Re-Evaluation of The Magnitude of Historic Floods on the Skagit River near Concrete

K.M. Leytham
Northwest Hydraulic Consultants

for

Skagit County Public works

Bellingham
land
es Island
Concrete
Burlington
Mt Vernon
Skagit
Fidalgo Island
and
15.88 mi
Image U.S. Geological Survey
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©2009 Google
Imagery Dates: Mar 31, 2006 - Sep 2, 2006
48°31'48.41" N 121°57'12.13" W elev 245 ft
Eye alt 54.59 mi


20
Concrete
Concrete
Image U.S. Geological Survey
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2.24 mi
©2009 Google
Imagery Date: Mar 31, 2006
48°32'17.29" N 121°46'04.84" W elev 282 ft
Eye alt 41177 ft

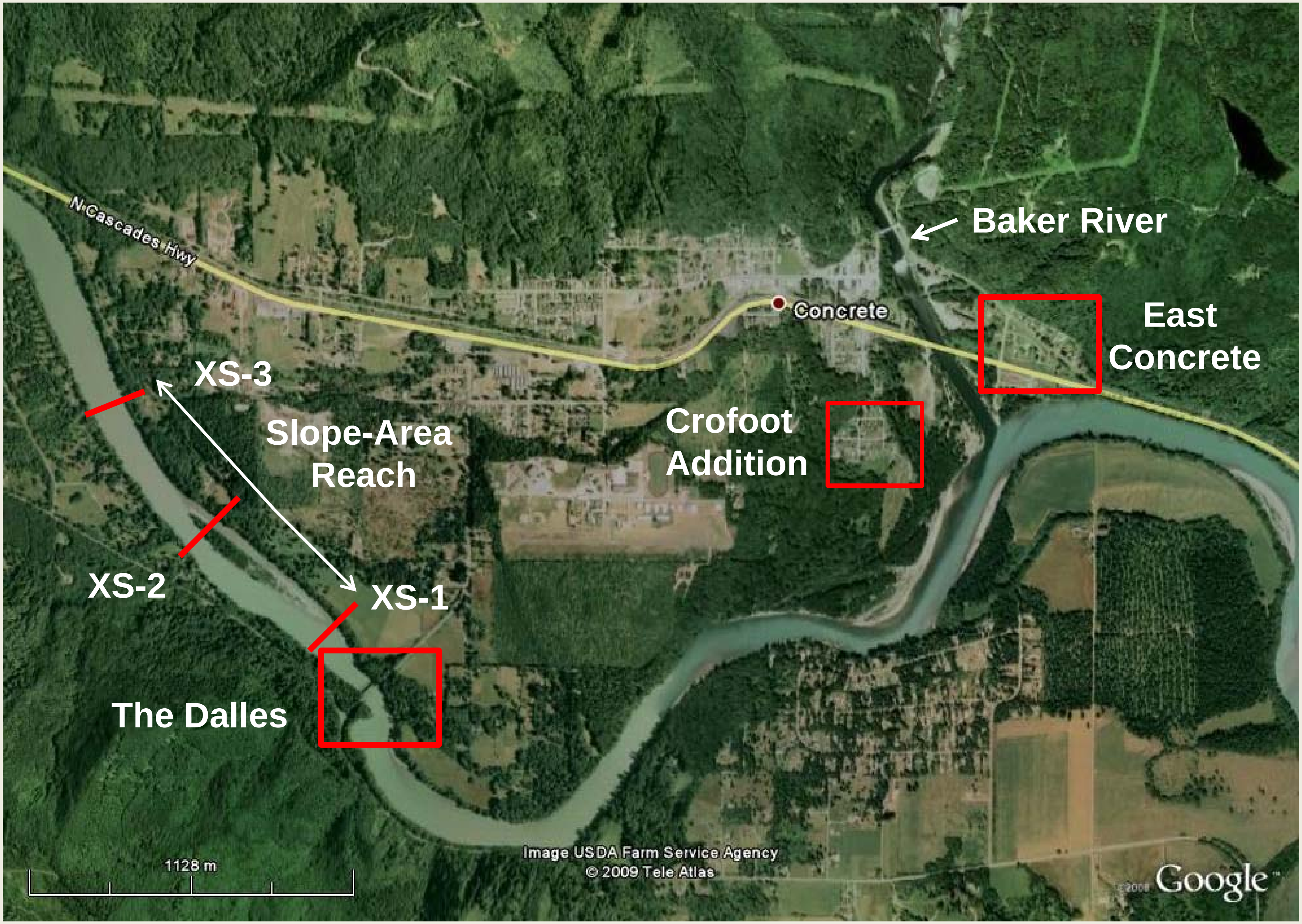
Rationale for (Further) Re-evaluation of Skagit River Hydrology

Previous re-evaluations of historic floods by the USGS, focusing on the slope-area measurement for the December1921 flood on the Skagit River near Concrete, have considered:

- Revised estimates of Manning’s “n” based on channel roughness verification.
- More sophisticated analytical approach (using complete energy equation and subdivision of cross-sections)
- Plotting position of the 1921 flood on the stage-discharge rating for the Skagit River near Concrete gage (incidental consideration).

Previous re-evaluations have **NOT** considered:

- The nature and likely reliability of historic high water marks upon which the slope-area measurement is based.
- The effects of uncertainty in high water data on peak discharge estimates.
- Alternative techniques for estimating peak discharges.
- The full body of evidence available for investigating the magnitude of the 1921 flood and other historic floods.



N Cascades Hwy
Concrete
Baker River
East Concrete
XS-3
Slope-Area Reach
Crofoot Addition
XS-2
XS-1
The Dalles
1128 m
Image USDA Farm Service Agency
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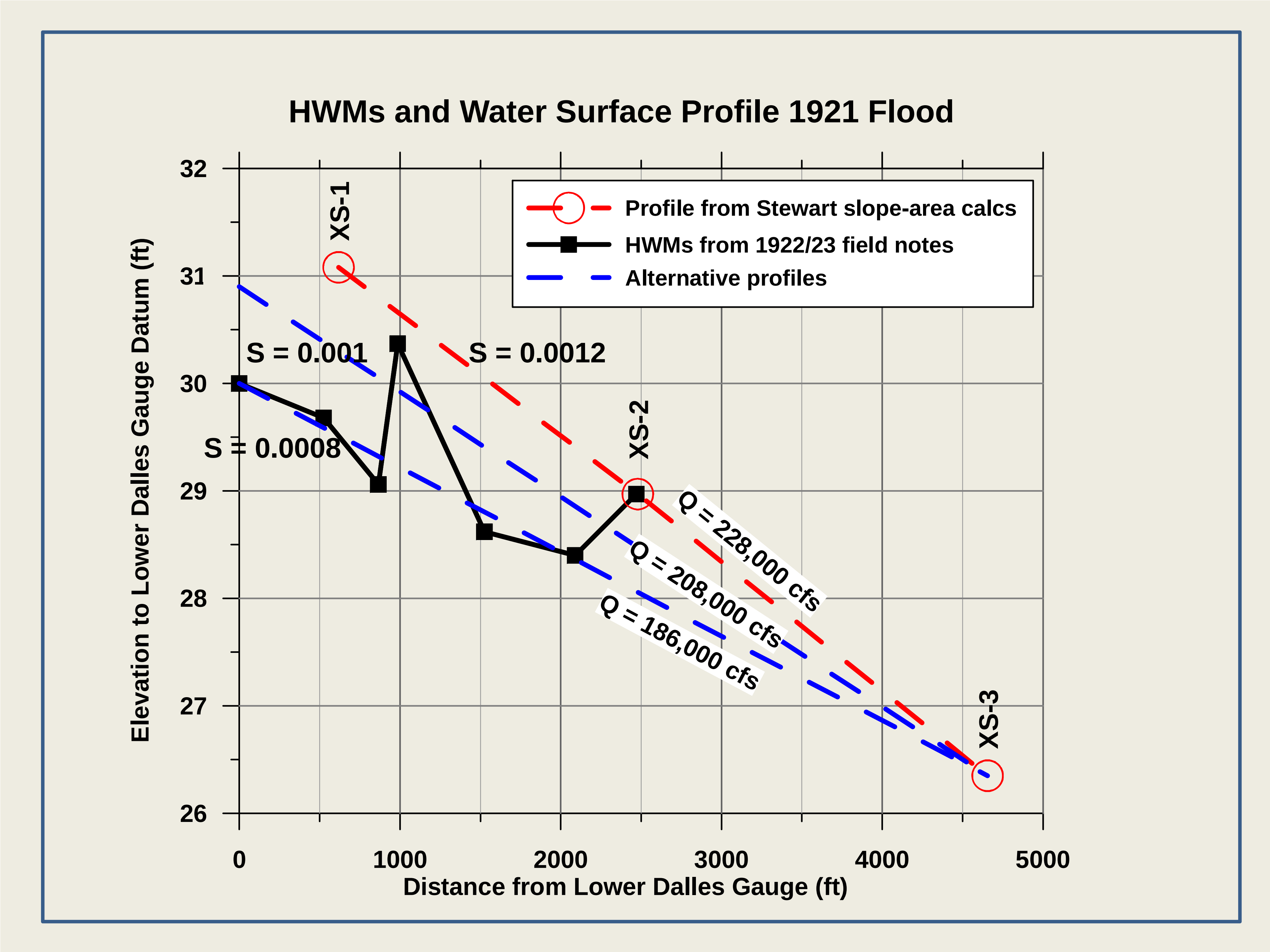
Water Level Gages at The Dalles

Some Comments on the Slope-Area Measurement for the 1921 Flood

“Good high-water marks are basic to a reliable slope-area computation …..” (Dalrymple and Benson, USGS TWI 3-A2, 1967).

