DPH-11 Report on Absolute Vertical Accuracy

The USGS Lidar Base Specification Version 2.1 states: "Absolute vertical accuracy of the lidar data and the derived DEM will be assessed and reported in accordance with ASPRS (2014). Vegetated and nonvegetated land cover types shall be assessed for absolute vertical accuracy.
Three absolute accuracy values shall be assessed and reported:

1. NVA for the point data
2. VVA for the point data
3. NVA for the DEM
4. VVA for the DEM

The minimum NVA and VVA requirements for all data, using the ASPRS methodology, are listed in table 4. Both the NVA and VVA required values shall be met. NVA for the point data shall be assessed by comparing check points surveyed for NVA assessment to a triangulated irregular network (TIN) constructed from ground-classified lidar points in those areas. VVA for the point data shall be assessed by comparing check points surveyed for VVA assessment to a triangulated irregular network (TIN) constructed from ground-classified lidar points in those areas. NVA and VVA for the DEM are assessed by comparing check points to the final bare-earth surface. The minimum required thresholds for absolute and relative accuracy may be increased by the USGS–NGP when any of the following conditions are met:

- A demonstrable, substantial, and prohibitive increase in cost is needed to obtain this accuracy, which is often the case in heavily vegetated project areas.
- An alternate specification is needed to conform to previously contracted phases of a single larger overall collection effort such as for multiyear statewide collections
- The USGS–NGP agrees that the use of an alternate specification is reasonable and in the best interest of all stakeholders."

Table 4. Absolute vertical accuracy for light detection and ranging data and digital elevation models.

[QL, quality level, $RMSE_z$, root mean square error in the z direction; NVA, nonvegetated vertical accuracy; VVA, vegetated vertical accuracy; m, meter; ≤, less than or equal to]

Quality level	$RMSE_z$ (nonvegetated) (m)	NVA at the 95-percent confidence level (m)	VVA at the 95th percentile (m)
QL0	≤0.050	≤0.098	≤0.15
QL1	≤0.100	≤0.196	≤0.30
QL2	≤0.100	≤0.196	≤0.30
QL3	≤0.200	≤0.392	≤0.60

The purpose of this section is to report on the absolute vertical accuracy of the lidar data and DEMs generated from it by testing for NVA (Nonvegetated Vertical Accuracy) and VVA (Vegetated Vertical Accuracy) against surveyed ground check points.

DPH-11 Report on Absolute Vertical Accuracy - continued

Data Source - Y:\Mapping\Projects\65220595_CO_SanLuisJuanMiguel\Production\Final_Client_Deliverables\Block1_Surdex\metadata\shapefiles\CO_SanLouisJuanMiguel_Block1_30nva_15vva.shp

Units: Meter (/Feet)

Vertical Accuracy Class tested: 10-cm

Check Points in defined project area (DPA):	45
Check Points with Lidar Coverage	45
Check Points with Lidar Coverage (NVA)	30
Check Points with Lidar Coverage (VVA)	15
Average Z Error (NVA)	0.015/0.050
Maximum Z Error (NVA)	0.097/0.319
Median Z Error (NVA)	0.024/0.080
Minimum Z Error (NVA)	-0.072/-0.235
Standard deviation of Vertical Error (NVA)	0.045/0.149
Skewness of Vertical Error (NVA)	-0.395
Kurtosis of Vertical Error (NVA)	-0.571
Non-vegetated Vertical Accuracy (NVA) RMSE(z) [1]	0.047/0.155 PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/- [1]	0.093/0.304 PASS
FGDC/NSSDA Vertical Accuracy at the 95% Confidence Level +/-	0.093/0.304
Non-vegetated Vertical Accuracy (NVA) RMSE(z) (DEM) [2]	0.049/0.159 PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level (DEM) +/- [2]	0.095/0.312 PASS
Vegetated Vertical Accuracy (VVA) at the 95th Percentile (TIN) +/- [1]	0.244/0.800 PASS
Vegetated Vertical Accuracy (VVA) at the 95th Percentile (DEM) +/- [2]	0.211/0.692 PASS

This data set was tested to meet ASPRS Positional Accuracy Standard for Digital Geospatial Data (2014) for a 10-cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSEz = 4.7cm, equating to +/- 9.3cm at the 95% confidence level. Actual VVA accuracy was found to be +/- 21.1cm at the 95th percentile.

[1] This value is calculated from TIN-based testing of the lidar point cloud data.

[2] This value is calculated from RAM-based grid testing of the lidar data. The grid cells are sized according to the Quality Level selected, and are defined in the USGS NGP Lidar Base Specification Version 2.1 (Table 6).

DPH-11 Report on Absolute Vertical Accuracy - continued

The purpose of this section is to report the results of measuring the lidar point cloud data against surveyed ground NVA (nonvegetated vertical accuracy) check points. All XY coordinates and Z values reported are in the selected data units.

