City of Lawrence, KS
Stratford Elevated Water Storage Tank
Preliminary Alternatives Evaluation Report (Phase 1) - FINAL

B&V Project 184715
B&V File 50.1000
December 17, 2014

To: Philip Ciesielski, P.E. – City of Lawrence, KS
From: Andrew Hansen, P.E. – Black & Veatch
John Bertrand, P.E. – Black & Veatch
Rob Zechmann, P.E. – Black & Veatch

1 Introduction

1.1 Purpose

The purpose of this report is to document and summarize work completed as part of Phase 1 of the tank evaluation and alternatives analysis. Phase 1 includes evaluation of the following alternatives:

1. Rehabilitate the interior and exterior of the existing tank to comply with current standards and encapsulate the existing coatings as recommended in the inspection report from Ozark Applicators.

2. Rehabilitate the interior and exterior of the existing tank to comply with current standards, but remove all paint down to the metal surface, including any lead based paint.

3. Construct a new 0.5 MG tank adjacent to the current tank location and demolish the existing tank once the new tank is in operation. This alternative includes the relocation of cellular equipment to a monopole at the existing site.

Phase 2 will be submitted at a later date and be contingent upon the results of Phase 1. If Phase 2 is required, it will include evaluation of the following alternative:

4. Construct a new, increased volume, tank adjacent to the current tank location and demolish the existing tank once the new tank is in operation. Determination of necessary increased storage volume will be determined by hydraulic modeling. This alternative includes the relocation of cellular equipment to a monopole at the existing site.

Phase 2 of the evaluation will be conducted once the City receives an updated hydraulic model which incorporates the new Oread Storage Tank(s) and booster pumping improvements at the Oread, Kasold, and Harper facilities. These updates are being completed by another consultant.

1.2 Reference Documents

Reference documents for this report include the following:

- Geotechnical Engineering Report
- Surface Soil Testing Results
- Overall Site Plan
- Preliminary Cost Comparison
- Architectural Perspective (To Be Submitted with Final Report)
- Anticipated Project Schedule (To Be Submitted with Final Report)

2 General Information

2.1 Stratford Elevated Water Storage Tank

The Stratford Elevated Storage Facility is a 500,000 gallon multi-legged steel tank located in Lawrence, Kansas. The Darby Corporation constructed the tank in 1954 for the City of Lawrence. The elevated tank has the following characteristics:

Capacity (gallons)	500,000
Diameter of Tank	56'-0"
Diameter of Riser	6'-0"
Support Columns	Eight – 30" Diameter
Height of Overflow	132'-0"
Cathodic Protection	Yes
Existing Paint Systems	
Exterior	Alkyd Enamel (encapsulated lead)
Interior	Epoxy (encapsulated lead)
Cellular Providers	AT&T Verizon Douglas County EMS Freenet

A perspective view of the tank is shown in Photo 1.

The Stratford Elevated tank is located within and services the West Hills service area. From previous operational experience it is understood that having the Stratford Elevated Tank out of service results in low pressure issues in the vicinity of the tank. Therefore, an alternative to build a new tank in the location of the existing tank was not considered.

