City of Houston, TX: Using CCTV to Recommend Sewer Rehabilitation (1990-2025)

Recently adopting Artificial Inttelligence to support the review and reporting of CCTV results in assessing its sanitary sewer system, the City of Houston finalized its latest consent decree with the State of Texas Commission on Environmental Quality (TCEQ) and US Environmental Protection Agency (EPA) to spend up to $ 9 billion on rehabilitating its sewer network to reduce sewer overflows and spills.

Representing a $3 billion increase from estimates of $6 billion from just a few years ago, the City of Houston is no stranger to consent decrees.

In 1989, the City of Houston entered into its first major consent decree with the EPA to address sanitary sewer overflows (SSOs) and improve the city's aging wastewater system, requiring a $2 billion investment over 15 years for upgrades and infrastructure improvements.

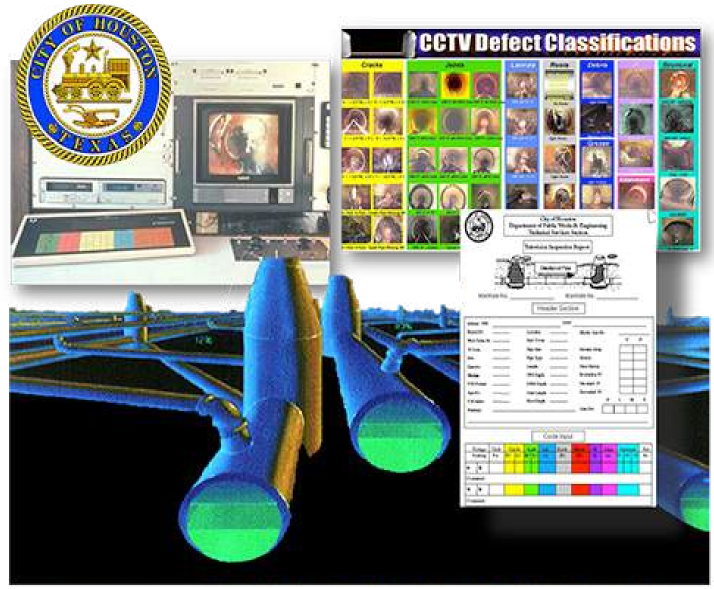
Largest CCTV Inspection Project in US Public Works History Begins

Supported by four major prime contractors, including Gutierrez Smouse Wilmut & Associates Inc.[1], and 250 CCTV trucks, the City of Houston began the public works industry largest sanitary sewer inspection project, starting in 1990.

Led by Henry Gregory, Director of Wasteload Control, City of Houston, Gregory was unhappy having previous contractors use different manhole numbering conventions and different standards for describing the condition of sewer mains and manholes.

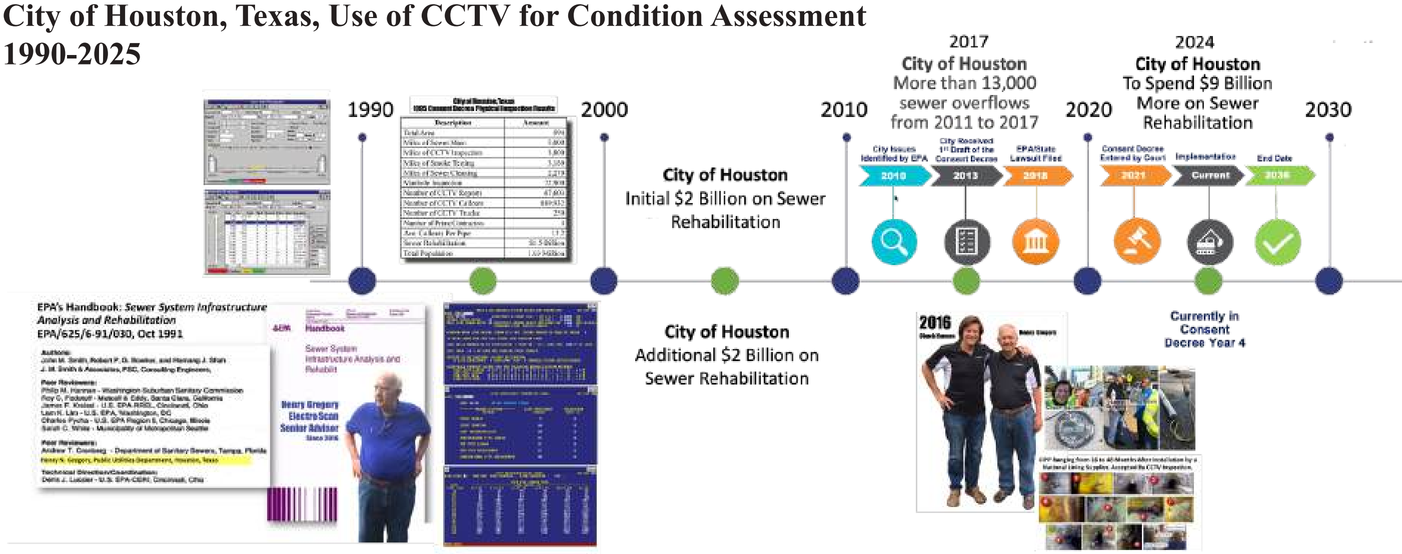
Working with Chuck Hansen, Chief Operating Officer, of Sacramento, Calif.-based Hansen Software Inc. to supply integrated field software, hardware, training, and ongoing support to manage all physical inspection data gathering, analysis, and reporting.

