Durability of Water Pipelines

Steven Taylor, Civil Engineering

Mentor: Dr. Kenneth Lamb

Kellogg Honors College Capstone Project

Introduction:

Steel pipes are expected to have a long service life, e.g. 75 years. Confidence in the long term durability of galvanized steel pipes has been challenged by recent unexpected early corrosion failures in the Los Angeles County. Premature corrosion incidents have occurred in many major roadways. These have taken place in near-neutral soil environments and have often been associated with corrosion concentration at or near the ribs. The objectives of this work are to establish to what extent the corrosion incidents can be ascribed to lifetime of pipes, corrosion of soils, or pressure from water within the pipes. Structural performance of metal pipes is affected by abrasion, backfill operations, improper choice of backfill material, presence of groundwater, level of compaction and compaction equipment used, and corrosion. Premature replacement of buried metallic components is costly, not only because of the price of the new unit, but also because of the associated road demolition and service outage. Of the factors mentioned above, corrosion is a key source of long term deterioration. It is important to have in place reliable means of anticipating the extent of corrosion damage so that materials selection commensurate with the desired service life.

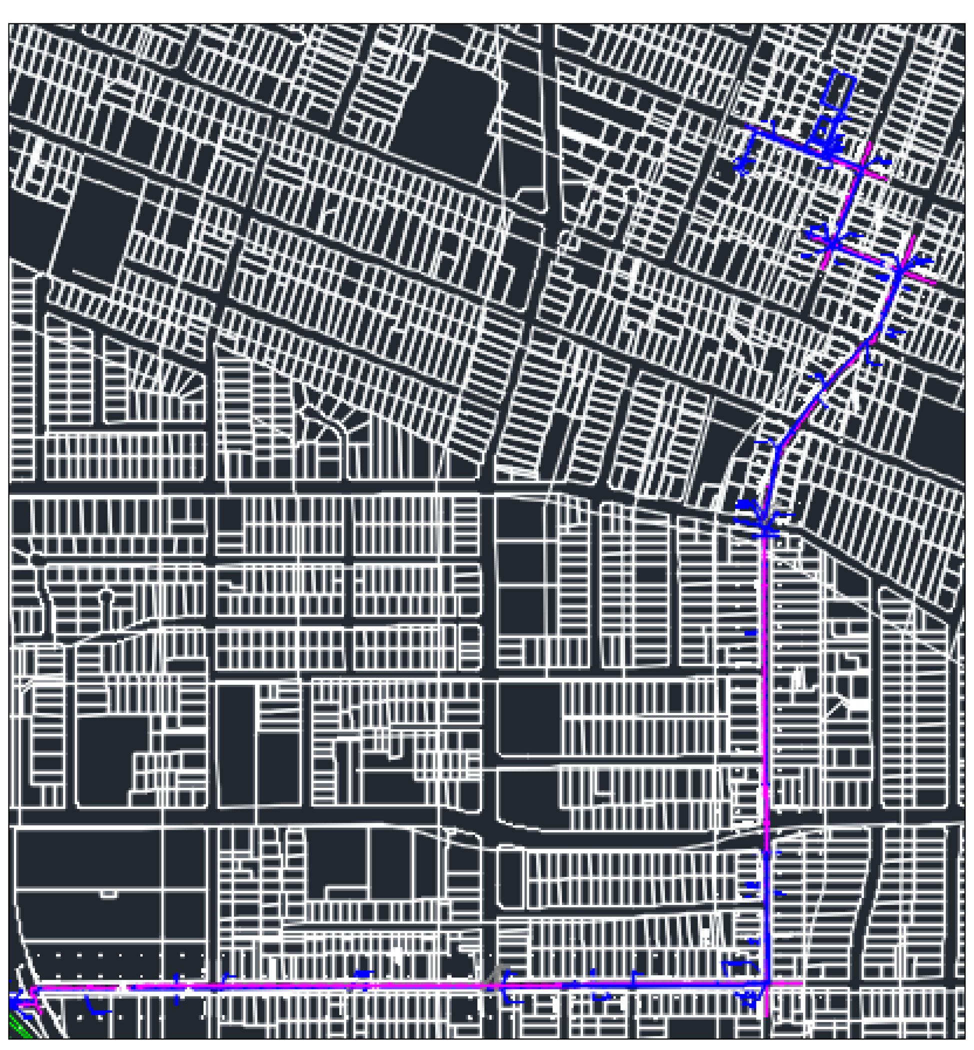

Figure 1: AutoCAD file of Altadena Water District pipelines

Current Ability of L.A.'s Pipes:

The data show that the average age of L.A.'s water pipes is 58 years and that two-thirds of the leaking pipes were installed before 1950. More than 5% of the DWP's water main pipes have reached or passed their expected useful life. More than 40% — 118,000 of the city's roughly 275,000 pipes — received a grade of C or lower, the data showed. Two pipes involved in last summer's major rupture on Sunset Boulevard near UCLA had received C and D grades. In 2011, L.A.'s leak rate was approximately 20 leaks per 100 miles and today, our leak rate is 15 leaks per 100 miles. This consistent and steady progress has reduced our leaks / breaks down to nearly ½ the national average.

Life Expectancy of Pipes:

The general rule of thumb for the life expectancy of water systems' pipes is about 70 years before corrosion creates the need for replacement. The longevity of pipes is roughly comparable to that of the very objects the pipes serve. Pipes have about the same lifespan of humans. Many utilities have set the expected life for pipes at 50 years to be cautious and stay ahead. However replacing pipes every 50 years is neither reasonable nor cost-effective and requires condition assessment and asset management to better match the timing of the investment to the need of the asset. Many agencies are request pipes with 100 years of life, which for metallic pipes, requires much maintenance.

Corrosion:

Stainless steels should be in the passive state in soils, but the presence of water and aggressive chemical species such as chloride ions, sulphates and as well as types of bacteria and stray current, can cause localized corrosion. Piping needs to be coated. Soils with the poorest drainage are the most corrosive while drained soils are the least corrosive. Backfilling pipe ditches with sand offers quite good, long-term protection in corrosive plastic clay soils. More acidic (less than 4.5) soils may represent a serious risk to common construction materials including some stainless steel grades. High resistivity is not corrosive. Low resistivity is corrosive. Chloride ions are harmful, as they participate directly in pitting initiation of stainless steels and their presence tends to decrease the soil resistivity. They may be found naturally in soils as result of brackish groundwater and historical geological sea beds or from external sources such as de-icing salts applied to roadway.

