United States Department of the Interior

U.S. Geological Survey

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May 6, 2010

To: Attendees of the Skagit River flood flow meeting of March 17, 2010

From: Mark Mastin
Surface Water Specialist, Washington Water Science Center, Tacoma, WA

Subject: USGS responses to issues raised by the Technical Memorandum, "Review and reevaluation of Skagit River 1921 flood peak discharge."

The following text summaries the USGS responses to specific issues raised by the Technical Memorandum, "Review and reevaluation of Skagit River 1921 flood peak discharge," that was distributed at our March 17 meeting. *(Responses from the Cities of Burlington and Mount Vernon shown in italicized blue font)*

1. Incorrect datum used by USGS in Transferring Stewart's HWMs.

   USGS hydrologist Mark Mastin provided a summary of information related to the datum for the Stewart highwater marks and streamgages in his letter of 10/31/08. In brief, Stewart based his highwater mark and streamgage datum surveys on a benchmark in Concrete, Washington, that no longer exists. All the USGS field inspections since 1924 suggest that the gage datum for the highwater marks and streamgages that Stewart installed should be 142.7 or 1.8 feet higher than used by Stewart.

   USGS records demonstrate continuity of datum control at the current streamgage at Skagit River at Concrete from the present time back to the establishment of the gage in 1924. The only area of uncertainty is the linkage of datum from this gage to its predecessor gage, which was established by Stewart and based on the same datum as Stewart's highwater marks.

   Cities' Comment: *Stating that "the only area of uncertainty" is the linkage of datum from this gage to its predecessor gage infers this critical and essential first step in establishing the new gage datum is somehow not important if all subsequent records refer to the current gage datum. This is simply not true. The transfer of the gage datum from Stewart's Upper Dalles gage to the existing gage location 330 feet downstream is the essential and single most important action that should have been carefully documented by the USGS when the new gage was established. The USGS (Mastin, letter dated November 5, 2008) has also pointed to station description notes dated 1931, 1932, and 1938 as additional evidence of its assertion of a datum 1.8 feet higher than established by Stewart; however, those notes simply carry forward the error, with no new information provided to shed light on what happened when the new gage was established. The notes closest in time to the establishment of the current gage location are shown in the following figures, pp. 2-5:*

Nos 1 - 267 (except #136)

9--275c

Listed by ____________

Plotted by ____________

File No. { Washington ____________ Field 9104

9-27-2 JMR

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

MISCEL. MEAS. *WATER RESOURCES BRANCH* REGULAR STATION

DISCHARGE MEASUREMENT NOTES

Date Sept. 16, 1924 No. of Meas. 1

Skagit River at Dalles, State of Wash.
Creek near Concrete

Width 3516 Area 2362 Mean Vel. 2.43 Cor. M. G. H. 2.57

Party Calkins and Wright Disch. 5740

Staff gage, checked with level and found ____________

Chain length, checked with steel tape, 12-lb. pull, found ________ft.

" " changed to ______ft. at ______o'clock. Correct length ______ft.

" " corrected on basis of levels to ______ft. at ______o'clock.

Gage reading	Time	Station
2.66	1:05 P.M.	Recorder
2.45	4:00 "	"
2.46	4:10 "	Upper gage

Meter No 718

Date rated 7-23-24

Meas. began 1:35; ended 3:45

Time of meas. (hrs.) 2.2 Method 2-8

No. meas. sec's 32 Coef 1.0

Av. width sec. 10 Av. depth 6

Weighted mean G. Ht 2.57 ft.

G. Ht. change (total) -.21

Correct " " " 2.57 ft.

-16 per cent diff. by Stewarts rating table.

Meas. from ~~cable, bridge,~~ boat, ~~wading.~~ Meas. at 3/4 Mi. ft. ~~above~~ below gage.

If not at regular section note location and conditions Excellent, except for tree tops in left half

Area from soundings (date) 9-16-24

Method of suspension Cable Stay wire No Approx. dist. to W. S. 4'

Arrangement of weights and meter; top hole 1; middle hole M; bottom hole 30

Gage inspected, found None Cable inspected, found None

Distance apart of measuring points ^obtained with tag line ~~verified with steel tape and found~~ ____________

Wind No upstr., downstr., across. Angle of current ⊥

Observer seen Yes G. Ht. book inspected ____________

Examine station locality and report any abnormal conditions which might change relation of G. Ht. to disch., e. g., change of control; ice or débris on control; back water from; condition of station equipment All clear. Results should be first class.

Sheet No. 1 of 13 sheets. If insufficient space, use back of sheet, with letters.

June 1918.

J.S.G. 10-4-24

USGS Station Notes, 16 September 1924, p. 1 of 13

Stream Skagit River.

Locality Dalles.

Party Calkins & Wright Date 9-16-, 1924

STATION	B. S.	HT. INST.	F. S.	ELEVATION	REMARKS
					27 on Gage I
B.M.	5.40	14.28		8.88	Iron Bolt 169.88
			11.40	2.88	Waterlev. Upper Gage
			11.36		Paint on rock for future u
B.M.	3.80	12.68		8.88	Iron Bolt.
			9.80	2.88	Water at Recorder site.
			6.02	6.66	Point of Rock future use.
			10.41		Check Back-more
			4.39		equable F.S. + B.S.
Lower Gage					
B.M.	4.45	13.95		(9.50)	Lower staff gage.
			11.08	2.87	Water line.
					~~2.70 on lower Ga. = 169.88~~
					3.92 below 6.66
					2.74 at 12 M.

No. 5 of 13 Sheets Comp. by Chk. by C.A.D.

GOVERNMENT PRINTING OFFICE

USGS Station Notes, 16 September 1924, p. 5 of 13

Skagit River at The Dalles, Near Concrete, Wash.

Equipment.- Stevens continuous recorder installed in reinforced concrete shelter over concrete well 41 feet deep, constructed by and at the expense of Skagit County. The shelter was constructed during the fall, and recorder installed Dec. 10, 1924. Prior to that time a staff gage on right bank had been read This staff gage was installed in 1922 by J. E. Stewart. A 1" ø plow steel cable with 46 ft. towers and span of 800 feet was erected about three-fourths of a mile below gage for purpose of making discharge measurements. The cable is equipped with standard gaging car, carrying 3-foot reel for use with 75# weight, also provided. An auxiliary gage of the tape and float type was placed in the gage house on Sept. 9, 1925 to assist in setting recorder. A bench mark was set several years ago by J. E. Stewart when making flood investigations in the vicinity but description is not at this time available.

Gage-height record.- Upper Dalles staff gage installed by J. E. Stewart, read Sept. 16, 1924 to Dec. 9, 1924, if not directly, by referring water surface to bench mark. Staff gage read by L. J. Wright, of the County Engineer's office, or by E. O. Stiles, a farmer living near the gage. Automatic gage began Dec. 10. 1:6 scale used until changed to 1:12 on Dec. 24. Trace is faint Dec. 30-31. Paper expanded against guides and stopped clock on Feb. 3. Ends of roll trimmed and clock started Feb. 9. Clock stopped April 24, not visited until May 18, when it was started and after which it ran until Sept. 6, but the lower intake not being open, gage heights for some of the period after Aug. 24 are doubtful. They will however, probably give as good results as any estimate we can made and have been used after correcting slightly for apparent sluggishness of intake.

Staff gage not read Sept. 21, 28, Oct. 5, 12, 19, 26, 1924. Gaps in record except for Sept. 28, Oct. 5, 12, 19, and 26, 1924 and Sept. 6-9, 1925, which were filled by interpolation, have been filled by hydrographic comparison with the combined flow of Skagit River near Marblemount, Sauk River at Darrington, and Baker River below Anderson Creek near Concrete, Wash.

Gage-height corrections.- None to well gage. It was set to datum of upper Dalles gage set by J. E. Stewart in 1921. The outside gage was found to require a correction of plus 0.13 foot when checked with a level on Sept. 18, 1925. This error dates from date of setting outside gage until corrected Sept. 18. The only gage heights needing corrections however, are those for Sept. 17 and 18., 1925, which were outside staff gage readings.

Ice.- Stage-discharge relation not affected by ice.

Rating.- Measurements 1-12 made since work began at the station. A curve has been drawn through all and point of zero flow determined 9-17-24, and misses none by as much as 3.5%. Discharge for the period of record has been determined from this curve; rating table dated 10-29-25.

D.J.F.Calkins, 2-15-26.

JMR 2-16-26.

USGS Station Notes, 15 February 1926, p. 1 of 2

1926. 1927 12-1940 910.

SKAGIT RIVER ~~AT THE DALLES~~ NEAR CONCRETE, WASH.

Location.- In sec. 16, T. 35 N., R. 8 E., at the dalles, two miles below mouth of Baker River, 2½ miles southwest of Concrete, Skagit County.

Drainage area.- 2,700 square miles. Area in United States measured on topographic maps and Washington National Forest map, edition of 1922. Area in British Columbia, 390 square miles. a/

a/ White, A. V., Water Powers of British Columbia, p. 483, Conservation Commission of Canada, 1919.

Records available.- September 15, 1924 to September 30, ~~1926~~ 1927. Flood peaks only as noted under "Extremes of Discharge."

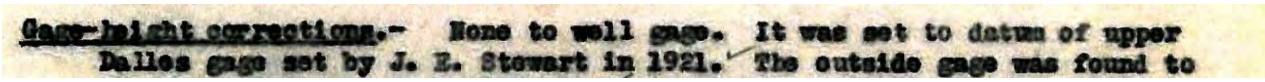
Equipment. **Gage.**- Since December 10, 1924 Stevens continuous recorder in concrete house over stilling well, on right bank at the dalles. Gage used prior to December 10, 1924 was vertical and inclined staff on right bank about 200 feet above present gage. Both gage readings refer to same datum, 163 feet above sea level.

Discharge measurements.- Made from cable equipped with gaging car and reel for handling 75 pounds of lead, three-fourths of a mile below the gage.

Channel and control.- Boulder riffle below canyon for low stages; rock canyon forming the dalles, for high stages.

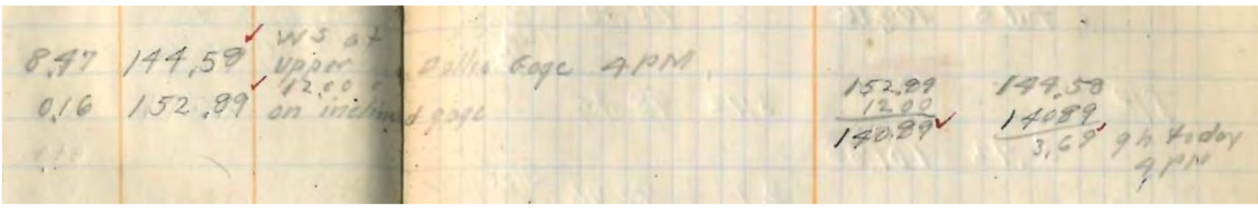
USGS Station Notes (presumed to be p. 2 of 2; February 15, 1926)

Cities' Comment (continued): *The only documentation from the gage station description notes of 2/15/26 state that the gage was "set to datum of upper Dalles gage set by J. E. Stewart in 1921" (page 4 above, w/ excerpt below)*[1].



Gage-height corrections.- None to well gage. It was set to datum of upper Dalles gage set by J. E. Stewart in 1921. The outside gage was found to

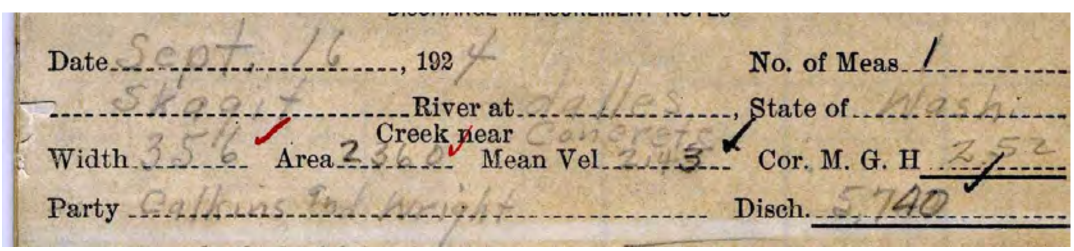
Page 87 of Stewart's field notes show that the datum of the upper Dalles gage was 140.89 feet above mean sea level:



Stewart's notes constitute the only direct evidence of the gage datum for the historic flood high water marks, and USGS' assertion that Stewart had improperly set the gage datum is theoretical, speculative, and inconsistent with available evidence.

(continued) While there are no notes of a direct survey linking the datums of the two gages, there is information indicating that the two datums are the same. It is the standard practice of the USGS to ensure consistency of streamflow records at concurrent downstream and upstream gages by making concurrent flow measurements or rating verification measurements whenever a gage is relocated. Indeed, on the day that the new downstream gage was established (9/16/1924) a streamflow measurement was performed. The field notes for that measurement record simultaneous water-level readings at both gages. The stage readings for both gages agree to within 0.01 feet of one another, suggesting that the two gages reference the same datum.

Cities' Comment: *It is expected that water surface elevations for the three gages, only 700 feet apart, would be close to the same under the low flow conditions that existed on September 16, 1924 (see station notes, sheet 1 of 13, 5,740 cfs):*



Date Sept. 16, 1924 No. of Meas. 1

Skagit River at Dalles, State of Wash.

Creek near Concrete

Width 356 Area 2,362 Mean Vel. 2.43 Cor. M. G. H. 2.52

Party Calkins and Knight Disch. 5740

Under these conditions, the island downstream of the Dalles would control the water surface elevation upstream through the Dalles. Therefore, this water surface survey does not provide any information from which to resolve the discrepancy.

