# Illustrated Guide to Bridge Conceptual Design

## (based on application of BPG tool)

Alberta Transportation, 2011

# What is BPG?

- **B**ridge **P**lanning **G**eometry
- Excel tool (with VBA code)
- Interacts with GIS viewing software (e.g. Global Mapper)
- Combines roadway and bridge layout geometry
- Quick ID/evaluation/visualization of bridge planning options

# Overview

- Project Data
- Horizontal Alignment
- Profile
- Bridge Fills
- River Protection Works
- Bridge Structure Geometry
- Grading Volume
- Application

# Project Data

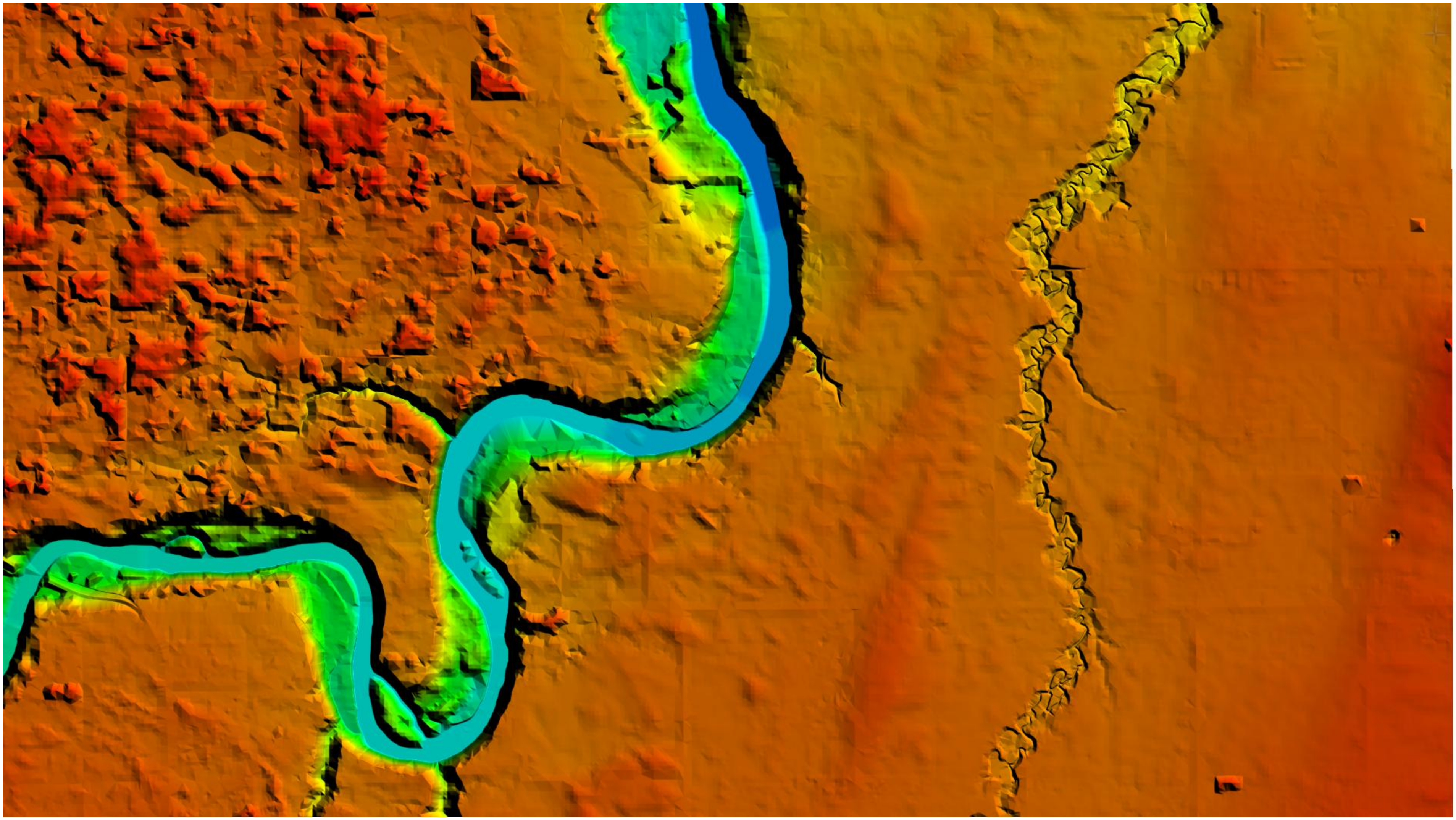
# Project Data

| | A | B | C | D |
|---|---|---|---|---|
| 1 | | **File Naming** | | |
| 2 | | **Project Name** | **NSR SW 1** | |
| 3 | | **DEM File Name (.asc)** | **SW1 DEM.asc** | |
| 4 | | | | |
| 5 | | **Spacing and Offsets** | | |
| 6 | | **Station Spacing** | **20** | |
| 7 | | **Offset (m) for SOD lines** | **20** | |
| 8 | | **Spacing for STA Labels** | **200** | |
| 9 | | **Spacing for Vol. Calcs** | **5** | |
| 10 | | | | |
| 11 | | **Alignment Options** | | |
| 12 | | **Design Speed (km/hr)** | **130** | |
| 13 | | **Spiral ('A') Multiplier** | **1.15** | |
| 14 | | | | |
| 15 | | | | |

# DEM File Preparation

- Elevations on a defined grid spacing
- Spacing – balance accuracy and speed
- Cover extents (along alignment and transverse)
- Source – LIDAR, Photogrammetry, Survey, Base DTM
- Located in same directory as BGP file
- ASC format (export from Global Mapper)
- Same projection as alignment coordinates

# DEM File Visualization



# Horizontal Alignment

# Horizontal Alignment Factors

- Crossing Location
  - Width - cost
  - Skew – cost, structural complexity
  - Lateral Stability – cost, reliability, environmental impact
  - Slides – cost, maintenance
- Bridge Geometric Requirements
  - Tangent Preferable
  - Increased R – sight distance (rails), max gradient (icing)
  - Constant XS (icing) – no spirals

# Horizontal Alignment - Draw

# Horizontal Alignment - Input

Hide Ink Annotations

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | |
| 2 | | STA | E | N | R | A | e | Delta | | GO | | | Offset | |
| 3 | | 1000.0 | 28932.25 | 5915757 | | | | | | | | | | |
| 4 | | | 24568.1 | 5915746 | 2000 | 380 | 0.041 | 37.9 | | | | | | |
| 5 | | | 21018.32 | 5918492 | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | |

# Horizontal Alignment – Output Data

| E | N | STA | EL grnd | Brng | e |
|---|---|---|---|---|---|
| 28932.251 | 5915756.661 | 1000 | 702.110 | 269.86 | 0.020 |
| 28912.251 | 5915756.613 | 1020 | 701.878 | 269.86 | 0.020 |
| 28892.251 | 5915756.565 | 1040 | 701.542 | 269.86 | 0.020 |
| 28872.251 | 5915756.517 | 1060 | 701.273 | 269.86 | 0.020 |
| 28852.251 | 5915756.470 | 1080 | 700.985 | 269.86 | 0.020 |
| 28832.251 | 5915756.422 | 1100 | 700.723 | 269.86 | 0.020 |
| | | | | | |
| 25332.261 | 5915748.049 | 4600 | 697.842 | 269.86 | 0.020 |
| 25312.261 | 5915748.001 | 4620 | 697.903 | 269.86 | 0.020 |
| 25292.261 | 5915747.953 | 4640 | 698.012 | 269.86 | 0.020 |
| 25272.261 | 5915747.912 | 4660 | 698.144 | 269.93 | 0.020 |
| 25252.261 | 5915747.920 | 4680 | 698.328 | 270.15 | 0.020 |
| 25232.262 | 5915748.034 | 4700 | 698.552 | 270.53 | 0.028 |
| 25212.264 | 5915748.307 | 4720 | 698.851 | 271.06 | 0.041 |
| 25192.269 | 5915748.777 | 4740 | 699.154 | 271.63 | 0.041 |
| 25172.281 | 5915749.448 | 4760 | 699.466 | 272.21 | 0.041 |
| 25152.300 | 5915750.317 | 4780 | 699.785 | 272.78 | 0.041 |
| 25132.328 | 5915751.387 | 4800 | 700.067 | 273.35 | 0.041 |

# Horizontal Alignment – Curve Points

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | **E** | **N** | **STA** | **Name** | |
| 2 | 25290.161 | 5915747.948 | 4642.100 | TS1 | |
| 3 | 25217.963 | 5915748.210 | 4714.300 | SC1 | |
| 4 | 24054.340 | 5916144.180 | 5963.666 | CS1 | |
| 5 | 23996.967 | 5916188.010 | 6035.866 | ST1 | |
| 6 | | | | | |
| 7 | | | | | |

