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# **GEOMATICS CANADA OPEN FILE 61**

# Mer Bleue, Ontario, arctic surrogate study-site project 2019 update **Global Navigation Satellite System survey report**

C. Prévost and H.P. White

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#### C. Prévost and H. P. White

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# 2020

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#### Note:

This document, strictly orientated toward high precision GNSS survey results, falls within the framework of a much larger project involving calibration and validation of various types of remote sensing data using *in situ* environmental surveys. The survey site, located in the Mer Bleue bog, east of Ottawa, provides a surrogate for an Arctic environment.

This project was undertaken as part of the Mer Bleue Arctic Surrogate Simulation Study (MBASSS) project under an *ad hoc* partnership with the National Research Council of Canada (NRC), LOOKNorth, and McGill University.

This document describes GNSS surveys undertaken in January, May, August and December 2019. Similar surveys were performed in 2015, 2016, 2017, 2018 and are referred to in the Publication section.

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#### <u>Abstract</u>

Natural Resources Canada (NRCan) has the mandate of providing essential geographic information. An improved knowledge of our physical environment represents one of the cores of this mandate. The Arctic is an important but challenging region to study, especially for wetland monitoring. To reduce survey costs, researchers often use surrogate sites located in less remote areas when evaluating and developing applications. The Mer Bleue Bog Peatlands, a conveniently accessible sub-arctic wetland similar to many wetlands found in the Arctic environment, is used as an arctic surrogate study site for the MBASSS Project.

This study site is used for the calibration and validation of various types of optical (spectral) remote sensing data acquired by several project partners using satellite, airborne and Unmanned Aerial Vehicle (UAV) platforms. Precise geo-located products require ground control points (reference points) which are visible to the sensor on the platform and whose geographic location is known with precision. To fulfill this need, high precision GNSS surveys are required.

This highly illustrated document describes in detail the methods and results of the GNSS surveys required for the geographic rectification of imagery, including Unmanned Aerial Vehicle photographs, airborne hyperspectral imagery, and space borne multi-spectral imagery acquired within the scope of the Mer Bleue Arctic Surrogate Simulation Study (MBASSS) during 2019.

Keywords: GNSS survey, UAV, UAV target, Peatland, Mer Bleue Bog.

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#### 1) Introduction

Natural Resources Canada (NRCan) has a priority to provide essential geographic information (Natural Resources Canada 2016). An improved knowledge of our physical environment represents one of the foundations of this mandate. The Canadian Arctic is an important, but difficult, area to study especially for wetland monitoring. To reduce survey costs, researchers can use surrogate sites at more conveniently accessed locations; this is why the Mer Bleue Bog Peatlands, featuring open space / low tree coverage and similar to many wetlands found in an arctic environment, is used as an arctic surrogate study site (Figure 3.1).

This study site is used for the calibration and validation of various types of remote sensing data, acquired by several *ad hoc* project partners, and using satellite, airborne and UAV platforms. Project partners include the National Research Council of Canada (NRC), LOOKNorth and McGill University. The site has been used to calibrate and validate European Sentinel-2a satellite data, NRC visible and infrared airborne hyperspectral imagery and, principally, unmanned aerial vehicle (UAV) imagery as part of the Mer Bleue Arctic Surrogate Simulation Study (MBASSS) project (Soffer, et al. 2016).

For the last few years, versatile and low-cost UAVs (also referred to as RPAS- Remote Piloted Aircraft Systems, or drones) allow for multi-temporal aerial surveys of an environment. Obtaining products that are geographically located and validated with precision requires establishing ground control points (reference points) that are visible to the sensors, and for which geographic locations are known with precision (Figure 3.2). To fulfill this need, a high precision GNSS survey of reference points is required. A high precision GNSS survey campaign was undertaken in the area of the Mer Bleue Research Boardwalk (MBR), maintained by the Mer Bleue Peatland Observatory (MBPO), starting in 2016 and repeated several times in 2017, 2018 (See Section 12 Related Publications), and 2019 (this document). These surveys were pursued to: i) establish the position of manmade ground targets that could be used to georeference imagery acquired by UAV and aircraft during the project; and ii) confirm the positional stability of the Mer Bleue Research Boardwalk site during the campaign.

This document, highly illustrated, describes in detail the method and results of the January, May, August and December 2019 GNSS survey. Related publications cover other aspects of the calibration / validation activities within this project.

Exceptionally, 2018 surveys also included the positioning of a large size target for NRC and a large size target for McGill University (See Reference Section). These targets

were repurposed to be mobile and were thus removed from our target acquisitions campaigns.

Figures 1.1 to 1.4 illustrate the overall environment of Mer Bleue test site for each of the four surveys throughout the year 2019



Figure 1.1 Field view of Mer Bleue in January 2019



Figure 1.2 Field view of Mer Bleue in May 2019



Figure 1.3 Aerial view of Mer Bleue in August 2019. Drone photo



Figure 1.4 Field view of Mer Bleue in December 2019.

#### 2) Positional Result Summary 2016-2017-2018-2019

Tables 2-1 to 2-24 provide summary information of the GNSS survey results for each target point during the campaign. As will be later expanded upon, the position of the MBR-Base Station site is determined using various methodologies: The NRCan Precision Point Processing (PPP) and the baseline processing using the NRCan Canadian Active Control System (CACS) station located approximately 9 km away from the research boardwalk. Two height indicators are provided: the ellipsoidal height (height above the reference ellipsoid that approximates the Earth's surface) and the orthometric height (the height above the geoid as determined by the Earth's gravity which can be approximated by the mean sea level, or MSL). Further details on each site (including potential variations in altitude) and each campaign are expanded upon after this summary. More details on these methodologies can be found in the Section 12, Related Publications.

Position established	Fasting	Northing	Height	Height
by NRCan - PPP	(metres)	(metres)	Filipsoidal	Orthometric
	(110100)	(110100)	(metres)	(metres)
UTM Zone 18	NAD-83-CSRS			CGVD28
MBR-2	459467.545	5028530.204	37.318	69.901
MBR-3	459426.437	5028647.469	37.858	70.442
MBR-4	459609.062	5028674.863	37.422	70.003
MBR-5	459292.857	5028403.057	37.083	69.670
MBR-6	459149.756	5028426.087	37.144	69.733
MBR-7	459396.056	5028377.023	38.307	70.892
Base station (PPP) <sup>1</sup>	459390.920	5028226.528	39.760	72.345
Base station (b-line) <sup>2</sup>	459390.919	5028226.527	39.758	72.343

Table 2.1: Summary of Results – GNSS positions – M	lay 2016 survey
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<sup>1</sup>: GNSS data processed using NRCan Precision Point Processing from static survey

Position established by NRCan - PPP	Easting (metres)	Northing (metres)	Height Ellipsoidal (metres)	Height Orthometric (metres)
UTM Zone 18	NAD-83-CSRS			CGVD28
MBR-2	459467.537	5028530.207	37.337	69.920
MBR-3	459426.435	5028647.479	37.875	70.459
MBR-4	459609.071	5028674.866	37.420	70.001
MBR-5	459292.859	5028403.057	37.094	69.681
MBR-6	459149.748	5028426.093	37.164	69.753
MBR-7	459396.054	5028377.026	38.313	70.898
Base station (PPP) <sup>1</sup>	459390.925	5028226.528	39.758	72.343
Base station (b-line) <sup>2</sup>	459390.921	5028226.525	39.762	72.347

<sup>2</sup>: GNSS data processed using baseline method from NRC – CACS station

Position established by NRCan - PPP	Easting (metres)	Northing (metres)	Height Ellipsoidal (metres)	Height Orthometric (metres)
UTM Zone 18	NAD-83-CSRS			CGVD28
MBR-2	459467.545	5028530.204	37.318	69.901
MBR-3	459426.435	5028647.469	37.865	70.449
MBR-4	459609.060	5028674.860	37.409	69.990
MBR-5	459292.859	5028403.060	37.089	69.676
MBR-6	459149.752	5028426.090	37.150	69.739
MBR-7	459396.060	5028377.029	38.311	70.896
MBR-8	459199.879	5028219.273	39.655	72.243
Base station (PPP) <sup>1</sup>	459390.922	5028226.525	39.758	72.343
Base station (b-line) <sup>2</sup>	459390.922	5028226.524	39.760	72.345

1: GNSS data processed using NRCan Precision Point Processing from static survey

Position established by NRCan - PPP	Easting (metres)	Northing (metres)	Height Ellipsoidal (metres)	Height Orthometric (metres)
UTM Zone 18	NAD-83-CSRS			CGVD28
MBR-2	459467.548	5028530.207	37.340	69.923
MBR-3	459426.437	5028647.479	37.876	70.460
MBR-4	459609.064	5028674.863	37.425	70.006
MBR-5	459292.857	5028403.054	37.104	69.691
MBR-6	459149.750	5028426.093	37.169	69.758
MBR-7	459396.067	5028377.010	38.323	70.908
MBR-8	459199.875	5028219.276	39.675	72.263
Base station (PPP) <sup>1</sup>	459390.920	5028226.528	39.773	72.358
Base station (b-line) <sup>2</sup>	459390.918	5028226.525	39.762	72.347

Table 2.4: Summary of Results – GNSS positions – September 2016 survey

<sup>2</sup>: GNSS data processed using baseline method from NRC – CACS station

Table 2.5: Summar	y of Results -	– GNSS po	sitions – Nover	nber 2016 survey	
De altiers					т.

Position	Easting	Northing	Height	Height
established by	(metres)	(metres)	Ellipsoidal	<u>Orthometric</u>
NRCan - PPP			(metres)	(metres)
UTM Zone 18	NAD-83-CSRS			CGVD28
MBR-2	459467.545	5028530.204	37.331	69.914
MBR-3	459426.435	5028647.479	37.881	70.465
MBR-4	5028674.860	5028674.860	37.425	70.006
MBR-5	459292.857	5028403.054	37.110	69.697
MBR-6	459149.750	5028426.093	37.175	69.764
MBR-7	459396.065	5028377.023	38.322	70.907
MBR-8	459199.870	5028219.279	39.670	72.258
Base station (PPP) <sup>1</sup>	459390.920	5028226.528	39.771	72.356
Base station (b-line) <sup>2</sup>	459390.919	5028226.522	39.760	72.345

1: GNSS data processed using NRCan Precision Point Processing from static survey

Position established by NRCan - PPP	Easting (metres)	Northing (metres)	Height Ellipsoidal (metres)	Height Orthometric (metres)
UTM Zone 18	NAD-83-CSRS			CGVD28
MBR-2	459467.548	5028530.195	37.321	69.904
MBR-3	459426.441	5028647.476	37.872	70.456
MBR-4	459609.073	5028674.857	37.416	69.997
MBR-5	459292.861	5028403.051	37.091	69.678
MBR-6	459149.750	5028426.090	37.156	69.745
MBR-7	459396.071	5028377.001	38.316	70.901
MBR-8	459199.879	5028219.270	39.667	72.255
Base station (PPP) <sup>1</sup>	459390.924	5028226.522	39.760	72.345
Base station (b-line) <sup>2</sup>	459390.918	5028226.523	39.759	72.344

Table 2.6: Summary of Results – GNSS positions – December 2016 survey

<sup>2</sup>: GNSS data processed using baseline method from NRC - CACS station

Table 2.7 - Summar	y of Results –	<b>GNSS</b> positions	– June 2017 survey
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Position established by NRCan - PPP	Easting (metres)	Northing (metres)	Height Ellipsoidal (metres)	Height Orthometric (metres)
UTM Zone 18	NAD-83-CSRS			CGVD28
MBR-2	459467.539	5028530.201	37.319	69.902
MBR-3	459426.432	5028647.479	37.861	70.445
MBR-4	459609.066	5028674.860	37.393	69.974
MBR-5	459292.861	5028403.057	37.093	69.680
MBR-6	459149.752	5028426.084	37.150	69.739
MBR-7	459396.069	5028376.998	38.304	70.889
MBR-8	459199.872	5028219.270	39.656	72.244
Base station (PPP) <sup>1</sup>	459390.921	5028226.525	39.761	72.346
Base station (b-line) <sup>2</sup>	459390.921	5028226.524	39.751	72.336

1: GNSS data processed using NRCan Precision Point Processing from static survey

Position established by NRCan - PPP	Easting (metres)	Northing (metres)	Height Ellipsoidal (metres)	Height Orthometric (metres)
UTM Zone 18	NAD-83-CSRS			CGVD28
MBR-2	459467.550	5028530.198	37.317	69.900
MBR-3	459426.443	5028647.472	37.874	70.458
MBR-4 – Moved <sup>3</sup>	459609.514	5028675.511	37.407	69.988
MBR-5	459292.863	5028403.051	37.101	69.688
MBR-6	459149.761	5028426.084	37.160	69.749
MBR-7	459396.097	5028377.001	38.305	70.890
MBR-8	459199.885	5028219.276	39.655	72.243
Base station (PPP) <sup>1</sup>	459390.927	5028226.519	39.756	72.341
Base station (b-line) <sup>2</sup>	459390.917	5028226.521	39.771	72.356

Table 2.8: Summary of Results – GNSS positions – May 2018 survey

<sup>2</sup>: GNSS data processed using baseline method from NRC – CACS station

<sup>3</sup>: This point is a new installation for 2018, offset from previous years

		•		
Position established by NRCan - PPP	Easting (metres)	Northing (metres)	Height Ellipsoidal (metres)	Height Orthometric (metres)
UTM Zone 18	NAD-83-CSRS			CGVD28
MBR-2	459467.540	5028530.201	37.314	69.851
MBR-3	459426.434	5028647.475	37.866	70.403
MBR-4 – Moved <sup>3</sup>	459609.495	5028675.513	37.389	69.923
MBR-5	459292.857	5028403.052	37.096	69.636
MBR-6	459149.754	5028426.084	37.163	69.705
MBR-7	459396.071	5028376.998	38.300	70.838
MBR-8	459199.872	5028219.275	39.654	72.196
Base station (PPP) <sup>1</sup>	459390.917	5028226.521	39.755	72.294
Base station (b-line) <sup>2</sup>	459390.919	5028226.519	39.766	72.305

Table 2.9: Summary of Results – GNSS positions – August 2018 survey

<sup>1</sup>: GNSS data processed using NRCan Precision Point Processing from static survey

<sup>2</sup>: GNSS data processed using baseline method from NRC – CACS station

<sup>3</sup>: This point is a new installation for 2018, offset from previous years

