



**Aero-Graphics, Inc.**

40 West Oakland Avenue  
Salt Lake City, UT 84115  
tel: 801.487.3273  
fax: 801.487.3313

**Montana Aerial LiDAR 2021  
Check Point Survey Report**

**For**

**Dewberry Engineers Inc.**

**November 2021**

# Table of Contents

1. Introduction	
1.1 Project Summary.....	3
1.2 Surveyor.....	3
1.3 Project Areas.....	4
2. Project Details	
2.1 Survey Equipment.....	6
2.2 Surveyed Point Details .....	6
2.3 Surveyed Point Network .....	6
2.4 Field Procedures and Analysis .....	7
2.5 Data Processing.....	7
3. Final Coordinates .....	8
4. GNSS Observations .....	14
5. Check Point Comparison .....	18
6. Deliverables .....	20

# 1. Introduction

## 1.1 Project Summary:

Aero-Graphics Inc. is under contract to Dewberry Engineers to provide surveyed ground check points to support the acquisition of aerial lidar for 4,470 sq. miles in eastern Montana. The survey field work was conducted August 20, 2021, thru October 4, 2021. The check point locations were well distributed across the project areas as evenly as the terrain would allow.

As a verification of field procedures, 50% of the check points surveyed were re-observed with the results shown in section 5 of this report.

The final horizontal coordinates are referenced to NAD83(2011) Montana Stat Plane meters. The final vertical elevations are referenced to NAVD88 meters using Geoid model 2018 (Geoid18).

## 1.2 Surveyor:

Questions regarding this report can be addressed to:

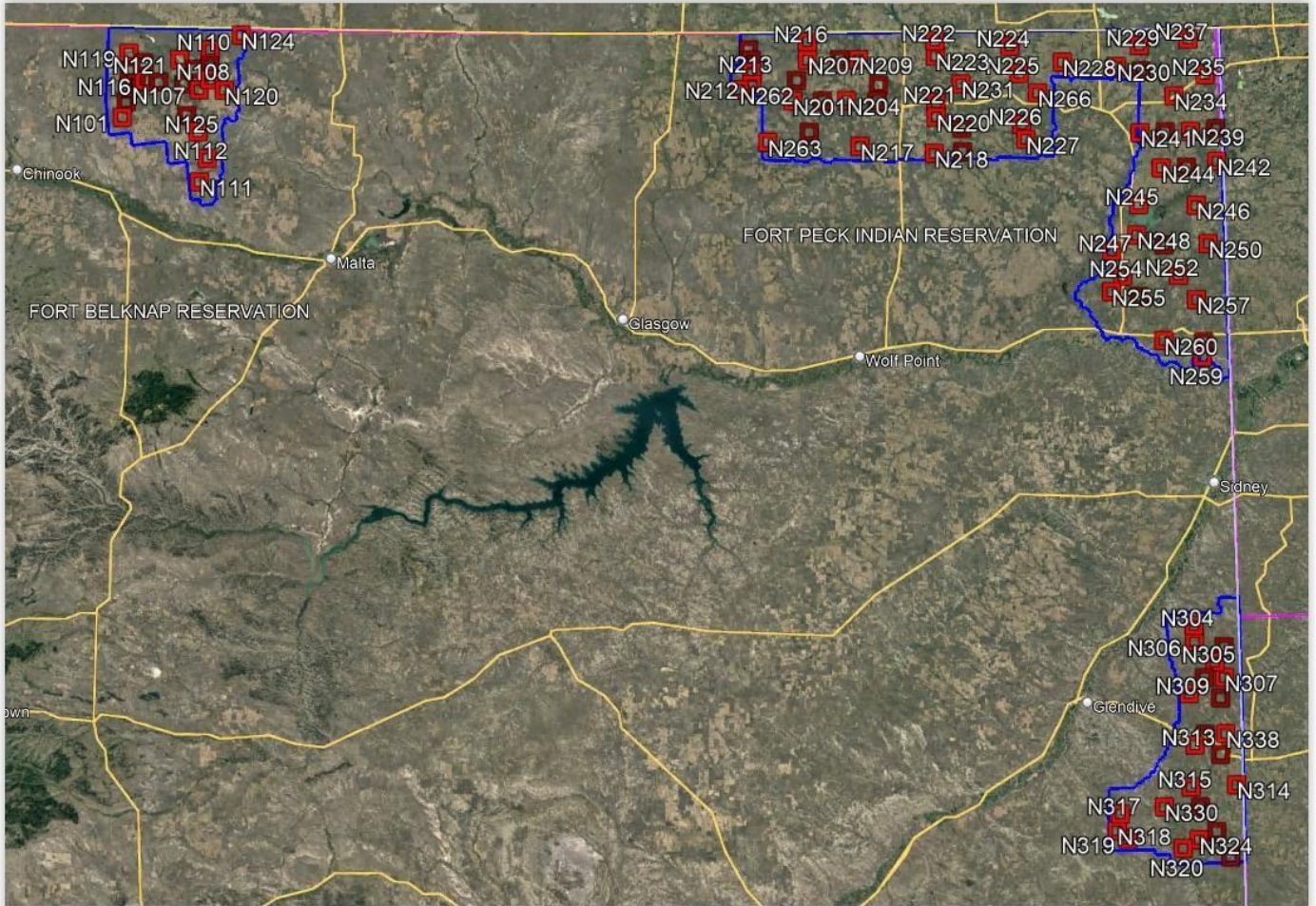
Karl Jensen, PLS, CP  
Surveying Manager  
Aero-Graphics, Inc  
40 W Oakland Ave  
Salt Lake City, Utah 84115  
801-487-3273  
801-891-2779 direct



