APPENDIX H

East Branch Clarion River Dam and Spillway Control Surveys (Pittsburgh District)

H-1. Introduction. This appendix is an example of establishing NSRS control on a Pittsburgh District dam and reservoir on the East Branch of the Clarion River (Figure H-1). A single primary PBM was connected by a combination of GPS and CORS observations from surrounding NSRS bench marks. Secondary deformation monitoring points were controlled from the primary PBM and dam and spillway profile surveys were run. Elevation data sets developed from LIDAR collected in 2006 was then used for comparative analysis against the profile surveys.

a. This appendix was compiled from survey reports by two Pittsburgh District Contractors: TerraSurv, Inc. and Photo Science, Inc. TerraSurv performed the initial NSRS network connections in May 2008 and Photo Science performed comparative data mapping analysis in 2009.

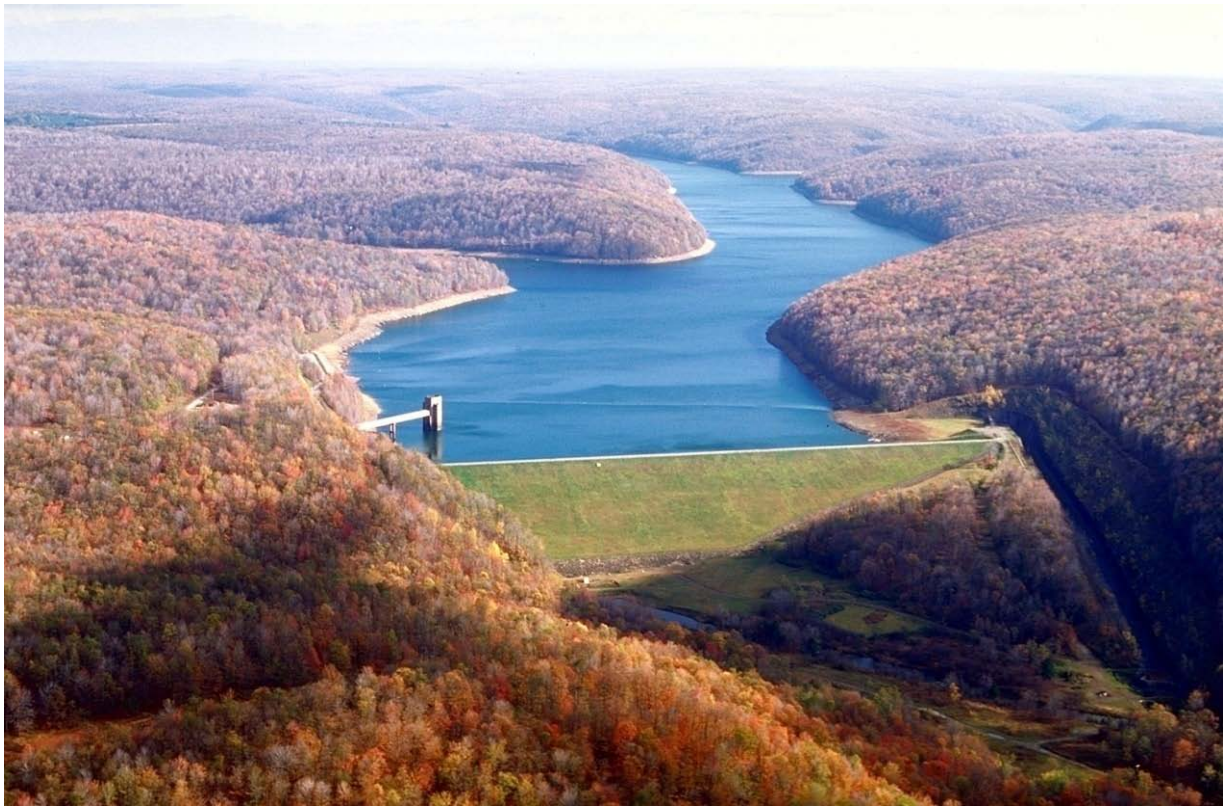

Figure H-1. East Branch Dam and Reservoir (Elk County, PA).

b. The Pittsburgh District issued task orders to TerraSurv and Photo Science to establish a positional relationship/correlation between the hydraulic, geodetic, and engineering design datum at the East Branch Clarion River Dam and Spillway located in Elk County, PA. This

work supports the District's adherence to ER 1110-2-8160 (*Policies for Referencing Project Elevation Grades to Nationwide Vertical Datums*), namely to address the "… need to firmly establish the relationships between hydraulic and geodetic datums…"

H-2. Project Location. Authorized by the Flood Control Act of 1944, East Branch Clarion River Lake is one of 16 projects in the USACE, Pittsburgh District. An important link in a system of flood risk management projects, East Branch provides flood protection for the Clarion River Valley as well as the lower Allegheny and upper Ohio Rivers. Completed in 1952, East Branch Lake has the capability to store the equivalent run-off of 21.84 inches of precipitation from its 72.4 square mile drainage area.

H-3. Scope of Work. The initial requirements outlined for the project were as follows:

a. Establish a primary NSRS bench mark and two secondary bench marks at each project location. This is intended to conform to the criteria in ER 1110-2-8160 that "...the designed, constructed, and maintained elevation grades of projects shall be reliably and accurately referenced to a consistent nationwide framework, or vertical datum—i.e., NSRS..."

b. Determine validity of dam/spillway design grade to current as-built surveys and other sources (LIDAR mapping).

c. Establish relationship/correlation between hydraulic and geodetic datums at each project.

H-4. CEPD Assessment.

a. As part of the 2007 Corps-wide CEPD review, the following actions were taken to accomplish the above objectives.

(1) Perform reconnaissance surveys at the dam site to verify existing local control.

(2) Develop recommendations for Corrective Actions.

(3) Establish NSRS Project Control, e.g., Primary bench mark and two secondary PBMs.

(4) Survey gage reference points.

(a) Pool.

(b) Outflow.

(5) Establish pool elevation relative to NAVD88.

(6) Profile dam and spillway.

(7) Reference deformation monitoring points to NAVD88 and PPCP.

(8) Perform alignment measurements.

b. A CEPD research of existing control data at the East Branch Dam site indicated that geodetic control was referenced to legacy datums of dated origins. The CEPD review is summarized below.

"East Branch Dam horizontal positions are controlled by traverses tied to USGS Stations TT3K, TT6K, and TT7K, datum uncertain, and are computed on Pa. North-Zone System of Coordinates. Elevations are based on those same USGS Stations. Topography was compiled by plane table in 1946 and traced on Map Sheet 038b-U1-16/1 through 10. Additional topography was compiled from aerial photographs exposed November 1979 and consists of Map Sheets 038b-U1-101/1 thru 4, scale 1:2,400, control based on N.A.D. 1927 and N.G.V.D. 1929."

H-5. Options Considered for Corrective Action Field Surveys.

a. The following methods were considered for connecting the Primary Project Control Point (PPCP) to the NSRS.

(1) Differential Leveling (Orthometric Height Accuracies ~ 0.5-2 cm).

(2) GPS Network-"Blue Booking" (Orthometric Height Accuracies ~ 2-3 cm).

(3) OPUS DB-Using CORS Network (Orthometric Height Accuracies ~ 5-10 cm).

b. Differential leveling options.

(1) Labor Intensive.

(2) High cost.

(3) Projects are in isolated areas, some are quite distant from existing level lines.

(4) Horizontal positions not determined.

(5) Determined to be not economically feasible.

c. Blue Book option.

(1) Create a GPS network, format and submit to NGS.

(2) Advantages:

(a) Ties to adjacent points and bench marks.

(b) Multiple occupations.

(c) Homogenous network.

(3) Disadvantages:

(a) More complex to implement.

(b) Requires multiple receivers and planned GPS campaign.

(c) Costly data processing.

d. OPUS-DB option.

(1) Advantage: Relatively simple to implement (Single GPS receiver).

(2) Disadvantages:

(a) No ties to bench marks or adjacent points.

(b) Single occupation.

(c) Requires minimum of two 4-hour occupations.

e. The Blue Book method was selected for the following reasons.

(1) Provides high quality control at each project, as requested by Project Managers.

(2) Utilizes ties to bench marks/HARN/CORS.

(3) Takes advantage of GPS data collected at each site 2005-2008 (i.e. less than 4 hour sessions, not acceptable to OPUS-DB).

H-6. Recommended Primary Control Bench Mark at Project Site. It was recommended that USACE mark "1-500" be used as the primary project bench mark, and M1 (right bank, on dam axis) and M2 (left bank, dam axis) be used as secondary bench marks. Yearly ties are made between these three marks during the alignment survey. Levels to the water gage reference marks could be run from any of the aforementioned marks. A precise level tie has been recently run to PBM 1-500 from an NSRS mark. This data could be used to submit a vertical blue book project to the NSRS. This will require that the raw data file be retrieved, and that a differential level tie be made from Z 337 to another mark on the same line (two mark tie). It is believed that an adjacent mark within a reasonable distance should not be hard to find. The initial evaluation assumed that PBM 1-500 would be obstructed and not suitable for GPS. Two options for GPS derived elevations were considered in the initial evaluation. One option was to simultaneously occupy a secondary project bench mark, M2, and two nearby NSRS bench marks. The primary PBM 1-500 is partially obstructed and not suitable for GPS. Levels are run yearly between M1, M2, and 1-500 so there would be sufficient data available to provide an accurate tie to PBM 1-

500. Alternatively, 1-500 or M2 could be occupied for two sessions of at least 240 minutes (4 hours) and submitted to OPUS-DB.