Desition established				111 1 1 1	11 1 1 1
Position established	Easting	Northing	Height	Height	Height
by NRCan - PPP	(metres)	(metres)	Ellipsoidal	Orthometric	Orthometric
	, , ,	· · · ·	(metres)	(metres)	(metres)
UTM Zone 18	NAD-83-CSRS			CGVD28	CGVD2013
MBR-2	No data				
MBR- 3	459426.449	5028647.479	37.875	70.409	70.154
MBR-4 – MOV <sup>3</sup>	459609.524	5028675.512	37.407	69.937	69.683
MBR-5	459292.869	5028403.057	37.091	69.627	69.373
MBR-6	459149.763	5028426.085	37.117	69.656	69.402
MBR-7	459396.129	5028377.016	38.297	70.831	70.577
MBR-8	459199.882	5028219.269	39.661	72.198	71.945
Base station (PPP) <sup>1</sup>	459390.924	5028226.525	39.763	72.298	72.045
Base station (b-line) <sup>2</sup>	459390.924	5028226.518	39.763		

Table 2.10 - Summary of Results – GNSS positions – January 2019 survey

<sup>2</sup>: GNSS data processed using baseline method from NRC – CACS station

MOV<sup>3</sup>: MB4-target was moved in early 2018

Table 2.11 - Summar	y of Results –	<b>GNSS</b> positions	– Ma	y 2019 survey	/
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Position established by NRCan - PPP	Easting (metres)	Northing (metres)	Height Ellipsoidal (metres)	Height Orthometric (metres)
UTM Zone 18	NAD-83-CSRS			CGVD2013
MBR-2	459467.550	5028530.201	37.301	69.580
MBR- 3	459426.444	5028647.476	37.874	70.153
$MBR-4 - MOV^3$	459609.513	5028675.515	37.406	69.682
MBR-5	459292.869	5028403.053	37.076	69.358
MBR-6	459149.775	5028426.082	37.124	69.408
MBR-7	459396.099	5028377.024	38.281	70.561
MBR-8	459199.878	5028219.270	39.642	71.926
MBR-10				
MBR-12	458926.359	5028072.015	41.256	73.545
Base station (PPP) <sup>1</sup>	459390.924	5028226.519	39.760	72.041
Base station (b-line) <sup>2</sup>	459390.922	5028226.519	39.762	

<sup>1</sup>: GNSS data processed using NRCan Precision Point Processing from static survey

<sup>2</sup>: GNSS data processed using baseline method from NRC – CACS station

MOV<sup>3</sup>: MB4-target was moved in early 2018

	T			
Position established	Easting	Northing	Height	Height
by NRCan - PPP	(metres)	(metres)	Fllipsoidal	Orthometric
-	(modiod)	(110000)	(metres)	(metres)
UTM Zone 18	NAD-83-CSRS			CGVD2013
MBR-2	No data	No data	No data	No data
MBR- 3	459426.444	5028647.470	37.885	70.164
MBR-4 – MOV <sup>3</sup>	459609.514	5028675.512	37.412	69.688
MBR-5	459292.866	5028403.051	37.085	69.367
MBR-6	459149.766	5028426.083	37.105	69.390
MBR-7	459396.079	5028377.013	38.269	70.549
MBR-8	459199.878	5028219.274	39.653	71.938
MBR-10	458905.881	5028155.559	39.989	72.279
MBR-12	458926.378	5028072.023	41.222	73.511
Base station (PPP) <sup>1</sup>	459390.920	5028226.519	39.756	72.037
Base station (b-line) <sup>2</sup>	459390.922	5028226.515	39.769	

Table 2.12 - Summary of Results – GNSS positions – August 2019 survey

<sup>2</sup>: GNSS data processed using baseline method from NRC – CACS station

MOV<sup>3</sup>: MB4-target was moved in early 2018

Position established by NRCan - PPP	Easting (metres)	Northing (metres)	Height Ellipsoidal (metres)	Height Orthometric (metres)
UTM Zone 18	NAD-83-CSRS			CGVD2013
MBR-2	459467.545	5028530.201	37.328	69.607
MBR- 3	459426.447	5028647.471	37.888	70.168
MBR-4 – MOV <sup>3</sup>	459609.512	5028675.511	37.419	69.695
MBR-5	459292.863	5028403.054	37.107	69.390
MBR-6	459149.773	5028426.090	37.146	69.431
MBR-7	459396.093	5028377.012	38.277	70.558
MBR-8	459199.878	5028219.272	39.667	71.951
MBR-10	458905.881	5028155.545	40.043	72.333
MBR-12	458926.366	5028072.005	41.242	73.531
Base station (PPP) <sup>1</sup>	459390.923	5028226.518	39.766	72.047
Base station (b-line) <sup>2</sup>	459390.924	5028226.515	39.762	

Table 2.13 - Summa	ry of Results –	GNSS	positions –	December	2019 surve	y
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<sup>1</sup>: GNSS data processed using NRCan Precision Point Processing from static survey

<sup>2</sup>: GNSS data processed using baseline method from NRC – CACS station

MOV<sup>3</sup>: MB4-target was moved in early 2018

Table 2.14: Summary of Results – GPS positions for the MBR-2 Station determined using NRCan Precision Point Processing (PPP) from static survey

MBR-2 established positions	Easting (metres)	Northing (metres)	Height <u>Ellipsoidal</u> (metres)	Height <u>Orthometric</u> (metres)	Height Orthometric metres)
				CGVD28	CGVD2013
May 2016	459467.545	5028530.204	37.318	69.901	
July 2016	459467.537	5028530.207	37.337	69.920	
August 2016	459467.545	5028530.204	37.318	69.901	
September 16	459467.548	5028530.207	37.340	69.923	
November 16	459467.545	5028530.204	37.331	69.914	
December 16	459467.548	5028530.195	37.321	69.904	
June 2017	459467.539	5028530.201	37.319	69.902	
May 2018	459467.550	5028530.198	37.317	69.900	
August 2018	459467.540	5028530.201	37.314	69.851 <sup>new</sup>	
January 2019	No data	No data	No data	No data	No data
May 2019	459467.550	5028530.201	37.301		69.580
August 2019	No data	No data	No data		No data
December 2019	459467.545	5028530.201	37.328		69.607
Maximum Delta (PPP) <sup>1</sup>	0.013	0.012	0.039		

<sup>1</sup>: GPS data processed using NRCan Precision Point Processing from static survey <sup>New</sup>: refers to a modification of PPP software – see p. 45 Table 2.15: Summary of Results – GPS positions for the MBR-3 Station determined using NRCan Precision Point Processing from static survey

MBR-3 established positions	Easting (metres)	Northing (metres)	Height <u>Ellipsoidal</u> (metres)	Height Orthometric (metres)	Height <u>Orthometric</u> (metres
				CGDV28	CGDV2013
May 2016	459426.437	5028647.469	37.858	70.442	
July 2016	459426.435	5028647.479	37.875	70.459	
August 2016	459426.435	5028647.469	37.865	70.449	
September 16	459426.437	5028647.479	37.876	70.460	
November 16	459426.435	5028647.479	37.881	70.465	
December 16	459426.441	5028647.476	37.872	70.456	
June 2017	459426.432	5028647.479	37.861	70.445	
May 2018	459426.443	5028647.472	37.874	70.458	
August 2018	459426.434	5028647.475	37.866	70.403 <sup>new</sup>	
January 2019	459426.449	5028647.479	37.875	70.409 <sup>new</sup>	70.154
May 2019	459426.444	5028647.476	37.874		70.153
August 2019	459426.444	5028647.470	37.885		70.164
December 2019	459426.447	5028647.471	37.888		70.168
Maximum Delta PPP <sup>1</sup>	0.017	0.010	0.030		

<sup>1</sup>: GPS data processed using NRCan Precision Point Processing from static survey <sup>New:</sup> refers to a modification of PPP software – see p. 45 Table 2.16: Summary of Results – GPS positions for the MBR-4 Station determined using NRCan Precision Point Processing from static survey

MBR-4 established positions	Easting (metres)	Northing (metres)	Height <u>Ellipsoidal</u> (metres)	Height <u>Orthometric</u> (metres)	Height <u>Orthometric</u> (metres)
				CGVD28	CGVD2013
May 2016	459609.062	5028674.863	37.422	70.003	
July 2016	459609.071	5028674.866	37.420	70.001	
August 2016	459609.060	5028674.860	37.409	69.990	
September 16	459609.064	5028674.863	37.425	70.006	
November 16	459609.060	5028674.860	37.425	70.006	
December 16	459609.073	5028674.857	37.416	69.997	
June 2017	459609.066	5028674.860	37.393	69.974	
May 2018	459609.514*	5028675.511*	37.407*	69.988*	
August 2018	459609.495*	5028675.513*	37.389*	69.923 <sup>new</sup>	
January 2019	459609.524*	5028675.512*	37.407*	69.937 <sup>new</sup>	69.683
May 2019	459609.513*	5028675.515*	37.406*		69.682
August 2019	459609.512*	5028675.514*	37.412		69.688
December 2019	459609.512	5028675.511	37.419		69.695
Maximum Delta PPP¹	0.013	0.009	0.030		

<sup>1</sup>: GPS data processed using NRCan Precision Point Processing from static survey <sup>New:</sup> refers to a modification of PPP software – see p. 45

\* MB-4 location and height was modified in 2018. Maximum delta does not include 2018-19.

Table 2.17: Summary of Results – GPS positions for the MBR-5 Station determined using NRCan Precision Point Processing from static survey

MBR-5 established positions	Easting (metres)	Northing (metres)	Height <u>Ellipsoidal</u> (metres)	Height <u>Orthometric</u> (metres)	Height Orthometric (metres)
			, ,	CGVD28	CGVD2013
May 2016	459292.857	5028403.057	37.083	69.670	
July 2016	459292.859	5028403.057	37.094	69.681	
August 2016	459292.859	5028403.060	37.089	69.676	
September 16	459292.857	5028403.054	37.104	69.691	
November 16	459292.857	5028403.054	37.110	69.697	
December 16	459292.861	5028403.051	37.091	69.678	
June 2017	459292.861	5028403.057	37.093	69.680	
May 2018	459292.863	5028403.051	37.101	69.688	
August 2018	459292.857	5028403.052	37.096	69.636 new	
January 2019	459292.869	5028403.057	37.091	69.627 new	69.373
May 2019	459292.869	5028403.053	37.076		69.358
August 2019	459292.866	5028403.051	37.085		69.367
December 2019	459292.863	5028403.054	37.107		69.390
Maximum Delta PPP <sup>1</sup>	0.012	0.009	0.042		

<sup>1</sup>: GPS data processed using NRCan Precision Point Processing from static survey <sup>New:</sup> refers to a modification of PPP software – see p. 45 Table 2.18: Summary of Results – GPS positions for the MBR-6 Station determined using NRCan Precision Point Processing from static survey

MBR-6 established positions	Easting Northing (metres) (metres)		Height <u>Ellipsoidal</u> (metres)	Height Orthometric (metres)	Height <u>Orthometric</u> (metres)
				CGVD28	CGVD2013
May 2016	459149.756	5028426.087	37.144	69.733	
July 2016	459149.748	5028426.093	37.164	69.753	
August 2016	459149.752	5028426.090	37.150	69.739	
September 16	459149.750	5028426.093	37.169	69.758	
November 16	459149.750	5028426.093	37.175	69.764	
December 16	459149.750	5028426.090	37.156	69.745	
June 2017	459149.752	5028426.084	37.150	69.739	
May 2018	459149.761	5028426.084	37.160	69.749	
August 2018	459149.754	5028426.084	37.163	69.705 <sup>new</sup>	
January 2019	459149.763	5028426.085	37.117	69.656 <sup>new</sup>	69.402
May 2019	459149.775	5028426.082	37.124		69.408
August 2019	459149.766	5028426.083	37.105		69.390
December 2019	459149.773	5028426.090	37.146		69.431
Maximum Delta PPP <sup>1</sup>	0.027	0.011	0.070		

<sup>1</sup>: GPS data processed using NRCan Precision Point Processing from static survey <sup>New:</sup> refers to a modification of PPP software – see p. 45 Table 2.19: Summary of Results – GPS positions for the MBR-7 Station determined using NRCan Precision Point Processing from static survey

MBR-7 established positions	Easting (metres)	Northing (metres)	Height <u>Ellipsoidal</u> (metres)	Height Orthometric (metres)	Height Orthometric (metres
				CGVD28	CGVD2013
May 2016	459396.056	5028377.023	38.307	70.892	
July 2016	459396.054	5028377.026	38.313	70.898	
August 2016	459396.060	5028377.029	38.311	70.896	
September 16	459396.067	5028377.010	38.323	70.908	
November 16	459396.065	5028377.023	38.322	70.907	
December 16	459396.071	5028377.001	38.316	70.901	
June 2017	459396.069	5028376.998	38.304	70.889	
May 2018	459396.097	5028377.001	38.305	70.890	
August 2018	459396.071	5028376.998	38.300	70.838 new	
January 2019	459396.129	5028377.016	38.297	70.831 new	70.577
May 2019	459396.099	5028377.024	38.281		70.561
August 2019	459396.079	5028377.013	38.269		70.549
December 2019	459396.093	5028377.012	38.277		70.558
Maximum Delta PPP <sup>1</sup>	0.075	0.031	0.046		

<sup>1</sup>: GPS data processed using NRCan Precision Point Processing from static survey <sup>New:</sup> refers to a modification of PPP software – see p. 45

Note: Long term trends indicate MBR-7 may be slowly sinking into the peatland

Table 2.20: Summary of Results – GPS positions for the MBR-8 Station determined using NRCan Precision Point Processing from static survey

MBR-8 established positions	Easting Northing (metres) (metres)		Height <u>Ellipsoidal</u> (metres)	Height <u>Orthometric</u> (metres)	Height Orthometric (metres)
					CGVD2013
		Site not vot o	otobliobod		
May 2016		Sile not yet e	Stablished.		
July 2016					
August 2016	459199.879	5028219.273	39.655	72.243	
September 16	459199.875	5028219.276	39.675	72.263	
November 16	459199.870	5028219.279	39.670	72.258	
December 16	459199.879	5028219.270	39.667	72.255	
June 2017	459199.872	5028219.270	39.656	72.244	
May 2018	459199.885	5028219.276	39.655	72.243	
August 2018	459199.872	5028219.275	39.654	72.196 new	
January 2019	459199.882	5028219.269	39.661	72.198 new	71.945
May 2019	459199.878	5028219.270	39.642		71.926
August 2019	459199.878	5028219.274	39.653		71.938
December 2019	459199.878	5028219.272	39.667		71.951
Maximum Delta PPP <sup>1</sup>	0.015	0.010	0.033		

<sup>1</sup>: GPS data processed using NRCan Precision Point Processing from static survey <sup>New:</sup> refers to a modification of PPP software – see p. 45

