Brown AND Caldwell

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Development of Defect Codes for Pressure Mains

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Topics

- Background
- Introduction of a case study
- Factors of safety
- Suggested Defect Codes for pressure mains
- Selecting follow-on actions – the “4R’s”

Background

- A little history – how did we get here?
- Where are we?
- Where are we going?
- The purpose of this paper

A Case Study

- Coastal Community in SC
  - 16 Inch DIP Force Main
  - Critical line through crowded commercial and residential corridor
  - Upper portion of force main experienced two failures due to crown corrosion
  - Client wanted to inspect the line to determine condition, reliability

Using Defect Codes to Develop Condition Ratings - Example

- Line was inspected using an RFEC tool

RFEC Inspection Results

Pit 1 to Pit 2 - Wall Thickness Table

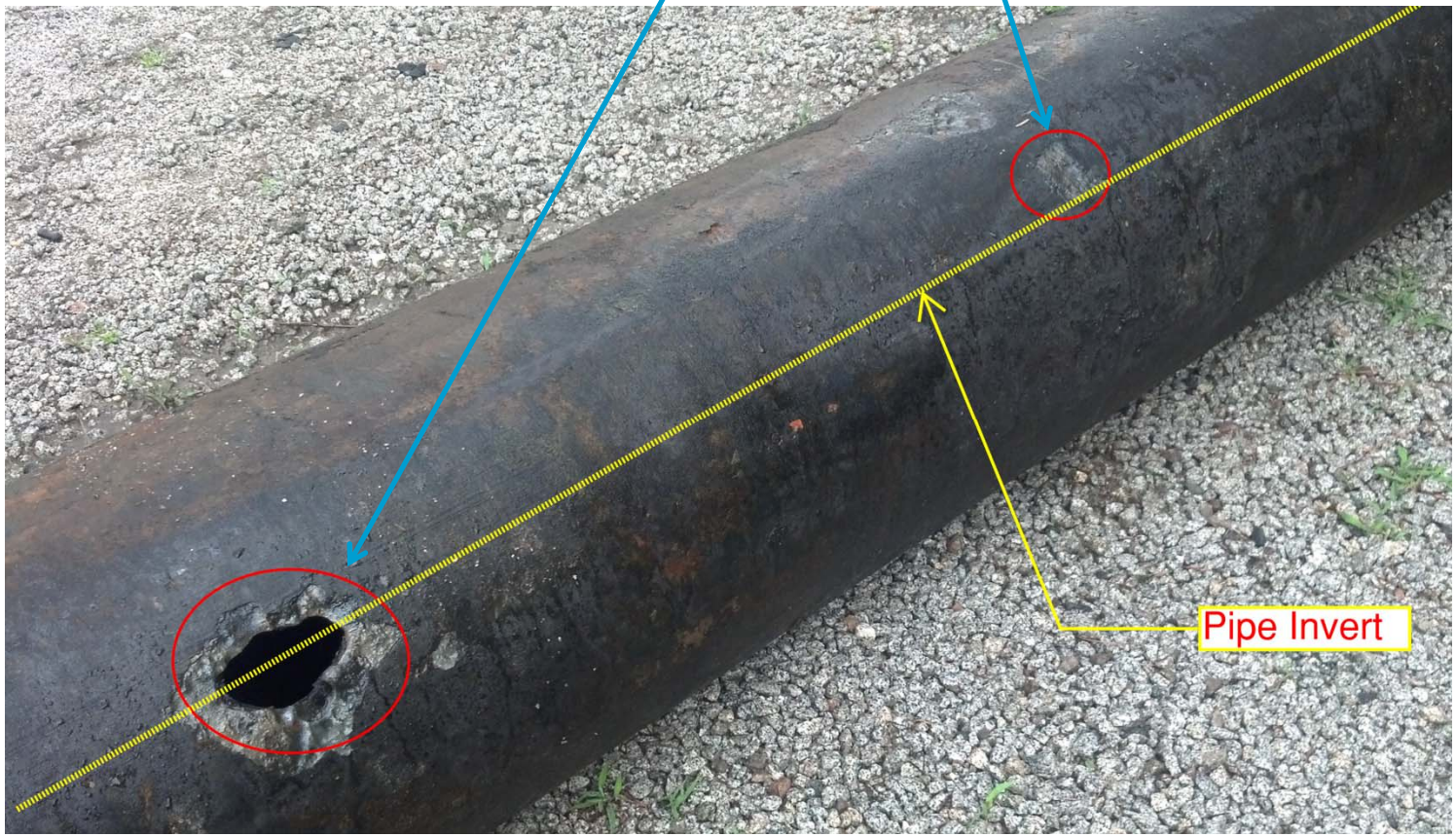
Pipe Number	Joint Location Information			Average Remaining Wall [%]	Circumferential Wall Thickness Information		Local Wall Thickness Information									Comment
	Start Location [ft]	End Location [ft]	Length [ft]		Max Circ Remaining Wall [%]	Min Circ Remaining Wall [%]	Min Local Remaining Wall 1	Location LRW1 [ft]	Clock Position LRW1	Min Local Remaining Wall 2	Location LRW2 [ft]	Clock Position LRW2	Min Local Remaining Wall 3	Location LRW3 [ft]	Clock Position LRW3	
0010	0.00	19.84	19.84	92%	96%	87%	74%	6.76	8:30							
0020	19.84	39.39	19.55	95%	115%	88%	46%	33.75	8:00	57%	30.64	5:30	72%	32.77	5:00	
0030	39.39	59.99	20.60	85%	94%	83%	0%	42.12	6:00	13%	45.76	6:00	16%	45.30	2:00	
0040	59.99	79.70	19.71	90%	102%	86%	52%	64.29	6:00	63%	69.60	7:00	65%	70.26	2:00	
0050	79.70	100.07	20.37	91%	96%	88%	59%	84.20	7:30	64%	83.08	0:30	66%	84.00	1:00	
0060	100.07	120.97	20.89	91%	104%	88%	11%	106.30	5:00	17%	109.09	5:00	36%	104.44	4:30	
0070	120.97	141.86	20.89	91%	105%	87%	45%	131.17	12:00	52%	127.53	7:30				
0080	141.86	161.67	19.81	85%	97%	83%	15%	148.22	5:30	23%	151.21	7:00	25%	144.48	4:30	
0090	161.67	181.55	19.88	89%	93%	87%	40%	166.53	5:30	51%	164.75	5:00				
