Replacing Seismically-Weak and Aging Water Pipes

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ASCE's Viewpoint

- Aging Infrastructure
- Score Card: D- to C-
- Is this Rational, Silly, or what?

Where's the Problem?

- Cause 1 (leaks):
- Existing Customers are CHEAP!
- Water Boards, City Councils are loathe to increase rates.
- "If we replace 0.2% per year, and no one yells (too much), we must be right!"

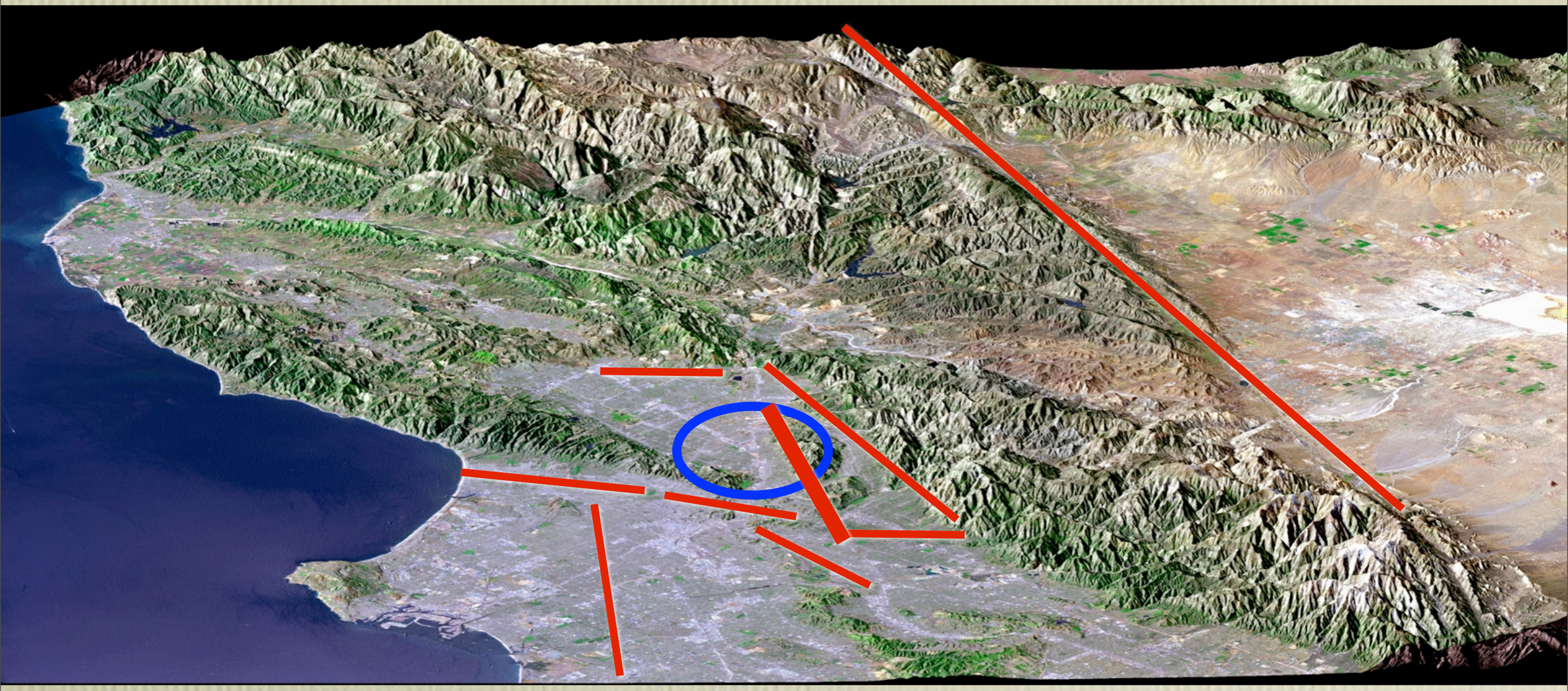
Why Replace Pipes?

- Cause 1. Pipes leak! Aging, Corrosion, Earthquake, etc.
- Cause 2. Relocations (new highway, etc.)
- Cause 3. Growth. Flow rate of an older 4” pipe no longer meets modern flow requirements
- Cause 4. After earthquakes, either patch the leaks (sporadic) or replace (severe damage)

Japan and USA Practices

- Japan: All water pipes are replaced after about 65 years. JWWA / DI manufacturers seem to set the rules. Customers pay.
  - Everyone is happy.
- USA. No water pipes are replaced until they are leaking like sieves. If asked, Customers say no. If asked, FEMA says no.
  - Everyone is unhappy.

Burbank Water and Power



Verdugo Fault

Other Nearby Faults

Oracle Headquarters

Redwood City

Liquefaction Potential

Very High

Moderate

Low

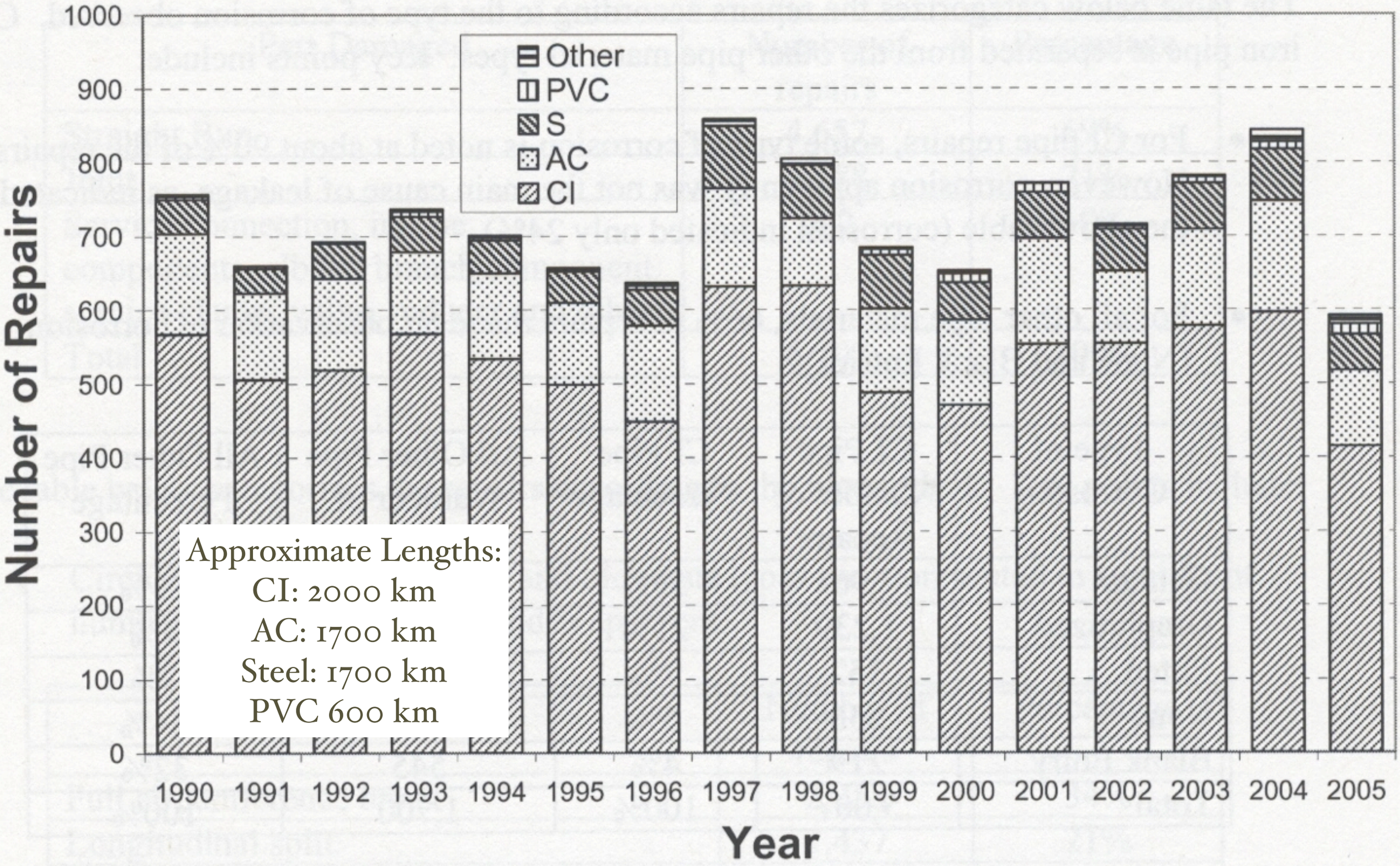
Where's the Problem?