# Horizontal Alignment - Plot

# Profile

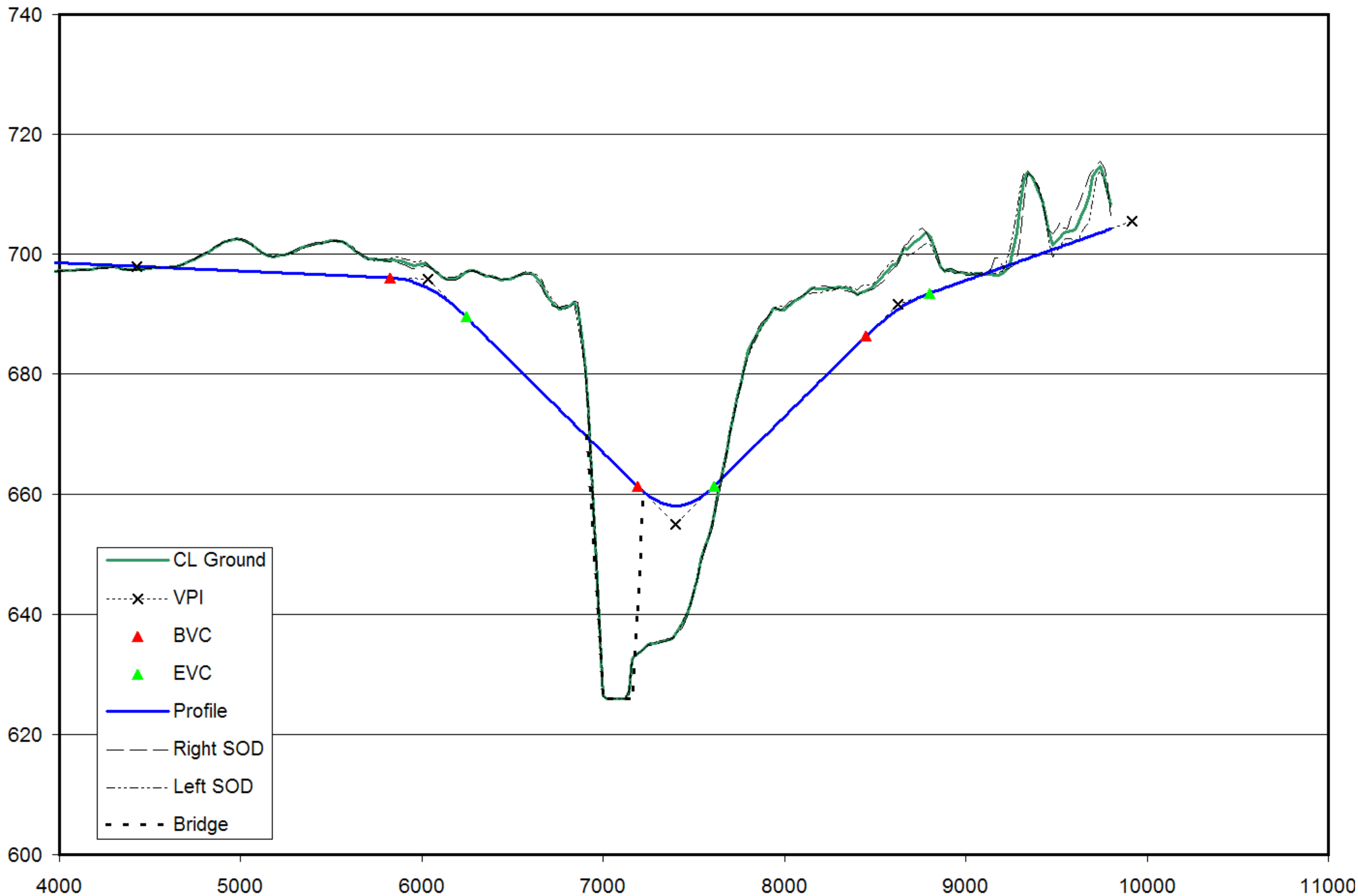
# Profile Factors

- Min Elevation (Hydraulic Control)
  - Min EL = HW EL + Freeboard + Structure Depth
  - HW EL based on AT HDG
  - Freeboard – BPG 12
  - Structure Depth – max span
- Deck Gradient Limits (AT BSDC)
  - Max 4% resultant (~ 3% longitudinal) – preferential icing
  - Min 1% - deck drainage (BPG 11)
- Valley Issues
  - Cut/Fill Balance
  - Max Hwy Grade – benefit/cost
  - Visual – Min. L(m) = 2X Design Speed (km/hr)

# Profile - Input

| B | C | D | E | F | G | L | M | N | O | P | Q | R | S | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Spot Elevations | | |
| STA | EL | L | G | K | Type | Lmx | Warn | | | | Pt | STA | EL | G |
| 4427 | 698.000 | | | | | | | | GO | | 1 | 7000.00 | 666.885 | -3.00 |
| 6035 | 695.800 | 420 | -0.14 | 146.9 | Crest | 2310 | OK | | | | 2 | | | |
| 7400 | 654.900 | 420 | -3.00 | 70.1 | Sag | 2100 | OK | | | | 3 | | | |
| 8625 | 691.600 | 350 | 3.00 | 182.4 | Crest | 2030 | OK | | | | 4 | | | |
| 9915 | 705.500 | | 1.08 | | | | | | | | 5 | | | |

# Profile - Plot



# Profile – Summary Output

| Curve | VC Len | Desc | K | G1 | G2 | STA BVC | EL BVC | STA EVC | EL EVC |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 420 | Crest | 146.88 | -0.001 | -0.030 | 5825.00 | 696.087 | 6245.00 | 689.508 |
| 2 | 420 | Sag | 70.09 | -0.030 | 0.030 | 7190.00 | 661.192 | 7610.00 | 661.191 |
| 3 | 350 | Crest | 182.44 | 0.030 | 0.011 | 8450.00 | 686.357 | 8800.00 | 693.486 |

# Profile – Align Data + Prof

| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | **E** | **N** | **STA** | **EL grnd** | **Brng** | **e** | **EL CL** | **Grade** |
| 2 | 28932.251 | 5915756.661 | 1000 | 702.110 | 269.86 | 0.020 | 702.689 | -0.14 |
| 3 | 28912.251 | 5915756.613 | 1020 | 701.878 | 269.86 | 0.020 | 702.661 | -0.14 |
| 4 | 28892.251 | 5915756.565 | 1040 | 701.542 | 269.86 | 0.020 | 702.634 | -0.14 |
| 5 | 28872.251 | 5915756.517 | 1060 | 701.273 | 269.86 | 0.020 | 702.607 | -0.14 |
| 6 | 28852.251 | 5915756.470 | 1080 | 700.985 | 269.86 | 0.020 | 702.579 | -0.14 |
| 7 | 28832.251 | 5915756.422 | 1100 | 700.723 | 269.86 | 0.020 | 702.552 | -0.14 |
| 8 | | | | | | | | |
| 9 | 25332.261 | 5915748.049 | 4600 | 697.842 | 269.86 | 0.020 | 697.763 | -0.14 |
| 10 | 25312.261 | 5915748.001 | 4620 | 697.903 | 269.86 | 0.020 | 697.736 | -0.14 |
| 11 | 25292.261 | 5915747.953 | 4640 | 698.012 | 269.86 | 0.020 | 697.709 | -0.14 |
| 12 | 25272.261 | 5915747.912 | 4660 | 698.144 | 269.93 | 0.020 | 697.681 | -0.14 |
| 13 | 25252.261 | 5915747.920 | 4680 | 698.328 | 270.15 | 0.020 | 697.654 | -0.14 |
| 14 | 25232.262 | 5915748.034 | 4700 | 698.552 | 270.53 | 0.028 | 697.626 | -0.14 |
| 15 | 25212.264 | 5915748.307 | 4720 | 698.851 | 271.06 | 0.041 | 697.599 | -0.14 |
| 16 | 25192.269 | 5915748.777 | 4740 | 699.154 | 271.63 | 0.041 | 697.572 | -0.14 |
| 17 | 25172.281 | 5915749.448 | 4760 | 699.466 | 272.21 | 0.041 | 697.544 | -0.14 |
| 18 | 25152.300 | 5915750.317 | 4780 | 699.785 | 272.78 | 0.041 | 697.517 | -0.14 |
| 19 | 25132.328 | 5915751.387 | 4800 | 700.067 | 273.35 | 0.041 | 697.490 | -0.14 |
| 20 | | | | | | | | |

# Bridge Fills

# Bridge Fills Factors

- Fill Location
  - Hydraulically Feasible – V, headloss, u/s flooding
  - Lateral tie-in to existing natural banks
  - Starting point – match existing natural banks
- Fill Configuration
  - Headslope ratio (typ 2:1, geotechnical, remediation)
  - Berms – geotechnical, access
  - Elliptical fill transition vs. guidebank

# Bridge Fills – Initial Fill STA

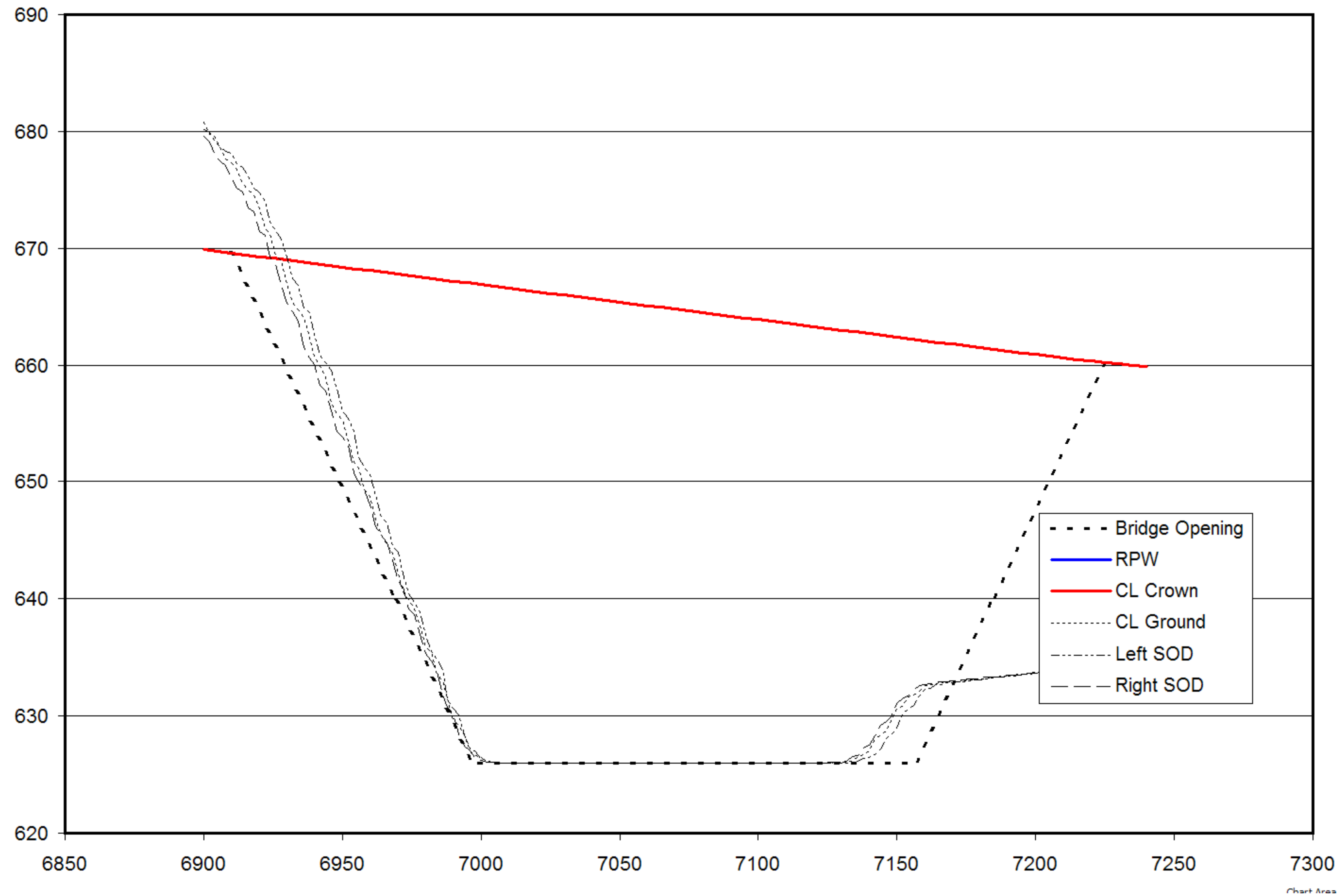
| Calc Top of Fill From Toe | STA | EL |
|---|---|---|
| Near Fill Toe | 7000.000 | 627.000 |
| Far Fill Toe | 7200.000 | 627.000 |
| | | |
| Near Fill Top | 6896.63 | 677.90 |
| Far Fill Top | 7280.01 | 666.40 |

