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# Leveraging Artificial Intelligence & Machine Learning for Aging Infrastructure

Source to Stream 2024

by Marya Jetten

**Acknowledgement:**

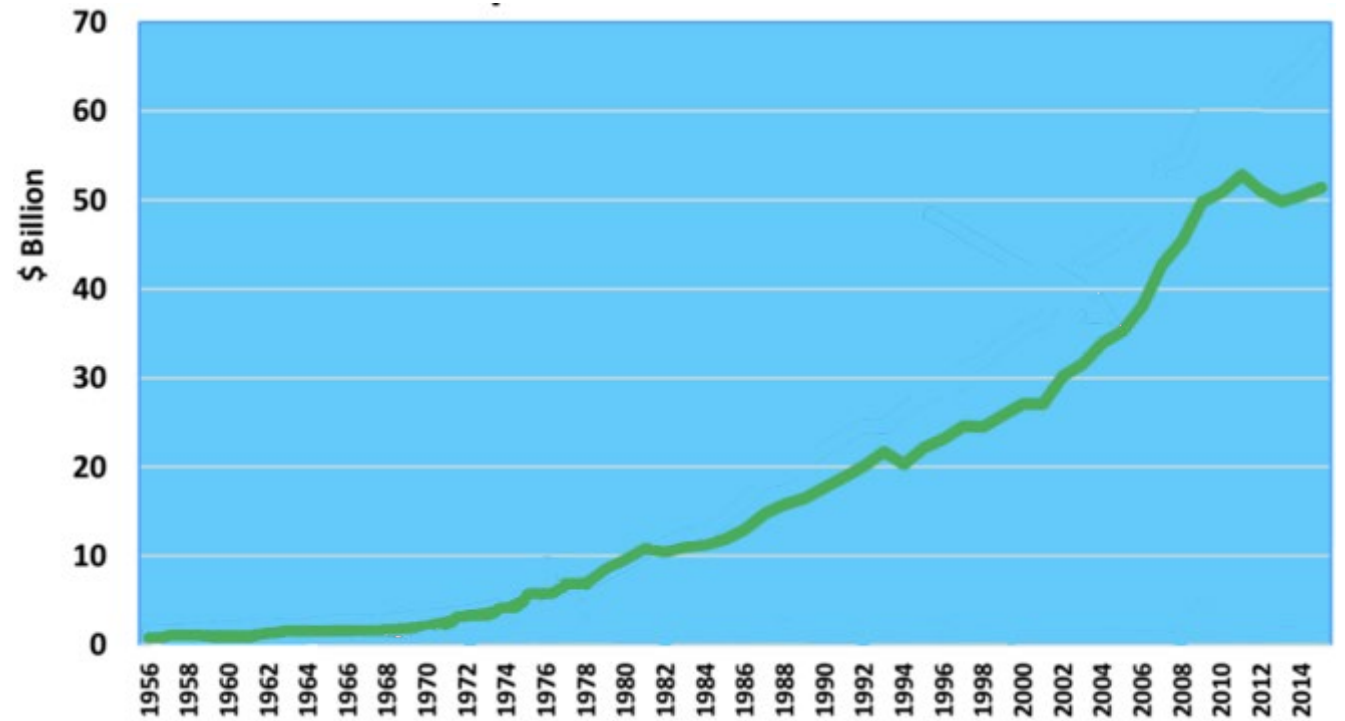
**Robert Cook, Adam  
Byard & Erin Milano**



## Sewer O&M is a \$50B/yr Government Expenditure (US)

- 800,000 miles of public sewer (1,287,500 km)
- 500,000 miles of private sewers (805,000 km)
- Earth-to-Moon is 238,900 miles (384,472 km)
- CCTV'ing even 1% of this produces 38,133 hours worth of video...

*...which must be viewed  
by a human being*



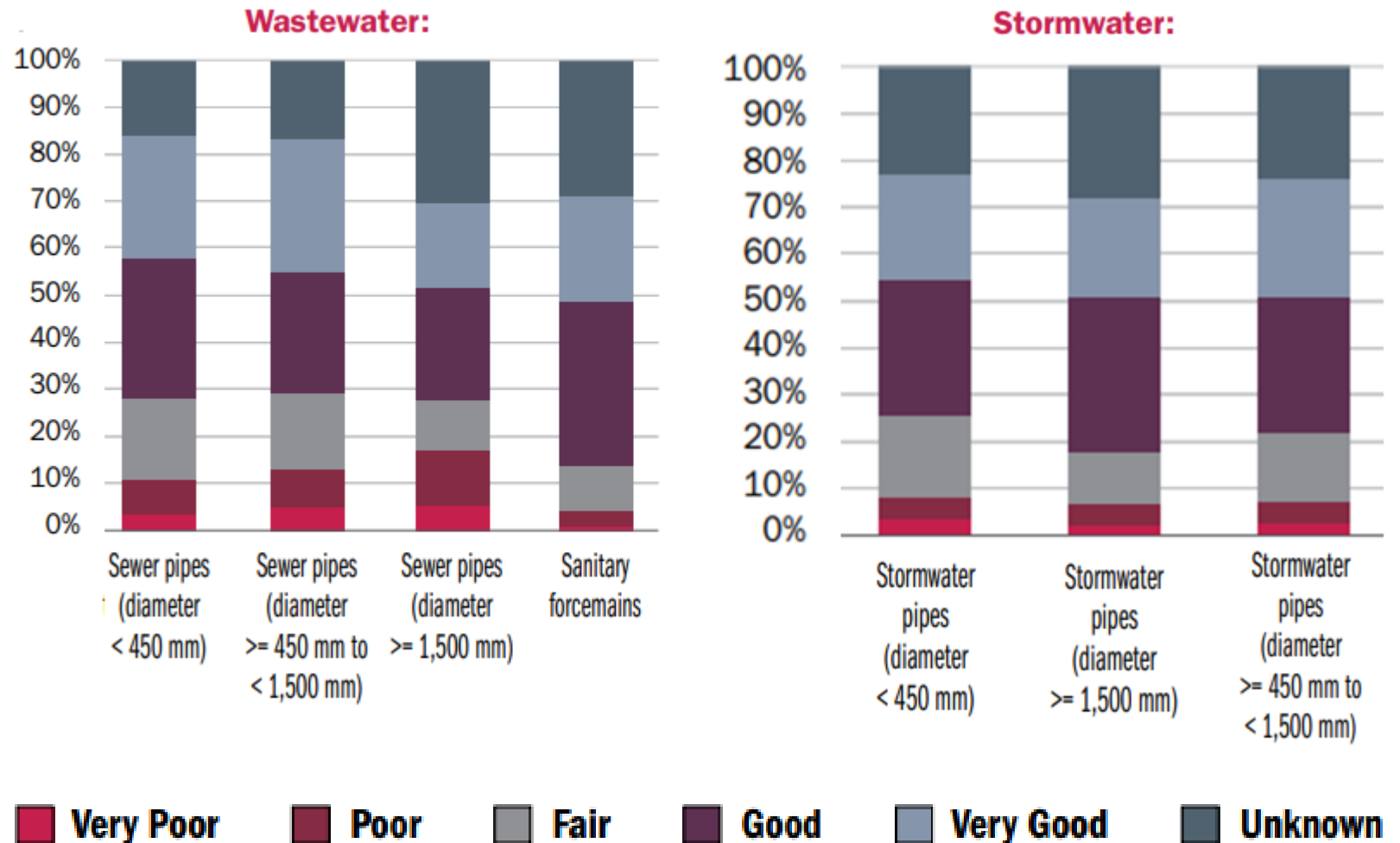
US Conference of Mayors. Local Government Investment in Water and Sewer, 2000-2015. Richard F. Anderson, Ph.D.

# Spotlight on Canada

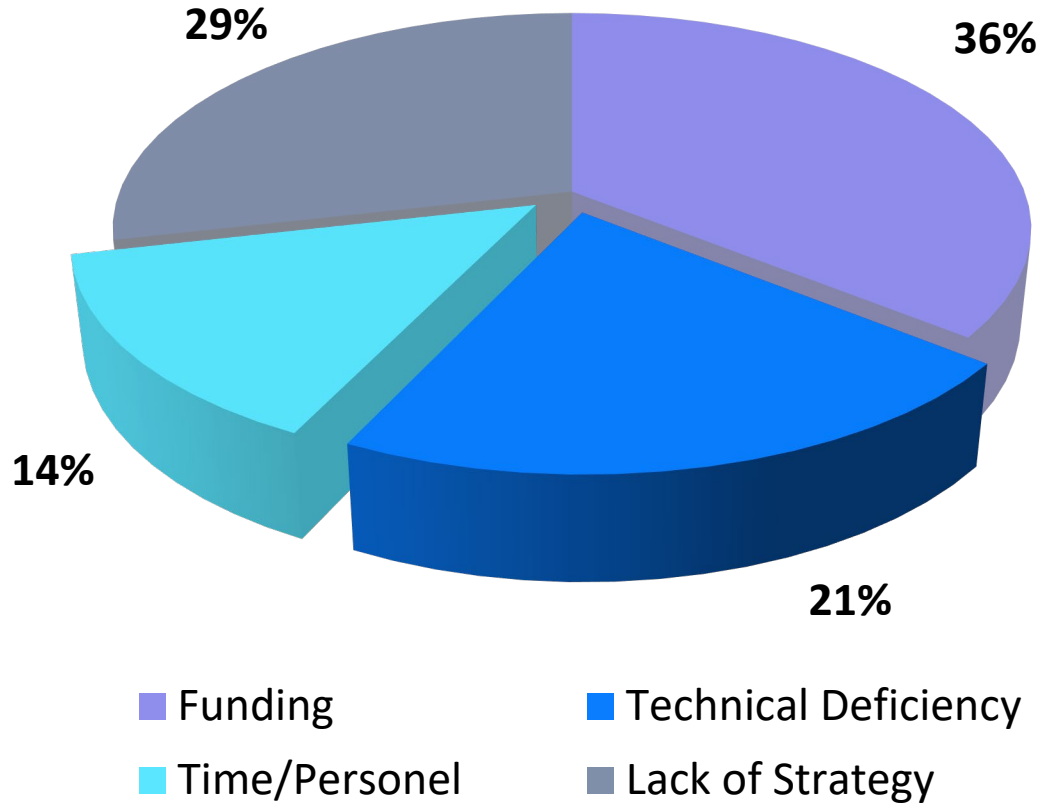
- Majority of wastewater pipes are >50 years old
- ~25% of assets are in fair or worse condition
- ~15-30% of assets are in unknown condition



