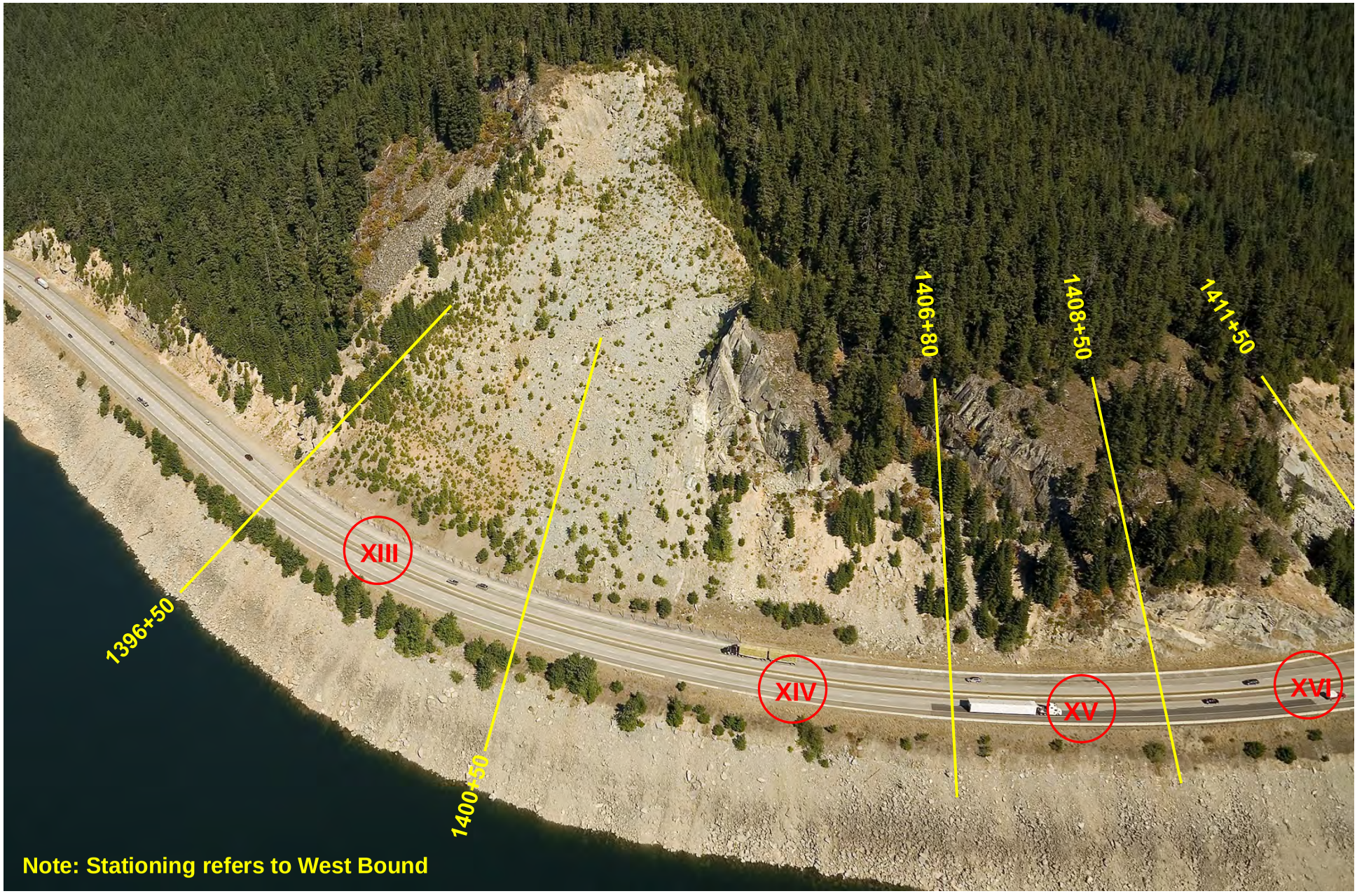
Figures

Figure 1

LOCATION MAP

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

Project No. 062-2002 **Date:** September 2008



Project No. 062-2002 Date: May 2008

Figure 2

Slide Curve - Rock Slope Design Sectors

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CADISubTasks\SCD\WN - SCD Figure 3 Topo Plan.dwg 01/08/2009, 08:29 Layout: Figure 3 Topo Plan

A Fig 7
B Fig 8
C Fig 9
D Fig 10
E Fig 11
F Fig 12
G Fig 13
H Fig 14
J Fig 15
K Fig 16
L Fig 17

Design Sector XIII
Stations 1396+50 to 1400+50

Design Sector XIV
Stations 1400+50 to 1406+00

Design Sector XV
Stations 1406+00 to 1408+50

Design Sector XVI
Stations 1408+50 to 1411+50

H-102-06 (2)
SI-05-07 (2)
Fissure #3
(4) SI-04-07
Fissure #2
H-110-06 (3)
(3) H-108-06
Fissure #1
H-107-06 (3)
(2) SI-03-07
(1) SI-12-07
(4) SI-01-07
SI-02-07 (4)
SEEP
SI-06-07 (1)
SI-07-07 (2)
RKS-19-07 (2)
SI-08-07 (4)
(2) H-103-06
SI-09-07 (4)
SI-10-07 (1)
RKS-20-07 (1)
H-101-06 (3)
SI-11-07 (1)
(1) RKS-21-07
(1) RKS-22-07
RKS-23-07 (2)
RKS-24-07 (1)
RKS-25-07 (1)
(1) RKS-26-07
(1) RKS-28-07
RKS-27-07 (2)
H-106-06 (2)
H-109-06 (1)
RKS-31-07 (1)
(2) H-105-06
RKS-30-07 (1)
RKS-29-07 (1)

1395
1400
1405
1410

0 50 100
SCALE IN FEET

Explanation

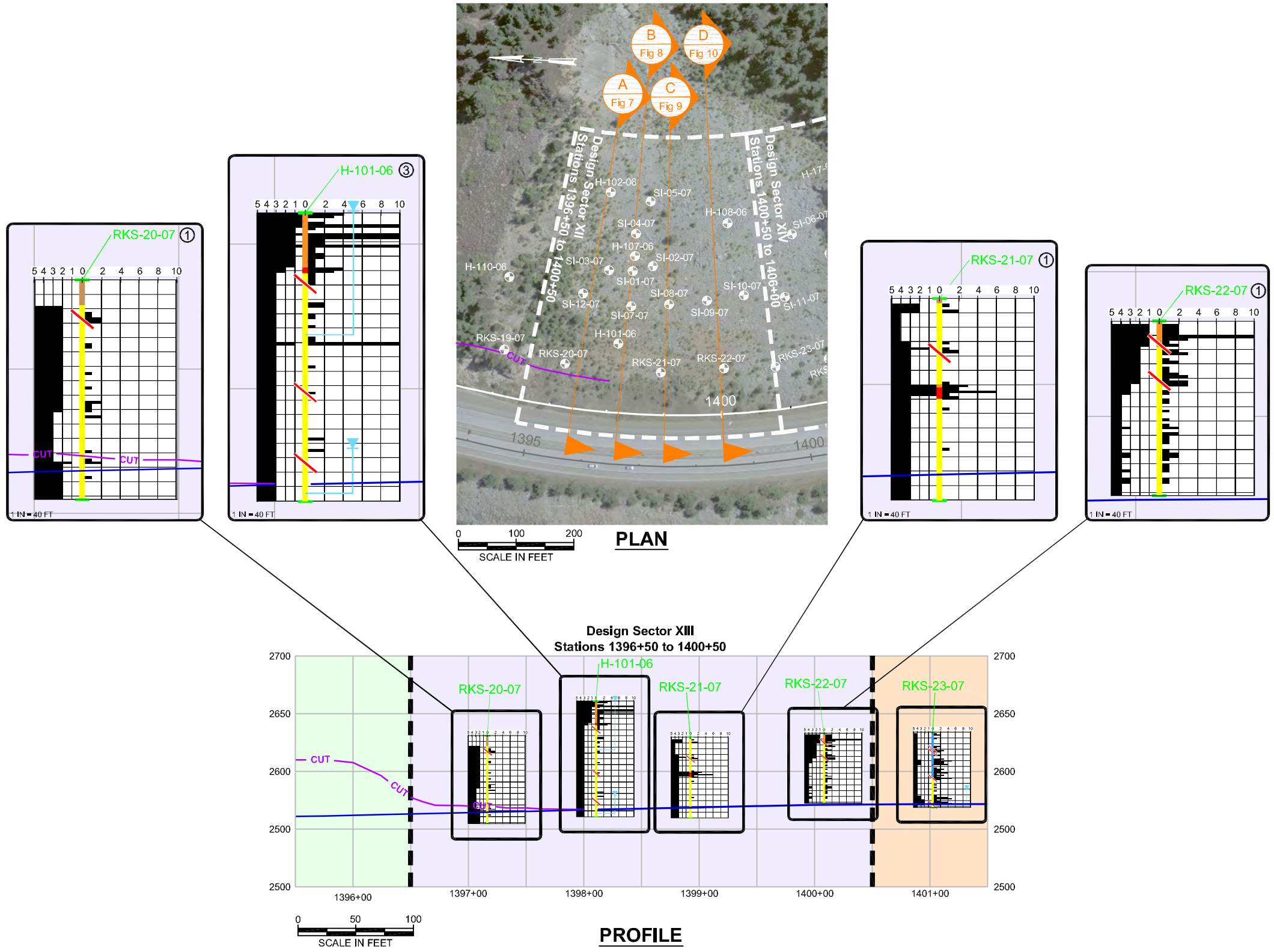
- Borehole
- H-xxx-06 — 2006 Fessibility Study
- RKS-xx-07 — 2007 Design Study
- SI-xx-07 — 2007 Scarp Investigation
- Seep
- CUT — Catch Line for Top-of-Cut (Subject to Revision Based on Overburden Template)
- Fissure

Instrumentation

- (1) No Instrumentation
- (2) VWPs Only
- (3) VWPs and TDR
- (4) Slope Inclinometers

VWP = Vibrating Wire Piezometer
TDR = Time Domain Reflectometer

FIGURE **3**
SITE PLAN AND BOREHOLE LOCATIONS
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Borehole Explanation

WSDOT Rock Strength / Fracture Frequency (F/ft)

5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type

- Overburden
- Domain 1
- Domain 2
- Domain 3
- Core Loss/Large Open or Broken Zone
- Significant Discontinuity

Piezometer

- Minimum Water Depth (11/03/06 to 5/27/08)
- Instrument Depth

Instrumentation

1. No Instrumentation
2. VWPs Only
3. VWPs and TDR
4. Slope Inclinometers

Plan and Profile Explanation

- Borehole
- CUT — Catch Line for Top-of-Cut (Subject to Revision Based on Overburden Template)
- Grade Line at Toe-of-Cut Slope

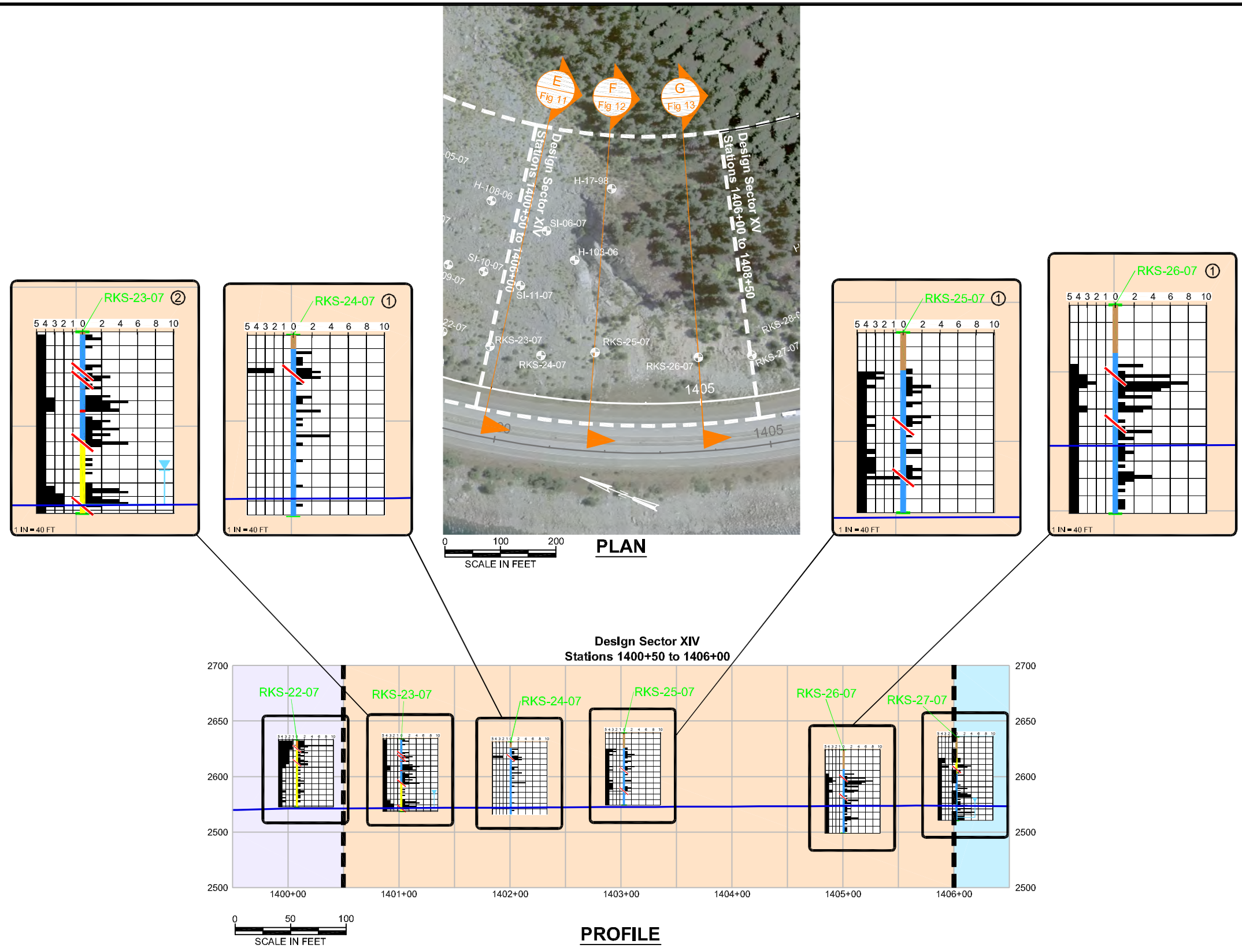
Source:
Profile Provided by WSDOT, June 10, 2008.

FIGURE **4**

DESIGN SECTOR XIII

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

K:\WSDOT I-90 Snoqualmie Pass\07000 CAD\7400 Rock Slopes Investigation\CAD\SubTasks\SCD\WN - SCD Plan & Profile.dwg 01/08/2009, 10:24 Layout: Figure 4 (Sector 13)



Borehole Explanation

WSDOT Rock Strength / Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Domain 1
- Domain 2
- Domain 3
- Core Loss/Large Open or Broken Zone
- Significant Discontinuity

Piezometer
- Minimum Water Depth (11/03/06 to 5/27/08)
- Instrument Depth

Instrumentation
1. No Instrumentation
2. VWPs Only
3. VWPs and TDR
4. Slope Inclinometers

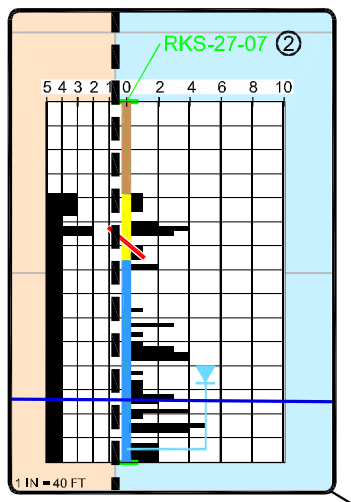
Plan and Profile Explanation

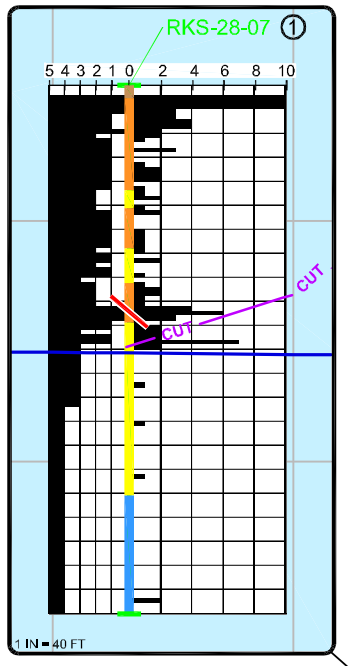
- Borehole
- CUT — Catch Line for Top-of-Cut (Subject to Revision Based on Overburden Template)
- Grade Line at Toe-of-Cut Slope

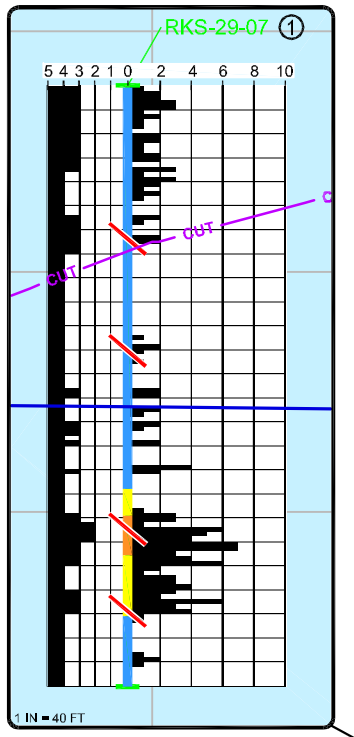
Source:
Profile Provided by WSDOT, June 10, 2008.

FIGURE **5**
DESIGN SECTOR XIV
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

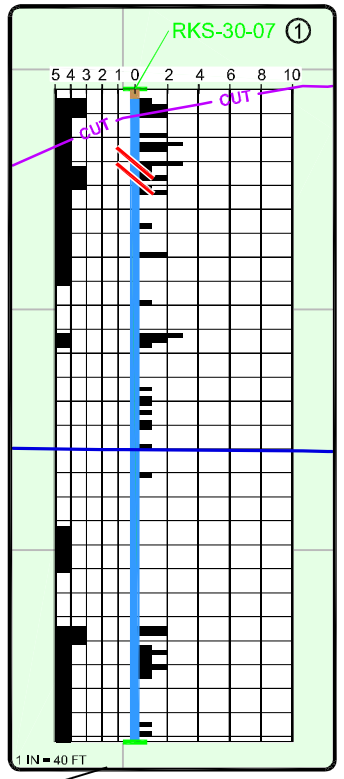
K:\WSDOT I-90 Snoqualmie Pass\07000 CAD\07400 Rock Slopes Investigation\CAD\SubTasks\SCD\WN - SCD Plan & Profile.dwg 01/08/2009, 10:25 Layout: Figure 5 (Sector 14)

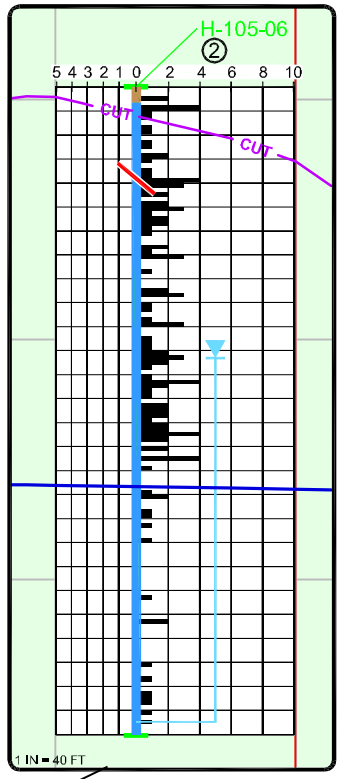


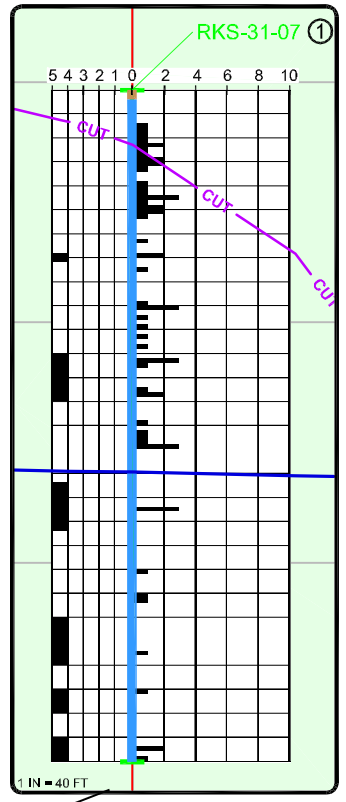


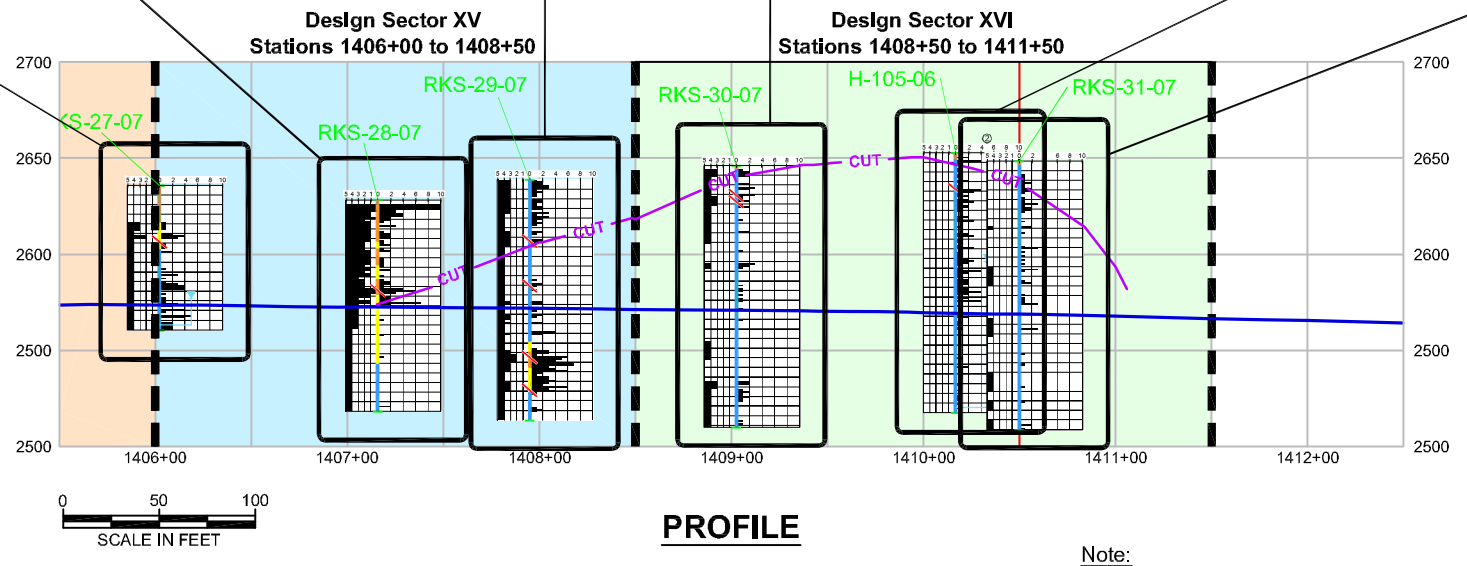


PLAN









PROFILE

Borehole Explanation

WSDOT Rock Strength / Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10
Borehole Centerline

Rock Type
- Overburden
- Domain 1
- Domain 2
- Domain 3
- Core Loss/Large Open or Broken Zone
- Significant Discontinuity

Piezometer
- Minimum Water Depth (11/03/06 to 5/27/08)
- Instrument Depth

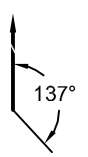
Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWPs and TDR
- ④ Slope Inclinometers

Plan and Profile Explanation

- Borehole
- CUT — Catch Line for Top-of-Cut (Subject to Revision Based on Overburden Template)
- Grade Line at Toe-of-Cut Slope

Note:
Borehole RKS-31-07 drilled at 66 degrees from horizontal at an azimuth of 137 degrees.

Azimuth Example:



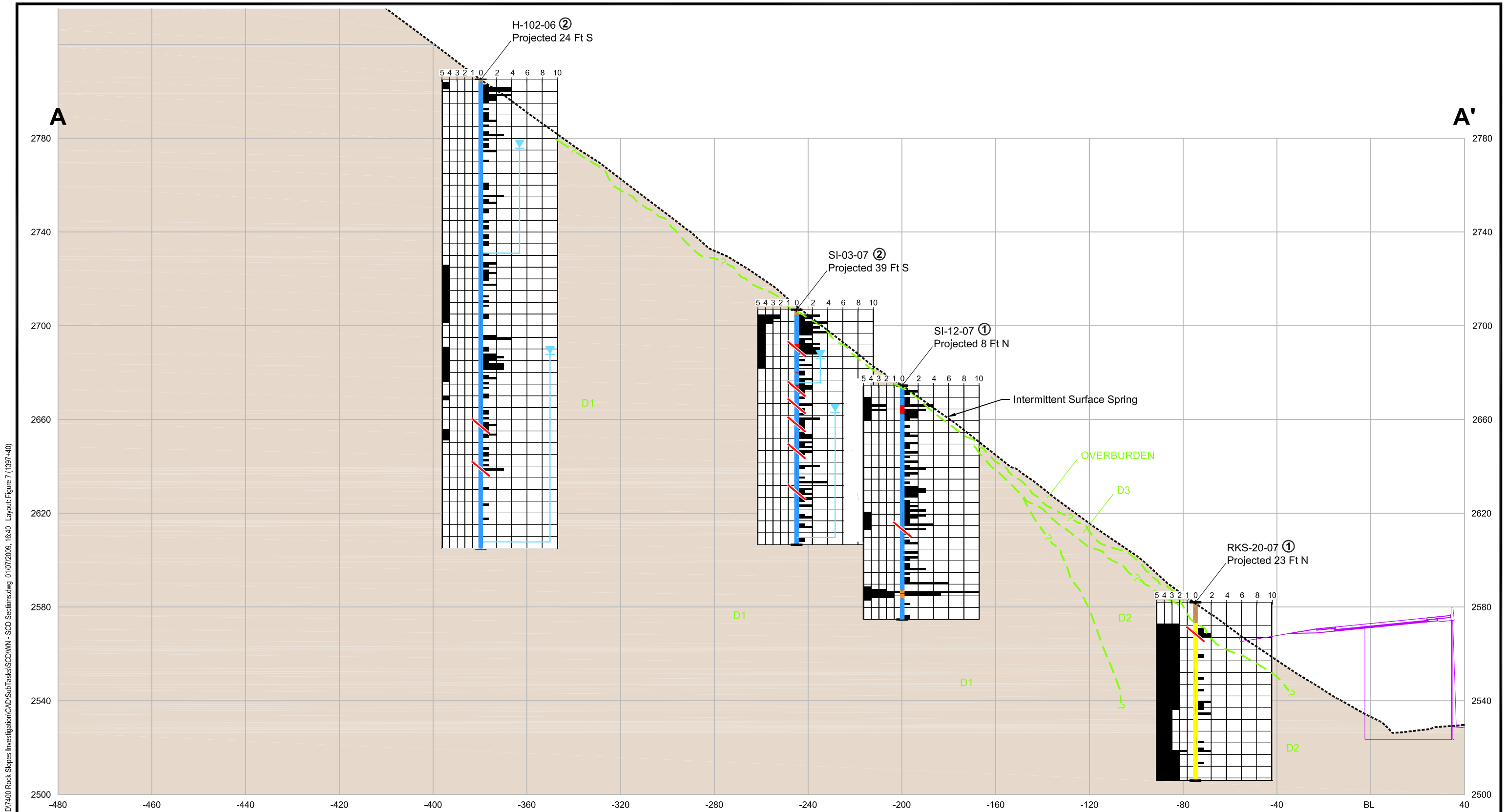
Source:
Profile Provided by WSDOT, June 10, 2008.