H-7. Primary NSRS Control Network. Existing USACE survey disk (PBM) "1-500" is the designated primary control point for this project. This disk is located atop the upstream parapet wall at the land abutment for the concrete bridge leading to the intake tower on the right bank of the reservoir. This abutment is not rigidly connected to the bridge; rather the bridge sits on the abutment seat. This mark is shown in Figure H-2.

Figure H-2. Primary Project Control Point 1-500 on bridge leading to intake tower.

a. Several options were available for bringing control in from the National Spatial Reference System (NSRS) to the project. A search was made of the NSRS database. There is a level line running north-south along a railroad located approximately 1.6 air miles west of the dam. Bench mark Z 337 (MA0592), located on a bridge abutment, was recovered on this line, and determined to be suitable for GPS observations. Research revealed that a survey crew from the Corps of Engineers had run a line of differential levels from this bench mark to PBM 1-500 and back in 2003 using a Zeiss DiNi 12 digital level and 2 m invar rods. However, only field notes were found, the raw data (which could be Blue Booked) was not found. A search was then made of the NSRS for bench marks located on stable structures that also have HARN horizontal positions published on NAD83 (NSRS2007). This search returned two marks listed Table H-1.

Table H-1. HARN Bench Marks.

Name of Mark	PID	Horizontal Accuracy	Vertical Order	Location	Setting
TTS 64 K	MA0735	0.3 cm	II-Class 0	17.9 mi west	Bedrock
V 25	MA0095	0.3 cm	II-class 0	19.9 mi east	Bridge abutment

b. All three NSRS marks are located on stable structures, and are shown on the map in Figure H-3. The data from these three marks to the on site primary control point 1-500 was formatted for Blue Book submittal to the NSRS. This resulted in the inclusion of PBM 1-500 in the NSRS database. The horizontal datum is NAD83 (CORS1996), obtained via an OPUS solution. The vertical datum is the NAVD88, obtained via direct GPS ties to the three bench marks described above. The three marks located at the dam, 1-500, M1, and M2, were connected via differential levels, static GPS, and EDM/angle measurements. This data was not Blue Booked.

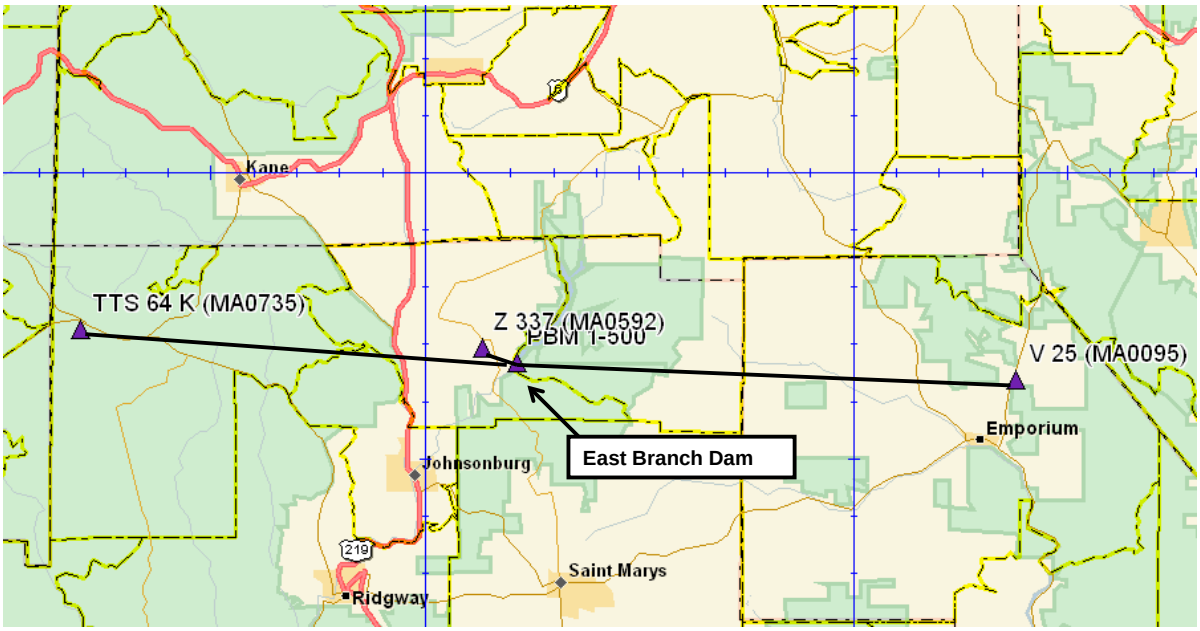

Figure H-3. NSRS control scheme for establishing elevation on PBM 1-500.

H-8. <u>GPS Survey Procedures to Connect PBM 1-500</u>. Three Trimble dual frequency receivers (a 5700 and two R8 GNSS receivers) were used on days 133 and 134 of 2008. Fixed height tripods were utilized for the occupations of the NSRS bench marks. A standard survey tripod with tribrach was used at PBM 1-500 due to the difficulty of using a fixed height tripod at that location. Each point had two independent occupations. The Trimble 5700 receiver with a Zephyr antenna was setup on both days on PBM 1-500, and collected data during the entire day. The two HARN/ bench marks (V 25 and TTS 64 K) were each occupied twice, once on day 133 and once on day 134, each time with a different operator/tripod/receiver. The nearby bench mark, Z 337, was occupied twice on day 134, at different times of the day. The data collected at PBM 1-500 (GPS# 08042A) was submitted to the Online Positioning User Service (OPUS). The OPUS online processor selected three nearby CORS and determined the position of the submitted point. The results are shown in Table H-2.

Table H-2. OPUS Solutions.

Day	Duration Minutes	CORS USED	Overall RMS	% OBSERVATIONS USED	% Ambiguity Fixed
133	337	UPTC NYSM NYFS	0.014 m	93%	97%
134	752	UPTC NYSM NYFS	0.015 m	92%	98%

a. The average of the OPUS derived positions was used as the horizontal position and ellipsoidal height of PBM 1-500. The data was downloaded to a PC and processed using the Weighted Ambiguity and Vector Estimator (WAVE) processor in Trimble Geomatics Office, V1.63. The single baseline method was used, with the precise (IGS Rapid) ephemeris. All of the baselines were integer bias fixed solutions. Table H-3 shows the results of the baseline processing:

Table H-3. WAVE Baseline Results.

From	To	UTC Start	Duration Minutes	Length Meters	Ratio	Variance	RMS
MA0095	08042A	5/12/08 19:33	45	32378	21.60	1.5	0.012
MA0095	MA0735	5/12/08 19:33	43	60774	26.48	1.1	0.010
MA0735	08042A	5/12/08 19:24	52	28411	20.69	1.4	0.012
MA0095	08042A	5/13/08 11:30	46	32378	15.82	1.7	0.016
MA0095	MA0735	5/13/08 11:42	34	60774	10.74	0.8	0.013
08042A	MA0592	5/13/08 21:47	30	2435	36.41	12.1	0.011
08042A	MA0592	5/13/08 13:01	30	2435	30.94	2.9	0.005
MA0735	08042A	5/13/08 11:42	46	28411	14.20	1.7	0.015

b. Each of the baselines was measured twice in independent sessions. The processed vector components were transformed to a local horizon system (north, east, & up) for analysis—see Table H-4.

Table H-4. Baseline Residuals (in meters).

From	To	Delta N	Delta E	Resultant	Delta U	Length
08042A	MA0095	-0.004	-0.003	0.005	-0.001	32379
MA0095	MA0735	0.001	0.008	0.008	0.009	60774
08042A	MA0735	0.001	0.003	0.003	0.013	28412
08042A	MA0592	-0.005	-0.006	0.008	-0.007	2435

H-9. Least Squares Adjustments. The GPS data was adjusted using ADJUST, a least squares adjustment program from the NGS. The processed baselines were parsed to form an input file in the G-file format. The results from the two OPUS solutions were also included. No scaling of the a priori baseline statistics was done. Station errors (HI and centering) of 0.005 m were also included. Geoid separations for each station were interpolated using the GEOID03 model. The first adjustment constrained the CORS UPTC ARP to the published NAD83 (epoch 2002.0) position (latitude, longitude, and ellipsoidal height). The standard deviation of unit weight was

2.42. This value was then used to scale the G file using the "modgee" program. The subsequent adjustment, utilizing the scaled G file, had a standard deviation of unit weight of 1.004. The misclosures at the three NSRS stations and the other two CORS used are shown in Table H-5.

Table H-5. Station Misclosures.