After visits to the UK to review WRc CCTV standards, it was determined that more precise data capture would be needed to assess SSOs and overflow conditions faced by the City of Houston.



Description	Amount
Total Area	594
Miles of Sewer Main	5,000
Miles of CCTV Inspection	3,800
Miles of Smoke Testing	3,180
Miles of Sewer Cleaning	2,270
Manhole Inspection	72,900
Number of CCTV Reports	67,603
Number of CCTV Callouts	889,932
Number of CCTV Trucks	250
Number of Prime Contractors	4
Ave. Callouts Per Pipe	13.2
Sewer Rehabilitation	$ 2 Billion
Total Population	1.63 Million

City of Houston, Texas, Use of CCTV for Condition Assessment 1990-2025



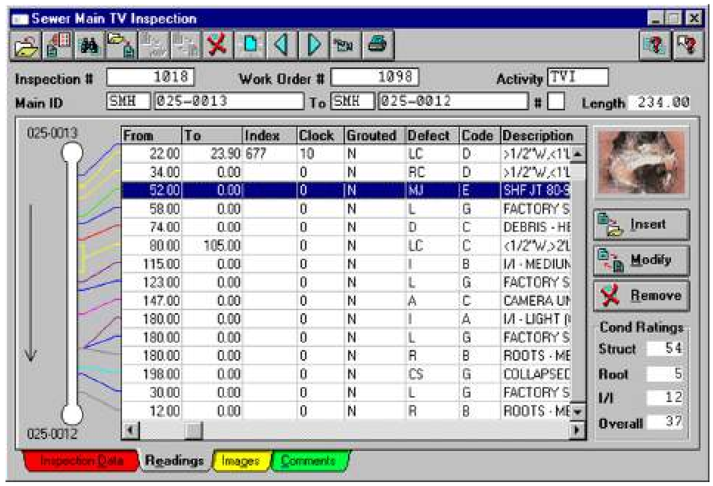
1. Charles Wilmut, PE,, co-author Hillsborough County study, former Partner, Gutierrez Smouse Wilmut & Associates Inc., Special Advisor, Electro Scan Inc.

First AI Decision Support Tool to Use CCTV Visual Inspections to Recommend Rehabilitation

Recording nearly 900,000 defects from 67,603 CCTV inspections averaging 13.2 readings per inspection, the project became a model for all cities. Supported by Hansen Software, Houston ran a 'find & fix' project with monthly EPA Region 6 reporting.

Keen to use its ridgely-enforced CCTV coding standards, the Houston project team wanted to harness modern day computing power with well-established construction & engineering standards to automatically recommend specific repairs.

