 1/100\,yr$
2	Unlikely	Remote occurrence in company. Occasional occurrence in industry.	$1/100\,yr < f \geq 1/1000\,yr$
1	Rare	Remote occurrence in industry.	$1/1000\,yr < f \geq 1/10{,}000\,yr$

Figure 4: Severity and Likelihood Assessment Guidelines

"What If" Assessment

Systems and Subsystems

The Cavern 45 Project was broken into 3 Systems to analyze, and each system was broken into subsystems. The systems, sub systems and their descriptions are listed below:

- Reservoir Considerations
    - Geological Issues – Any hazards related to the geology of the cavern and formations encountered while drilling into cavern
    - Neighbouring Activities – Any Hazards related to other subsurface operations such as nearby caverns and wells interacting with Cavern 45
- Drilling/Workover Activities
    - Site Preparation – Any hazards related to work required prior to drilling of wells (site surveying, Rig movement, etc.)
    - Drilling Operations – Any hazards related to Drilling of the proposed wellbores
    - Development Workovers – Any hazards related to workover operations such as logging, Mechanical Integrity testing, casing repair work, etc.
    - Abandonment – Any hazards related to abandoning this cavern
- Operations
    - Downhole Operations – Any hazards related to the well bores or cavern during operation. See Yellow Node on P&IDs
    - Brine System Operations – Any hazards related to the brine system piping and equipment required to operate this well and the existing system it will interface with. See Blue Node on P&IDs

- Hydrocarbon System Operations – Any Hazard related to the hydrocarbon piping and equipment required to operate this cavern and the existing system it will interface with. See Green Node on P&IDs

"What If" Worksheet

System: 1. Reservoir Considerations

Subsystem: 1. Geological Issues

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
Study of Available Geophysical Data	1. Lack of geophysical data could result in sub optimal drilling	1. Potential for whipstock or other additional drilling expenses	F	3	1	Low	1. Geomechanical report Completed by Respec 2. Sonar Surveys 3. Existing wellbore into cavern 4. Land Surveys					1. As Per CSA Z341.2-14 7.3.1 (a)
Regional Tectonic Activity, regional and Local Fault Zones and structural anomalies	1. If wellbore or formation is in area of high tectonic activity, wellbore could shift	1. Loss of production Containment, Environmental Release	E	4	1	Low	1. No history of major tectonic activity					1. As Per CSA Z341.2-14 7.3.1 (b)
		2. Potential Personnel Hazards	H&S	4	1	Low	2. Geomechanical report Completed by Respec					
		3. Financial Loss	F	3	1	Low						
Delineation of Subsurface Perimeter of Storage zone	1. Size and shape of cavern determines storage volume and mechanical storage properties	1. No Hazardous Consequences		1	1	Low						1. As Per CSA Z341.2-14 7.3.1 (c) 2. Sonar Surveys give very detailed limit of storage cavern
Formation Study from surface to 100 m below storage zone	1. Water zones or gas zones present	1. See Drilling operations for risks associated with flowing water and gas zones		1	1	Low						1. As Per CSA Z341.2-14 7.3.1 (d)

Risk Assessment – Cavern 45 Redrill

System: 1. Reservoir Considerations

Subsystem: 1. Geological Issues

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
Formations and Structures within 1 km subsurface radius	1. See Neighbouring operations	1. See Neighbouring operations		1	1	Low						1. As Per CSA Z341.2-14 7.3.1 (e)
Identification and Characterization of any potentially associated permeability zones and their impact	1. See Neighbouring operations	1. See Neighbouring operations		1	1	Low						1. As Per CSA Z341.2-14 7.3.1 (f)
A study of regional stresses and strains	1. Regional Stresses could cause damage to cavern	1. Loss of availability of cavern, financial impact	H&S	3	1	Low	1. Geomechanical report Completed by Respec 2. Long standing history of cavern and other caverns in area					1. As Per CSA Z341.2-14 7.3.1 (g)
Study of the mechanical and chemical properties of the salt and confining rock formations	1. Poor salt or confining rock could result in loss of containment of cavern, potentially to surface	1. Loss of production Containment, Environmental Release	E	4	1	Low	1. Geomechanical report Completed by Respec					1. As Per CSA Z341.2-14 7.3.1 (h)
		2. Potential Personnel Hazards	H&S	4	1	Low	2. Long standing history of cavern and other caverns in area					
		3. Financial Loss	F	3	1	Low	3. Sonar Surveys					
A study of structural anomalies including faulting	1. Existing Cavern, No faulting present	1. Poor salt or confining rock could result in loss of containment of cavern		1	1	Low						1. As Per CSA Z341.2-14 7.3.1 (i)
A study of regional dynamics of the formation including cavern closure, subsidence, salt behavior and	1. Poor salt closure, or undue interference from neighbouring activities could result in loss of containment of	1. Loss of production Containment, Environmental Release	E	4	1	Low	1. Geomechanical report Completed by Respec					1. As Per CSA Z341.2-14 7.3.1 (j)
		2. Potential Personnel Hazards	H&S	4	1	Low	2. Long standing history of cavern and					

Risk Assessment – Cavern 45 Redrill

System: 1. Reservoir Considerations

Subsystem: 1. Geological Issues

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
interference from neighbouring activities	cavern, potentially to surface						other caverns in area					
		3. Financial Loss	F	3	1	Low	3. Sonar Surveys					

System: 1. Reservoir Considerations

Subsystem: 2. Neighbouring Activities

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
There were fracture treatments within 1 km	1. Fracture treatments were completed on Dow caverns	1. Since Cavern 45 is an existing cavern with a history of usage there is no fracture concerns with this cavern		1	1	Low	1. Fractures occurred in A2, Cavern 45 within the B Salt					1. Without current inventory issues, no current concerns on caverns with fracture treatments
							2. Mechanical Integrity Testing Program, as per Ontario operating standard and per CSA Z341					2. 1. As Per CSA Z341.2-14 7.2 (a)
There are Active Production Wells within 1 km	1. No active Production Wells < 1 km	1. No Hazardous Consequences		1	1	Low						1. 1. As Per CSA Z341.2-14 7.2 (a)
There are Observation Wells within 1 km	1. There are several observation wells in the area	1. Observation wells are there to ensure no communication between Pembina Salt Caverns and Enbridge Dow Moore Reef, No Hazardous Consequences		1	1	Low						1. 1. As Per CSA Z341.2-14 7.2 (c)
Active Storage Caverns/Wells within 1 km	1. There are 26 Active Storage caverns/wells within 1 km. Small potential for communication between caverns.	1. Cavern communication could lead to product contamination. Financial Impact.	F	3	1	Low	1. Sonar Surveys					1. 1. As Per CSA Z341.2-14 7.2 (a)
							2. No Inventory issues in caverns					
							3. Mechanical Integrity Testing Program, as per Ontario operating standard and per CSA Z341					

Risk Assessment – Cavern 45 Redrill

System: 1. Reservoir Considerations

Subsystem: 2. Neighbouring Activities

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
Abandoned Storage Caverns/Wells within 1 km	1. There are 32 Abandoned Storage caverns/wells within 1 km. Small potential for communication between caverns.	1. Cavern communication could lead to product contamination. Financial Impact.	F	3	1	Low	1. Sonar Surveys 2. No Inventory issues in caverns 3. Mechanical Integrity Testing Program, as per Ontario operating standard and per CSA Z341					1. 1. As Per CSA Z341.2-14 7.2 (a)
There are Wells within 1 km of target that have no completion/abandonment records	1. All wells within 1 km all have detailed records	1. No Hazardous Consequences		1	1	Low						1. As Per CSA Z341.2-14 7.2 (a)
Active or abandoned conventional subsurface mining operations within a 20 km radius of the storage facility	1. There are 89 Solution mining wells within the 20 km. Small potential for loss of product to solution wells.	1. Loss of hydrocarbon, Financial Impact	F	3	1	Low	1. Sonar Surveys					1. 1. As Per CSA Z341.2-14 7.2 (b)
		2. Hydrocarbon into brine solution well, potential incident resulting in injury or fatality	H&S	5	1	Medium	2. No Inventory issues in caverns 3. Mechanical Integrity Testing Program, as per Ontario operating standard and per CSA Z341 4. Solution Mining Regulations and Practices to prevent unintentional growth of solution well beyond predetermined size.					2. Existing safeguards adequate