Station	Azimuth	Distance	Δ Ortho H	Δ Ellip H
MA0592 (Z 337)			+0.005 m	
MA0095 (V 25)	217°	0.002 m	-0.004 m	-0.001 m
MA0735 (TTS 64 K)	243°	0.008 m	-0.022 m	-0.008 m
NYSM ARP	285°	0.025 m		+0.006 m
NYFS ARP	280°	0.025 m		-0.002 m

a. The straight line distance between the two HARN bench marks is 60.8 km (37.8 miles), but the distance through the leveling network is about 105 km. Benchmarks Bench marks with that separation could be expected to have a relative accuracy in orthometric height of about 0.01 m between them. The final adjustment constrained PBM 1-500 horizontally and the three existing NSRS bench marks vertically (NAVD88 orthometric height). The estimated variance factor was 1.11. The vertical confidence region at the 95% level for PBM 1-500 from this adjustment was 0.007 m. This, combined with the estimated accuracy of the geoid model, gives an estimated accuracy of the GPS derived orthometric height at PBM 1-500 of ± 0.03 m. An additional check is given by comparing the NAVD88 orthometric height determined in this project to the NAVD88 height determined in 2003 by precise differential levels from **Z 337**, with a difference of 0.004 m.

b. The next adjustment constrained UPTC ARP horizontally and the nearest benchmark to the project, Z 337, vertically (NAVD88 orthometric height). The misclosures in orthometric height at the two HARN/benchmarks were then computed: -0.010 m at V 25 and -0.027 m at TTS 64 K. These misclosures were within the expected range, so the subsequent orthometric height adjustment constrained the three NSRS benchmarks to their published NAVD88 heights, along with the horizontal position of UPTC ARP. The standard deviation of unit weight was 1.34. This adjustment provided the adjusted NAVD88 orthometric height for the new station, EAST BRANCH.

c. The final adjustment constrained the three CORS and the two HARN stations in all three dimensions (latitude, longitude, and ellipsoidal height. The standard deviation of unit weight was 4.42. This adjustment provided the adjusted latitude, longitude, and ellipsoidal height for the new station, EAST BRANCH, as well as the NSRS benchmark Z 337.

H-10. Supplemental Deformation Surveys. A combination of GPS and conventional methods was used in the deformation survey of the six alignment pins nominally online between M1 and M2. A base receiver (Trimble 5700) was running on primary control monument PBM 1-500. Two Trimble R8 GNSS receivers were used to occupy M2, A5, A4, A3, A2, A1, and M1, in order (see Figure H-4). Each occupation had at least 15 minutes common occupation time with adjacent stations. The alignment pins (A1 thru A5) were occupied using a standard tribrach with a precise rotatable optical plummet. Height of antenna measurements were taken as slope measurements to the blue band on the antenna housing, and then corrected to the Antenna

Reference Point (ARP). M1 and M2 were occupied by placing a standard optical plummet directly atop the pedestal. The height of antenna measurements for the pedestals were converted to be the ARP height above the top of the 5/8" bolt. A Trimble S6 high accuracy total station was set up on pedestal M4 located upstream of the dam on the left bank, and angle and distance measurements were taken to each station during the GPS occupations. The distance measurements were corrected for atmospheric conditions and reduced to the mark-to-mark components. The GPS and conventional data were combined in a least squares adjustment to obtain adjusted coordinates for M1, M2, and alignment pins A1 through A5. These coordinates will be directly used in future surveys to monitor the movement of the alignment pins. Offsets of A1 through A5 from the M1→M2 line were also computed to maintain backwards compatibility with previous alignment surveys.

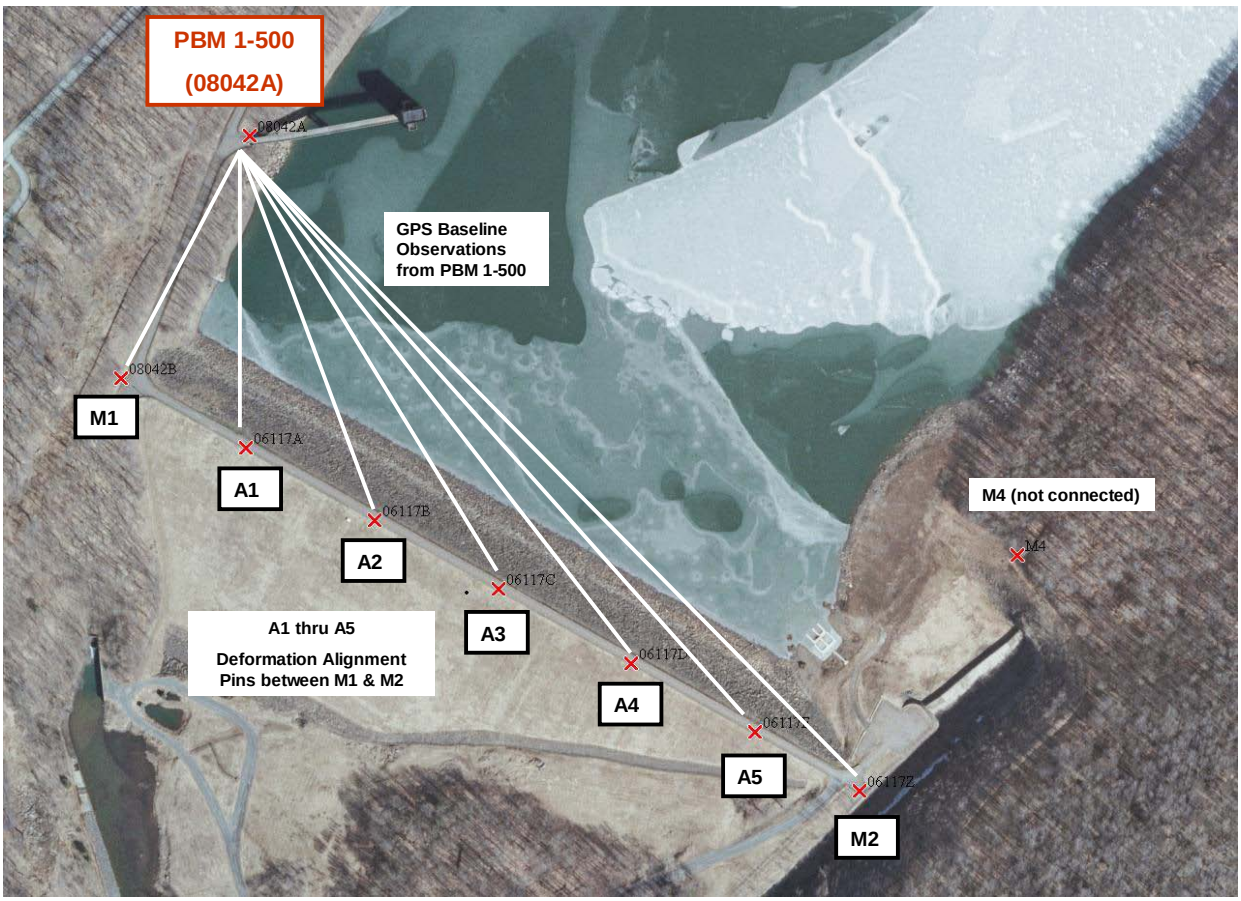

Figure H-4. Local deformation alignment points.

a. Figure H-5 shows the offsets from the line between M1 and M2 over the last several years:

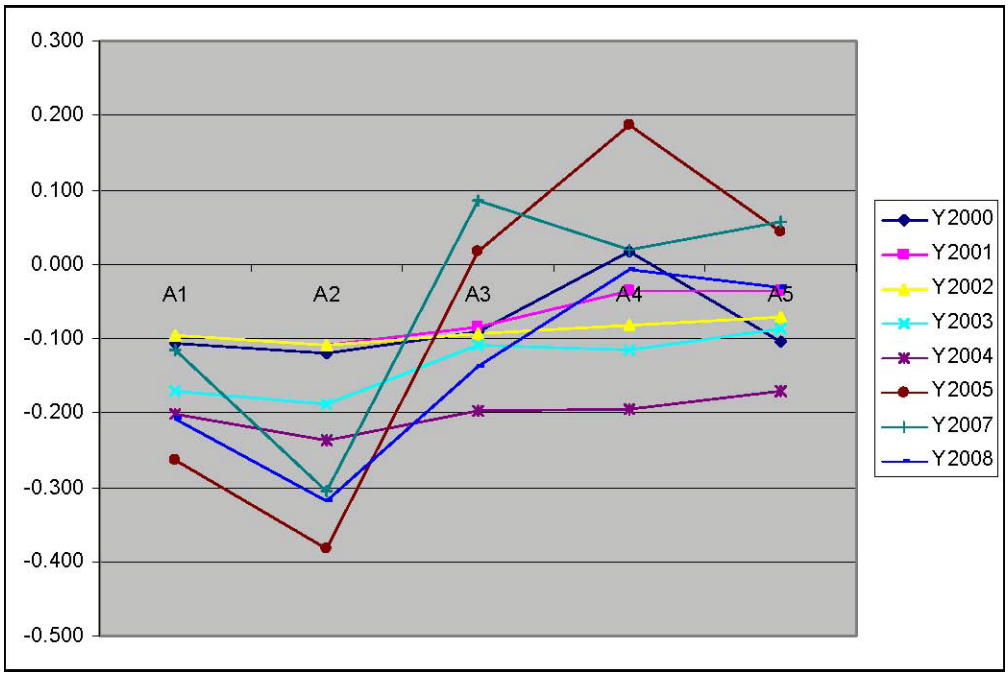

Figure H-5. Alignment point offsets from 2000 to 2008.

b. The settlement survey was executed using a DiNi 12 digital level and bar coded rod. A run was made from PBM 1-500 through each of the pedestals and alignment pins, and back to PBM 1-500 with a loop closure of 0.002 m over a distance of 1.5 km. A spur line was run from A5 down to the outflow area, and continued to the outflow gage located downstream of the dam. A loop was also run from PBM 1-500 to the gage located in the intake tower.