NVA (lidar data)

ID	X	Y	Coverage	Z	Z From Lidar	Z Error	Minimum Z	Median Z	Maximum Z	Intensity	Scan Angle Rank	Returns	Description	Comments
6071	461635.889	4129994.557	Yes	2433.868	2433.951	0.083	2433.942	2433.956	2433.956	11074	1751	1,1,1		
6075	451129.92	4134911.685	Yes	2345.978	2346.028	0.050	2346.009	2346.02	2346.042	10600	1059	1,1,1		
6084	424025.841	4114700.172	Yes	2356.219	2356.187	-0.032	2356.159	2356.19	2356.195	14350	1253	1,1,1		
6089	471536.495	4104521.829	Yes	2695.082	2695.097	0.015	2695.043	2695.073	2695.144	18031	2531	1,1,1		
6101	414440.763	4124196.82	Yes	2320.024	2319.953	-0.071	2319.952	2319.967	2319.972	9207	-3035	1,1,1		
6101A	417699.786	4125051.422	Yes	2314.258	2314.186	-0.072	2314.183	2314.189	2314.201	8063	-1585	1,1,1		
6120	469492.988	4134612.969	Yes	2577.043	2577.053	0.010	2577.04	2577.049	2577.059	16837	254	1,1,1		
6131	432811.842	4103800.665	Yes	2275.459	2275.491	0.032	2275.49	2275.498	2275.499	18757	-2546	1,1,1		
6132	467116.319	4126969.294	Yes	2592.705	2592.728	0.023	2592.712	2592.714	2592.737	19437	1573	1,1,1		
6142	412272.21	4114434.636	Yes	2358.976	2359.029	0.053	2359.006	2359.04	2359.049	9666	-148	1,1,1		
6149	447227.013	4115534.68	Yes	2330.149	2330.082	-0.067	2330.049	2330.08	2330.085	17670	2652	1,1,1		
6154	461792.016	4122572.531	Yes	2465.448	2465.508	0.060	2465.507	2465.51	2465.521	9579	2224	1,1,1		
6155	433880.175	4125010.845	Yes	2287.657	2287.661	0.004	2287.637	2287.656	2287.664	13144	492	1,1,1		
6160	463555.293	4095792.993	Yes	2571.652	2571.667	0.015	2571.644	2571.644	2571.687	21475	-861	1,1,1		
6173	465510.112	4104336.35	Yes	2549.979	2550.018	0.039	2550.006	2550.006	2550.021	19335	-1039	1,1,1		
6179	470468.29	4123000.951	Yes	2646.414	2646.402	-0.012	2646.336	2646.415	2646.416	20071	-1624	1,1,1		
6179A	468992.182	4123107.193	Yes	2606.253	2606.288	0.035	2606.272	2606.283	2606.332	16552	1860	1,1,1		
6186	439389.928	4135259.377	Yes	2310.762	2310.773	0.011	2310.758	2310.762	2310.783	22273	375	1,1,1		
6187	411252.037	4094818.955	Yes	2450.774	2450.777	0.003	2450.764	2450.786	2450.788	9368	-2121	1,1,1		
6191	410315.868	4104928.491	Yes	2403.741	2403.812	0.071	2403.782	2403.809	2403.818	15141	1918	1,1,1		
6195	435710.853	4114925.554	Yes	2277.195	2277.157	-0.038	2277.142	2277.158	2277.159	12302	1223	1,1,1		
6197	475958.999	4114913.637	Yes	2741.177	2741.274	0.097	2741.252	2741.26	2741.288	19360	2320	1,1,1		
6197A	470548.866	4114880.62	Yes	2587.163	2587.216	0.053	2587.2	2587.217	2587.235	12016	-1264	1,1,1		
6213	470369.412	4138365.711	Yes	2548.427	2548.453	0.026	2548.449	2548.459	2548.484	18010	-2763	1,1,1		
6216	464554.398	4111815.129	Yes	2464.038	2464.067	0.029	2464.052	2464.057	2464.074	8429	2467	1,1,1		
6217	453540.382	4096370.607	Yes	2352.979	2353.052	0.073	2353.027	2353.053	2353.058	9547	511	1,1,1		
6219	417628.121	4134797.464	Yes	2309.202	2309.167	-0.035	2309.146	2309.17	2309.171	9779	-3160	1,1,1		
6225	417482.699	4104042.706	Yes	2367.138	2367.09	-0.048	2367.086	2367.091	2367.094	13444	-1691	1,1,1		
6228	453719.449	4107570.993	Yes	2356.843	2356.869	0.026	2356.861	2356.869	2356.875	15915	2290	1,1,1		
6229	442505.138	4100423.801	Yes	2311.99	2312.017	0.027	2312.01	2312.017	2312.019	24306	-1480	1,1,1		

Check Points Vertical Accuracy - continued

ID	X	Y	Coverage	Z	Z From Lidar	Z Error	Minimum Z	Median Z	Maximum Z	Intensity	Scan Angle Rank	Returns	Description	Comments

DPH-11 Report on Absolute Vertical Accuracy - continued

The purpose of this section is to report the results of measuring the lidar point cloud data against surveyed ground VVA (vegetated vertical accuracy) check points. All XY coordinates and Z values reported are in the selected data units.