System: 2. Drilling/Workover Activities

Subsystem: 1. Site Preparation

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
General Work Activity Safety Considerations	1. This section is to document our general safety practices to prevent incidents	1.					1. Safe Work Permits 2. Non Routine Task Analysis 3. Toolbox Safety Meetings 4. Monthly general Safety Meetings 5. Job Procedures 6. Positive Safety Recognitions 7. Audits, Assessments, Observations 8. Site Orientation					
Public Access to well site surroundings	1. Well is located within Pembina Fenced Boundaries, card access required	1. No Hazardous Consequences		1	1	Low						
Another Well in area hit by vehicle	1. Slippery Conditions causing vehicle to lose control and strike wellhead	1. Shearing of wellhead, Loss of containment, Environmental impact	E	4	1	Low	1. Driver Training program					1. Existing safeguards adequate
		2. Shearing of wellhead, Potential Personnel Hazards	H&S	4	1	Low	2. Wellhead robustness					
		3. Shearing of wellhead, Financial Loss, operational impact	F	3	1	Low	3. Posted Speed limits					

		4. Minor Damage to wellhead, environmental release	E	2	1	Low	4. Well area chained off, visible barrier					
		5. Vapour Cloud in well 45 area, potential for hazard to multiple parties on site	H&S	5	1	Medium	5. Safe Work Permits 6. Spotting during high risk vehicle movement 7. Gas testing					
Piping in area hit by vehicle	1. Slippery Conditions causing vehicle to lose control and strike piping	1. Failure of piping, Loss of containment, Environmental impact	E	4	1	Low	1. Driver Training program					1. Existing safeguards adequate
		2. Failure of piping, Potential Personnel Hazards	H&S	4	1	Low	2. Posted Speed limits					
		3. Failure of piping, Financial Loss, operational impact	F	3	1	Low	3. Piping area chained off, visible barrier					
		4. Vapour Cloud in well 45 area, potential for hazard to multiple parties on site	H&S	5	1	Medium	4. Safe Work Permits 5. Spotting during high risk vehicle movement 6. Gas testing					
Farmers tile impacted by rig traffic	1. All traffic on Pre-existing roads, no tile impacted	1. No Hazardous Consequences		1	1	Low						
Landowner Implications	1. Pembina owns land	1. No Hazardous Consequences		1	1	Low						
Workover on nearby well	1. Not applicable	1. No Hazardous Consequences		1	1	Low						1. Any work in area would utilize shared services and hence not be completed simultaneously
Vehicles impact 600 V power lines	1. Slippery Conditions causing vehicle to lose control and strike power pole	1. Potential Personnel injury	H&S	4	1	Low	1. Driver Training program 2. Safe Work Permits					

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							3. Spotting during high risk vehicle movement					
	2. Rig height could catch powerlines in the area	1. Potential Personnel injury	H&S	4	2	**Medium**	1. Driver Training program 2. Safe Work Permits 3. Spotting during high risk vehicle movement	2. Perform Rig Move assessment, consider height, width, weight over underground facilities. If height of powerlines is a concern, reroute lines before rig move	4	1	**Low**	
Digging Equipment Strikes Underground Pipe	1. Underground pipes in general area	1. Pipe Loss of containment, environmental release	E	3	2	**Medium**	1. One Call					1. Existing safeguards adequate
		2. Potential hazards to personnel	H&S	4	2	**Medium**	2. Ground Disturbance Procedure 3. Well Placement with offset from underground piping					

Risk Assessment – Cavern 45 Redrill

System: 2. Drilling/Workover Activities

Subsystem: 2. Drilling Operations

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
Major Site Incident Occurs during drilling operations (unrelated to drilling)	1. Plant Upset / Evacuation, Propane truck loading upset	1. Rig must suspend operation until incident is rectified	F	1	4	Low						
Rig Impacts Well during Move	1. See wellhead hit in Site Preparation	1. See Site Preparation		1	1	Low						
Rig impacts pipe during move	1. See piping hit in Site Preparation	1. See Site Preparation		1	1	Low						
Rig Damages Underground Infrastructure	1. Weight of rig causes damage to underground piping	1. Pipe damage, loss of containment, potential hazards to personnel	H&S	4	1	Low	1. All rig traffic on existing roads	2. Perform Rig Move assessment, consider height, width, weight over underground facilities. If height of powerlines is a concern, reroute lines before rig move				
		2. Pipe damage, loss of containment, potential environmental release	E	4	1	Low						
		3. 1. Pipe damage, loss of containment, financial loss	F	3	1	Low						
Surface gas is hit	1. Surface Gas present	1. Potential for gas kick, potential injury	H&S	2	1	Low	1. Formations all known and potential gas zones will be prepared for					
		2. Potential for gas kick, financial loss	F	3	1	Low	2. Fluid Density Program					
							3. Blow out Preventer (BOP)					
Flowing water is hit	1. Detroit river has potential for flowing water	1. No Hazardous Consequences		1	1	Low						1. Has not been an issue in past drills in area

System: 2. Drilling/Workover Activities

Subsystem: 2. Drilling Operations

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
Traffic in the area	1. Heavier traffic within facility, increased risk for collision	1. Vehicle Collision, potential for personnel injury	H&S	4	1	Low	1. Speed Limits within plant 2. Driver Training programs 3. Safe Work Permits 4. Spotting during high risk vehicle movement					
Cement does not go to surface	1. Poor cementing job, loss of circulation	1. Failure to meet code, remediation required	F	2	3	Medium	1. Cementing program 2. Centralizer Program					1. Existing safeguards adequate
Casing Buckled or thread damaged	1. Improper torqueing technique, damage during shipping or assembly	1. Financial impact	F	2	2	Low	1. Casing Thread technician					
Surface Casing not set in solid part of formation	1. Wrong drill depth	1. Failure to meet code, remediation required	F	2	1	Low						
Surface gas present while welding on casing bowl	1. Surface gas leaks to surface during welding	1. Potential fire/explosion, hazard to personnel	H&S	4	1	Low	1. Personal Gas Detection 2. Safe Work Permits/Welding Procedure					
Installing/dismantling BOP	1. BOP impacts wellhead during install	1. Damage to Casing Bowl, Financial Loss	F	1	2	Low	1. Lifting Program 2. Job Task Analysis					
	2. BOP install impacts person	1. Personal Injury	H&S	3	2	Medium	1. Lifting Program 2. Job Task Analysis					1. Existing safeguards adequate

Risk Assessment – Cavern 45 Redrill

System: 2. Drilling/Workover Activities

Subsystem: 2. Drilling Operations

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
Loss of Circulation	1. Thief zone	1. Financial impact	F	1	4	Low	1. Fluid Density Program					
Stuck in Hole	1. Pressure Differential, bore hole collapse, poor circulation	1. Financial impact	F	2	4	Medium	1. Drilling Program 2. Fluid Density Program					1. Existing safeguards adequate
Formation hydrocarbons hit in upper formation	1. Hydrocarbons present	1. Potential for hydrocarbons to enter the drilling fluid tank, potential injury	H&S	4	1	Low	1. Formations all known and high risk zones will be prepared for					
		2. Potential for hydrocarbons to enter the drilling fluid tank, financial loss	F	3	1	Low	2. Rig gas monitoring 3. Personal Gas Detection 4. Blow out Preventer (BOP)					
Defective Casing cementing resulting in micro annulus	1. Poor Cement Job	1. Hydrocarbon leak to surface, environmental release	E	2	2	Low	1. Wellhead and casing annulus valves					
Tools Lost in Hole	1. Tools have tendency to get stuck	1. Fishing Operation, potential of loss of wellbore, financial loss	F	3	2	Medium	1. Tool running Procedures 2. Fishing tools					1. Existing safeguards adequate
Accumulator Fails (Loss of remote BOP operation)	1. Mechanical Failure	1. Lose the ability to remotely close BOP, potential release of hydrocarbon if occurs during gas kick event	H&S	4	1	Low	1. Triple Redundancy 2. Manual Override on BOP					
BOP Fails	1. Mechanical Failure	1. Lose the ability to close BOP, potential release of hydrocarbon if	H&S	4	1	Low	1. Manual Override on BOP 2. Two sets of rams					

System: 2. Drilling/Workover Activities

Subsystem: 2. Drilling Operations

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
		occurs during gas kick event					3. Fluid Density Program					
Cavern Roof Collapse	1. Drilling into existing cavern could cause damage to roof	1. Potential Loss of cavern	F	3	1	Low	1. Cavern Entry Plan					
NORMs present from drilling activities	1. No known NORMS in drilling area, no credible cause	1. No Hazardous Consequences		1	1	Low						
Improper/incomplete scaffolding used	1. Personnel use incomplete scaffold	1. Scaffold Collapse, potential injury	H&S	4	2	Medium	1. All scaffolding to be tagged prior to use 2. Fall arrest used for heights > 6 ft.					1. Existing safeguards adequate
Leaks in temporary piping	1. improper assembly	1. Environmental Impact	E	1	4	Low	1. Leak check on Temporary Piping					
Vehicle close to wellhead creates ignition source	1. Site movement	1. Potential fire/explosion, hazard to personnel	H&S	4	2	Medium	1. Vehicle Use Policy 2. Coordination of activities 3. Safe Work Permits 4. Gas testing 5. Hazard Assessment 6. PASO on diesel engines required					1. Existing safeguards adequate

