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C. Prévost, R. Fernandes, F. Canisius

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Ground Control Point Acquisition for Acadia Forest, New Brunswick, during winter 2016, in Support of Canada Centre for Mapping and Earth Observation Snow Depth from Unmanned Aerial Vehicle Activities

Note:
This document, strictly orientated toward high precision GPS survey results, falls within the framework of a much larger project aiming at mapping snow cover depth (winter and spring) for flood mapping using Unmanned Aerial Vehicle (UAV-drone). The site is located in the Acadia Forest near Fredericton, New Brunswick.

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Abstract

Natural Resources Canada has the mandate of providing essential geographic information. An improved knowledge of our physical environment represents one of the basis of this mandate. This knowledge is generally associated with the environment as it appears in summer. However, snow cover is present over most of Canada for a varying period of time during the year. Managers, engineers and researchers require up to date information with regard to snow: Its coverage, depth and water content. These elements are difficult to accurately measure and any initiative in this area must use a stepwise approach; mapping the snow surface extent, and monitoring of snow melt being the first steps of this process. Flood monitoring / forecasting practitioners also require up to date information about snow cover, specifically in the spring season.

For the last few years, versatile and low cost Unmanned Aerial Vehicles (UAV's), also called drones, allow for multitemporal aerial surveys of snow cover to extract various representations of the snow extent. To obtain products geographically located with precision, it is required to establish ground control points (reference points) which are visible to the UAV camera, and for which geographic location is known with precision. To fulfill this need, a high precision Global Positioning System (GPS) survey is required.

A case study was undertaken in a test site of a few tens of hectares located in the Acadia Forest near Fredericton, New Brunswick. This document describes in detail the method and results of the GPS survey required for the geographic rectification of the numerous photographs acquired by the UAV's within the scope of this project.

Keywords: GPS survey, UAV, UAV target, Acadia Forest.

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Summary of Results

Table i Summary of Results – GPS positions - UTM projection

GCP #		Northing (metre)	Easting (metre)	Error Ellipse[2] @95% (cm)		Height[1] Ellipsoïdal (metre)	Height[1] Orthometric (metre)
UTM Zone 20				North	East		CGVD28
NAD-83-CSRS							
Site A GCP-1		5093702.761	706970.655	2.1	6.8	11.941	33.807
Site A GCP-2		5093733.502	707005.814	2.0	6.3	11.228	33.093
Site A GCP-3 avrg		5093762.504	707044.191	2.0	6.2	10.073	31.937
Site A GCP-4		5093720.754	707108.749	2.3	6.4	6.625	28.488
Site B GCP-1		5093806.322	707169.568	1.1	2.4	6.733	28.594
Site B GCP-2		5093739.042	707217.232	1.7	5.3	0.760	22.621
Site B GCP-3		5093874.287	707283.873	1.6	4.5	5.836	27.694
Site B GCP-4		5093970.592	707233.297	1.2	2.5	9.222	31.080
Site B GCP-5		5093868.607	707188.183	1.5	4.6	8.818	30.678
Site C GCP-1		5094033.735	707201.748	1.5	4.3	11.961	33.819
Site C GCP-2		5093992.106	707134.322	2.0	6.1	12.409	34.269

[1]: Height at Antenna Reference Point (ARP)

[2]: Based on 30 second acquisition interval

Table ii Summary of Results – GPS positions - Latitude and Longitude

GCP #		Session duration	Latitude (deg-mn-sec)	Longitude (deg-mn-sec)	Height[1] Ellipsoïdal (metre)	Height[1] Orthometric (metre)
Site A GCP-1		4h. 39m.	45º 57’ 56.4007’’	-66º 19’ 43.3083’’	11.941	33.807
Site A GCP-2		4h. 37m.	45º 57’ 57.3575’’	-66º 19’ 41.6286’’	11.228	33.093
Site A GCP # 3		Multiple	45º 57’ 58.2545’’	-66º 19’ 39.8022’’	10.073	31.937
Site A GCP-4		4h. 13m.	45º 57’ 56.8331’’	-66º 19’ 36.8709’’	6.625	28.488
Site B GCP-1		13h. 9m.	45º 57’ 59.5365’’	-66º 19’ 33.9148	6.733	28.594
Site B GCP-2		5h. 42m.	45º 57’ 57.3071’’	-66º 19’ 31.8074’’	0.760	22.621
Site B GCP-3		5h. 56m.	45º 58’ 01.6120’’	-66º 19’ 28.5035’’	5.836	27.694
Site B GCP-4		11h. 45m	45º 58’ 04.7840’’	-66º 19’ 30.7008’’	9.222	31.080
Site B GCP-5		6h. 6m.	45º 58’ 01.5322’’	-66º 19’ 32.9537’’	8.818	30.678
Site C GCP-1		6h. 28m.	45º 58’ 06.8620’’	-66º 19’ 32.0667’’	11.961	33.819
Site C GCP-2		5h. 51m.	45º 58’ 05.5879’’	-66º 19’ 35.2612’’	12.409	34.269

[1]: Height at Antenna Reference Point (ARP)

1) Introduction

Natural Resources Canada has the mandate of providing essential geographic information. An improved knowledge of our physical environment represents one of the basis of this mandate. This knowledge is generally associated with the environment as it appears in summer. However, snow cover is present over most of Canada for a varying period of time during the year. Managers, engineers and researchers require up to date information with regard to snow: Its coverage, depth and water content. These elements are difficult to accurately measure and any initiative in this area must use a stepwise approach; mapping the snow surface extent, and monitoring of snow melt being the first steps of this process. Flood monitoring / forecasting practitioners also require up to date information about snow cover, specifically in the spring season.

For the last few years, versatile and low cost Unmanned Aerial Vehicle (UAV's), also called drones, allow for multitemporal aerial surveys of snow cover to extract various representations of the snow extent. One of the great capabilities of these tools is that they can acquire photographs in such a way that it is possible to produce an orthorectified mosaïc of the area as well as a digital elevation model, both from the same survey flight. A research project on that topic was undertaken by researchers at the Canada Centre for Mapping and Earth Observation of the Earth Science Sector of NRCAN. The case study was undertaken in a test site of a few tens of hectares located in the Acadian forest near Fredericton, New Brunswick.

To obtain products geographically located with precision, it is required to establish ground control points (reference points) which are visible to the UAV camera, and for which geographic location is known with precision. To fulfill this need, a high precision GPS survey is required.

This document, describes in detail the method and results of the GPS survey required for the geographic rectification of the numerous photographs acquired by the UAV'S within the scope of this project.

A high precision GPS survey campaign was undertaken between January 19 and 21, 2016 in the Acadia Forest in New-Brunswick. Its purpose was to establish the position of manmade ground targets with regards to imagery acquired by UAV surveys, to be conducted during the winter - spring period of 2016.

The positions (latitude-longitude-altitude) of the points were all established based on long (~4-13 hour) static GPS survey. In some cases, especially for shortest time of acquisition, position confirmation was also calculated using differential baseline processing. Processing report summary page is included for each point.

2) Survey Site and Material Used

The Acadia forest survey site is located 25 km east of Fredericton, NB. It mainly consists of harvested, regenerating and mature forests. Eleven GPS survey points were established.

Figure 1. Location of the Acadia forest survey site within New Brunswick, Canada.

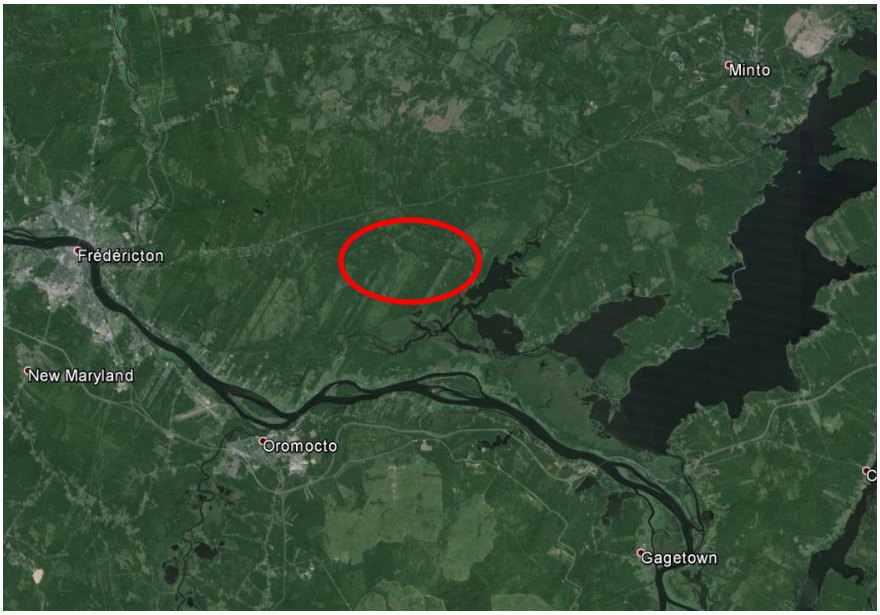


Figure 2. Location of the Acadian forest survey site near Fredericton, N.B.

