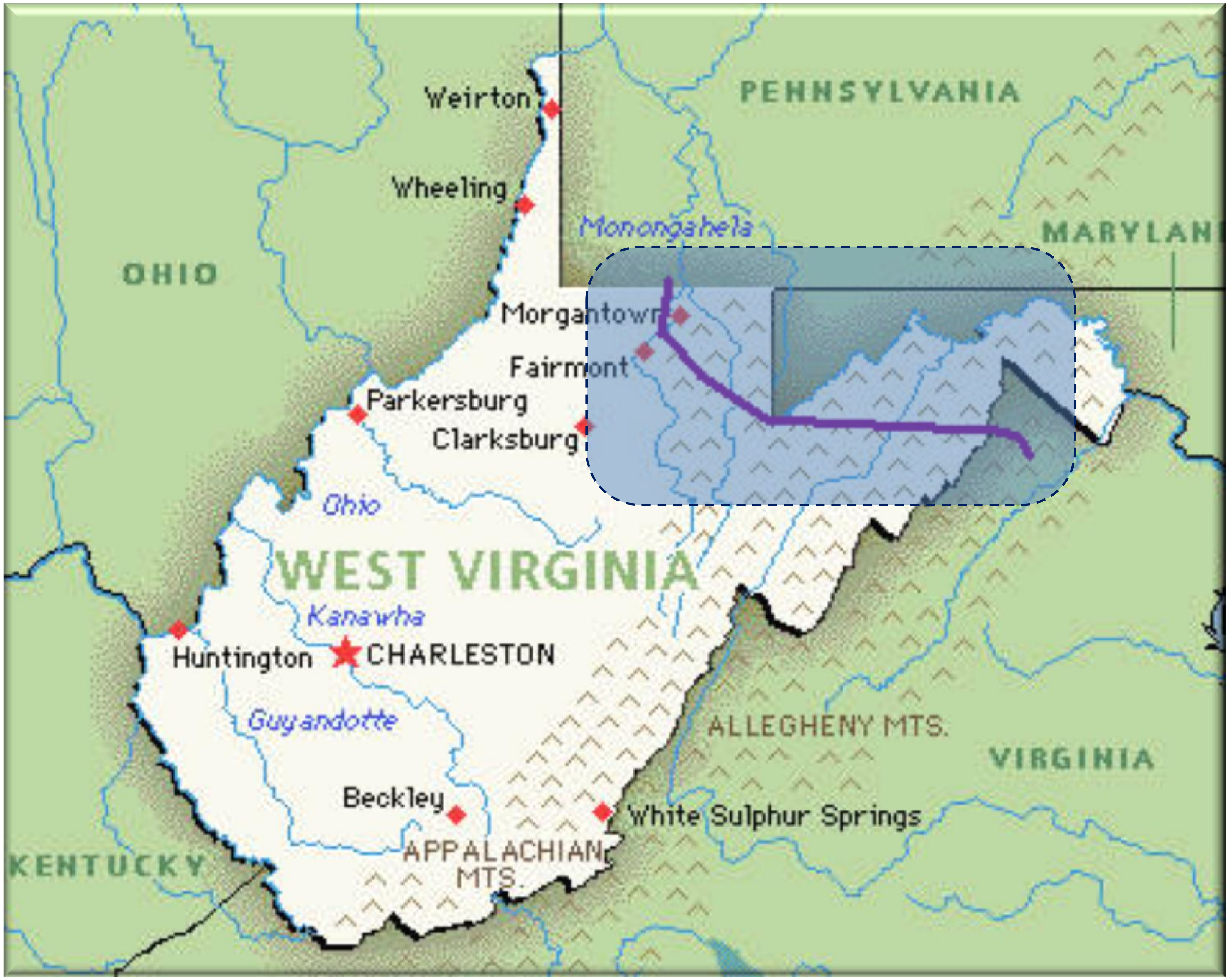
PLS-CADD Advanced Training and User Group Meeting
Leg and Body Extensions / XML

