ENSURING STRUCTURAL INTEGRITY

Lattice 161kV Tower Emergency Stabilization

Michael Miller P.E.

ATUG 2022, Madison, WI

Tower 58 : Clinton – Stilwell 161 kV - Central Missouri

1. What happened? How did it happen?

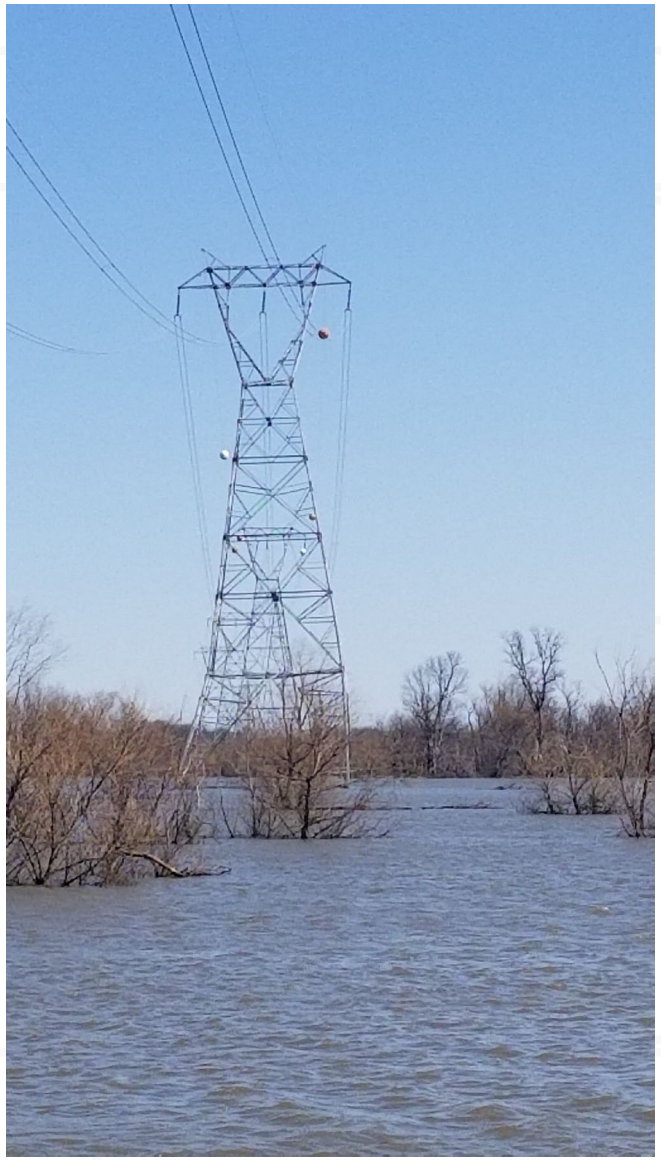
2. PLS-TOWER model assessments using **loading** from PLS-CADD.

3. Tension-Only System.

4. Data survey acquisition: 3D photogrammetry using **ContextCapture** – A new application of an old technology using concepts of Parallax and Photogrammetry.

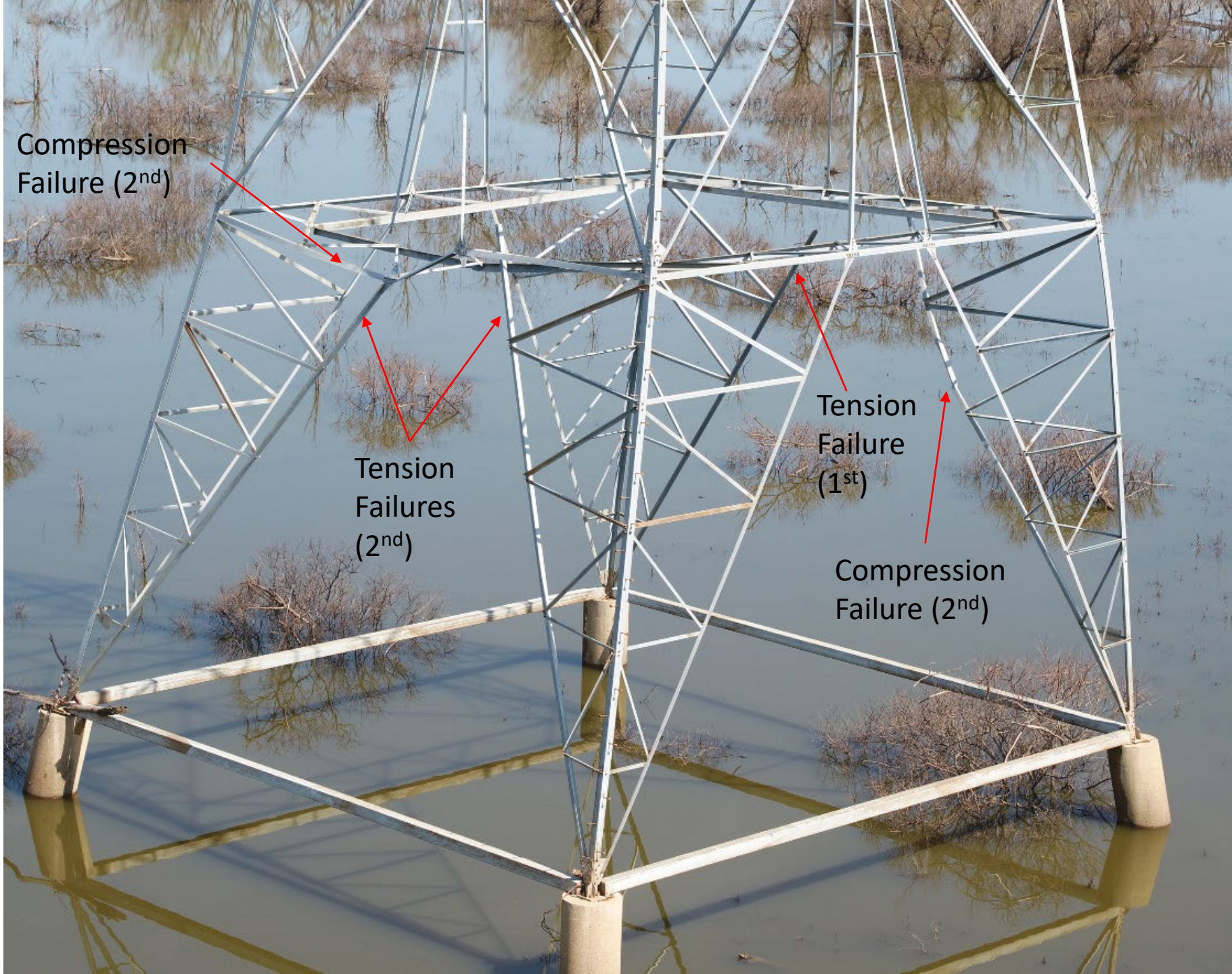
5. Temporary Stabilizing.

What happened?



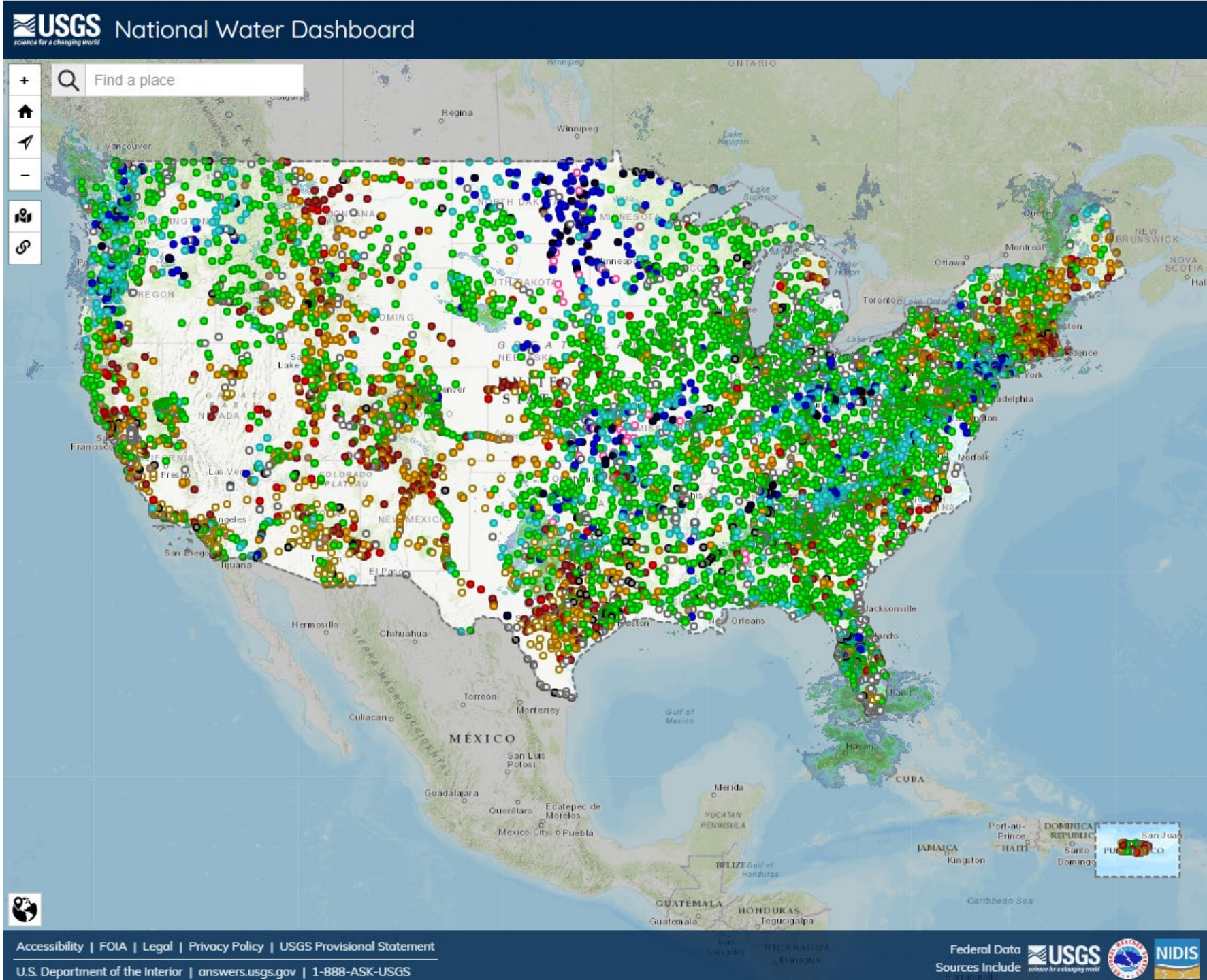
How did it happen?

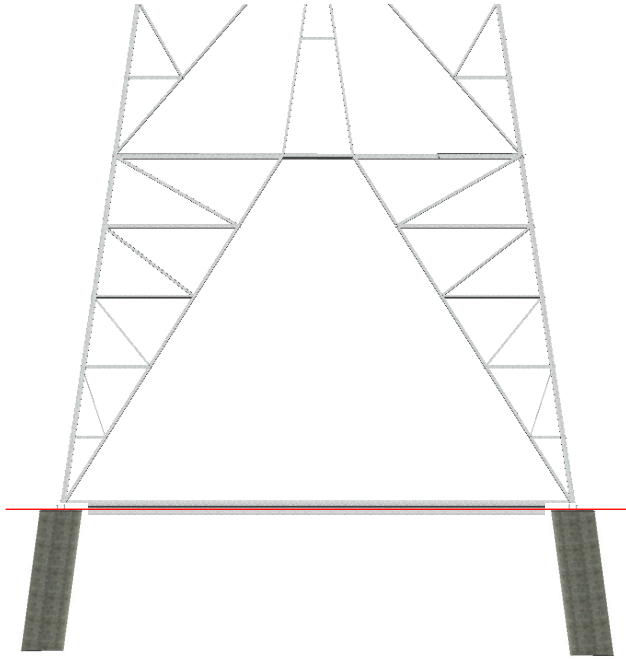
How did it happen?