MBR-Base Station established positions		Easting (metres)	Northing (metres)	Height <u>Ellips.</u> (metres)	Height <u>Ortho</u> (metres	Height <u>Ortho</u> (metres)
					CGVD28	CGVD2013
Observations start in May 2019. Quality result start in August						
August 2019	(PPP) <sup>1</sup>	458905.881	5028155.559	39.989		72.279
	(b-line) <sup>2</sup>	458905.881	5028155.546	40.035		
	(b-line) <sup>3</sup>	458905.877	5028155.557	40.034		
December 2019	(PPP) <sup>1</sup>	458905.881	5028155.545	40.043		72.333
	(b-line) <sup>2</sup>	458905.884	5028155.542	40.074		
	(b-line) <sup>3</sup>	458905.879	5028155.553	40.068		
Maximum Delta	(PPP) <sup>1</sup>	0.000	0.014	0.046		
	(b-line) <sup>2</sup>	0.003	0.004	0.039		
	(b-line) <sup>3</sup>	.004	.004	.140		

Table 2.21: Summary of Results - GPS positions for the MBR-10 Station

<sup>1</sup>: GPS data processed using NRCan Precision Point Processing from static survey
 <sup>2</sup>: GPS data processed using baseline method from NRC –CACS station
 <sup>3</sup>: GPS data processed using baseline method from Base station

MBR-Base Station established positions		Easting (metres)	Northing (metres)	Height <u>Ellips.</u> (metres)	Height <u>Ortho</u> (metres	Height <u>Ortho</u> (metres)
					CGVD28	CGVD2013
Observations starts in May 2019						
May 2019	(PPP) <sup>1</sup>	458926.359	5028072.015	41.256		73.545
	(b-line) <sup>2</sup>	458926.370	5028072.015	41.242		
	(b-line) <sup>3</sup>	458926.367	5028072.023	41.243		
August 2019	(PPP) <sup>1</sup>	458926.378	5028072.023	41.222		73.511
	(b-line) <sup>2</sup>	458926.379	5028072.018	41.218		
	(b-line) <sup>3</sup>	458926.376	5028072.029	41.208		
December 2019	(PPP) <sup>1</sup>	458926.366	5028072.009	41.230		73.519
	(b-line) <sup>2</sup>	458926.375	5028072.011	41.235		
	(b-line) <sup>3</sup>	458926.370	5028072.022	41.252		
Maximum Delta	(PPP) <sup>1</sup>	0.019	0.014	0.034		
	(b-line) <sup>2</sup>	0.009	0.008	0.024		
	(b-line) <sup>3</sup>	0.009	0.007	0.044		

Table 2.22: Summary of Results – GPS positions for the MBR-12 Station

<sup>1</sup>: GPS data processed using NRCan Precision Point Processing from static survey
 <sup>2</sup>: GPS data processed using baseline method from NRC –CACS station
 <sup>3</sup>: GPS data processed using baseline method from Base station

MBR-Base Station established positions		Easting (metres)	Northing (metres)	Height <u>Ellipso</u> (metres)	Height <u>Ortho</u> (metres)	Height <u>Ortho</u> (metres)
						CGVD201 3
			Not vet inst	alled.		
			<b>,</b>			
May 2016	(PPP) <sup>1</sup>	459390.920	5028226.528	39.760	72.345	
	(b-line) <sup>2</sup>	459390.919	5028226.527	39.758	72.343	
July 2016	(PPP) <sup>1</sup>	459390.925	5028226.528	39.758	72.343	
	(b-line) <sup>2</sup>	459390.921	5028226.525	39.762	72.347	
August 2016	(PPP) <sup>1</sup>	459390.922	5028226.525	39.758	72.343	
	(b-line) <sup>2</sup>	459390.922	5028226.524	39.760	72.345	
September 16	(PPP) <sup>1</sup>	459390.920	5028226.528	39.773	72.358	
	(b-line) <sup>2</sup>	459390.918	5028226.525	39.762	72.347	
November 16	(PPP) <sup>1</sup>	459390.920	5028226.528	39.771	72.356	
	(b-line) <sup>2</sup>	459390.919	5028226.522	39.760	72.345	
December 16	(PPP) <sup>1</sup>	459390.924	5028226.522	39.760	72.345	
	(b-line) <sup>2</sup>	459390.918	5028226.523	39.759	72.344	
June 2017	(PPP) <sup>1</sup>	459390.921	5028226.525	39.761	72.346	
	(b-line) <sup>2</sup>	459390.920	5028226.523	39.755	72.340	
May 2018	(PPP) <sup>1</sup>	459390.927	5028226.519	39.756	72.341	
	(b-line) <sup>2</sup>	459390.917	5028226.521	39.771	72.356	
August 2018	(PPP) <sup>1</sup>	459390.917	5028226.521	39.755	72.294 <sup>new</sup>	
	(b-line) <sup>2</sup>	459390.919	5028226.519	39.766	72.305 new	
January 2019	(PPP) <sup>1</sup>	459390.924	5028226.525	39.763	72.298 new	72.045
	(b-line) <sup>2</sup>	459390.924	5028226.518	39.763	72.305 <sup>new</sup>	
May 2019	(PPP) <sup>1</sup>	459390.924	5028226.519	39.760		72.041
	(b-line) <sup>2</sup>	459390.922	5028226.519	39.762		
August 2019	(PPP) <sup>1</sup>	459390.920	5028226.519	39.756		72.037
	(b-line) <sup>2</sup>	459390.922	5028226.515	39.769		
December 2019	(PPP) <sup>1</sup>	459390.923	5028226.518	39.766		72.047
	(b-line) <sup>2</sup>	459390.924	5028226.515	39.762		
Maximum Delta	(PPP) <sup>1</sup>	0.010	0.009	0.018		
	(b-line) <sup>2</sup>	0.007	0.011	0.016		

### Table 2.23: Summary of Results – GPS positions for the MBR-Base Station

<sup>1</sup>: GPS data processed using NRCan Precision Point Processing from static survey
 <sup>2</sup>: GPS data processed using baseline method from NRC –CACS station
 <sup>New:</sup> refers to a modification of PPP software – see p. 38

	Hoight	Hoight	Hoight	Hoight	Hoight	Hoight	Hoight
	(metres)	(metres)	(metres)	(metres)	(metres)	(metres)	(metres)
	(meacs)	(metres)	(metres)	(meres)	(meacs)	(meres)	(meacs)
	May	July	Διιαμετ	Sent	Nov	Dec	June
	2016	2016	2016	2016	2016	2016	2017
	2010	2010	2010	2010	2010	2010	2017
MBR-2 -PPP	37 318	37 337	37 318	37 340	37 331	37 321	37 319
MBR-2 -NRC	37 320	37 328	37 312	37 315	37 323	37 318	37 309
MBR-2 -Base	Not installed	37.323	37.311	37.311	37.317	37.321	37.307
		011020	011011	011011	011011	011021	011001
MBR- 3 -PPP	37.858	37.875	37.865	37.876	37.881	37.872	37.861
MBR- 3 -NRC	37.864	37.869	37.864	37.867	37.872	37.864	37.858
MBR-3 -Base	Not installed	37.871	37.862	37.863	37.868	37.869	37.863
MBR-4 - PPP	37.422	37.420	37.409	37.425	37.425	37.416	37.393
MBR-4 -NRC	37.429	37.427	37.413	37.418	37.419	37.415	37.396
MBR-4 -Base	Not installed	No data	37.411	37.413	37.417	37.420	37.401
MBR-5 - PPP	37.083	37.094	37.089	37.104	37.110	37.091	37.093
MBR-5 -NRC	37.081	37.088	37.085	37.085	37.095	37.093	37.087
MBR-5 -Base	37.085	No data	No data	37.082	37.093	37.095	37.092
MBR-6 - PPP	37.144	37.164	37.150	37.169	37.175	37.156	37.150
MBR-6 -NRC	37.147	37.159	37.153	37.154	37.162	37.157	37.152
MBR-6 -Base	37.151	37.154	No data	37.152	37.160	37.161	37.149
MBR-7 - PPP	38.307	38.313	38.311	38.323	38.322	38.316	38.304
MBR-7 - NRC	38.302	38.306	38.310	38.312	38.316	38.304	38.306
MBR-7 -Base	38.306	38.307	No data	38.308	38.309	38.309	38.303
MBR-8 - PPP	Not installed	Not install	39.655	39.675	39.670	39.667	39.656
MBR-8 NRC	Not installed	Not installed	39.661	39.658	39.661	39.658	39.658
MBR-8 -Base	Not installed	Not installed	No data	39.657	39.658	39.659	39.657
Base sta. P	39.760	39.758	39.758	39.773	39.771	39.760	39.761
Base sta N	39.762	39.761	39.760	39.762	39.760	39.759	39.755

Table 2.24- Summary	/ of Results -	<ul> <li>Height difference</li> </ul>	between surveys	(ellipsoidal)

\* MB-4 location and height was modified in 2018.

	Height	Heiaht	Heiaht	Heiaht	Height	Height
	(metres)	(meters)	(meters)	(meters)	(meters)	(meters)
	· · · · ·					, , ,
	Mav	August	January	Mav	August	December
	2018	2018	2019	2019	2019	2019
MBR-2 -PPP	37.317	37.314	No data	37.301	No data	37.328
MBR-2 -NRC	37.315	37.312	No data	37.301	No data	37.313
MBR-2 -Base	37.303	37.306	No data	37.294	No data	37.312
MBR- 3 - PPP	37.874	37.866	37.875	37.874	37.885	37.888
MBR- 3 -NRC	37.867	37.877	37.876	37.870	37.891	37.885
MBR-3 -Base	37.868	37.870	37.865	37.867	37.879	37.883
MBR-4 - PPP	37.407*	37.389*	37.407*	37.406	37.412	37.419
MBR-4 -NRC	37.400*	37.415*	37.422*	37.400	37.404	37.413
MBR-4 -Base	37.399*	37.407*	37.424*	37.401	37.403	37.410
MBR-5 - PPP	37.101	37.096	37.091	37.076	37.085	37.107
MBR-5 -NRC	37.103	37.099	37.088	37.078	37.090	37.105
MBR-5 -Base	37.091	37.092	37.077	37.075	37.078	37.102
MBR-6 - PPP	37.160	37.163	No data	37.124	37.105	37.146
MBR-6 -NRC	37.165	37.165	No data	37.121	37.118	37.138
MBR-6 -Base	37.153	37.158	No data	37.117	37.085	37.137
MBR-7 - PPP	38.305	38.300	38.297	38.281	38.269	37.277
MBR-7 - NRC	38.299	38.304	38.286	38.276	38.256	38.273
MBR-7 -Base	38.299	38.297	38.287	38.276	38.260	38.267
MBR-8 - PPP	39.655	39.654	39.661	39.642	39.653	39.667
MBR-8 NRC	39.670	39.662	39.658	39.658	39.666	39.664
MBR-8 -Base	39.657	39.655	39.655	39.658	39.656	39.659
					20,000	40.040
MDR-10 - PPP					39.909	40.043
MPR 10 Ross					40.035	40.074
WDR-TU- Dase					40.034	40.000
MBR-12 - PPP	<u>├</u>			11 256	11 222	/1 230
				41.230	41.222	41.230
MBR-12-NIC				41.242	41.210	41.233
				71.240	41.200	71.2J2
Base sta P	39 756	39 755	39 763	39 760	39 756	39 766
Base sta - NRC	39 771	39 766	39 763	39 762	39 769	39 762
5450 Std. 1410	00.111	00.700	00.100	00.102	00.100	00.102

# Table 2.24- (Suite) Summary of Results – Height difference between surveys (ellipsoidal)

\* MB-4 location and height was modified in 2018.

Table 2.25 provides details on the height variation through time of the National Research Council of Canada station. This CACS station is one of the GNSS recording station.

Table 2.25	Summary	of Result	s – NRC	CACS	station h	neight va	riation th	rough time	е
	May	June	Julv	Aug.	Sept.	Nov.	Dec.	June	

	May	June	July	Aug.	Sept.	Nov.	Dec.	June
	2016	2016	2016	2016	2016	2016	2016	2017
metre	015	010	.001	010	.003	.000	011	003

Table 2.25 (Suite) - Summary of Results-NRC CACS height variation through time

	May 2018	August 2018	January 2019	May 2019	August 2019	December 2019
metre	003	.012 /003	006/.018/005	002/.001/002	005	003

Source: Geodetic Survey Division, Canadian Active Control System.

Several figures illustrating the height variation of each point, established using various methods are show in Section 8 and 9.

#### 3) Survey site location and materials used

Mer Bleue (Figure 3.1) is a protected ombrotrophic bog with a hummock-hollow-lawn microtopography. It is located at the eastern boundary of the City of Ottawa, Ontario, Canada at 45.4°N and 75.5°W. This wetlands area has an east–west orientation dissected by two longitudinal sections of fluvial sand/gravel separating three distinct arms of the peatland (Lafleur, et al. 2005). The bog is slightly domed, with a peat depth greater than 5-6 m across most of the area. In the northern arm, this decreases to 0.3 m towards the edge where narrow beaver ponds are inundated year-round (Lafleur, et al. 2005) (Roulet, et al. 2007).



Figure 3.1: Mer Bleue Bog and locations of GNSS Survey site targets at the Mer Bleue Peatland Observatory in Ottawa, Ontario, Canada. Image: Google Earth<sup>tm</sup>

The Mer Bleue Bog is home to the Mer Bleue Peatland Observatory (MBPO), providing infrastructure for research activities since its inception in 1998. The MBPO has restricted access with a neighbouring grassland area and various pedestrian


boardwalks protecting the peat surface. Proximity of the Mer Bleue Bog to the city of Ottawa provides convenient deployment of field teams and equipment.

Figure 3.2: GNSS Point locations at the Mer Bleue Research Boardwalk area. MBR-8 and the Base Station are located on dry, upper ground while the others are located on stable but floating supports on the boardwalk itself.

At first, eight GPS survey points (Figure 3.2) were established on or near the MBPO. Six of these points are located in the bog itself using boardwalk structural supports mounted into the peat (but not reaching the sedimentary layer beneath the peat). Two other points are located outside of the bog on dry, upper ground to act as permanent stable points. These two points consist of a steel rod hammered several meters down in soft sediment below the frost line.

The MBR Base Station target site (Figure 3.3) was installed in May 2016. In early August 2016 it was agreed by team members that an additional reference point should be defined further west of the actual set of points to take into account the extended area covered by the airborne and UAV surveys, including the light drone survey for which the coverage limit extends outside the existing work zone.



Figure 3.3: MBR Base Station site with (left) and without (right) the pipe cap.



Figure 3.4: MBR-8 site with (left) and without (right) the pipe cap.

To that effect, a new point (MBR-8) was established outside of the bog itself on dry, upper ground (Figure 3.4). This new point also acts as a permanent stable point similar

to the Base Station. MBR-8 is made of a steel rod hammered 6.1 m down into the soft sediment below the frost line. A large diameter steel pipe 60 cm long was hammered over the steel rod to stabilize it. Since there is no bedrock in the area, it is expected that this point will be as stable as possible in this type of ground and location. The Base Station and MBR-8 sites being both stable points, can be used for phase difference GNSS. Having two stable points allows one to validate that no relative height variations occur with these base locations.