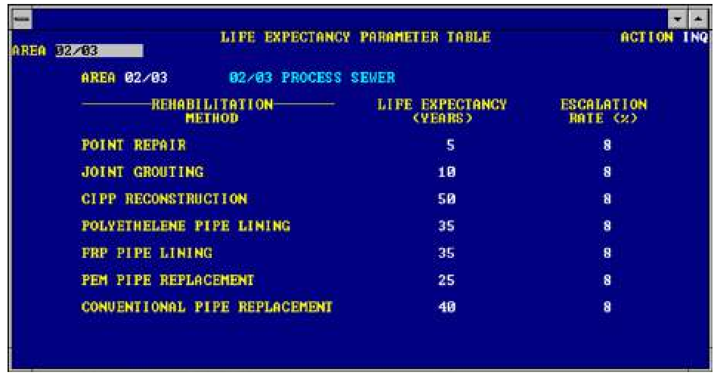
Used from 1990-2005, nearly $4 billion of rehabilitation was selected, using a first generation decision support model written by Hansen Software. But as SSOs grew, often occurring on the same pipes repaired, the use of CCTV became questionable.



From	To	Index	Clock	Grouted	Defect	Code	Description
22.00	23.90	677	10	N	LC	D	>1/2"W,<1'L
34.00	0.00		0	N	RC	D	>1/2"W,<1'L
52.00	0.00		0	N	MJ	E	SHF JT 80-9
58.00	0.00		0	N	L	G	FACTORY S
74.00	0.00		0	N	D	C	DEBRIS - HE
80.00	105.00		0	N	LC	C	<1/2"W,>2'L
115.00	0.00		0	N	I	B	I/I - MEDIUM
123.00	0.00		0	N	L	G	FACTORY S
147.00	0.00		0	N	A	C	CAMERA UN
180.00	0.00		0	N	I	A	I/I - LIGHT
180.00	0.00		0	N	L	G	FACTORY S
180.00	0.00		0	N	R	B	ROOTS - ME
198.00	0.00		0	N	CS	G	COLLAPSED
30.00	0.00		0	N	L	G	FACTORY S
12.00	0.00		0	N	R	B	ROOTS - ME

REHABILITATION SELECTION MODULE
REHABILITATION SELECTION TABLE MENU

A. MAIN LINE REHAB. PARAMETER
B. LIFE EXPECTANCY PARAMETER
C. RESULTANT FLOW FACTOR
D. REHAB EFFECTIVENESS FACTOR
E. I/I QUANTITY MATRIX
F. POINT REPAIR COST
G. JOINT GROUTING COST
H. CIPP RECONSTRUCTION COST
I. POLYETHYLENE PIPE LINING COST
J. FRP PIPE LINING COST
K. PEM PIPE REPLACEMENT COST
L. CONVENTIONAL PIPE REPLACEMENT COST
M. MANHOLE REHABILITATION COST
N. SERVICE LINE REHABILITATION COST

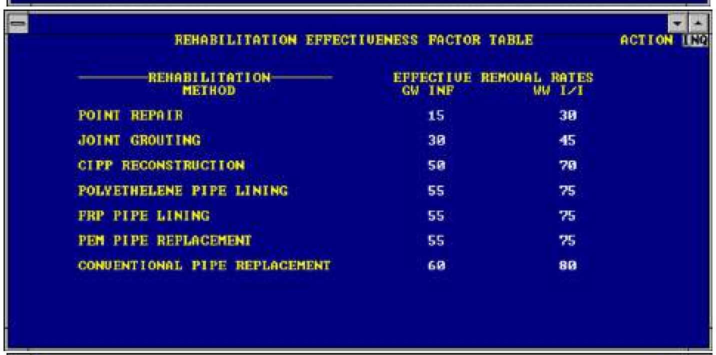


LIFE EXPECTANCY PARAMETER TABLE — ACTION INQ

AREA 02/03

AREA 02/03 — 02/03 PROCESS SEWER

REHABILITATION METHOD	LIFE EXPECTANCY (YEARS)	ESCALATION RATE (%)
POINT REPAIR	5	8
JOINT GROUTING	10	8
CIPP RECONSTRUCTION	50	8
POLYETHELENE PIPE LINING	35	8
FRP PIPE LINING	35	8
PEM PIPE REPLACEMENT	25	8
CONVENTIONAL PIPE REPLACEMENT	40	8