- Cause 4 (earthquake):
- BIG PROBLEM!
- But, is the cost to replace for earthquake justified, unless we can combine this with leaks?

The Big Question

- My pipes (Cast Iron) are 50 to 90 years old.
- Many of them are at the end of their lives.
- I need a rate increase of 30% in order to replace them on a 100 year cycle.
- How do I convince the Board / City Council / customers to accept this rate increase?

Pipe Repairs - EBMUD (11,500 Repair Database)

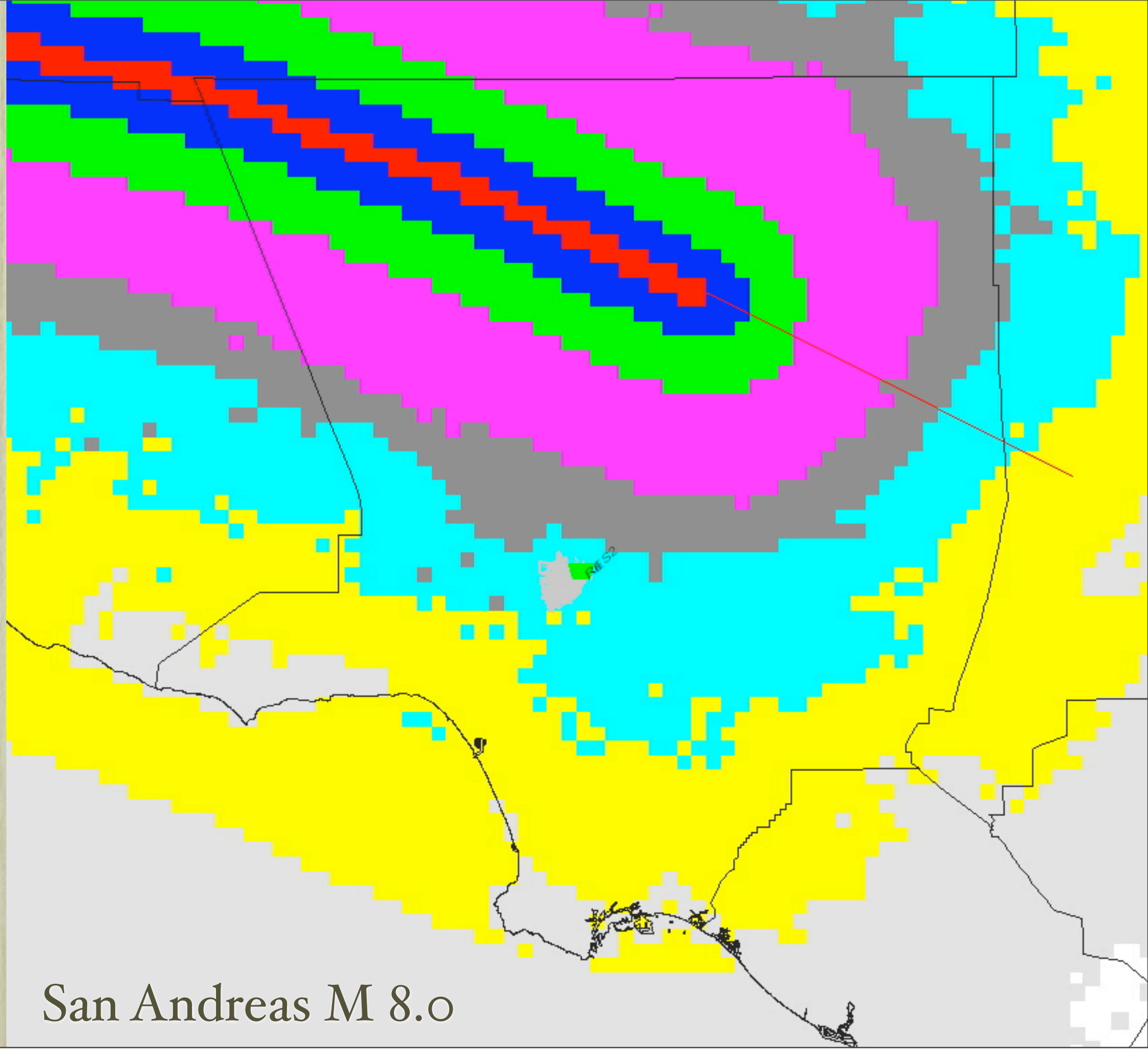


Approximate Lengths:
CI: 2000 km
AC: 1700 km
Steel: 1700 km
PVC 600 km

Actual Evidence Burbank Granular, Non-Corrosive Soils

PGA

Red: 0.70g+
Blue: 0.55g+
Green: 0.40g+
Magenta: 0.25g+
Grey: 0.20g+
L. Blue: 0.15g+
Yellow: 0.10g+
L. Grey: 0.05g+