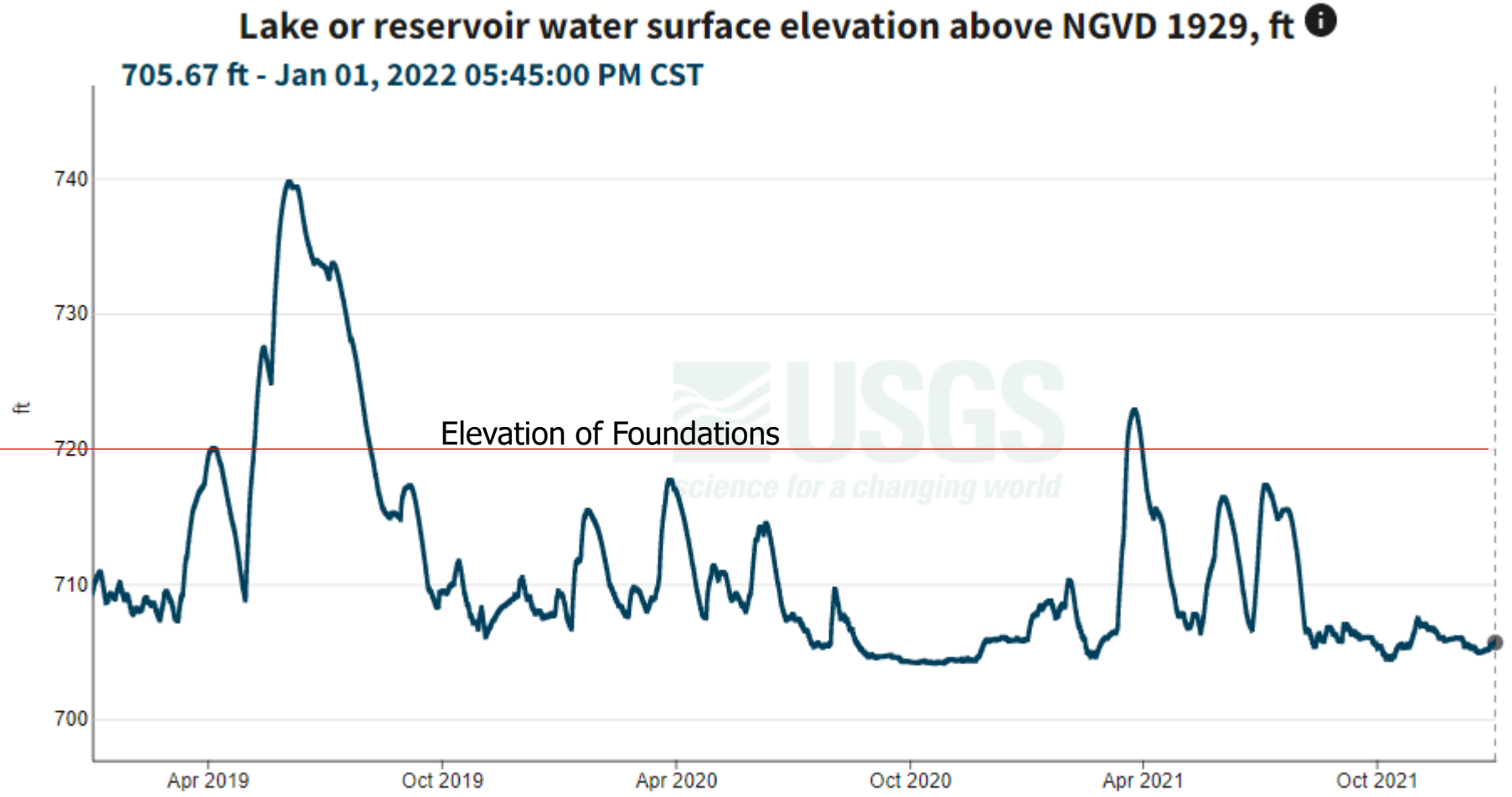


Real-time water data collected at the USGS observation stations

https://dashboard.waterdata.usgs.gov/





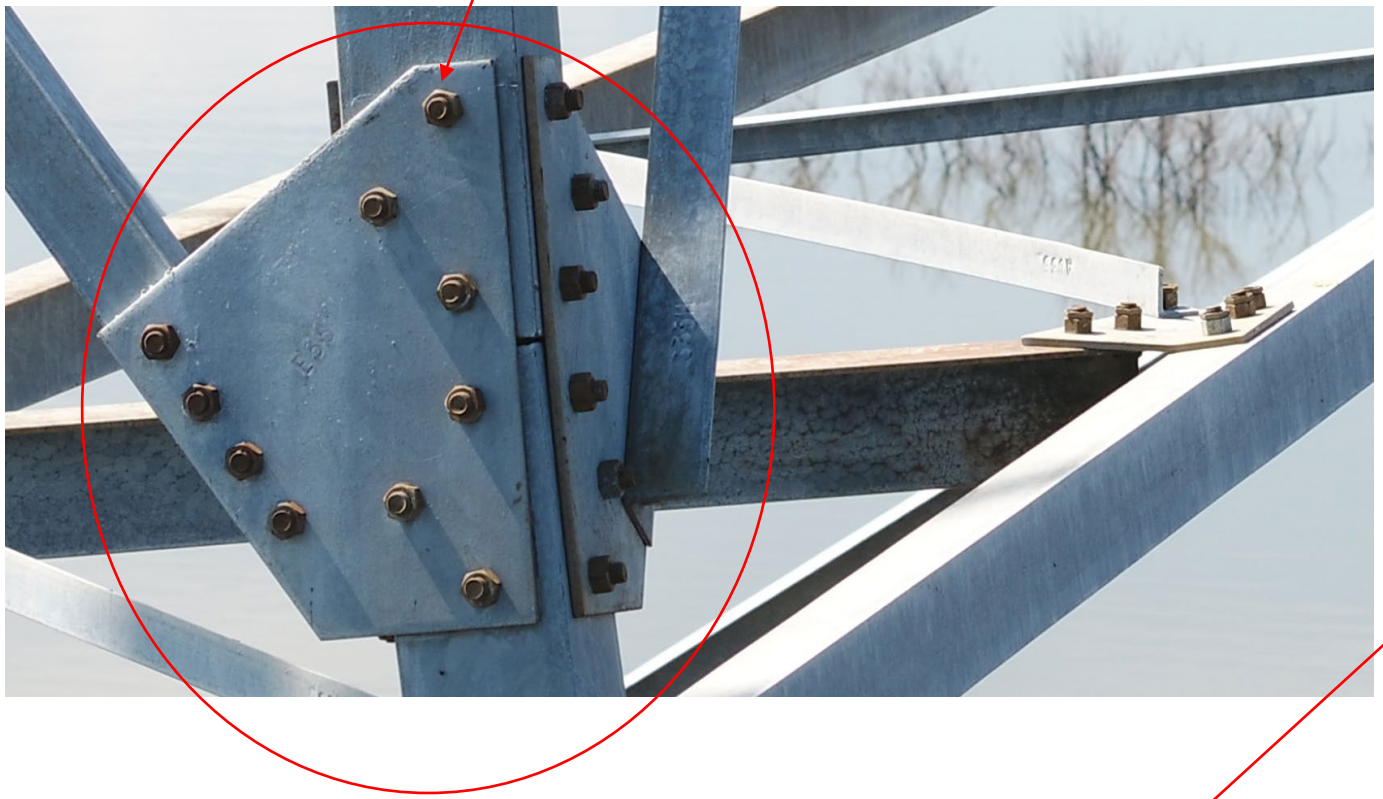

Lake or reservoir water surface elevation above NGVD 1929, ft
705.67 ft - Jan 01, 2022 05:45:00 PM CST
ft
740
730
720
710
700
Elevation of Foundations
Apr 2019
Oct 2019
Apr 2020
Oct 2020
Apr 2021
Oct 2021
USGS
science for a changing world

Video: Typical Failure when structures subjected to Flooding events.

The Clues

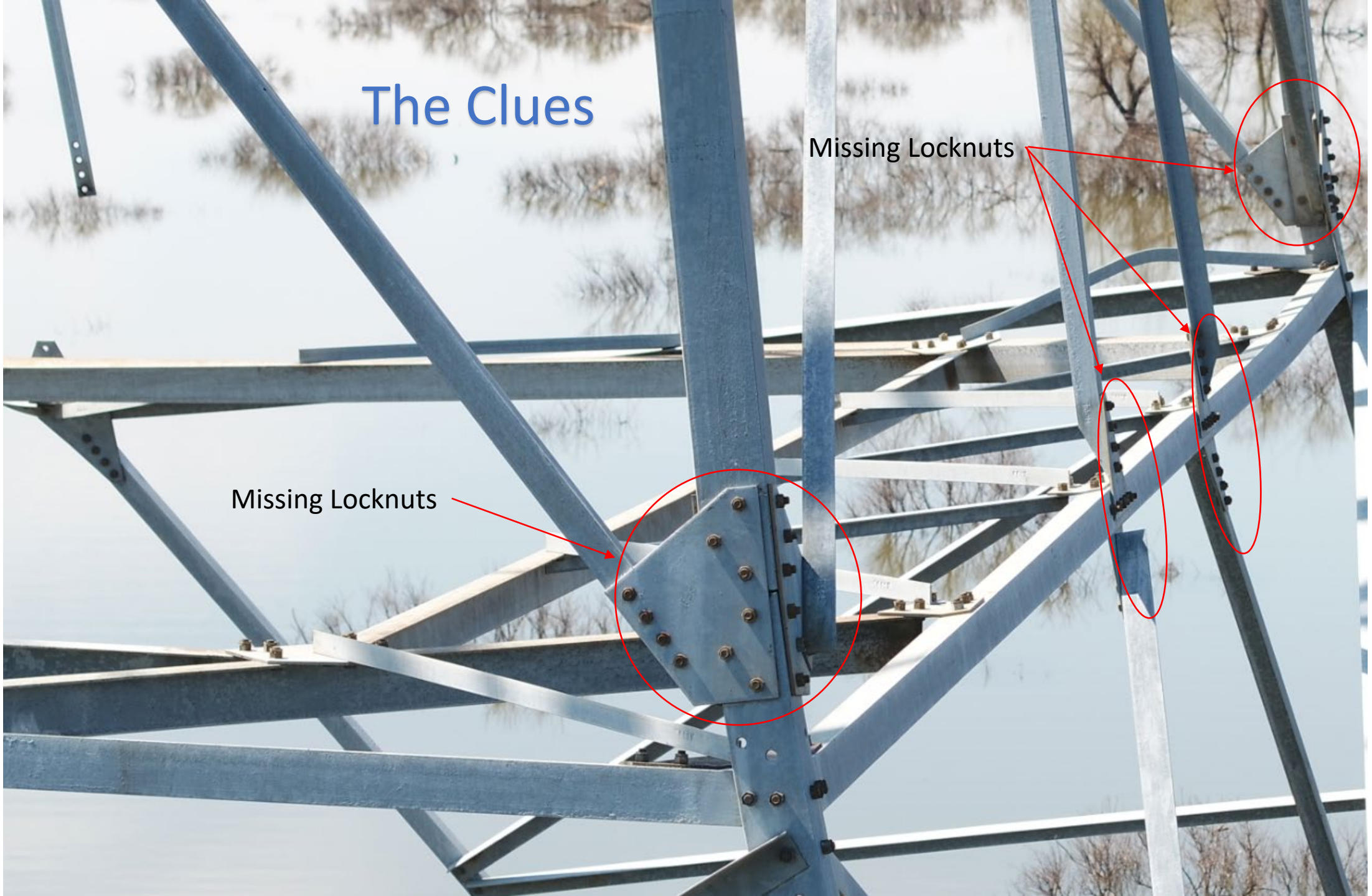
Tower 58

Twr 58:L Missing Locknuts



Locknuts

Missing Bolt


The Clues
Missing Locknuts
Missing Locknuts

Miss-fabrication from original supply and installation in plate

Tower 58

Typical Latticed Steel tower bolt Installation and Loosening mechanism:

Nuts for bolts are installed, ‘up and out’ such that if they fall out, they leave a hole that can be seen upon inspection.

Locknuts are externally applied galvanized sheet metal locking devices that keep the nut on.

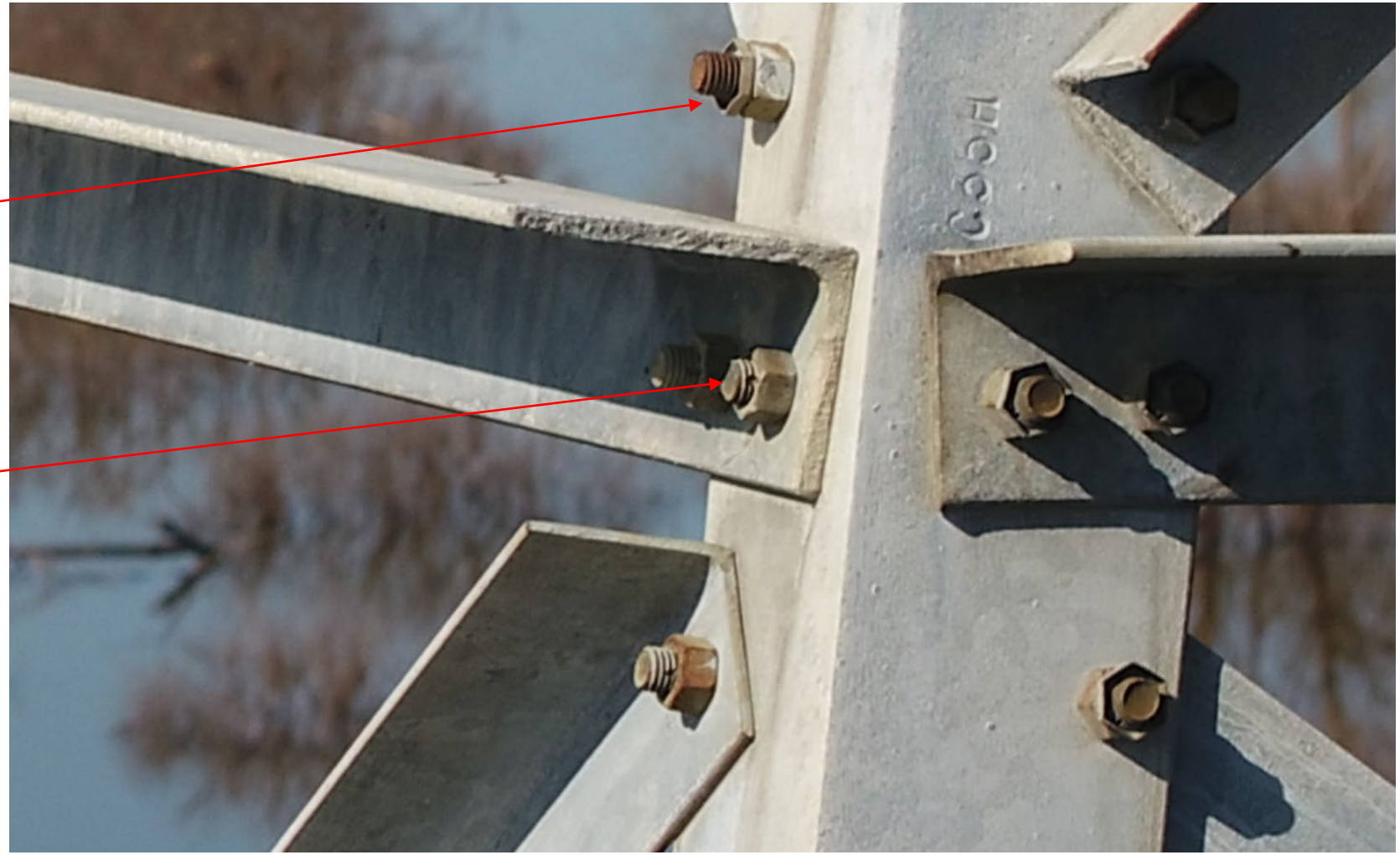
Over time, the locknut and nut work their way to the threaded end. First, the locknut falls off followed by the nut. Then finally the bolt falls out revealing a hole.

Tower 58

Two locking mechanisms were used of tower 58:

Locknuts (palnut type) - Sheet metal hot dipped galvanized locking device screwed onto the bolt after the nut is tightened.

Corking - After tightening the nut, the threaded end is punched with a die that permanently damages the bolt thread keeping the nut from backing off of the bolt.

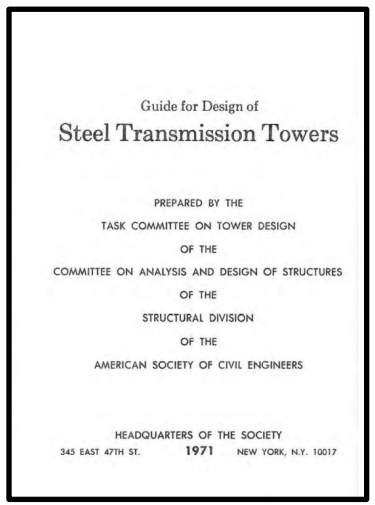


Tower Model
In PLS-TOWER
As designed

Tower designed:
1978

Available Standard:
None

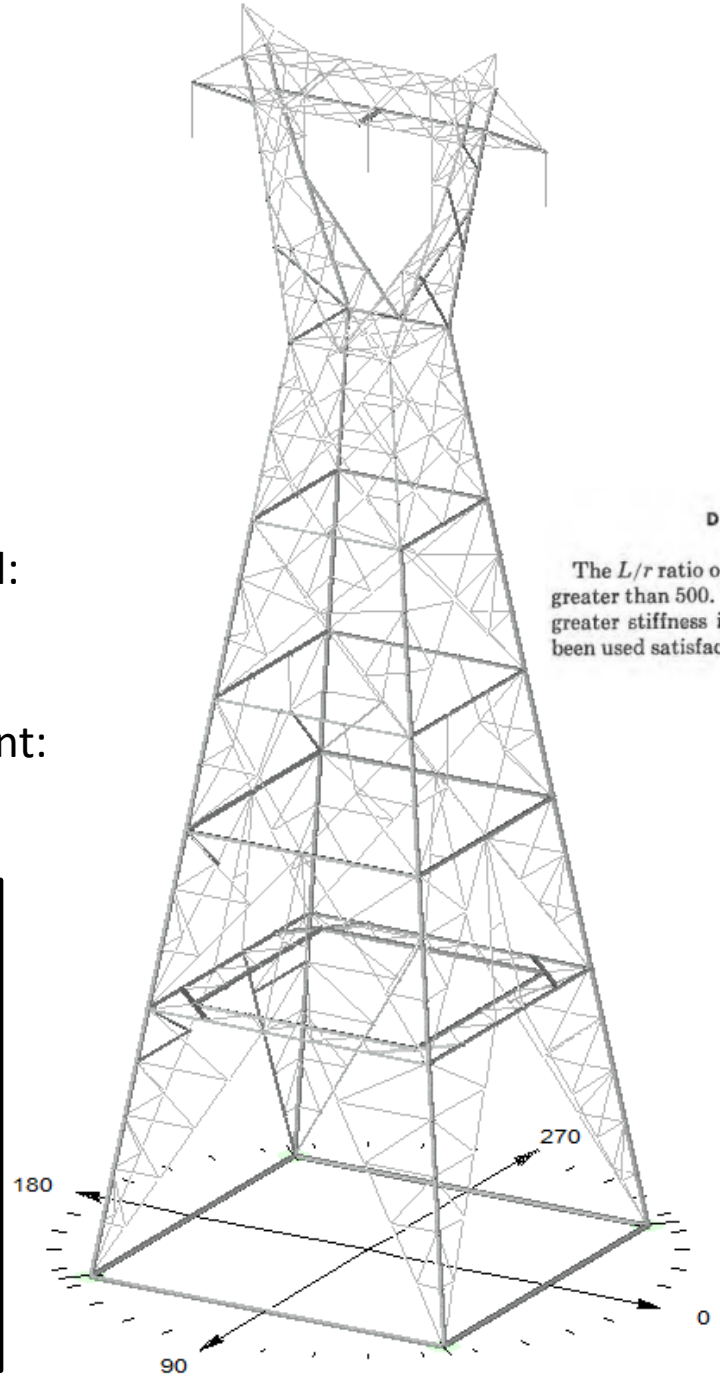
Available Document:
MOP 52, 1971



Guide for Design of
Steel Transmission Towers

PREPARED BY THE
TASK COMMITTEE ON TOWER DESIGN
OF THE
COMMITTEE ON ANALYSIS AND DESIGN OF STRUCTURES
OF THE
STRUCTURAL DIVISION
OF THE
AMERICAN SOCIETY OF CIVIL ENGINEERS