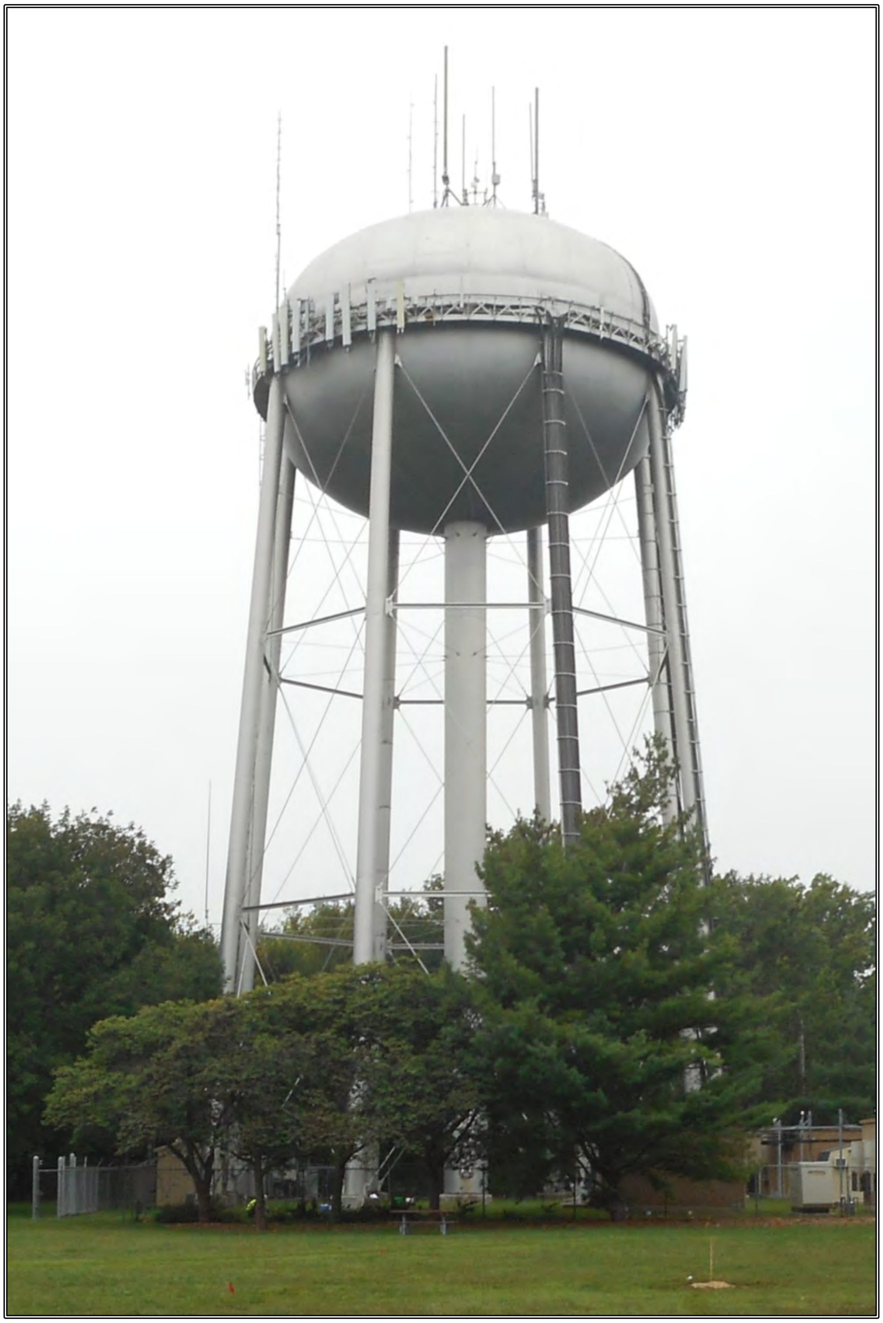

Photo 1: Overall View of Stratford Elevated Storage Tank.

3 Tank Inspection

3.1 Activities Prior to Inspection

3.1.1 Review of Existing Information

Prior to the inspection, the available construction drawings for the structure were reviewed. The drawings were beneficial in identifying the components of the structure, access points, and for developing the safety plan.

3.1.2 Safety and Health

Prior to the inspection all applicable Black & Veatch safety procedures were reviewed. A pre-planning checklist and other job hazard analyses required for a proper inspection were completed. Access for the inspection required fall protection procedures including harnesses and double lanyards. Site visit activities followed all applicable safety and health procedures, and the visit was conducted without incident.

3.2 Scope of Inspection

3.2.1 Inspection Personnel

The structural inspection was performed on September 19, 2014, by Black & Veatch Structural Engineers, Robert Zechmann, P.E. and Tawee Phattarak, P.E.. Philip Ciesielski of the City of Lawrence was also present during the inspection.

3.2.2 Inspection Methods

The inspection was conducted from the exterior of the tank from existing fixed ladders and walkways. One portable FRP access ladder was used to gain access to the fixed ladder at the base of the tank. The tank was generally in a clean state allowing clear view of exterior surfaces. The interior of the storage tank was observed by opening the top hatch and viewing with a flash light and flash photography. The concrete foundation was inspected for cracks, delaminations, spalling, soundness, and other concerns. The steel structure was inspected for visible damage to coatings, signs of corrosion, cracking, delaminations, or buckling of members.

The tank surfaces were inspected hands-on at the accessible portion and visually from a distance for portions beyond the reach of the inspectors. Hammer sounded areas included the exterior top of foundations. Steel thickness measurements were taken only at the accessible areas.

3.3 Structural Inspection and Condition Assessment

3.3.1 Elevated Tank Foundation Observations

Generally the eight support leg foundations are sound but have minor isolated cracking. The isolated cracking occurs adjacent to each of the two anchor bolts at each of the eight foundations as shown in Photo 2 and Photo 3. The widths varied from hairline to 0.05 inch wide. These cracks appear to have been present for an extended time based on coloration and sediment in the openings.

Throughout the eight support foundations and the riser foundation there is pattern cracking. The pattern cracking varies in severity from fine to severe. At the fine level the cracking is just apparent whereas at the severe level layers of aggregate are loose and as much as 2 inches of concrete has disintegrated. The worst case pattern cracking occurs at the riser foundation. At this location the concrete when hammer sounded was soft and friable. The respective pattern cracking is shown in Photo 4 and Photo 5. Additionally the grout under the riser bottom flange has spalled out reducing the bearing area of the riser bottom ring. The loss of grout is shown in Photo 6.

Photo 2: Overall View of Support Leg Footings.

Photo 3: Close up View of 0.05inch wide Crack with Spalling in Footing.

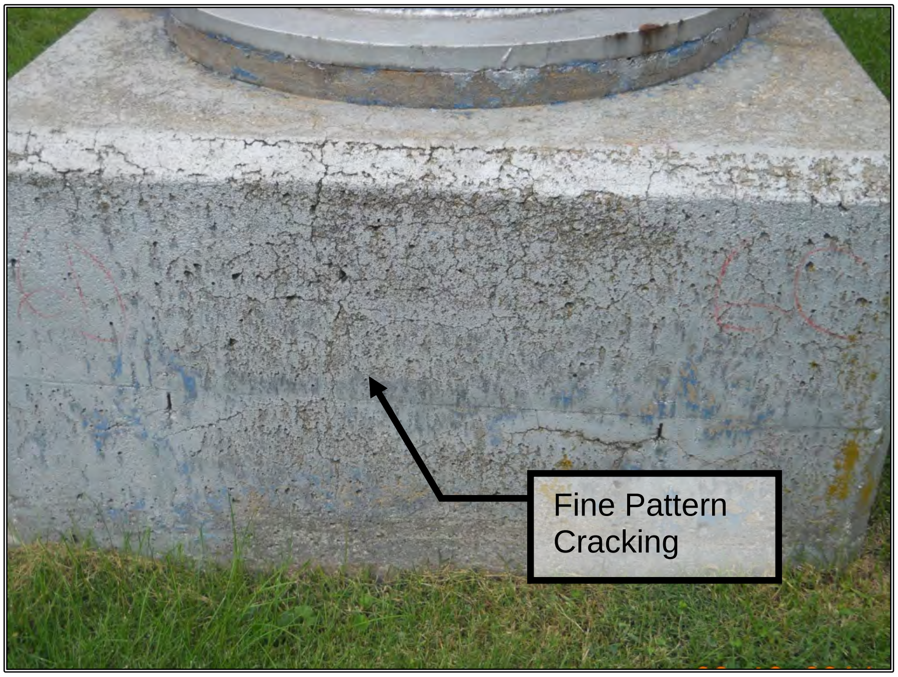

Photo 4: Fine Pattern Cracking at Footing No. 6.