Risk Assessment – Cavern 45 Redrill

System: 2. Drilling/Workover Activities

Subsystem: 3. Development Workovers

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
Plug is lost downhole and cannot be retrieved	1. Mechanical Failure	1. Financial impact	F	1	3	Low						
Adverse weather during Workover	1. Lightning, high winds, tornados	1. Shut down of operation until weather passes	F	1	4	Low						
Plug doesn't pressure test	1. Mechanical Failure	1. Financial impact	F	1	3	Low						
Obstruction in well casing	1. Bent Pipe, Salt Plug	1. Inability to perform well work, delay in workover, Financial Impact	F	2	2	Low						
There is a wireline breakage	1. Failure of wireline, downhole conditions cause breakage in wireline	1. Potential injury to personnel	H&S	4	2	Medium	1. Wireline Job Hazard Analysis					1. Existing safeguards adequate
		2. Financial Loss, fishing required	F	2	2	Low	2. Wireline Maintenance					
							3. Restricted access to area					
Leak in Pressure control equipment (IE Lubricator)	1. Mechanical Failure, o ring failure	1. Hydrocarbon to surface, environmental release	E	1	4	Low	1. Lubricator Maintenance					
		2. Hydrocarbon to surface, potential fire/explosion hazards to personnel	H&S	4	1	Low	2. Pressure testing					
							3. Blow out Preventer (BOP)					
Tubing stuck in hole	1. Bent Pipe	1. Financial impact	F	2	2	Low						
Accumulator Fails (Loss of remote BOP operation)	1. Mechanical Failure	1. Lose the ability to remotely close BOP, potential release of hydrocarbon if well is live	H&S	4	1	Low	1. Triple Redundancy					
							2. Manual Override on BOP					

Risk Assessment – Cavern 45 Redrill

System: 2. Drilling/Workover Activities

Subsystem: 3. Development Workovers

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
BOP Fails	1. Mechanical Failure	1. Lose the ability to close BOP, potential release of hydrocarbon if occurs if well is live	H&S	4	1	Low	1. Manual Override on BOP 2. Two sets of rams					
Casing Pressure test fails	1. Casing damage, corrosion, thread leaks	1. Casing would need to be repaired (liner install), financial impact	F	2	3	Medium	1. Casing Design 2. Corrosion Logging 3. Casing Thread technician 4. Assembly using hydraulic torque wrenches					1. Existing safeguards adequate
Radioactive Logging tool lost in hole	1. Tool Stuck, wireline break, operator error	1. Reporting required to Canadian Nuclear Safety Commission,	E	2	2	Low						
		2. Potential Financial Loss	F	1	2	Low						

System: 2. Drilling/Workover Activities

Subsystem: 4. Abandonment

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
Plug is lost downhole and cannot be retrieved	1. Mechanical Failure	1. Financial impact	F	1	3	Low						
Adverse weather during Workover	1. Lightning, high winds, tornados	1. Shut down of operation until weather passes	F	1	4	Low						
Plug doesn't pressure test	1. Mechanical Failure	1. Financial impact	F	1	3	Low						
Obstruction in well casing	1. Bent Pipe, Salt Plug	1. Inability to perform abandonment, delay in abandonment, Financial Impact	F	2	2	Low						
There is a wireline breakage	1. Failure of wireline, downhole conditions cause breakage in wireline	1. Potential injury to personnel	H&S	4	2	Medium	1. Wireline Job Hazard Analysis					1. Existing safeguards adequate
		2. Financial Loss, fishing required	F	2	2	Low	2. Wireline Maintenance 3. Restricted access to area					
Tubing stuck in hole	1. Bent Pipe	1. Financial impact	F	2	2	Low						
Accumulator Fails (Loss of remote BOP operation)	1. Mechanical Failure	1. Lose the ability to remotely close BOP, potential release of hydrocarbon if some still present	H&S	4	1	Low	1. Triple Redundancy 2. Manual Override on BOP					
BOP Fails	1. Mechanical Failure	1. Lose the ability to close BOP, potential release of hydrocarbon if some still present	H&S	4	1	Low	1. Manual Override on BOP 2. Two sets of rams					
Casing Pressure test fails	1. Casing damage, corrosion, thread leaks	1. Casing would need to be repaired (liner	F	2	3	Medium	1. Casing Design 2. Corrosion Logging					1. Existing safeguard

Risk Assessment – Cavern 45 Redrill

System: 2. Drilling/Workover Activities

Subsystem: 4. Abandonment

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
		install), financial impact					3. Casing Thread technician					s adequate
							4. Assembly using hydraulic torque wrenches					
Soil Contamination Present	1. Historic hydrocarbon leaks into soil	1. Remediation require to return land to acceptable state	F	2	5	**Medium**						1. Existing safeguards adequate
Digging Equipment Strikes Underground Pipe	1. Underground pipes in general area	1. Pipe Loss of containment, environmental release	E	3	2	**Medium**	1. One Call					1. Existing safeguards adequate
		2. Potential hazards to personnel	H&S	4	2	**Medium**	2. Ground Disturbance Procedure					
							3. Well Placement with offset from underground piping					

System: 3. Operations

Subsystem: 1. Downhole Operations

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
Wellhead impacted by vehicle during operation	1. Slippery Conditions causing vehicle to lose control and strike wellhead	1. Shearing of wellhead, Loss of containment, Environmental impact	E	4	1	Low	1. Driver Training program					
		2. Shearing of wellhead, Potential Personnel Hazards	H&S	4	1	Low	2. Wellhead robustness					
		3. Shearing of wellhead, Financial Loss, operational impact	F	3	1	Low	3. Posted Speed limits					
		4. Minor Damage to wellhead, environmental release	E	2	1	Low	4. Well area chained off, visible barrier					
Corrosion in well exceeds allowable by code	1. Casing corrosion grows over time, eventually will exceed code if not replaced	1. Financial Impact of replacing corroded casing	F	2	3	Medium	1. Corrosion Logging					1. Existing safeguards adequate
		2. Corrosion causes loss, of casing integrity, leak in casing, financial impact	F	2	3	Medium	2. Mechanical Integrity Testing Program, as per Ontario operating standard and per CSA Z341					
Excessive hydrocarbon withdrawn from well	1. Overflow of brine into hydrocarbon system	1. Salt in hydrocarbon pipe, financial burden	F	1	4	Low	1. Density Monitoring					
							2. Low inventory shutdowns					
							3. Differential pressure shutdown					
Excessive hydrocarbon added to well	1. Hydrocarbon into brine string	1. hydrocarbon into brine system, into degas vessel, to flare, Environmental Impact	E	2	3	Medium	1. Density Monitoring S/Ds EV-XXX7					1. Existing safeguards adequate

Risk Assessment – Cavern 45 Redrill

System: 3. Operations

Subsystem: 1. Downhole Operations

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
		2. Loss of product, Financial Impact	F	1	3	Low	2. High Pressure S/D on Brine System, EV-XXX7					
Terrorism/Vandalism	1. Disgruntled member of public intentionally damages wellhead	1. Loss of Containment, Personal injury	H&S	4	1	Low	1. Fenced Perimeter with Card access 2. Video camera system 3. 24/7 Manned Facility					
Annulus Valve Leaks	1. Normal wear and tear on valve	1. Release to atmosphere, Environmental Impact	H&S	2	2	Low	1. Wellhead Gas Detection to DCS					
		2. Financial Loss	F	1	2	Low	2. 24/7 Manned Facility					
Solids in Cavern (Drill cuttings, etc.)	1. Normal course of operation	1. No Hazardous Consequences		1	1	Low						
Surface Casing Vent Leaks	1. Poor Cement Job, local geology	1. Release to atmosphere, Environmental Impact	E	1	1	Low	1. Wellhead Gas Detection to DCS					
Seal problems that cause a wellhead leak	1. Normal wear and tear on wellhead	1. Release to atmosphere, Environmental Impact	H&S	2	2	Low	1. Wellhead Gas Detection to DCS					
		2. Financial Loss	F	1	2	Low	2. 24/7 Manned Facility 3. 3. 10 year, CSA required workovers					
Salting Off of tubing string	1. Cooling of brine, salt falls out	1. Financial Loss, Operational Inconvenience	F	1	5	Medium	1. Brine Flow meter 2. Pressure Transmitter on wellhead					1. Existing safeguards adequate
Brine Stringer break		1. hydrocarbon into brine system, into degas vessel, to	E	2	2	Low	1. Density Monitoring S/Ds EV-XXX7					