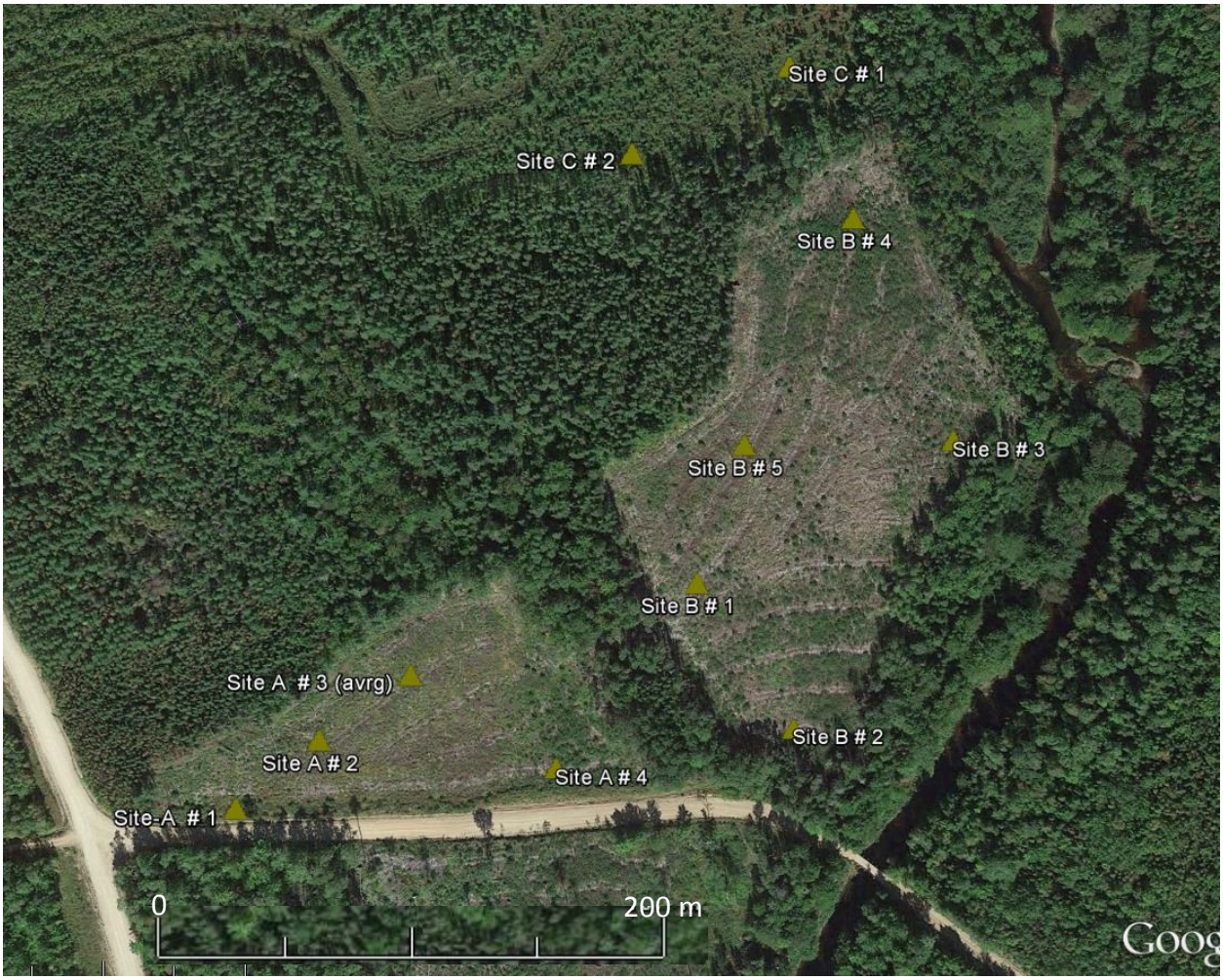


Figure 3. Location of the eleven GPS Points within the Acadia Forest site

Three working areas named site A-B-C were defined, each of which having 3 to 4 ground control points established for a total of 11 points. The GCPs were positioned so that a UAV flight over the site would be able to exploit the GCPs in the adjacent site. Previous work in Gatineau, Québec determined that four GCPs are sufficient for UAV absolute geolocation meeting the requirements of the project,

The positions (latitude-longitude-altitude) of the eleven points were all established based on acquisition period of 4 to 13 hours – Table 1) static GPS survey using Ashtech[tm] Pinwheel antennas and Ashtech dual frequency Zxtreme[tm] receivers. Processing of the resulting RINEX files was performed, several days after acquisition, by NRCAN Precision Point Processing (PPP) Service. Processing report summary page is included for each point. Planimetric precision is approximately 1.7-5.0 cm @95% probability, estimated with acquisition interval decimated to 30 seconds. None of the points are on rock, bedrock or solid concrete. They are made of temporary plastic/plywood targets placed on the ground, suitable for UAV camera photos.

GPS acquisition period where sometimes short for static processing. Therefore, latitude and longitude (planimetric) positions should be used with caution. As for the altitude of the points, they were calculated at the antenna reference point (ARP).

In brief, the 3D positions of these points are not of geodetic accuracy but they are the best position estimates obtainable in this type of physical environment.

In some cases, especially for shortest time of acquisition, position confirmation was also calculated using differential baseline processing using the Fredericton station of the Canadian Active Control System (CACS), 26 km away, as a reference station.

The Fredericton CACS station being fairly far, it was used only to verify estimated position previously obtained from static PPP processing.