Project Location Map

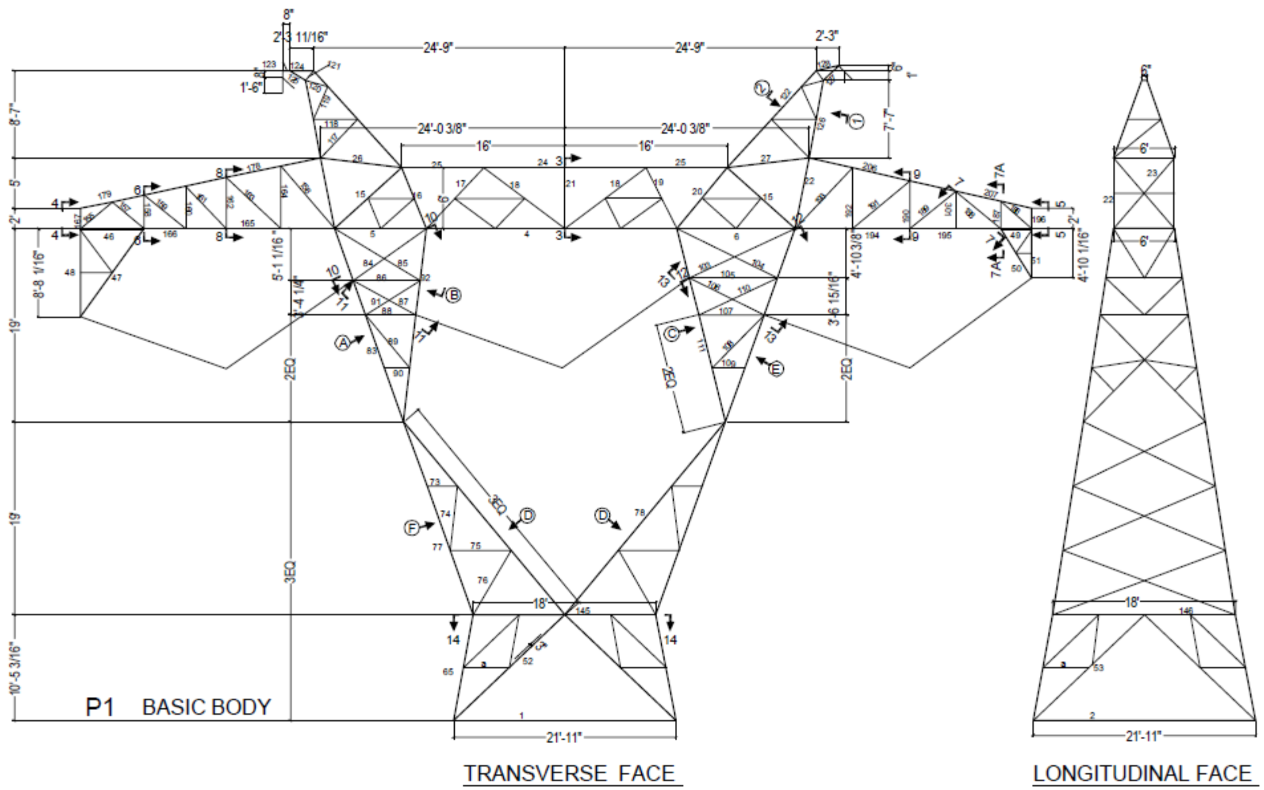


Project Overview

- 671 total structures (536 Lattice and 135 Tubular)
- 151.2 Miles of 500kV Transmission Line (25 miles with 138kV Underbuild)
- 252 Miles of access roads required due to mountainous terrain
- 17,176 tons of lattice steel
- >$900M Total Project Cost (Allegheny Power/TrAILCo Portion)

Engineering Design

- Series 8 tower family was developed for 3-bundle 1113 Finch ACSS conductor
- Family consisted of 7 tower & poles types (Short/Medium/Long Span Tangents, 10˚ Angle, 30˚ Angle, 49˚ Deadend, 90˚ Deadend)



Designed for Helicopter Installation

- Splices set for each section of the tangents

What's the Push on Design & Engineering?