FIGURE **6**

DESIGN SECTORS XV AND XVI

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

K:\WSDOT I-90 Snoqualmie Pass\07000 CAD\7400 Rock Slopes Investigation\CAD\SubTasks\SCD\WN - SCD Plan & Profile.dwg 01082009, 10:26 Layout: Figure 6 (Sections 15 and 16)



Borehole Explanation

WSDOT Rock Strength / Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Domain 1
- Domain 2
- Domain 3
- Core Loss/Large Open or Broken Zone
- Significant Discontinuity

Piezometer
- Minimum Water Depth (11/03/06 to 5/27/08)
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWP's and TDR
- ④ Slope Inclinometers

General Explanation
- Geologic Inferred Contact
- D1 Inferred Rock Type
- Proposed Roadway

Notes:
1. See Figure 3 for Section Locations.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Section Provided by WSDOT, May 14, 2008.

0 40 80
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **7**

DESIGN SECTOR XIII: SECTION A-A' AT STATION 1397+40

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\SCD\WN - SCD Sections.dwg 01/07/2009, 16:40 Layout: Figure 7 (1397+40)

B

B'

SI-05-07 ②
Projected 39 Ft S

Scarp #2

SI-04-07 ④
Projected 10 Ft S

Scarp #1

H-107-06 ③
Projected 11 Ft S

SI-01-07 ④
Projected 8 Ft S

SI-07-07 ②
Projected 10 Ft S

H-101-06 ③
Projected 9 Ft N

D1
D2
D3
?

2780
2740
2700
2660
2620
2580
2540
2500

-480 -460 -440 -420 -400 -360 -320 -280 -240 -200 -160 -120 -80 -40 BL 40

Borehole Explanation

WSDOT Rock Strength / Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Domain 1
- Domain 2
- Domain 3
- Core Loss/Large Open or Broken Zone
- Significant Discontinuity

Piezometer
- Minimum Water Depth (11/03/06 to 5/27/08)
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWP's and TDR
- ④ Slope Inclinometers

General Explanation

- ? Geologic Inferred Contact
- D1 Inferred Rock Type
- Proposed Roadway

Notes:
1. See Figure 3 for Section Locations.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Section Provided by WSDOT, May 14, 2008.

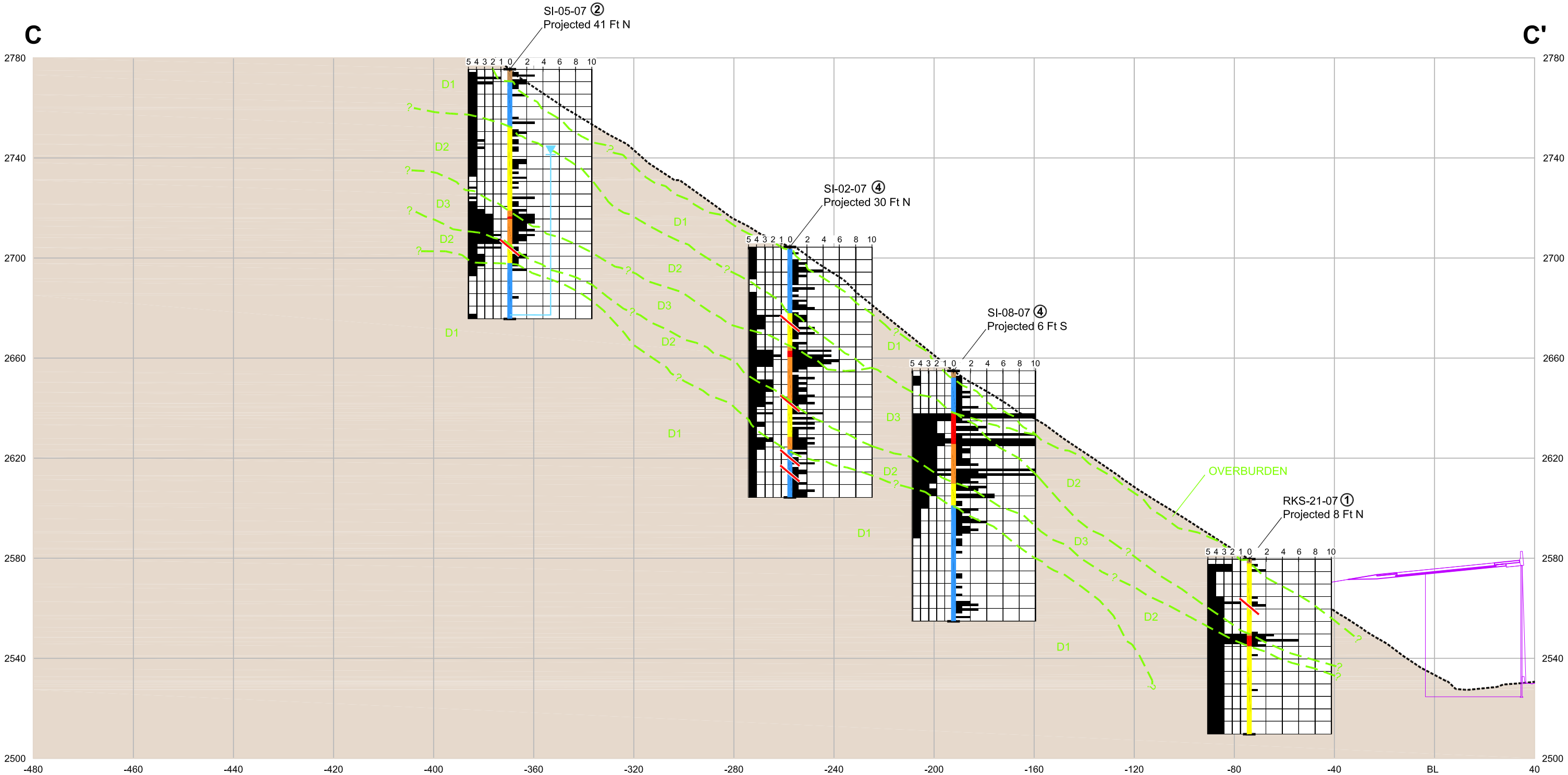
0 40 80
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **8**

DESIGN SECTOR XIII: SECTION B-B' AT STATION 1398+20

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\SCD\WN - SCD Sections.dwg 01/07/2009, 16:41 Layout: Figure 8 (1398+20)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type: Overburden; Domain 1; Domain 2; Domain 3; Core Loss/Large Open or Broken Zone; Significant Discontinuity

Piezometer: Minimum Water Depth (11/03/06 to 5/27/08); Instrument Depth

Instrumentation: ① No Instrumentation; ② VWPs Only; ③ VWP's and TDR; ④ Slope Inclinometers

General Explanation

? Geologic Inferred Contact

D1 Inferred Rock Type

Proposed Roadway

Notes:
1. See Figure 3 for Section Locations.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Section Provided by WSDOT, May 14, 2008.

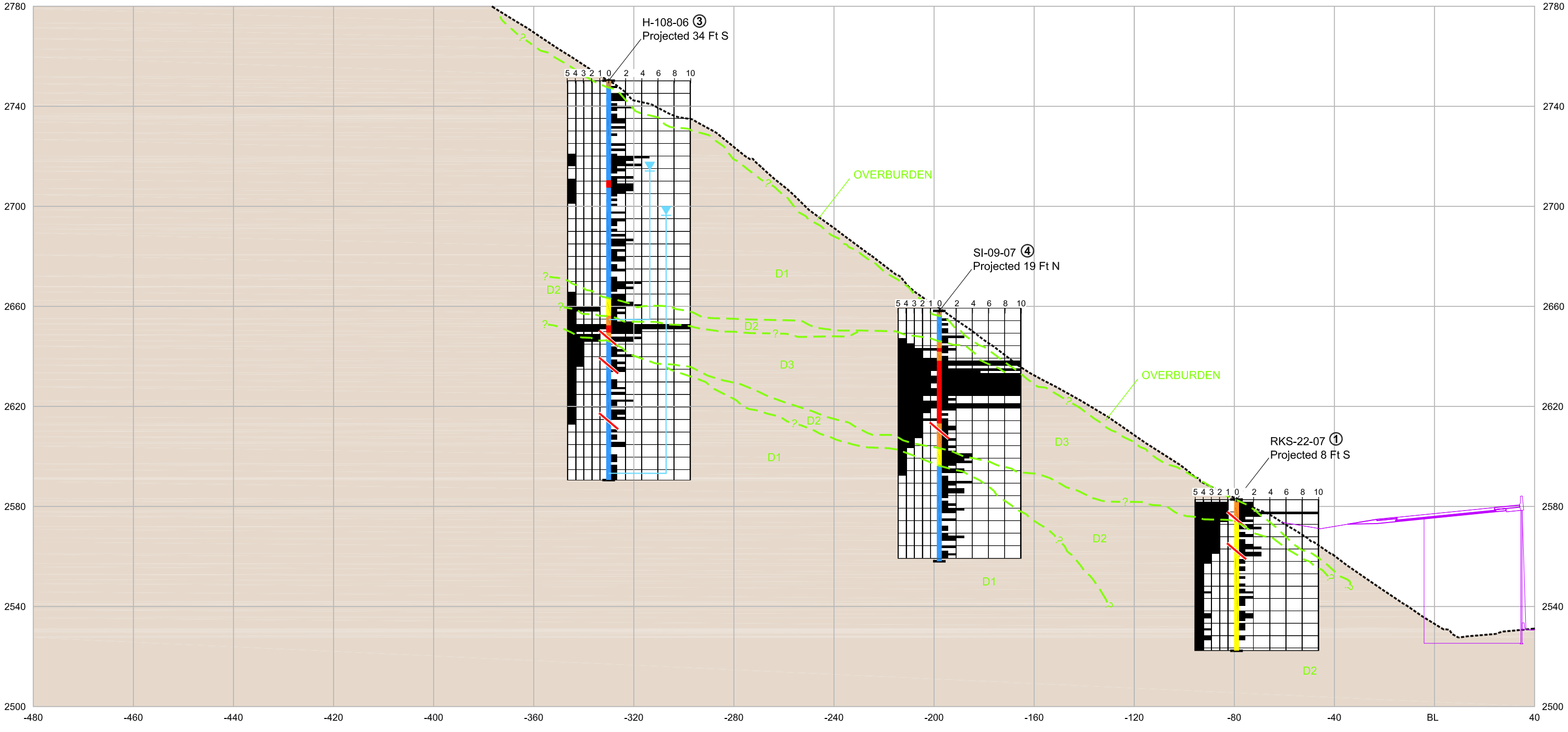
0 40 80
SCALE IN FEET
(Horizontal & Vertical)

FIGURE 9

DESIGN SECTOR XIII: SECTION C-C' AT STATION 1399+00

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\SCD\WN - SCD Sections.dwg 01/07/2009, 16:43 Layout: Figure 9 (1399+00)



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft) — 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type: Overburden; Domain 1; Domain 2; Domain 3; Core Loss/Large Open or Broken Zone; Significant Discontinuity

Piezometer: Minimum Water Depth (11/03/06 to 5/27/08); Instrument Depth

Instrumentation: ① No Instrumentation; ② VWPs Only; ③ VWP's and TDR; ④ Slope Inclinometers

General Explanation

? Geologic Inferred Contact

D1 Inferred Rock Type

Proposed Roadway

Notes:
1. See Figure 3 for Section Locations.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Section Provided by WSDOT, May 14, 2008.

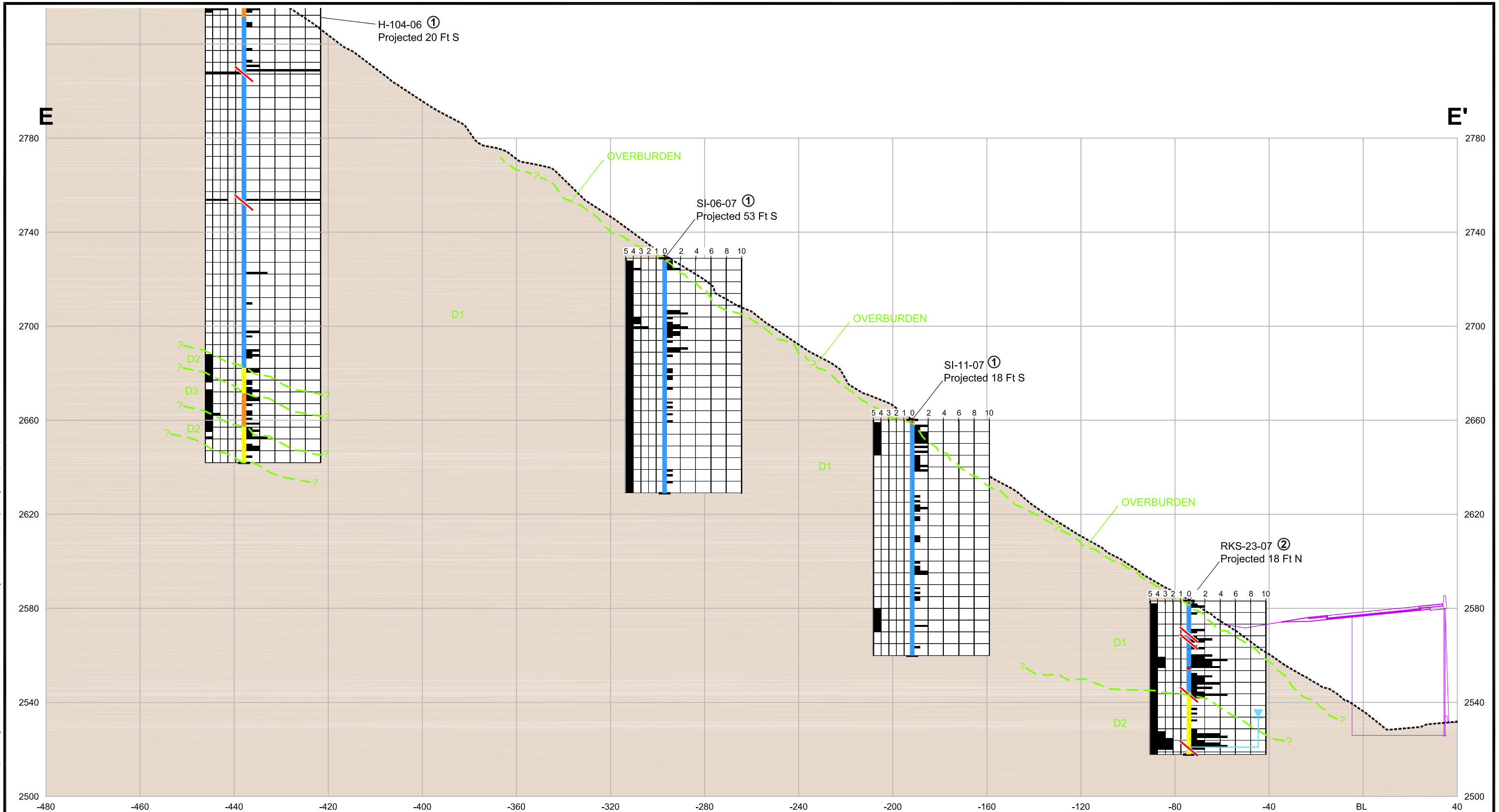
0 40 80
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **10**

DESIGN SECTOR XIII: SECTION D-D' AT STATION 1400+00

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\SCD\WN - SCD Sections.dwg 01/07/2009, 16:45 Layout: Figure 10 (1400+00)



Borehole Explanation

WSDOT Rock Strength / Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Domain 1
- Domain 2
- Domain 3
- Core Loss/Large Open or Broken Zone
- Significant Discontinuity

Piezometer
- Minimum Water Depth (11/03/06 to 5/27/08)
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWP's and TDR
- ④ Slope Inclinometers

General Explanation
- Geologic Inferred Contact
- D1 Inferred Rock Type
- Proposed Roadway

Notes:
1. See Figure 3 for Section Locations.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Section Provided by WSDOT, May 14, 2008.

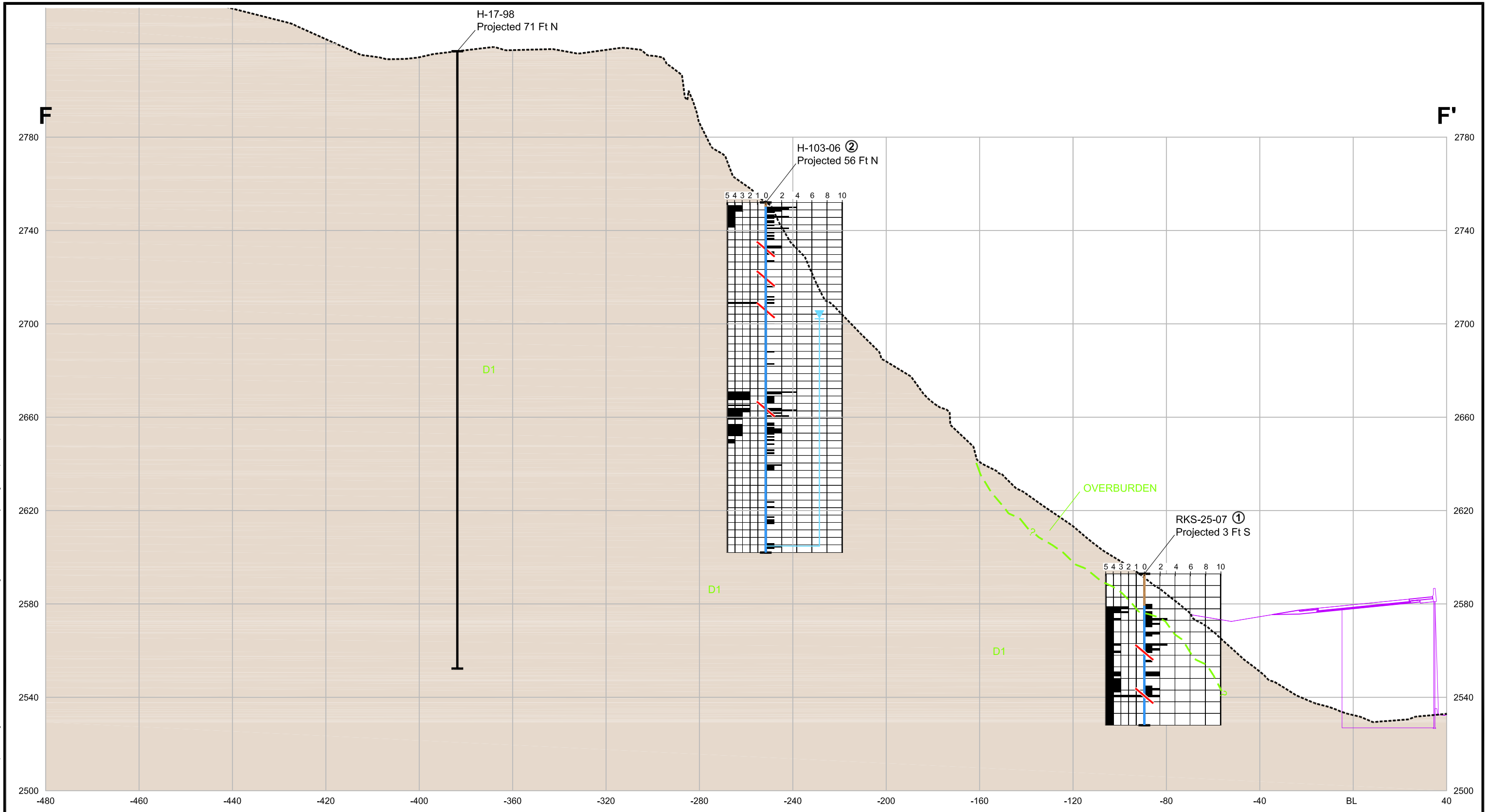
0 40 80
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **11**

DESIGN SECTOR XIV: SECTION E-E' AT STATION 1401+20

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\SCD\WN - SCD Sections.dwg 01/07/2009, 16:46 Layout: Figure 11 (1401+20)



Borehole Explanation

WSDOT Rock Strength / Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Domain 1
- Domain 2
- Domain 3
- Core Loss/Large Open or Broken Zone
- Significant Discontinuity

Piezometer
- Minimum Water Depth (11/03/06 to 5/27/08)
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWP's and TDR
- ④ Slope Inclinometers

General Explanation
- ? Geologic Inferred Contact
- D1 Inferred Rock Type
- Proposed Roadway

Notes:
1. See Figure 3 for Section Locations.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.
3. Comparable data from WSDOT borehole H-17-98 not available.

Source:
Section Provided by WSDOT, May 14, 2008.

0 40 80
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **12**

DESIGN SECTOR XIV: SECTION F-F' AT STATION 1403+00

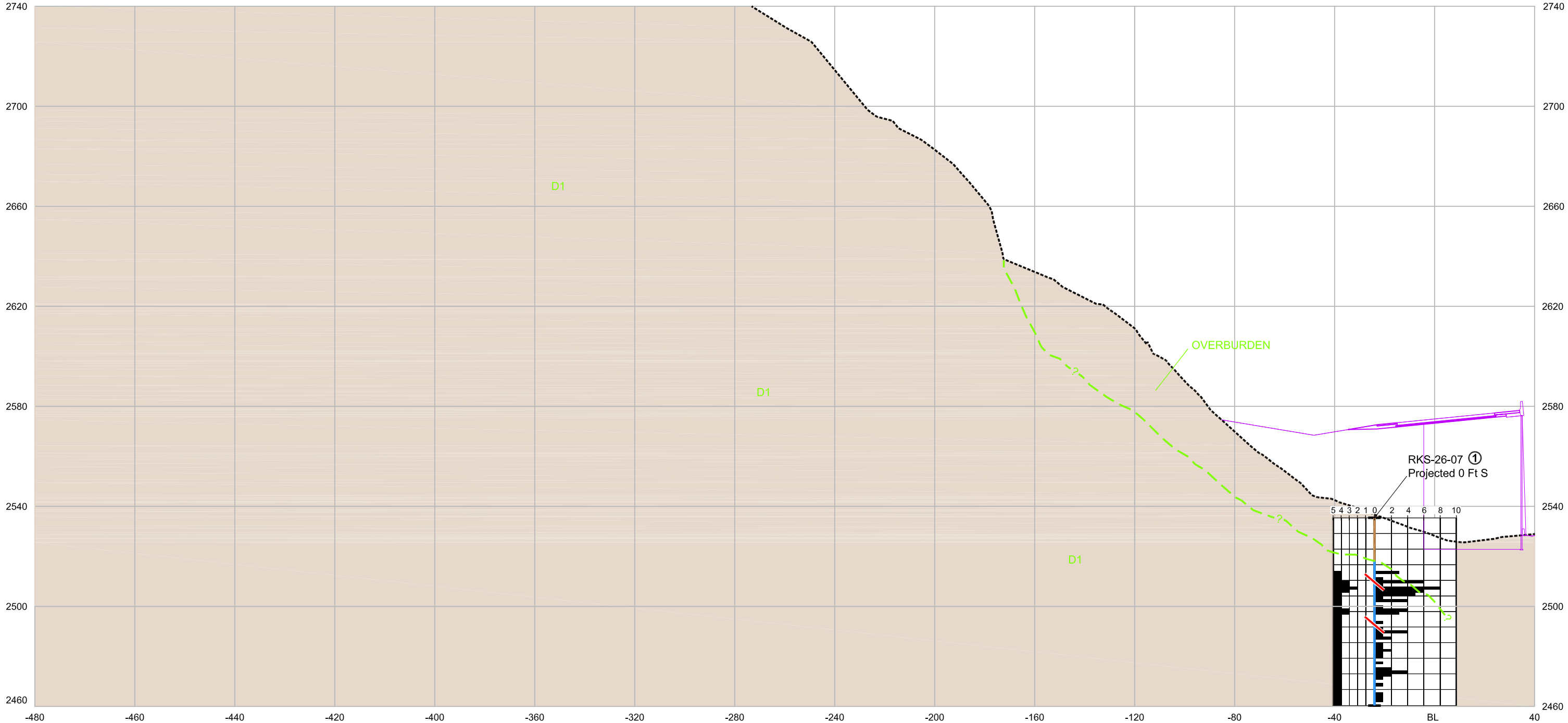
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\SCD\WN - SCD Sections.dwg 01/07/2009, 16:46 Layout: Figure 12 (1403+00)

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CADD\SubTasks\SCD\WN - SCD Sections.dwg 01/07/2009, 16:47 Layout: Figure 13 (1405+00)

G

G'



Borehole Explanation

WSDOT Rock Strength / Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Domain 1
- Domain 2
- Domain 3
- Core Loss/Large Open or Broken Zone
- Significant Discontinuity

Piezometer
- Minimum Water Depth (11/03/06 to 5/27/08)
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWP's and TDR
- ④ Slope Inclinometers

General Explanation
- ? Geologic Inferred Contact
- D1 Inferred Rock Type
- Proposed Roadway

Notes:
1. See Figure 3 for Section Locations.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Section Provided by WSDOT, May 14, 2008.