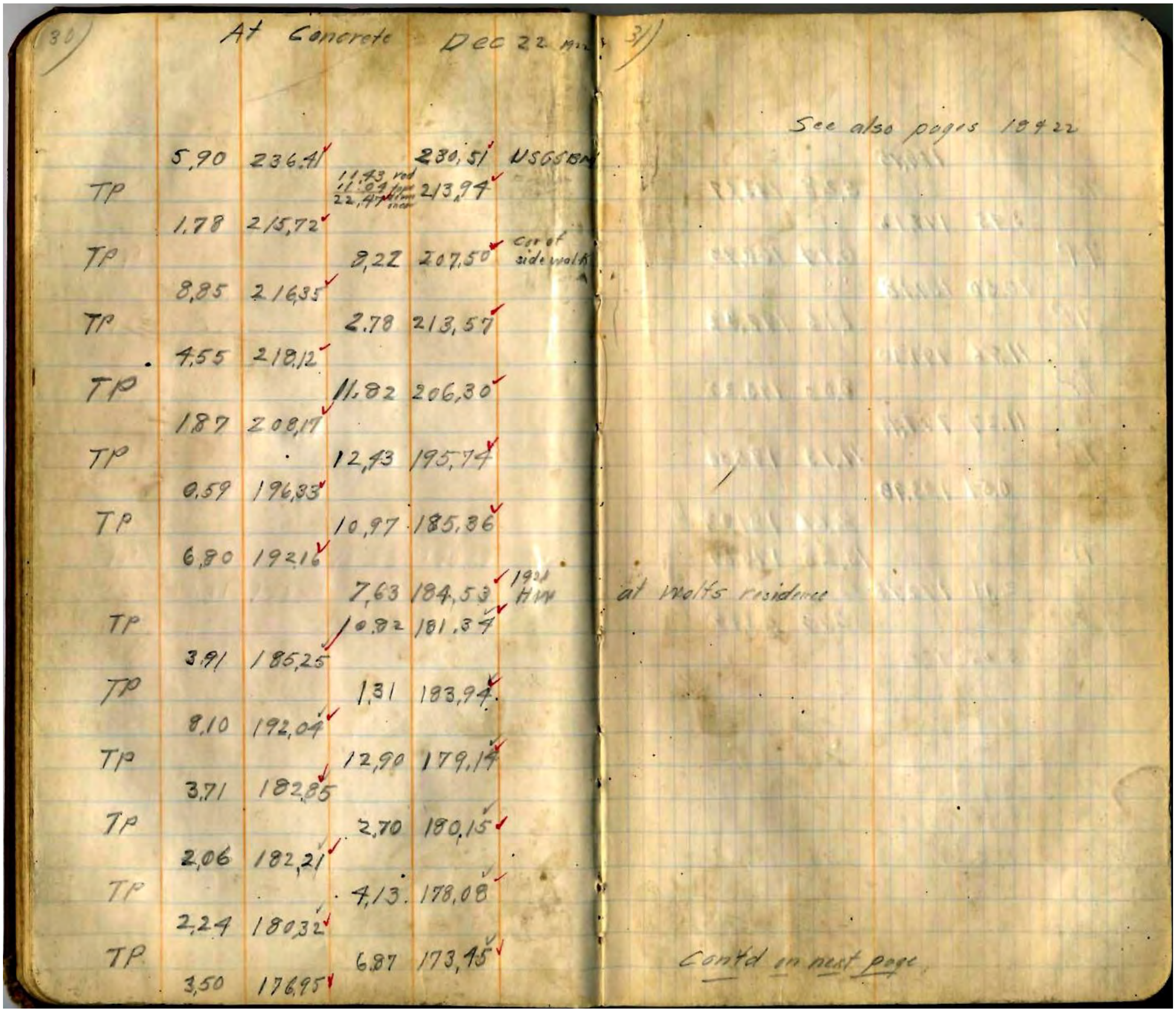
(continued) Furthermore, level notes made on that same day at the current streamgage

[1] *This is actually in error as the upper Dalles gage was not set by Stewart until 1922; however, we assume the author was referring to Stewart's field work following the flood of 1921.*

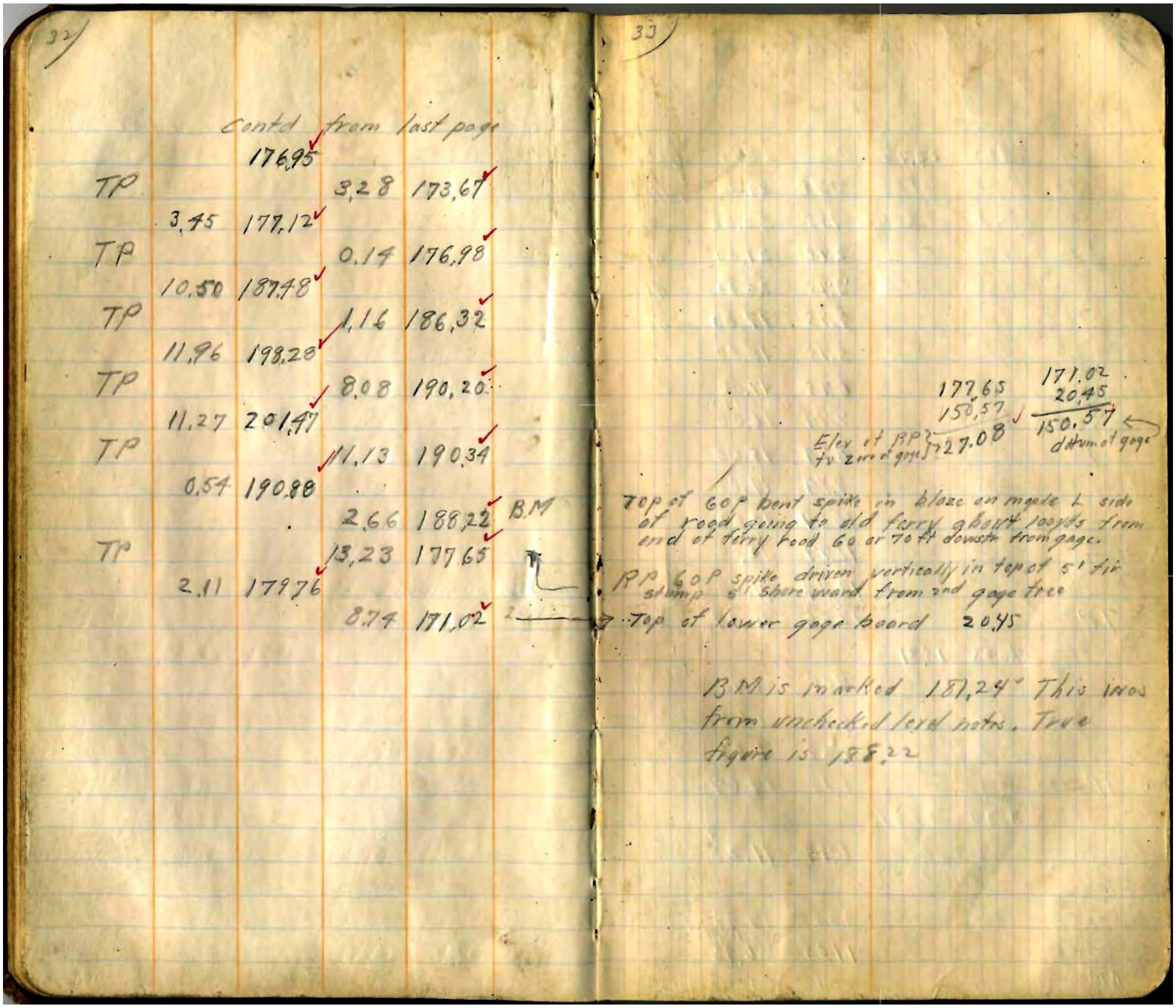
include a conversion equation. The notes include a remark saying: "27 on Gg =169.88". The reference implies that the old datum was 142.88 ft. (169.88-27.00), the same datum as used at the current streamgage at Concrete.

Cities' Comment: *This note does infer the datum on one or the other gage was 142.88; however, it provides no context for this information. For one thing, the datum should have been 142.7 feet, not 142.88. Why the discrepancy? Was there a survey conducted that ties elevation 27 on one of the gages, to the USGS benchmark in Concrete? If so, where are the notes to that survey? Or was the survey started from some other benchmark or temporary benchmark that had been established subsequent to Stewart's work? There is no documentation to tie this statement, "27 on Gg=169.88," to Stewart's gage datum. The one and only statement that does tie Stewart's upper Dalles gage datum to the new gage, states that the new gage was set to the same datum as Stewart's Upper Dalles gage. And the only documentation showing both the datum as well as documentation of Stewart's surveys that established the datum, appear in Stewart's notes (p. 87). The USGS has suggested Stewart's survey work establishing the datum is suspect, as the survey was not a closed-loop survey. This is a valid criticism but our challenge would be: show the survey that was the basis of the comment "27 on Gg=169.88." The new gage was under construction on September 16, 1924 and not ready for taking gage height readings until December 10, 1924, as all USGS documents (see USGS official web site for water data) have stated. How was the "B.M." referenced on p. 5 of 13 of the USGS-provided notes ("Iron bolt") set? What was the survey that set the bolt? Presumably, since this was only 1.5 years after the County survey crew completed surveying Stewart's high water marks (loose notes pp. 20-21; 25-28), the survey tied into Stewart's previous work. The survey work performed by Stewart is documented in his notes beginning on the next page. See also March 29, 200 letter from PSE Surveying and Engineering under separate cover.*

On December 22nd, 1922, Stewart began the survey from the USGS benchmark located in Concrete and referenced in a USGS publication at the time (Bulletin 674, Spirit Leveling in the State of Washington, 1897 to 1917, Inclusive). This survey is documented on pp. 30-33 of Stewart's field notes. The survey proceeded from the USGS benchmark to the old Ferry Landing downstream of the Crofoot's Addition in Concrete. There Stewart set a benchmark at 188.22 feet msl and also set a reference point at 177.65 feet msl, as well as providing a reference to the gage he located there, noting "Top of lower gage board 20.45" equated to a msl elevation of 171.02. See the following figures, pp. 8-9:



Stewart's field notes, pp. 30-31



32

Contd from last page

		176.95			
TP			3.28	173.67	
	3.45	177.12			
TP			0.14	176.98	
	10.50	187.48			
TP			1.16	186.32	
	11.96	198.28			
TP			8.08	190.20	
	11.27	201.47			
TP			11.13	190.34	
	0.54	190.88			
			2.66	188.22	BM
TP			13.23	177.65	
	2.11	179.76			
			8.74	171.02	

33

177.65
150.57
Elev of RP to zero of gage 27.08

171.02
20.45
150.57 datum of gage

Top of 60P bent spike in blaze on maple L side of road going to old ferry about 100yds from end of ferry road 60 or 70 ft downstr from gage.

RP 60P spike driven vertically in top of 5' fir stump 5' shore ward from 2nd gage tree

