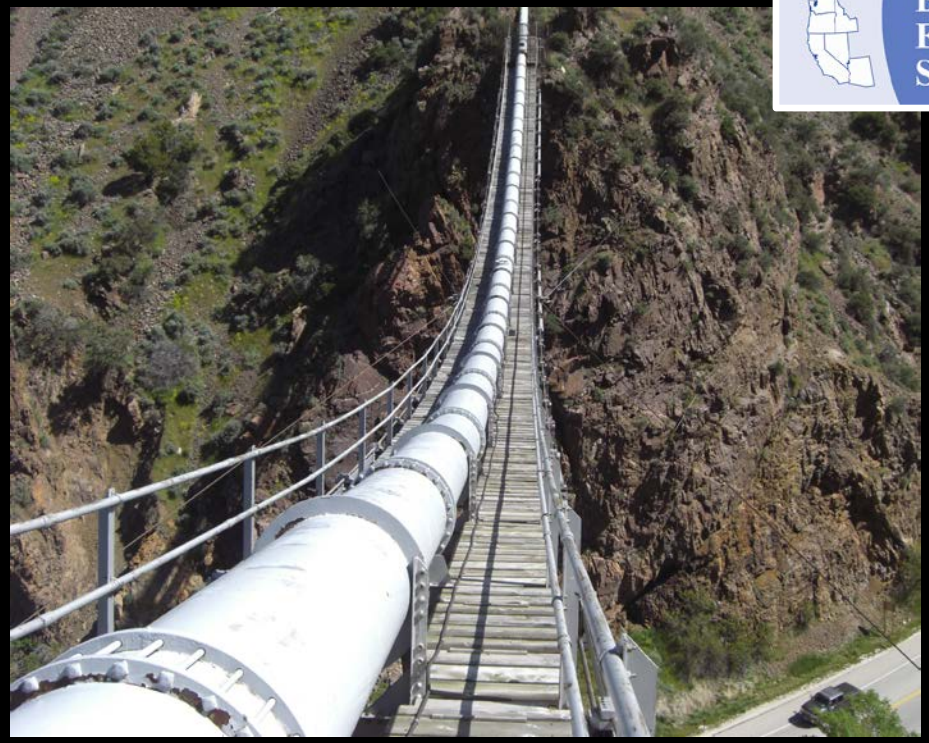
Seismic Retrofit of Ogden Siphon Pipe Suspension Bridge

Western Bridge Engineers' Seminar



QUINCY ENGINEERING

www.quincyeng.com

Mark L. Reno, P.E.

September 11, 2015

LOCATION

DESCRIPTION

- Designed in 1936 by U.S. Bureau of Reclamation
- 1,044 feet of 31.25 inch diameter pipe
- Supported by four 1.50 inch diameter main cables, with two 1.125 inch diameter wind cables
- Spans 360 feet across and 250 above the Ogden River and State Highway 39
- Structural land supports consist of braced fames and foundations spaced 40.0 feet on center

PIPELINE OPERATIONS

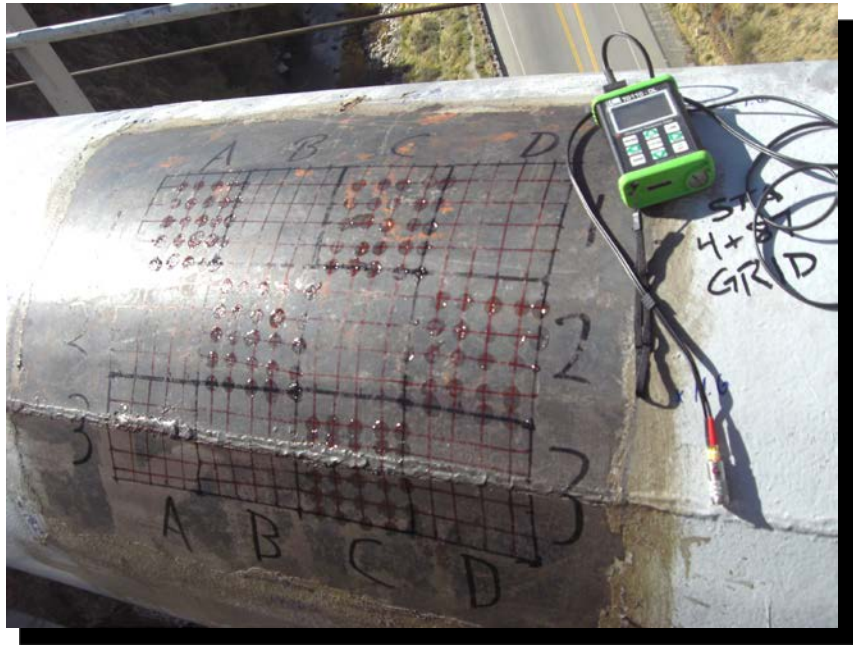
- Pipeline delivers water from the Pineview Reservoir, along Highway 39, across Ogden Canyon, to local water users for residential irrigation, from April to October only.
- Operated by Pineview Water Systems in Ogden, UT
- Water Service required to be continuous after a major wind or seismic event, as well as during construction of the new structure

RECLAMATION
Managing Water in the West

PINEVIEW WATER SYSTEMS

INVESTIGATIONS

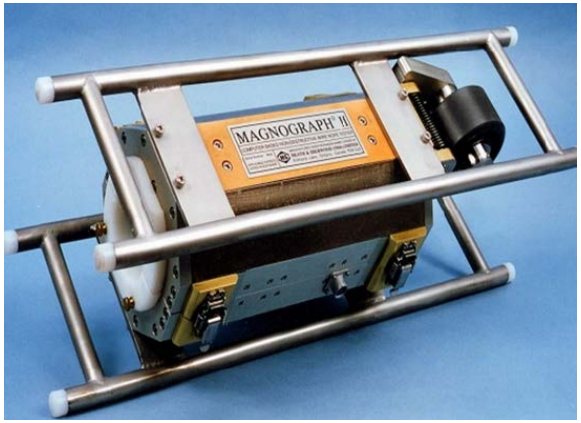
- Pipe condition evaluated by MWH
- Found active corrosion and loss of metal thickness
- Recommended relining and recoating