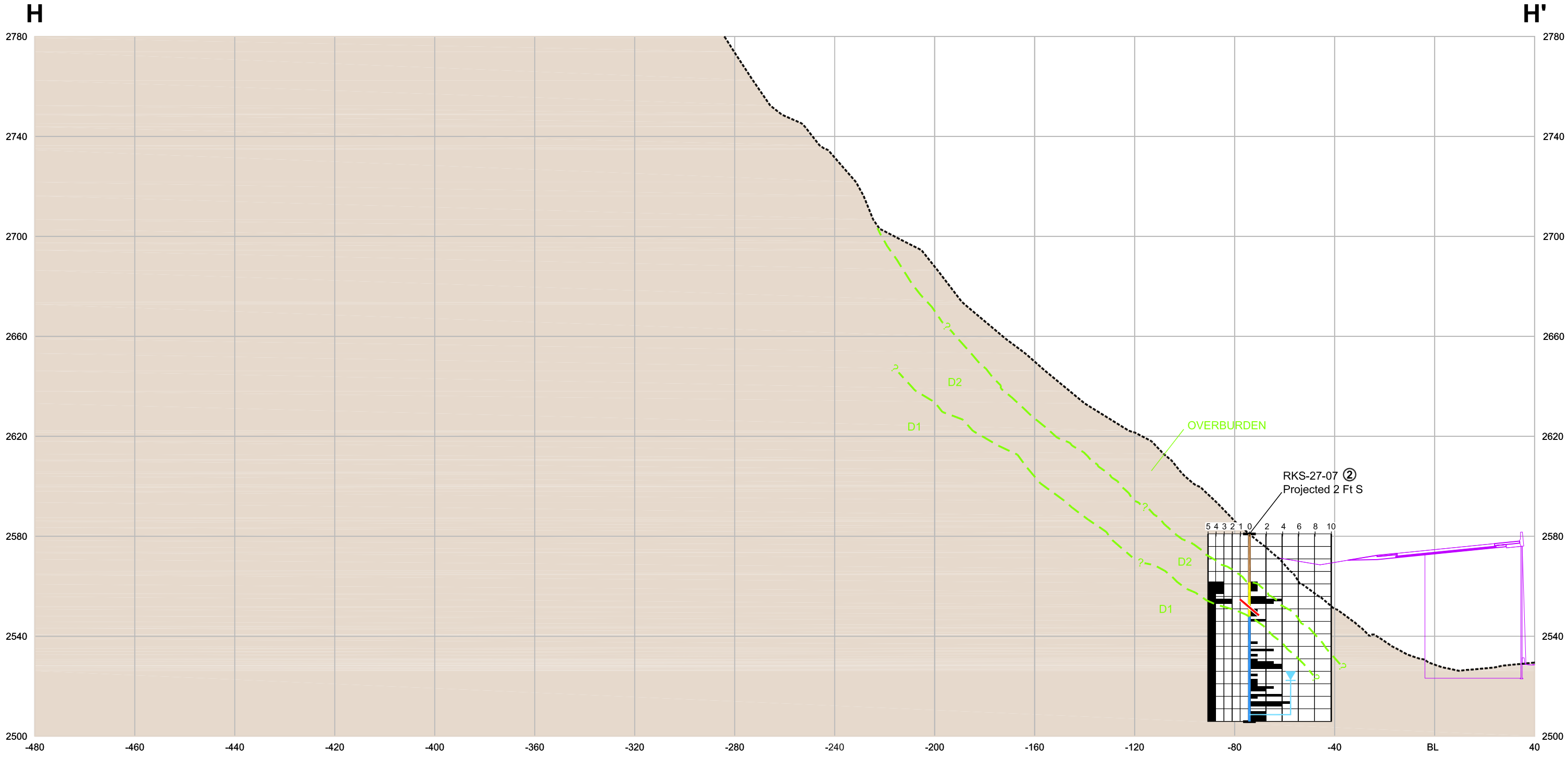
0 40 80
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **13**

DESIGN SECTOR XIV: SECTION G-G' AT STATION 1405+00

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\SCD\WN - SCD Sections.dwg 01/07/2009, 16:48 Layout: Figure 14 (1406+00)



Borehole Explanation

WSDOT Rock Strength / Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Domain 1
- Domain 2
- Domain 3
- Core Loss/Large Open or Broken Zone
- Significant Discontinuity

Piezometer
- Minimum Water Depth (11/03/06 to 5/27/08)
- Instrument Depth

Instrumentation
- ① No Instrumentation
- ② VWPs Only
- ③ VWP's and TDR
- ④ Slope Inclinometers

General Explanation
- ? Geologic Inferred Contact
- D1 Inferred Rock Type
- Proposed Roadway

Notes:
1. See Figure 3 for Section Locations.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

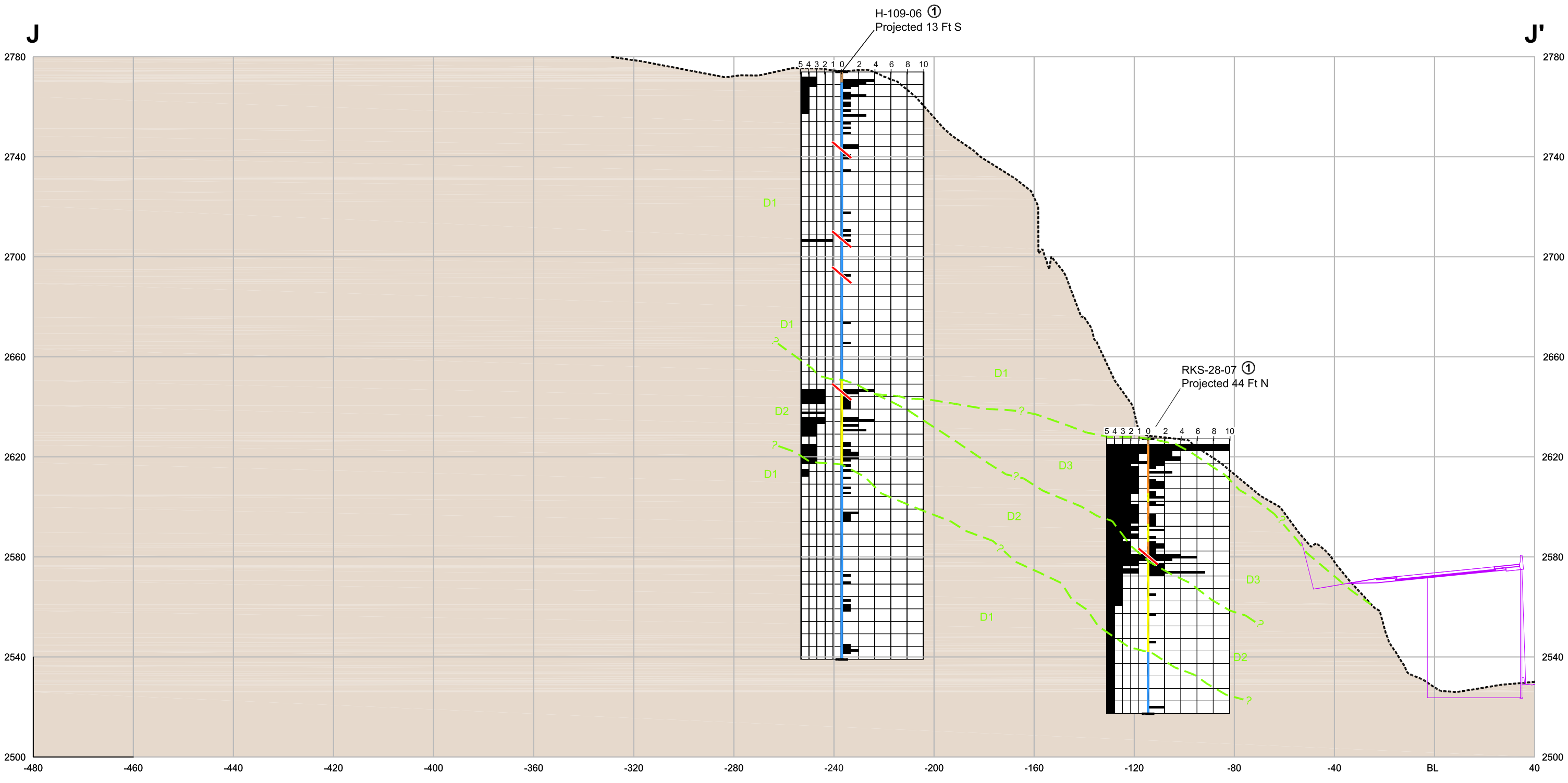
Source:
Section Provided by WSDOT, May 14, 2008.

0 40 80
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **14**

DESIGN SECTOR XV: SECTION H-H' AT STATION 1406+00

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Borehole Explanation

WSDOT Rock Strength — Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type: Overburden; Domain 1; Domain 2; Domain 3; Core Loss/Large Open or Broken Zone; Significant Discontinuity

Piezometer: Minimum Water Depth (11/03/06 to 5/27/08); Instrument Depth

Instrumentation: ① No Instrumentation; ② VWPs Only; ③ VWP's and TDR; ④ Slope Inclinometers

General Explanation

? Geologic Inferred Contact

D1 Inferred Rock Type

Proposed Roadway

Notes:
1. See Figure 3 for Section Locations.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Section Provided by WSDOT, May 14, 2008.

0 40 80
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **15**

DESIGN SECTOR XV: SECTION J-J' AT STATION 1407+60

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\SCD\WN - SCD Sections.dwg 01/07/2009, 16:49 Layout: Figure 15 (1407+60)

K

K'

H-106-06 ②
Projected 65 Ft S

RKS-30-07 ①
Projected 3 Ft S

OVERBURDEN

D1

D2

D1

D2

D1

D1

2780
2740
2700
2660
2620
2580
2540
2500

-480 -460 -440 -420 -400 -360 -320 -280 -240 -200 -160 -120 -80 -40 BL 40

Borehole Explanation

WSDOT Rock Strength / Fracture Frequency (F/ft)

5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type

- Overburden
- Domain 1
- Domain 2
- Domain 3
- Core Loss/Large Open or Broken Zone
- Significant Discontinuity

Piezometer

- Minimum Water Depth (11/03/06 to 5/27/08)
- Instrument Depth

Instrumentation

1. No Instrumentation
2. VWPs Only
3. VWP's and TDR
4. Slope Inclinometers

General Explanation

- ? Geologic Inferred Contact
- D1 Inferred Rock Type
- Proposed Roadway

Notes:
1. See Figure 3 for Section Locations.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Section Provided by WSDOT, May 14, 2008.

0 40 80
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **16**

DESIGN SECTOR XVI: SECTION K-K' AT STATION 1409+00

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\SCD\WN - SCD Sections.dwg 01/07/2009, 16:50 Layout: Figure 16 (1409+00)

L

L'

H-106-06 ②
Projected 55 Ft N

H-105-06 ②
Projected 3 Ft N

OVERBURDEN

D1

D2

2780
2740
2700
2660
2620
2580
2540
2500

-480 -460 -440 -420 -400 -360 -320 -280 -240 -200 -160 -120 -80 -40 BL 40

Borehole Explanation

WSDOT Rock Strength / Fracture Frequency (F/ft): 5 4 3 2 1 0 2 4 6 8 10

Borehole Centerline

Rock Type
- Overburden
- Domain 1
- Domain 2
- Domain 3
- Core Loss/Large Open or Broken Zone
- Significant Discontinuity

Piezometer
- Minimum Water Depth (11/03/06 to 5/27/08)
- Instrument Depth

Instrumentation
1. No Instrumentation
2. VWPs Only
3. VWP's and TDR
4. Slope Inclinometers

General Explanation

- Geologic Inferred Contact
- D1 Inferred Rock Type
- Proposed Roadway

Notes:
1. See Figure 3 for Section Locations.
2. Geologic cross-section data are inferred based on surface mapping and limited borehole results. Contacts between units are approximate and should not be used for construction purposes without verification.

Source:
Section Provided by WSDOT, May 14, 2008.

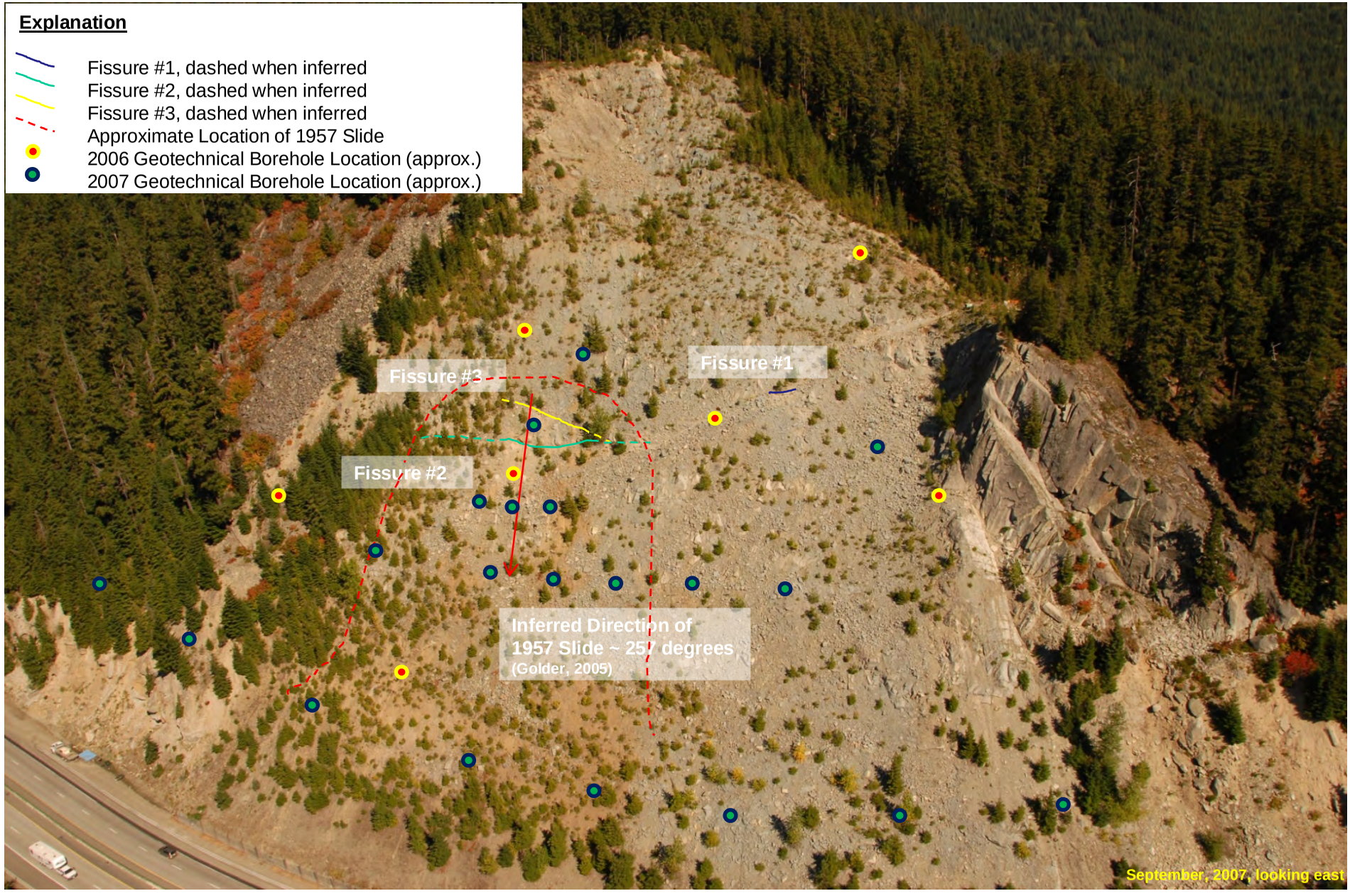
0 40 80
SCALE IN FEET
(Horizontal & Vertical)

FIGURE **17**

DESIGN SECTOR XVI: SECTION L-L' AT STATION 1410+20

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

K:\WSDOT I-90 Snoqualmie Pass\07000 CADD\7400 Rock Slopes Investigation\CAD\SubTasks\SCD\WN - SCD Sections.dwg 01/07/2009, 16:51 Layout: Figure 17 (1410+20)



Project No. 062-2002 Date: May, 2008

Figure 18

Fissure and Borehole Locations

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

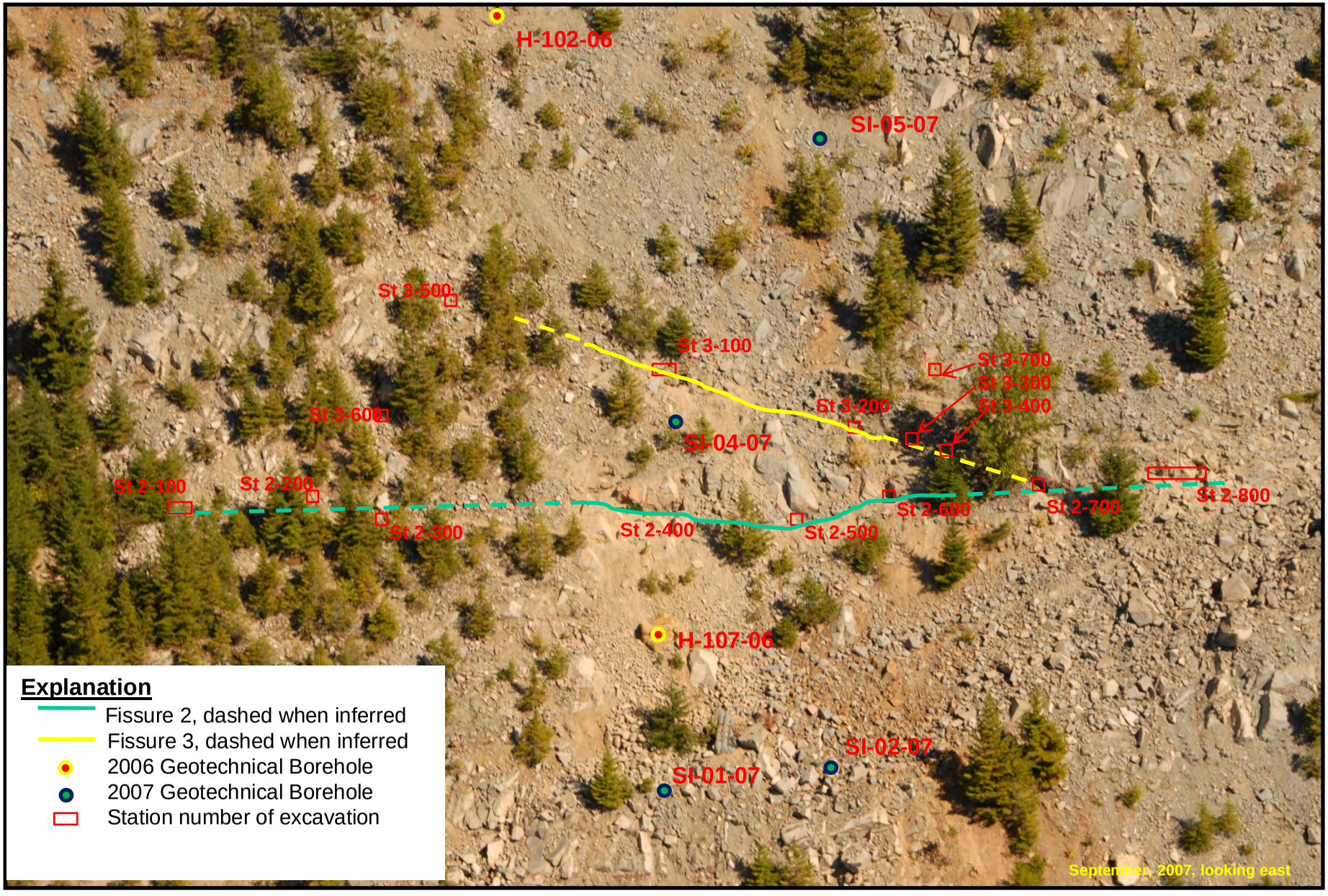


Figure 19

Fissure #2 and #3 Detail

Project No. 062-2002 Date: May, 2008

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

Drilling and splitting of boulder near Fissure #1.

Hand excavation of rubble and displaced rock mass from Fissure #2

Figure 20

Excavation Activities – August & September 2007

Project No. 062-2002 Date: May 2008

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

Areas shown have slight depressions (0 – 2 feet) with occasional void spaces observed.

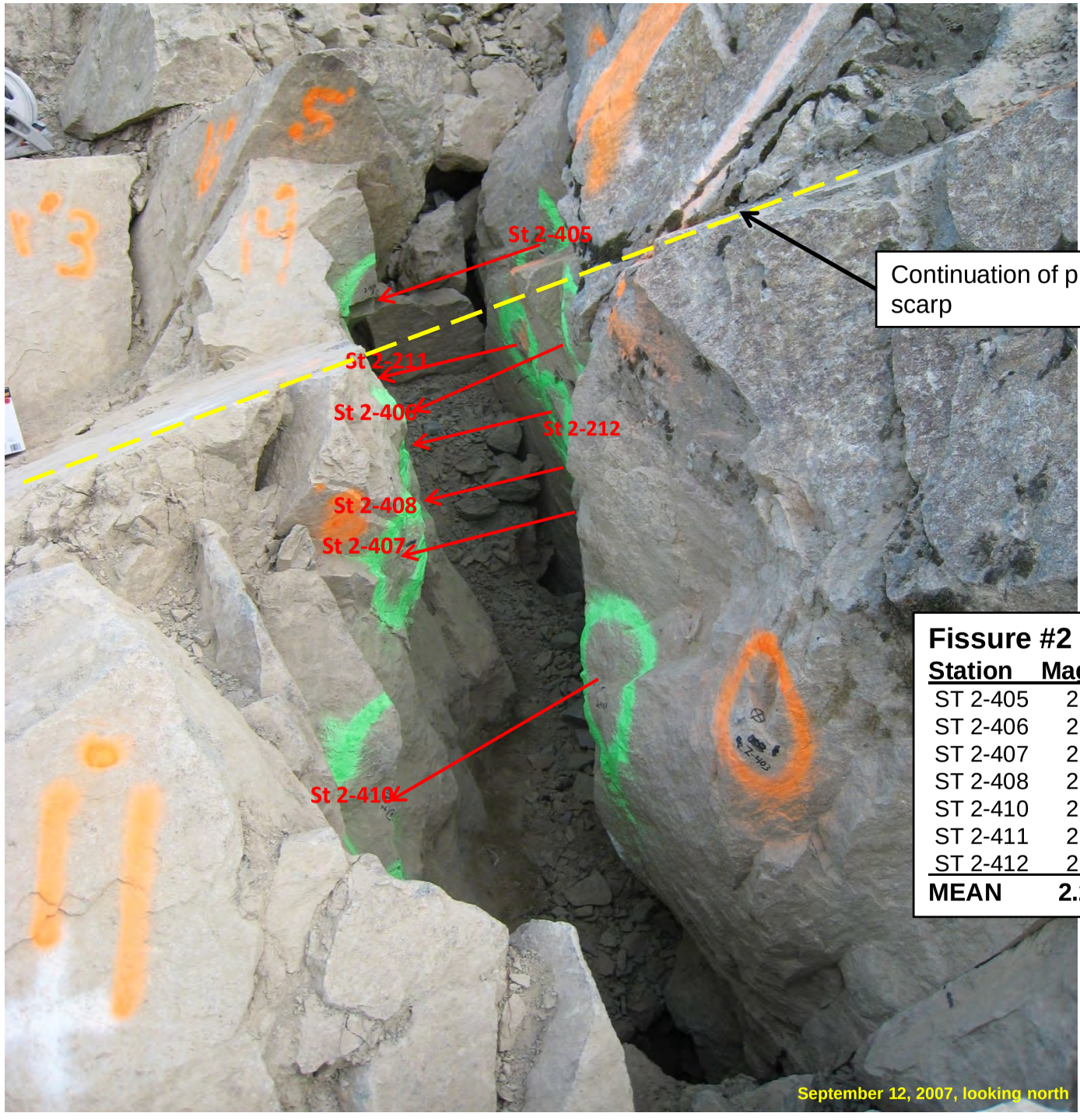
Void shown extends approximately 13 feet past opening and has a depth greater than 10 feet.

Figure 21

Fissure #2 Possible Post-Regrading Movement

Project No. 062-2002 Date: May 2008

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Fissure #2 Displacement Vectors

Station	Magnitude	Plunge / Trend
ST 2-405	2.28 ft	- 17° / 259°
ST 2-406	2.21 ft	- 18° / 255°
ST 2-407	2.45 ft	- 17° / 259°
ST 2-408	2.31 ft	- 20° / 257°
ST 2-410	2.10 ft	- 24° / 256°
ST 2-411	2.15 ft	- 16° / 259°
ST 2-412	2.21 ft	- 18° / 259°
MEAN	**2.26 ft**	**- 19° / 258°**

Project No. 062-2002 Date: May 2008

Figure 22

Fissure #2

Displacement Analysis

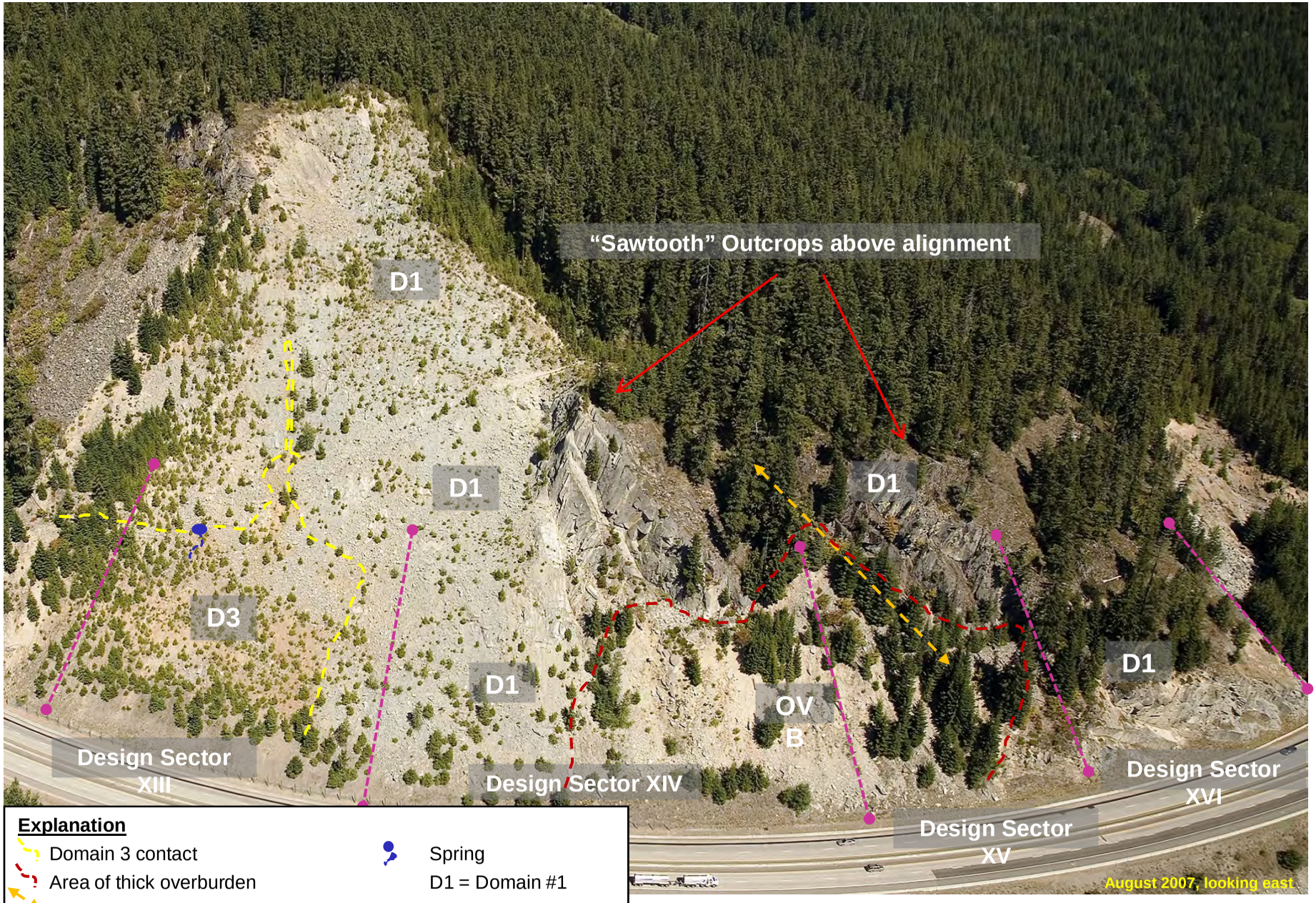
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

Project No. 062-2002 Date: May, 2008

Figure 23

Fissure #3

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Explanation

- Domain 3 contact
- Area of thick overburden
- Inferred location of Domain 2/3 lens
- Design Sector boundaries
- Spring
- D1 = Domain #1
- D3 = Domain #3
- OVB = Overburden

