aero-graphics

Aerial LiDAR 2020 Ground Control Survey Report

For

Dewberry Engineers Inc.

November 2020

Aero-Graphics, Inc.

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1. Introduction

1.1 Project Summary:

Aero-Graphics Inc. is under contract to Dewberry Engineers to provide surveyed ground control points to support the acquisition of aerial lidar for 9,170 sq. miles in eastern Utah. The survey field work was conducted August 5, 2020 thru November 16, 2020. The ground control point locations were distributed across the project areas as evenly as the terrain would allow.

Existing NGS control points were located and surveyed as part of the field work to verify the accuracy of survey. The results are shown in section 2.4 of this report.

As a verification of field procedures, fifteen (15) of the fifty (50) ground control points surveyed were re-observed with the results shown in section 5 of this report.

The final horizontal coordinates are referenced to NAD83(2011) UTM Zone 12 meters, EPSG Code 6341. 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:

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Surveying Manager
Aero-Graphics, Inc
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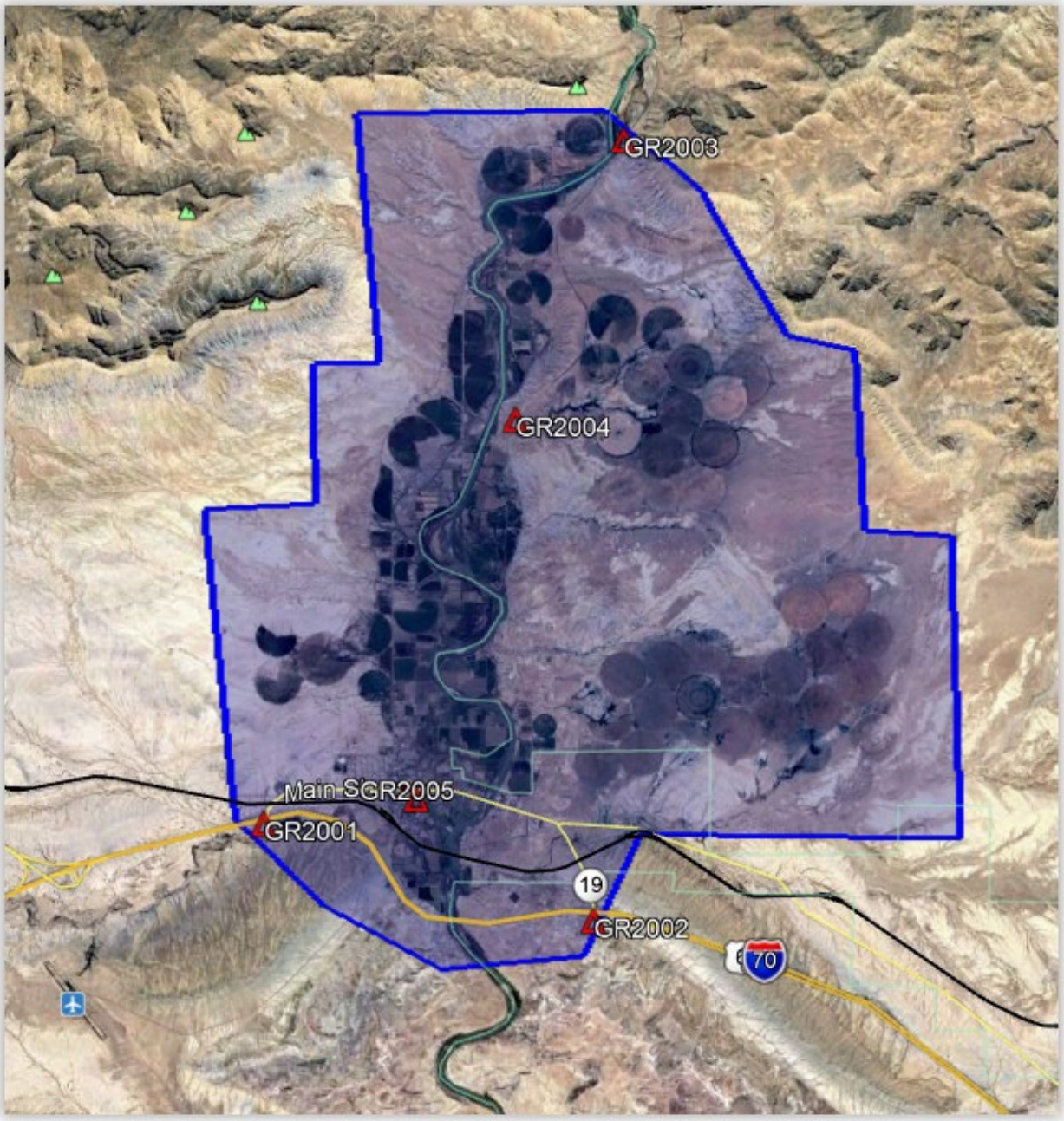
Salt Lake City, Utah 84115
801-487-3273
801-891-2779 direct

Utah Licensed Professional Land Surveyor #7643406, exp date 3/31/2021
Colorado Licensed Professional Land Surveyor #PLS-0038527, exp date 10/31/2021
ASPRS Certified Photogrammetrist, exp date 9/17/2023