San Andreas M 8.0

Verdugo M 6.9

PGA

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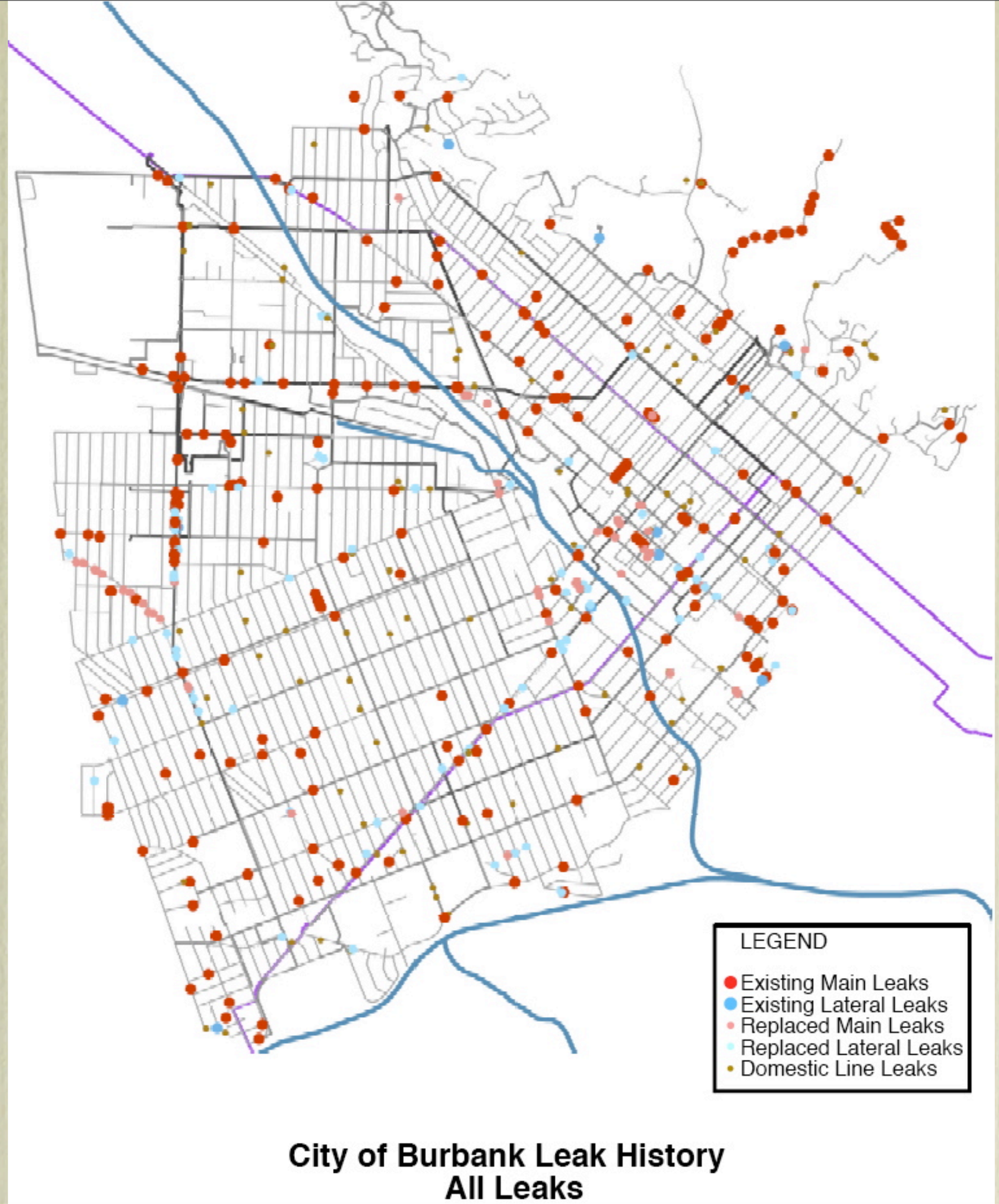
Burbank: Home of Movies!

105,000 people

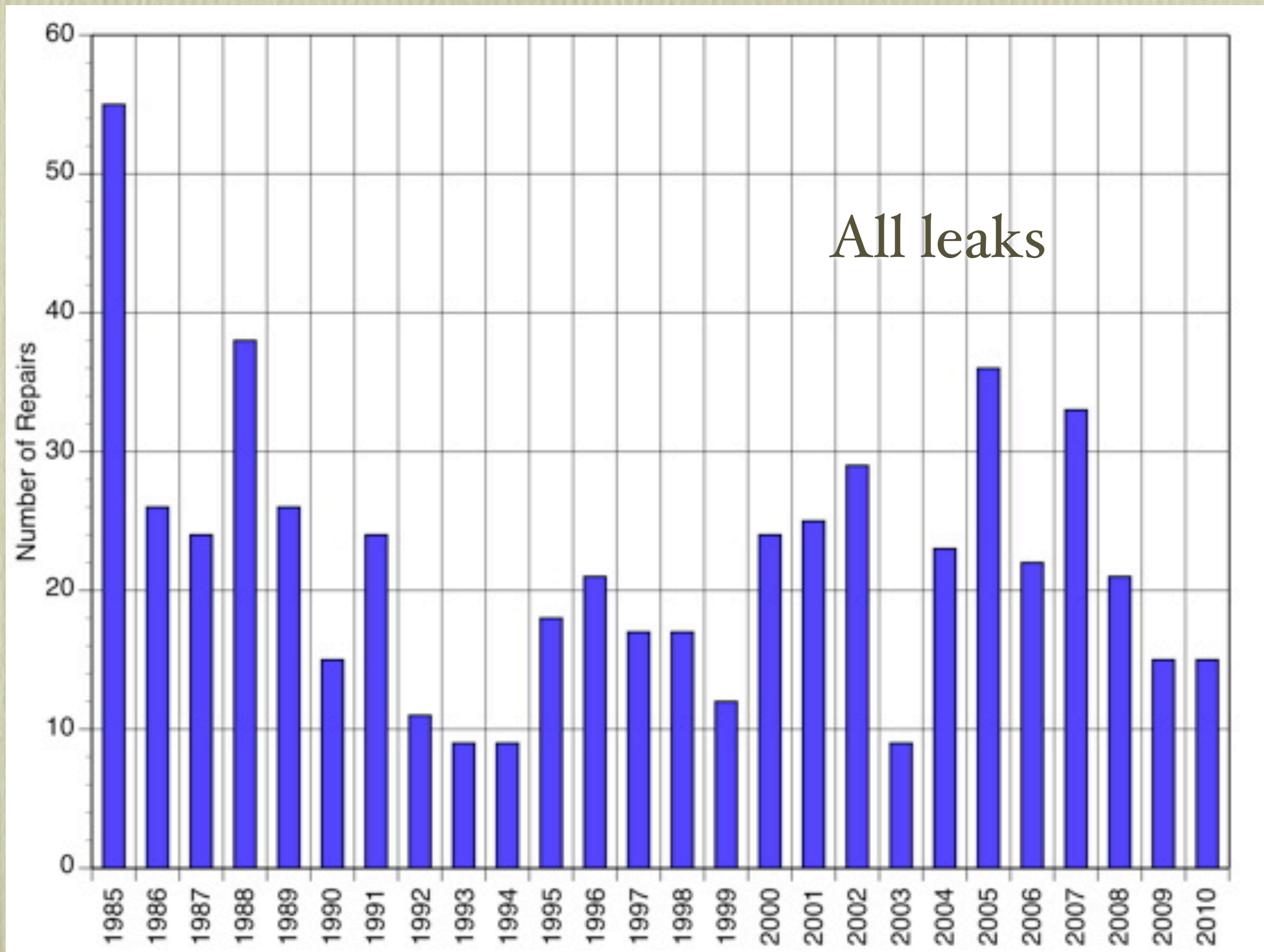
500 km of water pipes

85% are "old" Cast Iron Pipes (1910-1930)