Risk Assessment – Cavern 45 Redrill

System: 3. Operations

Subsystem: 1. Downhole Operations

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
	1. High flow in stringer, causing vibration, fails stringer	flare, Environmental Impact										
		2. Loss of product, Financial Impact	F	2	2	Low	2. High Pressure S/D on Brine System, EV-XXX7					
							3. Differential pressure shutdown					
Flange on wellhead leaks	1. Normal wear and tear on wellhead	1. Release to atmosphere, Environmental Impact	H&S	2	2	Low	1. Wellhead Gas Detection to DCS					
		2. Financial Loss	F	1	2	Low	2. 24/7 Manned Facility					
							3. 10 year, CSA required workovers					
Wellhead studs & nuts excessive corrosion	1. Weather erodes steel of nuts and bolts	1. Release to atmosphere, Environmental Impact	H&S	2	2	Low	1. Wellhead Gas Detection to DCS					
		2. Financial Loss	F	1	2	Low	2. 24/7 Manned Facility					
							3. 10 year, CSA required workovers					
Master valve seizes open	1. Normal wear and tear on valve	1. Inability to perform well work, Financial burden	F	1	3	Low	1. 10 year, CSA required workovers					
Master valve seizes closed	1. Normal wear and tear on valve	1. Inability to perform well work, Financial burden	F	1	3	Low	1. 10 year, CSA required workovers					
Master valve fails to seal	1. Normal wear and tear on valve	1. Inability to perform well work, Financial burden	F	1	3	Low	1. 10 year, CSA required workovers					
Off spec product sent into cavern	1. Operator Error, or Off spec Product sent to facility undetected	1. Financial Loss	F	1	4	Low	1. Density Monitoring					
							2. Spot Check Sampling, Checks					

Risk Assessment – Cavern 45 Redrill

System: 3. Operations

Subsystem: 1. Downhole Operations

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
							on Railcars and Pipelines					
Diluted brine sent into cavern	1. Rain causes diluted brine in pond	1. Unintentional Cavern mining, cavern gets slightly bigger	F	1	5	Medium	1. Density Monitoring 2. CSA regulated sonar surveys every 10 years to monitor growth					1. Existing safeguards adequate
Excessive Flow rate in/out of well	1. High flow in stringer, causing vibration, fails stringer	1. hydrocarbon into brine system, into degas vessel, to flare, Environmental Impact	E	2	2	Low	1. Density Monitoring S/Ds EV-XXX7					
		2. Loss of product, Financial Impact	F	2	2	Low	2. High Pressure S/D on Brine System, EV-XXX7 3. Differential pressure shutdown					
NORMS present in Propane	1. NORM contaminated product from other facility	1. Potential exposure to radiation for personnel, hazards to personnel (maintenance activities)	H&S	1	3	Low	1. Procedure during activities where potential for NORMS exist					

System: 3. Operations

Subsystem: 2. Brine System Operations

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
Excessive Erosion/Corrosion in Brine Piping	1. Brine is corrosive/erosive, potential for air ingress to accelerate corrosion	1. Failure of Brine Piping, release of brine, environmental impact	E	2	3	Medium	1. Pembina Pressure Equipment Integrity Management Program 2. Operator Rounds					1. Existing safeguards adequate
Extreme Cold causes brine to freeze	1. Ambient Weather Conditions	1. Operational Upset, Financial Impact	F	1	4	Low	1. Operator Rounds					1. Existing safeguards adequate
		2. Failure of Brine Piping, release of brine, environmental impact	E	2	3	Medium	2. Flow meter					
EV-XXX7 Fails to close when needed	1. Mechanical Malfunction, Frozen, salt debris in valve	1. Loss of remote shutdown of well, operations need to close master valve, operation inconvenience, shutdown slower than normal, environmental release extended	E	2	2	Low	1. Operations can close PV-XXX9 2. Weekly Brine EBV checks 3. DCS Alarms 4. EV Limit switches					
EV-XXX7 stuck closed	1. Airline freezes, solenoid fails, DCS failure	1. Operational Upset, Financial Impact	F	1	5	Medium	1. Procedure for blowing airlines 2. Redundant caverns					1. Existing safeguards adequate
EV-XXX7 Passes	1. Valve wear and tear	1. Hydrocarbon passes into brine system, environmental impact	E	1	3	Low	1. Operations can close PV-XXX9 2. Weekly Brine EBV checks 3. DCS Alarms					
PV-XXX9 Fails Open	1. Normal Operation	1. No Hazardous Consequences		1	1	Low						

Risk Assessment – Cavern 45 Redrill

System: 3. Operations

Subsystem: 2. Brine System Operations

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
PV-XXX9 Fails Closed	1. Airline freezes, positioner fails, DCS failure	1. Operational Upset, Financial Impact	F	1	5	Medium	1. Procedure for blowing airlines 2. Redundant caverns					1. Existing safeguards adequate
PV-XXX9 Passes	1. Normal wear and tear on valve	1. No Hazardous Consequences		1	1	Low						
Operator close brine manual valve inadvertently	1. Operator Error	1. Potential for vacuum on cavern, potential for high flow in stringer if valve is suddenly opened, could lead string damage, environmental impact	E	2	2	Low	1. Standard Operating Practices					
		2. Financial impact	F	2	2	Low	2. Lock Out / Tag Out Procedure 3. PV-XXX9					
Brine Stringer Break	1. See Downhole Operations	1. See Downhole Operations		1	1	Low						
Terrorism/Vandalism	1. See Downhole Operations	1. See Downhole Operations		1	1	Low						

Risk Assessment – Cavern 45 Redrill

System: 3. Operations

Subsystem: 3. Hydrocarbon System Operations

Document:

Design Conditions/Parameters:

What If	Causes	Consequences	CAT	Operating Risk, Before Additional Risk Reduction			Safeguards	What If Recommendations	Residual Risk - After Recommendations for Risk Reduction			Remarks
				S	L	RR			Severity	Likelihood	Risk Ranking	Remark
Excessive Corrosion in Propane Piping	1. External corrosion cause by weather	1. Loss of containment of hydrocarbon piping, environmental release	E	2	2	Low	1. Gas leak detection, alarm, trip					
		2. Financial impact	F	1	2	Low	2. Operator Rounds					
		3. Potential for fire/explosion, hazards to personnel	H&S	4	1	Low	3. Personal Gas detection					
							4. Pembina Pressure Equipment Integrity Management Program					
EV-XXX4 Fails to close when required	1. Mechanical Malfunction, Frozen,	1. Overpressure of cavern above maximum cavern operation pressure, potential for cavern fracture, Loss of cavern usage, financial impact.	F	3	1	Low	1. Built in safety factor into operating pressure limit					
							2. PV-XXX3					
							3. Manual Block valves					
							4. Pressure Transmitter on wellhead					
							5. Flow Meter FIT-XXX1					
EV-XXX4 Closes inadvertently	1. Airline freezes, solenoid fails, DCS failure	1. Financial Loss, Operational Inconvenience	F	1	5	Medium	1. Procedure for blowing airlines					1. Existing safeguards adequate
							2. Redundant caverns					
EV-XXX4 Passes	1. Normal wear and tear on valve	1. Overpressure of cavern above maximum cavern operation pressure, potential for cavern fracture, Loss of	F	3	1	Low	1. Built in safety factor into operating pressure limit					
							2. Quarterly HC EV testing					

		cavern usage, financial impact.					3. Operator rounds 4. Pressure Transmitter on wellhead 5. Flow Meter FIT-XXX1					
PV-XXX3 Seizes Open	1. Debris, mechanical Failure	1. High Flow into Cavern, high brine flow out, potential stringer damage, Environmental Damage	E	2	2	Low	1. EV-XXX4					
		2. Financial impact	F	2	2	Low	2. Flow Meter FIT-XXX1 3. Manual Block Valves					
PV-XXX3 Fails Closed	1. Airline freezes, solenoid fails, DCS failure	1. Financial Loss, Operational Inconvenience	F	1	5	Medium	1. Procedure for blowing airlines 2. Redundant caverns 3. Manual Bypass around valve	1. Add Gate Valve downstream of globe valve around PV-XXX3	1	5	Medium	1. Existing safeguards adequate
PV-XXX3 Passes	1. Normal wear and tear on valve	1. No Hazardous Consequences		1	1	Low						
Operator closes manual valve inadvertently	1. Operator Error	1. No Hazardous Consequences		1	1	Low						
Terrorism/Vandalism	1. See Downhole Operations	1. See Downhole Operations		1	1	Low						

"What If" Recommendations

Recommendations	Place(s) Used	Responsibility	Maximum Risk		Rec Pri	Rec Cat	Status	% Complete	Estimated Dates		Actual Dates		Cost		Comments
			Before Action	After Action					Start Date	End Date	Start Date	End Date	Estimated	Actual	
1. Add Gate Valve downstream of globe valve around PV-XXX3	Causes: 3.3.6.1	Chad Severs	Medium	Medium	4	Engineering	In Progress		7/1/2016	8/31/2016			$2500		
2. Perform Rig Move assessment, consider height, width, weight over underground facilities. If height of powerlines is a concern, reroute lines before rig move	Causes: 2.1.8.2, 2.2.4.1	Scott Morris	Low	Low	7	Administration	In Progress		7/1/2016	12/31/2016			$2000		

Conclusions

The “What If” hazard analysis completed for the Cavern 45 redrill was completed in a one day session. In the team’s opinion the assessment comprehensive and consistent with Pembina’s risk tolerance as well as met the requirements as set out in CSA Z341.2-14.