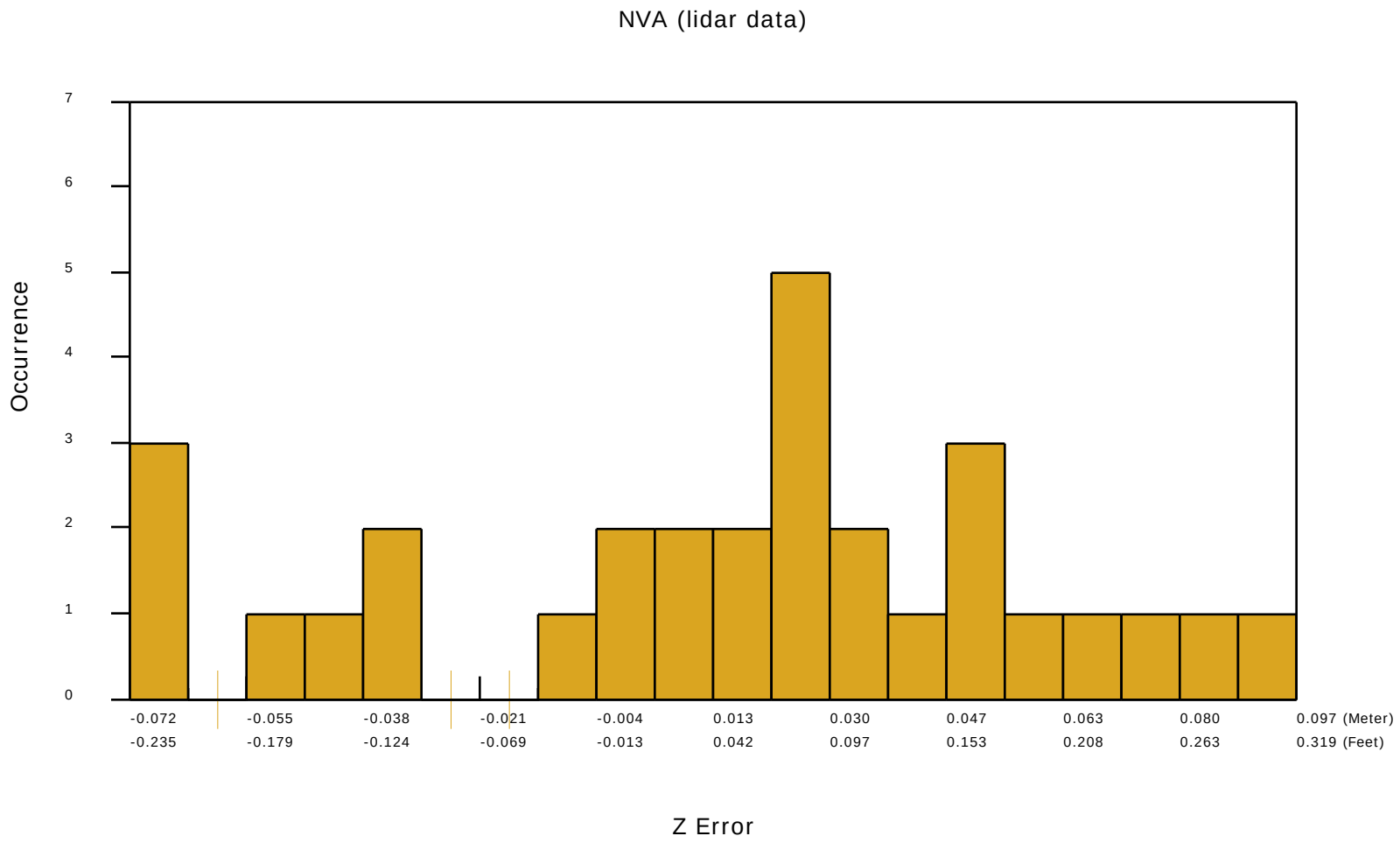
VVA (lidar data)

ID	X	Y	Coverage	Z	Z From Lidar	Z Error	Minimum Z	Median Z	Maximum Z	Intensity	Scan Angle Rank	Returns	Description	Comments
7068	461681.552	4128379.632	Yes	2445.373	2445.562	0.189	2445.443	2445.566	2445.629	12633	1877	1,1,1		
7068A	466824.781	4129467.548	Yes	2546.154	2546.217	0.063	2546.193	2546.219	2546.247	14375	538	1,1,1		
7072	450331.862	4134948.122	Yes	2346.735	2346.753	0.018	2346.716	2346.766	2346.817	12042	-1943	1,1,1		
7080	423636.937	4114624.008	Yes	2354.317	2354.446	0.129	2354.294	2354.348	2354.523	13547	-281	1,1,1		
7084	471681.27	4104393.271	Yes	2705.128	2705.367	0.239	2705.278	2705.349	2705.469	12096	2090	1,1,1		
7084A	468287.112	4106365.6	Yes	2576.494	2576.663	0.169	2576.654	2576.683	2576.696	5772	767	2,2,2		
7095	414238.836	4124554.085	Yes	2319.363	2319.345	-0.018	2319.294	2319.341	2319.395	9511	-1611	2,2,2		
7095A	414433.189	4124650.663	Yes	2319.021	2319.062	0.041	2319.049	2319.05	2319.074	14695	-2755	2,2,1		
7113	469793.11	4134957.234	Yes	2613.347	2613.517	0.170	2613.502	2613.53	2613.542	8410	-892	1,2,2		
7124	434483.16	4103810.489	Yes	2292.784	2292.947	0.163	2292.815	2292.95	2292.968	17072	2489	1,1,1		
7133	412587.479	4114279.037	Yes	2357.832	2357.988	0.156	2357.948	2357.95	2358.028	21664	1070	1,1,1		
7140	448858.814	4115490.878	Yes	2348.314	2348.477	0.163	2348.428	2348.481	2348.569	17201	-1700	1,1,1		
7144	461296.574	4122550.056	Yes	2457.853	2458.107	0.254	2458.09	2458.11	2458.128	13193	360	1,1,1		
7145	433806.188	4125395.989	Yes	2284.402	2284.53	0.128	2284.517	2284.536	2284.553	15260	255	2,2,1		
7150	464393.152	4097563.123	Yes	2586.567	2586.58	0.013	2586.408	2586.638	2586.665	16498	2311	1,1,1		

DPH-11 Report on Absolute Vertical Accuracy - continued

The purpose of this section is to show a frequency distribution chart of the non-vegetated vertical accuracy (NVA) of the lidar point cloud data measured against surveyed ground check points.