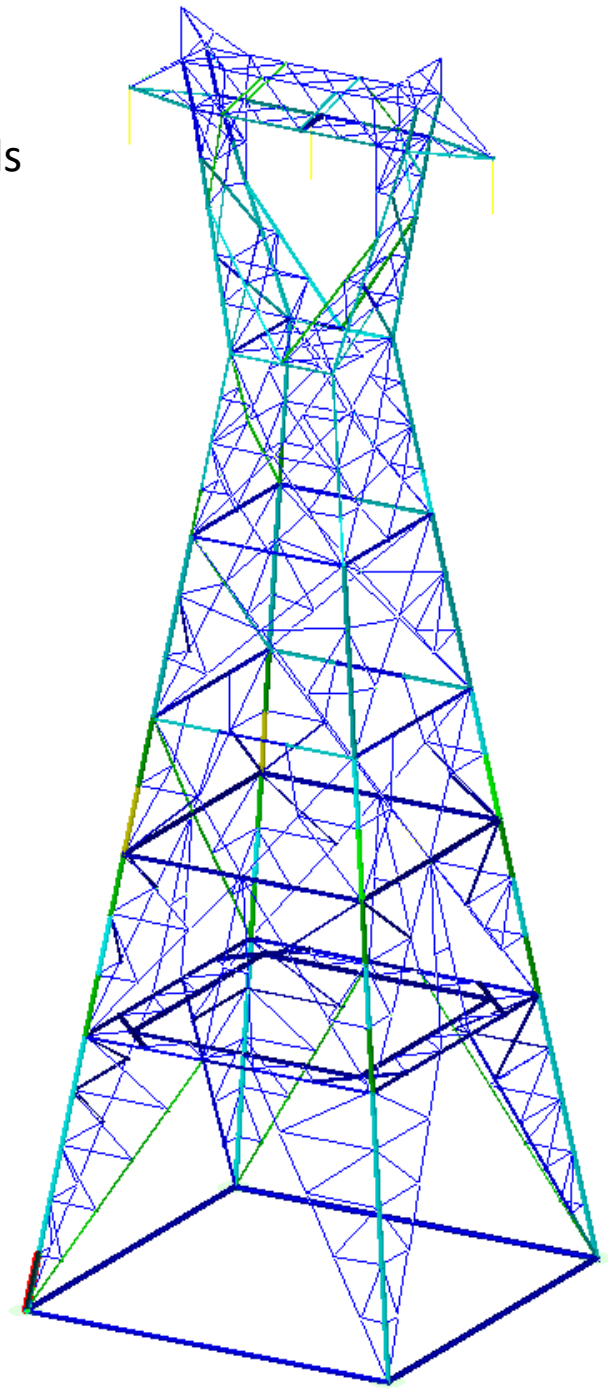
HEADQUARTERS OF THE SOCIETY
345 EAST 47TH ST. 1971 NEW YORK, N.Y. 10017



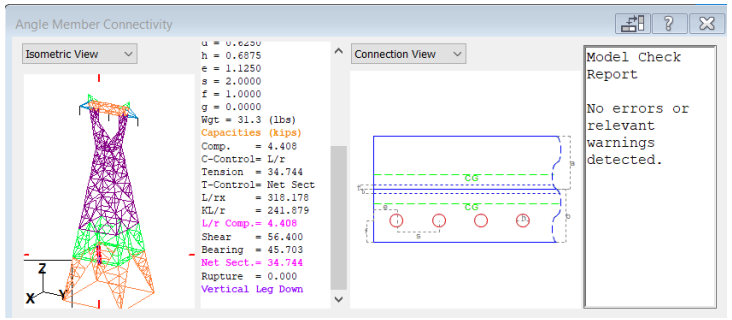
D. L/r RATIO FOR TENSION MEMBERS

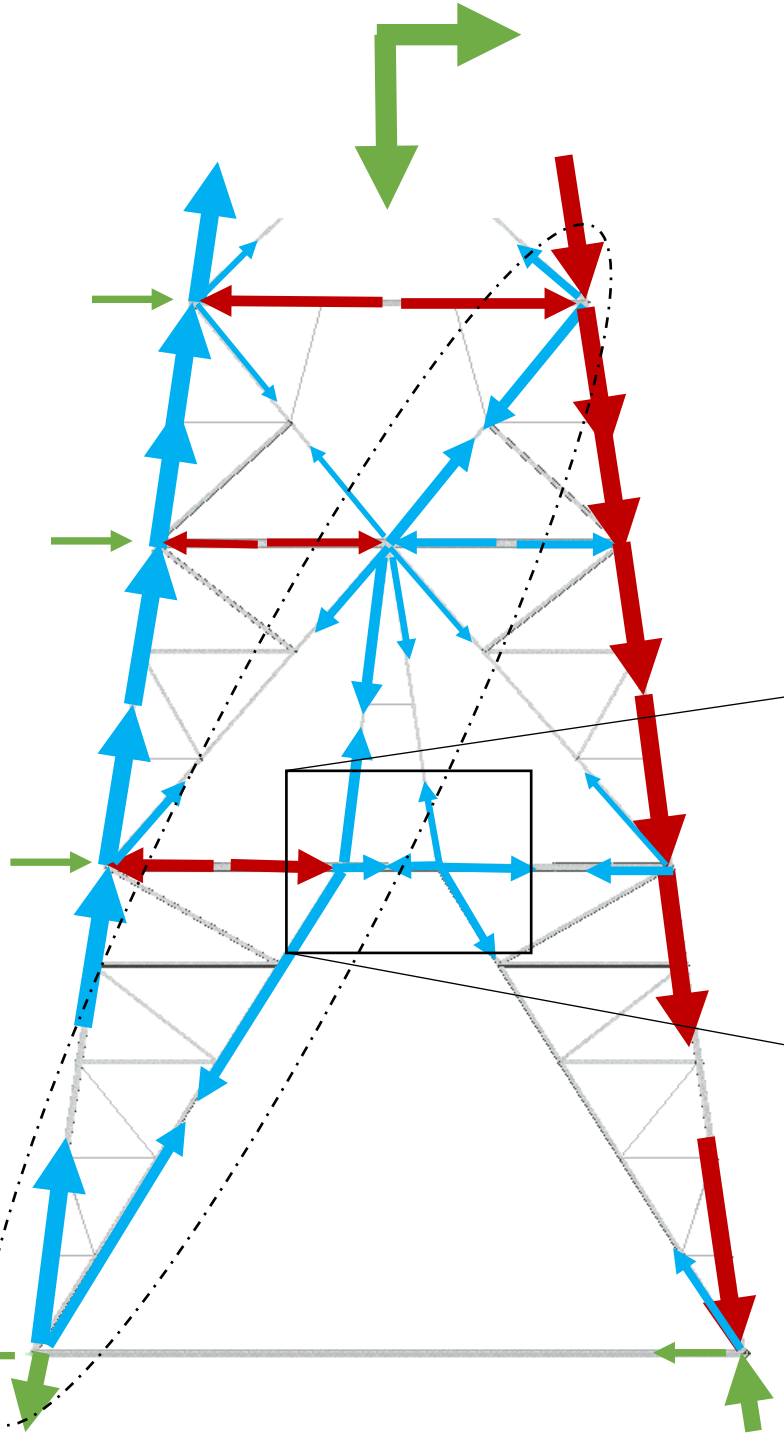
The L/r ratio of a tension member detailed with draw should not be greater than 500. Because of the possibility of wind-induced vibration, greater stiffness is required in the hangers. An L/r ratio of 375 has been used satisfactorily.

Under PLS-CADD loads
98% utilized



Aside:
Understanding Load Flow in tension-only bracing systems





Applied Loads
(+) Tension
(-) Compression

How do we know when a member was originally designed as a Tension-Only member?

Definition: Tension-Only members provide a mechanism to transfer *body* shear while providing support to bracing members.

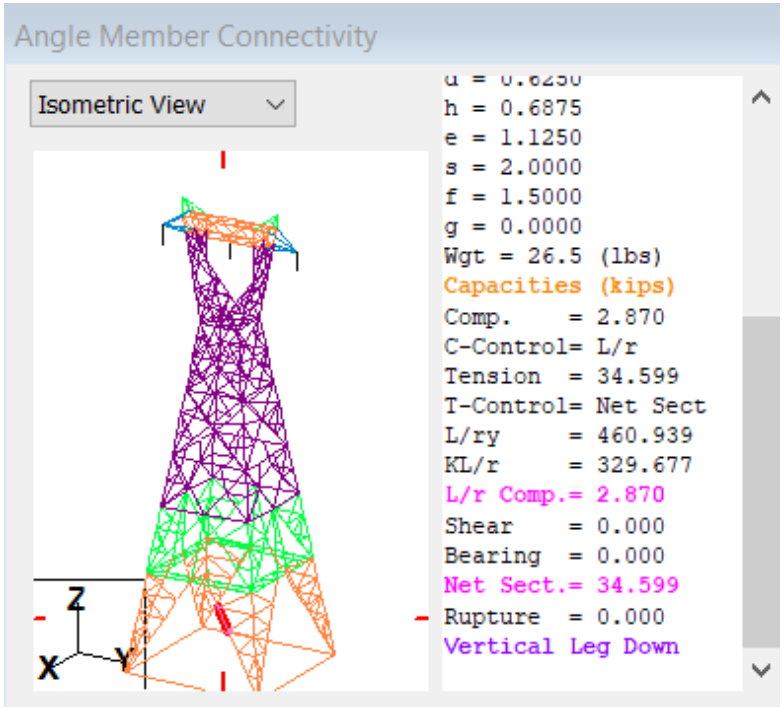
1. kL/r ratio > 200; ASCE 10-19 Limits: $300 < kL/r \leq 500$

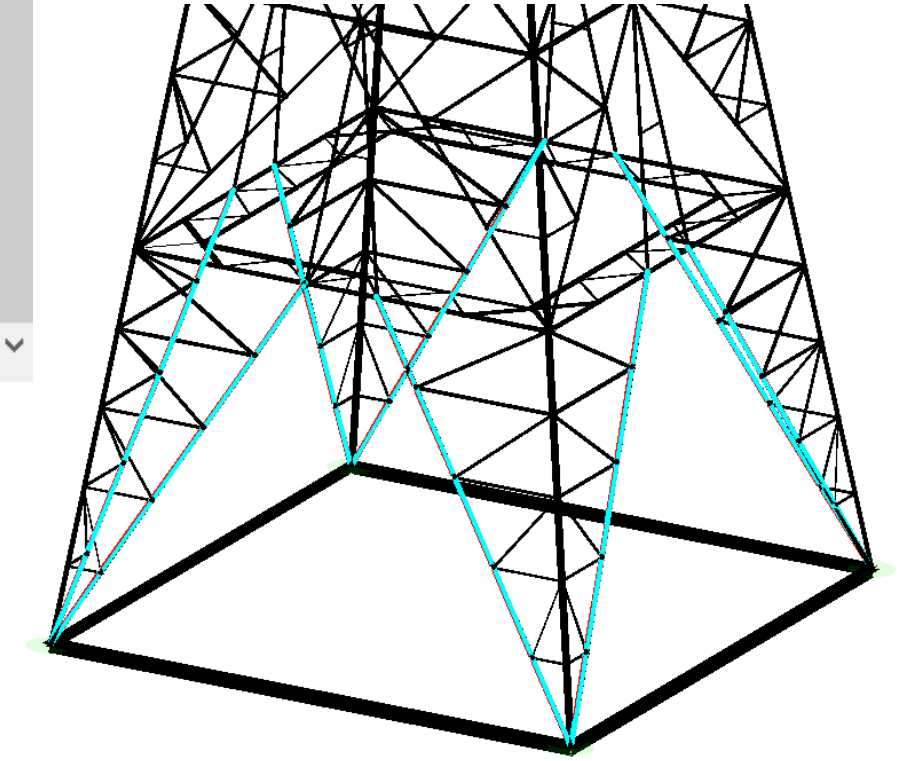
2. Original Table of Member stresses (loads) show +X values.

3. Detailing of member shows use of “Draw”.

How do we know when a member was originally designed as a Tension-Only member?

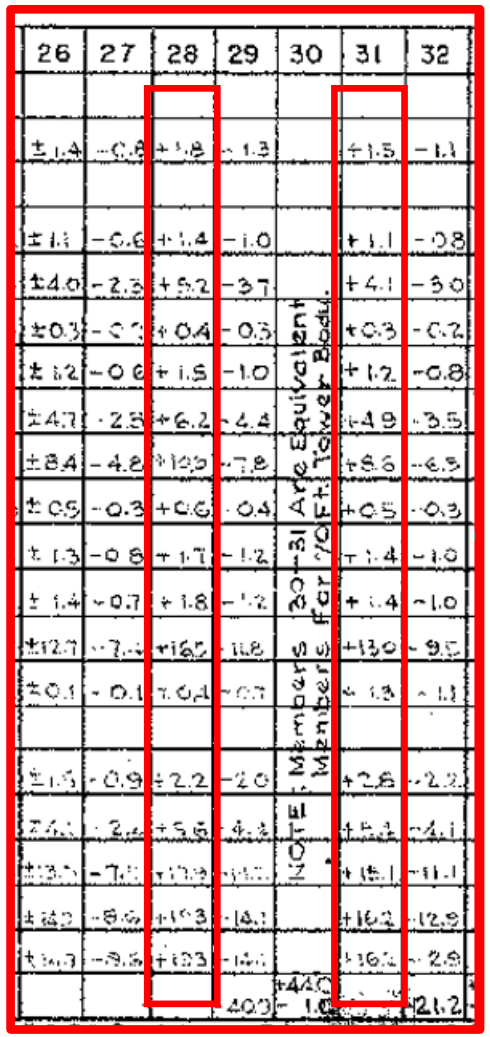
kL/r ratio > 200
> 300 (ASCE-10)