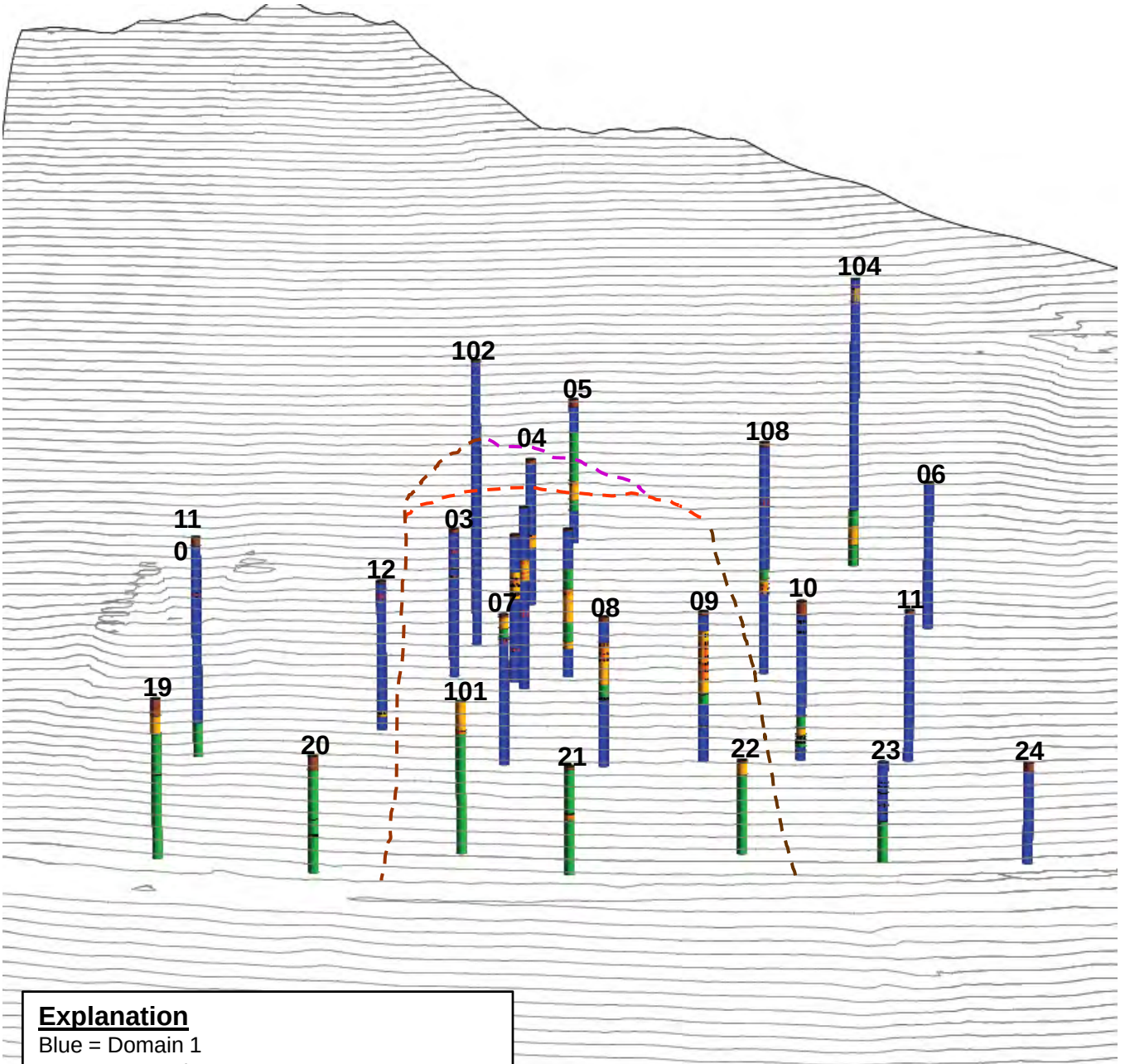
Note: Locations are approximate

Project No. 062-2002 Date: May 2008

Figure 24

Rock Domains by Slope Design Sector

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Explanation

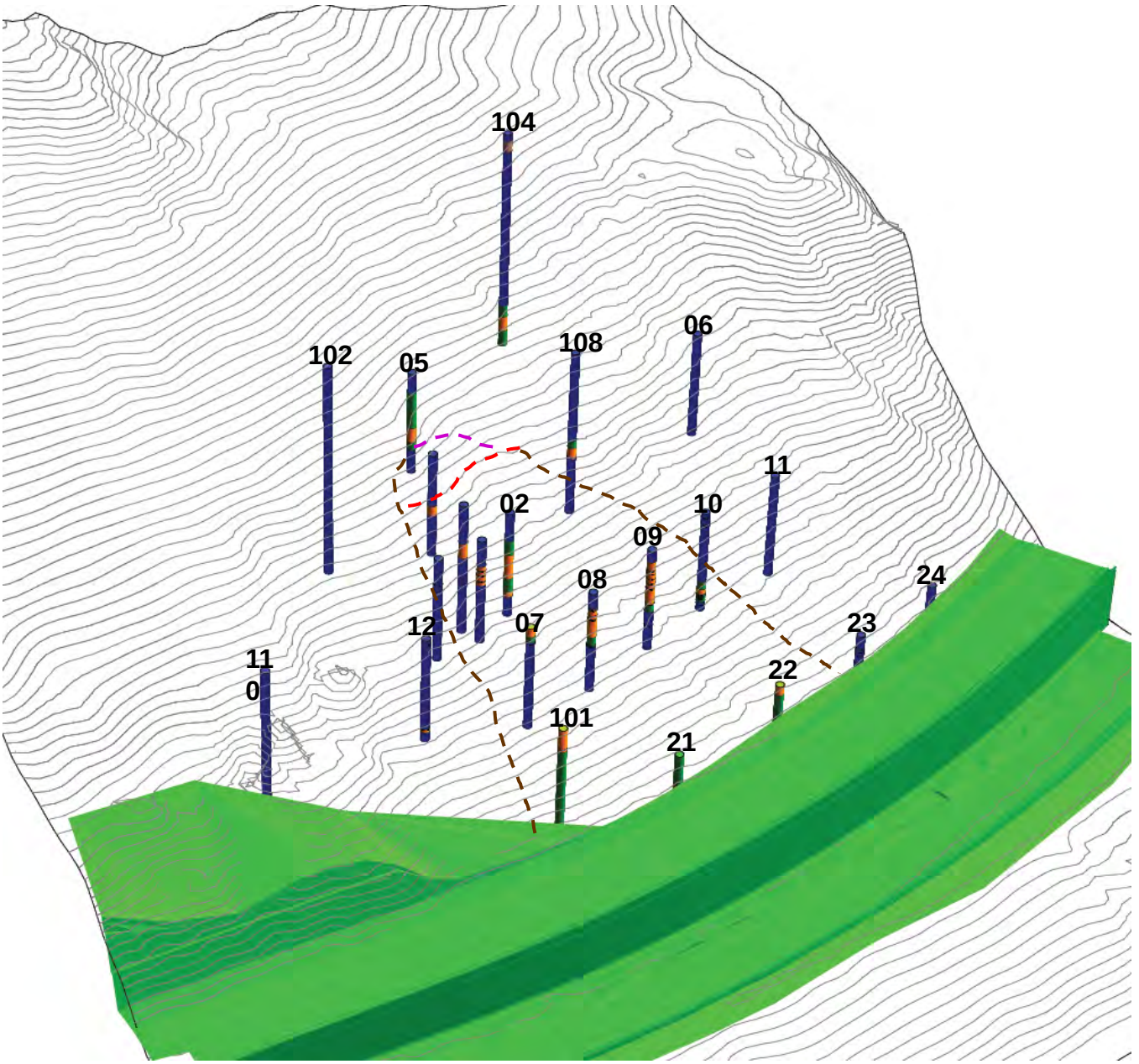
Blue = Domain 1
Green = Domain 2
Yellow = Domain 3
Black = Broken or core loss zones
Red Line = Fissure #2
Purple Line = Fissure #3
Brown Line = Perimeter of displaced rock mass

NOTE:
1. All locations are approximate
2. Looking East
3. Abbreviated borehole numbers provided at collar elevation of vertical boreholes

3-D Model developed by Haneberg Geosciences

Figure 25

Design Sector XIII: Borehole Projection – View East



Explanation

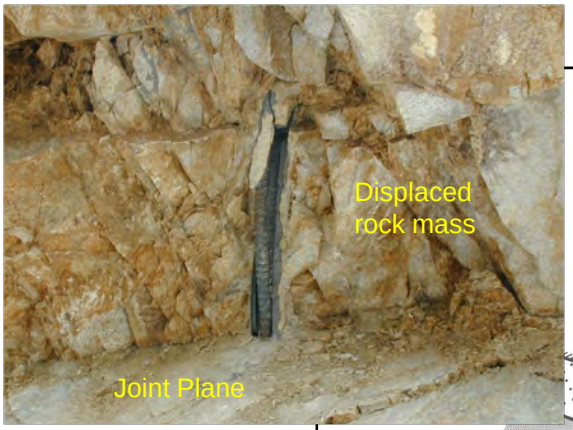
Blue = Domain 1
Green = Domain 2
Yellow = Domain 3
Black = Broken or core loss zones
Red Line = Fissure #2
Purple Line = Fissure #3
Brown Line = Perimeter of displaced rock mass

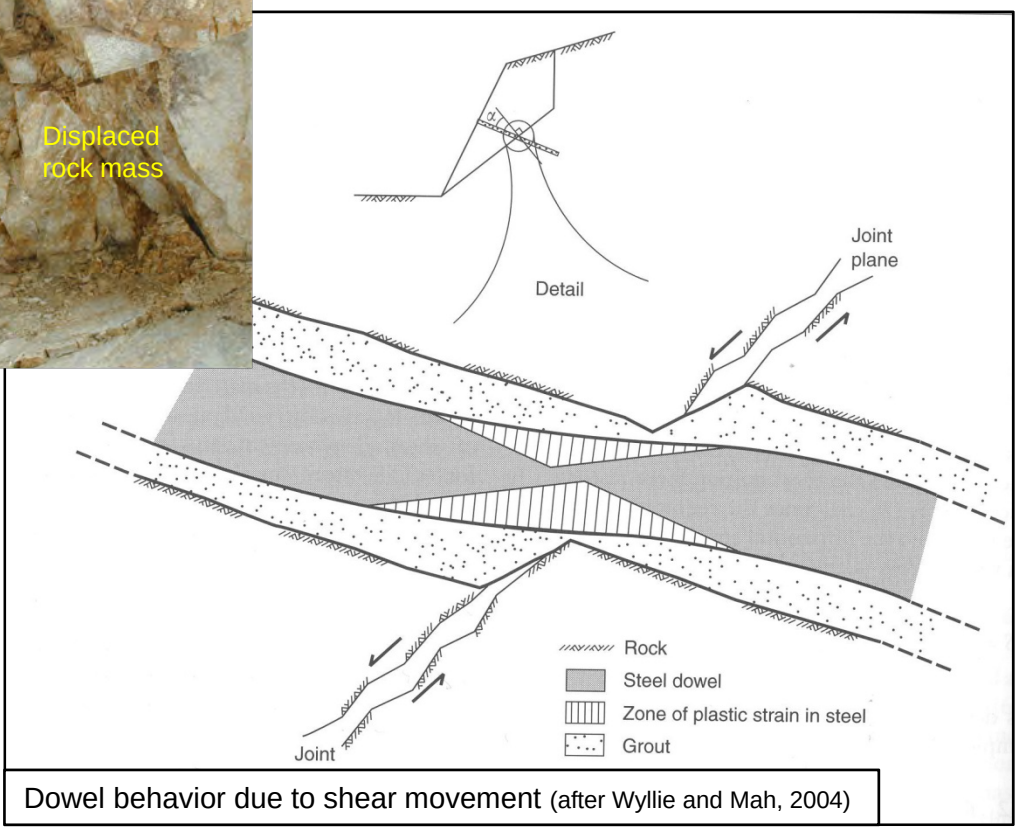
NOTE: All locations are approximate
Looking Southeast
Abbreviated borehole numbers provided

3-D Model developed by Haneberg Geosciences

Figure 26

Design Sector XIII: Borehole Projection – View Southeast





Dowel behavior due to shear movement (after Wyllie and Mah, 2004)

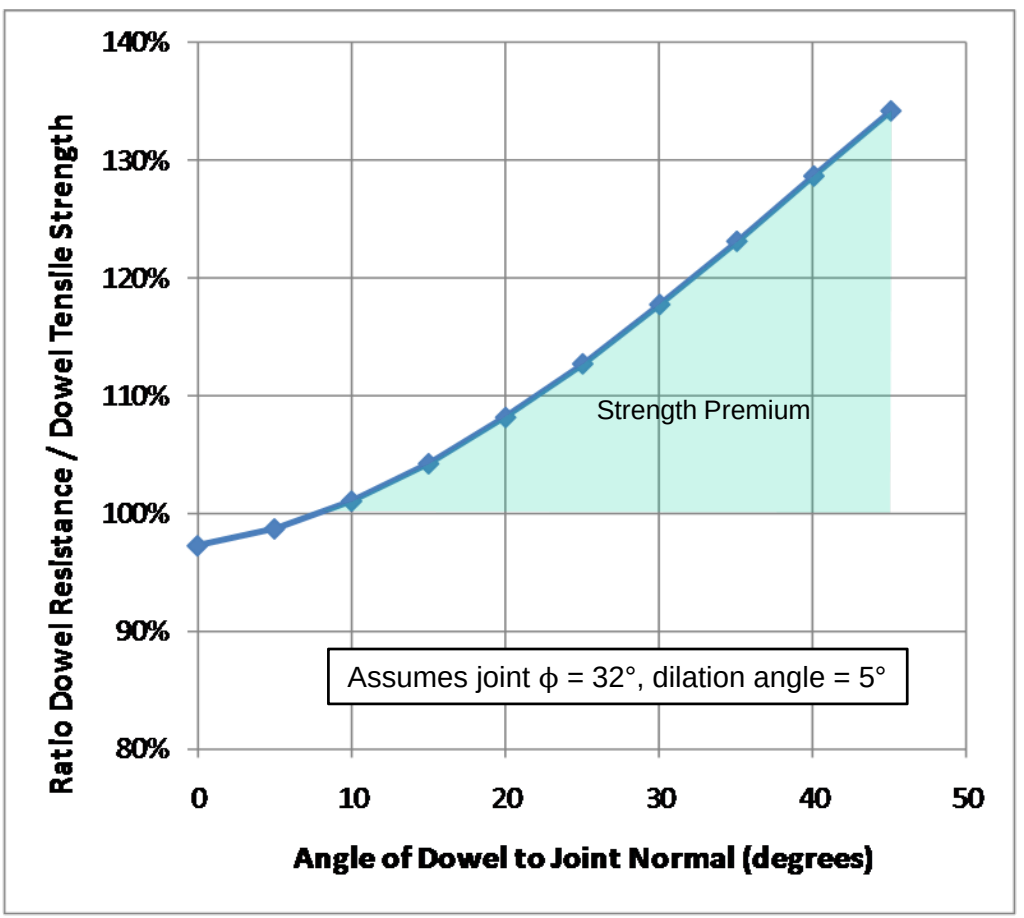
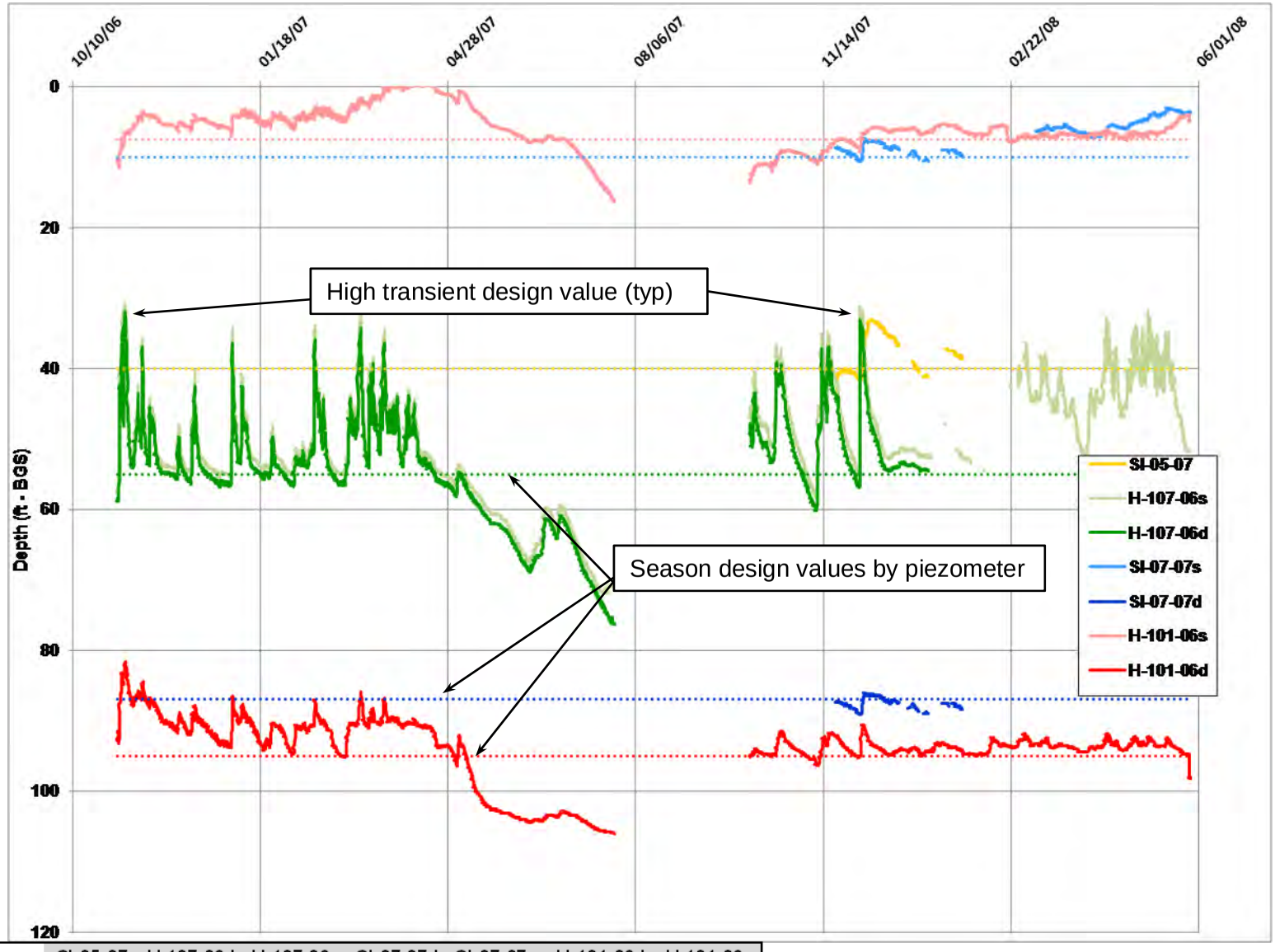


Figure 27

Dowel Reinforcement Behavior



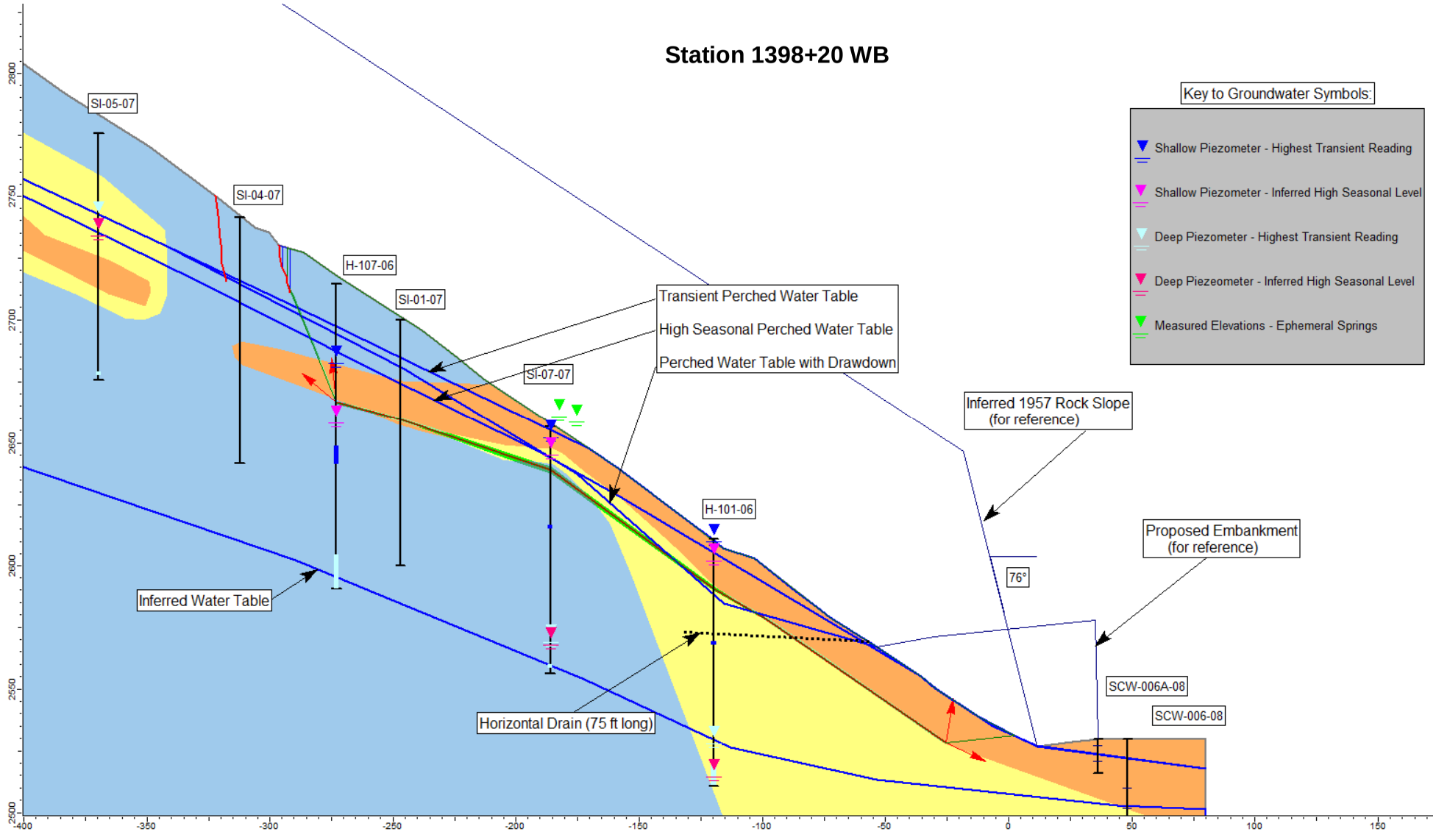
	SI-05-07	H-107-06d	H-107-06s	SI-07-07d	SI-07-07s	H-101-06d	H-101-06s
Collar Elevation:	2775.53	2714.7	2714.7	2656.52	2656.52	2610.85	2610.85
Minimum W/L Depth:	33.13	31.95	30.70	86.00	2.93	81.60	-0.68
Maximum W/L Depth:	44.73	76.30	71.90	89.20	10.56	106.10	16.29
Design W/L Depth:	40	55		* 87	10	95	8
Design W/L Elevation:	2736	2660	2715	2570	2647	2516	2603

* *Water levels for upper and lower piezometers in H-107-06 are equal (vertical communication)*

Project No. 062-2002 Date: May, 2008

Figure 28

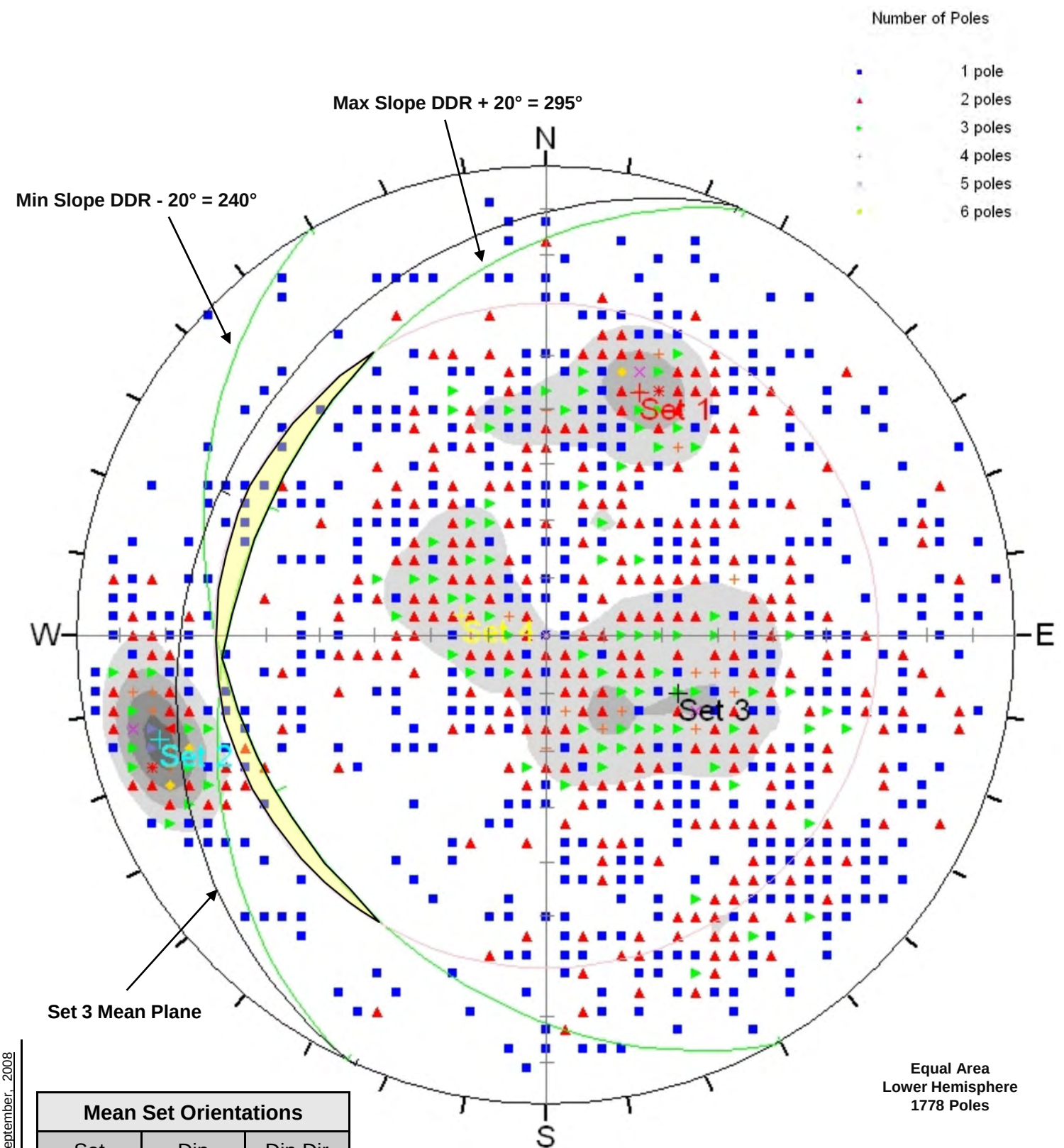
Design Sector XIII Station 1398+20 Piezometric Records



Project No. 062-2002 Date: September, 2008

Figure 29

Design Sector XIII – Inferred Groundwater Conditions



Equal Area
Lower Hemisphere
1778 Poles

Mean Set Orientations		
Set	Dip	Dip Dir
1	46º	201º
2	74º	075º
3	25º	294º
4	15º	104º

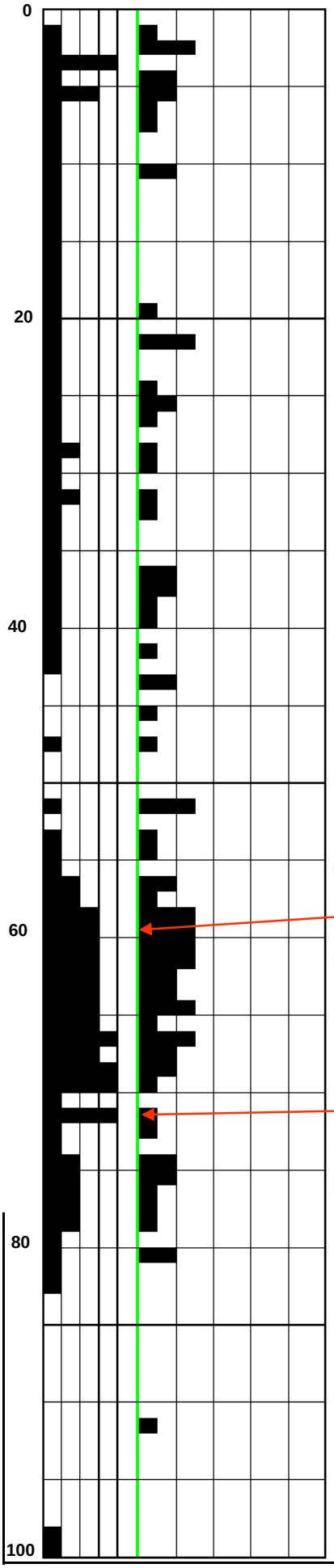
Project No. 062-2002 Date: September, 2008

