Leveraging Advancing Technologies for Pipe Replacement and Condition Assessment at WaterOne

75th Annual Environmental Engineering Conference

Wednesday, April 16th: 1:45 – 2:30

Jason Beyer & Peter Gaskamp, PE

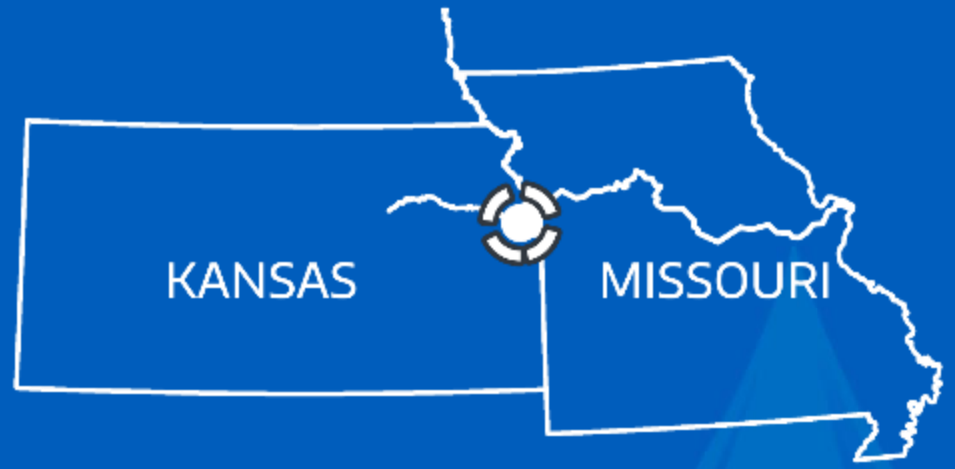
WaterOne | Distribution Division

AGENDA

1. GIS Data Validation & Data Collection for Pipe Replacement Prioritization
2. Machine Learning for Predicting Future Main Break Locations / High-Risk Water Mains
3. Risk Analysis modeling to prioritize Transmission Mains for Condition Assessment
4. Transmission Main Condition Assessment

ABOUT WATERONE

- 272 Square Mile Service Area
- 450,000 + Customers
- 150,000 + Accounts
- 200 MGD System Capacity
- 2 Treatment Plants
- Dual River Intake Sources
- 2,700 Miles of Infrastructure



- Founded in 1957
- Independent, non-profit public water utility
- Serves 17 cities throughout Johnson County
- The largest water utility in the state of Kansas

WaterOne's Infrastructure at a Glance

Miles of Main
180.33
Transmission Main [Potable]

Hydrants
19,029

Residential Connections
141,715

Commercial Connections
14,388
[includes Exempt, Special Agreement, Wholesale]

Miles of Main
2,652.79
Distribution Main

System Valves
50,678

Control Valves
4,922

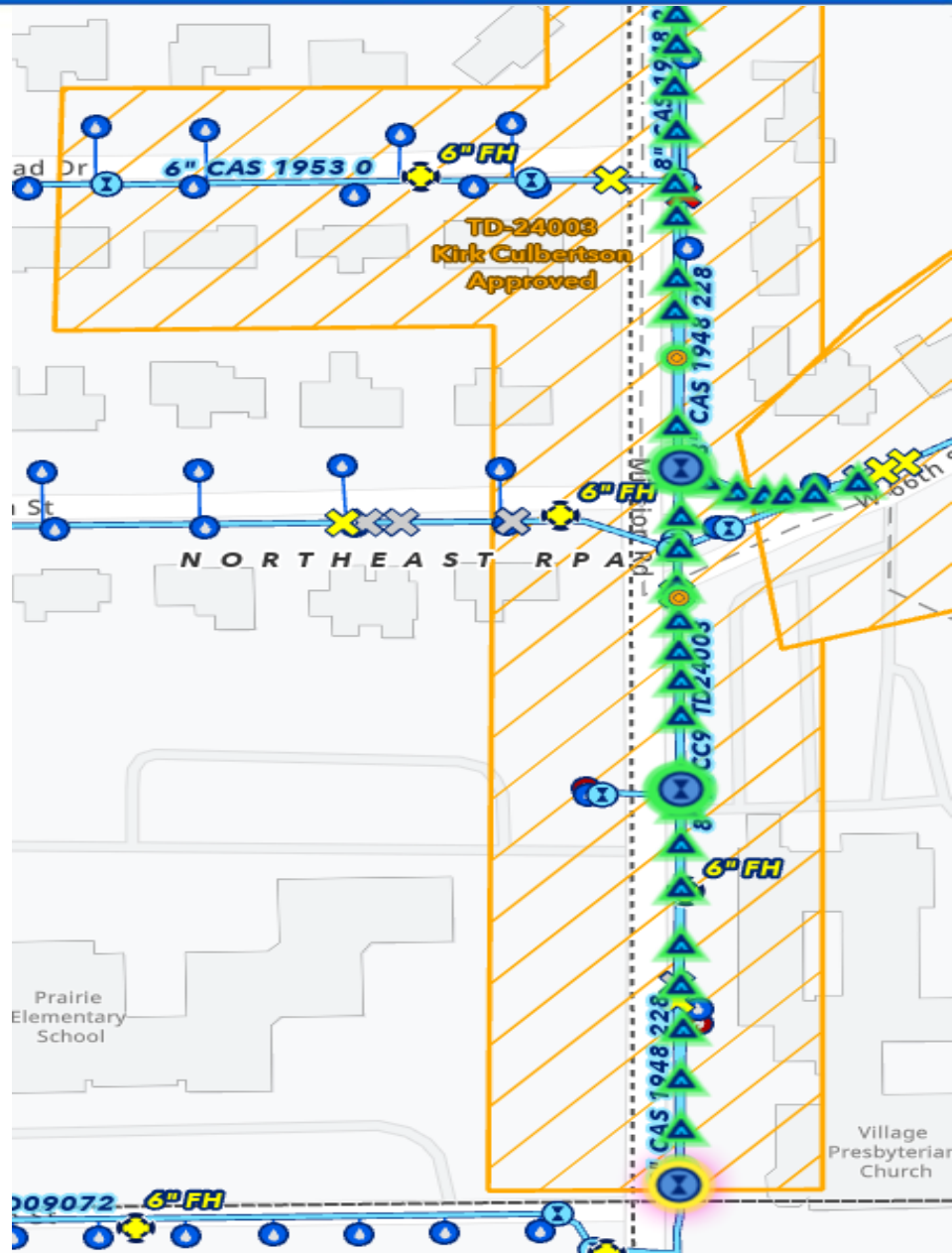
Main Breaks Last Month
39
212 this year

Data Cleanse & Data Validation

- Validated location and info of 8,000+ main breaks
- Validated 65,000+ segments of main for install date, material, diameter and project name
- Required all field crews to capture a GPS shot on all main breaks and every asset installed on construction projects (2018)
  - Used a mix of agreed upon required fields and default values in the collection software and extensive training to gain crew buy-in

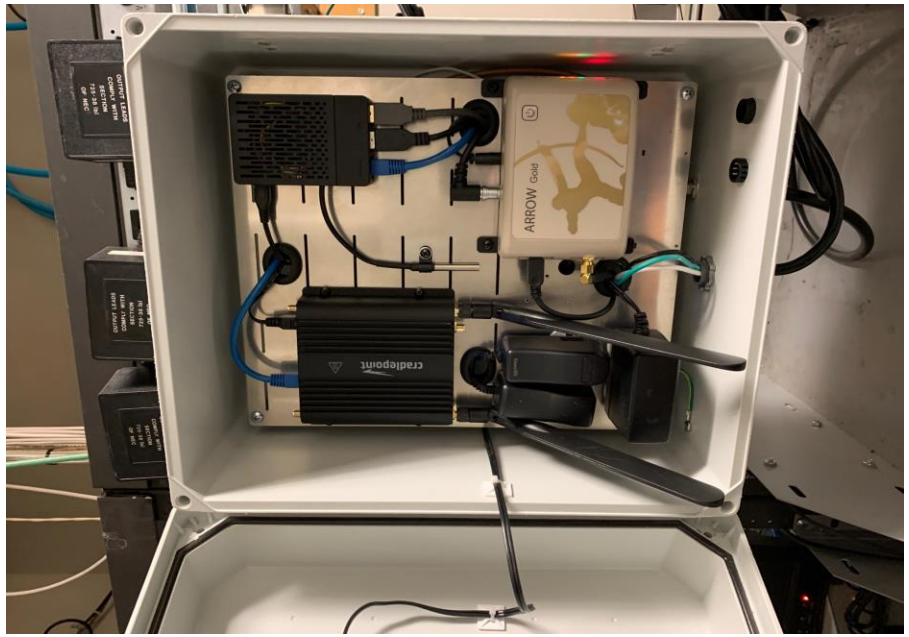
Real Time GPS & GIS Editing

- All assets are GPS'd in real time by either our in-house construction crews or inspectors monitoring contracted crews
- All assets then added to GIS in real time by editing staff
  - No longer referring to as-builts or paper forms when posting
- WaterOne VIEW – Internal GIS Mapping



EOS Arrow Gold

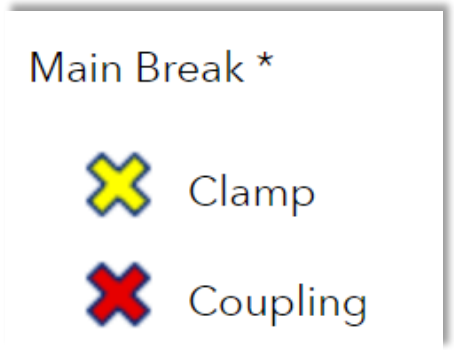
EOS Gold Base Station

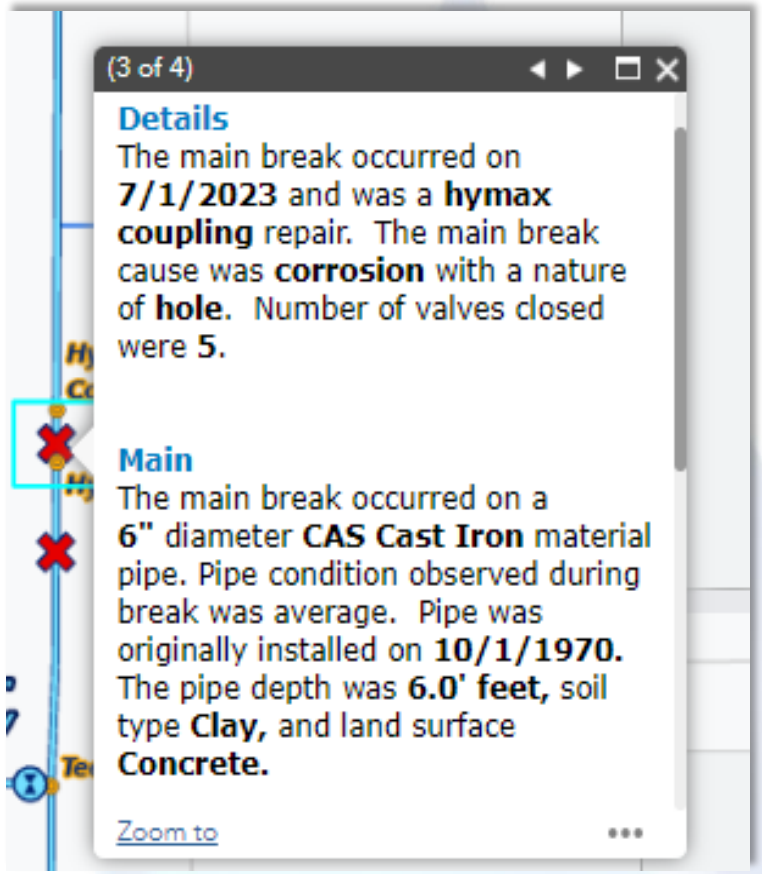


Field Maps

Comprehensive Main Break Data

- Main break data complete for past 10 years
- Repair date, type of repair, cause, depth, soil type, surface type, observed condition & repair cost
- Symbology & pop-up info helps crews easily identify break type and make informed decisions