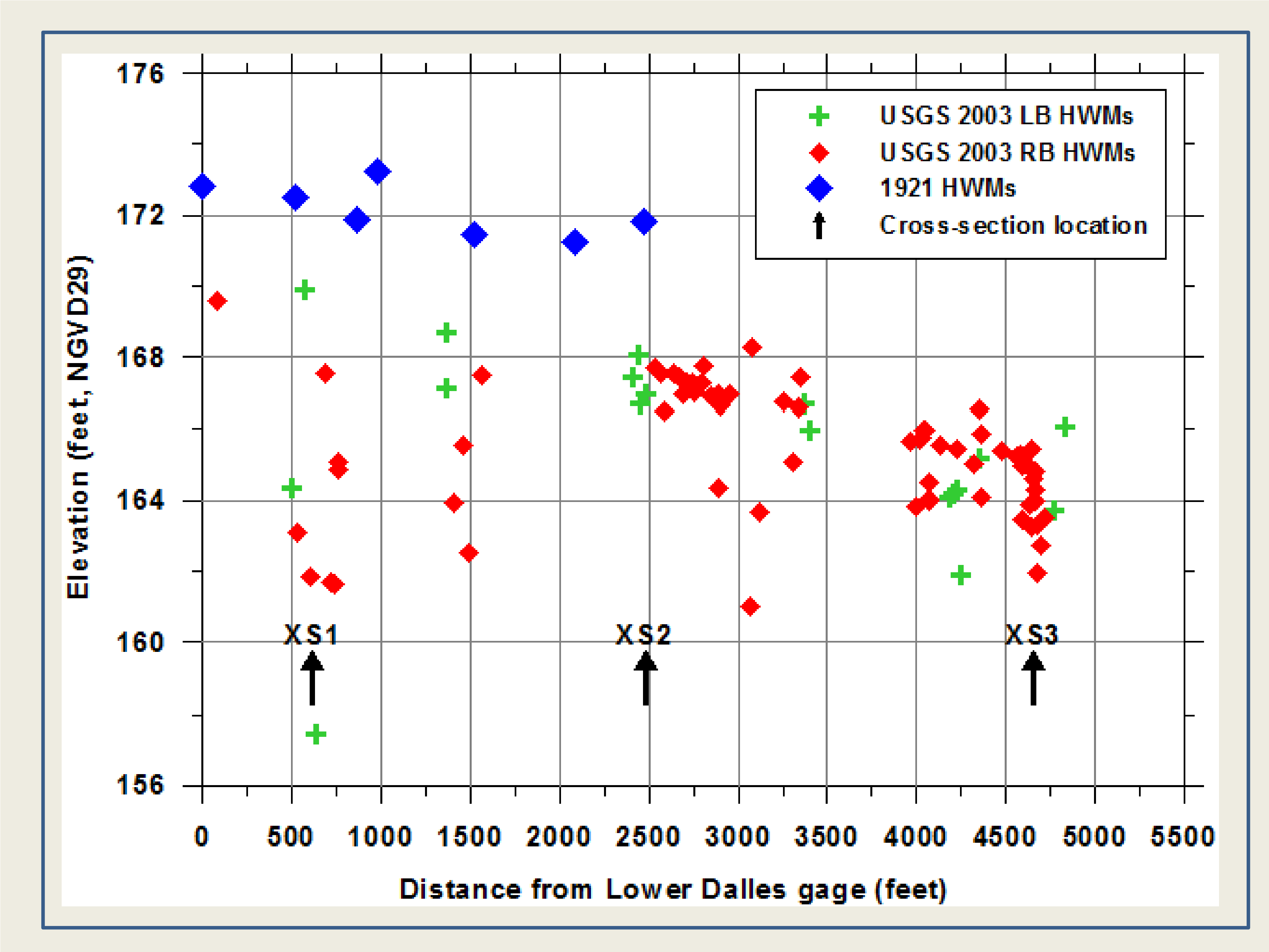
How good are the 1921 HWMs?

- HWMs in the slope-area reach are based on natural indicators such as sand deposited in moss on trees, moss scoured from trees, mud marks, drift along bank lines.
- HWMs were identified and surveyed more than a year after the event (January and March 1923).
- Unexplained inconsistencies exist between HWM data in field notes and profile used in slope-area calculations.

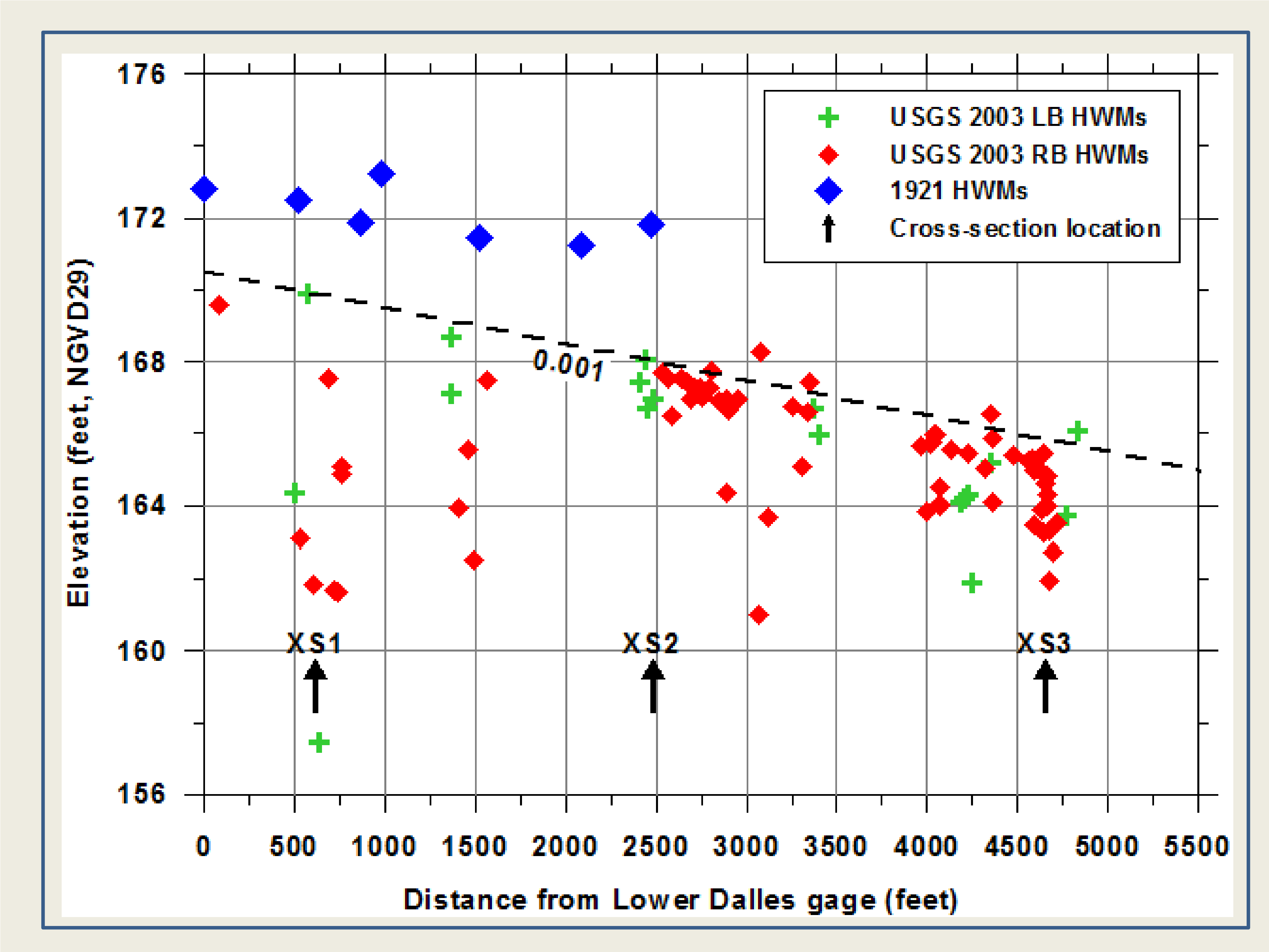

HWMs and Water Surface Profile 1921 Flood
Profile from Stewart slope-area calcs
HWMs from 1922/23 field notes
Alternative profiles
XS-1
XS-2
XS-3
S = 0.001
S = 0.0012
S = 0.0008
Q = 228,000 cfs
Q = 208,000 cfs
Q = 186,000 cfs
Elevation to Lower Dalles Gauge Datum (ft)
Distance from Lower Dalles Gauge (ft)
26
27
28
29
30
31
32
0
1000
2000
3000
4000
5000

“Re-Evaluation of the 1921 Peak Discharge at Skagit River near Concrete, Washington”
USGS SIR 2007-5159

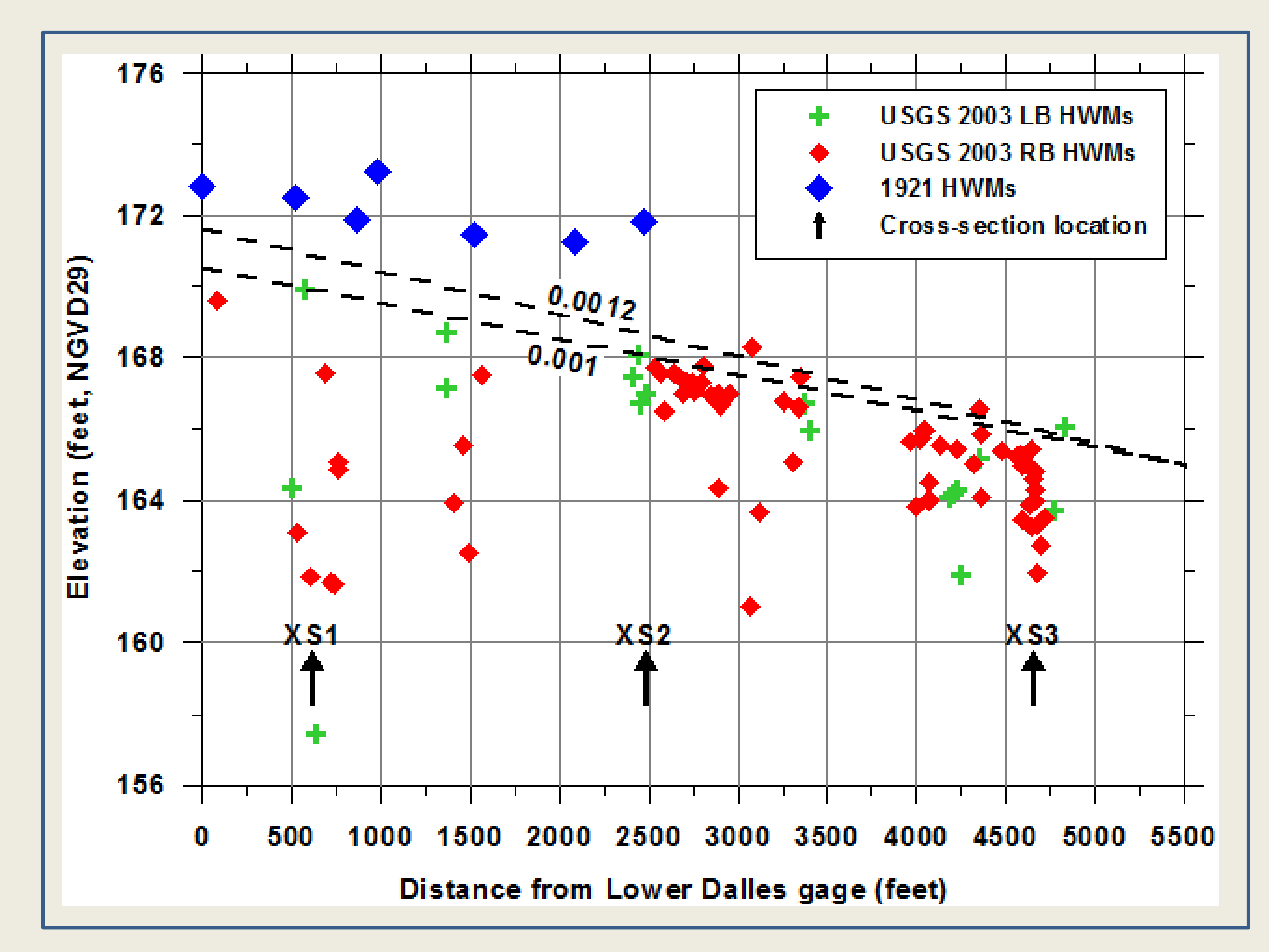
“.. a considerable amount of variation in the elevation of surveyed HWMs for the flood on October 21, 2003, precluded the determination of a single definitive water-surface slope for use in the n-verification analysis. The variability in surveyed HWMs for the flood on October 21, 2003, was attributed to the length of time between the event and the actual field survey, which was not completed until 9 months later in July-August 2004. “