Cable Inspection by Acuren

- Electromagnetic NDT found 5% loss of metallic area
- Portions of main cable require replacement similar to replacement recommended in 1991
- Recommended lifting of upper part of saddle saddles to inspect lower cables
- Cables require cleaning and painting

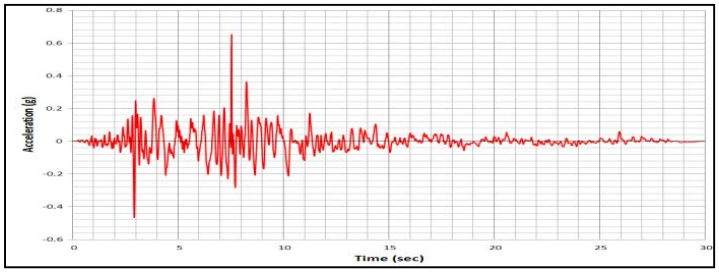
Magnograph II



INVESTIGATION

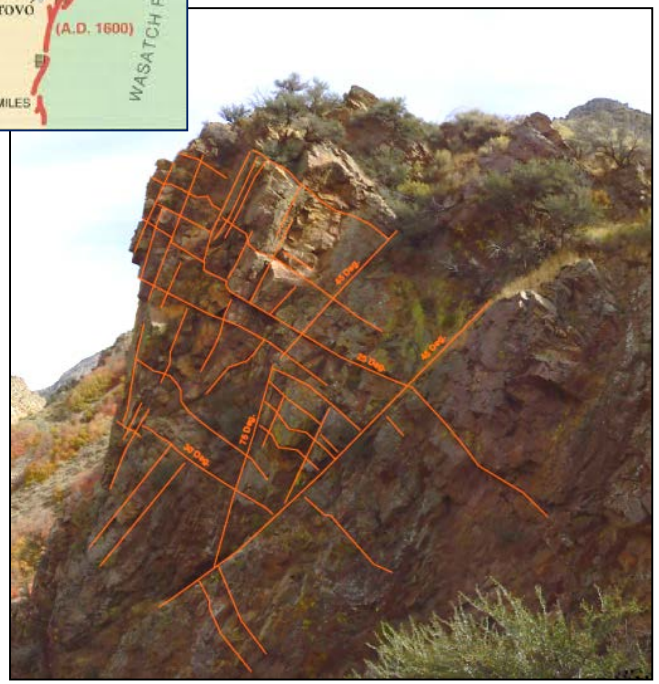
Geotechnical Investigation by Geostrata

- Prepared 3 sets of seismic time histories each with X,Y,Z components



- Evaluated Cable Anchors
  - Conducted LiDAR scans to map discontinuities in bedrock
  - Rock Core Samples Tested
  - Anchorage found adequate

Wasatch Fault
0.21 km from Site



DESIGN CRITERIA

Prepared Project Specific Design Criteria

- **Performance Criteria**
  - 50 year service life
  - Minimal damage after significant event
- **Loads**
  - 100 mph wind velocity
  - 3 - Site specific seismic time histories for 7.5 magnitude with seismic risk consistent with recent dam analysis
- **Member/Connection Capacity Definitions**
  - Components Remain Elastic
- **LRFD Analysis based on:**
  - ASCE 41, ASCE 7, AISC 360, ACI 318 and AASHTO
- **Derived Resistance Factors for Cable Capacity**

SUSPENSION BRIDGE

- **1936 Bureau of Reclamation connection design permitted framing to react to cable movements**

