

#### **Risk Assessments for Releases from Highly Volatile Liquid Pipelines**

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# Introduction

Pipeline operators are required by code (49 CFR Part 195.452) to have a process in place for identifying pipeline segments that could affect a high consequence area (HCA).

In addition to having the HCAs identified, pipeline operators must take special measures to protect these areas and mitigate the associated risks.

Depending on the type of product being transported, a product release could result in liquid plumes, vapor dispersion, or a combination of both; which the operators need to account for in their processes.



# Overview

- What is a High Consequence Area?
- What are Highly Volatile Liquids (HVLs)?
- Modeling of Releases of HVLs
- HCA Analysis for HVL Pipelines
- Mitigating Risk through Emergency Flow Restriction Device (EFRD) Analysis



# What is a High Consequence Area?

#### High Consequence Areas (HCAs) include:



High Population Areas



Commercially Navigable Waterways



Other Populated Areas



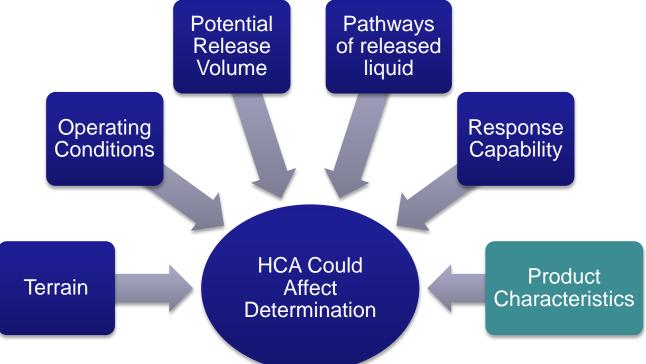
Unusually Sensitive Areas

- Two types of High Consequence Areas (HCAs)
  - Direct
  - Indirect



# HCA Could Affect Criteria

Factors that contribute to creating indirect HCA segments on a pipeline





# What are Highly Volatile Liquids (HVLs)

- Liquids when stored at a certain temperature or pressure
- Can quickly vaporize when released to atmospheric conditions
- Common HVLs transported in pipelines include:
  - Natural Gas Liquids
    - Ethane, propane, butane, Isobutane, Pentanes
  - Ethylene
  - Propylene
  - Anhydrous ammonia



# **HVL Releases**





# **HVL Implications for HCA Analysis**

- Requires determining impacted HCAs by considering:
  - Vapor cloud dispersion and concentrations
  - Liquid pooling and potential plume pathway
  - Evaporation from liquid plume
- How is this determined?
  - Atmospheric dispersion modeling
  - Liquid spill plume modeling





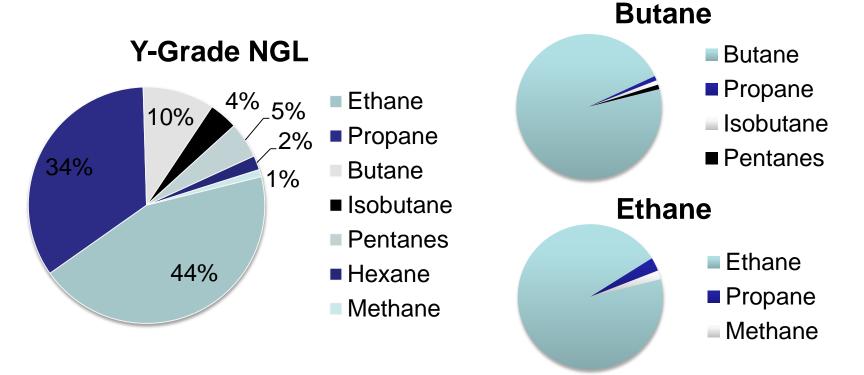
# Modeling of Releases of HVLs

- Step 1 Analysis of HVL Composition
- Step 2 Release Calculation
- Step 3 Atmospheric dispersion modeling
- Step 4 Liquid plume modeling
- Step 5 Evaporation from liquid plumes



# Analysis of HVL Composition

Most HVL products are composed of multiple chemicals, in varying quantities.





