Using GIS to Optimize Gathering Line Operations and Maintenance – A Risk Based Approach

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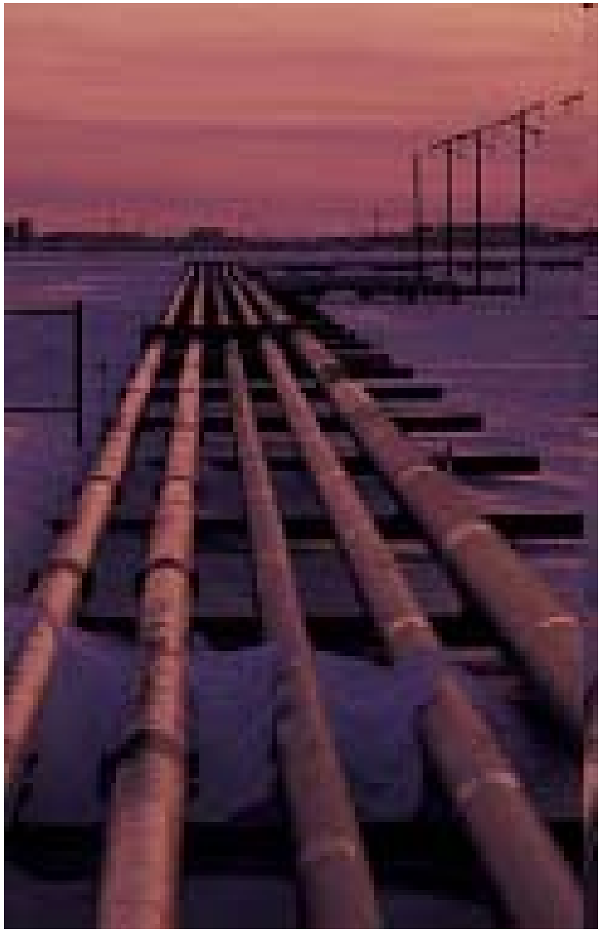
Terms

- GIS
- Gathering Lines
- O&M
- Optimize
- Risk Based



Gathering PL: One of Several Types of PL

… sometimes with unique designs

… and special requirements

… in interesting areas

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… and in challenging areas

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Definitions (for presentation)

- GIS = computer tools to use and manage data
- Gathering Line = a type of PL
- O&M = activities of running a PL
- Optimize = to make better
- Risk Based
  - Risk = PoF x CoF
  - Risk-based = using an understanding of risk

Key Message

Understanding Risk = Better Decision-Making

Unprecedented Opportunities to Understand Risk

Data Drives the Process

"If you don't have a number, you don't have a fact; you have an opinion"

IM Rule Data (Liquids)

- HCA info
- Results from previous testing inspection
- Leak history
- Corrosion or condition data
- CP history
- Soil corrosivity
- Type and quality of coating
- Age of pipe
- Product characteristics
- Pipe wall
- Pipe diameter
- Subsidence
- All ground movement potential
- Security of thru-put
- Time since last inspection
- Defect growth rates
- Stress levels
- Leak detection
- Physical support

IM Rule Data (Gas) Data Elements for Prescriptive IMP

Attribute Data

- Pipe wall
- Pipe OD
- Seam type
- Manufacturer
- Date of manufacture
- Material properties
- Equipment properties

Inspection

- Pressure tests
- In-line inspections
- Geometry inspections
- Bell hole inspections
- CP & close-interval surveys
- Coating condition and DCVG
- surveys
- Audits & reviews

ASME B31.8S Section 4

IM Rule Data (Gas) Data Elements for Prescriptive IMP, Cont'd

Construction

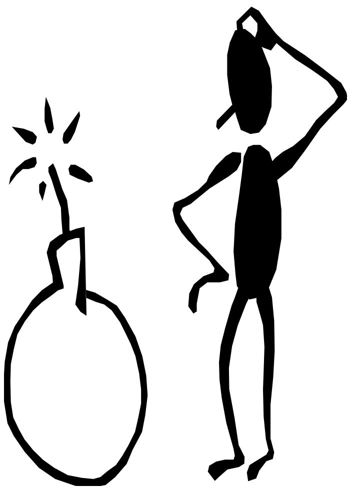
- Year installed
- Bending method
- Joining method and
- inspection
- Depth of cover
- Crossings, casings
- Pressure test
- Coating type
- Field coating method
- Soil and backfill
- Cathodic protection
- Inspection reports

Gas IM Rule
Data Elements for Prescriptive IMP

Considerations:

- Data must support risk assessment
- Data age and accuracy
- Missing data is not justification to exclude a threat from the IMP
- Common reference system needed – GIS and geospatial referencing a practical necessity for all but simplest systems
- Appendix A gives additional data needs on a threat specific basis

Dealing with Uncertainty



Error 1: Call it 'good' when its really 'bad'

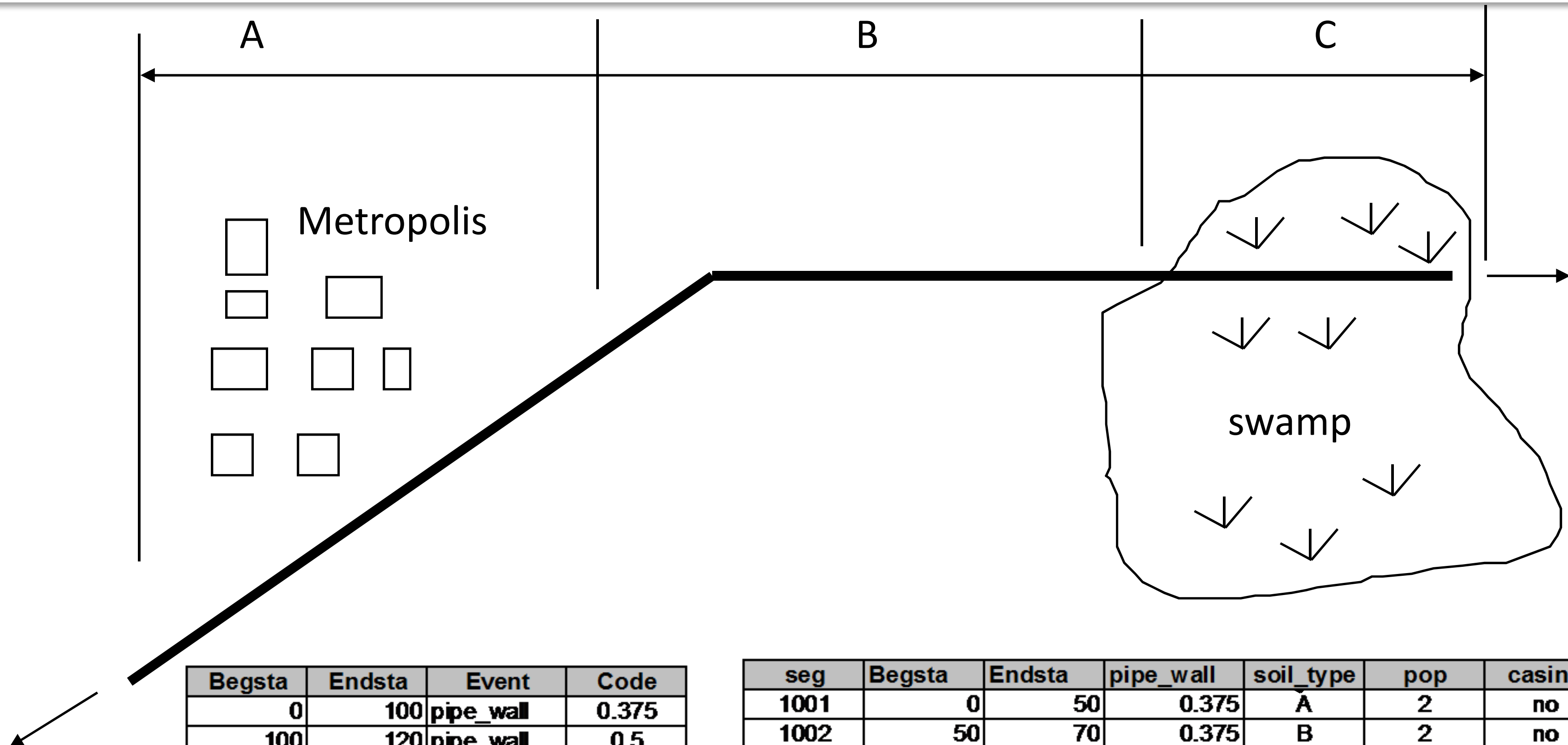
Error 2: Call it 'bad' when its really 'good'

Use of Data

- Not everything that matters can be counted;
- Not everything that can be counted matters

-Albert Einstein

Data Collection; Maintenance; Sectioning

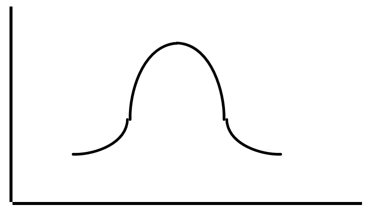


Begsta	Endsta	Event	Code
0	100	pipe_wall	0.375
100	120	pipe_wall	0.5
0	50	soil_type	A
50	120	soil_type	B
0	70	pop	2
70	110	pop	1
110	120	pop	2
75	85	casing	yes

seg	Begsta	Endsta	pipe_wall	soil_type	pop	casing
1001	0	50	0.375	A	2	no
1002	50	70	0.375	B	2	no
1003	70	75	0.375	B	1	no
1004	75	85	0.375	B	1	yes
1005	85	100	0.375	B	1	no
1006	100	110	0.5	B	1	no
1007	110	120	0.5	B	2	no

Risk Analysis: Turning Data into Information

- Risk = Probability x Consequences



- Probability = Degree of Belief
- Risk Mitigation via Integrity Mgmt in HCA

Threat Categories

- ASME B31.8 Supplement considers 3 categories of threat:
  - *Time Dependent* – May worsen over time; require periodic reassessment
  - *Time Stable* – Does not worsen over time; one-time assessment is sufficient (unless conditions of operation change)
  - *Time Independent* – Occurs randomly; best addressed by prevention

Time Dependent Threats

- External corrosion
- Internal corrosion
- Stress-corrosion cracking (SCC)
- Fatigue

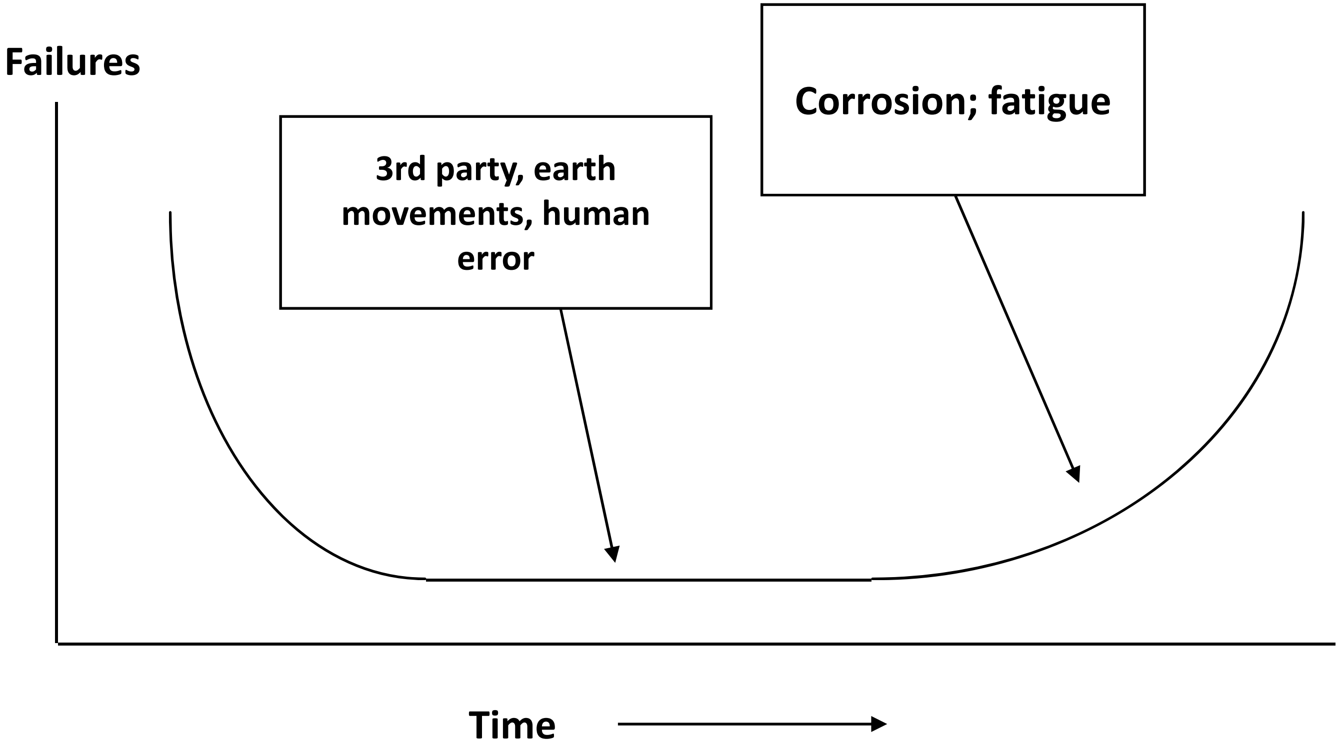
Time Stable Threats (resistance)

- Manufacturing-related flaws in
  - Pipe body
  - Pipe seam
- Welding / Fabrication-caused flaws in
  - Girth welds
  - Fabrication welds
  - Wrinkled / buckled bend
  - Threads / couplings
- Defects present in equipment
  - Gaskets, O-rings
  - Control / relief devices
  - Seals, packing
  - Other equipment

Time Independent (Random) Threats

- Third-party/Mechanical damage
  - Immediate failure
  - Delayed failure (previously damaged)
  - Vandalism
- Incorrect operations
- Weather related
  - Cold weather
  - Lightning
  - Heavy rain, flood
  - Earth movement

Failure Mechanisms



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Hawthorne Effect

"Anything that is studied, improves."