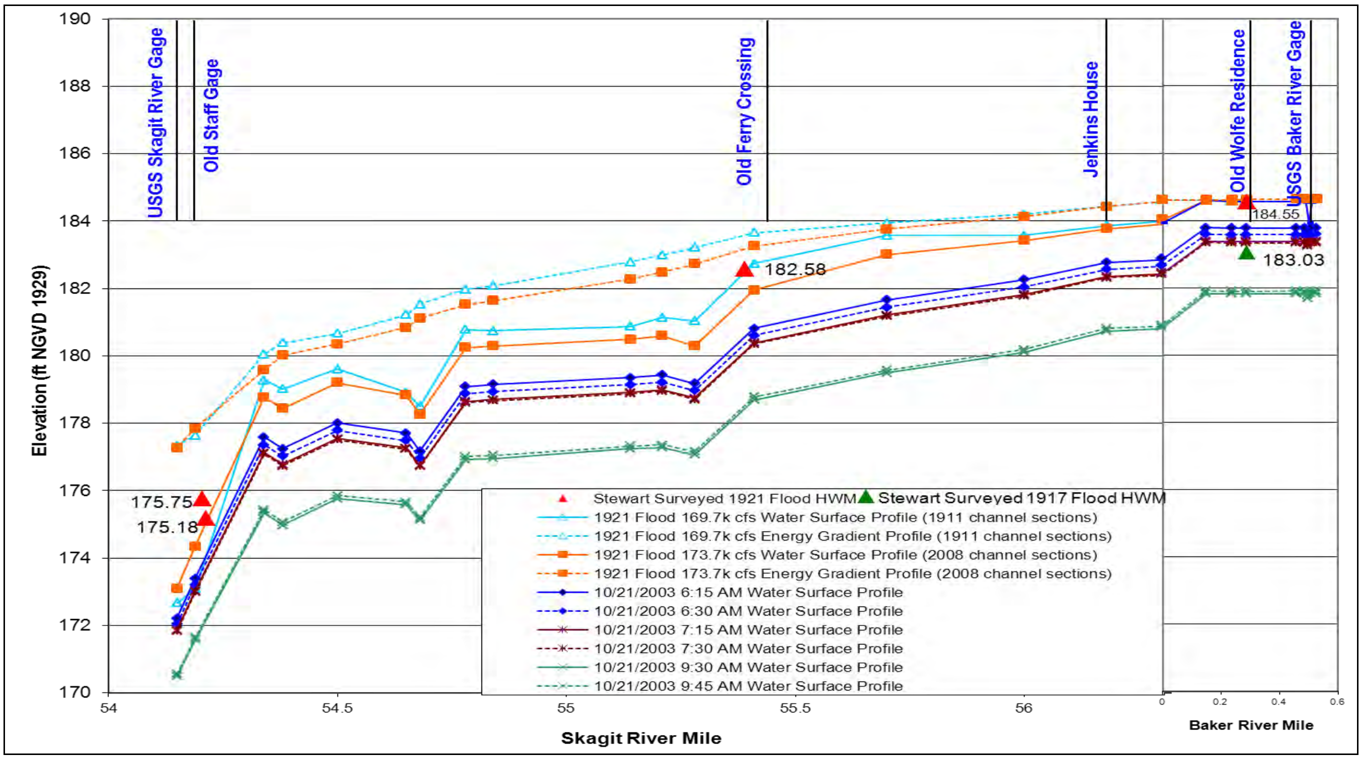
Top of lower gage board 20.45

BM is marked 181.24 This was from unchecked level notes. True figure is 188.22

Stewart's field notes, pp. 32-33

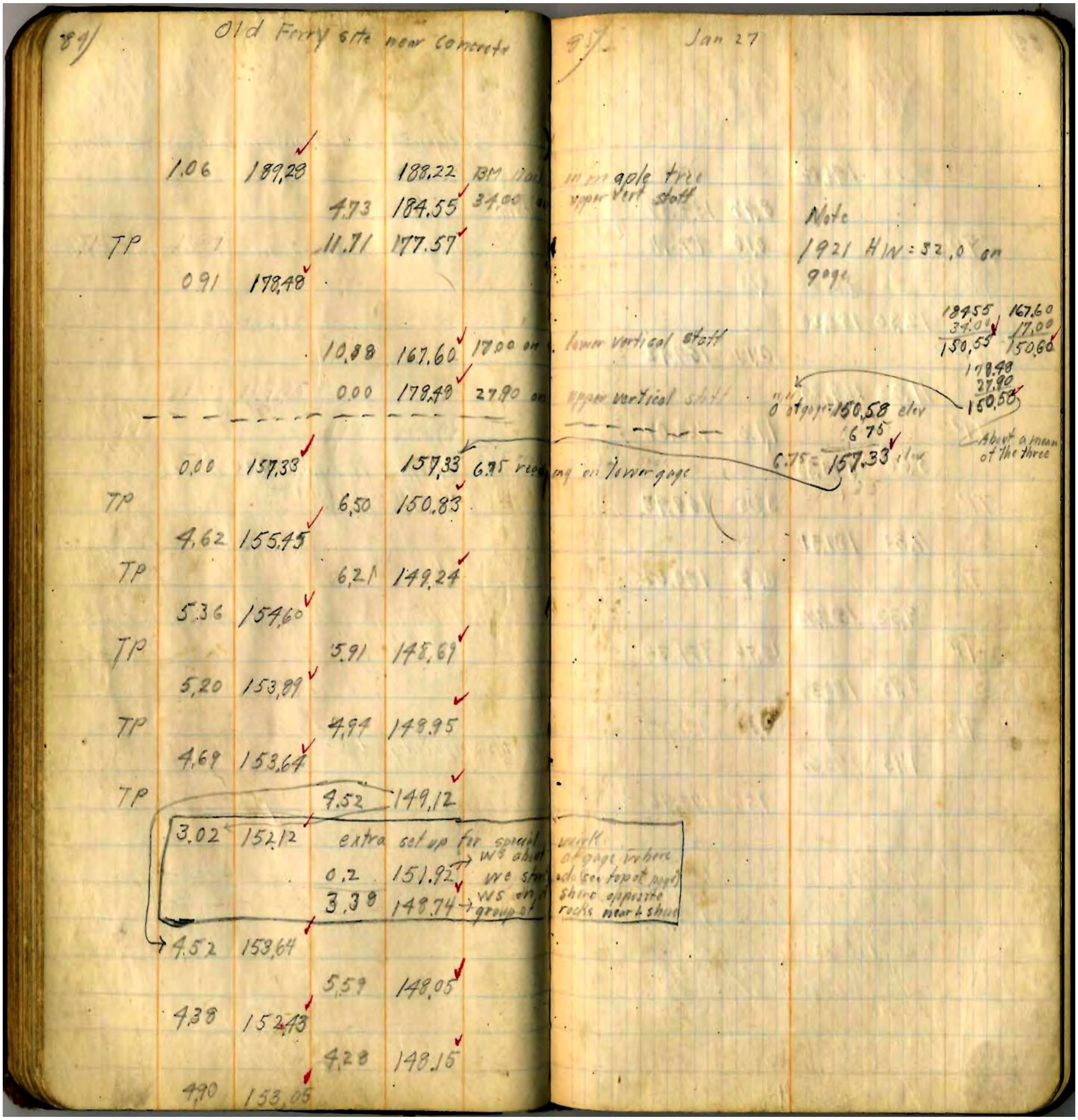
On January 27th, 1923, Stewart continued his survey to the upper Dalles location, beginning at the benchmark he had set at the old Ferry Landing (188.22 feet msl). Stewart first established the gage datum of the gage he had put in place at the old Ferry Landing. From his notes, that gage datum was 150.58 feet. Stewart noted a 1921 high water mark at that location "Note 1921 HW=32.0 on gage". PI Engineering used this information in the development of its hydraulic model.

This 32.0 gage height equates to a 1921 high water stage elevation of 150.58 + 32.0 = 182.58 feet at the old Ferry crossing. Note how well this stage elevation for the 1921 flood event correlates to the output of the hydraulic model developed by PI Engineering:

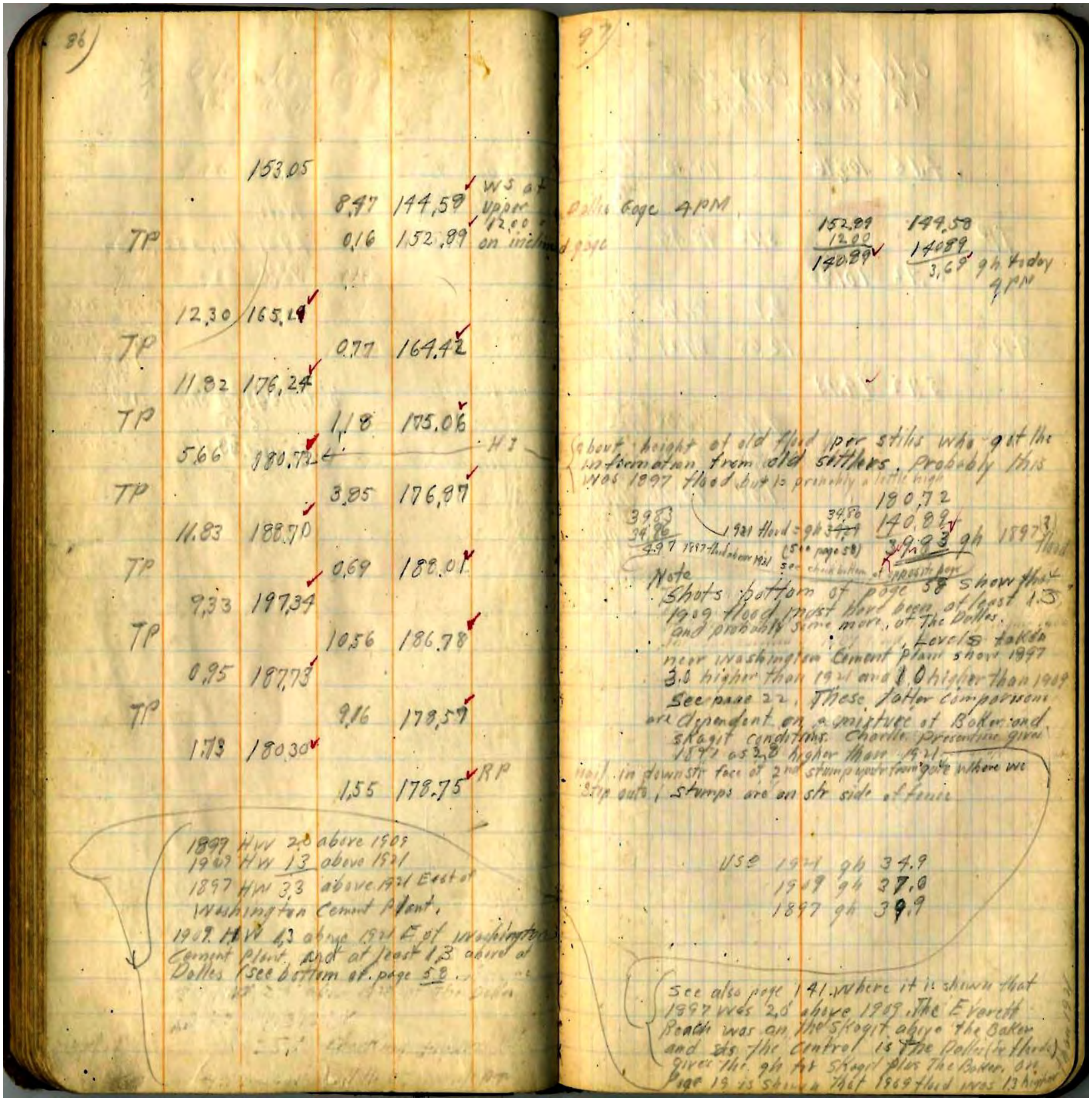


Hydraulic profiles from Concrete to the Dalles (PI Engineering, March 2011)

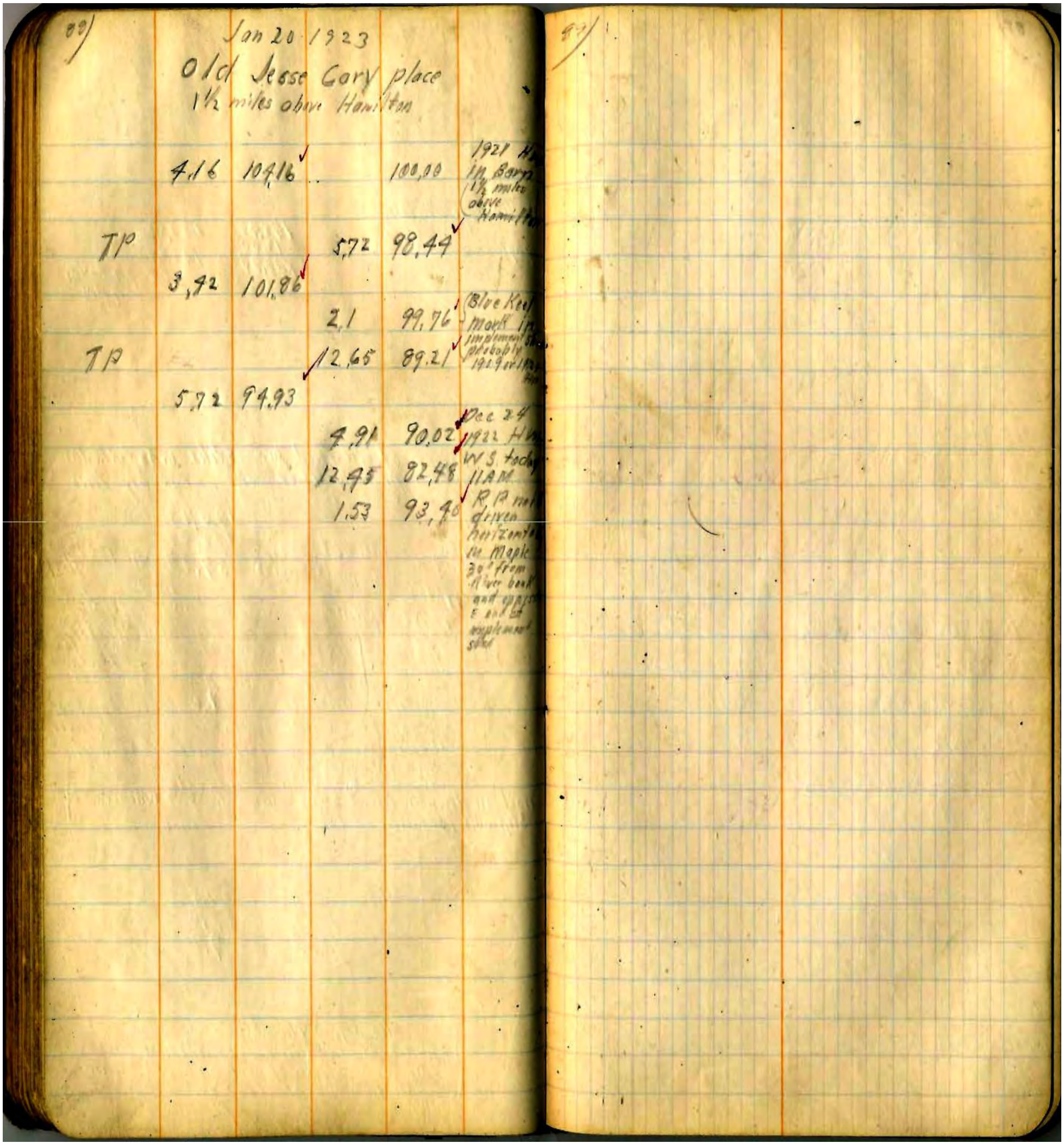
Stewart then proceeded downstream through 9 turning points to the Upper Dalles gage, where he calculated the Upper Dalles gage datum, based on a gage reading of 12.00 equating to an elevation of 152.89 feet, giving a gage datum of 140.89 feet. Stewart then proceeded on downstream through 6 turning points to the Lower Dalles gage, where he set a reference point at elevation 178.75. *See the following figures on pp. 11-13:*



Stewart's field notes, pp. 84-85

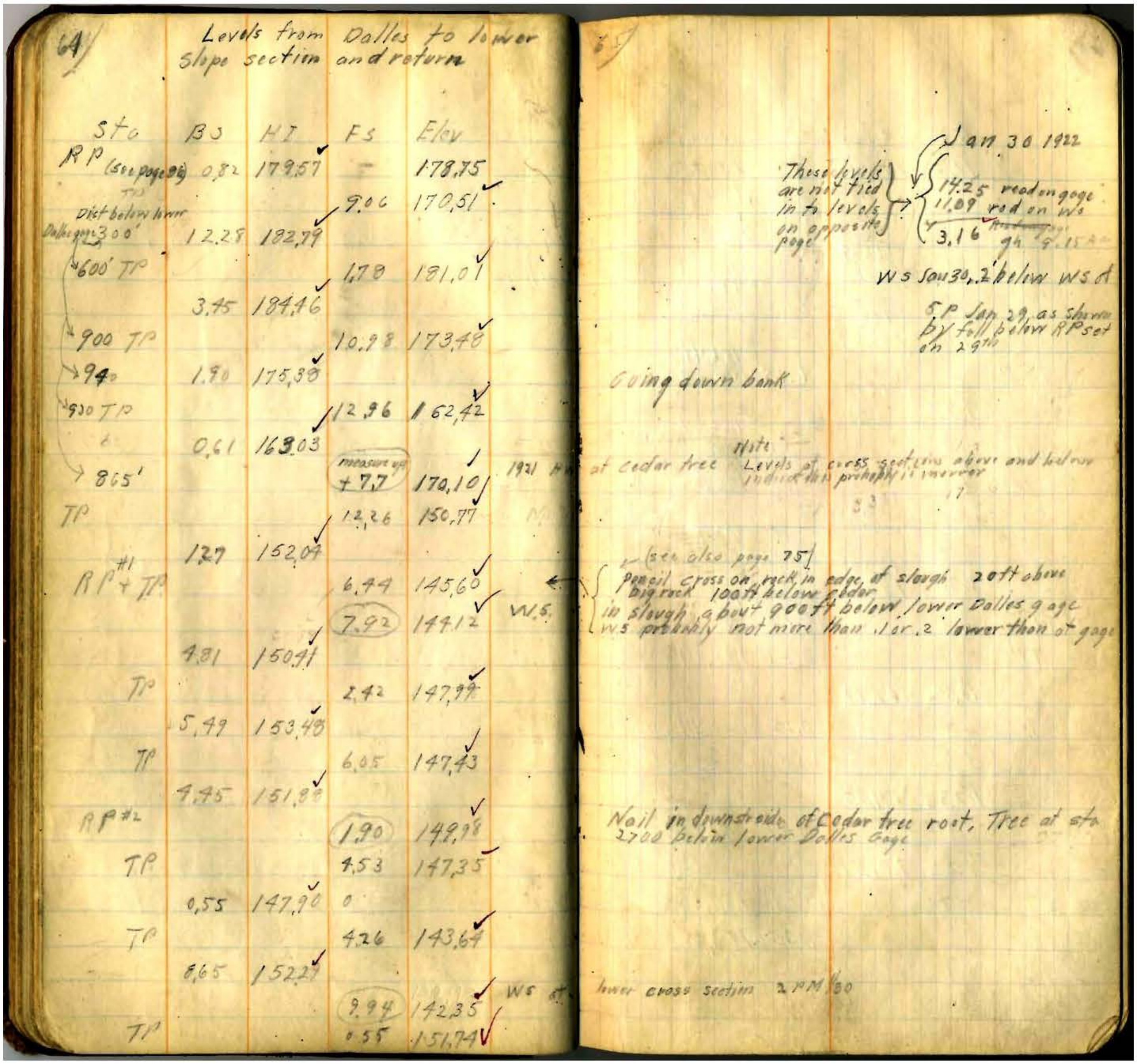


Stewart's field notes, pp. 86-87



Stewart’s field notes, pp. 88-89

Cities' Comment: *On January 30th, Stewart surveyed from the Upper Dalles gage to the lower slope section, and back. During this survey he established the datum for the Lower Dalles gage. This survey closed to within 14/100ths of a foot at the reference point Stewart had established at the Upper Dalles gage. See below:*