# Analysis of HVL Composition

- Each chemical has different physical properties and will behave differently in the event of a release
- Most models don't handle these mixtures
- The conservative approach is to model each chemical individually:
  - Perform release calculations on each chemical individually
  - Scale release calculations by overall composition
  - Simulate releases of each chemical individually



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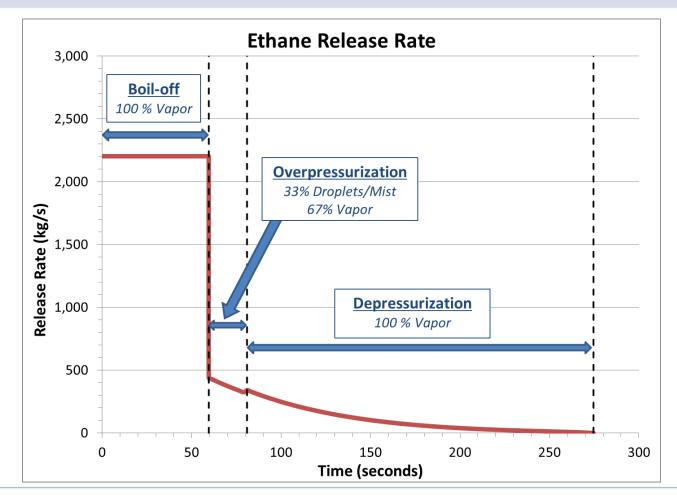


#### **Release Calculation**

- Releases can pass through multiple stages:
  - Liquid release, Boil-off, Over pressurization, Depressurization
- At each phase the released chemical can exist in one or many states:
  - Liquid, vapor, droplets/mist
- Release rates will vary over time, and through different stages of the release
- Release rate tapers off to zero once pipeline reaches atmospheric pressure.

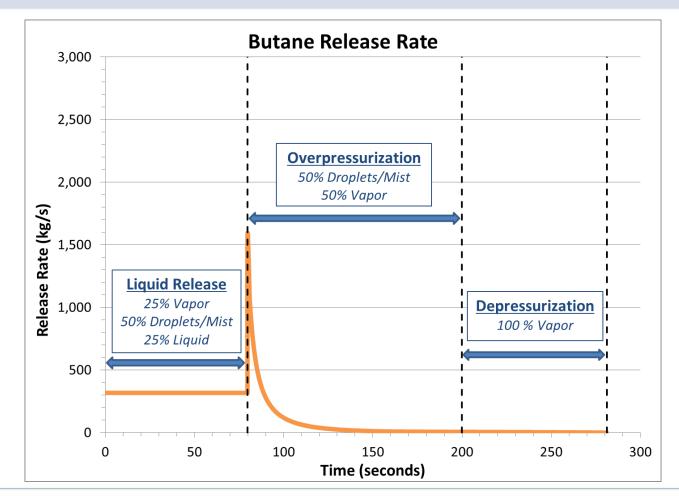


#### **Release Calculation**





#### **Release Calculation**





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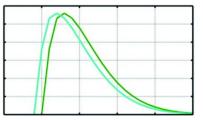


# **Atmospheric Dispersion Modeling**

- Used to determine the spatial extent of the vapor cloud and vapor concentrations from the ruptured pipeline
- Inputs to the modeling:



Release Rate and Duration



**Environmental Conditions** 



Wind speed, air temperature, land cover, humidity

- Outputs from the modeling:
  - Vapor plume dimensions (width, height)
  - Instantaneous & Time Averaged Concentrations
  - Maximum distance to specific concentration threshold



# Thresholds of Concern

- Lower Explosive Limit (LEL)
  - Concentration threshold at which the vapor could catch fire if there were an ignition source
- Health Risk Thresholds
  - Concentrations exceeding these for a defined time period can cause toxic effects
    - Level 1 reversible effects (discomfort, irritation, etc.)
    - Level 2 irreversible effects, long-lasting effects, impaired ability to escape
    - Level 3 life-threatening effects or death
  - Sources of thresholds
    - Acute Exposure Guideline Levels (AEGLs) EPA
    - Temporary Emergency Exposure Limit (TEEL) DOE