Better Estimates: Absolute Risk Values

Frequency of consequence

- Temporally
- Spatially
  - •Incidents per mile-year
  - •fatalities per mile-year
  - •dollars per km-decade

conseq prob

Better Modeling: PoF Triad

- Exposure: frequency or intensity of failure mechanism(s) reaching the pipe when no mitigation applied
- Mitigation measure: reduces frequency or intensity of the exposure reaching the pipe; keeps mechanism off the pipe
- Resistance: ability to resist failure given presence of exposure/threat

attack > defense > survival

Potential for Damage vs Failure

- Probability of Damage (PoD) = *f* (exposure, mitigation)
- Probability of Failure (PoF) = *f* (PoD, resistance)

Exposure

PoD

Mitigation

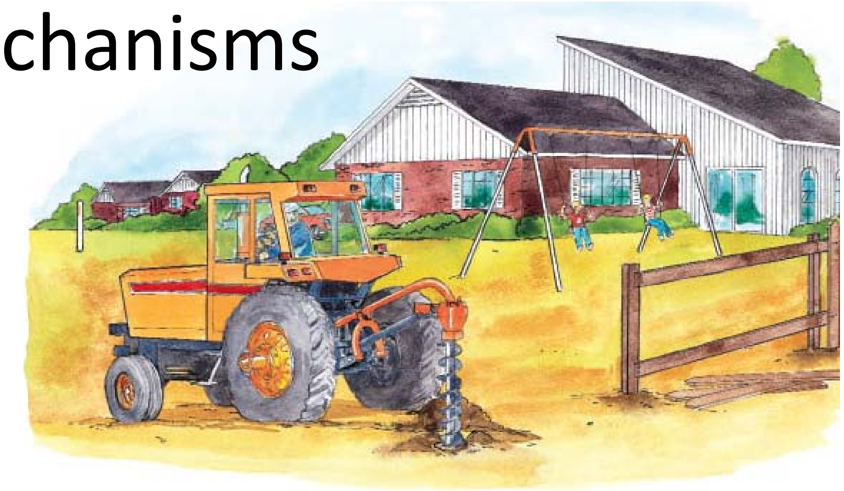
PoF

Resistance

Estimating Threat Exposure

- Events per mile-year for time independent / random mechanism
  - third party
  - incorrect operations
  - weather & land movements

- MPY for degradation mechanisms
  - ext corr
  - int corr
  - SCC / fatigue



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Rates: Failures, Exposures, Events, etc

Failures/yr	Years to Fail	Approximate Rule Thumb
1,000,000	0.000001	Continuous failures
100,000	0.00001	fails ~10 times per hour
10,000	0.0001	fails ~1 times per hour
1,000	0.001	fails ~3 times per day
100	0.01	fails ~2 times per week
10	0.1	fails ~1 times per month
1	1	fails ~1 times per year
0.1	10	fails ~1 per 10 years
0.01	100	fails ~1 per 100 years
0.001	1,000	fails ~1 per 1000 years
0.0001	10,000	fails ~1 per 10,000 years
0.00001	100,000	fails ~1 per 100,000 years
0.000001	1,000,000	One in a million chance of failure
0.0000000001	1,000,000,000	Effectively, it never fails

Time Dependent Mechanisms

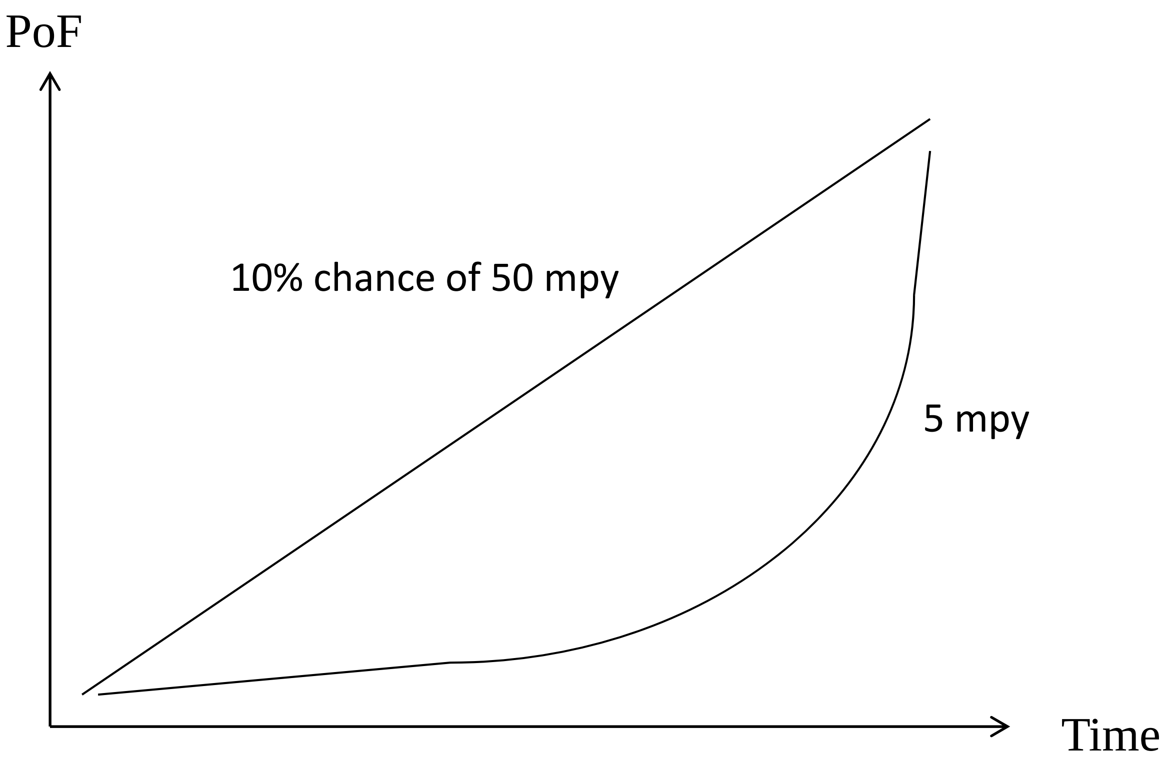
$PoF_{\text{time-dep}} = f\,(TTF)$

where

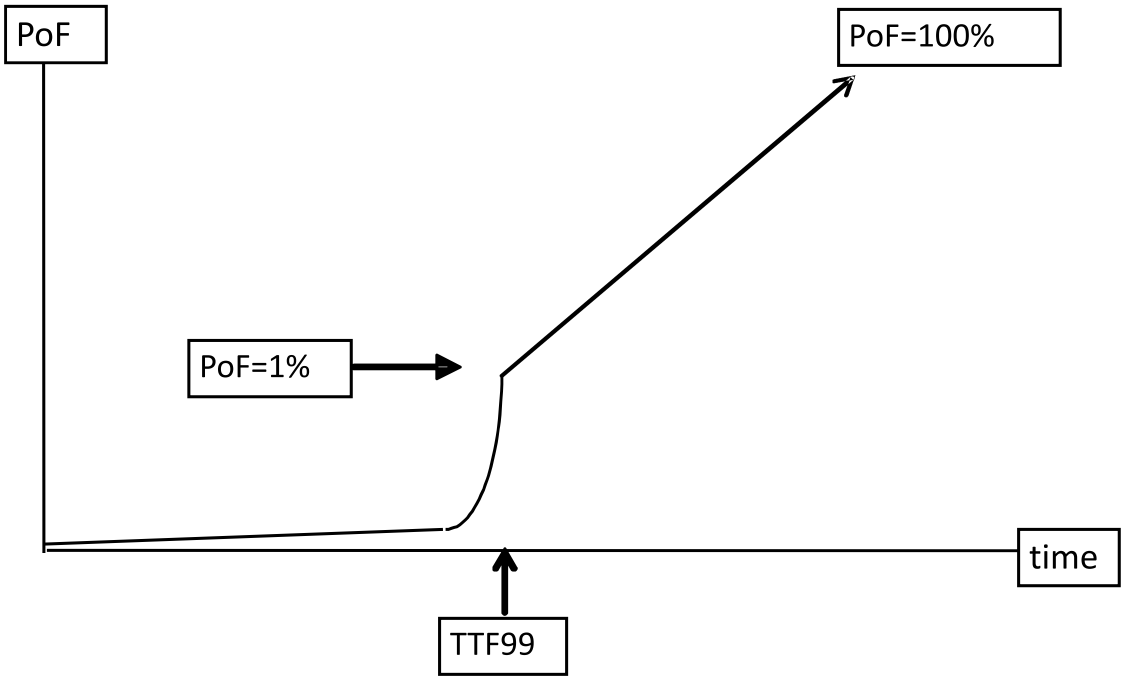
TTF = "time to failure"

TTF = (available pipe wall) / [(unmitigated mpy) x (1 – mitigation effectiveness)]

TTF to PoF



PoF: TTF & TTF99



Measuring Mitigation

Strong, single measure or Accumulation of lesser measures

Mitigation % = 1-[(1-mit1) x (1-mit2) x (1-mit3)…]

In words:

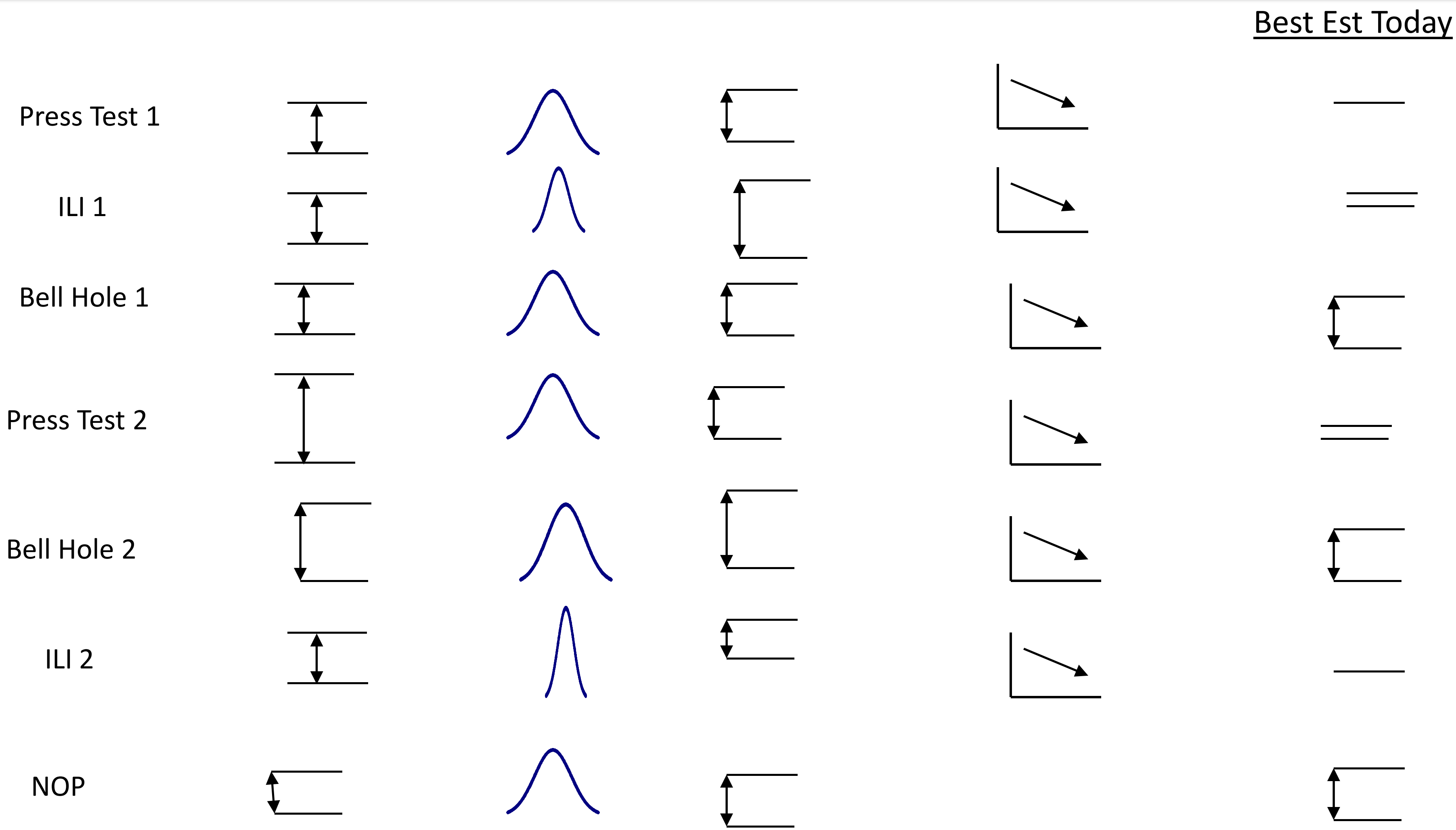
mitigation % = 1 - (remaining threat)