Small Diameter Water Main Replacement Prioritization

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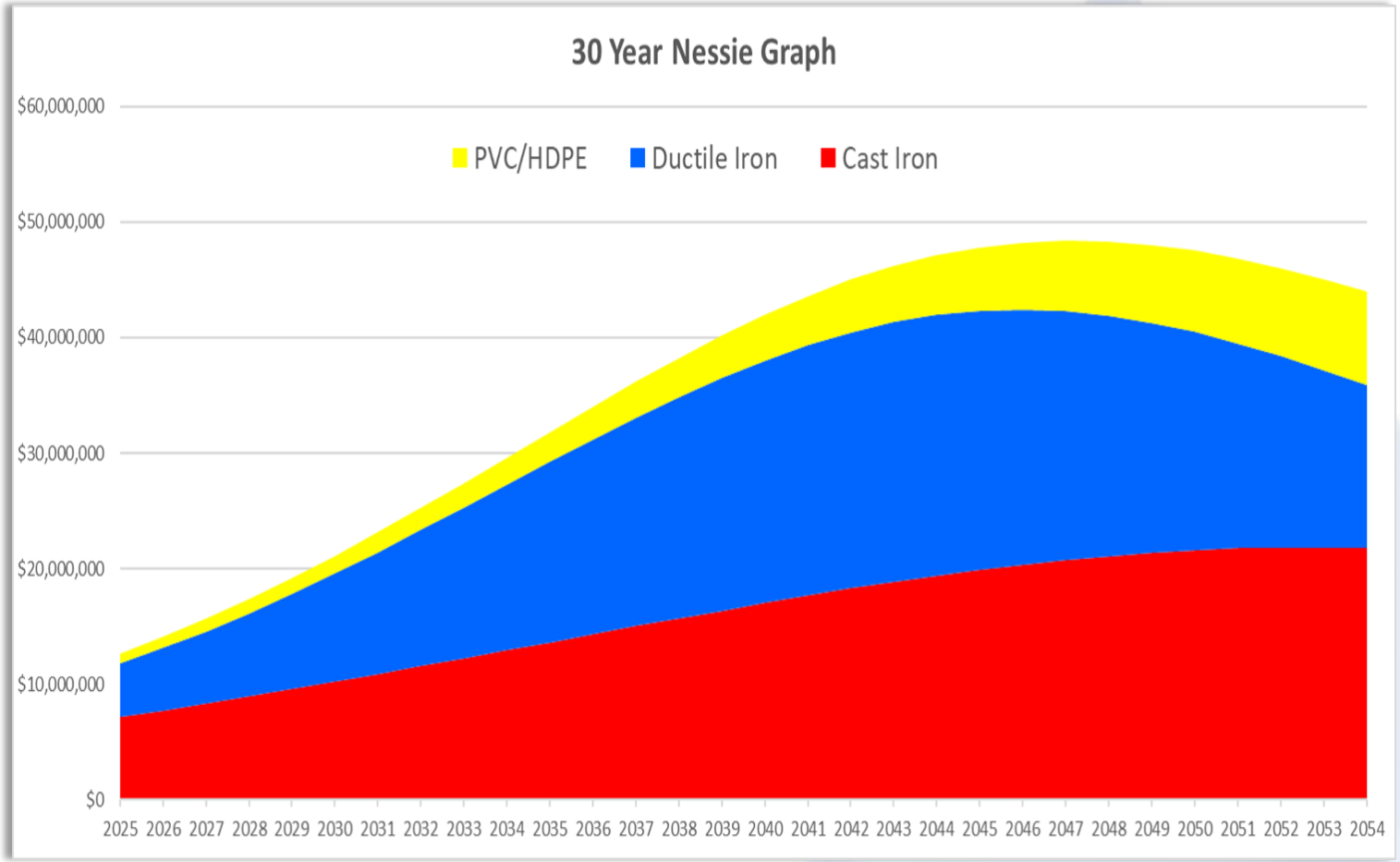
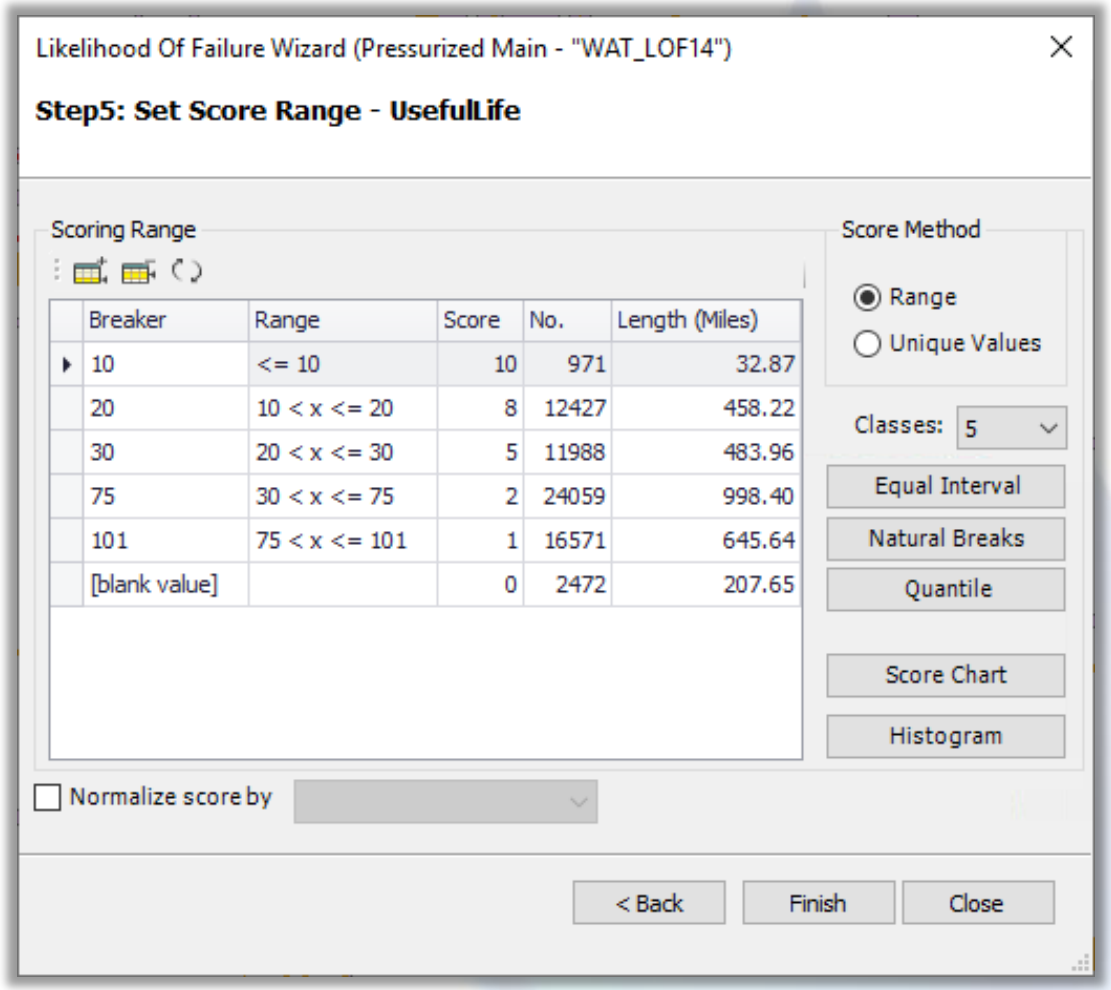
Future Miles/Cost of Replacement

- 2019 - 11.5 mi ($8.5M)
- 2025 - 17.1 mi ($15.7M)
- 2030 - 24.8 mi ($26.8M)
- 2042 – 36.8 mi ($57.5M)



Risk Criteria for Distribution Mains

- Likelihood of Failure (LOF)
  1. Pipe Diameter (16-inch and smaller)
  2. Remaining Useful Life
  3. Pipe Lined Y/N
  4. Soil Type
  5. Pressure
  6. Main Break History
  7. Main Breaks Within Previous Year
  8. Valve Criticality
  9. ML Score (Top 1%)
- Consequence of Failure (COF)
  1. Proximity to Large or Critical Users
  2. City Improvement Projects
  3. Location of System Upgrades (Master Plan)
  4. Location of System Expansion (Master Plan)
  5. Mains in Pavement (50% or more)
  6. Main Break Repair Costs



Distribution Engineering Dashboard Desktop

Cast Iron Failure Rate YTD

36.65

Ductile Iron Failure Rate YTD

9.81

Distribution Main Failure Rate YTD

16.26

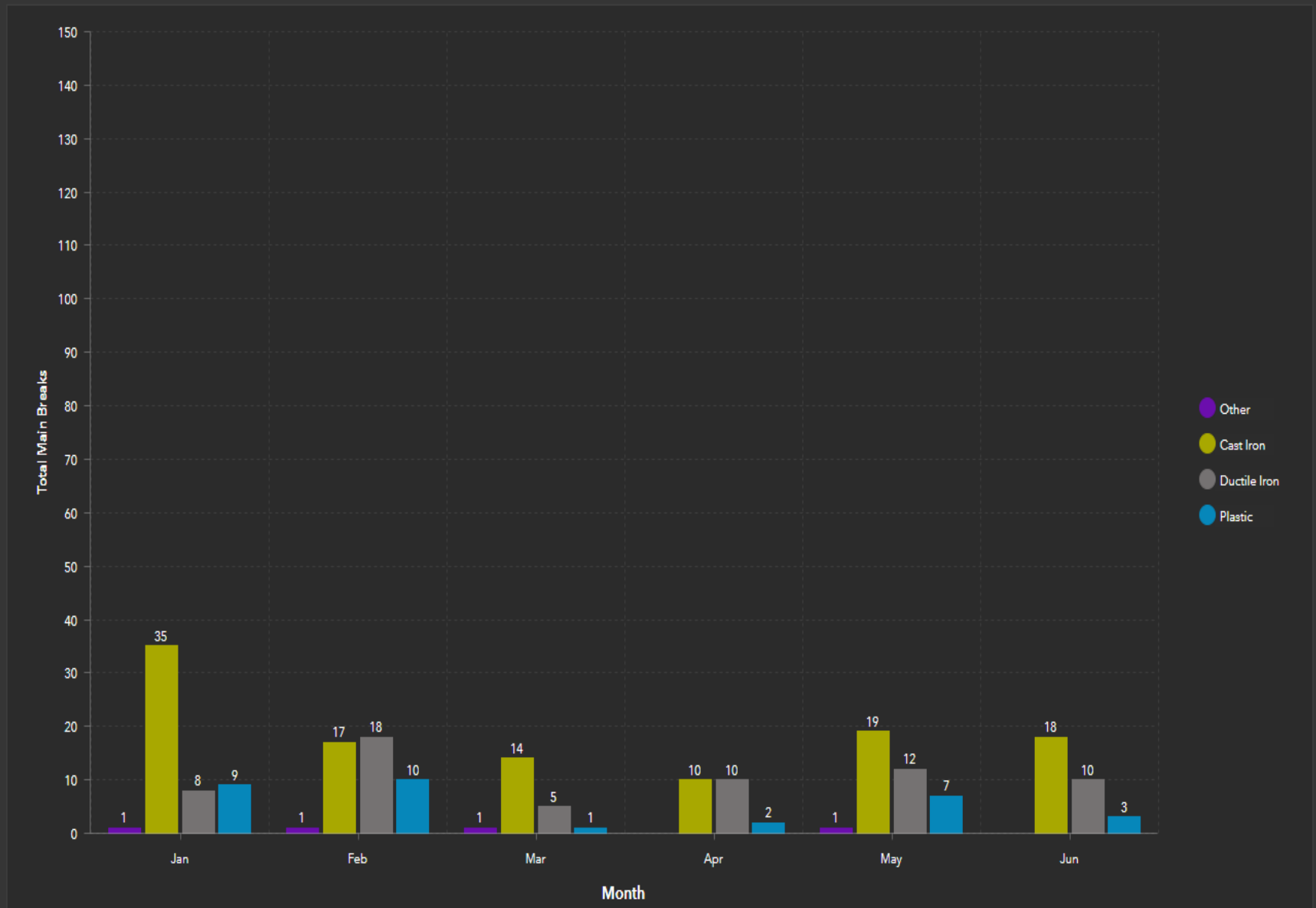
Historical Year Distribution Main Failure Rate

**Breaks per 100 miles of main*

Year	Cast Iron	Ductile Iron	Total Failure Rate
2018	64.8	13.3	25.9
2019	50.2	11.1	19.7
2020	52.5	13.4	20.9
2021	52.0	15.0	21.6
2022	82.8	15.9	30.1
2023	73.6	18.2	28.2

Historic Main Breaks By Material

Year Range (2000 - Pres...
2024



AI/ML Model Pilot Program

- To be EVEN MORE proactive in our replacement program, In 2021, Engineering and GIS staff started meeting with vendors to better understand the data requirements and capabilities of Machined Learned (ML) models.