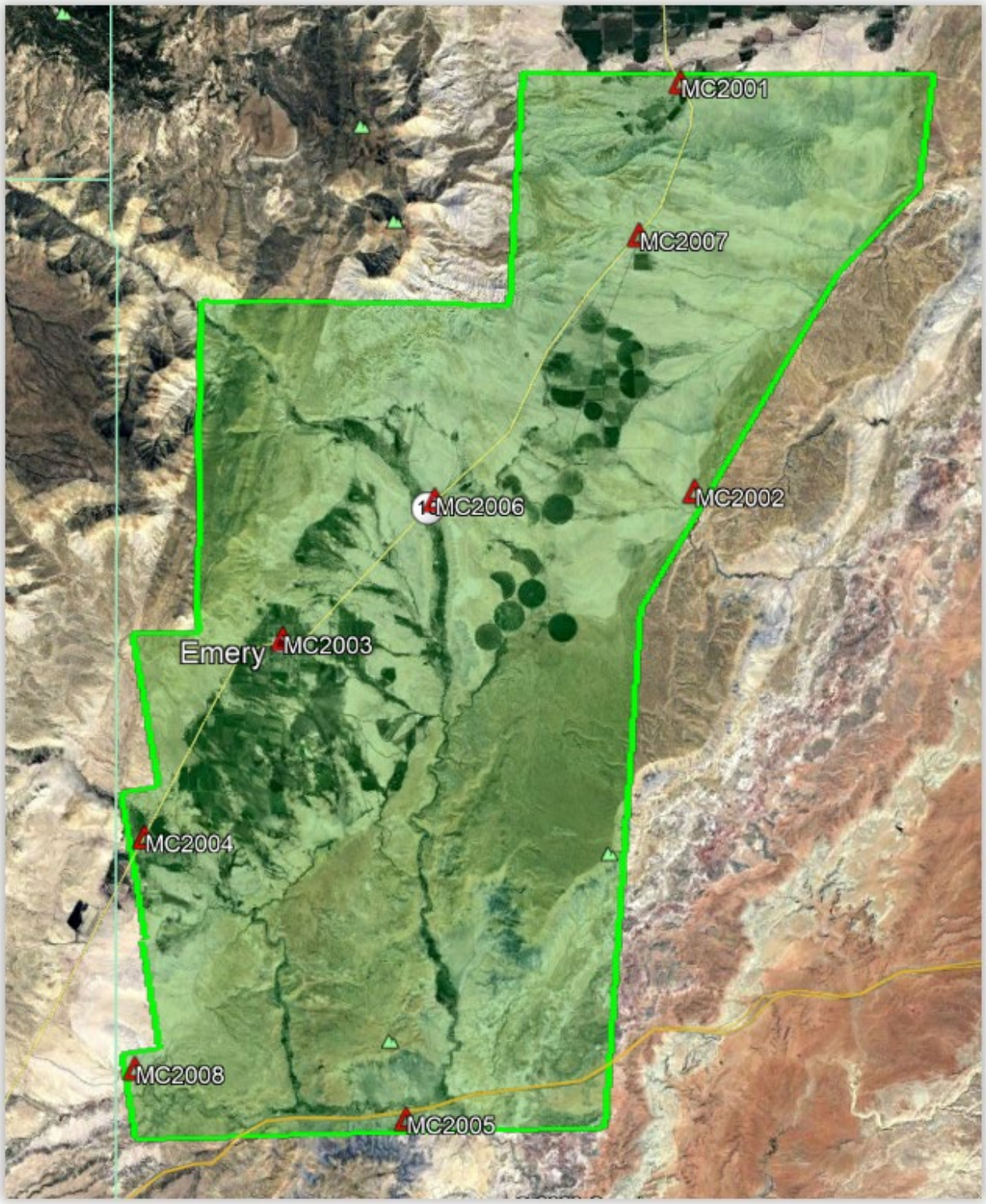
1.3 Project Areas:

Flaming Gorge (QL1)