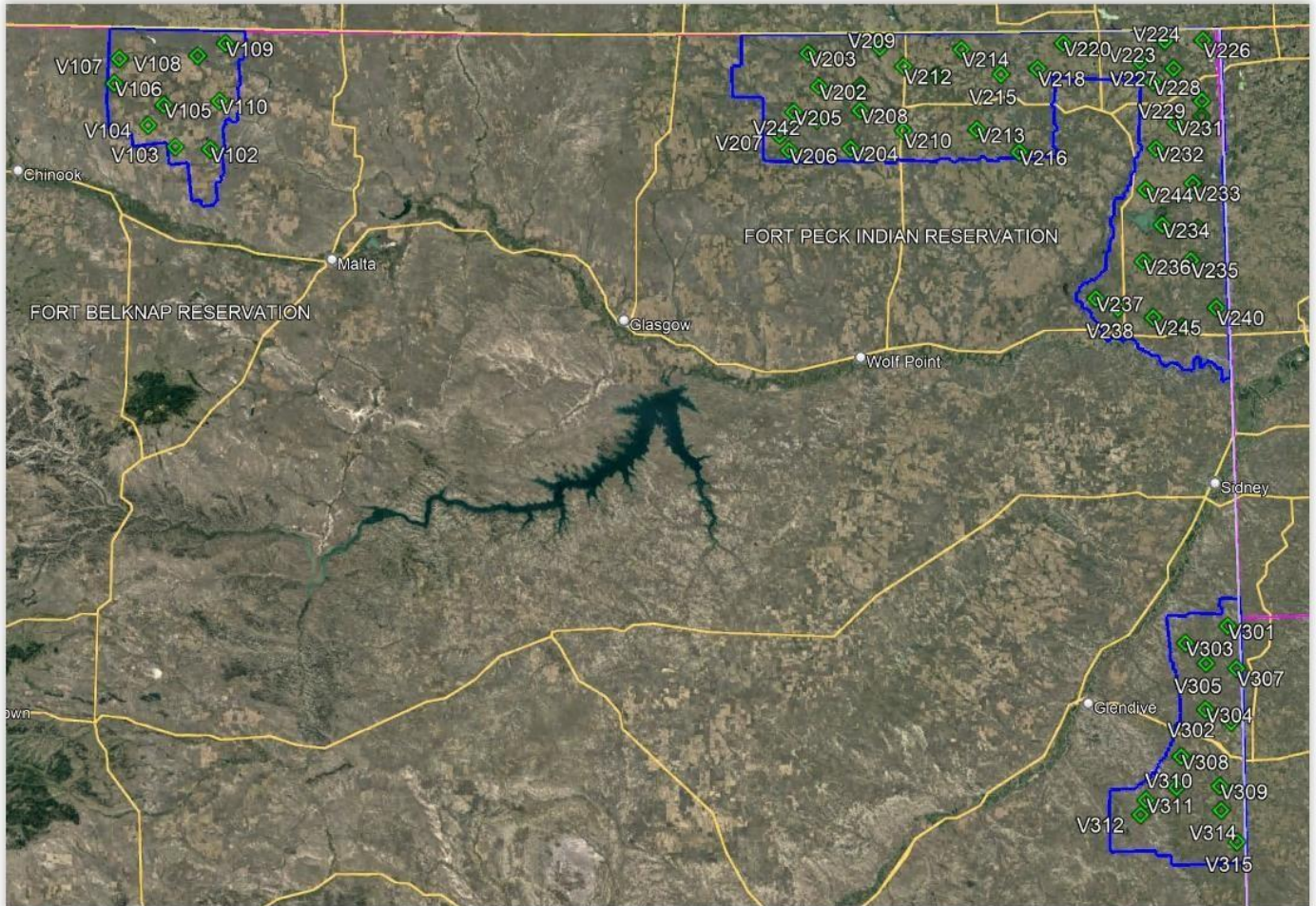
Utah Licensed Professional Land Surveyor #7643406, exp date 3/31/2023  
Colorado Licensed Professional Land Surveyor #PLS-0038527, exp date 10/31/2023  
ASPRS Certified Photogrammetrist, exp date 9/17/2023