Edge Angle

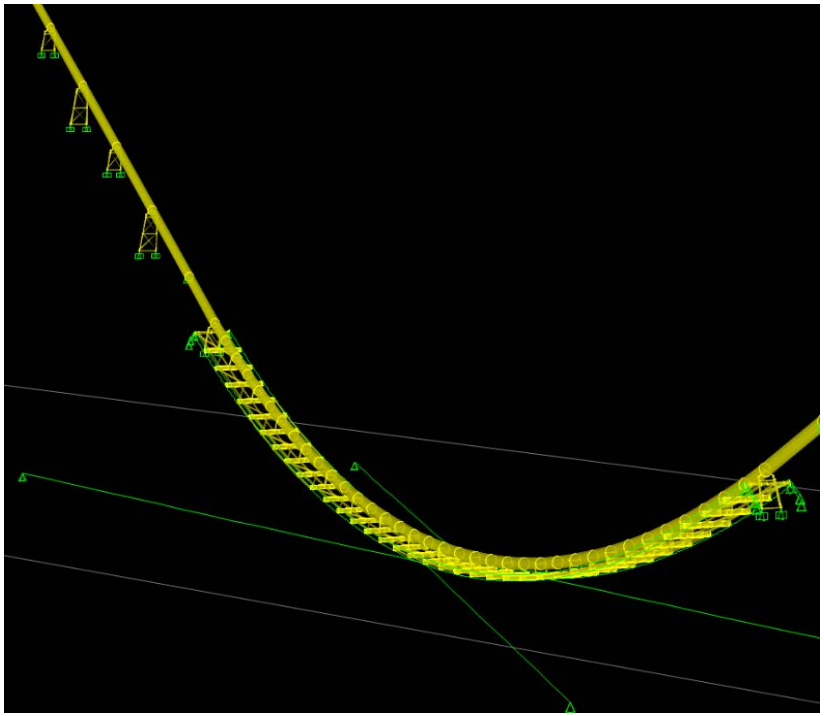
Channel Stringers

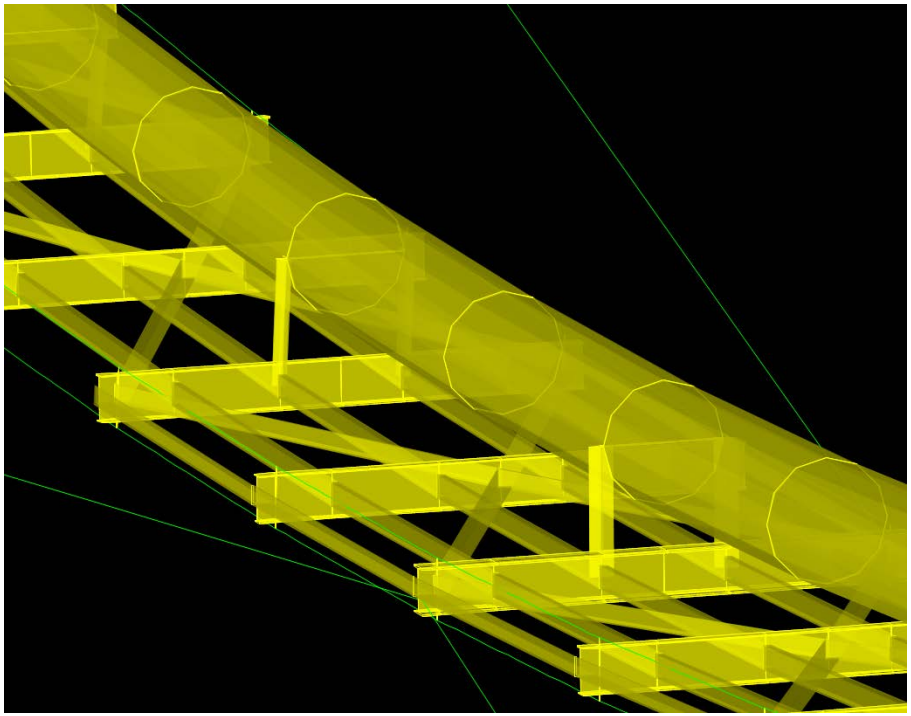
Diagonal Bracing

Slotted holes at connections permit framing to adjust to changing cable length

SAP MODEL

Detailed finite element model used to evaluate gravity loads, wind and seismic effects



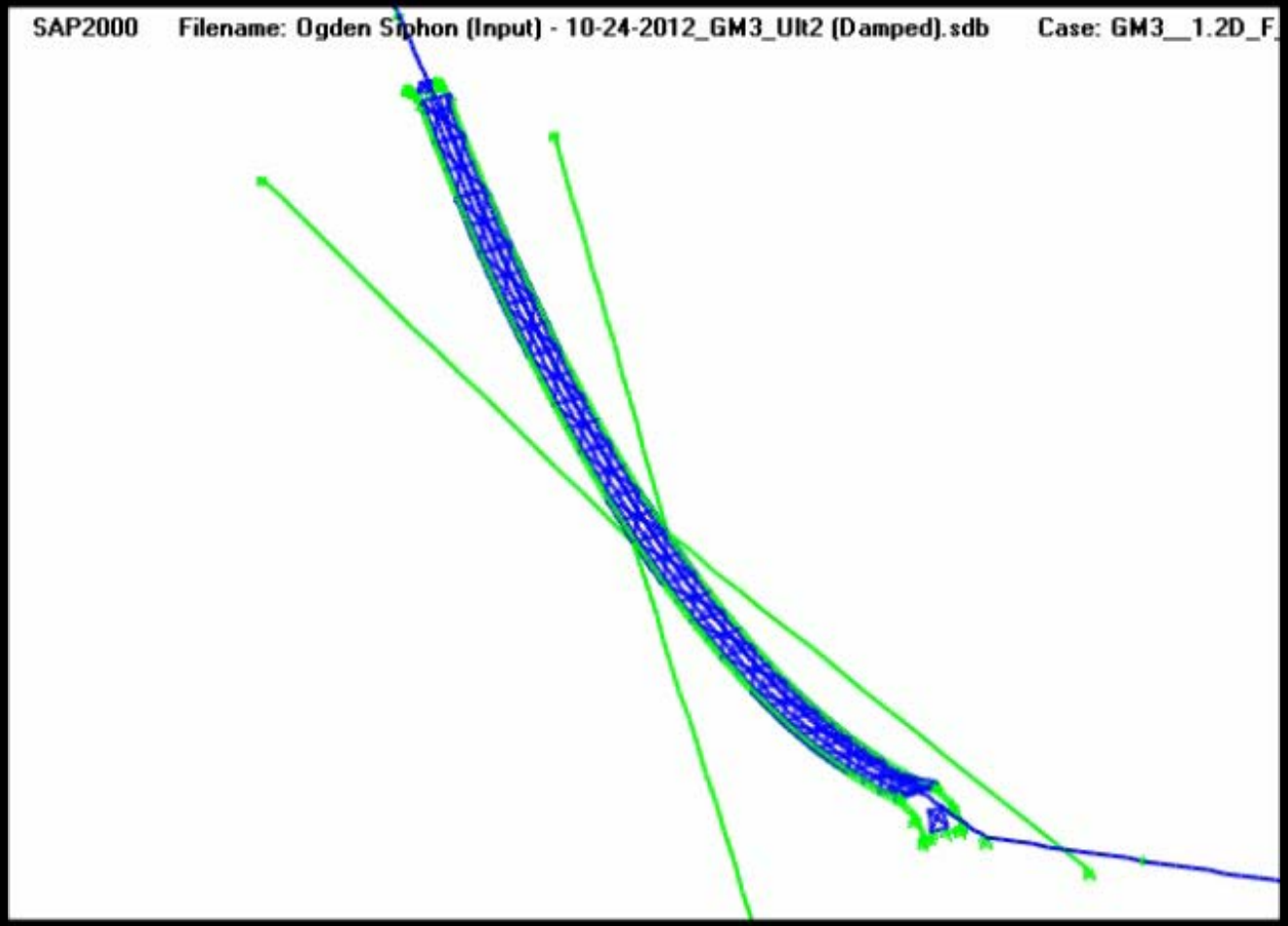


SAP MODEL

Model Features	Purpose	Significance
Large Displacements	Cable Elements	Capture response with change in length of cable
Time History 3 separate motions	Seismic Analysis	Required for non-linear analysis 8000 Time Steps at 0.005 sec
Staged Construction	Slotted connections at Edge Angles tightened after pipe installed	Realistic tension forces in components