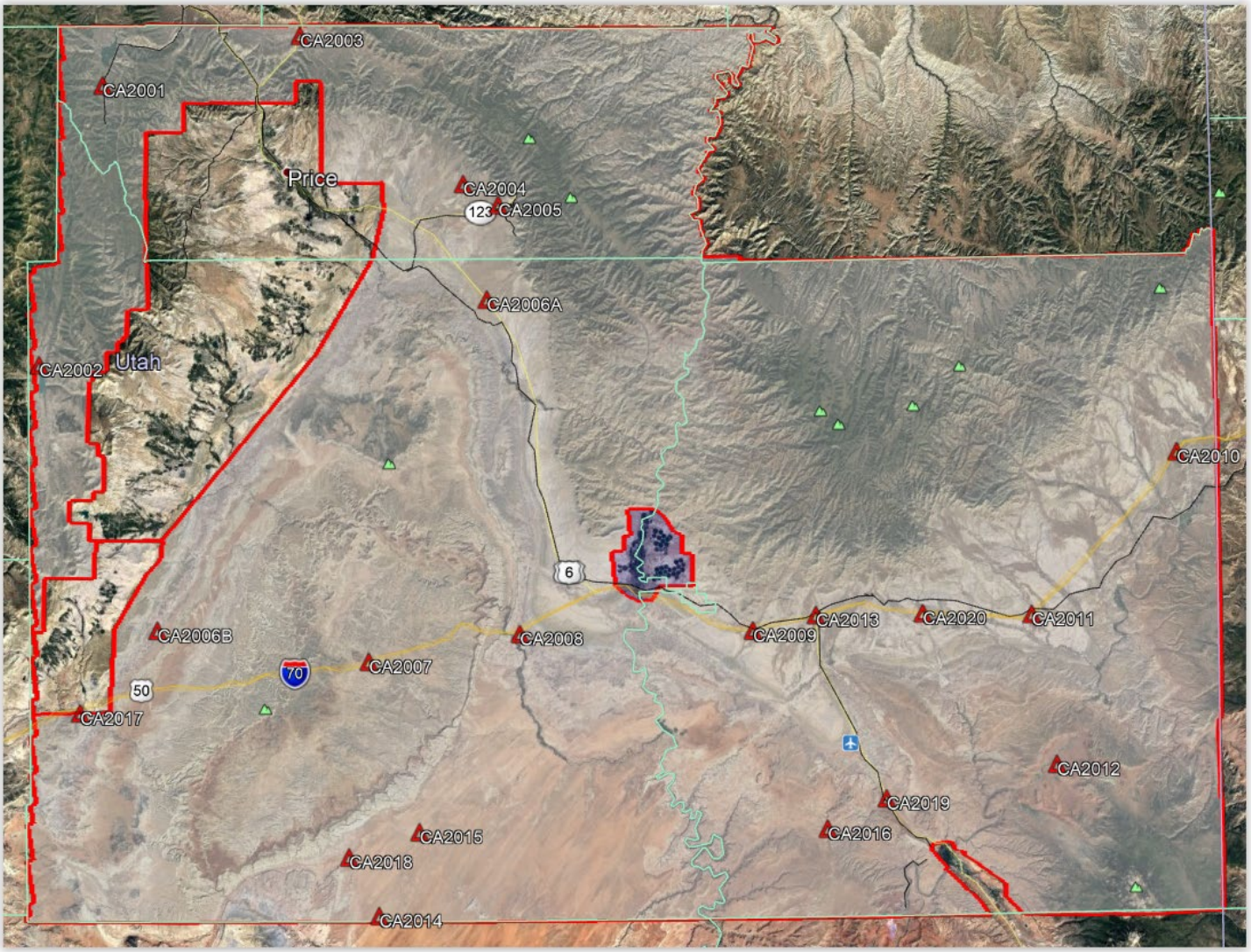
Green River (QL1)



Muddy Creek (QL1)



Carbon, Emery, Grand Counties



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 50 ground control 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 mag nail or spike was set at each location where possible. Some points were surveyed at photo\lidar identifiable locations.

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

2.3 Surveyed Point Network

Multiple methods were used during the ground survey to observe the control points. Each method is detailed below.

LiDAR identifiable features or surveyor set\painted targets were used as control points.

STATIC:

Static (or Rapid-Static) Surveying is a method that Aero-Graphics has employed for many years to collect ground control 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 control 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.

THE UTAH REFERENCE NETWORK (VRS):

The Utah Reference Network Virtual Reference Station (VRS) was used to survey control points where a cell phone signal was available. The field surveyor's data collector and roving GNSS receiver utilized the real-time broadcast positional correction to observe and survey the points.

The maximum baseline restriction for the roving receiver is 70km while using this method.

2.4 Field Procedures and Analysis

All control points were observed once and 30% of the locations were surveyed a second time on a different day or with 4 hours between observations. Each observation for static surveying occupied the point for a minimum of 20 minutes in duration. Each observation with the VRS occupied the points for a minimum of three (3) minutes in duration. All observations were on different days with one exception where the monument was surveyed with VRS and static on the same day.

Fourteen (14) NGS monuments were surveyed as part of the field procedures. Monuments were researched and located prior to field work commencing. While the highest order of monuments was preferred for surveying, this area does not have an abundance to pick from. Monuments

that were surveyed were chosen for accessibility and probable existence. Although all results are shown below, some are less than desirable due to imprecise data from the NGS datasheets. All surveyed GNSS data has been provided to the NGS to assist with updating these monuments.