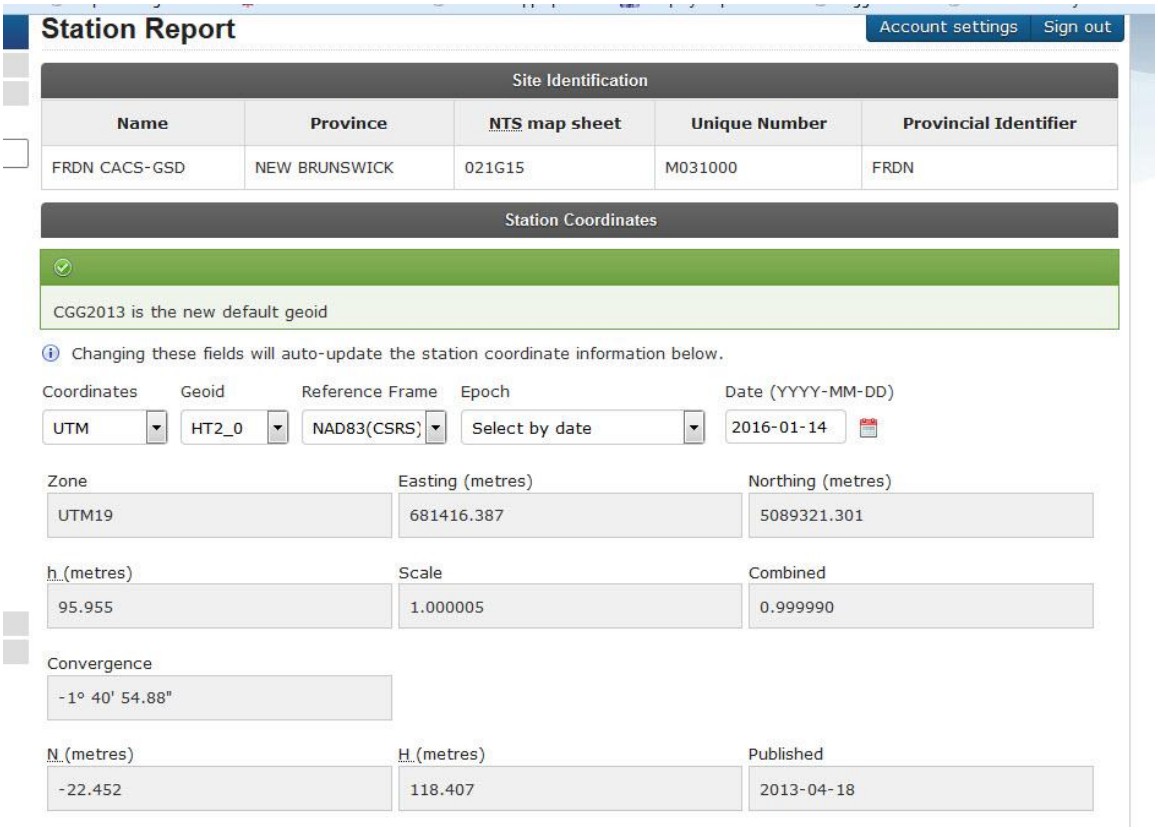


Figure 4. Position of the Fredericton CACS reference station

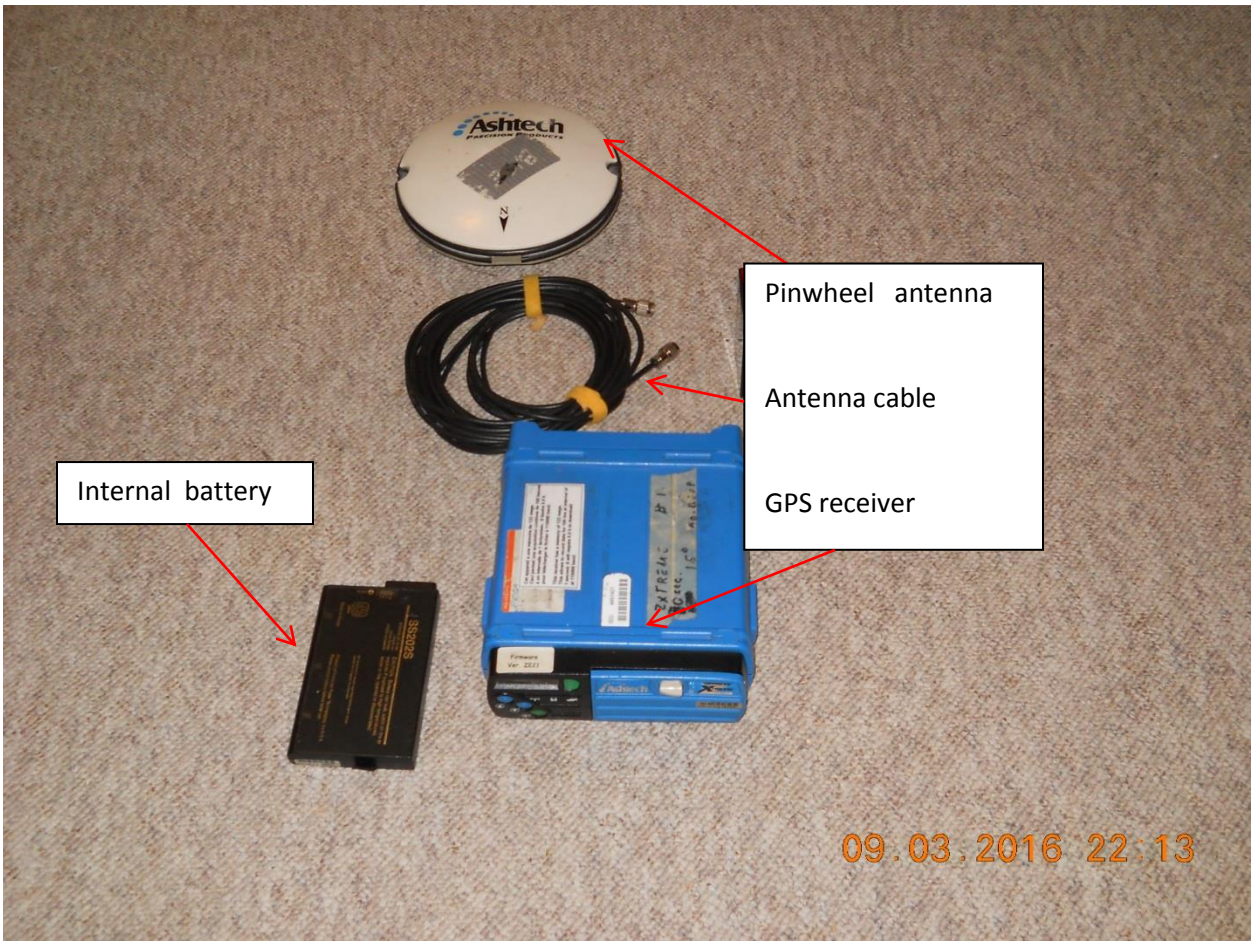


Figure 5. GPS receiver and associated components

The material used for the survey is comprised of GPS receivers, antenna cables, pinwheel antennas and internal batteries.

Table 1. GPS acquisition time

Reference Point		GPS acquisition time	Position confirmed by Fredericton CACS station[1]
Site A GCP- 1		4 h 39 min.	yes
Site A GCP- 2		4 h 37 min.	yes
Site A GCP- 3		4 h 40 min + 2 h 31 min	no
Site A GCP- 4		4 h 13 min.	yes
Site B GCP- 1		13 h 9 min	no
Site B GCP- 2		5 h 42 min.	no
Site B GCP- 3		5 h 56 min.	no
Site B GCP- 4		11h 45 min	no
Site B GCP- 5		6 h 6 min	no
Site C GCP-1		6 h 28 min.	no
Site C GCP- 2		5 h 51 min.	no

1 Processing performed using Differential baseline method with Canadian Active Control System (CACS) station.

3) Data Acquisition – GPS Survey

The reader will find hereafter the precise location (to the precision limits described above) of the 11 GPS points for the Acadia Forest UAV survey area:

-Latitude, Longitude, Altitude (ellipsoidal) and Altitude (orthometric – sea level)

-UTM zone 20, Easting and Northing

-Planimetric positions: NAD 83 CSRS

-Geoid model: CGVD28

-Geoid variation: 21.9 m

-Altitude is at Antenna Reference Point (ARP)

-Points acquired in January 2016

-Data recorded at 10 second intervals

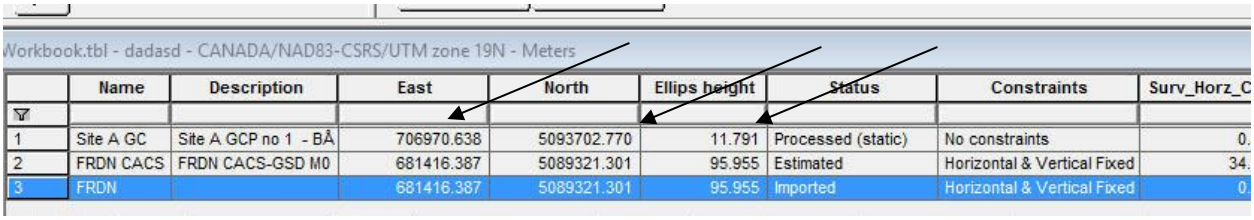
- Error ellipse calculated from measurements subsampled at a 30 second interval. This interval being considered as the reference for Precise Point Positioning (PPP) estimation of positioning error.

Table 2. GPS acquisition details of point : Site A GCP-1

Site :	Site A GCP-1
Receiver (GPS)	Ashtech Zxtreme
Antenna	Ashtech Pinwheel Model : ASH701975.01A
Antenna height	0 (See note above)
Acquisition start	2016 01 19 15 h 47 min. 40 sec. (day 019)
Acquisition end	2016 01 19 20 h 27 min 00 sec.
Duration	4h 39m 20.00
Acquisition interval	10 seconds
Number of acquisition	1676
Raw GPS files	S___A16.019
Rinex files	___0191.16n
	___0191.16o