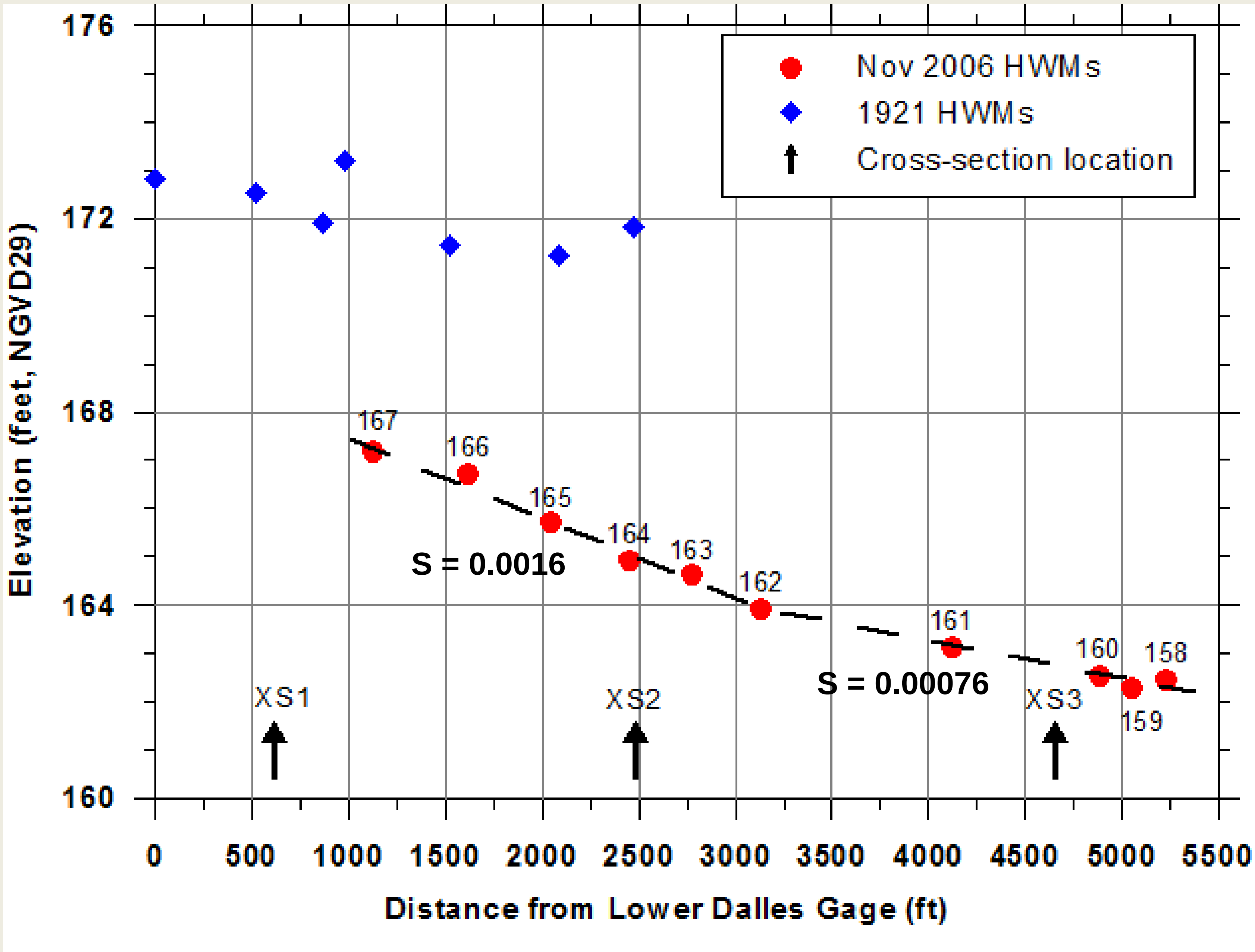
Elevation (feet, NGVD29)
176
172
168
164
160
156
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
Distance from Lower Dalles gage (feet)
USGS 2003 LB HWMs
USGS 2003 RB HWMs
1921 HWMs
Cross-section location
XS1
XS2
XS3



176
172
168
164
160
156
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
Elevation (feet, NGVD29)
Distance from Lower Dalles gage (feet)
USGS 2003 LB HWMs
USGS 2003 RB HWMs
1921 HWMs
Cross-section location
0.001
XS1
XS2
XS3



176
172
168
164
160
156
Elevation (feet, NGVD29)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
Distance from Lower Dalles gage (feet)
USGS 2003 LB HWMs
USGS 2003 RB HWMs
1921 HWMs
Cross-section location
0.0012
0.001
XS1
XS2
XS3



Nov 2006 HWMs
1921 HWMs
Cross-section location
Elevation (feet, NGVD29)
Distance from Lower Dalles Gage (ft)
176
172
168
164
160
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
167
166
165
164
163
162
161
160
158
159
S = 0.0016
S = 0.00076
XS1
XS2
XS3

Implications for slope-area measurement

- Insufficient information to allow us to relate Stewart's assumed water surface profile to available 1921 HWMs (in particular no absolute HWMs have been located between XS-2 and XS-3).
- Scatter in available HWMs is such that accurate determination of 1921 water surface slope is not possible.
- Estimate of peak discharge is sensitive to uncertainty in slope.

Water Level Gages at The Dalles

History of Water Level Gages at The Dalles

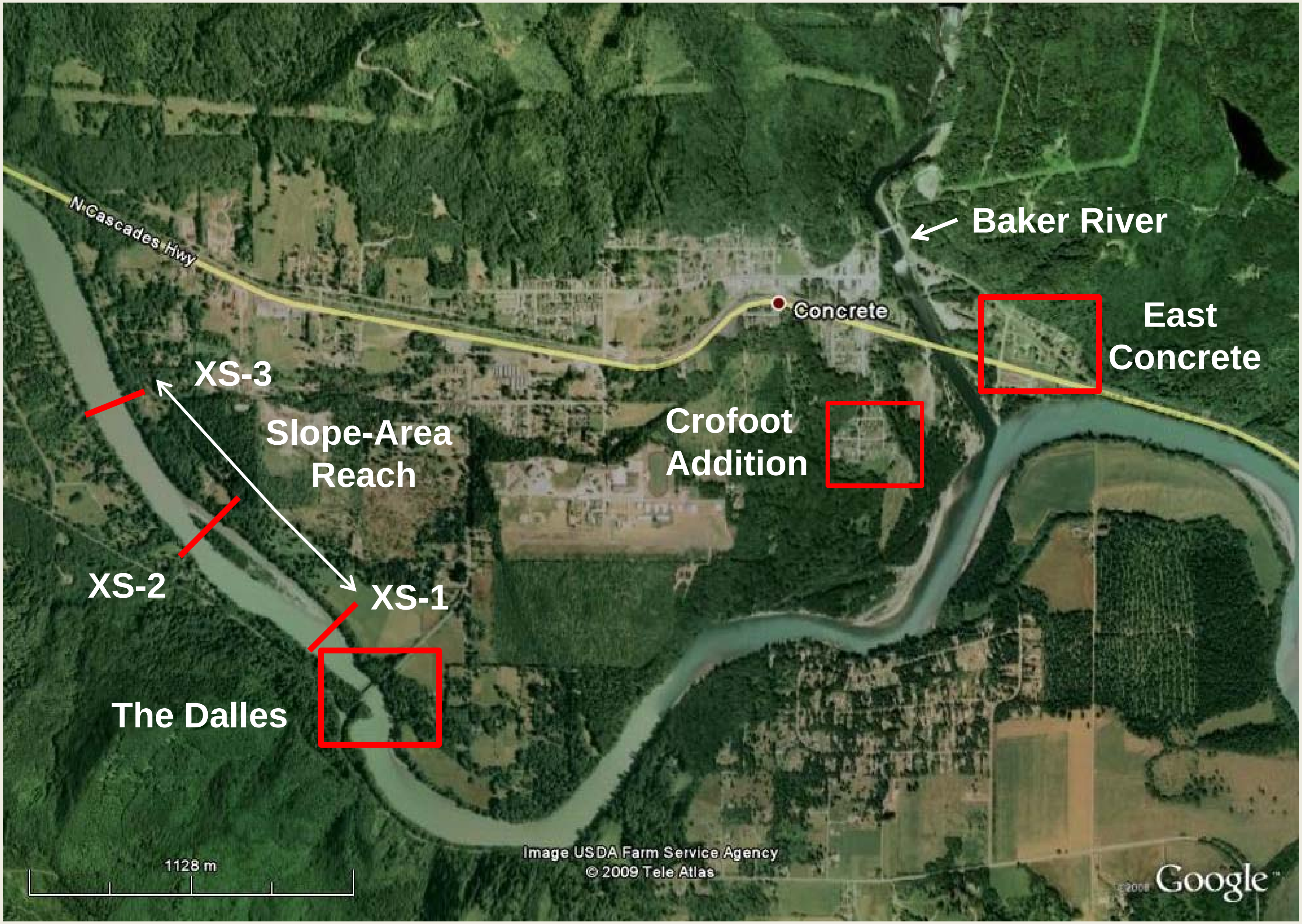
- Upper Dalles gage established by Stewart 23 Dec1922 – datum 140.89 MSL
- Lower Dalles gage established by Stewart Dec 1922 or Jan 1923 – datum 141.04 MSL.
- Recording gage installed 10 Dec 1924, 200-300 ft downstream (site of present gage) – datum 142.69 NGVD29
- Present gage from 28 Oct 1938 – datum 130.0 NGVD29
- Issues:

  - Stewart gage heights for historic events applied assuming gage datum of 142.69 ft NGVD.

  - Upper Dalles gage heights for historic events applied to current gage site without correction for water level drop between gauges.

Alternative Approach to Estimation of 1921 Peak Discharge

- Estimate 1921 HWMs for the reach between The Dalles and Concrete from :
  - Concrete Herald report of 17 December 1921
  - Stewart HWM's from January 1923
- Develop HEC-RAS model for the reach.
- Apply HEC-RAS to estimate 1921 peak discharge consistent with available HWMs.



N Cascades Hwy
Baker River
Concrete
East Concrete
XS-3
Slope-Area Reach
Crofoot Addition
XS-2
XS-1
The Dalles
1128 m
Image USDA Farm Service Agency
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THE CONCRETE HERALD, 17 DECEMBER 1921

About three o'clock in the afternoon it [i.e. the Skagit River] went over the banks in Crofoot addition and the residents of that part of town began to move out, being taken care of at the homes of friends in the higher part of town until the flood subsided. The waters also crept up around some of the dwellings in East Concrete, and some of the residents moved out for the night. In Crofoot addition only three residences remained above the high water mark, the water being to a depth of an inch to 14 inches in the others. No particular damage was done, except for small articles outside being washed away, and the job of cleaning out the mud left by the flood. The Vlist, Milton and Hempsenyer families lost a considerable number of chickens and several loads of wood were washed away. In East Concrete practically no damage was done.

Interpretation of Concrete Herald Report

- Obtain finished floor elevation of lowest remaining residence dating back to 1921 (45956 Albert Street, Concrete).
- Assume 1921 water level was 14 inches above finished floor level. (**Elevation 186.1 ft NGVD 1929**)

This elevation is probably a high-end estimate of water level:

- Results in HWM within 6 inches of floor level for East Concrete residence – inconsistent with statement that *"waters also crept up around some of the dwellings in East Concrete".*
- Some homes in Crofoot have been raised in elevation or replaced since 1921 – there may have been lower residences than 45956 Albert Street in 1921.