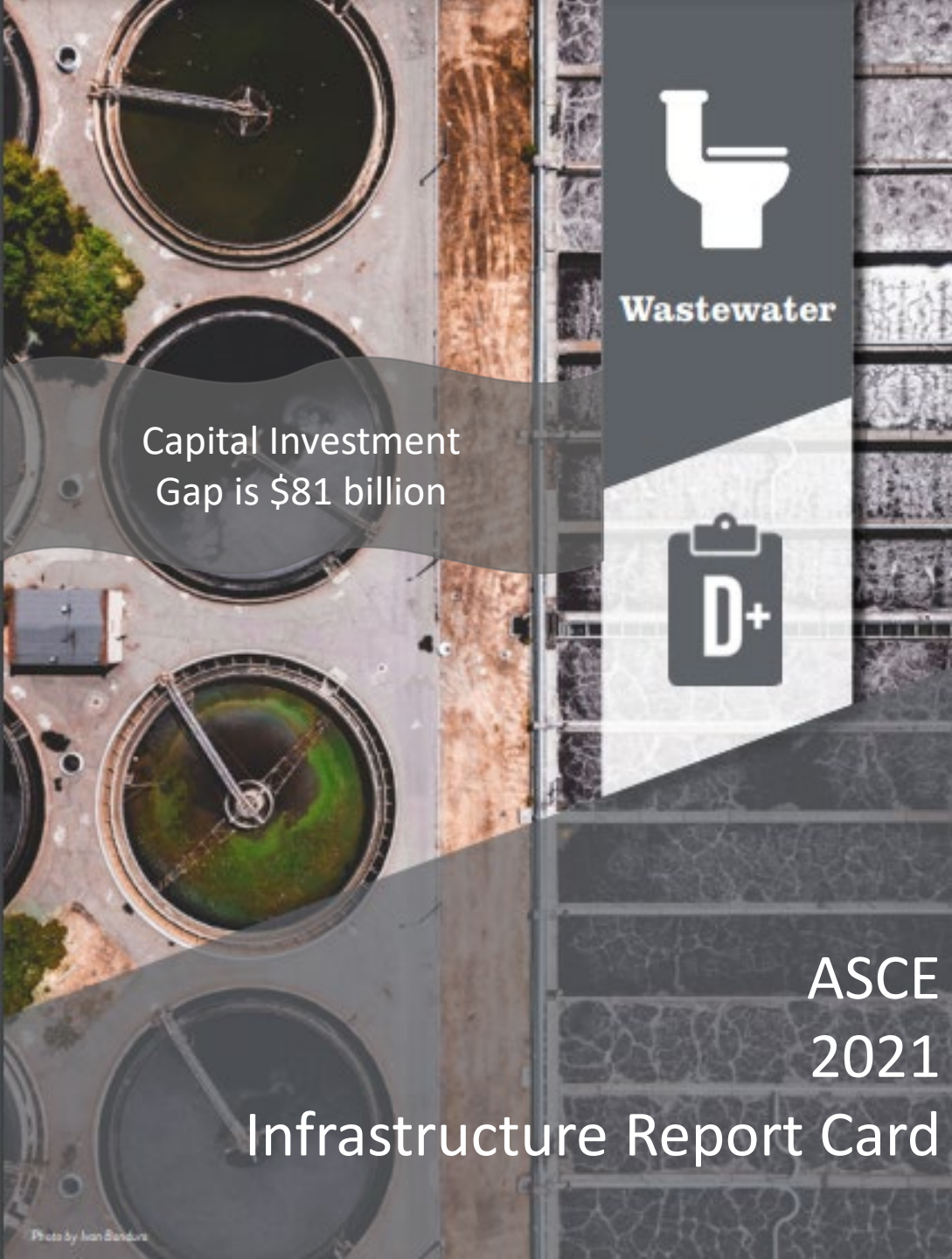
## Other Relevant Data – Municipally Owned Asset Condition (All Urban Municipalities)



# Impediments to Proactive Approach

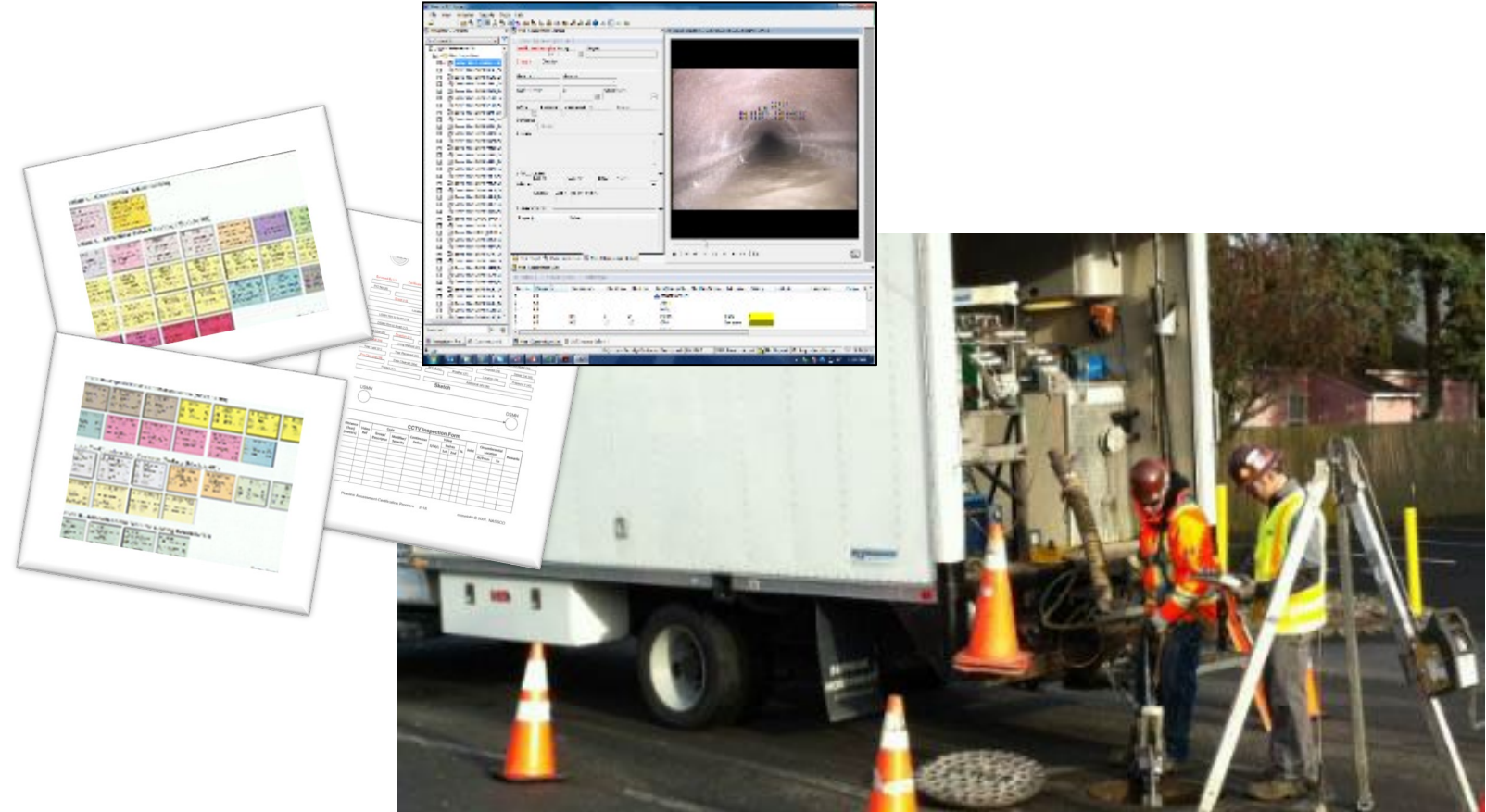


Source: 2012 WRF Study on Proactive Cond Assessment/Renewal

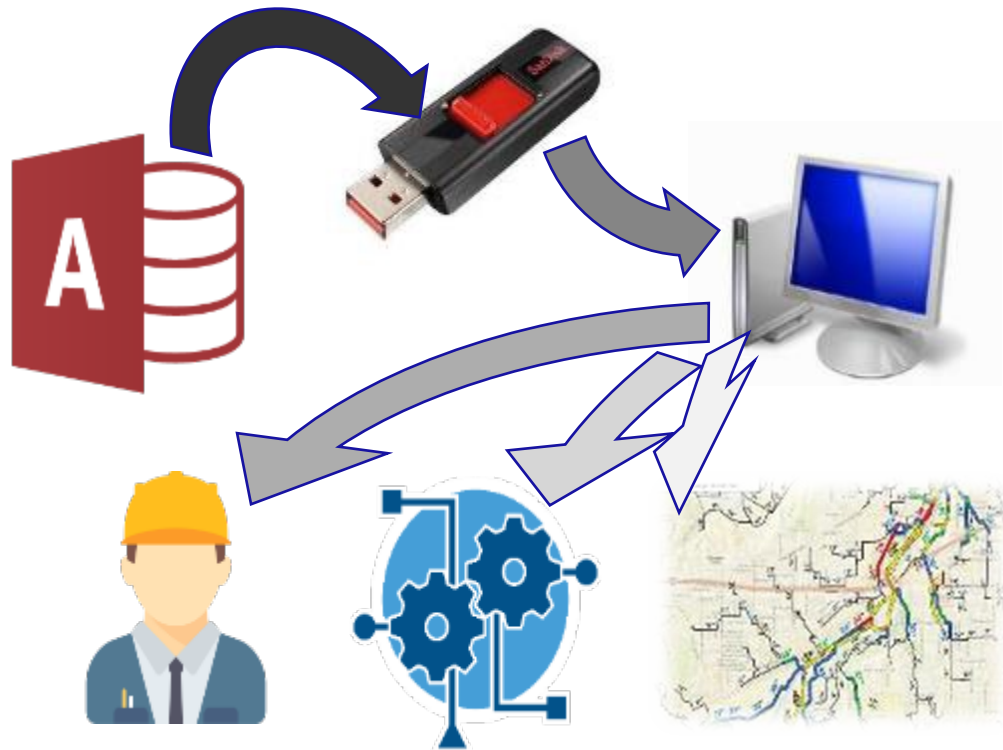


# What the CCTV inspector has to worry about...

- Mobilization
- Safety / Traffic Control
- Locating the manholes
- Setup
- Cleaning
- Inspection
- **Defect coding**
- Equipment maintenance & repairs
- Demobilization / Disposal
- Data transfer