0100	181.55	203.13	21.58	89%	94%	86%	45%	188.40	5:00	55%	197.42	2:30	59%	187.12	12:00	
0110	203.13	223.89	20.76	85%	103%	83%	19%	211.13	4:30	29%	207.62	5:00	30%	211.76	4:30	
0120	223.89	244.59	20.70	87%	96%	84%	14%	229.30	6:30	14%	239.77	4:00	46%	238.26	5:00	
0130	244.59	263.91	19.32	92%	105%	91%	1%	249.05	5:00	23%	250.92	6:00	24%	250.36	6:00	
0140															4:30	
0150															12:00	
0160															11:30	
0170															6:30	
0180															4:30	
0190	364.11	383.63	19.52	93%	103%	84%	41%	373.46	5:30	61%	368.41	5:00	62%	370.48	5:00	
0200	383.63	403.74	20.11	88%	101%	85%	0%	389.53	5:30	3%	390.16	5:30	14%	396.81	5:00	
0210	403.74	423.32	19.58	86%	99%	82%	0%	414.49	5:00	19%	413.87	5:00	29%	417.94	6:30	
0220	423.32	443.62	20.30	95%	112%	89%	35%	438.40	10:30	61%	429.35	12:00	63%	436.27	1:30	
0230	443.62	463.99	20.37	95%	111%	91%	0%	448.18	0:30	0%	450.18	1:00	12%	459.13	10:00	
0240	463.99	484.92	20.93	88%	102%	86%	11%	469.70	1:00	20%	470.88	6:00	27%	474.45	5:30	
0250	484.92	487.51	2.59													
0260	488.88	504.76	15.88	83%	89%	80%	45%	495.64	1:00	49%	496.92	12:00	50%	496.23	12:00	
0270	504.76	524.47	19.71	85%	91%	84%	0%	507.42	5:30	8%	509.84	6:30	11%	510.63	6:30	
0280	524.47	544.58	20.11	92%	97%	88%	58%	529.79	8:00	60%	533.30	1:00	60%	531.85	8:00	

- First 650 feet of force main showed significant damage
- Remaining 3900 feet of main was in good condition

Excavation of Stick 003 for Confirmation

Pit 1 to Pit 2 - Wall Thickness Table

Pipe Number	Joint Location Information			Average Remaining Wall [%]	Circumferential Wall Thickness Information		Local Wall Thickness Information									Comment
	Start Location [ft]	End Location [ft]	Length [ft]		Max Circ Remaining Wall [%]	Min Circ Remaining Wall [%]	Min Local Remaining Wall 1	Location LRW1 [ft]	Clock Position LRW1	Min Local Remaining Wall 2	Location LRW2 [ft]	Clock Position LRW2	Min Local Remaining Wall 3	Location LRW3 [ft]	Clock Position LRW3	
0010	0.00	19.84	19.84	92%	96%	87%	74%	6.76	8:30							
0020	19.84	39.39	19.55	95%	115%	88%	46%	33.75	8:00	57%	30.64	5:30	72%	32.77	5:00	
0030	39.39	59.99	20.60	85%	94%	83%	0%	42.12	6:00	13%	45.76	6:00	16%	45.30	2:00	