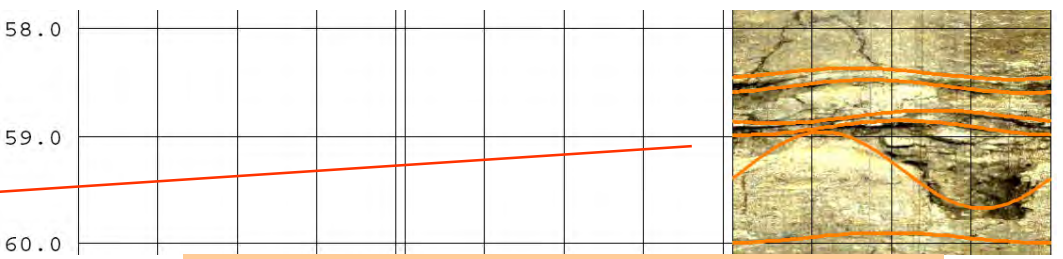
Figure 30

Design Sector XIII – Detailed Kinematic Analysis

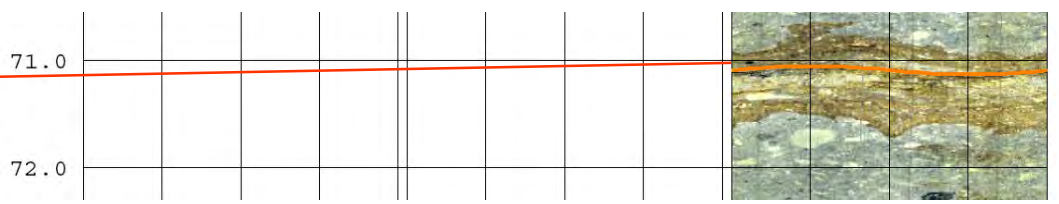
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

See Figure 7 for key to borehole histograms





58.9 – 59.8ft: High Probability (Core Loss / Broken zone)



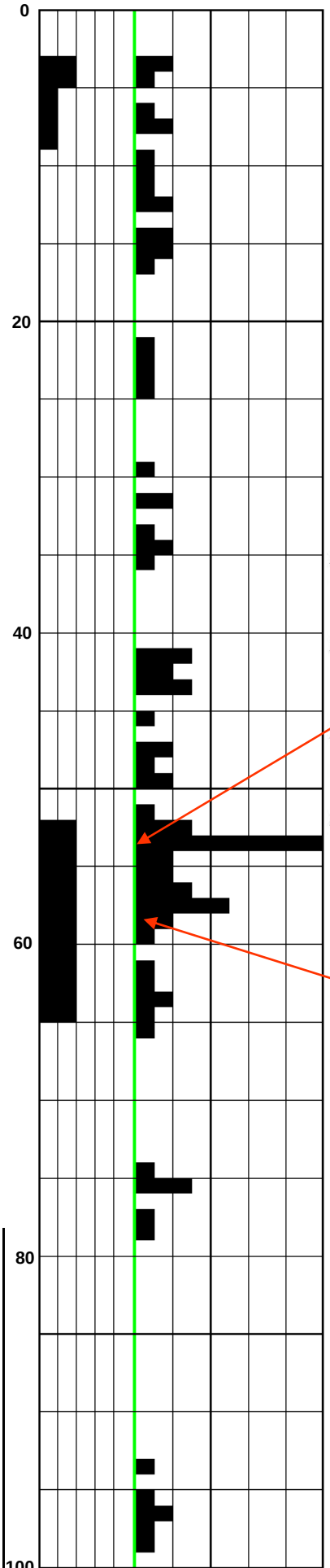
71.10 ft: Low Probability (Weathered Joint 15°/273°)

Project No. 062-2002 Date: May 2007

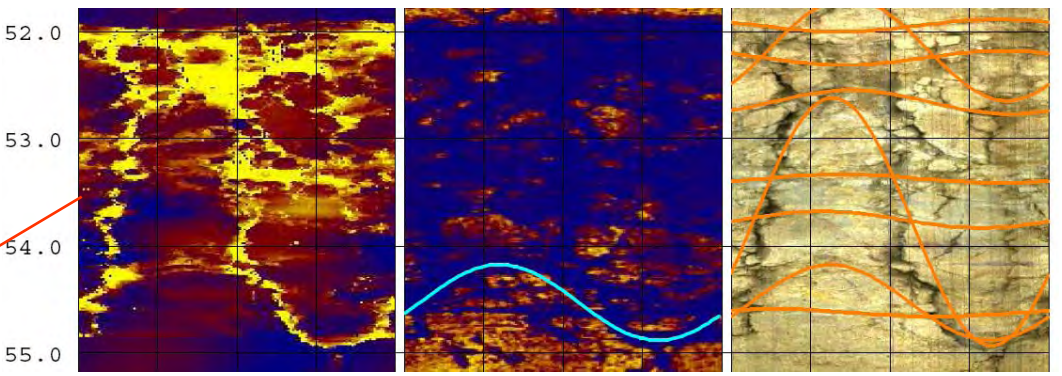
Figure 31

Shear Surface Ratings: SI-5-07

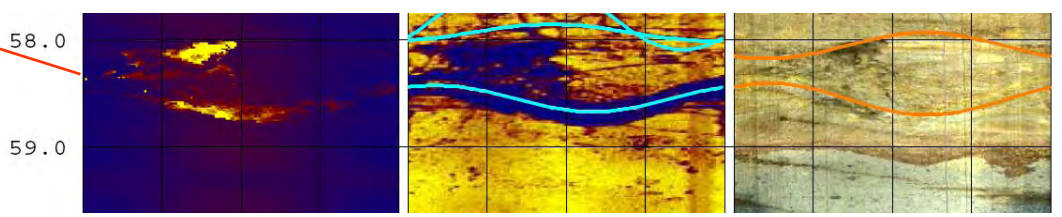
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



See Figure 7 for key to borehole histograms



52.0 – 54.7 ft: High Probability (Core Loss / Broken zone)



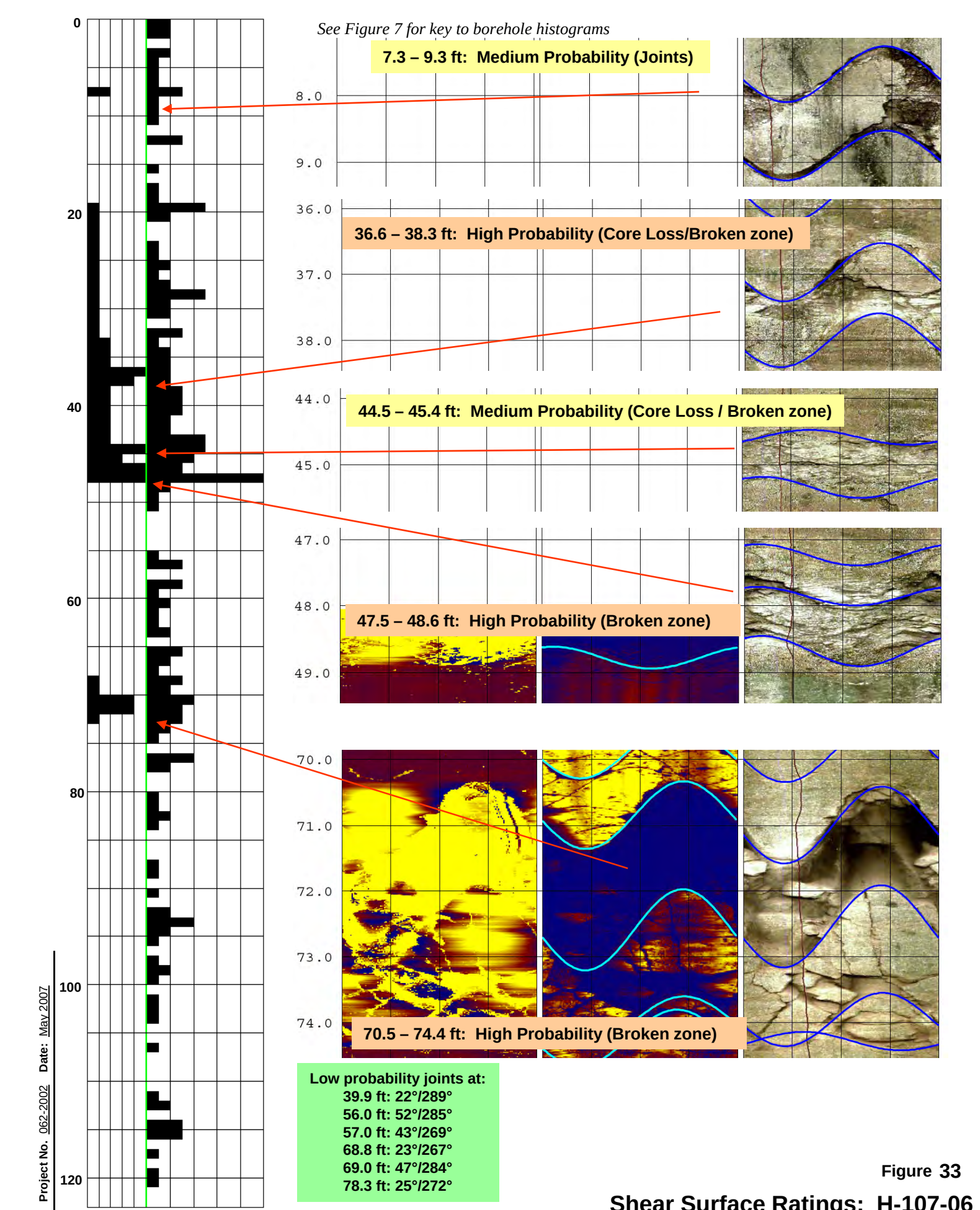
58.55 ft: Medium Probability (Joint 43°/220°)

Project No. 062-2002 Date: May 2007

Figure 32

Shear Surface Ratings: SI-4-07

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Low probability joints at:
39.9 ft: 22°/289°
56.0 ft: 52°/285°
57.0 ft: 43°/269°
68.8 ft: 23°/267°
69.0 ft: 47°/284°
78.3 ft: 25°/272°

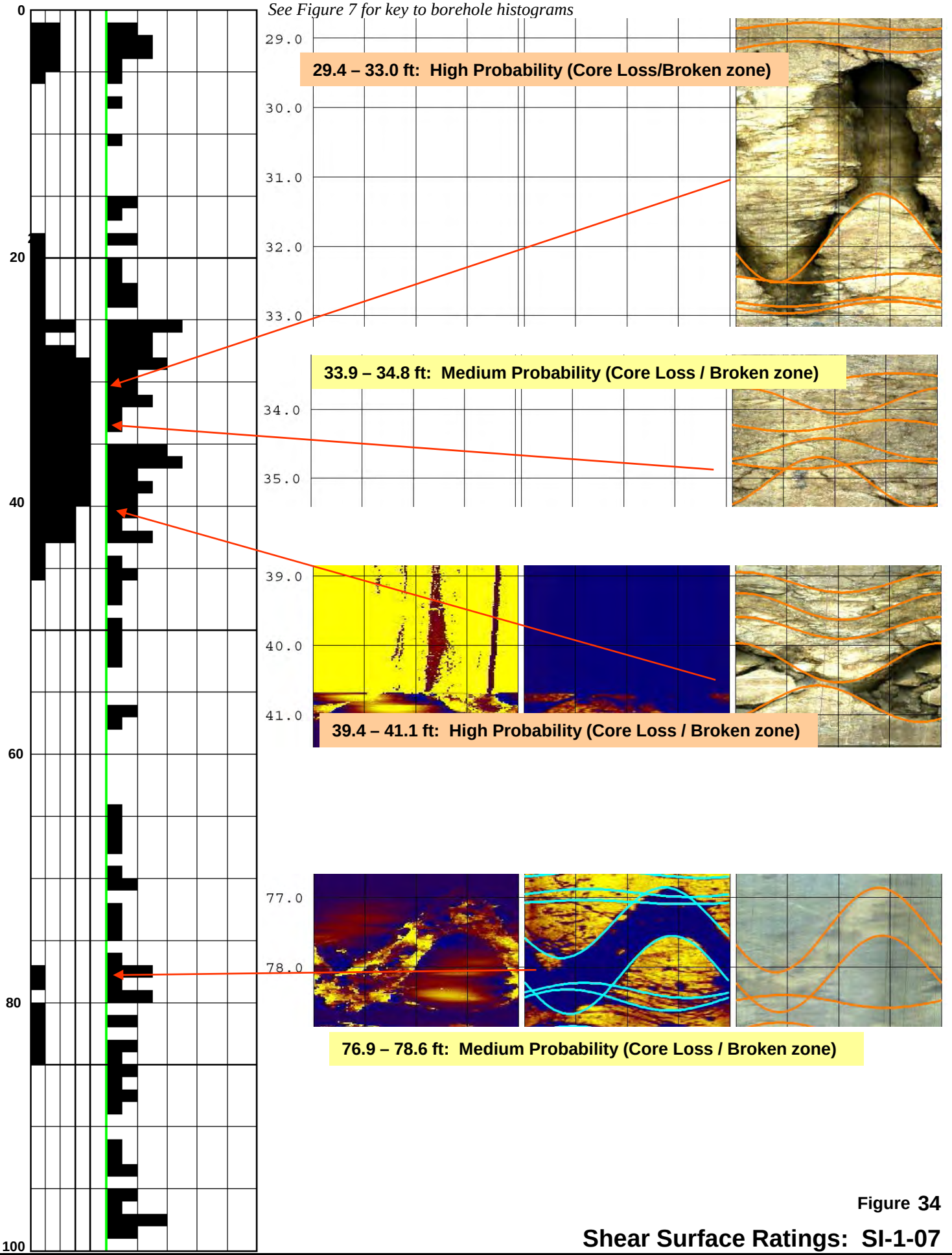
Project No. 062-2002 Date: May 2007

Figure 33

Shear Surface Ratings: H-107-06

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

See Figure 7 for key to borehole histograms

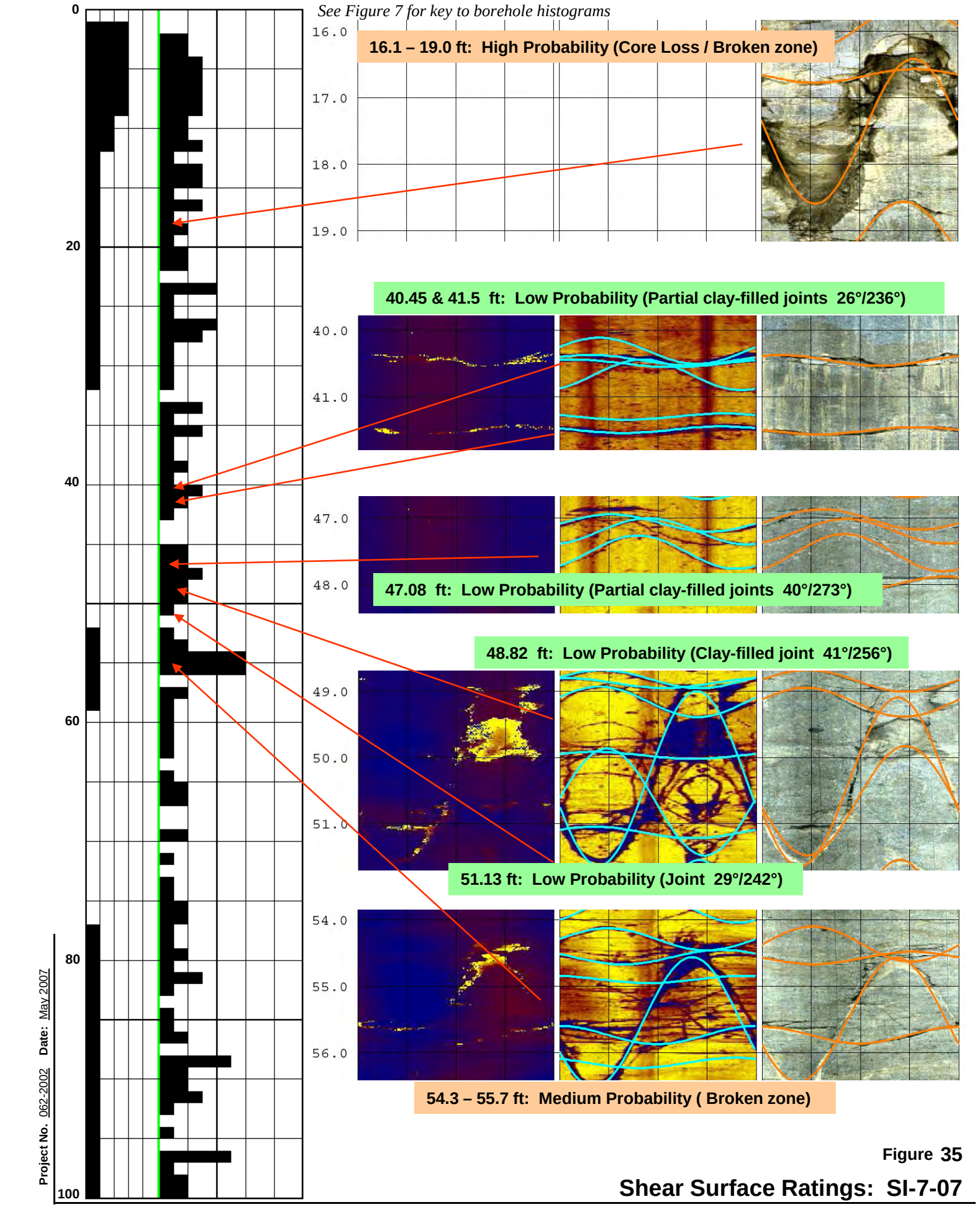


Project No. 062-2002 Date: May 2007

Figure 34

Shear Surface Ratings: SI-1-07

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

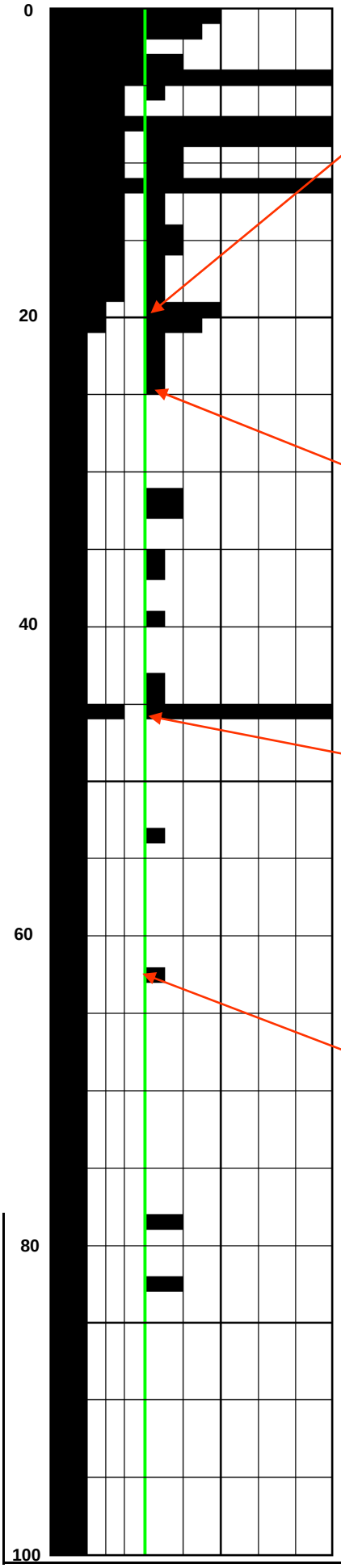


Project No. 062-2002 Date: May 2007

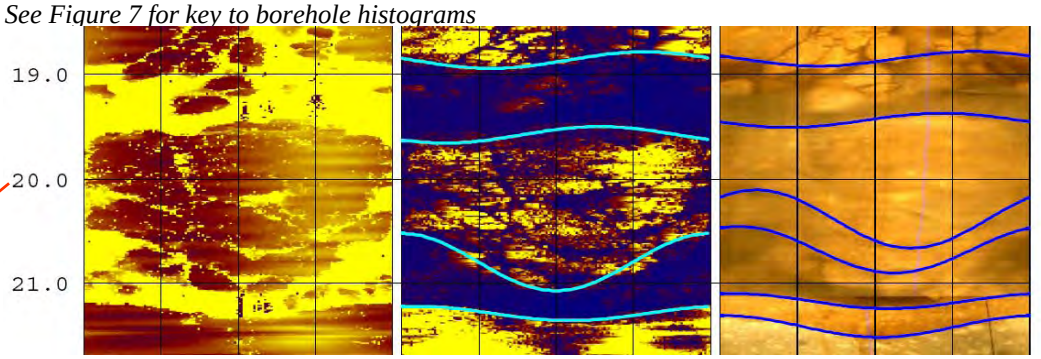
Figure 35

Shear Surface Ratings: SI-7-07

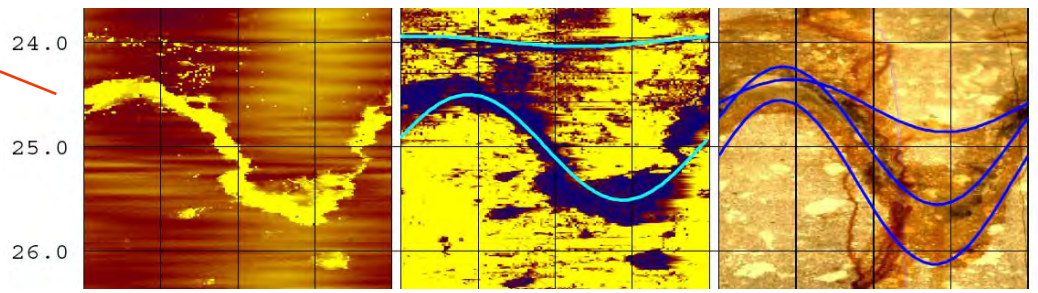
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



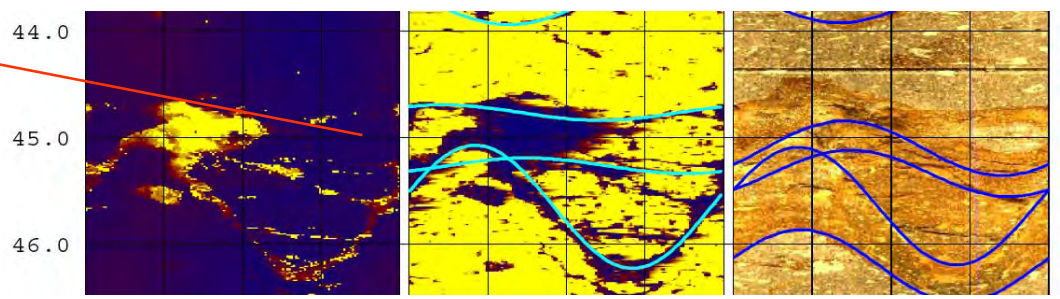
See Figure 7 for key to borehole histograms



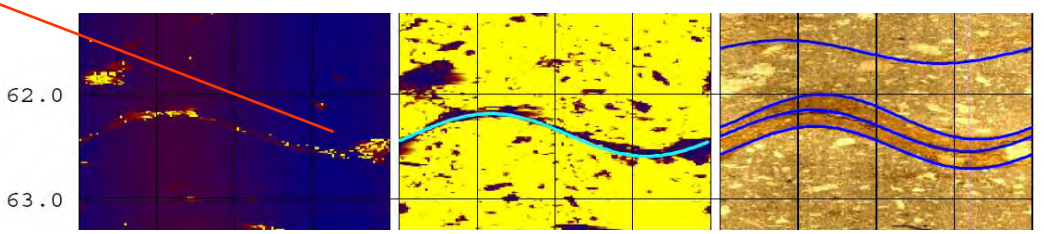
18.9 – 21.0 ft High Probability (Core Loss / Broken Zone)



24.6 ft Medium Probability (Clay-filled joint: 58°/264°)



44.7 – 45.6 ft High Probability (Broken Zone)



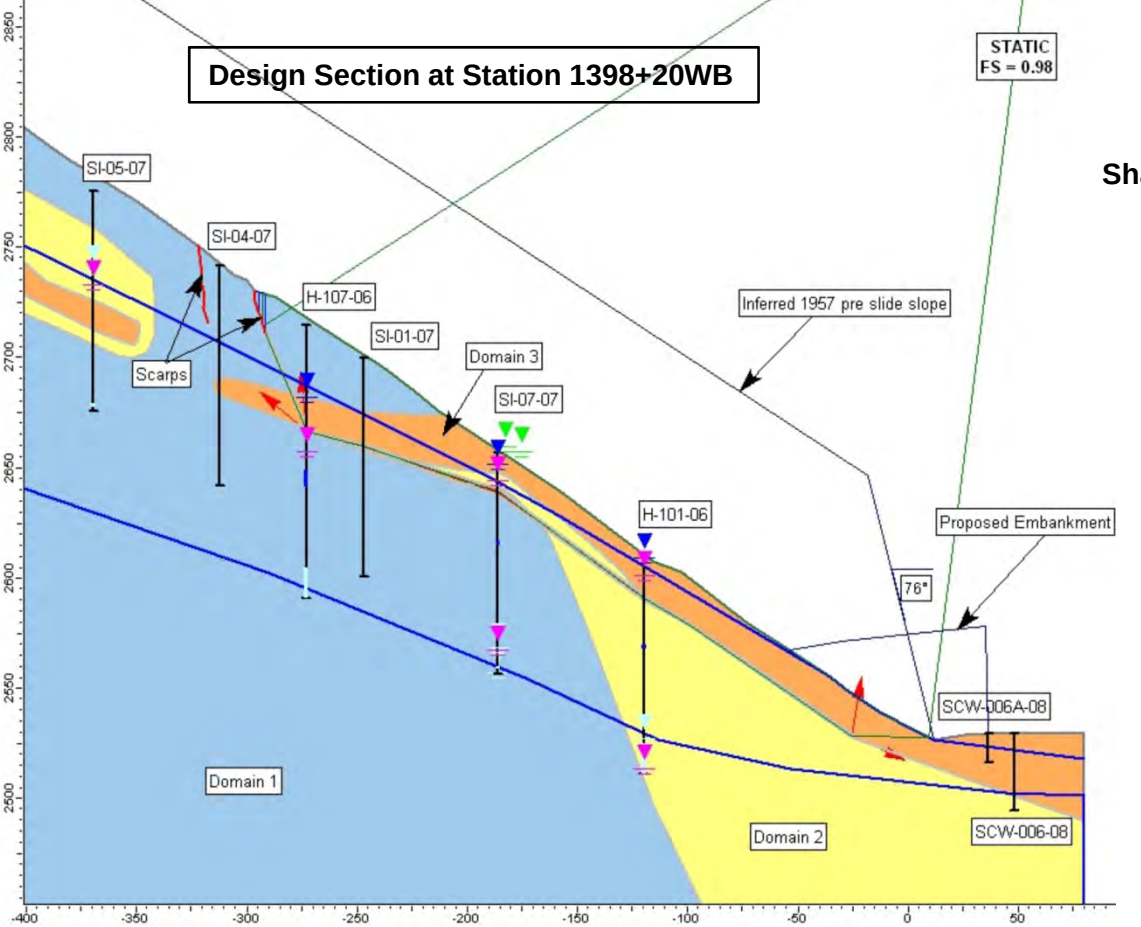
62.2 – 62.5 Low Probability (Clay – filled joints: 52°/290°)