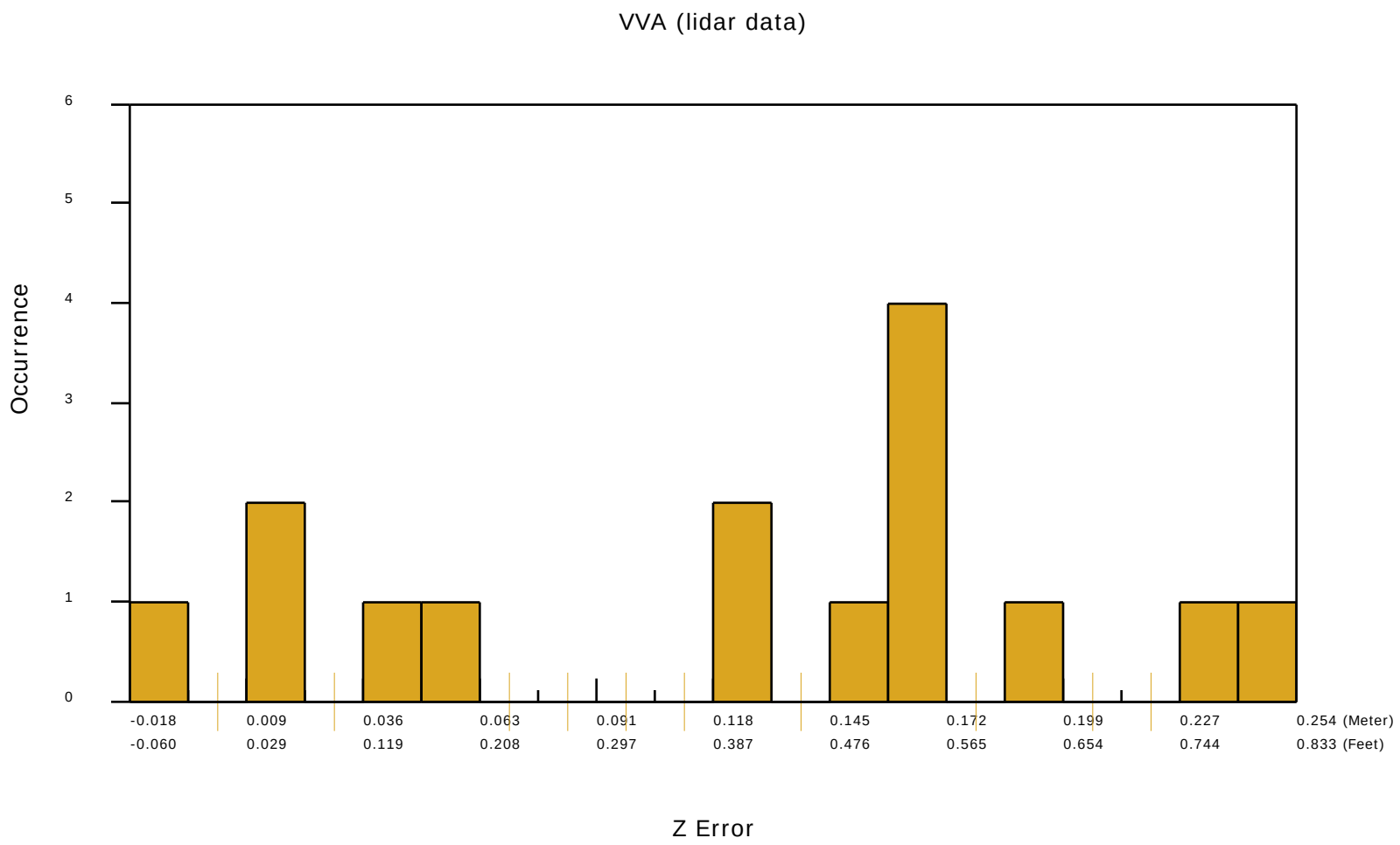
Data Source - Y:\Mapping\Projects\65220595_CO_SanLuisJuanMiguel\Production\Final_Client_Deliverables\Block1_Surdex\point_cloud\tilecls



DPH-11 Report on Absolute Vertical Accuracy - continued

The purpose of this section is to show a frequency distribution chart of the vegetated vertical accuracy (VVA) of the lidar point cloud data measured against surveyed ground check points.

Data Source - Y:\Mapping\Projects\65220595_CO_SanLuisJuanMiguel\Production\Final_Client_Deliverables\Block1_Surdex\point_cloud\tilecls



DPH-11 Report on Absolute Vertical Accuracy - continued

The purpose of this section is to report the results of measuring the DEM data against surveyed ground NVA (nonvegetated vertical accuracy) check points. All XY coordinates and Z values reported are in the selected data units.