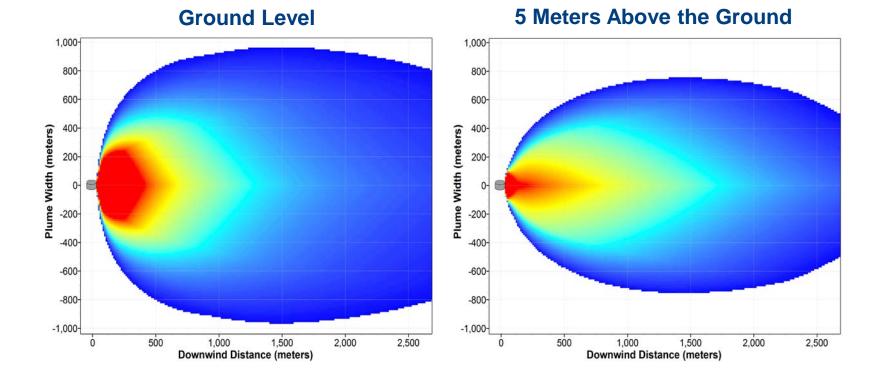
# Concentration Thresholds (ppm)

Threshold	LEL	Level-1	Level-2	Level-3	
Time Period	Instantaneous				
Methane	50,000	65,000	230,000	400,000	
Ethane	29,000	65,000	230,000	400,000	
Propane	21,000	5,500	17,000	33,000	
n-Butane	19,000	5,500	17,000	53,000	
IsoButane	18,000	5,500	17,000	53,000	
n-Pentane	15,000	3,000	33,000	200,000	
IsoPentane	14,000	3,000	33,000	200,000 8,600	
Hexanes	12,000	260	2,900		

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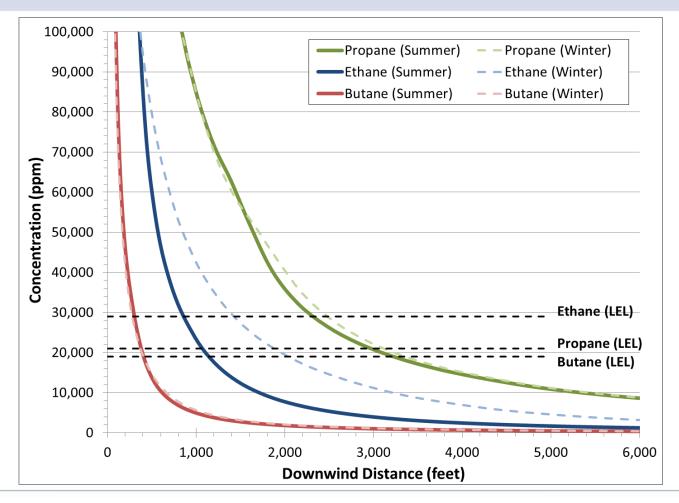