The three Time-history analyses took 24 hours to run on a PC

DYNAMIC ANALYSIS



MAIN CABLE

Element	Condition	Retrofit	Replacement
Upper NW & SW	Loss of Area	• Replace upper NW & SW cable • Inspect all lower cables at saddles and possibly replace	Install New Cables
Galvanizing	Loss of Corrosion Protection	Clean and Paint Cable	Install New Cables

Replacement option changed cable size from 1.50 inch to 1.625 inch to improve factor of safety

WIND CABLE

Element	Condition	Retrofit
Wind Cable	Inadequate Strength	Install new larger 1.25” dia cable
Wind Sheave Pin	Inadequate Strength	Install new with Fy = 70 ksi
Anchorage	Damaged by rock falls	Clean, paint and reinforce w/plates

COUPLERS

Element	Condition	Retrofit
Couplers	Rotation pipe geometry and from Wind and Seismic Motion produces rotation of existing couplers beyond capacity	Install coupler with greater rotation capacity

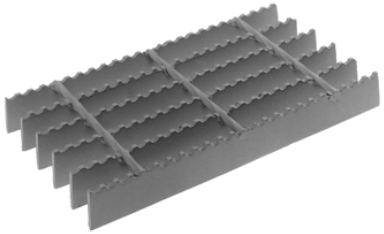
Rotational Capacity

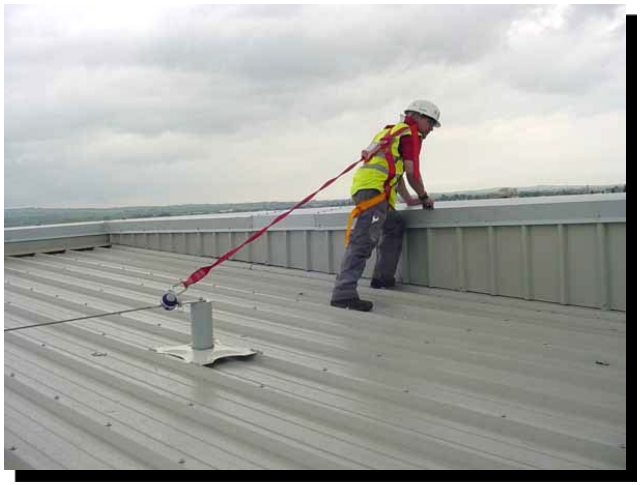
Existing 2.5 deg

Retrofit 5.5 deg

Tracked axial displacement and rotation about two axis for three seismic ground motions for each joint over 40 second ground motion with 0.005 second time steps.

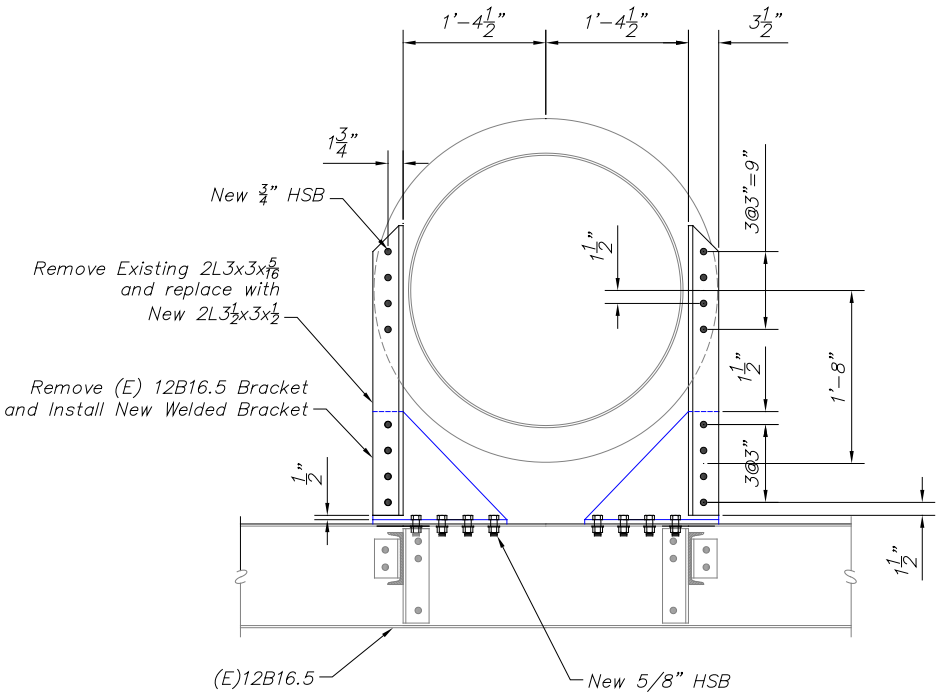
Element	Condition	Retrofit
Wood Deck	Poor Condition	Replace with grating
Wood Deck	Objects can fall	Add toe kick
Rail Posts	Inadequate strength	Strengthen
Worker Safety	No provisions	Add fall protection system