Convert Data to Absolute Measure

Pit 1 to Pit 2 - Wall Thickness Table (Absolute Measure)

Pipe Number	Joint Location Information			Average Remaining Wall [Inches]	Circumferential Wall Thickness Information		Local Wall Thickness Information Based on Field Data as %NWT Times Measured NWT								
	Start Location [ft]	End Location [ft]	Length [ft]		Max Circ Remaining Wall [Inches]	Min Circ Remaining Wall [Inches]	Min Local Remaining Wall 1	Location LRW1 [ft]	Clock Position LRW1	Min Local Remaining Wall 2	Location LRW2 [ft]	Clock Position LRW2	Min Local Remaining Wall 3	Location LRW3 [ft]	Clock Position LRW3
0010	0.00	19.84	19.84	0.303	0.316	0.286	0.244	6.76	8:30						
0020	19.84	39.39	19.55	0.312	0.379	0.288	0.152	33.75	8:00	0.187	30.64	5:30	0.235	32.77	5:00
0030	39.39	59.99	20.60	0.279	0.309	0.271	0.000	42.12	6:00	0.044	45.76	6:00	0.053	45.30	2:00
0040	59.99	79.70	19.71	0.296	0.335	0.282	0.170	64.29	6:00	0.207	69.60	7:00	0.213	70.26	2:00
0050	79.70	100.07	20.37	0.299	0.315	0.290	0.195	84.20	7:30	0.209	83.08	0:30	0.216	84.00	1:00
0060	100.07	120.97	20.89	0.297	0.341	0.288	0.036	106.30	5:00	0.054	109.09	5:00	0.117	104.44	4:30
0070	120.97	141.86	20.89	0.300	0.344	0.285	0.146	131.17	12:00	0.171	127.53	7:30			
0080	141.86	161.67	19.81	0.278	0.319	0.273	0.049	148.22	5:30	0.076	151.21	7:00	0.080	144.48	4:30
0090	161.67	181.55	19.88	0.293	0.305	0.286	0.131	166.53	5:30	0.167	164.75	5:00			
0100	181.55	203.13	21.58	0.293	0.308	0.281	0.147	188.40	5:00	0.182	197.42	2:30	0.195	187.12	12:00
0110	203.13	223.89	20.76	0.280	0.337	0.272	0.064	211.13	4:30	0.094	207.62	5:00	0.100	211.76	4:30
0120	223.89	244.59	20.70	0.285	0.313	0.275	0.045	229.30	6:30	0.046	239.77	4:00	0.150	238.26	5:00
0130	244.59	263.91	19.32	0.301	0.344	0.299	0.003	249.05	5:00	0.074	250.92	6:00	0.077	250.36	6:00
0140	263.91	283.82	19.91	0.298	0.354	0.277	0.019	271.72	4:30	0.056	268.89	0:30	0.113	270.14	4:30
0150	283.82	305.20	21.39	0.265	0.334	0.248	0.087	293.04	11:30	0.091	291.26	11:30	0.200	287.89	12:00
0160	305.20	324.29	19.09	0.255	0.313	0.223	0.002	315.83	2:00	0.058	312.78	5:30	0.070	312.42	11:30
0170	324.29	343.81	19.52	0.298	0.338	0.291	0.000	328.26	6:00	0.055	329.77	5:30	0.070	328.79	6:30
0180	343.81	364.11	20.30	0.290	0.352	0.275	0.056	346.83	4:30	0.059	351.71	7:00	0.062	361.72	4:30
0190	364.11	383.63	19.52	0.306	0.339	0.275	0.136	373.46	5:30	0.201	368.41	5:00	0.204	370.48	5:00
0200	383.63	403.74	20.11	0.290	0.333	0.279	0.000	389.53	5:30	0.009	390.16	5:30	0.044	396.81	5:00
0210	403.74	423.32	19.58	0.281	0.326	0.268	0.000	414.49	5:00	0.062	413.87	5:00	0.095	417.94	6:30
0220	423.32	443.62	20.30	0.310	0.368	0.292	0.115	438.40	10:30	0.200	429.35	12:00	0.205	436.27	1:30
0230	443.62	463.99	20.37	0.312	0.365	0.299	0.000	448.18	0:30	0.000	450.18	1:00	0.039	459.13	10:00
0240	463.99	484.92	20.93	0.288	0.333	0.283	0.036	469.70	1:00	0.064	470.88	6:00	0.087	474.45	5:30
0250	484.92	487.51	2.59												
0260	488.88	504.76	15.88	0.271	0.290	0.261	0.148	495.64	1:00	0.162	496.92	12:00	0.165	496.23	12:00
0270	504.76	524.47	19.71	0.279	0.298	0.275	0.000	507.42	5:30	0.025	509.84	6:30	0.037	510.63	6:30
0280	524.47	544.58	20.11	0.303	0.318	0.288	0.190	529.79	8:00	0.196	533.30	1:00	0.197	531.85	8:00
0290	544.58	564.68	20.11	0.300	0.351	0.275	0.153	561.86	12:00	0.173	562.65	3:30	0.214	550.65	5:00
0300	564.68	584.73	20.04	0.285	0.306	0.276	0.000	568.13	6:00	0.088	572.23	7:00	0.096	570.42	8:30
0310	584.73	610.11	25.39	0.305	0.346	0.281	0.145	589.48	5:00	0.151	589.12	11:30	0.158	588.99	8:00
0320	611.39	616.80	5.41	0.300	0.306	0.281									
0330	616.80	633.24	16.43	0.318	0.351	0.306	0.103	618.15	6:00	0.136	618.41	6:00	0.208	623.00	9:00
0340	633.24	652.85	19.61	0.284	0.323	0.259	0.026	641.60	0:30	0.110	648.39	6:30	0.128	643.34	0:30
0350	652.85	672.99	20.14	0.319	0.327	0.310	0.151	658.00	7:30	0.185	656.26	7:30	0.214	655.08	6:00
0360	672.99	693.75	20.76	0.316	0.364	0.290	0.268	677.55	7:30						