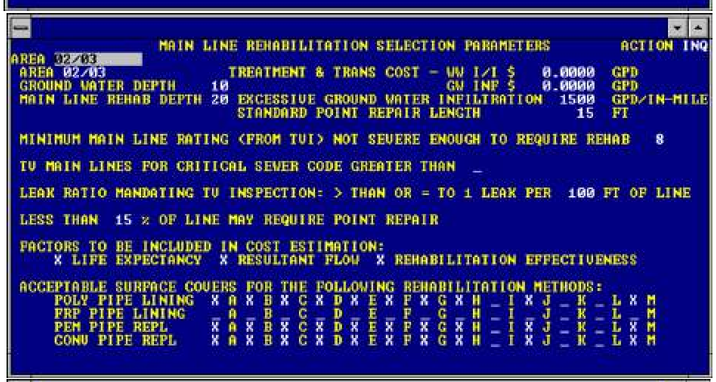
REHABILITATION EFFECTIVENESS FACTOR TABLE — ACTION INQ

REHABILITATION METHOD	EFFECTIVE REMOVAL RATES GW INF	WW I/I
POINT REPAIR	15	30
JOINT GROUTING	30	45
CIPP RECONSTRUCTION	50	70
POLYETHELENE PIPE LINING	55	75
FRP PIPE LINING	55	75
PEM PIPE REPLACEMENT	55	75
CONVENTIONAL PIPE REPLACEMENT	60	80

RESULTANT FLOW FACTOR TABLE — ACTION INQ

LINE SIZE 0

LINE SIZE (IN)	POINT REPAIR	JOINT GROUTING	CIPP RECONST	POLY PIPE LINING	FRP PIPE LINING	PEM PIPE REPL	CONV PIPE REPL
6	1.000	0.000	0.000	0.991	0.000	1.726	1.000
8	1.000	1.000	1.398	0.803	0.000	1.620	1.000
10	1.000	1.000	1.446	0.895	0.000	1.609	1.000
12	1.000	1.000	1.477	0.991	0.000	1.558	1.000
15	1.000	1.000	1.446	0.871	0.000	0.000	1.000
18	1.000	1.000	1.450	0.970	1.152	0.000	1.000
21	1.000	1.000	1.454	0.881	1.184	0.000	1.000
24	1.000	1.000	1.457	0.991	1.092	0.000	1.000
27	1.000	0.000	1.459	0.970	1.153	0.000	1.000
30	1.000	0.000	1.461	1.105	0.969	0.000	1.000
33	1.000	0.000	1.463	0.857	1.153	0.000	1.000
36	1.000	0.000	1.464	0.930	1.060	0.000	1.000
42	1.000	0.000	1.466	0.881	1.136	0.000	1.000
48	1.000	0.000	1.477	0.930	1.188	0.000	1.000
54	1.000	0.000	1.477	0.000	1.237	0.000	1.000
60	1.000	0.000	1.469	0.000	1.278	0.000	1.000



MAIN LINE REHABILITATION SELECTION PARAMETERS — ACTION INQ

AREA 02/03
AREA 02/03 — TREATMENT & TRANS COST - WW I/I $ 0.0000 GPD
GROUND WATER DEPTH 10 — GW INF $ 0.0000 GPD
MAIN LINE REHAB DEPTH 20 EXCESSIVE GROUND WATER INFILTRATION 1500 GPD/IN-MILE
STANDARD POINT REPAIR LENGTH 15 FT

MINIMUM MAIN LINE RATING (FROM TVI) NOT SEVERE ENOUGH TO REQUIRE REHAB 8

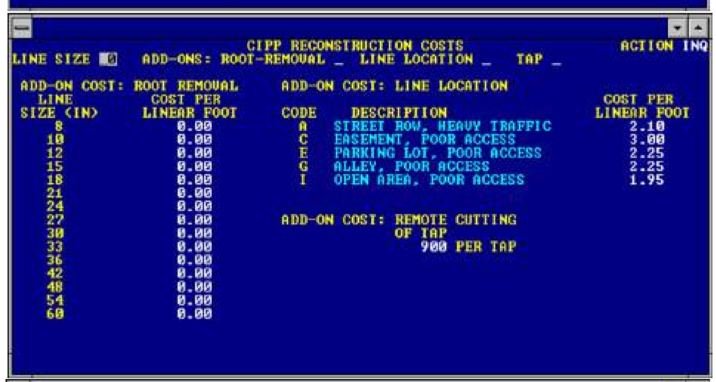
TV MAIN LINES FOR CRITICAL SEWER CODE GREATER THAN _