- The decision was made to pursue a pilot program using 250 mi (10%) of water main

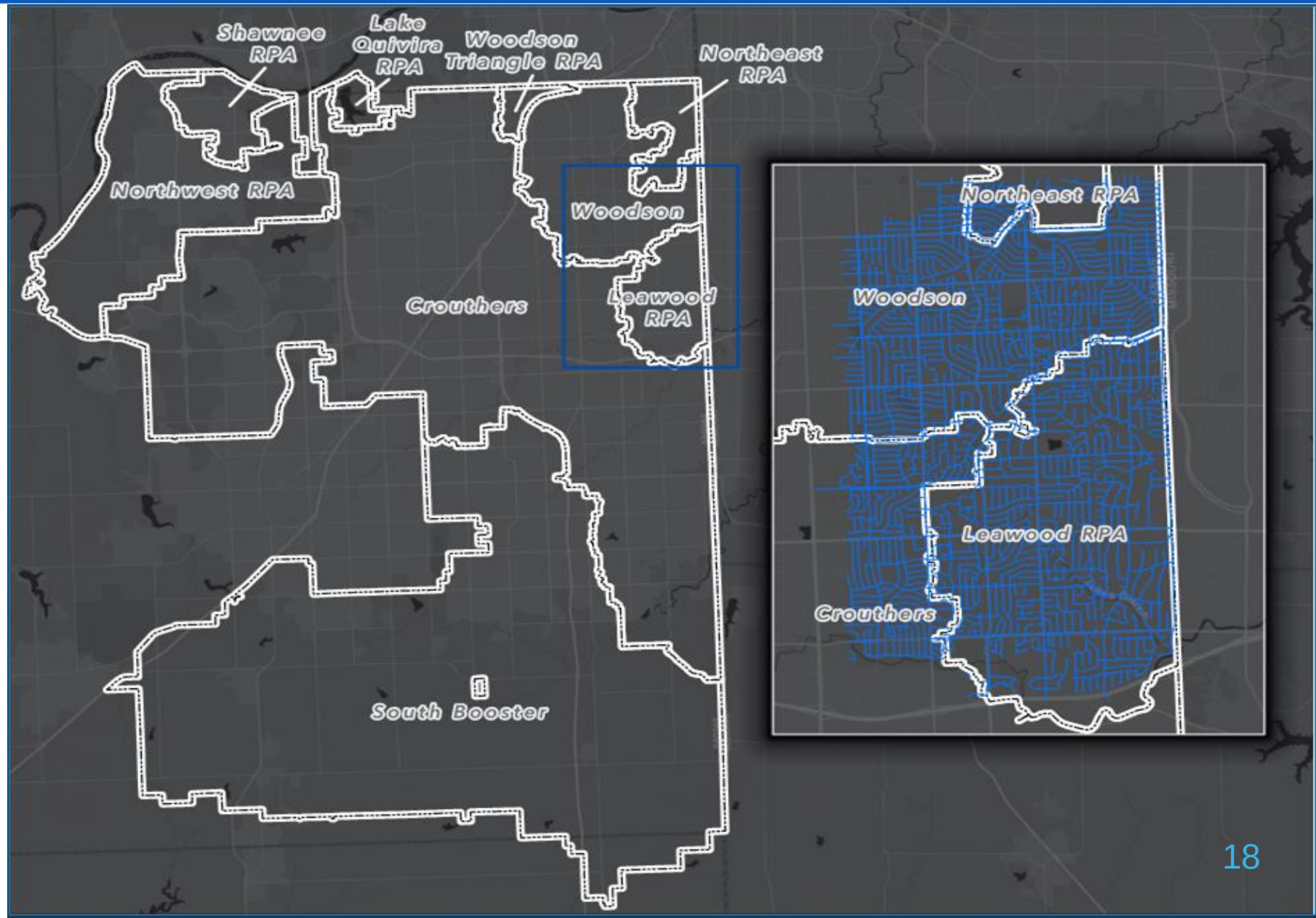
- Rezatec, our chosen vendor, had a unique approach to building an AI/ML model that we felt was a perfect fit for WaterOne and a joint ventured pilot program.

What to Consider Before Tackling AI/ML

- How much ownership/decision making do you want to have with the data?
- How will you validate the results? / How will you measure the success of the model?
- How will you utilize or incorporate the data?

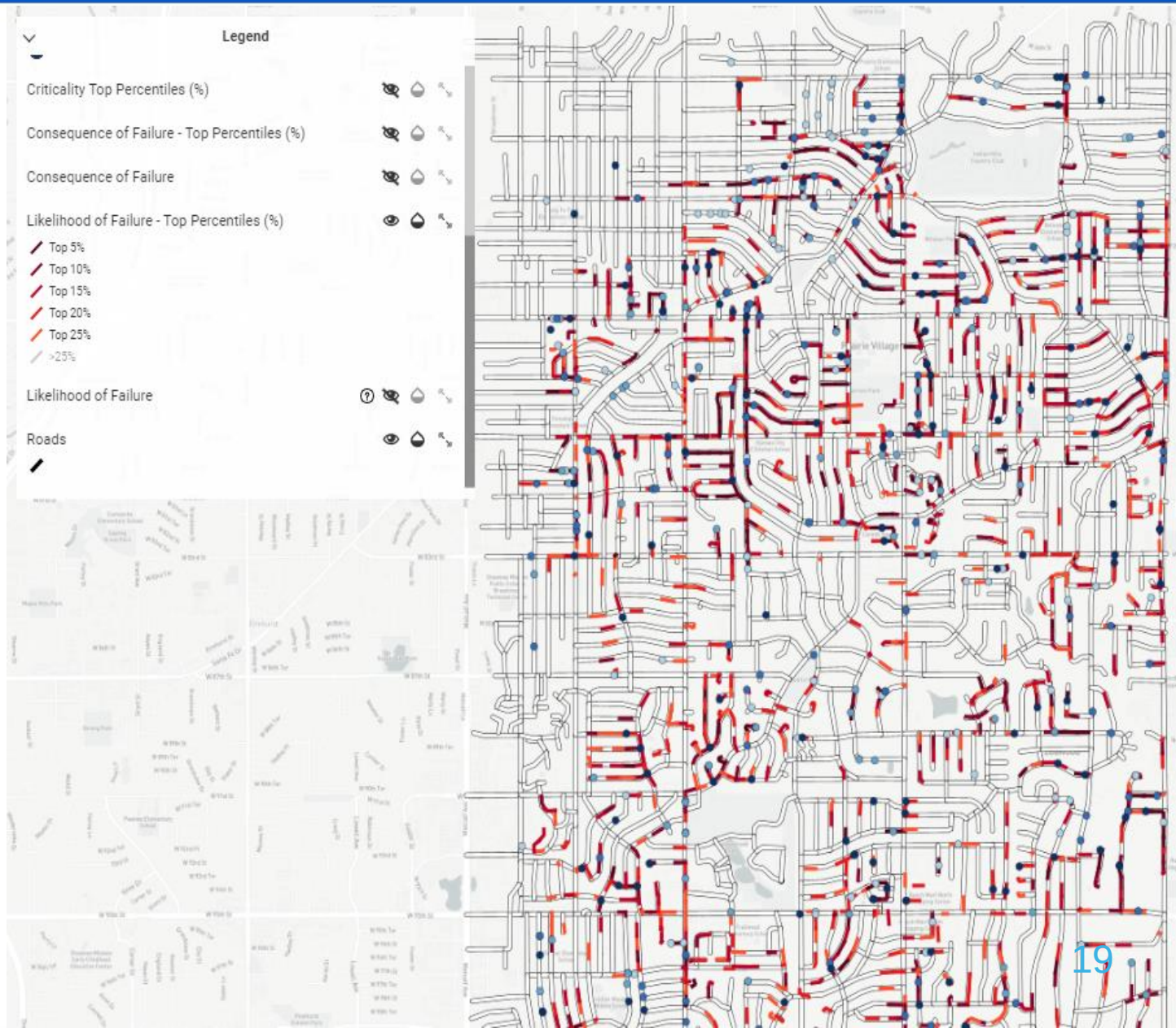
Pilot Area

- The chosen Pilot Area had a good variety of age and materials and has a relatively high break rate



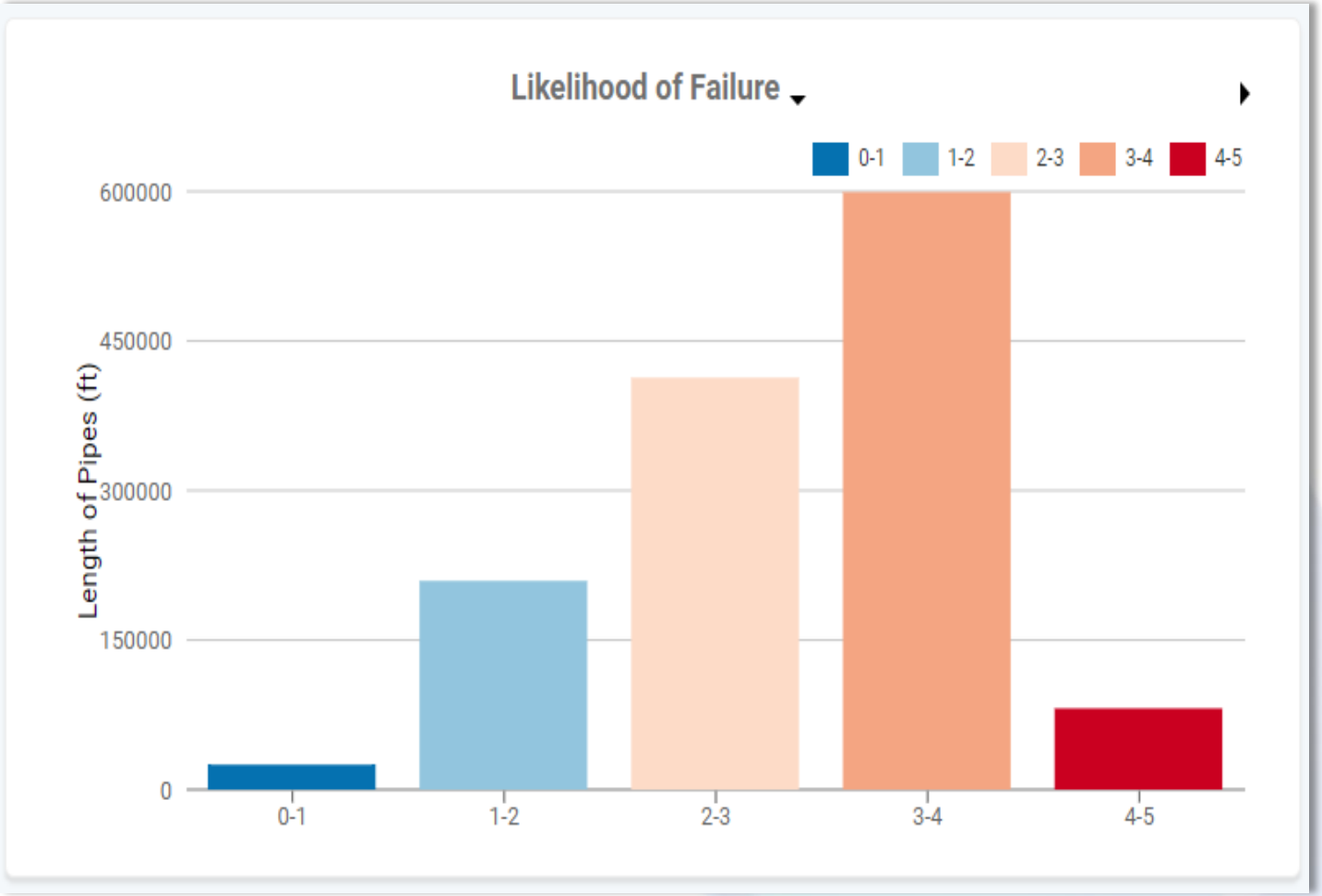
Building the Model

- Validation model was built using:
  - 3 years of main break data while the 4th year was withheld
  - Distribution water main dataset which included material, diameter, age, etc.
  - Satellite data specifically looking at changes in ground motion and vegetation growth as well as historic climate data



Validating Results

- Criteria:
  - Correctly predicting at least 70% of the breaks in the top 30% highest risk mains
  - **We each had a week to separately validate results**
- Results: First Model Run
  - Achieved **73%** Accuracy
  - But model was incorrectly associating newly installed water main with old/retired breaks