City of Burbank Leak History
All Leaks

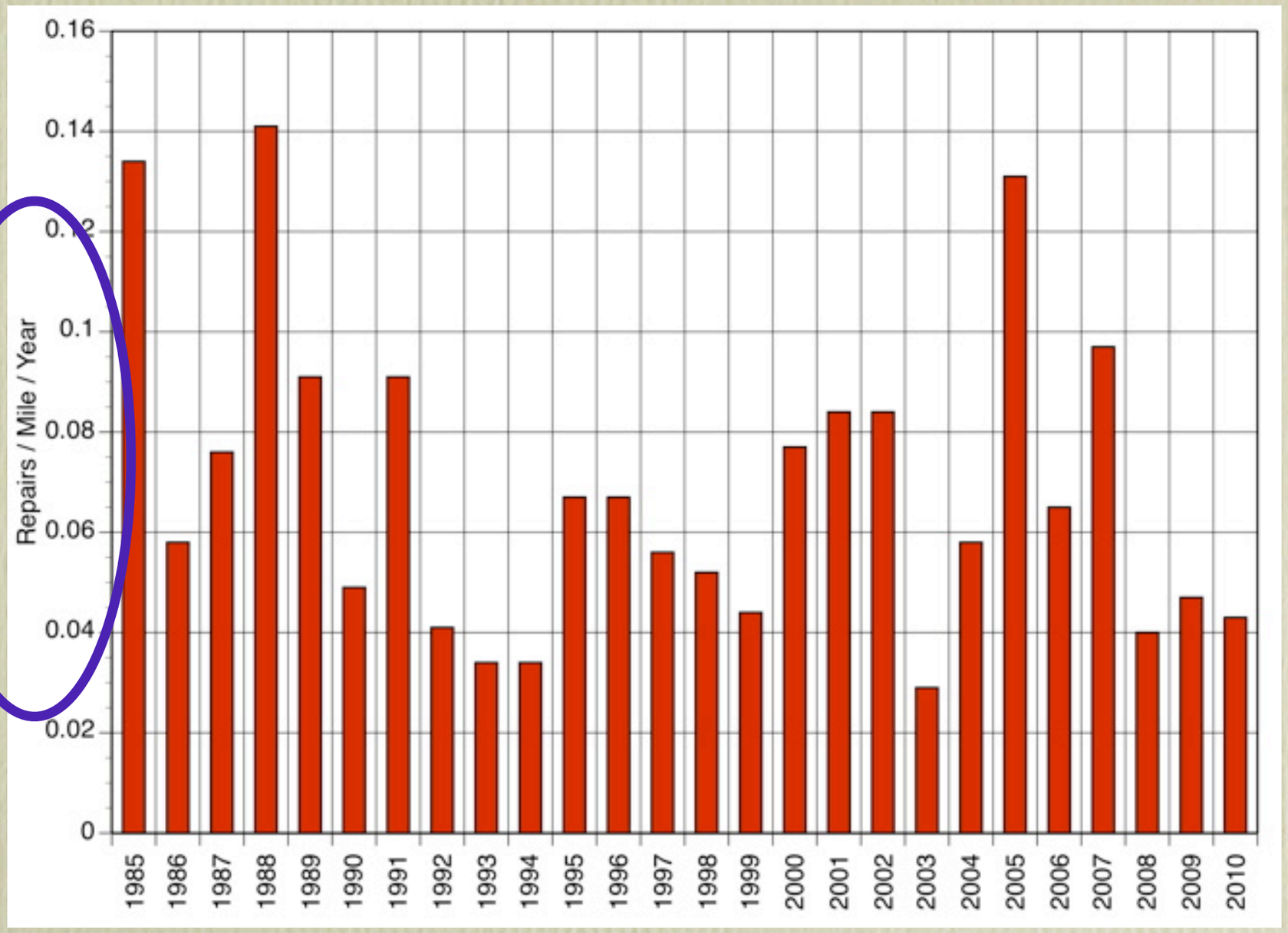
Leak History



No trend for increasing leaks in past 24.5 years

Leak History

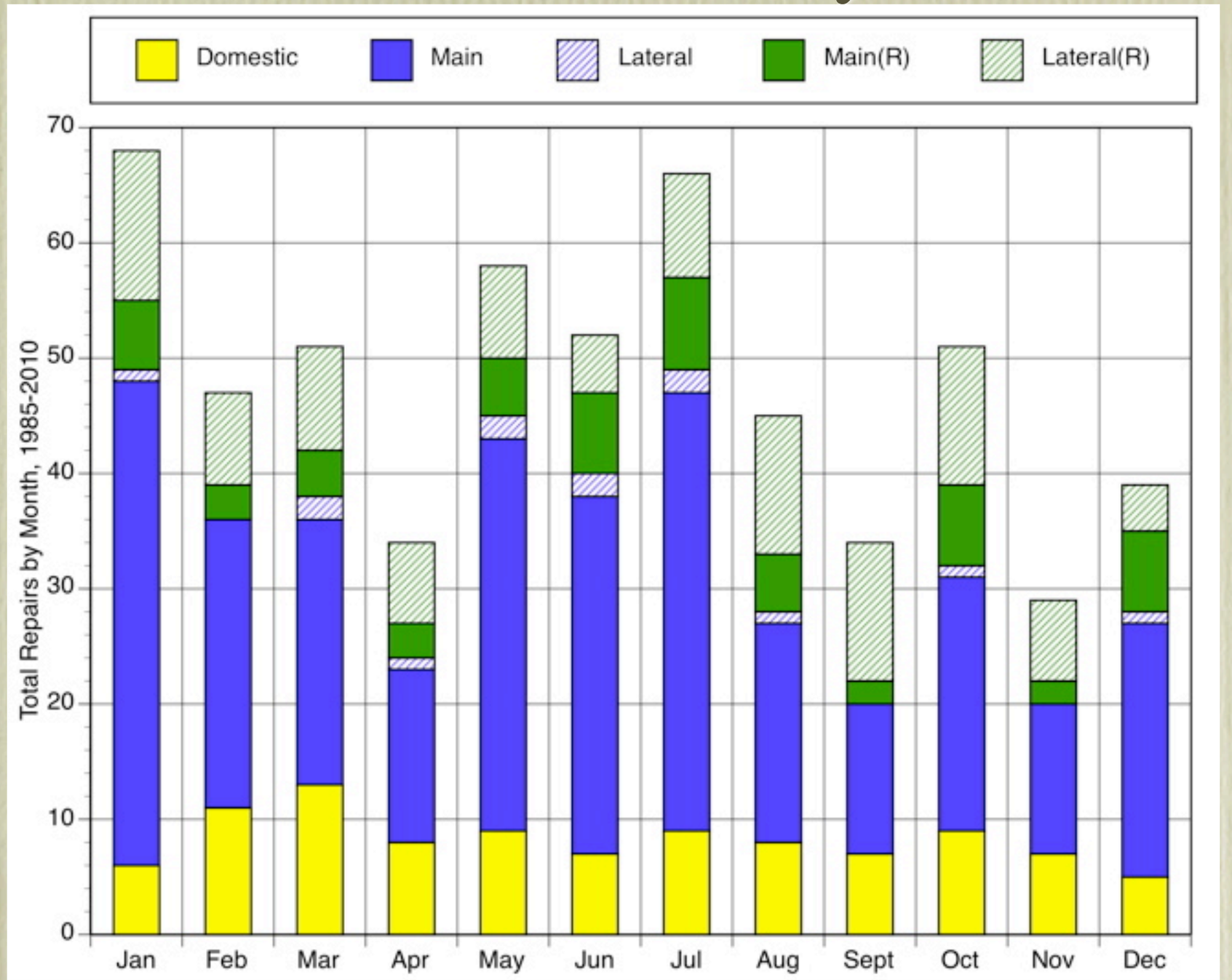
Industry Average: 0.24 to 0.27