LEAK RATIO MANDATING TV INSPECTION: > THAN OR = TO 1 LEAK PER 100 FT OF LINE

LESS THAN 15 % OF LINE MAY REQUIRE POINT REPAIR

FACTORS TO BE INCLUDED IN COST ESTIMATION:
X LIFE EXPECTANCY X RESULTANT FLOW X REHABILITATION EFFECTIVENESS

ACCEPTABLE SURFACE COVERS FOR THE FOLLOWING REHABILITATION METHODS:
POLY PIPE LINING X A X B X C X D X E X F X G X H _ I X J _ K _ L X M
FRP PIPE LINING _ A _ B _ C _ D _ E _ F _ G _ H _ I _ J _ K _ L _ M
PEM PIPE REPL X A X B X C X D X E X F X G X H _ I X J _ K _ L X M
CONV PIPE REPL X A X B X C X D X E X F X G X H _ I X J _ K _ L X M



CIPP RECONSTRUCTION COSTS — ACTION INQ

LINE SIZE 0 ADD-ONS: ROOT-REMOVAL _ LINE LOCATION _ TAP _

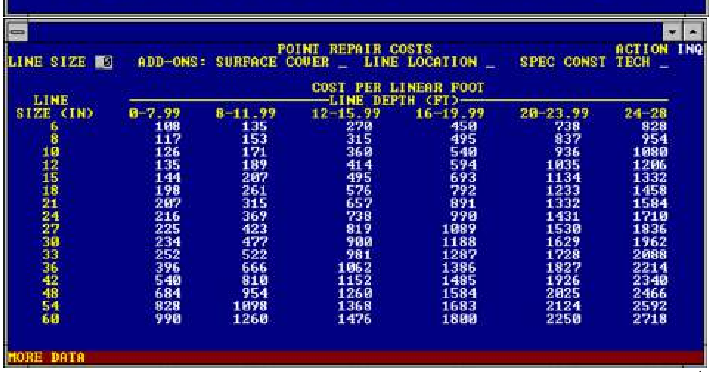
ADD-ON COST: ROOT REMOVAL

LINE SIZE (IN)	COST PER LINEAR FOOT
8	0.00
10	0.00
12	0.00
15	0.00
18	0.00
21	0.00
24	0.00
27	0.00
30	0.00
33	0.00
36	0.00
42	0.00
48	0.00
54	0.00
60	0.00

ADD-ON COST: LINE LOCATION

CODE	DESCRIPTION	COST PER LINEAR FOOT
A	STREET ROW, HEAVY TRAFFIC	2.10
C	EASEMENT, POOR ACCESS	3.00
E	PARKING LOT, POOR ACCESS	2.25
G	ALLEY, POOR ACCESS	2.25
I	OPEN AREA, POOR ACCESS	1.95

ADD-ON COST: REMOTE CUTTING OF TAP
900 PER TAP



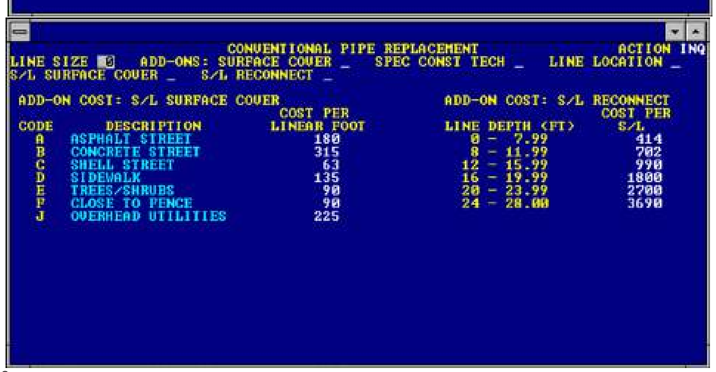
POINT REPAIR COSTS — ACTION INQ

LINE SIZE 0 ADD-ONS: SURFACE COVER _ LINE LOCATION _ SPEC CONST TECH _

COST PER LINEAR FOOT

LINE SIZE (IN)	LINE DEPTH (FT) 0-7.99	8-11.99	12-15.99	16-19.99	20-23.99	24-28
6	108	135	270	450	738	828
8	117	153	315	495	837	954
10	126	171	360	540	936	1080
12	135	189	414	594	1035	1206
15	144	207	495	693	1134	1332
18	198	261	576	792	1233	1458
21	207	315	657	891	1332	1584
24	216	369	738	990	1431	1710
27	225	423	819	1089	1530	1836
30	234	477	900	1188	1629	1962
33	252	522	981	1287	1728	2088
36	396	666	1062	1386	1827	2214
42	540	810	1152	1485	1926	2340
48	684	954	1260	1584	2025	2466
54	828	1098	1368	1683	2124	2592
60	990	1260	1476	1800	2250	2718