Calculate Actual Factors of Safety

Pit 1 to Pit 2 - Calculation of Factors of Safety					
Pipe Number	Existing Factor of Safety				Comment
	Minimum Wall Thickness (Inches)	Minimum FS for Internal Pressure	Minimum FS for External Load	Minimum FS	
0010	0.244	9.822	7.009	7.009	No Action Needed
0020	0.152	6.129	4.688	4.688	No Action Needed
0030	0.000	0.000	0.000	0.000	Repair or Replace
0040	0.170	6.823	5.071	5.071	No Action Needed
0050	0.195	7.841	5.651	5.651	No Action Needed
0060	0.036	1.435	0.586	0.586	Repair or Replace
0070	0.146	5.879	4.547	4.547	No Action Needed
0080	0.049	1.962	1.059	1.059	Repair or Replace
0090	0.131	5.267	4.175	4.175	No Action Needed
0100	0.147	5.933	4.577	4.577	No Action Needed
0110	0.064	2.564	1.697	1.697	Reinspect in 5 years
0120	0.045	1.817	0.918	0.918	Repair or Replace
0130	0.003	0.107	0.003	0.003	Repair or Replace
0140	0.019	0.764	0.169	0.169	Repair or Replace
0150	0.087	3.505	2.720	2.720	No Action Needed
0160	0.002	0.079	0.002	0.002	Repair or Replace
0170	0.000	0.000	0.000	0.000	Repair or Replace
0180	0.056	2.243	1.348	1.348	Reinspect in 5 years
0190	0.136	5.456	4.294	4.294	No Action Needed
0200	0.000	0.000	0.000	0.000	Repair or Replace
0210	0.000	0.000	0.000	0.000	Repair or Replace
0220	0.115	4.645	3.741	3.741	No Action Needed
0230	0.000	0.000	0.000	0.000	Repair or Replace
0240	0.036	1.437	0.587	0.587	Repair or Replace
0250	0.000	0.000	0.000	0.000	Repair or Replace
0260	0.148	5.963	4.594	4.594	No Action Needed
0270	0.000	0.000	0.000	0.000	Repair or Replace
0280	0.190	7.624	5.523	5.523	No Action Needed
0290	0.153	6.166	4.709	4.709	No Action Needed
0300	0.000	0.000	0.000	0.000	Repair or Replace
0310	0.145	5.839	4.523	4.523	No Action Needed
0320	0.300	12.075	9.067	9.067	No Action Needed
0330	0.103	4.138	3.325	3.325	No Action Needed
0340	0.026	1.060	0.324	0.324	Repair or Replace
0350	0.151	6.070	4.655	4.655	No Action Needed
0360	0.268	10.781	7.814	7.814	No Action Needed