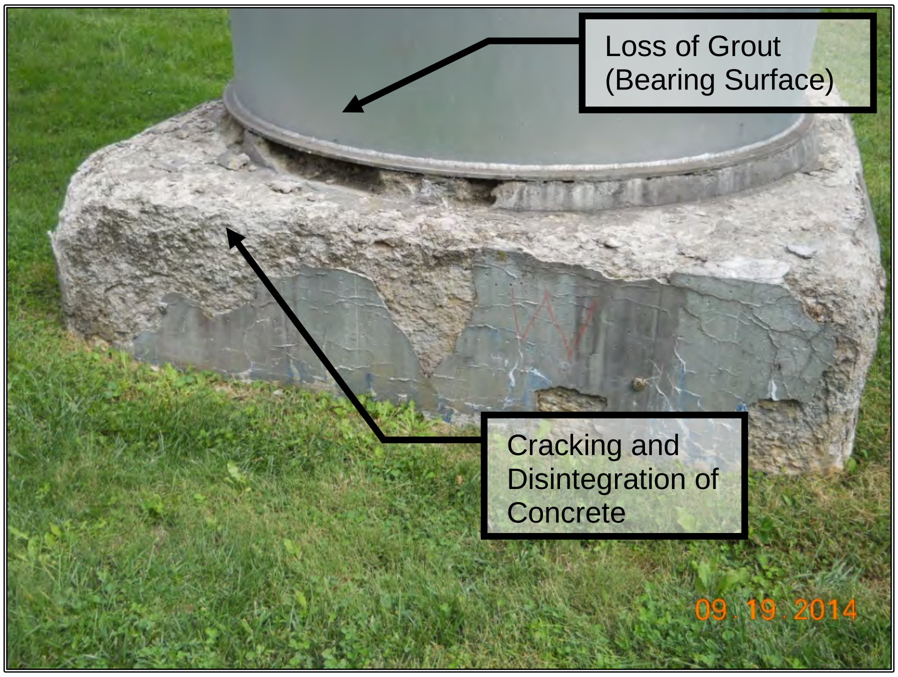

Photo 5: Severe Pattern Cracking and Disintegration of Concrete at Riser Footing.

Photo 6: Close Up View of Grout Loss. Original Steel Construction Shims are Exposed.

3.3.2 Elevated Tank Support Legs and Bracing Observations

The elevated tank support legs and bracing appear to be in adequate structural condition. Only one brace rod appeared to have a slight kink. This kink is indistinguishable in photos. All other items appeared to be in alignment and have only sporadic surface corrosion at failures in the coating system. The existing coating system showed signs of deterioration throughout. In particular most edges, threads, and points of metal to metal contact are chipped, pitting, or worn. These failures are most prevalent on the rod bracing threaded ends, turnbuckles, eye plates, and gusset plates as shown in Photo 7 and Photo 8.

Surface corrosion was also commonly found at the gusset to support leg weld. Photo 9 and Photo 10 show samples of this corrosion. Additionally the support legs have isolated small areas that are pitting with occasional areas of chipping. One location of pitting is shown in Photo 11. Further coating system failures were found at joints and edges of the support legs. Photo 12 illustrates coating failures at the top of support legs.

The exterior ladder does not meet current OSHA regulations. The ladder needs slip resistant ladder rungs to be compliant with OSHA regulations. It also does not have a safety climbing system.