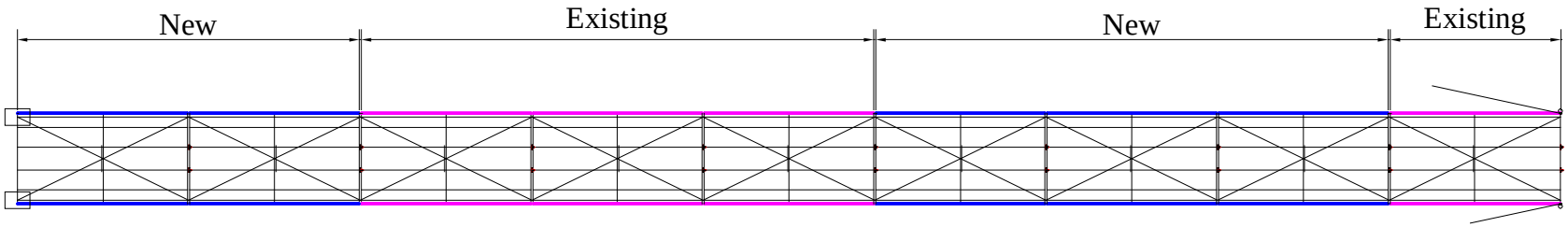
PIPE SUPPORTS

Element	Condition	Retrofit
Pipe Supports	Overstressed	Increase angle depth and thickness. Use Fy = 50 ksi
Support Bracing	Overstressed	Install brace on two sides. Use Fy = 50 ksi



EDGE ANGLES

Element	Condition	Retrofit
Edge Angles	Inadequate strength	Strengthen Existing and Install New Elements



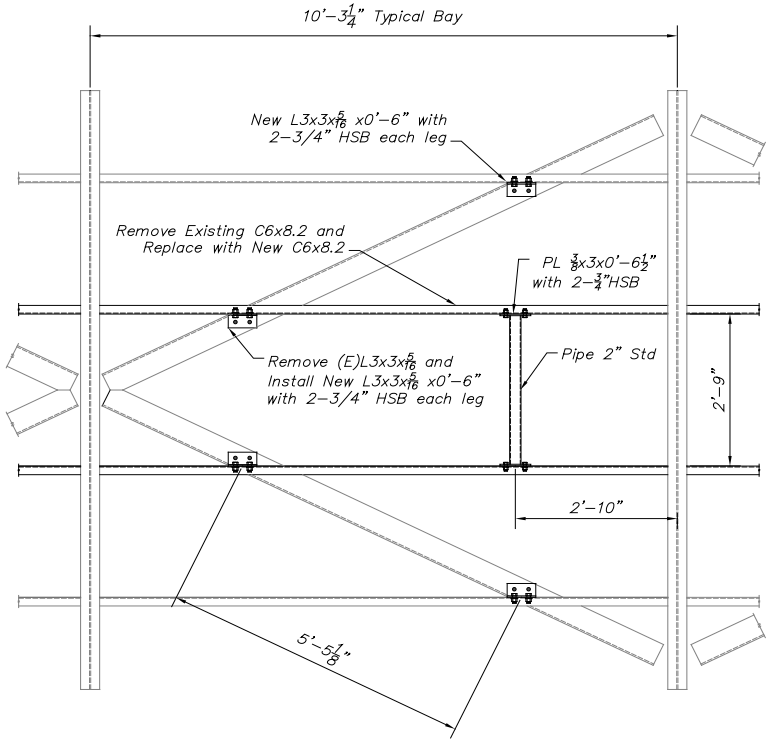
Use slotted holes and tighten HS Bolts after pipe installed to limit tension in members

FLOOR BEAMS

Element	Condition	Retrofit Option	Replacement Option
Floor Beam	Overstressed	Add Reinforcing Plates	Use larger size and Fy = 50 ksi

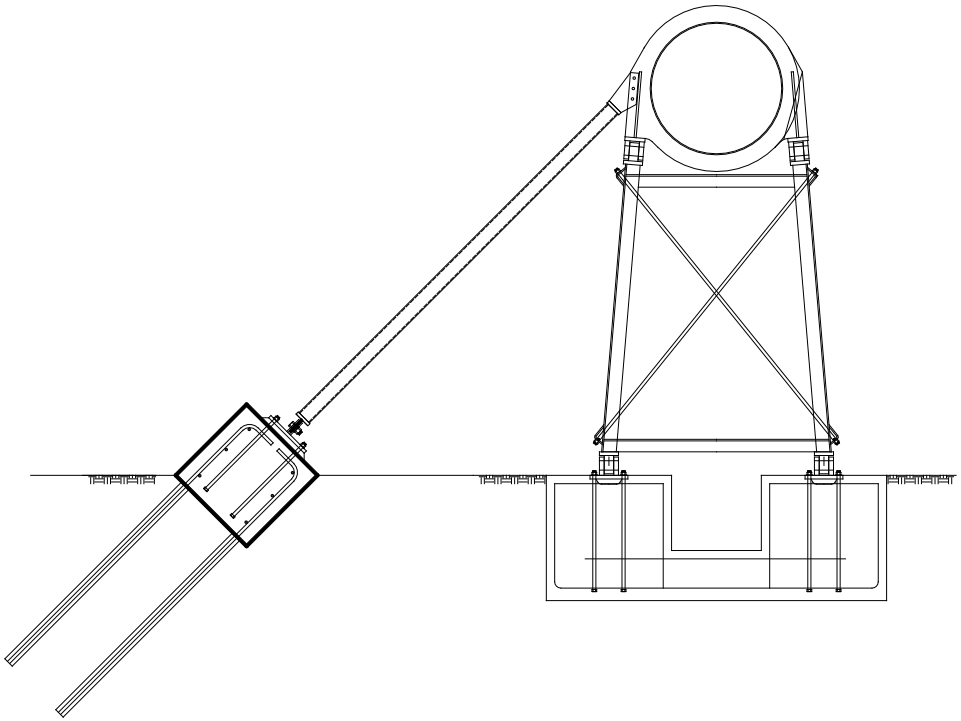
DIAGONAL BRACING

Element	Condition	Retrofit Option	Replacement Option
Diagonal Brace	Overstressed	Reduce Buckling Length	Use Fy = 50 ksi