The positions (latitude-longitude-altitude) of the of the six points on the peatland boardwalk, and the two points on the upper ground were all established based on long (~24 – 40 hour) static GNSS surveys using Ashtech<sup>™</sup> Choke Ring antennas with either Ashtech<sup>™</sup> dual frequency Zxtreme<sup>™</sup> receivers or Trimble NetR9<sup>™</sup> receivers (Table 3.1). Other materials required for the survey included antenna cables, power cables, internal and external batteries, painted plywood targets, bolts and nuts, and camera (Figure 3.6).

In May 2019, two new points were established approximately .5 km west of the main working area (Figure 3.5). These points consist of a red painted concrete slab laid on the ground. They will be used to evaluate the planimetric and altimetric accuracy of various drone surveys. They are named MBR-10 and MBR-12.



Figure 3.5: MBR-10 and MBR-12 sites

	Jan. 2019		May 2019		Aug. 2019		Dec. 2019	
Site								
MBR-2	GPS	0 h	GPS	23 h	GPS	0 h	GPS	22 h
MBR-3	GPS	15 h	GPS	23 h	GPS	21 h	GPS	22 h
MBR-4	GPS+Glon <sup>1</sup>	22 h	GPS	24 h	GPS	23 h	GPS	22 h
MBR-5	GPS	18 h	GPS	23 h	GPS	22 h	GPS	22 h
MBR-6	GPS	18 h	GPS	43 h	GPS	18 h	GPS	22 h
MBR-7	GPS	14 h	GPS	23 h	GPS	16 h	GPS	22 h
MBR-8	GPS	46 h	GPS	48 h	GPS+ Glon <sup>1</sup>	46 h	GPS+ Glon <sup>1</sup>	13 h
MBR-10			GPS+Glon <sup>2</sup> (L1)	15	GPS+ Glon <sup>1</sup> (L1)	24	GPS	22 h
MBR-12			GPS	24	GPS	20	GPS+ Glon <sup>1</sup>	14 h
Base -1 <sup>st</sup> day	GPS+Glon <sup>1</sup> .	17 h	GPS+Glon <sup>1</sup>	21	GPS+ Glon <sup>1</sup>	47	GPS+ Glon <sup>1</sup>	23 h
Base -2 <sup>nd</sup> day	GPS	17 h						

Table 3.1: GNSS acquisition time for individual surveys - Rounded to the hour

<sup>1</sup>Glon. = Glonass <sup>2</sup> GPS+Glon (L1) = GPS and Glonass single frequency only



Figure 3.6: GNSS receivers and associated components

Processing of the resulting RINEX files (the receiver raw output files) was performed days after acquisition by NRCan Precision Point Processing (PPP) Service. A processing report summary page is included for each point and acquisition. MBR-2 to MBR-7 are located on "semi-stable" ground (i.e. on posts used to support the boardwalk used by scientists to circulate throughout the site). None of the points are on rock, bedrock or solid concrete. Latitude and longitude (planimetric) positions should be used with caution. To our knowledge, no boardwalk maintenance has been performed near these posts.

With respect to the altitude of each location, a few considerations must be noted. The altitude of any of those positions is, as by design of the set-up, the altitude of the top face of the plywood target (as illustrated in site pictures). No attempt was made to estimate the ground altitude as the moss creates a very rough and seasonally variable microtopography, potentially changing with moisture levels, phenological state, etc. The plywood target height would however provide a base location to determine the altitude of the vegetation layer using the UAV surveys. It is the responsibility of the

user to measure the plywood target height above "ground" to obtain the ground altitude. As the altitude estimated of the MBR points during this GNSS survey could also vary seasonally as the posts base do not reach the "solid" bottom beneath the bog, these points are compared to the MBR-8 and Base Station positions. We should note that there have been no anecdotal reports of the boardwalk vertical motion impacting any of the MBPO infrastructure, so it was assumed stable as a start.

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 order to increase the confidence of the height estimation, point heights were also estimated using baseline processing in relation to the NRCan Canadian Active Control System (CACS) station located 9 km away in Ottawa (Figure 3.7 - 3.10), and also using baseline processing in relation to the Base Station Site.

La coordonnée de la statior	n ci-dessous sera automatique	ment mise à jour après un char	igement de ces champs.	
coordonnées Cao	lre de référence	Datum altimétrique	Géoïde	Époque
UTM •	IAD83(SCRS)	• ( CGVD2013 • )	CGG2013a ·	Choisir par la da
ate (YYYY-MM-DD)				
01/24/2019				
Zone	Abscisse	(mètres)	Ordonnée (mètre	35)
Zone UTM18	Abscisse 451223	(mètres) .145 ± 0.0010	Ordonnée (mètre 5033592.286 ±	əs) 0.0025
Zone UTM18 <u>h</u> (mètres)	Abscisse 451223 Échelle	(mètres) .145 ± 0.0010	Ordonnée (mètre 5033592.286 ± Échelle combiné	əs) : 0.0025 e
Zone UTM18 <u>h</u> (mètres) 83.619 ± 0.0020	Abscisse 451223 Échelle 0.99962	(mètres) . 145 ± 0.0010 29	Ordonnée (mètre 5033592.286 ± Échelle combiné 0.999616	es) : 0.0025 :e
Zone UTM18 <u>h</u> (mètres) 83.619 ± 0.0020 Convergence	Abscisse 451223 Échelle 0.99962	(mètres) .145 ± 0.0010 29	Ordonnée (mètre 5033592.286 ± Échelle combiné 0.999616	es) : 0.0025 :e
Zone UTM18 h (mètres) 83.619 ± 0.0020 Convergence 0° 26' 40.56"	Abscisse 451223 Échelle 0.99962	e (mètres) 1.145 ± 0.0010 29	Ordonnée (mètre 5033592.286 ± Échelle combiné 0.999616	es) : 0.0025 :e
Zone UTM18 h (mètres) 83.619 ± 0.0020 Convergence 0° 26' 40.56" <u>N (</u> mètres)	Abscisse 451223 Échelle 0.99962	s (mètres) 145 ± 0.0010 29 s)	Ordonnée (mètre 5033592.286 ± Échelle combiné 0.999616 Date publié et ID	es) : 0.0025 :e : du projet

Figure 3.7. Position of NRC Canadian Active Control System Station used for baseline processing based on default altimetric datum – CGVD2013- January survey

		G	oordonnees du repe	ere	
CGG2013a est	la matérialisation actuelle o	lu CGVD2013 et l	e modèle du géoïde par	défaut.	
3 La coordonnée de	la station ci-dessous sera	automatiquement	mise à jour après un ch	angement de ces champs.	
Coordonnées	Cadre de référence		Datum altimetrique	Géoïde	Époque
UTM	NAD83(SCRS)	•	CGVD2013 •	CGG2013a •	Choisir par la da
Date (YYYY-MM-DD)					
05/30/2019					
Les vilesses so	ni esumees a partir de la se	ane temporelle Gr	155 a la station.		
Zone	_	Abscisse (mèt	res)	Ordonnée (mě	tres)
Zone UTM18		Abscisse (mèt 451223.146	res) ± 0.0010	Ordonnée (mě 5033592.286	tres) 5 ± 0.0025
Zone UTM18 h (mètres)		Abscisse (mèt 451223.146 : Échelle	res) ± 0.0010	Ordonnée (mě 5033592.286 Échelle combi	tres) ± 0.0025 née
Zone UTM18 b (mètres) 83.619 ± 0.0020		Abscisse (mèt 451223.146 Échelle 0.999629	res) ± 0.0010	Ordonnée (mě 5033592.280 Échelle combi 0.999616	tres) ± ± 0.0025 née
Zone UTM18 h (mètres) 83.619 ± 0.0020 Convergence		Abscisse (mèt 451223.146 : Échelle 0.999629	res) ± 0.0010	Ordonnée (mě 5033592.286 Échelle combi 0.999616	tres) 5 ± 0.0025 née

Figure 3.8. Position of NRC Canadian Active Control System Station used for baseline processing based on default altimetric datum – CGVD2013- May survey

Coordonnées	Cadre de référence	Datum altimétrique	Géoïde	Époque
UTM •	NAD83(SCRS)	• CGVD2013 •	CGG2013a •	Choisir par la de
Date (YYYY-MM-DD)	. ,			
08/21/2019				
<ol> <li>Les vitesses sont est</li> </ol>	mées à partir de la série temporel	le GNSS à la station.		
Zone	Abscisse	(mètres)	Ordonnée (mètre	s)
UTM18	451223	.146 ± 0.0010	5033592.285 ±	0.0025
h (mètres)		Échelle		
h (mètres)	Échelle		Echelle combiné	9
h (mètres) 83.620 ± 0.0020	Échelle 0.99962	29	0.999616	9
h (mètres) 83.620 ± 0.0020	Échelle 0.99962	29	0.999616	9
h (mètres) 83.620 ± 0.0020 Convergence 0° 26' 40.56"	Échelle 0.99962	9	0.999616	3
<u>h</u> (mètres) 83.620 ± 0.0020 Convergence 0° 26' 40.56"	Échelle 0.99962	29	Echelle combine 0.999616	3
h (mètres) 83.620 ± 0.0020 Convergence 0° 26' 40.56" <u>N.(mètres)</u>	Échelle 0.99962 <u>H.(</u> mètre:	5)	Date publié et ID	e du projet

Figure 3.9 Position of NRC Canadian Active Control System Station used for baseline processing based on default altimetric datum – CGVD2013- August survey

oordonnées	Cadre de référence	Datum altimétrique	Géoïde	Époque
UTM • ate (YYYY-MM-DD) 12/18/2019	NAD83(SCRS)	• CGVD2013 •	CGG2013a •	Choisir par la de
Les vitesses sont	estimées à partir de la sér	ie temporelle GNSS à la station.		
lone		Abscisse (mètres)	Ordonnée (mètre	es)
UTM18		451223.147 ± 0.0010	5033592.285 ±	± 0.0025
(mètres)		Échelle	Échelle combiné	be
83.621 ± 0.0020		0.999629	0.999616	
Convergence				
0° 26' 40.56"				
(mètres)		<u>H.(</u> mètres)	Date publié et ID	) du projet
32 439 + 0.021		116.060	2010.02.14 M18.020	

Figure 3.10 Position of NRC Canadian Active Control System Station used for baseline processing based on default altimetric datum – CGVD2013- December survey

## 4) Data Acquisition – GNSS survey in January 2019

Presented here are the precision GNSS survey reports for the January 2019 campaign (to the limits discussed above), as well as sample photos, of the MBR site targets (Figure 4.1 to 4.4). Information provided in these detailed reports include the latitude, longitude and altitude (both ellipsoidal and orthometric representing sea level) of the base of the antenna as installed on the target, the UTM zone, and the UTM Easting and Northing. Planimetric positions are in NAD 83 CSRS.

Two geoid model are used: 1) CGVD28 as a legacy model of previous surveys since 2016 with a geoid variation of 32.58 m. 2) CGVD 2013 the default model established few years ago and presently applied by most users, with a geoid variation of 32.33 m This said, the change in geoid model has an impact mainly on the orthometric height estimation. Therefore the impact is minimal for this project since calculations are performed using ellipsoidal height.

Point positions were also estimated in May 2016, July 2016, August 2016, September 2016, November 2016, December 2016, June 2017, May 2018 and August 2018.

During the summer of 2018, between the May and August surveys, the software used to calculate the orthometric height from the ellipsoidal height was lightly modified. As a result, orthometric height are ~ 4 cm higher for the August 2018 survey onward. As well, MB-4 target was moved in early 2018. Therefore 3D positions differ from previous years. No data were acquired on MB-2 for unexplained reason (technical or human) and MB-6 showed a problem with antenna height due to ice and snow covering the post. Consequently MB-6 data were not compiled in the height trend calculations.

MB-4 target was moved in early 2018. Therefore 3D positions differ from previous years.

For the purpose of the baseline processing between the base station and individual MB points, the base station position was set at the following values, which represent the average over time since 2017. Easting and Northing are set at 459390.920 metres and 5028226.526 metres, in UTM zone 18. Ellipsoidal height is set at 39.760 metres above sea level.

During the January survey, an experiment was undertaken to estimate the precision of positioning of drone targets using a Stop & Go approach, along with a lightweight, low cost, single frequency GNSS receiver (See details at Section 10).

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Figure 4.1: Field views of GPS locations MBR-2 (left) and MBR-3 (right) (January, 2019).



Figure 4.2: Field views of GPS locations MBR-4 (left) and MBR-5 (right) (January, 2019).



Figure 4.3: Field views of GPS locations MBR-6 (left) and MBR-7 (right) (January, 2019).



Figure 4.4: Field views of GPS locations MBR-8 (left) and MBR-Base (right) (January, 2019).

Table 4.1 to 4.19 report the acquisition detail of all 8 points for the month of January 2019. Figures 4.5 to 4.22 report the position associated with each point.

Site :	
	MBR-2
Installation Type	Antenna reference point (ARP) in physical contact with top
	face of plywood UAV target. Plywood target bottom face in
	physical contact with top of post
Receiver (GNSS)	Trimble NetR-9 s/n 1059 CCRS: # 3
Antenna	Ashtech Chokering
	ASH701945C_M NONE (4 caract. between M and None).
Antenna height	
Acquisition start	NO DATA ACQUIRED – memory empty
Acquisition end	NO DATA ACQUIRED – memory empty
Duration	
Acquisition interval	
Raw GNSS files	
Rinex files	

 Table 4.1. GNSS acquisition details of point MBR-2- January 2019

Site :		MBR-3	B Geo	id model CGV	d model CGVD 28	
Installation Type		Antenn	a reference point (AF	RP) in physical o	contact with top	
		face of	plywood UAV target.	. Plywood targe	t bottom face in	
		physica	al contact with top of	post		
Receiver (GNSS)		Trimble	e NetR-9 s/n 1072 (	CCRS: # 2		
Antenna		Ashtech Chokering # 5875				
		ASH70	1945C_M NONE (4	caract. between	M and None).	
Antenna height		0	(See note above)			
Acquisition start		2019 0	01 23 18 h 11 mir	n. 00 sec.	(jour 023)	
Acquisition end		2019 0	01 24 08 h 46 mir	1 30 sec.		
Duration	-	14 h 35 m 30 sec.				
Acquisition interva		30 seconds				
Raw GNSS files		10720230C.t02				
Rinex files		10720230C.19N				
		107202	30C.19O			
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by PPP				Height (m)	Height (m) CGVD 28	
Geographic	45° 24' 36	.61212"	-75° 31' 6.62051"	37.875	70.409	
UTM	5028647.4	79	459426.449			
Error ellipse	.6 cm		1.1 cm			
@95%						
	±0.005m		±0.009m	±0.014m		

Table 4.2. GNSS acquisition details of point MBR-3 – January 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028647.469	459426.444	37.876	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028647.478	459426.441	37.865	



Figure 4.5 Position of point MBR-3 from NRCan – PPP Service – January 2019, Geoid model CGVD 28 Orange circles represent most frequently requested information.