Project No. 062-2002 Date: May 2007

Figure 36

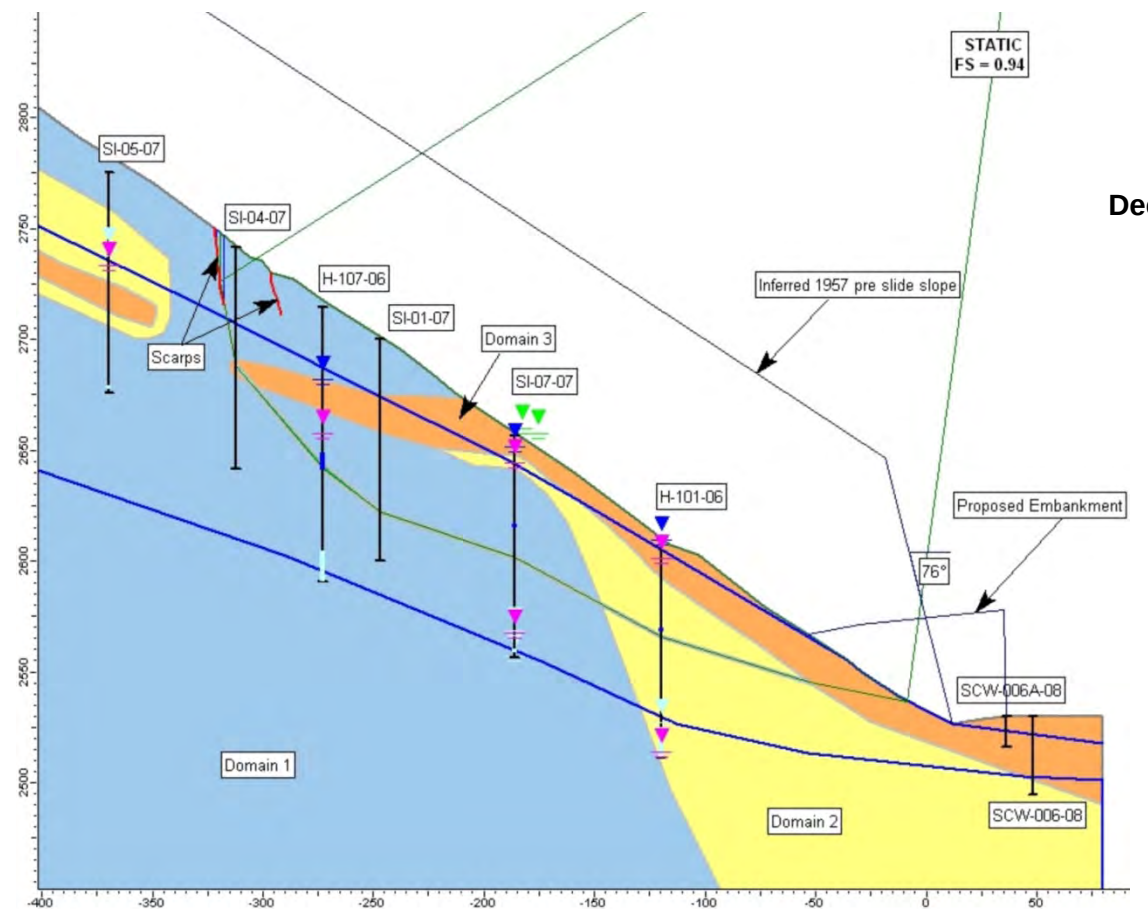
Shear Surface Ratings: H-101-06

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Shallow Surface

Section at 1398+20 WB



Deep Surface

Figure 37

Design Sector XIII – Back Analyses

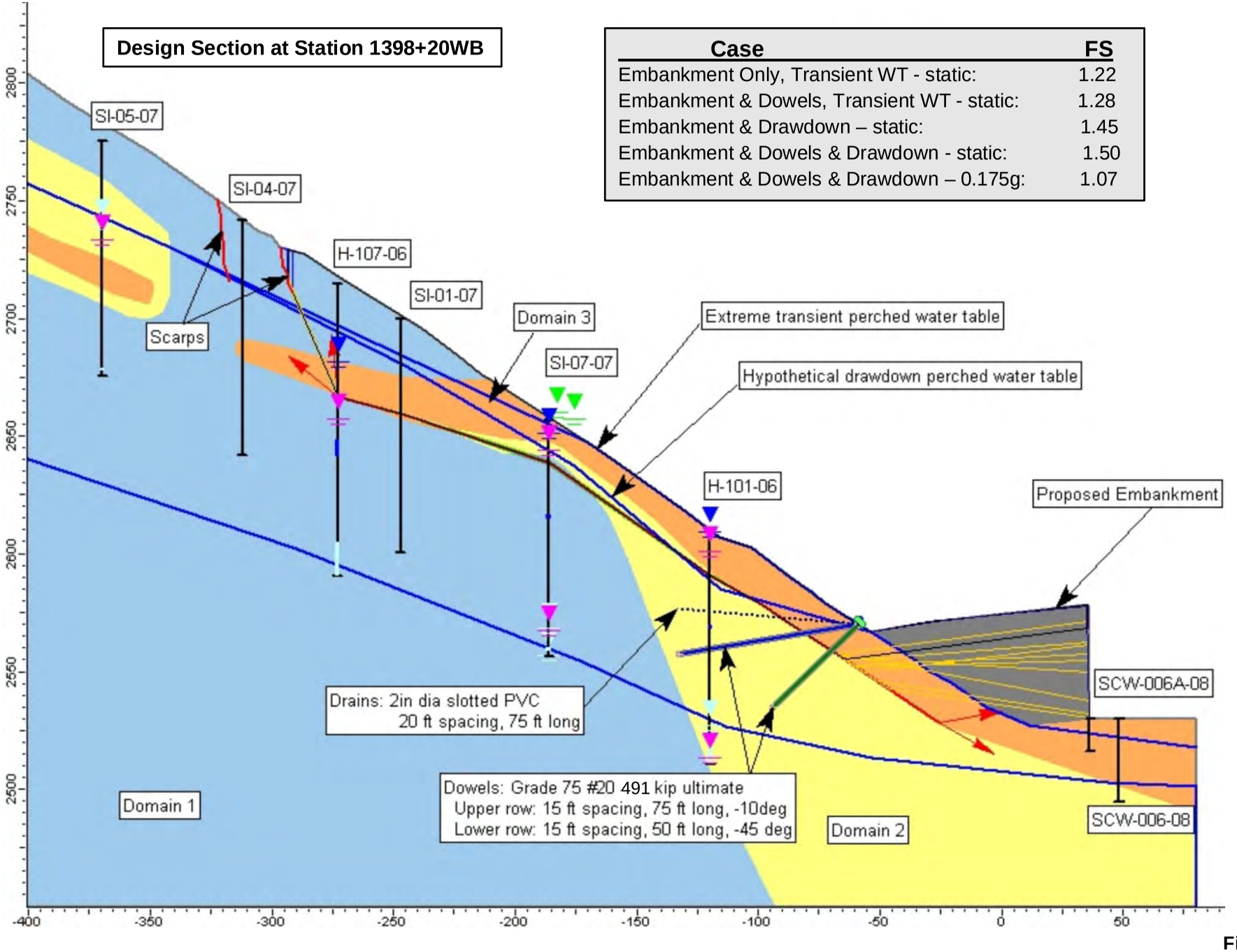


Figure 38

Design Sector XIII – Forward Analysis Shallow Surface

Project No. 062-2002 Date: September, 2008

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

Design Section at Station 1398+20WB

Case	FS
Embankment Only, Transient WT - static:	1.19
Embankment & Dowels, Transient WT - static:	1.22
Embankment & Drawdown – static:	1.30
Embankment & Dowels & Drawdown - static:	1.33
Embankment & Dowels & Drawdown – 0.175g:	0.91

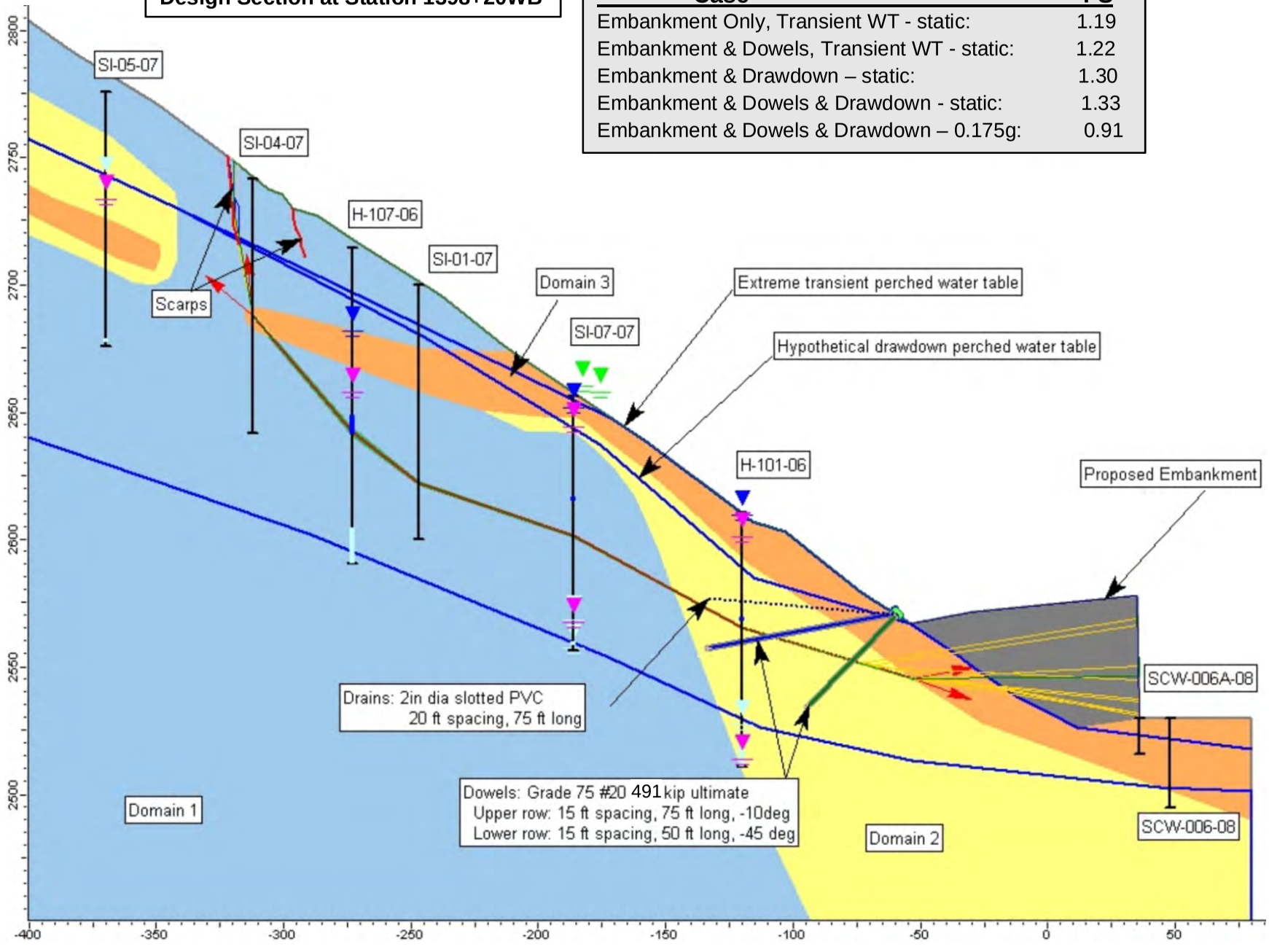
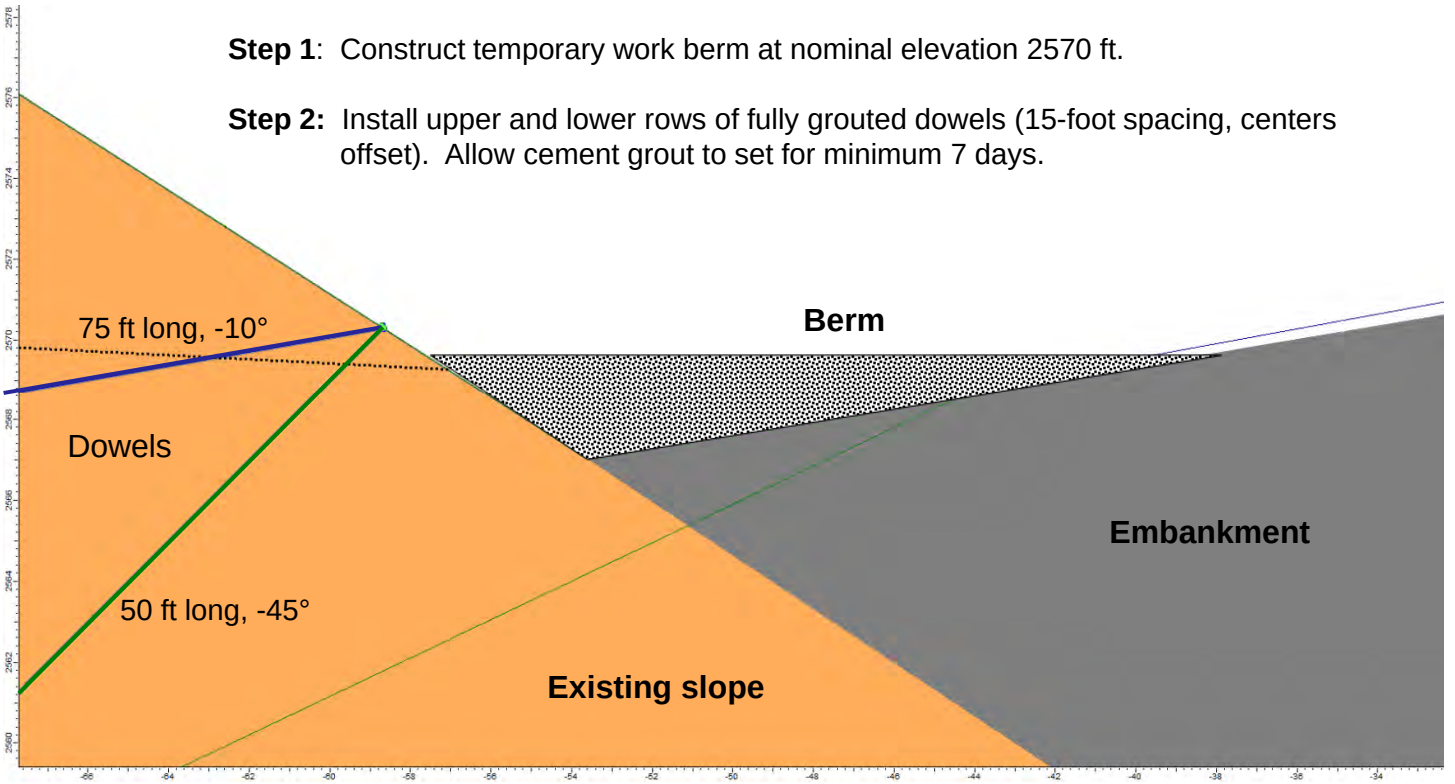


Figure 39

Design Sector XIII – Forward Analysis Deep Surface

Step 1: Construct temporary work berm at nominal elevation 2570 ft.

Step 2: Install upper and lower rows of fully grouted dowels (15-foot spacing, centers offset). Allow cement grout to set for minimum 7 days.



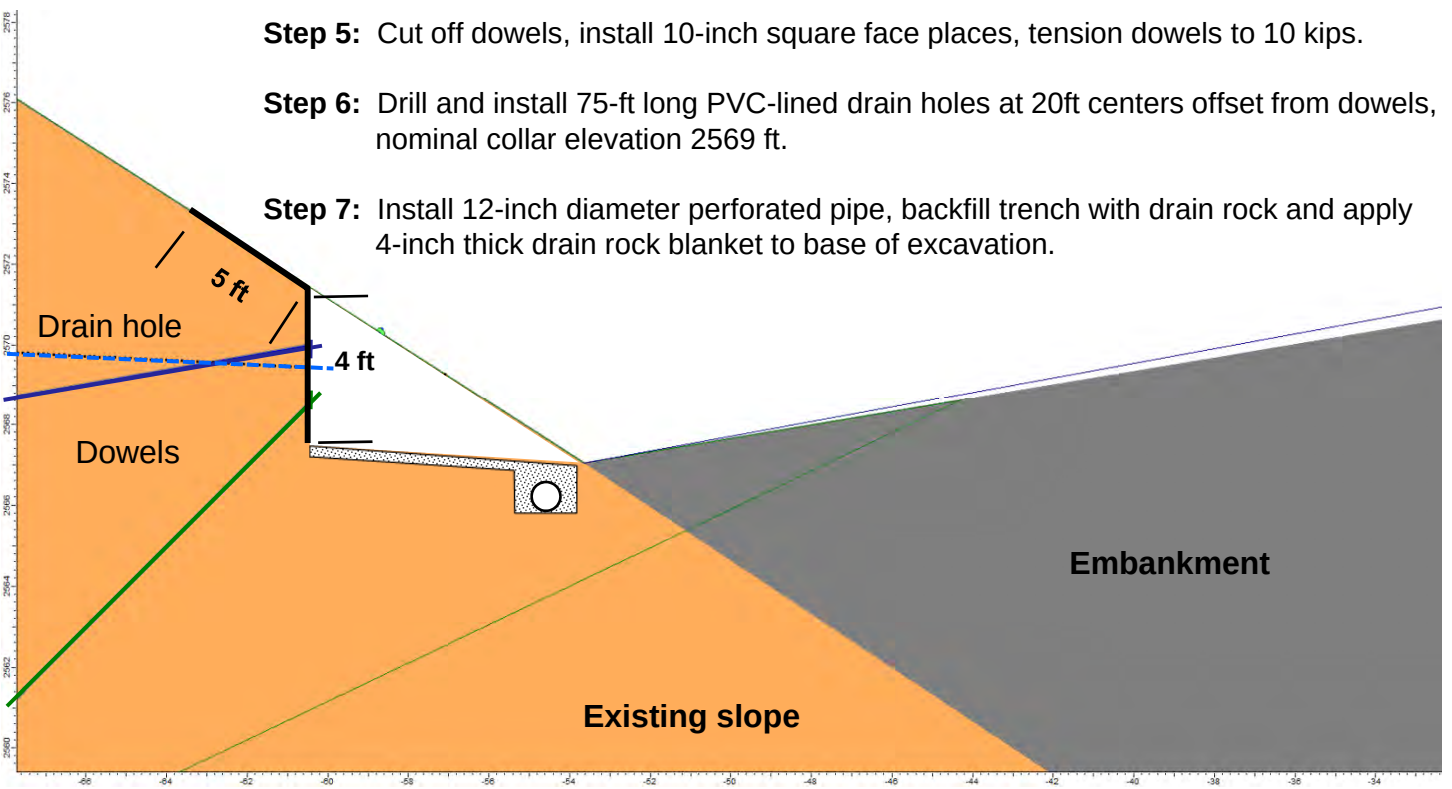
Step 3: Remove berm, make excavation cut to create nominal 4 ft high vertical face.

Step 4: Apply 4-inch thick, fiber reinforced shotcrete to limits shown, graded to direct water to embankment underdrain.

Step 5: Cut off dowels, install 10-inch square face places, tension dowels to 10 kips.

Step 6: Drill and install 75-ft long PVC-lined drain holes at 20ft centers offset from dowels, nominal collar elevation 2569 ft.

Step 7: Install 12-inch diameter perforated pipe, backfill trench with drain rock and apply 4-inch thick drain rock blanket to base of excavation.



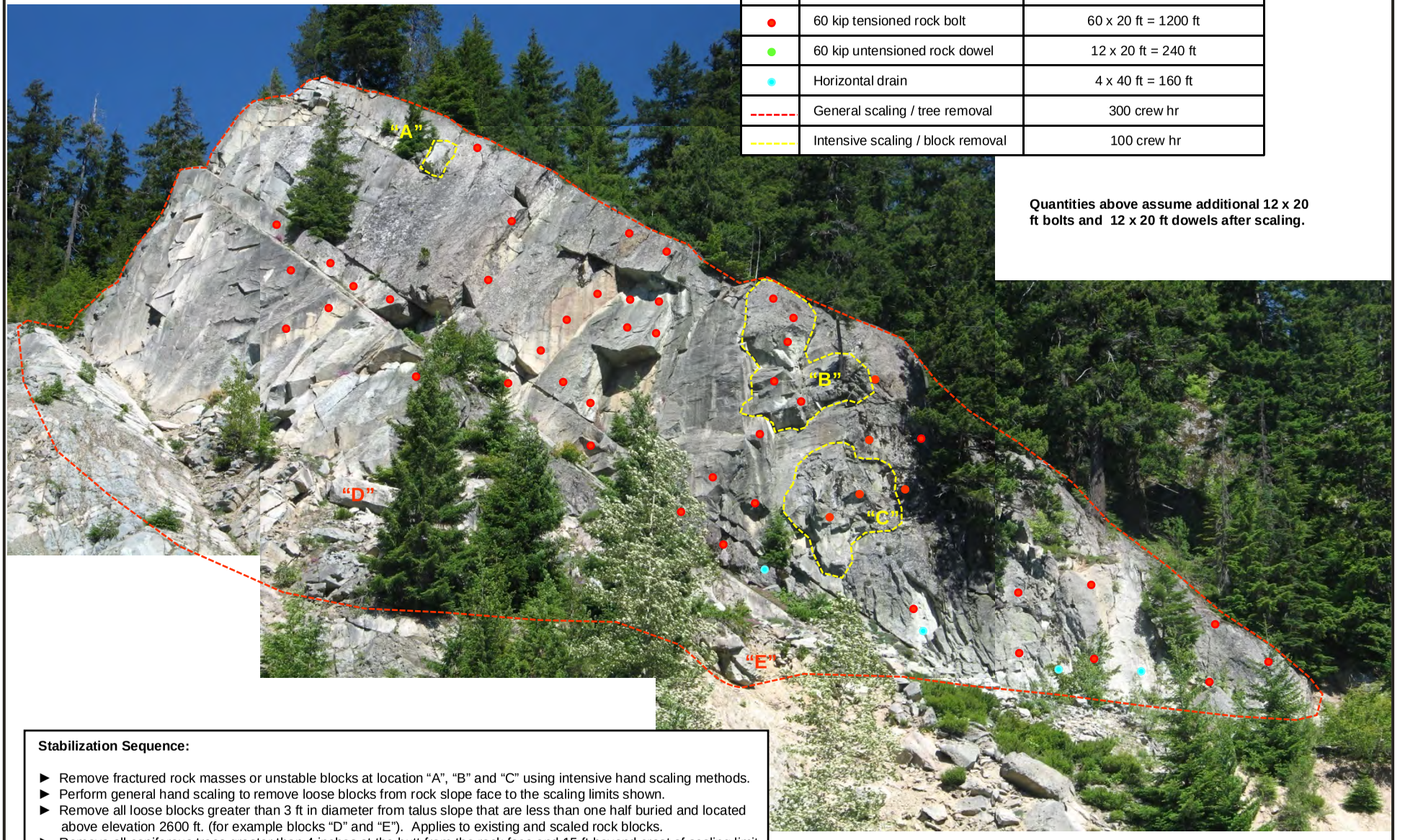
Note: Treatment extends from Station 1397+00 to 1400+00 WB

Figure 40

Design Sector XIII – Ditch Detail

KEY	STABILIZATION ITEM	EST QTY (Sheet 41)
●	60 kip tensioned rock bolt	60 x 20 ft = 1200 ft
●	60 kip untensioned rock dowel	12 x 20 ft = 240 ft
●	Horizontal drain	4 x 40 ft = 160 ft
- - -	General scaling / tree removal	300 crew hr
- - -	Intensive scaling / block removal	100 crew hr

Quantities above assume additional 12 x 20 ft bolts and 12 x 20 ft dowels after scaling.



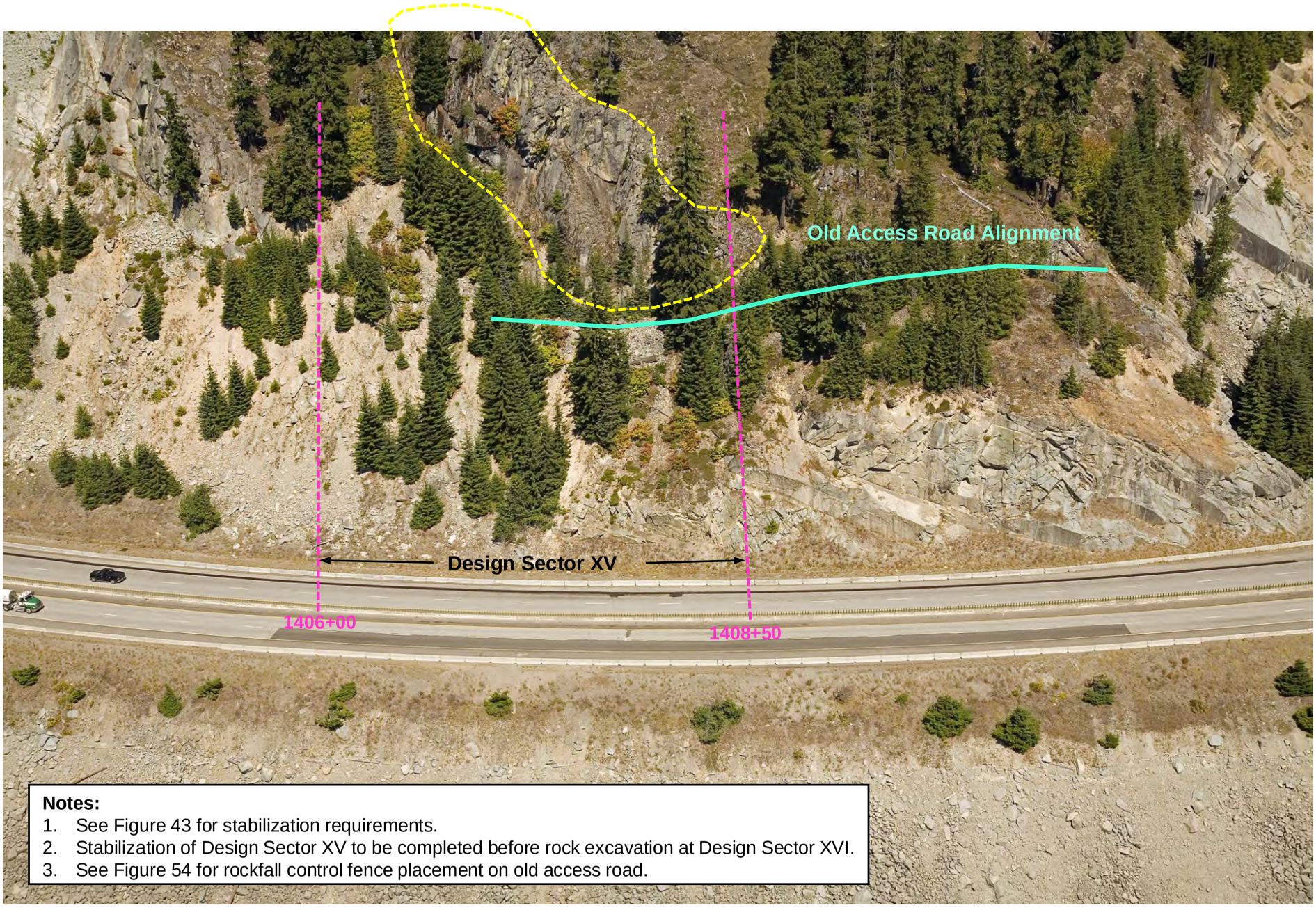
Stabilization Sequence:

- ► Remove fractured rock masses or unstable blocks at location "A", "B" and "C" using intensive hand scaling methods.
- ► Perform general hand scaling to remove loose blocks from rock slope face to the scaling limits shown.
- ► Remove all loose blocks greater than 3 ft in diameter from talus slope that are less than one half buried and located above elevation 2600 ft. (for example blocks "D" and "E"). Applies to existing and scaled rock blocks.
- ► Remove all coniferous trees greater than 4 inches at the butt from the rock face and 15 ft beyond crest of scaling limit.
- ► Install rock bolts or dowels from **top down** at specified locations and as directed by the Engineer. Dowels may be substituted for bolts at the discretion of the Engineer to suit rock conditions.
- ► Install horizontal drains at locations shown.

