



MANAGING RISK

DNV

Reliability: Statistical Applications



Facility Reliability, Probability of Exceedance, Corrosion Growth

Bill Harper, DNV-Columbus
August 2009

- Summary of presentation
 - **Sequential Evaluations on Facilities:** estimated 32 years to complete planned inspections
 - How can this be done more effectively given reliability goals?
 - **Reduced Major Axis Regression & Probability of Exceedance:** need to account for error in both NDE tool measurements and field measurements
 - **Corrosion Rate estimation**
 - US DOT project: remaining useful life estimation
 - Statistically Active Corrosion
 - **Sample sizes** needed to attain desired reliability

- Stop inspection because the desired reliability metrics have been met.
 - The point of diminishing returns has been met based on the good inspection results. Further sampling will add reduced value to the reliability assessment.

- Stop inspection because the estimated reliability metrics have not been met.
 - Current assessment indicates the facility may need repair or replacement. Engineers/managers may make a decision that includes a variety of factors including safety and economics of the feasible alternates in both the short and long term.

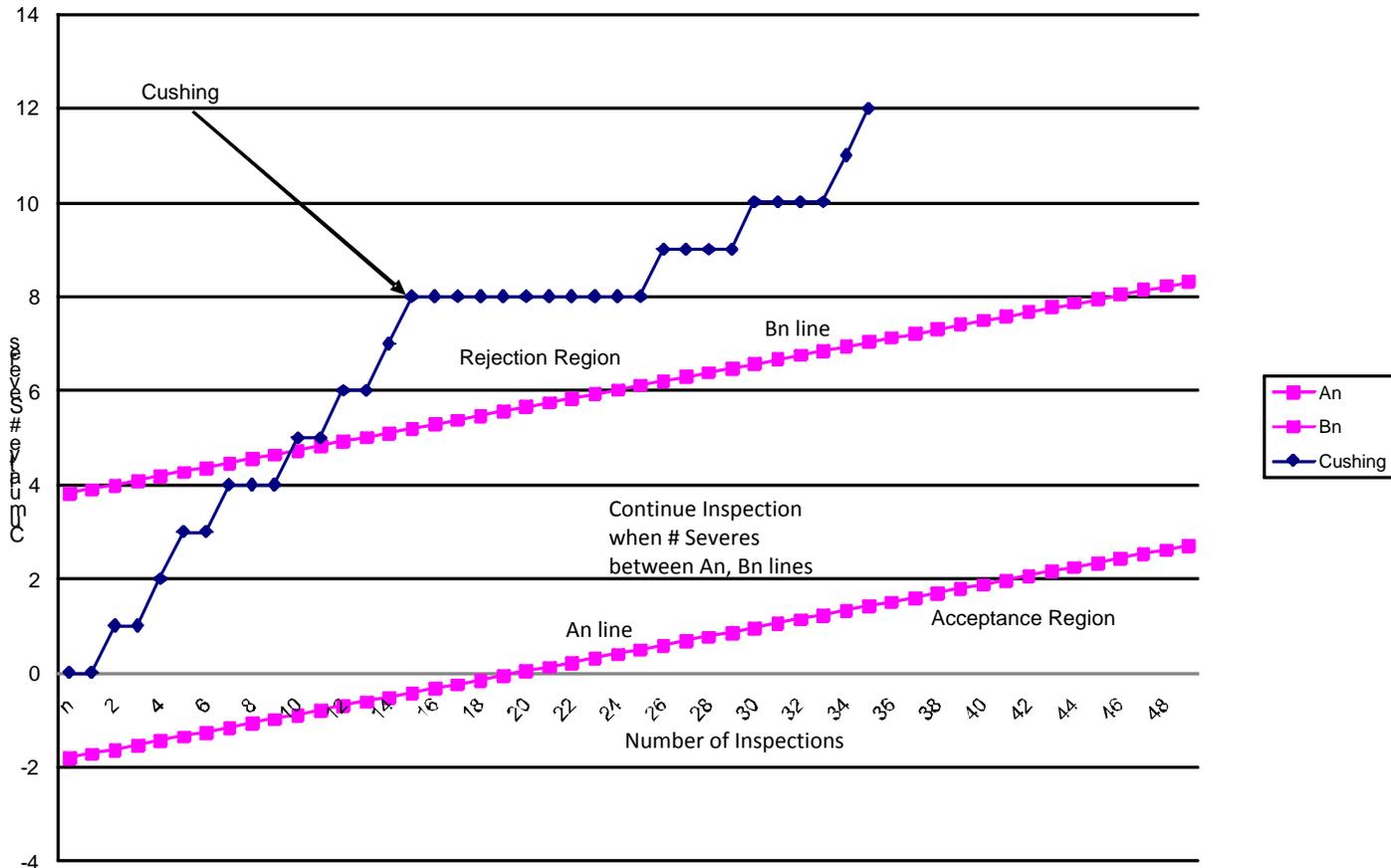
- Continue inspection because insufficient data have been collected to determine whether the reliability metrics have been met.