64 Levels from Dalles to lower slope section and return

Sta	BS	HI	FS	Elev	
RP (see page 29)	0.82	179.57	–	178.75	
TP			9.06	170.51	
Dist below lower Dalles gage 300'	12.28	182.79			
600' TP			1.78	181.01	
	3.45	184.46			
900 TP			10.98	173.48	
940	1.90	175.38			
930 TP			12.96	162.42	
	0.61	163.03			
865'			measure up +7.7	170.10	1921 HW at cedar tree
TP			12.26	150.77	
	1.27	152.04			
RP#1 + TP			6.44	145.60	
			7.92	144.12	W.S.
	4.81	150.41			
TP			2.42	147.99	
	5.49	153.48			
TP			6.05	147.43	
	4.45	151.88			
RP#2			1.90	149.98	
TP			4.53	147.35	
	0.55	147.90	0		
TP			4.26	143.64	
	8.65	152.29			
			9.94	142.35	WS at lower cross section 2 PM 30
TP			0.55	151.74	

65

Jan 30 1922

These levels are not tied in to levels on opposite page

14.25 read on gage
11.09 read on W.S.
3.16

W.S. Jan 30, .2' below W.S. of S.P. Jan 29, as shown by fall below RP set on 29th

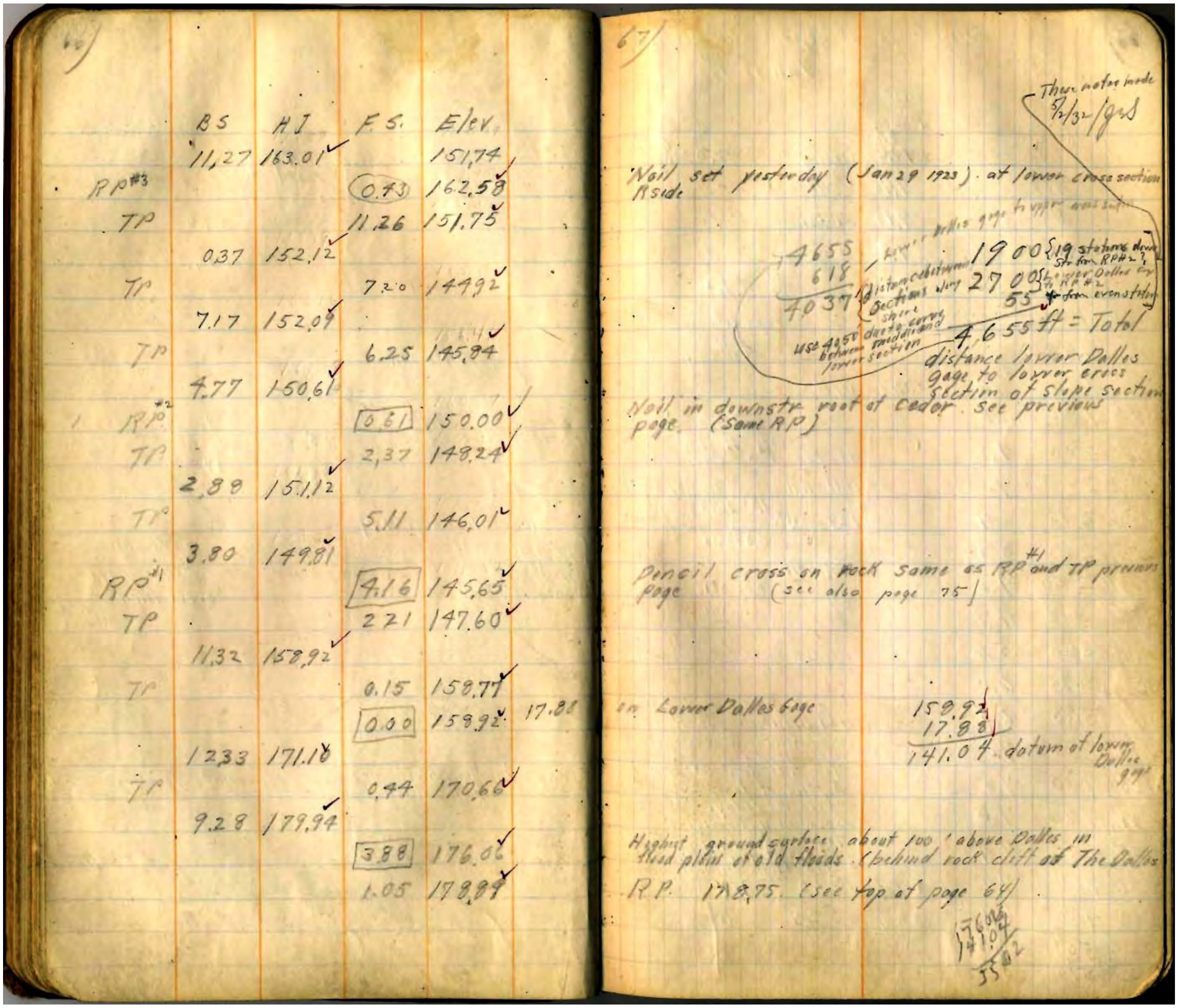
Going down bank

Note Levels of cross section above and below indicate this probably is in error

(see also page 75)
Pencil cross on rock in edge of slough 20 ft above big rock 100 ft below cedar
in slough about 900 ft below lower Dalles gage
W.S. probably not more than .1 or .2 lower than at gage

Nail in downstream side of cedar tree root, Tree at sta 2700 below lower Dalles Gage

Stewart's field notes, pp. 64-65



Stewart's field notes, pp. 66-67

Taken as a whole, these survey notes indicate Stewart was a competent surveyor. These notes constitute direct evidence and document how the gage datum was arrived at. The USGS cannot produce any direct evidence showing how its datum of 142.7 feet was determined for the current gage site, and most certainly can not attribute the 142.7 datum to Stewart's upper Dalles gage. The USGS states that "all the other USGS notes indicated that the datum between the continuous gage and the staff gage prior to 1937 are the same, and levels to another more recent benchmark show that it is 142.7 ft." (Mastin ltr 5 Nov 2007). Unfortunately the key and essential information – exactly how the new gage was tied to the Upper Dalles gage datum set by Stewart, is not available. Only the 1926 note stating that the new gage was, in fact, set to the same datum as Stewart's upper Dalles gage -- and the documentation of the upper Dalles gage datum comes directly from Stewart's notes. Because the USGS can not show a direct link, as we do, to the datum that applied to the historic flood high water marks, the USGS position is not defensible.

We also note here other discrepancies in the USGS-provided documentation of the time. Gage notes annotated with a typed "1926" which has hand-written next to it, "1927" contain an entry stating "both gage readings refer to same datum, 163 feet above sea level." 163 feet above sea level is clearly incorrect and these errors bring into question the quality control of the field work and the associated notes, as this statement appears to have been reviewed and checked (see red check marks on the notes).

1926. 1927

12-1940 910.

SKAGIT RIVER ~~AT THE DALLES~~ NEAR CONCRETE, WASH.

Location.- In sec. 16, T. 35 N., R. 8 E., at the dalles, two miles below mouth of Baker River, 2½ miles southwest of Concrete, Skagit County.

Drainage area.- 2,700 square miles. Area in United States measured on topographic maps and Washington National Forest map, edition of 1922. Area in British Columbia, 390 square miles. a/

a/ White, A. V., Water Powers of British Columbia, p. 483, Conservation Commission of Canada, 1919.

Records available.- September 15, 1924 to September 30, 1926. 1927 Flood peaks only as noted under "Extremes of Discharge."

Equipment. Gage.- Since December 10, 1924 Stevens continuous recorder in concrete house over stilling well, on right bank at the dalles. Gage used prior to December 10, 1924 was vertical and inclined staff on right bank about 200 feet above present gage. Both gage readings refer to same datum, 163 feet above sea level.

Discharge measurements.- Made from cable, equipped with gaging car and reel for handling 75 pounds of lead, three-fourths of a mile below the gage.

Channel and control.- Boulder riffle below canyon for low stages; rock canyon forming the dalles, for high stages.

USGS Station Notes (presumed to be p.2 of 2; February 15, 1926)

2. Incomplete energy equation used in Stewart's computations.

This issue was acknowledged and addressed by the USGS in Scientific Investigations Report 2007-5159 in which the complete energy equation was used to revise and lower the Stewart flood estimates.

Cities' Comment: *We concur.*

3. Incorrect flow area used for lower slope section.

While there are strong similarities between the 2003 Mastin cross-section surveys and the 1921 Stewart surveys, there are clearly significant differences between them, especially near the right bank as indicated in the technical memorandum in figure 3. These differences suggest the very real possibility that the surveys were made at different locations or that the stream cross-sections have changed over the 80 years that have transpired between the surveys.

The USGS acknowledges that Stewart adjusted the cross-sectional width and area for the upper and lower cross-sections. He did report that he was unsure about the precise correction that should be used and he applied the corrections developed for the upstream cross-section to the downstream cross-section measurements. But Stewart did so having first-hand experience with the survey and knowing whether or not the rope had become wet, stretched, and in need of adjustment. Given that a correction was clearly necessary at the upper section and that the same survey techniques and conditions prevailed at both sections, the USGS sees no compelling reason to nullify Stewart's judgment.

Cities' Comment: *Compelling evidence to adjust the cross sectional area of the lower slope section comes from the USGS' cross section measurements at Stewart's furthest downstream cross section. The following figure overlays Stewart's cross section with a cross section developed by USGS in 2004:*

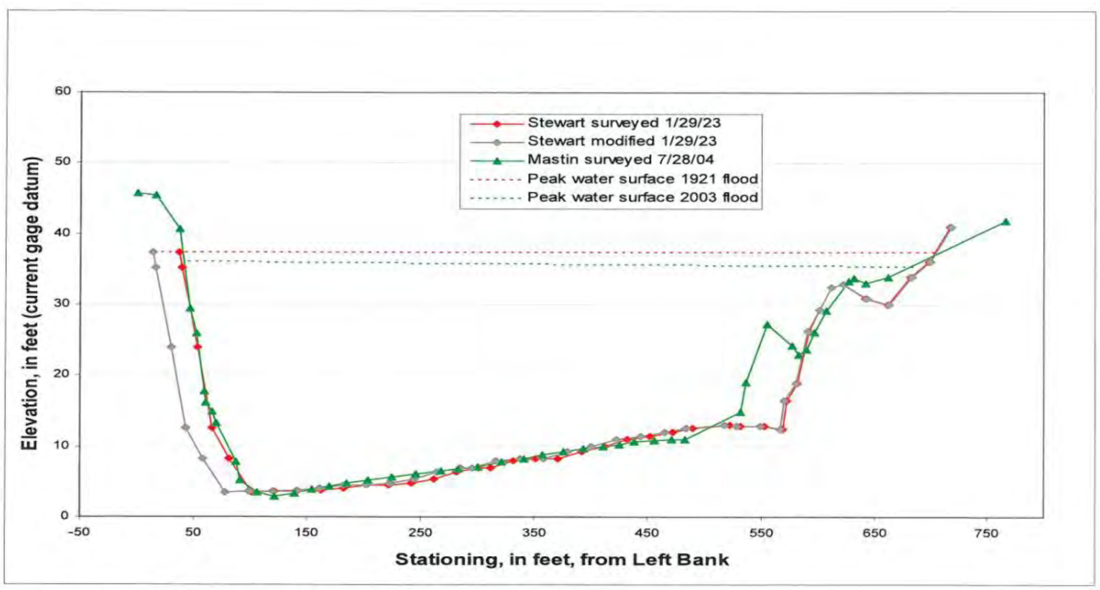
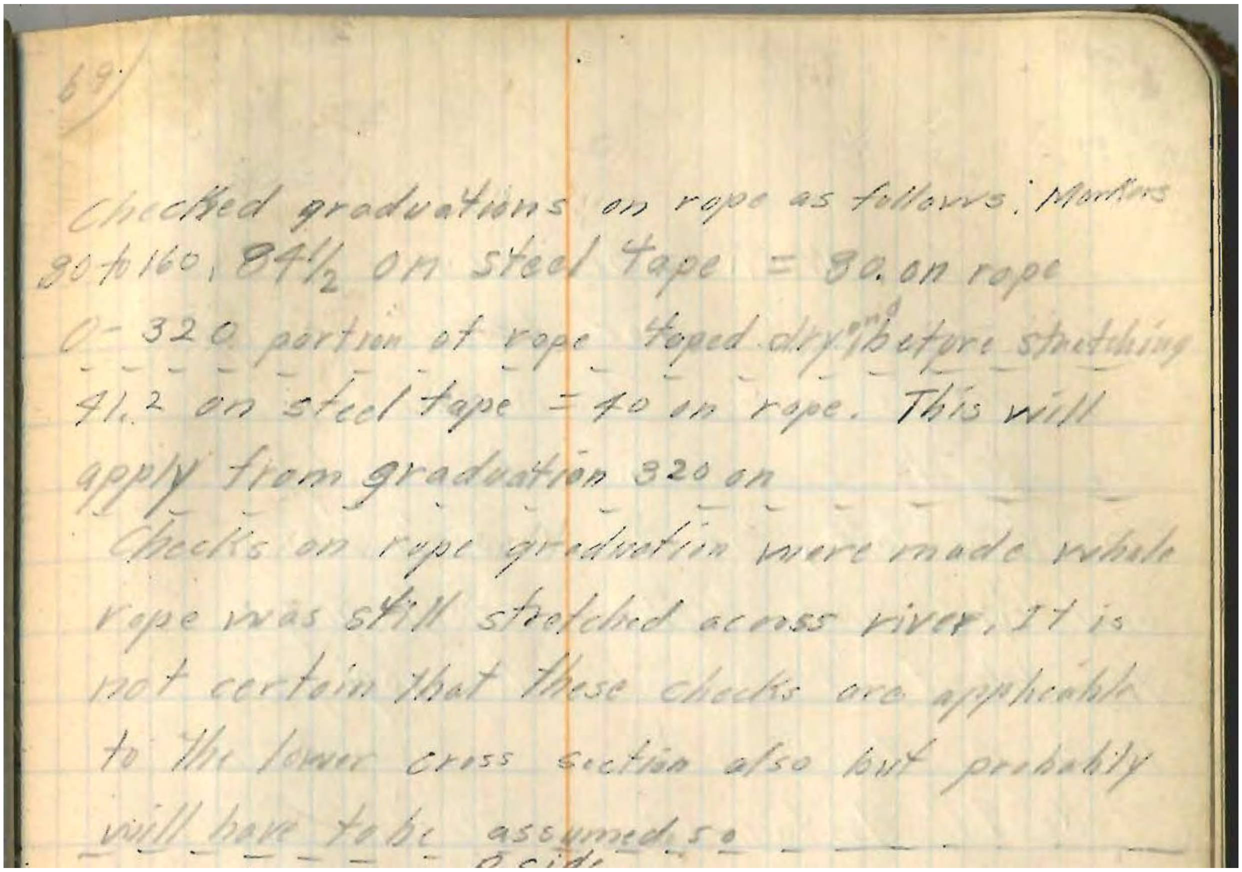