For Internal Pressure :

- Nominal wall thickness – 0.328 inches
- OD = 17.4 inches
- P_w = 20 psi
- P_s = 100 psi
- S_y = 42,000 psi

$$FS = \frac{2t_a S_y}{(P_w + P_s)D}$$

Use of Actual Factors of Safety to aid in Four R Selection

- If FS > 2.0
  - Pipe segment is in good condition – re-inspect. Routine inspection cycle of 10 years
- If FS from 1.2 to 2.0
  - Pipe segment is deteriorating but still serviceable. Re-inspect on accelerated rate
- If FS < 1.2
  - Pipe segment is heavily deteriorated and should be repaired, rehabilitated or replaced

Suggested Defect Codes for Pressure mains

- Codes for actionable defects
- Based on PACP codes
  - New codes reflecting pressure main failure modes
  - Additional codes
- Codes for observations, screening

Suggested Codes for Defects
Part 1 – PACP Based

DEFECTS	UTILITY TYPES	PIPE TYPES	APPLICABLE INSPECTION TECHNOLOGIES	CODES		
				CODE	MODIFIER	GRADE BASIS
Cracks	W, WW	PCCP, RCP, CP	Sounding, CCTV, visual	C	PACP	PACP
Deformed	W, WW	All	CCTV for W, visual for WW	D	PACP	PACP
Leak	W, WW	All	Acoustics	LK	PACP	PACP
Lining Failure	W,WW	Ferrous, cementitious	CCTV	LF	PACP	PACP
Deposits	W,WW	All	CCTV	DA, DS	PACP	PACP

Suggested Codes for Defects Part 2 – Failure Mode Based

DEFECTS	UTILITY TYPES	PIPE TYPES	APPLICABLE INSPECTION TECHNOLOGIES	CODES		
				CODE	MODIFIER	GRADE BASIS
Wall loss	W,WW	Ferrous,	RFEC, UST, BEM, MFL	WLF	Wt Rem	% loss
		Concrete, RCP, PCCP	PPR, CCTV	WLC	Wt Rem	% loss
		AC	Indicator solution	WLAC	pH	% loss
Wall pitting	W,WW	Ferrous, graphitization	RFEC, UST, BEM, MFL	WP	Depth	% Wo
Tuberculation	W,WW	Ferrous	CCTV	WT	X-section	% loss
Wire break zones	W,WW	PCCP	RFEC/TC, Sounding	WBZ	Number	FEA
Wire break rate	W,WW	PCCP	AFO	WBR	No/Yr	FEA
Cylinder defects	W,WW	PCCP	RFEC/TC	WCY	Size	% loss

Suggested Codes for Defects
Part 3 – Additional

DEFECTS	UTILITY TYPES	PIPE TYPES	APPLICABLE INSPECTION TECHNOLOGIES	CODES		
				CODE	MODIFIER	GRADE BASIS
Exterior Staining	W,WW	PCCP or RCP	Visual	WS	C or L	Length
Soil Voids	W,WW	All, primarily HDPE, PVC	PPR	SV	Size	% circum

Suggested Codes for Observations
Part 1 – System Elements

OBSERVATION	UTILITY TYPES	PIPE TYPES	APPLICABLE INSPECTION TECHNOLOGIES	CODES	
				CODE	MODIFIER
Valves	W, WW	All	CCTV	OV	Type (G, BF, PL, etc)
Fittings	W, WW	All	CCTV	OF	Type (Tee, 90, 45, etc)
Fire Hydrant Lead	W	All	CCTV	OFH	Diameter, clock location
House Connection	W	All	CCTV	OHC	Clock location

Suggested Codes for Observations Part 2 – System Elements

OBSERVATION	UTILITY TYPES	PIPE TYPES	APPLICABLE INSPECTION TECHNOLOGIES	CODES	
				CODE	MODIFIER
Diameter Change	W, WW	All	CCTV	ODC	Diameter
Material Change	W, WW	All	CCTV	OMC	Material
Point Repair	W, WW	All	CCTV	OPR	Length, material
Turbidity	W	All	CCTV	OWQ	Degree – H, M or L
Turbulence	W, WW	All	Acoustics	OTU	Degree – H, M or L

Suggested Codes for Observations Part 3 – Screening Inspections

OBSERVATION	UTILITY TYPES	PIPE TYPES	APPLICABLE INSPECTION TECHNOLOGIES	CODES	
				CODE	MODIFIER
Gas pockets	W, WW	All	Acoustics	OGP	Location, length
Corrosive Soils	W, WW	Ferrous	Wenner Four Pin	OCS	Resistivity (ohms-cm)
		Cementitious	pH in-situ or lab tests	OSCp	pH (0 to 14)
Stray Currents	W, WW	Ferrous	Rosette test in situ	OSCr	Voltage, rosette direction
Active cell	W, WW	Ferrous	Close interval cell to cell	OCA	Voltage