remaining threat = (remnant from mit1) AND (remnant from mit2) AND (remnant from mit3) …

What is cumulative mitigation benefit from 3 measures that independently produce effectiveness of 60%, 60%, and 50%?
92%

Exposure	Mitigation	Reduction	freq damage	prob damage
events/mi-yr			events/mi-yr	Prob/mi-yr
10	90.0%	10	1	63.2%
10	99.0%	100	0.1	9.52%
10	99.9%	1000	0.01	1.00%

Best Estimate of Pipe Wall Today



Final PoF

$$PoF_{overall} = PoF_{thdpty} \text{ OR } PoF_{corr\ ext} \text{ OR } PoF_{corr\ int} \text{ OR } PoF_{incops} \text{ OR } PoF_{geohazard}$$

$$PoS = 1 - PoF$$

$$PoF_{overall} = 1-[(1-PoF_{thdpty}) \times (1-PoF_{corr\ ext}) \times (1-PoF_{corr\ int}) \times (1-PoF_{incops}) \times (1-PoF_{geohazard})]$$

Understanding Consequence of Failure

- Risk = (PoF)·(Consequence)
- Consequence of Failure
  - Leak vs rupture
  - Estimate of hazard area
  - Estimate of damages (property, people, etc)

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Initiating Event

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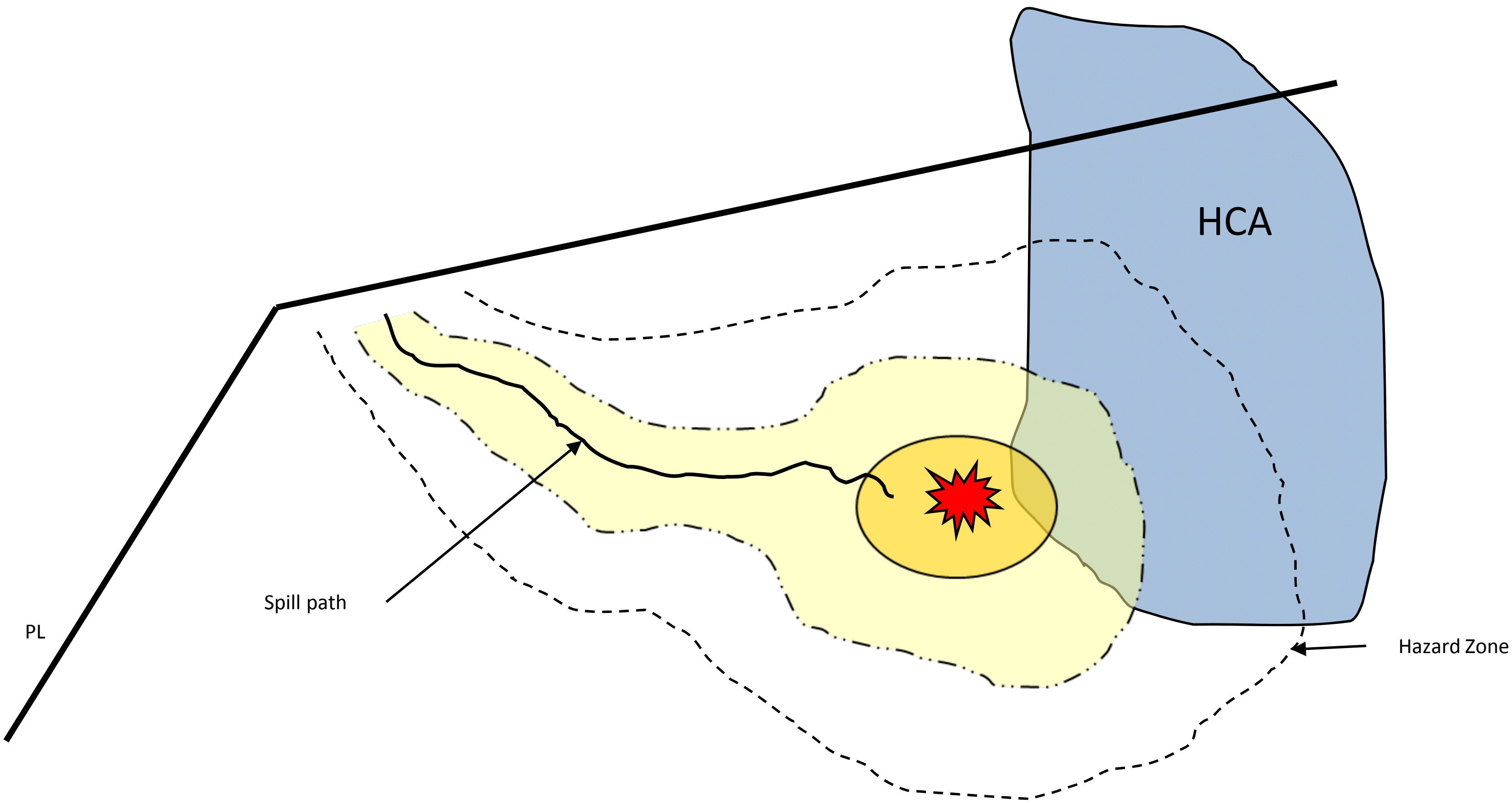
Hazard Zones



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PIR Calculations

TTO13 & TTO14

Table 7.1 Summary of Potential Impact Radius Formula

Product	PIR Formula
Ethylene	$r = 1.04 \cdot \sqrt{p \cdot d^2}$
Hydrogen	$r = 0.47 \cdot \sqrt{p \cdot d^2}$
Natural Gas (Lean)	$r = 0.69 \cdot \sqrt{p \cdot d^2}$
Natural Gas (Rich)	$r = 0.73 \cdot \sqrt{p \cdot d^2}$
Syngas	$r = 0.49 \cdot \sqrt{p \cdot d^2}$ Note 1

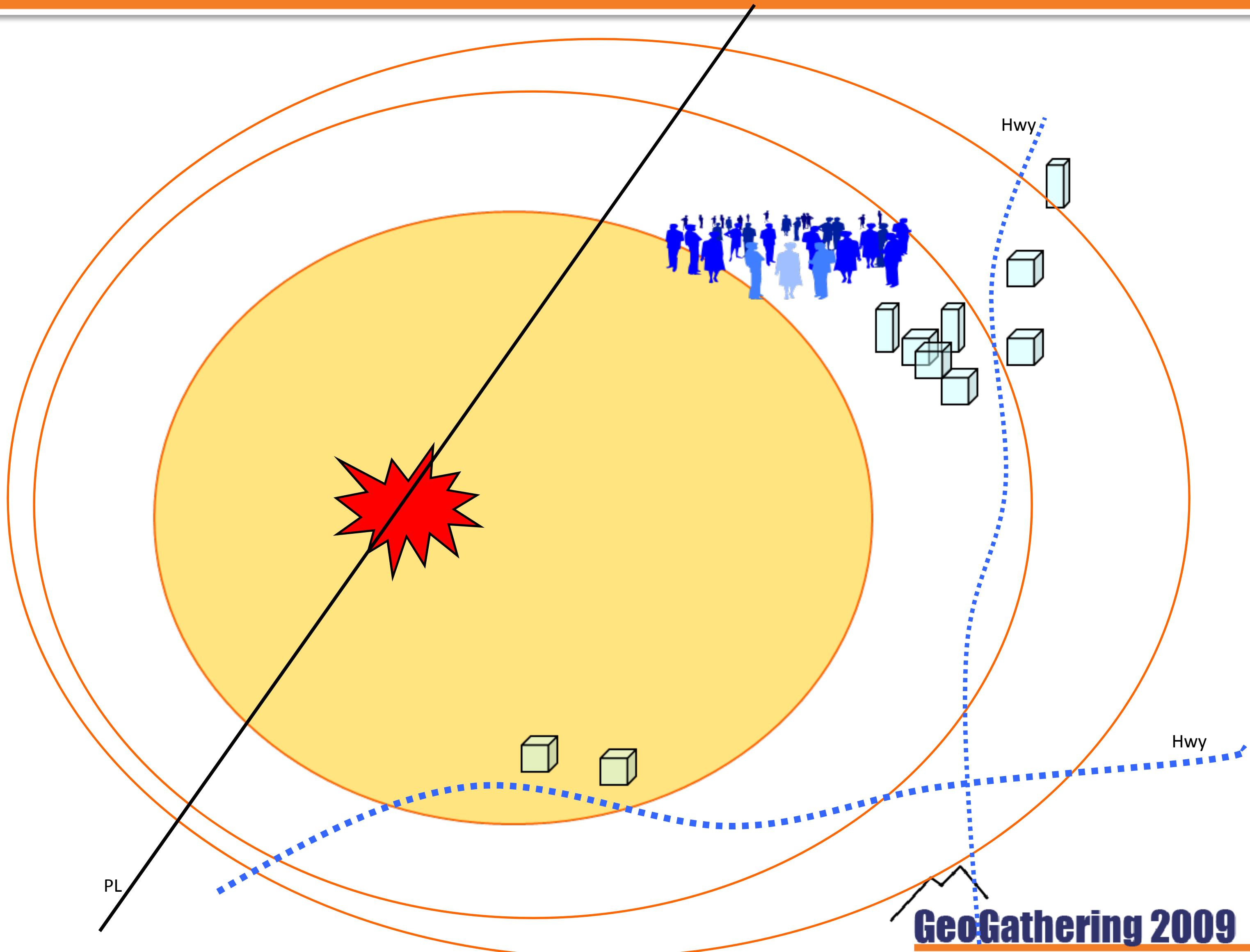
Note 1 See discussion in Section 4.8.5

Table 8.1 Summary of PIR Formulae

Product		PIR Formula
Acetylene	1 psi Overpressure	$r = 0.021 \cdot (d^2 \cdot p)^{1/3}$
Anhydrous Ammonia (Liquefied under pressure)	1 psi Overpressure	$r = 0.014 \cdot (d^2 \cdot p)^{1/3}$
	Rural Conditions	$r = 0.08 \cdot (d^2 \cdot p)^{0.48}$
	Urban Conditions	$r = 0.07 \cdot (d^2 \cdot p)^{0.45}$
Carbon Monoxide	1 psi Overpressure	$r = 0.012 \cdot (d^2 \cdot p)^{1/3}$
	Rural Conditions	$r = 0.04 \cdot (d^2 \cdot p)^{0.5}$
	Urban Conditions	$r = 0.03 \cdot (d^2 \cdot p)^{0.45}$
Chlorine	Rural Conditions	$r = 0.38 \cdot (d^2 \cdot p)^{0.49}$
	Urban Conditions	$r = 0.16 \cdot (d^2 \cdot p)^{0.5}$
Ethylene	1 psi Overpressure	$r = 0.021 \cdot (d^2 \cdot p)^{1/3}$
Hydrogen Sulfide	1 psi Overpressure	$r = 0.015 \cdot (d^2 \cdot p)^{1/3}$
	Rural Conditions	$r = 0.37 \cdot (d^2 \cdot p)^{0.45}$
	Urban Conditions	$r = 0.27 \cdot (d^2 \cdot p)^{0.46}$
Methane	1 psi Overpressure	$r = 0.019 \cdot (d^2 \cdot p)^{1/3}$
Rich Gas	1 psi Overpressure	$r = 0.020 \cdot (d^2 \cdot p)^{1/3}$