NVA (DEM)

ID	X	Y	Coverage	Z	Z From Lidar	Z Error	Description	Comments
6071	461635.889	4129994.557	Yes	2433.868	2433.948	0.080		
6075	451129.92	4134911.685	Yes	2345.978	2346.010	0.032		
6084	424025.841	4114700.172	Yes	2356.219	2356.162	-0.057		
6089	471536.495	4104521.829	Yes	2695.082	2695.125	0.043		
6101	414440.763	4124196.82	Yes	2320.024	2319.984	-0.040		
6101A	417699.786	4125051.422	Yes	2314.258	2314.182	-0.076		
6120	469492.988	4134612.969	Yes	2577.043	2577.033	-0.010		
6131	432811.842	4103800.665	Yes	2275.459	2275.475	0.016		
6132	467116.319	4126969.294	Yes	2592.705	2592.736	0.031		
6142	412272.21	4114434.636	Yes	2358.976	2359.014	0.038		
6149	447227.013	4115534.68	Yes	2330.149	2330.085	-0.064		
6154	461792.016	4122572.531	Yes	2465.448	2465.510	0.062		
6155	433880.175	4125010.845	Yes	2287.657	2287.655	-0.002		
6160	463555.293	4095792.993	Yes	2571.652	2571.687	0.035		
6173	465510.112	4104336.35	Yes	2549.979	2550.021	0.042		
6179	470468.29	4123000.951	Yes	2646.414	2646.422	0.008		
6179A	468992.182	4123107.193	Yes	2606.253	2606.326	0.073		
6186	439389.928	4135259.377	Yes	2310.762	2310.766	0.004		
6187	411252.037	4094818.955	Yes	2450.774	2450.781	0.007		
6191	410315.868	4104928.491	Yes	2403.741	2403.805	0.064		
6195	435710.853	4114925.554	Yes	2277.195	2277.145	-0.050		
6197	475958.999	4114913.637	Yes	2741.177	2741.244	0.067		
6197A	470548.866	4114880.62	Yes	2587.163	2587.231	0.068		
6213	470369.412	4138365.711	Yes	2548.427	2548.458	0.031		
6216	464554.398	4111815.129	Yes	2464.038	2464.085	0.047		
6217	453540.382	4096370.607	Yes	2352.979	2353.057	0.078		
6219	417628.121	4134797.464	Yes	2309.202	2309.147	-0.055		
6225	417482.699	4104042.706	Yes	2367.138	2367.091	-0.047		
6228	453719.449	4107570.993	Yes	2356.843	2356.864	0.021		
6229	442505.138	4100423.801	Yes	2311.99	2312.022	0.032		

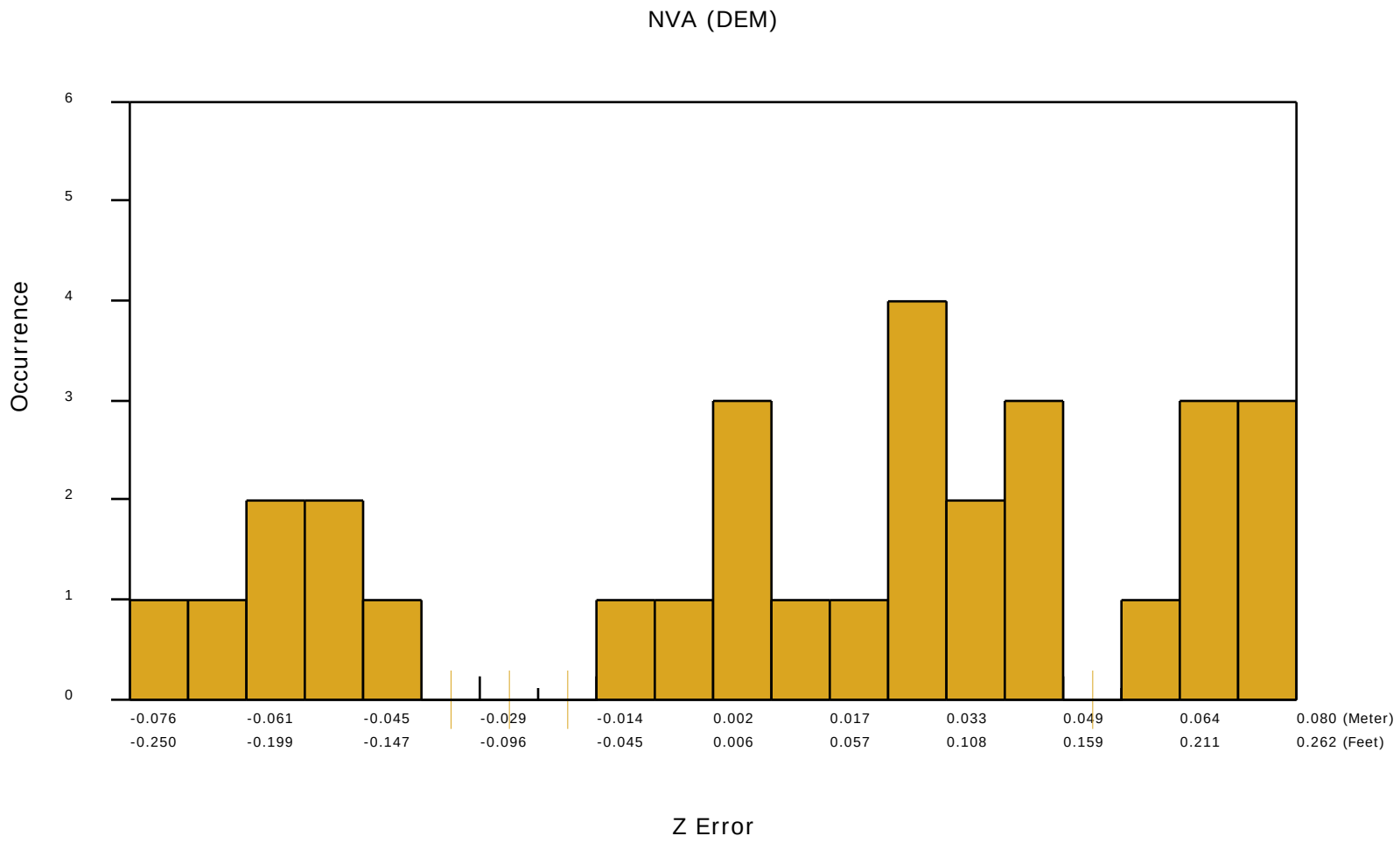
Check Points Vertical Accuracy - continued