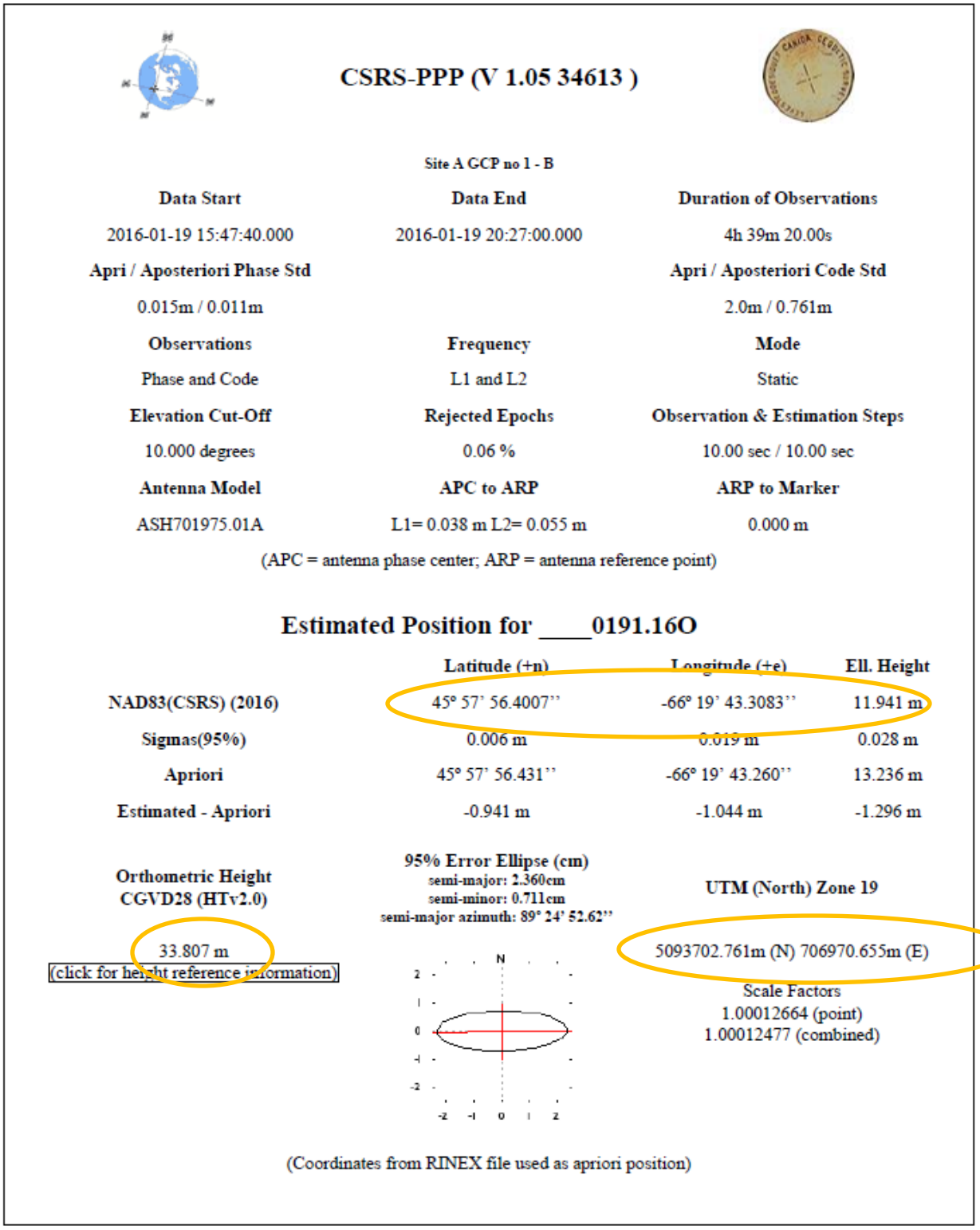
Position established by PPP	**Latitude**	**Longitude**	**Ellipsoïdal Height (metre)**	**Orthometric Height (metre)**
Geographic	45º 57' 56.4007''	-66º 19' 43.3083''	11.941 m	33.807 m
UTM	5093702.761	706970.655		33.807 m
Error Ellipse[1] @95%	2.1 cm	6.8 cm		

1 : Calculated from decimated recording at 30 second intervals.



	Name	Description	East	North	Ellips height	Status	Constraints	Surv_Horz_C
1	Site A GC	Site A GCP no 1 - BÅ	706970.638	5093702.770	11.791	Processed (static)	No constraints	0.
2	FRDN CACS	FRDN CACS-GSD M0	681416.387	5089321.301	95.955	Estimated	Horizontal & Vertical Fixed	34.
3	FRDN		681416.387	5089321.301	95.955	Imported	Horizontal & Vertical Fixed	0.

Figure 6. Confirmation of position (approximate) using baseline processing. Site A GCP-1



CSRS-PPP (V 1.05 34613)

Site A GCP no 1 - B

Data Start	Data End	Duration of Observations
2016-01-19 15:47:40.000	2016-01-19 20:27:00.000	4h 39m 20.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.011m		2.0m / 0.761m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.06 %	10.00 sec / 10.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
ASH701975.01A	L1= 0.038 m L2= 0.055 m	0.000 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for ____0191.16O

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2016)	45° 57' 56.4007''	-66° 19' 43.3083''	11.941 m
Sigmas(95%)	0.006 m	0.019 m	0.028 m
Apriori	45° 57' 56.431''	-66° 19' 43.260''	13.236 m
Estimated - Apriori	-0.941 m	-1.044 m	-1.296 m

Orthometric Height CGVD28 (HTv2.0)

33.807 m

(click for height reference information)

95% Error Ellipse (cm)

semi-major: 2.360cm
semi-minor: 0.711cm
semi-major azimuth: 89° 24' 52.62''

UTM (North) Zone 19

5093702.761m (N) 706970.655m (E)

Scale Factors
1.00012664 (point)
1.00012477 (combined)

(Coordinates from RINEX file used as apriori position)

Figure 7. Position of site A GCP-1 from NRCAN – PPP Service. Orange circles represent most frequently requested information.

Table 3. GPS acquisition details of point : Site A GCP-2

Site :	**Site A GCP-2**
Receiver (GPS)	Ashtech Zxtreme
Antenna	Ashtech Pinwheel Model ASH701975.01A
Antenna height	0 (See note above)
Acquisition start	2016 01 19 15 h 54 min. 10 sec. (day 019)
Acquisition end	2016 01 19 20 h 31 min 30 sec.
Duration	4h 37 20.00
Acquisition interval	10 seconds
Number of acquisition	1664
Raw GPS files	S___A16.019
Rinex files	___0191.16O
	___0191.16N

Position established by PPP	**Latitude**	**Longitude**	**Ellipsoïdal Height** (metre)	**Orthometric Height** (metre)
Geographic	45º 57' 57.3575''	-66º 19' 41.6286''	11.228	33.093
UTM	5093733.502	707005.814		33.093
Error Ellipse @ 95 %[1]	2.0 cm	6.3 cm		

1 : Calculated from decimated recording at 30 second intervals.

Differential baseline processing position confirmation

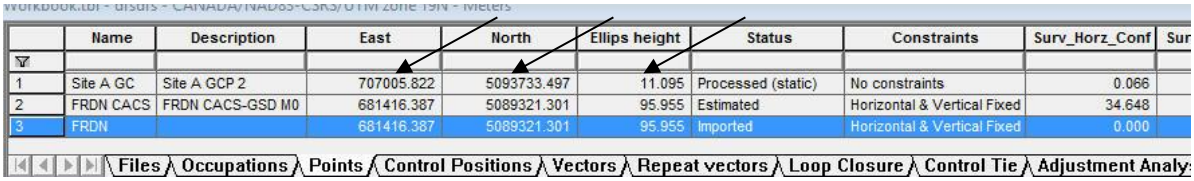


Figure 8. Confirmation of position (approximate) using baseline processing. Point Site A GCP-2

CSRS-PPP (V 1.05 34613)

Site A GCP 2

Data Start	Data End	Duration of Observations
2016-01-19 15:54:10.000	2016-01-19 20:31:30.000	4h 37m 20.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.008m		2.0m / 0.571m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.18 %	10.00 sec / 10.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
ASH701975.01A	L1= 0.038 m L2= 0.055 m	0.000 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for ____0191.16O

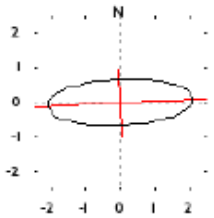
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2016)	45° 57' 57.3575''	-66° 19' 41.6286''	11.228 m
Sigmas(95%)	0.005 m	0.017 m	0.022 m
Apriori	45° 57' 57.515''	-66° 19' 41.653''	21.785 m
Estimated - Apriori	-4.869 m	0.516 m	-10.557 m

Orthometric Height CGVD28 (HTv2.0)

33.093 m

(click for height reference information)

95% Error Ellipse (cm)
semi-major: 2.125cm
semi-minor: 0.669cm
semi-major azimuth: 87° 28' 41.78''



UTM (North) Zone 19

5093733.502m (N) 707005.814m (E)

Scale Factors
1.00012682 (point)
1.00012506 (combined)

(Coordinates from RINEX file used as apriori position)

Figure 9. Position of site A GCP-2 from NRCAN – PPP Service

Table 4. GPS acquisition details of point : Site A GCP-3

Site :	**Site A GCP-3**
	Nota: This point was acquired during two sessions. The results of the two sessions were merged.
	First acquisition
Receiver (GPS)	Ashtech ZXteme
Antenna	Ashtech Pinwheel Model: ASH701975.01A
Antenna height	0 (See note above)
Acquisition start	2016 01 19 15 h 58 min. 40 sec. (day 019)
Acquisition end	2016 01 19 20 h 38 min 40 sec.
Duration	4h 40m 00 sec
Acquisition interval	10 seconds
Number of acquisition	1680
Raw GPS files	S___A16.019
Rinex files	___0191.16O
	___0191.16N

Position established by PPP	**Latitude**	**Longitude**	**Ellipsoïdal Height** (metre)	**Orthometric Height** (metre)
Geographic	45º 57' 58.2535''	-66º 19' 39.8030''	10.172	32.036
UTM	5093762.473	707044.175		32.036
Error Ellipse[1] **@ 95%**	2.0 cm	6.2 cm		

1 : Calculated from decimated recording at 30 second intervals..