45956 Albert Street, Crofoot Addition showing highest plausible December 1921 water level per Concrete Herald report (186.1 ft)

46335 Forest Place, East Concrete showing finished floor level (186.6 ft)

Bird's eye
Labels
Traffic
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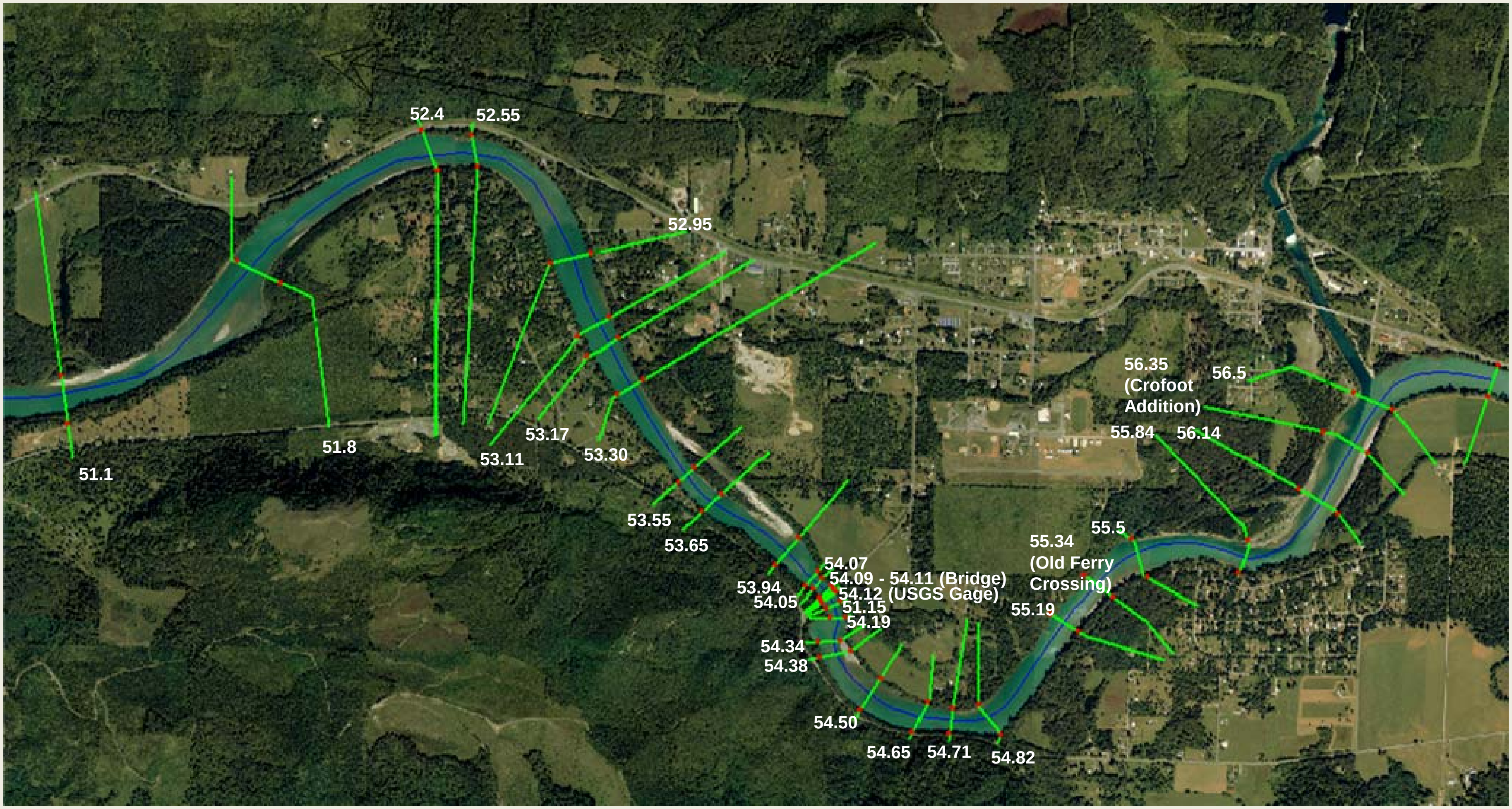
December 1921 High Water Data – The Dalles to Concrete

Description	**Location**	**1921 High Water Elevation (ft NGVD 1929)**
Upper Dalles gage (Stewart)	RM 54.17	175.8 – 177.6
Old Ferry Crossing gage (Stewart)	RM 55.34	182.58 – 184.38
Wolf residence (Stewart)	RM 56.5	184.55 – 186.35
Crofoot (Concrete Herald)	RM 56.35	Max 186.1

HEC-RAS Model Schematic



Hydraulic Modeling Issues

- Model representation of The Dalles.
  - Complex 3D flow conditions
  - No reliable data on head loss through The Dalles
  - Approach adopted brackets hydraulic conditions by using two alternate models with low and high losses through The Dalles.


497 m
Image USDA Farm Service Agency
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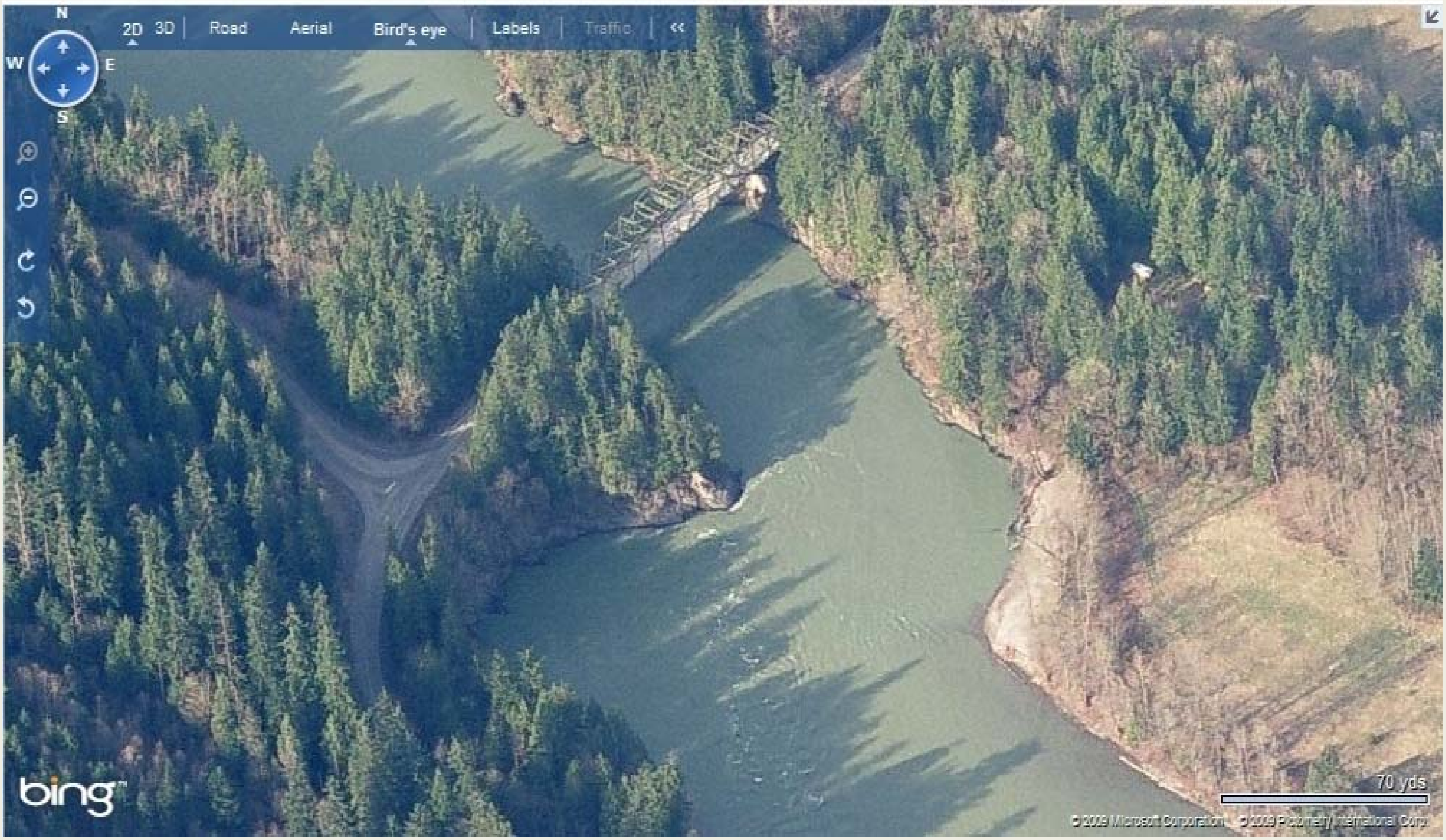
N
W
E
S
2D
3D
Road
Aerial
Bird's eye
Labels
Traffic
bing
70 yds
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Skagit River at The Dalles, 7 November 2006, Q = 117,000 cfs

Hydraulic Modeling Issues

- Model representation of The Dalles:
  - Complex 3D flow conditions
  - No reliable data on head loss through The Dalles
  - Approach adopted brackets hydraulic conditions by using two alternate models with low and high losses through The Dalles.

- Model calibration:
  - High water data October 2003 at The Dalles and Crofoot
  - USGS stage-discharge relationship at The Dalles gauge
  - HWMs below The Dalles (?)