Digging Through the Results

Top 30% Highest Risk Pipe		
Material	**Length (ft)**	**% of Pipe**
Ductile & Cas	291,650	72%
Plastic	102,779	26%

Main Breaks During Validation Period	
Material	# of Breaks
Ductile & Cas	163
Plastic	3

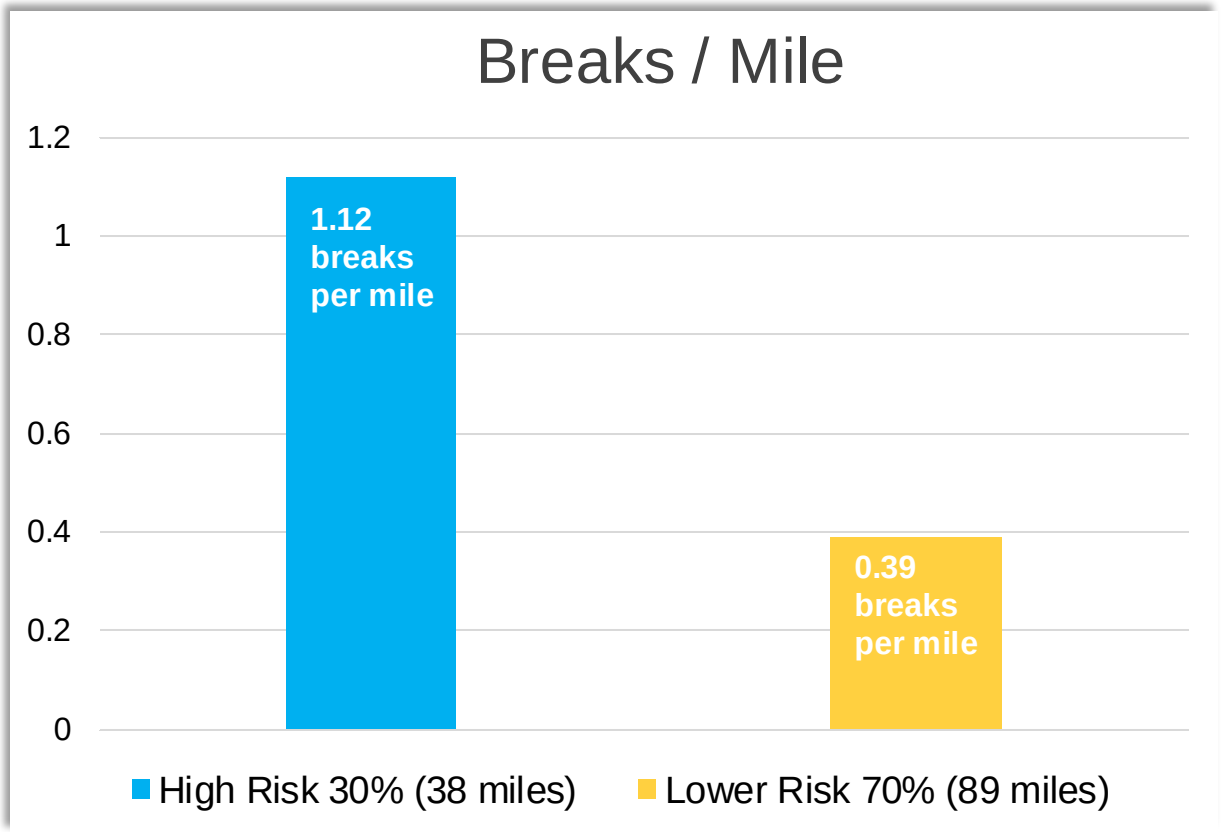
Top 5% Highest Risk Pipe		
Material	Length (ft)	% of Pipe
Ductile & Cas	44,327	67%
Plastic	21,695	33%

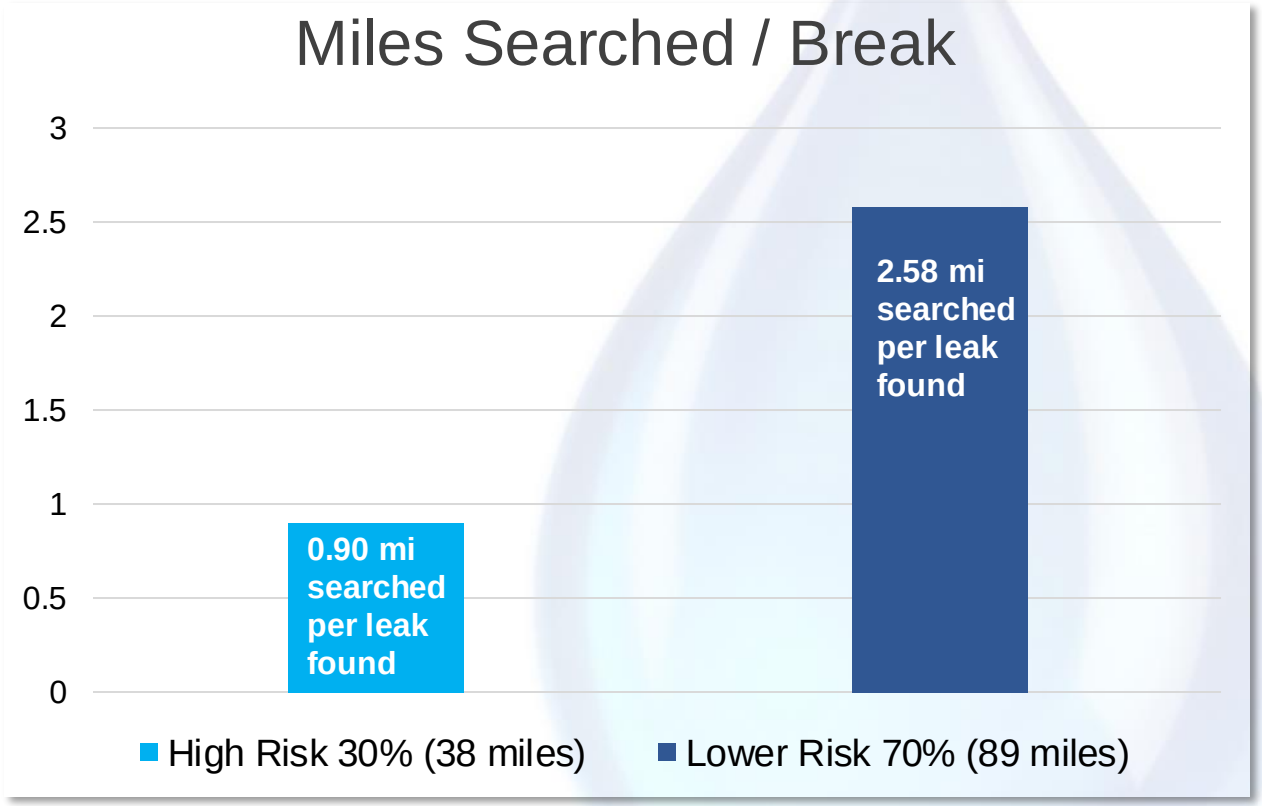
Digging Through the Results

- Second Model Run
  - Achieved 78% Accuracy
  - No Plastic pipe included in the top 30%
- 2023 Forward predicting model provided further validation

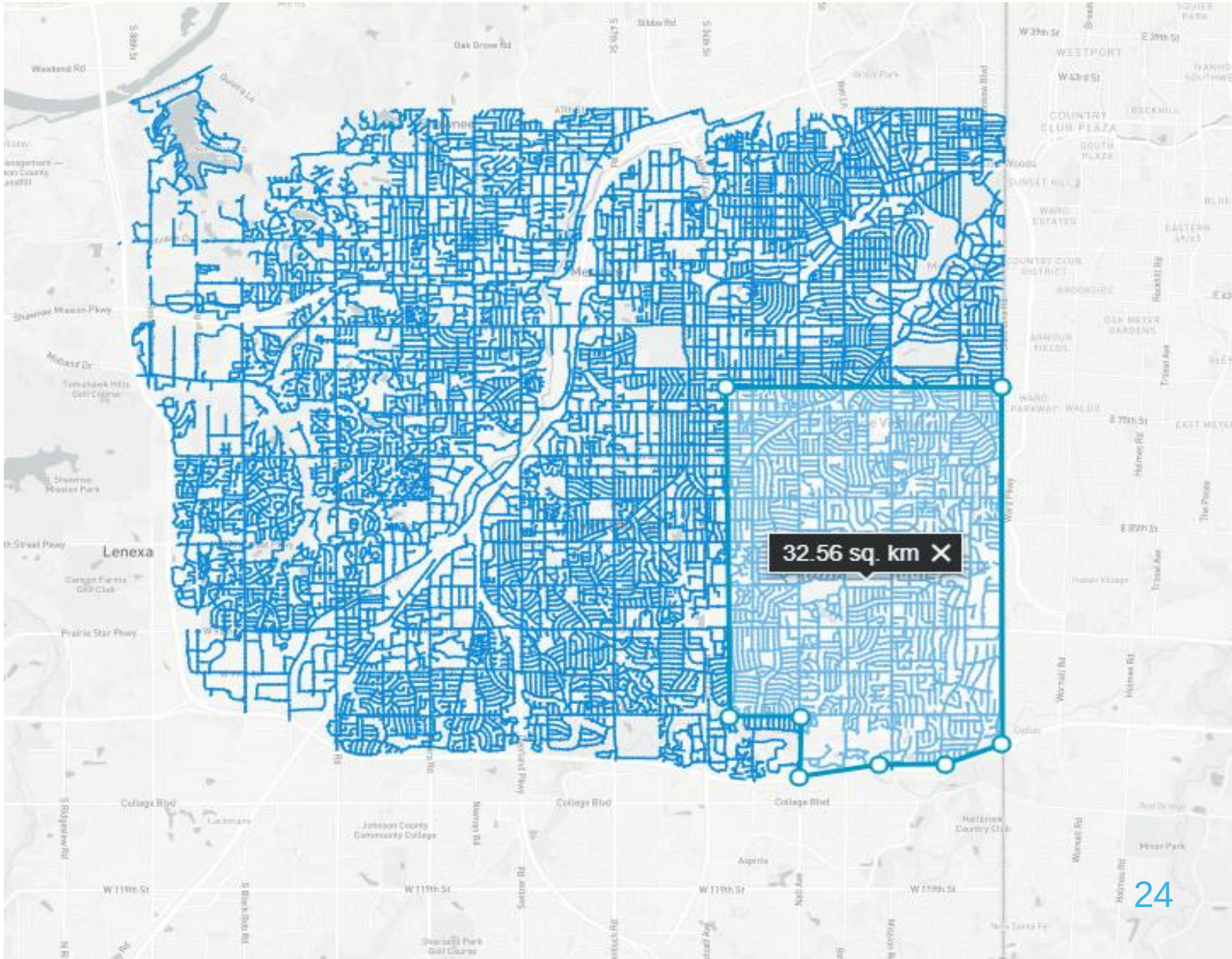
Age (years)	Material	Diameter (in)	Road Name	Valve FacilityID	Valve GlobalID	Likelihood of Failure (LoF)	LoF - Top Percentile
101	CAS	6	W 74TH ST	723324	{8C021B62-...	3.84	15
96	CAS	6	W 68TH ST			3.67	20
96	CAS	6	W 68TH ST			4.03	10
92	CAS	6	W 71ST TER			3.59	25
92	CAS	6	W 71ST TER			3.89	15
87	CAS	6	W 79TH ST	508614	{159D0B6B-...	4.08	10
84	CAS	6	W 75TH ST	502990	{9B43A721-...	4.33	5
84	CAS	8	SOMERSET ...			3.56	25
84	CAS	8	SOMERSET ...	666488	{83CFBD90-...	3.56	25
84	CAS	8	SOMERSET ...			3.56	25