MORE DATA



CONVENTIONAL PIPE REPLACEMENT — ACTION INQ

LINE SIZE 0 ADD-ONS: SURFACE COVER _ SPEC CONST TECH _ LINE LOCATION _
S/L SURFACE COVER _ S/L RECONNECT _

ADD-ON COST: S/L SURFACE COVER

CODE	DESCRIPTION	COST PER LINEAR FOOT
A	ASPHALT STREET	180
B	CONCRETE STREET	315
C	SHELL STREET	63
D	SIDEWALK	135
E	TREES/SHRUBS	90
F	CLOSE TO FENCE	90
J	OVERHEAD UTILITIES	225

ADD-ON COST: S/L RECONNECT

LINE DEPTH (FT)	COST PER S/L
0 - 7.99	414
8 - 11.99	702
12 - 15.99	990
16 - 19.99	1800
20 - 23.99	2700
24 - 28.00	3690

CCTV Begins to Falter Assessing Sewers, 2010

Despite widespread adoption of cured-in-place pipe (CIPP) oftentimes claiming a 50-70 year useful life, liner failures began to emerge. Using resin-based materials heated to thermoset to form a new pipe, service connections that are temporarily covered in the initial lining process would utilize remote cutting tools to re-open services to allow flow from a household.

It was about this time that long-time educator and advisor to Hansen Software, now Hansen Information Technologies, Kenneth D. Kerri, PhD, PE, approached Chuck Hansen to see if he knew any new technology that could locate leaks in CIPP.

A number of Dr. Kerri's former students had been reporting liner collapses and other failures, some occurring as early as 1-2 years after installation and outside of the manufacturer's warranty period.

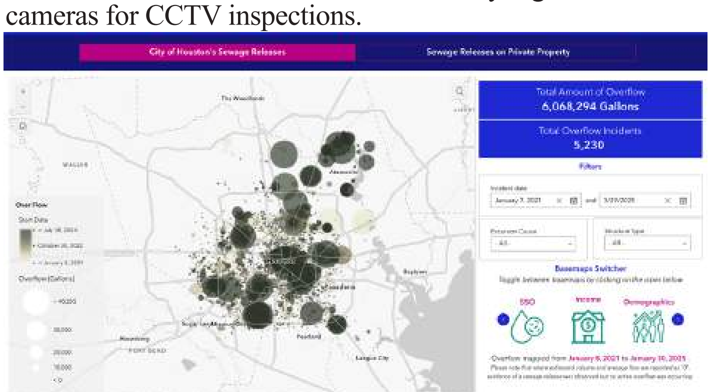
After nearly 100 projects, covering sewer mains & service laterals, pipe materials including over 50 pipe materials, and rehabilitation methods, including Conventional Replacement, CIPP, Danby, Fold & Form, Joint Grout, Point Repairs, Sliplining, Spiral Wrap, and Spray In Place,

Henry Gregory Investigates 'What Happened in Houston After SSOs Grew at Repaired Pipes?'

Retiring from the City of Houston after a 40 year career with the City of Houston, Henry Gregory watched as the city continued to grapple with SSOs and flooding, especially as part of wet weather events that are commonplace in Houston.

Responsible for much of the rehabilitation that took place between 1990 and 2010, Gregory was interested to see how Houston apparently did everything right, yet still seeing increasing levels in infiltration and overflows.

Called by Chuck Hansen at Electro Scan to help diagnose issues on a recently lined CIPP at the City of Roseville, California, Hansen wanted to use Focused Electrode Leak Location (FELL) technology, a promising machine-intelligent, artifical intelligence-based solution and get Gregory's input. Visiting in May 2016, Gregory saw a solution that could find leaks in CIPP, undetectable by visual inspection. He also began to realize the shortcomings of his earlier work in Houston, as defects at service connections, liner quality, and inverts were not able to be evaluated by high resolution cameras for CCTV inspections.