## ...what the CCTV engineer has to worry about.



- Data import
- *QC code review*
- *Code adjustment (correct for bias)*
- *Individual video interpretation*
- *Pipe scoring (RUL analysis)*
- *Correction action/preventive maintenance recommendations*
- *Cost estimating*
- Business case evaluations
- Work order assignment/tracking
- Continuous updating

# The Life of 1,000LF (305 m) of Sewer Video

Task	Duration	Total Time
<b>FIELD CREWS</b>		
Mob/Recon/Setup	1-2 hr	1-2 hr
Cleaning	3 hr	4-5 hr
Pilot the Robot	0.5 hr	4.5-5.5 hr
Data Coding	1.5-3.5 hr	6-8 hr
Extract/Demob	1 hr	7-9 hr
Robot Repairs	0.5-1 hr	7.5-10 hr
Data/Transfer	1 hr	8.5-11 hr
<b>OFFICE ENGINEERS</b>		
Import	0.5-1 hr	9-12 hr
QC Review Coding	2-3 hr	11-15 hr
Report	1 hr	12-16 hr



30-40% of total is related to just coding & review

Technology has improved the process over the decades but not conquered it. It remains a time-consuming effort.

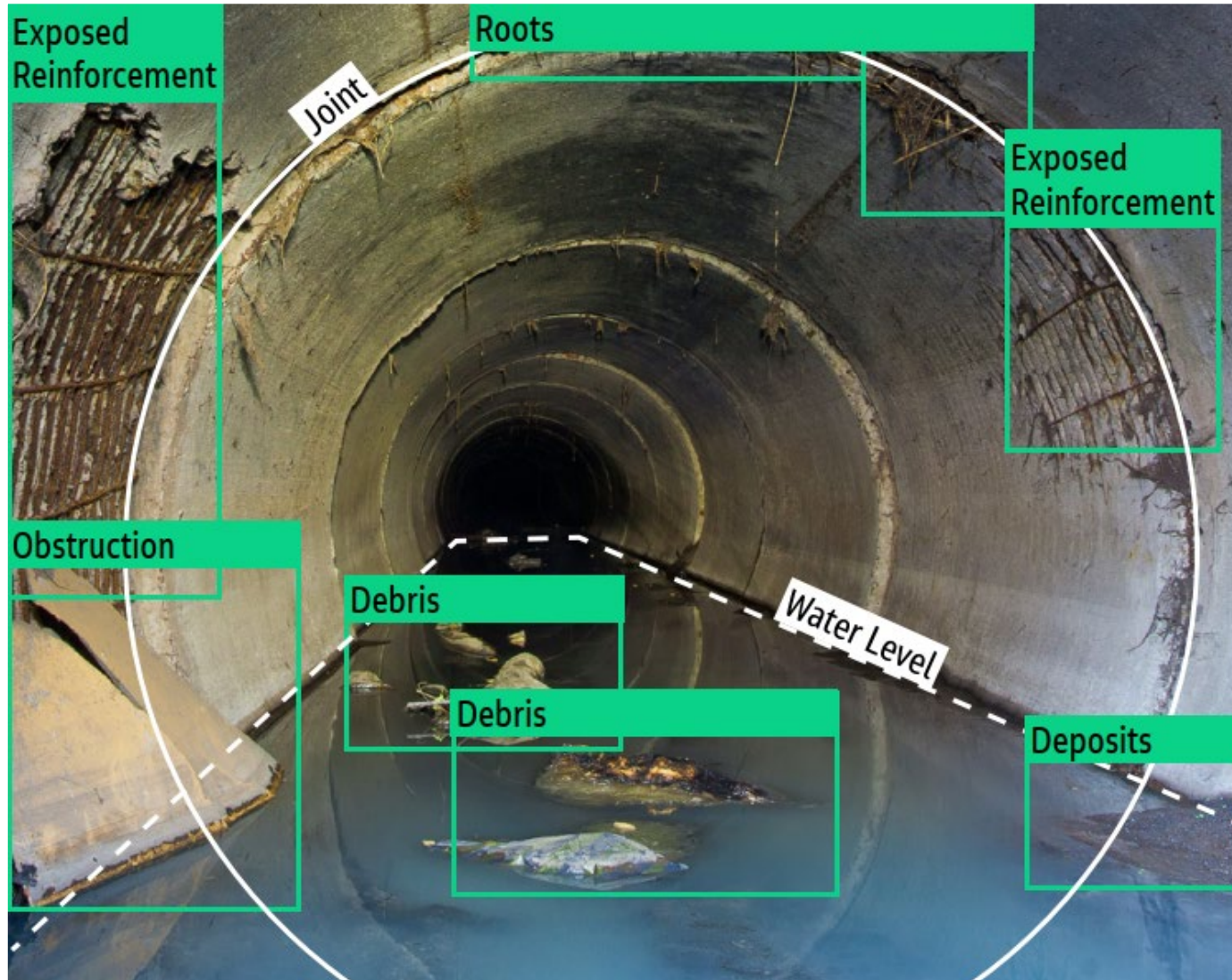


# Artificial Intelligence in Sewer Inspection

- Several AI Tools and Products are In the Market



# Dragonfly is Jacobs' digital solution to sewer condition assessment, co-created with Hitachi.



## Automated Sewer CCTV Defect Coding

Dragonfly applies artificial intelligence to automatically detect defects in raw CCTV inspection videos

## Industry Standard Output

Dragonfly rapidly produces consistent, accurate PACP output, usable in any pre-existing workflow and CMMS/CCTV software

## Reliable Business Intelligence

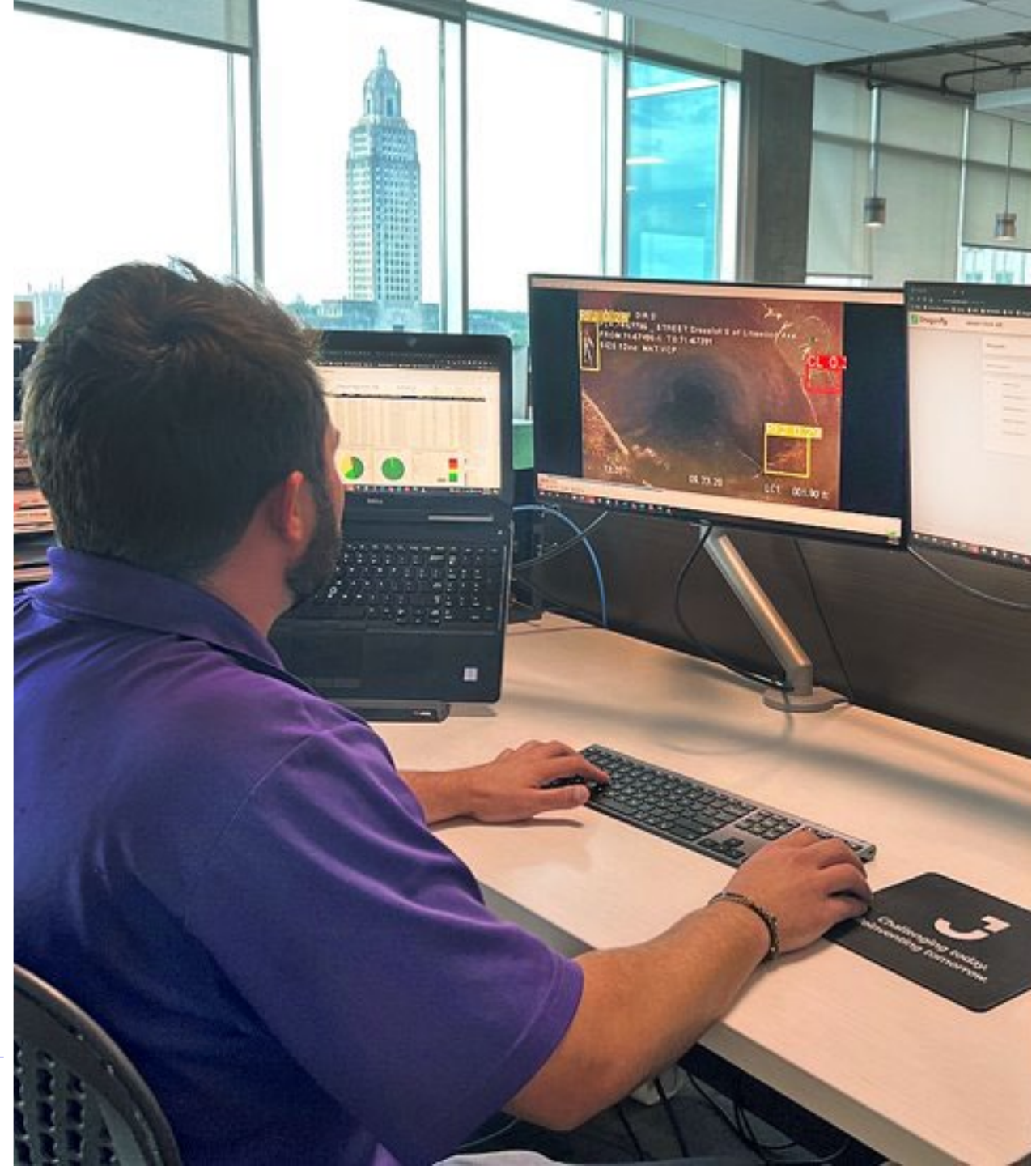
Dragonfly integrates with Jacobs' **Argon** tool and supports asset management