ID	X	Y	Coverage	Z	Z From Lidar	Z Error	Description	Comments

DPH-11 Report on Absolute Vertical Accuracy - continued

The purpose of this section is to show a frequency distribution chart of the non-vegetated vertical accuracy (NVA) of the DEM data measured against surveyed ground check points.

Data Source - Y:\Mapping\Projects\65220595_CO_SanLuisJuanMiguel\Production\Final_Client_Deliverables\Block1_Surdex\point_cloud\tilecls



DPH-11 Report on Absolute Vertical Accuracy - continued

The purpose of this section is to report the results of measuring the DEM data against surveyed ground VVA (vegetated vertical accuracy) check points. All XY coordinates and Z values reported are in the selected data units.

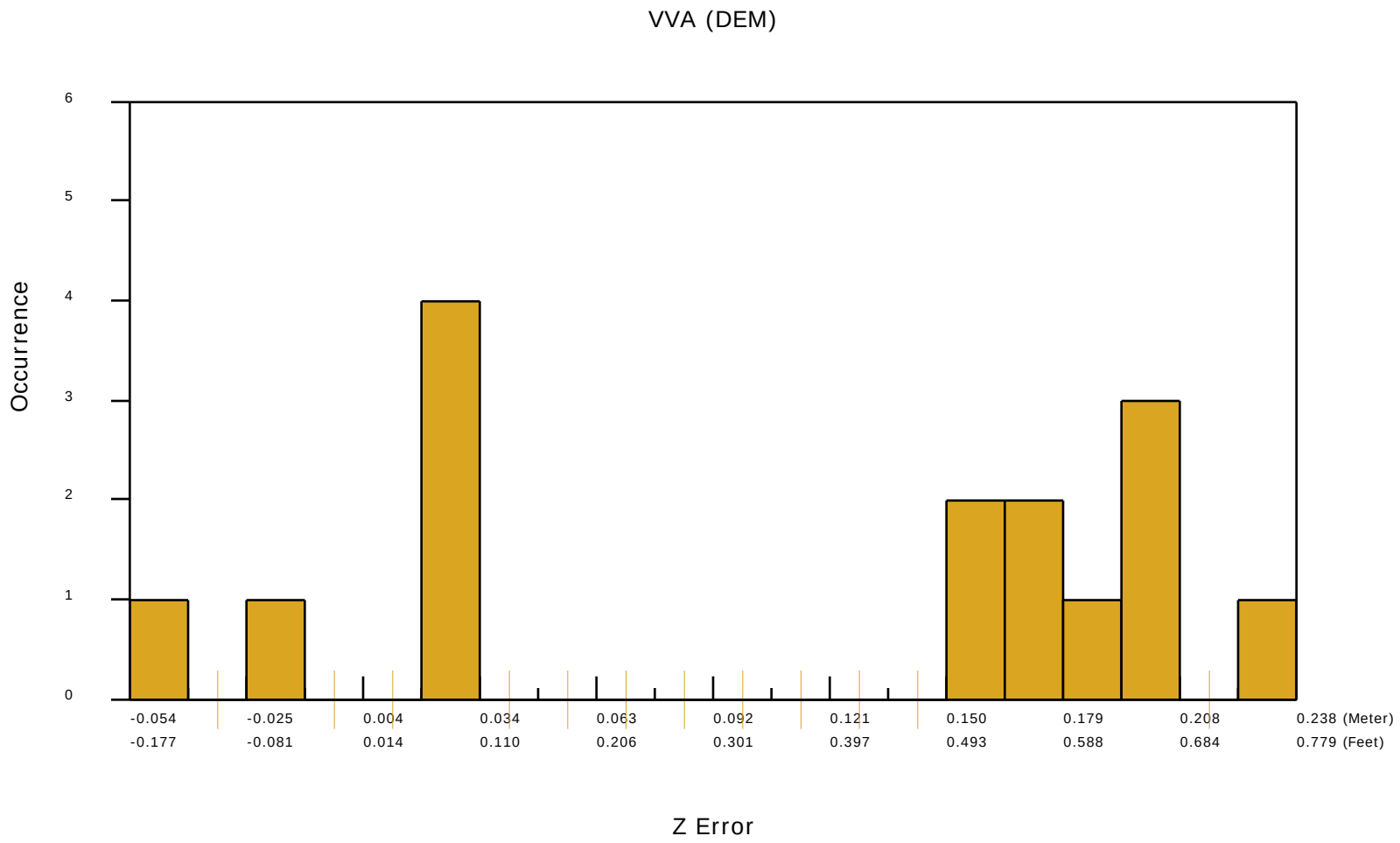
VVA (DEM)