Find More Breaks in Less Time





- Expansion from 250 miles to 1,100 miles

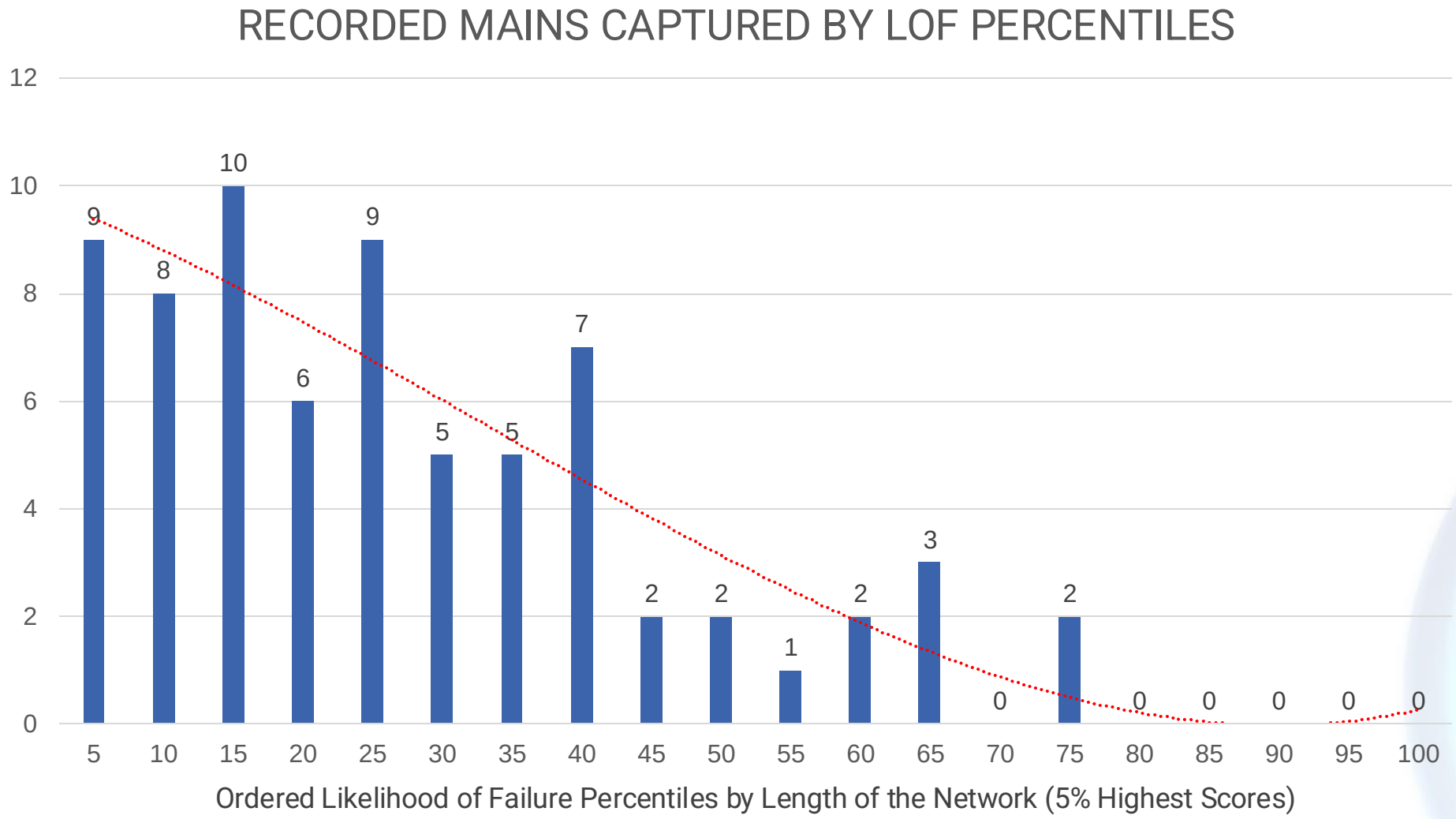


Aggregating the Data for Optimal Use

Road ID	Road Name	Length (ft)	Mean Diameter (in)	Material(s)	Max LoF	Min LoF	Average LoF	Max CoF	Min CoF	Average CoF	Max Criticality	Min Criticality	Average Criticality
3898	W FRONTAGE RD	4302.57	9.806	DIP,PVCC9	2.89	0.17	1.53	1.01	0.67	0.82	0.66	0.05	0.36
4590	ABERDEEN RD	4282.93	8.211	CAS,DIP,PVCC9	3.34	0.29	1.61	1.01	0.50	0.69	0.49	0.04	0.27
7722	LAKESHORE SOUT...	3589.84	6.421	DIP,CAS,PVC	3.96	0.73	3.12	0.67	0.50	0.54	0.67	0.11	0.49
1829	W 71ST ST	3307.07	6.000	PVCC9	1.05	0.56	0.75	0.50	0.50	0.50	0.15	0.08	0.11
7503	FOXRIDGE DR	3288.22	12.000	CAS,DIP	3.15	0.25	1.64	1.01	1.01	1.01	0.92	0.07	0.48
10910	GODDARD ST	3213.38	7.840	DIP	2.90	1.07	2.04	0.67	0.50	0.66	0.56	0.21	0.39
1800	W 69TH ST	3200.39	12.000	PVCC9,HDPE	0.38	0.23	0.31	1.01	1.01	1.01	0.11	0.07	0.09
8314	BELL RD	3150.62	6.000	PVCC9,DIP,CAS,PVC	4.05	0.51	2.45	0.50	0.50	0.50	0.59	0.07	0.36
964	BELINDER RD	3043.26	6.462	CAS,PVCC9	3.02	0.27	0.90	0.67	0.50	0.54	0.59	0.04	0.15
22994	W COUNTRY CLUB ...	3011.80	10.286	CAS,DIP,HDPE	3.59	0.23	1.51	1.34	0.67	0.86	0.70	0.09	0.31

Showing 1 - 10 of 13764 rows

‹ 1 2 3 ... 1376 1377 ›

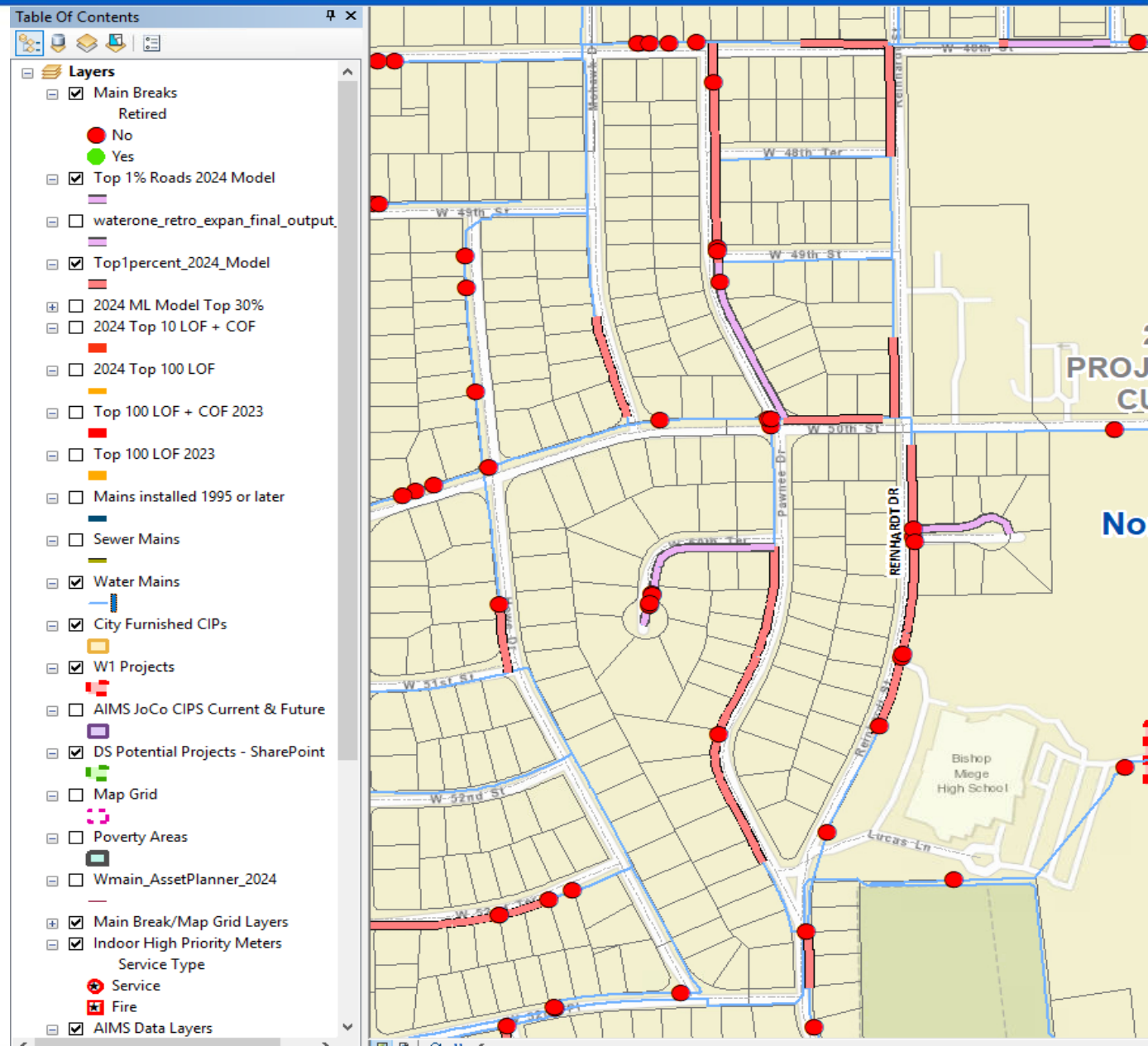


Post Modelling Validation:

- 71 total main breaks used for validation
- Significant skew towards highest risk brackets.
- 27 breaks in top 15% of risk.
- More breaks in top 5% of risk (12%) than the bottom 50% (11%).

So, What's next?

- 13 replacement projects have gone to design over the course of the last few months solely off the ML results
- Currently validating the remainder of the 2024 breaks to identify final success rate
- Pilot project using leak detection investigation is being considered



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Transmission Main Condition Assessment

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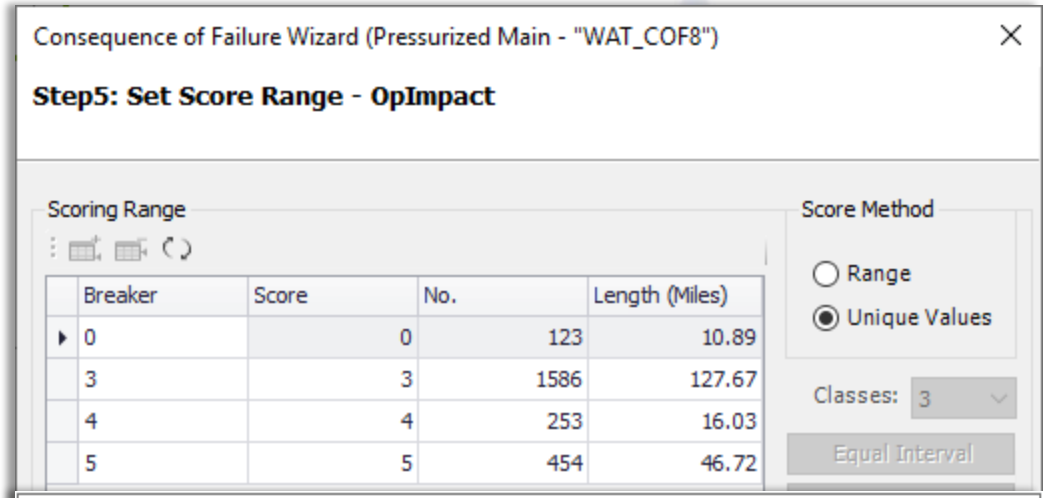
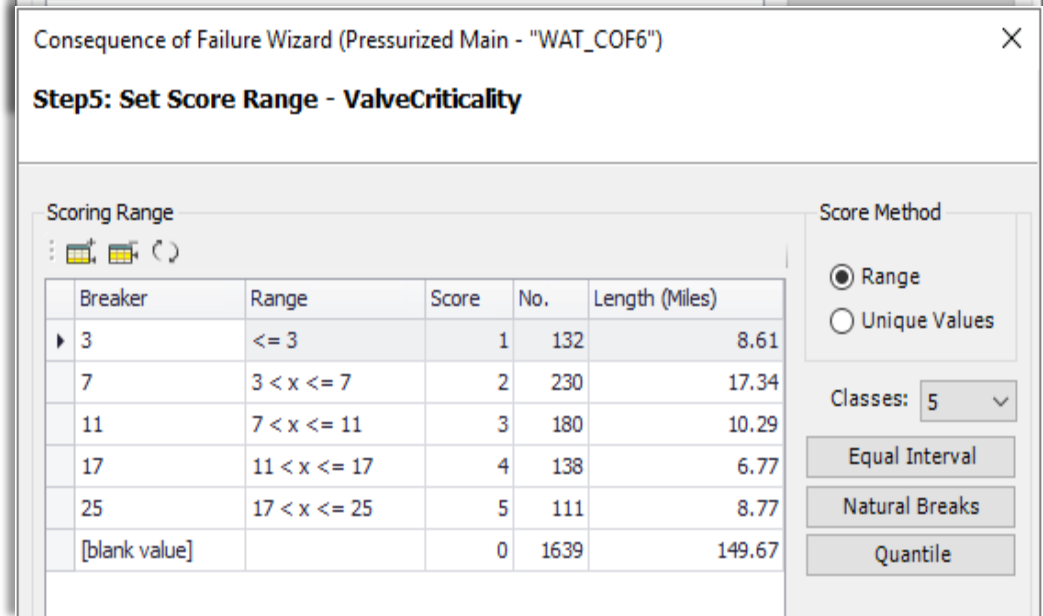
Risk Criteria for Transmission Mains