# **Plume Cross Section Concentration**



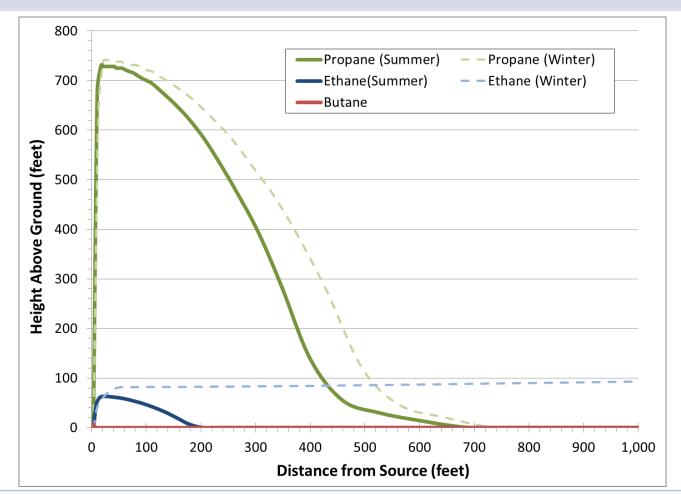


# Plume Centerline Concentration



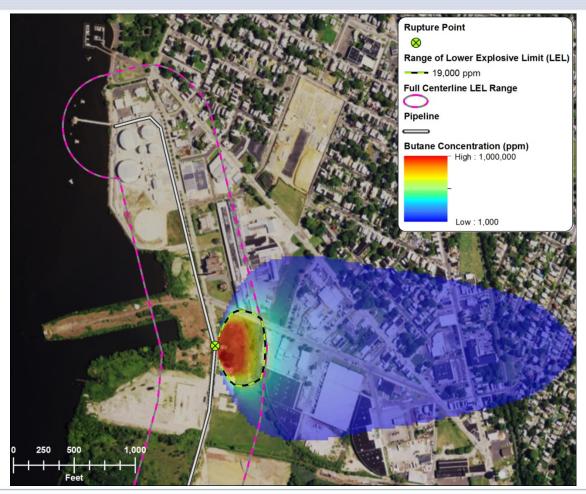


# Plume Height of Max Concentration





# Applying Results for the Whole Pipeline

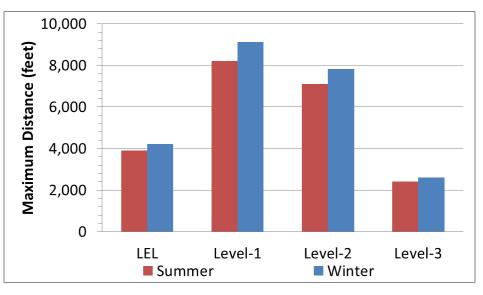


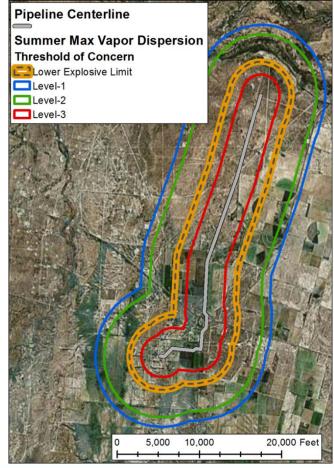
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# **Overall Max Distance by Season/Threshold**

Threshold Of Concern	Distance (feet)				
Threshold Of Concern	Summer	Winter			
Lower Explosive Limit	3,900	4,200			
Level-1	8,200	9,100			
Level-2	7,100	7,800			
Level-3	2,400	2,600			







# Modeling of Releases of HVLs

- Step 1 Analysis of HVL Composition
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- Step 3 Atmospheric dispersion modeling

#### Step 4 – Liquid plume modeling

Step 5 – Evaporation from liquid plumes



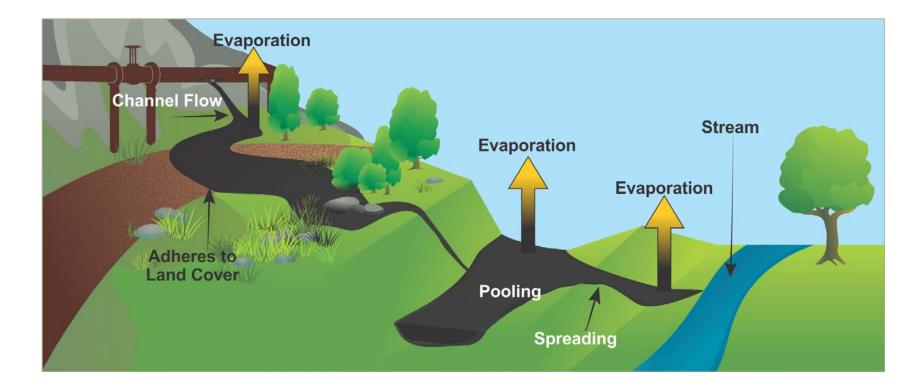
# Liquid Plume Modeling

- OILMAP Land<sup>TM</sup> ArcGIS Extension
- Total liquid pool volume simulated at interval along pipeline
- Determines trajectory of spill over land, in streams, and spreading over lake surface



