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U.S. Geological Survey

USGS Washington Water Science Center

934 Broadway, Suite 300

Tacoma, Washington 98402

(253) 552-1600 . FAX (253) 552-1581

<http://wa.water.usgs.gov/>

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To Distribution List at Bottom of Letter

Gentlemen:

At our August meeting, I promised to do look into the datum issue concerning the vertical datum used by U.S. Geological Survey (USGS) hydrologist James Stewart in his surveys in and near Concrete, Washington, after the 1921 flood. I apologize for the delayed response, but I've recently completed a review of the USGS notes from Stewart and level notes at the gage site that were recently retrieved from the Federal archives.

Central to the datum issue is the discrepancy of the vertical datum used by James Stewart and others at the time for the elevation of the historical floods at the Skagit River near Concrete streamgage and upstream of the gage in Concrete. The current gage uses a gage datum of 130.00 ft beginning in 1937 which is 12.69 ft lower than the prior gage datum or 142.69 ft (often rounded to a 12.7 ft difference) that has been used as the gage datum by the USGS to adjust Stewart's high-water marks (HWMs) to NGVD'29 elevation (HWM elev. + 142.69 ft) or to current gage datum (HWM elev. + 12.7). There is information in Stewart's field notes uncovered by Albert Liou that suggests that this was not the datum used for his flood elevations. Albert has used a revised datum (140.9 ft.) to adjust the elevations of the 1921 HWMs used to calibrate his hydraulic model to estimate the 1921 peak-flow discharges. This summary of my findings does not definitively answer the question of which datum is correct, but it outlines the evidence that I have uncovered so far.

James Stewart's bounded field notebook contains data from November 1922 to March 1923. These notes contain the survey information recorded by Stewart to establish the elevation of the historical HWMs and include a levels survey to the staff gage. I made a scanned version of the notes several years ago and I believe everyone has access to those files. In our office, we have some additional notes and station records available, including level notes, station descriptions, and station analyses made at the time when the continuous gage was first operated.

Since the widely used NGVD'29 datum did not exist in 1922-1923, the first question is what was the datum used prior to NGVD'29. This question was posed to the National Geodetic Survey (NGS) and their Chief Geodetic Surveyor, David Doyle, responded in an email addressed to myself and Malcolm Leytham (10/06/08) that the U.S. Coast and Geodetic Survey did not "extend any geodetic leveling into Skagit County until 1922 and nothing within 20 miles of the town of Concrete until around 1934." Mr. Doyle attached a spreadsheet of 11 benchmarks in and around Burlington established prior to 1929 and their difference in elevation using the NAVD'88 datum. The differences ranged from 3.765 ft to 4.172 feet. Using the NGS VERCON program for converting the elevations from NGVD'29 to NAVD'88 and looking at the NGS datasheets for several of the benchmarks, the pre-1929 elevations are within 0.15 ft of the elevations using the NGVD'29 datum.

Stewart made many sets of level surveys to HWMs of the historical floods, but many times these were at an assumed datum, presumably since no established benchmarks were nearby. These surveys allowed him to compare the peak stages of the floods to one another and establish local elevation reference points. I did not find any specific level notes that established the inclined staff-gage elevation or the "iron bolt" benchmark that Stewart established 200 feet upstream of the present gage site on the Skagit River near Concrete at the time of construction.

Stewart refers to a "USGS BM" on pages 22 and 30 of his notes with an elevation of 230.51 ft. that is consistent with a benchmark described in the 1918 USGS Bulletin 674 "Spirit Leveling in the State of Washington 1896 to 1917, Inclusive" at an elevation of 230.506 ft. located 0.25 mi. west of Baker (p. 78). This benchmark was used to establish a 1921 flood HWM at Wolfe's residence of 184.55 ft. (p. 22 and p. 30 of Stewart's notebook), check a benchmark (bent spike on Maple, left side of road to Old ferry, elev. = 188.22 ft, p. 32 Stewart's notebook), and establish the gage datum of the staff gage at the old ferry site (datum = 150.57 ft, p. 32 and 33 Stewart's notebook). The maple tree benchmark was used to level in the inclined staff-gage datum established by Stewart (called "Upper Dalles Gage," datum = 140.89, p. 87 Stewart's notebook) and a reference point (RP, nail in stump, elev. = 178.75 ft., p. 86-87 Stewart's notebook). This gage is described to be "near an old cabin belonging to Mr. H.O. Stiles" (Stewart's Preliminary Report "Stage and Volume of Past Floods in Skagit Valley and Advisable Protective Measures prior to the Construction of Permanent Flood Controlling Works") and 200 feet upstream of the current gage in the 1927 station analysis (attached with this report). This datum is 1.8 ft lower than the datum used by the USGS to determine the elevation of the historical HWMs at the current gage's datum. Stewart later used the nail in the stump RP to run levels again to the "Lower Dalles Gage," datum = 141.04 ft., p. 67 Stewart's notebook). The Lower Dalles staff gage is inferred to be 560 feet below the Upper Dalles staff gage from a profile graph of the 1921 and 1856 floods through the Dalles gorge drawn by Stewart. Along with this graph are graphs of the Lower to Upper gage-height relationship, and there are no notes of an adjustment of the readings of the gages to suggest that they are at a different datum.