Criteria allow the user to create different reliability designs

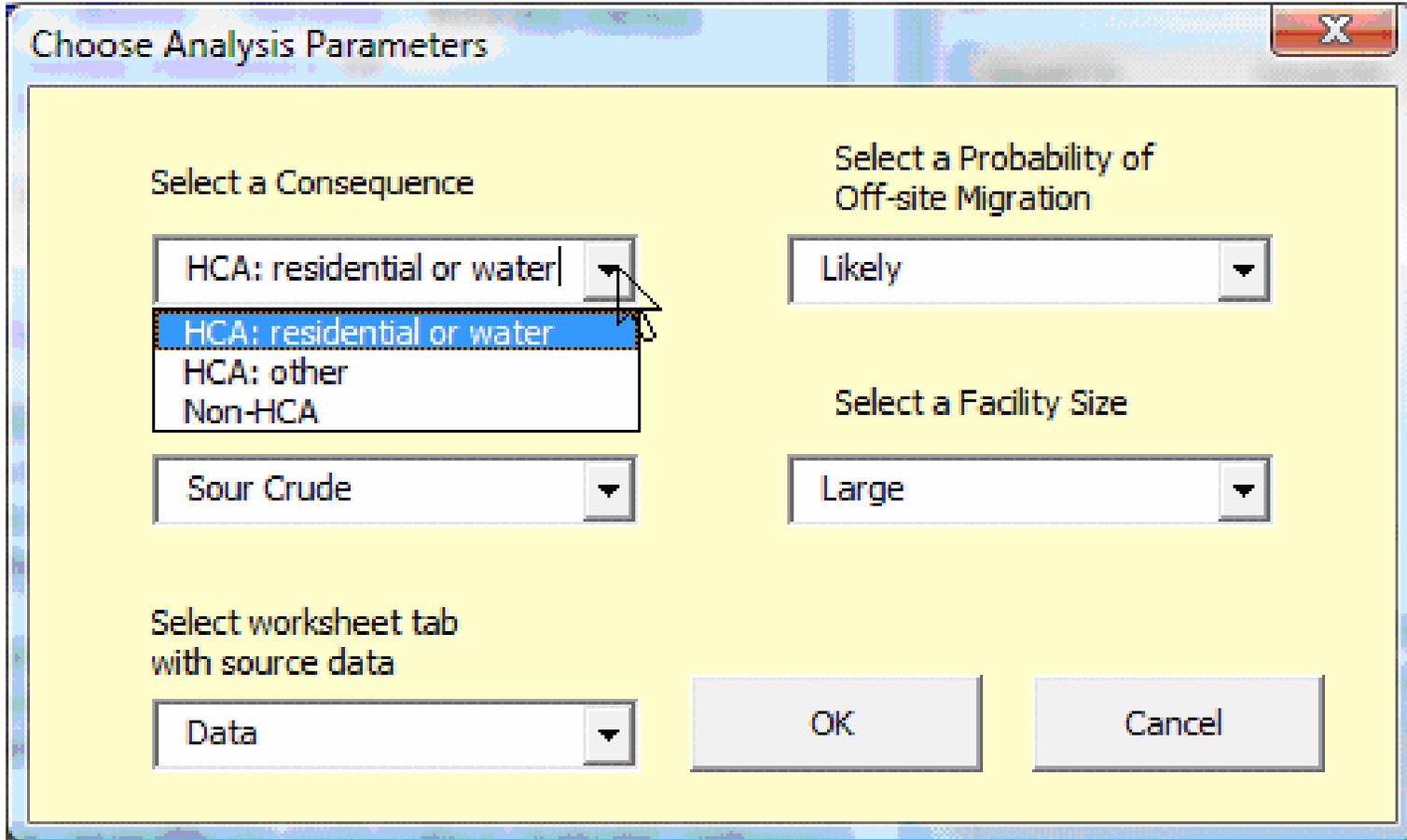
- Consequence
- Off Site Migration Probability
- Product Type
- Facility Size