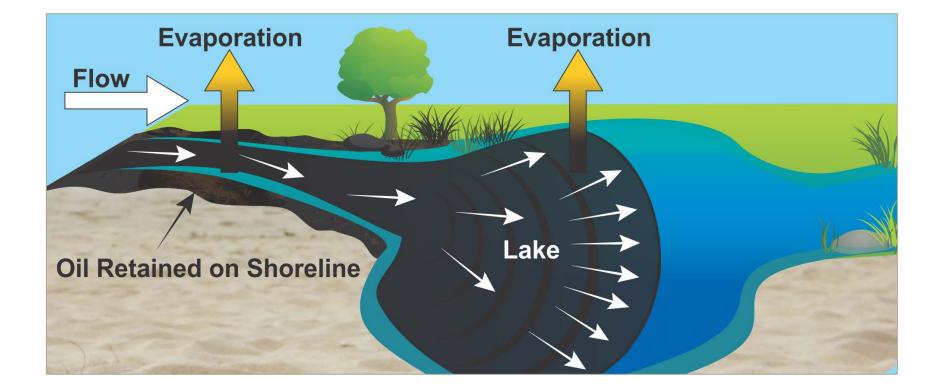


# **Overland Transport Model**



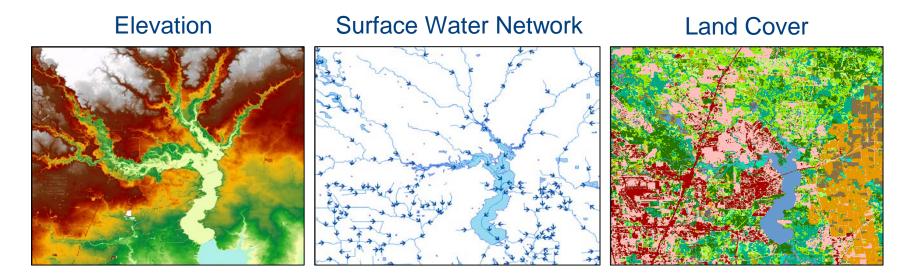


# Surface Water Transport Model





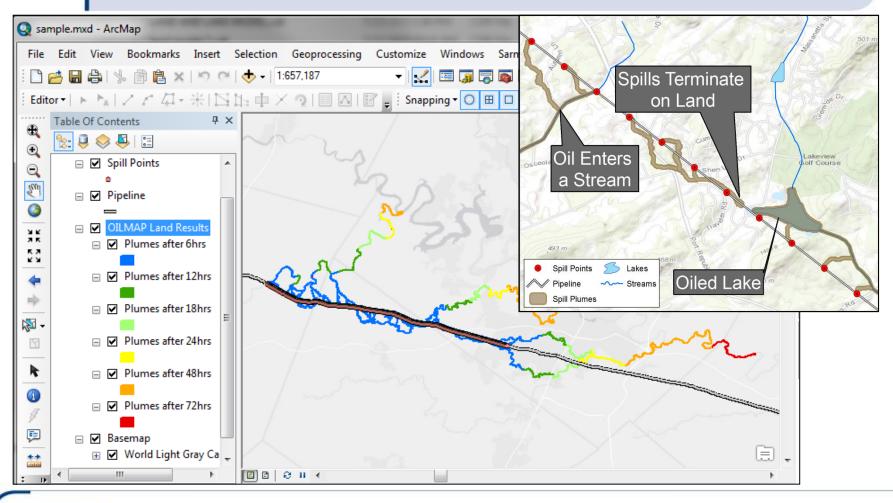
# Liquid Plume Model Inputs



Environmental Data – air temperature, wind speed
Oil Characteristics – physical, chemical properties



# Liquid Plume Model Outputs





# Modeling of Releases of HVLs

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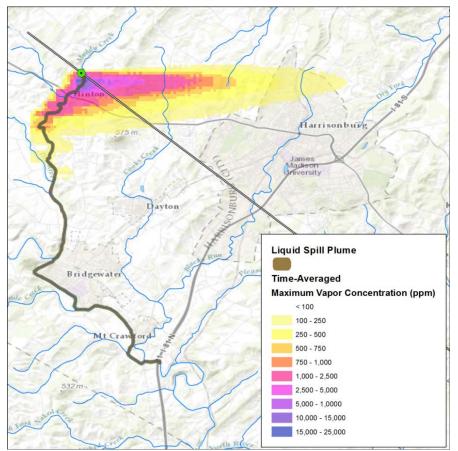
# **Evaporation from Liquid Plumes**

- Repeat the atmospheric dispersion modeling based on an evaporating pool
- Updated inputs:
  - Volume of pooled liquid
  - Surface area of the liquid pool (from liquid pool modeling)
  - Seasonal variability (temperature and wind)
  - Duration of the liquid pool