- Aggressive project timeline in conjunction with the risk of foreign sourcing and ocean delivery of lattice steel delivery forced the early material ordering to support construction
- The TrAIL Project Management Team wanted the tower material ordering process to uphold several basic philosophies :
  - Accommodate landowner requests in relation to structure location to reduce condemnations
  - Construction materials would not become critical path items
  - Construction would never have to wait on materials.

Tower Testing

- Tested 3 Towers (one tangent, one angle, one deadend)
- Testing is important, fabrication and detail mistakes will become apparent under failure loading conditions

Deadend Structure passed all loading without a failure

Incorrectly detailed bolt pattern failed during testing of 10 degree angle structure

Structure Pads

- Drilled Pier Foundations – “If you can get concrete trucks there you can get a tower crane there.”

Stub Angles

- Stubs needed to be onsite for the foundation sub-contractor

Steel Erection

- Steel must be available to crews June 2009 to January 2011
- At peak there were 7 x 14 man crews

Lattice Steel Procurement

- Procurement began in 2007
- Invited North American & International companies to bid due to timeline and tonnage required
- Existing Allegheny Structure Family drawings used for RFP

Material Ordering

- 29 Material Releases - each release was based on tonnage and tower types

Tubular Steel Procurement

- Procurement began in 2008
- Invited six North American companies to bid

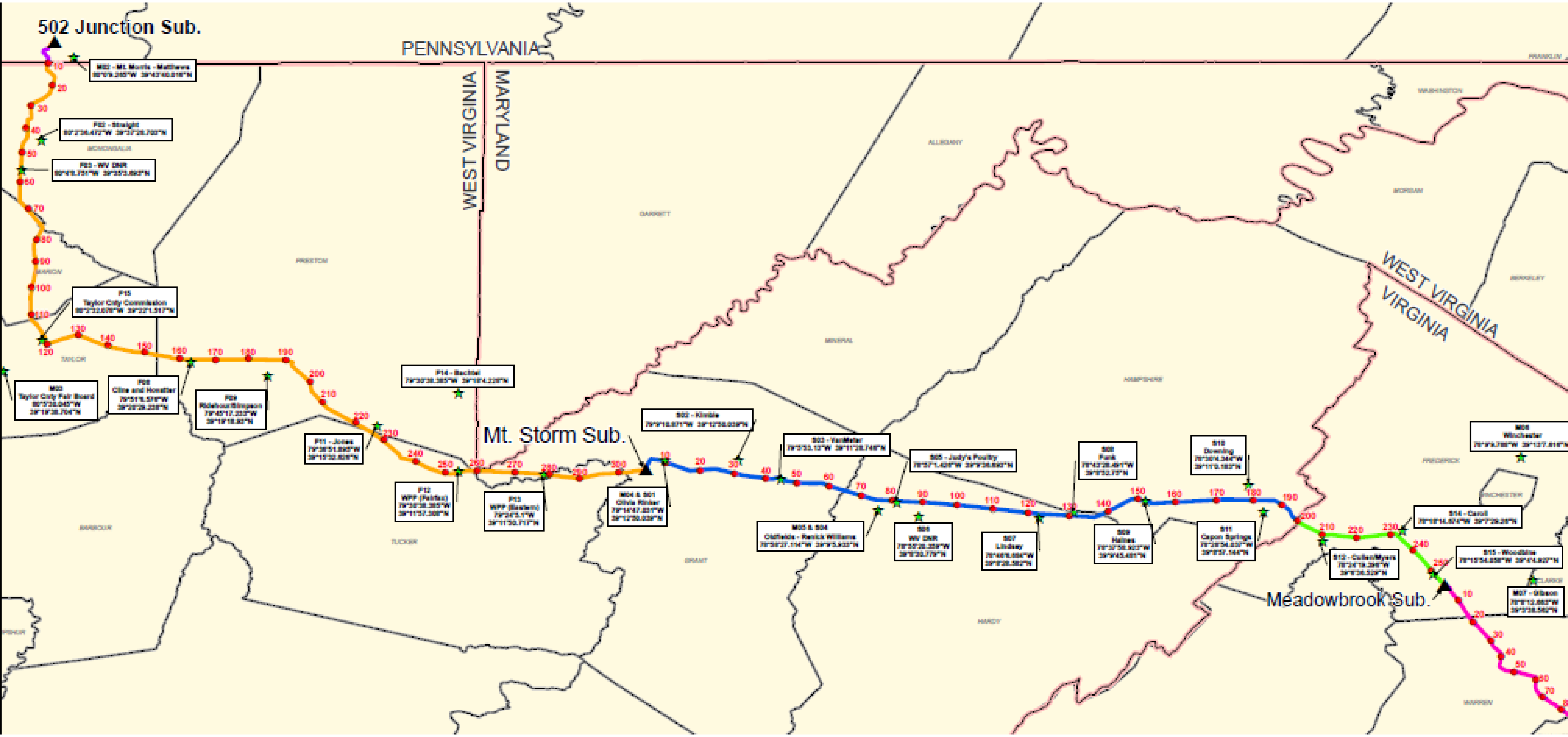
Material Ordering

- 11 Material Releases – based upon confirmed structure locations

Material Delivery

- Liaison at delivery port set up trucking to three major material yards
- From material yards, delivered to staging yards every 5 miles along the Transmission Line route
- Barcoding System used for all bundles

Material Yard Locations



Use of Differential Legs

- Reduction in Earthwork on Tower Construction Pads
- Permitting and Permit Closeout
  - Requires less reclamation work
  - Return site to near as original contours as practical
- Compressed and Aggressive Schedule