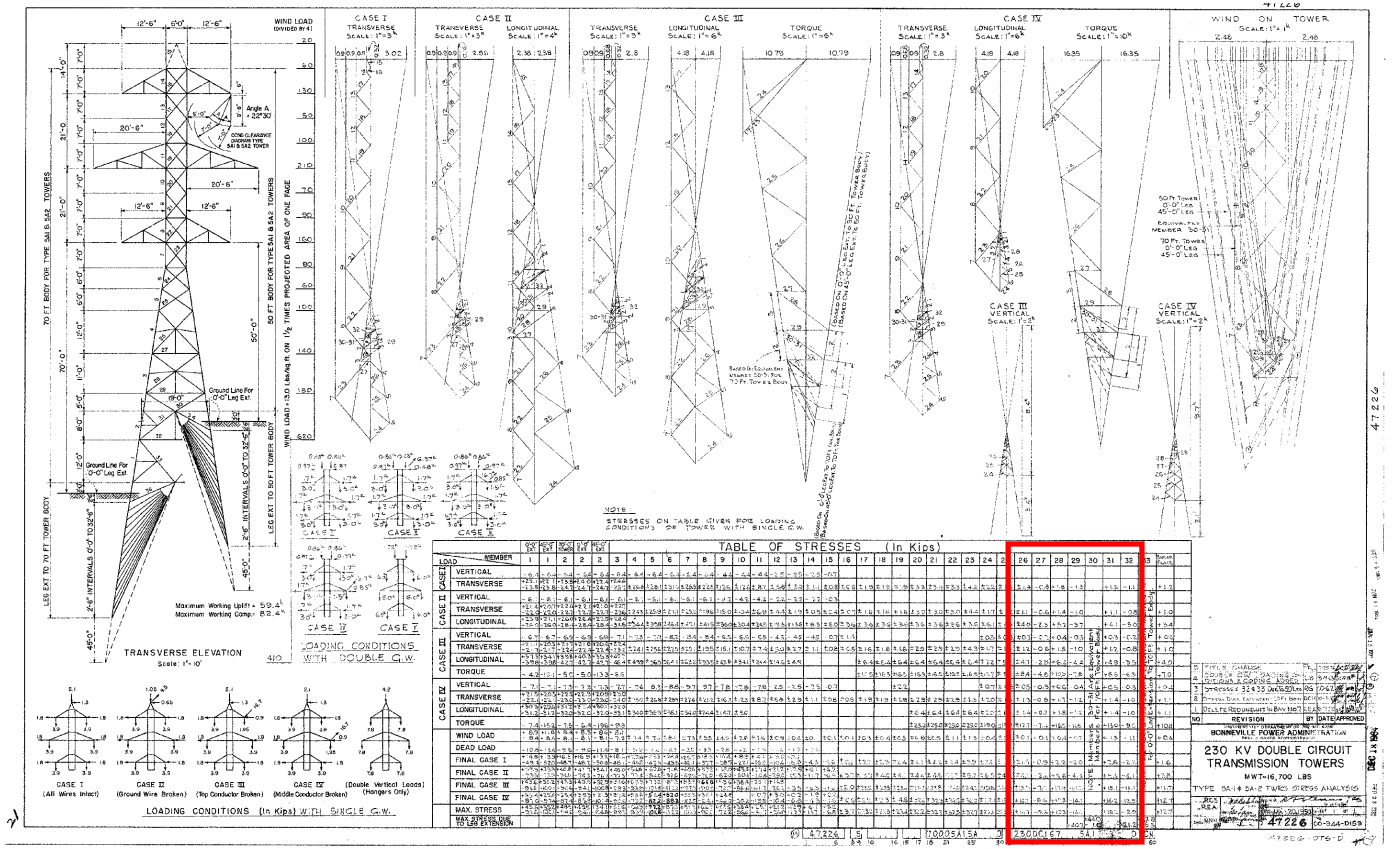




How do we know when a member was originally designed as a Tension-Only member?

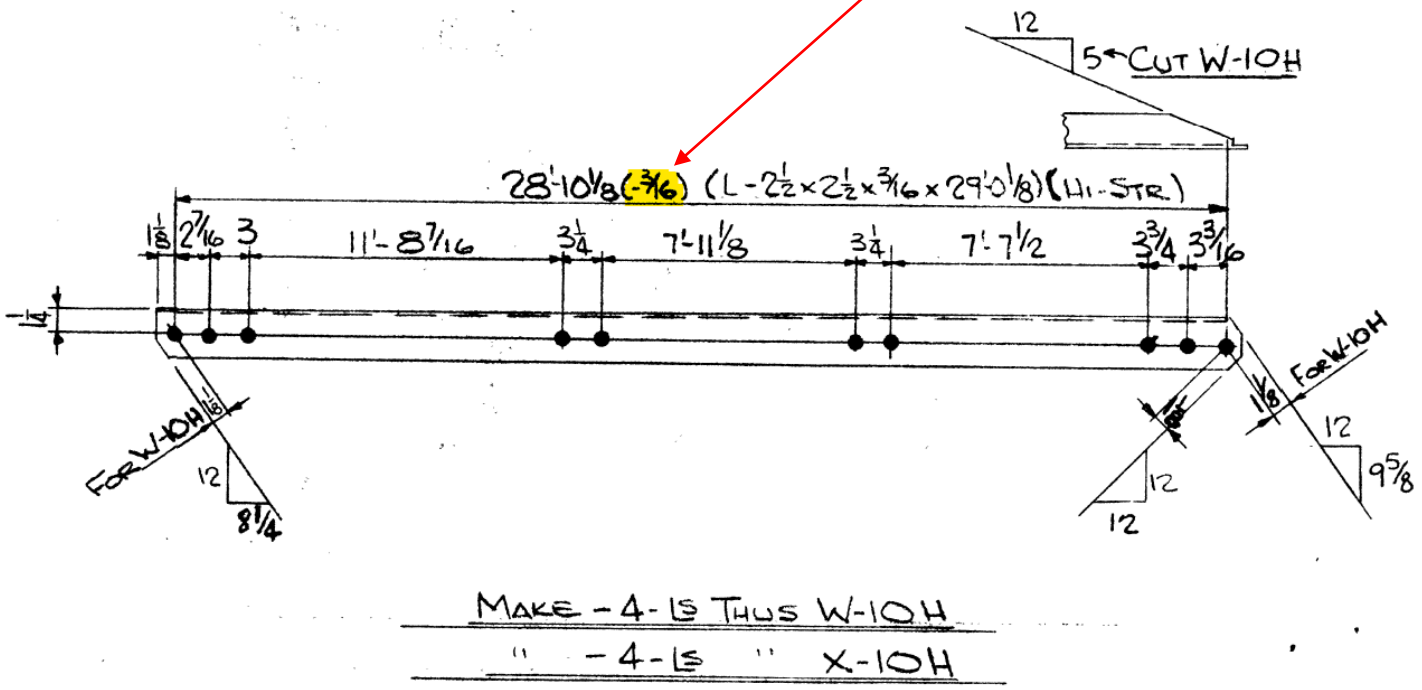
Original Table of Member stresses (loads) show +X values.

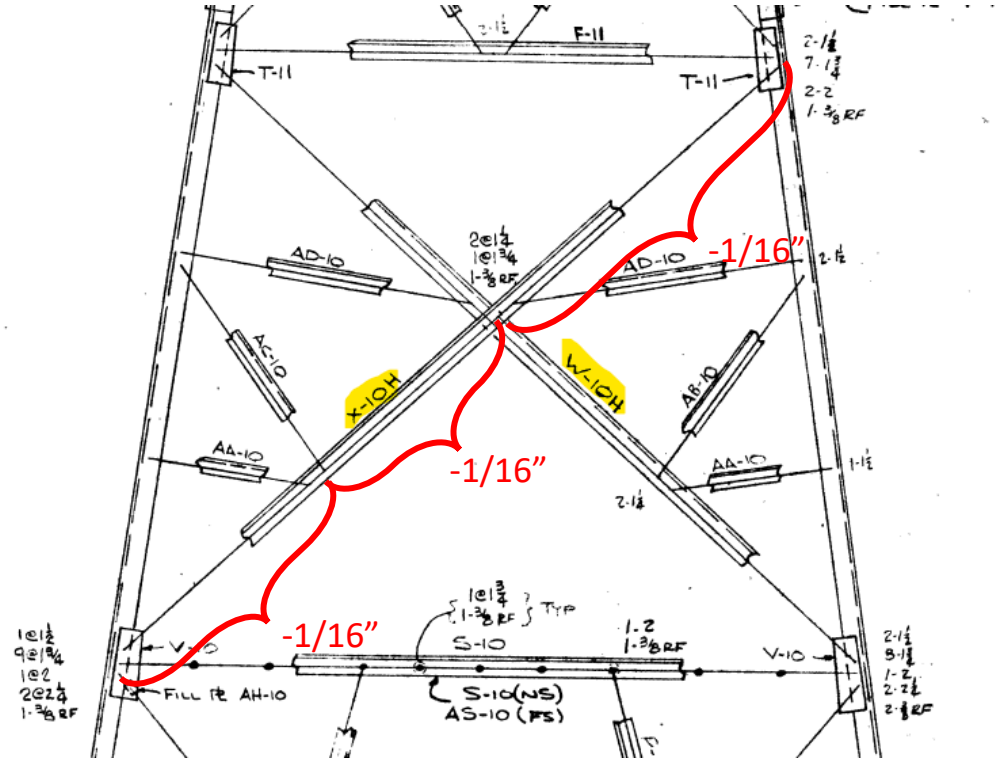




How do we know when a member was originally designed as a Tension-Only member?

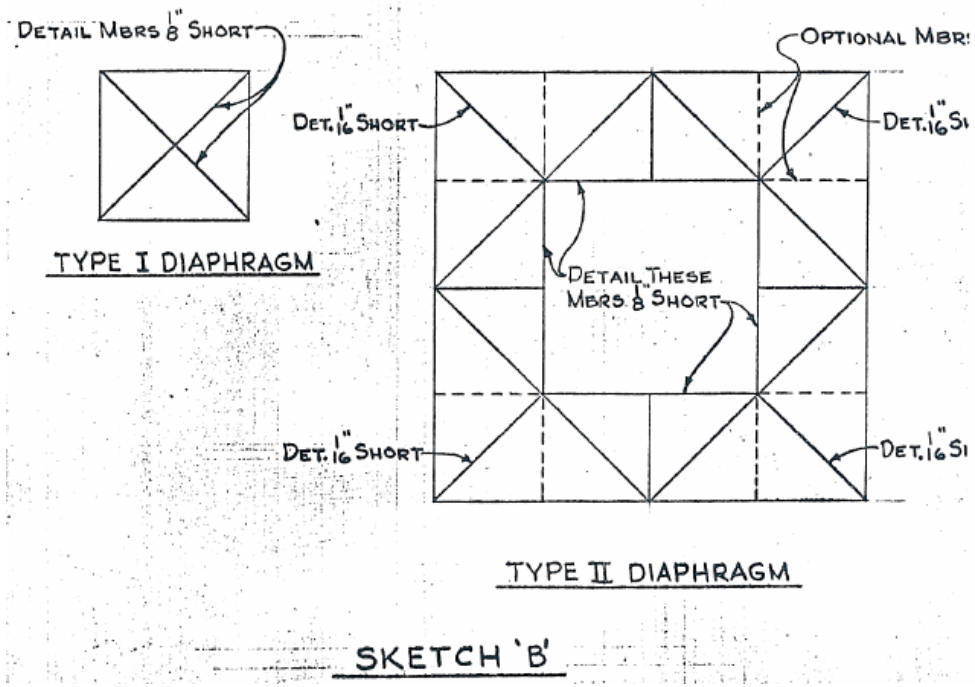
Detailing of member shows use of "Draw".

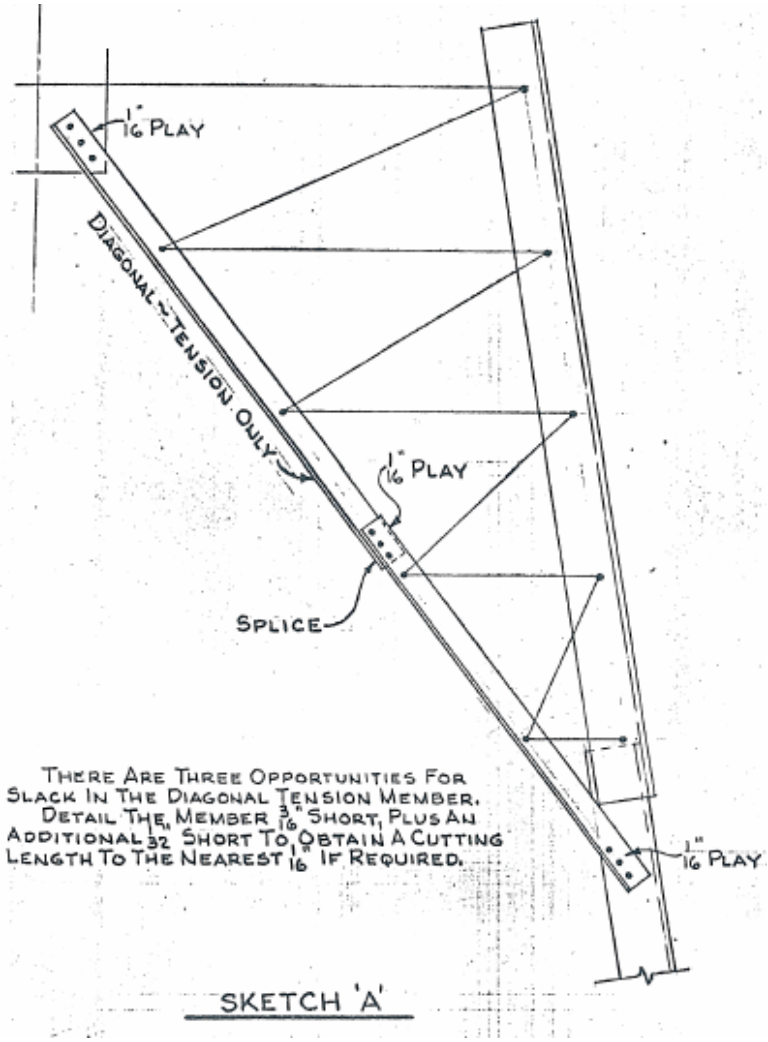




How do we know when a member was originally designed as a Tension-Only member?

At the design stage…





Line/Structure Modeling

Security Loading

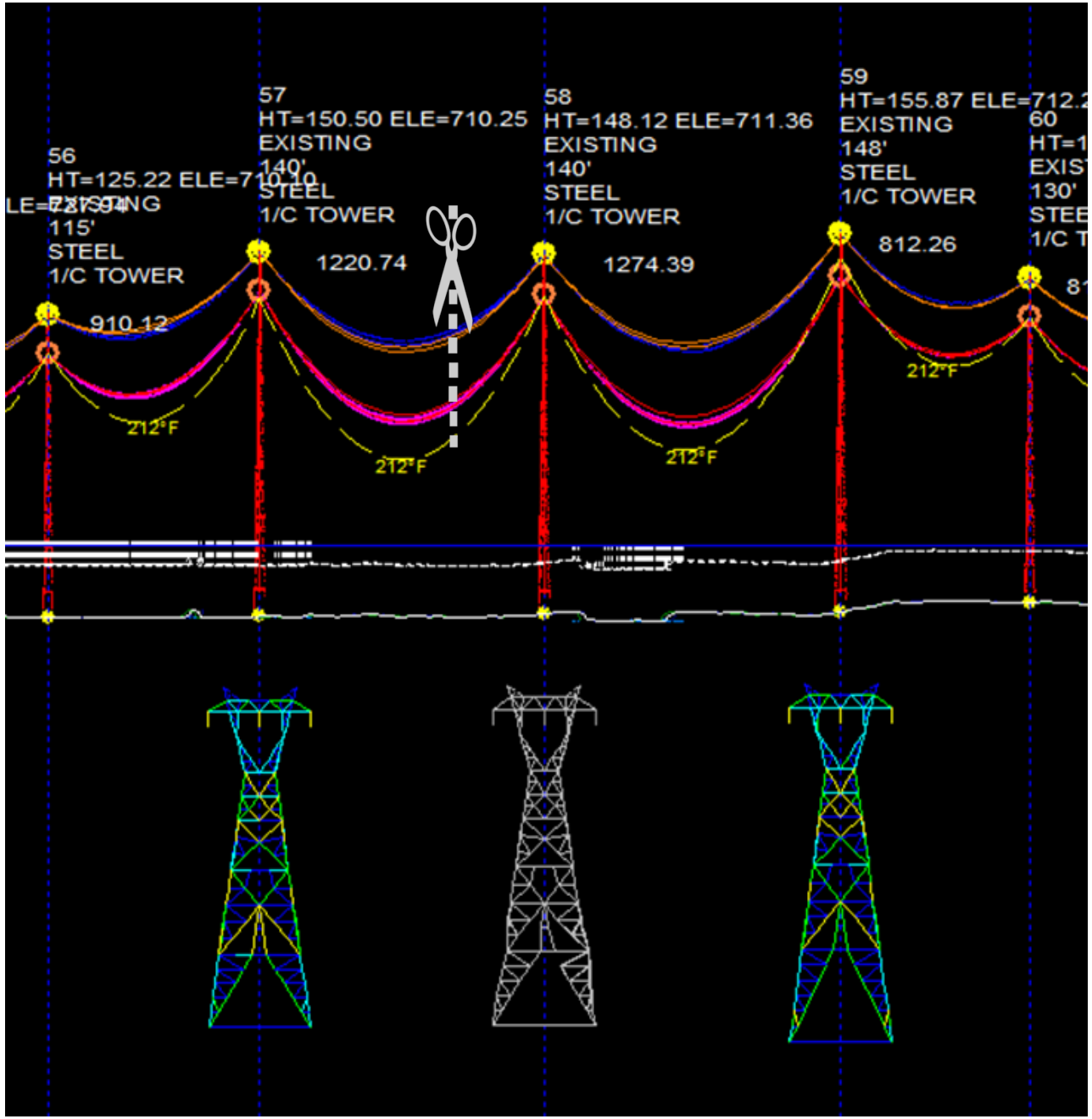
In the event of full collapse, 2 limit state conditions are assessed:

Case 1. Longitudinal Load due to broken wire.