Jenkins Residence, 7752 South Dillard, Crofoot Addition
21 October 2003


Bird's eye
Labels
Traffic
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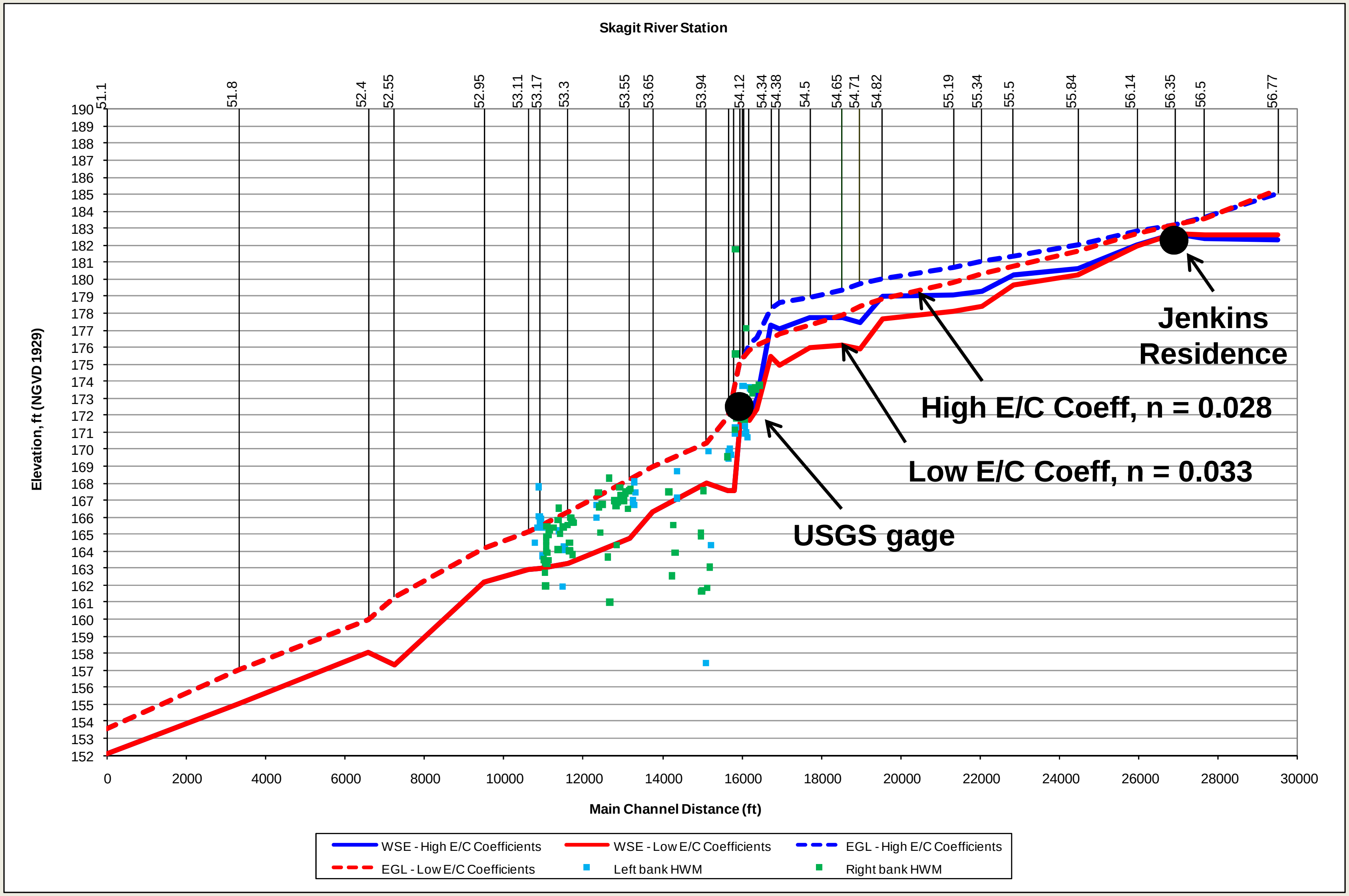
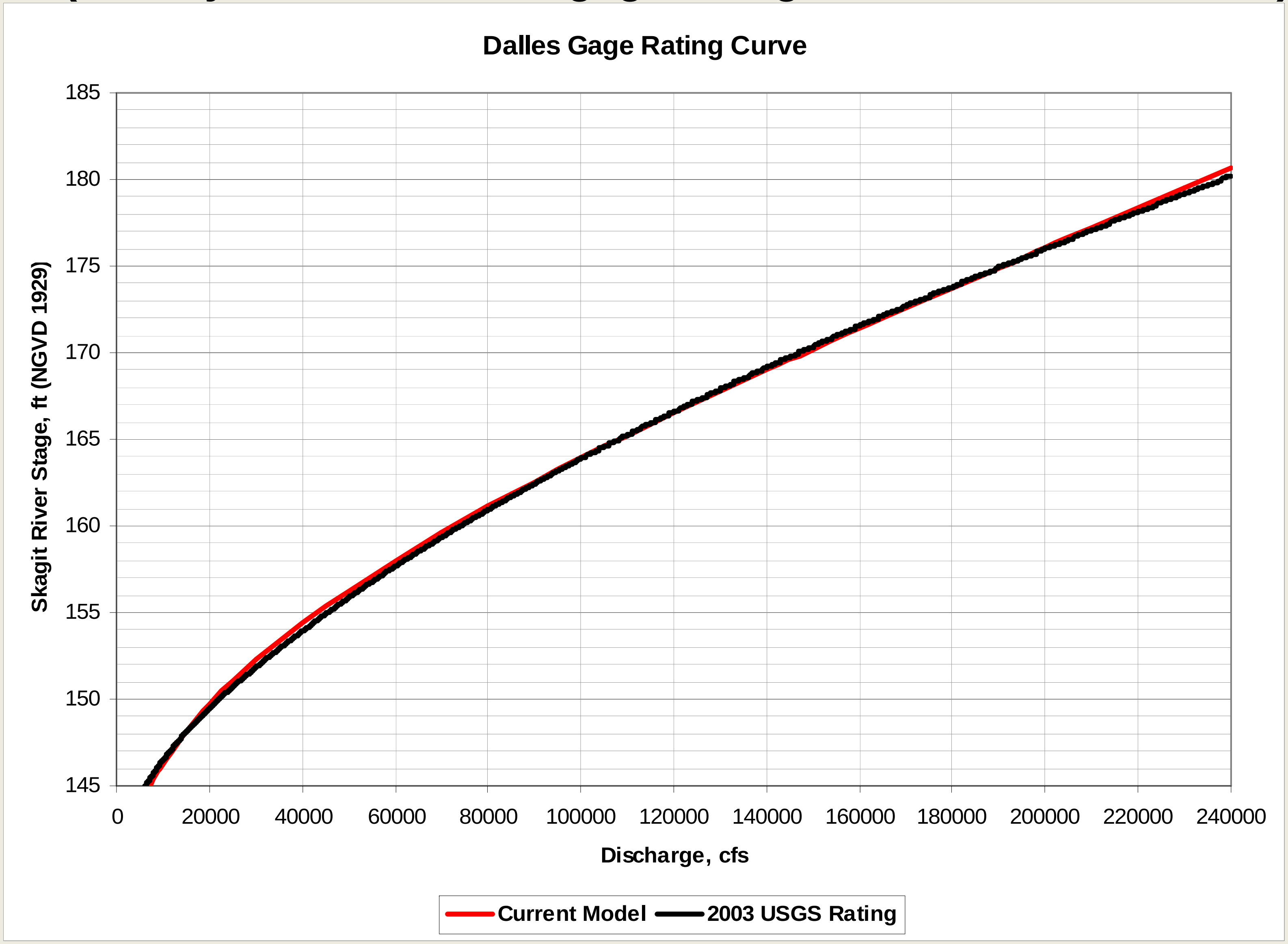
HEC-RAS Model Parameters
(Priority to match USGS gage rating and Jenkins residence)

Reach	Contraction Coefficient	Expansion Coefficient	In-Channel Roughness
High expansion/contraction coefficient model (High EC)			
RM 51.1 – RM 53.65	0.1	0.3	0.03
RM 53.94 – RM 54.05	0.3	0.5	0.03
RM 54.07 – RM 54.12	0.6	0.9	0.03
RM 54.15 – RM 54.34	0.6	0.9	0.028
RM 54.38	0.3	0.5	0.028
RM 54.50 – RM 56.77	0.1	0.3	0.028
Low expansion/contraction coefficient model (Low EC)			
RM 51.1 – RM 53.65	0.1	0.3	0.03
RM 53.94 – RM 54.05	0.3	0.5	0.03
RM 54.07 – RM 54.12	0.6	0.9	0.03
RM 54.15 – RM 56.77	0.1	0.3	0.033

Skagit River HEC-RAS model calibration – October 2003, 166,000 cfs (Priority to match USGS gage rating and Jenkins residence)



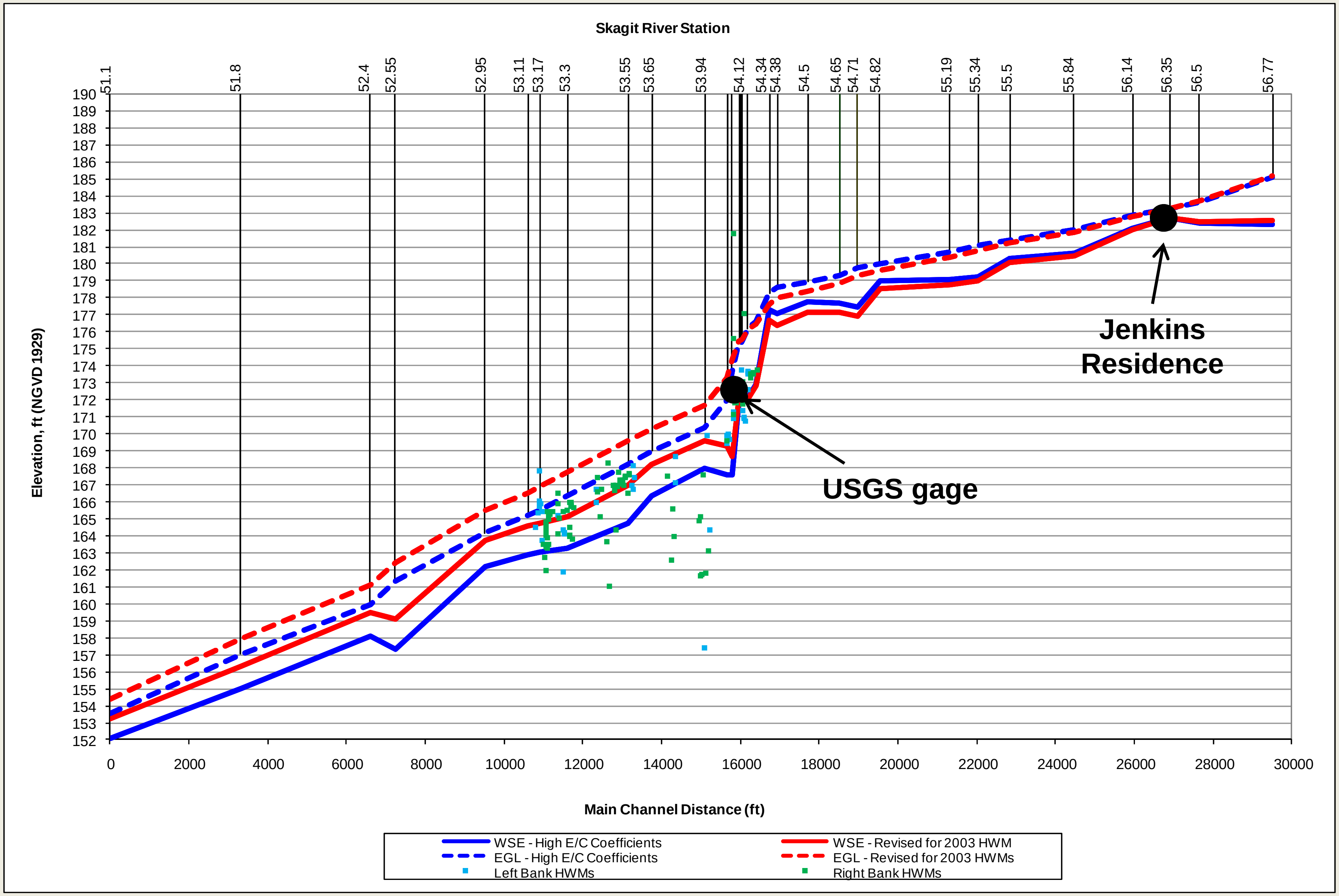
Skagit River HEC-RAS model calibration
(Priority to match USGS gage rating and Jenkins residence)