- Likelihood of Failure (LOF)
  1. Pipe Material
  2. PCCP Class IV
  3. Pipe Polywrap Status
  4. Remaining Useful Life
  5. Main Break History
  6. Cathodic Protection
  7. Condition Assessment Results

- Consequence of Failure (COF)
  1. Pipe Diameter
  2. Operational Impact
  3. General Alignment – Under Pavement
  4. Impact to Public Safety
  5. City CIP Projects
  6. Major Street Crossings
  7. Prox. to Buildings
  8. # of Distribution Tie-Ins
  9. Service Connections





- Every pipe was assigned a score then scores were normalized by project number

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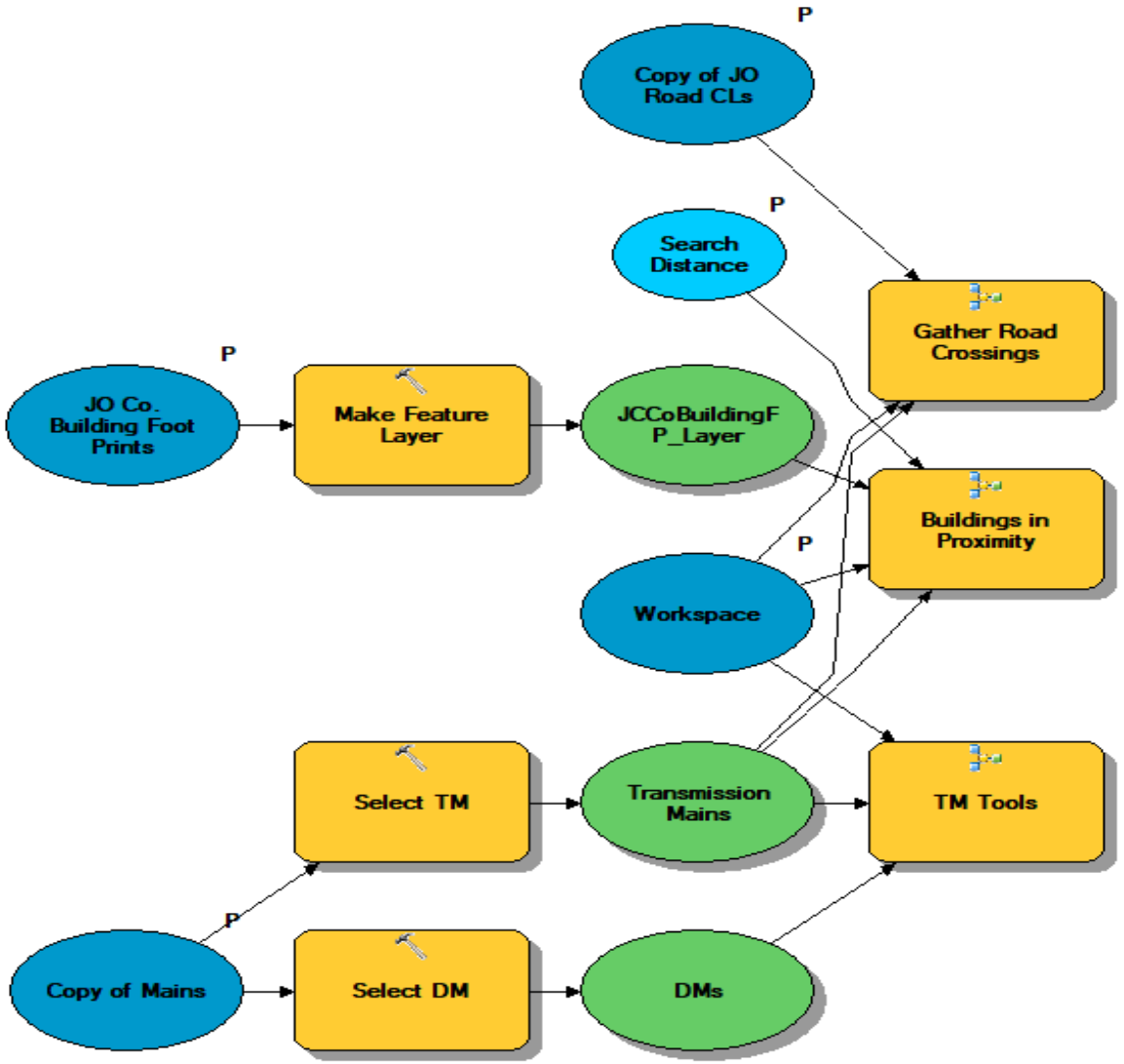
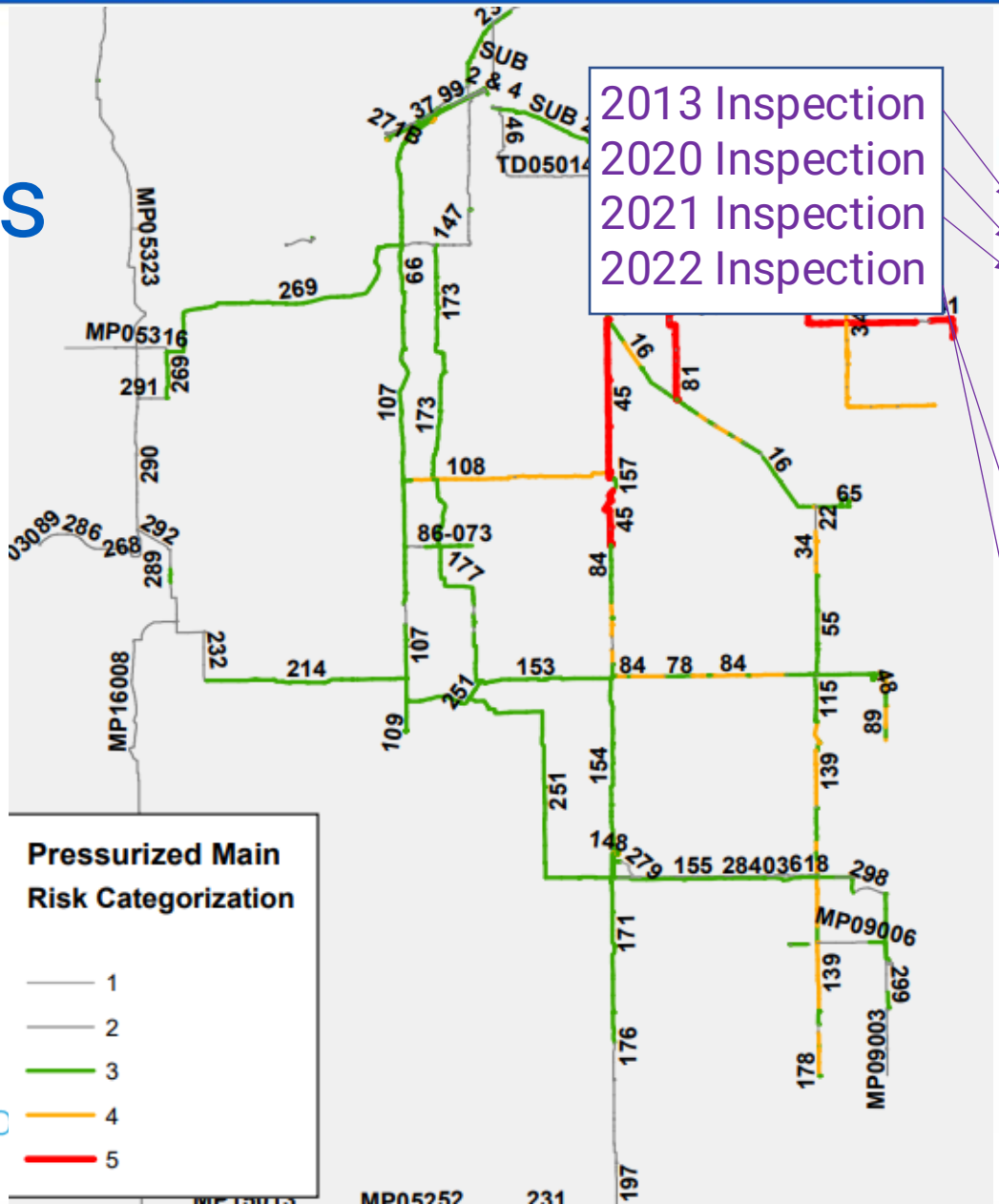
Use of Model Builder to Automate Workflows

- Several of the criteria for Condition Assessment are not existing attributes in our GIS
- Extra time investment on the front end saves time for future outputs and revisions on the back end
- Allowed us to perform more extensive geoprocessing before importing the data to Asset Planner and assigning scores



InfoAsset Planner Results

- Validation of what pipes/projects have Been inspected so far
- Identified new projects to inspect that are further away from major facilities
- 5-Year Rolling Plan For Future Inspections/Re-Inspections



Summary of Project LOF, COF, and Risk Scores 10.06.2021

Total Risk Score = LOF X COF / # of GIS Pipe Segments

Rank	Project No.	LOF Totals	COF Totals	Total Risk Score
1	29	1863	1890	51030
2	81	1358	1944	33860
3	45	1020	1469	29380
4	34	943	2721	27604
5	84	1006	1421	22694
6	107	552	1861	14888
7	148	674	1345	14618
8	141	578	818	13906
9	139	471	1238	11198
10	93	539	1586	11102
11	99	362	1719	9904
12	9915	364	656	9184
13	SUB 2	352	1095	8760
14	153	318	1171	8275
15	16	483	875	8214
16	147	456	1145	8034
17	173	308	1120	7840
18	231	352	933	7464
19	208	360	919	7352
20	269	280	970	6790
21	177	288	824	6592
22	55	263	1053	6151
23	108	225	615	5535
24	89	248	377	5492
25	154	210	731	5117