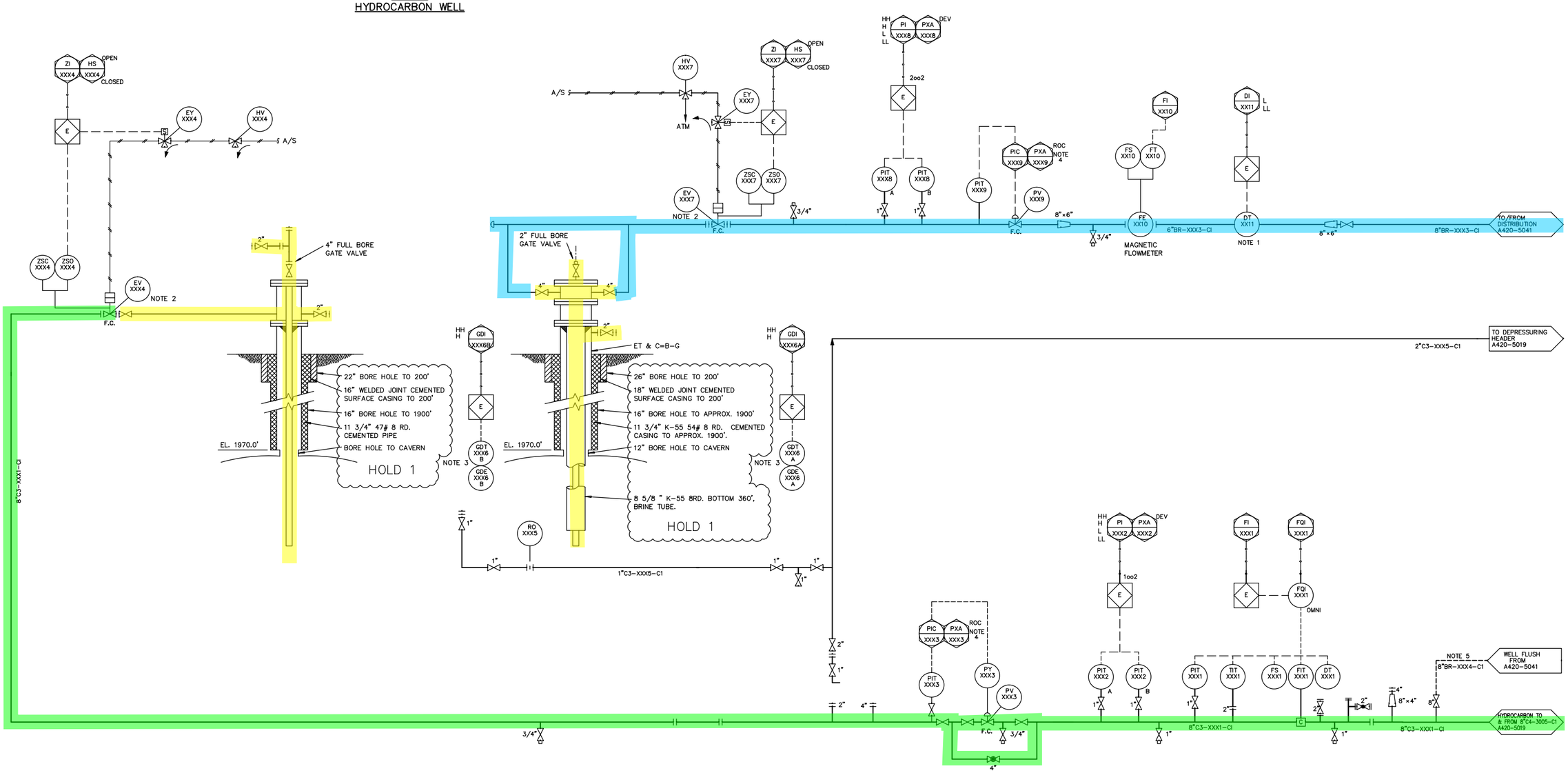
Over the 3 systems analyzed 112 Potential Hazards were identified. Those 112 hazards had a total of 153 consequences related to them. As per the Pembina Risk Assessment Matrix 123 of these consequences were deemed “Low” risk and 30 were deemed “Medium” risk with all existing safeguards considered. The medium risk items were all considered as low as reasonably practicable by the “What If” team.

Two recommendations were generated out of this review, they have been assigned to the appropriate parties and will be completed within the timelines outlined within the recommendations section.

This analysis has satisfied both Pembina’s and CSA’s requirements and there are no identified hazards that have residual risk above the acceptable levels deemed by the Pembina Risk Matrix. The “What If” team concludes the study and the project can continue as planned.

Appendix A – Noded Process and Instrumentation Diagrams (P&IDS)

HC-45
HYDROCARBON WELL



NOTES:
1. USE CAUTION. DENSITY TRANSMITTER CONTAINS A RADIATION SOURCE.
2. PLASTIC TUBING PROVIDED FOR THE FIRE PROTECTION.
3. LOCATE NEAR WELLHEAD AT HIGHEST CONCENTRATION OF VALVES AND LEAK SOURCES.
4. ROC = RATE OF CHANGE.
5. ------ TEMPORARY WELL FLUSH PIPING

HOLDS:

1. PENDING VENDOR CONFIRMATION

EMPOWERING EPCM
www.twdepcm.com

PROJECT NUMBER: 16-3326

REFERENCE DRAWINGS	DRAWING #	NO.	DATE	REVISION PROJECT DESCRIPTION	PPL PROJECT	EPCM Co.	EPCM No.	ENG	REV	ISSUE STAGE	DATE	BY	CHKD.	APPD.
		0	MAR 2016	CAVERN 45 PROJECT		TWD	16-3326		A	ISSUED FOR REVIEW	MAR 18, 2016	KAJ	KAJ	IWD
									B	ISSUED FOR REVIEW	MAR 23, 2016	KAJ	KAJ	IWD
									C	ISSUED FOR HAZOP	MAR 30, 2016	KAJ	KAJ	IWD