- Optimizes reinspection and maintenance schedules
- Prioritizes asset rehabilitation lists



**Dragonfly**<sup>SM</sup>  
by **Jacobs**

**How it Works!**



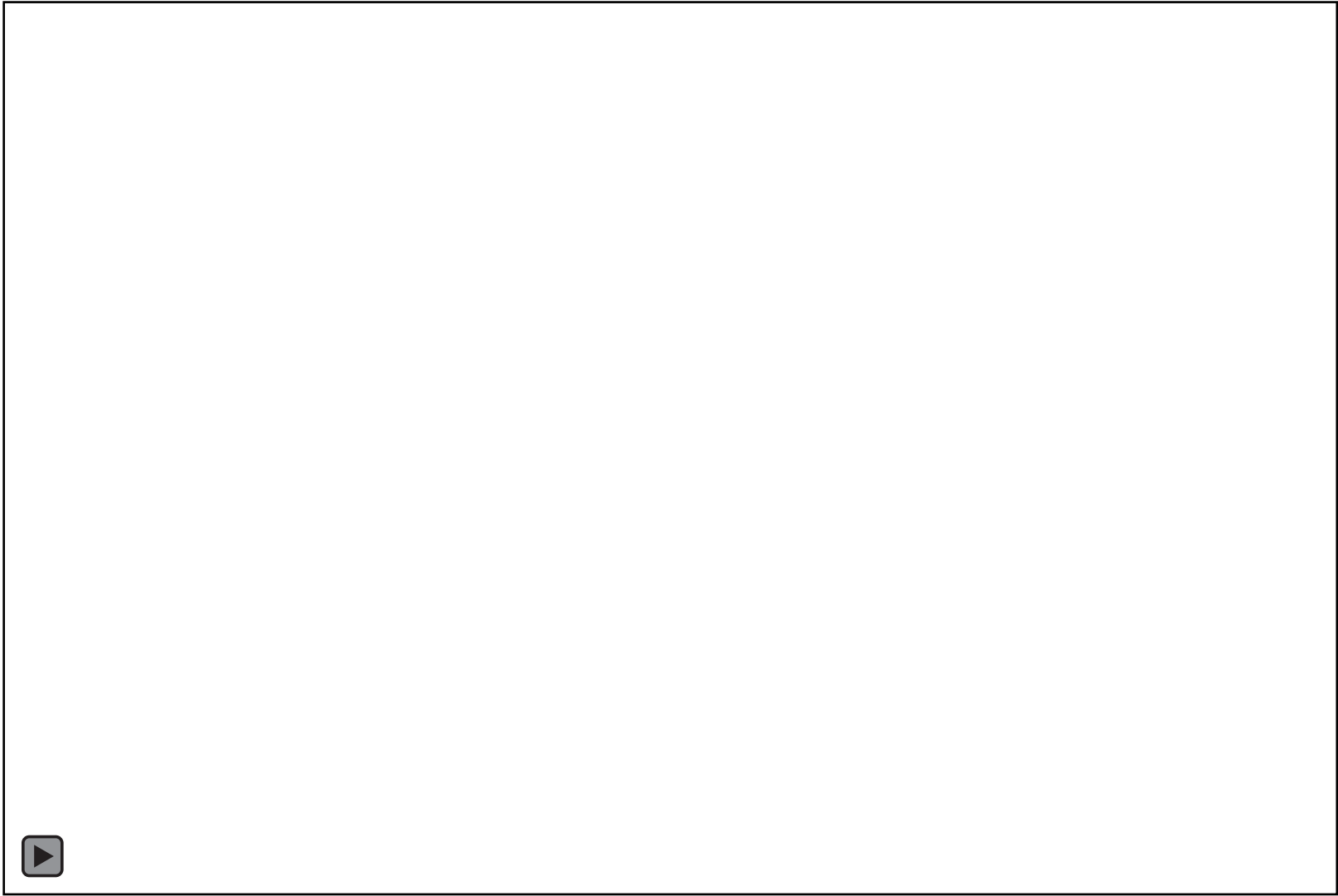
# A glimpse into the analysis models ...

Original Inspection Video

Defect Heatmap Algorithm

Anomaly Threshold Algorithm

Defect Labeling



## PACP certified technicians review and verify machine output.

### Model output defects pre-screening

045-00298A\_045-00001A\_20220321.124400.mp4


CANCEL
SAVE [S]
COMPLETE

Status	PACP Code	Distance	Value	Clock	Joint	Time
✓ Accepted	AMH	0	-	12	False	00:00
✏ Modified	MWL	1.6 → 0	30	-	False	01:47
✗ Rejected	ISSRH	37.4	-	11 - 12	True	02:35
✓ Accepted	CL	39.7	-	12	False	02:37
✓ Accepted	CL	42.8	-	11 - 12	True	02:40
✓ Accepted	MWL	43.8	20	-	False	02:41
✓ Accepted	DAE	52.2	5	9 - 10	True	02:50
➔ Current defect	CL → FL	61.5	-	12	True	03:00
✓ Accepted	CL	66.6	-	12	True	03:23
✓ Accepted	FL	71.3	-	2	True	03:29
✓ Accepted	DAE	85.5	5	8 - 10	True	03:44
✓ Accepted	FC	88.8	-	1 - 3	True	03:48
✓ Accepted	MWL	91.8	30	-	False	04:21
✓ Accepted	DAE	95.2	5	9 - 10	False	04:25

### Selected defect

PREVIOUS [←]    NEXT [→]

045-00298A\_045-00001A Downstream →



045-00298A\_045-00001A Downstream →

2022

P PACP Code: **FL**

V Value: \_\_\_\_\_

D Distance: **61.5**

C Remarks: \_\_\_\_\_

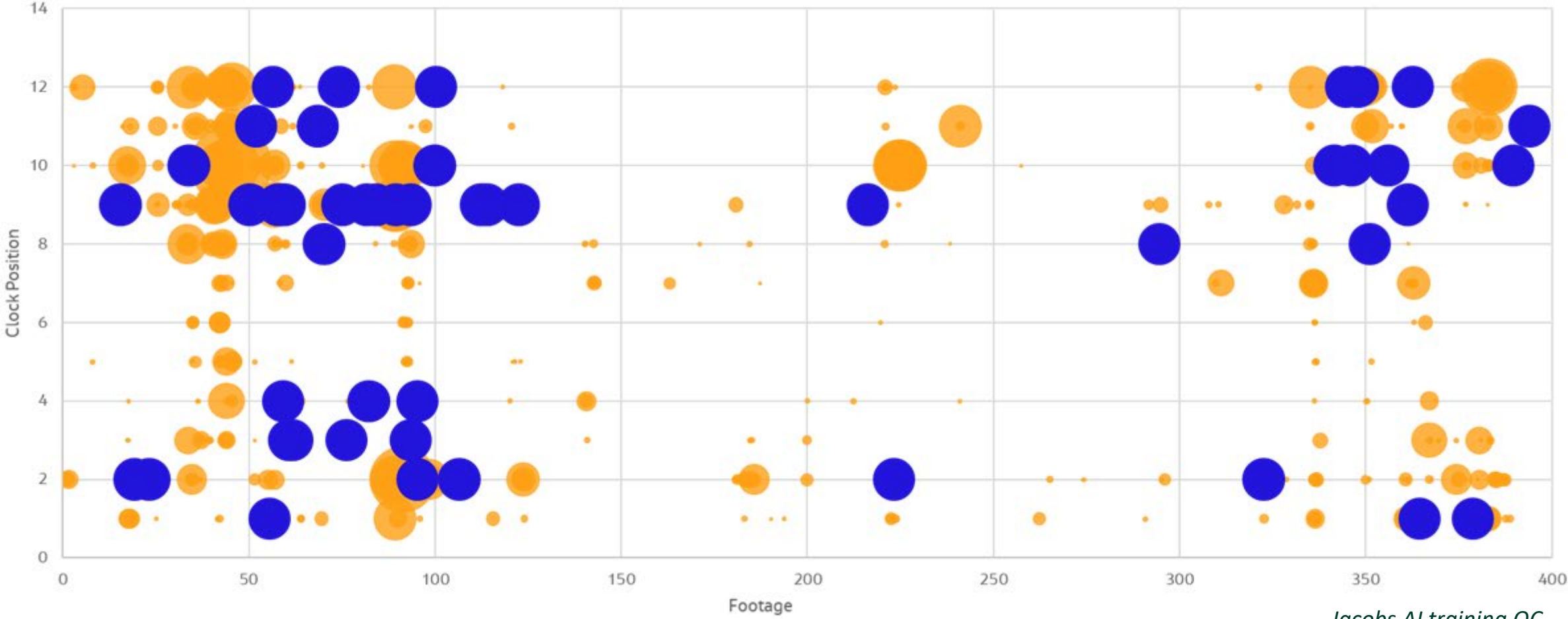
J Joint: **Yes**

F Clock From: **12**

T Clock To: **None**

ACCEPT [A]
REJECT [R]

# Refinement and calibration for a consistent PACP deliverable



Machine Output      QC Refinement

*Jacobs AI training QC*



## Dragonfly produces a NASSCO Standard Exchange PACP database.

Analysis completed  
Your videos are successfully analysed. All associated files are listed below. You can download them by clicking on the file.