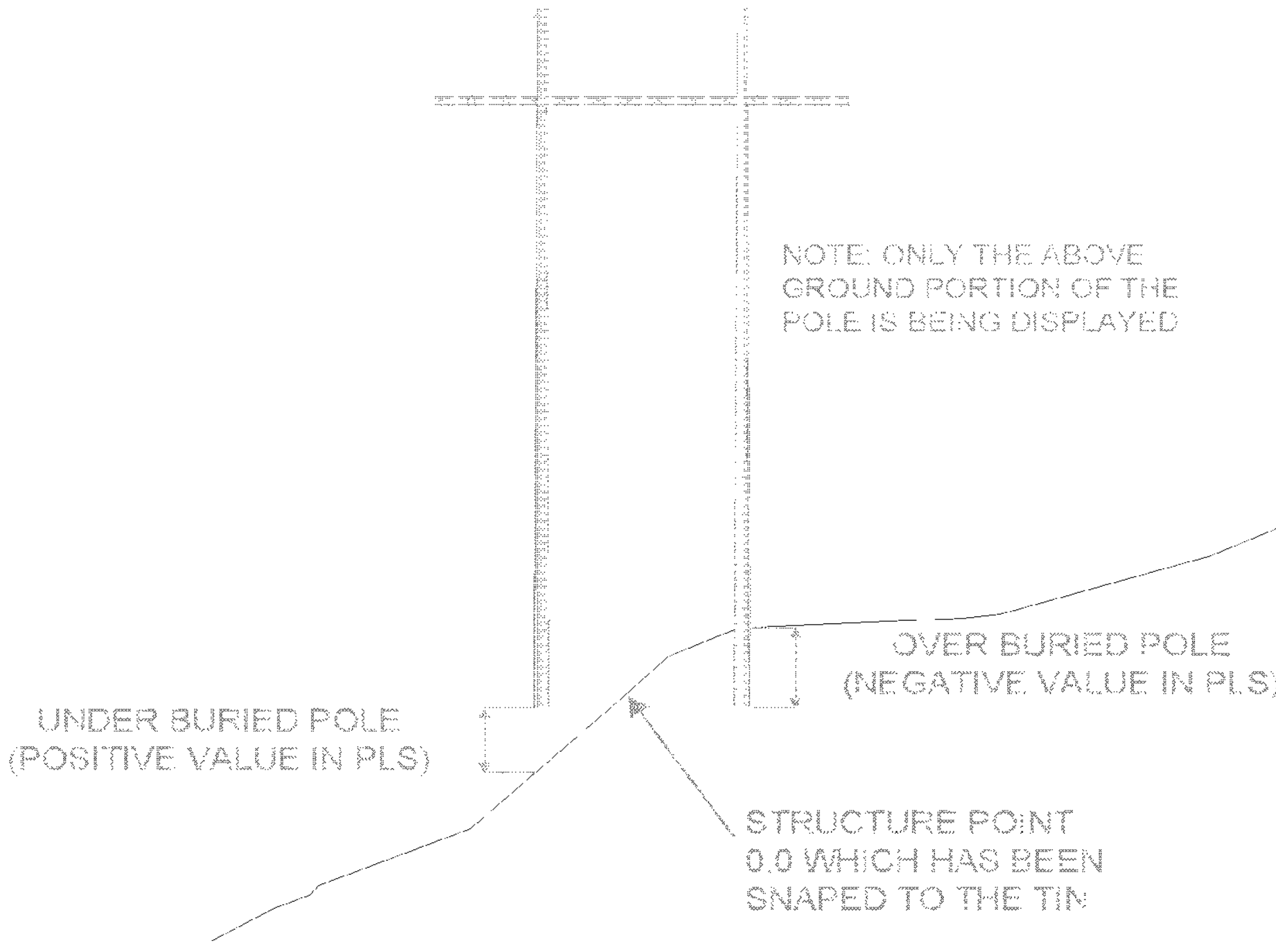
Engineering Dilemma

- Lattice tower orders were required prior to the completion of the design
- With over 500 lattice towers on the project, a time consuming, iterative process would have to be performed numerous times
- <u>Solution</u>: develop an Excel spreadsheet that manipulates PLS-CADD data via XML exports to assist in developing the required material order

History Leading to XML Tower Leg Extension Spreadsheet

- Prior to the TrAIL project, an XML Excel spreadsheet was developed to determine the pole lengths of multiple pole structures in steep terrain
- Values were analyzed from PLS-CADD's *Leg-Guy Extension* report