Calc Top

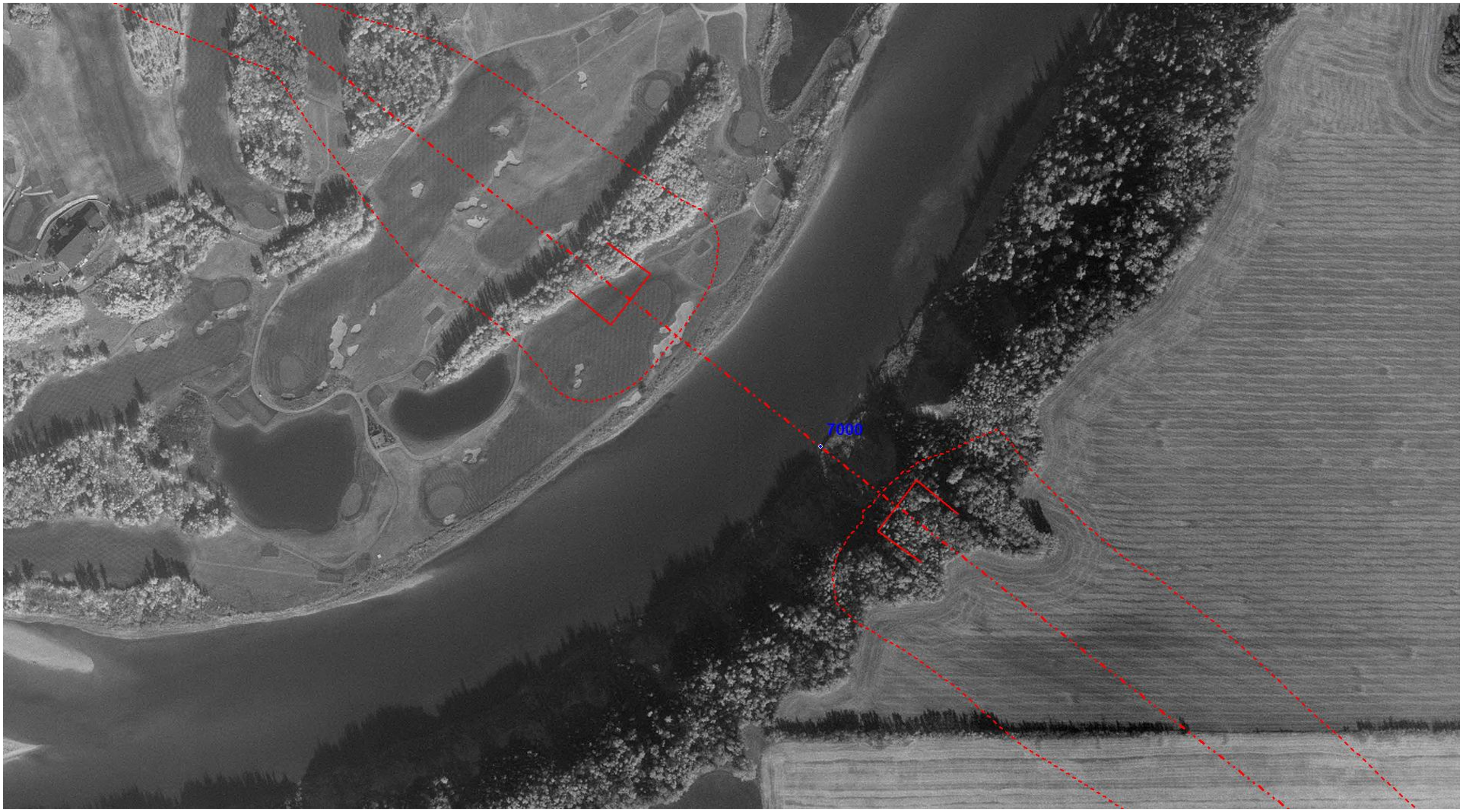
# Bridge Fills - Input

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | | | EL | G | |
| 2 | Near Fill Station | 6910.000 | 669.582 | -2.996 | |
| 3 | Far Fill Station | 7225.000 | 660.231 | -2.497 | |
| 4 | Top of Fill Width | 60.0 | | | |
| 5 | Headslope Ratio | 2.0 | | | |
| 6 | Fill Sideslope Ratio | 3.0 | | | |
| 7 | Skew | 0.0 | | | |
| 8 | Bed EL (Theor.) | 627.000 | | | |
| 9 | Berm EL | 640.000 | | | |
| 10 | Headslope Berm Width | 0.0 | | | |
| 11 | GB Berm Width | 0.0 | | | |
| 12 | Protection (H,G,N) | N | | | |

# Bridge Fills - Elevation



# Bridge Fills - Plan

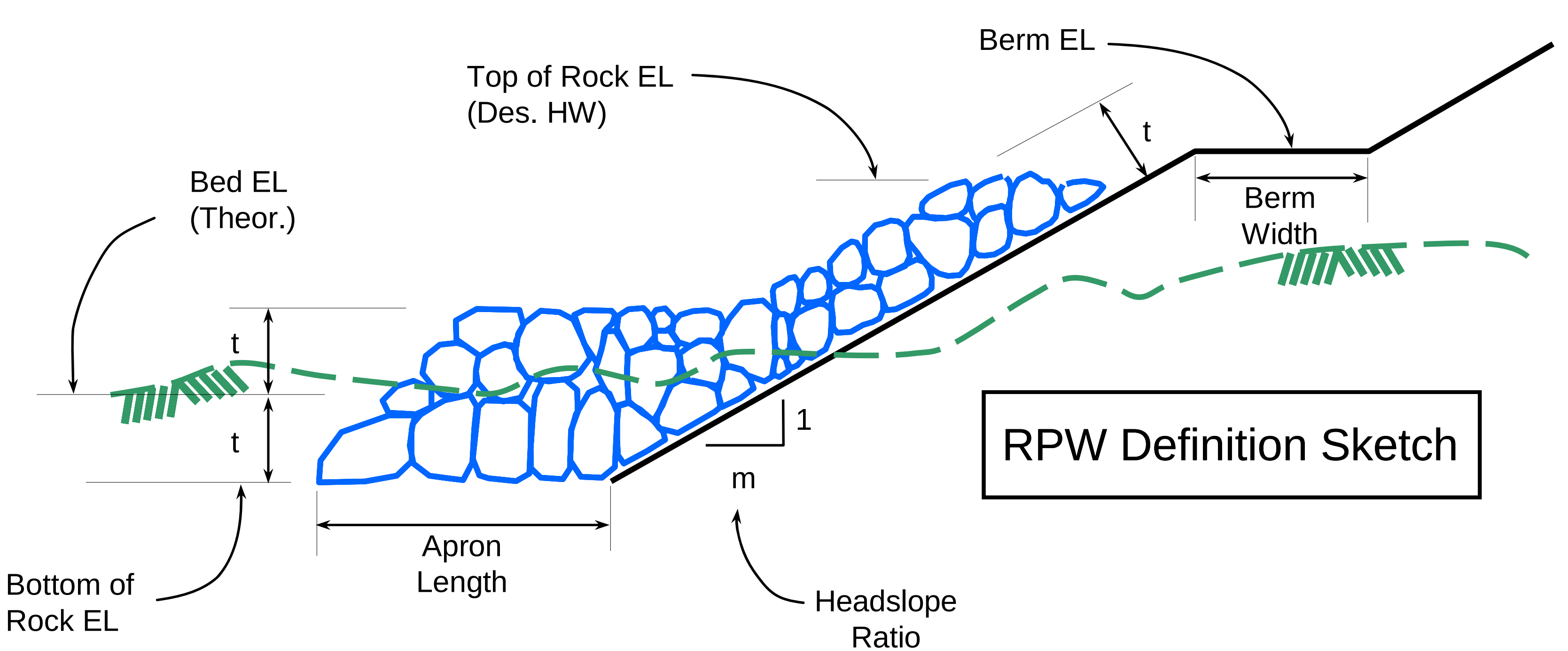


# River Protection Works

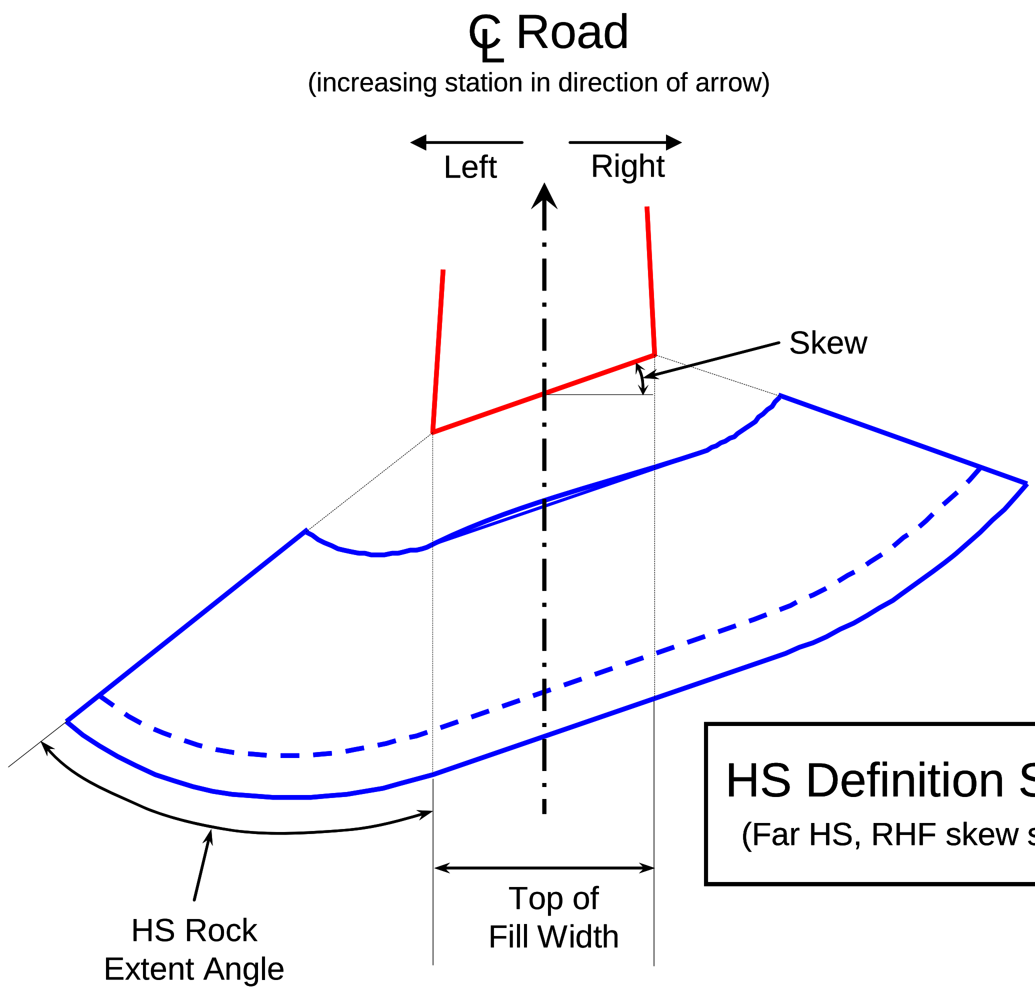
# Bridge Fills Protection Factors

- Need
  - Fill in active channel
  - Lateral movement history
  - Signs of local bank instability
- Protection Details (BPG 9)
  - Rock (Class 1,2,3 – size distribution, BCS, Section 10)
  - Select based on V, lateral movement history
  - Launching Apron, rock to HW
- Extent
  - Configuration - headslope vs. guidebank
  - Tie apron into toe of banks
  - Smooth transition, target 2:1 (along stream vs. lateral)
- Additional River Engineering Features
  - Spurs – groups, spacing, projection
  - Channel realignment – align flow, reduce skew, maintain S