No trend for increasing leak rate in past 24.5 years

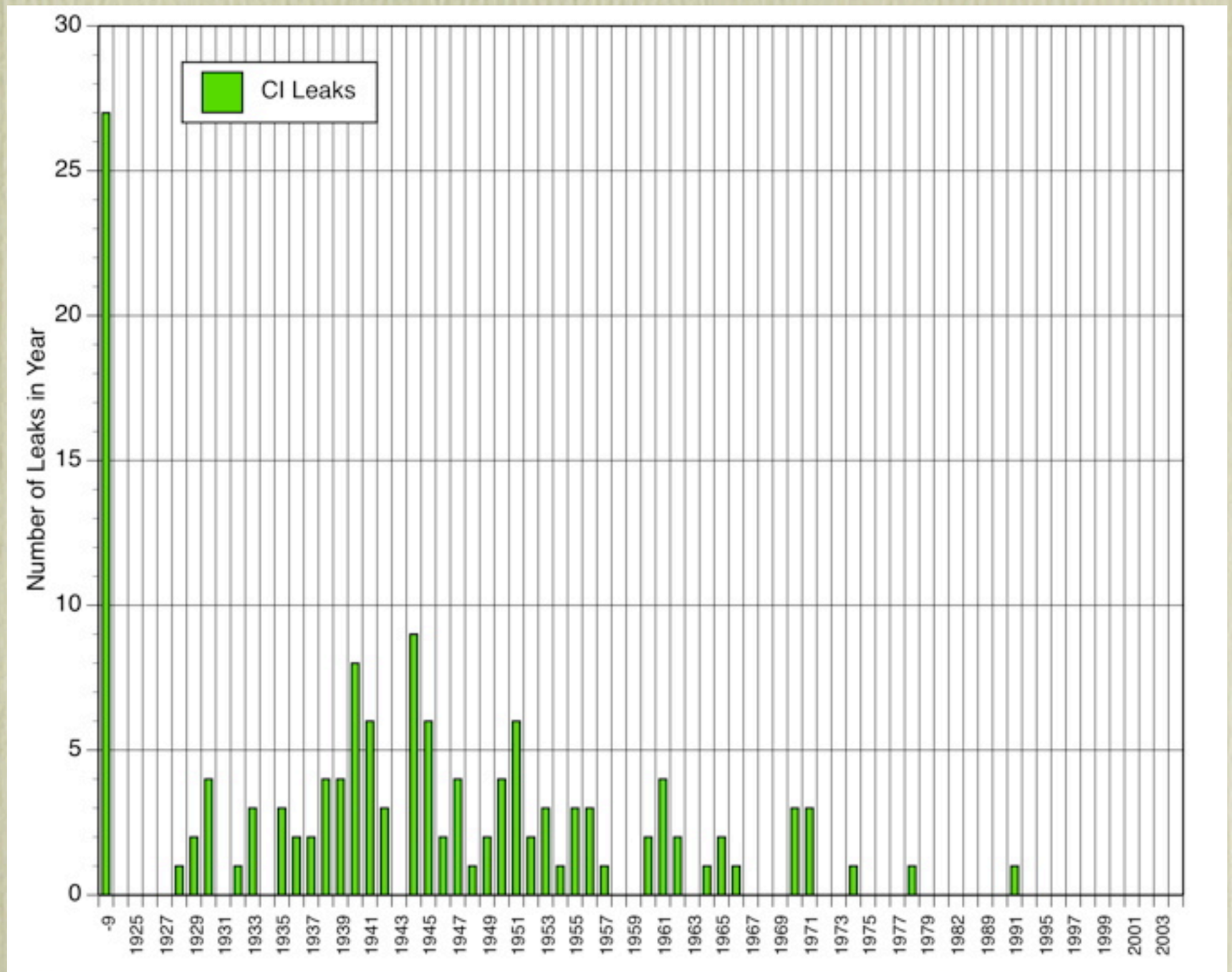
excludes leaks on domestic pipes

Seasonality



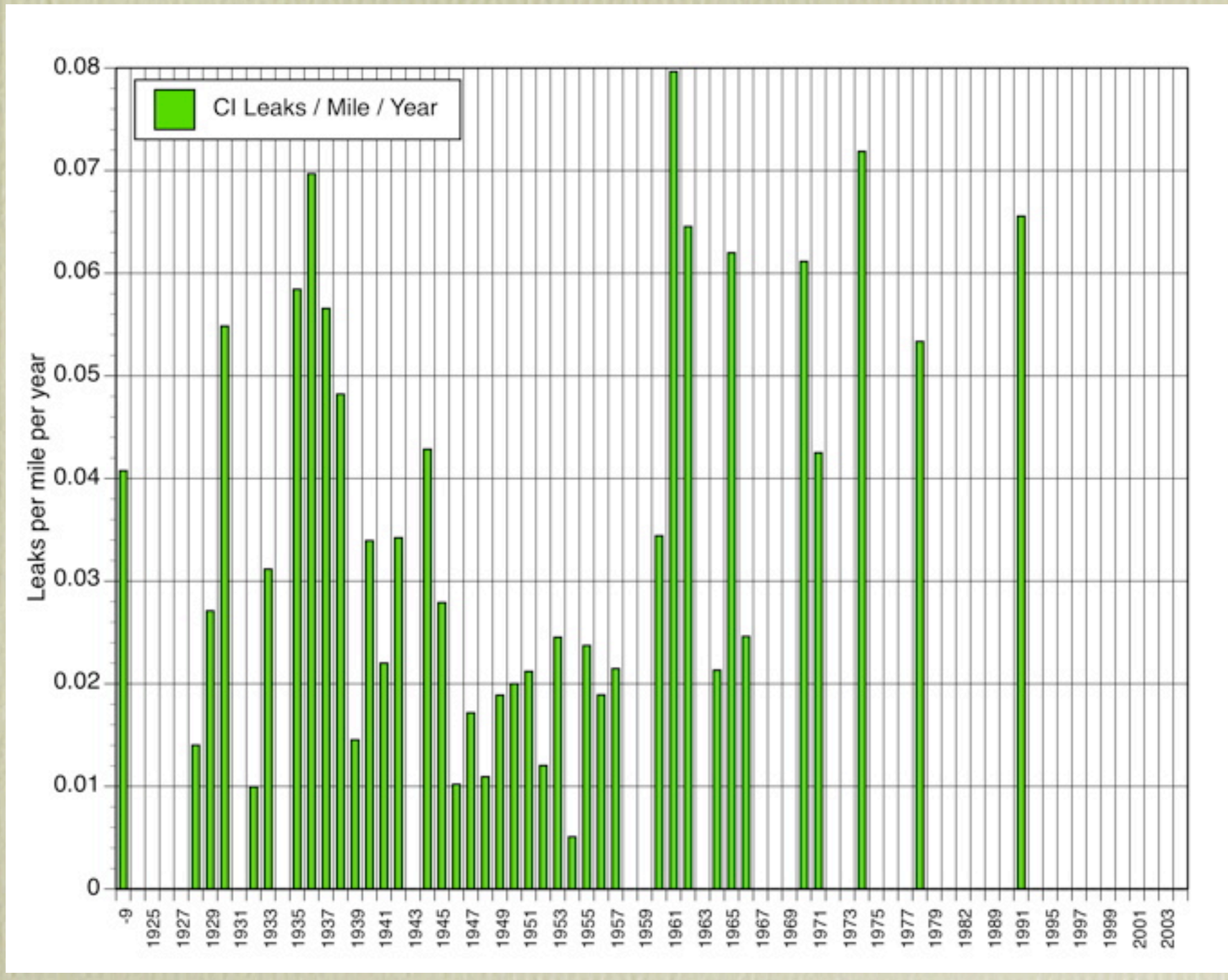
No seasonality

Aging Effect for Cast Iron



Increasing number of Leaks

Aging Effect for Cast Iron