Overall Schematic on Inspection Protocol

An, Bn lines with good reliability $p_0 = 95\%$; reliability bad $p_1 = 85\%$. $\alpha = 0.01$, $\beta = 0.10$.
 Most stringent conditions in system. Could Accept as early as 21; Reject as earlier as 5.



- The choices are used to set the reliability goals



Choose Analysis Parameters

Select a Consequence

HCA: residential or water
HCA: residential or water
HCA: other
Non-HCA

Sour Crude

Select a Probability of Off-site Migration

Likely

Select a Facility Size

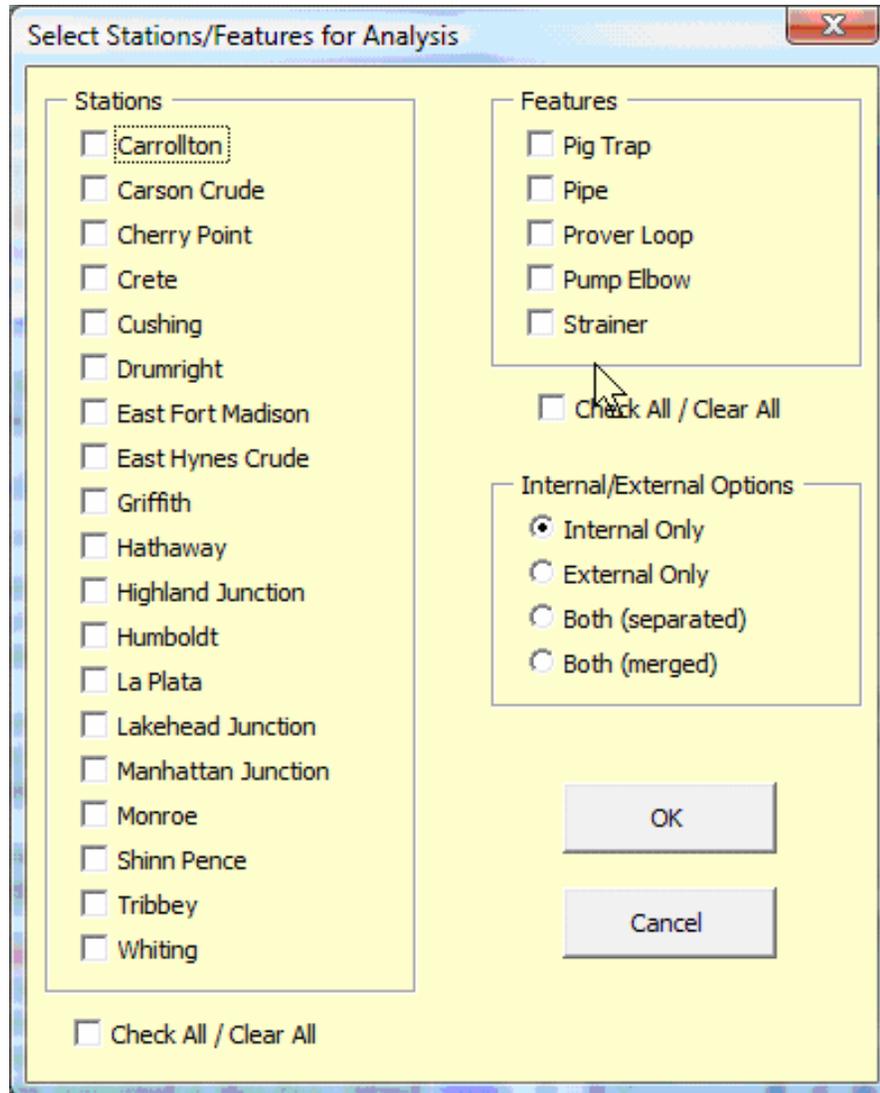
Large

Select worksheet tab with source data

Data

OK Cancel

Menu items dynamically generated from data



The screenshot shows a dialog box titled "Select Stations/Features for Analysis" with a close button (X) in the top right corner. The dialog is divided into three main sections: "Stations", "Features", and "Internal/External Options".