# Bridge Fills Protection - Detail

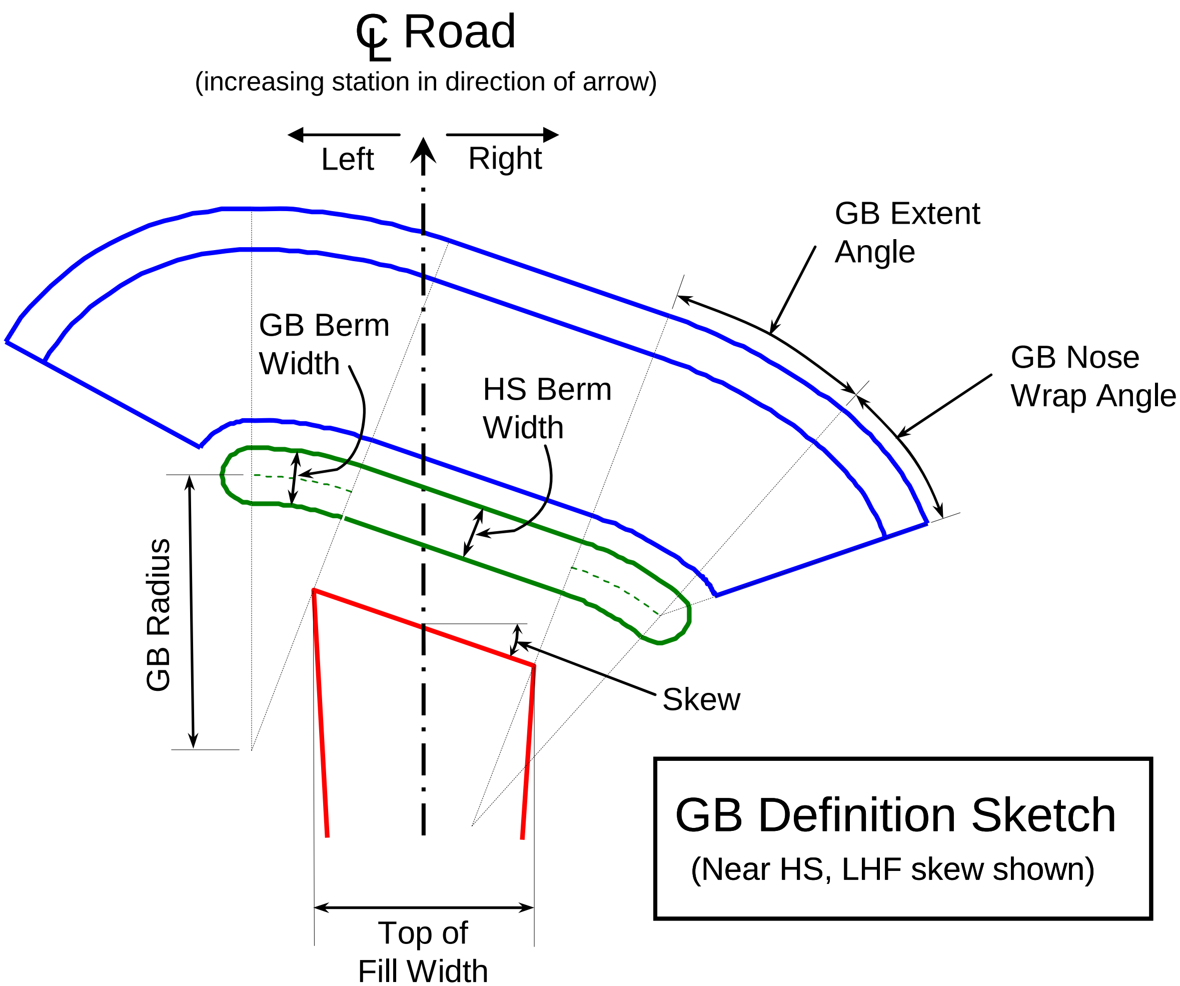


# Bridge Fills Protection - Headslope




HS Definition Sketch
(Far HS, RHF skew shown)

# Bridge Fills Protection - Guidebank



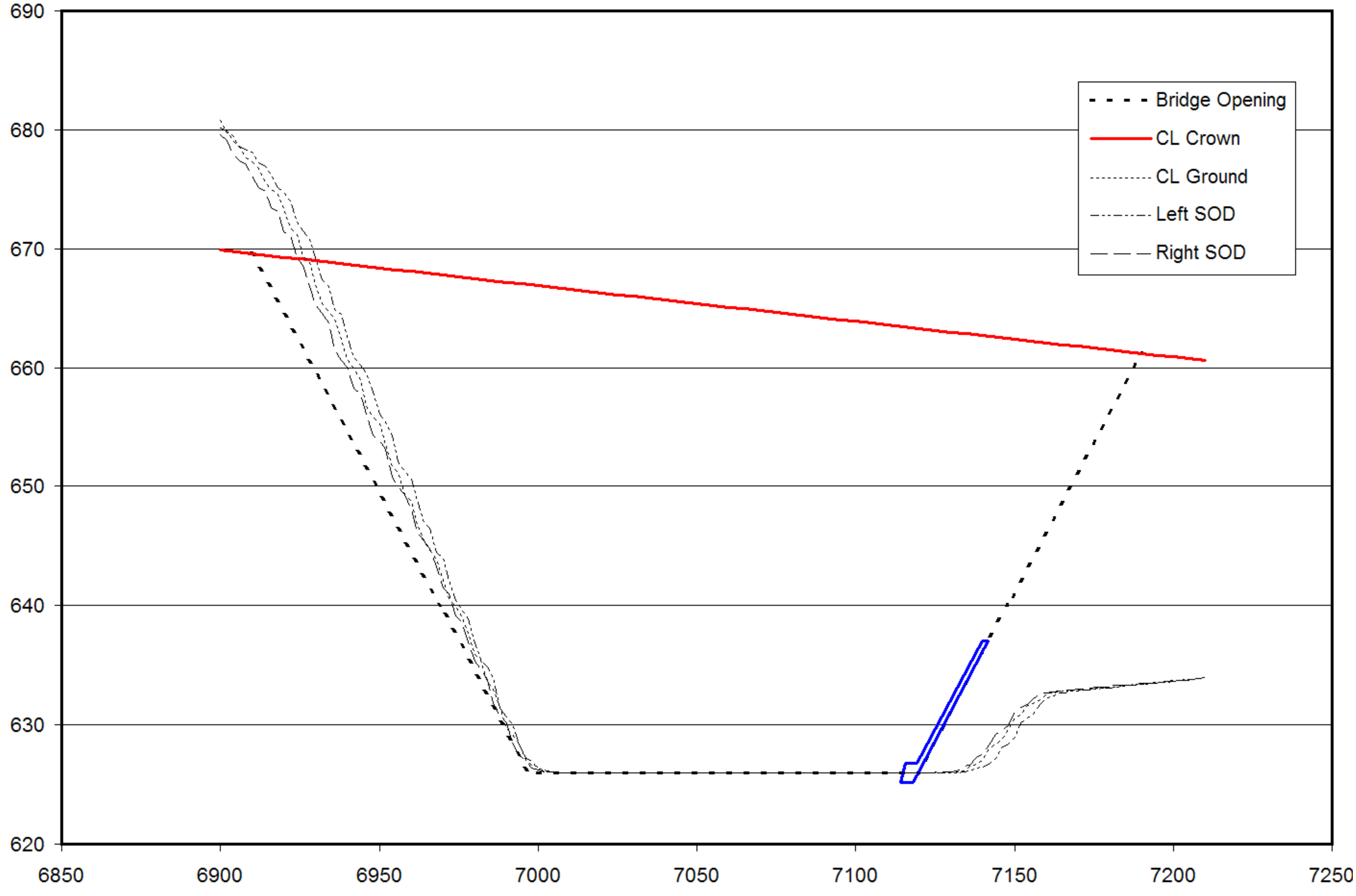

GB Definition Sketch

(Near HS, LHF skew shown)