Table H-6. East Branch Clarion River Lake Dam Adjusted Coordinates. PA North Zone State Plane Coordinates – NAD 1983. (NSRS 2007)

Station Name	GPSID	Northing Meters	Easting Meters	NAVD88 Meters	Northing US FT	Easting US FT	NAVD88 US FT	Convergence	Scale Factor	Elevation Factor	Combine Factor
BM 1-500	08042A	155221.009	529463.570	521.442	509254.259	1737081.728	1710.764	0°33'33.91"	0.99995998	0.99992305	0.99988304
V 25	MA0095	153851.210	561809.546	338.217	504760.177	1843203.487	1109.634	0°18'10.21"	0.99995956	0.99995185	0.99991140
Z 337	MA0592	156229.738	527247.172	526.900	512563.732	1729810.096	1728.671	0°34'37.47"	0.99996038	0.99992220	0.99988258
TTS 64 K	MA0735	157712.792	501164.981	573.625	517429.386	1644238.776	1881.968	0°47'02.76"	0.99996089	0.99991491	0.99987580
A1	06117A	155026.225	529461.356	520.157	508615.208	1737074.465	1706.548	0°33'33.92"	0.99995991	0.99992325	0.99988316
A2	06117B	154981.286	529541.580	520.182	508467.770	1737337.666	1706.630	0°33'31.61"	0.99995989	0.99992326	0.99988315
A3	06117C	154938.210	529618.493	520.187	508326.444	1737590.005	1706.647	0°33'29.41"	0.99995987	0.99992325	0.99988312
A4	06117D	154891.929	529701.125	520.217	508174.603	1737861.108	1706.745	0°33'27.03"	0.99995986	0.99992325	0.99988311
A5	06117E	154848.789	529778.141	520.313	508033.069	1738113.784	1707.060	0°33'24.82"	0.99995984	0.99992323	0.99988307
M2	06117Z	154812.168	529843.522	521.536	507912.922	1738328.287	1711.073	0°33'22.95"	0.99995983	0.99992304	0.99988286
M1	08042B	155069.850	529383.483	521.504	508758.334	1736818.978	1710.968	0°33'36.15"	0.99995992	0.99992304	0.99988297
M4	M4	154959.204	529941.779	526.281	508395.322	1738650.654	1726.640	0°33'20.18"	0.99995988	0.99992228	0.99988217

c. Updated NAVD88 elevations at the project site as determined by differential levels from PBM 1-500 are shown in Table H-7.

Table H-7. Updated NAVD88 Elevations.

Station Name	NAVD88 meters	NAVD88 US FT	Description
1-500	521.442	1710.764	BM on intake bridge parapet wall
A1	520.157	1706.548	Alignment pin
A2	520.182	1706.630	Alignment pin
A3	520.187	1706.647	Alignment pin
A4	520.217	1706.745	Alignment pin
A5	520.313	1707.060	Alignment pin
BOLT	520.385	1707.296	Bolt on floor of intake tower near gage
FLOOR	520.378	1707.273	Floor elevation in intake tower near gage, +0.090 m up to sill
M1	521.504	1710.968	Pedestal (top of bolt)
M2	521.536	1711.073	Pedestal (top of bolt)
M3	521.312	1710.338	Pedestal (top of bolt)
TABLE	521.213	1710.013	Table surface in intake tower, +0.027 m up to knife edge
TBM1	485.854	1594.006	Anchor bolt
TBM2	466.543	1530.650	Square painted on NW corner of building, Weir 6
TBM3	467.505	1533.806	Square painted on south end of left bank training wall at outflow
TBM4	465.819	1528.275	Top of angle iron for weir gage at downstream end of spillway
TBM5	467.489	1533.753	Nail in triple black cherry, upstream of gage house, set by USGS
TBM6	467.331	1533.235	Nail in red maple, downstream of gage house, set by USGS
TBM7	465.774	1528.127	Bolt (lower of 2) protruding from downstream side of gage

d. A portion of the published NGS NSRS description for PBM 1-500 (i.e., EAST BRANCH PID = DK7088) is shown below:

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**********************************************************************
DK7088  HT_MOD       -  This is a Height Modernization Survey Station.
DK7088  DESIGNATION -  EAST BRANCH
DK7088  PID          -  DK7088
DK7088  STATE/COUNTY-  PA/ELK
DK7088  USGS QUAD    -  GLEN HAZEL (1969)
DK7088                          *CURRENT SURVEY CONTROL
DK7088* NAD 83(2007)-  41 33 40.56863(N)    078 35 44.27202(W)     ADJUSTED
DK7088* NAVD 88      -       521.44   (meters)    1710.8    (feet)  GPS OBS
DK7088  EPOCH DATE   -        2002.00
DK7088  X            -     945,126.312 (meters)                     COMP
DK7088  Y            -  -4,685,460.249 (meters)                     COMP
DK7088  Z            -   4,209,591.236 (meters)                     COMP
DK7088  LAPLACE CORR-           1.76  (seconds)                    USDV2009
DK7088  ELLIP HEIGHT-         489.730 (meters)          (10/02/08) ADJUSTED
DK7088  GEOID HEIGHT-         -31.70  (meters)                     GEOID09
DK7088  HORZ ORDER   -  B
DK7088  ELLP ORDER   -  THIRD      CLASS II
DK7088.The horizontal coordinates were established by GPS observations
DK7088.and adjusted by the TERRA SURV in October 2008.
DK7088.The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).
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H-11. Comparative Analysis of LIDAR Mapping. A comparative analysis of existing mapping data was performed at the East Branch Dam site in 2009. This involved comparisons with design (as built) data, gage reference elevations, and established pool reference elevations. The comparative analysis performed by Photo Science involved the use of three independent data sources. The "hydraulic" data source used in the analysis consisted of 2006, high-resolution, PaMAP LIDAR elevation data obtained by Photo Science from the Pennsylvania State University, Institute of State and Regional Affairs, Center for Geospatial Information Services located in Middletown, PA. The "geodetic" data source used in the analysis consisted of spillway survey profiles in *.csv format established by Photo Science sub consultant, TerraSurv Inc., in May of 2008. Lastly, the USACE supplied, "East Branch Dam Plan Elevation and Section Drawing" in PDF format dated 30 September 1982 was utilized to compare both the hydraulic and geodetic data sources against the original dam and spillway design elevations. Using these three sources a comparative analysis of the survey profiles along the top of the dam and spillway structures was performed by measuring, comparing, and recording survey elevations along each profile to their respective engineering design elevation and the existing LIDAR surface elevation.

H-12. Data Source Projection/Datum. In order to perform the comparative analysis it was necessary to ensure that all data sources were in the same projection, datum, and units of measurement. The horizontal projection/datum established for the analysis was the Pennsylvania State Plane Coordinate System (PASPCS), North Zone, North American Datum 1983 (NAD83). The vertical datum established for the analysis was expressed in orthometric heights using North American Vertical Datum 1988 (NAVD88). Both horizontal and vertical units were expressed in US Survey Feet.

H-13. East Branch Dam Plan Elevation and Section Drawing. An Adobe PDF file of the East Branch Dam Plan Elevation and Section Drawing was provided by the Pittsburgh District (see Figure H-6). The drawing identifies a design elevation of 1,707.0 feet at the top of the dam structure and 1,685.0 feet at the top of the spillway structure. Although the vertical datum is not explicitly identified on this design drawing, the drawing predates by some 6 years the release of the NAVD88, and therefore an assumption was made for NGVD29 elevations. To support the analysis it was necessary to convert these design elevations to NAVD88. Using NGS BM Z339, which is in the immediate vicinity of the dam and spillway, USACE personnel reviewed the NGS data sheet for BM Z339 and computed a (-) 0.49 foot difference between NGVD29 to NAVD88. Photo Science then applied the (-) 0.49 foot reduction to the NGVD29 design elevations resulting in the computed NAVD88 elevations of 1,706.51 feet for the top of dam structure and 1,684.51 feet for the top of the spillway structure. These computed NAVD88 design elevations were then used in the comparative analysis.