History Leading to XML Tower Leg Extension Spreadsheet

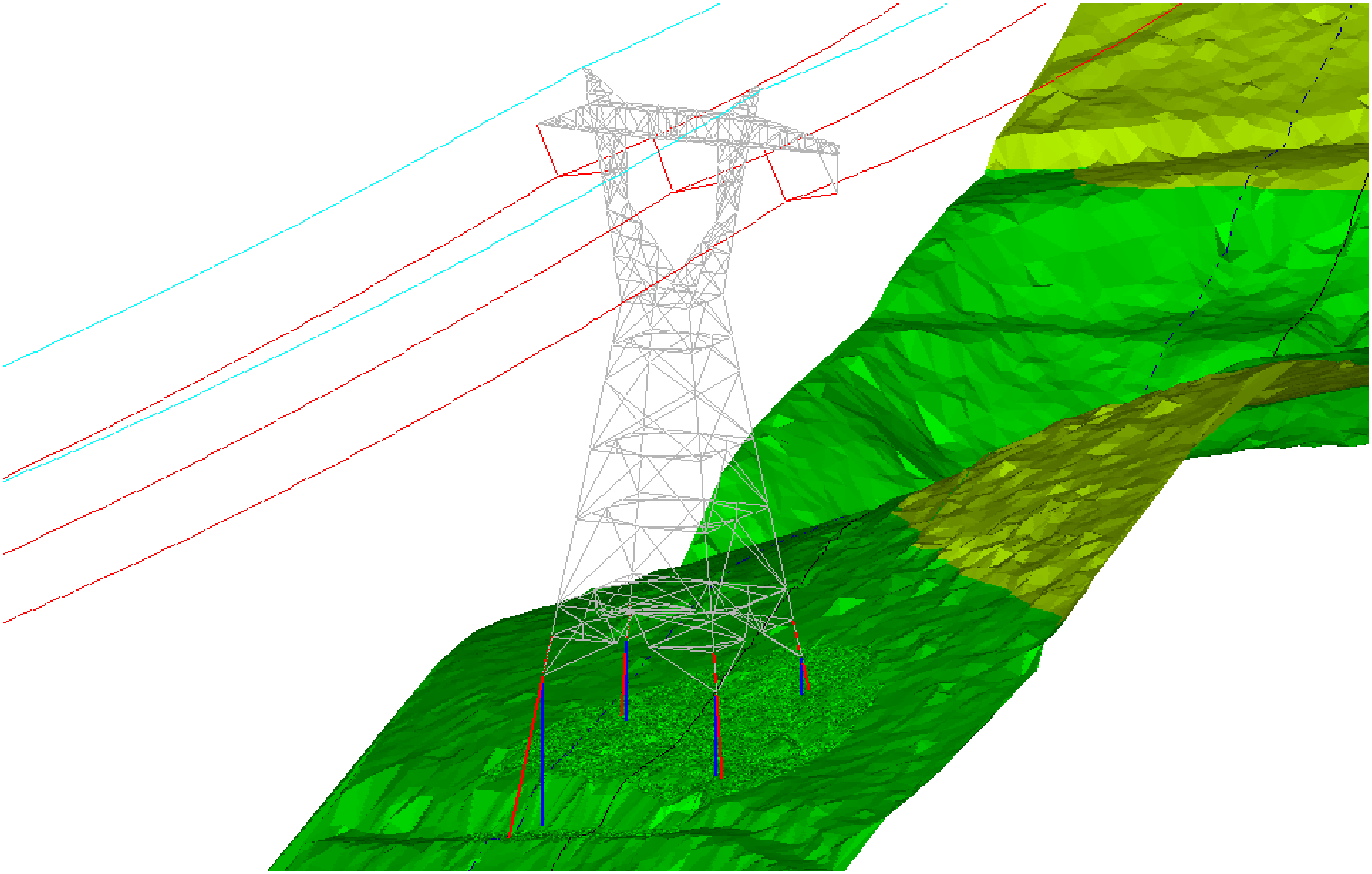


Note: PLS-CADD now has a command that will automatically snap the legs to the TIN, but will not determine if the magnitude of an overburied leg warrants shortening.

Developing the XML Tower Leg Extension Spreadsheet

- Challenges Faced:
  - Working with a 3-D structure configuration
  - Battered legs
  - Leg designations
  - Set up spreadsheet to only add leg length
    - Spot PLS-TOWERS with shortest leg lengths
    - Height adjust towers to obtain desired attachment heights
  - Defined allowable body & leg combinations

Developing the XML Tower Leg Extension Spreadsheet



Developing the XML Tower Leg Extension Spreadsheet

- Assumptions & Criteria:
  - Minimum pier reveal: 1.0’
  - Maximum pier reveal: 5.0’
  - Tower families were previously defined
  - Tower legs were in 5.0’ increments
- Definition:
  - T.O.C. = Top Of Concrete pier

Developing the XML Tower Leg Extension Spreadsheet

- Theory:
  - Determine if it is beneficial to increase the length of 1 (or more) legs by increasing the T.O.C. of the remaining piers
  - Set the maximum amount for raising the T.O.C. of the 3 piers in order to lengthen 1 of the legs (1.0’ was used on the TrAIL project)

Hand Calculation Example

Original Design before Top Of Concrete (T.O.C) Adjustments

1st Iteration, Adjust T.O.C. by 0.8' = (5' leg + 1' min reveal) – 5.2'

2nd Iteration, Adjust T.O.C. by 0.5' = (5' leg + 1' min reveal) – 5.5'

3rd Iteration, Adjust T.O.C. by 1.2' = (5' leg + 1' min reveal) – 4.8'

AL

Reveal Length

5.2'
1.0' w/ 5' Leg Extension
1.5' w/ 5' Leg Extension
2.7' w/5' Leg Extension

AR

Reveal Length

4.7'
5.5'
1.0' w/ 5' Leg Extension
2.2 ' w/ 5' Leg Extension

BL

Reveal Length

1.0'
1.8'
2.3'
3.5'