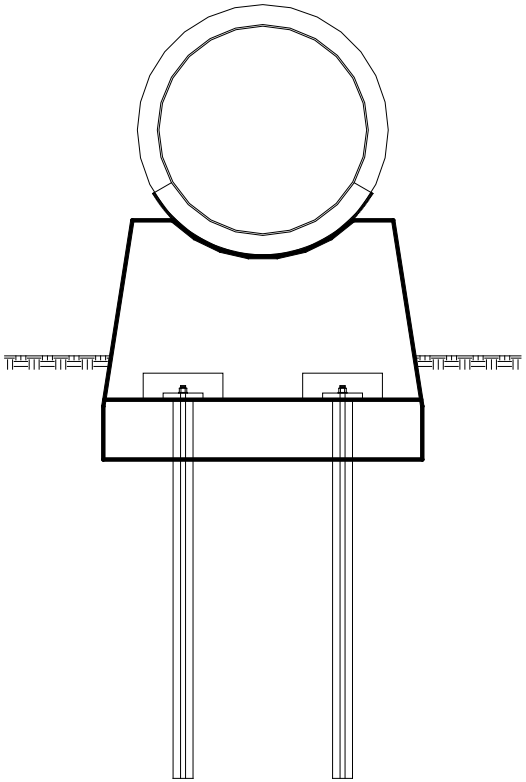
LAND TOWERS

Element	Condition	Retrofit
Rod Bracing	Overstressed	Install external bracing
Foundations	Overstressed	Install external bracing foundation



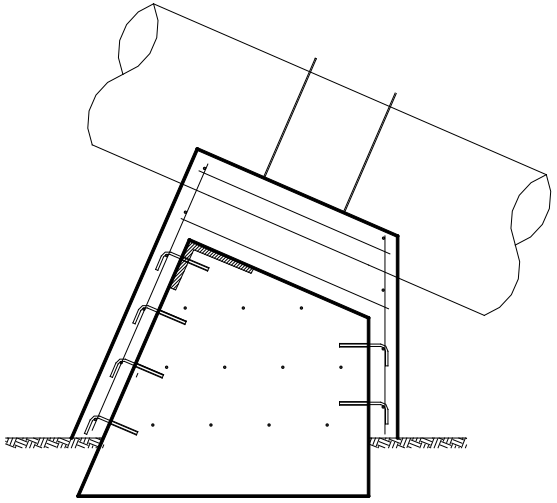
LAND PIERS

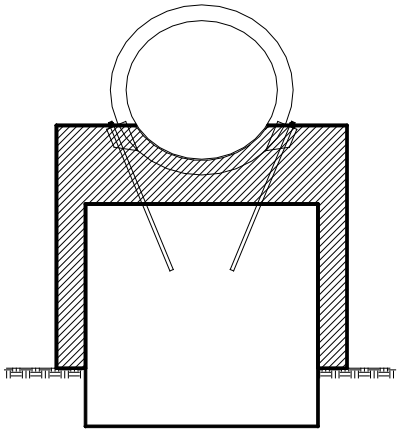
Element	Condition	Retrofit
Land Pier Foundation	Subject to Overturning	Add Rock Anchors



ANCHOR FOUNDATIONS

Element	Condition	Retrofit
Anchor Foundations	Cracked and Spalled Concrete	Remove unsound concrete and add new concrete cover





PAINT SYSTEM

Element	Condition	Retrofit
Paint System	Failed at some locations	Clean and Paint

Existing Paint System contains lead

CONSTRUCTION CHALLENGES

Challenge	Impact
Steep Terrain under Pipeline	Access Difficult
Suspension Span over Highway	Protective Barrier Required
High Winds in Canyon	Reduces productivity
Freezing Weather	Impacts Painting
Pipe must remain in service From April to October	Limits work window
Power Lines on North Side	Impacts use of helicopters and high-lines