(Above) Dr. Kerri first points out the failure of CCTV to properly assess pipes (2010).

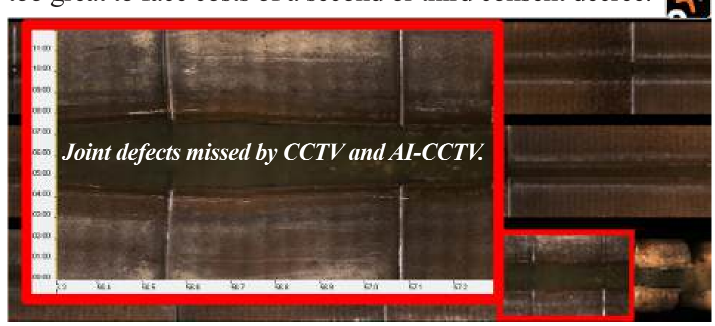
(Below) Henry Gregory reviews CCTV and FELL technologies on a failed West Coast CIPP lining project (2016).

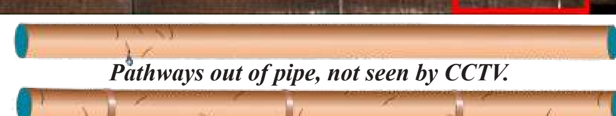
Days after Hurricane Harvey hit Houston, Gregory called in Electro Scan to test FELL on large diameter sewer mains in the downtown where major flooding occurred and previously rehabilitated, with results shown on the next page.

Not only was major corrosion confirmed on concrete pipe, major leaks were recorded in a downstream CIPP lined pipe.

With the inability for CCTV cameras to (1) differntiate between superficial cracks and cracks that go through the wall of a pipe, (2) determine whether pipe joints are watertight, (3) confirm if service connections leak, and (4) approve or accept the operational readiness of post-rehabilitation or repairs, CCTV should no longer be used as a means to either select or prioritize pipes for rehabilitation.

And, despite the speed and consistency of AI-CCTV image recognition algorthms, the risk of false-positive readings (i.e. sewer mains that allow infiltration, not identified by CCTV) is too great to face costs of a second or third consent decree.