Site :		MBR-3	Geo	oid mode	el CGVD 2013	3
Installation Type		Antenn	a reference p	point (AR	P) in physical o	contact with top
		face of	plywood UA	V target.	Plywood targe	t bottom face in
		physica	al contact with	n top of p	ost	
Receiver (GNSS)	Trimble NetR-9 s/n 1072 CCRS: # 2					
Antenna	Ashtech Chokering # 5875					
		ASH701945C_M NONE (4 caract. between M and None).				
Antenna height		0	(See note at	pove)		
Acquisition start		2019 0	01 23 18 h	11 min.	00 sec.	(jour 023)
Acquisition end		2019 0	01 24 08 h	46 min	30 sec.	
Duration	14 h 35 m 30 sec.					
Acquisition interva	l	30 seconds				
Raw GNSS files		10720230C.t02				
Rinex files		10720230C.19N				
		107202	30C.19O			
Position	Latitude		Longitude		Ellipsoidal	Orthometric
established by					Height (m)	Height (m)
PPP						CGVD2013
Geographic	45° 24' 36	.61212"	-75° 31' 6.62	2051"	37.875	70.154
UTM	5028647.4	79	459426.450			
Error ellipse	.6 cm		1.1 cm			
@95%						
	±0.005m		±0.009m		±0.014m	

Table 4.3. GNSS acquisition details of point MBR-3 – January 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028647.469	459426.444	37.876	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028647.478	459426.441	37.865	



Figure 4.6. Position of point MBR-3 from NRCan – PPP Service – January 2019 - Geoid model CGVD 2013

Site :		MBR-4	4 Geoid model is CGVD 28			
Installation Type		Antenn	Antenna reference point (ARP) in physical contact with top			
, , , , , , , , , , , , , , , , , , , ,		face of plywood UAV target. Plywood target bottom face in				
		physica	l contact with top of p	post.	,	
		This po	oint is a new installa	tion made in	2018. Point is	
		offset from previous years measurements.				
Receiver (GNSS)		Trimble NetR-9 s/n 1205 CCRS: # 5 Battery yellow top			Battery yellow top	
Antenna		Ashtec	h Chokering #5875			
		ASH70	1945C_M NONE (4	caract. betwee	n M and None).	
Antenna height		0	(See note above)			
Acquisition start	art 20		01 24 17 h 13 min	. 30 sec.	(jour 024)	
Acquisition end	2019		2019 01 25 15 h 12 min 00 sec.			
Duration	21		21 h 58 m 30 sec.			
Acquisition interval		30 seconds				
Raw GNSS files		12050240C				
Rinex files		12050240C.19N				
	-	120502	40C.19O			
Position	Latitude		Longitude	Ellipsoïdal	Orthometric	
established by				Height (m)	Height (m)	
PPP						
Geographic	45° 24' 37	.55861"	-75° 30' 58.20666"	37.407	69.937	
UTM	5028675.512		459609.524			
Error ellipse	.5 cm		.9 cm			
@95%						
	±0.004m		±0.007m	±0.013m		

Table 4.4. GNSS acquisition details of point MBR-4 - January 2019 – geoid CGVD 28

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028675.502	459609.519	37.422	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028675.512	459609.515	37.424	



Figure 4.7. Position of point MBR-4 from NRCan – PPP Service- January 2019. Geoid model CGVD 28

Site :		MBR-4	Geoid m	odel CGVD 20	13	
Installation Type		Antenn	Antenna reference point (ARP) in physical contact with top			
		face of plywood UAV target Plywood target bottom face in				
		physica	al contact with top of	post		
		This po	pint is a new install	ation for made	<b>in 2018</b> , Point	
		is offse	t from previous vears	s measurements	s	
Receiver (GNSS)		Trimble NetR-9 s/n 1205 CCRS: # 5				
Antenna		Ashtec	h Chokering			
		ASH70	1945C M NONE (4	caract between	M and None)	
Antenna height		0	(See note above)			
			(			
Acquisition start		2019 0	01 24 17 h 13 mir	n. 30 sec.	(iour 024)	
Acquisition end	2019		$019 \ 01 \ 25 \ 15 \ h \ 12 \ min \ 00 \ sec$			
Duration	21 h 5		1 h 58 m 30 sec.			
Acquisition interva	cquisition interval		30 seconds			
Raw GNSS files		120502	12050240C			
Rinex files		120502	12050240C.19N			
		120502	40C.19O			
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP						
Geographic	45° 24' 37	.55861"	-75° 30' 58.20666"	37.407	69.683	
UTM	5028675.512		459609.524			
Error ellipse	.5 cm		.9 cm			
@95%						
	±0.004m		±0.007m	±0.013m		

Table 4.5. GNSS acquisition details of point MBR-4 - January 2019 - Geoid CGVD 2013

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028675.502	459609.519	37.422	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028675.512	459609.515	37.424	



Figure 4.8. Position of point MBR-4 from NRCan – PPP Service- January 2019 -Geoid model is CGVD 2013

Site :		MBR-5	Geoid mo	Geoid model CGVD 28		
Installation Type		Antenna ref	erence point (ARP) in physical contact with top face			
		of plywood	UAV target. Plywood	target bottom	face in physical	
		contact with	top of post.			
Receiver (GNSS)		Trimble Net	R-9 S/N 1059 CCR	S:#1 No e>	t. battery	
Antenna		Ashtech Ch	okering Antenna 69	910		
		ASH701945	5C_M NONE (4 cara	ct. between M an	d None).	
Antenna height		0 (See	e note above)			
Acquisition start		2019 01 23	3 17 h 58 min. 00	sec. (jou	<sup>-</sup> 023)	
Acquisition end		2019 01 24	4 11 h 40 min 00 sec.			
Duration		17 h 42 m	00 sec.			
Acquisition interval	uisition interval 30 seconds		nds			
Raw GNSS files		10590230c.	30c.t02			
Rinex files		10590230c.	.19N			
		10590230c.	190		_	
Position	Latit	tude	Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP						
Geographic	45° 2	24' 28.66412"	-75° 31' 12.69306"	37.091	69.627	
UTM	5028403.057		459292.869			
Error ellipse	.5 cm	ı	1.0 cm			
@95%						
	±0.00	05 m	±0.008 m	±0.015 m		

Table 4.6 GNSS acquisition details of point MBR5-January 2019-Geoid model CGVD28

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028403.057	459292.870	37.088	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028403.066	459292.867	37.077	



Figure 4.9 Position of point MBR-5 from NRCan-PPP Service-January 2019 - Geoid model CGVD 28

Site :		MBR-5	Geoid	Geoid model CGVD 2013		
Installation Type		Antenna	Antenna reference point (ARP) in physical contact with top			
		face of plywood UAV target. Plywood target bottom face in				
		physica	I contact with top c	f post.		
Receiver (GNSS)		Trimble	NetR-9 S/N 1059	CCRS: # 1		
Antenna		Ashtech	n Chokering			
		ASH70	1945C_M NONE	(4 caract. between	M and None).	
Antenna height		0	(See note above)			
Acquisition start	2019 (		1 23 17 h 58 m	in. 00 sec.	(jour 023)	
Acquisition end	2019 0		1 24 11 h 40 m	in 00 sec.		
Duration	17 h 4		h 42 m 00 sec.			
Acquisition interva	ion interval 30 sec		) seconds			
Raw GNSS files		105902	)590230c.t02			
Rinex files		105902	0590230c.19N			
	-	105902	590230c.19O			
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP						
Geographic	45° 24' 28	.66412"	-75° 31' 12.69306"	37.091	69.373	
UTM	5028403.057		459292.869			
Error ellipse	.5 cm		1.0 cm			
@95%						
	±0.005 m		±0.008 m	±0.015 m		

 Table 4.7
 GNSS acquisition details of point MBR-5- January 2019-geoid model 2013

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028403.057	459292.870	37.088	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028403.066	459292.867	37.077	



Figure 4.10. Position of point MBR-5 from NRCan–PPP Service–January 2019- Geoid model CGVD 2013

Site :		MBR-6	6 Geoi	d CGDV 28		
Installation Type		Antenn	Antenna reference point (ARP) in physical contact with top			
		face of plywood UAV target. However, there is 65 mm gap				
		below t	he plywood due to ic	e in bolt hole. P	lvwood target	
		bottom	face 65 mm gap with	top of post.	, ,	
				<u> </u>		
Receiver (GNSS)		Ashtec	h ZXtreme # 1 E	attery #1		
Antenna		Ashtec	h Chokering Antenr	na #6010		
		ASH701945C_M NONE (4 caract. between M and None).				
Antenna height		0	(See note above)			
Acquisition start		2019 0	2019 01 24 17 h 05 min. 00 sec. (jour 024)			
Acquisition end	Acquisition end 2		2019 01 25 10 h 49 min 00 sec.			
Duration		17 h 44 m 00 sec.				
Acquisition interval		30 seconds				
Raw GNSS files		BA19.024				
Rinex files		024	1.19N			
		024	1.190			
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP						
Geographic	45° 24' 29.38024"		-75° 31' 19.28308"	37.117	69.656	
UTM	5028426.085		459149.763			
Error ellipse	.6 cm		1.0 cm			
@95%						
	±0.005 m		±0.008 m	±0.015 m		

Table 4.8 GNSS acquisition details of point MBR-6 – January 2019-geoid CGDV28

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028426.081	459149.764	37.102	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028426.093	459149.760	37.103	



Figure 4.11. Position of point MBR-6 from NRCan–PPP Service – January 2019- geoid model CGVD28

Table 4.9 GNSS acquisition details of point MBR-6 – January 2019 –geoid model CGDV 2013

	MBR-6	Geoi	d CGDV 2013		
	Antenna reference point (ARP) in physical contact with top				
	face of plywood UAV target. However, there is 65 mm gap				
	below the plywood due to ice in bolt hole. Plywood target				
	bottom	face 65 mm gap with	top of post.		
	Ashteck	n ZXtreme #1 Ba	attery #1		
	Ashtech	h Chokering Antenr	na #6010		
	ASH70	1945C_M NONE (4	caract. between	M and None).	
	0.065	(See note above	)		
Acquisition start		2019 01 24 17 h 05 min. 00 sec. (jour 024)			
Acquisition end		2019 01 25 10 h 49 min 00 sec.			
Duration		17 h 44 m 00 sec.			
Acquisition interval		30 seconds			
	BA19.024				
	0241.19N				
	024	1.190			
titude		Longitude	Ellipsoidal	Orthometric	
			Height (m)	Height (m)	
24' 29.	38024"	-75° 31' 19.28308"	37.117	69.402	
5028426.085		459149.763			
.6 cm		1.0 cm			
005 m		±0.008 m	±0.015 m		
	24' 29. 24' 29. 8426.0	MBR-6         Antenn         face of         below t         bottom         Ashtecl         Ashtecl         Ashtecl         Ashtecl         Ashtecl         Ashtecl         2019         2019         2019         17 h         30 secc         BA^2        024         itude         24' 29.38024"         :8426.085         :m         :005 m	MBR-6         Geoin           Antenna reference point (AR         face of plywood UAV target.           below the plywood due to ice         bottom face 65 mm gap with           Ashtech ZXtreme # 1         Ba           Ashtech Chokering Antenr         Ashtech Chokering Antenr           ASH701945C_M         NONE (4           0.065         (See note above           2019         01         24           2019         01         25         10 h           30 seconds	MBR-6         Geoid CGDV 2013           Antenna reference point (ARP) in physical of face of plywood UAV target. However, there below the plywood due to ice in bolt hole. P bottom face 65 mm gap with top of post.           Ashtech ZXtreme # 1         Battery #1           Ashtech Chokering Antenna #6010           ASH701945C_M NONE (4 caract. between 0.065 (See note above)           2019 01 24 17 h 05 min. 00 sec.           2019 01 25 10 h 49 min 00 sec.           17 h 44 m 00 sec.           30 seconds           BA19.024          0241.19N          0241.19O           titude         Longitude           Ellipsoidal Height (m)           24' 29.38024"         -75° 31' 19.28308"           37.117           ::::::::::::::::::::::::::::::::::::	

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028426.081	459149.764	37.102	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028426.093	459149.760	37.103	



Figure 4.12. Position of point MBR-6 from NRCan–PPP Service–January 2019-geoid model CGVD2013

 Table 4.10 GNSS acquisition details of point MBR-7 – January 2019 – geoid model

 CGDV 28

Site :			_			
		MBR-7	Geoid r	nodel is CGVD 2	.8	
Installation Type		Antenna reference point (ARP) in physical contact with top				
		face of	plywood UAV targ	get. Plywood targe	et bottom face in	
		physica	I contact with top	of post.		
Receiver (GNSS)		ZXtrem	e no 2			
Antenna		Ashtec	h Chokering			
		ASH70	1945C_M NONE	(4 caract. between	M and None).	
Antenna height		0	(See note above)			
Acquisition start		2019 0	1 24 16 h 54 ı	min. 00 sec.	(jour 024)	
Acquisition end 201		2019 0	1 25 07 h 11 ı	min 30 sec.		
Duration	ration 14 h			14 h 17 m 30 sec.		
Acquisition interval 30			30 seconds			
Raw GNSS files		A19.02	4			
Rinex files		024	1.19N			
		024	1.190			
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP						
Geographic	45° 24' 27	.84191"	-75° 31' 7.93513"	38.297	70.831	
UTM	5028377.016		459396.129			
Error ellipse .6 cm		1.1 cm				
@95%						
	±0.005 m		±0.009 m	±0.016m		
				1		

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028377.010	459396.134	38.286	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028377.023	459396.131	38.287	



Table 4.11. GNSS acquisition details of point MBR-7 – January 2019 –geoid model CGVD 2013