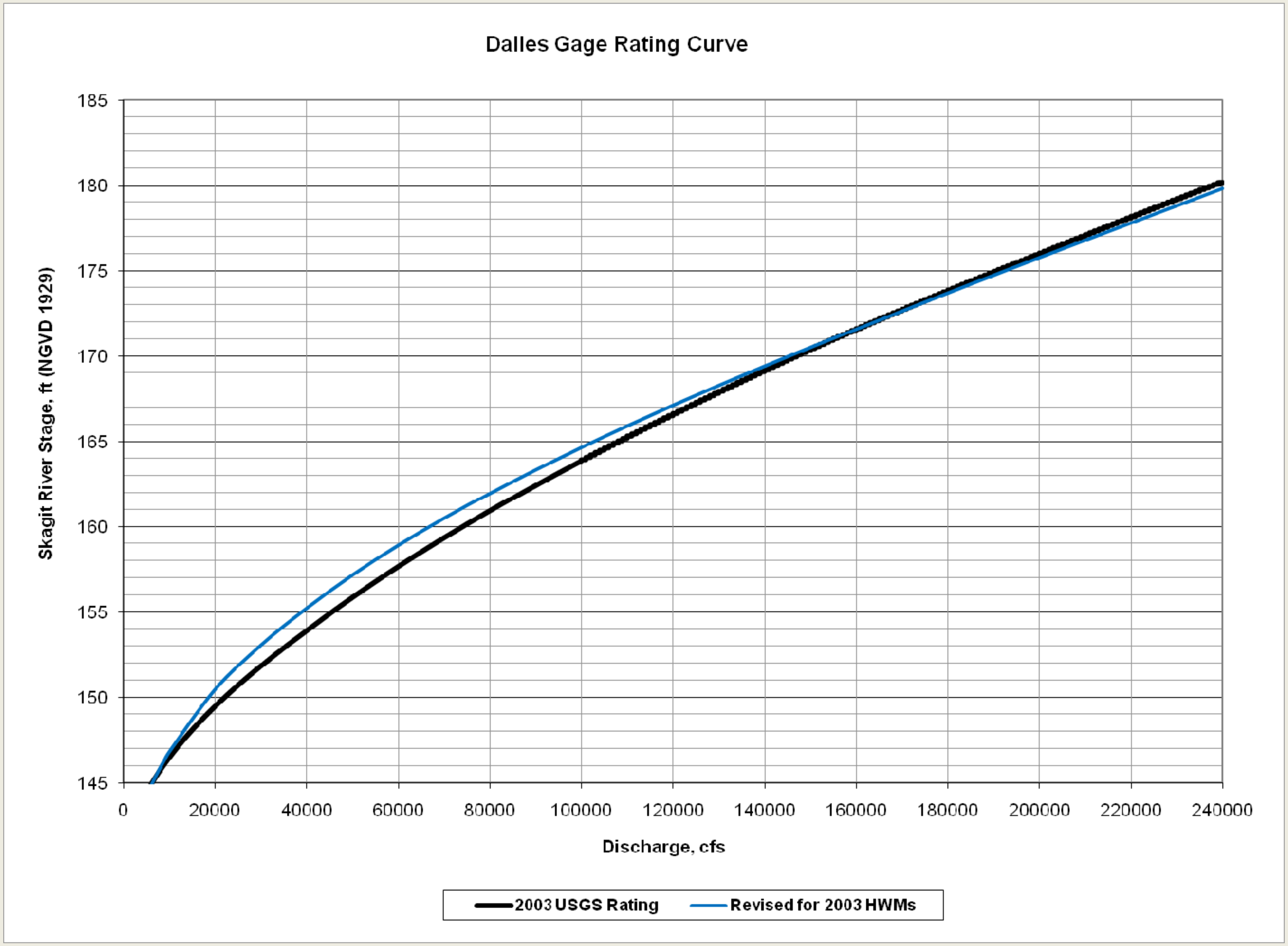
HEC-RAS Model Parameters
(Match USGS rating, USGS HWMs, Jenkins residence)

Reach	Contraction Coefficient	Expansion Coefficient	In-Channel Roughness
RM 51.1 – RM 53.65	0.1	0.3	0.035
RM 53.94 – RM 54.05	0.3	0.5	0.035
RM 54.07 – RM 54.11	0.4	0.5	0.035
RM 54.12	0.4	0.6	0.035
RM 54.15 – RM 54.34	0.4	0.6	0.03
RM 54.38	0.3	0.5	0.03
RM 54.50 – RM 56.77	0.1	0.3	0.03

Skagit River HEC-RAS model calibration – October 2003, 166,000 cfs (Match USGS rating, USGS HWMs, Jenkins residence)



Skagit River HEC-RAS model calibration
(Match USGS rating, USGS HWMs, Jenkins residence)



Hydraulic Modeling Issues

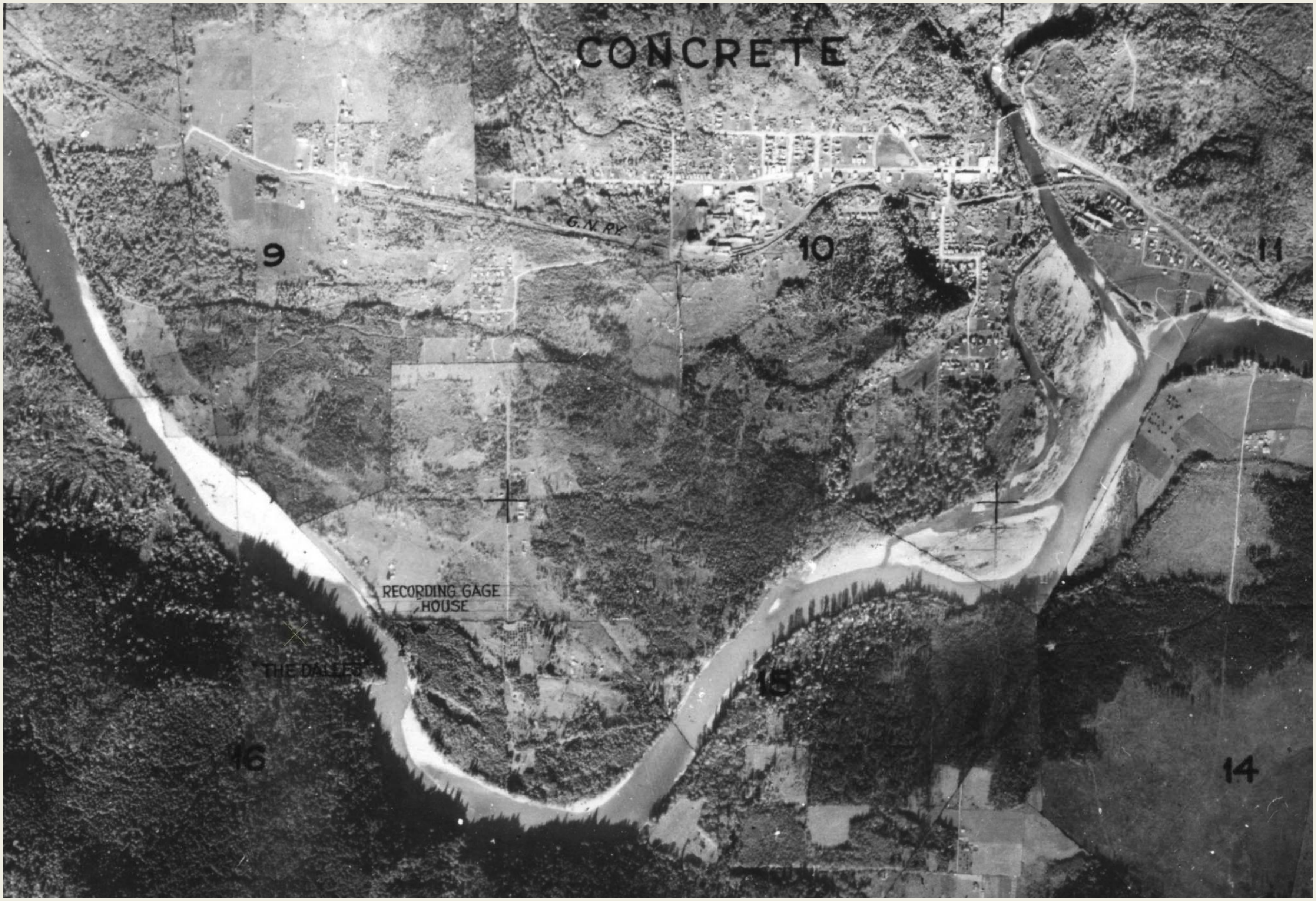
- Model representation of The Dalles:
  - Complex 3D flow conditions
  - No reliable data on head loss through The Dalles
  - Approach adopted brackets hydraulic conditions by using two alternate models with low and high losses through The Dalles.

- Model calibration:
  - High water data October 2003 at The Dalles and Crofoot
  - USGS stage-discharge relationship at The Dalles gauge

- Conditions in 1921 (from 1937 aerial and 1911 channel survey):
  - No significant planform changes
  - Bar downstream of The Dalles clear of vegetation
  - Bar at confluence with Baker River clear of vegetation
  - Minor changes in channel cross-sections since 1911
  - Stable rating at The Dalles

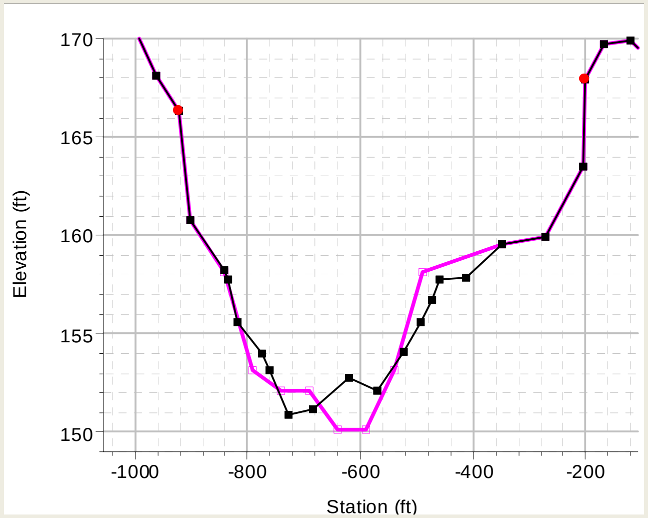
Skagit River, The Dalles to Confluence with Baker River, 2001