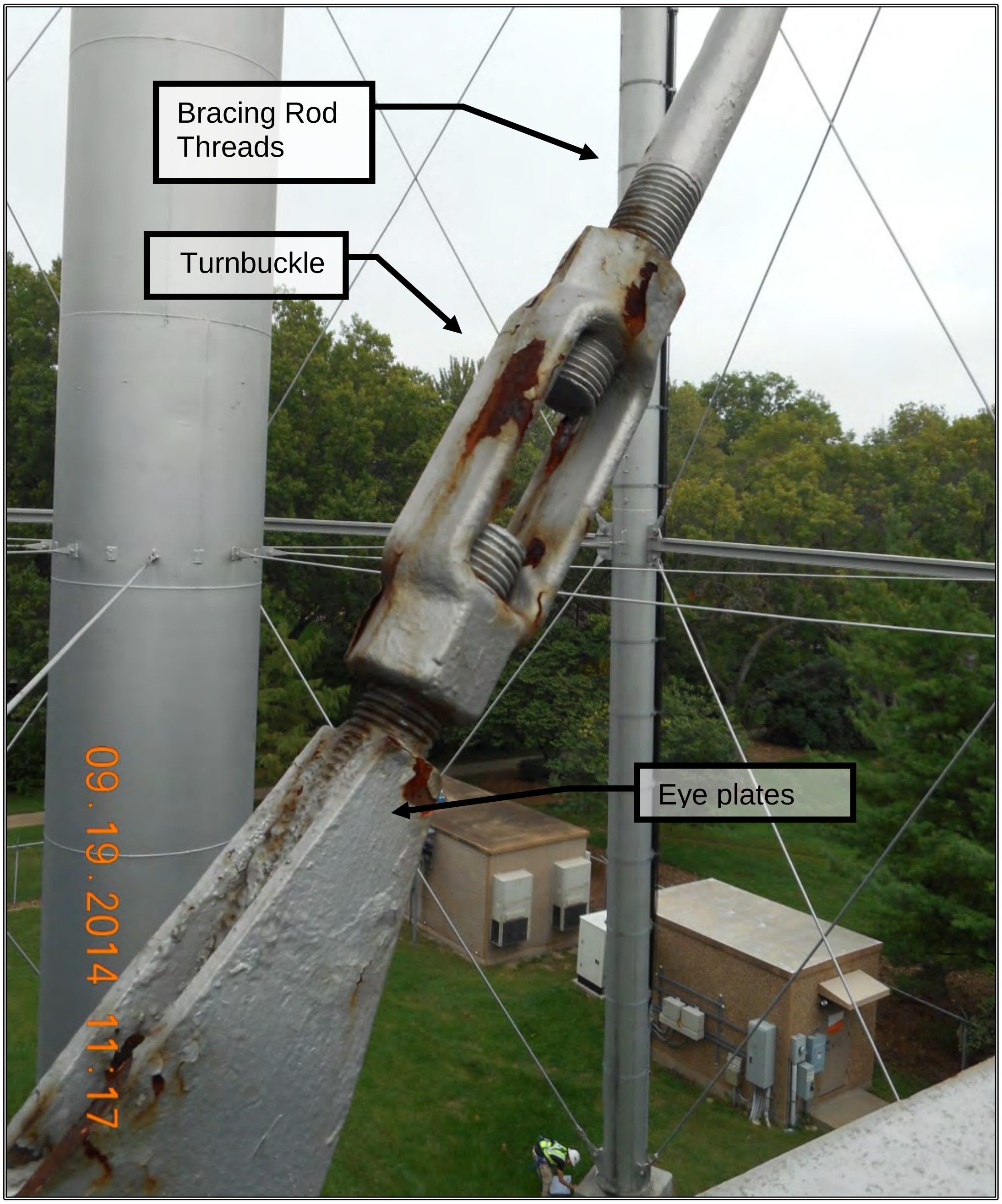

Photo 7: Surface Corrosion at Chipped, Cracked, and Pitted Coating.

Photo 8: Surface Corrosion on Threaded Bracing Rods.

Photo 9: Cracking and Chipping of Coating on Gussets.

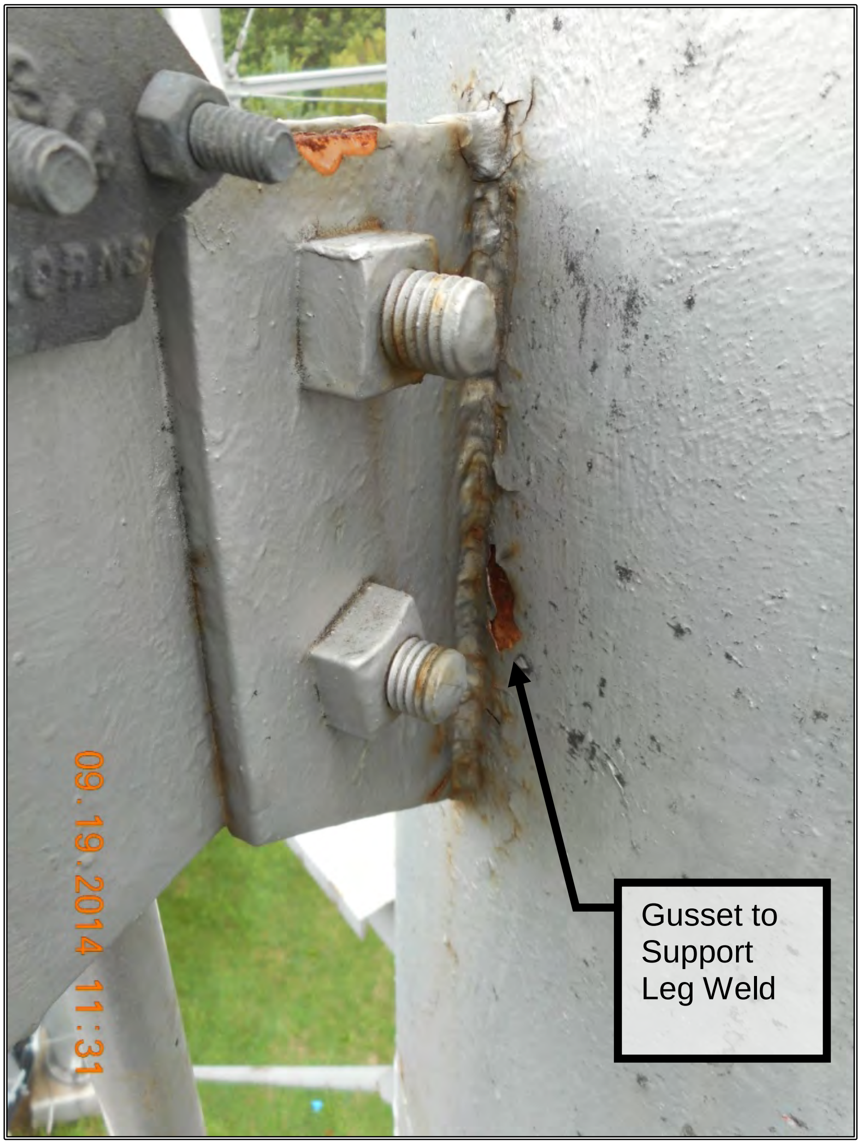

Photo 10: Surface Corrosion and Cracked Coating at Gusset to Support Leg Connections.

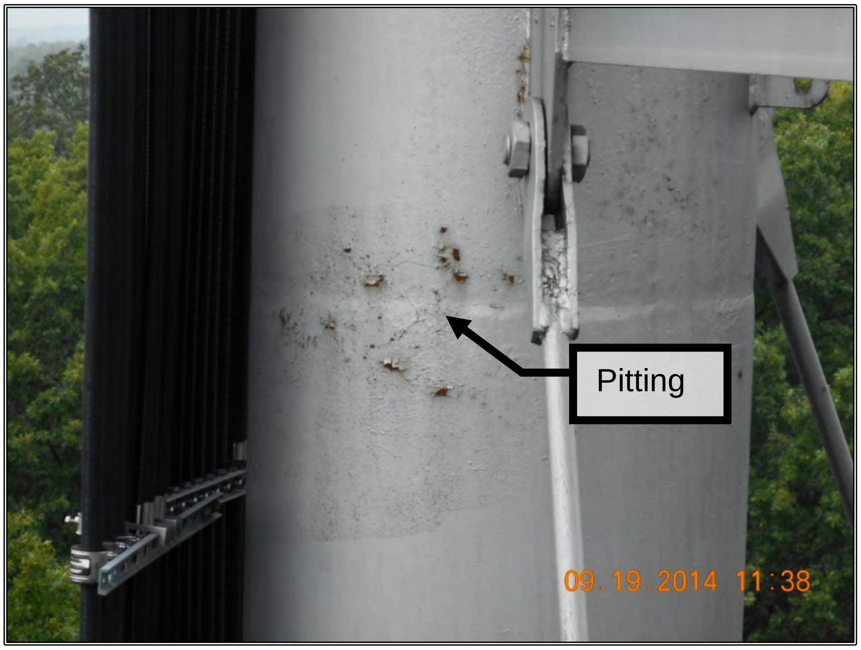

Photo 11: Pitting on Support Legs.