Differential baseline processing position confirmation

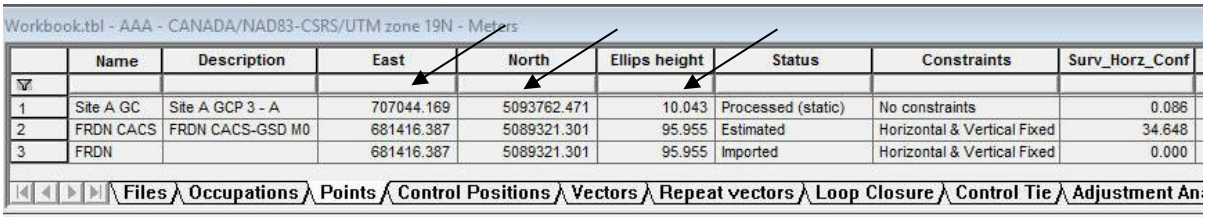


Figure 10. Confirmation of position (approximate) using baseline processing. Point Site A GCP-3

SCRS-PPP (V 1.05 34613)

Site A GCP 3 - A

Début des données	Fin des données	Duré des observations
2016-01-19 15:58:40.000	2016-01-19 20:38:40.000	4h 40m 0.00s
Dév. std. apri / apost - Porteuse		**Dév. std. apri / apost - Pseudo-distances**
0.015m / 0.008m		2.0m / 0.586m
Observations	**Fréquence**	**Mode**
Porteuse et pseudo-distances	L1 et L2	Statique
Coupure d'élévation	**Données rejetées**	**Intervalles des observations & estimés**
10.000 degrés	0.18 %	10.00 sec / 10.00 sec
Antenne	**CPA au PRA**	**PRA au Repère**
ASH701975.01A	L1= 0.038 m L2= 0.055 m	0.000 m

(CPA = centre de phase de l'antenne; PRA = point de référence de l'antenne)

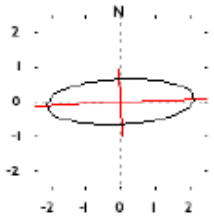
Positions estimées pour ____0191.16O

	Latitude (+n)	Longitude (+e)	Hauteur Ell.
NAD83(SCRS) (2016)	45° 57' 58.2535''	-66° 19' 39.8030''	10.172 m
Sigmas(95%)	0.005 m	0.017 m	0.022 m
Apriori	45° 57' 58.285''	-66° 19' 39.818''	16.109 m
Position calculée - Apriori	-0.958 m	0.329 m	-5.937 m

H Ortho CGVD28 (HTv2.0)

32.036 m
(lien pour la référence altimétrique)

Ellipse d'erreur 95% (cm)
semi-majeur: 2.150cm
semi-mineur: 0.654cm
azimut de l'axe semi-majeur: 87° 12' 20.50''



UTM (Nord) Zone 19

5093762.473m (N) 707044.175m (E)

Facteurs échelle
1.00012702 (point)
1.00012542 (combiné)

(Position apriori initialisée à partir des coordonnées du fichier RINEX)

Figure 11. Position of site A GCP-3 – 1st acquisition - from NRCAN – PPP Service

Table 5. GPS acquisition details of point : Site A GCP-3

Site :	**Site A GCP-3**
	Second acquisition
Receiver (GPS)	Ashtech Zxtreme
Antenna	Ashtech Pinwheel Model: ASH701975.01A
Antenna height	0 (See note above)
Acquisition start	2016 01 19 20 h 49 min. 00 sec. (day 019)
Acquisition end	2016 01 19 23 h 20 min 24 sec.
Duration	2h 31m 40 sec
Acquisition interval	10 seconds
Number of acquisition	910
Raw GPS files	S___C16.019
Rinex files	___0193.16O
	___0193.16N

Position established by PPP	**Latitude**	**Longitude**	**Ellipsoïdal Height** (metre)	**Orthometric Height** (metre)
Geographic	45º 57’ 58.2555’’	-66º 19’ 39.8014’’	9.974	31.838
UTM	5093762.536	707044.208		31.838

SCRS-PPP (V 1.05 34613)

Site A GCP 3 - C

Début des données	Fin des données	Duré des observations
2016-01-19 20:49:00.000	2016-01-19 23:20:40.000	2h 31m 40.00s
Dév. std. apri / apost - Porteuse		**Dév. std. apri / apost - Pseudo-distances**
0.015m / 0.010m		2.0m / 0.625m
Observations	**Fréquence**	**Mode**
Porteuse et pseudo-distances	L1 et L2	Statique
Coupure d'élévation	**Données rejetées**	**Intervalles des observations & estimés**
10.000 degrés	0.44 %	10.00 sec / 10.00 sec
Antenne	**CPA au PRA**	**PRA au Repère**
ASH701975.01A	L1= 0.038 m L2= 0.055 m	0.000 m

(CPA = centre de phase de l'antenne; PRA = point de référence de l'antenne)

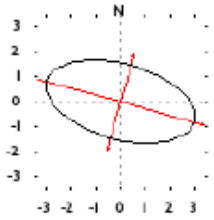
Positions estimées pour ____0193.16O

	Latitude (+n)	Longitude (+e)	Hauteur Ell.
NAD83(SCRS) (2016)	45° 57' 58.2555''	-66° 19' 39.8014''	9.974 m
Sigmas(95%)	0.013 m	0.024 m	0.045 m
Apriori	45° 57' 58.364''	-66° 19' 39.808''	18.688 m
Position calculée - Apriori	-3.335 m	0.150 m	-8.714 m

H Ortho CGVD28 (HTv2.0)

31.838 m
(lien pour la référence altimétrique)

Ellipse d'erreur 95% (cm)
semi-majeur: 3.115cm
semi-mineur: 1.504cm
azimut de l'axe semi-majeur: 104° 58' 19.63''



UTM (Nord) Zone 19

5093762.536m (N) 707044.208m (E)

Facteurs échelle
1.00012702 (point)
1.00012545 (combiné)

(Position apriori initialisée à partir des coordonnées du fichier RINEX)

Figure 12. Position of site A GCP-3 – 2nd acquisition -from NRCAN – PPP Service

Table 6. GPS acquisition details of point : Site A GCP-3

Averaged position for : Site A GCP-3

Position established by PPP	**Latitude**	**Longitude**	**Ellipsoïdal Height** (metre)	**Orthometric Height** (metre)
Geographic	45º 57’ 58.2545’’	-66º 19’ 39.8022’’	10.073	31.937
UTM	5093762.504	707044.191		31.937

Table 7. GPS acquisition details of point : Site A GCP-4

Site :	**Site A GCP- 4**
Receiver (GPS)	Ashtech ZXtreme
Antenna	Ashtech Pinwheel Model : ASH701975.01A
Antenna height	0 (See note above)
Acquisition start	2016 01 19 16 h 39 min. 20 sec. (day 019)
Acquisition end	2016 01 19 20 h 52 min 40 sec.
Duration	4h 13 m 20.00
Acquisition interval	10 seconds
Number of acquisition	1520
Raw GPS files	S___B16.019
Rinex files	___0192.16O
	___0192.16N

Position established by PPP	**Latitude**	**Longitude**	**Ellipsoïdal Height** (metre)	**Orthometric Height** (metre)
Geographic	45º 57’ 56.8331’’	-66º 19’ 36.8709’’	6.625	28.488
UTM	5093720.754	707108.749		28.488
Error Ellipse @ 95%[1]	2.3 cm	6.4 cm		

1 : Calculated from decimated recording at 30 second intervals.