Skagit River, The Dalles to Confluence with Baker River, 1937

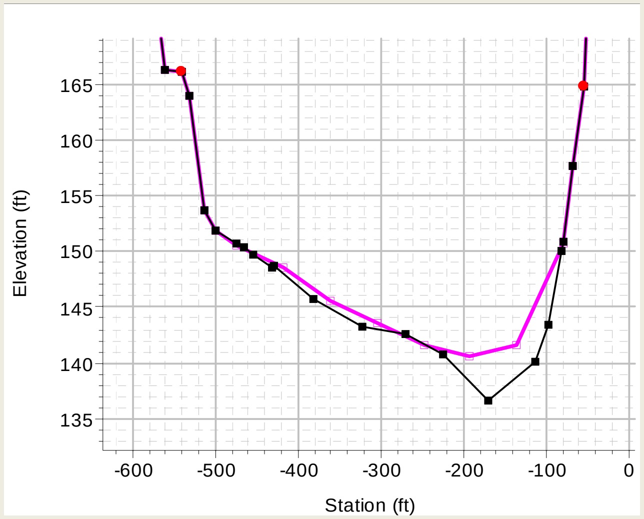


Comparison of Current (black) and 1911(pink) cross-sections

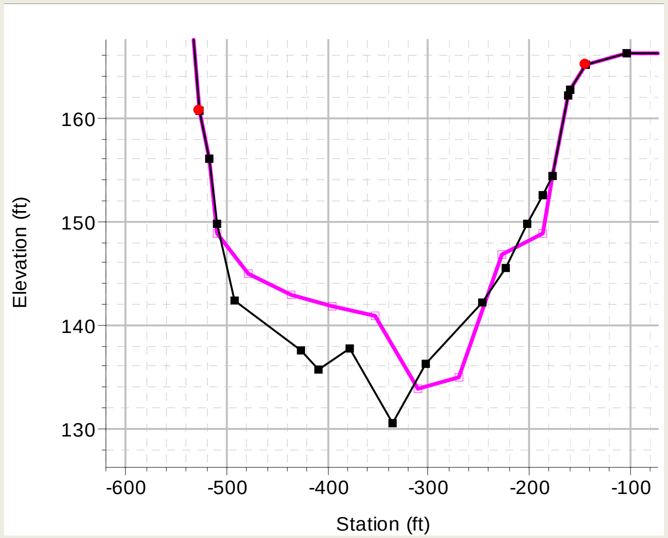
RM 56.35



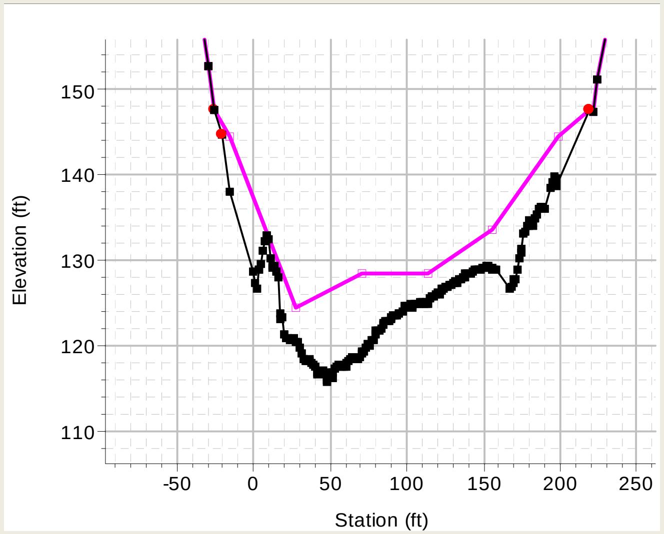
RM 55.19



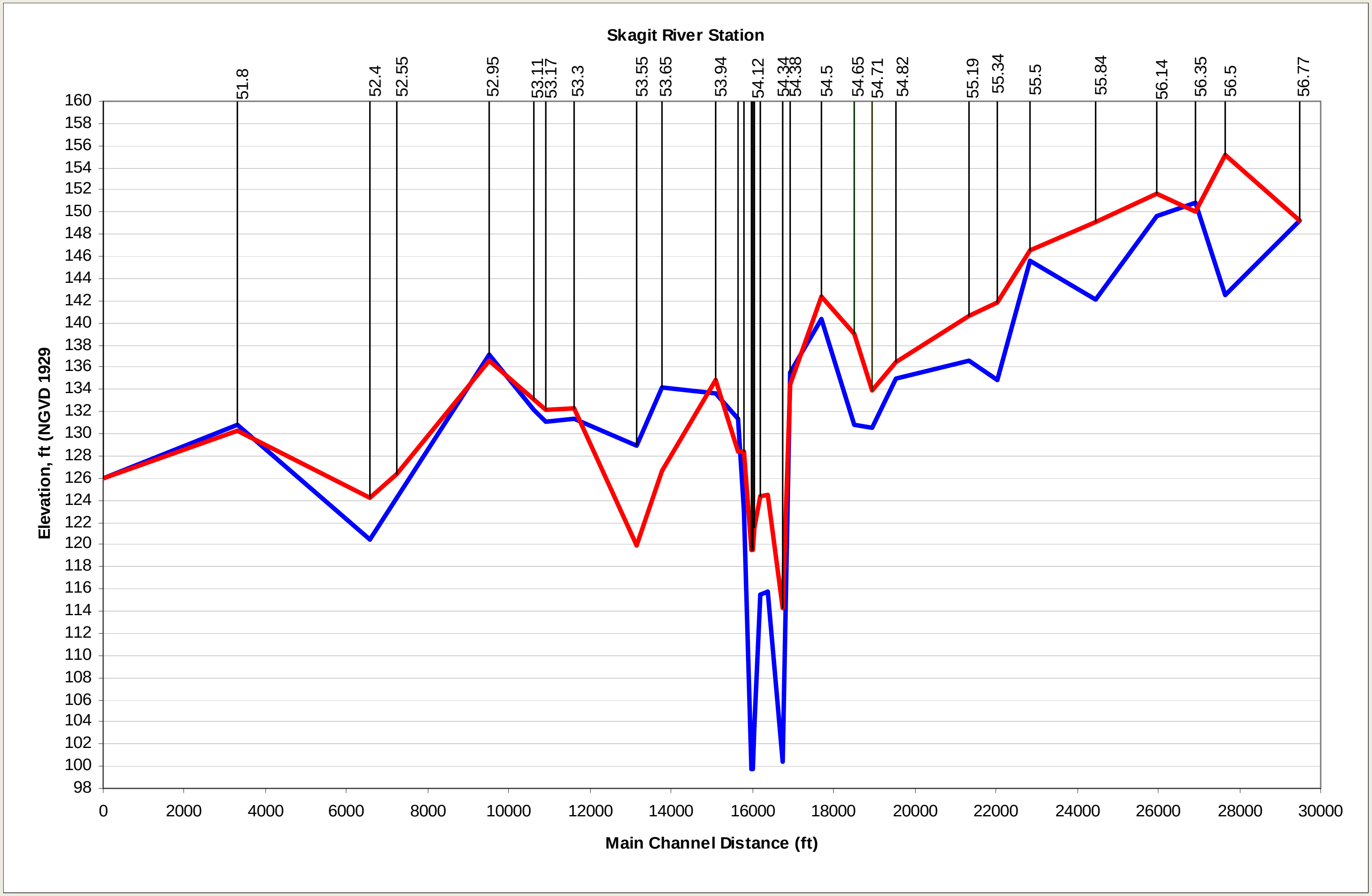
RM 54.71



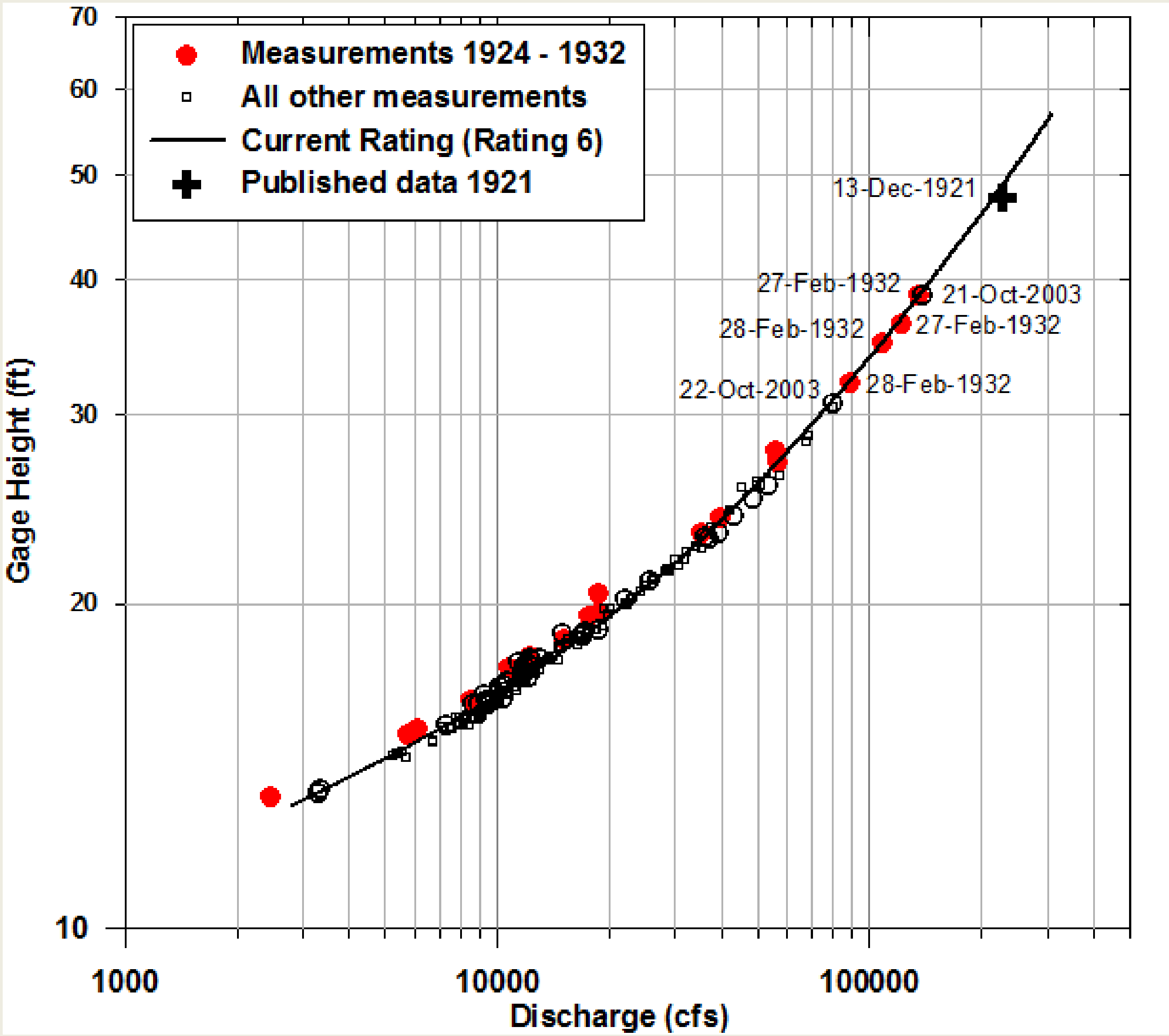
RM 54.19



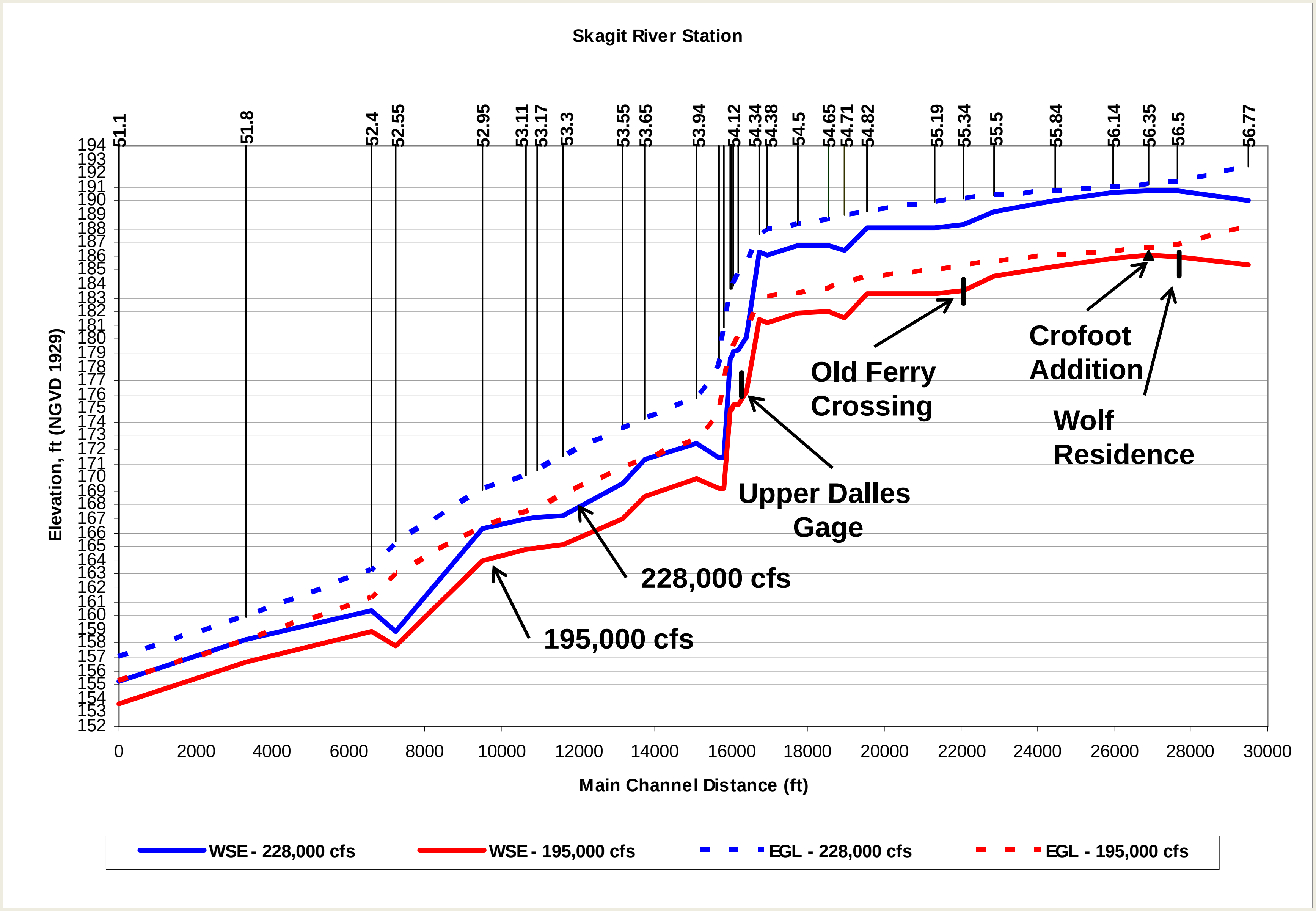
Thalweg Comparison:
1911 (red) and Current Condition Models (blue)