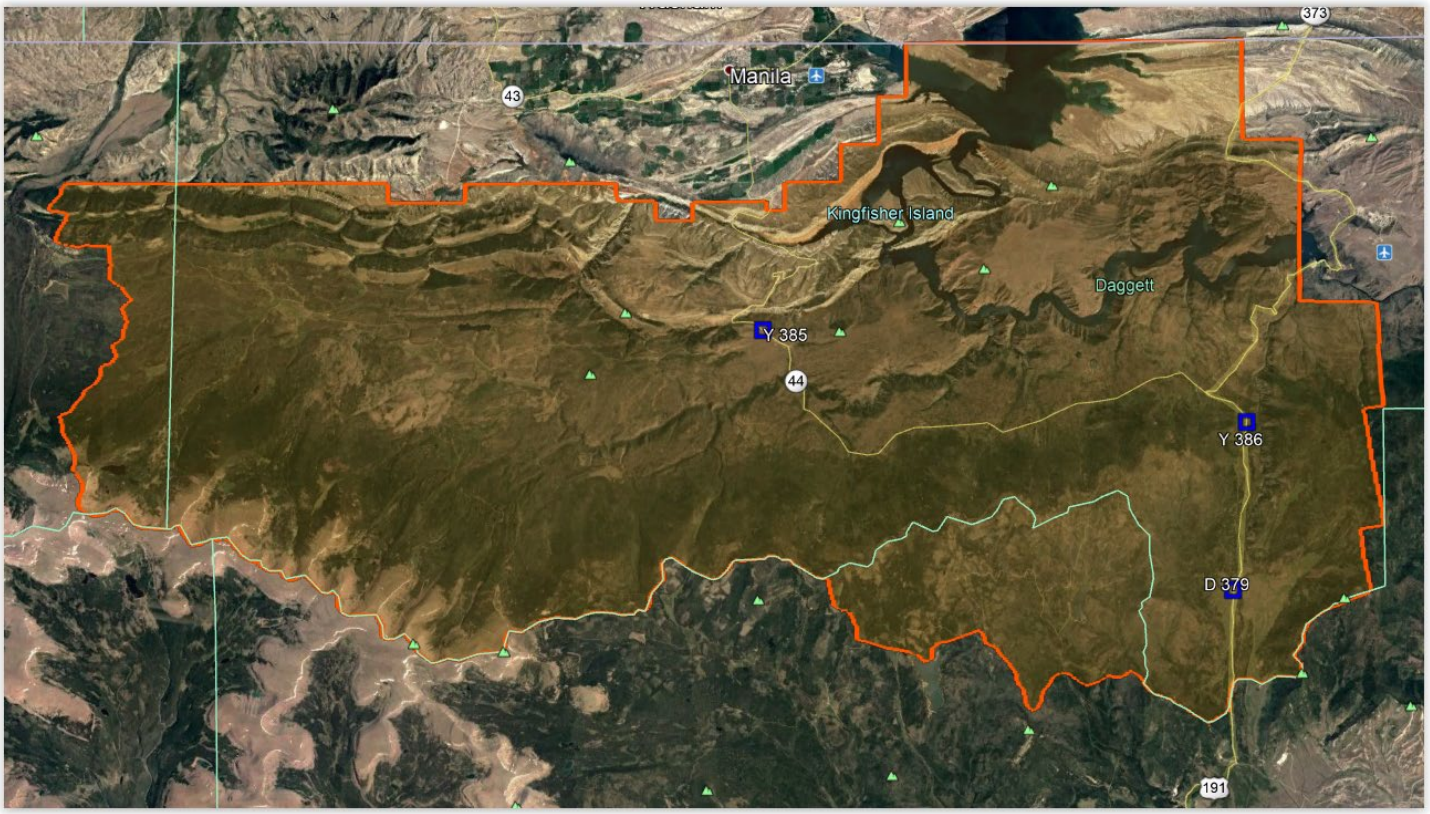
The NGS monuments were occupied to provide a QC/QA for the survey methods used. Ten (10) of the monuments were occupied twice, seven (7) of the monuments were occupied three times, and 1 monument was occupied four times. The observed values and data sheet values are shown below along with the differences. The latitude and longitude from the data sheets were converted to UTM zone 12 meters.

NGS Monuments

POINT		OBSERVED VALUES			DATASHEET VALUES			DIFFERENCE		
ID	NGS PID	NORTHING	EASTING	ELEVATION	NORTHING	EASTING	ELEVATION	NORTHING	EASTING	VERTICAL
44FMK	KM0398	4341055.075	662775.106	1440.426	4341056.165	662772.831	1440.334	-1.090	2.275	0.092
44FMK-1	KM0398	4341055.068	662775.117	1440.418	4341056.165	662772.831	1440.334	-1.097	2.286	0.084
44FMK-2	KM0398	4341055.078	662775.109	1440.400	4341056.165	662772.831	1440.334	-1.087	2.278	0.066
72FMK	KM0430	4324357.325	647686.329	1395.379	4324358.934	647695.630	1395.312	-1.609	-9.301	0.067
72FMK-1	KM0430	4324357.336	647686.330	1395.382	4324358.934	647695.630	1395.312	-1.598	-9.300	0.070
BOYD	JN0392	4314817.474	576947.927	1317.218	4314817.488	576947.905	1317.300	-0.014	0.022	-0.082
BOYD-VRS1	JN0392	4314817.505	576947.920	1317.218	4314817.488	576947.905	1317.300	0.017	0.015	-0.082
BOYD-VRS2	JN0392	4314817.478	576947.919	1317.233	4314817.488	576947.905	1317.300	-0.010	0.014	-0.067
C41	KN0222	4346820.698	487026.428	1891.903	4346811.883	487036.884	1891.834	8.815	-10.456	0.069
CISCO	JM0489	4313638.010	647041.201	1356.867	4313638.030	647041.189	1356.815	-0.020	0.012	0.052
CISCO-1	JM0489	4313638.000	647041.198	1356.860	4313638.030	647041.189	1356.815	-0.030	0.009	0.045
D379	LN0468	4516540.994	629058.015	2489.041	4516509.511	629062.796	2488.892	31.483	-4.781	0.149
HORSE	KN0487	4363459.122	550035.126	1705.073	4363459.101	550035.088	1704.100	0.021	0.038	0.973
HORSE-1	KN0487	4363459.126	550035.139	1705.099	4363459.101	550035.088	1704.100	0.025	0.051	0.999
HORSE-VRS	KN0487	4363459.110	550035.127	1705.062	4363459.101	550035.088	1704.100	0.009	0.039	0.962
J18	JM0287	4313524.465	610474.871	1549.417	4313530.051	610472.310	1549.256	-5.586	2.561	0.161
K112	JN0110	4251626.787	526667.822	1349.310	4251626.806	526667.813	1349.299	-0.019	0.009	0.011
Q18	JM0293	4303759.957	603115.146	1416.787	4303761.683	603111.177	1416.619	-1.726	3.969	0.168
Q18-1	JM0293	4303759.975	603115.101	1416.831	4303761.683	603111.177	1416.619	-1.708	3.924	0.212
R40	KN0249	4322207.534	488670.713	1820.101	4322208.464	488675.824	1820.046	-0.930	-5.111	0.055
R40-1	KN0249	4322207.536	488670.709	1820.107	4322208.464	488675.824	1820.046	-0.928	-5.115	0.061
R40-VRS	KN0249	4322207.536	488670.711	1820.052	4322208.464	488675.824	1820.046	-0.928	-5.113	0.006
VVCEM	AI5829	4377903.354	551489.032	1957.946	4377903.359	551489.033	1957.929	-0.005	-0.001	0.017
VVCEM-1	AI5829	4377903.359	551489.042	1957.959	4377903.359	551489.033	1957.929	0.000	0.009	0.030
VVCEM-2	AI5829	4377903.350	551489.041	1957.952	4377903.359	551489.033	1957.929	-0.009	0.008	0.023
Y385	LN0441	4527154.531	609020.782	2343.157	4527157.844	609019.346	2343.096	-3.313	1.436	0.061
Y385-1	LN0441	4527154.532	609020.780	2343.143	4527157.844	609019.346	2343.096	-3.312	1.434	0.047
Y385-2	LN0441	4527154.534	609020.779	2343.146	4527157.844	609019.346	2343.096	-3.310	1.433	0.050
Y385-3	LN0441	4527154.533	609020.777	2343.157	4527157.844	609019.346	2343.096	-3.311	1.431	0.061
Y386	LN0463	4523635.617	629608.308	2414.070	4523582.581	629595.129	2414.015	53.036	13.179	0.055
Y386-1	LN0463	4523635.613	629608.298	2414.105	4523582.581	629595.129	2414.015	53.032	13.169	0.090
Y386-2	LN0463	4523635.624	629608.280	2414.072	4523582.581	629595.129	2414.015	53.043	13.151	0.057