Differential baseline processing position confirmation

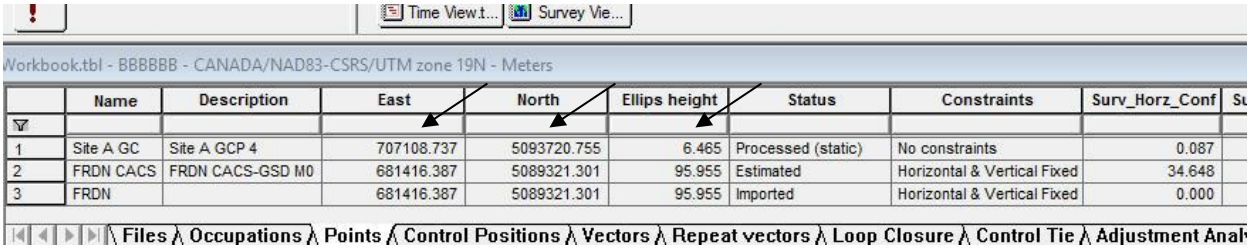


Figure 13. Confirmation of position (approximate) using baseline processing. Site A - GCP-4

CSRS-PPP (V 1.05 34613)

Site A GCP 4

Data Start	Data End	Duration of Observations
2016-01-19 16:39:20.000	2016-01-19 20:52:40.000	4h 13m 20.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.009m		2.0m / 0.517m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.39 %	10.00 sec / 10.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
ASH701975.01A	L1= 0.038 m L2= 0.055 m	0.000 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for ____0192.16O

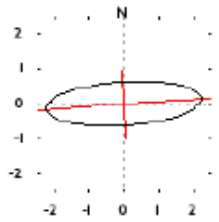
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2016)	45° 57' 56.8331''	-66° 19' 36.8709''	6.625 m
Sigmas(95%)	0.005 m	0.018 m	0.021 m
Apriori	45° 57' 56.848''	-66° 19' 36.820''	10.372 m
Estimated - Apriori	-0.464 m	-1.094 m	-3.747 m

Orthometric Height CGVD28 (HTv2.0)

28.488 m

(click for height reference information)

95% Error Ellipse (cm)
semi-major: 2.265cm
semi-minor: 0.620cm
semi-major azimuth: 86° 10' 56.26''



UTM (North) Zone 19

5093720.754m (N) 707108.749m (E)

Scale Factors
1.00012735 (point)
1.00012631 (combined)

(Coordinates from RINEX file used as apriori position)

Figure 14. Position of site A GCP-4 from NRCAN – PPP Service

Table 8. GPS acquisition details of point : Site B GCP-1

Site :	**Site B GCP-1**
Receiver (GPS)	Ashtech ZXtreme
Antenna	Ashtech Pinwheel Model: ASH701975.01A
Antenna height	0 (See note above)
Acquisition start	2016 01 20 14 h 24 min. 40 sec. (day 020)
Acquisition end	2016 01 21 03 h 34 min 40 sec.
Duration	13h 09 m 60.00
Acquisition interval	10 seconds
Number of acquisition	4740
Raw GPS files	S___A16.020
Rinex files	___0201.16O
	___0201.16N

Position established by PPP	**Latitude**	**Longitude**	**Ellipsoïdal Height** (metre)	**Orthometric Height** (metre)
Geographic	45º 57’ 59.5365’’	-66º 19’ 33.9148	6.733	28.594
UTM	5093806.322	707169.568		28.594
Error Ellipse @95%[1]	1.1 cm	2.4 cm		

1 : Calculated from decimated recording at 30 second intervals.

CSRS-PPP (V 1.05 34613)

Site B GCP no 1

Data Start	Data End	Duration of Observations
2016-01-20 14:24:40.000	2016-01-21 03:34:40.000	13h 9m 60.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.010m		2.0m / 0.625m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.00 %	10.00 sec / 10.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
ASH701975.01A	L1= 0.038 m L2= 0.055 m	0.000 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for ____0201.16O

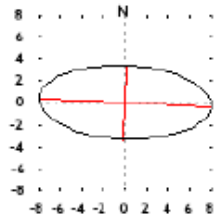
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2016)	45° 57' 59.5365''	-66° 19' 33.9148''	6.733 m
Sigmas(95%)	0.003 m	0.006 m	0.013 m
Apriori	45° 57' 59.558''	-66° 19' 33.976''	12.831 m
Estimated - Apriori	-0.672 m	1.311 m	-6.098 m

Orthometric Height CGVD28 (HTv2.0)

28.594 m

(click for height reference information)

95% Error Ellipse (mm)
semi-major: 7.999mm
semi-minor: 3.356mm
semi-major azimuth: 92° 34' 8.33''



UTM (North) Zone 19

5093806.322m (N) 707169.568m (E)

Scale Factors
1.00012765 (point)
1.00012659 (combined)

(Coordinates from RINEX file used as apriori position)

Figure 15. Position of site B GCP-1 from NRCAN – PPP Service

Table 9. GPS acquisition details of point : Site B GCP-2

Site :	**Site B GCP-2**
Receiver (GPS)	Ashtech ZXtreme
Antenna	Ashtech Pinwheel Model: ASH701975.01A
Antenna height	0 (See note above)
Acquisition start	2016 01 20 15 h 03 min. 40 sec. (day 020)
Acquisition end	2016 01 20 20 h 45 min 40 sec.
Duration	5 h 42m 00
Acquisition interval	10 seconds
Number of acquisition	2052
Raw GPS files	S___A16.020
Rinex files	___0201.16O
	___0201.16N

Position established by PPP	**Latitude**	**Longitude**	**Ellipsoïdal Height** (metre)	**Orthometric Height** (metre)
Geographic	45º 57’ 57.3071’’	-66º 19’ 31.8074’’	0.760	22.621
UTM	5093739.042	707217.232		22.621
Error Ellipse @ 95%[1]	1.7 cm	5.3 cm		

1 : Calculated from decimated recording at 30 second intervals.

CSRS-PPP (V 1.05 34613)

Site B GCP no 2

Data Start	Data End	Duration of Observations
2016-01-20 15:03:40.000	2016-01-20 20:45:40.000	5h 42m 0.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.012m		2.0m / 0.658m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.00 %	10.00 sec / 10.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
ASH701975.01A	L1= 0.038 m L2= 0.055 m	0.000 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for ____0201.16O

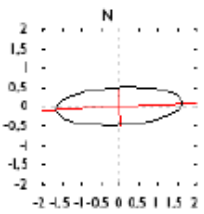
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2016)	45° 57' 57.3071''	-66° 19' 31.8074''	0.760 m
Sigmas(95%)	0.004 m	0.013 m	0.032 m
Apriori	45° 57' 57.366''	-66° 19' 31.865''	4.781 m
Estimated - Apriori	-1.825 m	1.242 m	-4.021 m

Orthometric Height CGVD28 (HTv2.0)

22.621 m

(click for height reference information)

95% Error Ellipse (cm)
semi-major: 1.651cm
semi-minor: 0.490cm
semi-major azimuth: 86° 28' 31.24''



UTM (North) Zone 19

5093739.042m (N) 707217.232m (E)

Scale Factors
1.00012790 (point)
1.00012778 (combined)

(Coordinates from RINEX file used as apriori position)

Figure 16. Position of site B GCP-2 from NRCAN – PPP Service

Table 10. GPS acquisition details of point : Site B GCP-3

Site :	**Site B GCP-3**
Receiver (GPS)	Ashtech ZXtreme
Antenna	Ashtech Pinwheel Model: ASH701975.01A
Antenna height	0 (See note above)
Acquisition start	2016 01 21 15 h 01 min. 40 sec. (day 021)
Acquisition end	2016 01 21 20 h 58 min 30 sec.
Duration	5h 56m 50.00
Acquisition interval	10 seconds
Number of acquisition	2141

Raw GPS files	S___A16.021
Rinex files	___0211.16O
	___0211.16N

Position established by PPP	**Latitude**	**Longitude**	**Ellipsoïdal Height** (metre)	**Orthometric Height** (metre)
Geographic	45º 58’ 01.6120’’	-66º 19’ 28.5035’’	5.836	27.694
UTM	5093874.287	707283.873		27.694
Error Ellipse @ 95%[1]	1.6 cm	4.5 cm		

1 : Calculated from decimated recording at 30 second intervals.