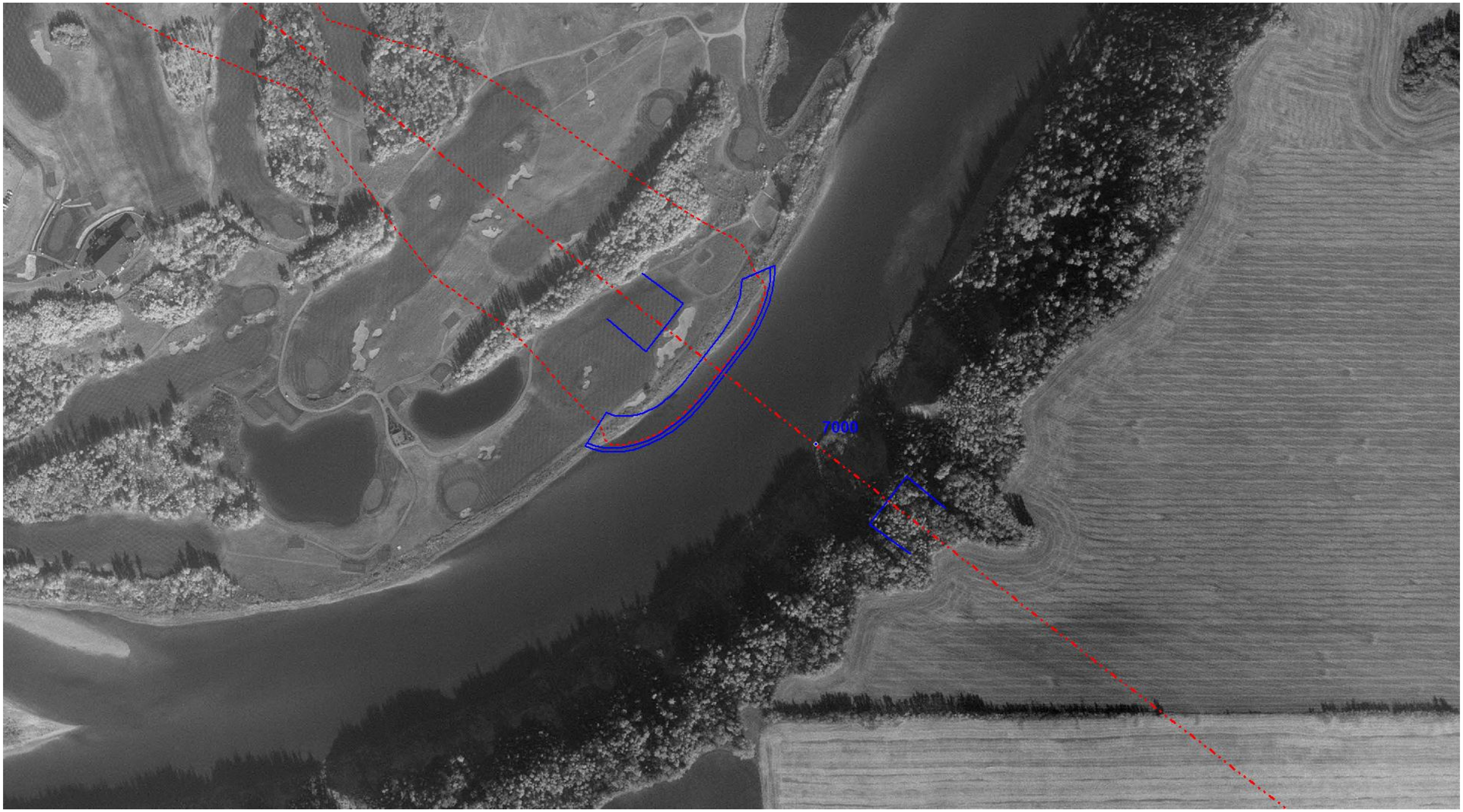
# Bridge Fills Protection - Input

| | | | | | |
|---|---|---|---|---|---|
| 10 | Headslope Berm Width | 0.0 | | | |
| 11 | GB Berm Width | 0.0 | | | |
| 12 | Protection (H,G,N) | H | | | |
| 13 | Rock Thickness 't' (m) | 0.8 | | | |
| 14 | Top Of Rock EL | 637 | | | |
| 15 | Bottom Of Rock EL | 625.2 | | | |
| 16 | Apron Length | 4.0 | | | |
| 17 | | | | | |
| 18 | | Near Fill | | Far Fill | |
| 19 | | Left | Right | Left | Right |
| 20 | HS Rock Extent Angle | 50.0 | 50.0 | 85.0 | 60.0 |
| 21 | GB Radius | 20.0 | 20.0 | 80.0 | 80.0 |
| 22 | GB Extent Angle | 25.0 | 25.0 | 30.0 | 20.0 |
| 23 | GB Nose Wrap Angle | 30.0 | 30.0 | 30.0 | 30.0 |
| 24 | | | | | |
| 25 | | Square | Skew | | |
| 26 | Out to Out of Fill Length | 280.000 | 280.000 | | |
| 27 | Theoretical Bed Width | 122.451 | 122.451 | | |
| 28 | | | | | |
| 29 | Rock Vol. (Near) | 5675 | | | |
| 30 | Rock Vol. (Far) | 6981 | | | |
| 31 | Total Rock Volume | 12656 | | | |
| 32 | | | | | |

# Bridge Fills – Elevation + RPW



# Bridge Fills – Plan + RPW

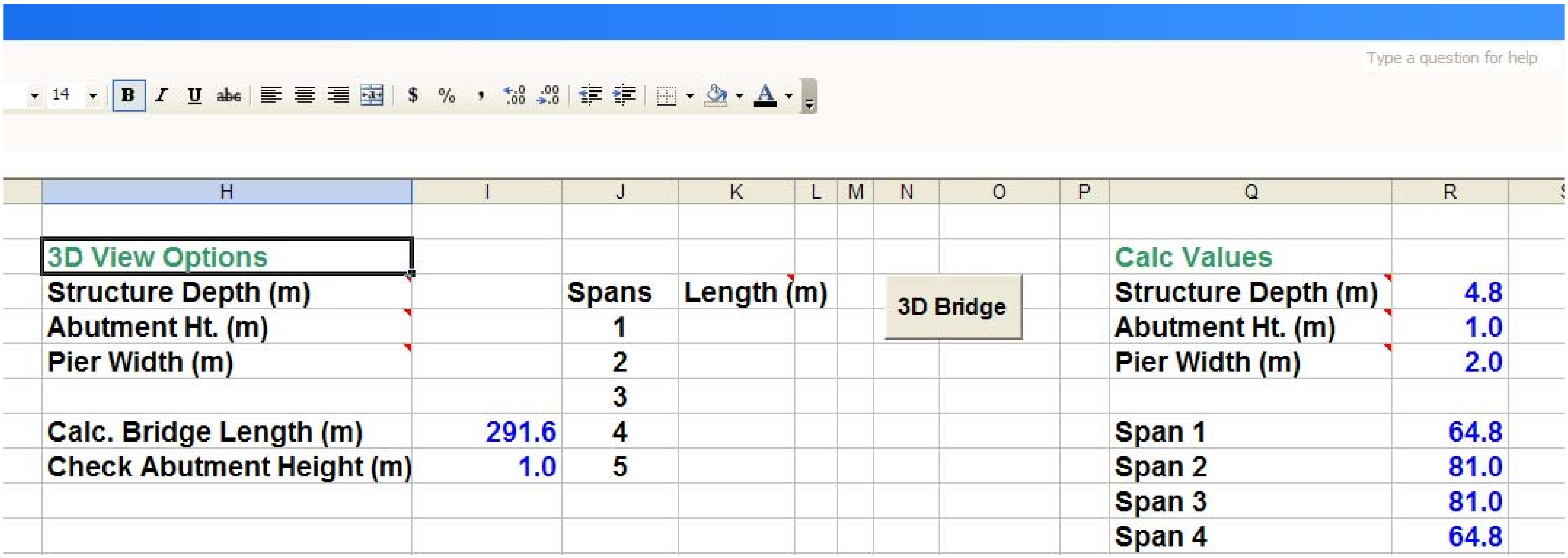


# Bridge Structure Geometry

# Bridge Structure Geometry Factors

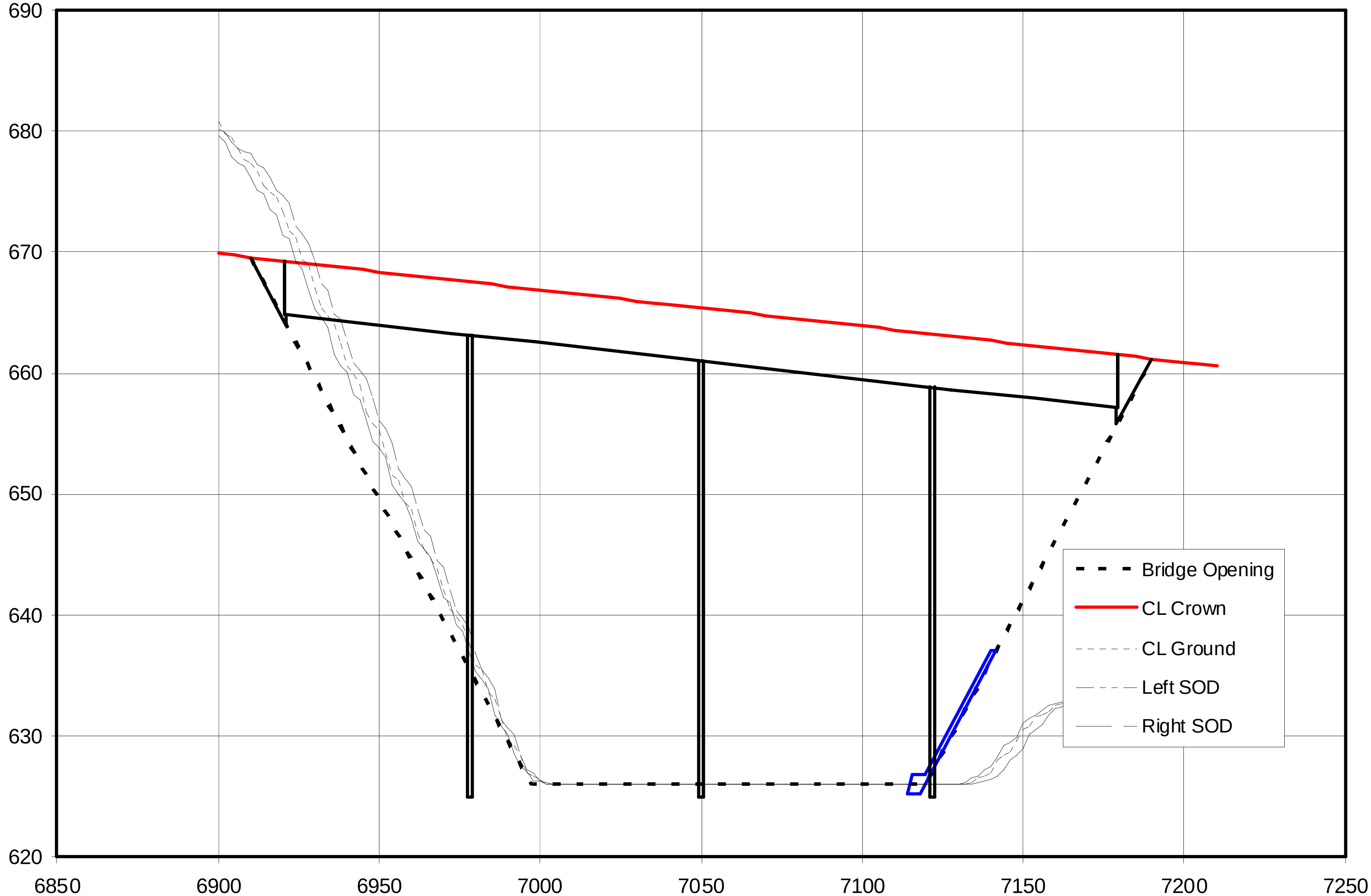
- Check grades, XS at bridge ends
- Visually check flow alignment, skew in 3D
- ID potential span options
  - No. Spans, Piers
  - Span lengths – structure options
- Pier location issues
  - Drift, ice – blockage potential
  - Construction berm extents
  - Bank proximity – blockage, erosion