Use of Defect Codes to aid in Four R Selection

- The “Four R’s”:
  - Re-inspection
  - Repair
  - Rehabilitation
  - Replacement
- Selection process facilitated using grading system
  - Similar to PACP Grading system : 1 to 5
  - Based on failure modes and defect codes for each type of pipe material
    - Ferrous Pipe – Steel, DIP and CIP
    - AC Pipe
    - Concrete Pipe – PCCP and RCP
    - Plastic – HDPE and PVC

Decision Tool for Selecting Four R Actions

Example For DIP

PIPE MATERIAL	SELECTION CRITERIA: DEFECTS: Defect Type	Defect Criterion 1	Defect Criterion 2	Defect Criterion 3	SURFACE CONDITIONS	Suggested GRADE	REINSPECTION: When	Technology	REPAIRS: Open Cut (1) All sizes	REHABILITATION TECHNOLOGIES: CIPP (2) 6 to 144	Swage lining (3) 6 to 60	SPRAY LINING: CML (4) See note	Epoxy (5) See Note	REPLACEMENT TECHNOLOGIES: PIPE BURSTING (6) 6 to 36	OPEN CUT (1) All Sizes
ALL PIPE	Inadequate Hyd. Capacity				Open (easement, field)	5	Not Required								X
					Sensitive (no trenching)	5								X	
	Leaks	Single Site			All Conditions	4			X						
		Multiple Sites				5			X						
FERROUS PIPE (DIP, CIP or STEEL)	LOSS OF WALL THICKNESS USING RFEC FULL LENGTH	Heavy Minimum FS < 1.2 (See Note 7)	Single Site	Any Age	Open (easement, field)	4	Not Required		X						
					Sensitive (no trenching)	4			X						
			Numerous Sites	Any Age	Open (easement, field)	5			X	X	X			X	X
					Sensitive (no trenching)	5			X	X	X			X	
		Moderate Minimum FS > 1.2 <2.0	Single Site	RUL < 50%	All Conditions	3	5 years	BEM, MFL	X						
				RUL > 50%		3	7 years	BEM, MFL	X						
			Numerous Sites	RUL < 50%	Open (easement, field)	4	Not Required		X	X	X	X	X	X	X
					Sensitive (no trenching)	4			X	X	X	X	X	X	X
				RUL > 50%	All Conditions	3	5 Years	BEM, MFL, RFEC							
		Light Minimum FS >= 2.0	Single Site	RUL < 50%	All Conditions	2	7 Years	BEM, MFL							
				RUL > 50%	All Conditions	2	10 Years	BEM, MFL							
			Numerous Sites	RUL < 50%	All Conditions	3	5 Years	BEM, MFL, RFEC				X	X		
				RUL > 50%	All Conditions	2	7 Years	BEM, MFL, RFEC				X	X		
	LOSS OF WALL THICKNESS USING UST OR BEM AT LOCAL SITES	Heavy Minimum FS < 1.2	Single Site	Any Age	Open (easement, field)	3	Now	Additional Sites w/BEM or MFL	X						
					Sensitive (no trenching)	3			X						
			Numerous Sites	Any Age	Open (easement, field)	4			X	X	X			X	X
					Sensitive (no trenching)	4			X	X	X			X	
		Moderate Minimum FS > 1.2 <2.0	Single Site	Any Age	Open (easement, field)	3	Now	Additional Sites w/BEM or MFL	X						
					Sensitive (no trenching)	3			X						
			Numerous Sites	RUL < 50%	Open (easement, field)	3	Not Required		X	X	X	X	X	X	X
					Sensitive (no trenching)	3			X	X	X	X	X	X	X
				RUL > 50%	All Conditions	2	5 Years	BEM, MFL, RFEC							
		Light Minimum FS >= 2.0	Single Site	RUL < 50%	All Conditions	2	7 Years	BEM, MFL							
				RUL > 50%	All Conditions	1	10 Years	BEM, MFL							
			Numerous Sites	RUL < 50%	All Conditions	2	5 Years	BEM, MFL, RFEC				X	X		
				RUL > 50%	All Conditions	2	7 Years	BEM, MFL, RFEC				X	X		
	WATER QUALITY ISSUES	If unlined	Rare	Any Age	All Conditions	4	Investigate operations					X	X		
			Repeated		All Conditions	5						X	X		
		If lined		Any Age	All Conditions	3	Now	Inspect lining							