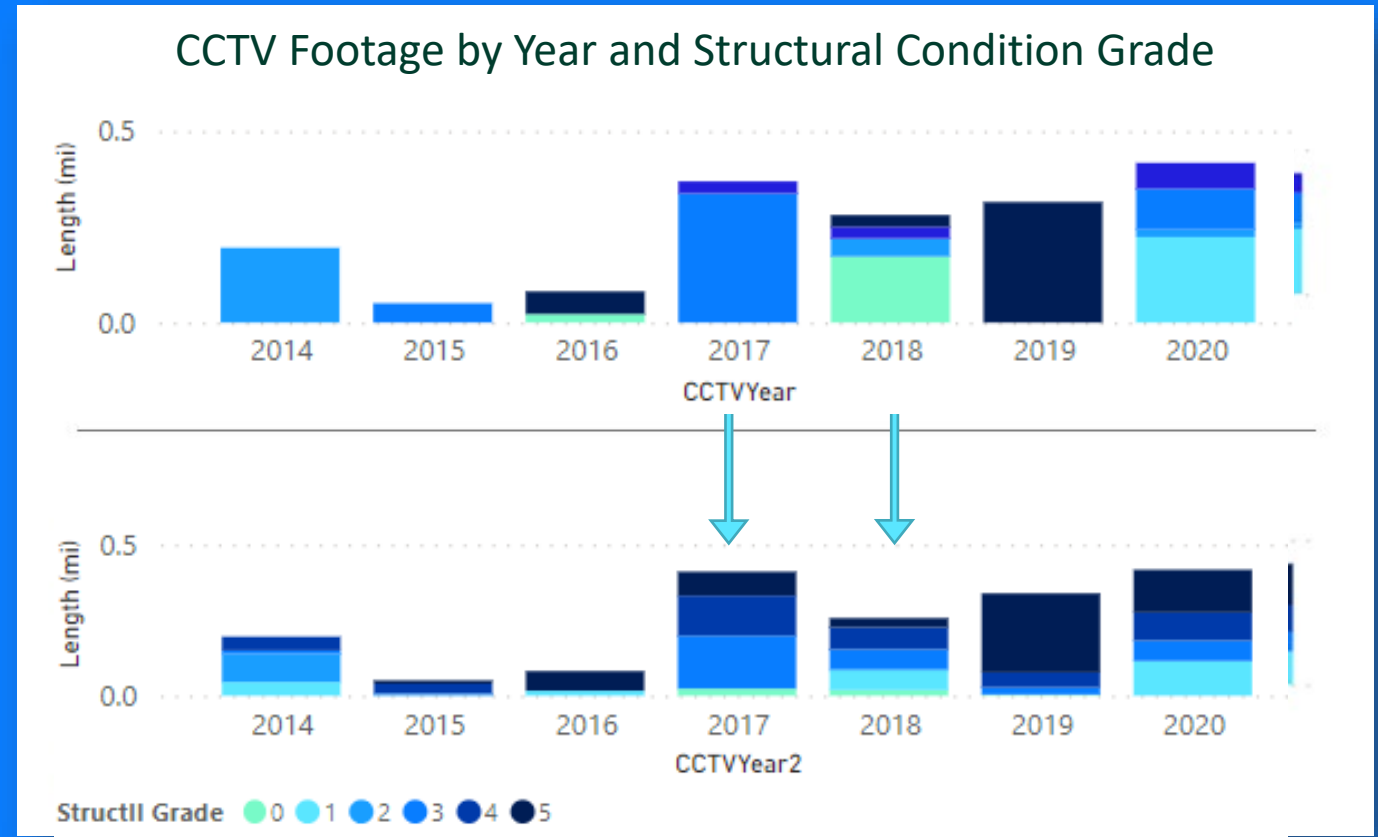
StandardPacpExchange.mdb

ConditionID	InspectionID	Distance	Counter	PACP_Code	Continuous	Value_1st_Di	Value_2nd_D	Value_Percent	Joint	Clock_At_Frc	Clock_To
1	1	0	0	AMH							
2	1	190.5	1044	CL						12	
3	1	184.5	1026	TBC		3				11	
4	1	183.3	1024	DAGS				5		7	8
5	1	180.7	1005	DAGS				5		4	5
6	1	180	1005	ISJ						3	9
7	1	174.3	994	CL						11	
8	1	164.4	962	CL						11	
9	1	162.1	928	TFI		3				2	
10	1	191.7	1056	TFA		1				9	
11	1	158.2	921	CL						10	
12	1	144.3	867	CL						10	
13	1	143.7	853	MWL				10			
14	1	142.7	852	CL						11	
15	1	139.6	819	TFA		3				3	
16	1	139.6	819	CL						12	
17	1	132	795	CL						12	
18	1	129.6	781	DSZ				5		5	6
19	1	193.4	1071	TFA		3				2	
20	1	210.3	1118	CL						12	
21	1	215.8	1147	CM						9	3
22	1	323.2	1528	CM						9	3
23	1	323.2	1478	CL						3	
24	1	320.2	1473	CM						9	3
25	1	306.5	1431	CM						8	4
26	1	303.8	1425	CM						9	3
27	1	301.8	1401	CL						9	
28	1	273.4	1311	TBA		3				2	
29	1	252.8	1277	CL						12	
30	1	247.3	1242	TFI		3				2	
31	1	241.3	1235	DAGS				5		7	8

## AI in action: Proven Effectiveness

### Case Study: Side-by-Side Comparison

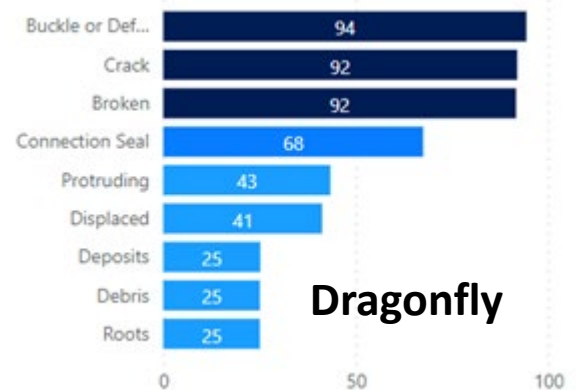
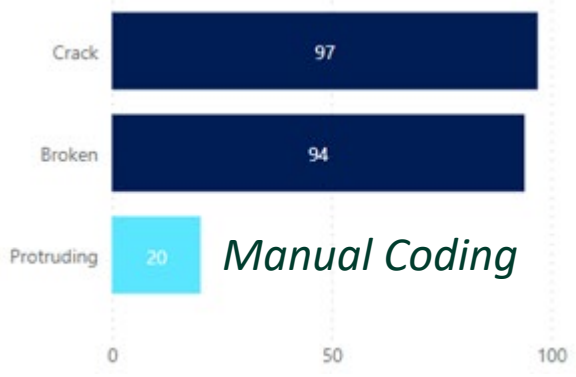
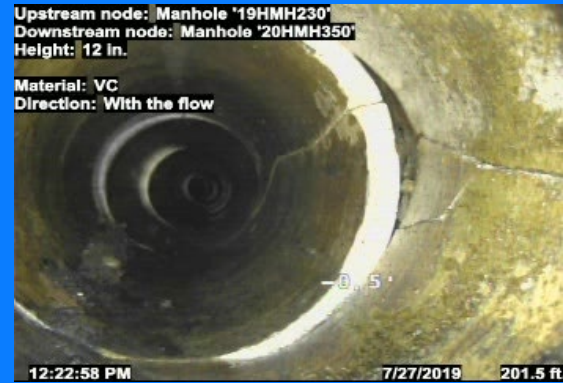
- Large USA municipal utility piloted Dragonfly and compared against 17,000LF of trusted, manually coded, legacy data
- **AI** identified important nuanced defects and overall pipe severity levels that were overlooked
- Client enabled to better optimize preventive maintenance and repair plans





# Dragonfly in action: Reliable Quality

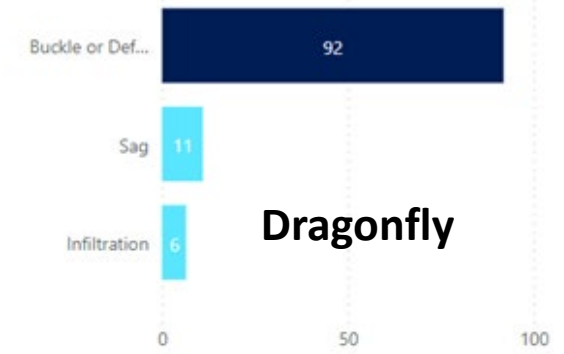
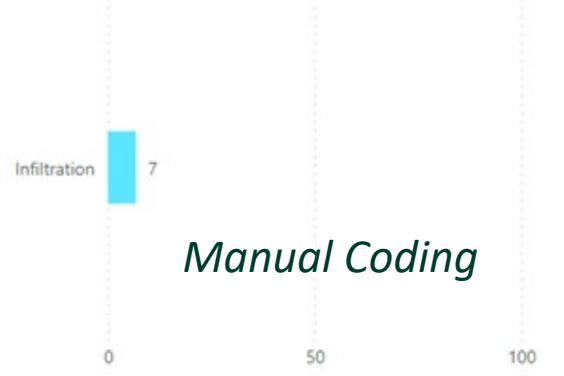
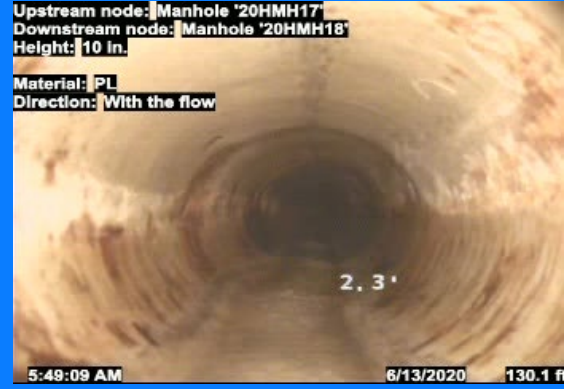
## Case Study: 12-inch VCP