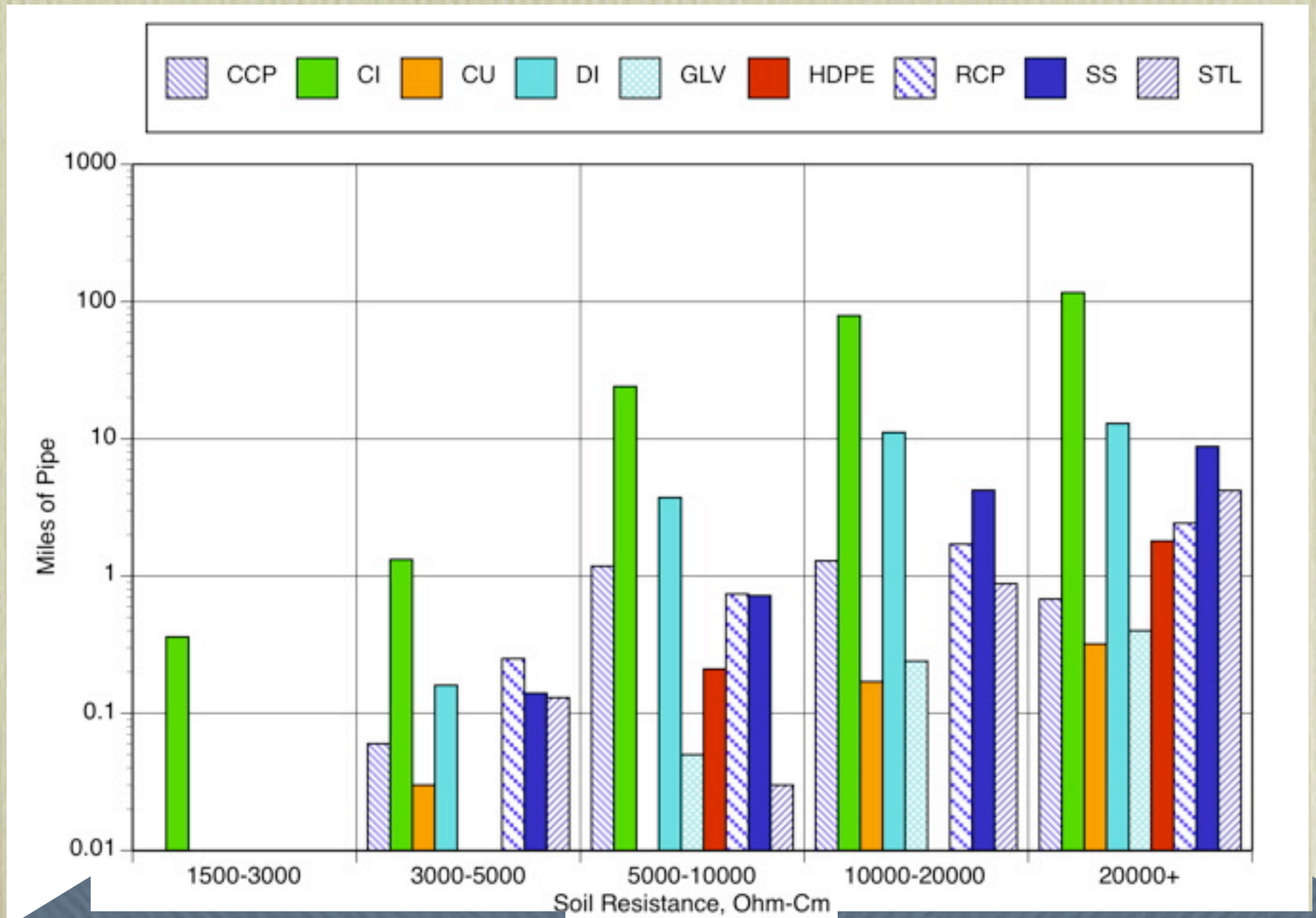
?

No Increase in the number of Leaks / Mile / Year

Corrosion

- Does soil resistance (R) have influence over leak rates for metal pipes?
- Measure R at 193 locations
- Correlate R versus historical leak rate