Case 2. Additional span length due to complete loss of structure and wires remain intact.

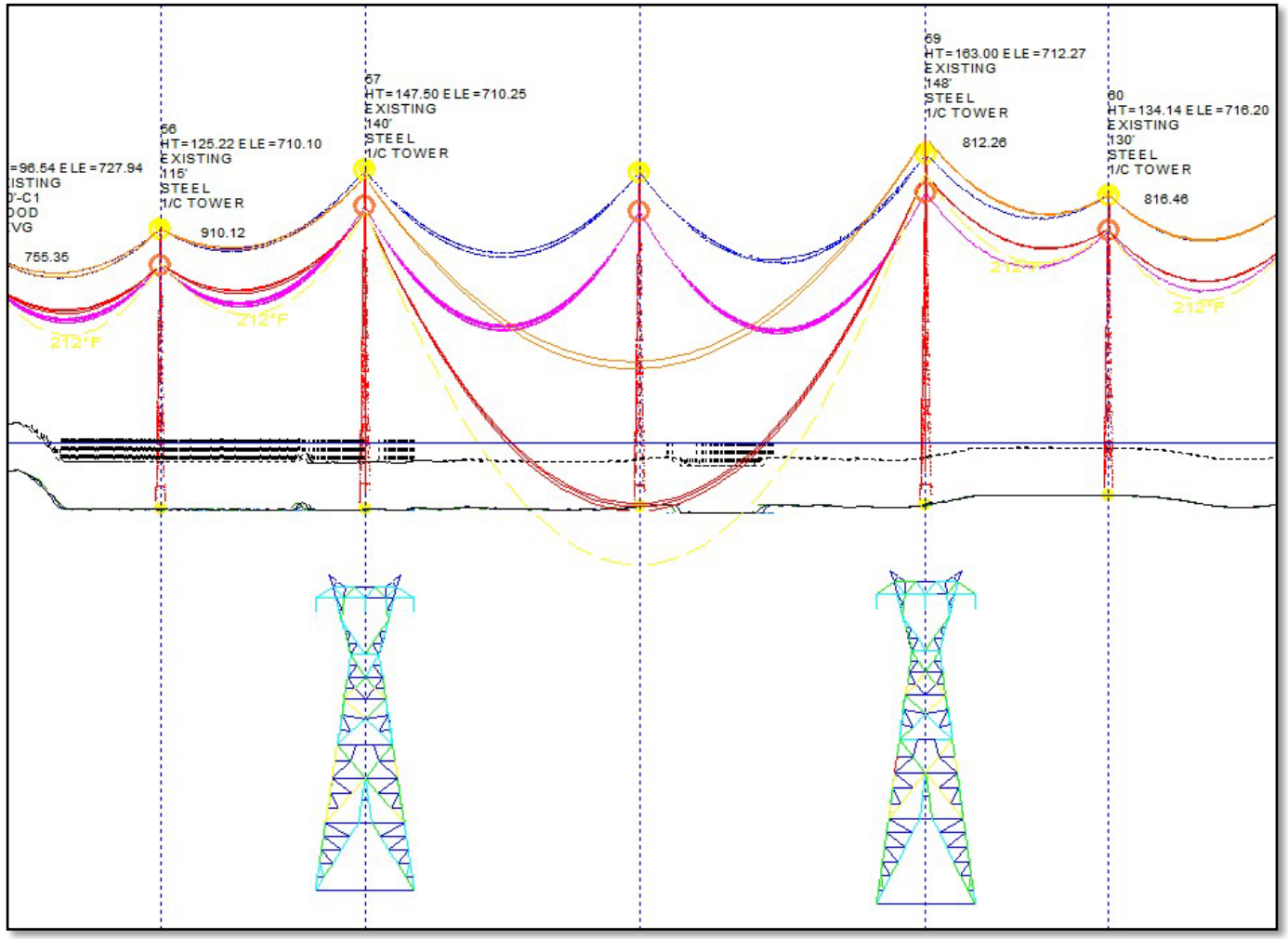
Line/Structure Modeling

- Failure containment per ASCE 74-20, EPRI Method. 70% Tension under everyday conditions.
- Adjacent towers modeled to assess failure containment capacity.



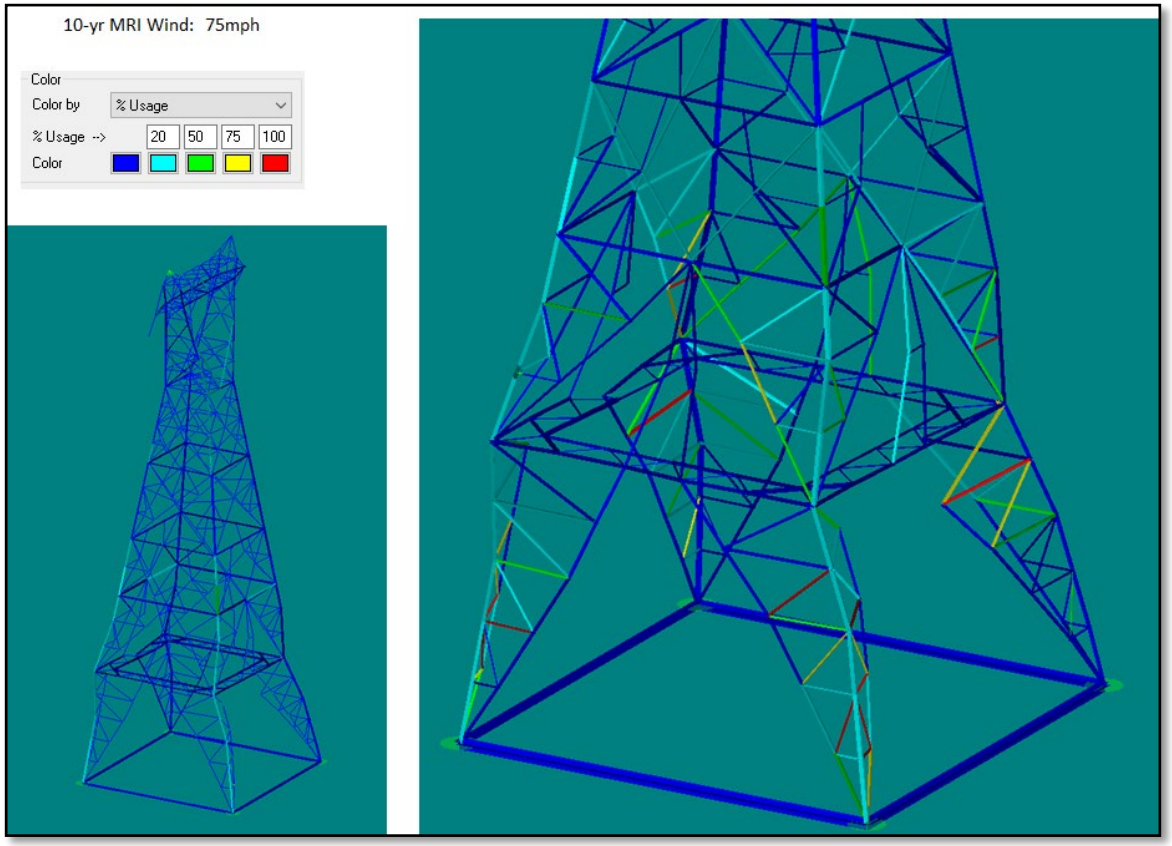
Line/Structure Modeling

- Additional weight and wind span.
- Resulted in knowing that existing adjacent towers have *reasonable* capacity to withstand 3-phase broken wire event
- Provided some assurances that a longitudinal cascade was unlikely



Line/Structure Modeling

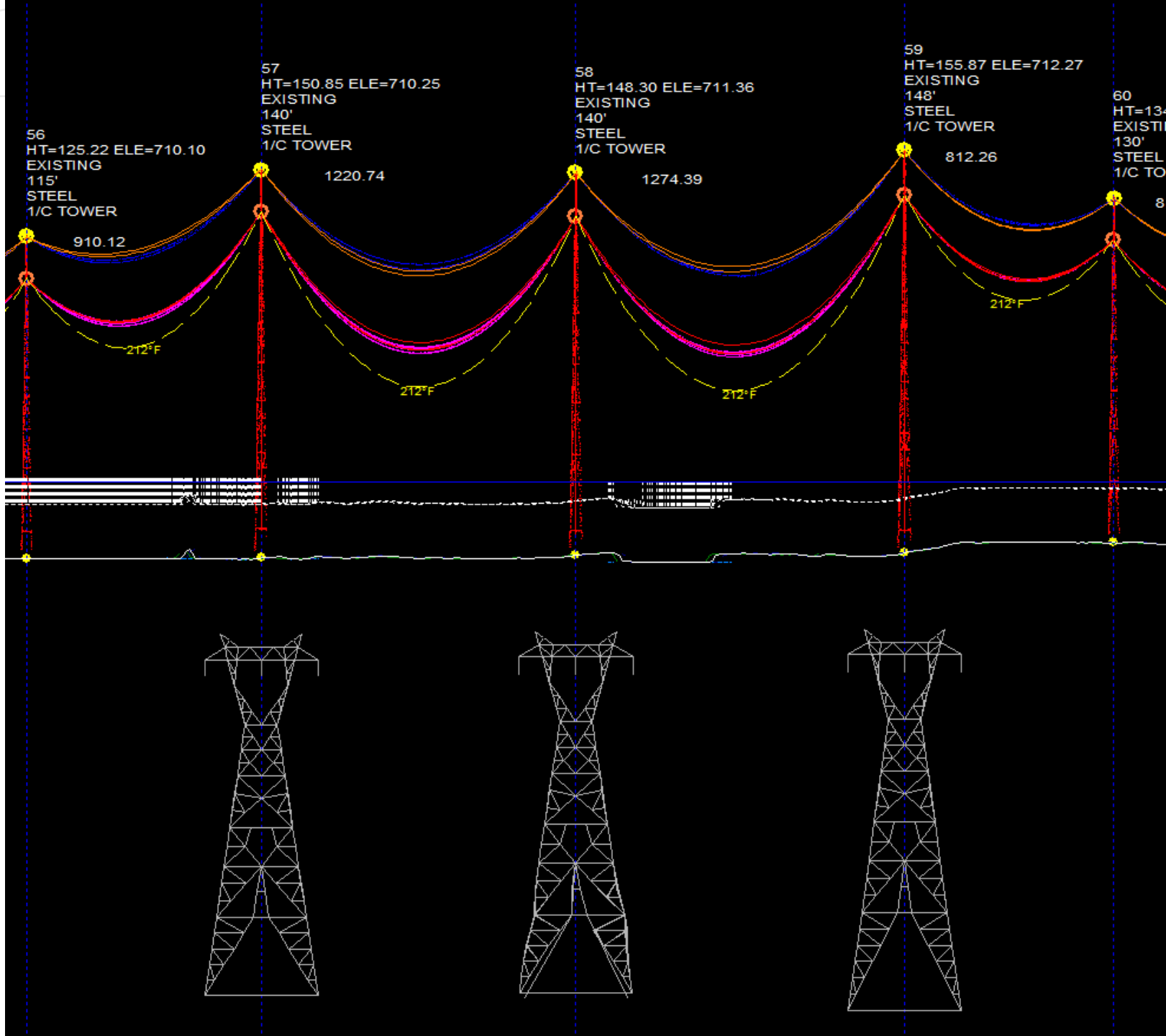
- Modeled true geometry
- Existing main legs have remaining capacity
- Pre-load in main legs due to deflected shape
- Selected a 10-yr MRI wind speed 75-mph (3 sec gust) for stabilization loads



PLS-CADD Profile

The probability for a transverse or longitudinal cascade if the tower fails… LOW

Stabilized tower is shown.

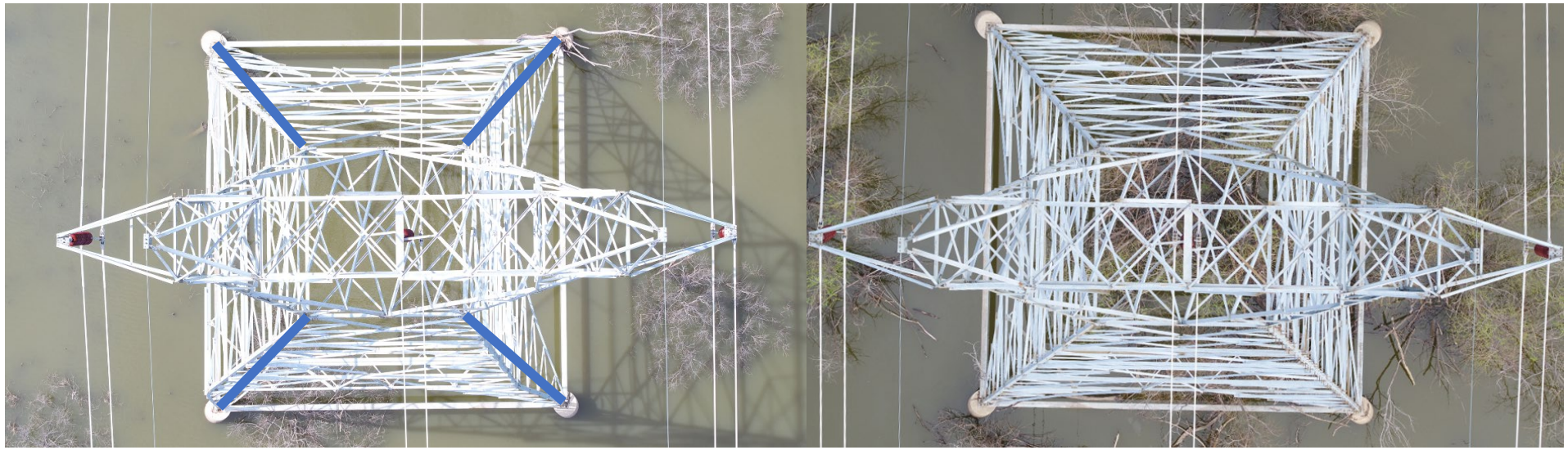


Tower Surface Modeling

- UAV survey
- Photogrammetry to develop 3D surface mesh model using **ContextCapture**.
- Used to determine deflected geometry, stabilization approaches and member distances