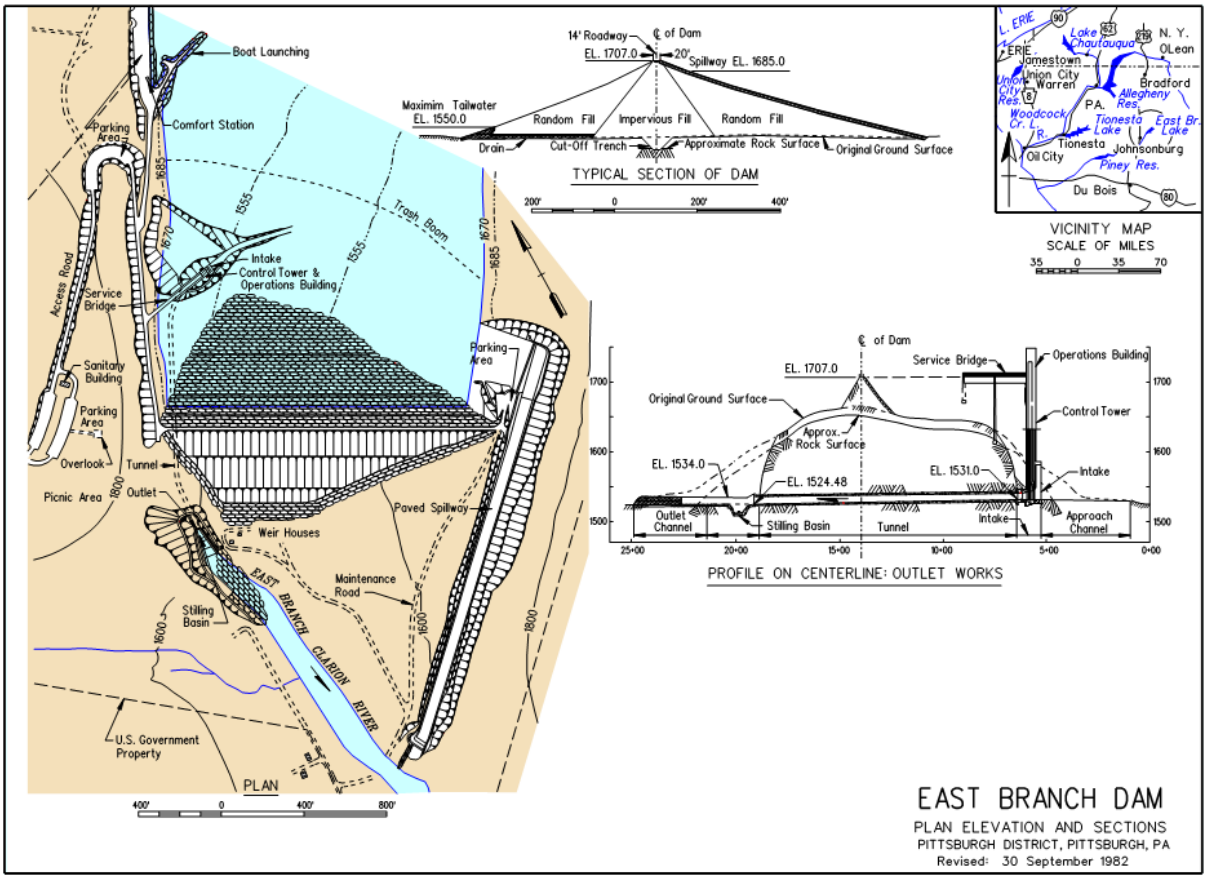


Figure H-6. East Branch Dam plan/elevation drawing.

H-14. Survey Profile Dataset. In May of 2008, Photo Science sub consultant, TerraSurv Inc., performed a series of field surveys at East Brach Clarion River Lake Dam to establish a primary control network, deformation monitoring and profiling. TerraSurv developed profiles along the dam and uncontrolled spillway. The profile data in *.csv format of the dam and spillway obtained under this task order was supplied to Photo Science for use in the comparative analysis. A total of 36 points were collected along the top of the dam and an additional 7 points were collected on the top of the spillway. Figure H-7 depicts the individual profile stations of both the dam and spillway on top of the 2006 PaMAP orthophoto imagery. Photo Science converted the survey data provided by TerraSurv from UTM, Zone 17N, NAD83 (meters) to Pennsylvania State Plane Coordinate System, North Zone, NAD83 (feet). Elevation values were provided in NAVD88, meters and converted to feet. The dam and spillway profile data provided the "geodetic" input in the comparative analysis.

Figure H-7. Dam and Spillway Profile Stations displayed with 2006 PaMAP Ortho Imagery.

H-15. PaMAP LIDAR Elevation Dataset. The "hydraulic" data source used to support the comparative analysis was the State of Pennsylvania's spring 2006 PaMAP LIDAR elevation dataset. Photo Science obtained the classified LIDAR point cloud data in native LAS file format covering the dam and spillway area from the Pennsylvania State University, Institute of State and Regional Affairs, Center for Geospatial Information Services located in Middletown, PA. The LIDAR data was acquired by the PaMAP program in the spring of 2006 during leaf off conditions. As depicted in Figures H-8 and H-9, Photo Science utilized the bare earth point class contained in the LAS file to create a ground surface of the dam and spillway area.

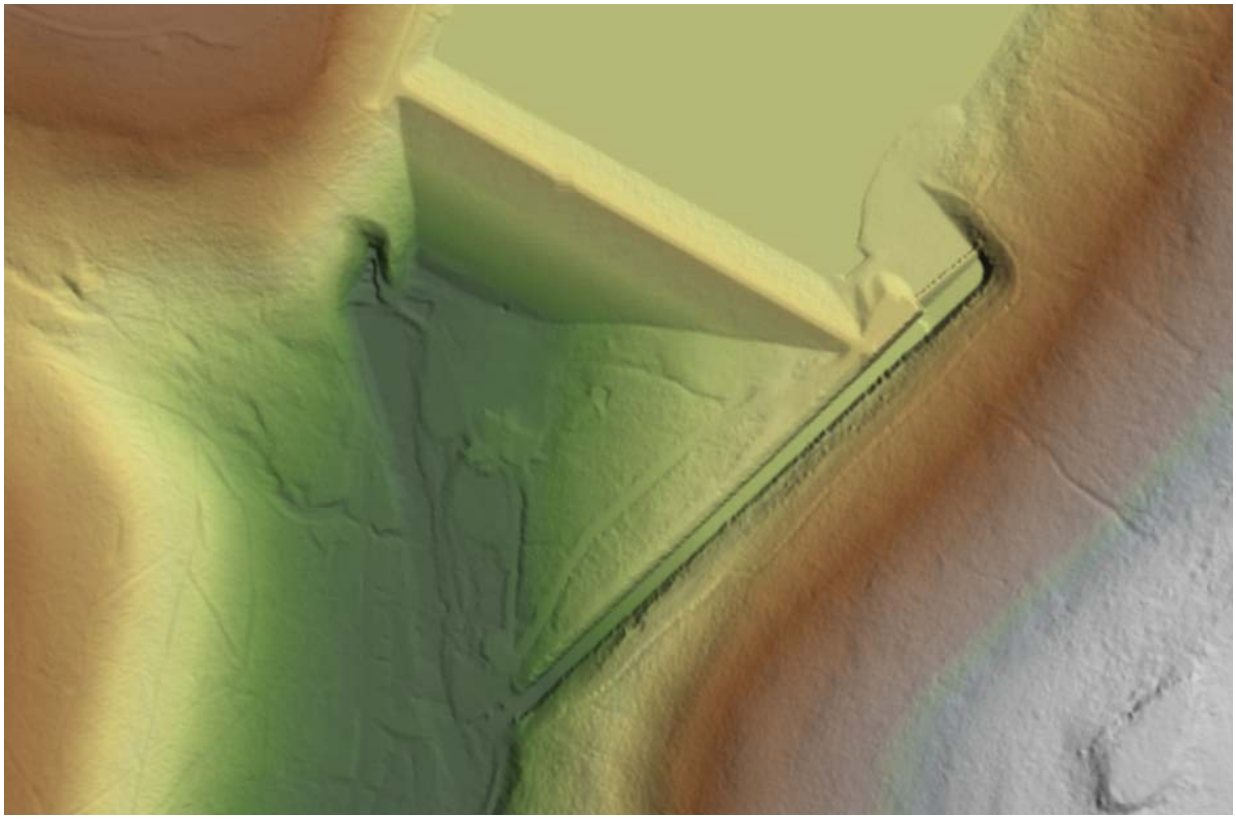


Figure H-8. Top View of East Branch Clarion River Dam & Spillway.