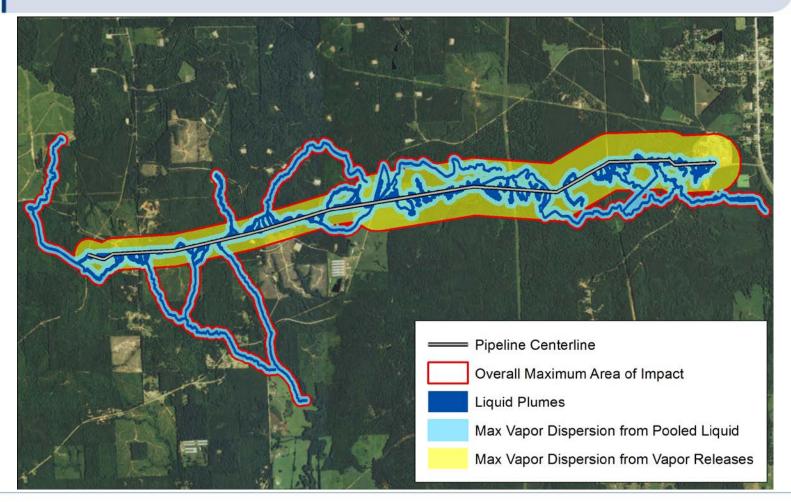
# **Evaporation from Liquid Plumes**

- Rate of vaporization much lower then initial vapor release.
- Vapor concentrations drop below thresholds after a short distance and might not ever exceed thresholds





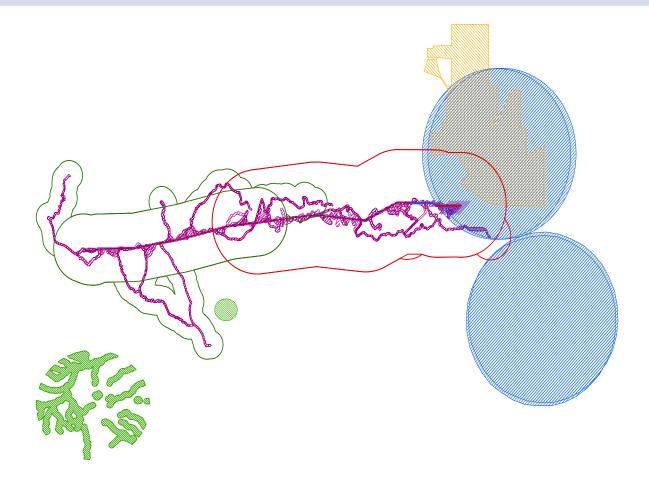
# **Overall Results**



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# From Modeling Results to HCA Segments





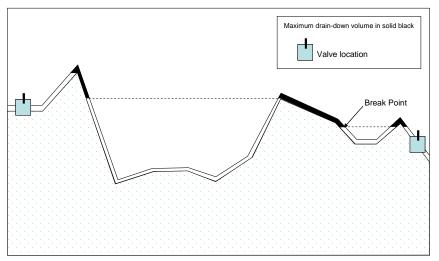
# From HCA Segments to the EFRD Study

What is an EFRD?

- Remote Operated Valve (ROV) or a Check Valve
- Protect high consequence areas (HCAs)

Why is an EFRD so important to a pipeline?

- Topography or elevation profile
- Swiftness of shutdown
- Reduce drain down volumes