CSRS-PPP (V 1.05 34613)

Site B GCP no 3

Data Start	Data End	Duration of Observations
2016-01-21 15:01:39.999	2016-01-21 20:58:30.000	5h 56m 50.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.014m		2.0m / 0.758m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.00 %	10.00 sec / 10.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
ASH701975.01A	L1= 0.038 m L2= 0.055 m	0.000 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for ____0211.16O

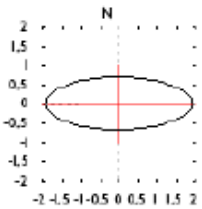
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2016)	45° 58' 01.6120''	-66° 19' 28.5035''	5.836 m
Sigmas(95%)	0.005 m	0.015 m	0.031 m
Apriori	45° 58' 01.643''	-66° 19' 28.464''	10.591 m
Estimated - Apriori	-0.944 m	-0.851 m	-4.755 m

Orthometric Height CGVD28 (HTv2.0)

27.694 m

(click for height reference information)

95% Error Ellipse (cm)
semi-major: 1.936cm
semi-minor: 0.687cm
semi-major azimuth: 89° 59' 18.13''



UTM (North) Zone 19

5093874.287m (N) 707283.873m (E)

Scale Factors
1.00012824 (point)
1.00012732 (combined)

(Coordinates from RINEX file used as apriori position)

Figure 17. Position of site B GCP-3 from NRCAN – PPP Service

Table 11. GPS acquisition details of point : Site B GCP-4

Site :	**Site B GCP - 4**
Receiver (GPS)	Ashtech ZXtreme
Antenna	Ashtech Pinwheel Model: ASH701975.01A
Antenna height	0 (See note above)
Acquisition start	2016 01 20 14 h 47 min. 40 sec. (day 020)
Acquisition end	2016 01 21 02 h 33 min 00 sec.
Duration	11h 45m 20.00
Acquisition interval	10 seconds
Number of acquisition	4232

Raw GPS files	S___A16.020
Rinex files	___0201.16O
	___0201.16N

Position established by PPP	**Latitude**	**Longitude**	**Ellipsoïdal Height** (metre)	**Orthometric Height** (metre)
Geographic	45º 58' 04.7840''	-66º 19' 30.7008''	9.222	31.080
UTM	5093970.592	707233.297		31.080
Error Ellipse @95%[1]	1.2 cm	2.5 cm		

1 : Calculated from decimated recording at 30 second intervals.

CSRS-PPP (V 1.05 34613)

Site B GCP no 4

Data Start	Data End	Duration of Observations
2016-01-20 14:47:40.000	2016-01-21 02:33:00.000	11h 45m 20.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.012m		2.0m / 0.813m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.00 %	10.00 sec / 10.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
ASH701975.01A	L1= 0.038 m L2= 0.055 m	0.000 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for ____0201.16O

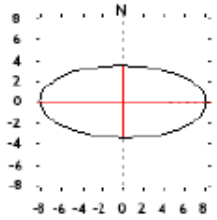
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2016)	45° 58' 04.7840''	-66° 19' 30.7008''	9.222 m
Sigmas(95%)	0.003 m	0.006 m	0.014 m
Apriori	45° 58' 04.827''	-66° 19' 30.765''	16.885 m
Estimated - Apriori	-1.337 m	1.391 m	-7.663 m

Orthometric Height CGVD28 (HTv2.0)

31.080 m

(click for height reference information)

95% Error Ellipse (mm)
semi-major: 8.118mm
semi-minor: 3.496mm
semi-major azimuth: 90° 28' 43.57''



UTM (North) Zone 19

5093970.592m (N) 707233.297m (E)

Scale Factors
1.00012798 (point)
1.00012653 (combined)

(Coordinates from RINEX file used as apriori position)

Figure 18. Position of site B GCP-4 from NRCAN – PPP Service

Table 12. GPS acquisition details of point : Site B GCP-5

Site :	**Site B GCP-5**
Receiver (GPS)	Ashtech ZXtreme
Antenna	Ashtech Pinwheel Model: ASH701975.01A
Antenna height	0 (See note above)
Acquisition start	2016 01 20 14 h 34 min. 20 sec. (day 020)
Acquisition end	2016 01 20 20 h 40 min 50 sec.
Duration	06 h 06 m 20 sec.
Acquisition interval	10 seconds
Number of acquisition	2198

Raw GPS files	S___A16.020
Rinex files	___0201.16O
	___0201.16N

Position established by PPP	**Latitude**	**Longitude**	**Ellipsoïdal Height** (metre)	**Orthometric Height** (metre)
Geographic	45º 58' 01.5322''	-66º 19' 32.9537''	8.818	30.678
UTM	5093868.607	707188.183		30.678
Error Ellipse @95%[1]	1.5 cm	4.6 cm		

1 : Calculated from decimated recording at 30 second intervals.

CSRS-PPP (V 1.05 34613)

Site B GCP no 5

Data Start	Data End	Duration of Observations
2016-01-20 14:34:20.000	2016-01-20 20:40:50.000	6h 6m 30.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.010m		2.0m / 0.557m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.32 %	10.00 sec / 10.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
ASH701975.01A	L1= 0.038 m L2= 0.055 m	0.000 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for ____0201.16O

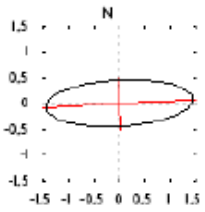
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2016)	45° 58' 01.5322''	-66° 19' 32.9537''	8.818 m
Sigmas(95%)	0.004 m	0.012 m	0.019 m
Apriori	45° 58' 01.569''	-66° 19' 33.025''	17.106 m
Estimated - Apriori	-1.130 m	1.535 m	-8.288 m

Orthometric Height CGVD28 (HTv2.0)

30.678 m

(click for height reference information)

95% Error Ellipse (cm)
semi-major: 1.451cm
semi-minor: 0.456cm
semi-major azimuth: 86° 54' 41.04''



UTM (North) Zone 19

5093868.607m (N) 707188.183m (E)

Scale Factors
1.00012775 (point)
1.00012637 (combined)

(Coordinates from RINEX file used as apriori position)

Figure 19. Position of site B - GCP-5 from NRCAN – PPP Service

Table 13. GPS acquisition details of point : Site C GCP-1

Site :	**Site C GCP-1**
Receiver (GPS)	Ashtech ZXtreme
Antenna	Ashtech Pinwheel Model : ASH701975.01A
Antenna height	0 (See note above)
Acquisition start	2016 01 21 14 h 15 min. 10 sec. (jour 021)
Acquisition end	2016 01 21 20 h 43 min 10 sec.
Duration	6h 28m 00.00
Acquisition interval	10 seconds
Number of acquisition	2328

Raw GPS files	S___A16.021
Rinex files	___0211.16O
	___0211.16N

Position established by PPP	**Latitude**	**Longitude**	**Ellipsoïdal Height** (metre)	**Orthometric Height** (metre)
Geographic	45º 58’ 06.8620’’	-66º 19’ 32.0667’’	11.961	33.819
UTM	5094033.735	707201.748		33.819
Error Ellipse @95%[1]	1.5 cm	4.3 cm		

1 : Calculated from decimated recording at 30 second intervals.

CSRS-PPP (V 1.05 34613)

Site C GCP no 1

Data Start	Data End	Duration of Observations
2016-01-21 14:15:10.000	2016-01-21 20:43:10.000	6h 28m 0.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.011m		2.0m / 0.710m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.04 %	10.00 sec / 10.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
ASH701975.01A	L1= 0.038 m L2= 0.055 m	0.000 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for ____0211.16O

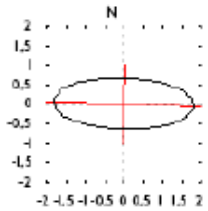
	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2016)	45° 58' 06.8620''	-66° 19' 32.0667''	11.961 m
Sigmas(95%)	0.005 m	0.015 m	0.028 m
Apriori	45° 58' 06.867''	-66° 19' 32.060''	19.682 m
Estimated - Apriori	-0.165 m	-0.143 m	-7.722 m

Orthometric Height CGVD28 (HTv2.0)

33.819 m

(click for height reference information)

95% Error Ellipse (cm)
semi-major: 1.824cm
semi-minor: 0.660cm
semi-major azimuth: 91° 45' 47.99''



UTM (North) Zone 19

5094033.735m (N) 707201.748m (E)

Scale Factors
1.00012782 (point)
1.00012594 (combined)

(Coordinates from RINEX file used as apriori position)

