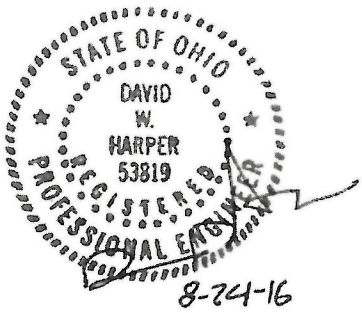
HARPER ENGINEERING, Inc.
815 Superior Ave.
Suite 1514
Cleveland, OH 44114
Ph: 216.344.3855
Email: dwharper@harperengineering.org

STRUCTURAL EVALUATION LETTER



8-24-16

SITE INFORMATION

Site Name:	Murifield/Dublin WT
Site Type:	Water Tower
Site Address:	7697 Avery Road, Dublin, Ohio 43017
T-Mobile Site No.:	A6C0070A
HPE Site No.:	14-188-223

DESIGN CRITERIA

1. Meets Ohio Building Code 2011/IBC 2009.
2. ANSI/TIA/EIA-222-G Structural Standard for Antenna Supporting Structures and Antennas.
3. ANSI/AWWA D100-11 (Standard for welded steel tanks for water storage).
4. AISC 9th. Edition (Allowable Stress Design).

DATA SOURCES

1. Site photographs taken by Harper Engineering, Inc. dated 08/02/2016.
2. RFDS data configuration sheet by T-Mobile dated 07/29/2016.

PROPOSED MODIFICATIONS

1. Remove three (3) existing TMBX-6517-A1M panel antennas (1 per sector) at 122 ft. elevation.
2. Install three (3) new LNX-6515DS-A1M panel antennas (1 per sector) on three (3) existing mount pipes (1 per sector), mounted on tank wall of the Water Tower at 122 ft. elevation.
3. Install three (3) TMA's behind antennas at 122 ft. elevation.

ASSUMPTIONS

1. Existing water tower is in good condition and without any structural defects.
2. The original design was performed in accordance with the ANSI/AWWA D100-11 (Standard for welded steel tanks for water storage) and governing building code.
3. The existing wall mount antenna was designed in accordance with the Telecommunication Industry Association standard TIA/EIA 222 and governing building code.

CONCLUSION

Harper Engineering, Inc. performed structural evaluation of new antennas and equipment supports. Based on the results, Harper Engineering can conclude that the proposed antennas and equipment supports, including building structure, meet the design criteria listed above and are structurally adequate to support the proposed T-Mobile modifications.