MBR-7	<u>Geoid mod</u>	el CGVD 20 <sup>2</sup>	13
Antenna reference point (ARP) in physical contact with top			
face of plywood UAV target. Plywood target bottom face in			
ohysical contact	with top of p	ost.	
ZXtreme no 2			
Ashtech Chokerii	ng		
ASH701945C_M	NONE (4 d	caract. between	M and None).
0 (See note above)			
2019 01 24 1	6 h 54 min.	00 sec.	(jour 024)
2019 01 25 0	7 h 11 min	30 sec.	
14 h 17 m 30 sec.			
30 seconds			
19.024	19.024		
0241.19N			
0241.190			
Longitu	de	Ellipsoidal	Orthometric
		Height (m)	Height (m)
4191" -75° 31' 7	.93513"	38.297	70.577
6 459396.1	29		
		1	
1.1 cm			
1.1 cm			
	Antenna reference         ace of plywood L         bhysical contact w         ZXtreme no 2         Ashtech Chokerin         ASH701945C_M         0       (See note         2019       01       24         2019       01       25       0         4       h       17       m       30 seconds         Antenna	Antenna reference point (AR         ace of plywood UAV target.         ohysical contact with top of p         ZXtreme no 2         Ashtech Chokering         ASH701945C_M NONE (4 co)         (See note above)         2019 01 24 16 h 54 min.         2019 01 25 07 h 11 min         4 h 17 m 30 sec.         30 seconds         A19.024        0241.19N        0241.19O         Longitude         459396.129	Antenna reference point (ARP) in physical of ace of plywood UAV target. Plywood target ohysical contact with top of post. ZXtreme no 2 Ashtech Chokering ASH701945C_M NONE (4 caract. between 0 (See note above) 2019 01 24 16 h 54 min. 00 sec. 2019 01 24 16 h 54 min. 00 sec. 2019 01 25 07 h 11 min 30 sec. 2019 01 26 07 h 11 min 30 sec. 2019 01 27 07 h 11 min 30 sec. 2019 01 28 07 h 11 min 30 sec. 2019 01 29 07 h 11 min 30 sec. 2019 01 29 07 h 11 min 30 sec. 2019 01 20 10 07 h 11 min 30 sec. 2019 01 21 10 00 sec. 2019 01 22 07 h 11 min 30 sec. 2019 01 23 07 h 11 min 30 sec. 2019 01 24 16 h 54 min. 00 sec. 2019 01 25 07 h 11 min 30 sec. 2019 01 26 07 h 11 min 30 sec. 2019 01 27 07 h 11 min 30 sec. 2019 01 28 07 h 11 min 30 sec. 2019 01 29 07 h 11 min 30 sec. 2019 01 29 07 h 11 min 30 sec. 2019 01 29 07 h 11 min 30 sec. 2019 01 20 07 h 11 min 30 sec. 2010 07 h 11 min 30 sec. 2010 07 h 11 min 30 sec. 2010 07 h 11 min 30 sec

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028377.010	459396.134	38.286	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028377.023	459396.131	38.287	





Table 4.12 GNSS acquisition details of point MBR-8 January 2019-geoid model CGVD 28

Site :		MBR-8	8 Geoid model CGVD 28		
Installation Type		Antenna reference point (ARP) in physical contact with top			
		of vertical steel rod coupler.			
Receiver (GNSS)		Trimble NetR-9 S/N 0352 CCRS: #6 Battery 20 amps.			
Antenna		Ashtech Chokering # 3670			
		ASH701945C_M NONE (4 caract. between M and None).			
Antenna height		0 (See note above)			
Acquisition start		2019 0	01 23 16 h 11 min	. 30 sec.	(jour 023)
Acquisition end		2019 01 25 14 h 57 min 00 sec.			
Duration		46 h 45 m 30 sec.			
Acquisition interval		30 seconds			
Raw GNSS files		03520230C.t02			
Rinex files		03520230C.18N .18G .18H			
		03520230C.18O			
Position	Latitude		Longitude	Ellipsoidal	Orthometric
established by				Height (m)	Height
PPP					
Geographic	45° 24' 22.68928"		-75° 31' 16.91587"	39.661	72.198
UTM	5028219.269		459199.882		
Error ellipse .3 cm			.6 cm		
@95%					
	±0.003 m		±0.005 m	±0.008 m	

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM 23-24	5028219.269	459199.882	39.664	
UTM 24-25	5028219.270	459199.883	39.651	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028219.279	459199.880	39.655	



Figure 4.15. Position of point MBR-8 from NRCan-PPP Service - January 2019. Geoid model CGVD 28

Table 4.13. GNSS acquisition details of point MBR-8–January 2019-Geoid model CGVD 2013

Site :		MBR-8	<b>BR-8</b> Geoid model is CGVD 2013		
Installation Type		Antenna reference point (ARP) in physical contact with top			
		of vertical steel rod coupler.			
Receiver (GNSS)		Trimble NetR-9 S/N 0352 CCRS: # 6			
Antenna		Ashtech Chokering			
		ASH701945C_M NONE (4 caract. between M and None).			
Antenna height		0 (See note above)			
Acquisition start		2019 01 23 16 h 11 min. 30 sec. (jour 023)			
Acquisition end		2019 01 25 14 h 57 min 00 sec.			
Duration		46 h 45 m 30 sec.			
Acquisition interval		30 seconds			
Raw GNSS files		03520230C.t02			
Rinex files		03520230C.18N .18G .18H			
		03520230C.18O			
Position	Latitude	atitude Longitude		Ellipsoidal	Orthometric
established by				Height (m)	Height (m)
PPP Coographia			750 041 40 04505"	00.004	74.045
Geographic	45° 24' 22.68928"		-75-31 16.91585"	39.661	71.945
	5028210.260		450100 882		
	5028219.269		409199.002		
	2 om		6 om		
(1993)	±0.002 m		+0.005 m	+0.008 m	
	±0.005 m		±0.003 m	±0.000 m	

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM 23-24	5028219.269	459199.882	39.664	
UTM 24-25	5028219.270	459199.883	39.651	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028219.279	459199.880	39.655	




Figure 4.17 Field view of MBR-8

Table 4.14. GNSS acquisition details of point "Base station" - 1° day-CGDV 28						
Site :						
		Base station Geoid CGDV28 1 <sup>st</sup> day				
Installation Type		Antenn	a reference point (A	RP) in physical o	contact with top	
		of verti	cal steel rod coupler			
Receiver (GNSS)		Trimble	e Net-R9 #07 S/N	1216		
Antenna		Ashtec	h Chokering			
		ASH70	1945C_M NONE (4	4 caract. between	M and None).	
Antenna height		0	(See note above)			
			-			
Acquisition start		2019 0	)1 23 16 h 52 mi	n. 00 sec.	(jour 023)	
Acquisition end		2019 0	)1 24 09 h 42 mi	n 00 sec.		
Duration		16 h. 5	50 min. 00 sec.			
Acquisition interva	al	30 seco	30 seconds			
Raw GNSS files		012602	30C.t02			
Rinex files		012602	01260230C.19O 19N 19G 19H			
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by	(average	)	(average)	Height (m)	Height (m)	
PPP		-				
Géographic	45° 24' 22	.96429"	-75° 31' 8.13001"	39.767	72.301	
UTM	5028226.5	22	459390.922			
Error ellipse	.5 cm		1.0 cm			
@95 %						
	±0.004m		±0.008m	±0.014m		

Table 4.14. GNSS acquisition details of point "Base station" - 1<sup>st</sup> day-CGDV 28

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028226.517	459390.923	39.769	



1<sup>st</sup> day

Site :	Base station geoid CGDV 28 2nd day				l day		
Installation Type		Antenna reference point (ARP) in physical contact with top					
		of vertie	cal steel rod	coupler.	, . <b>.</b>		
Receiver (GNSS)	Trimble Net-R9 # 04 S/N 1297						
Antenna		Ashtec	h Chokering	ļ			
		ASH70	1945C_M	NONE (4	caract. between	M and None).	
Antenna height		0	(See note a	ibove)			
Acquisition start		2019 0	01 24 17	h 41 min.	00 sec.	(jour 024)	
Acquisition end		2019 0	01 25 10	h 17 min	00 sec.		
Duration		16 h. 3	16 h. 36 min. 00 sec.				
Acquisition interva	I	30 seconds					
Raw GNSS files		12970240C.t02					
Rinex files		12970240C.19O .19N					
Position	Latitude		Longitude	9	Ellipsoidal	Orthometric	
established by	(average	)	(average)		Height (m)	Height (m)	
PPP							
Géographic	45° 24' 22	.96449"	-75° 31' 8.1	9278"	39.760	72.295	
UTM	5028226.528		459390.927	7			
Error ellipse	.5 cm		1.0 cm				
@95 %							
	±0.004m		±0.008m		±0.014m		

Table 4.15. GNSS acquisition details of point 'Base station'' - 2<sup>nd</sup> day-CGDV28

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028226.519	459390.924	39.756	



Figure 4.19. Position of point "Base station" from NRCan – PPP Service- CGDV 28 2<sup>nd</sup> day

Site :		Bases	station	Geoid	CGDV 2013	1 <sup>st</sup> day	
Installation Type		Antenna reference point (ARP) in physical contact with top					
		of verti	cal steel ro	d coupler.	, . <b>.</b>		
Receiver (GNSS)	Trimble Net-R9 #07 S/N 1216						
Antenna		Ashtec	h Chokerin	g			
		ASH70	1945C_M	NONE (4	caract. between	M and None).	
Antenna height		0	(See note	above)			
Acquisition start		2019 0	01 23 16	6 h 52 min	. 00 sec.	(jour 023)	
Acquisition end		2019 01 24 09 h 42 min 00 sec.					
Duration		16 h. 5	16 h. 50 min. 00 sec.				
Acquisition interva	l	30 seconds					
Raw GNSS files		01260230C.t02					
Rinex files		01260230C.19O 19N 19G 19H					
Position	Latitude		Longitud	le	Ellipsoidal	Orthometric	
established by	(average	)	(average	)	Height (m)	Height (m)	
PPP							
Géographic	45° 24' 22	.96429"	-75° 31' 8.	13001"	39.767	72.048	
UTM	5028226.522		459390.92	22			
Error ellipse	.5 cm		1.0 cm				
@95 %							
	±0.004m		±0.008m		±0.014m		

Table 4.16 GNSS acquisition details of point 'Base station'-1<sup>st</sup> day-CGDV 2013

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028226.517	459390.923	39.769	



Figure 4.20. Position of point "Base station" from NRCan – PPP Service- 1st day CGDV 2013

Site :		Bases	station	Geoid	CGDV 2013	2nd day	
Installation Type	Antenna reference point (ARP) in physical contact with top						
		of verti	cal steel ro	d coupler.	,		
Receiver (GNSS)		Trimble	e Net-R9	#04 S/N	1297		
Antenna		Ashtec	h Chokerir	ng			
		ASH70	1945C_M	NONE (4	caract. between	M and None).	
Antenna height		0	(See note	above)			
Acquisition start		2019 0	)1 24 1	7 h 41 mir	n. 00 sec.	(jour 024)	
Acquisition end		2019 0	01 25 1	0 h 17 mir	n 00 sec.		
Duration	16 h. 36 min. 00 sec.						
Acquisition interva		30 seconds					
Raw GNSS files		129702	12970240C.t02				
Rinex files		12970240C.19O .19N					
Position	Latitude		Longitu	de	Ellipsoidal	Orthometric	
established by	(average	)	(average	e)	Height (m)	Height (m)	
PPP							
Géographic	45° 24' 22	.96449"	-75° 31' 8	.19278"	39.760	72.041	
UTM	5028226.528		459390.9	27			
Error ellipse	.5 cm		1.0 cm				
@95 %							
	±0.004m		±0.008m		±0.014m		

Table 4.17. GNSS acquisition details of point "Base station" - 2<sup>nd</sup> day-CGVD 2013

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height
UTM	5028226.518	459390.924	39.763	



	5 1	,			,
	Northing	Easting	Ellipsoidal	Orthometric	Orthometric
	PPP		height (m)	height (m)	Height (m)
				CGVD28	CGVD2013
23 January	5028226.522	459390.922	39.767	72.301	72.048
24 January	5028226.528	459390.927	39.760	72.295	72.041
Average	5028226.525	459390.924	39.763	72.298	72.045

Table 4.18 Average position of both days of acquisition – Base station 23-24 January

Table 4.19 Average position of both days of acquisition – Base station - 23-24 January

	Northing	Easting	Ellipsoidal
	Baseline NRC		height (m)
23 January	5028226.517	459390.923	39.769
24 January	5028226.519	459390.924	39.756
Average	5028226.518	459390.924	39.763



Figure 4.22 Field view of Base station

# 5) Data Acquisition - GNSS survey in May 2019

Presented here are the precision GNSS survey reports for the May 2019 campaign (to the limits discussed above), as well as sample photos, of the MBR site targets (Figures 5.1 to 5.5). Information provided in these detailed reports include the latitude, longitude and altitude (both ellipsoidal and orthometric representing sea level) of the base of the antenna as installed on the target, the UTM zone, and the UTM Easting and Northing. Planimetric positions are in NAD 83 CSRS.

For the purpose of the baseline processing between the base station and individual MB points, the base station position was set at the following values, which represent the average over time since 2017. Easting and Northing are set at 459390.920 metres and 5028226.526 metres, in UTM zone 18. Ellipsoidal height is set at 39.760 metres.

Unlike the January survey where two geoid models were used, this May survey applied CGVD 2013 only; the default model established few years ago and presently applied by most users, with a geoid variation of 32.33 m. This said, the change in geoid model has an impact mainly on the orthometric height estimation. Therefore the impact is minimal for this project since calculations are performed using ellipsoidal height.

It is worth mentioning that during the summer of 2018, between the May and August surveys, the software used to calculate the orthometric height from the ellipsoidal height was lightly modified. As a result, orthometric height are ~ 4 cm higher for the August 2018 survey onward. As well, MB-4 target was moved in early 2018. Therefore 3D positions differ from previous years.

For May 2019 survey onward, two new points were established. These new points, MBR-10 and MBR-12 are to be used in various tests involving drone flights.



Figure 5.1: Field views of GPS locations MBR-2 (left) and MBR-3 (right) (May, 2019).



Figure 5.2: Field views of GPS locations MBR-4 (left) and MBR-5 (right) (May, 2019).



Figure 5.3: Field views of GPS locations MBR-6 (left) and MBR-7 (right) (May, 2019).



Figure 5.4: Field views of GPS locations MBR-8 (left) and MBR-Base (right) (May, 2019).



Figure 5.5: Field views of GPS locations MBR-10 (left) and MBR-12 (right) (May, 2019).

Table 5.1 to 5.9 report the acquisition detail of all points for the month of May 2019. Figures 5.6 to 5.16 report the position associated with each point.

One point namely MBR-10 was surveyed with a single frequency receiver. The PPP result for a single frequency receiver is imprecise by nature. As a consequence, and to avoid any misunderstanding results are not shown in this report

It is worth mentioning for an observation time of 15 h, the difference between single frequency processed by PPP and the single frequency processed by Phase differential baseline are approximately, .030m in Easting, .010m in Northing and .225m in altitude.