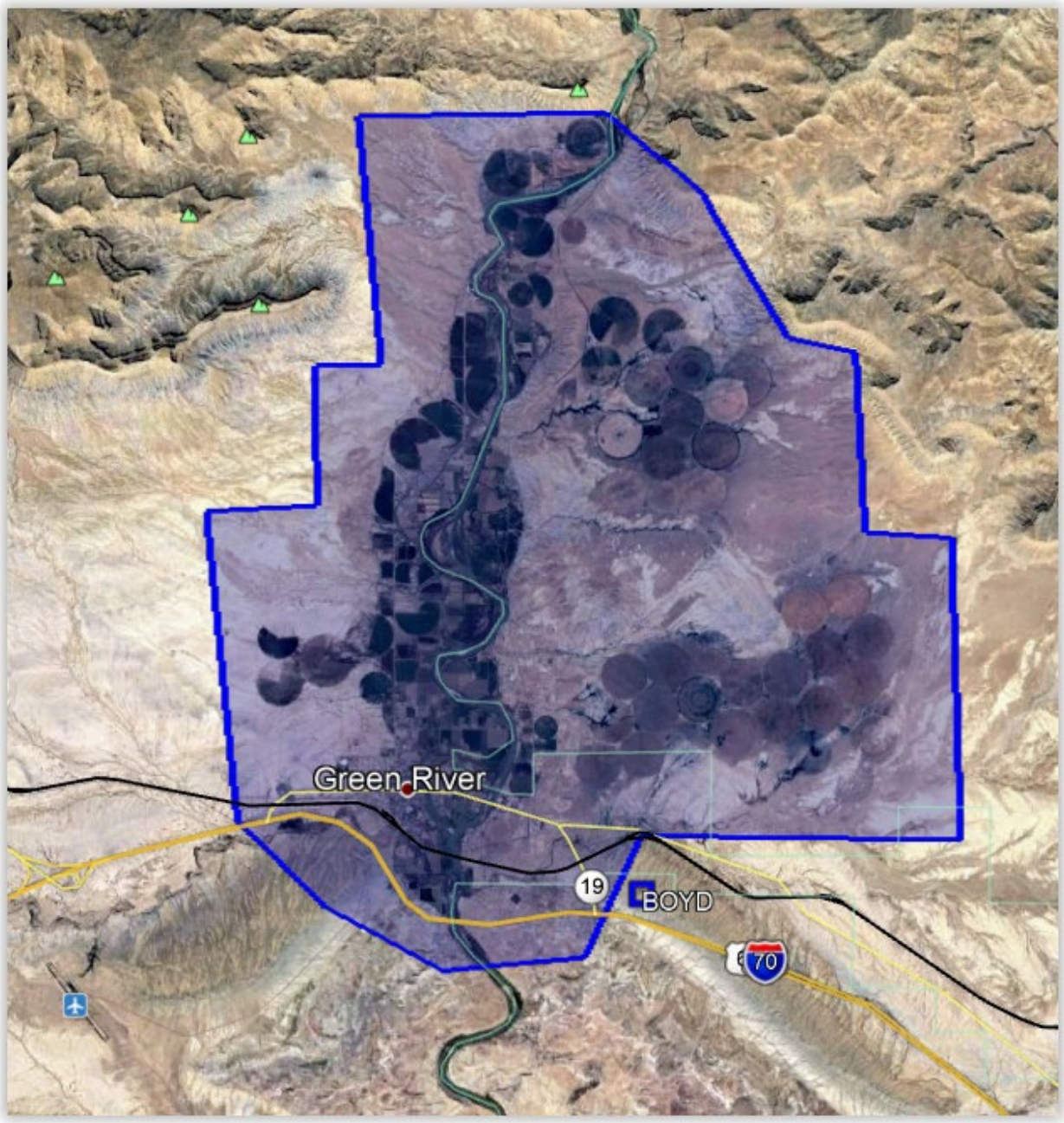
NGS Monuments

Flaming Gorge



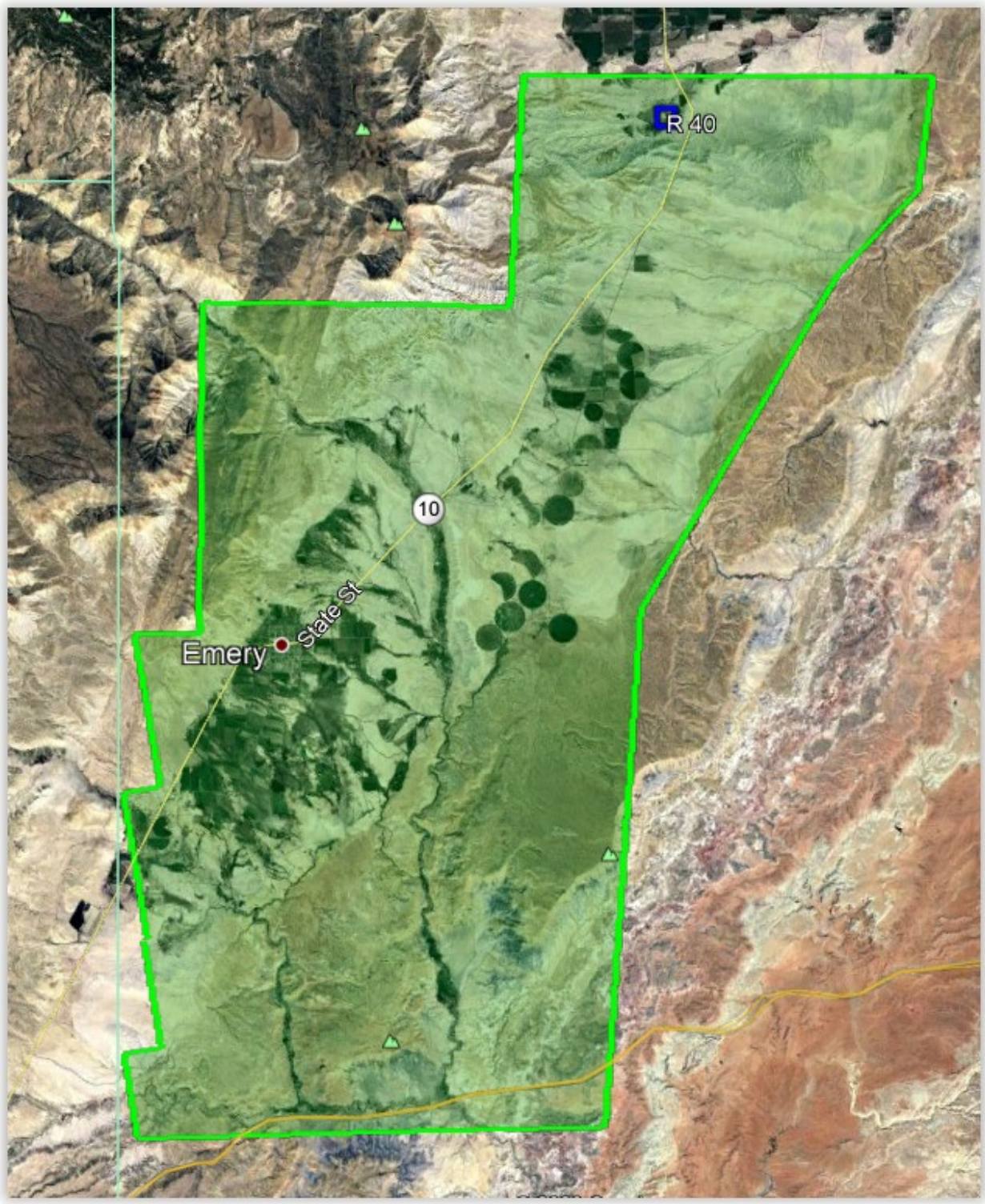
NGS Monuments

Green River



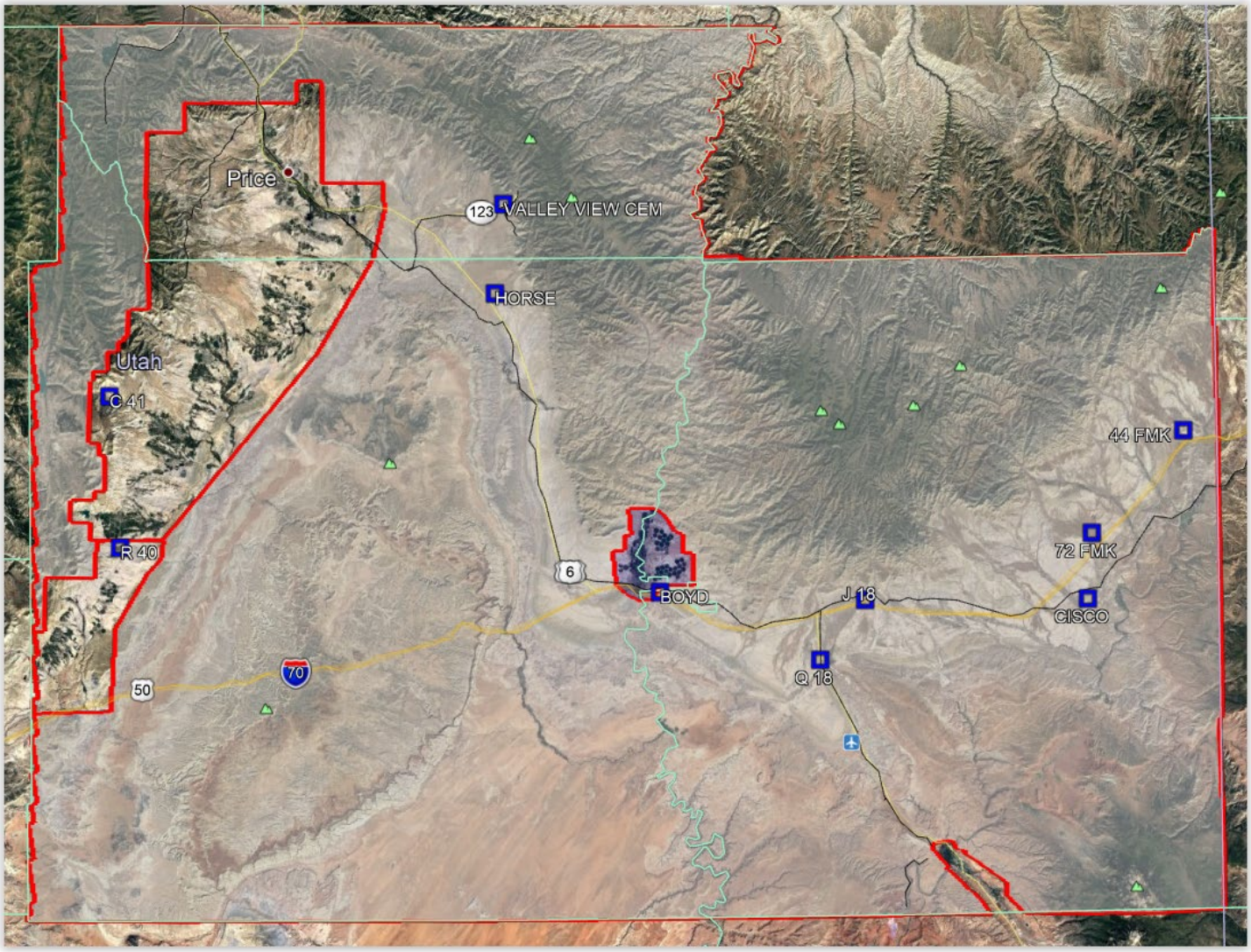
NGS Monuments

Muddy Creek



NGS Monuments

Carbon, Emery, Grand Counties



2.5 Data Processing Procedures

The data from the data collector for the points that were surveyed with VRS was downloaded each day and emailed to the office. 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 ephemeras 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 control 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.

After receiving the control points surveyed with the VRS system from the field crew, the points were converted to UTM zone 12 meters coordinates and merged with the static surveyed control points.

3. Final Coordinates