PERMIT STAMP

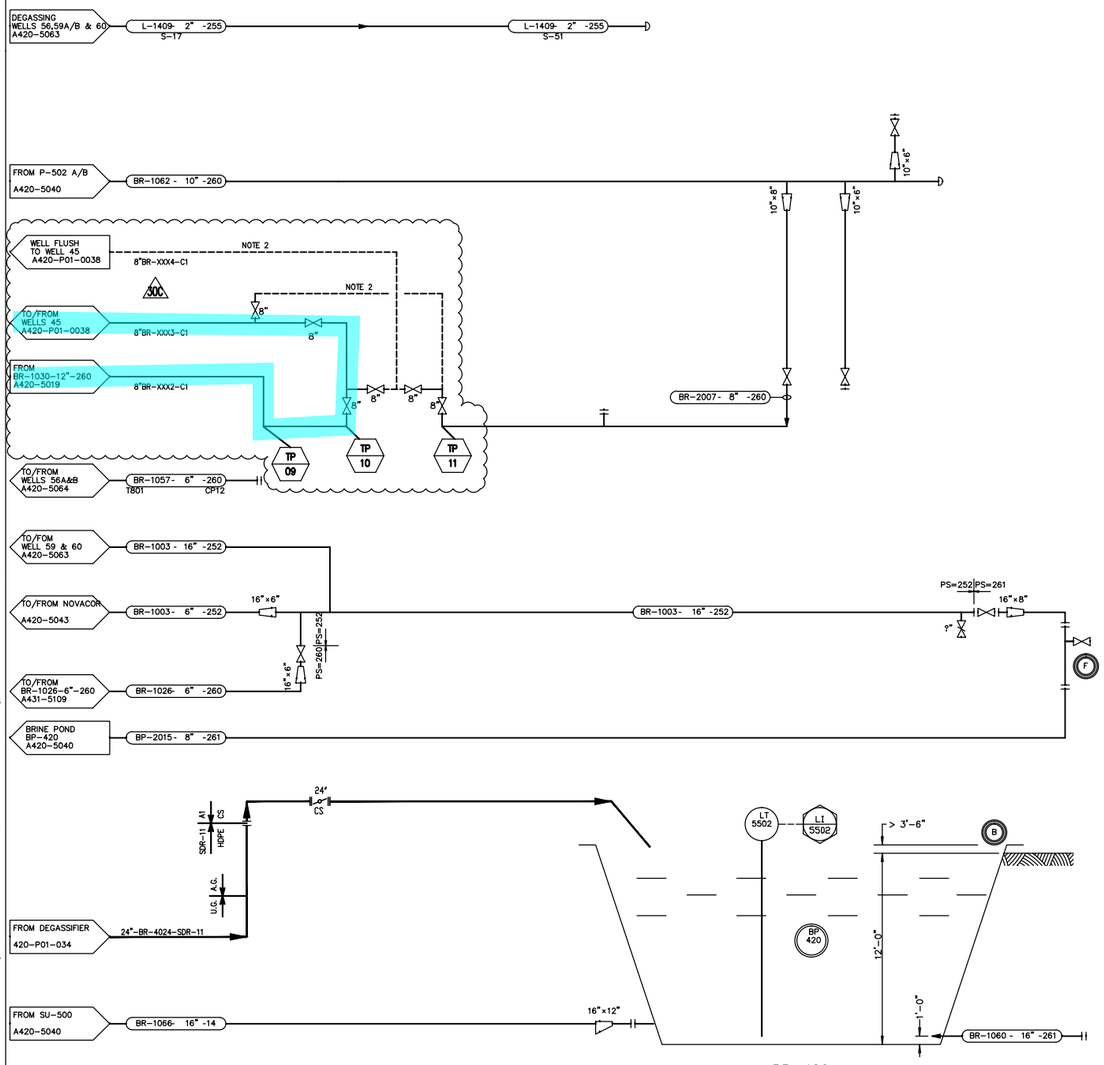
ENGINEER'S STAMP

PERMIT STAMP AND PROFESSIONAL STAMP AFFIXED ABOVE SHALL APPLY ONLY TO REV(s) △

Pembina NGL Corporation

PROCESS AND INSTRUMENT DIAGRAM
HC-45 HYDROCARBON WELL

AREA NAME:	CLASS:	SCALE:	PPL DRAWING NUMBER	
CORUNNA	P&ID	NONE	A420-P01-0038	0C



BP-420
BP-420 **ADDED BY SA**
MANUFACTURER:
MODEL:

NOTES:
1. DI-5399 INTERLOCKED TO EBV-5416 AND EBV-5418, TRIPS AT 0.9 SG
2. ----- TEMPORARY WELL FLUSH PIPING

LEGEND:
----- TEMPORARY WELL FLUSH PIPING

ITEM STATUS LEGEND:
- (N) NEW
- (E) EXISTING
- (R) EXISTING TO BE RELOCATED
- (V) VENDOR SUPPLIED PACKAGE UNIT OR ITEM
- (F) FUTURE
- (D) SUPPLIED BY DOW
- (M) EXISTING TO BE MODIFIED

NOTES:
- (A) BLEED BY MAG. SHALL BE FLANGED.
- (B) BR-1058 OUTLETS TO BE MINIMUM OF 1'-6" BELOW BR-1060 B.O.P.
- (C) 15'-4" OUTLETS ON 1'-6" C/C, FIRST OUTLET 12" BELOW MIN. LIQ. LEVEL.
- (D) ELBOW WITH A VENT
- (E) VALVE IS TO BE REMOVED AND (2) BLIND FLANGES ARE TO BE INSTALLED.
- (F) CONNECTION IS TO BE MADE ABOVE GRADE. A 4'-0" SPOOL PIECE IS TO BE INSTALLED FOR FUTURE PIPING.
- (G) (2) PILOTS INSTALLED. BOTH USE SAME IGNITION SOURCE (IGN-5437). EACH PILOT HAS ITS OWN TE/TT. TE/TT-5438 (NORTH) AND TE/TT-5439 (SOUTH).

UNLESS OTHERWISE NOTED, ALL ITEMS ON THIS DRAWING ARE: EXISTING.

REV. MARK	REVISION	BY	CHK	APP	DATE
29	REVISED AS NOTED	SME	RH	WER	3/15
30C	ISSUED FOR HAZOP (TWD PROJECT #16-3326)	KAJ		IWD	3/16
13	GENERAL REVISIONS	PGH	KN	CH	3/96
14	CHANGED PCV-5436 TO PCV-5480 AS BUILT.	PGH	SM		4/96
15	REVISED AS BUILT	RPD	SA		7/96
16	ADDED TE-5439 & TT-5439; DELETED BT-5439 & BE-5439.	CPJ	SM	SM	5/97
17	ADDED STREAM NOS. FOR FUGITIVE EMISSIONS PROJECT.	CPJ	RN	JW	7/00
18	ADDED NEW ITEMS FOR FS-5/D-501 UPGRADE.	CPJ	HD	LC	12/02
19	UPDATED; REVISED AS BUILT.	CPJ	LC	LC	10/05
20	MOVED BP-420 FROM P&ID A420-5040.	CPJ	SM	LC	9/06
21	UPDATED; REVISED AS BUILT.	CPJ	LC	LC	12/06
22	UPDATED; REVISED AS BUILT.	CPJ	DL	DL	2/07
23	ADDED FS-5 IGNITION AND TEMPERATURE INSTRUMENTS.	CPJ	SM	SM	2/07
24	AS BUILT	DM	JRS		9/12
25	UPDATED AS PER OPS MODS - AS BUILT	KL	JRS		1/13
26	UPDATED AS PER OPS MODS - AS BUILT	JS	JRS		5/13
27	ADDED 1" VALVE BEFORE PCV-5433 - AS BUILT	KL	JRS		10/13
28	ISSUED FOR CONSTRUCTION	JRL	WER	CWC	2/15

DRAWING ISSUE RECORD

ISSUE NO.	REV	MATERIAL OR JOB SPEC	DATE ISSUED FOR: BID	FAB	CONST	REF

DESIGNED	R. SMEDING	10/85
DRAWN	R. DUTOURGEERLING	02/92
CHECKED	C. LYONS	
APPROVED	C. HILL	
PROJ. ENGR.	D. CUTHBERT	
MFG. REF.	C. HILL	

STATUS | PLANT NO. 420
P.E. SEAL

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PROJECT NUMBER: 16-3326
EMPOWERING EPCM
www.twdepcm.com

Pembina NGL Corporation

EASTERN CANADA OPERATIONS — SARNIA, ONTARIO
BRINE WELLS — BLOCK 420

PIPING AND INSTRUMENT DIAGRAM
LPG BRINE SYSTEM D-501 & DP-500

PROJECT NO.	SCALE		REV.
W.O.# 43163	NONE	A420-5041	30C

1 PID

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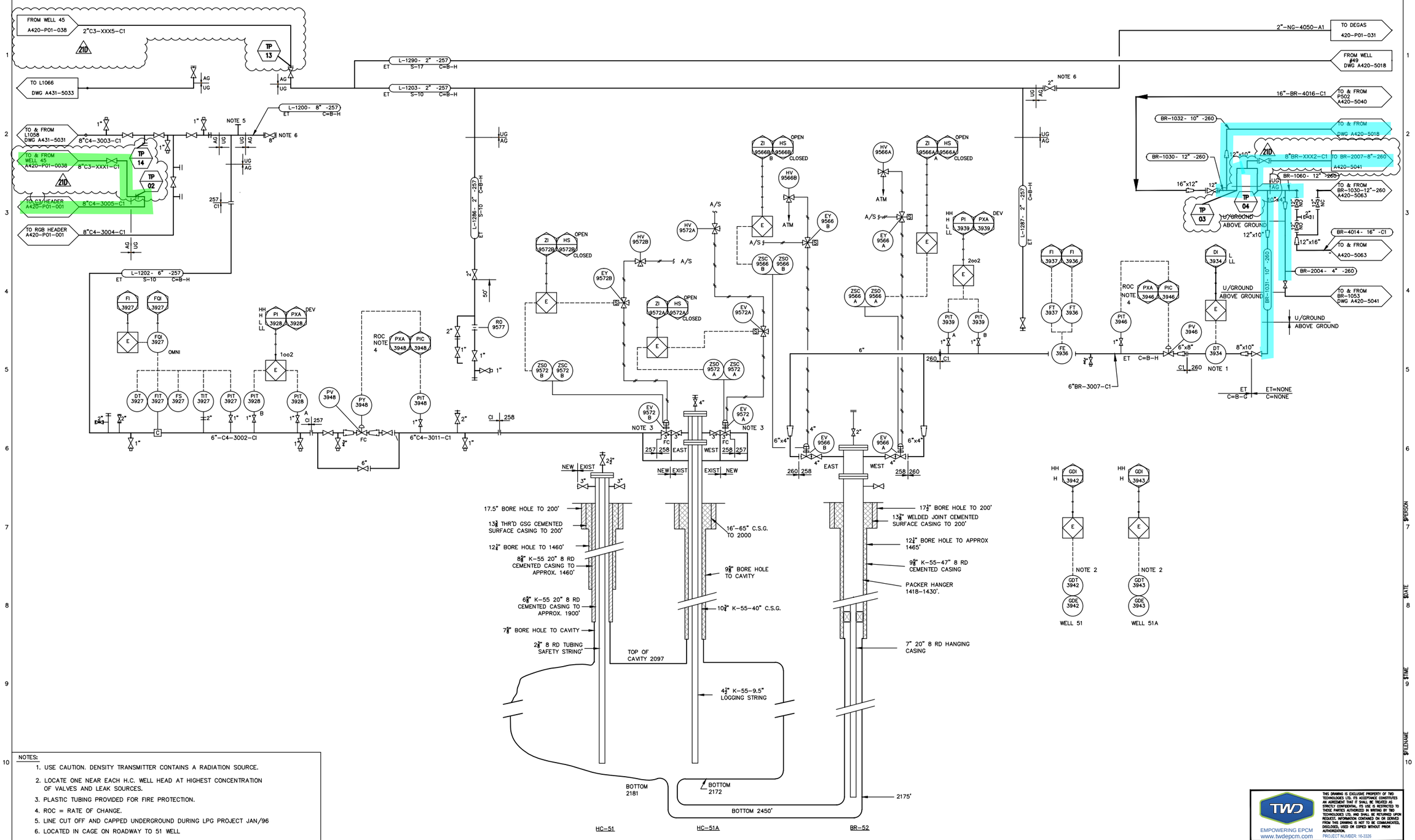
$PERSON $DATE $TIME $FILENAME $INSTRUCTIONS