Transmission Main Condition Assessment at WaterOne

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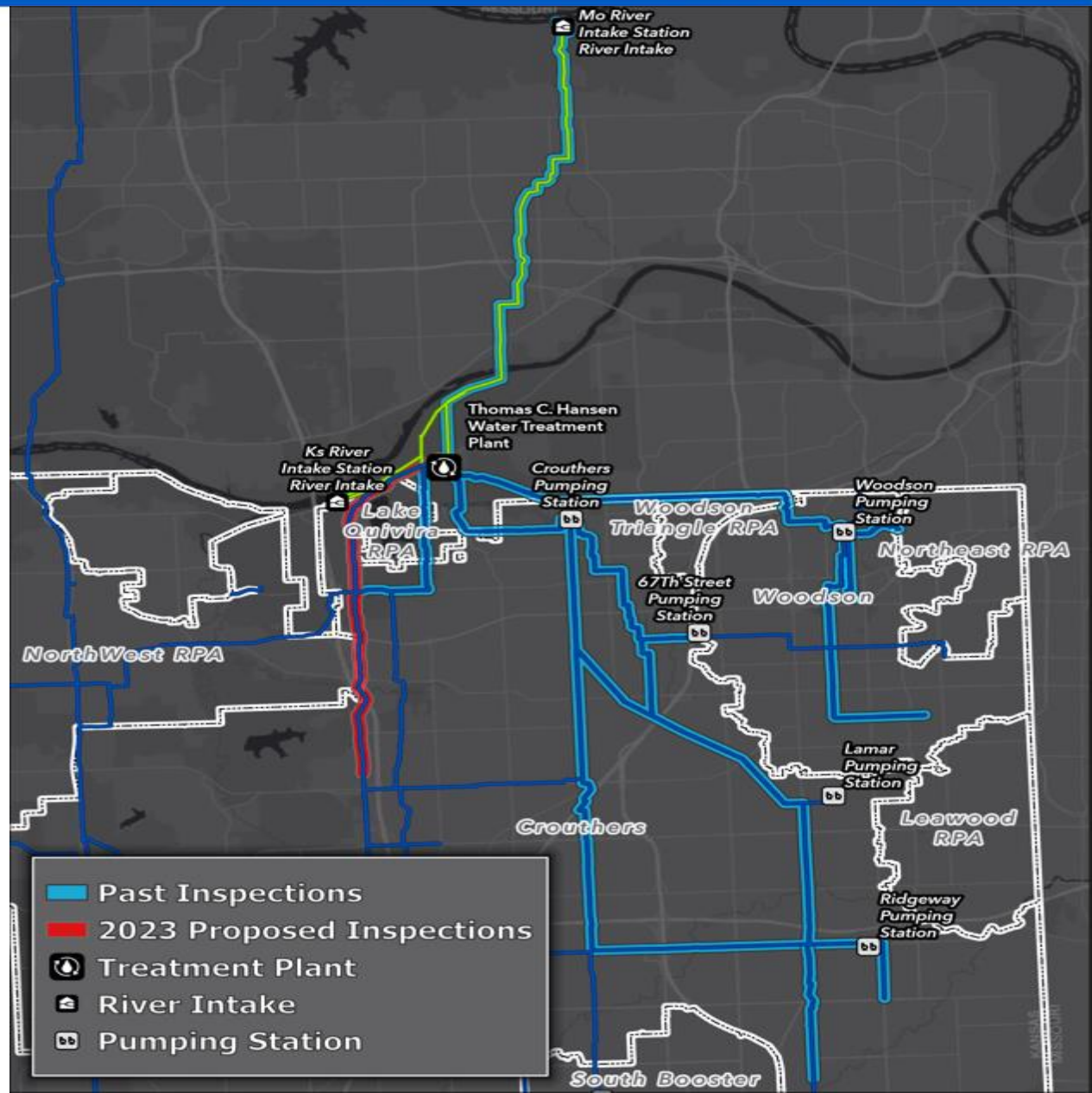
Transmission Main Condition Assessment Program

- 2024 budget of 640K
- Over 91 mi inspected to date (46% of 200 mi)
- Over 55 pipe repairs/replacements have been made (2007-2024)
- Expected results from condition assessment
  - Schedule future re-inspections
  - Targeted repairs
  - Future Master plan projects



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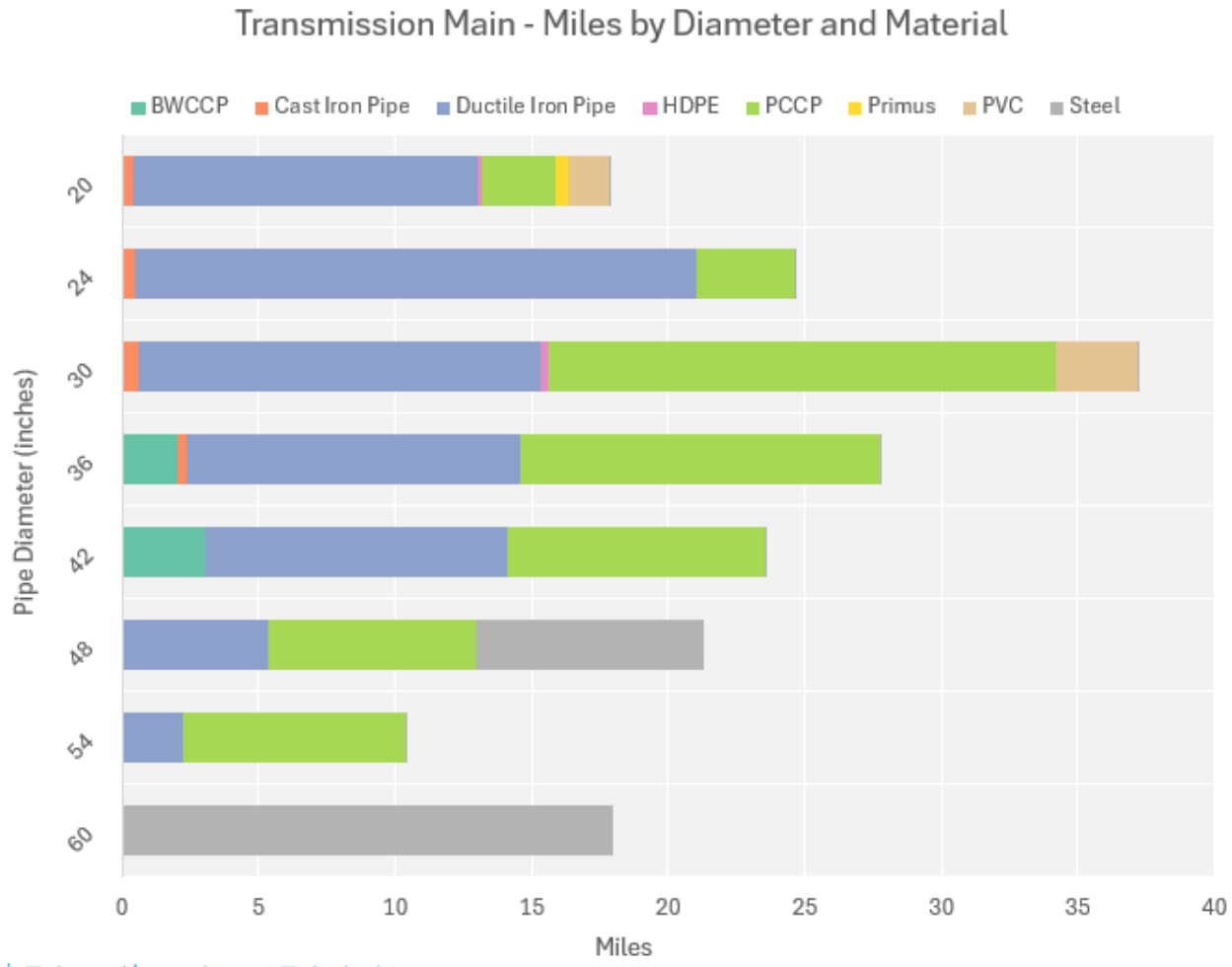
WaterOne Transmission Mains



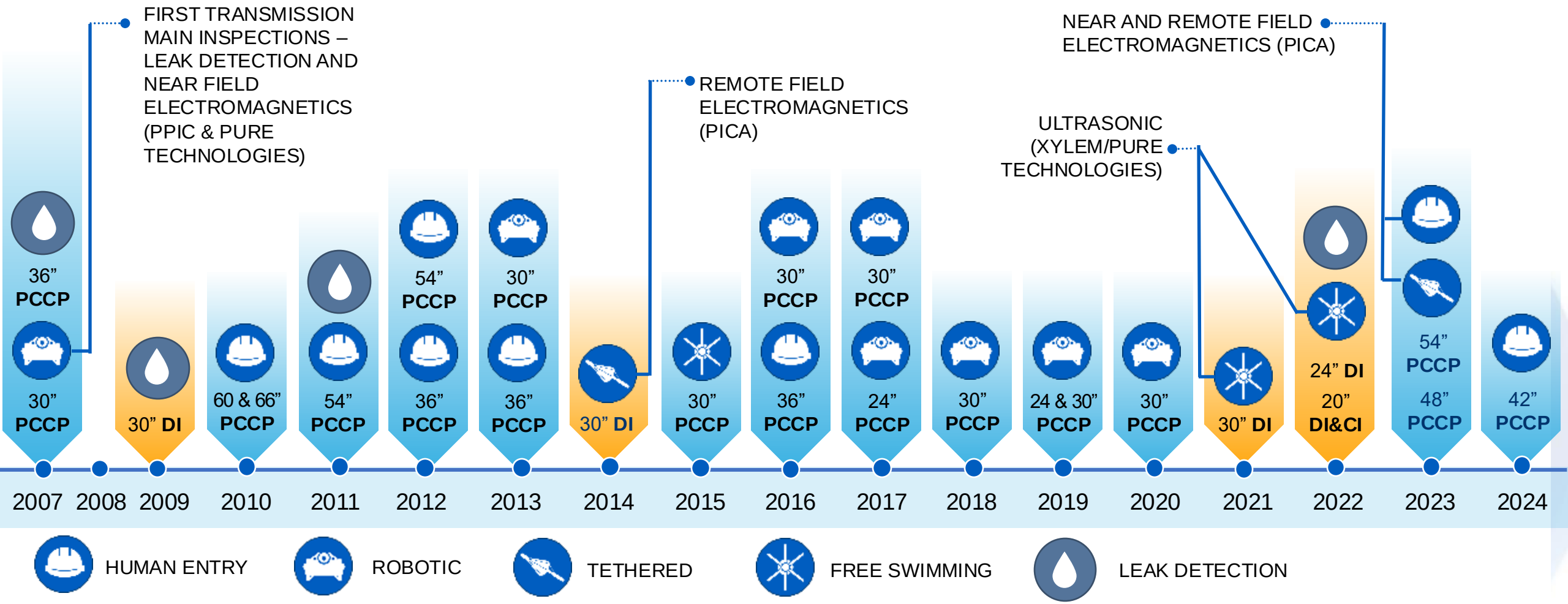
Why Perform Condition Assessment?

Overview of Water Pipeline Inspection

- Hire external companies with technology, use own crews for prep work, combined team effort
- Primary high-resolution technologies
  - Electromagnetic (Near Field and Remote Field)
  - Ultrasonic
- Four inspection methods
  - Human entry (≥ 36”)
  - Robotic
  - Tethered
  - Free-Swimming

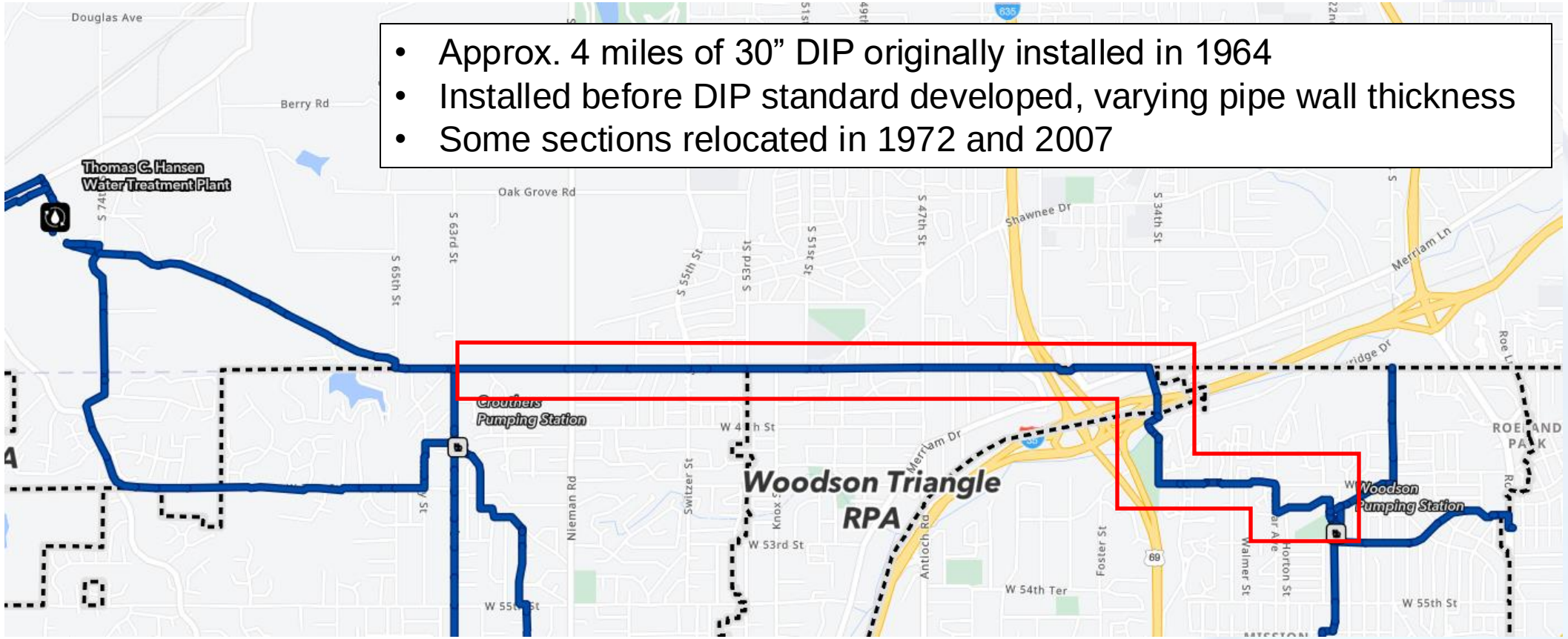
WaterOne Condition Assessment Inspection History