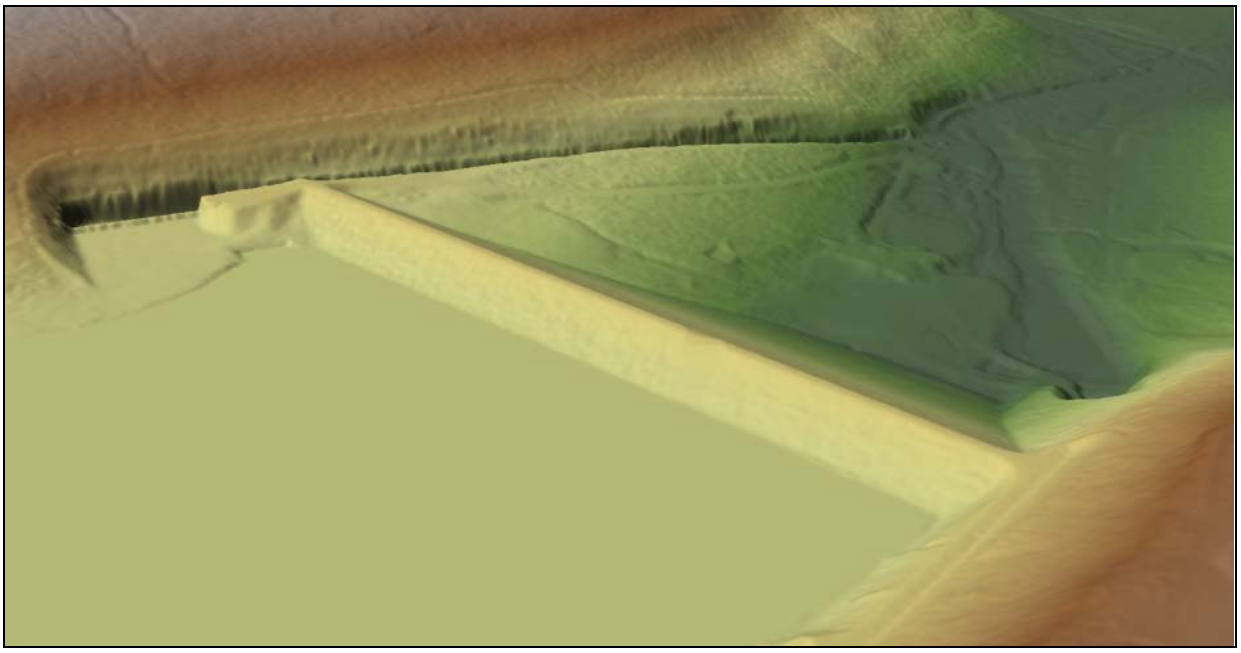


Figure H-9. Isometric view above the East Branch Clarion River Dam & Spillway.

a. The PaMAP LIDAR bare earth data set (in Elk County, PA) was designed to achieve 18.5 cm (0.61feet) vertical RMSE for LIDAR bare earth elevation surface in open terrain. The data was independently tested by PaMAP Quality Assurance Consultant, Dewberry. As shown in Figure H-10, the accuracy of the bare earth in open terrain achieved an RMSE of 0.34 feet and a consolidated RMSE of 0.54 feet for all categories tested.

Dewberry

8401 Arlington Boulevard
Fairfax, Virginia 22031-4666

703 849 0396
703 849 0182 fax
www.dewberry.com

Date: April 7, 2008

Subject: Report of Vertical Accuracy Testing of LiDAR Data for LandAirWoolpert Lidar Block

Project Name: PAMAP
Product Tested: LiDAR DTM
State Plane Zone: Pennsylvania North and South NAD83
Production Block: LandAirWoolpert Block, 2006
Accepted/Rejected: Accepted
Production Company: BAE

Counties in Production Block:
- Elk
- Cameron
- Clearfield
- Centre
- Cambria
- Blair

Table 1. Vertical Accuracy Statistics per NSSDA/FEMA Guidelines

100 % of Totals	RMSE (ft) Open Terr. Spec=0.61ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	# of Points	Min (ft)	Max (ft)
Consolidated	0.54	0.22	0.12	2.70	0.49	100	-0.54	2.99
Open Terrain	0.34	0.11	0.12	0.26	0.33	19	-0.40	0.73
High Grass	0.31	0.14	0.11	0.61	0.28	21	-0.26	0.81
Brush	0.74	0.44	0.15	1.53	0.61	20	-0.11	1.99
Forest	0.74	0.34	0.30	3.32	0.68	20	-0.54	2.99
Urban	0.35	0.07	-0.05	1.42	0.36	20	-0.31	0.89

Figure H-10. Dewberry Vertical Accuracy Report of 2006 LIDAR Block covering Elk County, PA.

b. The PaMAP Bare Earth LIDAR surface generated for the dam and spillway provided the "hydraulic" input in the comparative analysis.

H-16. Data Processing. A rectangular polygon was placed around the dam and spillway area, buffered by 1000 feet, for the purposes of reviewing and validating the visual quality the bare earth surface generated from the PaMAP LIDAR data. Minor editing of the bare earth points was performed to improve the quality of the final surface used to perform the analysis. TerraScan and TerraModeler software packages were used to perform for all data classification, manual cleanup, and data analysis. Once the bare earth surface was generated the technician imported the coordinate locations of the survey profiles into the project workspace. These included 36 points along the top of the dam (Figure H-11) and an additional 7 points along the top of the spillway. The profile station locations were then intersected with the 3-D bare earth LIDAR surface. Interpolated LIDAR elevations were then generated using the software at each profile station location. The common coordinates of each survey profile station along with its surveyed elevation, its LIDAR derived elevation and the constant design elevation for the dam and spillway were then exported from TerraScan and imported into Microsoft Excel 2007 for a

final statistical analysis. The tabular and graphed results of the analysis of both the dam and spillway are shown in Section H-20 through H-23.

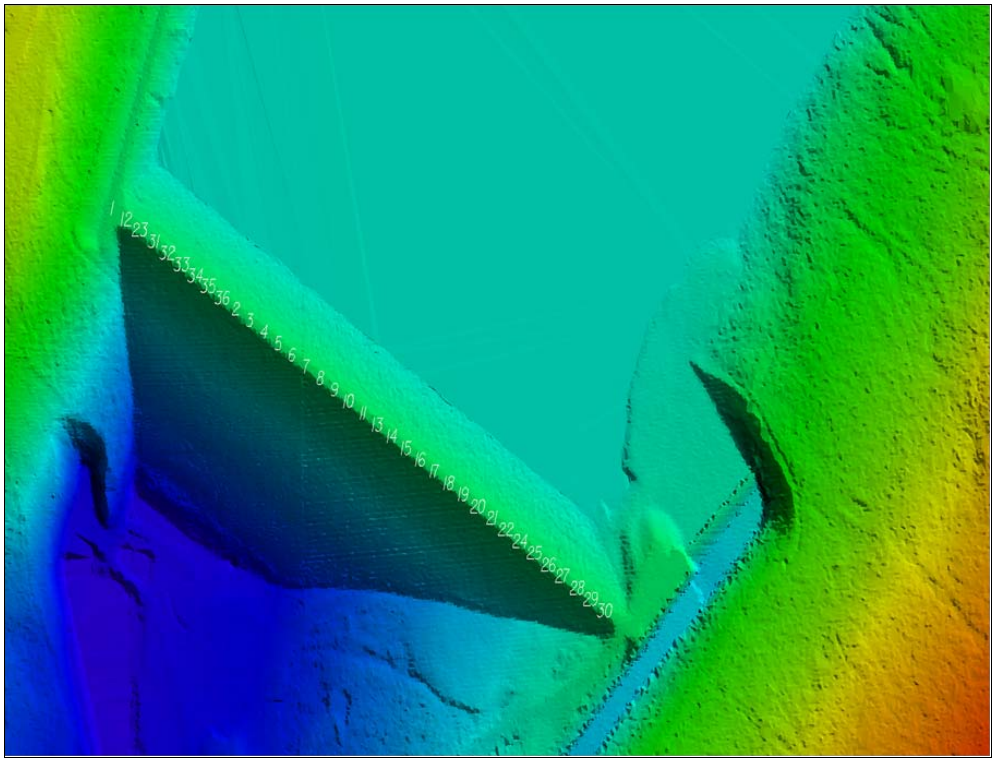


Figure H-11. Bare Earth LIDAR Surface showing Dam profile stations.

H-17. Comparative Analysis Observations. The field survey elevations established along the top of the dam and spillway were consistently higher than the plan elevation. For the dam the magnitude was approximately one half foot and approximately three tenths of a foot for the spillway. The elevations along the top of the dam and spillway established from the LIDAR elevation model were also consistently higher than the plan elevation, but there was considerably more "noise" and variability in the LIDAR elevations as compared to the other two elevation sources. This noise is likely a result of both the nature of LIDAR elevation data, which is acquired in an aerial platform flown several thousand feet above the ground, and the lack of breakline data along the tops of the slopes on the dam that would have improved the performance of the LIDAR only data in modeling the top of the dam. The "noise" in the LIDAR data is not necessarily unusual. As described earlier in this document, this LIDAR dataset was acquired to support a 2-foot contour equivalent surface and as such, included a requirement for an 18.5 cm, or 0.61 feet root mean square error (RMSE). The RMSE basically defines the 68 percent confidence interval, or put in other words, 68 percent of the elevation points within this dataset should fit the actual surface of the earth within 18.5 cm, or 0.61 feet. By visual inspection of the graphs for both the dam and the spillway profiles we can see that the LIDAR elevations fit the ground elevations established by field survey within 0.5 feet at most of the comparison locations, which would fit within our statistical expectations for the LIDAR data based on the accuracy standard

H-18. Project Glossary.