BR

Reveal Length

3.5'
4.3'
4.8'
1.0' w/ 5' Leg Extension

Total Amount of Concrete Reveal for ALL 4 Piers

14.4'
12.6' with 1 Leg Lengthened
9.6' with 2 Legs Lengthened
9.4' with 3 Legs Lengthened

TOTAL PIER LENGTH SAVING = 0.2'

NOT BENEFICIAL

Cost Saving Breakdown

- Leg Extension Cost
  - 5’ Leg Extension Weight ≈ 300 lbs @ $0.97
  - **$291** per 5’ Leg Extension
- Concrete Installed Costs
  - Approximately $1,200 per Yard
  - Average Pier Diameter ≈ 3.5’
  - **$420** per Linear Foot (@ 3.5’ Diameter Pier)
- Labor for Earth Work
  - **$520** per 4 man crew hour

Cost Saving Breakdown

DESIGN ITERATION	# 5' LEG EXTENSIONS	TOTAL PIER REVEAL (ALL 4 PIERS)	EXTENDED COST
Original Design	0	14.4'	-
Approx Cost	$0	$6,048	$6,048
1st Iteration	1	12.6'	-
Approx Cost	$291	$5,292	$5,583
2nd Iteration	2	9.6'	-
Approx Cost	$582	$4,032	$4,614
3rd Iteration	3	9.4'	-
Approx Cost	$873	$3,948	$4,821

- Approximate Cost Savings for 2nd Iteration = $1,434
- If $1,500 is Assumed as the Average Cost Savings per Tower, Extended Savings for 536 Towers ≈ $800,000

Cost Saving Breakdown

DESIGN ITERATION	EXTENDED COST (Leg Extension + Pier Costs)	EQUIVALENT CREW HOURS FOR COMPLETING EARTH WORK
Original Design	$6,048	12 Hours
1st Iteration	$5,583	11 Hours
2nd Iteration	$4,614	9 Hours
3rd Iteration	$4,821	9.5 Hours

- The Additional Costs for Permitting and Reclamation is NOT Accounted for in the Above Values

XML Exporting / Importing Overview

- What is XML?
  - *eXtensible Markup Language*
  - A file in this format allows for the easy sharing and managing of data between computer softwares (i.e. PLS-CADD and Excel or other software)
  - A civil engineer’s interpretation: it is a way of copying data from one program to another in an organized way

What does a XML file look like?

<staking_table rownum="**1">**

<structure_number>**1</structure_number>**

<station units="**ft">205.102</station>**

<orientation_angle units="**deg" />**

<x_easting units="**ft">2496105.399</x_easting>**

<y_northing units="**ft">2087913.337</y_northing>**

<tin_z_elevation units="**ft">736.566</tin_z_elevation>**

<ahead_span units="**ft">378.952</ahead_span>**

<line_angle units="**deg">42.8919</line_angle>**

<structure_description>**138kV, 3-PoleDead-End </structure_description>**

<struct_height units="**ft">77.000</struct_height>**

<embedded_length units="**ft">13.000</embedded_length>**

Attribute Assigned to the Data

Starting Tag

Data Assigned to the Tags

Ending Tag

Demonstrations

- Demonstrate an XML export in PLS-CADD
- Overview of importing and manipulating an XML file in Excel
- Run the Lattice Tower Leg Extension XML Excel spreadsheet