Decision Tool for Selecting Four R Actions

PIPE MATERIAL	SELECTION CRITERIA					Suggested GRADE
	DEFECTS				SURFACE CONDITIONS	
	Defect Type	Defect Criterion 1	Defect Criterion 2	Defect Criterion 3		
ALL PIPE	Inadequate Hyd. Capacity				Open (easement, field)	5
					Sensitive (no trenching)	5
	Leaks	Single Site			All Conditions	4
		Multiple Sites				5
FERROUS PIPE (DIP, CIP or STEEL)	LOSS OF WALL THICKNESS USING RFEC FULL LENGTH	Heavy Minimum FS < 1.2 (See Note 7)	Single Site	Any Age	Open (easement, field)	4
					Sensitive (no trenching)	4
			Numerous Sites	Any Age	Open (easement, field)	5
					Sensitive (no trenching)	5
		Moderate Minimum FS > 1.2 <2.0	Single Site	RUL < 50%	All Conditions	3
				RUL > 50%		3
			Numerous Sites	RUL < 50%	Open (easement, field)	4
					Sensitive (no trenching)	4
				RUL > 50%	All Conditions	3
		Light Minimum FS >= 2.0	Single Site	RUL < 50%	All Conditions	2
				RUL > 50%	All Conditions	2
			Numerous Sites	RUL < 50%	All Conditions	3
				RUL > 50%	All Conditions	2
	LOSS OF WALL THICKNESS USING UST OR BEM AT LOCAL SITES	Heavy Minimum FS < 1.2	Single Site	Any Age	Open (easement, field)	3
					Sensitive (no trenching)	3
			Numerous Sites	Any Age	Open (easement, field)	4
					Sensitive (no trenching)	4
		Moderate Minimum FS > 1.2 <2.0	Single Site	Any Age	Open (easement, field)	3
					Sensitive (no trenching)	3
			Numerous Sites	RUL < 50%	Open (easement, field)	3
					Sensitive (no trenching)	3
				RUL > 50%	All Conditions	2
		Light Minimum FS >= 2.0	Single Site	RUL < 50%	All Conditions	2
				RUL > 50%	All Conditions	1
			Numerous Sites	RUL < 50%	All Conditions	2
				RUL > 50%	All Conditions	2
	WATER QUALITY ISSUES	If unlined	Rare	Any Age	All Conditions	4
			Repeated		All Conditions	5
		If lined		Any Age	All Conditions	3

Example For DIP
Defects and Suggested Grades

Decision Tool for Selecting Four R Actions

REINSPECTION		REPAIRS	REHABILITATION TECHNOLOGIES				REPLACEMENT TECHNOLOGIES	
When	Technology	Open Cut	CIPP	Swage lining	SPRAY LINING		PIPE BURSTING	OPEN CUT
					CML	Epoxy		
		(1)	(2)	(3)	(4)	(5)	(6)	(1)
All Sizes		All sizes	6 to 144	6 to 60	See note	See Note	6 to 36	All Sizes
Not Required								X
							X	
		X						
		X						
Not Required		X						
		X						
		X	X	X			X	X
		X	X	X			X	
5 years	BEM, MFL	X						
7 years	BEM, MFL	X						
Not Required		X	X	X	X	X	X	X
		X	X	X	X	X	X	X
5 Years	BEM, MFL, RFEC							
7 Years	BEM, MFL							
10 Years	BEM, MFL							
5 Years	BEM, MFL, RFEC				X	X		
7 Years	BEM, MFL, RFEC				X	X		
Now	Additional Sites w/BEM or MFL	X						
		X						
		X	X	X			X	X
		X	X	X			X	
Now	Additional Sites w/BEM or MFL	X						
		X						
Not Required		X	X	X	X	X	X	X
		X	X	X	X	X	X	X
5 Years	BEM, MFL, RFEC							
7 Years	BEM, MFL							
10 Years	BEM, MFL							
5 Years	BEM, MFL, RFEC				X	X		
7 Years	BEM, MFL, RFEC				X	X		
Investigate operations					X	X		
					X	X		
Now	Inspect lining							