Figure 20. Position of site C GCP-1 from NRCAN – PPP Service

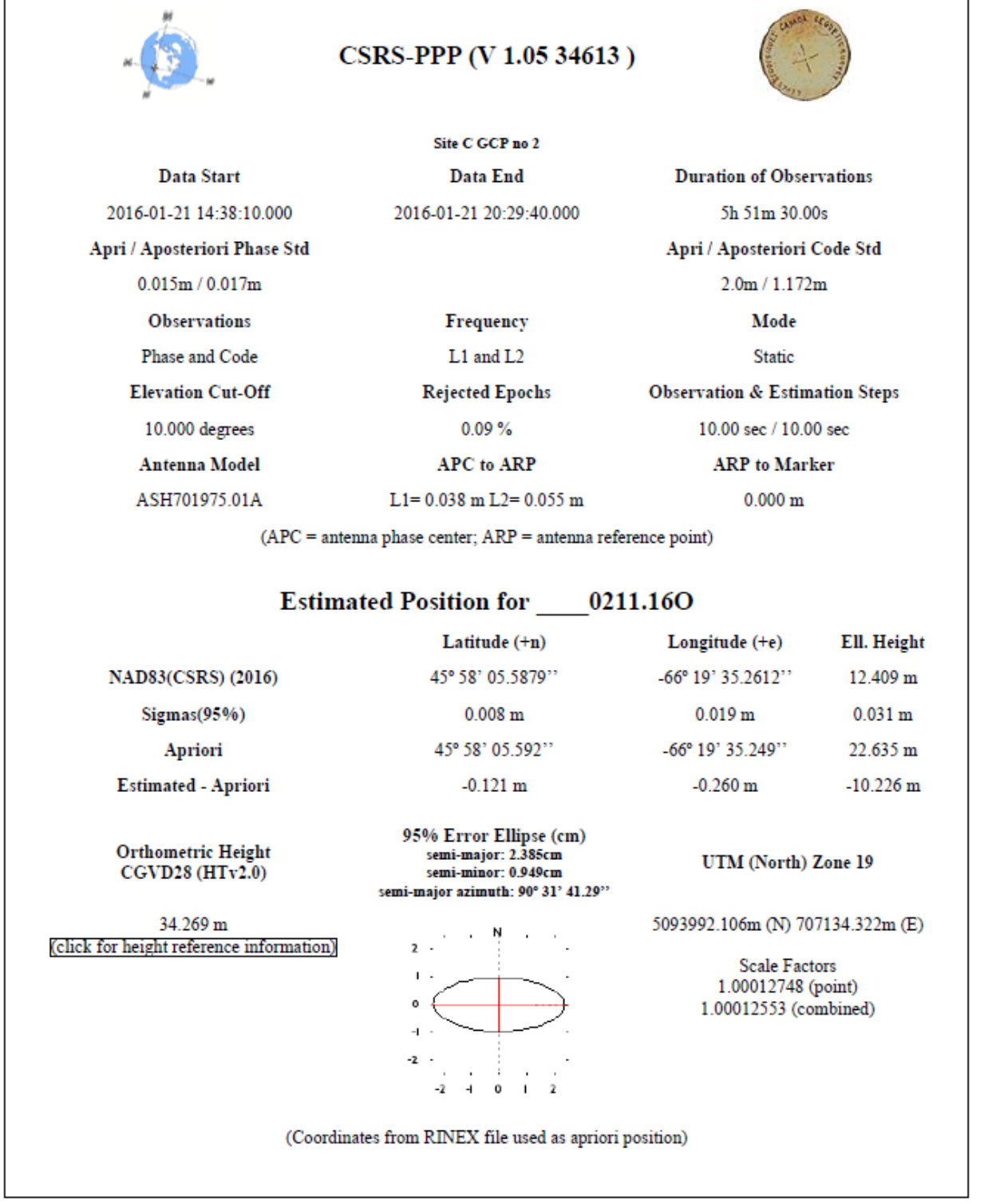
Table 14. GPS acquisition details of point : Site C GCP-2

Site :	**Site C GCP-2**
Receiver (GPS)	Ashtech ZXtreme
Antenna	Ashtech Pinwheel ASH701975.01A
Antenna height	0 (See note above)
Acquisition start	2016 01 21 14 h 38 min. 10 sec. (day 021)
Acquisition end	2016 01 21 20 h 29 min 40 sec.
Duration	5h 51m 30.00
Acquisition interval	10 seconds
Number of acquisition	2109

Raw GPS files	S___A16.021
Rinex files	___0211.16O
	___0211.16N

Position established by PPP	**Latitude**	**Longitude**	**Ellipsoïdal Height** (metre)	**Orthometric Height** (metre)
Geographic	45º 58’ 05.5879’’	-66º 19’ 35.2612’’	12.409	34.269
UTM	5093992.106	707134.322		34.269
Error Ellipse @95%[1]	2.0 cm	6.1 cm		

1 : Calculated from decimated recording at 30 second intervals.



CSRS-PPP (V 1.05 34613)

Site C GCP no 2

Data Start	Data End	Duration of Observations
2016-01-21 14:38:10.000	2016-01-21 20:29:40.000	5h 51m 30.00s
Apri / Aposteriori Phase Std		**Apri / Aposteriori Code Std**
0.015m / 0.017m		2.0m / 1.172m
Observations	**Frequency**	**Mode**
Phase and Code	L1 and L2	Static
Elevation Cut-Off	**Rejected Epochs**	**Observation & Estimation Steps**
10.000 degrees	0.09 %	10.00 sec / 10.00 sec
Antenna Model	**APC to ARP**	**ARP to Marker**
ASH701975.01A	L1= 0.038 m L2= 0.055 m	0.000 m

(APC = antenna phase center; ARP = antenna reference point)

Estimated Position for ____0211.16O

	Latitude (+n)	Longitude (+e)	Ell. Height
NAD83(CSRS) (2016)	45° 58' 05.5879''	-66° 19' 35.2612''	12.409 m
Sigmas(95%)	0.008 m	0.019 m	0.031 m
Apriori	45° 58' 05.592''	-66° 19' 35.249''	22.635 m
Estimated - Apriori	-0.121 m	-0.260 m	-10.226 m

Orthometric Height CGVD28 (HTv2.0)

34.269 m

(click for height reference information)

95% Error Ellipse (cm)
semi-major: 2.385cm
semi-minor: 0.949cm
semi-major azimuth: 90° 31' 41.29''

UTM (North) Zone 19

5093992.106m (N) 707134.322m (E)

Scale Factors
1.00012748 (point)
1.00012553 (combined)

(Coordinates from RINEX file used as apriori position)

Figure 21. Position of site C GCP-2 from NRCAN – PPP Service

4) Conclusion

Reference targets were located using dual frequency GPS receivers in static mode. Raw GPS data were processed using NRCAN Precision Point Processing online software. These targets are marked on the ground such that they could be used in future years for the geocoding of airborne imagery. As the targets are not located on bedrock, care should be taken to ensure the vertical position is not modified by changes in local soil (erosion) or vegetation (regrowth).

5) Related Publications & References

This document is one of many documents related to the use of Unmanned Aerial Vehicle imagery for snow melt and flood monitoring. GPS positioning of georeference targets is one of the elements of these initiatives. The reader will find below a list of publications related to this topic.

-Fernandes, R.A., Canisius, F., Leblanc, S., Maloley, M., Oakes, S., Prévost, C., Assessment of UAV Based Photogrammetry for Snow Depth Mapping: Data Collection and Processing , Geomatics Canada Open File, 8058.

-Prévost, C., R. Fernandes, 2016, Relevé GPS de cibles de référence au site test de Gatineau, Québec, dans le cadre du projet d'évaluation de l'épaisseur de neige par aéronef sans pilote. 67 pages, Geomatics Canada - Dossier Public no 8088.

-Prévost, C., P. White, 2016. Mer Bleue Arctic Surrogate Study Site Project - GPS Survey Report. Geomatics Canada Open File, 51 pages, in review

-Maloley, M., Leblanc, S., Canisius, F., Fernandes, R., 2016. Operations manual for Phantom 3 Professional UAV surveys of Gatineau and Acadia in Support of CCMEO Snow Depth from UAV Activities, Geomatics Canada Open File, in review.

-Oakes, S., Fernandes, R.A., Canisius, F., 2016. Protocol for photographic survey of snow depth stakes in Support of CCMEO Snow Depth from UAV Activities, Geomatics Canada Open File, 8057..

-Ashtech Precision Product. Z-Xtreme GPS Receiver-System Guide for Post Process Surveying. November 2000, 49 pages. http://sup.xenya.si/sup/info/magellan(thalesnavigation)/z-xtreme/Manuals/630845-01-Post-ProcessSurveying.pdf

-Natural Resources Canada, Precision Positioning System (PPP) Tools and Applications. http://www.nrcan.gc.ca/earth-sciences/geomatics/geodetic-reference-systems/tools-applications/10925

-Natural Resources Canada, Geodetic Reference Systems, Canadian Active Control System (CACS). http://www.nrcan.gc.ca/earth-sciences/geomatics/geodetic-reference-systems/data/10923#cacs