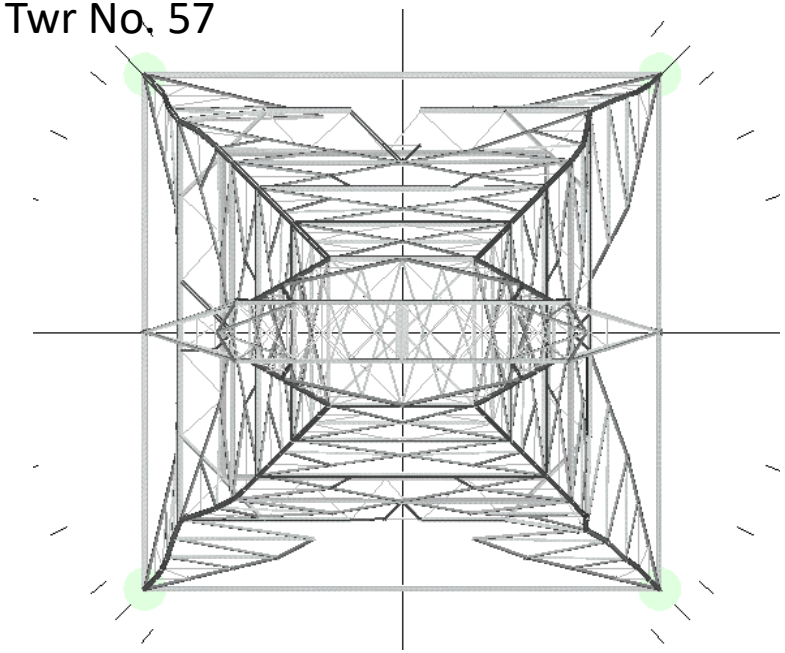
Video: ContextCapture mesh model using free viewer

Tower True Geometry Modeling



Twr No. 58

Twr No. 57



<u>Model updated to true geometry by:</u>

1. Remove symmetry by;
   Assign all members to one Section.

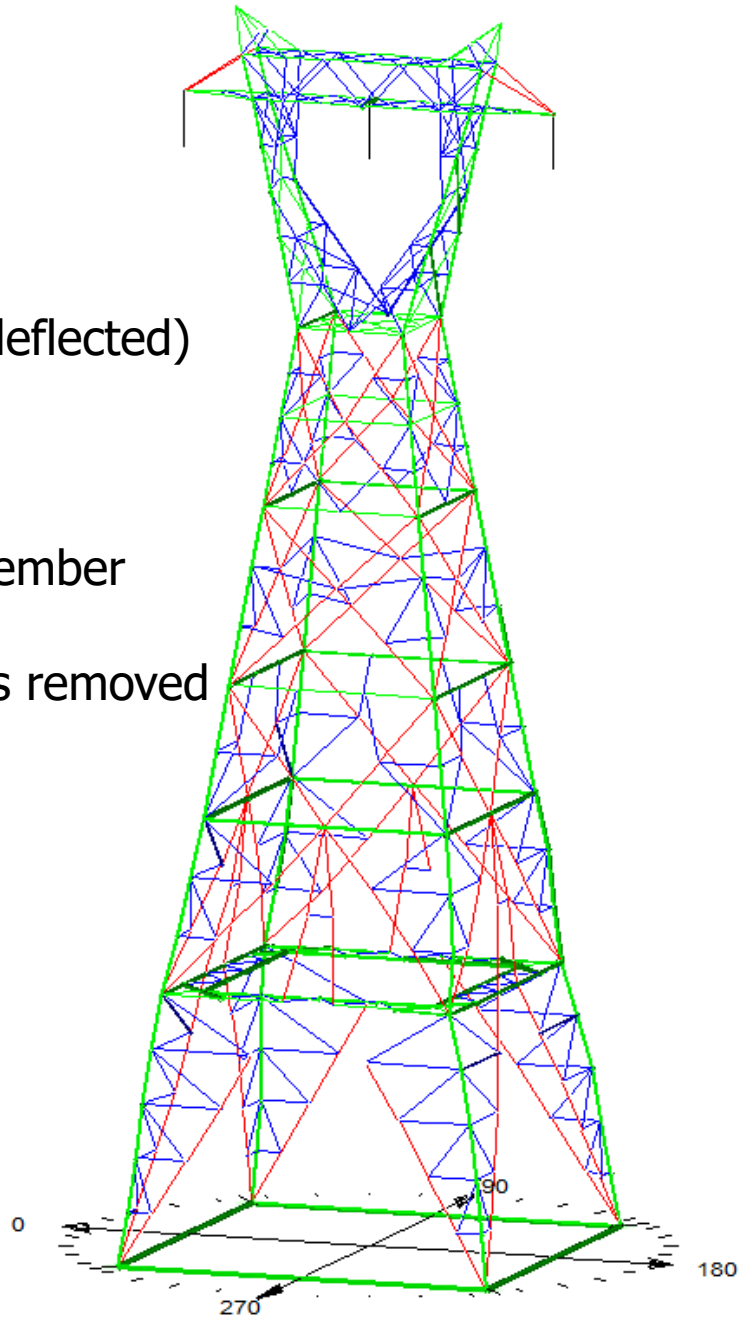
2. Arbitrary Transform Section:
   Section Move via. Transform

3. Adjust joint geometry joint-by-joint.

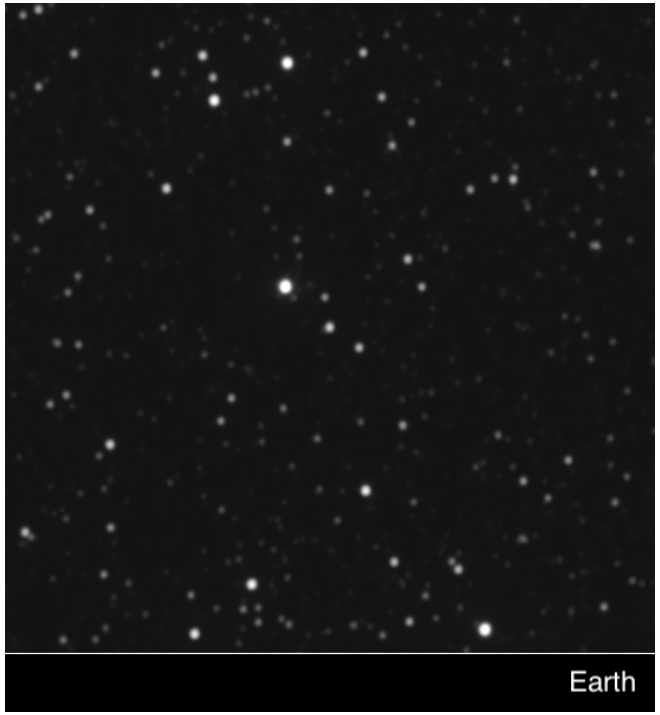
Tower Model (deflected)
In PLS-TOWER

Red indicates
tension-only member

Failed members removed



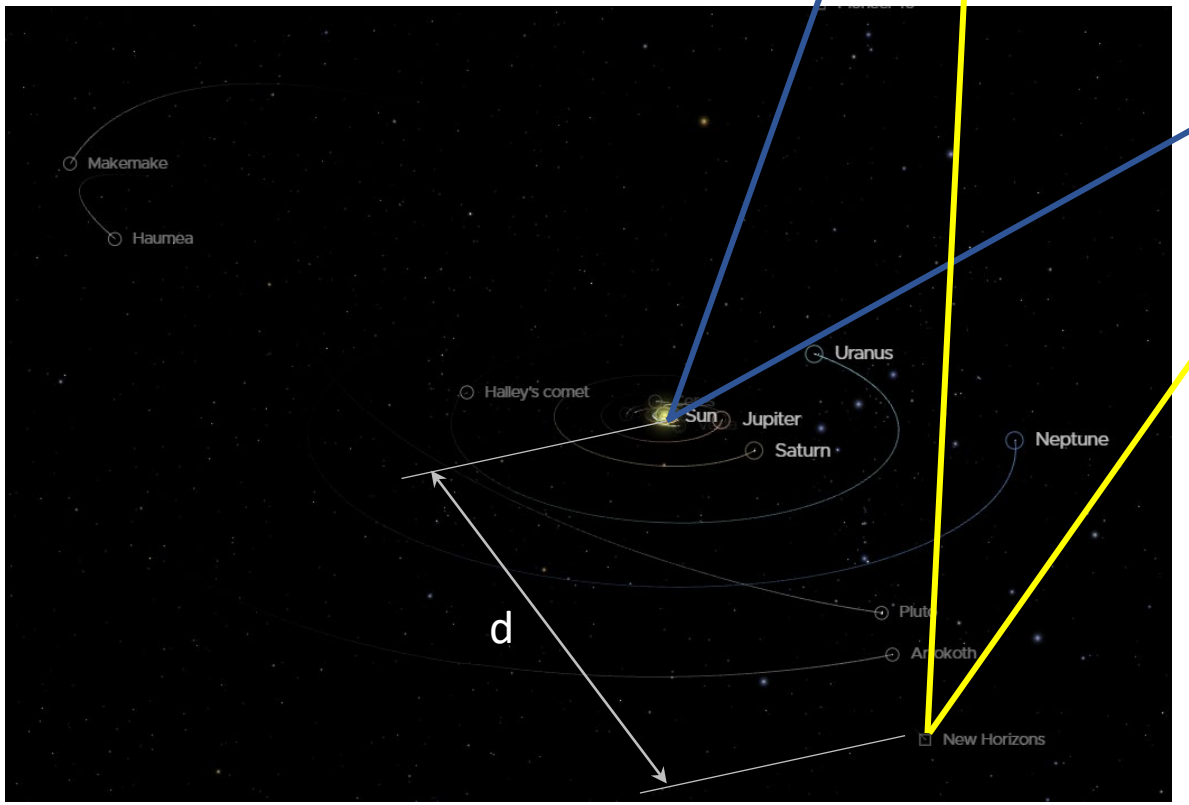
Aside:
Parallax and Photogrammetry

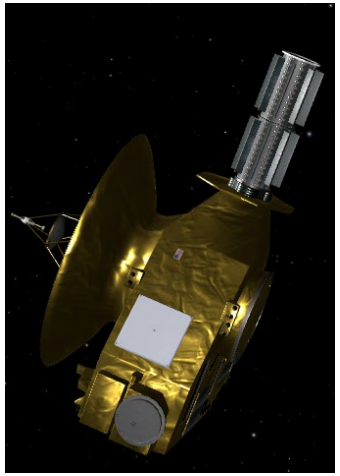


Parallax in Astronomy

First Interstellar Parallax
2020

Proxima Centauri
M-type
4-light years

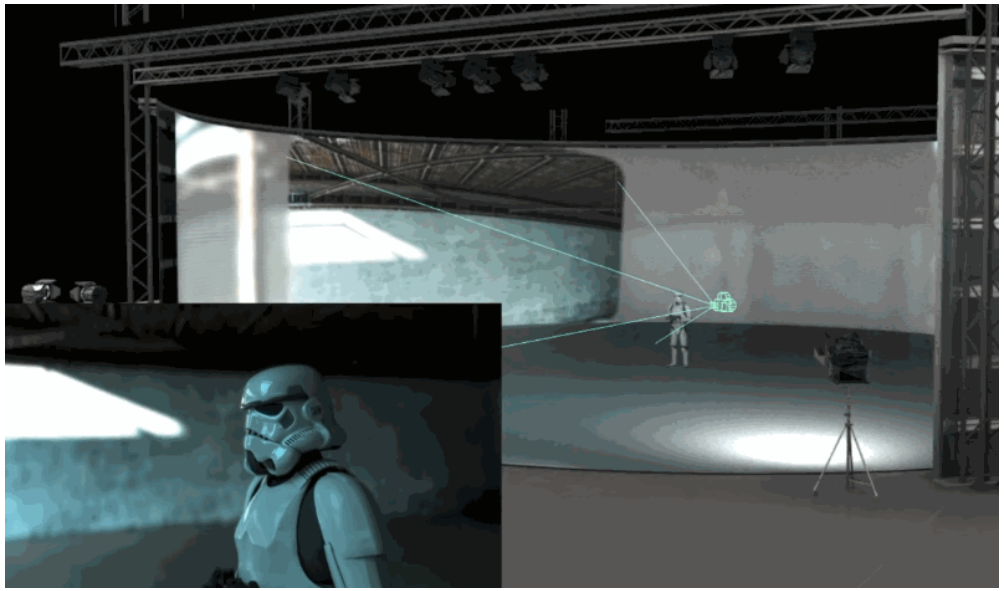




Spacecraft: New Horizons

Parallax in Film

ILM Studio – “Stagecraft”



Real time adjustments in background image using back-fed positional coordinates from gaming technologies and parallax from photogrammetry.

Video: ContextCapture demo using free viewer

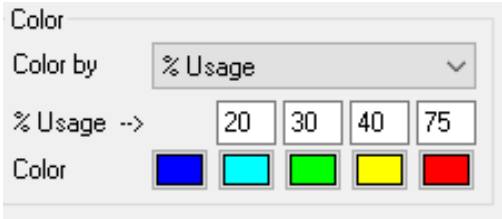
era Display Tools Help

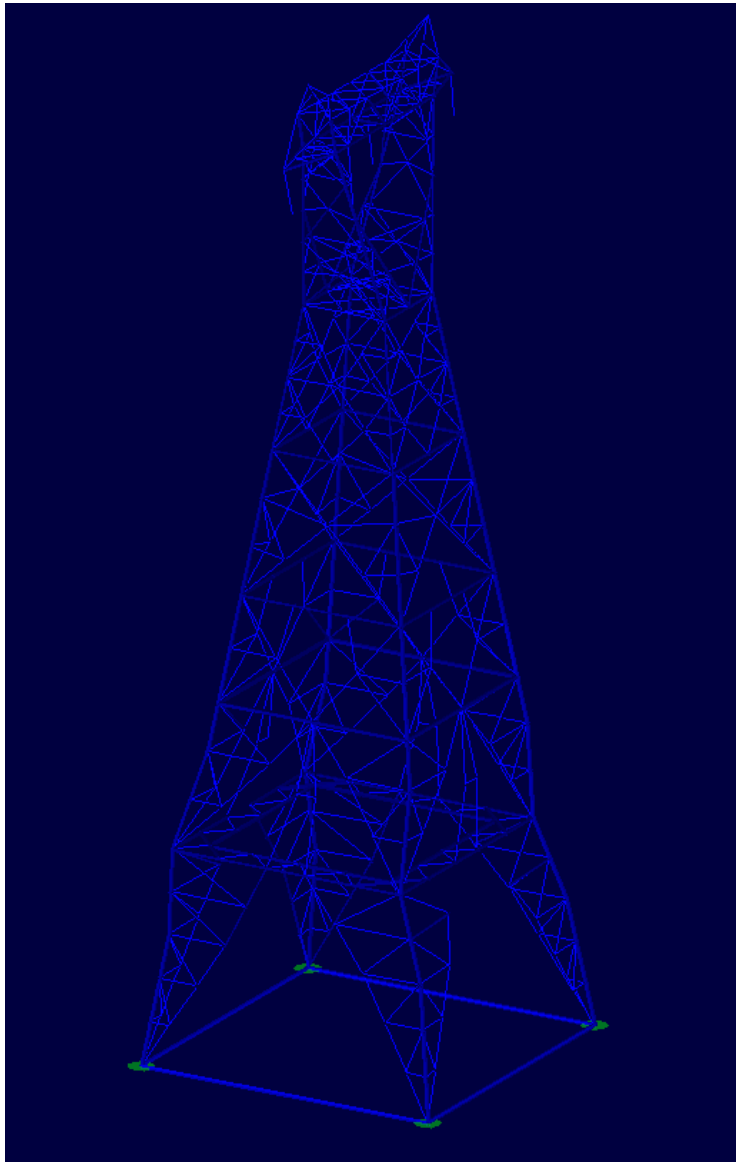
contextcapture™ v

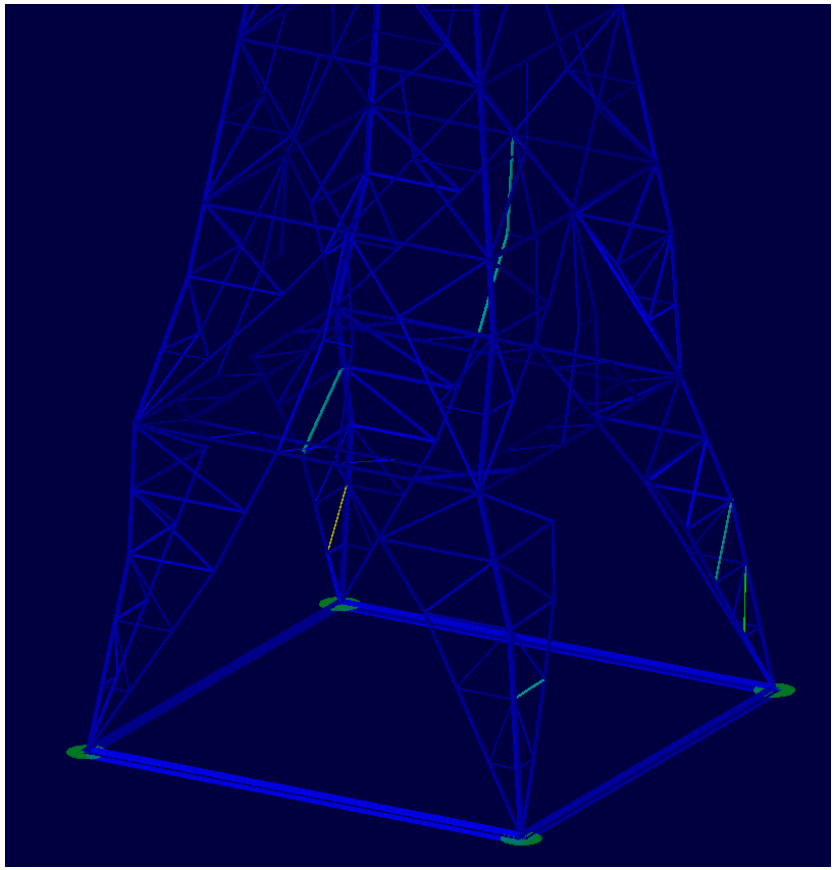
Video: ContextCapture demo using free viewer