# Bridge Geometry - Input

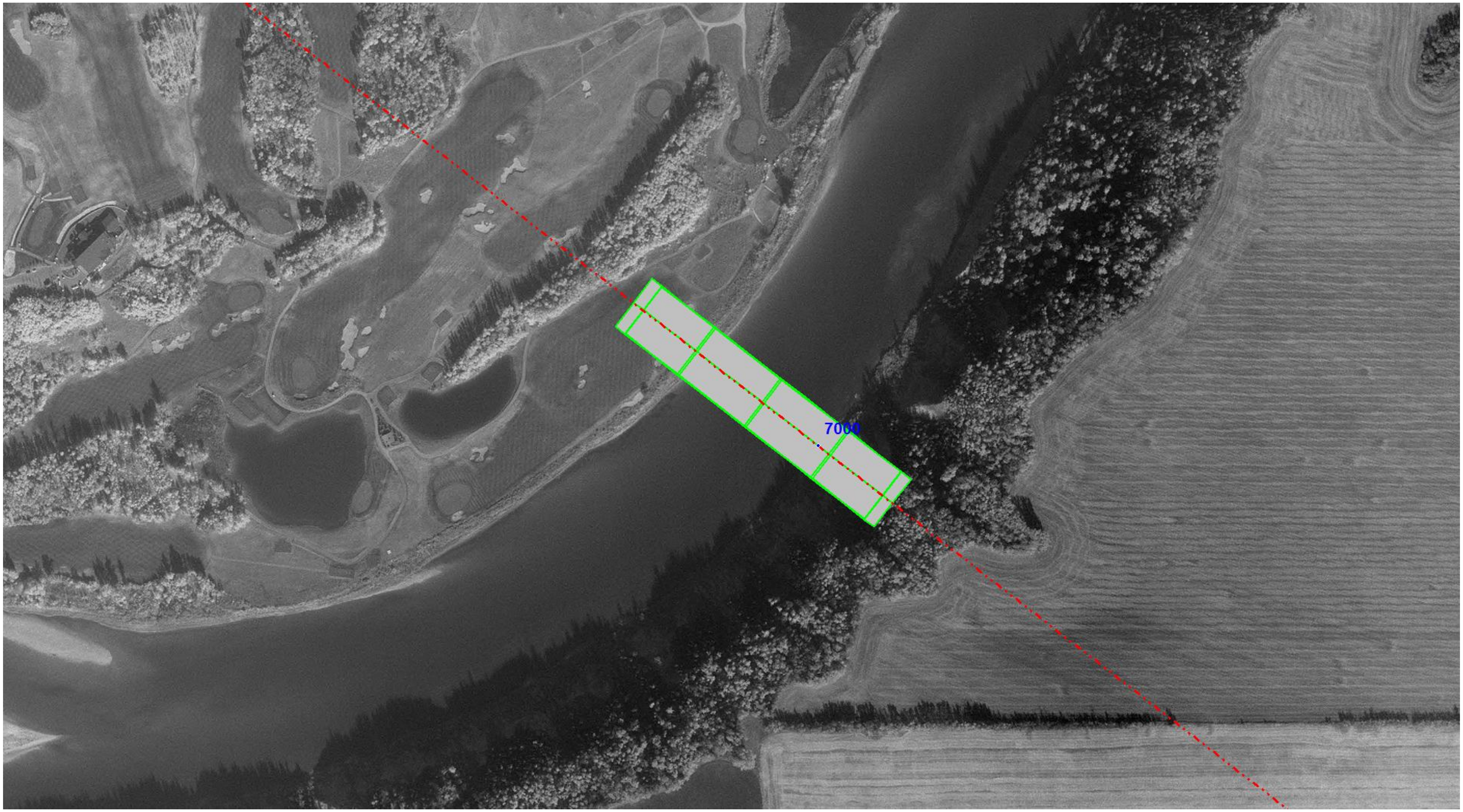



| H | I | J | K | N | Q | R |
|---|---|---|---|---|---|---|
| 3D View Options | | | | | Calc Values | |
| Structure Depth (m) | | Spans | Length (m) | 3D Bridge | Structure Depth (m) | 4.8 |
| Abutment Ht. (m) | | 1 | | | Abutment Ht. (m) | 1.0 |
| Pier Width (m) | | 2 | | | Pier Width (m) | 2.0 |
| | | 3 | | | | |
| Calc. Bridge Length (m) | 291.6 | 4 | | | Span 1 | 64.8 |
| Check Abutment Height (m) | 1.0 | 5 | | | Span 2 | 81.0 |
| | | | | | Span 3 | 81.0 |
| | | | | | Span 4 | 64.8 |

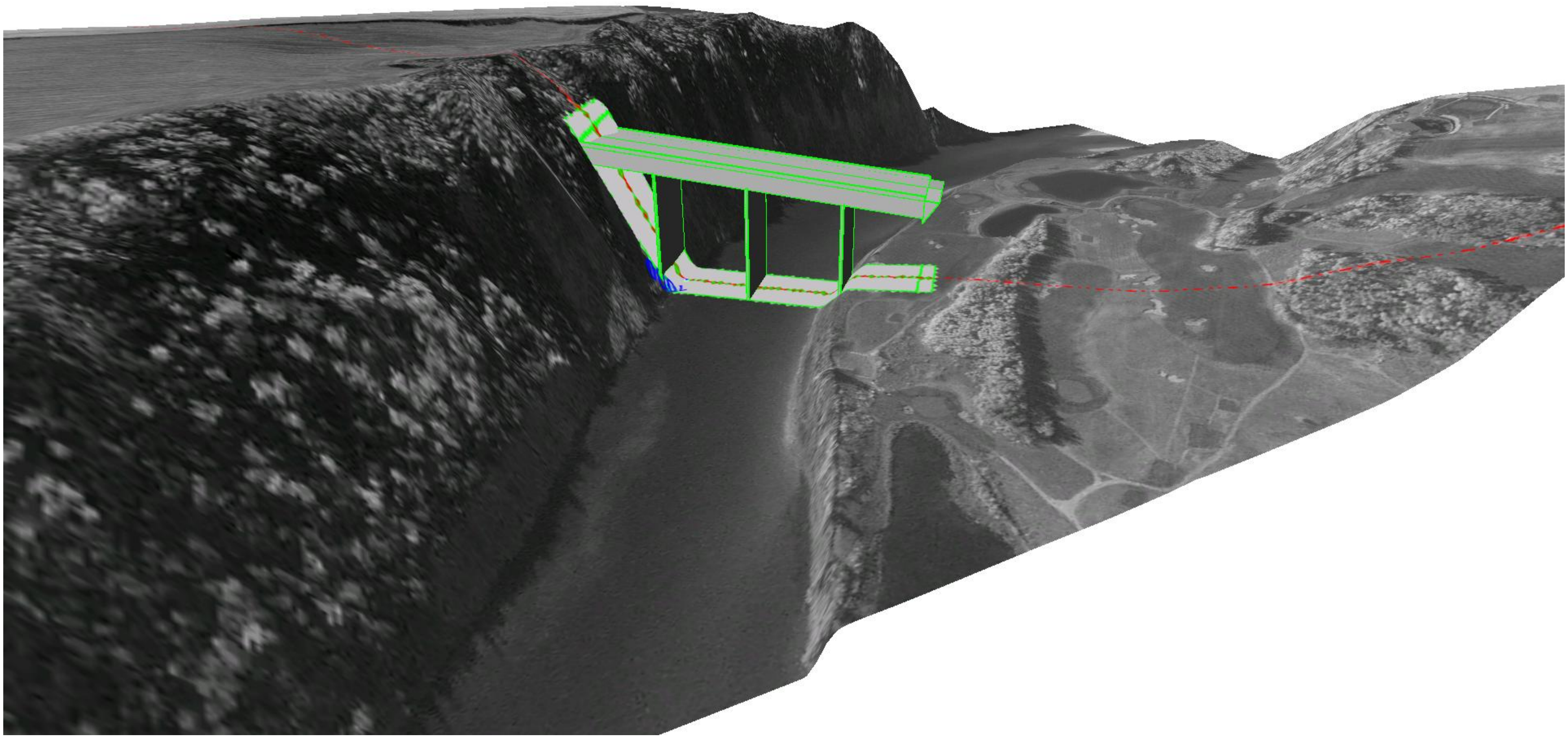
# Bridge Geometry – Elevation View



# Bridge Geometry - Plan



# Bridge Geometry – 3D



# Grading Volume

# Grading Volume Factors

- Grading Volume Costs
  - Alignment
  - Profile
  - Bridge Length
  - XS
- Feasibility
  - Depth of cut, Height of fill – geotechnical stability
  - Lateral Extent of impact – land, river, wetland, development
- Issues
  - Balance cut and fill
  - Borrow Source / Waste areas

# Grading Volume - Input

| | |
|---|---|
| **Cross Section Parameters** | |
| Design Road Width (m) | 60 |
| Road Sideslope Ratio (H:V) | 3 |
| Backslope Ratio (H:V) | 3 |
| Ditch Depth (m) | 1.5 |
| Ditch Width (m) | 4 |
| Sideslope Transition Location (m) | 100 |
| Sideslope Transition Length (m) | 20 |

| | |
|---|---|
| **XS Data and Plot** | |
| STA | 6700.000 |
| Left Limit | -106.4 |
| Right Limit | 94.3 |
| Area - Fill | 0.0 |
| Area - Cut | 2557.0 |

Go XS

| | |
|---|---|
| **Road Grading Volume** | |
| STA 1 | 4600.000 |
| STA 2 | 9200.000 |
| Vol. Fill | 849455 |
| Vol. Cut | 4135113 |