Site :		MRD	)		
Installation Type		Antenn	Antenna reference point (ARP) in physical contact with top		
Installation Type		Antenna reference point (ARP) in physical contact with top			
			piywood OAV largel.	Flywood large	
		physica	a contact with top of p	JOSI.	
		<u> </u>			
Receiver (GNSS)		Irimble	e NetR-9 s/n 1072	CCRS: # 2	
Antenna		Ashtec	h Chokering # 1125		
		ASH70	1945C_M NONE (4	caract. between	M and None).
Antenna height		0	(See note above)		
Battery		# 1	Endurar	nce: ~ 8 h	
Acquisition start		2019 0	05 29 15 h 02 min	. 00 sec.	(jour 149)
Acquisition end		2018 0	05 30 13 h 56 min	30 sec.	
Duration		22 h 5	4 m 30 sec.		
Acquisition interva		30 sec	onds +1 sec 10 se	ec	
Raw GNSS files		107214	92C.t02		
Rinex files		107214	92C.19N		
		107214	92C.19O		
Position	Latitude		Longitude	Ellipsoidal	Orthometric
established by				Height (m)	Height (m)
PPP				_	CGVD 2013
Geographic	45° 24' 32	.82051"	-75° 31' 4.69498"	37.301	69.580
UTM	5028530.201		459467.550		
Error ellipse	.5 cm		.9 cm		
@95%					
	±0.004m		±0.007m	±0.012m	
L	1		1		

Table 5.1: GNSS acquisition details of point MBR-2- May 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028530.199	459467.549	37.296	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028530.206	459467.547	37.294	



Figure 5.6: Position of point MBR-2 from NRCan – PPP Service – May 2019. Orange circles represent most frequently requested information.

Site :			5		
Installation Type		Antonn	Antonna reference point (APD) in physical contact with ten		
Installation Type		Antenna reference point (ARP) in physical contact with top			
		face of plywood UAV target. Plywood target bottom face in			
		pnysica	al contact with top of	post.	
Receiver (GNSS)		Trimble	Trimble NetR-9 s/n 1059 CCRS: # 1		
Antenna		Ashtec	h Chokering #6910		
		ASH70	1945C_M NONE (4	caract. between	M and None).
Antenna height		0	(See note above)		
Battery		#2	Endurance > 24 h		
Acquisition start		2019 0	)5 29 15 h 08 mir	n. 30 sec.	(jour 149)
Acquisition end		2019 0	2019 05 30 13 h 59 min 00 sec.		
Duration 22		22 h 50 m 30 sec.			
Acquisition interval		30 seconds + 1 sec & 10 sec.			
Raw GNSS files		10591490C.t02			
Rinex files		10591490C.19N			
		105914	90C.19O		
Position	Latitude		Longitude	Ellipsoidal	Orthometric
established by				Height (m)	Height (m)
PPP					CGVD 2013
Geographic	45° 24' 36	.61202"	-75° 31' 6.62077"	37.874	70.153
UTM	5028647.4	76	459426.444		
Error ellipse	.5 cm		.9 cm		
@95%					
	±0.004m		±0.007m	±0.012m	
	1		1	1	

 Table 5.2:
 GNSS acquisition details of point MBR-3 – May 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028647.470	459426.443	37.870	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028647.477	459426.440	37.867	

	10591490c.19o MB-3		
Début des données	Fin des données	Durée d	les observations
2019-05-29 15:08:30.00	2019-05-30 13:59:00.00		22:50:30
Heure de traitement		Тур	e de produits
13:14:20 UTC 2019/06/04		R	VCan rapide
Observations	Fréquence		Mode
Porteuse et pseudo-distance	Double		Statique
Masque d'élévation	Données rejetées	Interva	lle des estimés
7.5 degrés	0.07 %		30.00 sec
Antenne	CPA au PRA	PR	A au Repère
ASH701945C_M NONE	L1 = 0.090 m L2 = 0.119 n	H:0.000m /	E:0.000m / N:0.000m
(CPA = centre de ph	ase de l'antenne: PRA = noint (	le référence de l'anter	ine)
	Latitude (+n)	Longitude (+e)	Altitude Ell
	Latitude (+n)	I ondiffide (+e)	
		201 gittade (10)	Alutude Eli.
NAD83(SCRS) (2019)	45° 24' 36.61202"	-75° 31' 6.62077"	37.874 m
NAD83(SCRS) (2019) Sigmas(95%)	45° 24' 36.61202" 0.004 m	-75° 31' 6.62077" 0.007 m	37.874 m 0.012 m
NAD83(SCRS) (2019) Sigmas(95%) A priori*	45° 24' 36.61202" 0.004 m 45° 24' 36.64764"	-75° 31' 6.62077" 0.007 m -75° 31' 6.65728"	37.874 m 0.012 m 37.190 m
NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori	45° 24' 36.61202" 0.004 m 45° 24' 36.64764" -1.100 m	-75° 31' 6.62077" 0.007 m -75° 31' 6.65728" 0.794 m	37.874 m 0.012 m 37.190 m 0.684 m
NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori	45° 24' 36.61202" 0.004 m 45° 24' 36.64764" -1.100 m Ellipse d'erreur 95% (cm demi-grand axe: 0.899 cm	-75° 31' 6.62077" 0.007 m -75° 31' 6.65728" 0.794 m	37.874 m 0.012 m 37.190 m 0.684 m
NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori Altitude orthométrique CGVD2013	45° 24' 36.61202" 0.004 m 45° 24' 36.64764" -1.100 m Ellipse d'erreur 95% (cm demi-grand axe: 0.899 cm demi-petit axe: 0.524 cm	-75° 31' 6.62077" 0.007 m -75° 31' 6.65728" 0.794 m	37.874 m 0.012 m 37.190 m 0.684 m
NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori Altitude orthométrique CGVD2013 (CGG2013a)	45° 24' 36.61202" 0.004 m 45° 24' 36.64764" -1.100 m Ellipse d'erreur 95% (cm demi-grand axe: 0.899 cm demi-petit axe: 0.524 cm azimut du demi-grand axe: 89° 42'	-75° 31' 6.62077" 0.007 m -75° 31' 6.65728" 0.794 m	37.874 m 0.012 m 37.190 m 0.684 m
NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori Altitude orthométrique CGVD2013 (CGG2013a)	45° 24' 36.61202" 0.004 m 45° 24' 36.64764" -1.100 m Ellipse d'erreur 95% (cm demi-grand axe: 0.899 cm demi-petit axe: 0.524 cm azimut du demi-grand axe: 89° 42'	-75° 31' 6.62077" 0.007 m -75° 31' 6.65728" 0.794 m ) 9.2" UTM	37.874 m 0.012 m 37.190 m 0.684 m (Nord) Zone 18
NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori Altitude orthométrique CGVD2013 (CGG2013a)	45° 24' 36.61202" 0.004 m 45° 24' 36.64764" -1.100 m Ellipse d'erreur 95% (cm demi-grand axe: 0.899 cm demi-grand axe: 0.524 cm azimut du demi-grand axe: 89° 42'	-75° 31' 6.62077" 0.007 m -75° 31' 6.65728" 0.794 m ) 9.2" UTM 5028 4594	Andude Ell. 37.874 m 0.012 m 37.190 m 0.684 m (Nord) Zone 18 647.476 m (N) 426.444 m (E)
NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori Altitude orthométrique CGVD2013 (CGG2013a) 70.153 m (lien pour la référence altimétrique)	45° 24' 36.61202" 0.004 m 45° 24' 36.64764" -1.100 m Ellipse d'erreur 95% (cm demi-grand axe: 0.899 cm demi-petit axe: 0.524 cm azimut du demi-grand axe: 89° 42'	-75° 31' 6.62077" 0.007 m -75° 31' 6.65728" 0.794 m 9.2" UTM 5028 4594 Fac	Annuae En. 37.874 m 0.012 m 37.190 m 0.684 m (Nord) Zone 18 647.476 m (N) 426.444 m (E) teurs échelle
NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori Altitude orthométrique CGVD2013 (CGG2013a) 70.153 m (lien pour la référence altimétrique)	45° 24' 36.61202" 0.004 m 45° 24' 36.64764" -1.100 m Ellipse d'erreur 95% (cm demi-grand axe: 0.899 cm demi-grand axe: 0.899 cm demi-grand axe: 89° 42' 0.75 0.50 0.25 0.00 -0.25 0.50 0.75	-75° 31' 6.62077" 0.007 m -75° 31' 6.65728" 0.794 m 9.2" UTM 5028 4594 Fac 0.99	Antude Ell. 37.874 m 0.012 m 37.190 m 0.684 m (Nord) Zone 18 647.476 m (N) 426.444 m (E) teurs échelle 99620 (point) 1614 (combiné)
NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori Altitude orthométrique CGVD2013 (CGG2013a) 70.153 m (lien pour la référence altimétrique)	45° 24' 36.61202" 0.004 m 45° 24' 36.64764" -1.100 m Ellipse d'erreur 95% (cm demi-grand axe: 0.899 cm demi-grand axe: 0.899 cm demi-grand axe: 89° 42' 0.75 0.50 0.25 0.00 0.25 0.50 0.75 0.50 0.	-75° 31' 6.62077" 0.007 m -75° 31' 6.65728" 0.794 m 9.2" UTM 5028 4594 Fac 0.995	Antidade En. 37.874 m 0.012 m 37.190 m 0.684 m (Nord) Zone 18 647.476 m (N) 426.444 m (E) teurs échelle 99620 (point) 614 (combiné)



	MBR-4				
	Antenna reference point (ARP) in physical contact with top				
	face of plywood UAV target. Plywood target bottom face in				
	physical contact with top of post.				
	This po	oint is a new installa	ation for May a	nd August	
	<b>2018</b> . F	Point is offset from pro	evious years me	easurements.	
	Trimble	Trimble NetR-9 CCRS: # 1 S/N 1059			
	Ashtecl	n Chokering # 6910			
	ASH701945C_M NONE (4 caract. between M and None).				
	0	(See note above)			
Battery		Endurance: ~	16 h		
Acquisition start		5 30 14 h 33 min	. 30 sec.	(jour 150)	
Acquisition end		2019 05 31 14 h 30 min 00 sec.			
Duration		23 h 56 m 30 sec.			
Acquisition interval		30 seconds + 1 sec. & 10 sec.			
	105915000C.To2				
	105915000C.19N				
	105915	000C.19O			
Latitude		Longitude	Ellipsoidal	Orthometric	
			Height (m)	Height (m)	
				CGVD 2013	
45° 24' 37	.55872"	-75° 30' 58.20713"	37.406	69.682	
5028675.5	515	459609.513			
.5 cm		.8 cm			
±0.004m		±0.007m	±0.011m		
	Latitude 45° 24' 37 5028675.5 .5 cm ±0.004m	MBR-4         Antenn         face of         physica         This point         2018. F         Trimble         Ashteol         Ashteol         Ashteol         Ashteol         Ashteol         2019. 0         2019. 0         2019. 0         2019. 0         2019. 0         2019. 0         2019. 0         105915         105915         105915         105915         105915         105915         105915         105915         105915         105915         105915         105915         105915         105915         105915         105915         5028675.515         .5 cm         ±0.004m	MBR-4Antenna reference point (AF face of plywood UAV target. physical contact with top of pThis point is a new installat 2018. Point is offset from pro- Trimble NetR-9 CCRS: # 1Ashtech Chokering # 6910Ashtech Chokering # 6910ASH701945C_M NONE (4 0 (See note above)0 (See note above)# 7 Endurance: ~2019 05 30 14 h 33 min 2019 05 31 14 h 30 min 23 h 56 m 30 sec.105915000C.To2105915000C.To2105915000C.19N105915000C.19N105915000C.19N105915000C.19OLatitude45° 24' 37.55872"-75° 30' 58.20713"5028675.515459609.513.5 cm.5 cm±0.004m±0.007m	MBR-4Antenna reference point (ARP) in physical of face of plywood UAV target. Plywood target physical contact with top of post.This point is a new installation for May a 2018. Point is offset from previous years material for market and the sector of the sec	

 Table 5.3:
 GNSS acquisition details of point MBR-4
 - May 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028675.511	459609.516	37.400	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028675.519	459609.513	37.401	



# SCRS-PPP 2.26.1 (2019-05-31)



10591500c.19o MB-4

Fin des données

2019-05-31 14:30:00.00

Début des données 2019-05-30 14:33:30.00 Heure de traitement 13:30:34 UTC 2019/06/04 Observations Porteuse et pseudo-distance Masque d'élévation 7.5 degrés Antenne ASH701945C\_M NONE

Fréquence Double Données rejetées 0.00 % CPA au PRA L1 = 0.090 m L2 = 0.119 m Durée des observations 23:56:30 Type de produits RNCan rapide Mode Statique Intervalle des estimés 30.00 sec PRA au Repère H:0.000m / E:0.000m / N:0.000m

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

# Positions estimées pour 10591500c.19o

	Latitude (+n)	Longitude (+e)	Altitude Ell.
NAD83(SCRS) (2019)	45° 24' 37.55872"	-75° 30' 58.20713"	37.406 m
Sigmas(95%)	0.004 m	0.007 m	0.011 m
A priori*	45° 24' 37.59293"	-75° 30' 58.25509"	36.039 m
Position calculée – A priori	-1.056 m	1.043 m	1.367 m
Altitude orthométrique CGVD2013	Ellipse d'erreur 95% (m demi-grand axe: 8.367 mm demi-petit axe: 4.995 mm	m)	
(CGG2013a)	azimut du demi-grand axe: 89° 50	" 33.55" UTM (I	Nord) Zone 18
69.682 m	7.5 5.0 2.5 0.0	50286 4596	675.515 m (N) 09.513∣m (E)
(lien pour la référence altimétrique)	-2.5	Fact	eurs échelle
	-5.0-	0.9990	614 (combiné)
*(Position a priori ir	nitialisée à partir des coordonn	ées de l'en-tête du RINE	X)
	•		



Site :			-			
lu stallation Trus s						
Installation Type		Antenna reference point (ARP) in physical contact with top				
		face of	face of plywood UAV target. Plywood target bottom face in			
		physica	al contact with top of p	oost.		
Receiver (GNSS)		Trimble	Trimble NetR-9 S/N 1216 CCRS: # 3			
Antenna		Ashtec	h Chokering # 3670	1		
		ASH70	1945C_M NONE (4	caract. between	M and None).	
Antenna height		0	(See note above)			
Battery		#3	Endurance: ~ > 24 h	1		
Acquisition start	Acquisition start 2		05 29 15 h 48 min	. 30 sec.	(jour 149)	
Acquisition end	2019		05 30 15 h 01 min 00 sec.			
Duration		23 h 1	12 m 30 sec.			
Acquisition interval 30 s		30 seco	30 seconds			
Raw GNSS files		121614	12161490C.t02			
Rinex files		121614	90C.19N			
		121614	90C.19O			
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 28	.66398"	-75° 31' 12.69302"	37.076	69.358	
UTM	5028403.053		459292.869			
Error ellipse	.5 cm		.9 cm			
@95%						
	±0.004 m		±0.007 m	±0.012 m		

Table 5.4: GNSS acquisition details of point MBR-5- May 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028403.050	459292.868	37.078	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028403.057	459292.866	37.075	