### 1.3 Project Areas:

#### NVA Points



## VVA Points



## **2. Project Details**

### **2.1 Survey Equipment**

The equipment listed below was used to survey the ground points for this LiDAR project.

TOPCON Dual Frequency/ Dual Constellation GNSS Receivers:

HiPER Ga, S/N: 498-00418	HiPER Ga, S/N: 457-02513
HiPER SR, S/N: 1064-16270	HiPER SR, S/N: 1209-11478
HiPER SR, S/N: 1209-10832	HiPER SR, S/N: 1209-14758
HiPER SR, S/N: 1209-18284	HiPER SR, S/N: 1209-18273

Spectra Precision Ranger 3 Data Collector

Two meter fixed height range pole for each Topcon GNSS HiPER receiver with attached bipod legs for stability.

### **2.2 Surveyed Point Details**

The check points were well distributed throughout the project areas. Five (5) photographs were taken of each point, looking north, east, south, west, and close on the point\ nail. A paint mark, mag nail, or spike was set at each location where possible. Some points were surveyed at photo\lidar identifiable locations.

Check point locations are detailed in the “Check Point Documentation Report” sheets attached to this report.

### **2.3 Surveyed Point Network**

Static GNSS survey methods were used during the field survey to observe the check points. The process for this method is detailed below.

LiDAR identifiable features were observed as NVA check points where available.

## **STATIC:**

Static (or Rapid-Static) Surveying is a method that Aero-Graphics has employed for many years to collect ground check points. A base station location is selected, usually at one or more control locations, and a GNSS receiver is left there for the duration of the day to complete the survey. The other GNSS receivers are then used as rovers to survey the other point locations.

The duration of the rover receivers will vary depending upon the distance from the base receiver. Normally the rover will not be further than 10 km from the base. The greater the distance the rover is from the base receiver, the longer the recording duration of the rover needs to be. Each rover location is surveyed for a minimum of 20 minutes or greater.

Static Surveying was used to collect the check points.

The individual point locations are post-processed after the field survey is completed. The GNSS data collected by the receivers is downloaded and processed in NovaTel's Waypoint GravNET software. The base station coordinates are used to differentially correct the other point's locations.

The NGS Online Positioning User Service (OPUS) was used to process the base station location data. A minimum of 2+ hours of GNSS data was collected for base stations to be processed through OPUS.

## **2.4 Field Procedures and Analysis**

All check points were observed once and 50% of the locations were surveyed a second time on a different day. Each observation for static surveying occupied the point for a minimum of 20 minutes in duration.

## **2.5 Data Processing Procedures**

The data from the static GNSS receivers was downloaded each day and a copy was uploaded to the office FTP server.