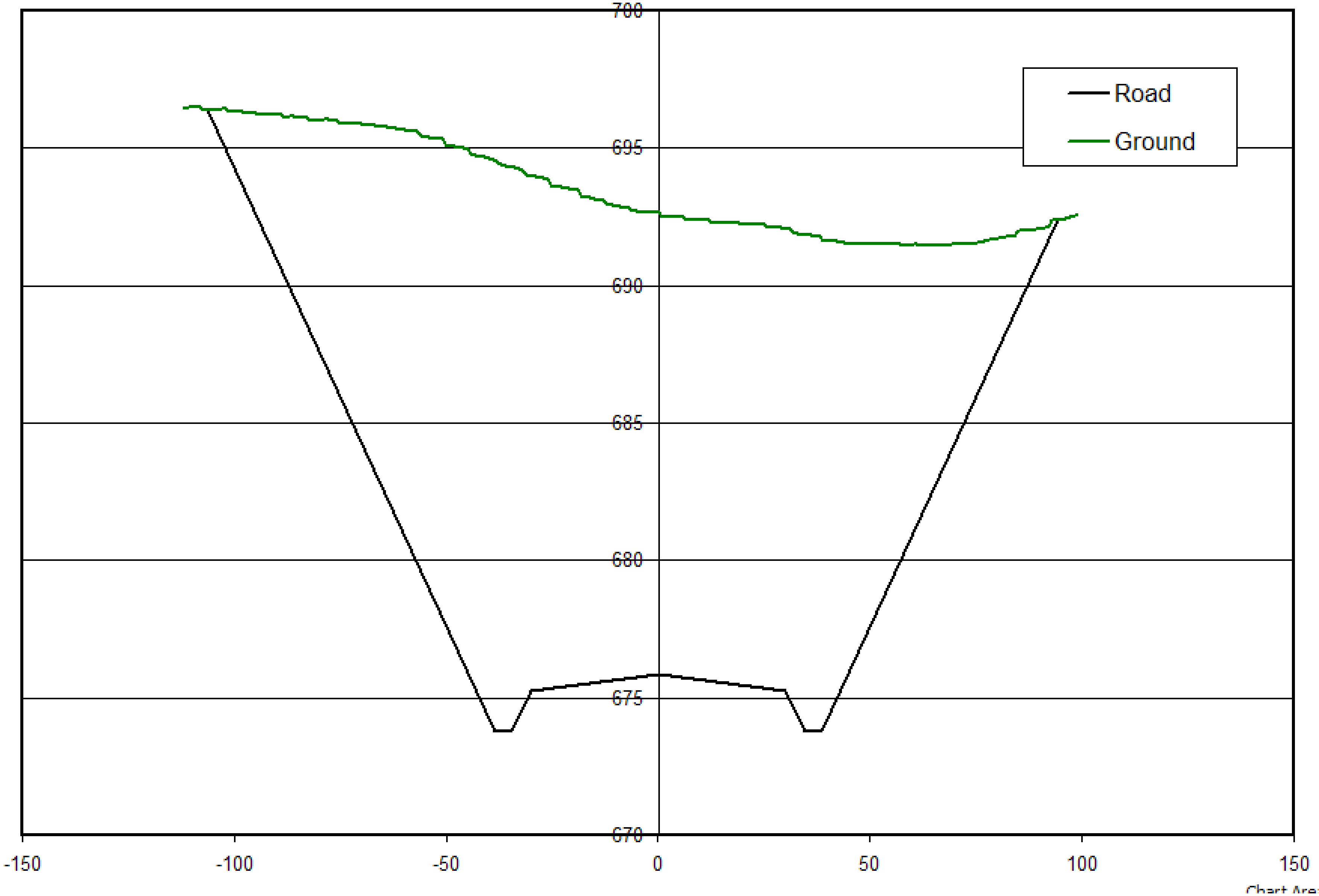
Go Vol

Make Grading Limits File

Make 3D Road Vector File

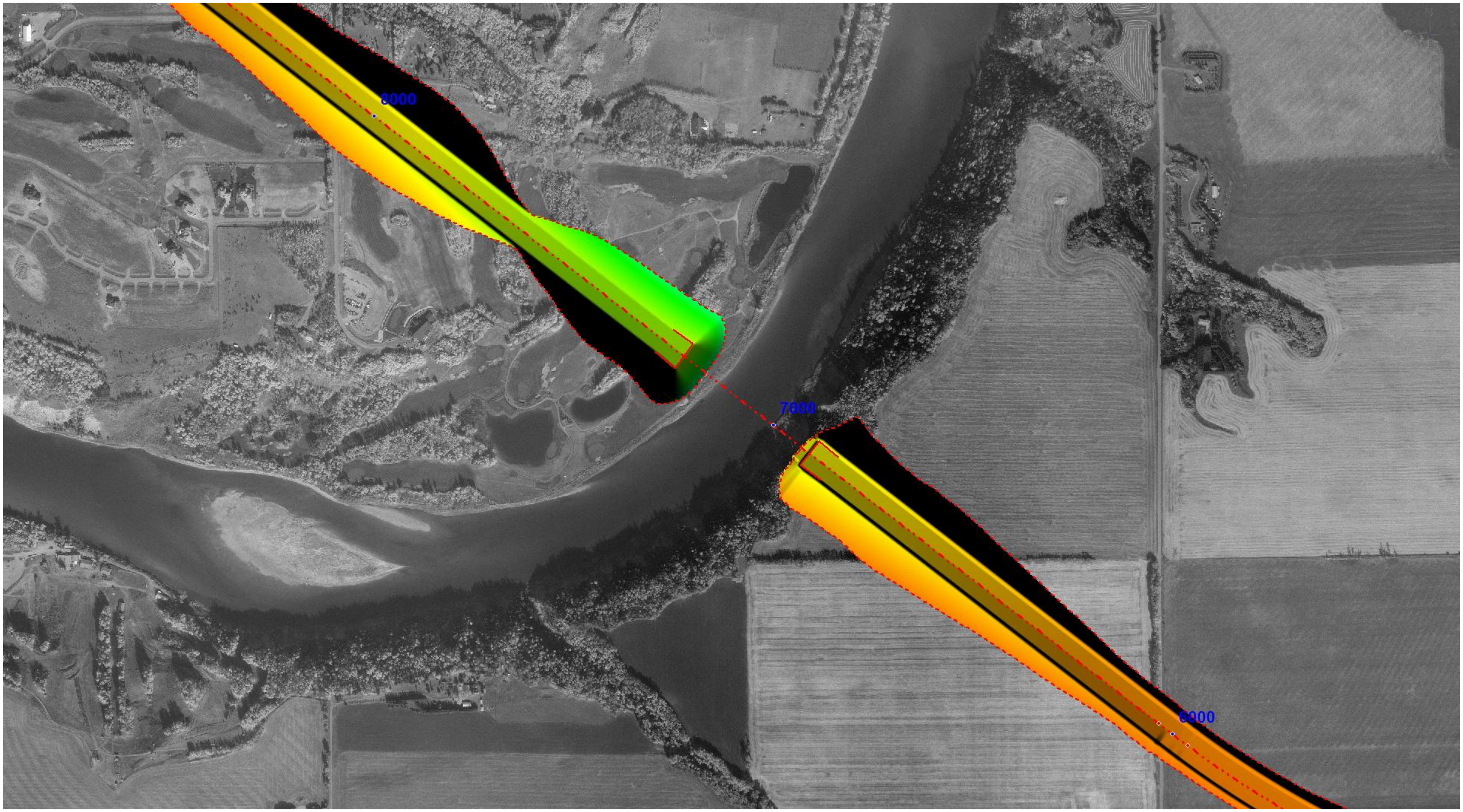
Make 3D Road Pts File

# XS Plot

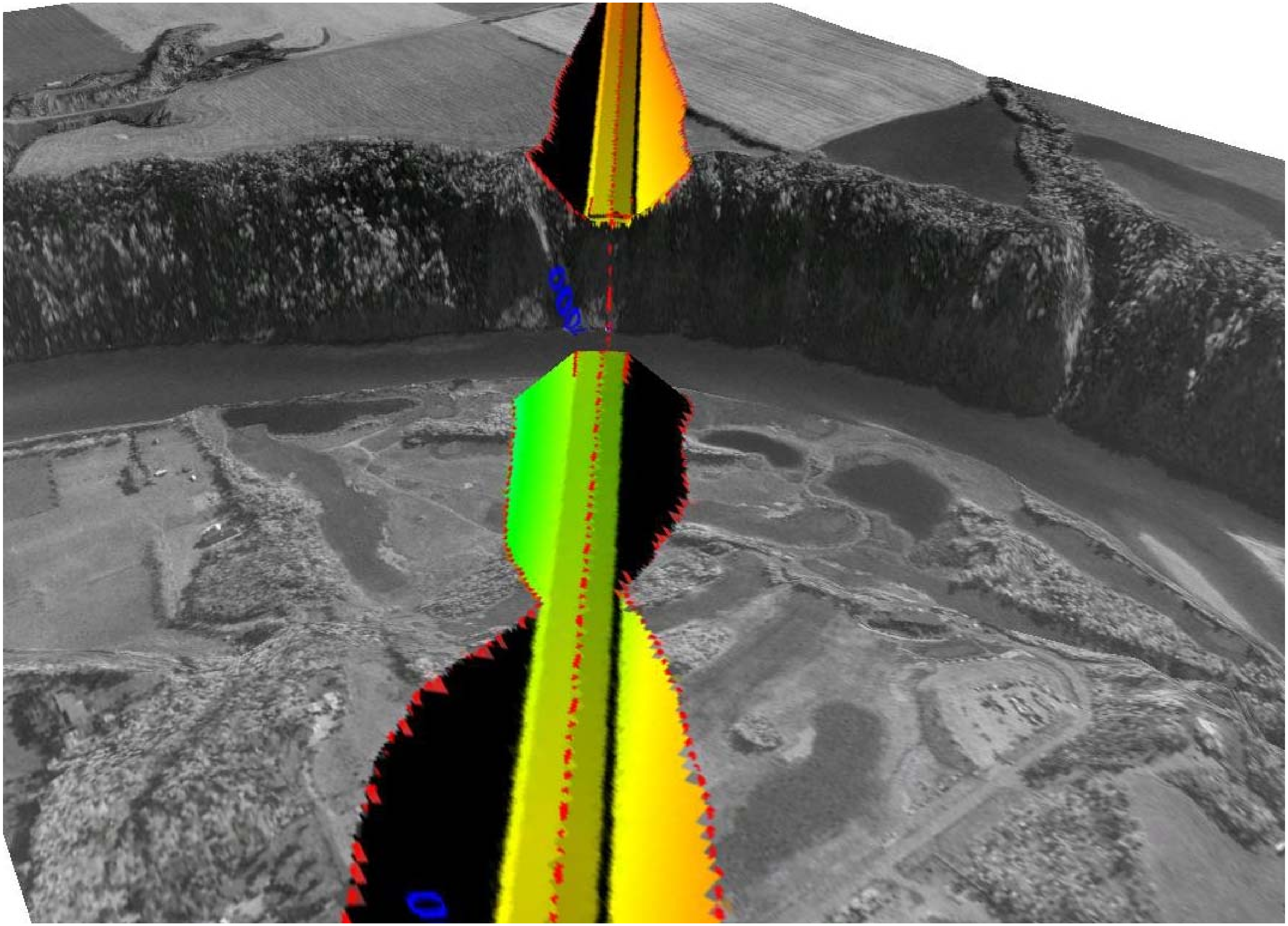


# Grading Limits

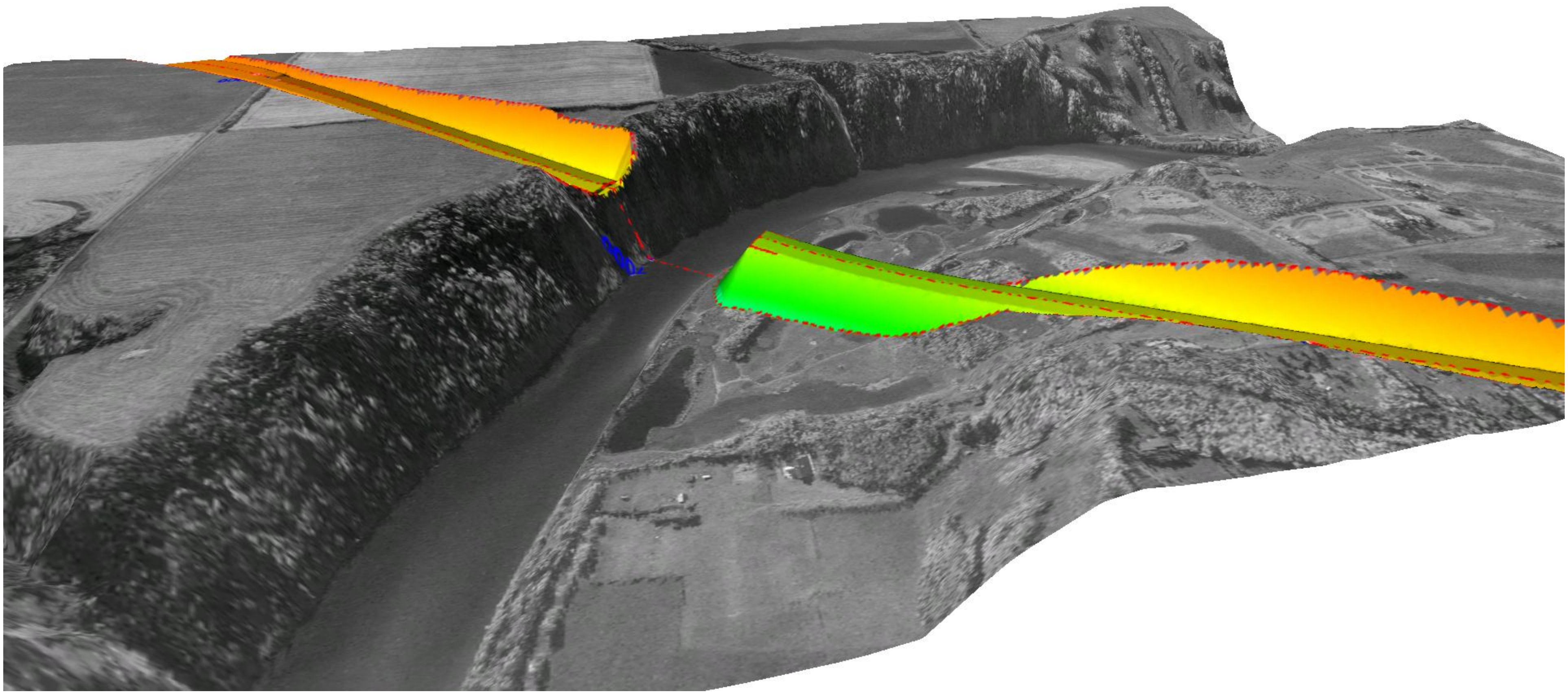
# 3D Grading Plan



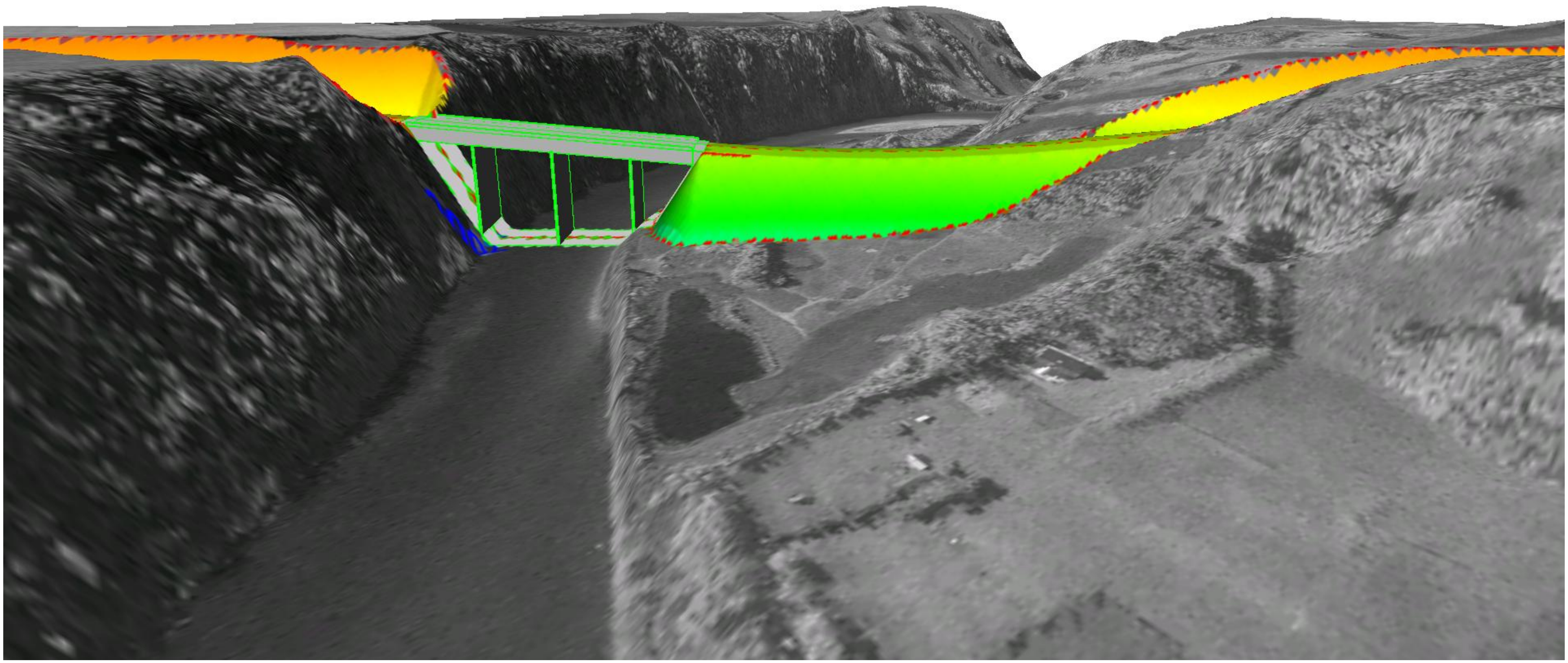
# 3D Grading View – Along Hwy



# 3D Grading View – Along Stream



# 3D Grading View – Bridge

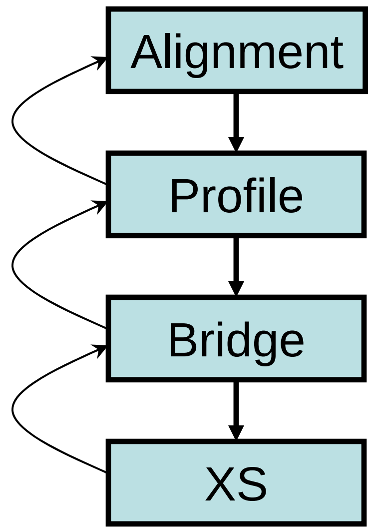


Application

# Study Types

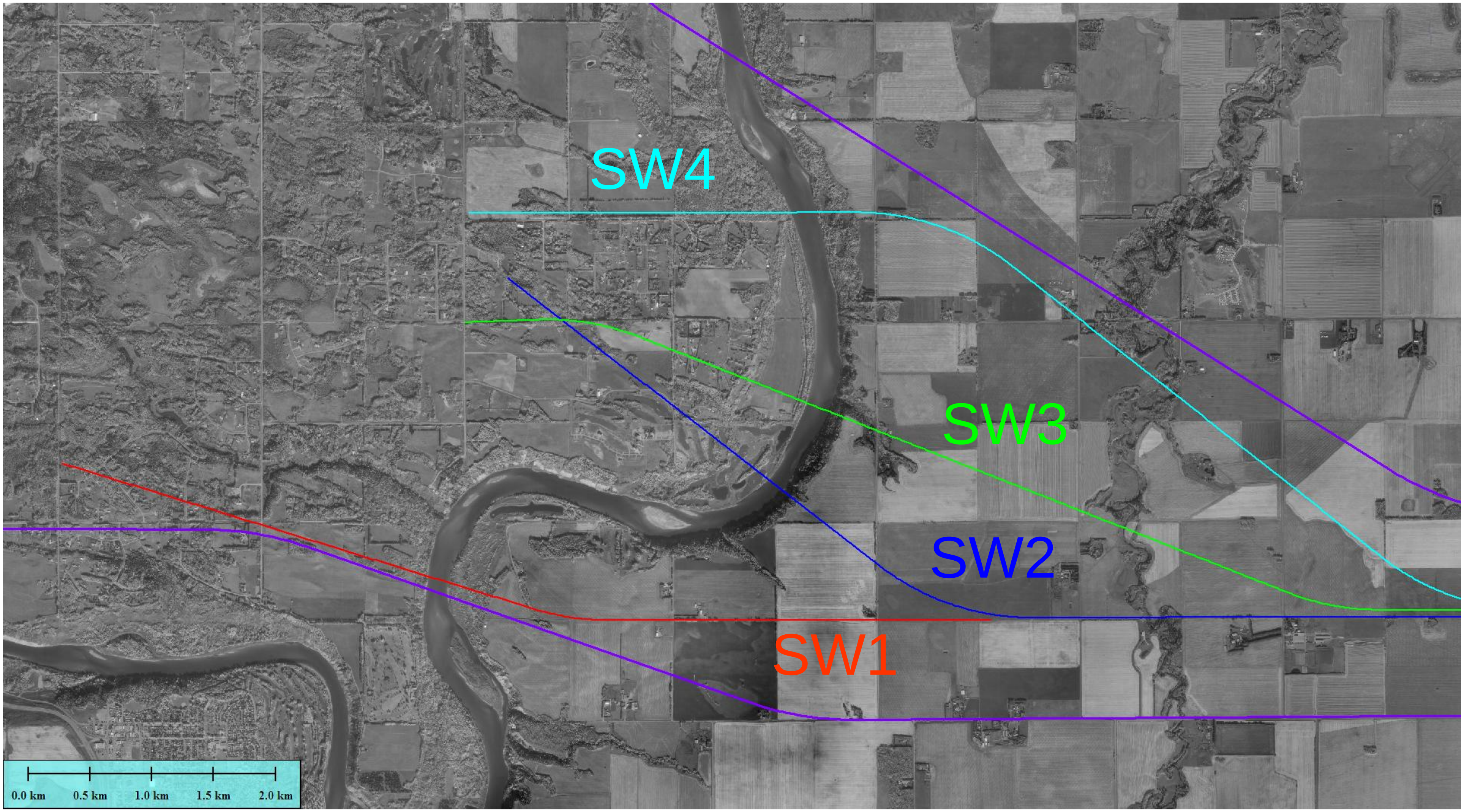
- Bridge Location Studies
  - Develop and Compare Alignment Options
- Participate in FPS
  - Interact with Roadway Planning
- Design - Bridge Planning Phase
  - Optimize bridge plan
  - Assist DD Drafting - CAD ready files

# Work Flow




- Many Combinations of Alignment, Profile, and Bridge
- Iterative Process To Develop a Feasible Option