Defect Severity Grade

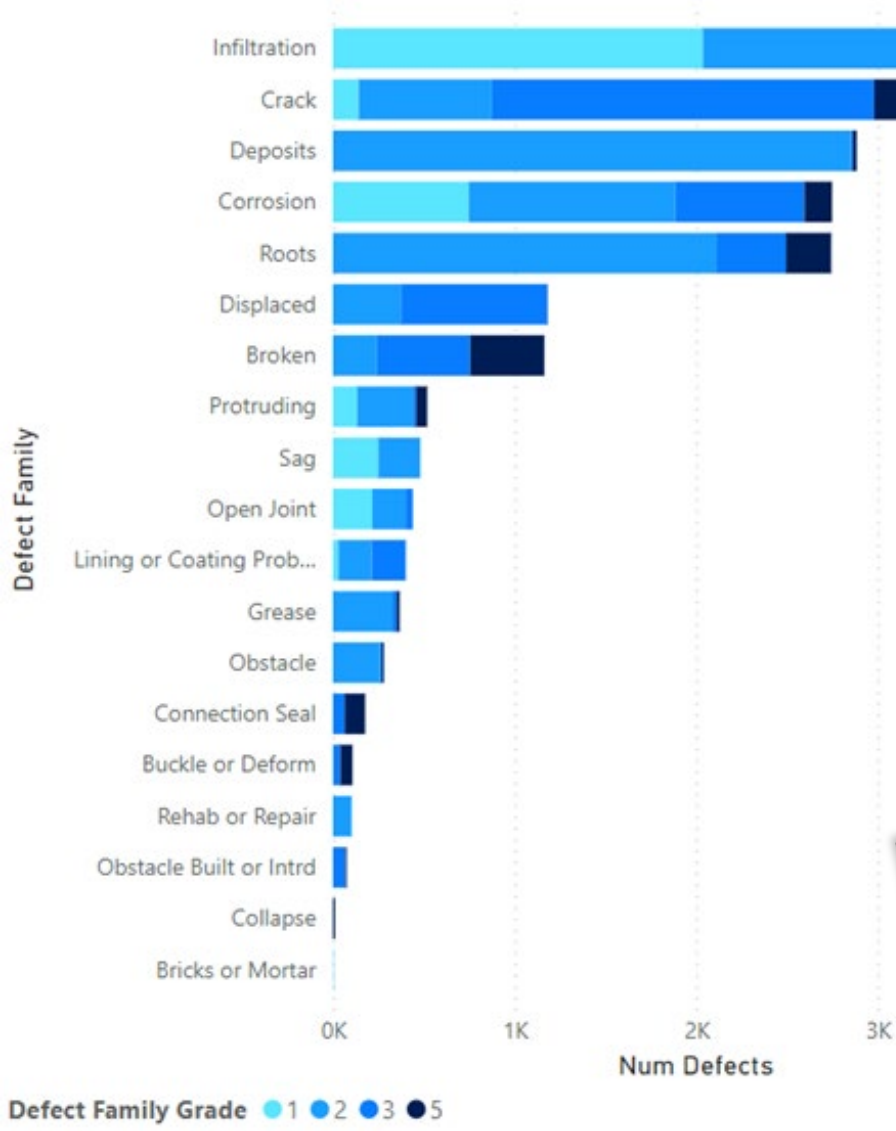


## Case Study: 10-inch CIPP Liner



Defect Severity Grade



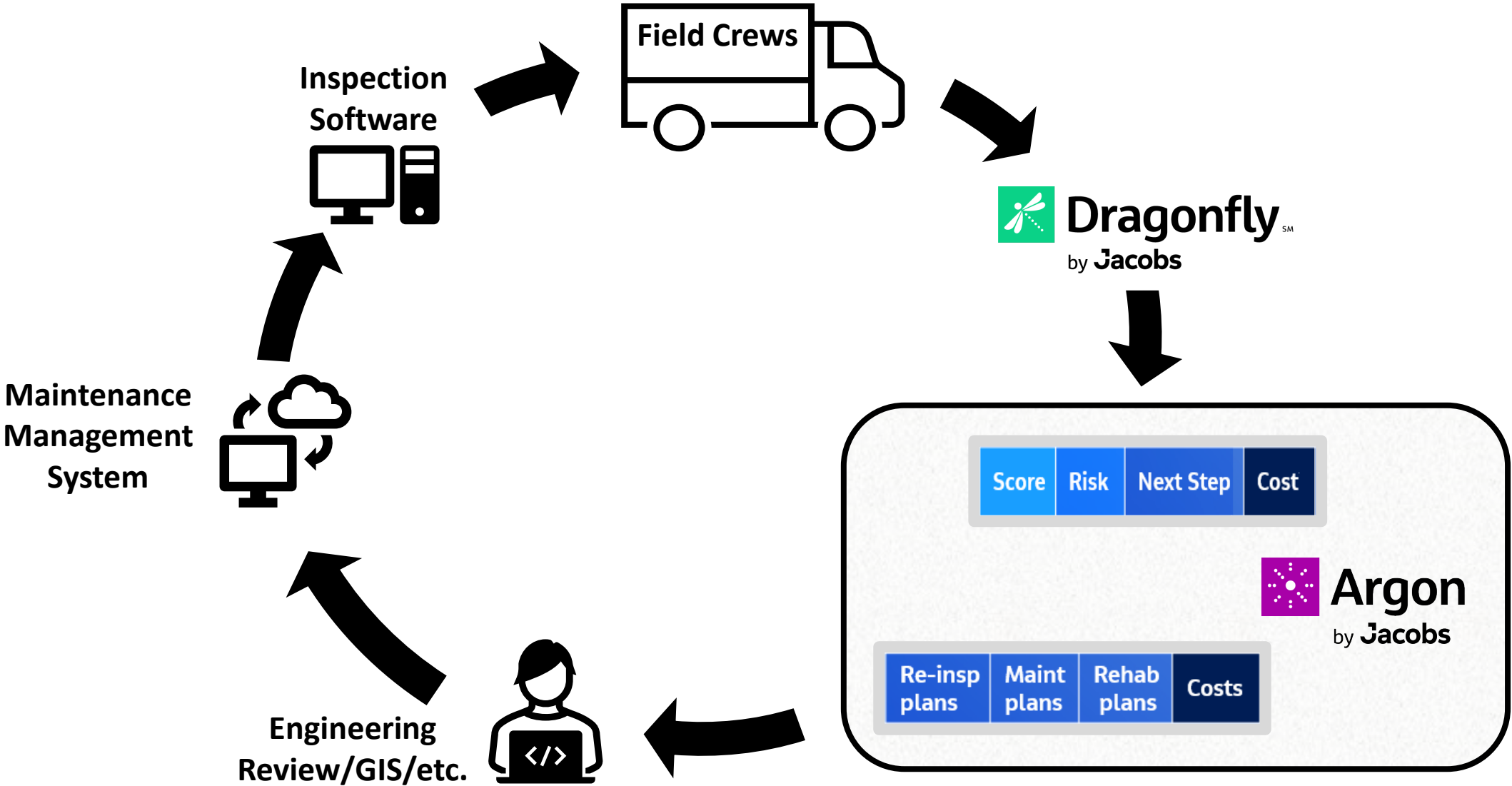


- Provides prescriptive asset management
- Analyzes your pipes and produces:
  - Advanced condition scores
  - Reinspection and maintenance schedules
  - Prioritized lists of pipes needing rehab
  - Repair/replacement cost estimates

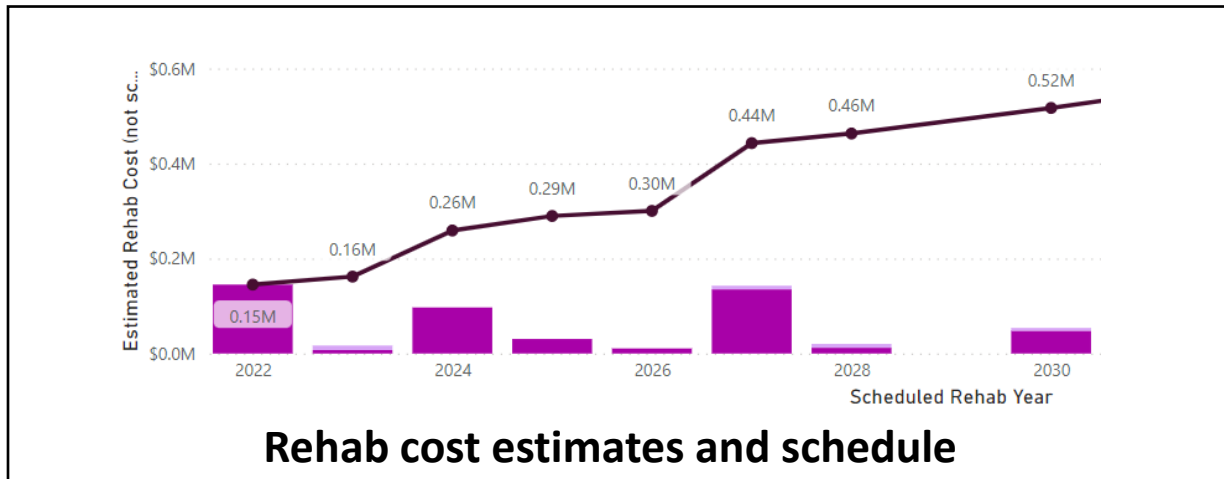


**Featured in EPA Technology Review:**  
*Innovative Internal Camera Inspection and Data Management for Effective Condition Assessment of Collection Systems, 2010*

# Completes the inspection to work order cycle.



# Added value with Argon insights: reliable and optimized pre-engineering recommendations, schedules, and costs



Leverage your information through dynamic, customizable dashboards.