Miles of Pipe vs Soil R



Corrosive

Mild

Low

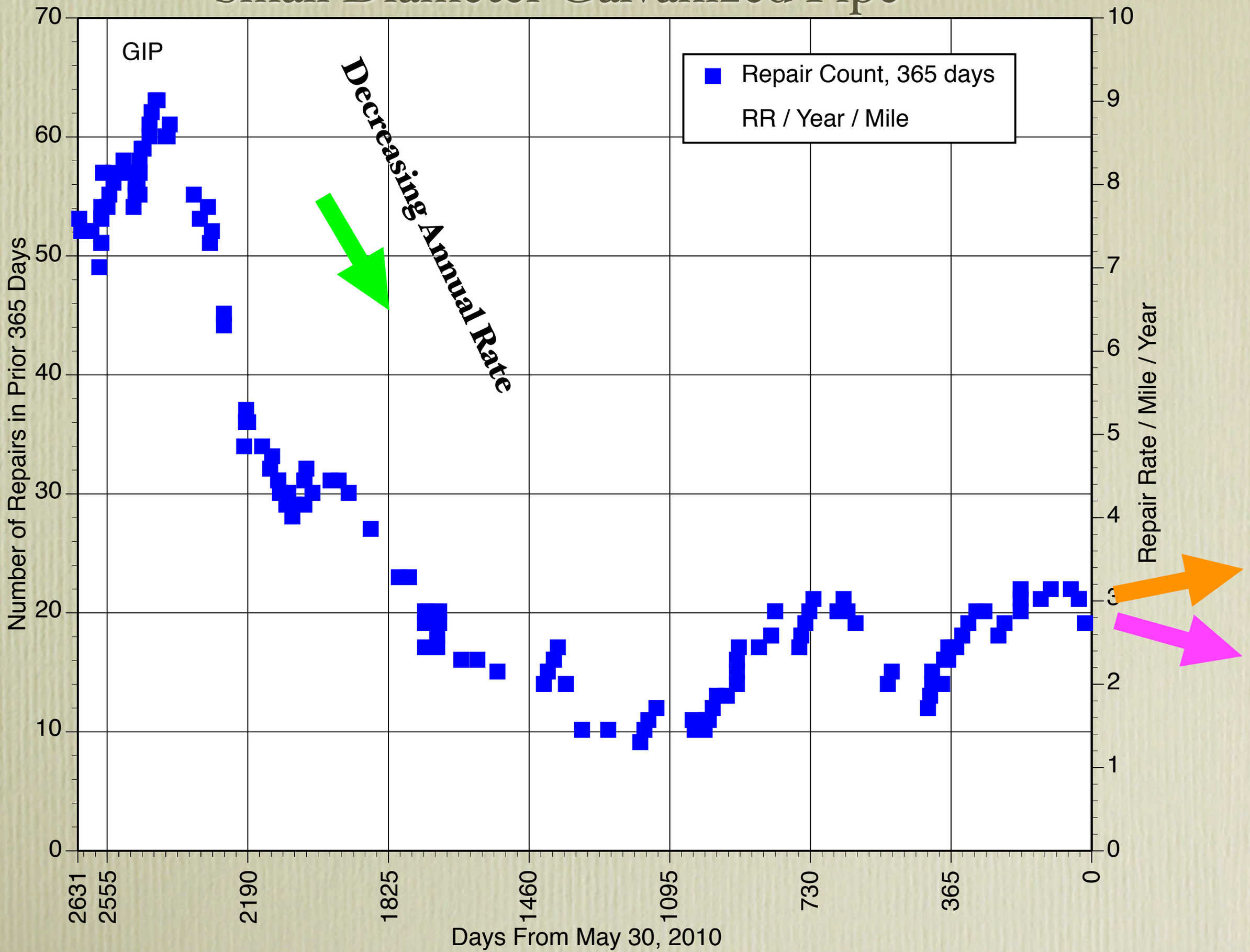
Age Based Model

- After the "break in" period, there is no empirical evidence to say that ferrous pipes leak at a higher rate as they age

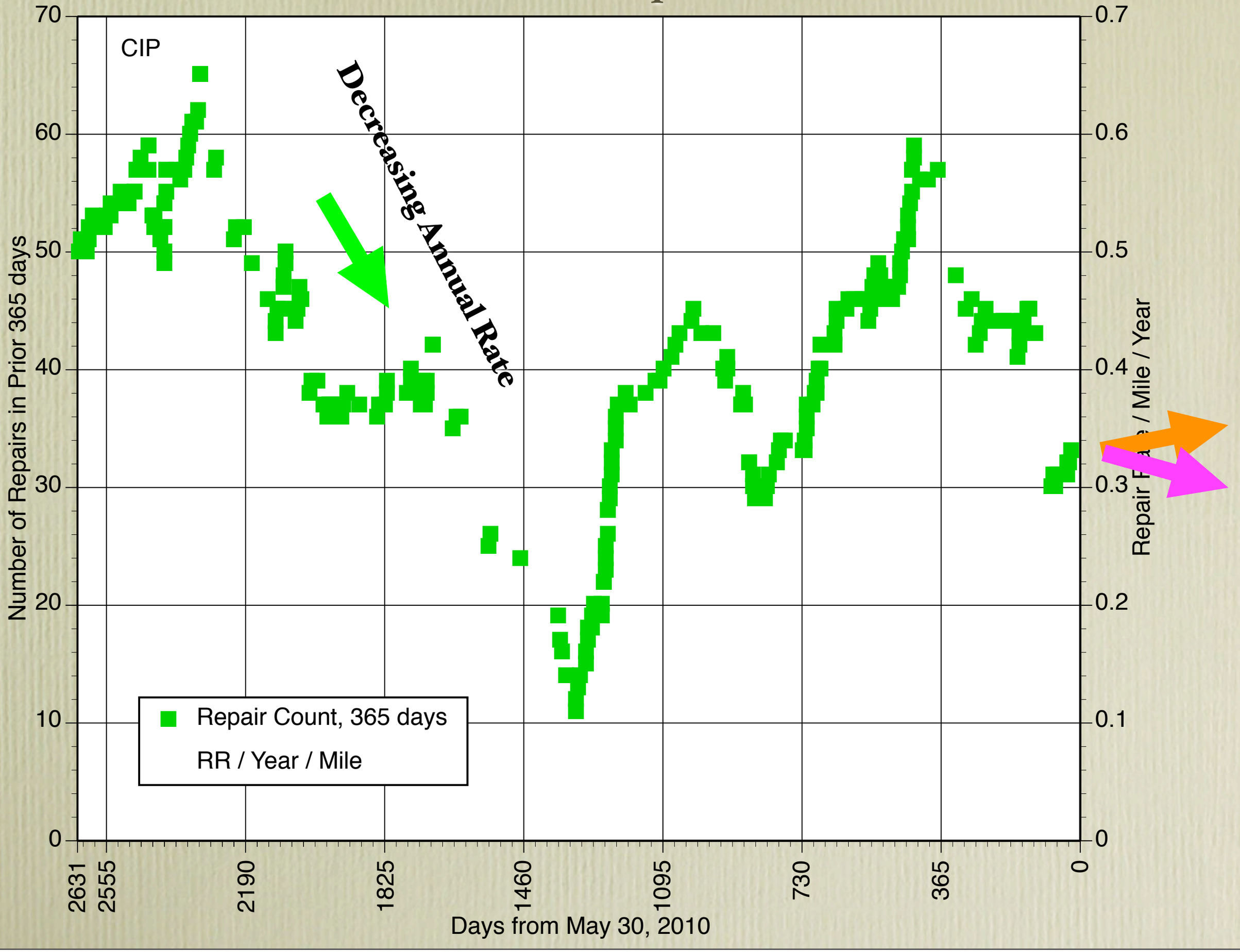
- "If it ain't broke, don't fix it"

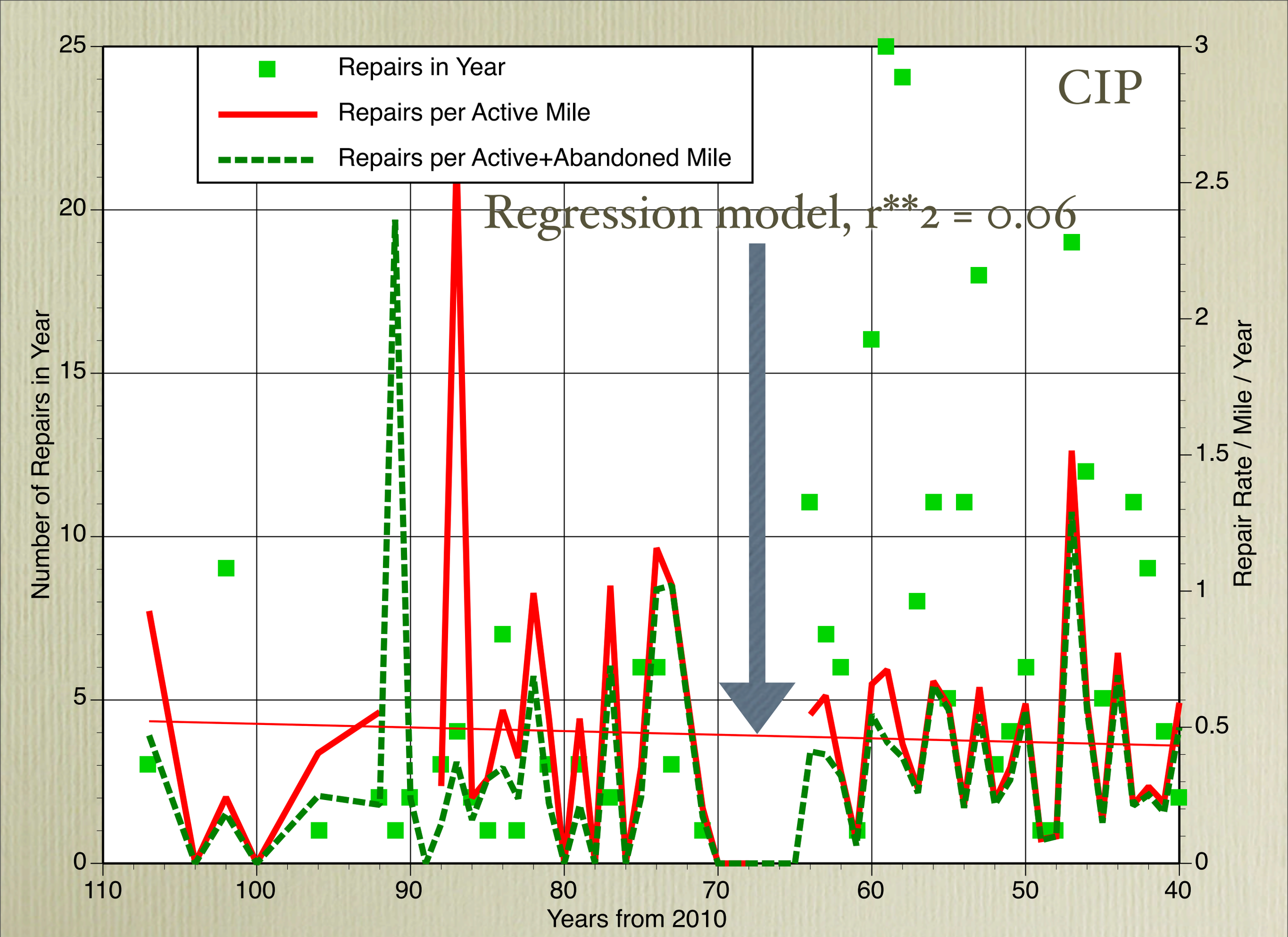
More Evidence Redwood City Clay, Corrosive Soils