- Stations:** A list of 18 stations, each with an unchecked checkbox. The first item, "Carrollton", is highlighted with a dashed border. The list includes: Carrollton, Carson Crude, Cherry Point, Crete, Cushing, Drumright, East Fort Madison, East Hynes Crude, Griffith, Hathaway, Highland Junction, Humboldt, La Plata, Lakehead Junction, Manhattan Junction, Monroe, Shinn Pence, Tribbey, and Whiting.
- Features:** A list of 5 features, each with an unchecked checkbox: Pig Trap, Pipe, Prover Loop, Pump Elbow, and Strainer. Below this list is a "Check All / Clear All" checkbox, which is currently unchecked.
- Internal/External Options:** A section with four radio button options: "Internal Only" (selected), "External Only", "Both (separated)", and "Both (merged)".

At the bottom of the dialog, there are two buttons: "OK" and "Cancel". Additionally, there is a "Check All / Clear All" checkbox at the bottom left of the dialog area.

Sample Output showing quicker decision

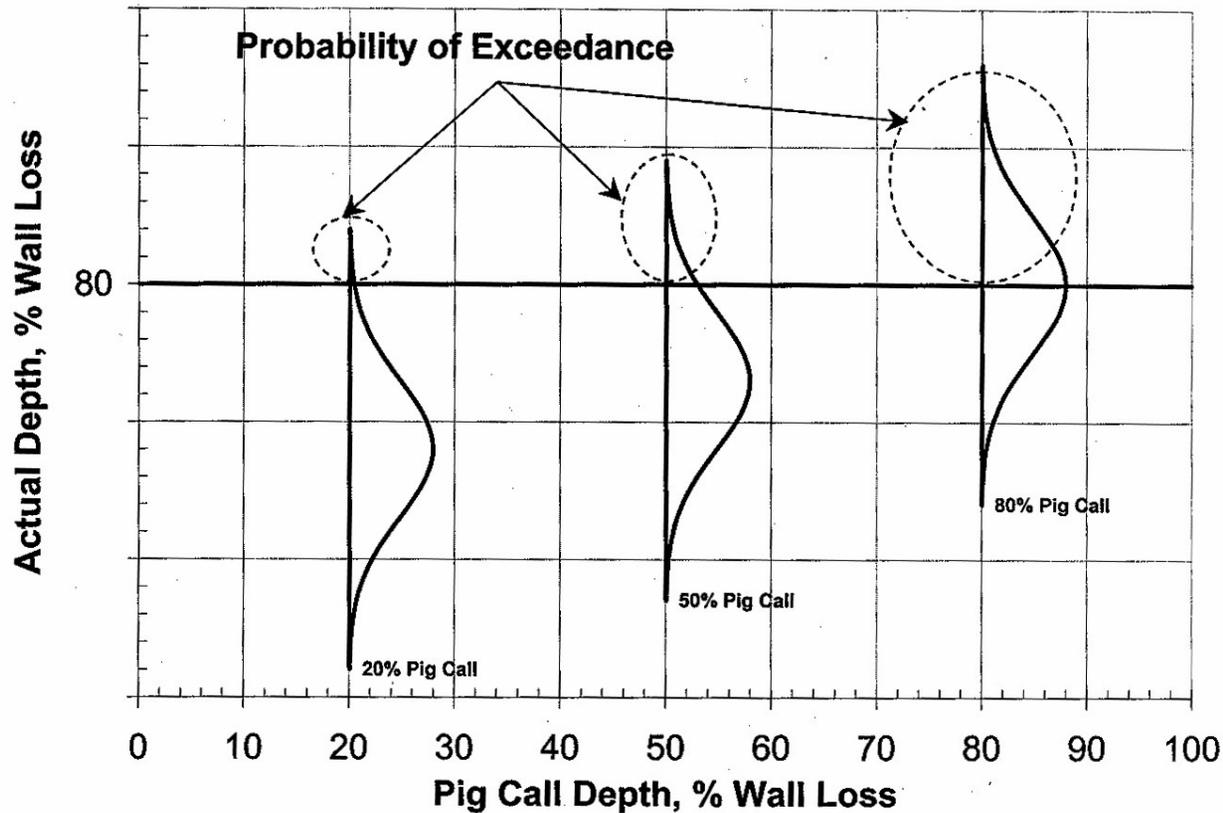
- Cushing actually inspected 36, could have stopped at 11.