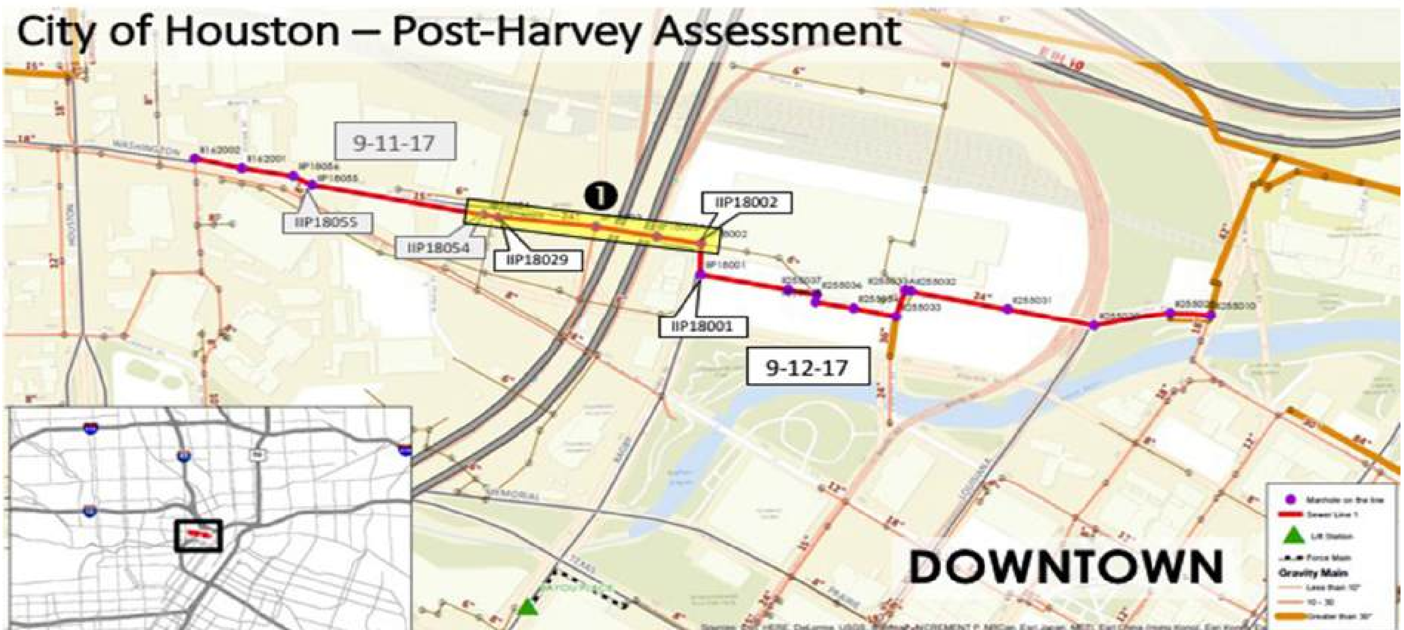


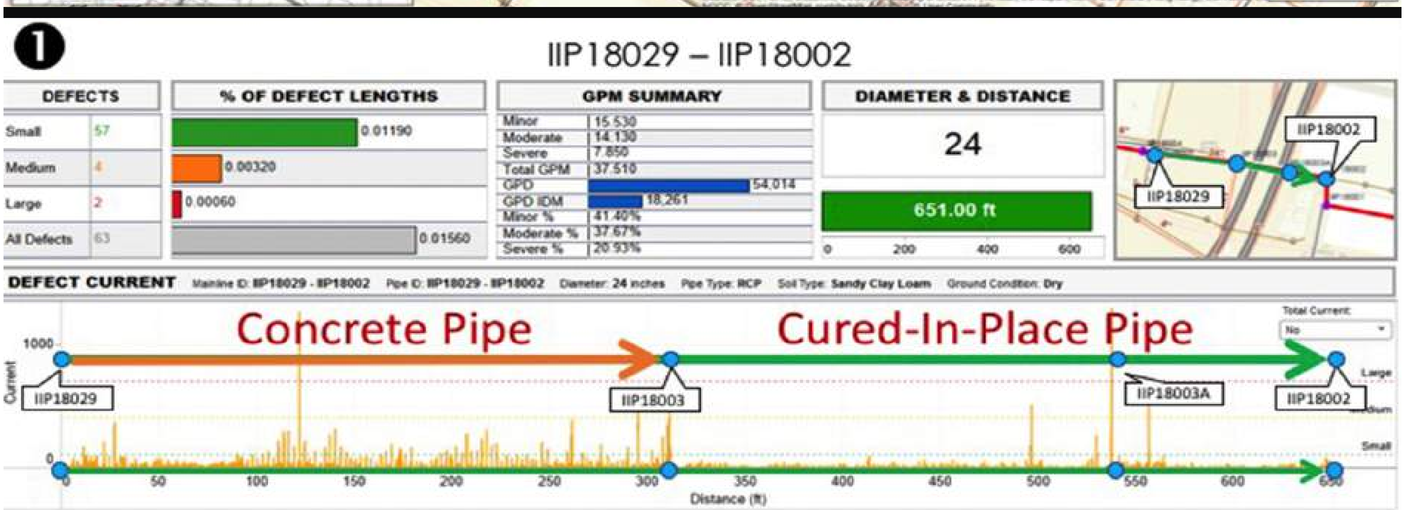
Pathways out of pipe, not seen by CCTV.


September 12, 2017
Chuck Hansen


CITY OF HOUSTON
SEWER
CITY OF HOUSTON


Henry Gregory
Greg Davis


City of Houston – Post-Harvey Assessment
9-11-17
IIP18055
IIP18054
IIP18029
IIP18002
IIP18001
9-12-17
DOWNTOWN


IIP18029 – IIP18002
DEFECTS
Small 57
Medium 4
Large 2
All Defects 63
% OF DEFECT LENGTHS
0.01190
0.00320
0.00060
0.01560
GPM SUMMARY
Minor 15.530
Moderate 14.130
Severe 7.850
Total GPM 37.510
GPD 54,014
GPD IDM 18,261
Minor % 41.40%
Moderate % 37.67%
Severe % 20.93%
DIAMETER & DISTANCE
24
651.00 ft
IIP18002
IIP18029
DEFECT CURRENT
Concrete Pipe
Cured-In-Place Pipe
IIP18029
IIP18003
IIP18003A
IIP18002
Distance (ft)

electroscaninc.

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