Project No. 062-2002 **Date:** September 2008

STABILIZATION REQUIREMENTS
Design Sector XIV

Figure 41

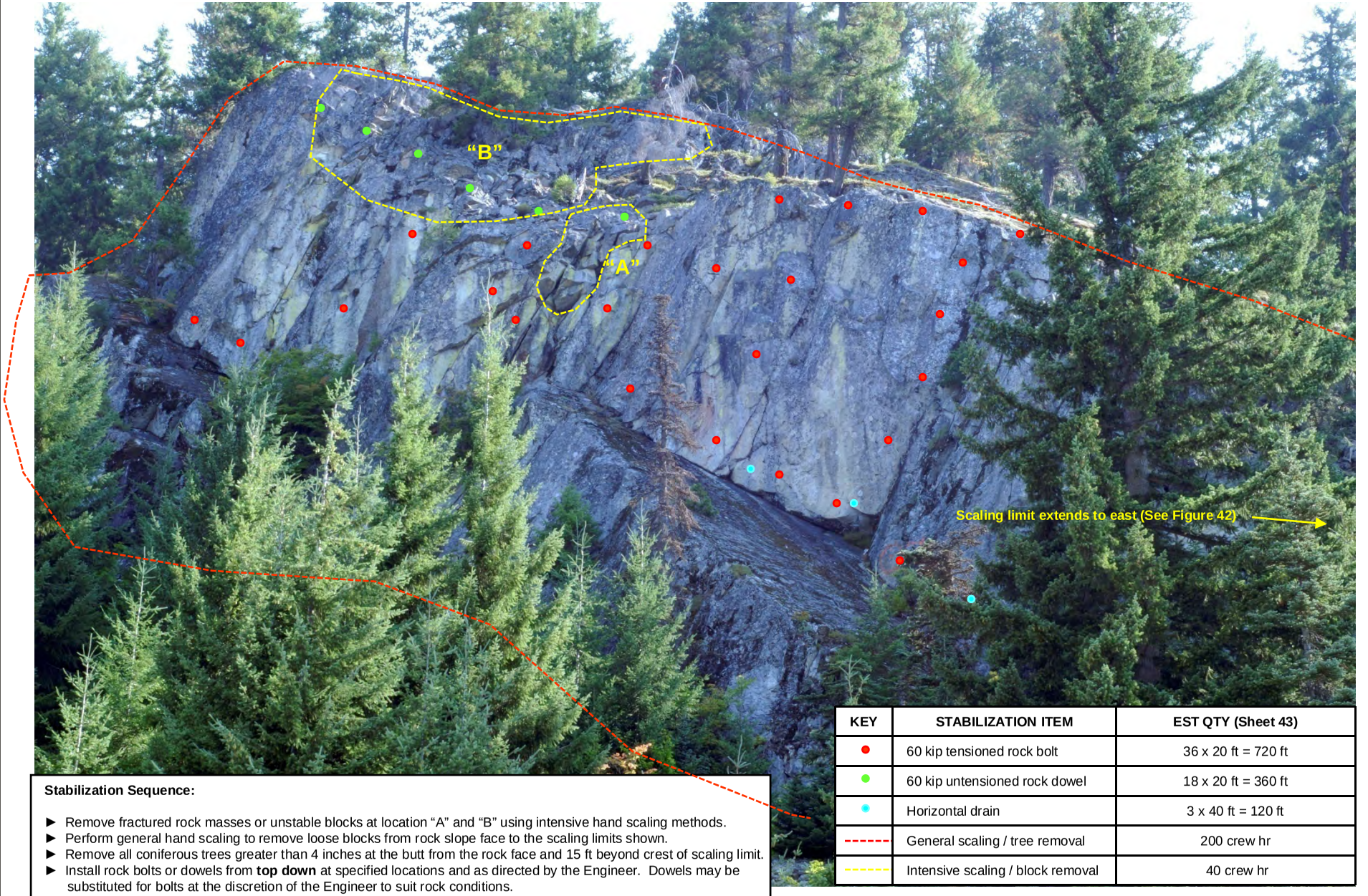


Notes:

1. See Figure 43 for stabilization requirements.
2. Stabilization of Design Sector XV to be completed before rock excavation at Design Sector XVI.
3. See Figure 54 for rockfall control fence placement on old access road.

Figure 42

Design Sector XV: Scaling and Tree Removal Limits



KEY	STABILIZATION ITEM	EST QTY (Sheet 43)
●	60 kip tensioned rock bolt	36 x 20 ft = 720 ft
●	60 kip untensioned rock dowel	18 x 20 ft = 360 ft
●	Horizontal drain	3 x 40 ft = 120 ft
----	General scaling / tree removal	200 crew hr
----	Intensive scaling / block removal	40 crew hr

Quantities above assume additional 12 x 20 ft bolts and 12 x 20 ft dowels after scaling .

Stabilization Sequence:

- ► Remove fractured rock masses or unstable blocks at location "A" and "B" using intensive hand scaling methods.
- ► Perform general hand scaling to remove loose blocks from rock slope face to the scaling limits shown.
- ► Remove all coniferous trees greater than 4 inches at the butt from the rock face and 15 ft beyond crest of scaling limit.
- ► Install rock bolts or dowels from **top down** at specified locations and as directed by the Engineer. Dowels may be substituted for bolts at the discretion of the Engineer to suit rock conditions.
- ► Install horizontal drains at locations shown.
- ► Clear trees and rock from old access road beneath rock slope after scaling. Install rockfall control fence on outboard side (see Figures 53 and 54).

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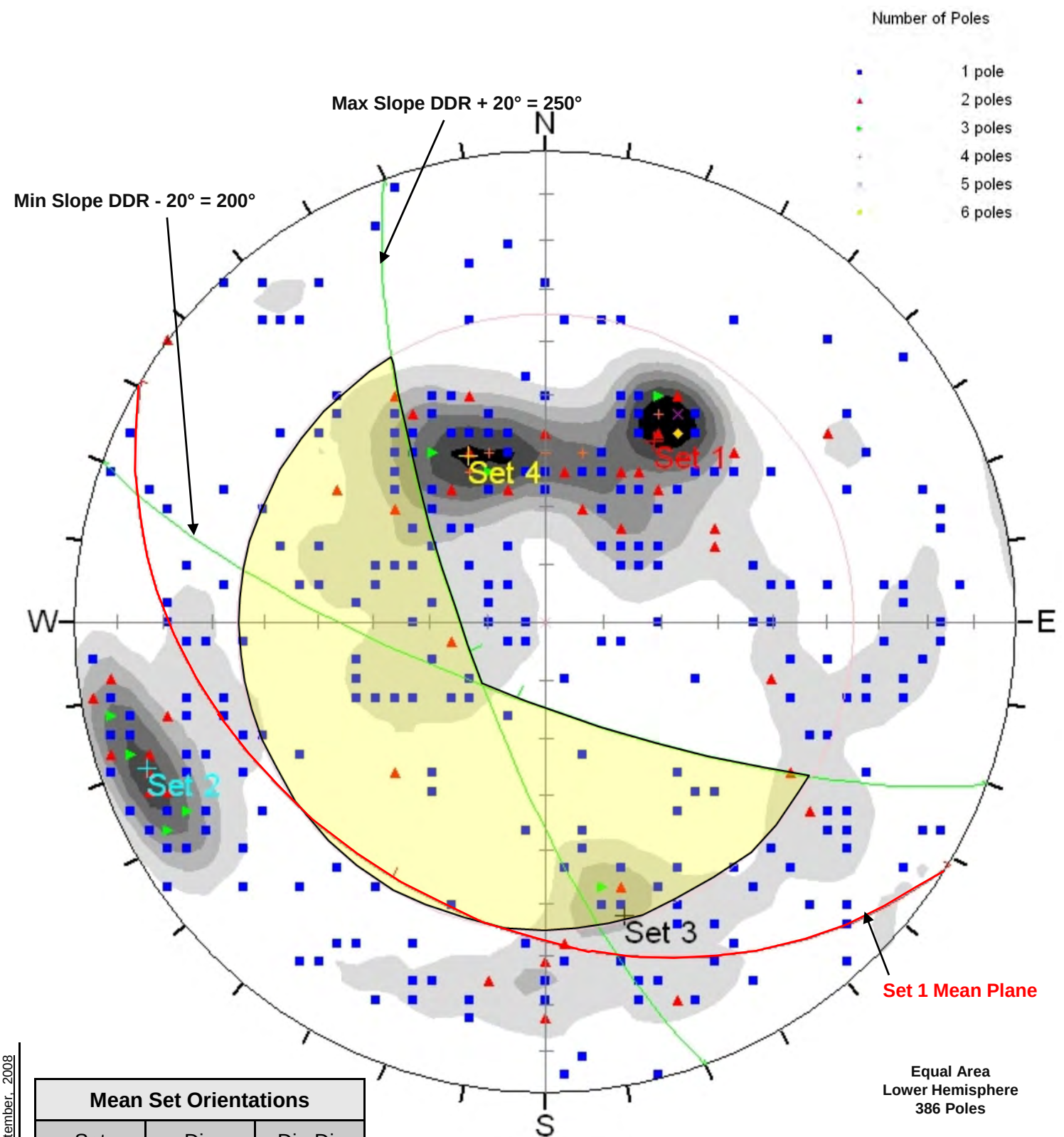
STABILIZATION REQUIREMENTS
Design Sector XV

Figure 43



Mean Set Orientations		
Set	Dip	Dip Dir
1	37°	211°
2	79°	070°
3	54°	345°
4	32°	155°

Equal Area
Lower Hemisphere
386 Poles

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Figure 44

Design Sector XVI – Detailed Kinematic Analysis

I-90 Snoqualmie Pass East
Hyak to Keechelus Dam

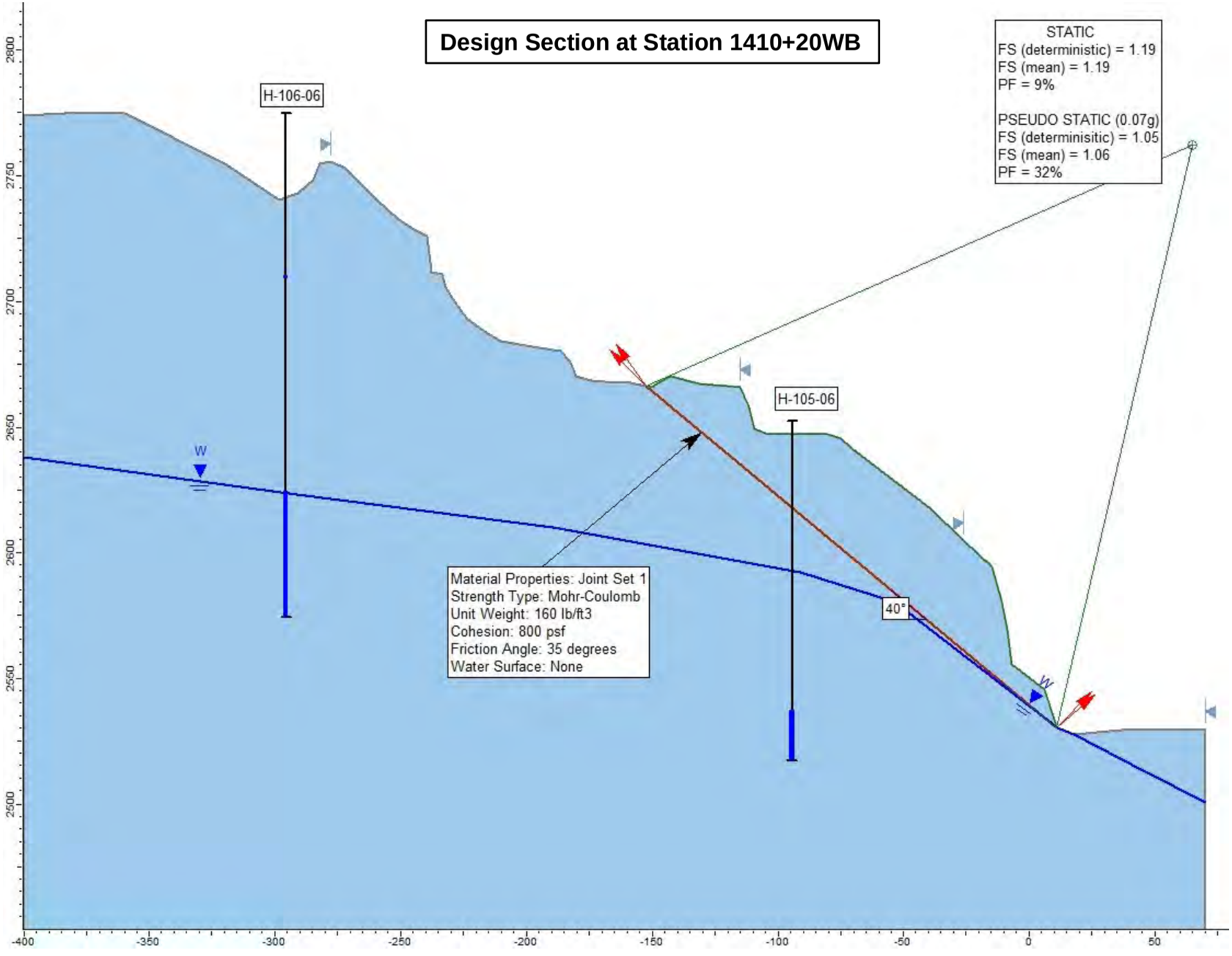
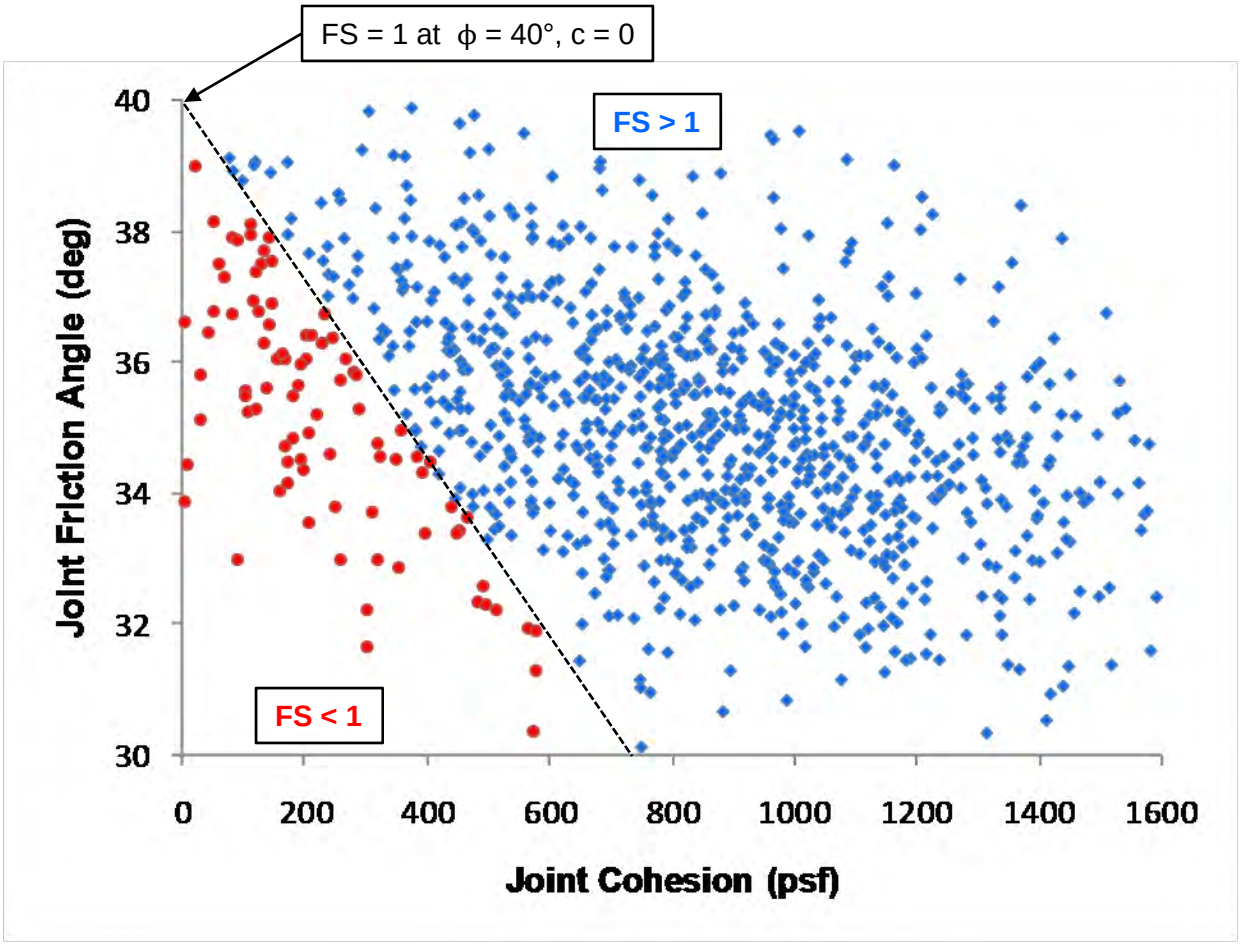


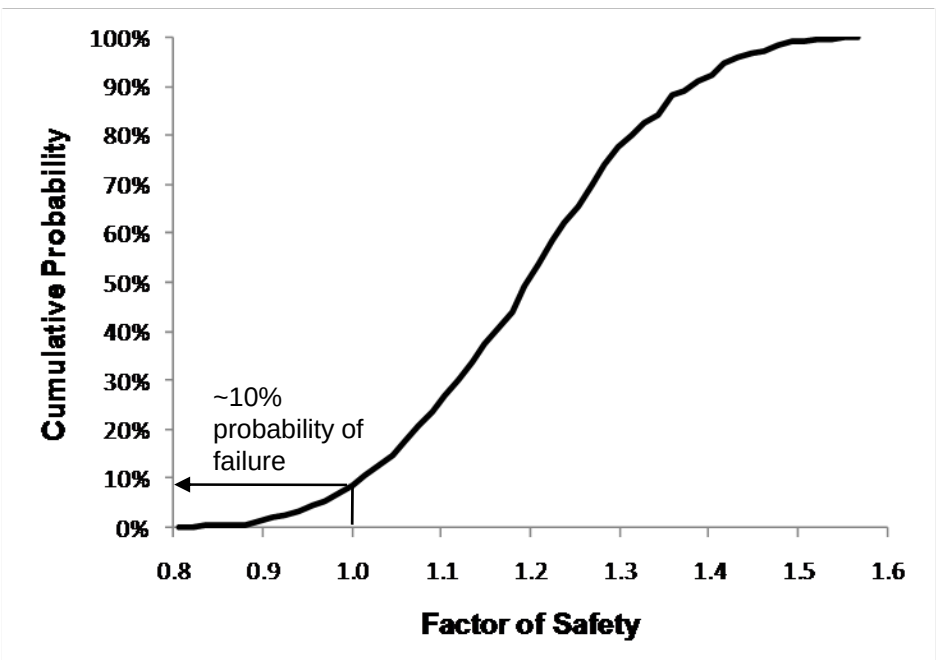
Figure 45

Design Sector XVI – Existing Slope Back Analysis

Project No. 062-2002 Date: August, 2008



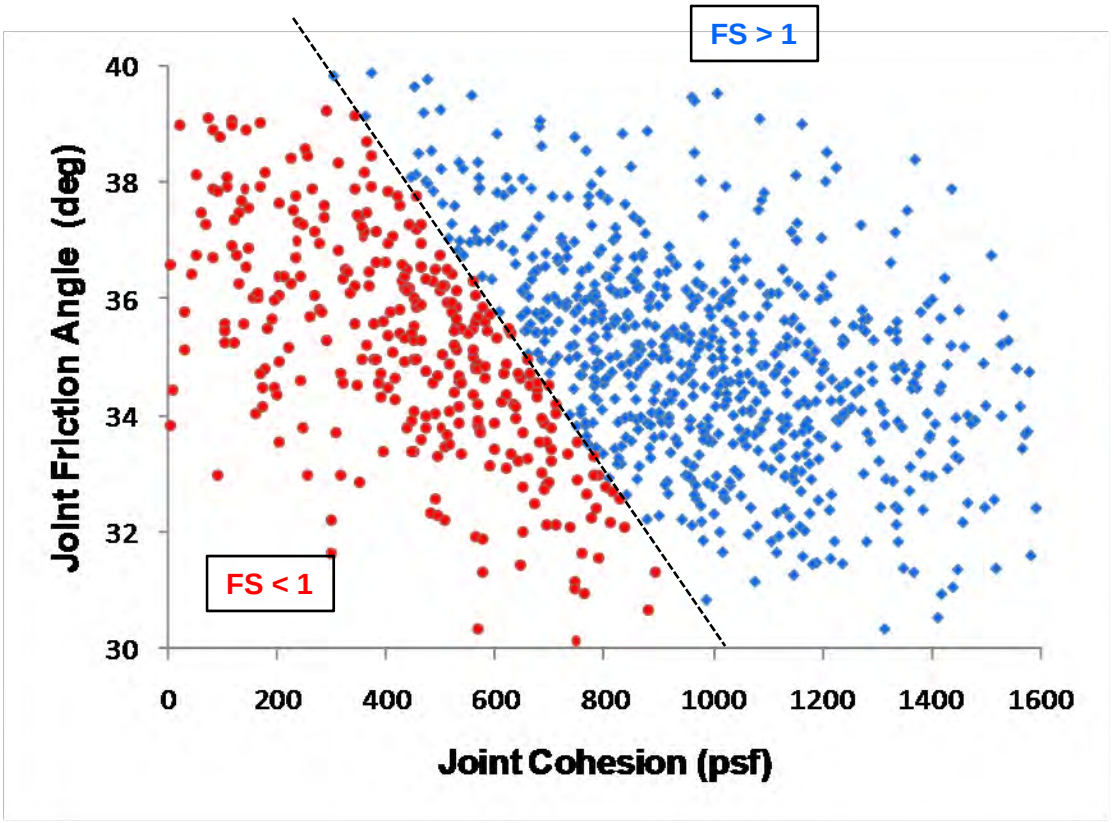
Note : Analysis for existing slope at Station 1410+20WB.

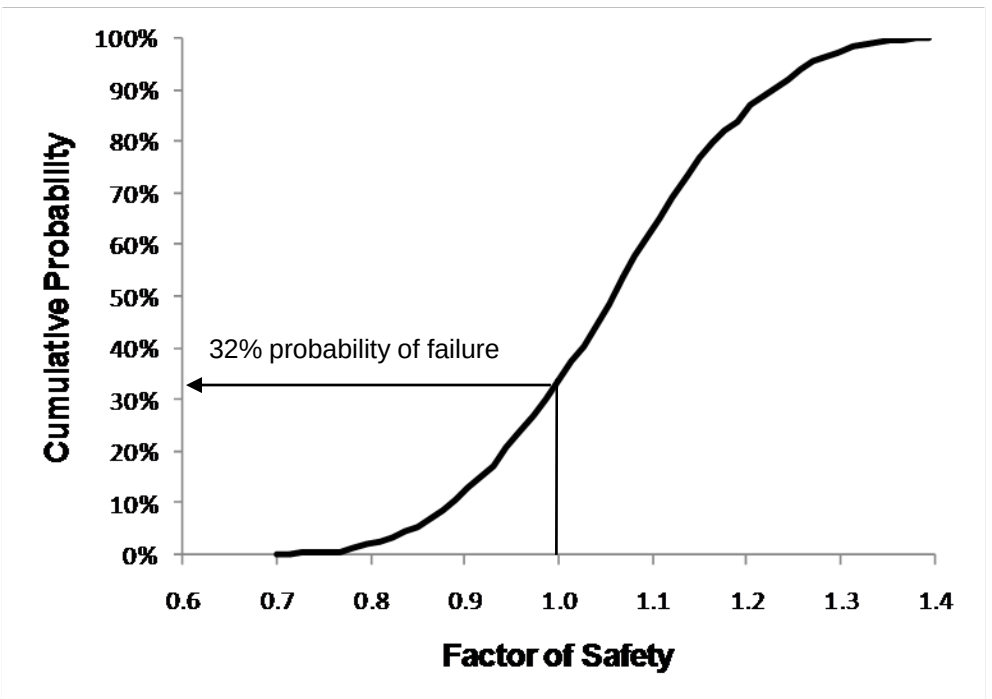


Project No. 062-2002 Date: August, 2008

Figure 46

Design Sector XVI – Static Back Analysis





Note: Analysis for existing slope at Station 1410+20WB with seismic coefficient = 0.07g.