de: 129m

Everyday Loading Condition: No wind, 32 deg F







Max. wind speed = 30 mph

Temporary Stabilizing

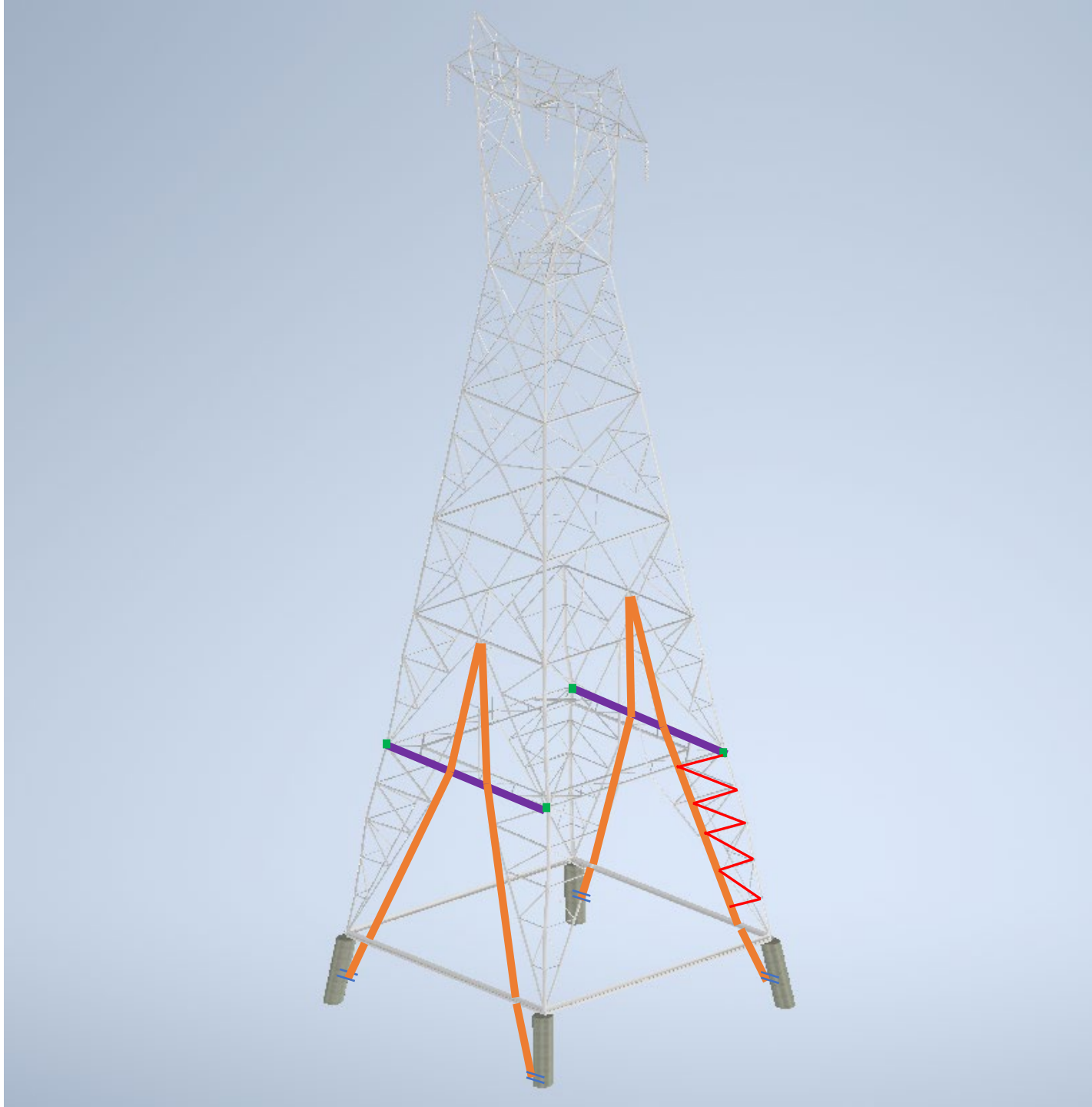
Temporary Stabilizing – Tower 58

Approach:
Reinforce existing failed horizontal and tension-only diagonal members to re-establish load path.

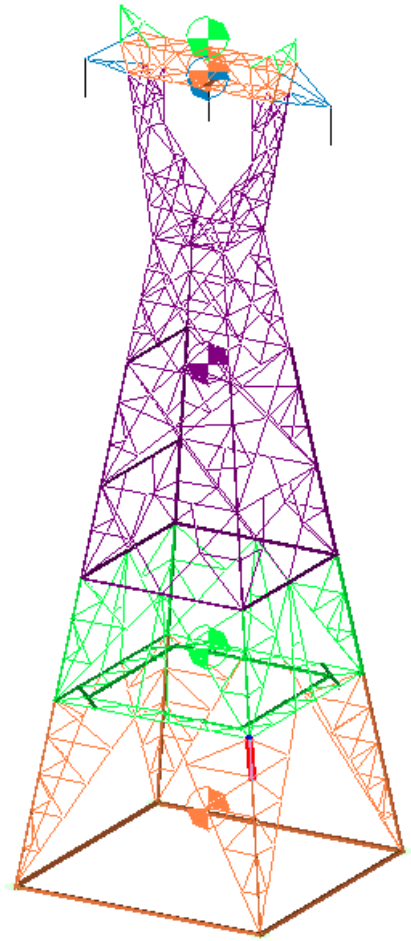
Steps:

1. Install Saddle supports on concrete piers
2. Install Horizontal Beam
3. Install Diagonal tension-only members
4. Install corner reinforcements
5. Install upper tension-only members
6. Install leg bracing on one leg

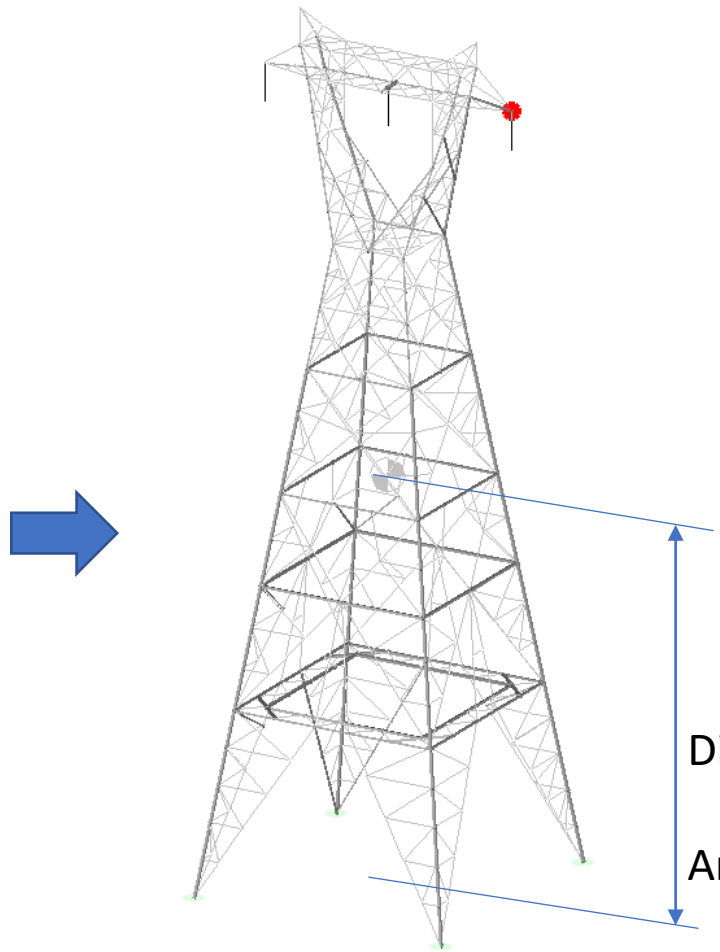
Note: Maximum vertical load on any member or joint is 300 lbs. during erection.



Safety Support Cranes



Multiple Sections

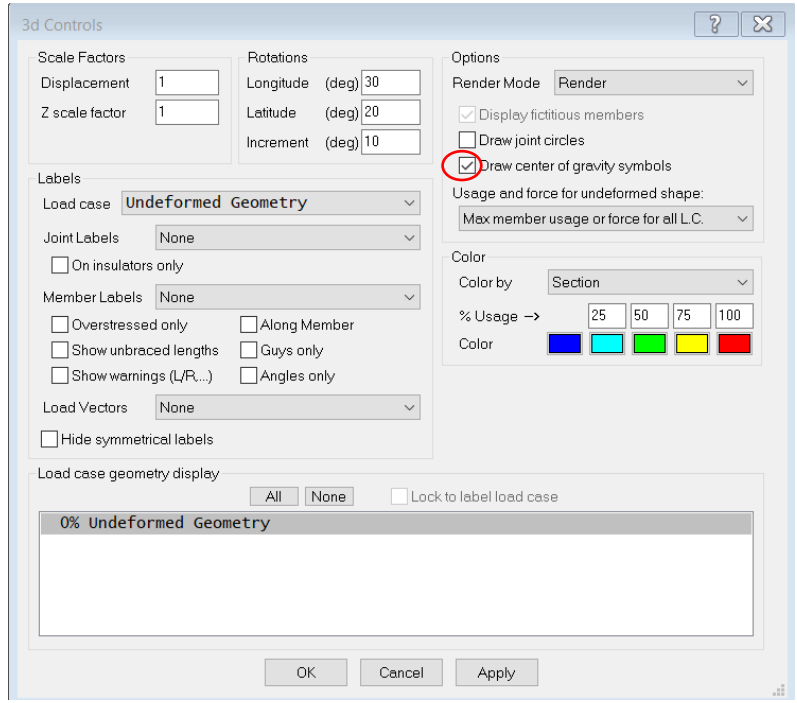


Single Section

Distance to Center of Gravity of overall tower

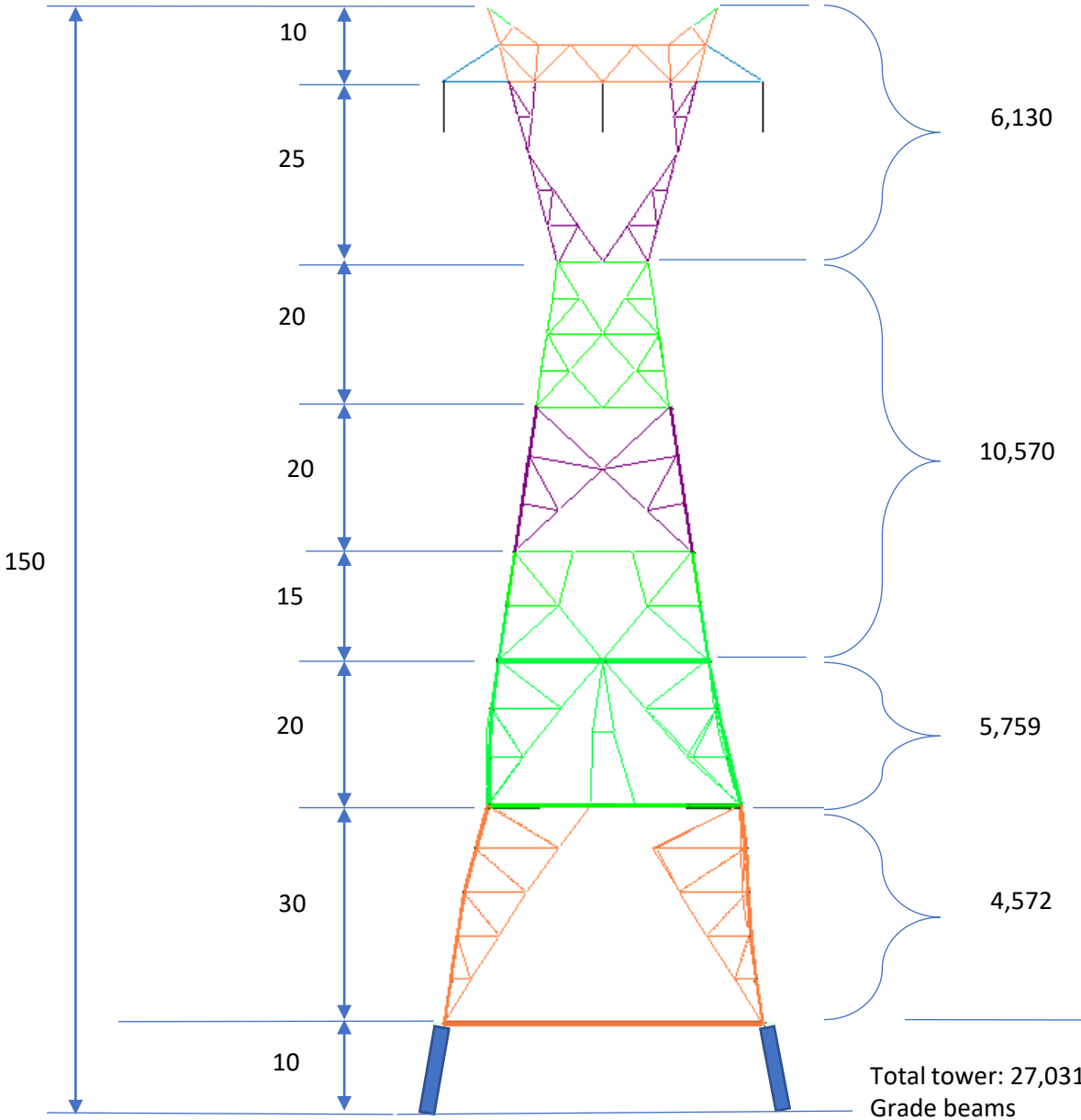
Analysis Report:

"Section Information" to obtain distance

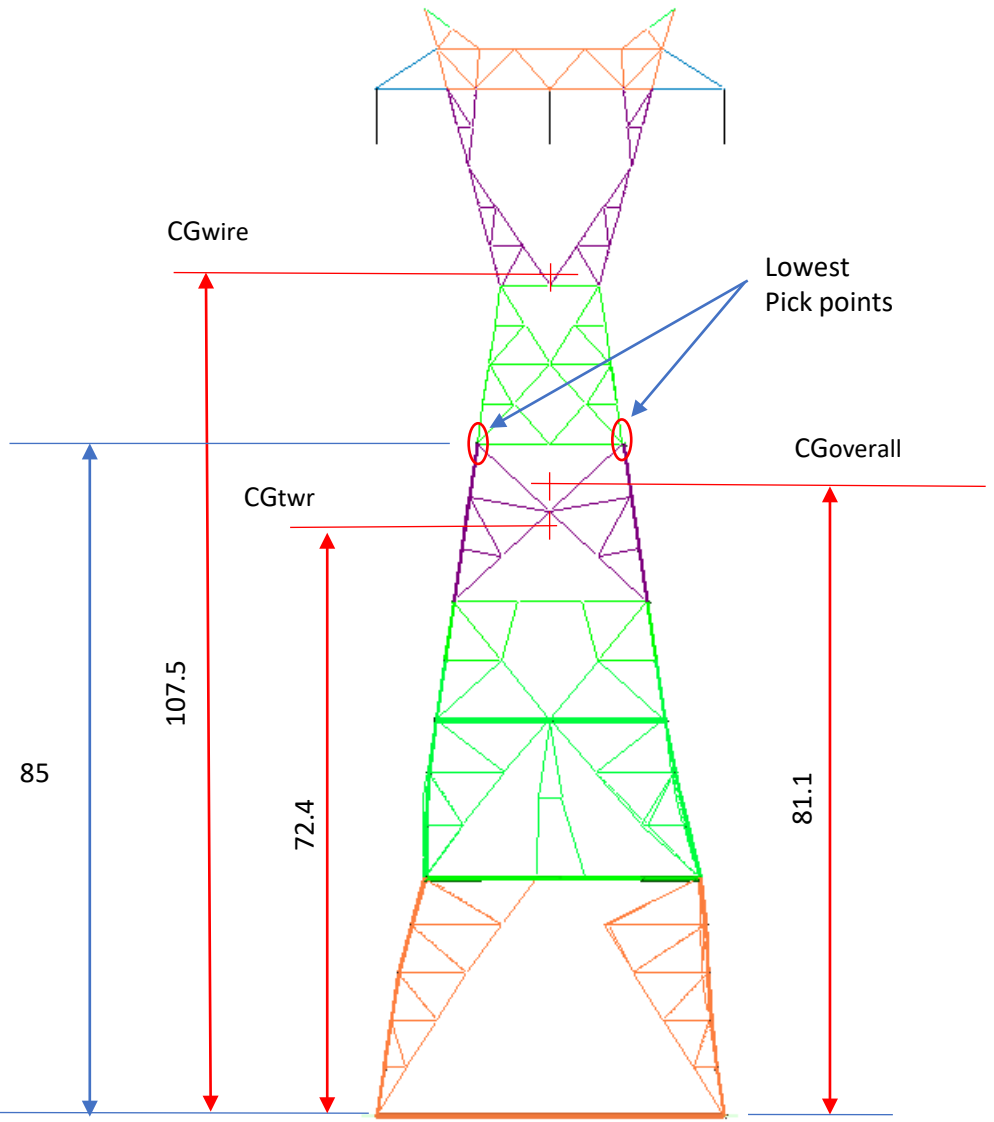


Str. 58 height (ft)

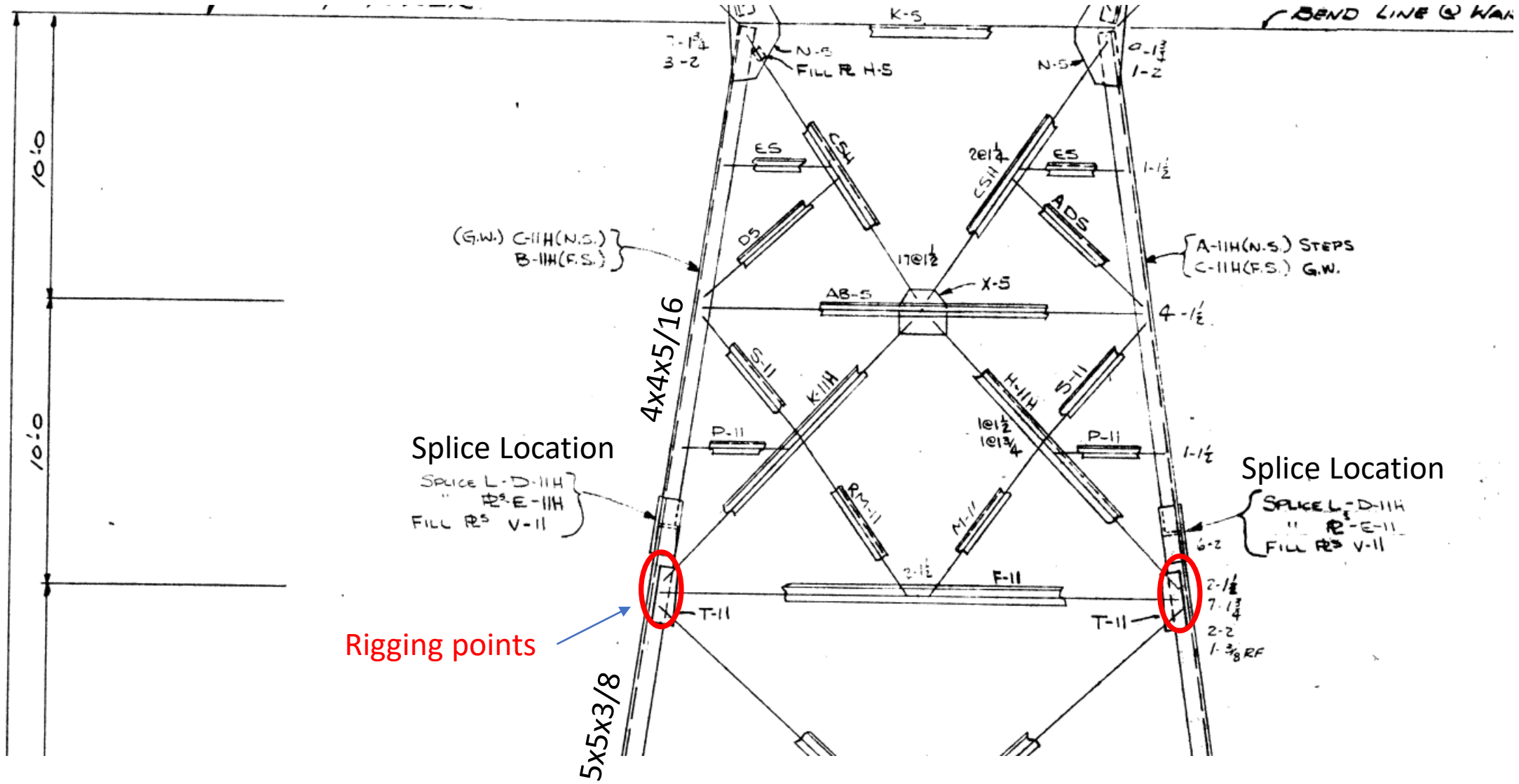
Str. 58 weights (lbs)



Total tower: 27,031 lbs. w/o shoes and Grade beams

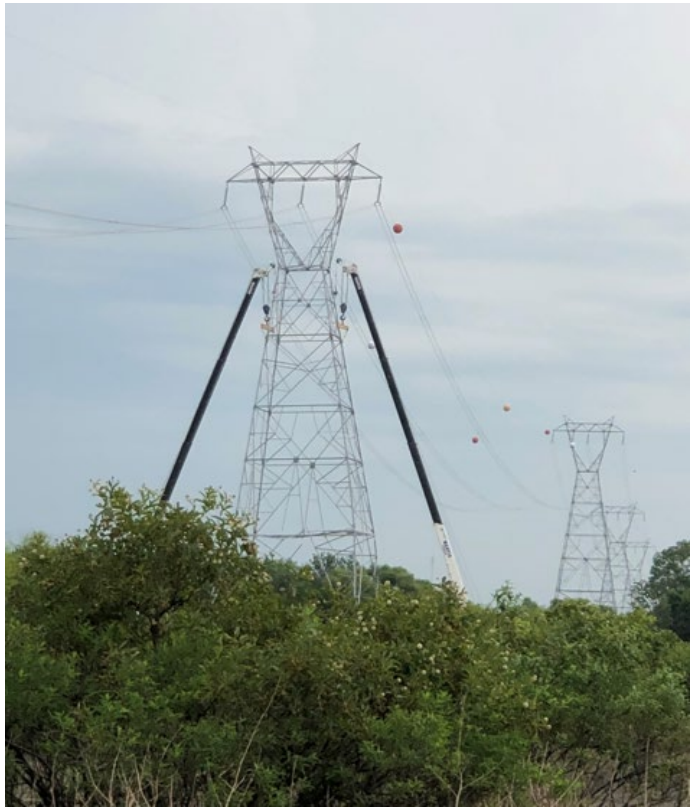


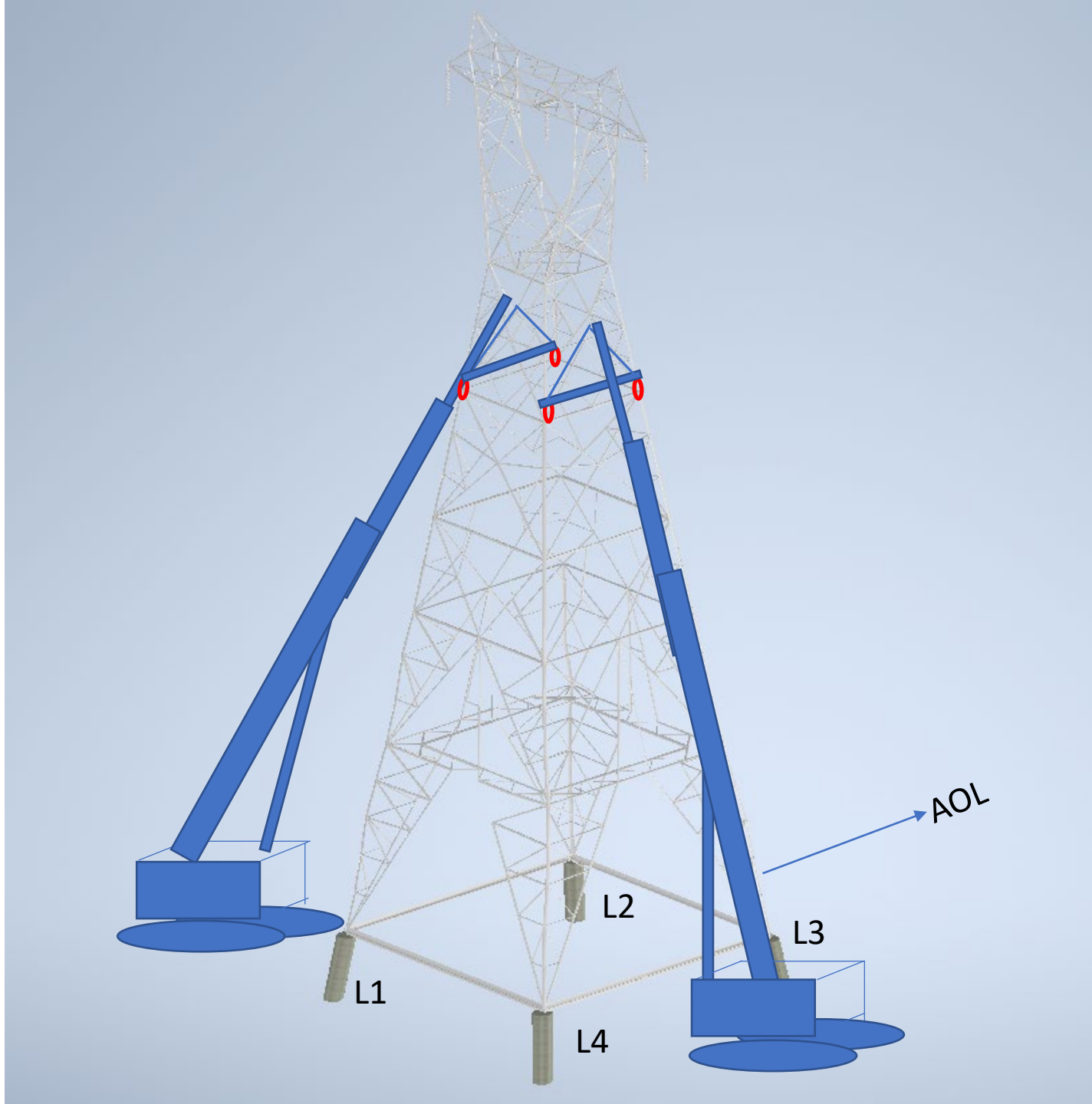
Total tower+wire for safety support : 35,922 lbs


10'-0
10'-0
4x4x5/16
5x5x3/8
K-5
N-5
FILL PL H-5
ES
CSH
DS
ADS
(G.W.) C-11H(N.S.)
B-11H(F.S.)
17@1½
X-5
AB-5
A-11H(N.S.) STEPS
C-11H(F.S.) G.W.
S-11
K-11H
H-11H
P-11
M-11
F-11
T-11
Splice Location
SPLICE L-D-11H
" PL-E-11H
FILL PL V-11
Splice Location
SPLICE L-D-11H
" PL-E-11
FILL PL V-11
Rigging points

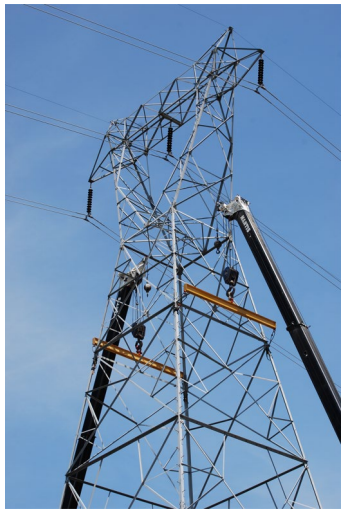
Temporary Stabilizing – Tower 58

Safety support:
Crane connected to 4-corners supported with spreader beam.

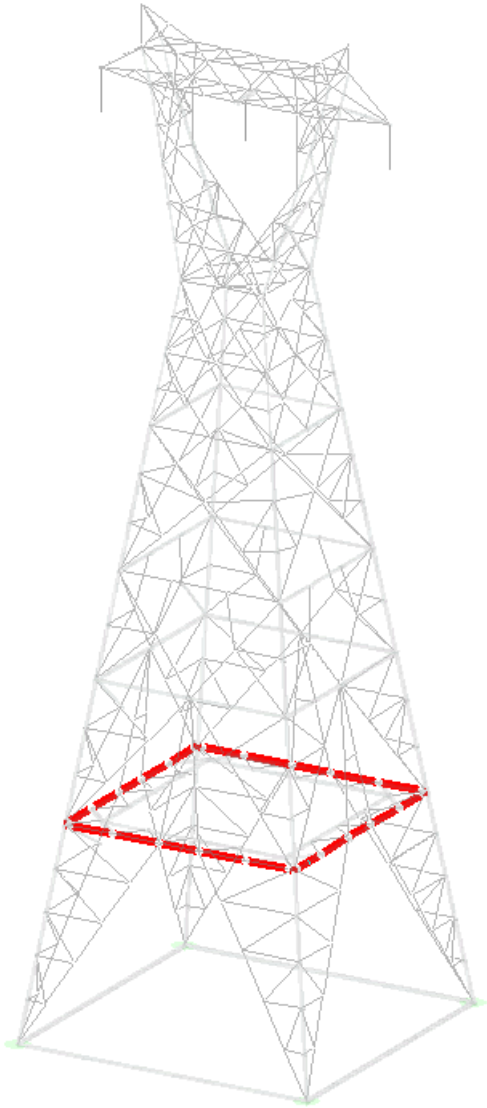




Installation



Installation



Completed

Questions?