Receptor Characterization

- fatalities
- injuries
- occupancy
- shielding
- escape
- prop damage
- waterways
- ground water
- wetlands
- T&E wildlife
- preserves
- historical sites



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Monetized Risk: Expected Loss

Surrogate for ‘risk’ and ‘financial exposure’

- Benefits
  - Common denominator allows unlimited comparisons
  - Defines the magnitude of the problem
  - Implies appropriate reaction
- Difficulties
  - Some consequences difficult to monetize
  - Annual (averages) vs Extremes

Damage State Estimates

- Create Zones Based on Threshold Distances
- Estimate Damage States (or PoD) for Each Zone

Hazard Zone	injury rate	fatality rate	environ damage rate	service interruption rate
<100'	80%	8%	50%	100%
100'-50% PIR	50%	5%	30%	90%
50% -100% PIR	20%	2%	10%	80%

Sample EL Calculations

						unit cost	*unit cost*		*unit cost*	
						$100,000	*$3,500,000*		*$ 50,000*	**Expected Loss**
Hole Size	**Ignition Scenario**	**Maximum Distance (ft)**	**Probability of Maximum Distance**	**Hazard Zone Group**	**# people**	**Human injury costs**	**Human fatality costs**	**# environ units**	**Environ Damage Costs**	**Probability weighted dollars per failure**
rupture	immediate	400	4.8%	100'-50% PIR	5	$ 3,600	$ 12,600	1	$ 720	$ 16,920
	delayed	1500	1.6%	50% -100% PIR	10	$ 960	$ 3,360	1	$ 80	$ 4,400
	no ignition	300	1.6%	100'-50% PIR	5	$ 1,200	$ 4,200	1	$ 240	$ 5,640
medium	immediate	300	1.8%	100'-50% PIR	5	$ 1,350	$ 4,725	1	$ 270	$ 6,345
	delayed	600	1.8%	100'-50% PIR	5	$ 1,350	$ 4,725	1	$ 270	$ 6,345
	no ignition	100	8.4%	100'-50% PIR	5	$ 6,300	$ 22,050	1	$ 1,260	$ 29,610
small	immediate	50	8.0%	<100'	1	$ 1,920	$ 6,720	0.5	$ 1,000	$ 9,640
	delayed	80	8.0%	<100'	1	$ 1,920	$ 6,720	0.5	$ 1,000	$ 9,640
	no ignition	30	64.0%	<100'	1	$15,360	$ 53,760	0.5	$ 8,000	$ 77,120
			100.0%	Total expected loss per failure at this location						$165,660

Final EL Value

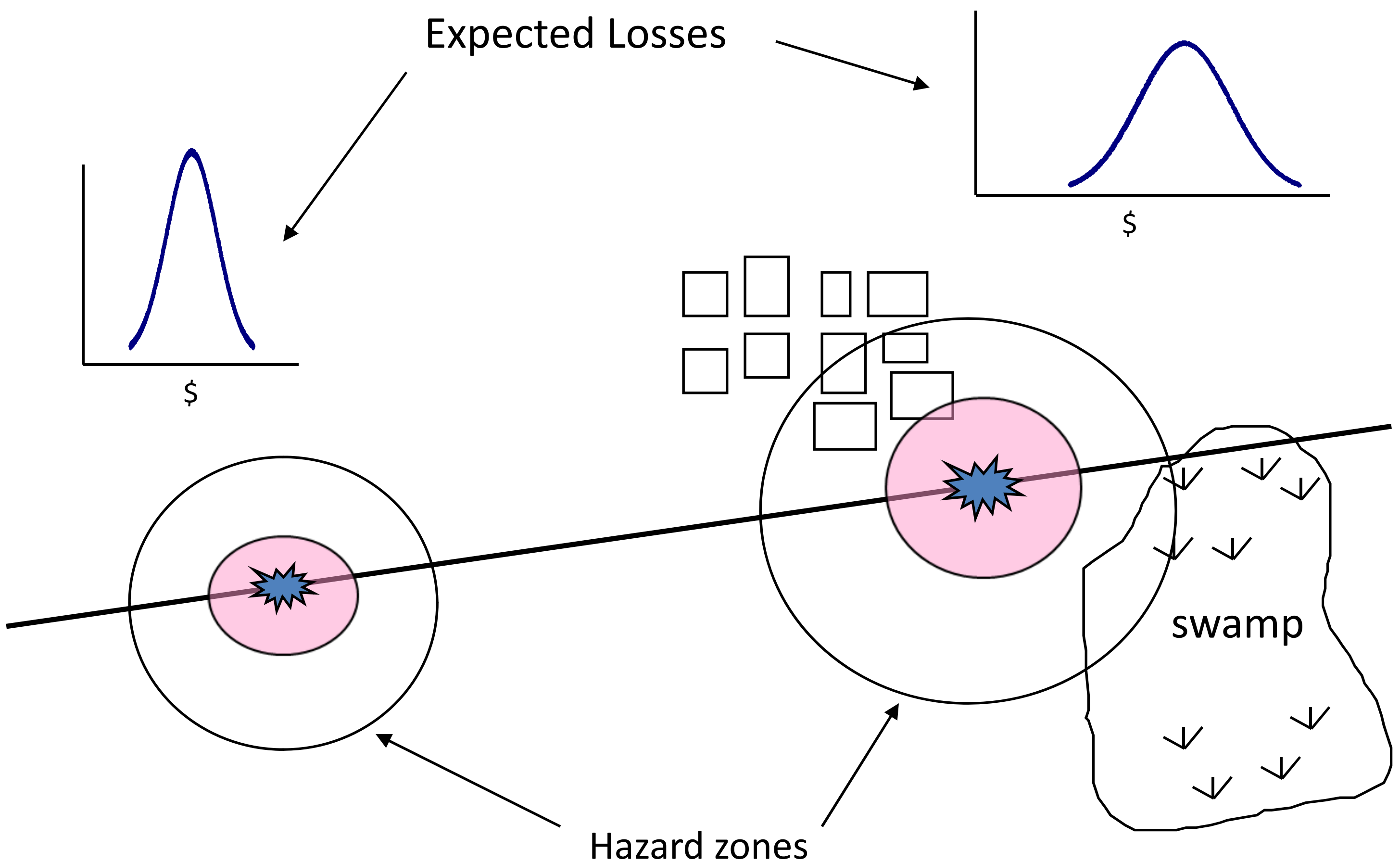
At a specific location along a pipeline:

Expected Loss			
Failure Rate (failures per mile-year)	Probability of Hazard Zone[1,2]	Probability weighted dollars[2,3]	Probability weighted dollars per mile-year
0.001	4.80%	$16,920	$0.81
	1.60%	$4,400	$0.07
	1.60%	$5,640	$0.09
	1.80%	$6,345	$0.11
	1.80%	$6,345	$0.11
	8.40%	$29,610	$2.49
	8.00%	$9,640	$0.77
	8.00%	$9,640	$0.77
	64.00%	$77,120	$49.36
	100.00%	**$165,660**	**$54.59**

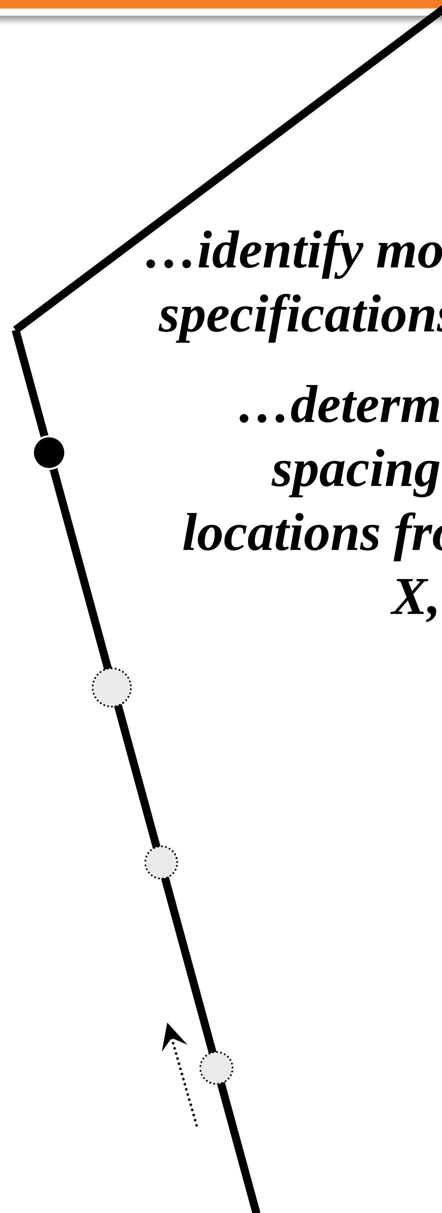
Table Notes

1. *after a failure has occurred*
2. *from Table 2 above, per event*
3. *(damage rate) x (value of receptors in hazard zone), per event*

Expected Losses Vary Along PL



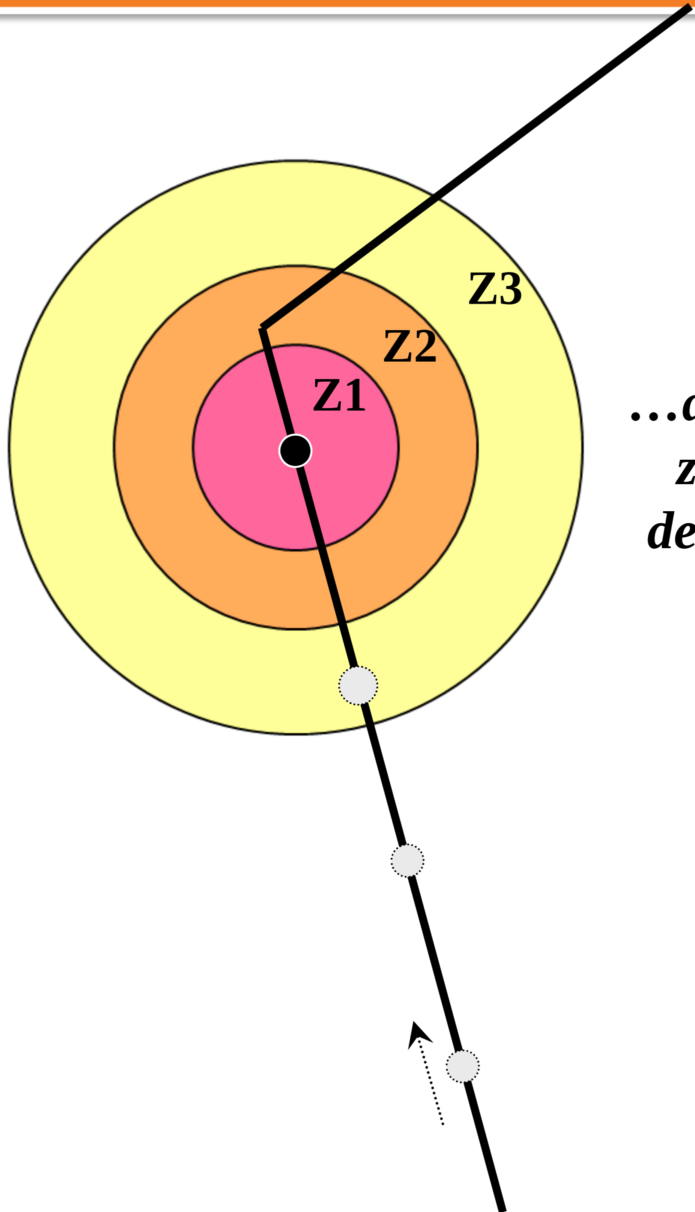
Step 1: Determine On-Line Sampling Interval



…identify model and pipeline specifications (e.g., product)

…determine the interval spacing or read point locations from a stored file of X,Y points