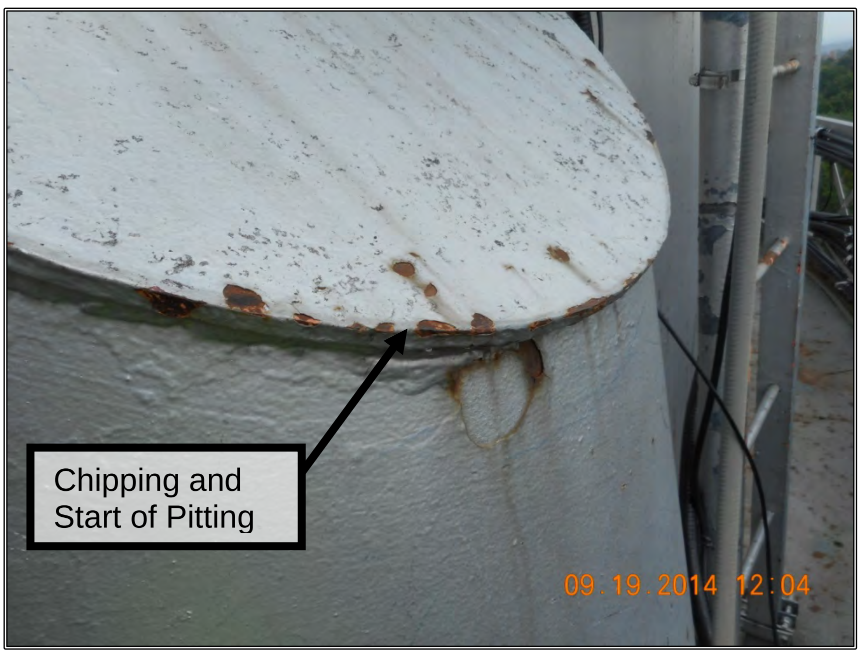

Photo 12: Coating Failures at the Top of Tank Support Legs.

3.3.3 Elevated Tank Dome Shell and Internal Platform Observations

The elevated tank dome shell generally appears to be in good structural condition. The bottom shell has very little pitting, chipping, or areas of cracking on the exterior. The exterior of the top shell has consistent surface corrosion at the lap welds and significant amounts of chips in the coating in the body of the plates. Photo 13, Photo 14, Photo 15, and Photo 16 show representative views of the respective dome surfaces. The interior of the top shell has radial stiffeners with corrosion consistently present at the welds. The interior also has a platform with significant corrosion. For the platform at least one ladder rung is missing and many of the braces are corroded through. The interior of the dome and the platform are shown in Photo 17, Photo 18, Photo 19, and Photo 20.

Photo 13: Butt Welded Bottom Shell at Connection to Riser.

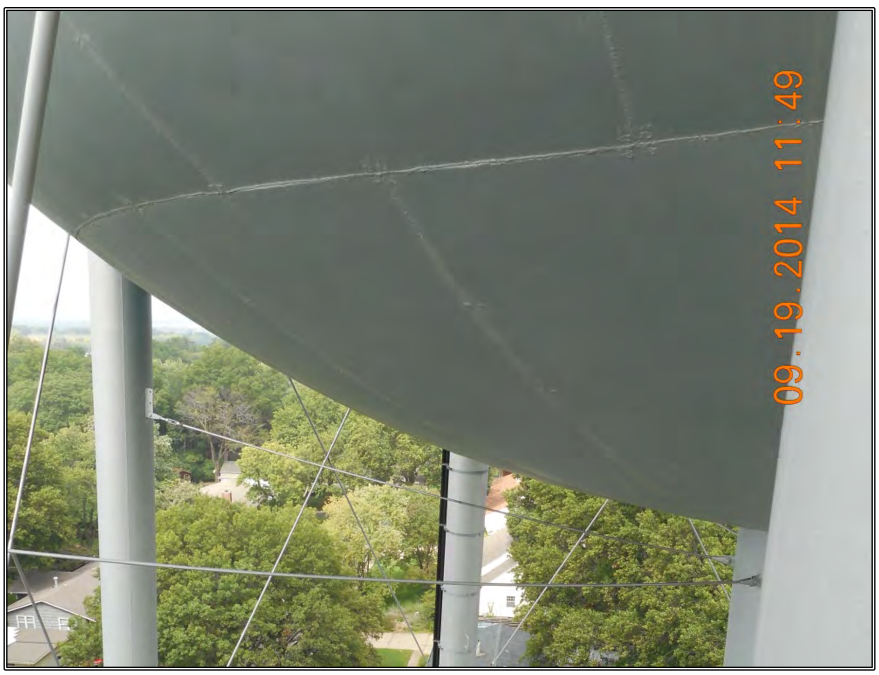

Photo 14: Butt Welded Bottom Shell.

Photo 15: Exterior of Lap Welded Top Shell.

Photo 16: Exterior of Lap Welded Top Shell.