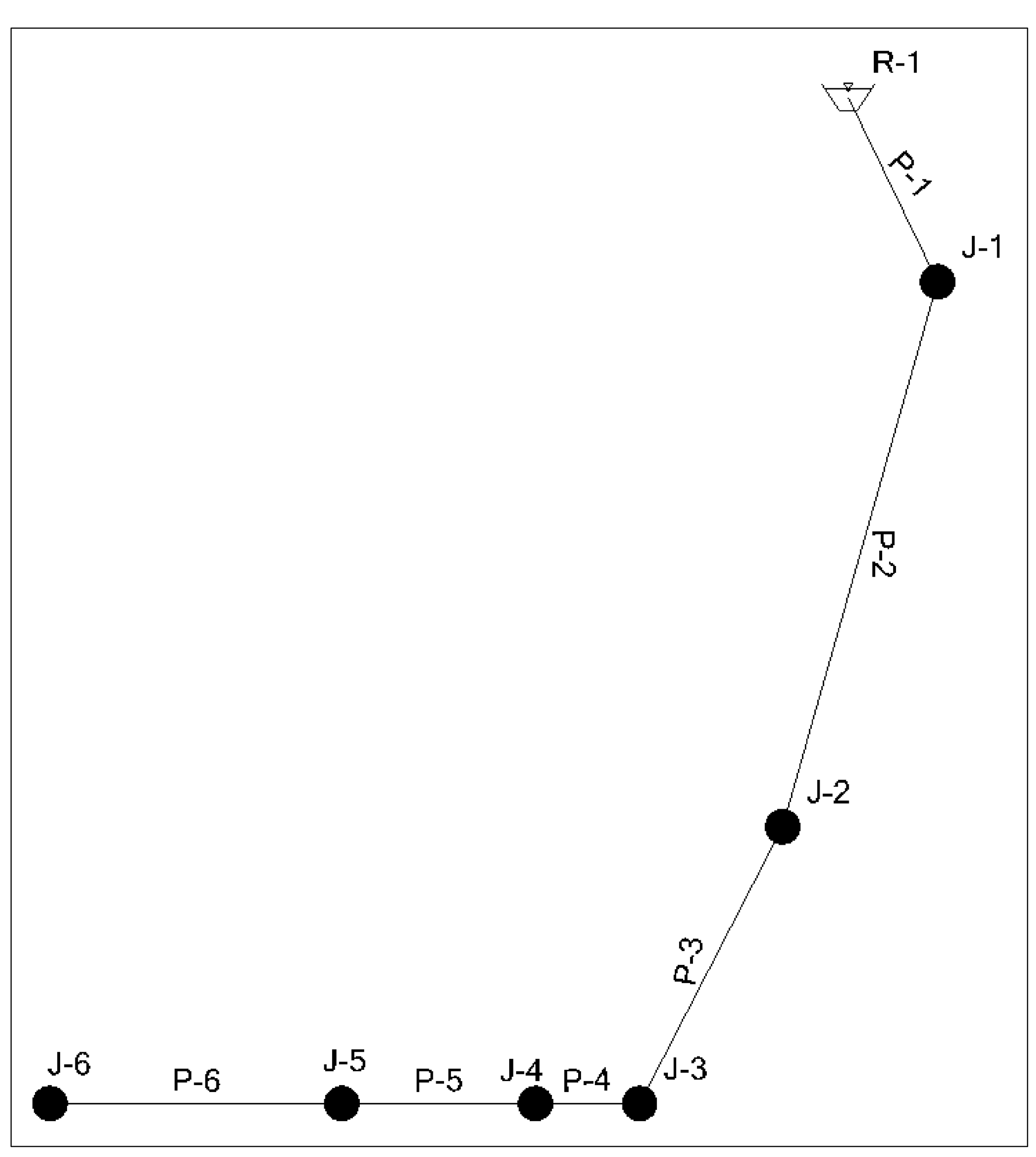

Figure 1: WaterCAD file representing Altadena Water District reservoirs and pipelines

Water Pressure within Pipes:

There are very mixed results for the effect of flow velocity. It is thought that two factors are dominant: increased flow provides more oxygen for the corrosion reaction, but it can also hasten the precipitation of a protective layer. If the velocity is very high, the water can scour away the protective scale. Oxygen dissolved in water is a primary corrosive agent. Water exposed to the air absorbs oxygen. Oxygen in rain and surface water is usually removed when water seeps into the ground; deep wells are usually oxygen free. In contrast, shallow wells and surface water often contain more oxygen. Water also may absorb oxygen when a pneumatic pressure tank is used. Hydrogen sulfide in groundwater also can corrode metals significantly. In water that is soft, corrosion occurs because of the lack of dissolved cations, such as calcium and magnesium in the water. In scale forming water, a precipitate or coating of calcium or magnesium carbonate forms on the inside of the piping. This coating can inhibit the corrosion of the pipe, because it acts as a barrier, but it can also cause the pipe to clog. Water with high levels of sodium, chloride, or other ions will increase the conductivity of the water and promoting corrosion.

Table 1: Residual Pressure Results

	Elevation (feet)	Flowrate (cf/s)	Diameter (in)	Velocity (ft/s)	Residual Pressure (psi)
Resevoirs	1221	4.02	16	2.88	-
Joint 1	1162	4.02	16	2.88	25.3
Joint 2	1066	4.02	24	1.28	67.2
Joint 3	1043	4.02	24	1.28	77.1
Joint 4	840	4.02	24	1.28	164.9
Joint 5	840	4.02	24	1.28	176.6
Joint 6	835	4.02	24	1.28	181.5

Conclusion:

Iron pipe corrosion is extremely complicated and is affected by practically every physical, chemical, and biological parameter in water distribution systems. This work provides a summary of key factors that utilities must evaluate in order to mitigate iron corrosion problems. Utilities should also consider potential secondary impacts on corrosion due to compliance efforts for new regulations. The causes of corrosion showed that high pH values, sufficient to cause dissolution of the passive film on steel, can develop under exposure of limestone to flowing natural water. In these conditions, extensive loss of coating was. In contrast, exposure to water in contact with sand did not result in alkaline conditions, and aluminized steel, in the absence of mechanical deformation, remained essentially corrosion free. The findings substantiate for the first time an important vulnerability of aluminized steel in limestone soils and provide an explanation for the rapid onset deterioration. Therefore, these findings provide strong evidence in support of service guidelines to disallow the use of limestone bedding for aluminized steel pipe.

Acknowledgements:

Special thanks to Dr. Kenneth Lamb, Foothill Municipal Water District