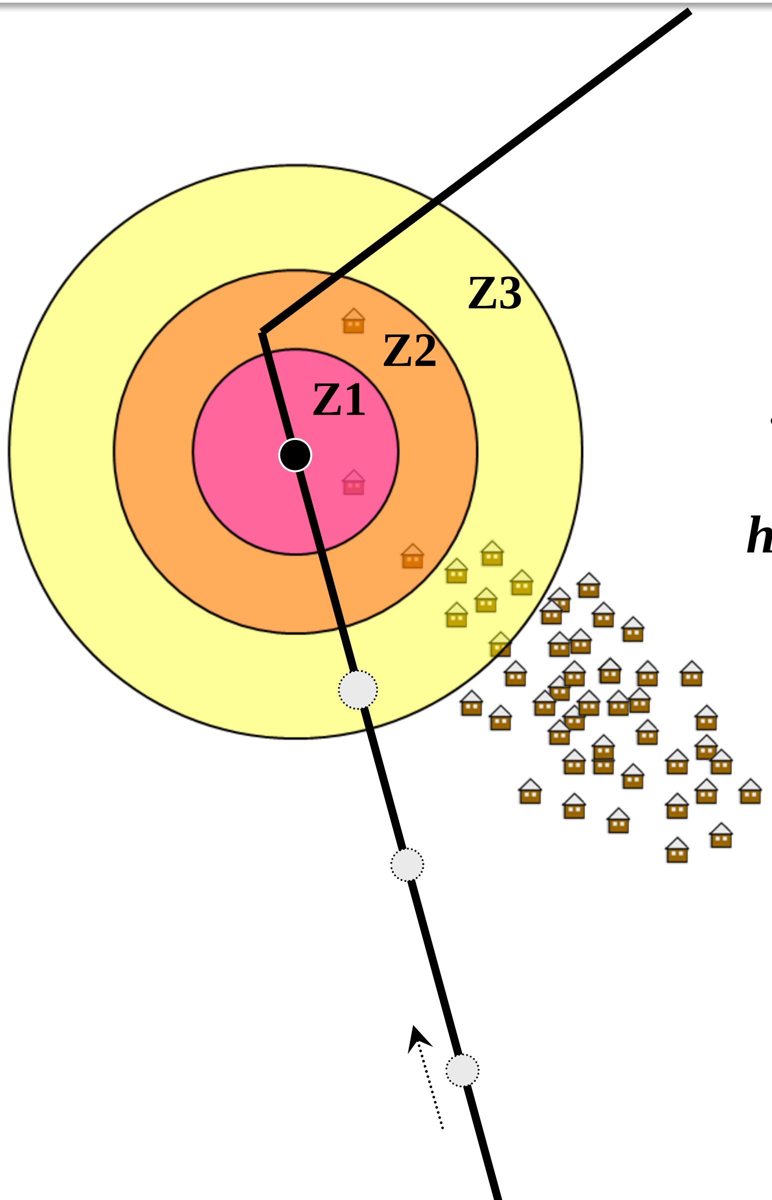
Step 2: Establish Hazard Zones



…determine the # of zones and reach defining each zone

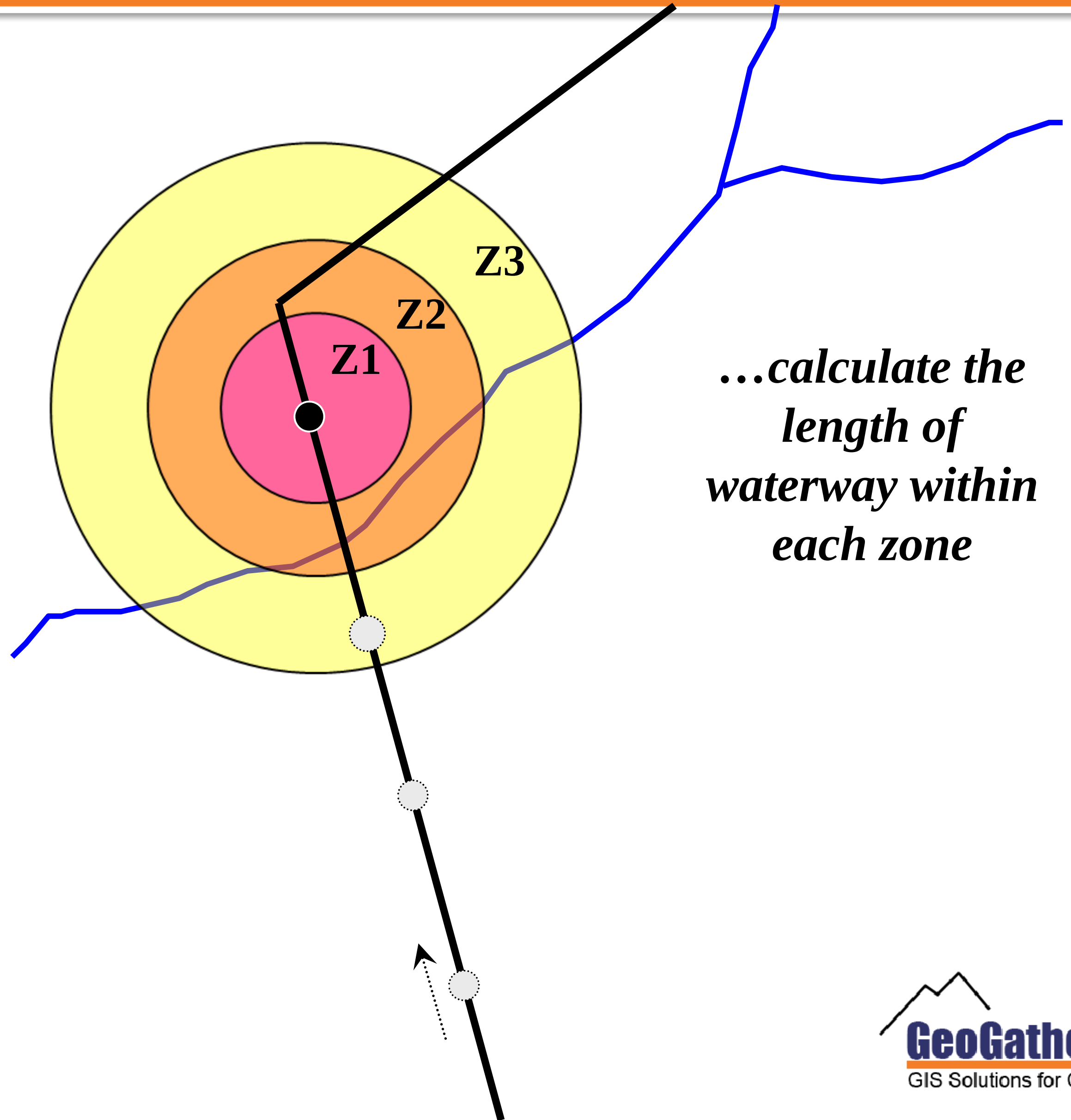
Step 3: Determine Number of Houses in Each Zone

(Point Features)



…count the number of houses within each zone

Step 4: Determine Length of Waterways in Each Zone *(Line Features)*



…calculate the length of waterway within each zone

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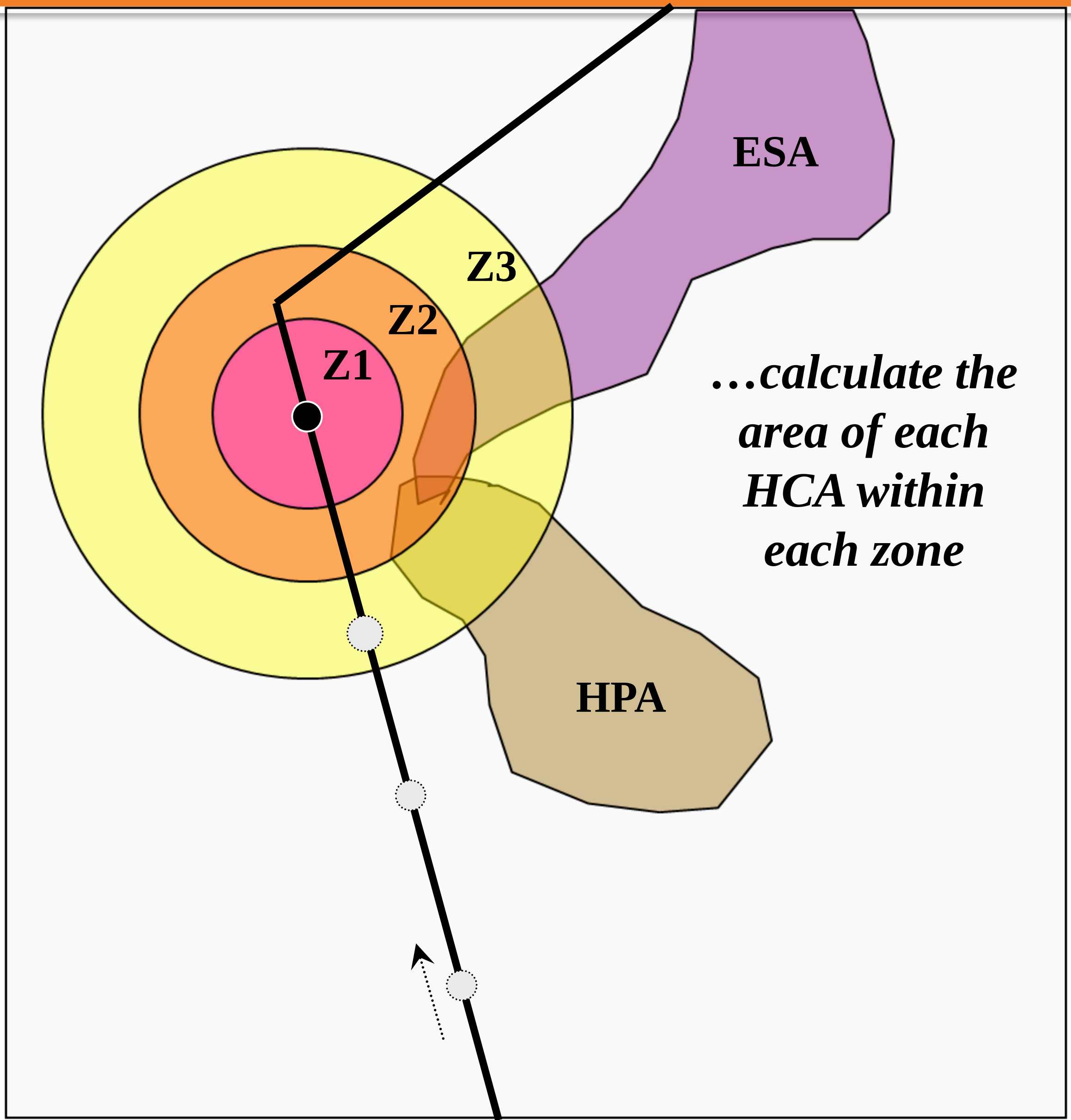
Step 5: **Determine Area of HCAs in Each Zone** ***(Polygon Features)***