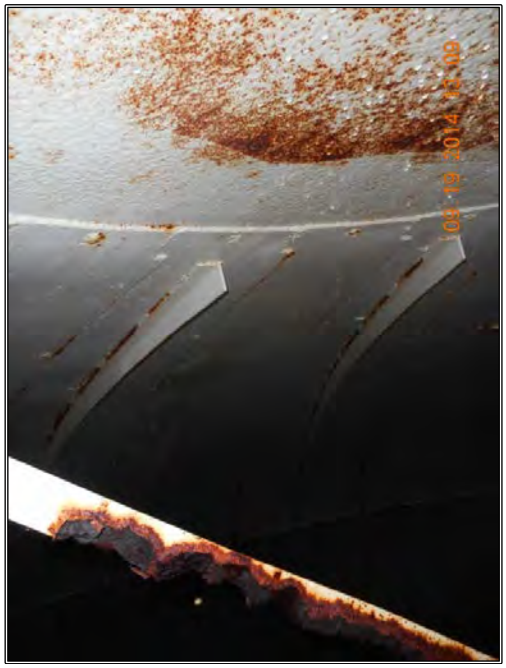

Photo 17: Interior View of Top Shell and Platform.

Photo 18: View of Platform Looking Down from Top Hatch.

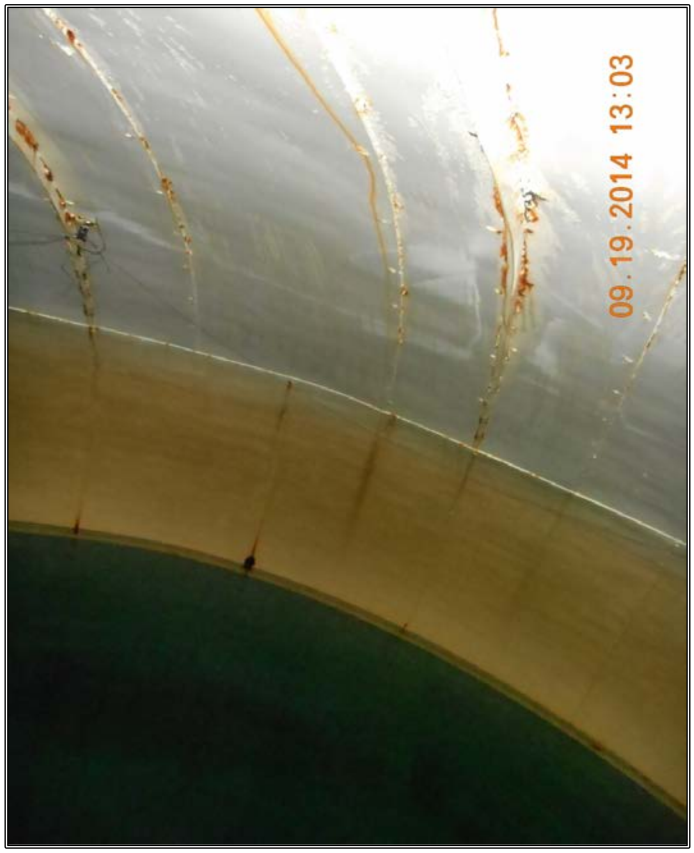

Photo 19: Interior View of Tank Top Shell

Photo 20: Interior View of Platform and Spot Corrosion of Top Shell Plates

3.3.4 Elevated Tank Exterior Balcony Observations

The exterior circumferential balcony is generally in good condition however there are three locations of significant cracks in the balcony checker plate to tank shell weld. The cracks are full width through the balcony checker plate and vary in length from approximately 10 inches long to 3 inches long. These cracks are shown in Photos 21, Photo 22, and Photo 23. Additionally there is significant pitting over the balcony support brackets. When measured with a pit gauge there was as much as 3/16" pitting in the plate over the bracket.

Photo 21: Crack in Balcony Checker Plate.

Photo 22: Smaller Crack in Balcony Checker Plate.

Photo 23: Deep Pitting of Checker Plate Over Support Bracket.

3.3.5 Elevated Tank Evaluation and Recommendations

Most of the noted observations are not a threat to the integrity of the tank at this time, however there are immediate and long term steps required to prevent future impacts to the structural integrity of the tank. These recommendations are included below.

3.3.6 Elevated Tank Foundation Recommendations

Pattern cracking and areas of isolated cracking are present in the concrete foundations. Typically pattern cracking in concrete foundation is more concerning than isolated cracking, and may be due to a number of causes. One potential cause of the pattern cracking may be a chemical reaction within the concrete. Pattern cracking observed at the riser foundation resembles reactive aggregates or carbonation of the concrete. This pattern cracking was present at the riser foundation but not at the support leg foundations; however, this does not necessarily mean that reactive aggregates are not present in the support leg foundations. If reactive aggregates were present in the riser foundation, they would also likely be present in the support leg foundations but not yet exhibiting signs of degradation.

Another cause may be freeze thaw damage which occurs in concrete that was not air entrained. Air-entraining is essential because it creates optimum internal voids structure. If concrete is not air-entrained the expansion of water in the internal voids destroys the concrete matrix. The center riser foundation is the most likely foundation to be susceptible to this damage because the flat top surface would allow ponding and saturation, whereas the perimeter support leg foundations have a sloped top surface.

All of these possible causes of deterioration require unique solutions ranging from a simple patch of the exposed concrete surfaces to removal and replacement of the concrete footings. Petrographic testing of core drilled samples is required to better determine the cause of the deterioration and to determine the most appropriate long term fix. Petrographic testing would provide an estimated remaining life expectancy of the concrete footings. Petrographic testing would range in cost from $40,000 to $60,000 and testing results can take six months, from the time samples are received at the lab, to receive results. The cost provided for petrographic testing would cover testing of all concrete foundations.

If petrographic testing is not desired, or replacement of the footings is not required, the following repairs are recommended:

- Patch the spalled grout at the riser bearing ring. This can be done with standard non-shrink grout following the manufacturer's recommendations for surface preparation, mixing, placement and curing. Of particular importance is to remove all loose materials prior to cleaning and surface preparation. We recommend using a scrub coat for bonding preparation versus options utilizing bonding agents.