Base station observations were uploaded to OPUS only after the rapid ephemeris was available for processing. Whether the base station was located on an NGS monument or a at new point location, all GNSS data sets with a duration longer than two (2) hours were processed through OPUS.

The static surveyed points were post-processed using NovaTel's Waypoint software. Some of the static check point observations of less than two (2) hours in duration were processed with OPUS Rapid Static (OPUS-RS) as a QA\QC on the static post processing.

### 3. Final Coordinates

	MT SP NAD83(2011)	MT SP NAD83(2011)	ORTHO HGT
Point ID	NORTHING	EASTING	(Geoid18)
NVA	Meter	Meter	Meter
N101	499872.362	654367.601	997.040
N102	504776.514	655338.287	994.178
N103	508939.521	655862.682	994.273
N105	501081.479	674743.009	948.541
N107	509343.269	678260.826	933.086
N108	512658.115	681442.802	923.263
N109	517098.009	681346.931	921.221
N110	522048.710	681231.478	900.836
N111	480442.660	679625.922	877.457
N112	487894.892	681819.082	907.752
N114	510936.382	673356.619	936.361
N115	511344.407	665404.295	945.788
N116	511617.195	660831.475	960.541
N117	510799.640	658277.573	984.830
N118	514623.631	655798.927	982.995
N119	520156.058	655542.373	965.613
N120	509505.044	686304.898	930.413
N121	518678.655	671742.901	941.656
N122	515809.406	676575.175	933.331
N123	517267.182	660587.216	954.838
N124	527029.992	690858.356	889.149
N125	496104.628	678532.777	938.105



N201	512786.823	864952.938	831.372
N203	513213.107	874235.600	827.893
N204	513629.652	881828.310	770.425
N206	513953.006	891452.150	736.536
N207	525815.157	869092.667	822.012
N208	526353.024	879165.840	789.092
N209	526605.214	885132.490	738.642
N210	518944.093	891733.418	764.755
N212	517457.163	851954.562	833.384
N213	521314.533	851791.272	866.991
N214	525049.559	851404.318	929.961
N215	528210.315	850455.276	931.424
N216	531591.580	868840.763	828.822
N217	499472.941	886580.836	810.347
N218	498219.595	909980.575	760.194
N220	509644.285	910173.171	847.666
N221	514209.807	909946.560	846.222
N222	533536.300	908928.692	770.504
N223	528756.412	909223.782	808.168
N224	532925.724	932585.690	665.550
N225	524458.951	935771.901	645.036
N226	508467.857	937153.014	738.199
N227	503831.592	938636.506	801.966
N228	528572.931	949353.413	730.284
N229	534928.894	973480.700	731.092
N230	527990.436	966455.181	739.534
N231	520325.435	917619.722	772.993
N232	506413.743	918353.104	807.162
N234	519581.873	985015.462	720.737

N235	526685.290	994643.862	649.592
N236	526959.367	974455.125	751.659
N237	537626.552	988904.776	674.716
N238	509864.517	998608.763	624.648
N239	508650.760	990627.889	669.522
N240	508106.083	982613.942	701.757
N241	507450.433	974588.206	661.531
N242	499588.589	999301.716	611.754
N243	497280.150	989763.979	640.717
N244	496703.878	981752.922	665.592
N245	484931.828	974976.288	611.240
N246	485435.920	993262.812	615.698
N247	470001.654	966994.060	596.455
N248	475328.726	974754.122	626.209
N249	472606.219	983476.981	657.704
N250	473606.181	997445.468	672.899
N252	463324.691	988347.706	711.949
N254	462210.257	970717.521	627.736
N255	457248.165	967364.995	696.413
N256	456091.752	975936.441	649.176
N257	455865.469	994374.525	691.114
N258	442798.303	997116.497	590.939
N259	438062.226	996957.423	581.960
N260	442632.334	984521.941	614.110
N261	503209.749	870495.003	799.756
N262	515648.398	848059.505	880.624
N263	499560.278	857564.004	885.490
N264	499071.413	918784.659	802.693
N265	519265.564	865899.234	842.342