…calculate the area of each HCA within each zone

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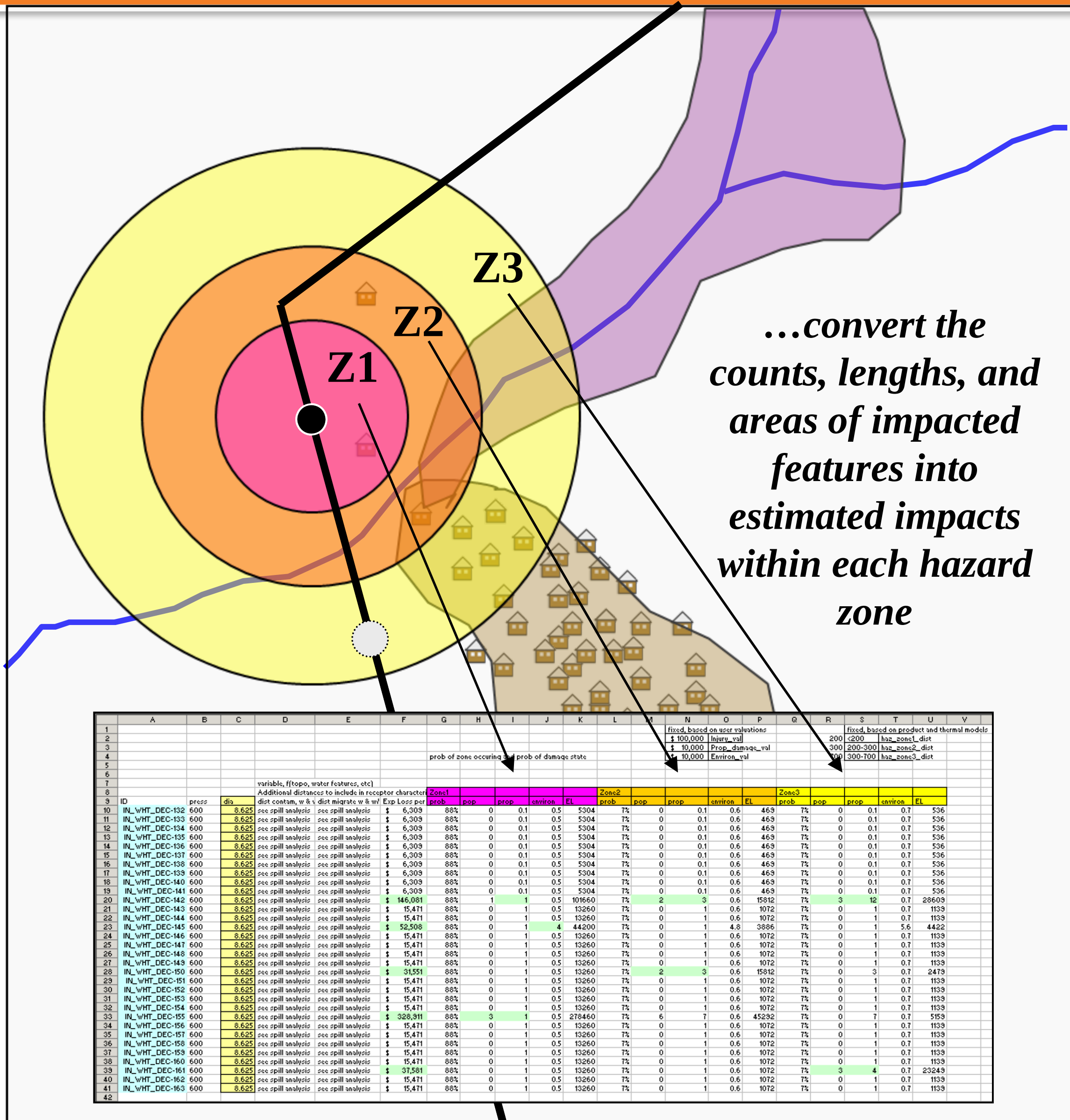
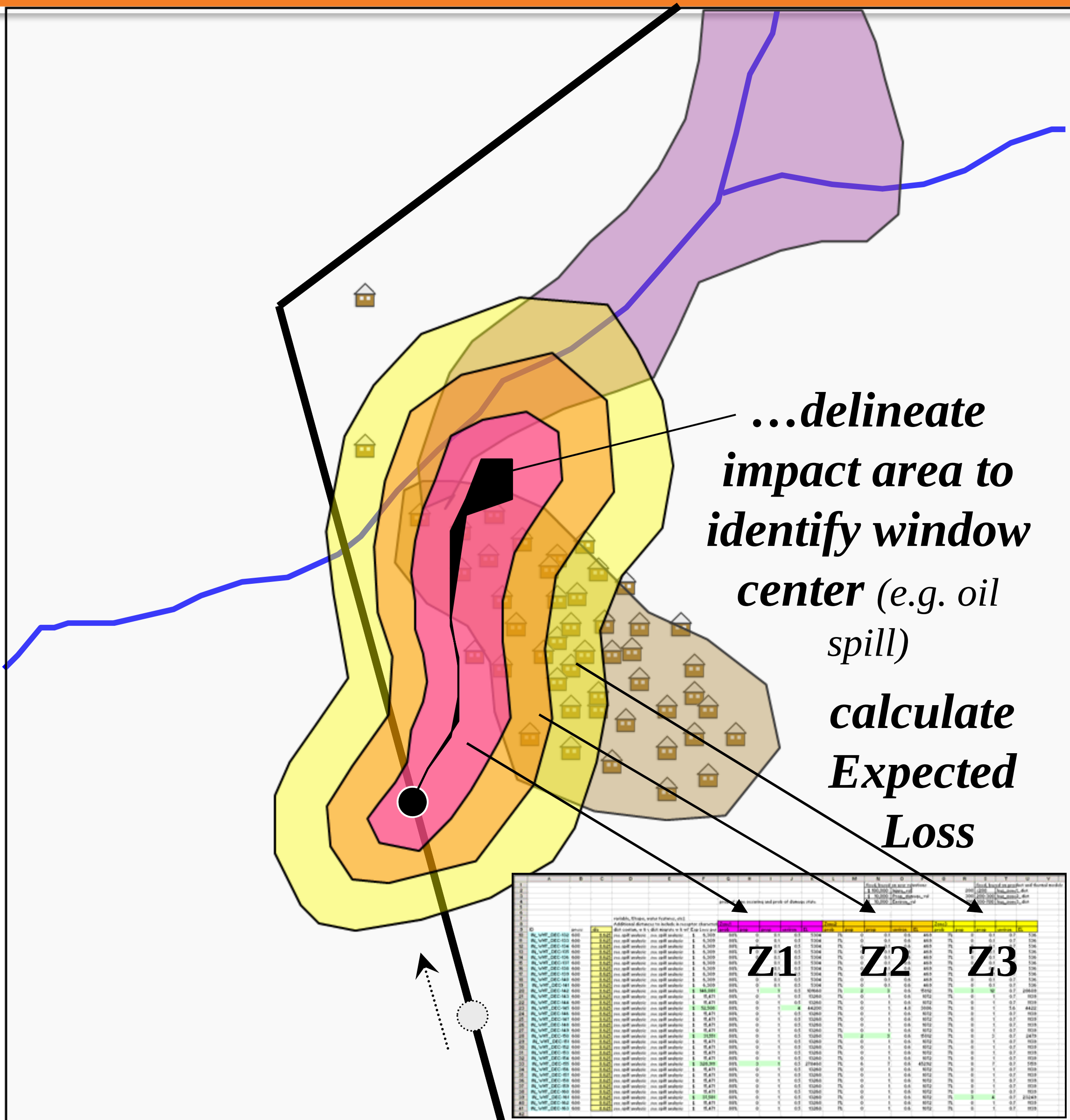
Summarize Impacted Receptors *(Data Table)*



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1														fixed, based on user valuations					fixed, based on product and thermal models		
2														$ 100,000	Injury_val			200	<200	haz_zone1_dist	
3														$ 10,000	Prop_damage_val			300	200-300	haz_zone2_dist	
4							prob of zone occuring and prob of damage state							$ 10,000	Environ_val			[illegible]00	300-700	haz_zone3_dist	
5																					
6																					
7				variable, f(topo, water features, etc)																	
8				Additional distances to include in receptor characteri			Zone1					Zone2					Zone3				
9	ID	press	dia	dist contam, w & v	dist migrate w & w/	Exp Loss per	prob	pop	prop	environ	EL	prob	pop	prop	environ	EL	prob	pop	prop	environ	EL
10	IN_WHT_DEC-132	600	8.625	see spill analysis	see spill analysis	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
11	IN_WHT_DEC-133	600	8.625	see spill analysis	see spill analysis	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
12	IN_WHT_DEC-134	600	8.625	see spill analysis	see spill analysis	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
13	IN_WHT_DEC-135	600	8.625	see spill analysis	see spill analysis	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
14	IN_WHT_DEC-136	600	8.625	see spill analysis	see spill analysis	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
15	IN_WHT_DEC-137	600	8.625	see spill analysis	see spill analysis	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
16	IN_WHT_DEC-138	600	8.625	see spill analysis	see spill analysis	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
17	IN_WHT_DEC-139	600	8.625	see spill analysis	see spill analysis	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
18	IN_WHT_DEC-140	600	8.625	see spill analysis	see spill analysis	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
19	IN_WHT_DEC-141	600	8.625	see spill analysis	see spill analysis	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
20	IN_WHT_DEC-142	600	8.625	see spill analysis	see spill analysis	$ 146,081	88%	1	1	0.5	101660	7%	2	3	0.6	15812	7%	3	12	0.7	28609
21	IN_WHT_DEC-143	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
22	IN_WHT_DEC-144	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
23	IN_WHT_DEC-145	600	8.625	see spill analysis	see spill analysis	$ 52,508	88%	0	1	4	44200	7%	0	1	4.8	3886	7%	0	1	5.6	4422
24	IN_WHT_DEC-146	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
25	IN_WHT_DEC-147	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
26	IN_WHT_DEC-148	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
27	IN_WHT_DEC-149	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
28	IN_WHT_DEC-150	600	8.625	see spill analysis	see spill analysis	$ 31,551	88%	0	1	0.5	13260	7%	2	3	0.6	15812	7%	0	3	0.7	2479
29	IN_WHT_DEC-151	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
30	IN_WHT_DEC-152	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
31	IN_WHT_DEC-153	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
32	IN_WHT_DEC-154	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
33	IN_WHT_DEC-155	600	8.625	see spill analysis	see spill analysis	$ 328,911	88%	3	1	0.5	278460	7%	6	7	0.6	45292	7%	0	7	0.7	5159
34	IN_WHT_DEC-156	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
35	IN_WHT_DEC-157	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
36	IN_WHT_DEC-158	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
37	IN_WHT_DEC-159	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
38	IN_WHT_DEC-160	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
39	IN_WHT_DEC-161	600	8.625	see spill analysis	see spill analysis	$ 37,581	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	3	4	0.7	23249
40	IN_WHT_DEC-162	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
41	IN_WHT_DEC-163	600	8.625	see spill analysis	see spill analysis	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
42																					

…convert the counts, lengths, and areas of impacted features into estimated impacts within each hazard zone

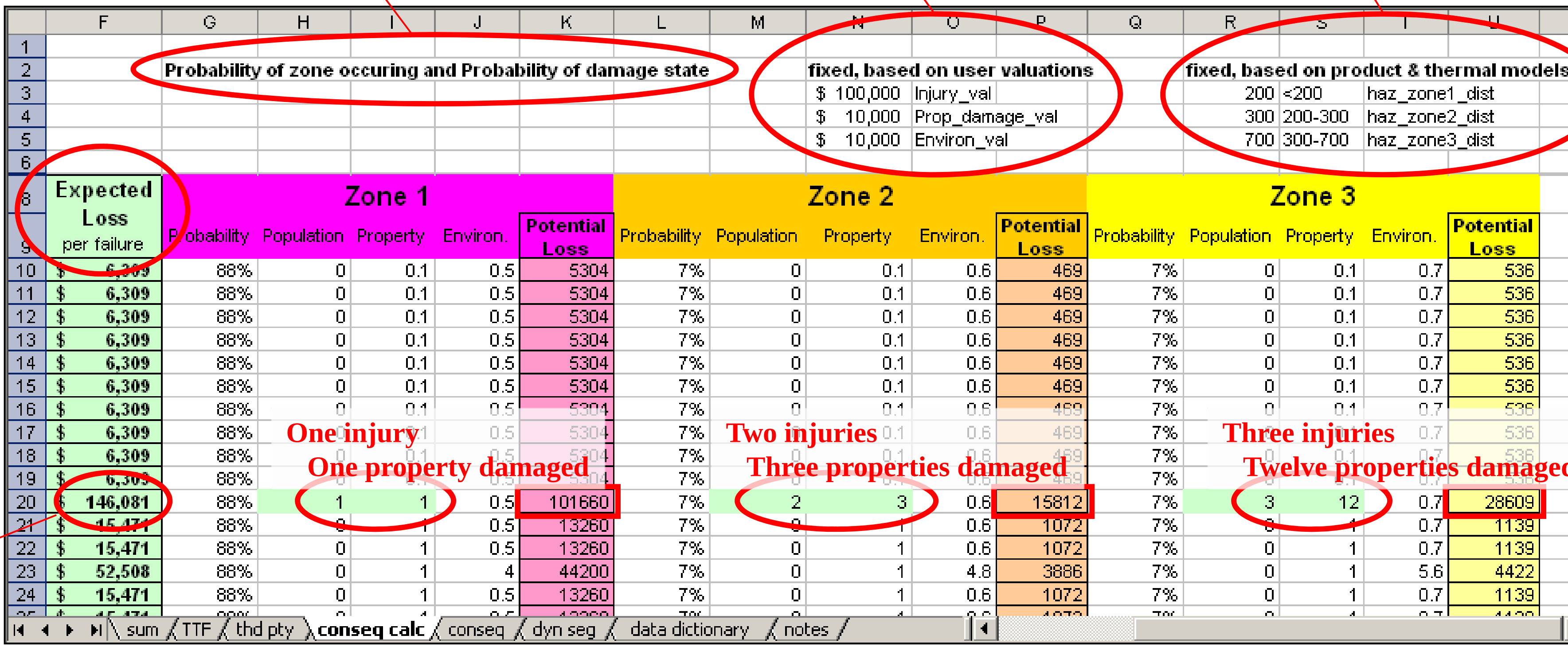
Hazard Zones & Consequence Estimates



The Sliding Impact Area based on—

- ***Product specifications***
- ***Spill quantity***
- ***Terrain configuration***
- ***Infiltration, evaporation and Pooling***