- Inject cracks with structural epoxy to prevent future deterioration.
- Patch and repair any spalled surfaces prior to structural epoxy injection. After spalls are repaired the structural epoxy will glue the surfaces of the crack together in order to return the footings monolithic behavior and prevent any loss in anchorage capacity.

Budgetary cost of the footings repairs listed would be approximately $10,000. This cost includes anticipated contractor mobilization.

3.3.7 Elevated Tank Supports, Bracing, Shell and Balcony Recommendations

The cracking of the balcony connection to the tank shell most likely formed due to a stress concentration at the end of the circumferential weld. Stresses due to temperature differential between the tank shell and the balcony steel are the most likely repetitive source and will continue to be a factor in crack propagation. This crack will only get larger if it is not arrested. If allowed to grow it may cause local excessive deflection of the balcony checker plate walking surface and eventual destabilization of the checker plate walking surface. This can be prevented by drilling out the end of the crack to stop future propagation.

The external dome ladder is no longer useable as a rotating ladder and the position of the ladder is not ideal. There is now equipment blocking the proper seating of the ladder and the current location creates an awkward transition from the cage ladder below. If the tank is selected to remain in long term service this ladder should be modified to a permanent clear and fixed position.

The internal platform is significantly deteriorated and is not in a useable condition. If the elevated tank is selected to remain in long term service the interior platform should be removed and a new OSHA approved internal ladder and/or platform should be installed. Final configuration of this would be based on anticipated needs of the City.

Finally of significant note regarding the elevated tank superstructure are the coating failures. These failures are all currently small in nature but are numerous on the exterior and appear to be more significant at the visible portions of the interior. It is apparent that the coating has reached the end of its useable life. If this tank is to remain in long term service it will need to be recoated. Patching of the isolated chips, cracks and pitting will not provide a long term solution. The entire tank should be coated. Specifically we recommend coating both the interior and exterior of the tank.

3.3.8 Summary of Recommendations Repairs

Overall the Stratford Elevated Storage Tank appears to be in adequate structural condition given its age. However, a number of repairs are recommended to rehabilitate and extend the life of the elevated tank. Items noted during the structural inspection and condition assessment are summarized in Table 1. The estimated quantity for each repair item listed in Table 1 is based on observation during the structural inspection. For items which are not possible to define in the scope of work a conservative assumption has been made.

Table 1
Summary of Repairs Recommended for Stratford Elevated Storage Tank

Tank Component	Deterioration	Repair Needed	Estimated Quantity
Foundation	Isolated Cracks at Anchors*	Structural epoxy injection and caulk	65 lf
	Spall Repair Cracks*	Surface Repair of Spalled Edges on Cracks	10 lf
	Pattern Cracking	Conservative - Potentially remove and replace all footings	100 cyd
	Riser Grout Spall*	Patch Riser Bearing Surface Grout	10 sf
Steel Tank	Balcony Floor Plate Cracks	Drill End of Cracks – Periodically Monitor	3 Locations
	Dome Ladder	Remove Ladder and Install New Dome Access Ladder	1 Location
	Access Ladder	Install safety climbing system and update ladder rungs	1 System and approx 110 rungs
	Dilapidated Internal Platform	Remove Platform and Install new internal Ladder (to be coordinated with City)	1 Location
	Existing Coating Failures	Recoat Internal and External tank surfaces	Entire Structure
Note:	*Temporary repair measures; not needed if footing removal and replacement is required.		

4 Telecommunications

B&V Site Acquisition professionals within the Telecommunications division were involved to provide a cursory review of the existing cellular provider agreements provided by the City. The following three agreements were reviewed:

APT 1997 Agreement
Verizon 2003 Agreement
SWB 2004 Agreement

In addition to the above providers, Douglas County Emergency Services also have facilities that utilize the Stratford Elevated Tank. Any agreement between the City and County, for use of these facilities, has not been reviewed and these facilities would be affected by any of the alternatives presented herein.

4.1.1 Cellular Agreement Review

Review of these agreements found that all uses of the water tower by any cellular providers are subordinate to the City's use of the water tower. The agreements indicate that if relocation or removal of cellular provider equipment is needed, the City is obligated to notify the provider, but not liable for any expense associated with the removal or relocation of the equipment. Once notification is provided, the cellular provider will have the option of relocating their equipment as needed to maintain their service or terminating the agreement. Paragraph 6 "Interference", of the SWB 2004 Agreement, states that "Any relocation or adjustment shall be at the sole cost and expense of the tenant."

It is important to note that the agreements are valid for a term of 5 years, and provide an extension option for the tenant of two additional 5 year terms. If any cellular agreements have been entered into, outside of those provided for review, they would need to be reviewed prior to disrupting existing cellular provider service.

4.1.2 Tank Cellular Compatibility

There are three primary styles when choosing an elevated storage tank. Multi-legged steel tanks, such as the Stratford Tank, and pedesphere tanks are typically not designed to accommodate cellular providers. These two styles typically require cellular conduit to be routed up the exterior of the tank, which can be unappealing aesthetically. Typically cellular providers are required to construct "outbuildings" to house each individual provider's equipment.

Composite style tanks are more adaptable and more appealing to cellular providers than other tank styles. Composite style tanks have a large open cylindrical concrete base that can be utilized by cellular providers to route their conduit and house their equipment. The lack of exterior cellular provider conduit and facilities is more aesthetically pleasing and allows for more flexibility when accommodating cellular providers.