N266	518567.415	941811.494	730.886
N303	347498.525	1007352.237	721.813
N304	353827.498	997518.734	713.150
N305	342634.170	1004582.899	775.069
N306	348713.103	997848.323	778.301
N307	337886.134	1007787.594	827.382
N308	337625.196	1001470.976	770.084
N309	332440.280	996837.872	790.321
N310	331435.634	1006871.430	784.563
N311	319831.795	1002585.821	802.820
N312	313709.604	1007655.828	860.111
N313	316389.561	999382.880	852.339
N314	304330.774	1013176.506	851.969
N315	303156.245	998743.255	918.170
N317	293913.377	976731.839	757.972
N318	288630.525	975914.888	834.362
N319	286058.590	979537.379	835.001
N320	283766.802	997019.061	976.078
N321	297015.710	1001986.855	868.001
N323	289395.519	1007512.748	911.821
N324	286665.822	1001948.024	893.318
N325	281573.537	1012277.319	938.741
N330	296598.253	990502.813	879.118
N338	320286.044	1008987.502	826.148
<b>VVA</b>			
V102	491061.710	682440.979	895.975
V103	491590.182	671322.177	955.279
V104	497972.611	662453.395	969.540
V105	504458.448	667130.922	954.424
V106	510726.828	651034.556	1000.413
V107	518553.746	652343.045	984.690
V108	520578.277	677253.845	866.913

V109	524457.285	685763.500	912.214
V110	506302.962	684687.476	931.282
V202	517995.613	872793.050	797.849
V203	528282.713	869004.765	810.827
V204	499128.008	883372.466	796.372
V205	509614.497	865156.656	812.655
V206	497557.055	864129.121	865.376
V207	502093.394	860953.928	835.790
V208	510992.790	885976.849	796.419
V209	530987.305	891398.375	825.452
V210	505201.568	899816.782	702.319
V211	523065.798	909439.364	851.546
V212	525398.934	899121.023	748.980
V213	506452.860	922806.897	780.097
V214	531497.385	917139.267	826.324
V215	525805.490	930049.920	721.488
V216	500357.498	936436.510	761.121
V218	526482.259	941350.549	733.690
V220	534783.860	949166.697	748.943
V221	533970.937	958094.648	749.265
V223	530082.536	973651.668	790.000
V224	537030.898	981221.516	674.952
V226	537814.174	993434.153	667.837
V227	528436.375	984457.925	707.796
V228	523928.149	977945.499	768.323
V229	518605.433	993763.468	650.704
V230	513723.674	993790.638	642.362
V231	511369.082	985547.479	729.615
V232	502987.912	979675.317	690.131
V233	492599.574	991697.368	602.638
V234	479135.010	982105.623	607.172
V235	468430.788	991935.574	673.133
V236	467396.122	977208.246	645.396
V237	455203.601	962292.299	711.698

V238	452339.897	969392.087	697.774
V239	447564.874	989920.890	604.555
V240	453841.199	1000488.453	709.847
V241	518596.289	885569.920	768.740
V242	507476.903	872513.790	848.734
V243	479393.819	993729.372	664.076
V244	489963.061	976874.992	644.537
V245	449963.486	980681.605	646.727
V301	354078.007	1007996.261	687.086
V302	324196.403	1010355.925	842.456
V303	348430.726	994752.681	728.422
V304	327886.058	1001960.031	832.743
V305	342323.037	1001530.326	781.016
V307	340371.786	1011271.044	781.938
V308	312880.163	994966.718	863.265
V309	303970.493	1007615.170	846.644
V310	303055.858	993903.832	891.435
V311	298815.252	984422.010	867.159
V312	294132.193	982887.143	824.285
V314	297079.233	1008321.001	885.940
V315	286698.816	1013837.944	954.684