Expected Loss Calcs *(Probability * Impacted Feature Valuation)*



fixed, based on user valuations	
$ 100,000	Injury_val
$ 10,000	Prop_damage_val
$ 10,000	Environ_val

fixed, based on product & thermal models		
200	<200	haz_zone1_dist
300	200-300	haz_zone2_dist
700	300-700	haz_zone3_dist

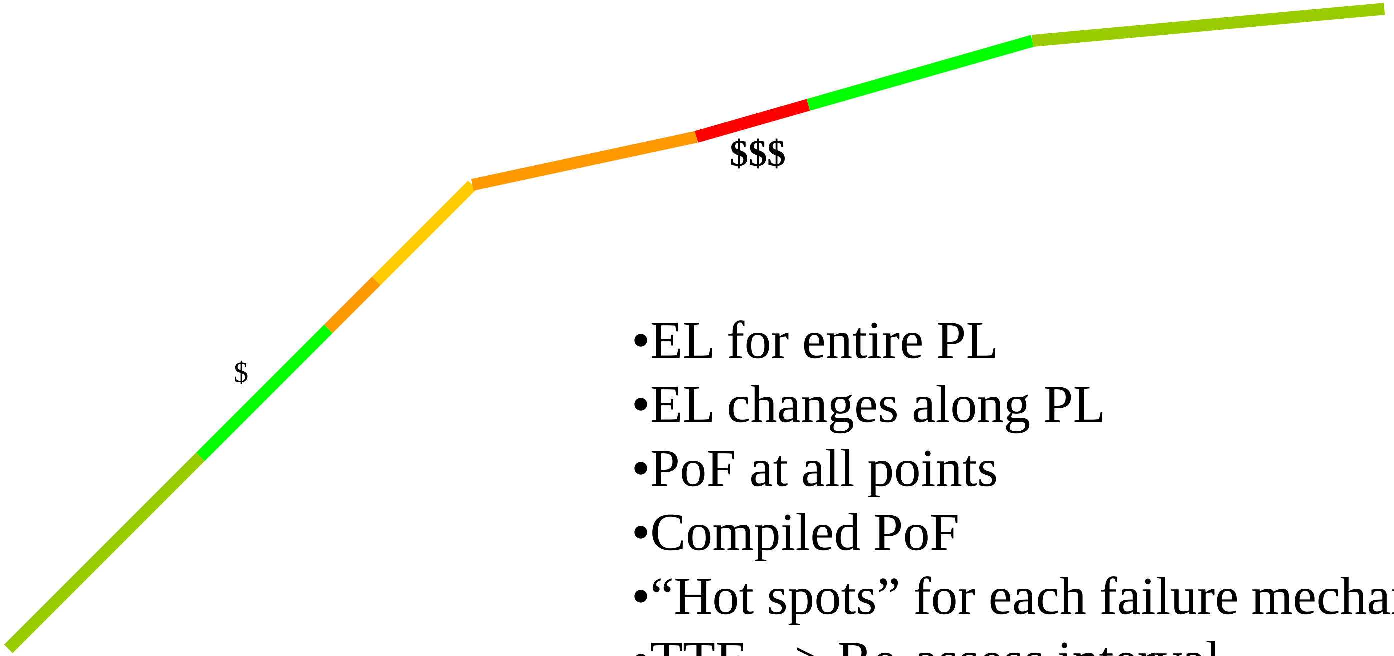
	Expected Loss per failure	Zone 1					Zone 2					Zone 3				
		Probability	Population	Property	Environ.	Potential Loss	Probability	Population	Property	Environ.	Potential Loss	Probability	Population	Property	Environ.	Potential Loss
10	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
11	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
12	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
13	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
14	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
15	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
16	$ 6,309	88%	0	0.1	0.5	5304	7%	0	0.1	0.6	469	7%	0	0.1	0.7	536
17	$ 6,309	88%	[illegible]	0.1	0.5	5304	7%	[illegible]	0.1	0.6	469	7%	[illegible]	[illegible]	0.7	536
18	$ 6,309	88%	0	0.1	0.5	5304	7%	[illegible]	0.1	0.6	469	7%	0	0.1	0.7	536
19	$ 6,309	88%	[illegible]	[illegible]	0.5	5304	7%	[illegible]	[illegible]	0.6	469	7%	[illegible]	[illegible]	0.7	536
20	$ 146,081	88%	1	1	0.5	101660	7%	2	3	0.6	15812	7%	3	12	0.7	28609
21	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
22	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139
23	$ 52,508	88%	0	1	4	44200	7%	0	1	4.8	3886	7%	0	1	5.6	4422
24	$ 15,471	88%	0	1	0.5	13260	7%	0	1	0.6	1072	7%	0	1	0.7	1139

<u>Each row</u> represents one pipeline release location

Expected Loss is a function of each Zone's Probability of occurring and the Zone's Potential Loss
Expected Loss = (Z1_Prob * Z1_PLoss) + (Z2_Prob * Z2_PLoss) + (Z3_Prob * Z3_PLoss)

EL_{20} = (.88 * 101660) + (.07 * 15812) + (.07 * 28609) = $146,081 …*<u>considerable</u> risk exposure at this location*

Visualization of Risks



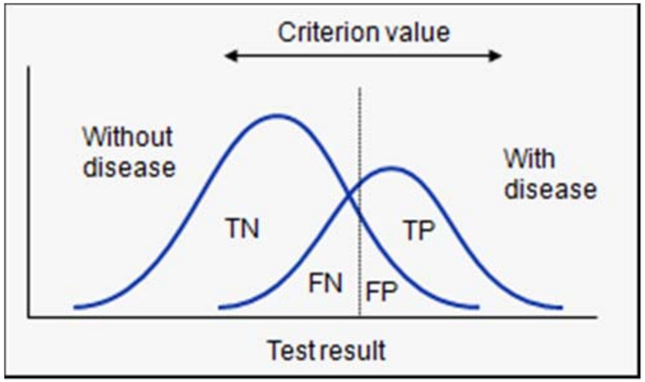
- EL for entire PL
- EL changes along PL
- PoF at all points
- Compiled PoF
- “Hot spots” for each failure mechanism
- TTF --> Re-assess interval

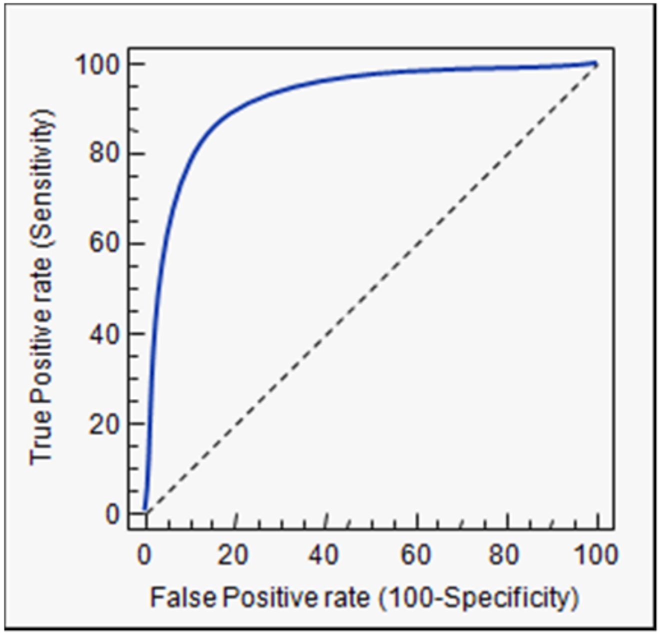
If you put tomfoolery into a computer, nothing comes out of it but tomfoolery. But this tomfoolery, having passed through a very expensive machine, is somehow ennobled and no-one dares criticize it.

- Pierre Gallois

Receiver Operating Characteristic (ROC) Curve

statistical perspective	management perspective	public perspective
false positive	false alarm	crying wolf
false negative	missed alarm	wolf in sheep's clothing
true positive	actual alarm	wolf in plain sight
true negative	no alarm	no wolf



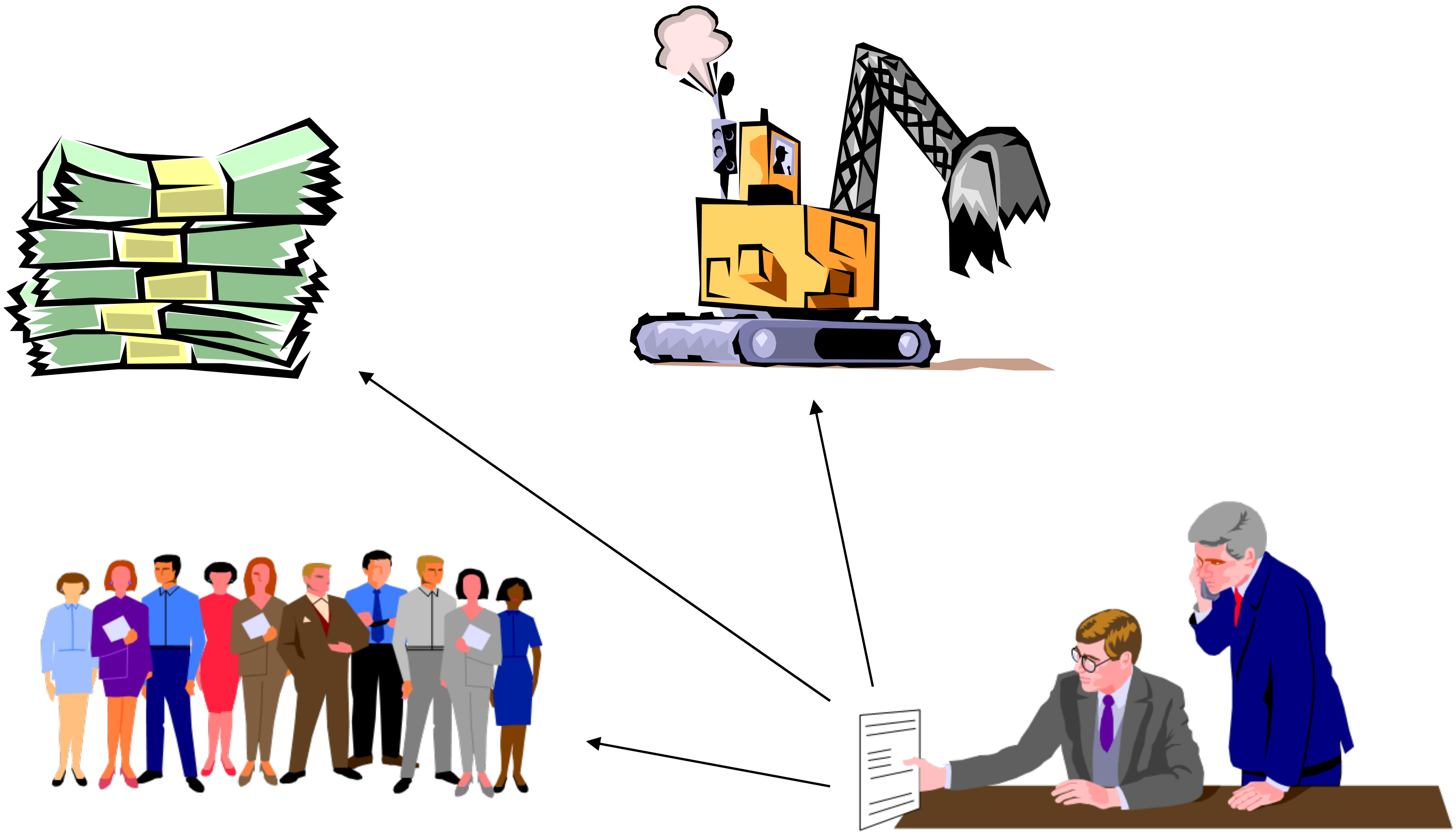


Can you tolerate 20% FP in exchange for only missing one in one-hundred?