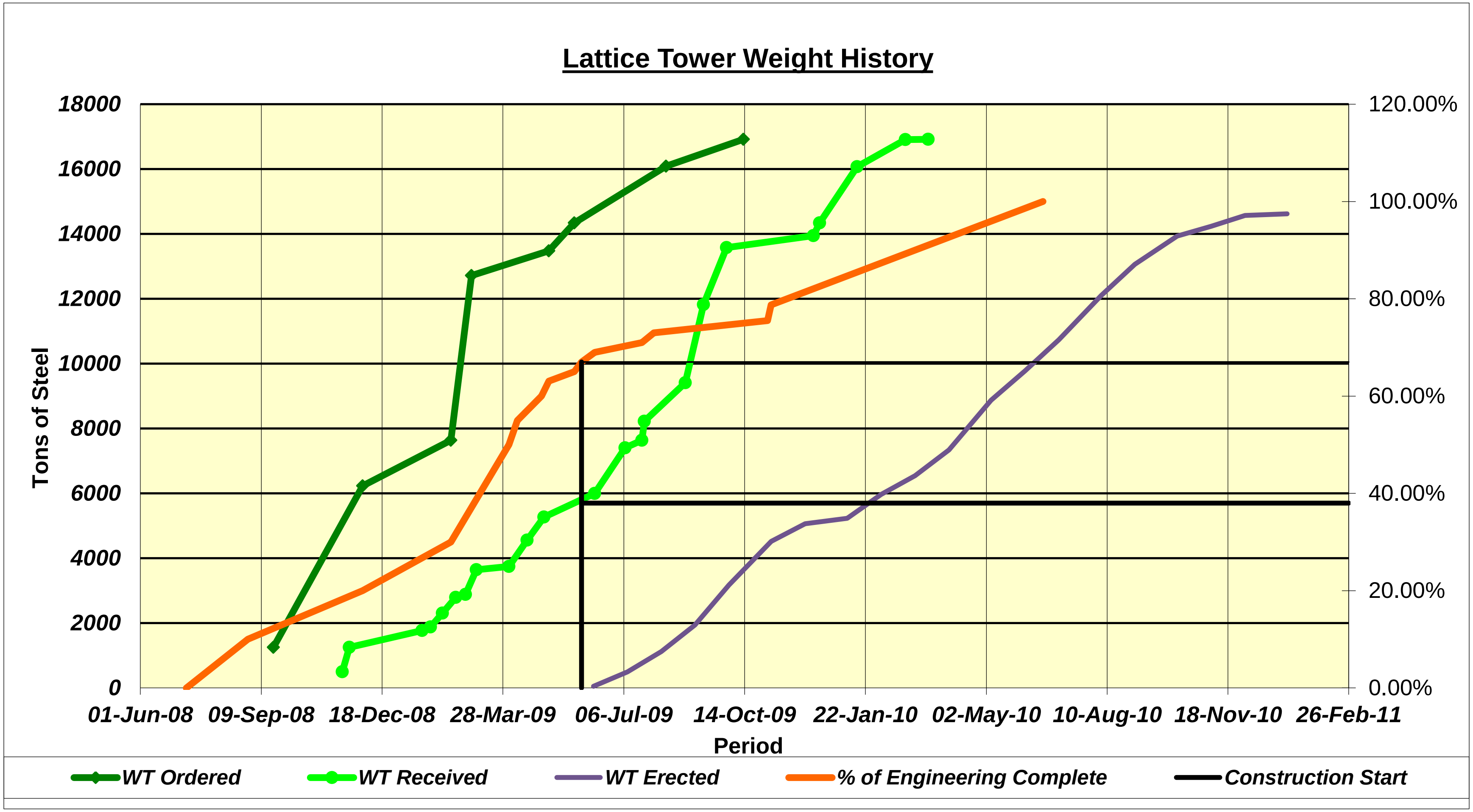
Why Use XML?

- Once the original setup is complete:
  - Mapping the elements
  - Setting up the equations
  - Formatting
- The XML data can be updated or referenced to a new project, while the equations and formatting will remain unchanged with the new data

XML Spreadsheets Created

- H-frame & lattice tower leg extension calculations
- Reorganization of the wire stringing charts
- Calculating level sag and angle of sight stringing values
- Reformatting PLS-CADD tables and reports such as the Construction Staking Table
- Line rating analysis calculations

Lattice Steel Procurement



Construction

- Structure 200 towards 199

Construction

- Structure 159L

Construction

- Structure 116

Construction

- Structure 248

Construction

- Structure 106 – Parallel existing 500kV

Construction

- Structure 104

Questions?

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Thank You

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