Figure 3. Slope Section XS3 – Skagit River near Concrete, WA

As the overlayed surveys demonstrate, this cross section has remained nearly the same over the years, especially along the left bank, and Stewart's adjustments for this lower cross section as *reflected on page 69 of Stewart's field notes below, based on rope gradation measurements Stewart took while conducting soundings of the upper Dalles: "Checks on rope gradation were made while rope was still stretched across river. <u>It is not certain that these checks are applicable to the lower cross section also</u> but probably will have to be assumed so."*



69

Checked graduations on rope as follows; Markers 80 to 160, 84½ on steel tape = 80 on rope
0-320 portion of rope taped dry before stretching
41.2 on steel tape = 40 on rope. This will apply from graduation 320 on
Checks on rope graduation were made while rope was still stretched across river. It is not certain that these checks are applicable to the lower cross section also but probably will have to be assumed so

In consideration of the overlaid cross sections, and Stewart's own observations, it is reasonable to conclude that Stewart underestimated the rope stretch for the lower cross section. As such, it is appropriate to adjust the cross sectional area of the lower slope section.

4. Unsupported hydraulic grade line slope used for upper slope-section reach.

Table 5 of the technical memorandum does not list all of the HWM data available for computing the flood flow estimates. A complete listing is provided below in table 1 and shows 13 HWMs available to Stewart including those surveyed by Wright and/or Thirit in 1923.

Table 1 -Highwater mark data for the 1921 peak flow of Skagit River at Concrete, Washington.

Stationing in feet below Mouth of Dalles Gorge	Elevation, in feet (NGVD '29)	Left Bank (LB) or Right Bank (RB)	Page in field notes
0	172.70	RB	14/14 in loose notes file
525	172.38	RB	14/14 in loose notes file
538	173.49	RB	69
618	172.40	**RB**	69
618	173.79	**RB**	69
618	173.75	**LB**	68
865	171.9	RB	64
985	173.07	RB	14/14 in loose notes file
1525	171.32	RB	14/14 in loose notes file
2090	171.1	RB	14/14 in loose notes file
2470	**171.67**	**RB**	**14/14 in loose** notes file
4655	169.14	**RB**	78-79
4655	169.1	LB	78-79

Stewart was careful in selecting highwater marks on which to base his water-profile. It is very rare for all high-water mark elevations that are identified in a field survey to be used or considered in determination of a water-profile slope. Some marks are clearer or more vivid and can be more precisely surveyed, because the seedlines, mudlines, or debris that defines them is narrower, more tightly banded, or more continuous than other marks. Even among those marks that are well defined, however, most serve as only low- elevation bounds on the peak high-water elevation simply because they did not occur at the peak flow but AFTER it has occurred. They are more numerous because they occur over a longer period of time, during the flood recession and in generally calmer, relatively low-water flows. Because they do not represent peak flow conditions, the USGS generally disregards the lower highwater marks in favor of the higher marks, particularly when multiple highwater marks provide confirmation of those higher elevations.

This is precisely what Stewart did. He emphasized the highest marks, attributing them to the water levels occurring at peak flow and the lower marks to water levels that occurred after the peak. On p. 25 of Stewart's 1923 report, "Floods in Skagit River Basin, Washington" he writes, "When looking for the 1921 crest, there was danger of obtaining a lower point than the flood crest." As such, the five marks that figure most prominently in the development of his surface-water profile were the most reliable estimates of the water profile during the peak flow. Significantly, two sets of marks (those of cross-sections 1 and 3) are confirmed by independent marks found on the opposite bank. Stewart did not blindly extend the profile from cross-section 2 and 3, he had highwater marks at both locations, and in addition to those he had marks along the reach from cross-section 1 and 2. The result was a single, consistent slope of 0.00119 feet/foot.

This slope has also been confirmed by other flood data. In November 2006, soon after a peak of 145,000 ft^3/s, the USGS surveyed HWMs between locations approximating cross- sections 2 and 3 and defined a peak water slope of 0.00114 (fig. 1, Mastin 2007). This slope matches to within 3 significant figures the surface-water slope computed by Stewart.

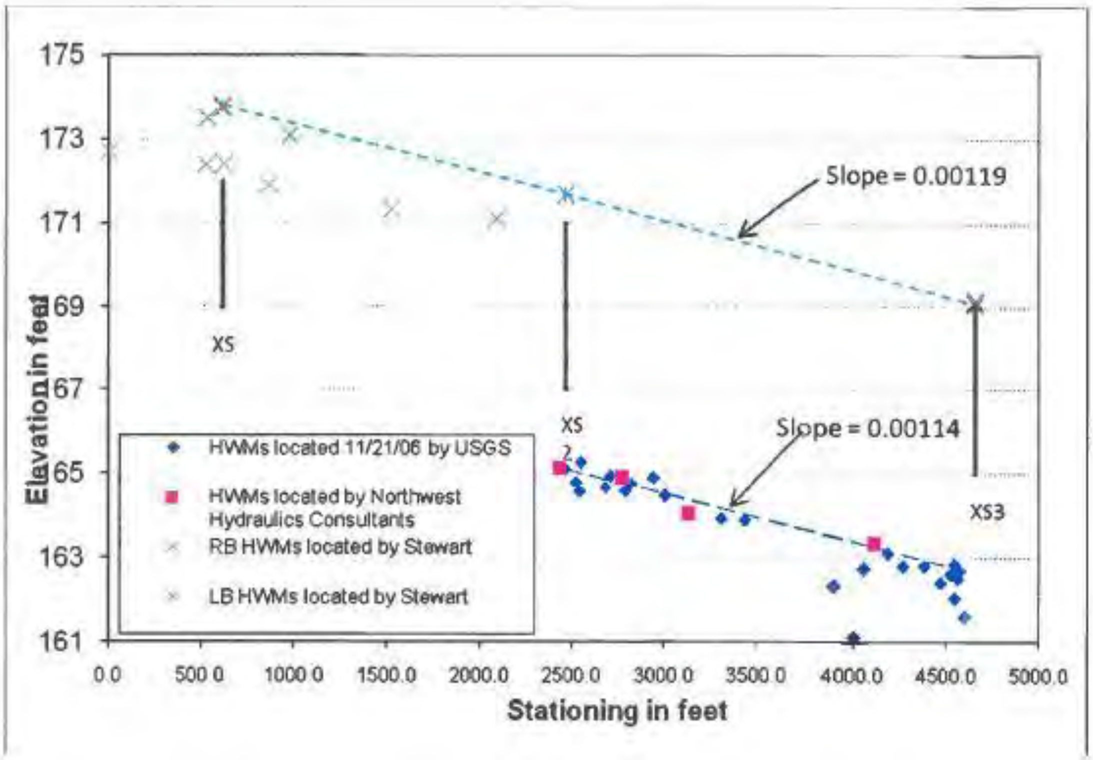


Figure 1 -- High-water marks and peak water-surface profiles in the slope-area reach downstream of USGS streamgage Skagit River near Concrete, WA Station Number 12194000 for the Dec. 1921 and Nov. 2006 floods.

Cities' Comment: *The USGS did not gather any data following the 2006 flood, upstream of XS2. This is a significant weakness, as the USGS only uses the lower slope section to attribute the hydraulic grade line to the entire slope-area reach.*

The table below comes from the USGS 2005 report, and contains high water marks collected by the USGS 9-10 months after the October 2003 flood event. Shown below is a profile showing the high water marks surveyed by USGS in the summer of 2004 following the October 2003 flood of record.

Note that the high water marks in the vicinity of cross section XS2 are well clustered, with "good" or "excellent" high water marks within a 2-foot range. The range of high water marks collected by the USGS in the vicinity of XS3 indicate that gathering high water marks in this area was a more difficult task than at XS2. In the case of XS1, it is clear the difficulty of gathering accurate high water marks is very challenging. Note that right bank marks rated "good" are 5-8 feet below the expected water surface elevation.

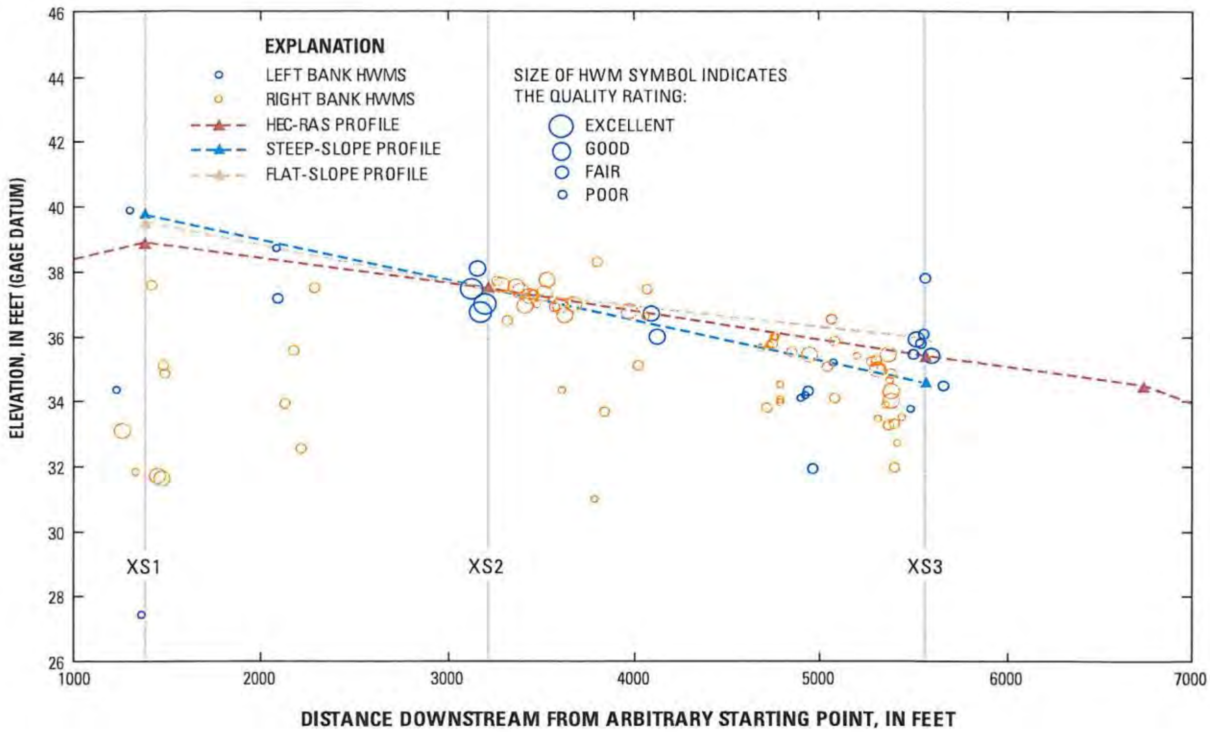


Figure 4. High-water marks (HWMs), flattest- and steepest-sloped water-surface profiles, and a HEC-RAS water-surface profile near cross sections XS1, XS2, and XS3, at Skagit River near Concrete, Washington.

(Cities' comment continued) *Stewart surveyed the high water marks 11-13 months after the 1921 flood event, starting in late November and continuing through late January 1922-23 (see Stewart's field notes). Later, a survey crew from Skagit County surveyed additional high water marks in early March 1923, such marks presumably marked by Stewart to be surveyed later (see survey notes of Wright, Thiret and Stiles March 5-8, 1923).*

The USGS-surveyed high water marks of the flood of record in October 2003 were surveyed in July-August of 2004, about 10 months following the flood (USGS SIR 2005). Presumably, high water mark evidence available to the USGS would therefore have been similar to evidence available to Stewart, as he gathered high water marks 11-13 months following the 1921 flood.

The difficulties of gathering high water marks, even a few days after a flood, are further highlighted in a subsequent USGS effort following the Skagit flood of 2006. The USGS figure 1 (page 20, above) includes high water marks gathered following the smaller flood of 2006 (peak flow at the Dalles (USGS Concrete gage) was 145,000 cfs (compared to 166,000 cfs for the October 2003 flood). In the 2006 flood, the USGS was on site gathering high water marks within a few days of the flood receding.