Point ID	NAD83(2011) UTM12 NORTHING Meter	NAD83(2011) UTM12 EASTING Meter	ORTHO HGT (Geoid18) Meter	TYPE
CA2001	4397408.763	486153.973	2345.831	GCP
CA2002	4350613.635	476459.610	2138.463	GCP
CA2003	4405426.122	518425.977	2173.894	GCP
CA2004	4379465.043	542874.220	1792.761	GCP
CA2005	4377797.159	550811.893	1937.344	GCP
CA2006	4362499.485	548873.091	1660.870	GCP
CA2007	4303707.057	529545.031	2018.168	GCP
CA2007-CK	4303707.028	529545.036	2018.204	GCP
CA2008	4308132.007	554145.536	1299.616	GCP
CA2008-CK	4308131.998	554145.517	1299.631	GCP
CA2009	4308634.256	592284.358	1409.959	GCP
CA2009-CK	4308634.259	592284.430	1409.965	GCP
CA2010	4337692.069	661830.850	1485.067	GCP
CA2011	4311224.851	637970.699	1360.161	GCP
CA2011-CK	4311224.848	637970.699	1360.157	GCP
CA2012	4285236.798	640298.792	1263.461	GCP
CA2013	4311131.002	602550.458	1489.513	GCP
CA2014	4263075.022	531417.128	1456.967	GCP