## 4. GNSS Observations

POINT ID	DATE SURVEYED	JULIAN DATE	Point ID	DATE RESURVEYED	JULIAN DATE
<b>NVA</b>					
N101	August 31, 2021	243	N101R	September 1, 2021	244
N102	August 31, 2021	243	N102R	September 1, 2021	244
N103	August 31, 2021	243	N103R	September 1, 2021	244
N105	September 4, 2021	247			
N107	September 2, 2021	245	N107R	September 3, 2021	246
N108	September 2, 2021	245	N108R	September 3, 2021	246
N109	September 2, 2021	245	N109R	September 3, 2021	246
N110	September 2, 2021	245	N110R	September 3, 2021	246
N111	September 4, 2021	247			
N112	September 4, 2021	247			
N114	September 2, 2021	245	N114R	September 3, 2021	246
N115	August 31, 2021	243	N115R	September 1, 2021	244
N116	August 31, 2021	243	N116R	September 1, 2021	244
N117	August 31, 2021	243	N117R	September 1, 2021	244
N118	August 31, 2021	243	N118R	September 1, 2021	244
N119	August 31, 2021	243	N119R	September 1, 2021	244
N120	September 2, 2021	245	N120R	September 3, 2021	246
N121	September 2, 2021	245			
N122	September 2, 2021	245	N122R	September 3, 2021	246
N123	August 31, 2021	243	N123R	September 1, 2021	244
N124	September 2, 2021	245			
N125	September 4, 2021	247			
N201	September 6, 2021	249			
N203	September 6, 2021	249			
N204	September 6, 2021	249	N204R	September 7, 2021	250
N206	September 6, 2021	249	N206R	September 7, 2021	250
N207	September 7, 2021	250			
N208	September 8, 2021	251			
N209	September 8, 2021	251			
N210	September 6, 2021	249	N210R	September 7, 2021	250
N212	September 5, 2021	248	N212R	September 6, 2021	249
N213	September 5, 2021	248	N213R	September 6, 2021	249
N214	September 5, 2021	248	N214R	September 6, 2021	249
N215	September 5, 2021	248	N215R	September 6, 2021	249
N216	September 7, 2021	250			
N217	September 7, 2021	250			
N218	September 9, 2021	252	N218R	September 10, 2021	253
N220	September 9, 2021	252	N220R	September 10, 2021	253
N221	September 9, 2021	252	N221R	September 10, 2021	253
N222	September 9, 2021	252	N222R	September 10, 2021	253

N223	September 9, 2021	252	N223R	September 10, 2021	253
N224	September 23, 2021	266			
N225	September 23, 2021	266			
N226	September 10, 2021	253			
N227	September 10, 2021	253			
N228	September 23, 2021	266	N228R	September 24, 2021	267
N229	September 24, 2021	267			
N230	September 24, 2021	267	N230R	September 25, 2021	268
N231	September 9, 2021	252	N231R	September 10, 2021	253
N232	September 9, 2021	252	N232R	September 10, 2021	253
N234	September 25, 2021	268	N234R	September 26, 2021	269
N235	September 25, 2021	268	N235R	September 26, 2021	269
N236	September 24, 2021	267			
N237	September 25, 2021	268			
N238	September 26, 2021	269			
N239	September 25, 2021	268			
N240	September 26, 2021	269			
N241	September 26, 2021	269			
N242	September 26, 2021	269	N242R	September 27, 2021	270
N243	September 26, 2021	269	N243R	September 27, 2021	270
N244	September 26, 2021	269	N244R	September 27, 2021	270
N245	September 27, 2021	270			
N246	September 27, 2021	270			
N247	September 28, 2021	271	N247R	September 29, 2021	272
N248	September 27, 2021	270			
N249	September 27, 2021	270	N249R	September 28, 2021	271
N250	September 27, 2021	270			
N252	September 28, 2021	271			
N254	September 28, 2021	271	N254R	September 29, 2021	272
N255	September 28, 2021	271	N255R	September 29, 2021	272
N256	September 28, 2021	271	N256R	September 29, 2021	272
N257	September 29, 2021	272	N257R	September 30, 2021	273
N258	September 29, 2021	272	N258R	September 30, 2021	273
N259	September 29, 2021	272	N259R	September 30, 2021	273
N260	September 29, 2021	272	N260R	September 30, 2021	273
N261	September 7, 2021	250			
N262	September 5, 2021	248	N262R	September 6, 2021	249
N263	September 7, 2021	250			
N264	September 9, 2021	252	N264R	September 10, 2021	253
N265	September 6, 2021	249			
N266	September 23, 2021	266			
N303	October 1, 2021	274			
N304	October 1, 2021	274			
N305	October 1, 2021	274	N305R	October 2, 2021	275
N306	October 1, 2021	274	N306R	October 2, 2021	275