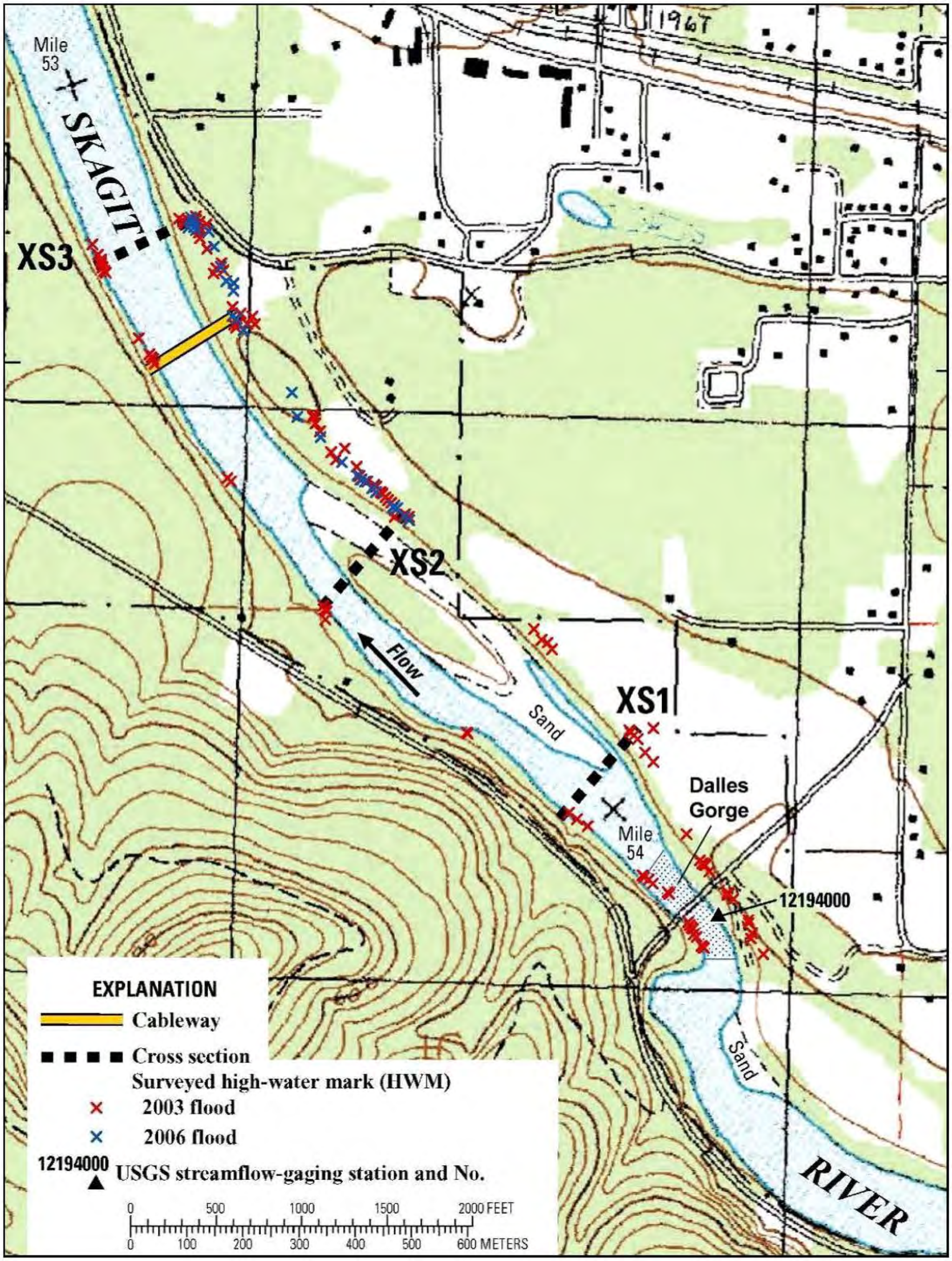
We concur with the slope drawn for the 2006 flood between slope sections XS2 and XS3. However, we observe that the USGS did not attempt to estimate the slope between XS1 and XS2, instead attributing the slope for the entire reach by simply extending the slope obtained from the data from XS2 to XS3. This is unreasonable because the river is expanding between XS-1 and XS-2, and contracting between XS2 and XS3. From the USGS 2007 report, here is a description of the USGS difficulties in collecting accurate high water marks in the vicinity of XS1:

"HWMs were particularly difficult to find near cross section 1 (labeled XS1 in fig. 1) and marks that were found were rated poor. Most of the marks were scour lines, flood-deposited sand, mud lines or small debris piles. Cross section 1 is near a rapidly expanding section just downstream of the Dalles Gorge, where it is difficult to assess the amount of energy loss due to expansion. Slope-area calculations are best applied to reaches where bed friction losses dominate and are less accurate when applied to reaches with expansions. Because only limited, poor quality HWMs could be located and the difficulties in estimating the energy loss due to expansion, XS1 was not used and only XS2 and XS3 were used in a two-section slope-area calculation to estimate the n value."

Aerial view of the Dalles gorge showing current and old gage locations and the locations of Stewart's slope-area cross sections XS1, XS2, and XS3.

Cities' Comment (continued): *Due to the difficulty in collecting accurate high water marks upstream of Stewart's XS2, the USGS in 2006 did not collect any high water marks upstream of XS2. Lack of information regarding the peak flow stage at XS1 is a significant deficiency in a study intended to reconstitute Stewart's approach to estimating the 1921 flood peak discharge. (See PI Engineering, March 2011, sections 2.2.5 and 2.2.6)*

The figure on the next page, taken from the USGS 2007 report, shows the location of Stewart's cross sections in relation to the Dalles gorge; high water marks collected by the USGS following the 2003 Skagit flood of record and the smaller 2006 flood event, and the location of the USGS cableway.



Topographic map of the slope-area measurement reach on the Skagit River near Concrete showing the three cross sections (XS1, XS2, and XS3), the streamflow gaging station, and HWMs from the 2003 flood and the 2006 flood surveyed by the U.S. Geological Survey (source of data: Scientific Investigation Report 2007-5159, USGS)

Cities' Comment (continued): *The data in Fig. 4 below was collected by the USGS in the summer of 2004, following the flood of record in October 2003. The high water marks in the vicinity of cross section XS-2 are well clustered. However, the range of high water marks collected by the USGS in the vicinity of XS-3 indicate that gathering high water marks in this area was a more difficult task than at XS-2. And, in the case of XS-1, it is clear the difficulty of gathering accurate high water marks is very challenging. Note that right bank marks rated "good" are 5-8 feet below the expected water surface elevation. Two left bank marks, both rated "poor," are over 5 feet different. But the marks rated "good" at XS-3 support a flatter slope profile between XS-1 and XS-2 than that utilized by the USGS.*

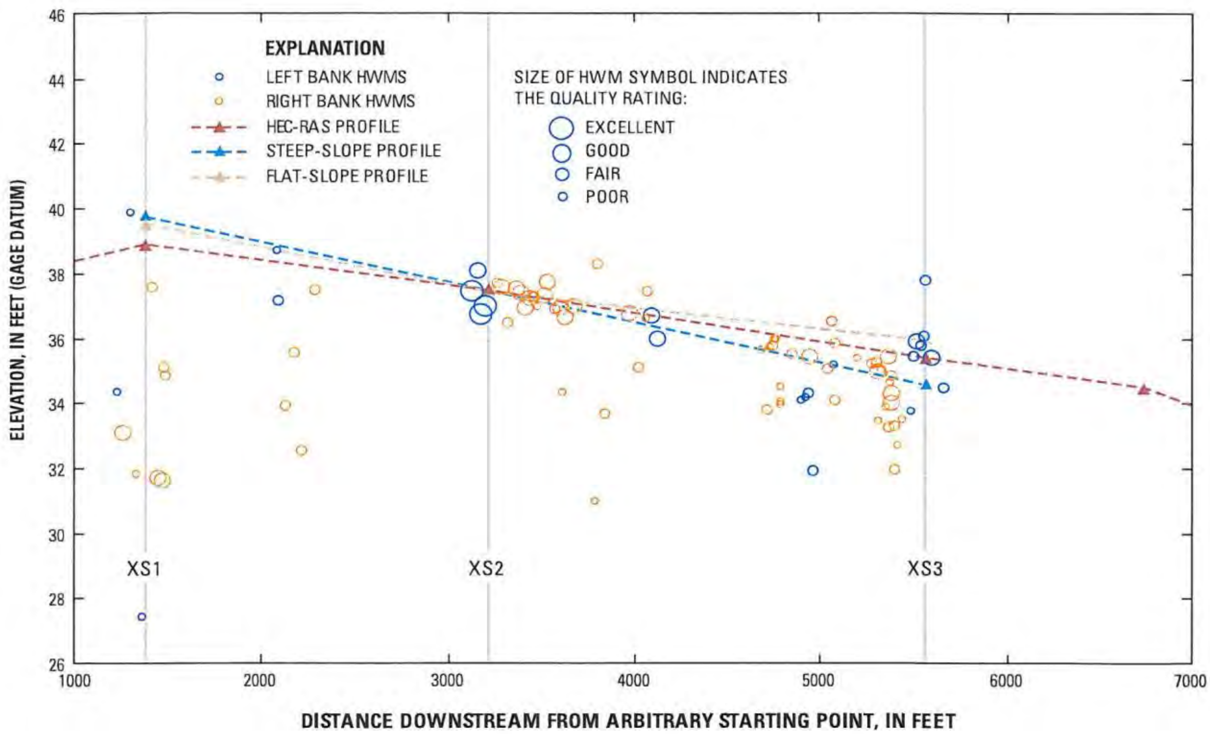


Figure 4. High-water marks (HWMs), flattest- and steepest-sloped water-surface profiles, and a HEC-RAS water-surface profile near cross sections XS1, XS2, and XS3, at Skagit River near Concrete, Washington.

Similarly, USGS, in its 2007 report, used high water mark information gathered below the Dalles reach following the flood of 1949. See Fig. 5 below. For reference, cross section "A" of the 1949 study is about 300 feet downstream of Stewart's XS1 cross section; cross section "D" of this study is about 700 feet upstream of Stewart's XS3 cross section (near the cableway). High water marks gathered by the USGS following the 1949 flood (peak discharge in this area 154,000 cfs) are shown on the next page in Figure 5 of the 2007 USGS report on the following page:

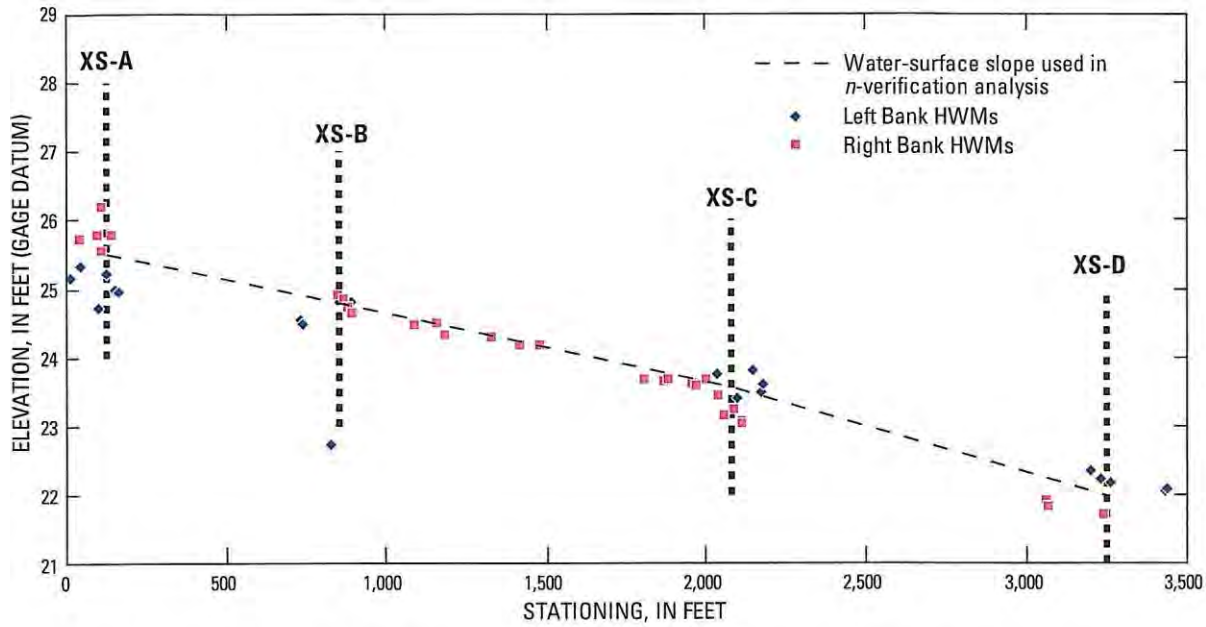


Figure 5. High-water marks (HWMs), cross sections (XS), and water-surface profile from the peak flow of November 27, 1949 on the Skagit River about 3,000–5,000 feet downstream of the streamflow-gaging station, Skagit River near Concrete, Washington (station No. 12194000).