ID	X	Y	Coverage	Z	Z From Lidar	Z Error	Description	Comments
7068	461681.552	4128379.632	Yes	2445.373	2445.551	0.178		
7068A	466824.781	4129467.548	Yes	2546.154	2546.181	0.027		
7072	450331.862	4134948.122	Yes	2346.735	2346.760	0.025		
7080	423636.937	4114624.008	Yes	2354.317	2354.304	-0.013		
7084	471681.27	4104393.271	Yes	2705.128	2705.327	0.199		
7084A	468287.112	4106365.6	Yes	2576.494	2576.692	0.198		
7095	414238.836	4124554.085	Yes	2319.363	2319.309	-0.054		
7095A	414433.189	4124650.663	Yes	2319.021	2319.054	0.033		
7113	469793.11	4134957.234	Yes	2613.347	2613.541	0.194		
7124	434483.16	4103810.489	Yes	2292.784	2292.949	0.165		
7133	412587.479	4114279.037	Yes	2357.832	2357.984	0.152		
7140	448858.814	4115490.878	Yes	2348.314	2348.507	0.193		
7144	461296.574	4122550.056	Yes	2457.853	2458.091	0.238		
7145	433806.188	4125395.989	Yes	2284.402	2284.559	0.157		
7150	464393.152	4097563.123	Yes	2586.567	2586.592	0.025		

DPH-11 Report on Absolute Vertical Accuracy - continued

The purpose of this section is to show a frequency distribution chart of the vegetated vertical accuracy (VVA) of the DEM data measured against surveyed ground check points.

Data Source - Y:\Mapping\Projects\65220595_CO_SanLuisJuanMiguel\Production\Final_Client_Deliverables\Block1_Surdex\point_cloud\tilecls

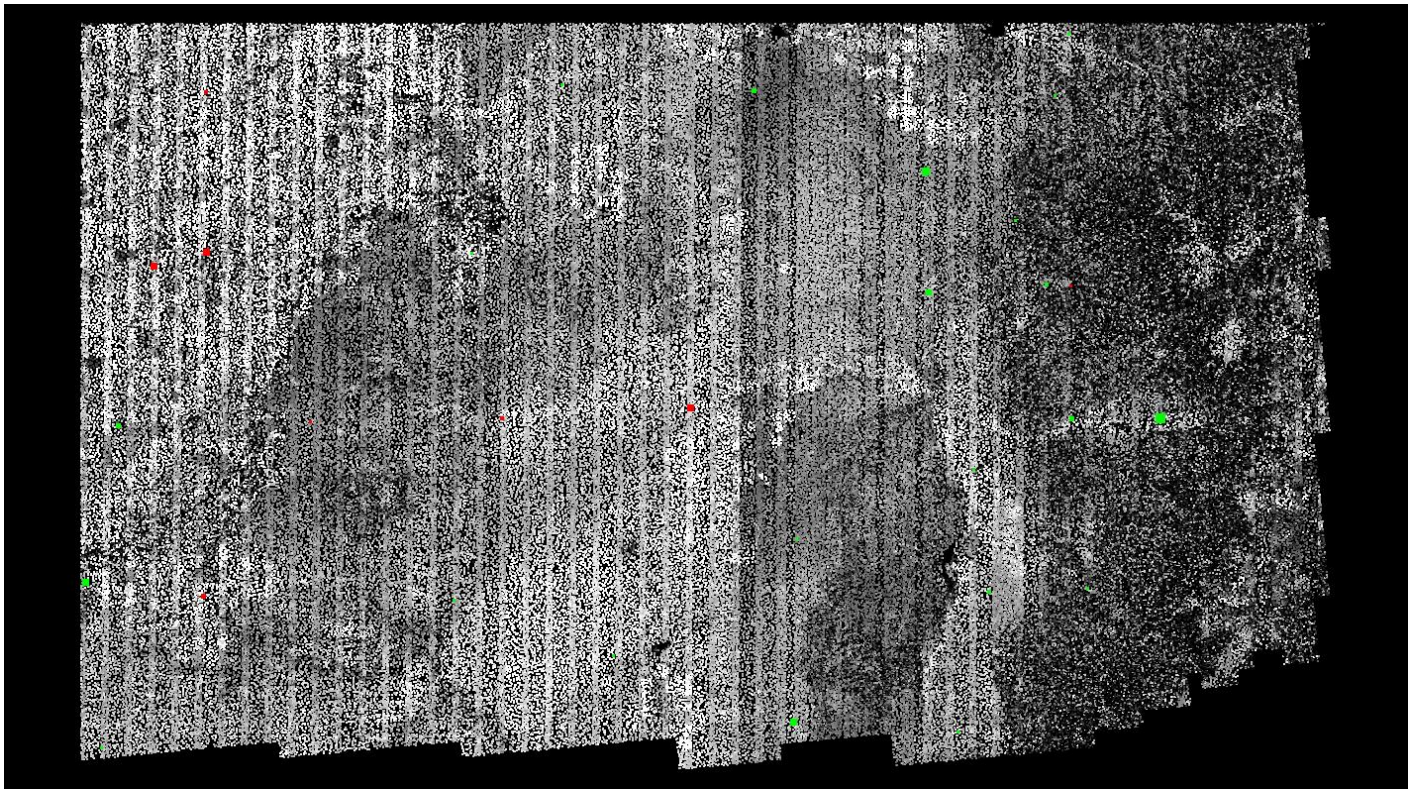


DPH-11 Report on Absolute Vertical Accuracy - continued

The purpose of this section is to show a graphic of lidar data points colored by intensity with NVA check points rendered "thematically" showing the green and red squares sized by Z error.