N307	October 1, 2021	274			
N308	October 1, 2021	274	N308R	October 2, 2021	275
N309	October 1, 2021	274	N309R	October 2, 2021	275
N310	October 1, 2021	274			
N311	October 1, 2021	274	N311R	October 2, 2021	275
N312	October 1, 2021	274	N312R	October 2, 2021	275
N313	October 1, 2021	274	N313R	October 2, 2021	275
N314	October 2, 2021	275			
N315	October 2, 2021	275	N315R	October 3, 2021	276
N317	October 4, 2021	277			
N318	October 4, 2021	277			
N319	October 4, 2021	277			
N320	October 3, 2021	276			
N321	October 2, 2021	275	N321R	October 3, 2021	276
N323	October 3, 2021	276			
N324	October 3, 2021	276			
N325	October 3, 2021	276			
N330	October 4, 2021	277			
N338	October 1, 2021	274			
<b>VVA</b>					
V102	September 4, 2021	247			
V103	September 4, 2021	247			
V104	September 4, 2021	247			
V105	September 4, 2021	247			
V106	August 31, 2021	243	V106R	September 1, 2021	244
V107	August 31, 2021	243	V107R	September 1, 2021	244
V108	September 2, 2021	245	V108R	September 3, 2021	246
V109	September 2, 2021	245	V109R	September 3, 2021	246
V110	September 2, 2021	245	V110R	September 3, 2021	246
V202	September 6, 2021	249			
V203	September 7, 2021	250			
V204	September 7, 2021	250			
V205	September 6, 2021	249			
V206	September 7, 2021	250			
V207	September 7, 2021	250			
V208	September 6, 2021	249	V208R	September 7, 2021	250
V209	September 8, 2021	251			
V210	September 8, 2021	251			
V211	September 9, 2021	252	V211R	September 10, 2021	253
V212	September 8, 2021	251			
V213	September 9, 2021	252	V213R	September 10, 2021	253
V214	September 9, 2021	252	V214R	September 10, 2021	253
V215	September 23, 2021	266			
V216	September 10, 2021	253			



V218	September 23, 2021	266			
V220	September 23, 2021	266	V220R	September 24, 2021	267
V221	September 23, 2021	266	V221R	September 23, 2021	266
V223	September 24, 2021	267	V223R	September 25, 2021	268
V224	September 24, 2021	267			
V226	September 25, 2021	268			
V227	September 24, 2021	267	V227R	September 25, 2021	268
V228	September 24, 2021	267			
V229	September 26, 2021	269			
V230	September 25, 2021	268			
V231	September 26, 2021	269			
V232	September 26, 2021	269			
V233	September 26, 2021	269	V233R	September 27, 2021	270
V234	September 28, 2021	271			
V235	September 28, 2021	271			
V236	September 28, 2021	271			
V237	September 28, 2021	271	V237R	September 29, 2021	272
V238	September 28, 2021	271	V238R	September 29, 2021	272
V239	September 29, 2021	272	V239R	September 30, 2021	273
V240	September 29, 2021	272	V240R	September 30, 2021	273
V241	September 6, 2021	249	V241R	September 7, 2021	250
V242	September 7, 2021	250			
V243	September 27, 2021	270			
V244	September 27, 2021	270			
V245	September 29, 2021	272	V245R	September 30, 2021	273
V301	October 1, 2021	274			
V302	October 1, 2021	274			
V303	October 1, 2021	274			
V304	October 1, 2021	274	V304R	October 2, 2021	275
V305	October 1, 2021	274	V305R	October 2, 2021	275
V307	October 1, 2021	274			
V308	October 2, 2021	275			
V309	October 2, 2021	275			
V310	October 3, 2021	276			
V311	October 4, 2021	277			
V312	October 4, 2021	277			
V314	October 2, 2021	275	V314R	October 3, 2021	276
V315	October 3, 2021	276			