100% web-based application that offers easy and secure uploads, processing, and access to results

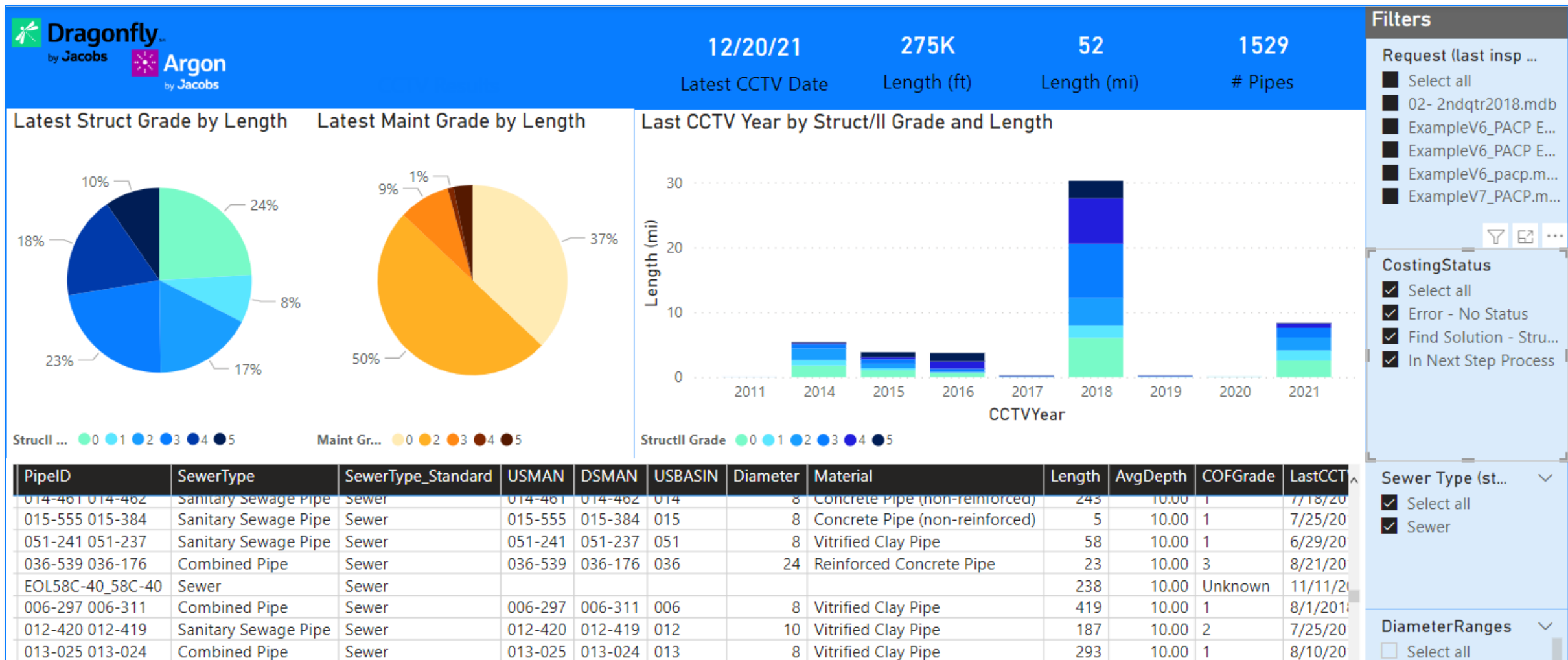
- Uses informed-AI to identify priority pipes, plan reinspection and maintenance needs, and produce cost estimates
- Interactive business intelligence visualizations provide insight into current and future conditions
- Output files can be downloaded and imported into any tabular-based data management system

# Advanced analytics for asset management

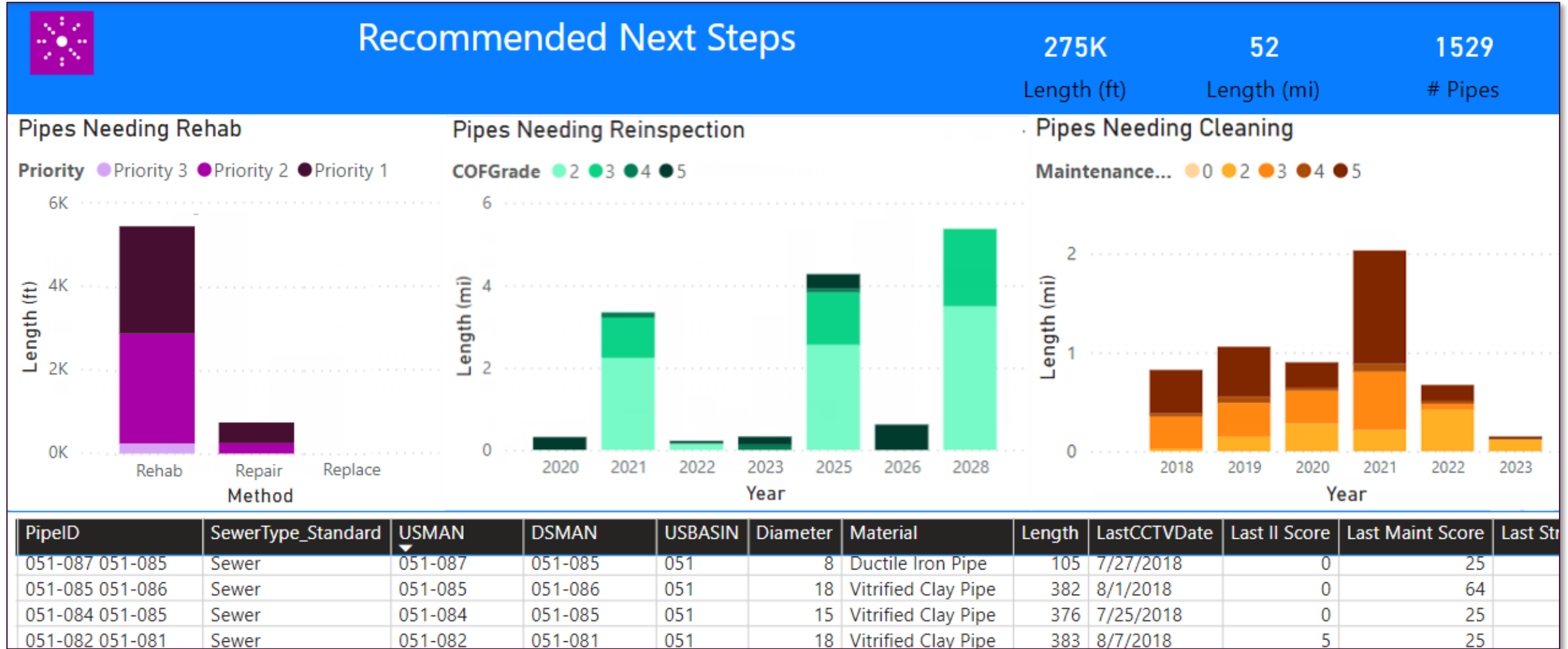




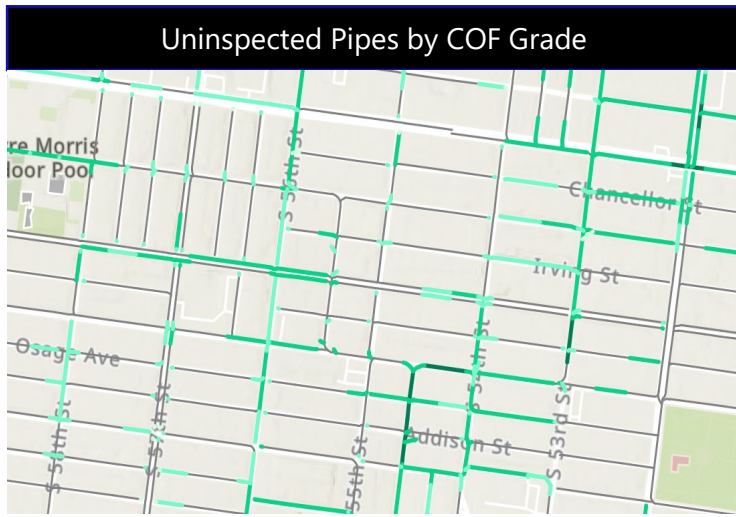
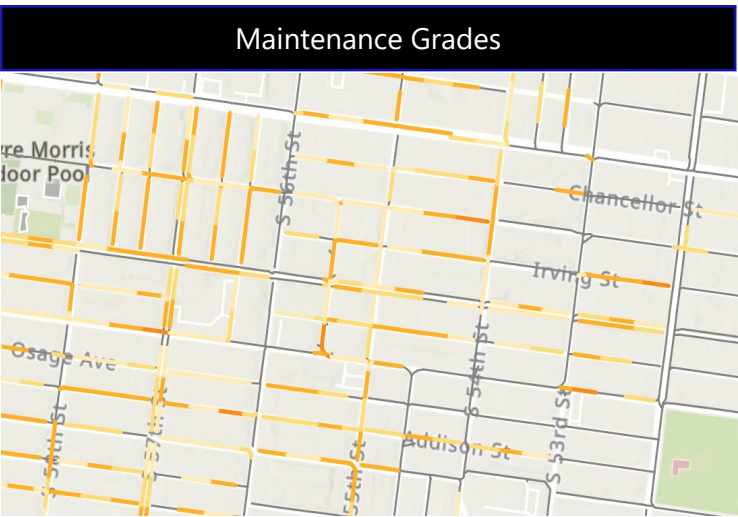
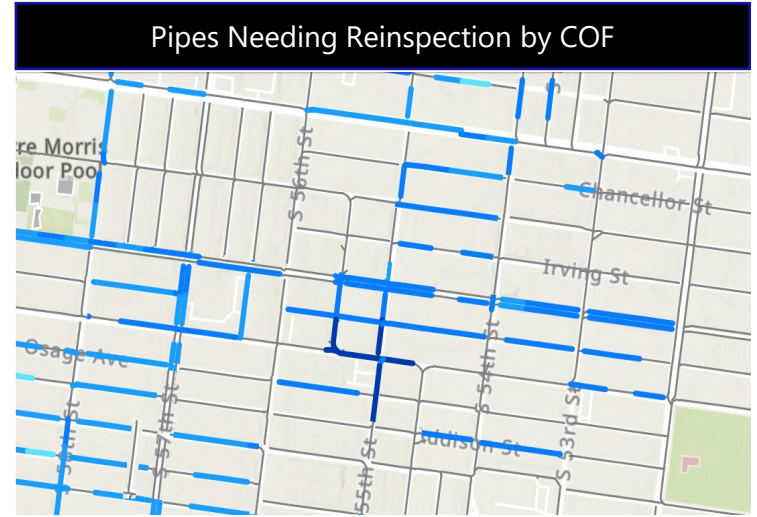
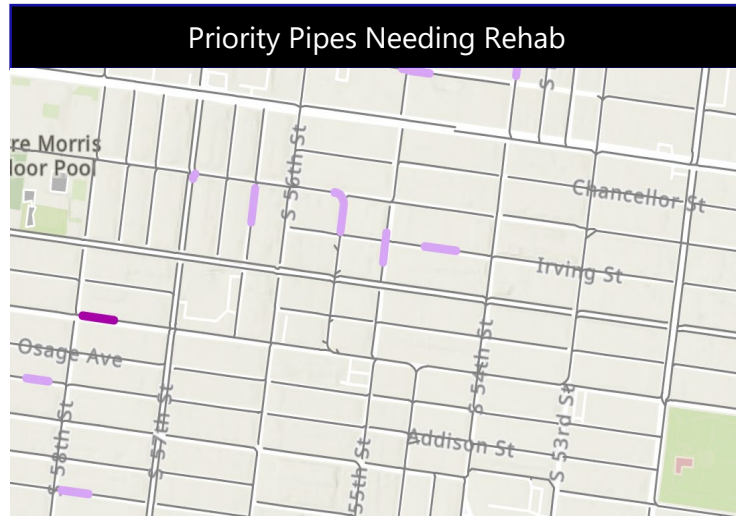
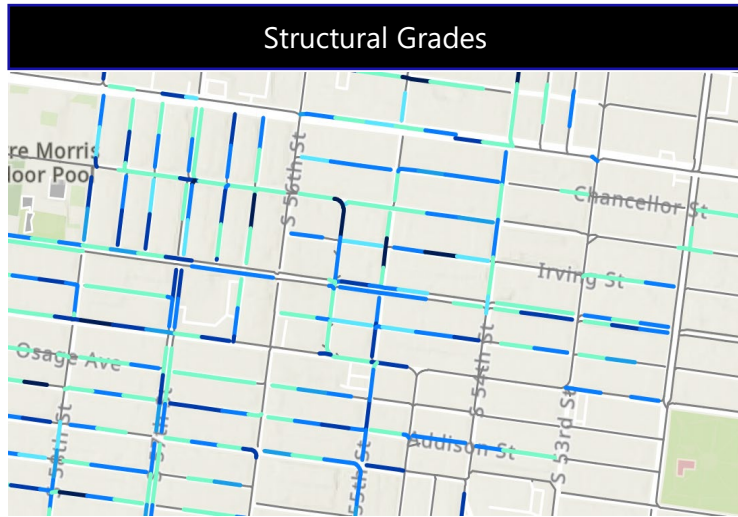
# Glimpse into Output: Scores