There are several USGS documents that tie the gage datum for the Stewart-established inclined gage at 142.7 ft rather than 140.9 ft. The concrete stilling well gaging station at the current gaging location was constructed in the fall of 1924. Level and discharge measurement notes dated 9/16/24 taken at the time when the continuous-recording gage was installed show a gage height of 2.45 ft at 4:00 pm at the "Recorder site" and a gage height of 2.46 ft at 4:40 pm at the "Upper Gage." Levels were begun with an "Iron Bolt" benchmark at an elevation of 8.88 ft. with a note "27 on Gg. = 169.88." Water surface at the Upper Gage was at an elevation of 2.88 ft, 2.88 ft at the "Recorder site," and 2.87 ft. at the Lower staff gage. In the text of the notes, it stated that the "Elev. of BM = 8.88 Old dalles gage datum, or 171.76 US.GS.datum." It is clear that the gage datum at the Upper Gage is the same as the gage datum at the newly constructed recording-gage site because the gage height readings are virtually the same and the note saying the gage height of 27 on the staff gage = 169.88 ft. implies a gage datum of 142.88 ft. (close to the published gage datum of 142.69 ft.). However, it is unclear how the elevation 169.88 ft. for a gage height of 27 was determined. How the elevation of 171.76 ft. for the iron bolt benchmark that equates to a datum of 162.88 ft. (163 ft.) was determined is also not known. The station analysis for the 1925 water year says the gage height was set to the datum of the Upper Dalles gage set by J.E. Stewart in 1921. The 1926 station analysis says "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." This gage datum appears to be in error and is also found in the USGS Water-Supply Paper 612.

In the station description for the gage dated 3/6/31 (revised), it lists a USGS bronze tablet at an "Elevation, of 41.067 feet, gage datum." Level notes dated 4/6/32 began with the staff gage on the well and read 27.714 ft. on the Upper Staff gage at a gage reading of 27.60 ft. suggesting that the well had settled 0.12 ft. The levels found the bronze tablet to be at the elevation of 41.067 ft., a 2/27/32 HWM at 27.48 ft. at the Upper Gage and 26.02 ft. at the Lower Gage (peak stage at the gage was 27.30 ft). In a station description dated 11-14-38 (revised), after the well was lowered and the staff gages re-established, the benchmark section of the description describes the same USGS bronze tablet

with an "Elevation 53.761 gage datum. Elevation 183.761 m.s.l. 1929 adjustment, referred to U.S.C and G.S. B.M C61,1934." This last description ties the gage to the current datum of 130.00 ft NGVD '29 and the previous datum of 142.7 ft NGVD'29 prior to 1937 which was the same datum as the staff gage 200 ft upstream. I have not found any documents that suggest the first continuous gage was at a different datum than the staff gage that Stewart used to reference his 1921 HWMs. Scanned copies of the two level sheets, two station analyses, and the two station descriptions are attached with this letter

On one hand, the survey notes by Stewart suggest that the datum should be 140.9 ft. based on a benchmark established by the USGS and assuming it is at NGVD'29 datum; but, on the other hand, all the other USGS notes indicate 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. Which is correct? One indication of the correct datum is the fact that newspaper articles concerning the Crofoot Addition in Concrete during the flood of 1921 and recent County surveys suggest that the 1921 peak stage may have been at an elevation of 186.1 feet in this subdivision (Memorandum by Malcolm Leytham, Northwest Hydraulic Consultants to Ric Boge and Jim Voetberg, dated 8/5/08). Stewart ran levels to a 1921 HWM at the Wolf's Residence which is believed to be nearby and probably at a slightly upstream, shoreward position from the Crofoot Addition. His elevation of 184.55 ft., using the USGS benchmark, seems about 2 feet too low and would suggest that the 142.7 ft datum may be correct. Though not a definitive resolution of the datum, it is another example of how all the available survey information since 1923 show that the gage datum of Stewart's historical HWM elevations was likely to be 142.7 ft NGVD'29 and not 140.9 ft.

It should be stated that at this time the USGS considers the peak-discharge estimate of 228,000 ft³/s for the 1921 flood on the Skagit River near Concrete as documented in the USGS Scientific Investigations Report 2007-5159 as the best estimate of the 1921 peak discharge. It utilizes modern indirect hydraulic analysis at a relatively uniform site selected to minimize complications in the flow hydraulics. Also, it utilizes HWMs and channel geometry data surveyed soon after the peak, and it does not require the data to be tied to an elevation datum.

Sincerely yours,

//s//

Mark Mastin
Surface-Water Specialist

Distribution List

Ric Boge
Surface Water Manager
Skagit County Public Works
1800 Continental Place
Mount Vernon, WA 98273

Albert Liou
Pacific International
Engineering, PLLC
123 Second Avenue South
P.O. Box 1599
Edmonds, WA 98020

Malcolm Leytham
Northwest Hydraulic
Consultants
16300 Christensen Road,
Suite 350
Seattle, WA 98188

Ryan Ike, CFM
Senior Floodplain
Management Specialist
DHS - FEMA Region X
130 228th Street, Southwest
Bothell, WA 98021-8627

Ted Perkins
U.S. Army Corps of Engineers
P.O. Box 3755
Seattle, WA 98124-3755