- Many Steps to Develop Optimized Option for Alignment

# Alignment Options



# Alignment Comparison

| | Option | SW1 | SW2 | SW3 | SW4 |
|---|---|---|---|---|---|
| | | | | | |
| **Quantities** | Bridge Width (m) | 42 | 42 | 42 | 42 |
| | Bridge Length oto (m) | 355 | 318 | 375 | 395 |
| | Bridge Height (m) | 40 | 40 | 40 | 35 |
| | Bridge Skew (degrees) | 10 | 10 | 0 | 15 |
| | Max Span (m) | 79 | 74 | 82 | 84 |
| | Fill (1000m$^3$) | 385 | 830 | 1170 | 130 |
| | Cut (1000m$^3$) | 4530 | 4030 | 2890 | 2860 |
| | Rock (m$^3$) | 0 | 0 | 0 | 0 |
| | | | | | |
| **Costs ($M)** | Height factor | 1.40 | 1.40 | 1.40 | 1.35 |
| | Span Factor | 1.13 | 1.10 | 1.15 | 1.17 |
| | Bridge | 106.2 | 92.3 | 114.1 | 118.0 |
| | Grading | 52.1 | 43.4 | 27.7 | 33.5 |
| | Rock | 0.0 | 0.0 | 0.0 | 0.0 |
| | **Total** | **158.3** | **135.7** | **141.8** | **151.5** |