Cushing	Pipe					
n	An	Bn	# Severe	Decision	LCL	UCL
1	-1.8030	3.8113	0	Continue	0.0500	1.0000
2	-1.7110	3.9032	0	Continue	0.2236	1.0000
3	-1.6191	3.9952	1	Continue	0.1354	0.9830
4	-1.5272	4.0871	1	Continue	0.2486	0.9873
5	-1.4352	4.1790	2	Continue	0.1893	0.9236
6	-1.3433	4.2710	3	Continue	0.1532	0.8468
7	-1.2514	4.3629	3	Continue	0.2253	0.8712
8	-1.1594	4.4548	4	Continue	0.1929	0.8071
9	-1.0675	4.5468	4	Continue	0.2514	0.8312
10	-0.9756	4.6387	4	Continue	0.3035	0.8500
11	-0.8836	4.7306	5	Reject Ho	0.2712	0.8004
12	-0.7917	4.8226	5	Reject Ho	0.3152	0.8190
13	-0.6998	4.9145	6	Reject Ho	0.2870	0.7760

Advantages of Sequential Reliability Assessment

- Quicker Decisions to save time and money
 - May inspect more sites in a timely manner
- Reliability quantified at each step
 - 95% reliability confidence intervals
- Scorecard of site results broken down by database driven categories
 - No predetermination of sites or items to be inspected as software builds forms based on what is in database.
- Methodology kept generic to be easily adapted to a wide variety of situations

- Reduced Major Axis regression
 - Accounts for errors in both NDE, field



Pipeline Corrosion Life Estimation



External Corrosion Rate Estimation including Years until Corrosion reaches Threshold

Input Data Location: 'more data'!\$E\$2:\$E\$16

Who to Contact for Help

Wall Thickness: 9.52

Units for both Input rates and Wall Thickness: mm

Threshold of Concern as a % of Wall Thickness: 80

mV Cathodic Protection Polarization: 125

mV Cathodic Protection Polarization Base for Decade reduction in corrosion rate: 100

Deepest Pit as % Wall Thickness: 45

Title Header for Output: Demo for August 2009 DC JSM

Desired Output Location: Sheet1!\$A\$1

Click When All Information Entered

Pipeline Exterior Corrosion Life Output



Estimates Benefit of Cathodic Protection

External Corrosion Rate Life Prediction Tool	Demo for August 2009 DC JSM	Date/Time of Analysis: 7/28/2009 9:00:17 AM
<u>Weibull Parameter</u>	<u>Estimate</u>	
Threshold	0.063727632	
Scale	0.107462782	
Shape	1.518008266	
Goodness of Fit P Value	0.591884735	Passes Goodness of Fit
Wall thickness = 9.52 mm		
User Input Threshold % = 80%		
User Input Max Pit % = 45%		
All rates in mm/year		
Rates unadjusted for CP Potential mm/year		
99th Percentile Growth Rate/Year	Lower 95% Confidence Limit	Upper 95% Confidence Limit
0.35761	0.25593	0.51308
Expected Years to Threshold	Lower 95% Confidence Level	Upper 95% Confidence Level
9.32	6.49	13.02
CP Potential Adjusted Growth Rates mm/year		
Current CP Potential mV = 125	CP Potential Polarization Base mV = 100	Cathodic Protection Corrosion Rate Divisor = 17.78
99th Percentile Adjusted Growth Rate/Year	Lower 95% Confidence Limit	Upper 95% Confidence Limit
0.02011	0.01439	0.02885
Expected Years to Threshold	Lower 95% Confidence Level	Upper 95% Confidence Level
165.69	115.48	231.51

- Statistically Active Corrosion
- Sample sizes needed to attain desired reliability