Example For DIP

Four R Options

Decision Tool for Selecting Four R Actions

Example For DIP

PIPE MATERIAL	SELECTION CRITERIA: DEFECTS: Defect Type	Defect Criterion 1	Defect Criterion 2	Defect Criterion 3	SURFACE CONDITIONS	Suggested GRADE	REINSPECTION: When	Technology	REPAIRS: Open Cut	REHABILITATION TECHNOLOGIES: CIPP	Swage lining	SPRAY LINING: CML	SPRAY LINING: Epoxy	REPLACEMENT TECHNOLOGIES: PIPE BURSTING	OPEN CUT
									(1)	(2)	(3)	(4)	(5)	(6)	(1)
							All Sizes		All sizes	6 to 144	6 to 60	See note	See Note	6 to 36	All Sizes
ALL PIPE	Inadequate Hyd. Capacity				Open (easement, field)	5	Not Required								X
					Sensitive (no trenching)	5								X	
	Leaks	Single Site			All Conditions	4			X						
		Multiple Sites				5			X						
FERROUS PIPE (DIP, CIP or STEEL)	LOSS OF WALL THICKNESS USING RFEC FULL LENGTH	Heavy Minimum FS < 1.2 (See Note 7)	Single Site	Any Age	Open (easement, field)	4	Not Required		X						
					Sensitive (no trenching)	4			X						
			Numerous Sites	Any Age	Open (easement, field)	5			X	X	X			X	X
					Sensitive (no trenching)	5			X	X	X			X	
			Single Site	RUL < 50%	All Conditions	3	5 years	BEM, MFL	X						
				RUL > 50%		3	7 years	BEM, MFL	X						
		Moderate Minimum FS > 1.2 <2.0	Numerous Sites	RUL < 50%	Open (easement, field)	4	Not Required		X	X	X	X	X	X	X
					Sensitive (no trenching)	4			X	X	X	X	X	X	X
				RUL > 50%	All Conditions	3	5 Years	BEM, MFL, RFEC							
		Light Minimum FS >= 2.0	Single Site	RUL < 50%	All Conditions	2	7 Years	BEM, MFL							
				RUL > 50%	All Conditions	2	10 Years	BEM, MFL							
			Numerous Sites	RUL < 50%	All Conditions	3	5 Years	BEM, MFL, RFEC				X	X		
				RUL > 50%	All Conditions	2	7 Years	BEM, MFL, RFEC				X	X		
	LOSS OF WALL THICKNESS USING UST OR BEM AT LOCAL SITES	Heavy Minimum FS < 1.2	Single Site	Any Age	Open (easement, field)	3	Now	Additional Sites w/BEM or MFL	X						
					Sensitive (no trenching)	3			X						
			Numerous Sites	Any Age	Open (easement, field)	4			X	X	X			X	X
					Sensitive (no trenching)	4			X	X	X			X	
		Moderate Minimum FS > 1.2 <2.0	Single Site	Any Age	Open (easement, field)	3	Now	Additional Sites w/BEM or MFL	X						
					Sensitive (no trenching)	3			X						
			Numerous Sites	RUL < 50%	Open (easement, field)	3	Not Required		X	X	X	X	X	X	X
					Sensitive (no trenching)	3			X	X	X	X	X	X	X
				RUL > 50%	All Conditions	2	5 Years	BEM, MFL, RFEC							
		Light Minimum FS >= 2.0	Single Site	RUL < 50%	All Conditions	2	7 Years	BEM, MFL							
				RUL > 50%	All Conditions	1	10 Years	BEM, MFL							
			Numerous Sites	RUL < 50%	All Conditions	2	5 Years	BEM, MFL, RFEC				X	X		
				RUL > 50%	All Conditions	2	7 Years	BEM, MFL, RFEC				X	X		
	WATER QUALITY ISSUES	If unlined	Rare	Any Age	All Conditions	4	Investigate operations					X	X		
			Repeated		All Conditions	5						X	X		
		If lined		Any Age	All Conditions	3	Now	Inspect lining							

EPA Primer on Condition Curves for Water Mains

- Empirical/Statistical for small diameter.
- Hard data for large diameter.
- RUL is not a quantifiable value.
- Additional research is needed on how to design more efficient and cost-effective data collection strategies, how to extract information from existing datasets, and how to standardize names and definitions for water utility assets, which subsequently will allow the data to be shared and compared across utilities.
- A longer-term goal should be to develop a national database of assets and failures with common terminology and methods of data collection and analysis for assets and breaks.

Summary and Recap

- Described an approach for using calculated factors of safety to prioritize pressure pipelines for follow-on work
- Presented a draft set of defect codes for pressure pipelines
- Suggested a method for using defect codes to develop quantifiable condition assessment evaluations
- Developed a decision tool to aid in selecting follow-on actions based on the inspection and condition assessment

Brown AND Caldwell

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Condition Assessment of Pressure Mains

Henry R. (Kelly) Derr
Presented by Ralph Gabriel, P.E., (Oregon)

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