5 Comparative Cost Evaluation

To assist the City in assessing the value of rehabilitating the existing tank as compared to the construction of new tank, conceptual level pricing was developed for the repairs and improvements noted in 'Summary of Recommended Repairs' versus budgetary pricing for a new 0.5 MG composite tank. Budgetary pricing for a new composite tank was obtained from two composite tank manufacturers, CBI and Landmark. Landmark pricing was inclusive of sitework, and yard piping, but these were typical costs not necessarily applicable to our site. CBI pricing was less than Landmark because only pricing for the new tank was included. Therefore, CBI budgetary pricing for the new tank was utilized in the comparative cost evaluation. Budgetary pricing for a new pedesphere tank was obtained from Caldwell Tanks. Caldwell's estimate included only pricing for the new tank, therefore, providing a fair cost comparison with the CBI composite tank. The conceptual opinion of probable construction cost for repairs and improvements for each alternative as compared to construction of a new tank are as follows:

Alternative 1 – Rehabilitate Existing Tank & Encapsulate Lead Paint	$1,033,000
Alternative 2 – Rehabilitate Existing Tank & Remove Lead Paint	$1,445,000
Alternative 3A – New 0.5 MG Composite Tank	$2,695,000
Alternative 3B – New 0.5 MG Pedesphere Tank	$2,398,000

Detailed breakdown of these costs can be found in the attached Preliminary Cost Comparison. Painting costs were based on budgetary pricing from similar coating projects. Demolition and salvage costs were obtained from Midland Wrecking. The estimated demolition cost was comprehensive including costs for demolition of the tank structure, concrete footings, and any cellular structures. Cellular costs for Alternatives 1 and 2 include temporary relocation of existing cellular antennas to a "cell on wheels"(COW) and equipment reinstallation once rehabilitation is complete. Cellular costs for Alternatives 3A and 3B include temporarily relocation of cellular equipment to a COW and installation of cellular equipment at the new tank. Estimated cost for a new monopole and associated relocation of cellular equipment would be $120,000, however, this is not included in the cost analysis or recommended due to aesthetic concerns and site restraints.

Estimated cost for alternatives 1 and 2 includes 20 percent contingencies to account for unknown factors such as construction risk. Alternative 3 included less unknown factors; therefore, contingency was lowered to 10 percent. Engineering costs associated with the alternatives was included with 12 percent for Alternatives 1 and 2, and 20 percent for Alternatives 3A and 3B.

The useful service life normally expected for a multi-legged steel tank is typically between 60 and 100 years, depending on service conditions and level of maintenance. The Stratford Tank is approximately 60 years. Based on our inspection, substantial structural repairs are required to maintain safe operation. If these repairs are completed the tank could potentially have 20 years of additional life remaining before decommissioning.

To provide comparative costs between rehabilitation of the existing tanks versus construction of a new tank, an economic evaluation was performed to determine the net present value of each alternative at the end of the effective service life for the existing tank (20 additional years). The results are summarized in the table below. The remaining value of the new tank after 20 years was based on a straight line depreciation of the initial cost over a tank life of 80 years; this value was then adjusted to a present value based on an interest rate of 3 percent over 20 years. Alternatives 1 and 2 assume tank recoating would occur after 10 years, and that after 20 years the existing tank would be unserviceable. The coatings on a new tank will last longer than 10 years, therefore, Alternatives 3A and 3B assume tank recoating would occur after 20 years. A 20 year lifespan for new tank coatings is typically guaranteed by manufacturers.

NET PRESENT VALUE EVALUATION FOR ALTERNATIVES 1 THRU 3

	Alternative 1 - Rehab Existing	**Alternative 2 - Rehab. & Remove Lead Paint**	**Alternative 3A - New 0.5 MG Composite Tank**	**Alternative 3B - New 0.5 MG Pedosphere Tank**
Initial Cost	$1,033,000	$1,445,000	$2,695,000	$2,398,000
Recoat Tank in 2024*	$298,000	$298,000	$0	$0
Recoat Tank in 2034*	$0	$0	$148,000	$166,000
Net Present Value of Expenditures	$1,331,000	$1,743,000	$2,843,000	$2,564,000
Remaining Tank Value Year 2034*	$0	$0	$(1,119,000)	$(996,000)
Total Net Present Value	$1,331,000	$1,743,000	$1,724,000	$1,568,000

*Net present value based on i=3%

Based solely upon the total net present value the lowest cost option is Alternative 1, which includes spot repairs and a new coating system that encapsulates the existing lead based coating. Although this option has the lowest cost, there is some risk of additional repairs over the next 20 years, especially with regard to the existing concrete foundations. In order to mitigate additional interim repairs and improve overall reliability, the City should consider constructing Alternative 3A. This alternative is preferred over Alternative 3B when economic and non-economic factors are considered.

BLACK & VEATCH

City of Lawrence, KS
Stratford Elevated Water Storage Tank
Preliminary Alternatives Evaluation Report - FINAL
Comparison of Opinion of Probable Project Cost
Revised: December 2014

	Alternative 1 - Rehab. Existing			Alternative 2 - Rehab. Existing & Lead Paint Removal			Alternative 3A - New 0.5 MG CompositeTank			Alternative 3B - New 0.5 MG Pedesphere Tank			
						January-14			June-14			June-14	
Treatment Plant Facilities													**Notes:**
General Requirements	5%	$	25,000	5%	$	38,000	12%	$	180,000	12%	$	157,800	
Sitework	10%	$	49,000	10%	$	76,000	10%	$	150,000	10%	$	131,500	
Rehabilitation Cost		$	494,000		$	761,000		$	-		$	-	
New Tank Cost		$	-		$	-		$	1,500,000		$	1,315,000	
Cellular		$	200,000		$	200,000		$	152,000		$	152,000	
Demolition/Salvage		$	-		$	-		$	60,000		$	60,000	
Subtotal			$768,000			$1,075,000		$	2,042,000		$	1,816,300	
Contingency	20%	$	154,000	20%	$	215,000	10%	$	204,000	10%	$	182,000	
Total Probable Construction Cost			**$922,000**			**$1,290,000**		**$**	**2,246,000**		**$**	**1,998,000**	
Engineering	12%	$	111,000	12%	$	155,000	20%	$	449,000	20%	$	400,000	
Preliminary Design													
Detailed Design													
Construction Phase Services													
Project Administration Fee													
Total Probable Project Cost		**$**	**1,033,000**		**$**	**1,445,000**		**$**	**2,695,000**		**$**	**2,398,000**	