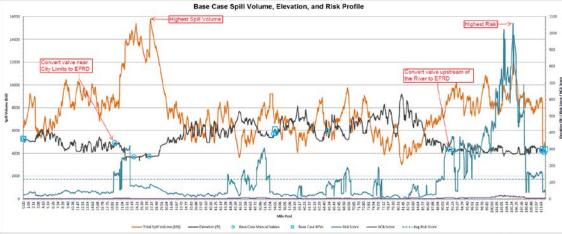
# From HCA Segments to the EFRD Study

**Risk Rankin** 

	Station	MP	Vol_bbl	Elev_ft	GPS Coordinate		Total Rating	Risk Ranking		
- 5	10+39	0.20	6795.632	360.77	39.070801*, -94.590733*	H	26.57	1		
- 1	12+48	0.24	6926.158	345.63	39.070801*, -94.590733*		27.49			Total Rating
- 1	12+72	0.24	6967.564	340.27	39.070801*, -94.590733*	t	27.78	1		963 <
	14+57	0.28	6825.928	360.48	39.070801*, -94.590733*		26.79			> 856, ≤ 963
	16+66	0.32	6688.729	361.12	39.070801*, -94.590733*		518,70	5		> 749, ≤ 856
	18+72	0.35	6570,968	361.53	39.070801", -94.590733"		526.59	5		> 642. ≤ 749
- 12	20+78	0.39	6494.353	361.63			549.51	6		> 535, ≤ 642
	22+84	0.43	6518.386	361.58			563.98	6		>428, ≤ 535
	24+90	0.47	6582.299	361.27	39.070801*, -94.590733*		686.93	7		> 321, ≤ 428
	26+96	0.51	6674.512	360.59	39.070801*, -94.590733*		687.77	7		> 214, ≤ 321
	29+02	0.55	6742.685	360.35	39.070801*, -94.590733*		681.54	7		>107, ≤214
	31+08	0.59	6820.601	359.97	39.070801*, -94.590733*		786.15	8		≤ 107
	33+14	0.63	6887.971	359,44	39.070801", -94.590733"		768.32	8		
	35+20	0.67	6998.023	358.95	39.070801*, -94.590733*		763.79	8		
	37+25	0.71	7063.636	358.41	39.070801*, -94.590733*		598.40	6		
	39+31	0.74	7139.527	357.75	39.070801*, -94.590733*		589.02	6		
	41+37	0.78	7211.506	357.21	39.070801", -94.590733"		593.95	6		
	43+43	0.82	7275.885	356.81	39.070801", -94.590733"		733.44	7		
	45+49	0.86	7376.166	356.5	39.070801°, -94.590733°		745.83	7		
Г	47+55	0.90	7451.797	356.25	39.070801°, -94.590733°		995.29	10		
	49+61	0.94	7511.168	355.97	39.070801°, -94.590733°		1000.21			
	51+67	0.98	7614.237	355.46	39.070801*, -94.590733*		1024.79			
	53+73	1.02	7689.423	354.28	39.070801*, -94.590733*		1008.40			
- E	54+59	1.03	7726.903	351.99	39.070801*, -94.590733*		753.32	8		
	55+79	1.06	7776.911	351.91	39.070801", -94.590733"		735.92	7		
	57+84	1.10	7863.192	351.61	39.070801", -94.590733"		716.12	7		
	59+90	1.13	7930.158	351.46	39.070801°, -94.590733°		962.73	9		
- E	61+96	1.17	8053.932	351.08	39.070801°, -94.590733°		96			
- L	64+02	1.21	8190.838	350.78	39.070801°, -94.590733°		94			
- E	66+08	1.25	8287.313	350.16	39.070801*, -94.590733*		74 160	.00		
	68+14	1.29	8381.677	348.64	39.070801*, -94.590733*		73			
	70+20	1.33	8570.929	347.3	39.070801*, -94.590733*		72			
	72+26	1.37	9076.134	346.36	39.070801", -94.590733"		71 140	200		
	74+32	1.41	9248.748	346.21	39.070801°, -94.590733°		32			
	76+38	1.45	9200.616	346.33	39.070801°, -94.590733°		32	1		
	78+43	1.49	9118.675	346.38	39.070801°, -94.590733°		31 120			rt valve near
_ L	80+49	1.52	8996.472	346.48	39.070801*, -94.590733*		3	1 1	City Li	mits to EFRI
	82+55	1.56	8897.358	346.72	39.070801*, -94.590733*		3			
_	84+61	1.60	8811.285	346.85	39.070801*, -94.590733*		3 10	100		AN
_	86+67	1.64	8743.88	346.8	39.070801*, -94.590733*		3	1		11/10
_	88+73	1.68	8763.727	346.84	39.070801", -94.590733"		3 2	M		1111
- 1-	90+79	1.72	8644.187	346.9	39.070801°, -94.590733°		w w 4 4	00 1	_	14
-	92+85	1.76	8573.073	347.17	39.070801°, -94.590733°		4 3			N
-	94+73	1.79	8477.847	346.83	39.070801°, -94.590733°				14	
- 1-	94+91	1.80	8450.478	346.83	39.070801°, -94.590733°	H	4 6	100	JVY	
	96+97	1.84	8275.766	348.17	39.070801*, -94.590733*		4 00		MM.	
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#### Factors Considered:

- Swiftness of leak detection and pipeline shutdown capabilities
- Type of commodity carried
- Rate of potential leakage
- Volume that can be released
- Topography or pipeline profile
- Location of nearest response personnel
- Benefits expected by reducing the spill size





# Summary

- Releases from HVL pipelines can result in dangerous vapor clouds and possibly liquid spill plumes.
- Identifying HCA "could affect" segments may require both atmospheric dispersion modeling and liquid plume modeling.
- Risk from HVL releases can be reduced through strategic placement of EFRDs



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