Figure 47

Design Sector XVI – Pseudo Static Back Analysis

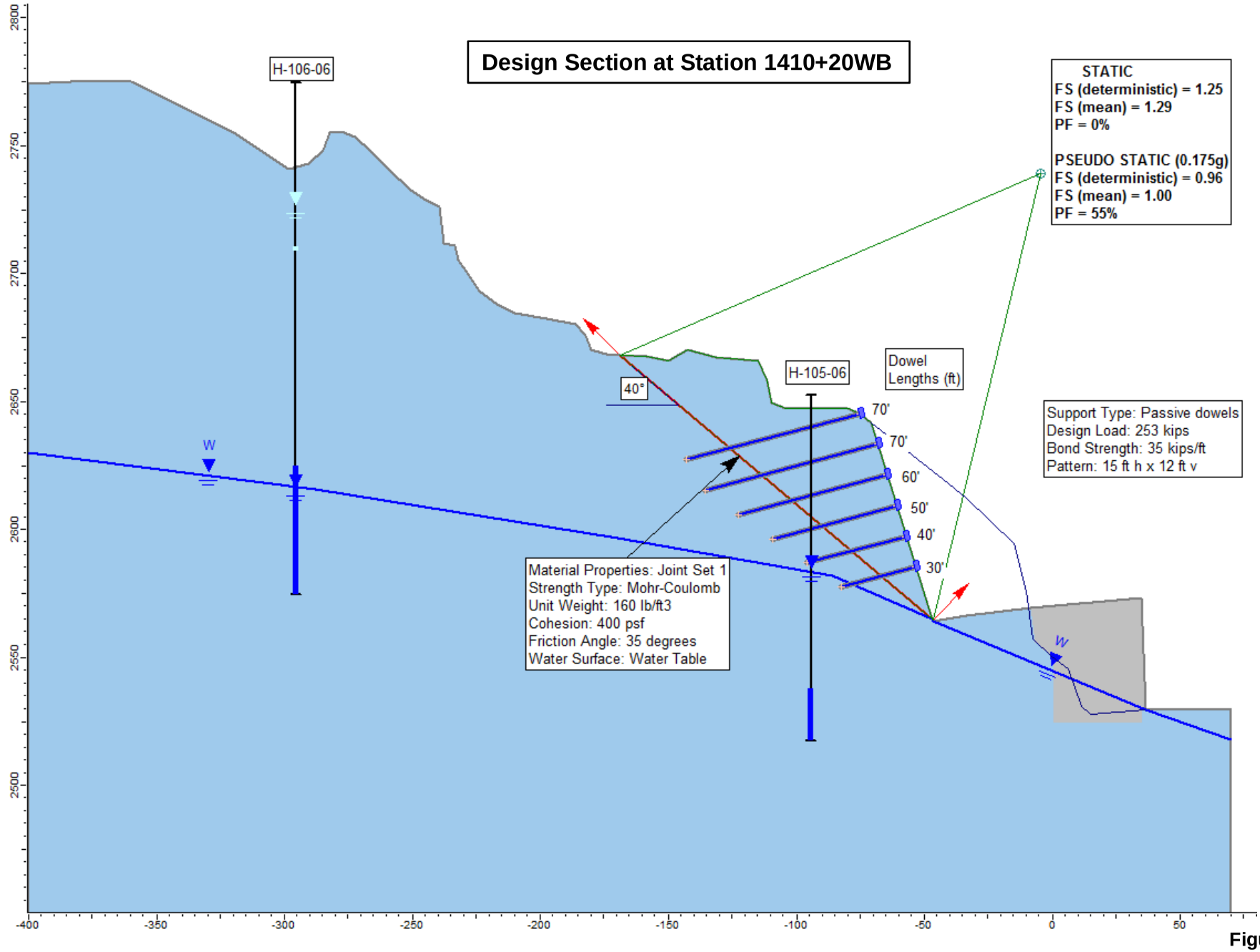
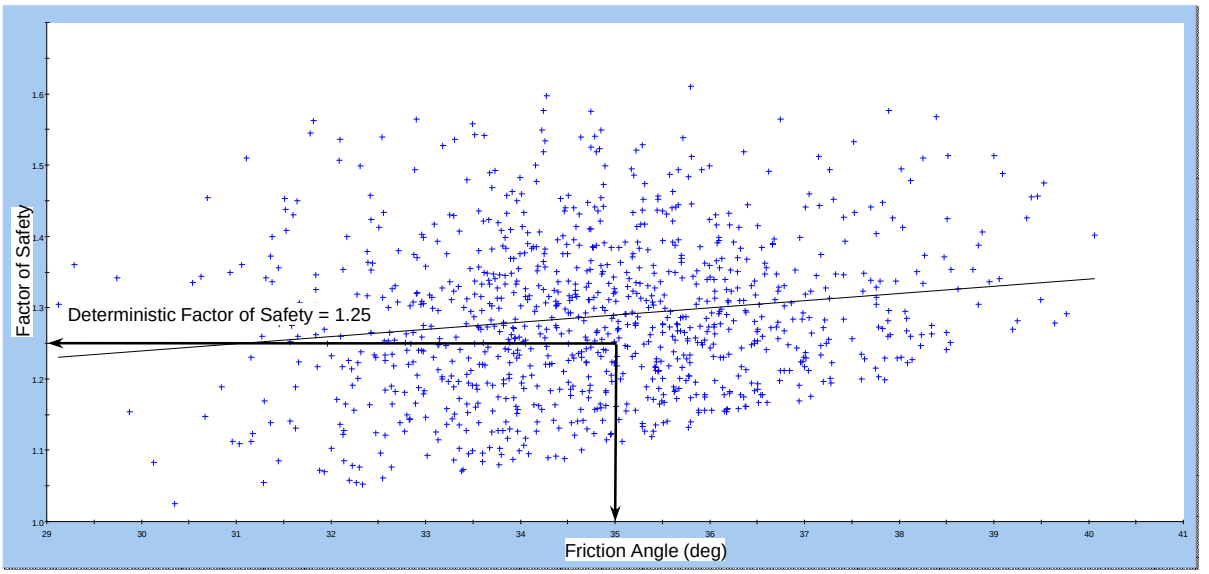
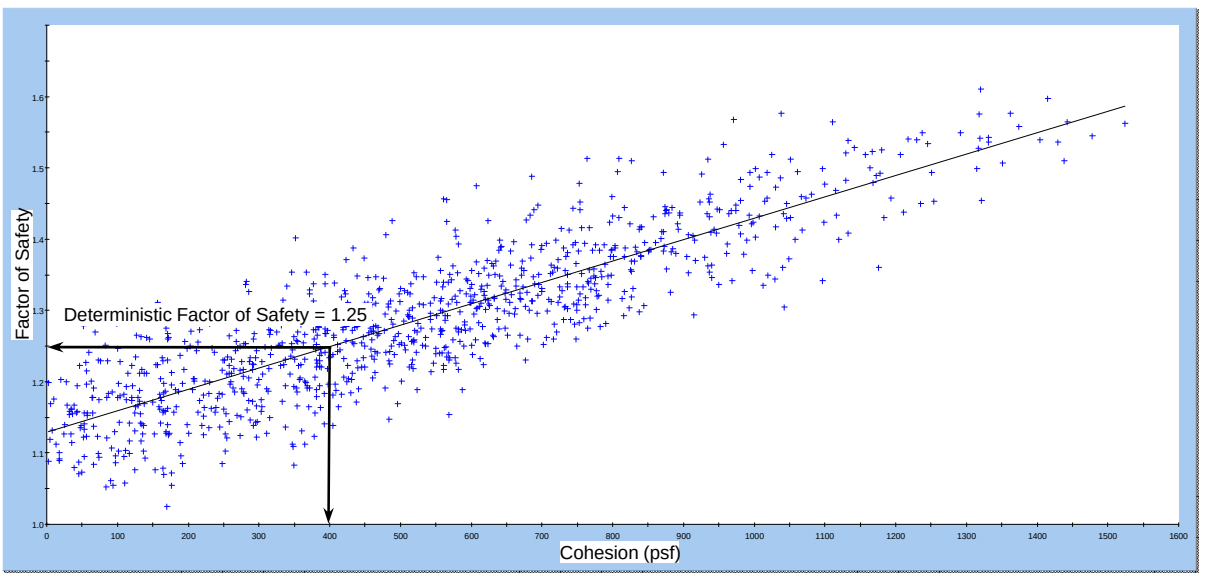


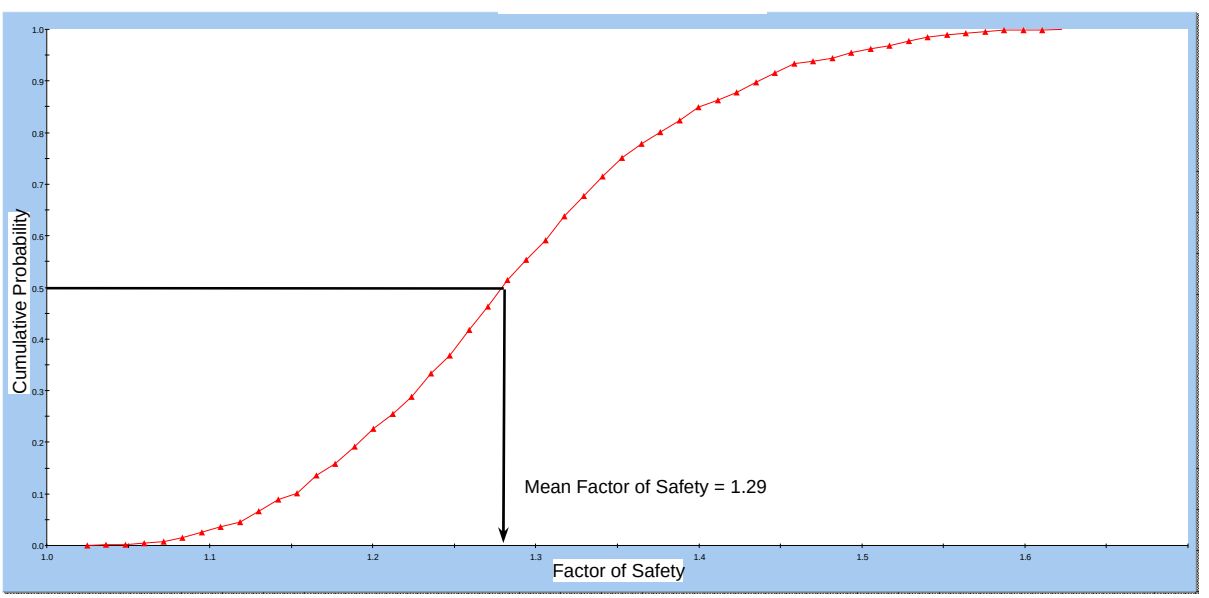
Figure 48

Design Sector XVI – Stability Analysis

Project No. 062-2002 Date: July, 2008







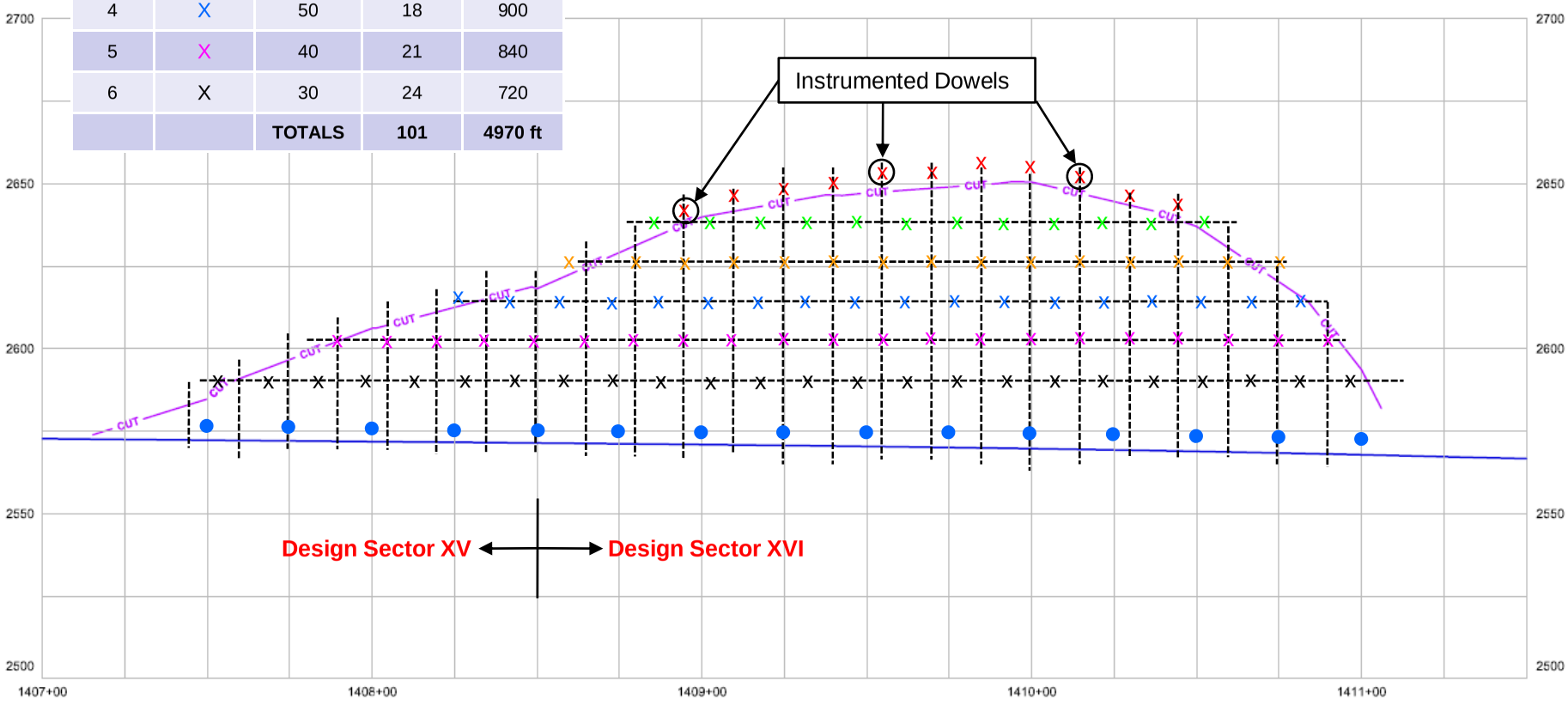
Project No. 062-2002 Date: May, 2008

Figure 49

(For reinforced slope per Figure 48)

Design Sector XVI – Probabilistic Stability Analysis

Row	Dowel Symbol	Dowel Length	No. Dowels	Cum. Length
1	X	70	11	770
2	X	70	12	840
3	X	60	15	900
4	X	50	18	900
5	X	40	21	840
6	X	30	24	720
		TOTALS	**101**	**4970 ft**



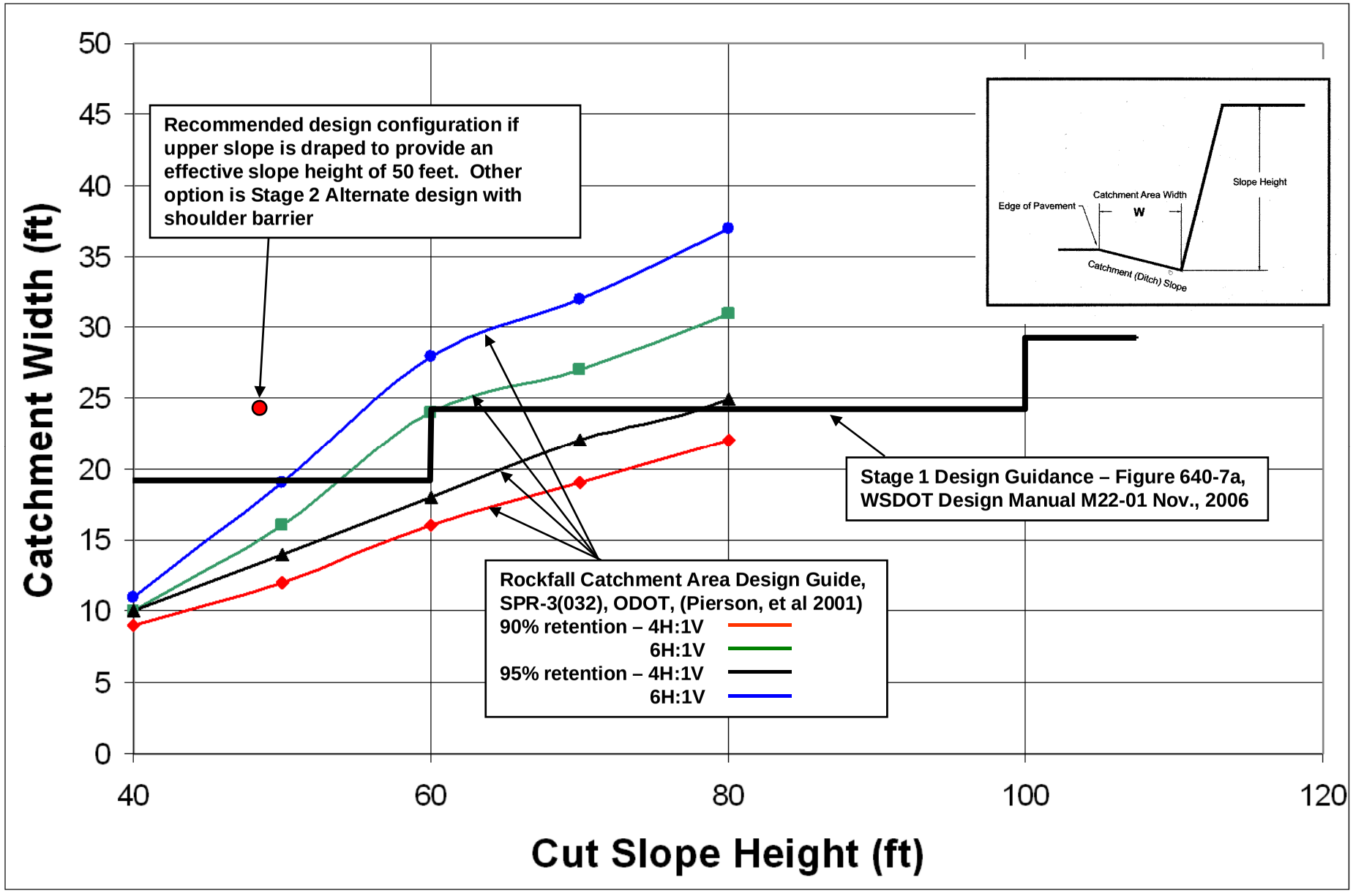
Horizontal Drains: ●
25 ft horizontal spacing x 50 ft long
Total Length = 15 x 50 = 750 ft

Dowel pattern:
15 ft horizontal x 12 ft vertical
Adjacent rows with centers offset

Project No. 062-2002 **Date:** May, 2008

Figure 50

Design Sector XVI – Dowel Reinforcement Design



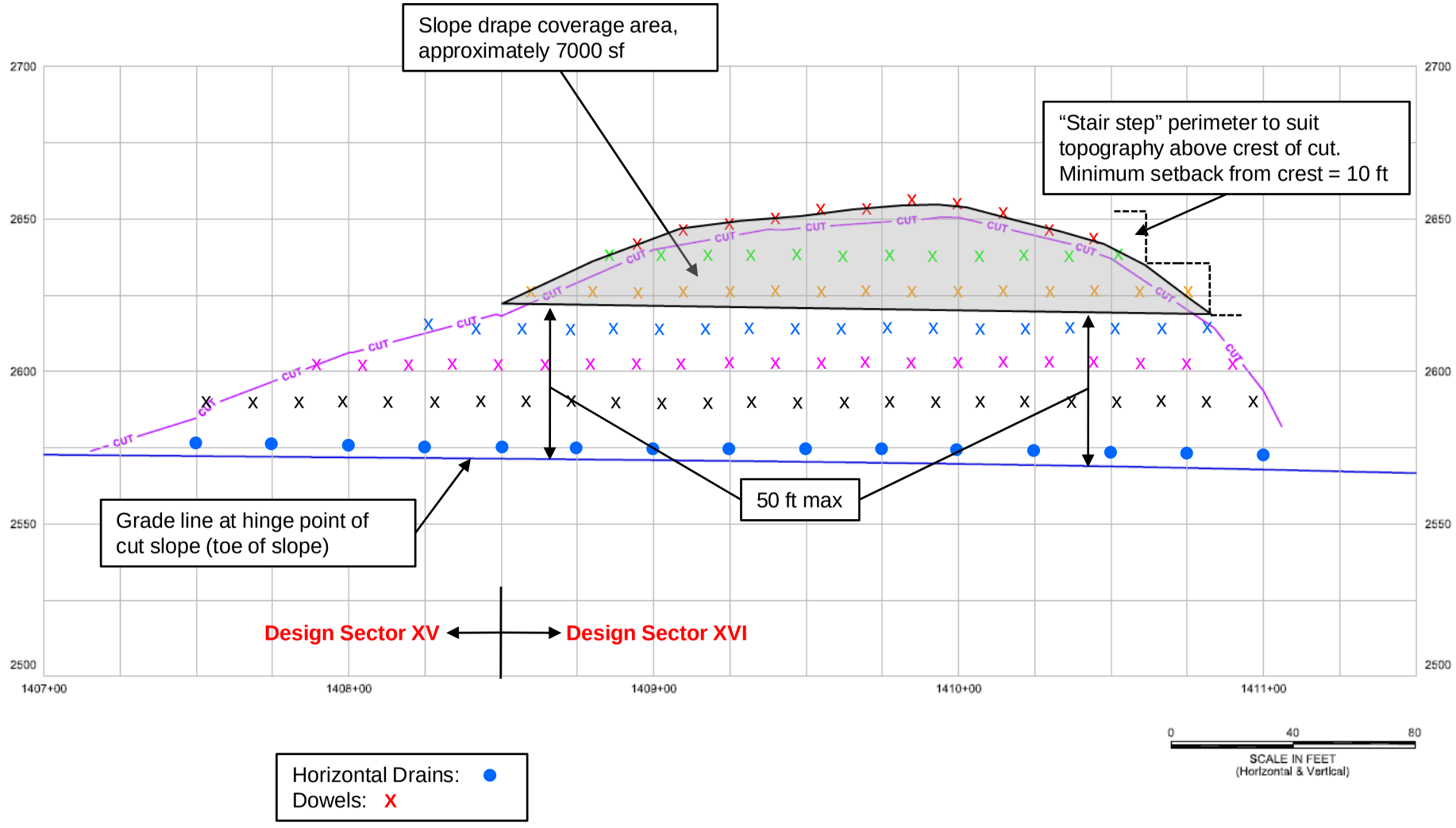
Modified after Wyllie & Norrish, 2007b

Figure 51

CATCHMENT DESIGN GUIDE FOR 0.25H:1V ROCK SLOPES

Project No. 062-2002 Date: November 21, 2006

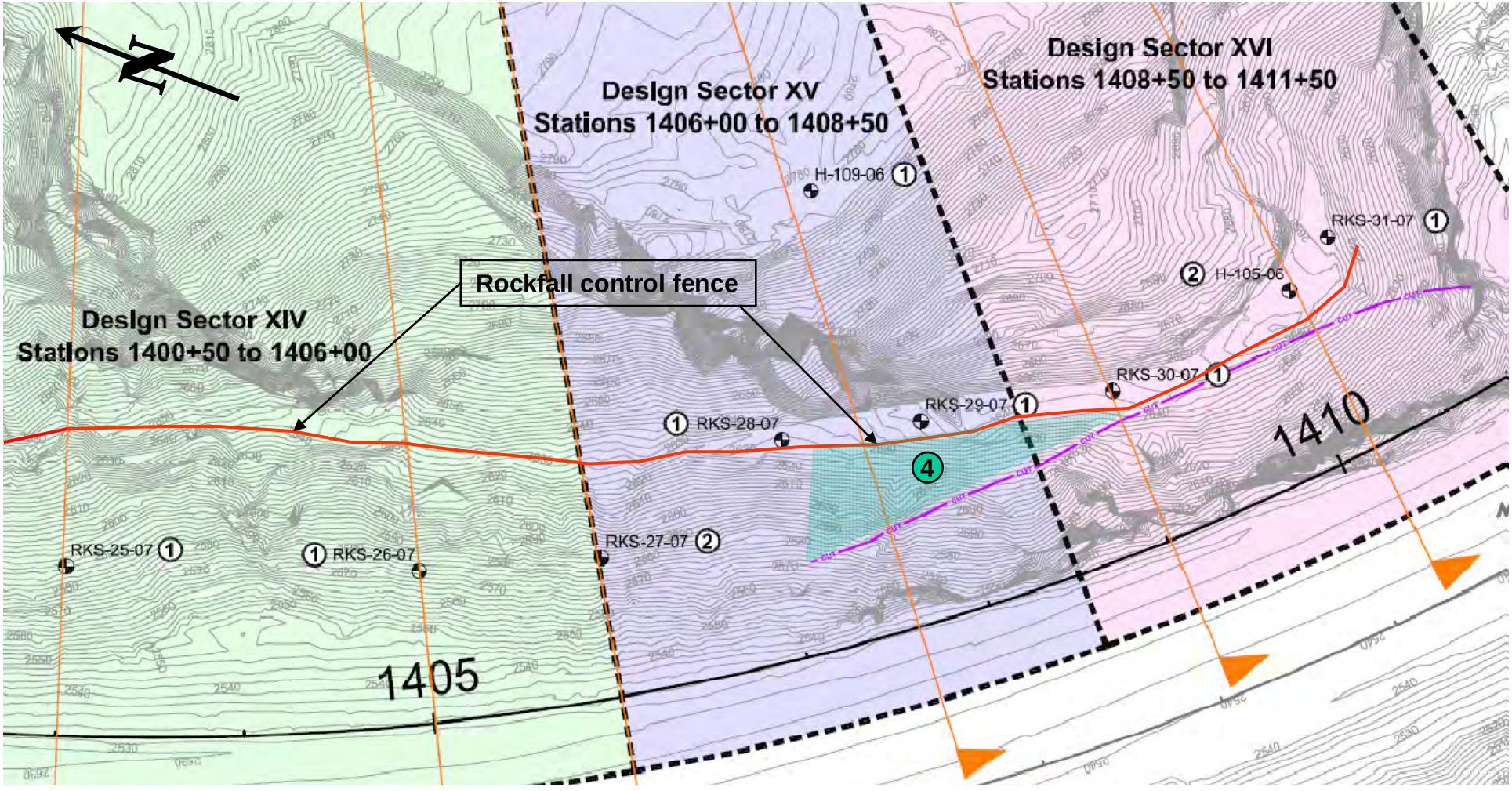
I-90 Snoqualmie Pass East
Hyak to Keechelus Dam



Project No. 062-2002 Date: September, 2008

Figure 52

Design Sector XVI – Slope Drape Conceptual Design



Notes:

1. Rockfall control fence to extend from Station 1402+50 WB to 1410+50 WB.
2. Fence location at nominal elevation 2630 feet, increasing to top of cut at eastbound limit and to 2650 feet at westbound limit.
3. Fence height = 10 feet, Minimum impact energy capacity = 150 ft-tons.

(4) Variable thickness talus and fill should be removed down to bedrock in this area. May partially remove access road.

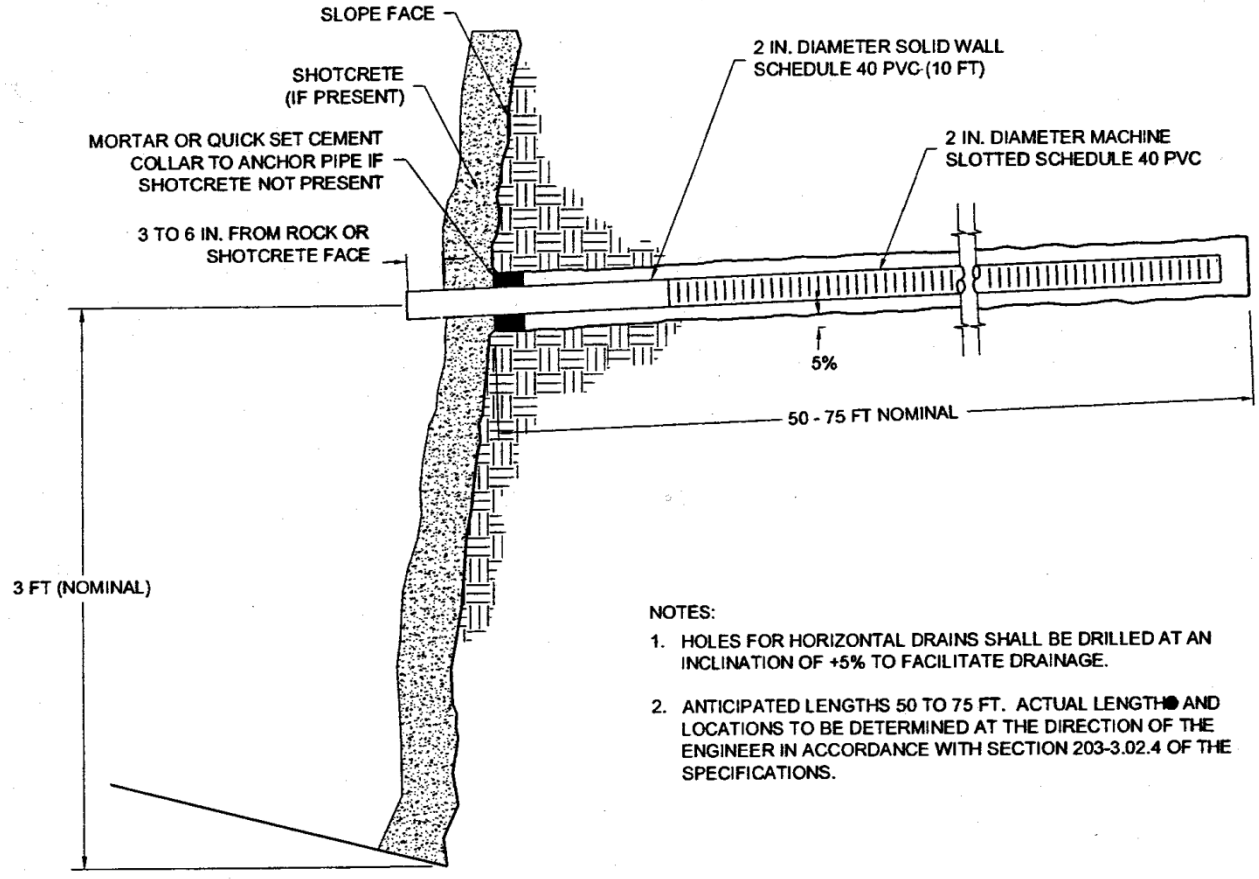
Figure 53

Design Sectors XIV to XVI – Rockfall Control Fence

See Figure 53 for access road location.

Figure 54

Design Sector XV: Access Road Rockfall Barrier



HORIZONTAL DRAIN
NOT TO SCALE

Figure 55

Horizontal Drain Detail