Small Diameter Galvanized Pipe



Cast Iron Pipe




Repairs in Year
Repairs per Active Mile
Repairs per Active+Abandoned Mile
CIP
Regression model, r**2 = 0.06
Number of Repairs in Year
Repair Rate / Mile / Year
Years from 2010
25
20
15
10
5
0
3
2.5
2
1.5
1
0.5
0
110
100
90
80
70
60
50
40

Leak Model. RR = k1 * k2 * k3

k1 Matl, Diam

Type / Diameter	CCP, RCP	HDPE	CI	CU	DI	GLV	SS, STL (≤12")	STL (>12")	UNK
Any	0.015	0.010	0.030	0.150	0.015	0.600	0.500	0.015	0.070
1" to 2"		0.010	0.400	0.150	0.015	0.600	0.500		0.400
4"		0.010	0.150		0.015	0.600	0.500		0.150
6"		0.010	0.030		0.015		0.500		0.070
8" – 12"	0.015	0.010	0.020		0.015		0.500		0.050
16" – 30"	0.015	0.010	0.020		0.015			0.015	0.015

k2 Age

Type / Age (Years)	CCP, RCP	HDPE	CI	CU	DI	GLV	SS, STL (≤12")	STL (>12")	UNK
Any	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
0 to 20	0.90	0.95	0.90	0.75	0.80	0.80	0.80	0.90	0.90
20 to 40	1.00	1.00	0.95	1.00	1.00	1.00	0.90	0.95	1.00
40 to 60	1.10	1.05	1.00	1.25	1.10	1.00	0.95	1.00	1.00
60 to 80	1.15	1.10	1.25	1.50	1.15	1.20	1.00	1.00	1.10
80 to 100	1.20	1.15	1.50	2.00	1.25	2.00	2.00	1.10	1.15
100 +	1.50	2.00	2.00	2.50	2.00	2.50	2.50	1.30	

k3 R

Applicability: Granular Soils

Type / Resistance (Ohm-cm)	CCP, RCP	HDPE	CI	CU	DI	GLV	SS, STL (≤12")	STL (>12")	UNK
Any	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1500-3000	1.50	1.00	1.50	2.00	1.25	2.00	2.00	1.25	1.25
3000-5000	1.10	1.00	1.10	1.25	1.10	1.25	1.25	1.10	1.10
5000-10000	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10000-20000	0.90	1.00	0.90	0.90	0.90	0.90	0.90	0.90	0.90
20000+	0.90	1.00	0.90	0.90	0.90	0.90	0.90	0.90	0.90

Different for Clay Soils

How to combine Pipe Aging with Earthquakes?

- Benefit Cost Ratio (BCR)
  - BCR > 1, Replace the pipe
  - BCR < 1, Let the customer be cheap

EXAMPLES

r=4%, 60 Years

Parameter	MainID 7	MainID 4326	Units
MainID	7	4326	
Length	928.72	185.17	Feet
Year installed	1991	1971	
Age	20	40	Years
Material	CI	CI	
Diameter	6	4	Inches
Soil resistance	17402	28421	Ohm-cm
Liquefaction susceptibility	L	H	
Fault susceptibility	VL	VL	
Background repair rate	0.0243	0.1283	Repairs / mile / year
Number of Leaks	1	0	In past 24.5 years
Number of recent leaks	1	0	Since 1/1/2003
De-facto repair rate	0.1290	0.0045	Repairs / pipe / year
Outage time	6.79	6.05	Hours
Outage Length	750	500	Feet
Replacement Cost	$83,585	$11,110	
Repair cost per year	$516	$18	
Claim cost per year	$52	$2	
GDP loss per year	$312	$3	
Sales loss per year	$1	$0	
Repair costs per year (E)	$882	$23	Existing Pipe
Material Replacement Pipe	DI	HDPE	
Repair costs per year (N)	$22	$2	Replaced Pipe
NPV, Reduced repair costs	$19,455	$475	
BCR, Replacement (Repair)	0.233	0.043	
Losses per year, Seismic (E)	$72	$977	Existing Pipe
Losses per year, Seismic (N)	$7	$98	Replaced Pipe
NPV, Reduced seismic costs	$1,465	$19,893	
BCR, Replacement (Seismic)	0.018	1.791	
BCR, Total	0.250	1.833	

Example Results - Redwood City

Existing Pipe	Replaced Pipe	Seismic Hazards	Recent Breaks	Corrosivity	BCR Aging	BCR Seismic	BCR Total
6" CIP, 90 yrs	6" HDPE	PGV, PGD	1	High	0.46	2.14	2.60
6" CIP, 90 yrs	6" PVC	PGV	1	High	0.46	0.10	0.56
2" GIP, 90 yrs	6" PVC	PGV	1	High	1.05	0.13	1.18
12" DIP, 30 yrs	12" PVC	PGV	0	High	0.00	0.05	0.05
8" CIP, 50 yrs	8" PVC	PGV	3	Mod	1.29	0.08	1.37
20" CCP, 40 yrs	20" WSP	PGV, PGD	0	High	0.002	0.643	0.644

Conclusions

- Beyond the initial "break in" period, there is no observable trend that says older pipes leak "much" more often
- Seismic only: upgrade only the worst pipes in zones with PGDs and very high economic activity
- Aging Only: Cast Iron: replace if 2 or more breaks in past 8+ years; otherwise, live with repairs
- Seismic + Aging. Rank Replacement Priority using BCR Model