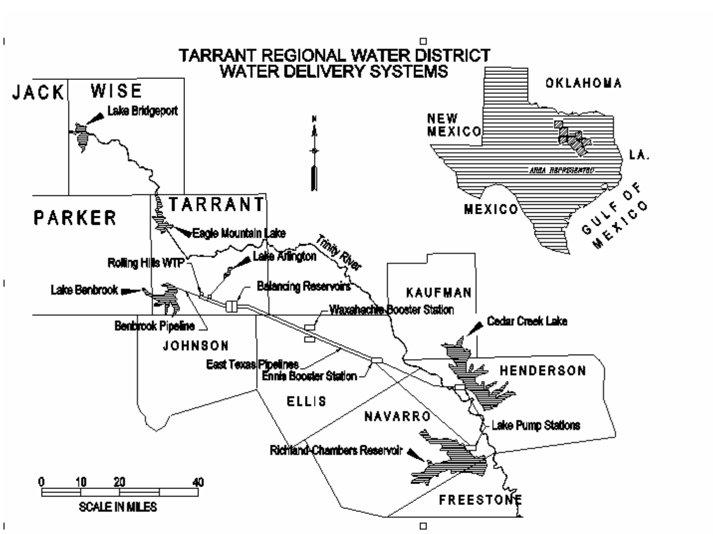
Challenges in Large Diameter Water Pipelines

David H. Marshall, P.E., Engineering Services Director

Tarrant Regional Water District, Forthworth, Texas 76196
E-mail: DMarshall@trwd.com

The Tarrant regional Water District is a raw water supplier in North Central Texas, serving communities in ten counties, including Fort Worth and surrounding communities. The District has twenty-six municipal customers who supply treated water to about 1.5 million people. Water use in Tarrant County is about 92% of the District's total use. The District's supply, shown on the map below, consists of four supply reservoirs and two pipelines. The two western reservoirs, Bridgeport and Eagle Mountain hold about twenty percent of the total supply, and release water down the Trinity River to Tarrant County. Water from Cedar Creek is pumped using a 72-inch diameter, sixty-eight mile long pipeline and an 84-inch diameter six-mile long pipeline to Tarrant County. Water is pumped from Richland Chambers in a 90-inch diameter seventy-two mile long pipeline and a 108-inch diameter six-mile long pipeline to Tarrant County. Since Cedar Creek and Richland Chambers Reservoirs are eighty percent of the water supply, the reliability of the pipelines is essential.



The Cedar Creek Pipeline was constructed in 1972. The pipeline has suffered nine failures, the first in 1981. Eight of the nine failures have been due to corrosion of the prestressing wires. One failure has been due to hydrogen embrittlement damage. All have been catastrophic failures, with a large hole in the pipe being formed and the loss of millions of gallons of water. One area of the Cedar Creek Pipeline was under an impressed current cathodic protection system, with the on-current voltage set at 1.2 volts. The hydrogen embrittlement segment that failed was connected to the rectifier. The Richland Pipeline was constructed in 1988. The Richland pipeline has suffered thirteen failures: four thrust restraint failures, six corrosion failures, one due to hydrogen embrittlement, one from a spigot cracking, and one from operator error. All but the thrust restrain and spigot cracking was catastrophic failures. Richland Chambers had no cathodic protection, and the embrittled segment was probably due to the wire characteristics being influenced by light surface corrosion of the wire.

The District recognized in 1989 that the pipe integrity was lacking and began to study and mitigate the problems. The entire system was cathodically protected using sacrificial zinc anodes to minimize further embrittlement damage. Water hammer was identified as a possible cause of cracking the outer mortar and mitigated by using programmable logic controllers on the pump control valves to prevent premature closing. The pipelines were also internally inspected and obvious damaged segments repaired or replaced. Beginning in 1998, the District employed the Pressure Pipe Inspection Company (PPIC) to inspect the pipeline using the remote field eddy current/coupled transformer system. About 20 miles have been inspected annually and in January 2005 the inspection will cover the last twenty miles of the system.

Results of the PPIC inspections revealed that of the 32232 segments inspected prior to January 2005, 800 segments have wire breaks. The Cedar Creek Pipeline has about four percent of the segments damaged, a total of 718 segments. The inspection of the Cedar Creek pipeline near the rectifier location revealed about nine percent of the pipe was damaged, likely due to embrittlement. The Richland line has about 0.5 percent of the segments damaged, a total of 82 segments. Of those 800 damaged segments, about 70 have been replaced or repaired. Repairs were done the follow winter of the inspecting, generally choosing the pipe with 50 or more broken wires. The first repairs of the embrittled area revealed that although the pipe may be damaged with 100 broken wires, the force required to remove the pipe showed the pipe had a lot of residual strength. Embrittled pipe was then replaced when over 125 broken wires were detected in subsequent work.

During the initial investigation of the pipeline integrity problems, the District contacted other agencies that were facing similar issues. A number of agencies jointly funded a study by Simpson Gumpertz & Heger (SGH) to develop a simplified finite element analysis to determine residual strength of damaged pipe. The District employed SGH to examine the pipe designs specific to the District, develop and calibrate the model for embrittlement damage and determine the residual strength and repair priorities of the damaged pipe.

Yehuda Kleiner, of the National Research Council of Canada, through an AWWARF study, introduced a new approach to modeling the deterioration of buried pipes, using a fuzzy rule-based, non-homogeneous Markov process. This deterioration model yields the possibility (as opposed to probability) of failure at every point along the life of the pipe. Kleiner expanded this approach by expressing the possibility of failure, as a fuzzy number, and then coupled it with the failure consequence (also expressed as a fuzzy number) to obtain the failure risk as a function of pipe age. The District participated in this study and will build on the model.

Based on the strength model and inspection result, there are several hundred segments of pipe that have enough damage to warrant concern. The cost to repair or replace a single segment varies from about $35,000 to $75,000. Using $40,000 as n average cost, 300 pipe segments would cost $12,000,000. Through analyses to reduce the uncertainty in some parameters (inspection error, water hammer pressures, rate of deterioration as it becomes available) and using the fuzzy logic modeling, a logical prioritization and timing of replacement of the damaged pipe segments may be developed to keep risk to a minimum and efficiently replacing pipe when needed.