# Glimpse into Output: Next Step



# Integrate Argon results with GIS





# Glimpse into Output: Costs

27K      5      161

## Cost Estimates and Rehab Recommendations for Priority Pipes

Length (ft)      Length (mi)      # Pipes

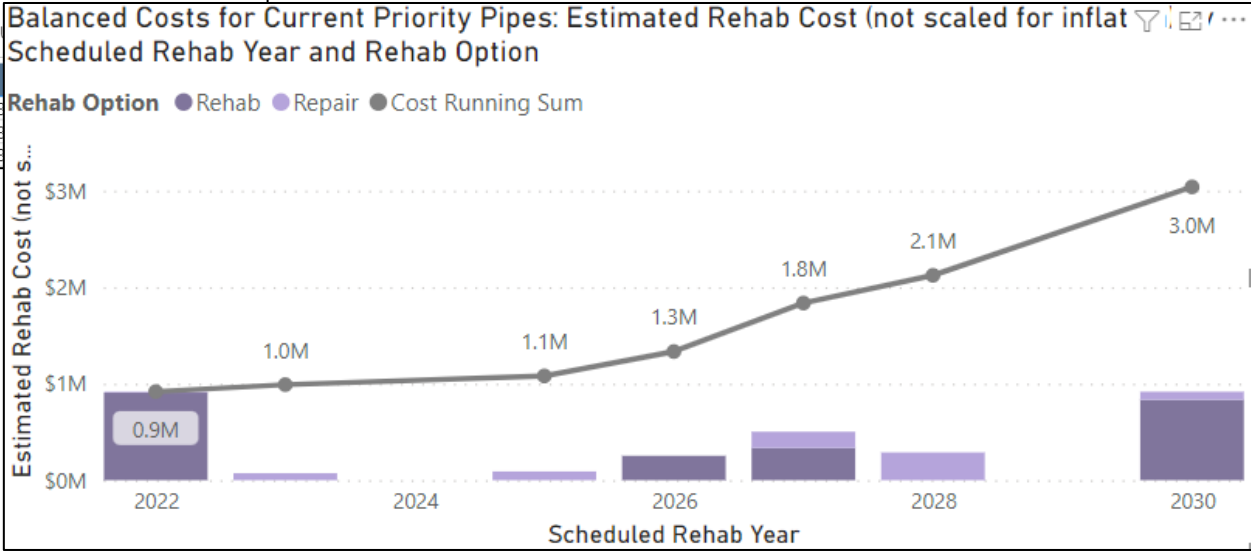
**Cost, length (ft) and Num Pipes by Rehab Method**

	Rehab	Repair
Cost	\$758,886	\$245,708
length (ft)	19060	7546
Num Pipes	130	31

**Cost by COFGrade**

COFGrade	Cost
1	\$50.8K
2	\$240.0K
3	\$287.4K
5	\$426.4K

PipeID	SewerType_Std	USBASIN	Diameter	Length	LastCCTVDate	Last Structl Score	COFGrade	Status	Priority
006-296 006-297	Sewer	006	8	427	6/27/2018	96	1	Find Solution - Structural	Priority 3
006-298 006-310	Sewer	006	8	457	8/2/2018	91	1	Find Solution - Structural	Priority 3
013-170 013-169	Sewer	013	8	240	8/1/2018	94	1	Find Solution - Structural	Priority 3



# How you can use **Artificial Intelligence**

## Process Historic Data



- Code your old videos and turn old data into a forecasting tool for the future
- A 10% increase in accuracy lifecycle forecasts can result in up to 25% reduction in ownership costs

## Conduct QA/QC Checks



- Enforce quality expectations on existing deliverables
- Automating the defect coding process for QC can save between 8% to 45% of office costs

## Save on In-Field Time



- Empower crews to focus on logistics and safety – not defect coding
- Deferring defect coding can reduce in-house inspection costs by 3-14% and 3<sup>rd</sup> party costs by 20-26%

## Standardize Surveys



- Objective coding for effective comparison of Pre- and Post-Construction Surveys and Warranty Surveys
- Quality assessment of new construction pipeline prior to being assumed



# Thank you!

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<https://www.jacobs.com/technology/dragonfly>

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**Jacobs**

Challenging today.  
Reinventing tomorrow.

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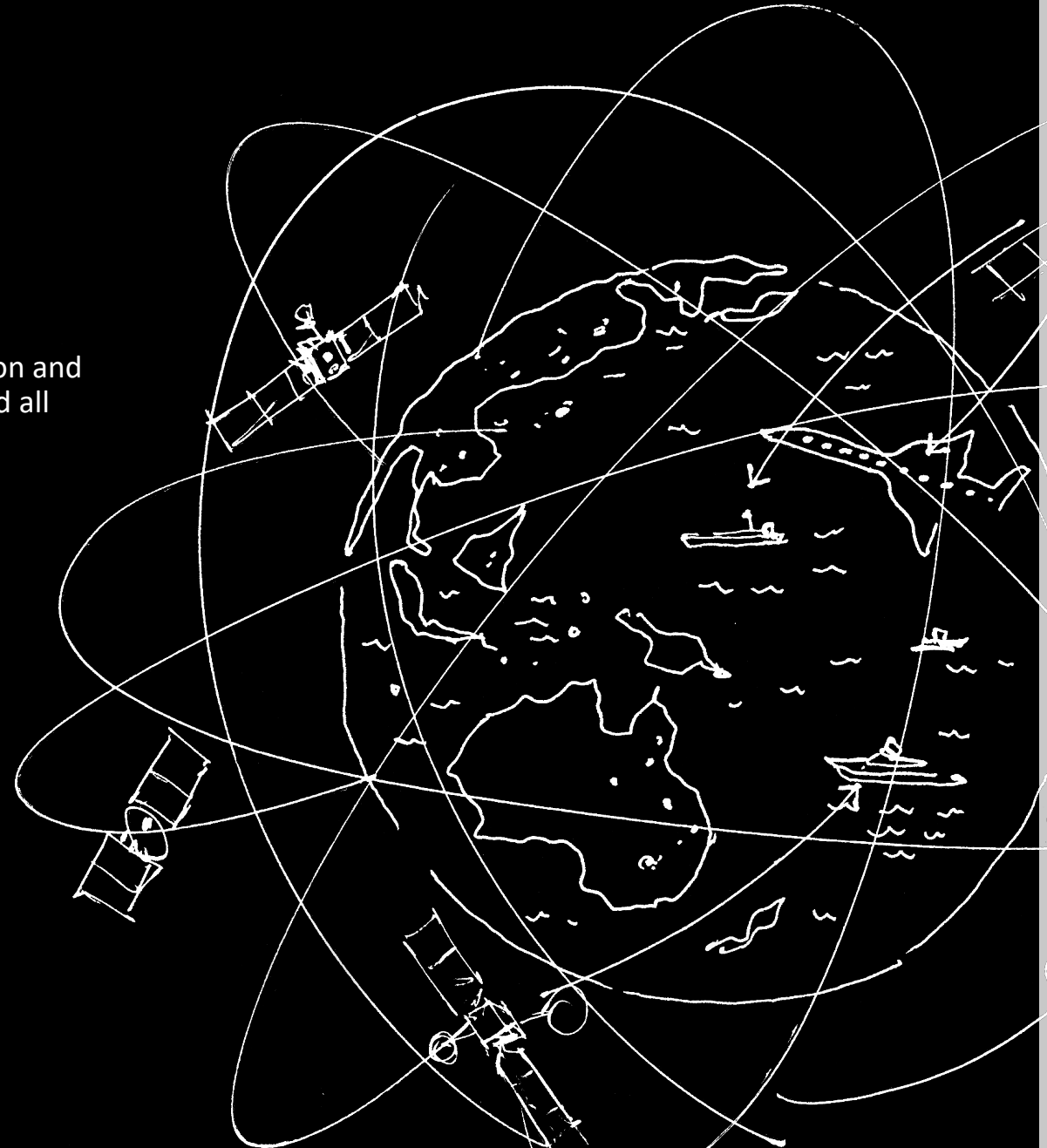
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