80+ miles of transmission mains inspected



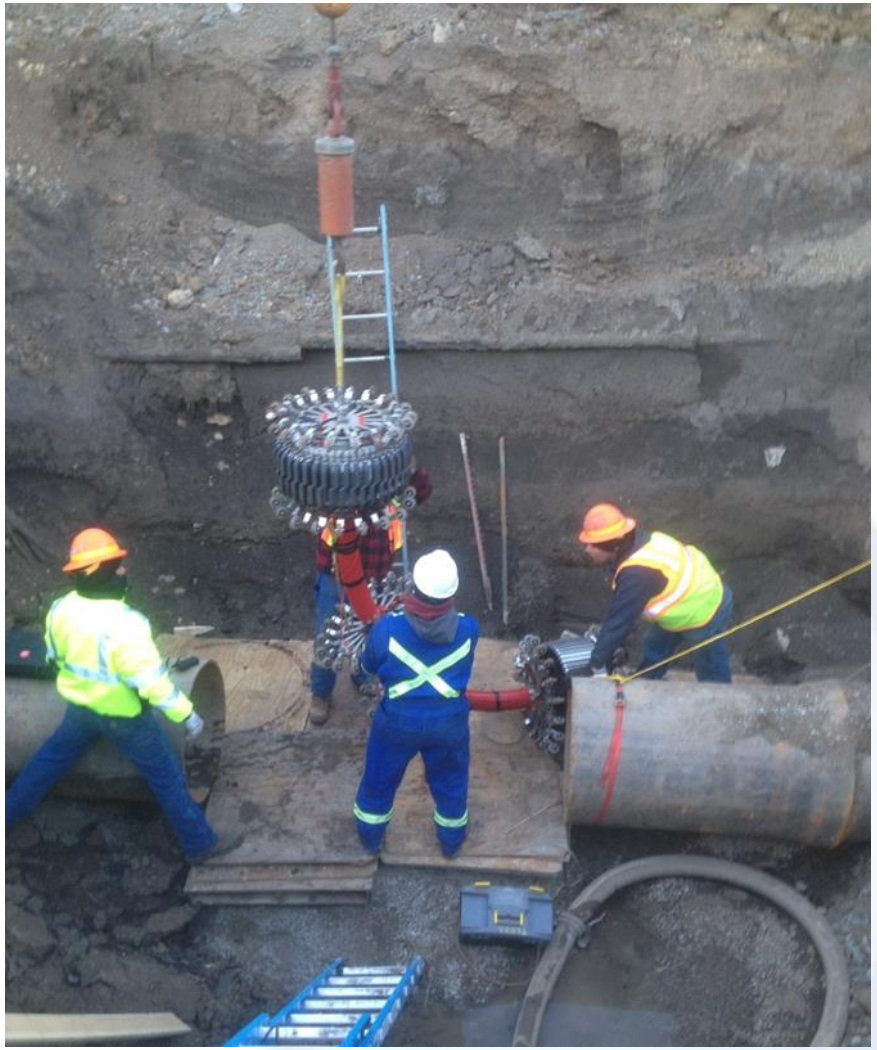
Woodson Transmission Main

- Approx. 4 miles of 30” DIP originally installed in 1964
- Installed before DIP standard developed, varying pipe wall thickness
- Some sections relocated in 1972 and 2007

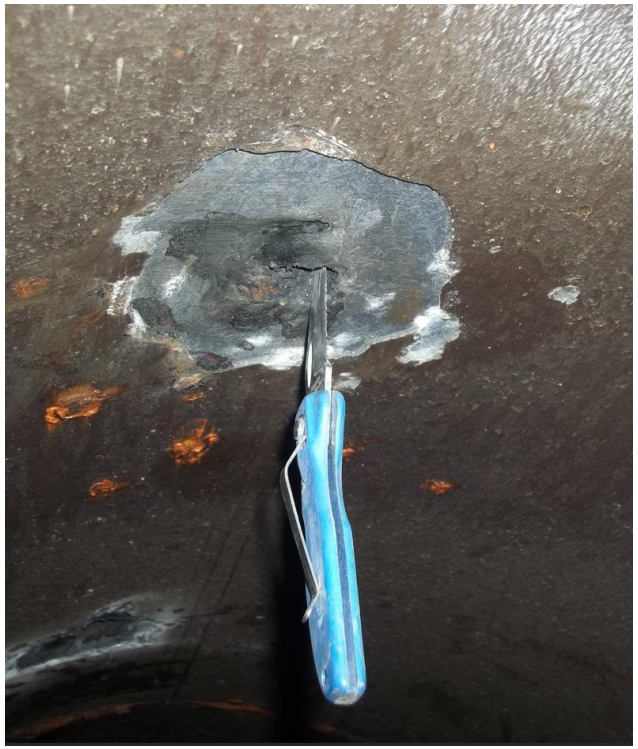


2014 Inspection

- Inspected in 2014 using electromagnetic remote field technology tool, winched through pipeline.
- High resolution data gave percentage of remaining wall along the pipeline, picking up localized pitting.
- Inspection revealed multiple locations with less than 5% wall remaining, some with through holes.
- Finds were validated



2014 RFT Inspection



Make a Plan

- Address immediate needs – spot repairs with clamps or short replacements
- Divide pipeline into segments and evaluate
  - Risk = probability of failure x consequence of failure
- Developed three phase replacement plan, with ~5 years between phases.
- Add projects to Master Plan, estimate budget
- Start designing

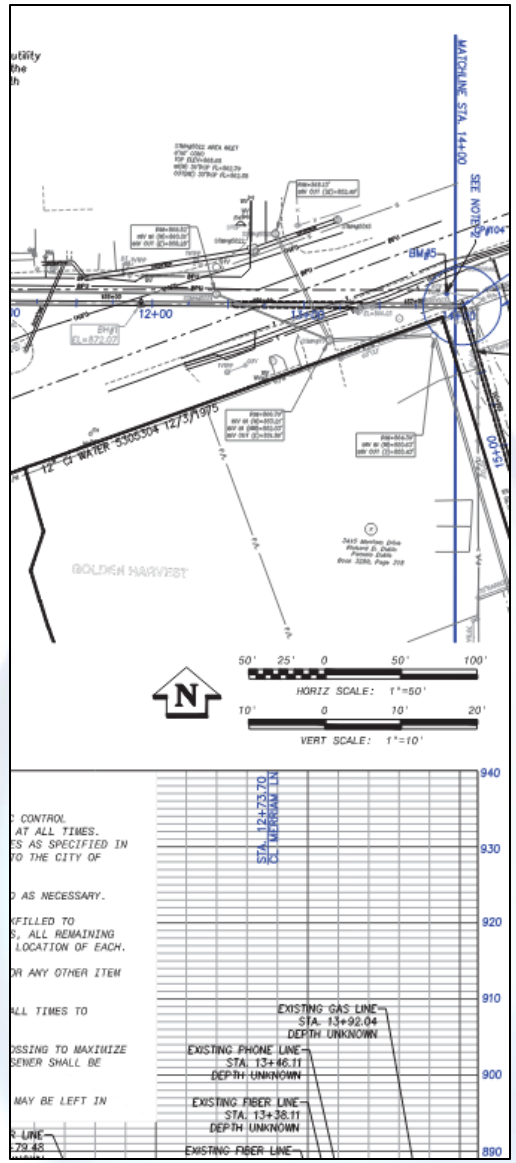
INTERNAL PRESSURE DESIGN

$$t = \frac{P_i D}{2S}$$

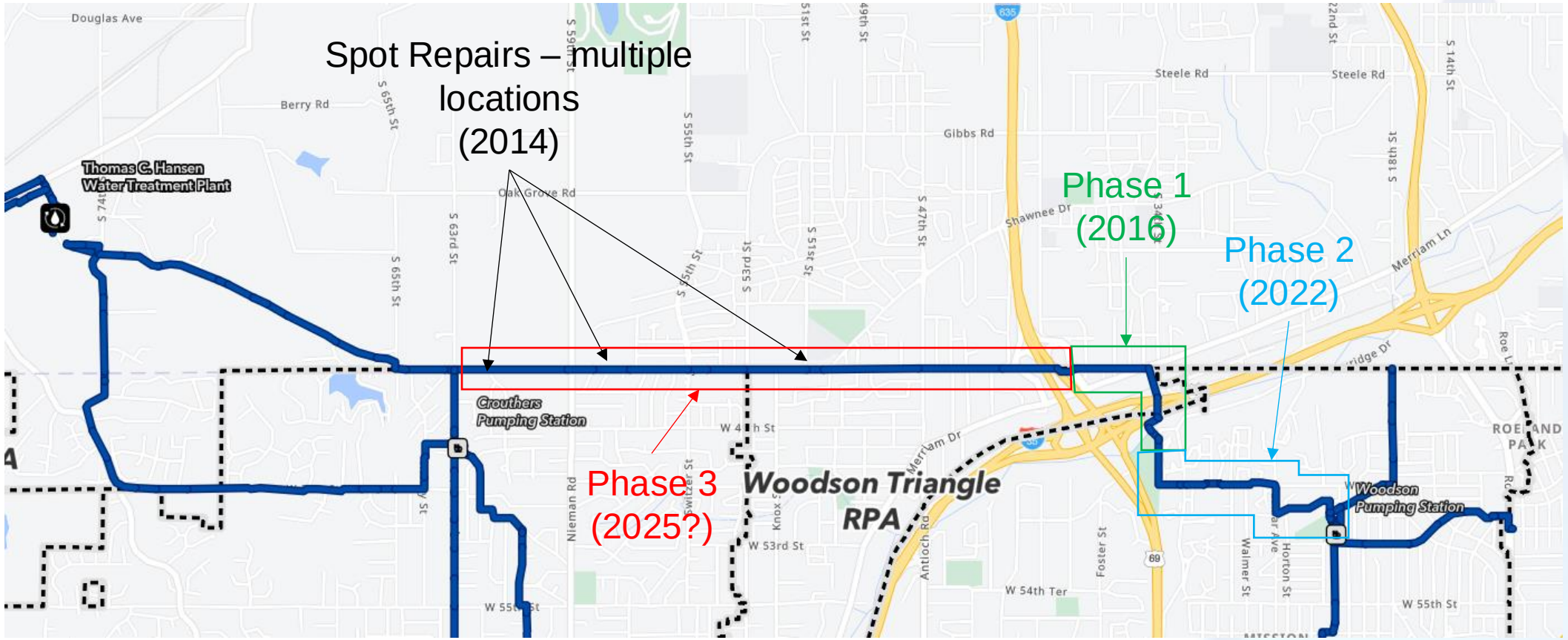
Where:

t	=	net pipe wall thickness, in.
P_i	=	design internal pressure, psi = 2 ($P_w + P_s$)
P_w	=	working pressure, psi
P_s	=	standard surge allowance, 100 psi
D	=	outside diameter of pipe, in.
S	=	minimum yield strength in tension = 42,000 psi

5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5



Woodson Transmission Main



Woodson Transmission Main

- Main runs under County Line Road
- North:
  - Wyandotte County (KCK)
- South:
  - Shawnee
  - Merriam
  - Overland Park
- No upcoming Capital Improvement Projects for the road

Woodson Transmission Main

- Reinspected in 2025 with free swimming ultrasonic technology
  - Inform schedule for replacement
  - Quantify rate of corrosion
  - Bonus – comparison of different vendors technology on the same pipeline.
- Draft report due April 2025
- Low investment relative to cost of replacement:
  - Phase II Replacement Cost (just contractor): approx. $450/LF
  - Phase III Reinspection Cost (just contractor): approx. $20/LF

Woodson Transmission Main

Key Benefits of Condition Assessment

- Maximize useful life of 200-mile transmission main system valued at over $500M
- Avoid catastrophic failures and reduce risk of water supply and quality interruptions
- With good data, better decisions can be made on extending the life of the pipe, defer replacements, and budget future Master Plan projects
- Make targeted repairs in non-emergency conditions, less costly

Thank You!

Jason Beyer
Supervisor – GIS Services
Email: Jbeyer@waterone.org
Phone: 913/895-5731

Peter Gaskamp
Lead Engineer – Distribution Engineering
Email: pgaskamp@waterone.org
Phone: 913/895-5765

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