CA2015	4275885.766	537694.666	1515.308	GCP
CA2016	4276406.811	604475.528	1669.606	GCP
CA2017	4295301.865	482155.870	1739.920	GCP
CA2018	4270812.924	525375.629	1499.104	GCP
CA2019	4281261.773	614137.234	1372.948	GCP
CA2020	4311394.050	620072.800	1473.297	GCP
CA2020-CK	4311394.054	620072.808	1473.261	GCP
CA2021	4308294.607	495492.804	1831.550	GCP
FG2001	4532147.480	609219.125	2026.731	GCP
FG2001-CK	4532147.490	609219.131	2026.720	GCP
FG2002	4527835.908	588501.448	2751.863	GCP
FG2003	4522108.363	614162.924	2463.603	GCP
FG2003-CK	4522108.365	614162.933	2463.609	GCP
FG2004	4514194.071	628996.635	2505.973	GCP
FG2004-CK	4514194.076	628996.628	2505.972	GCP
FG2005	4535676.350	621489.697	1854.857	GCP
FG2005-CK	4535676.351	621489.680	1854.777	GCP
FG2006	4529975.212	630733.485	1850.765	GCP
FG2006-CK	4529975.230	630733.464	1850.811	GCP
FG2007	4528978.389	582733.309	2896.228	GCP