CONSTRUCTION ACCESS

- 10,000 lbs capacity required
- Each contractor had preferred method

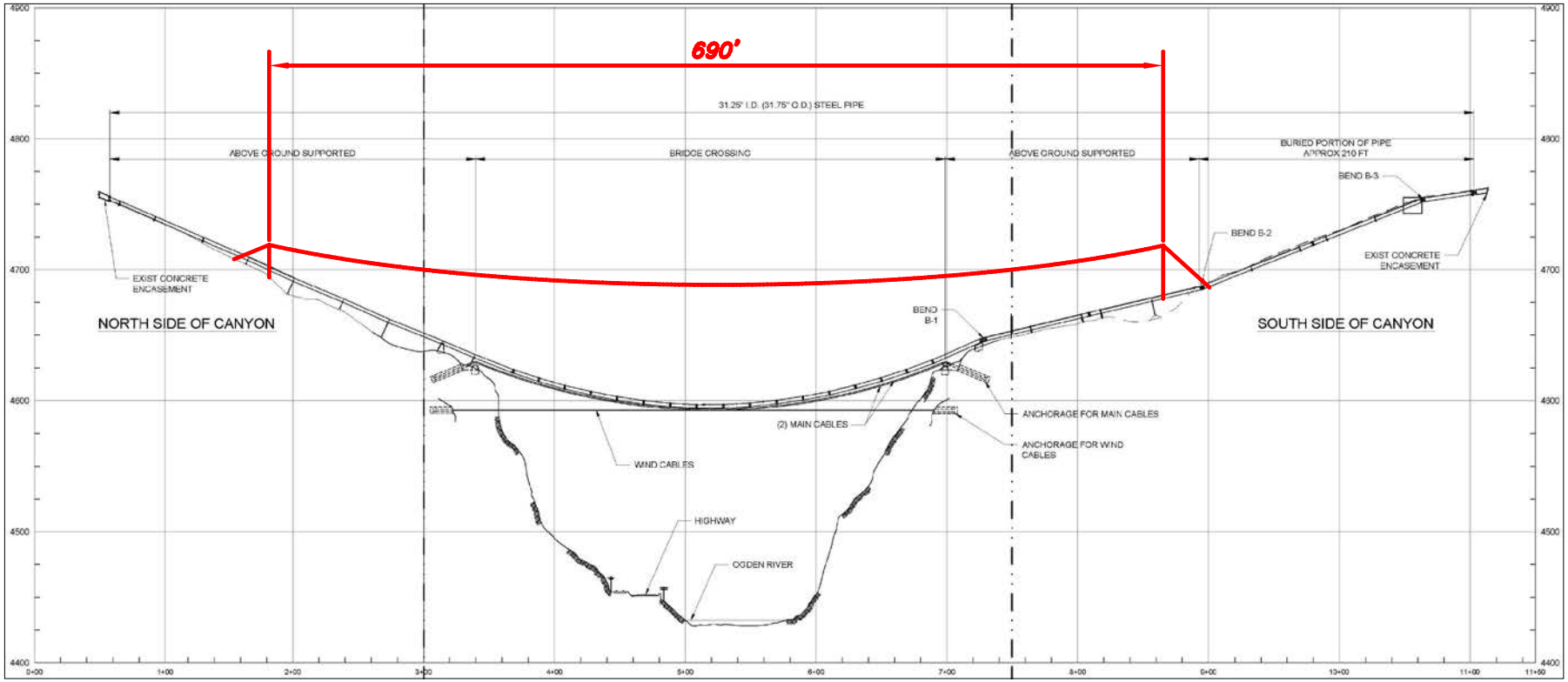
Helicopter

High Line

Hydraulic Crane
350T – 300 ft reach

HIGH LINE

Seismic Retrofit of
Ogden Siphon Pipe Suspension Bridge



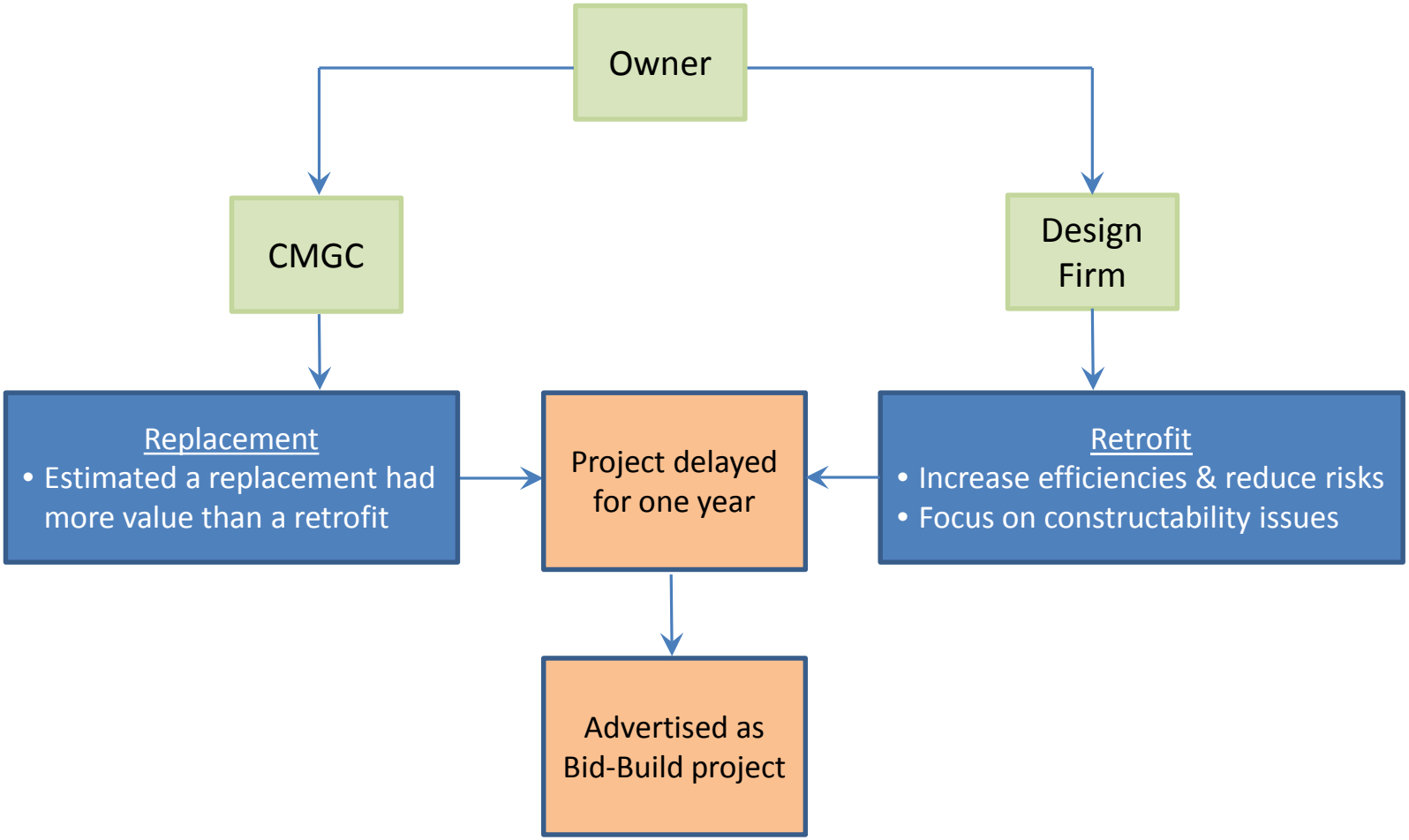
The erection subcontractor Adams and Smith, Lindon, UT, will use a high line to remove existing piping and structures and erect new pipeline and structures