LIDAR- Light Detection and Ranging.

Average dZ – the average elevation value from the list of each series of readings.

Minimum dZ – the minimum elevation value from the list of each series of readings.

Maximum dZ – the maximum elevation value from the list of each series of readings.

MSE - Mean Square Error is achieved by calculating the square of the deviations of points from their true position, summing up the measurements, and then dividing by the total number of points.

RMSE – Root Mean Square Error is calculated by taking the square root of the MSE.

Standard Deviation – measure of how widely values are dispersed from the average dZ.

H-19. Methodology for Calculating the dZ Values.

dZ (Survey/Plan) – Plan elevation was subtracted from the surveyed elevation.

dZ (Survey/LIDAR) – LIDAR elevation was subtracted from the survey elevation.

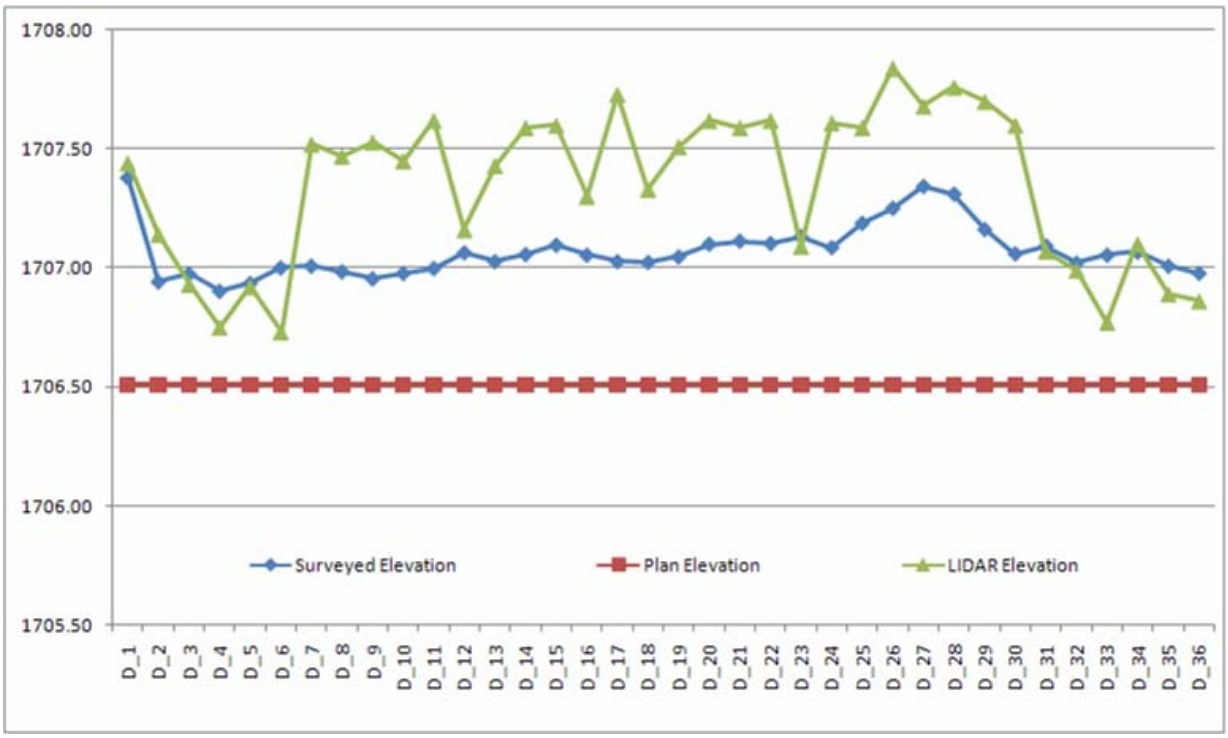
dZ (Plan/LIDAR) – LIDAR elevation was subtracted from the plan elevation.

H-20. Statistical Analysis—Dam.

Dam Statistical Analysis			
Average Dz	0.56	-0.278	-0.838
Minimum Dz	0.39	-0.70	-1.33
Maximum Dz	0.87	0.28	-0.22
RMSE	0.571	0.398	0.899
St. Dev.	0.11	0.289	0.33

Point	Elevation			dZ			Easting	Northing
	Surveyed	Plan	LIDAR	Survey/Plan	Survey/LIDAR	Plan/LIDAR		
D_1	1707.38	1706.51	1707.44	0.87	-0.06	-0.93	1736840.37	508754.83
D_2	1706.94	1706.51	1707.14	0.43	-0.20	-0.63	1737189.90	508558.95
D_3	1706.98	1706.51	1706.93	0.46	0.04	-0.42	1737229.23	508537.05
D_4	1706.90	1706.51	1706.75	0.39	0.15	-0.24	1737269.25	508514.86
D_5	1706.94	1706.51	1706.92	0.43	0.02	-0.41	1737309.73	508492.06
D_6	1707.00	1706.51	1706.73	0.49	0.27	-0.22	1737349.08	508469.89
D_7	1707.01	1706.51	1707.52	0.50	-0.51	-1.01	1737390.15	508446.86
D_8	1706.99	1706.51	1707.47	0.47	-0.49	-0.96	1737429.28	508425.16
D_9	1706.96	1706.51	1707.53	0.44	-0.58	-1.02	1737468.98	508402.62
D_10	1706.98	1706.51	1707.45	0.47	-0.47	-0.94	1737508.45	508380.57
D_11	1707.00	1706.51	1707.62	0.49	-0.62	-1.11	1737549.94	508357.56
D_12	1707.06	1706.51	1707.16	0.55	-0.10	-0.65	1736879.94	508733.03
D_13	1707.03	1706.51	1707.43	0.52	-0.40	-0.92	1737590.29	508334.64
D_14	1707.06	1706.51	1707.59	0.55	-0.53	-1.08	1737630.73	508312.62
D_15	1707.10	1706.51	1707.60	0.59	-0.50	-1.09	1737671.51	508289.43
D_16	1707.05	1706.51	1707.30	0.54	-0.25	-0.79	1737711.33	508267.09
D_17	1707.03	1706.51	1707.73	0.52	-0.70	-1.22	1737752.00	508244.48
D_18	1707.02	1706.51	1707.33	0.51	-0.31	-0.82	1737792.72	508221.76
D_19	1707.05	1706.51	1707.51	0.54	-0.46	-1.00	1737832.91	508199.68
D_20	1707.10	1706.51	1707.62	0.59	-0.52	-1.11	1737873.90	508176.72
D_21	1707.11	1706.51	1707.59	0.60	-0.48	-1.08	1737914.50	508154.14
D_22	1707.10	1706.51	1707.62	0.59	-0.52	-1.11	1737953.58	508131.90
D_23	1707.13	1706.51	1707.09	0.62	0.04	-0.58	1736918.46	508711.93
D_24	1707.09	1706.51	1707.61	0.58	-0.52	-1.10	1737993.20	508109.57
D_25	1707.19	1706.51	1707.59	0.68	-0.40	-1.08	1738034.14	508086.55
D_26	1707.25	1706.51	1707.84	0.74	-0.59	-1.33	1738074.32	508063.43
D_27	1707.34	1706.51	1707.68	0.83	-0.34	-1.17	1738114.04	508041.69
D_28	1707.31	1706.51	1707.76	0.80	-0.45	-1.25	1738155.30	508018.97
D_29	1707.16	1706.51	1707.70	0.65	-0.54	-1.19	1738193.35	507997.10
D_30	1707.06	1706.51	1707.60	0.55	-0.54	-1.09	1738232.99	507974.79
D_31	1707.09	1706.51	1707.07	0.58	0.02	-0.56	1736957.60	508690.05
D_32	1707.02	1706.51	1706.99	0.51	0.03	-0.48	1736995.53	508667.85
D_33	1707.05	1706.51	1706.77	0.54	0.28	-0.26	1737036.58	508644.95
D_34	1707.07	1706.51	1707.10	0.56	-0.03	-0.59	1737074.70	508623.45
D_35	1707.01	1706.51	1706.89	0.50	0.12	-0.38	1737111.47	508602.91
D_36	1706.98	1706.51	1706.86	0.47	0.12	-0.35	1737151.46	508580.47

H-21. Dam Statistical Analysis – Graph.