## 5. Check Point Comparison

Point ID	Point ID	N DELTA	E DELTA	Z DELTA
NVA	NVA	Meter	Meter	Meter
N101	N101R	0.289	0.004	-0.036
N102	N102R	0.189	-0.183	-0.023
N103	N103R	0.029	0.001	-0.002
N107	N107R	0.002	0.006	-0.011
N108	N108R	0.000	-0.013	-0.013
N109	N109R	0.009	-0.004	0.002
N110	N110R	0.000	0.000	0.000
N114	N114R	0.004	-0.013	-0.023
N115	N115R	0.011	-0.002	-0.002
N116	N116R	-0.004	0.004	-0.012
N117	N117R	0.004	-0.003	0.002
N118	N118R	0.000	0.010	-0.021
N119	N119R	0.000	0.000	0.000
N120	N120R	0.010	0.003	-0.011
N122	N122R	-0.003	0.015	-0.019
N123	N123R	-0.022	0.041	0.018
N204	N204R	0.005	0.027	0.022
N206	N206R	0.002	-0.003	0.001
N210	N210R	-0.009	0.003	0.009
N212	N212R	-0.012	-0.004	0.016
N213	N213R	0.005	-0.006	0.022
N214	N214R	-0.012	-0.013	0.027
N215	N215R	-0.033	-0.005	0.000
N218	N218R	0.001	0.008	-0.024
N220	N220R	0.003	0.006	0.002
N221	N221R	0.019	-0.006	0.006
N222	N222R	0.005	-0.008	-0.003
N223	N223R	0.010	0.007	-0.002
N228	N228R	0.006	-0.001	-0.047
N230	N230R	-0.001	-0.012	-0.014
N231	N231R	-0.008	-0.010	-0.005
N232	N232R	-0.004	-0.009	0.058
N234	N234R	0.005	0.004	-0.003
N235	N235R	-0.004	0.008	0.009
N242	N242R	-0.012	0.004	-0.003
N243	N243R	0.005	-0.019	0.000
N244	N244R	0.011	0.007	0.006
N247	N247R	0.000	-0.024	0.014
N249	N249R	-0.104	0.014	-0.013
N254	N254R	0.003	0.009	0.013

N255	N255R	0.006	0.000	0.004
N256	N256R	0.040	0.037	-0.001
N257	N257R	-0.001	-0.012	-0.004
N258	N258R	-0.009	0.006	0.002
N259	N259R	0.013	0.003	-0.006
N260	N260R	-0.011	0.008	-0.016
N262	N262R	0.002	-0.011	-0.005
N264	N264R	0.011	0.012	-0.016
N305	N305R	0.004	0.010	-0.014
N306	N306R	0.020	0.011	-0.040
N308	N308R	0.022	-0.007	-0.007
N309	N309R	0.010	-0.003	-0.008
N311	N311R	-0.001	0.003	-0.004
N312	N312R	0.000	0.002	0.017
N313	N313R	0.012	0.004	-0.021
N315	N315R	0.023	0.003	0.008
N321	N321R	0.012	0.004	0.008
<b>VVA</b>				
V106	V106R	0.025	0.013	-0.027
V107	V107R	0.013	0.002	-0.024
V108	V108R	0.016	-0.003	-0.017
V109	V109R	0.013	-0.022	-0.004
V110	V110R	0.002	-0.023	-0.021
V208	V208R	0.024	-0.005	0.005
V211	V211R	0.009	-0.002	-0.002
V213	V213R	0.002	-0.012	0.006
V214	V214R	0.010	0.024	-0.017
V220	V220R	-0.005	-0.035	-0.003
V221	V221R	0.010	-0.011	-0.204
V223	V223R	-0.002	-0.007	0.002
V227	V227R	-0.706	0.030	-0.018
V233	V233R	0.009	-0.042	-0.011
V237	V237R	0.003	-0.009	0.028
V238	V238R	-0.006	-0.004	0.004
V239	V239R	-0.021	0.015	0.001
V240	V240R	0.008	0.003	-0.017
V241	V241R	0.002	0.003	0.017
V245	V245R	0.036	0.006	0.011
V304	V304R	0.000	-0.007	-0.008
V305	V305R	0.037	-0.004	-0.027
V314	V314R	0.002	0.012	0.017

## **6. Deliverables**

Along with this report, the deliverables to Dewberry Engineers include the Check Point Documentation Report sheets and an Excel Spreadsheet including all check point data.