ATTACHMENTS

1. Harper Engineering, Inc. structural analysis.

16-096ARTW

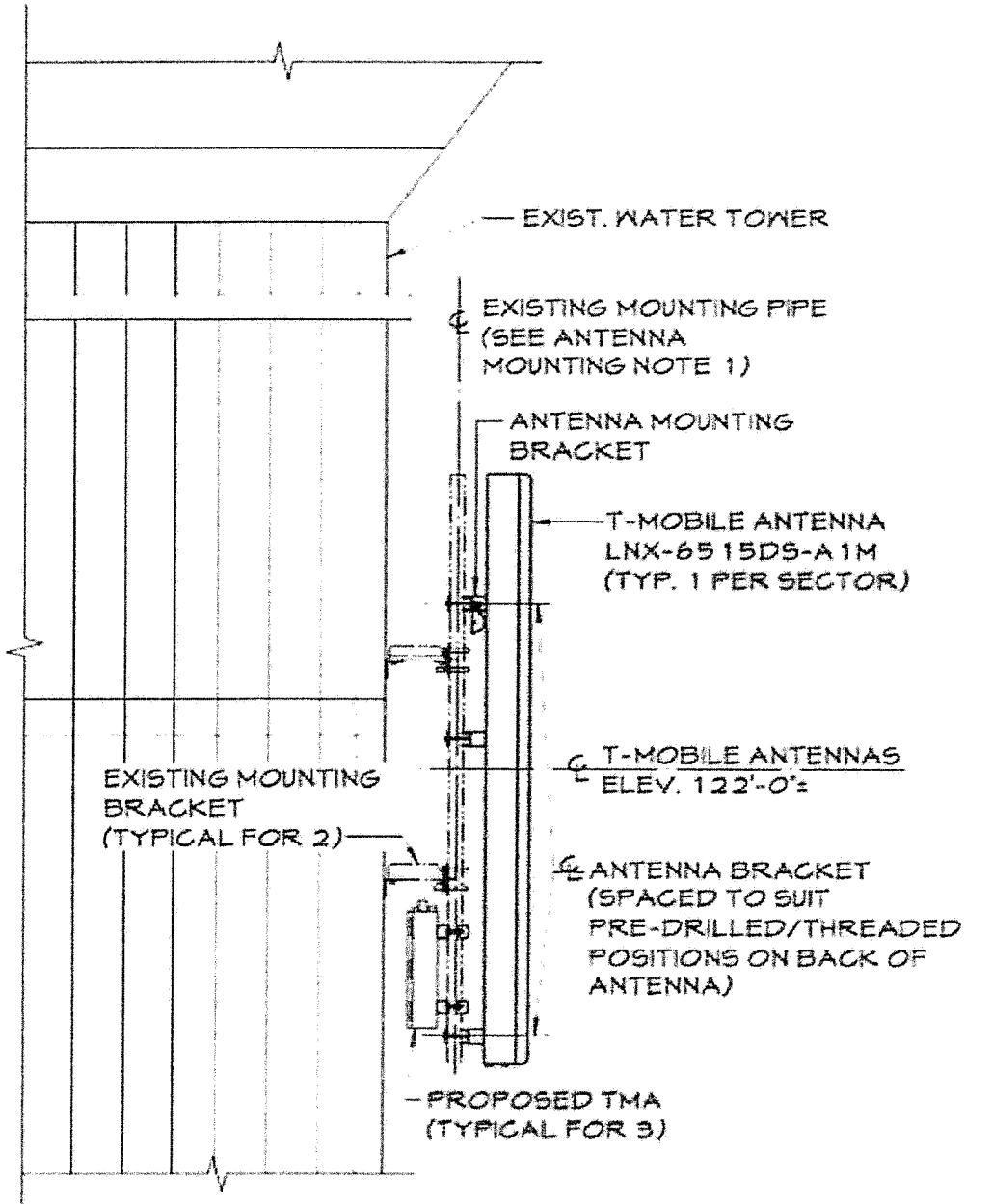
Wind pressure calculation

The wind load calcuations are based on the ANSI/TIA-222-G-2009 Structural Standard for Antenna Supporting Structures and Antennas. Specific equiation numbers and/or tables and table values have been listed in the equations listed below.

Velocity pressure	$q_z = 0.00256 \cdot K_z \cdot K_{zt} \cdot K_d \cdot V^2 \cdot I$	Eq. 2.6.9.6.
Height above ground level	$z = 122$ ft	
	$a = 7$	Table 2-4
	$z_g = 1200$ ft	Table 2-4
Velocity pressure cefficient	$K_z = 2.01 \cdot \left[\frac{z}{z_g}\right]^{\frac{2}{a}}$	Eq. 2.6.5.2.
Topographic factor	$K_{zt} = 1$	Eq. 2.6.6.4.
Wind direction probability factor	$K_d = 0.95$	Table 2-2
Basic wind speed	$V = 90$ mph	
Importance factor	$I = 1$	Table 2-3
	$q_z = 20.61$ psf	
Wind pressure	$q_p = q_z \cdot G_h$	
Gust effect factor	$G_h = 0.85$	
	$q_p = 17.51$ psf	

New antenna and pipe wind load (tank wall mounted)

Antenna wind force	$F_a = q_p \cdot [C_{df} \cdot A_a]$	$F_a = 122.57$ lbs
Antenna area (side) LNX6515DS-A1M	$A_a = 5$ sqft	
Force coefficient for flat members	$C_{df} = 1.4$	
Wind pressure	$q_p = 17.51$ psf	
Mounting pipe forces	$F_p = q_p \cdot [C_{dr} \cdot A_r]$	$F_p = 40.34$ lbs
Force coefficient for round members	$C_{dr} = 1.2$	
Pipe area	$A_r = 1.92$ sqft	
RRH area (Side)	$A_{RRH} = 1.7$ sqft	
RRH wind force	$F_{RRH} = q_p \cdot [C_{df} \cdot A_{RRH}]$	$F_{RRH} = 41.67$ lbs



ANTENNA MOUNTING DETAIL

Anchor bolt forces (wind load paralel with wall face)

Gravity load moment	$M_g = [W_p \cdot d_2] + [W_a \cdot d_1] + [W_{RRH} \cdot d_3]$	
Weight of the pipe	$W_p = 46.4$ lbs	
Weight of Antenna + bracket	$W_a = 63$ lbs	
Weight of RRH (TMA)	$W_{RRH} = 55$ lbs	
Distance of Antenna from wall	$d_1 = 1.5$ ft	
Distance of pipe from wall	$d_2 = 1$ ft	
Distance of RRH (TMA) from wall	$d_3 = 0.5$	
Max gravity moment	$M_g = 168.4$ lbsft	
Tension on one upper bolt	$T_1 = \frac{M_g}{a_1} \cdot \frac{1}{2}$	$T_1 = 21.05$ lbs
Distance between brackets	$a_1 = 4$ ft	
Shear per bolt (4 bolts)	$V_1 = \frac{W_p + W_a}{4}$	$V_1 = 27.35$ lbs
Reaction on upper bracket	$R_1 = \frac{F_p \cdot a_p + F_a \cdot a_a + F_{RRH} \cdot a_{RRH}}{a_1}$	$R_1 = 71.02$ lbs
Pipe wind force	$F_p = 40.34$ lbs	
RRH wind force (TMA)	$F_{RRH} = 41.76$ lbs	
Antenna wind force	$F_a = 122.57$ lbs	
CL pipe to bottom bracket	$a_p = 2$ ft	
CL RRH (TMA to bottom bracket)	$a_{RRH} = -1$ ft	
CL of Antenna to bottom bracket	$a_a = 2$ ft	
Shear per bolt on upper bracket (4 bolts)	$V_2 = R_1 \cdot \frac{1}{4}$	$V_2 = 17.75$ lbs
Reaction at bottom bracket	$R_2 = F_p + F_a - R_1$	$R_2 = 91.9$ lbs
Moment on the bracket	$M = R_1 \cdot d_2$	
	$M = 71.02$ lbsft	
Horizontal distance between bolts	$a_2 = 0.5$ ft	
Tension on bolts	$T_2 = \frac{M}{a_2}$	$T_2 = 142.03$ lbs
Total tension on one bolt	$T = T_1 + T_2$	$T = 163.08$ lbs
Total shear on one bolt	$V = \sqrt{[V_1]^2 + [V_2]^2}$	$V = 32.61$ lbs

Assume existing anchors minimum 1/2" dia. bolts are within allowable tension and shear:
Tension= 2700 lbs , Shear= 2300 lbs.
so 1/2" dia. anchor bolts will have plenty of capacity for the new antenna load.
Based on above we safely say that existing anchors bolts and mounts are O.K.