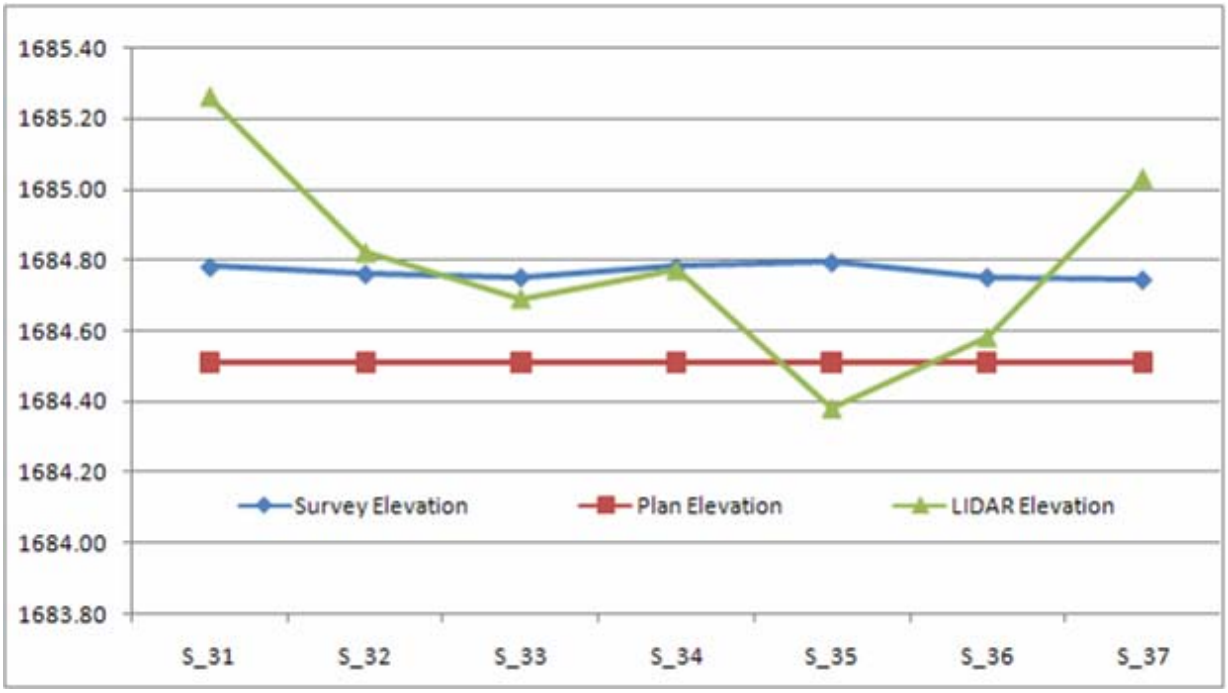


H-22. Statistical Analysis—Spillway.

Spillway Statistical Analysis			
Average Dz	0.256	-0.024	-0.28
Minimum Dz	0.23	-0.48	-0.75
Maximum Dz	0.28	0.41	0.13
RMSE	0.256	0.272	0.387
St. Dev.	0.019	0.293	0.289

Point	Elevation			dZ			Easting	Northing
	Surveyed	Plan	LIDAR	Survey/Plan	Survey/LIDAR	Plan/LIDAR		
S_31	1684.78	1684.51	1685.26	0.27	-0.48	-0.75	1738491.30	508110.83
S_32	1684.76	1684.51	1684.82	0.25	-0.06	-0.31	1738513.26	508128.62
S_33	1684.75	1684.51	1684.69	0.24	0.06	-0.18	1738535.40	508146.52
S_34	1684.78	1684.51	1684.77	0.27	0.01	-0.26	1738557.30	508164.61
S_35	1684.79	1684.51	1684.38	0.28	0.41	0.13	1738579.46	508182.41
S_36	1684.75	1684.51	1684.58	0.24	0.17	-0.07	1738601.59	508200.15
S_37	1684.74	1684.51	1685.03	0.23	-0.29	-0.52	1738624.87	508219.20

H-23. Spillway Statistical Analysis – Graph.



H-24. East Branch Control Tower Gage. The following is a copy of a 2008 USGS gage inspection report for the Control Tower gage. Note that elevations are referenced to both "MSL" and local gage (and electric tape) datums. The 2008 TerraSurv surveys described above subsequently provided relationships for this gage to the NSRS (NAVD88). The legacy datum (MSL) should be retained along with its relationship to the updated NAVD88 elevations. Figure H-12 is a close up of the gage reference point. Figure H-13 is a copy of the U-SMART datasheet for this gage.

Gage Station Description 03027000
East Branch Clarion River Lake, PA

Responsible Office U.S. Geological Survey, Pittsburgh Field Office, 1000 Church Hill Rd., Pittsburgh, PA 15205 (412) 490-3800

Most recent revision: 5/13/2008 Revised by: ajruddy

LOCATION.--Lat 41°33'35", long 78°35'40" referenced to North American Datum of 1927, Elk County, PA, Hydrologic Unit 05010005, gage house in control tower at East Branch Clarion River Dam on East Branch Clarion River, 1.7 miles northeast of Glen Hazel, and 7.5 miles upstream from confluence with West Branch Clarion River.

ROAD LOG.--To reach station from Johnsonburg travel east on Bendingo Rd. from Johnsonburg to village of Glen Hazel. At Glen Hazel make left turn at "T" intersection onto Glen Hazel Rd. (SR240011). Follow Glen Hazel Rd. across bridge over the East Branch Clarion River and proceed 1.0 mile. Make right turn onto Corps of Engineers access road at sign. Follow access road to Corps office and obtain key for access and directions if necessary (Glen Hazel, 7 1/2 minute quadrangle).

DRAINAGE AREA.--72.4 mi2.

ESTABLISHMENT AND HISTORY.--June 1952 to Oct. 1991 and from July 2005 to current year. Prior to October 1970 published as "East Branch Clarion River Reservoir".

GAGE.--Sutron (model 8210) data collection platform at top of concrete stilling well built into gate tower building. Recorders are referenced to an electric tape-gage at 1710.323 ft. gage datum. Elevation of gage datum provided by Corps of Engineers. Electric tape index is 210.323 ft gage datum. Electric tape-gage reading plus 1,500.00 equals reservoir elevation to sea level. Corps Conventions for Recording Pool Levels: E.T. plus 1500 ft is sea level for pool reading. Electric Tape reading minus 85 ft is DCP reading for transmissions.

RESERVOIR: Rock faced earthfill dam with a capacity of 83,300 acre-ft. Range in usual operation is between 1,651 ft and 1,670 ft above sea level. Full range of operation is between 1,555 ft (sill of outlet gates) and 1,685 ft (full pool).

CONTROL.--Spillway and gate opening are the control factors.

DISCHARGE.--Controlled by two outlet gates whose dimensions are 3' by 4' and 1' by 1.5'.

FLOODS.--The high water of June 24, 1972 reached an elevation of 1,685.55 ft (85,010 acre-ft).

POINT OF ZERO FLOW.--Elevation of sill of the outlet gates is 15.0 ft. gage datum.

REGULATION AND DIVERSIONS.--Reservoir is operated for flood control, low-flow augmentation of Clarion River and recreational use.

ACCURACY.--Records good.

COOPERATION.--The station is maintained cooperatively by the U.S. Army Corps of Engineers and the U.S. Geological Survey.

REFERENCE MARKS.-- BM 1-500 COE brass disk on top of parapet wall at service bridge to control tower on upstream right bank. Elevation is 1711.003 ft, MSL. BM M-1 COE pipe monument right bank just downstream of dam access road. Elevation is 1711.209 ft, MSL. BM M-2 COE pipe monument, left bank just downstream of dam access road. Elevation is 1711.293 ft, MSL.

DATE OF LAST LEVELS. Last run: Jun 15, 2006; Next run: Jun 14, 2009; Frequency: 3 years; Status: OPEN

Figure H-12. East Branch Control Tower gage reference point.

USACE Survey Marker Archive & Retrieval Tool Datasheet Type: New

Designation: Gauge East Branch (inflow)
Project: East Branch
Stamping:
PID NGS: COE:
State: Pennsylvania
County: Elk
District Pittsburgh
Nearest Town: Johnsonburg
USGS Quad:
T.R.S.:
Nearest Hwy/Mi:
B/L Sta/Off:
Date Recovered: Apr 22, 2008
By: CELRP (LeBlanc)
Condition/Stability: Good
Setting/Monument Type:
Owner:
GPS Suitable: ◯ Yes ◉ No
Obstructions: ☐ N ☐ E ☐ S ☐ W

- Horizontal -
Datum: NAD83 ( )
Lat: 41.56140000 N
Lon: 78.59470000 W
Local Accuracy: 10-m+
NSRS Accuracy: 10-m+
Survey/Computation Method: Scaled
Date Observed: May 20, 2008

- Vertical -
Datum: NAVD88 ( )
Elevation Ht: 1,710.323
Ellip Ht: Ft
Local Accuracy: 2-cm
NSRS Accuracy: 0.25'
Survey/Computation Method: Geodetic Levels
Date Observed: May 20, 2008 Geoid09

Description/Comments:
East Branch Clarion River Lake, PA (EBRP)

Rovergages.com
http://www2.mvr.usace.army.mil/WaterControl/stationinfo2.cfm?sid=EBRP1&fid=EBRP1&dt=S

Access:

- Tidal/Hydraulic Gauge Relationships -
Owner/Code: USGS
Gauge ID: EBRP Epoch:

- Datum -	- Elevation -
Gage Index	210.323
DCP Datum	85
Select	
Select	

Zone: Northing: Easting: Convergence: CSF:

- Horizontal View -

- Close-Up View -

Required Fields In Red Reset Form Submit U-SMART ver 1.1 9/24/2009

Figure H-13. U-SMART datasheet for East Branch Control Tower gage.