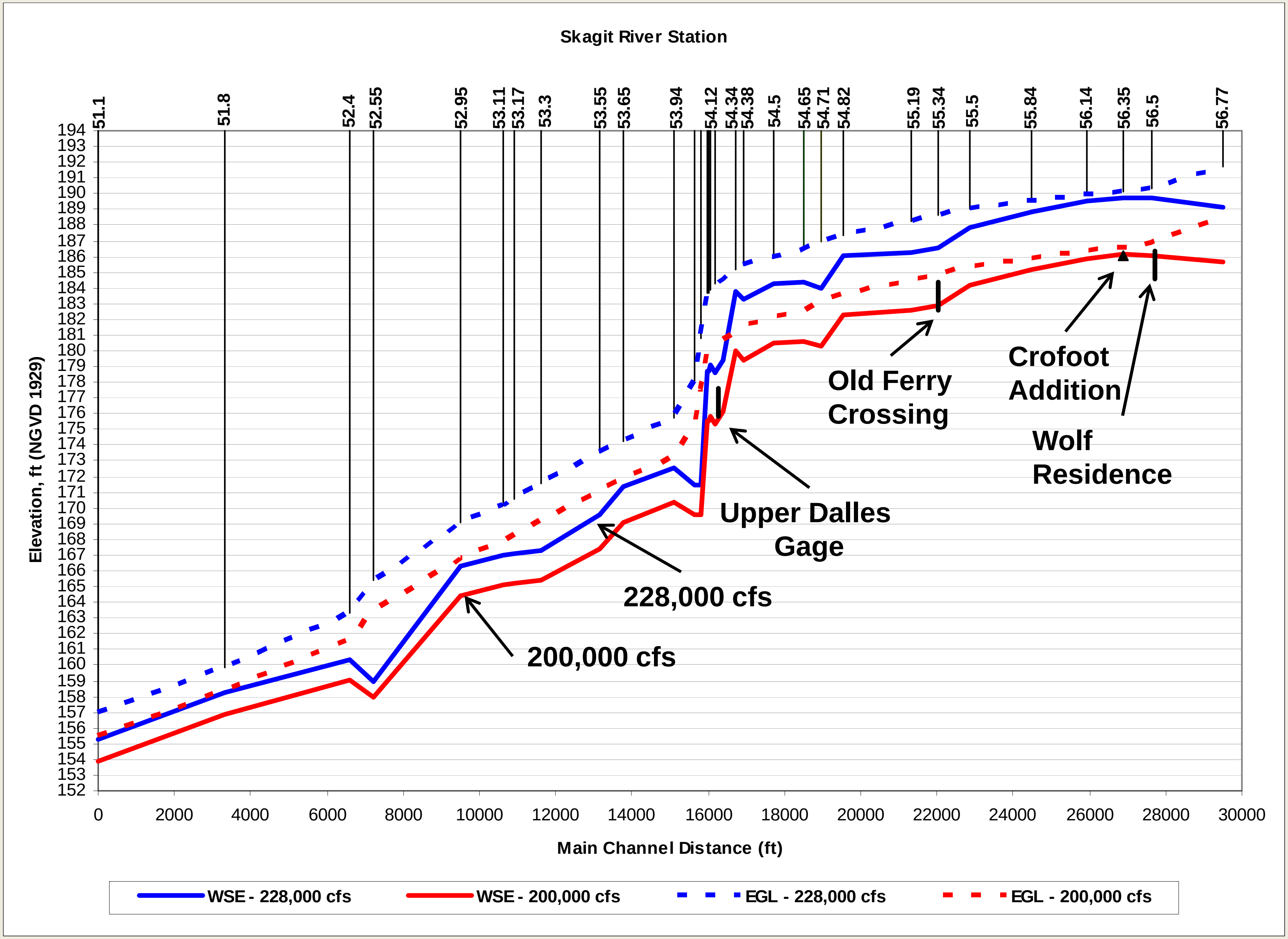
Rating Data, Skagit River near Concrete (The Dalles)



Skagit River HEC-RAS 1921 model – high expansion/contraction



Skagit River HEC-RAS 1921 model – low expansion/contraction



HEC-RAS Model Results

Model Configuration	WSE in Crofoot Corresponding to Discharge of 228,000 cfs	Discharge producing WSE of 186.1 ft in Crofoot
Calibration priority to match USGS rating and Jenkins residence		
1921 High E/C model	190.77 ft	195,000 cfs
1921 Low E/C model	189.73 ft	200,000 cfs
Calibration to match USGS rating, USGS HWMs blw The Dalles, and Jenkins residence		
1921 model	190.17 ft	196,000 cfs

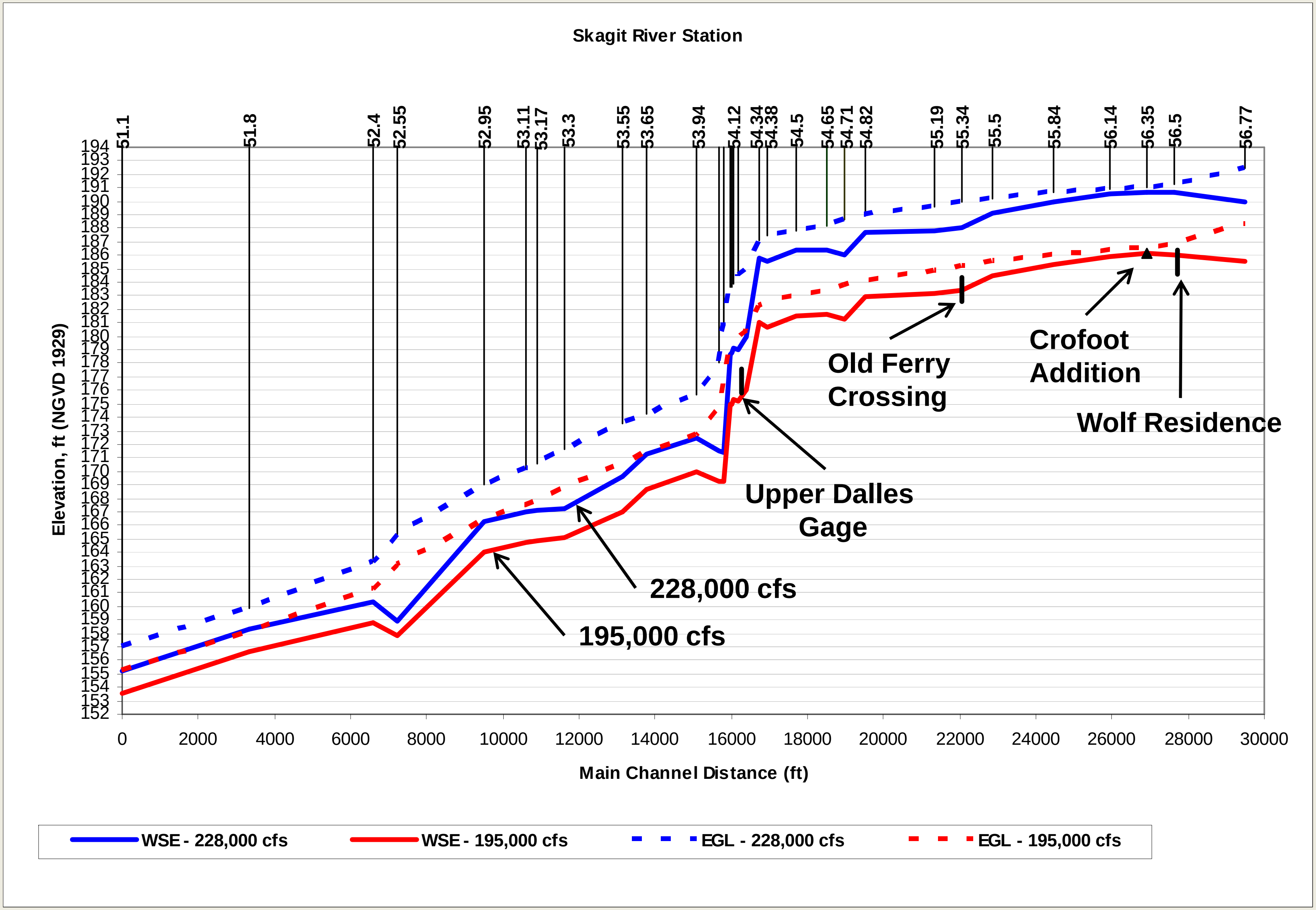
Sensitivity Runs
(changes applied u/s from current gage site)

Model Configuration	WSE in Crofoot Corresponding to Discharge of 195,000 cfs	Discharge producing WSE of 186.1 ft in Crofoot
1921 “base-line” model (High E/C)	186.1 ft	195,000 cfs
In-channel roughness increased 10%	186.6 ft	191,000 cfs
Overbank roughness decreased 30%	186.0 ft	195,500 cfs
Expansion/contraction coefficients decreased 20% at The Dalles	185.2 ft	202,000 cfs
1921 Channel Geometry	187.3 ft	187,000 cfs

HEC-RAS Final Model Parameters

Reach	Contraction Coefficient	Expansion Coefficient	In-Channel Roughness
Final 1921 Model Parameters			
RM 51.1 – RM 53.65	0.1	0.3	0.03
RM 53.94 – RM 54.05	0.3	0.5	0.03
RM 54.07 – RM 54.12	0.6	0.9	0.03
RM 54.15 – RM 54.34	0.5	0.7	0.03
RM 54.38	0.3	0.5	0.03
RM 54.50 – RM 56.77	0.1	0.3	0.03
Note: Dalles gage at RM 54.12			

Skagit River HEC-RAS 1921 model – adopted final results



45956 Albert Street, Crofoot Addition showing highest plausible December 1921 water level per Concrete Herald report (186.1 ft) and maximum water level from HEC-RAS model at 228,000 cfs

Conclusions

- The currently published value of 228,000 cfs for the December 1921 peak discharge is high and is inconsistent with available high water data from Concrete.
- The primary source of uncertainty in the published slope-area estimate is the high water data derived from indirect indicators below The Dalles.
- Based on a conservative interpretation of high water data from Concrete and hydraulic modeling we conclude that the 1921 peak discharge was no greater than 195,000 cfs.

Recommended Revised Peak Discharges

Flood	Peak (cfs)	
	USGS Published	Revised
November 1897	265,000	220,000
November 1909	245,000	205,000
December 1917	210,000	185,000
December 1921	228,000	195,000