Data Source - Y:\Mapping\Projects\65220595_CO_SanLuisJuanMiguel\Production\Final_Client_Deliverables\Block1_Surdex\point_cloud\tilecls

Result Path - D:\00_San_Miguel\San_Luis_Juan_Miguel_B1A_QC\DPH_11\ColorByIntensity_CheckPoints_NVA.jpg



Green represents where the lidar surface is above the check point (positive elevation error).

Red represents where the lidar surface is below the check point (negative elevation error).

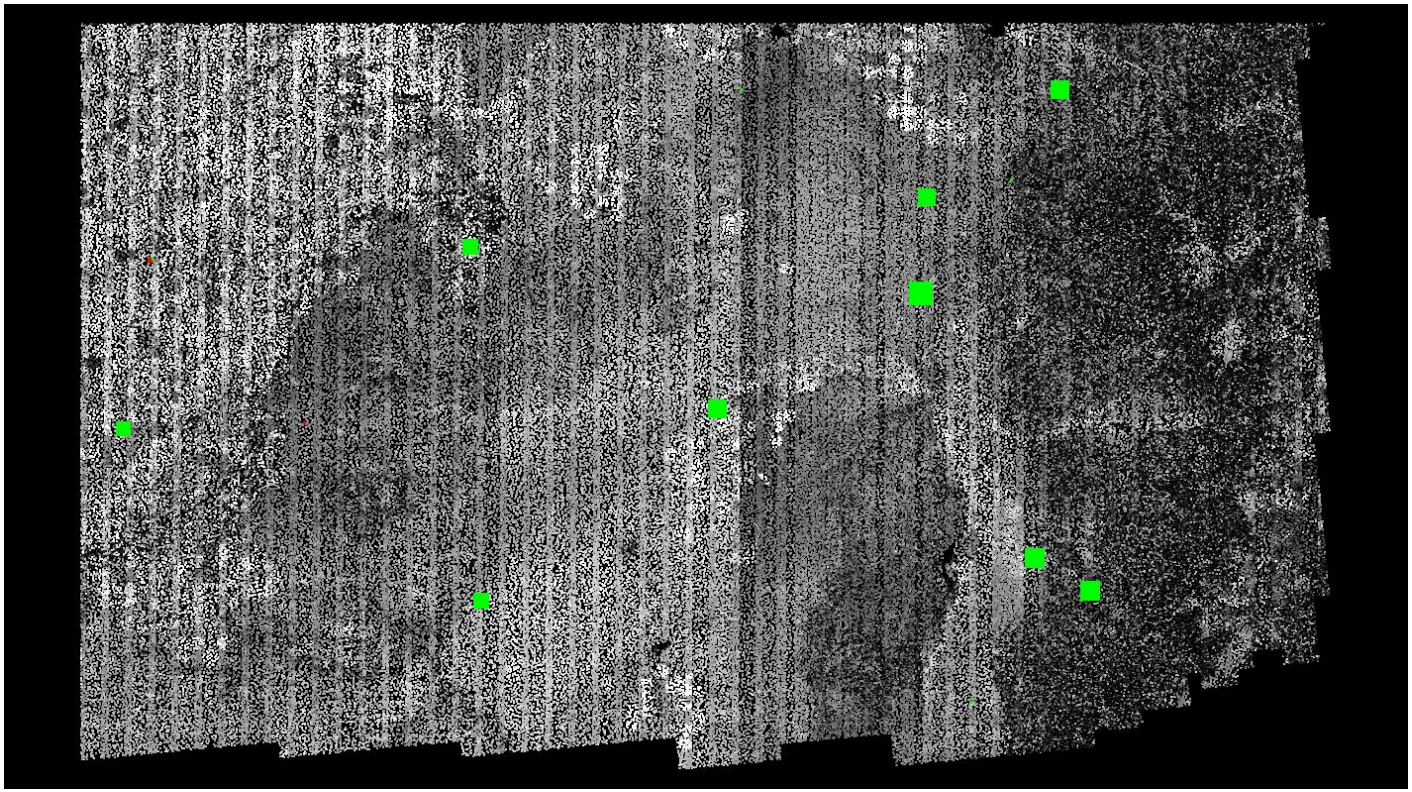
The size of the square symbol represents the absolute value magnitude of error.

DPH-11 Report on Absolute Vertical Accuracy - continued

The purpose of this section is to show a graphic of lidar data points colored by intensity with VVA check points rendered "thematically" showing the green and red squares sized by Z error.

Data Source - Y:\Mapping\Projects\65220595_CO_SanLuisJuanMiguel\Production\Final_Client_Deliverables\Block1_Surdex\point_cloud\tilecls

Result Path - D:\00_San_Miguel\San_Luis_Juan_Miguel_B1A_QC\DPH_11\ColorByIntensity_CheckPoints_VVA.jpg



Green represents where a DEM of the lidar surface is above the check point (positive elevation error).

Red represents where a DEM of the lidar surface is below the check point (negative elevation error).

The size of the square symbol represents the absolute value magnitude of error.