Cities' Comment (continued): *As can be seen from the figure above, the 1949 data supports a flatter slope in the upstream reach, and a steeper slope in the downstream reach. In summary, we do not concur with the USGS methodology and do not concur that the information provided by the USGS in support of its slope-area calculations, particularly using the 2006 downstream high water marks and then extending the hydraulic grade line obtained from the downstream data, through the entire upstream reach. Stewart's work should be given deference unless it can be demonstrated through newer methodologies or clearly identified inconsistencies that Stewart's data should be modified. USGS has not done so.*

*The table on the next page, **Compendium of Stewart's high water marks below the Dalles, 1922-23,** is a comprehensive compendium of Stewart's measurements, along with the supplemental survey high water mark measurements of the 1921 flood event in the Dalles. This table provides more detailed information pertaining to the source of the high water mark data, how it was modified, and why, whereas the USGS Table 1 (page 19 above) does not explain where the source data came from, and how it was modified.*

Compendium of Stewart's high water marks below the Dalles, 1922-23

Station	Bank	Comment	Source Document and Source Document Explanatory Comment	Survey Elev from source document	Datum Adjustment from Source Document	Datum Elev from source document	msl/NGVD29 from source documents	USGS Datum Adjustment	USGS msl/ NGVD29 Assertion
0+00	R	Site of "Lower Dalles" Gage	3/8/23 supplemental survey notes at the lower Dalles -- "On rotten stump 25' N guage"	30	0	Page 67 Stewart's notes: "datum of lower Dalles gage 141.04"	171.04	1.66	172.7
5+25	R		Supplemental survey notes 3/8/23: "H.W. - Mapletree 60' L. of Line"	29.68	0	141.04	170.72	1.66	172.38
5+38	R		Stewart's notes p.68; 1/31/23: "1921 HW sand in stump 80' upstream from cross section"	27.9	2.89 (see bottom right corner Stewart's notes p. 69)	141.04	171.83	1.66	173.49
6+18	L	Upper slope section XS-1	Stewart's notes, p. 68: "1921 HW mark on tree at L end of cross section"	28.16	2.89	141.04	172.09	1.66	173.75
6+18	R		Stewart's notes, p. 68: "1921 drift"	26.81	2.89	141.04	170.74	1.66	172.4
6+18	R		Stewart's notes, p. 68: "1921 HW mk about OK I think use this"	28.2	2.89	141.04	172.13	1.66	173.79
8+65	unk	High water mark is likely on the right bank	Stewart's notes p. 64-65, 1/30/23: "1921 HW at cedar tree Note Levels of cross sections above and below indicate this probably is in error"	170.1	0	0	170.1	1.8	171.9
9+85	R		Supplemental survey notes 3/8/23: "10" Alder - 50' Left H.W."	30.37	0	141.04	171.41	1.66	173.07
15+25	R		Supplemental survey notes 3/8/23: "H.W. - 30" Hemlock 30' Left"	28.62	0	141.04	169.66	1.66	171.32
20+90	R		Supplemental survey notes 3/8/23: "H.W. 10' Left Line - Moss on Vine Maple - Poorest Evidence"	28.4?*	0	141.04	169.4?	1.66	171.1
24+70	R	Middle slope section XS-2 at 2479 feet below lower gauge at the Dalles	Supplemental survey notes 3/8/23: "H.W. 12" Alder 10' L."	28.97	0	141.04	170.01	1.66	171.67
46+55	L	This is the lower slope section, XS-3. Stewart recommended using 24.75 (bottom of pg. 79).	Stewart's notes p. 78-79 1/29/23: "1921 flood mk 1.45' above this TP = Elev 24.74"	24.75**	1.51***	141.04	167.3	1.8	169.1
46+55	R	Stewart recommended using 24.79 (bottom of pg. 79)	Stewart's notes p. 78-79 1/29/23: "about .25 above HI looks like 1921 HW, moss scoured off of tree"	24.79**	1.51	141.04	167.34	1.8	169.14

* The last digit cannot be read from the supplemental survey notes

** Stewart also recommended using 24.80 as the 1921 HWM for both sides of the river at this cross section

*** Water surface 30 Jan 142.35 (pg 64/65). WS 30 Jan 0.2 feet below WS of 29 Jan (p. 65), or 142.55. Lower Dalles gage datum is 141.04. 142.55-141.04=1.51 feet. 1.51+24.79+141.04=167.34

Cities' Comment: *The USGS Table 1 (page 19) asserts a datum of 142.7 feet; however, it does not describe the logical path leading to that conclusion. The only direct link between Stewart's established Upper Dalles datum (140.89) and the USGS datum comes from the 2/15/26 gage description memo by Calkins, (page 4), stating "It was set to datum of Upper Dalles gage set by J. E. Stewart in 1921." If that was true, then the gage datum should have been 140.89 feet. The USGS points to low flow water surface measurements documented in the station notes of 9/16/24 (page 2), and state that the low flow measurements provide evidence of the new datum, since the water surface elevations are nearly the same between the upper Dalles gage, the current gage location (recorder site), and the lower Dalles gage. But this evidence provides no information about the datum, since both the upper Dalles Gage datum (140.89) and the lower Dalles gage datum (141.04) were already very close to each other and the recorder site was supposed to be at the same datum as upper Dalles. The critical piece of information that is needed, is some kind of memo or survey showing an error in Stewart's established gage datums. This information cannot be found anywhere in the record, yet is foundational to the entire analysis in and through the Dalles, and continues to cast a shadow of uncertainty over the USGS slope-area analysis, since that analysis depends on accurate high water marks. In an effort to reduce this uncertainty, PI Engineering developed alternative methodologies to estimate the peak discharges of the historic floods. (See letter dated March 29, 2011 from PSE Surveyors, under separate cover).*

5. Unknown quality of highwater marks; surge effects.

The USGS acknowledges that Stewart did not characterize the quality of his HWMs and surge may have affected some of the marks. However, the technical memorandum greatly over estimates the likely effect of the surge, reporting a surge of 0.6 to 2.1 feet based on the spread between the elevations of the highwater marks and the peak water elevation in the USGS stilling well reported in the 2003 Mastin survey.

There was a lot of vertical variation in the HWMs, but these variations were due as much to the differences in timing and types of HWMs and their resulting quality, as much as to any surge effect. Indeed, most of Stewart's highwater marks are located in low-energy environments on the right back away from the main flow and there the surge should be relatively small.

Regardless, USGS standard practice for computing flow from indirects does not generally include correction for surge effects. As reported by Benson and Dalrymple (1967):

> Observation and photographs of flood flow in natural channels show that, although there may be extensive wave action in the middle of a fast-flowing stream, at the sides, velocities are low and the water surface quiet. Although there undoubtedly is some effect from surge, the high-water marks should be used as found and no adjustments attempted for surge. Any adjustments would necessarily be subjective and would lead to questionable results. This is justified by the fact that roughness values as determined from "verification" studies are determined from high-water marks on the banks, and any effect of surge is contained in the n values determined; if similar n values are applied for like conditions using the same methods, then the effect of surge would be minimized.

The n-value that Stewart used was based on an n-verification study using a moderately high flow on the Skagit River at Sedro Woolley, though it is not known to what extent the highwater marks (or directly observed water-levels) included surge effects. More importantly, Mastin (2005, 2007) back-computed a new n-value based on directly measured streamflow and the many highwater marks he surveyed in 2003. These marks included surge effects present at that flow. Hence, surge effects are already factored into his n-value and into his revised estimate of the 1921 peak flows. Making additional corrections for surge is not necessary and would unduly bias the results.

Cities' Comment: *To the extent possible, PI Engineering has attempted to use Stewart's data and documentation when developing estimates of the historic flood events. Stewart, in his letter of June 1, 1950 to F.M. Veatch, District Engineer of the USGS at Tacoma, Washington, suggested to the USGS that the high water marks needed to be adjusted for an unknown amount of surging. Based on cableway measurement data provided by the USGS which included velocity information, PI Engineering has conservatively estimated surge effects in this reach at 1.3 feet.*

6. Reevaluation of the 1921 flood peak discharge using slope-area method

The flood-peak computations performed by PIE and summarized in table 7 of the technical memo were derived based on fundamentally different input data than that used by Stewart or the USGS. All of these inputs are important, but the over riding input is the water slope and cross-sectional area. As discussed above (item 5), the USGS does not concur in use of a water slope significantly different from that used by Stewart and confirmed by Mastin. Furthermore, the USGS disagrees with altering the cross-sectional areas as described above (item 3). Computations based on other slopes or areas, regardless of similarity of roughness coefficients or treatment of surge effects, will provide different and less reliable peak flow estimates.

Cities' Comment: *From the beginning of its analysis of the USGS slope-area approach to estimating the 1921 peak discharge, PI Engineering noted significant shortcomings with that approach (including the points discussed above). The cities' analysis, for reasons described earlier in our responses, provides a more reasonable and accurate analysis given the constraints of the slope-area methodology. The USGS study is conservative at every step of the calculations; these conservative estimates compound, resulting in a peak discharge estimate of the 1921 flood event that is in error. Significantly, PI Engineering undertook its own slope area analysis, using the tools available to us today, combined with the abundant documentation contained in Stewart's notes and other sources describing the nature of the historic floods. Taken together, these methodologies consistently demonstrate a more accurate result.*

7. Reevaluation of the 1921 flood peak discharge using the stage-discharge rating

The extension of the 1921 high-water marks from their original locations to the current streamgage is ultimately based on assumptions about the location of the marks and past streamgages, and the resulting distances between them. The exact location of the marks or the old streamgages is not well known. While the technical memorandum asserts that the highwater marks were 400 feet upstream of the current gage, USGS survey notes, station descriptions, and published reports, most made prior to 1925 and by persons familiar with the old sites and the area configuration as it existed then, place the upper Dalles gage approximately 200 feet upstream of the current streamgage and in an area where the water slope is much milder than that of the downstream reaches.

Cities' Comment: *Stewart noted that the upper Dalles is 695 ft above the lower end of the Dalles (Stewart's survey notes, p. 62). The current gage is located approximately 365 ft above the lower Dalles (from map). This leads to an approximate distance of 330 ft between Stewart's upper Dalles gage and the current gage.*[2]

Notwithstanding the discussion about the exact location of the Upper Dalles gage with respect to the existing gage, recent new data collected by Skagit County strongly supports our assertion that these high water marks should have been adjusted for the head loss that is occurring and did occur in 1921 in this 300-foot reach. Pursuant to suggestions by the USGS to obtain head loss data through the Dalles gorge, Skagit County in November 2010 installed several

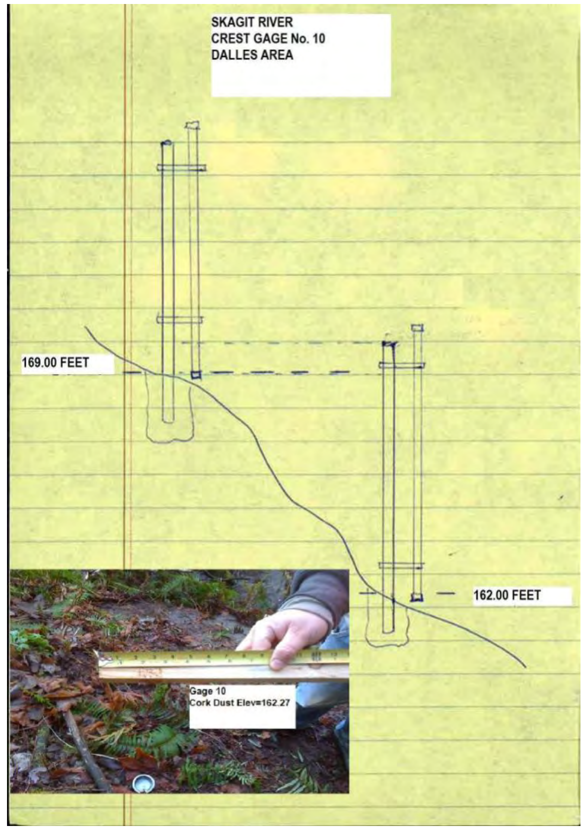
[2] *This distance is more than* "about 200 feet above present gage" *stated incorrectly by the USGS-published Water Supply Paper 612 (USGS 1925, p. 62)).*

*crest stage gages upstream and downstream of the current USGS gage location. As it happened, a minor Skagit flood occurred on December 12, 2010, triggering a reading on one of the crest stage gages 200 feet upstream from the current USGS gage.[3] The USGS stage elevation for this minor flood, with a discharge of 81,900 cfs at the Concrete gage, was 161.22 feet NGVD 29. The crest stage gage reading 200 feet upstream was 162.27 feet, for a difference of **1.05 feet** in a 200-foot distance. This data strongly infers an estimate of as much as a 2-foot drop between Stewart's Upper Dalles gage, located 300 feet upstream of the current USGS gage for the 1921 flood is reasonable for a flood discharge in the neighborhood of 170,000 cfs.*

Photograph showing cork dust marks left on inside crest stage gage 200 feet upstream of the USGS Concrete gage at the Dalles, WA. December 2010.

[3] *The gage was installed by Skagit County in deference to the USGS position that the Upper Dalles gage was located 200 feet upstream of the current gage location, not 300 feet as we believe.*

Skagit County Crest Stage Gage #10. Note the Dalles bridge 200 feet down-stream. The current USGS gage is on the right bank just upstream of the bridge.



Schematic showing crest stage gage installation and cork reading from lower gage (#10) that was triggered during the minor flood event of Dec 2010.

The technical memorandum asserts that the elevation of the Stewart highwater marks was 175.75, 175.18, and 171.04 feet, respectively. These elevations are possible only if one negates the USGS datum correction of 1.8 feet for which there is ample documentation as described in item 1 above. Once the datum correction is made, these elevations become 177.5, 176.0, and 172.8.

Cities' Comment: *As discussed previously, there is no documentation showing why or how Stewart's datum at the upper Dalles gage, 140.89 feet as shown in our responses above and supported by Stewart's field notes, was modified. A datum "correction" of 1.8 feet is speculative and improper. . (See letter dated March 29, 2011 from PSE Surveyors, under separate cover).*

In past USGS publications on the historic floods that show the current stage-discharge rating and the historic flood peaks, the gage height was not corrected for the different locations of the streamgages. It may be more correct to make that correction, but the estimated drop of 1.18 feet shown in the Technical Memorandum between the two gage locations suggests a slope of 0.0059, a much steeper slope than what would be expected and does not agree with levels taken in 1932. Levels dated April 7, 1932 shows an elevation of a HWM at 27.714 feet (gage datum) on the "upper dalles gage" and 27.468 on the "upper section" of the current gage. This is a difference of 0.246 feet or a slope of approximately 0.0012, a more reasonable slope in the backwater of a constriction. At 27.5 feet, the flood that deposited the highwater marks was a minor flood, but there is no reason that the water slope would be much different at higher stages. A correction of -0.25 feet to the gage height of the 1921 flood (based on observations in 1932) would result in reduction of approximately, 2,500 ft^3/s or a revised estimate of 226,500 ft^3/s, about 1 percent below the current estimate of 228,000 ft^3/s.

Cities' Comment: *The slope of the hydraulic grade line through the upstream reach of the Dalles gorge is significant and therefore the USGS failure to adjust the high water marks to account for the hydraulic grade line drop, combined with the additional affect of raising these high water marks by 1.8 feet through an undocumented datum shift, result in an inaccurate estimate of the 1921 peak flood discharge. Combined effects are conservatively estimated as follows (See PI Engineering's March 2011 report, sections 2.1.4, 2.2.2, and 2.3.1):*

Element		*Impact (Feet)*
1) USGS Gage Datum Shift		*1.8*
2) Downstream transfer of Upper Dalles gage HWMs		*1.2*
3) No consideration of surge effects on HWMs		*1.3*
	Total	*4.3*

8. Although not covered in the Technical Memorandum, some of the discussion and presentation at the meeting included the modeling efforts by Pacific International Engineering which was also mimicked by Northwest Hydraulic Consultants (NHC). Both consulting firms used a one-dimensional HEC-RAS hydraulic model and upstream HWMs to estimate the 1921 peak discharge on the Skagit River near Concrete. The USGS has not examined the specific details of either HEC-RAS models. However, the 2010 NHC report, "Re-evaluation of the Magnitude of Historic Floods on the Skagit River near Concrete, Revised Final Report," provides enough information for the USGS to comment.