ADAMS & SMITH, INC.
Engineers • Contractors

PAINTING

Challenge	Impact
Access Platform Required	Limited capacity in existing main cable system
Containment System Required	Limited capacity in existing wind cable system
Cold Weather	Heat required to cure paint
High Winds in Canyon	Limits production
Pipe must remain in service From April to October	Forces work in cold weather
Lead Paint	Environmental Controls required

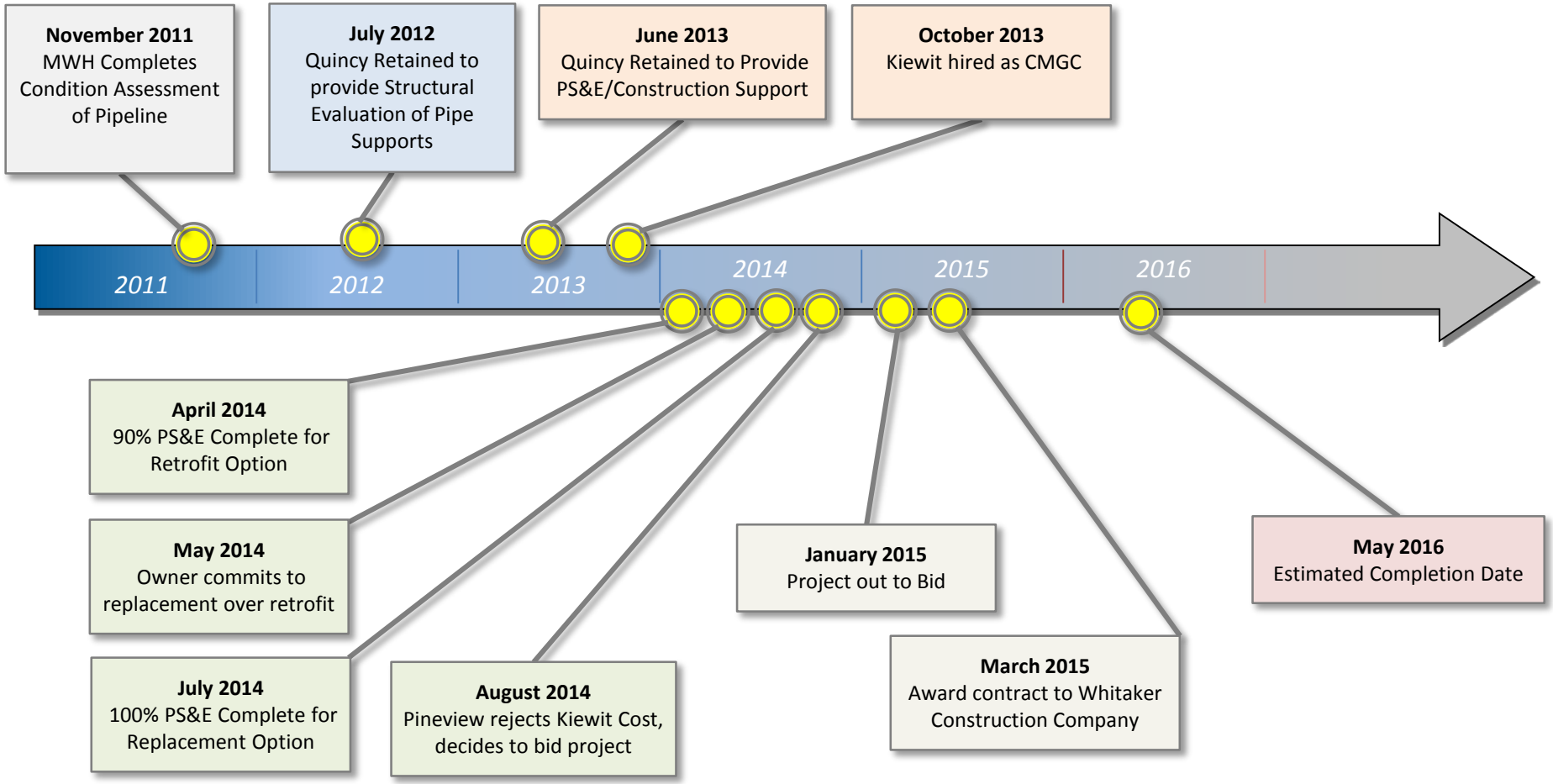
DESIGN PROCESS



REPLACEMENT OPTION

- Cost was very close to Retrofit Option
- Cleaning and Painting existing members in place is very expensive as production rates are very low
- Cleaning and Painting must be coordinated with installation of retrofit measures
- Structural System of Replacement Option remained the same as the original suspension bridge design
  - Reconfigured structural system to a panelized system to make erection more efficient
- Land Support Structural System reused existing elements with retrofitted bracing and foundations

TIMELINE


November 2011
MWH Completes Condition Assessment of Pipeline
July 2012
Quincy Retained to provide Structural Evaluation of Pipe Supports
June 2013
Quincy Retained to Provide PS&E/Construction Support
October 2013
Kiewit hired as CMGC
2011
2012
2013
2014
2015
2016
April 2014
90% PS&E Complete for Retrofit Option
May 2014
Owner commits to replacement over retrofit
July 2014
100% PS&E Complete for Replacement Option
August 2014
Pineview rejects Kiewit Cost, decides to bid project
January 2015
Project out to Bid
March 2015
Award contract to Whitaker Construction Company
May 2016
Estimated Completion Date

COST ESTIMATES

Level	Retrofit		Replacement		
Estimator	Engineer	CMGC	3rd Party	CMGC	Bid
60%	$6,775,000	$8,884,000			
90%	$7,592,000	$8,422,000	$7,999,000	$8,367,000	
Low Bid					$5,975,000
High Bid					$6,934,000

Questions?