FG2008	4525388.314	597747.491	2595.032	GCP
FG2008-CK	4525388.315	597747.483	2594.987	GCP
FG2009	4525689.936	626733.519	2254.439	GCP
FG2010	4525945.605	604552.854	2528.508	GCP
FG2010-CK	4525945.621	604552.857	2528.509	GCP
FG2011	4515817.708	620979.234	2786.508	GCP
FG2011-CK	4515817.727	620979.226	2786.521	GCP
FG2012	4535451.403	628758.630	1999.553	GCP
FG2012-CK	4535451.429	628758.614	1999.522	GCP
GR2001	4315973.933	570263.478	1249.629	GCP
GR2002	4314286.687	576099.739	1265.184	GCP
GR2002-V1	4314290.321	576099.910	1265.216	GCP
GR2002-V2	4314277.358	576099.178	1265.285	GCP
GR2003	4328015.595	576505.889	1255.433	GCP
GR2004	4323889.926	575453.866	1288.737	GCP
GR2004-V1	4323886.864	575450.366	1288.727	GCP
GR2004-V2	4323892.454	575456.515	1288.844	GCP
GR2005	4316417.475	572957.820	1238.355	GCP
MC2001	4323101.600	489067.291	1803.762	GCP
MC2002	4312227.013	489427.319	1885.530	GCP
MC2003	4308366.918	478513.018	1904.040	GCP
MC2003-CK	4308366.910	478513.019	1904.069	GCP
MC2004	4303190.208	474841.272	1837.753	GCP
MC2005	4295714.549	481716.863	1739.144	GCP
MC2006	4312138.980	482700.318	1902.681	GCP
MC2007	4318982.263	487967.298	1903.844	GCP
MC2008	4297061.004	474616.959	1829.544	GCP

4. GNSS Observations

POINT ID	DATE SURVEYED	JULIAN DATE	POINT ID	RESURVEYED DATE	JULIAN DATE
CA2001	September 10, 2020	253			
CA2002	September 21, 2020	264			
CA2003	September 5, 2020	248			
CA2004	September 19, 2020	262			
CA2005	September 11, 2020	254			
CA2006	September 19, 2020	262			
CA2007	October 31, 2020	304	CA2007-CK	November 5, 2020	309
CA2008	October 30, 2020	303	CA2008-CK	November 5, 2020	309
CA2009	October 13, 2020	286	CA2009-CK	November 7, 2020	311
CA2010	August 20, 2020	232			
CA2011	August 24, 2020	236	CA2011-CK	August 24, 2020	236
CA2012	October 11, 2020	284			
CA2013	October 13, 2020	286			
CA2014	November 3, 2020	307			
CA2015	November 3, 2020	307			
CA2016	November 2, 2020	306			
CA2017	September 13, 2020	256			
CA2018	November 3, 2020	307			
CA2019	November 2, 2020	306			
CA2020	August 25, 2020	237	CA2020-CK	August 26, 2020	238
CA2021	November 3, 2020	307			
GR2001	October 10, 2020	283			
GR2002	October 10, 2020	283			
GR2002-V1	October 10, 2020	283			
GR2002-V2	October 10, 2020	283			
GR2003	October 10, 2020	283			
GR2004	October 10, 2020	283			
GR2004-V1	October 10, 2020	283			
GR2004-V2	October 10, 2020	283			
GR2005	October 10, 2020	283			
MC2001	September 12, 2020	255			
MC2002	September 12, 2020	255			
MC2003	September 12, 2020	255	MC2003-CK	September 13, 2020	256
MC2004	September 12, 2020	255			
MC2005	September 13, 2020	256			
MC2006	September 12, 2020	255			
MC2007	September 12, 2020	255			
MC2008	September 12, 2020	255			
FG2001	August 8, 2020	220	FG2001-CK	August 12, 2020	224
FG2002	August 10, 2020	222			

FG2003	August 7, 2020	219	FG2003-CK	August 12, 2020	224
FG2004	August 5, 2020	217	FG2004-CK	August 12, 2020	224
FG2005	August 6, 2020	218	FG2005-CK	August 12, 2020	224
FG2006	August 6, 2020	218	FG2006-CK	August 12, 2020	224
FG2007	August 10, 2020	222			
FG2008	August 9, 2020	221	FG2008-CK	August 12, 2020	224
FG2009	August 7, 2020	219			
FG2010	August 8, 2020	220	FG2010-CK	August 12, 2020	224
FG2011	August 5, 2020	217	FG2011-CK	August 12, 2020	224
FG2012	August 6, 2020	218	FG2012-CK	August 12, 2020	224

5. Control Point Comparison

		N DELTA	E DELTA	Z DELTA
Point ID	**Point ID**	**Meter**	**Meter**	**Meter**
CA2007	CA2007-CK	0.029	-0.005	-0.036
CA2008	CA2008-CK	0.009	0.019	-0.015
CA2009	CA2009-CK	-0.003	-0.072	-0.006
CA2011	CA2011-CK	0.003	0.000	0.004
CA2020	CA2020-CK	-0.004	-0.008	0.036
FG2001	FG2001-CK	-0.010	-0.006	0.011
FG2003	FG2003-CK	-0.002	-0.009	-0.006
FG2004	FG2004-CK	-0.005	0.007	0.001
FG2005	FG2005-CK	-0.001	0.017	0.080
FG2006	FG2006-CK	-0.018	0.021	-0.046
FG2008	FG2008-CK	-0.001	0.008	0.045
FG2010	FG2010-CK	-0.016	-0.003	-0.001
FG2011	FG2011-CK	-0.019	0.008	-0.013
FG2012	FG2012-CK	-0.026	0.016	0.031
MC2003	MC2003-CK	0.008	-0.001	-0.029

6. Deliverables

Along with this report, the deliverables to Dewberry Engineers includes the Control Point Documentation Report sheets and an Excel Spreadsheet including all control point data.