The USGS has concerns with the model construction and calibration. NHC writes in their report (p.17):

> "Considerable difficulties were encountered in achieving a model calibration which both matched the USGS gage rating over a wide range of flows and which also reasonably matched the HWMs below The Dalles. Emphasis was given to matching the gage stage-discharge rating in preference to the HWMs below The Dalles."

This stated approach is not the best way to calibrate the model. The HWMs downstream from the Dalles represent a better dataset to calibrate the main channel roughness values. It is odd that the calibrated model predicts water-surface elevations about 2.5 feet below the excellent-good HWMs surveyed after the 2003 flood. The U.S. Army Corp of Engineer's model based on 1975 and 2004 data was readily calibrated to these HWMs (Mastin and Kresch, 2005).

Calibration of a 1-D model should not be made in a bedrock constriction where multidimensional flows predominate. It is exceedingly difficult for 1-D models to predict water-surface elevations directly in constrictions, particularly for larger discharges (Magirl and others, 2008). More importantly, it is potentially erroneous to calibrate a 1-D model from a gage located directly in a constriction, as is the case with the Concrete gage. In 1-D modeling, the simultaneous solution of the energy and continuity equations near constrictions often results in numerical artifacts where the predicted water-surface elevation is artificially lower that the actual water surface in the river. At least four water- surface depressions with adverse (negative) slopes are visible for the simulation of 166,000 cfs in figure 7, p. 21 of the NHC report. These numerical artifacts were more severe at larger simulated discharges (figure 14 of the NHC report). More importantly, near the gage within the bedrock constriction, steep drops in the profile are visible with two or three adverse slope sections. The surveyed HWMs of the 2003 flood upstream from the gage indicates that the water-surface profile upstream of the constriction is relatively flat. In contrast, the predicted water-surface profile in the 1-D model upstream from the gage is steep, dropping 5 ft in a distance of about 580 ft. This predicted water- surface profile poorly matched the observed and surveyed water-surface profile. These water-surface artifacts are common in 1-D models of bedrock rivers (Kidson and others, 2006; Magirl and others, 2008). For example, Kidson and others (2006) found similar model behavior in their HEC-RAS simulation of a large flood in a bedrock-confined channel in northern Thailand. In figure 8 of the NHC report, the model shows a close agreement between the stage-discharge rating of the gage and the model. This figure is given as evidence of a calibrated model. However, we suspect that the predicted water- surface profile in the vicinity of the gage suffers from the 1-D numerical artifacts described earlier.

Therefore, we are concerned because a match of the model's stage- discharge rating with the observed stage-discharge rating (fig 8, NHC report) would indicate that the model is poorly calibrated for analysis upstream from the constriction. Without testing the model, it is hard to determine how much this potential error might affect the water-surface profile in the vicinity of the Crofoot's Addition where the 1921 newspaper-account HWM exists.

The roughness values for the upstream portion of the NHC model appear to be overestimated. A calibrated in-channel roughness by Mastin (2007) for the channel below the Dalles Gorge indicated a roughness value of 0.033 for the existing vegetated gravel bar and 0.0305 for the 1949, sparsely-vegetated gravel bar. While not stated in the NHC report, it appears as though n=0.033 was used as the in-channel roughness value upstream of the Dalles for modeling the 1921 flood (Table 3). Aerial imagery (figure 11 in the NHC report) shows most of the river channel in 1937 was bare with large, open areas of unvegetated gravel bars in the main channel, suggesting channel roughness in 1921 would be less than in 2003. In addition, it is widely reported that roughness coefficient decreases with increasing depth in channels as the relative size of the roughness elements on the channel bed decreases (Limerinos, 1970; Jarrett, 1984; Bathurst, 2002; Yen, 2002), suggesting that the channel upstream from the Dalles would have a lower roughness for the 1921 discharge. Also, the right bank from RM 55.5 to RM 56.5 appears different in the 1937 aerial photo (fig. 11, NHC report) than the 2001 aerial photo (fig. 6). A side channel is visible in the 1937 photo that is not seen in the 2001 photo. The right-bank portions of the cross sections in this reach should have roughness values similar to the in-channel values and significantly lower than the roughness values in the current model. The NHC report does state that an n value of 0.06 was used for pastures and 0.20 was used for the forested overbank portions of the channel. The 0.20 roughness value is at the extreme upper end of reported roughness values used for heavy vegetation. While information on verified roughness values for overbank areas is limited, the USGS in Washington has rarely used roughness values larger than 0.10 in forested areas for computations of flood magnitude. In the 1937 photo, the forest in the Crofoot Addition appears to be less dense than it is in the 2001 photo, and though not explicitly stated, it appears an unrealistically large roughness value was applied to the overbank regions in the model.

Cities' Comment: *Although the USGS in this response letter did not comment directly on the PI Engineering hydraulic model, which differs significantly from the NHC model as further explained below, it is important to first emphasize the purpose of both hydraulic models: that is, to estimate the December 1921 flood stage and discharge in the Crofoot's Addition to Concrete, located about 2 miles upstream. The purpose of the model is not to estimate the hydraulic gradient through the Dalles; however, the model does a reasonable job of doing that, based on the recent information obtained from the crest stage gage #10 in December 2011, described above. Further, the USGS inference that PI Engineering's hydraulic model contains uncertainty due to unknown expansion/contraction coefficients in the Dalles is not supported by the analysis. The model is very accurate due to the upstream proximity of a USGS gage. Sensitivity runs of the model demonstrated that varying the expansion/contraction coefficients in the Dalles vicinity had almost no impact on the results returned by the model 2 miles upstream which was linked to the USGS gage data only a few hundred yards away from the point of interest. This hydraulic model is much more accurate than the USGS slope/area methodology below the Dalles gorge, because of the uncertainty surrounding these issues with the USGS slope-area methodology in the Dalles:*

- *Whether the slope used by USGS is supported by the high water marks*
- *Whether the USGS change to Stewart's n-value was defensible*
- *Whether the lower slope section should be modified to account for rope stretch as PI Engineering demonstrated*
- *Whether a surge adjustment, as suggested by Stewart in his 1950 letter to the USGS Tacoma office, should be factored into the analysis by adjusting the high water marks downward some amount – and if so, what amount*
- *The USGS unsupported upward datum adjustment of 1.8 feet*

- *The USGS unsupported direct transcription of high water marks 300 feet upstream without accounting for the hydraulic grade line*
- *The accuracy, overall, of the high water marks in light of the difficulty the USGS experienced attempting to gather high water marks in the same reach following the 2003 flood of record*

Additional details of PI Engineering's hydraulic model and the accuracy of the model can be reviewed in PI Engineering's Technical Report – Supporting Data and Analysis for Skagit River RFIS Appeal.

In summary, after reviewing the material provided at the March 17 meeting, the USGS remains unconvinced that a peak-flow estimate based on a poorly calibrated 1-dimensional model and made 80 years after the event is more reliable than an estimate made using slope area methods made within a year of the event. Hydraulic models have complications in retrodicting past floods stemming from uncertainty of the channel morphology, unknown impacts from dredging, changes to vegetation, reliable HWMs, and other unforeseen influences. When evaluating the discharge of the 1921 peak event, the slope-area computation was made by a competent hydrologist that searched for a uniform reach and surveyed HWMs strictly for the computation of peak discharge. This computation has been reevaluated several times over the years by other USGS hydrologists. Often, the largest unknown in a slope-area computation is the roughness coefficient and several n-verifications have been made to reduce this uncertainty as much as possible. The water-surface slope used in the computation has also been verified with comparisons with a recent surveyed peak water surface from a lesser flood. Also, this method does not depend on knowledge of the correct datum used in the 1921 surveys, whereas the HEC-RAS model does require HWM elevations referenced to a known datum.

Cities' Comment: *It is difficult to understand how USGS has arrived at the conclusion that the work of two hydraulic engineering firms, working independently, is poorly calibrated, when USGS admits that it has not studied "the details of either HEC-RAS models." At the same time, the slope-area method does depend on accurate high water marks. The USGS' own work (see SIR 2005-5029 Rev2) highlights the difficulty of obtaining accurate marks.*

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May 7, 2010

To: Attendees of the Skagit River flood flow meeting of March 17, 2010

From: Mark Mastin
Surface Water Specialist, Washington Water Science Center, Tacoma, WA

Subject: USGS responses to issues raised by the Technical Memorandum, "Review and reevaluation of Skagit River 1921 flood peak discharge."—CORRECTION to the response dated May 6, 2010.

After reviewing the level notes dated April 7, 1932, I noticed that I had misinterpreted the notes in my response to Item number 7, Reevaluation of the 1921 flood peak discharge using the stage-discharge rating, in the response I sent out via email on May 6, 2010. I apologize for this error.

In the previous memo, I stated that

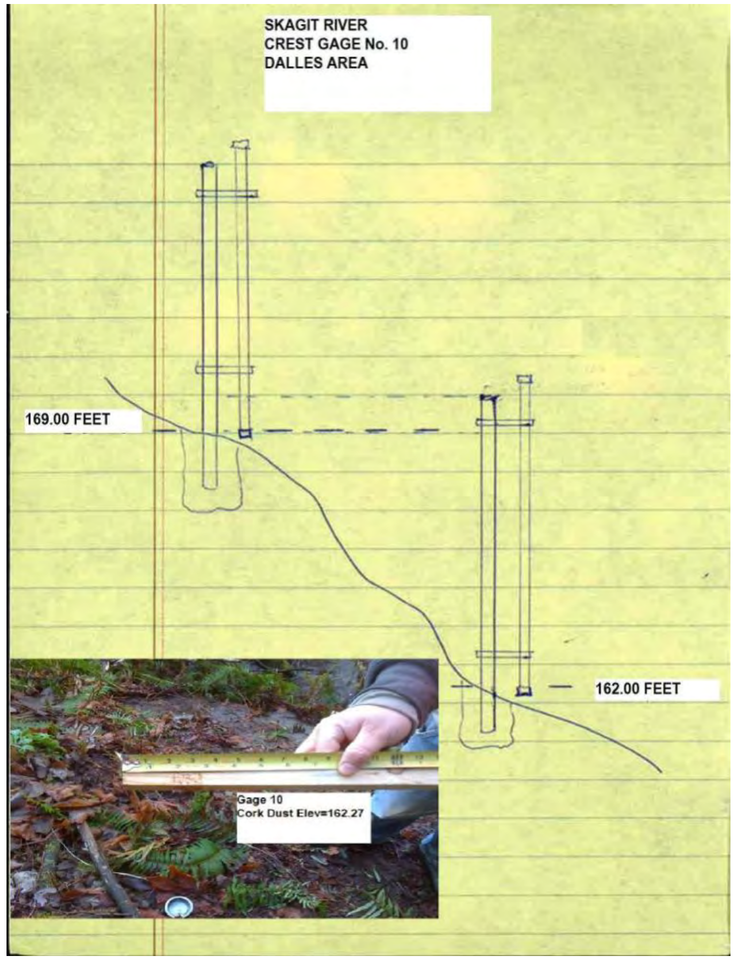
> "Levels dated April 7, 1932 shows an elevation of a HWM at 27.714 feet (gage datum) on the "upper dalles gage" and 27.468 on the "upper section" of the current gage. This is a difference of 0.246 feet or a slope of approximately 0.0012, a more reasonable slope in the backwater of a constriction."

Rereading these notes, the HWM at the upper gage was at an elevation of 27.468 feet (gage datum) not 27.714 feet. It was located at the upper section of the upper gage not the current gage. The recorded gage height for the February 27,1932 peak was 27.30 feet (gage datum) at the current gage. Thus, the difference of 0.17 feet would equate to a slope of 0.00085 computed over a distance of 200 feet and not 0.0012 as previously stated.

Cities' Comment: *This information is inconsistent with recently gathered (December 2010) peak stage data 200 feet upstream of the current gage by Skagit County. The location of Stewart's Upper Dalles Gage was actually 300 feet upstream of the location of today's USGS station, (see PI Engineering, March 2011, section 2.3.2) At issue is the amount of head loss to assign to high water marks gathered in the vicinity of the Upper Dalles gage that are (or were) transferred to the current gage location, 300 feet downstream. Stewart, in 1922 and early 1923, and later a survey crew from Skagit County, surveyed 1921 high water marks at the Upper Dalles Gage, and these high water marks were later transferred directly to the* *current gage location without any adjustment for head loss through this gorge, which is significant and could easily amount to 1.5 – 2 feet in a flood of the magnitude of 1921. Recent new data collected by Skagit County (December 2010) strongly supports our assertion that these high water marks should have been adjusted for the head loss that is occurring and did occur in 1921 in this 300-foot reach. Pursuant to suggestions by the USGS to obtain head loss data through the Dalles gorge, Skagit County in November 2010 installed several crest stage gages upstream and downstream of the current USGS gage location. As it happened, a minor Skagit River flood occurred on December 12, 2010, triggering a reading on one of the crest stage gages 200 feet upstream from the current USGS gage. The USGS stage elevation for this minor flood, with a discharge of 81,900 cfs at the Concrete gage, was 161.22 feet NGVD 29. The crest stage gage reading 200 feet upstream was 162.27 feet, for a difference of **1.05 feet in a 200-foot distance**. This data strongly infers an estimate of as much as a 2-foot drop between Stewart's Upper Dalles gage, located 300 feet upstream of the current USGS gage for the 1921 flood is reasonable for a flood discharge in the neighborhood of 170,000 cfs. Nevertheless, PI Engineering's estimate of the head loss is only 1.2 feet – clearly conservative in light of this new data.*

Photograph showing cork dust marks left on inside crest stage gage 200 feet upstream of the USGS Concrete gage at the Dalles, WA. December 2010.

Skagit County Crest Stage Gage #10. Note the Dalles bridge 200 feet down-stream. The current USGS gage is on the right bank just upstream of the bridge.



Schematic showing crest stage gage installation and cork reading from lower gage (#10) that was triggered during the minor flood event of Dec 2010.