GeoGathering 2009
GIS Solutions for Oil and Gas Gathering

Optimizing O&M

Resource Allocation Modeling



Responding to Changes Along ROW

Risk-based thinking to avoid inefficient, one-size-fits-all solutions

Example:

Increased CoF potential

- Change CoF
  - Product, pressure, ignition, containment, response
- Change PoF
  - Design factors
  - Respond to threat(s)
    - Increase patrol
    - Protective slab
    - Surveys: coating, CP
    - Training
    - Geotech study

Reported Mitigation Benefits

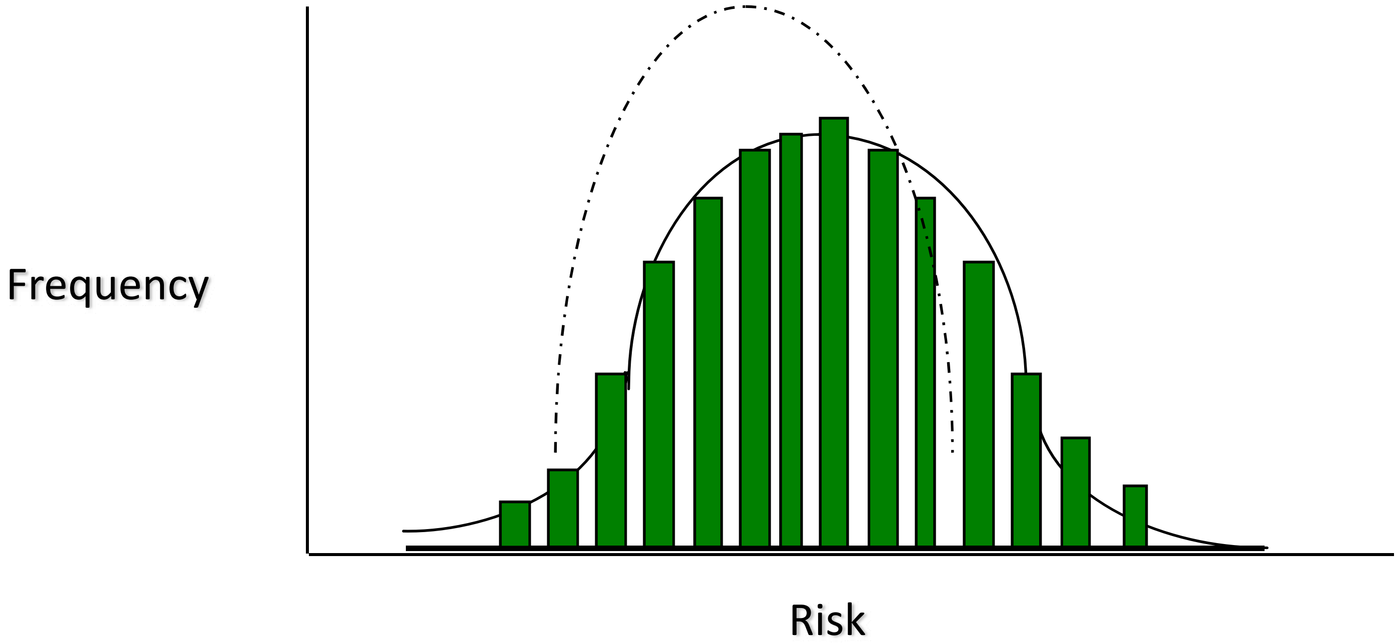
Mitigation	Impact on risk
Increase soil cover	56% reduction in mechanical damage when soil cover increased from 1.0 to 1.5 m
Deeper burial	25% reduction in impact failure frequency for burial at 1.5 m; 50% reduction for 2m; 99% for 3m
Increased wall thickness	90% reduction in impact frequency for >11.9-mm wall or >9.1-mm wall with 0.3 safety factor
Concrete slab	Same effect as pipe wall thickness increase
Concrete slab	Reduces risk of mechanical damage to "negligible"
Underground tape marker	60% reduction in mechanical damage
Additional signage	40% reduction in mechanical damage
Increased one-call awareness and response	50% reduction in mechanical damage
Increased ROW patrol	30% reduction in mechanical damage
Increased ROW patrol	30% heavy equipment-related damages; 20% ranch/farm activities; 10% homeowner activities
Improved ROW, signage, public education	5–15% reduction in third-party damages

Risk Management Options

Resource Allocation Choice	Cost Impact	Risk Impact
Increase Public Education	+ $4000	- 0.8%
Perform Close Interval Survey	+ $11000	- 2.6%
Reduce Air Patrol	- $7600	+ 1.1%
Perform Hydrostatic Test	+ $67000	- 8.2%

Action Triggers / Strategies

When to take action
Proportional level of action

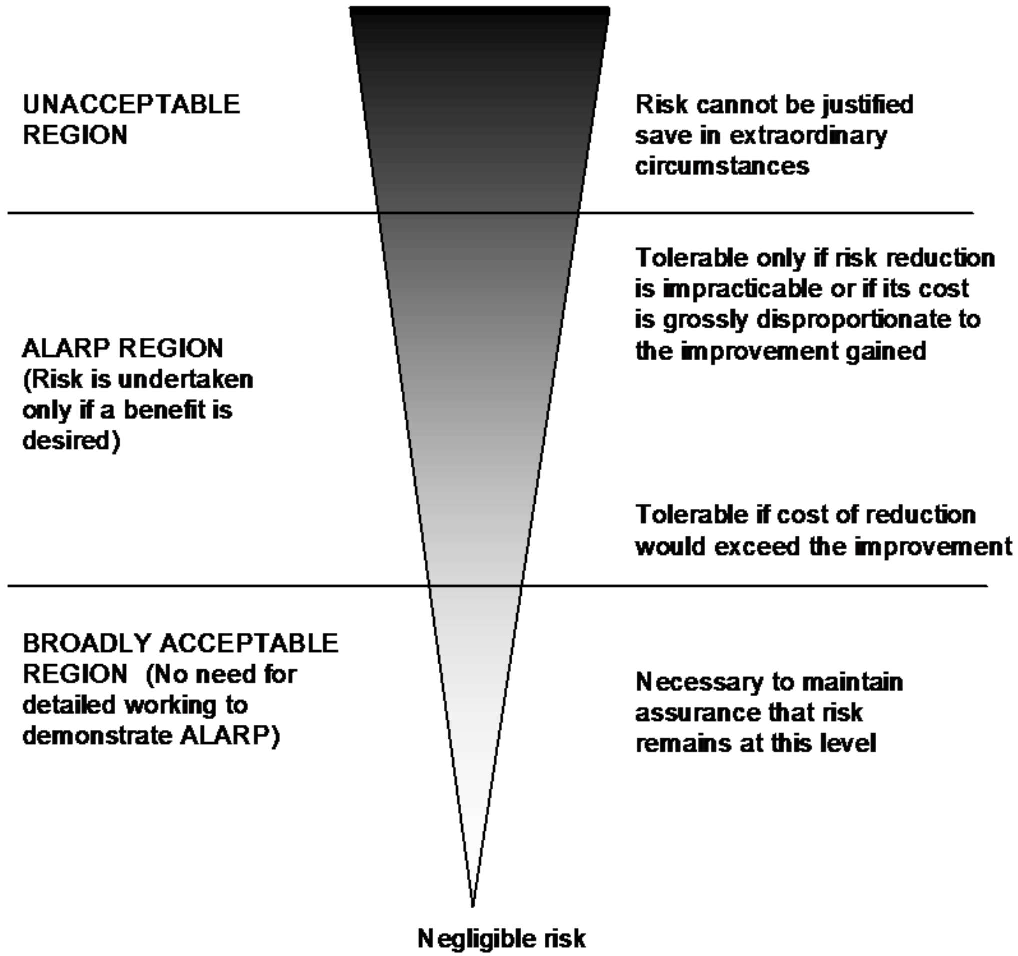


GeoGathering 2009
GIS Solutions for Oil and Gas Gathering

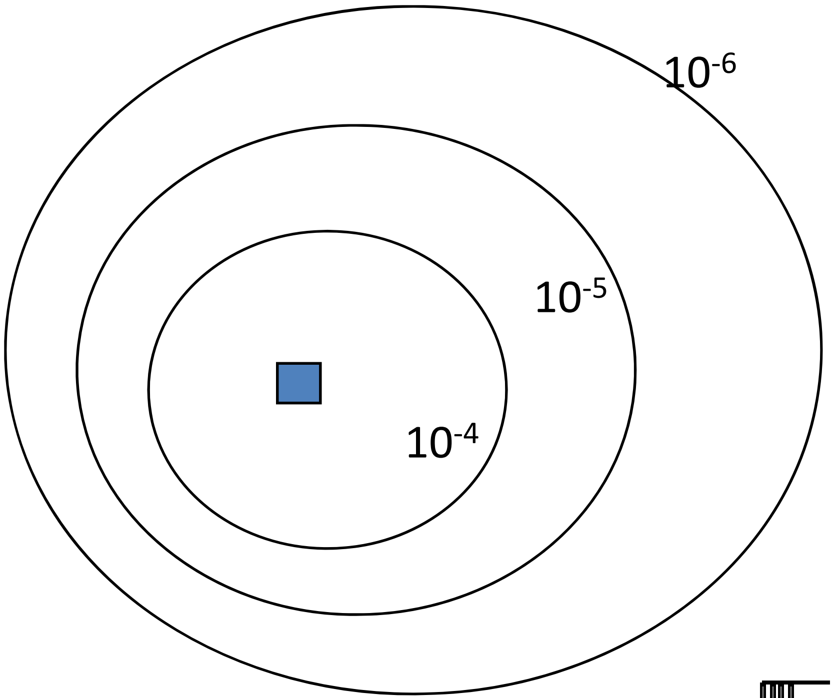
What is "Safe Enough"?

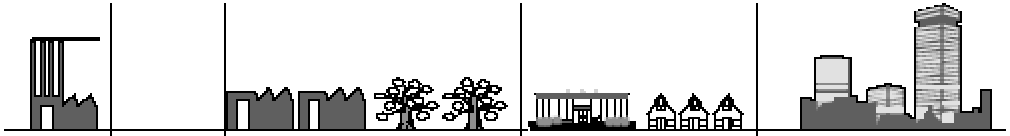
- Many risk levels are considered insignificant or tolerable
  - Regulatory precedents
    - ALARP
    - land use/facility siting
    - Environmental clean up criteria
    - EIS, EA
  - Industry precedents
    - Reliability Based Design
    - Limit state
  - Often measured in terms of fatalities
- Philosophical challenges placing this in IMP context
  - 'acceptable risk' argument is not explicitly recognized in IMP
  - very low risk levels can be shown in many covered segments, especially when short

Acceptable Risk



Canadian Risk-Based Land Uses

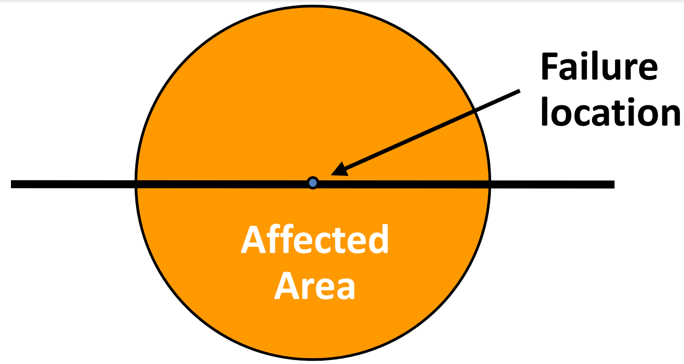




CSChE Risk Assessment – Recommended Practices, MIACC risk acceptability

Reliability Based Design

Safety risk



Number of people affected = A x P x ρ

Affected area - proportional to pd^2

Ignition probability - proportional to d

Population density

Expected number of people affected α ρpd^3

Nessim et al. Target Reliability Levels for Design and Assessment of Onshore Natural Gas Pipelines. International Pipeline Conference, Calgary, Alberta, 2004

New Possibilities: Reliability Targets

PRCI work

- Acceptable risk as implied by current regs & stds
- Based on probability of fatality
- Considers both individual and societal risk criteria
- Annex in CSA Z662; considered for ASME B31.8
- Tolerable PoF: 5E-5 failures per km-yr in Class 3

$$R_T = \begin{cases} 1 - \dfrac{9}{(\rho P D^3)^{0.66}} & \rho P D^3 \leq 1.0\times 10^5 \\ 1 - \dfrac{450}{\rho P D^3} & 1.0\times 10^5 < \rho P D^3 \leq 6.0\times 10^7 \\ 1 - \dfrac{2.1\times 10^7}{(\rho P D^3)^{1.6}} & \rho P D^3 > 6.0\times 10^7 \end{cases}$$

(Nessim, et al, IPC 2002, 2004, 2006)

New Possibilities: Optimizing Decisions

Unprecedented opportunities to understand risk issues

- New Tools & Techniques
- New ways of thinking emerging

Range of Opportunities

From

Tweaking existing O&M programs and design protocols

To

Establishing corporate/regional/national acceptable risk levels

He who shoots at nothing, hits nothing

Chinese proverb