NOTES:

1. USE CAUTION. DENSITY TRANSMITTER CONTAINS A RADIATION SOURCE.
2. LOCATE ONE NEAR EACH H.C. WELL HEAD AT HIGHEST CONCENTRATION OF VALVES AND LEAK SOURCES.
3. PLASTIC TUBING PROVIDED FOR FIRE PROTECTION.
4. ROC = RATE OF CHANGE.
5. LINE CUT OFF AND CAPPED UNDERGROUND DURING LPG PROJECT JAN/96
6. LOCATED IN CAGE ON ROADWAY TO 51 WELL

REV. MARK	REVISION	BY	CHK	APP	DATE
21D	RE-ISSUED FOR HAZOP (TWD PROJECT #16-3326)	KAJ		IWD	04/16
7	ADDED BR-2004-4"-260.	CPJ			08/94
8	GENERAL REVISIONS.	PGH			05/95
9	REVISED AS BUILT.	RPD			07/96
10	MOVED FT-5983; ADDED PT-9516; AS BUILT.	CPJ	SM	SM	09/96
11	MOVED FT-5983 BACK TO FE-9551.	CPJ	SM	SM	10/96
12	ADDED STREAM NOS. FOR FUGITIVE EMISSIONS.	CPJ	RN	JW	7/00
13	GENERAL REVISIONS.	CPJ	SM	SM	05/01
14	REMOVED RTU-2 ITEMS; AS BUILT.	CPJ	SM	SM	08/01

REV. MARK	REVISION	BY	CHK	APP	DATE
15	ADDED SPEC. BREAK TO EBV-9566A/B.	CPJ	LC	LC	05/05
16	GENERAL UPDATES AS BUILT.	CPJ	LC	LC	07/06
17	UPDATED; REVISED AS BUILT.	CPJ	LC	LC	08/07
18A	ISSUED FOR REVIEW.		KAJ		04/11
18B	ISSUED FOR HAZOP	DHH	KAJ		04/11
18C	ISSUED FOR CONSTRUCTION.	DHH	KAJ		05/11
18D	RE-ISSUED FOR CONSTRUCTION.	EGB	KAJ		06/11
19	FIELD UPDATES - AS-BUILT	JRS	IS		09/14
20	ISSUED FOR CONSTRUCTION	JRL	WER	CWC	02/15

DRAWING ISSUE RECORD

ISSUE NO.	REV	MATERIAL OR JOB SPEC	DATE ISSUED FOR: BID	FAB	CONST	REF

DESIGNED	K.G. SMY	02/08
DRAWN	M. VASEK	02/08
CHECKED	KL?	04/08
APPROVED	?	04/08
PROJ. ENGR.		
MFG. REP.		

STATUS: PLANT NO. 431
P.E. SEAL

Pembina NGL Corporation

EASTERN CANADA OPERATIONS — SARNIA, ONTARIO

H.C. WELLS — AREA 420

HC - 51A&B/52
HYDROCARBON WELL

PROJECT NO.	SCALE		REV.
41810	NONE	A420-5019	21D

1 PID

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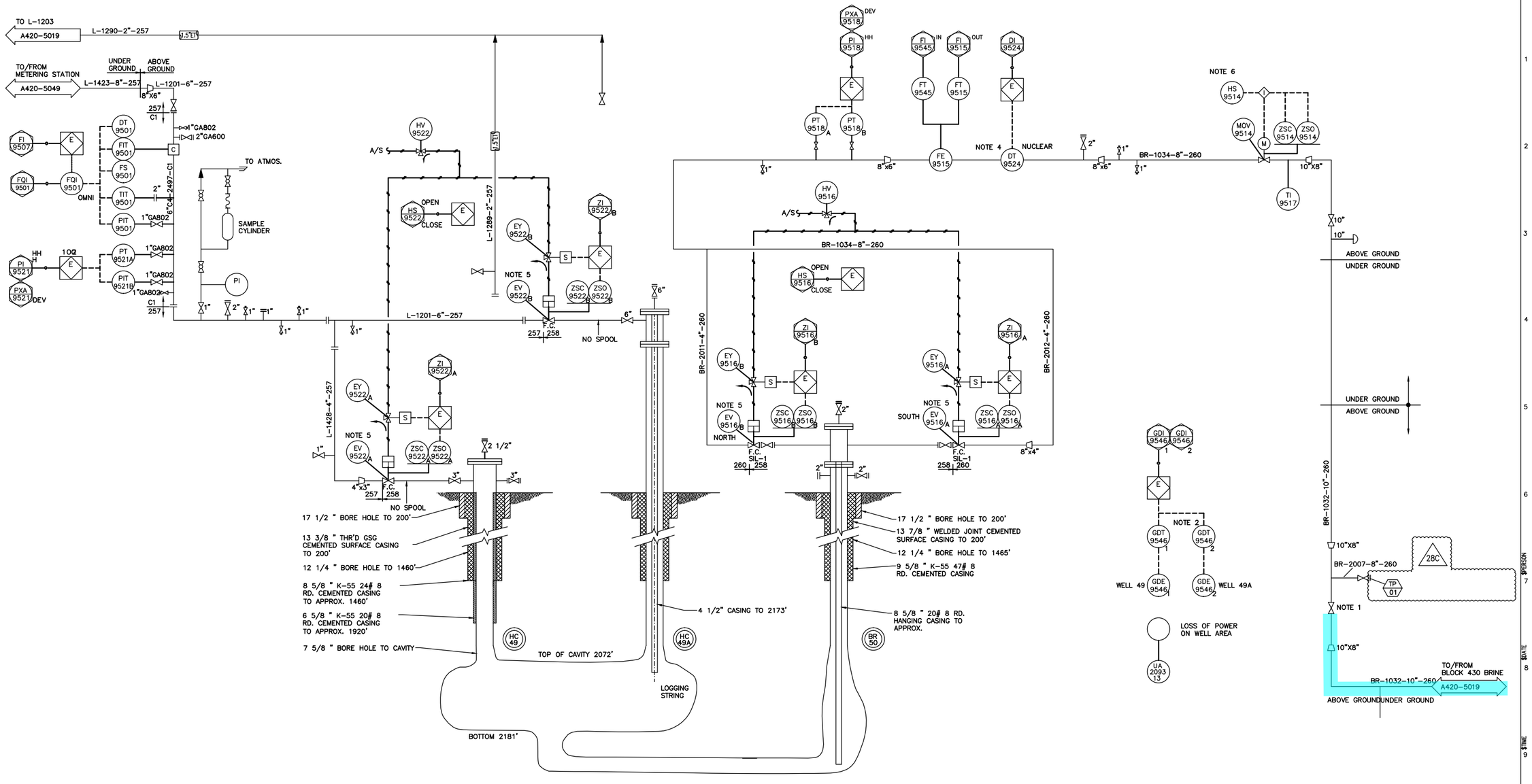
$PERSON $DATE $TIME $FILENAME $INSTRUCTIONS



NOTES:

1. VALVE STATION LOCATED ABOVE GROUND JUST SOUTH OF THE ROADWAY.
2. LOCATE ONE NEAR EACH WELLHEAD AT HIGHEST CONCENTRATION OF VALVES AND LEAK SOURCES.
3. REPLACE FLOW CONTROL VALVE AND BLOCK VALVES WITH A SPOOL PIECE.
4. USE CAUTION. DENSITY TRANSMITTER CONTAINS A RADIATION SOURCE.
5. PLASTIC TUBING PROVIDED FOR FIRE PROTECTION.
6. MOV-9514 WORKS FROM THE FIELD LOCATION ONLY. CONTROL ROOM HAS NO CONTROL OFF VALVE

THIS DRAWING WAS MADE FROM DOW CHEMICAL INC. DWG # A420-5018, REV 22

REV. MARK	REVISION	BY	CHK	APP	DATE
19	UPDATED; REVISED AS BUILT.	CPJ	SM	SM	4/07
20	REMOVED PT-9526 & PI-9519 FROM TOP OF HC-49A.	CPJ	SM	SM	1/08
21	UPDATED; REVISED AS BUILT.	CPJ	LC	LC	5/08
22	ADDED F.C./SIL-1 DESIGNATION TO EBV'S.	CPJ	AE	AE	9/09
23A	ISSUED FOR REVIEW (WP PROJECT# 10S1938.)	SC		NM	10/10
23B	IFC (WP PROJECT# 10S1938.)	SC	VT	AO	11/10
23C	RE-IFC (WP PROJECT# 10S1938.)	DM	SC	AO	02/11
24	AS-BUILT	RJ	JRS		10/11
25	ADDED NOTE 6 AS-BUILT	KL	JRS		03/13
26	BRINE SYSTEM MARK UP - AS BUILT	KL	JRS		11/13
27	AS-BUILT PER FIELD MARK-UPS	RAM	IS		05/15
28C	ISSUED FOR HAZOP (TWD PROJECT #16-3326)	KAJ	IWD		03/16
13	ADDED PIPE SPEC. BREAK/CHANGE TO BR-1034.	CPJ	CL		11/94
14	REVISED AS BUILT ON W.O.# 30503-501.	CPJ	CH	CH	5/95
15	REVISED AS BUILT FOR LPG PROJECT.	PGH	KN		1/96
16	REVISED MOD V POINTS FOR SOME INSTRUMENTS	OGH	CH		3/96
17	ADDED STREAM NOS. FOR FUGITIVE EMISSIONS PROJECT.	CPJ	RN		7/00
18	UPDATED; REVISED AS BUILT.	CPJ	LC	LC	4/06

DRAWING ISSUE RECORD

ISSUE NO.	REV	MATERIAL OR JOB SPEC	BID	FAB	CONST	REF
			DATE ISSUED FOR			

DESIGNED	K.G. SMY	02/07/80
DRAWN	M. VASEK	02/07/80
CHECKED	K.G. SMY	23/04/80
APPROVED	J.E. GATES	24/06/80
PROJ. ENGR.	D. CUTHBERT	
MFG. REP.	C. HILL	

STATUS | PLANT NO. 420

P.E. SEAL

Pembina NGL Corporation

EASTERN CANADA OPERATIONS — SARNIA, ONTARIO

BRINE WELLS — BLOCK 420

PIPING AND INSTRUMENT DIAGRAM
HC-49, HC-49A & BR-50 WELLS

PROJECT NO.	SCALE		REV.
W.O.# 43748-000	NONE	A420-5018	28C

1 PID

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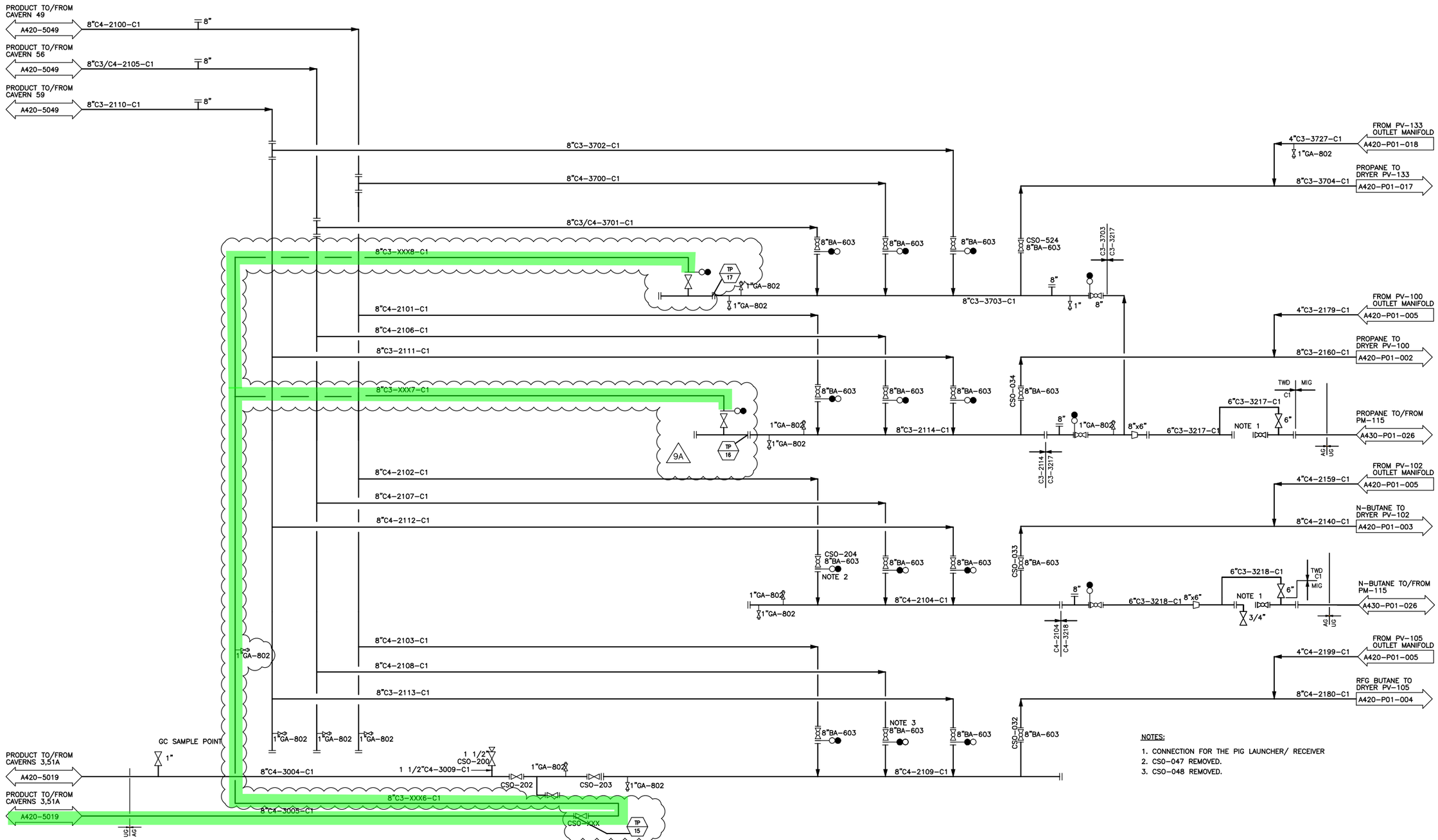
$PERSON $DATE $TIME $FILENAME $INSTRUCTIONS



REFERENCE DRAWINGS	DRAWING #	NO.	DATE	REVISION PROJECT DESCRIPTION	PPL PROJECT	EPCM Co.	EPCM No.	ENG	REV	ISSUE STAGE	DATE	BY	CHKD.	APPD.
SYMBOLS LEGEND SHEET	A400-P01-001	3	2012.12.20	TWD #12-948		TWD	12-948		9A	ISSUED FOR HAZOP	2016.04.06	KAJ		IWD
		4	2013.01.14	CSO REVISION - AS BUILT		PPC	PPC							
		5	2013.02.06	SUNCOR LPG D&S (TWD #12-948)		TWD	12-948							
		6	2014.07.23	CORUNNA EXPANSION PROJECT		SNC LAVALIN	620513	JL						
		7	2015.08.27	AS-BUILT PER MOC	2015-257	PEMBINA								
		8	2016.02.23	UPDATED AS PER PROJECT AS-BUILTS: SNC PROJECT		PEMBINA	620513	IS						
		9	2016.04.06	CAVERN 45 PROJECT (TWD PROJECT #16-3326)		TWD	16-3326							

PERMIT STAMP

ENGINEER'S STAMP

PERMIT STAMP AND PROFESSIONAL STAMP AFFIXED ABOVE SHALL APPLY ONLY TO REV(s) △

Pembina NGL Corporation

PROCESS AND INSTRUMENT DIAGRAM
PROPANE, N-BUTANE & RGB BUTANE INLET MANIFOLDS

AREA NAME:	CLASS:	SCALE:	PPL DRAWING NUMBER	
CORUNNA	P&ID	NONE	A420-P01-001	9A

A-420-P01-0001