	MB-5			
Début des données	Fin des données	Durée de	es observations	
2019-05-29 15:48:30.00	2019-05-30 15:01:00.00	0 23:12:30		
Heure de traitement		Туре	de produits	
14:00:54 UTC 2019/06/04		RN	Can rapide	
Observations	Fréquence		Mode	
Porteuse et pseudo-distance	Double	1	Statique	
Masque d'élévation	Données rejetées	Interval	lle des estimés	
7.5 degrés	0.07 %	3	0.00 sec	
Antenne	CPA au PRA	PRA	au Repère	
ASH701945C_M NONE	L1 = 0.090 m L2 = 0.119 n	n H:0.000m / E	:0.000m / N:0.000m	
(CPA = centre de pr	ase de l'antenne; PRA = point d	de reference de l'anteni	ne)	
Position	s estimées pour 121	61490C.19o		
Position	s estimées pour 1210 Latitude (+n)	61490C.19o Longitude (+e)	Altitude Ell.	
Position NAD83(SCRS) (2019)	s estimées pour 1210 Latitude (+n) 45° 24' 28.66398"	61490C.19o Longitude (+e) -75° 31' 12.69302"	Altitude Ell. 37.076 m	
Position NAD83(SCRS) (2019) Sigmas(95%)	Latitude (+n) 45° 24' 28.66398" 0.004 m	61490C.19o Longitude (+e) -75° 31' 12.69302" 0.007 m	Altitude Ell. 37.076 m 0.012 m	
Position NAD83(SCRS) (2019) Sigmas(95%) A priori*	Latitude (+n) 45° 24' 28.66398" 0.004 m 45° 24' 28.70473"	61490C.19o Longitude (+e) -75° 31' 12.69302" 0.007 m -75° 31' 12.71256"	Altitude Ell. 37.076 m 0.012 m 36.058 m	
Position NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori	Latitude (+n) 45° 24' 28.66398" 0.004 m 45° 24' 28.70473" -1.258 m	61490C.19o Longitude (+e) -75° 31' 12.69302" 0.007 m -75° 31' 12.71256" 0.425 m	Altitude Ell. 37.076 m 0.012 m 36.058 m 1.017 m	
Position NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori	Latitude (+n) 45° 24' 28.66398" 0.004 m 45° 24' 28.70473" -1.258 m Ellipse d'erreur 95% (cm demi-grand axe: 0.899 cm	61490C.190 Longitude (+e) -75° 31' 12.69302" 0.007 m -75° 31' 12.71256" 0.425 m	Altitude Ell. 37.076 m 0.012 m 36.058 m 1.017 m	
Position NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori Altitude orthométrique CGVD2013 (CGG2013a)	Latitude (+n) 45° 24' 28.66398" 0.004 m 45° 24' 28.70473" -1.258 m Ellipse d'erreur 95% (cm demi-grand axe: 0.899 cm demi-petit axe: 0.537 cm azimut du demi-grand axe: 90° 4' 1	61490C.190 Longitude (+e) -75° 31' 12.69302" 0.007 m -75° 31' 12.71256" 0.425 m ) 8.69" UTM ()	Altitude Ell. 37.076 m 0.012 m 36.058 m 1.017 m	
Position NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori Altitude orthométrique CGVD2013 (CGG2013a)	Latitude (+n) 45° 24' 28.66398" 0.004 m 45° 24' 28.70473" -1.258 m Ellipse d'erreur 95% (cm demi-grand axe: 0.899 cm demi-petit axe: 0.537 cm azimut du demi-grand axe: 90° 4' 1	61490C.19o Longitude (+e) -75° 31' 12.69302" 0.007 m -75° 31' 12.71256" 0.425 m ) 8.69" UTM (1	Altitude Ell. 37.076 m 0.012 m 36.058 m 1.017 m	
Position NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori Altitude orthométrique CGVD2013 (CGG2013a)	Latitude (+n) 45° 24' 28.66398" 0.004 m 45° 24' 28.70473" -1.258 m Ellipse d'erreur 95% (cm demi-grand axe: 0.899 cm demi-petit axe: 0.537 cm azimut du demi-grand axe: 90° 4' 1	61490C.19o Longitude (+e) -75° 31' 12.69302" 0.007 m -75° 31' 12.71256" 0.425 m ) 8.69" UTM (1	Altitude Ell. 37.076 m 0.012 m 36.058 m 1.017 m	
Position NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori Altitude orthométrique CGVD2013 (CGG2013a)	Latitude (+n) 45° 24' 28.66398" 0.004 m 45° 24' 28.70473" -1.258 m Ellipse d'erreur 95% (cm demi-grand axe: 0.899 cm demi-petit axe: 0.537 cm azimut du demi-grand axe: 90° 4' 1	61490C.19o Longitude (+e) -75° 31' 12.69302" 0.007 m -75° 31' 12.71256" 0.425 m ) 8.69" UTM (1 50284 4592	Altitude Ell. 37.076 m 0.012 m 36.058 m 1.017 m Nord) Zone 18	
Position NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori Altitude orthométrique CGVD2013 (CGG2013a)	Latitude (+n) 45° 24' 28.66398" 0.004 m 45° 24' 28.70473" -1.258 m Ellipse d'erreur 95% (cm demi-grand axe: 0.899 cm demi-petit axe: 0.537 cm azimut du demi-grand axe: 90° 4' 1	61490C.19o Longitude (+e) -75° 31' 12.69302" 0.007 m -75° 31' 12.71256" 0.425 m ) 8.69" UTM (1 50284 4592	Altitude Ell. 37.076 m 0.012 m 36.058 m 1.017 m Nord) Zone 18	
Position NAD83(SCRS) (2019) Sigmas(95%) A priori* Position calculée – A priori Altitude orthométrique CGVD2013 (CGG2013a) 69.358 m (lien pour la référence altimétrique)	Latitude (+n) 45° 24' 28.66398" 0.004 m 45° 24' 28.70473" -1.258 m Ellipse d'erreur 95% (cm demi-grand axe: 0.899 cm demi-petit axe: 0.537 cm azimut du demi-grand axe: 90° 4' 1	61490C.190 Longitude (+e) -75° 31' 12.69302" 0.007 m -75° 31' 12.71256" 0.425 m ) 8.69" UTM (1 50284 4592 Fact 0.99	Altitude Ell. 37.076 m 0.012 m 36.058 m 1.017 m Nord) Zone 18 403.053 m (N) 92.869 m (E) eurs échelle 9620 (point)	



Site :					
Installation Turns		NIBR-	) o roforonoo noint (AF		antaat with tan
Installation Type		Antenn	Antenna reference point (ARP) in physical contact with top		
		face of	plywood UAV target.	Plywood targe	et dottom face in
		pnysica	al contact with top of	DOST.	
Receiver (GNSS)		Trimble	e NetR-9 S/N 1205	CCRS: # 5	
Antenna		Ashtec	h Chokering 5875		
		ASH70	1945C_M NONE (4	caract. between	M and None).
Antenna height		0	(See note above)		
Battery		#4	Endurance:	>24 h < 33 h	1
Acquisition start		2019 05 29 15 h 30 min. 30 sec. (jour 149)			(jour 149)
Acquisition end		2019 05 31 10 h 11 min 30 sec.			
Duration		42 h 41 m 00 sec.			
Acquisition interva	I	30 seconds			
Raw GNSS files		12051490C.t02			
Rinex files		120514	90C.19N		
		120514	90C.19O		
Position	Latitude		Longitude	Ellipsoidal	Orthometric
established by				Height (m)	Height (m)
PPP					CGVD 2013
Geographic	45° 24' 29	.38015"	-75° 31' 19.28256"	37.124	69.408
UTM	5028426.082		459149.775		
Error ellipse	.4 cm		.7 cm		
@95%					
	±0.003 m		±0.005 m	±0.009 m	
			•		

 Table 5.5:
 GNSS acquisition details of point MBR-6 - May 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028426.079	459149.773	37.121	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028426.087	459149.771	37.117	





Site :		MBP-7	7		
Installation Type		Antenn	a reference point (AF	P) in physical (	contact with top
		face of	face of physical LIAX terrat. Dhysical contact with top		
			prywood OAV largel.	Flywood large	
		physica	a contact with top of p	JOSI.	
		Trimble NotD 0 C/N 1216 CCDS: # 2			
Receiver (GNSS)		Irimble	NetR-9 S/N 1216	0 CCRS: # 3	
Antenna		Ashtec	h Chokering 3670		
		ASH70	1945C_M NONE (4	caract. between	M and None).
Antenna height		0	(See note above)		
Battery		#8 E	ndurance ~ 16 h		
Acquisition start		2019 0	05 30 15 h 22 min	. 00 sec.	(jour 150)
Acquisition end		2019 0	05 31 14 h 44 min	00 sec.	
Duration		23 h 22 m 00 sec.			
Acquisition interva	l	30 seconds			
Raw GNSS files		12161500C.t02			
Rinex files		121615	00C.19N		
		121615	00C.19O		
Position	Latitude		Longitude	Ellipsoidal	Orthometric
established by				Height (m)	Height (m)
PPP				_	CGVD 2013
Geographic	45° 24' 27	.84214"	-75° 31' 7.93652"	38.281	70.561
UTM	5028377.024		459396.099		
Error ellipse	.5 cm		.8 cm		
@95%					
	±0.004 m		±0.007 m	±0.012m	
	1				

Table 5.6: GNSS acquisition details of point MBR-7 – May 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028377.019	459396.104	38.276	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028377.027	459396.102	38.276	



Figure 5.11: Position of point MBR-7 from NRCan - PPP Service- May 2019.

Site :		MBR-8	3		
Installation Type		Antenn	a reference point (AF	RP) in physical	contact with top
	of vertica			,	
Receiver (GNSS)		Trimble	e NetR-9 S/N 1297	CCRS: # 4	
Antenna		Trimble geodetic #4811118313			
Antenna height		0 (See note above)			
Battery		#5	Endurance > 4	18 h	
Acquisition start		2019 0	05 29 15 h 26 min	. 00 sec.	(jour 149)
Acquisition end		2019 0	05 31 15 h 05 min	30 sec.	
Duration		47 h 39 m 30 sec.			
Acquisition interva		30 seconds			
Raw GNSS files		12971491C.t02			
Rinex files		129714	91C.18N		
	1	129714	91C.18O		-
Position	Latitude		Longitude	Ellipsoidal	Orthometric
established by				Height (m)	Height (m)
PPP					CGVD 2013
Geographic	45° 24' 22.68930"		-75° 31' 16.91602"	39.642	71.926
υтм	5028219.270		459199.878		
Error ellipse	.4 cm		.6 cm		
@95%					
	±0.003 m		±0.005 m	±0.009 m	

 Table 5.7:
 GNSS acquisition details of point MBR-8 - May 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028219.270	459199.882	39.658	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028219.278	459199.880	39.658	



# SCRS-PPP 2.26.1 (2019-05-31)



#### 12971491C.19o MB-8

Début des données 2019-05-29 15:26:00.00 Heure de traitement 15:25:34 UTC 2019/06/04 Observations Porteuse et pseudo-distance Masque d'élévation 7.5 degrés Antenne TRM57971.00 Fin des données 2019-05-31 15:05:30.00

Fréquence Double Données rejetées 0.03 % CPA au PRA L1 = 0.065 m L2 = 0.058 m 1 jour, 23:39:30 Type de produits RNCan rapide Mode Statique Intervalle des estimés 30.00 sec

Durée des observations

PRA au Repère

H:0.000m / E:0.000m / N:0.000m

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

### Positions estimées pour 12971491C.190

Latitude (+n)	Longitude (+e)	Altitude Ell.
45° 24' 22.68930"	-75° 31' 16.91602"	39.642 m
0.003 m	0.005 m	0.009 m
45° 24' 22.70178"	-75° 31' 16.95911"	39.299 m
-0.385 m	0.937 m	0.343 m
	Latitude (+n) 45° 24' 22.68930" 0.003 m 45° 24' 22.70178" -0.385 m	Latitude (+n) Longitude (+e) 45° 24' 22.68930" -75° 31' 16.91602" 0.003 m 0.005 m 45° 24' 22.70178" -75° 31' 16.95911" -0.385 m 0.937 m



Figure 5.12: Position of point MBR-8 from NRCan – PPP Service – May 2019.



Figure 5.13 Field view of MBR-8

Site :		R. Fraser # 2 Point MB-12					
Installation Type		Receive	eceiver in physical contact with concrete target (drone				
		target).	Centered	d on colors	junction.		
Receiver (GNSS)		Trimble NetR9 S/N 1072 CCRS # 2			2		
Antenna		Ashtec	h Pinwhee	el ASH701	975.01A		
Antenna height		0	(See note	e above)			
Acquisition start		2019 0	5 30 1	5 h 16 min	. 00 sec.	(jour 150)	
Acquisition end		2019 0	05 31 0	5 h 18 min	30 sec.		
Duration	24 h 02 min 3 <sup>4</sup>			ec.			
Acquisition interval	al 30 seconds						
Raw GNSS files		10721501C.T02					
Rinex files		10721	501C.190	D.19N			
Position established by PPP	Latitude		Longitu	de	Ellipsoidal Height (m)	Orthometric Height (m) CGVD 2013	
Geographic	45° 24' 17.	86015"	-75° 31' 2	9.45392"	41,256	73,545	
UTM	5028072.015		458926.3	59			
Error ellipse	.5 cm		.8 cm				
@95 %							
-	±0.004 m		±0.007 m		±0.011 m		

 Table 5.8:
 GNSS acquisition details of point ''R Fraser # 2 (Point 12) May 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028072.015	458926.370	41.242	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028072.023	458926.367	41.243	





Site :		Base s	station		
Installation Type		Antenna reference point (ARP) in physical contact with top			
		of verti	cal steel rod coupler.	,	-
Receiver (GNSS)		Trimble Net-R9 #07 S/N 0126			
Antenna		Ashtech Chokering 5815			
		ASH701945C_M NONE (4 caract. between M and None).			
Antenna height		0 (See note above) (Ref.: 502 mm from base)			
Battery		# 10			
Acquisition start		2019 05 29 15 h 06 min. 30 sec. (jour 149)			
Acquisition end		2019 05 30 12 h 21 min 00 sec.			
Duration		21 h. 14 min. 30 sec.			
Acquisition interval		30 seconds			
Raw GNSS files		01261490C.t02			
Rinex files		01261490C.19O 19N 19G 19H			
Position	Latitude		Longitude	Ellipsoidal	Orthometric
established by	(average	)	(average)	Height (m)	Height (m)
PPP					CGVD 2013
Geographic	45° 24' 22.96422"		-75° 31' 8.12990"	39.760	72.041
UTM	5028226.519		459390.924		
Error ellipse	or ellipse .4 cm		.7 cm		
@95 %					
	±0.003m		±0.005m	±0.011m	

Table 5.9: GNSS acquisition details of point "Base station" - May 2019

Note: Another acquisition occured for six hours on next day. It ended out of power. Data were acquired from 30 May 14 h 22 to 20 h 15. Rinex file was produced but no PPP process applied.

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028226.519	459390.922	39.762	



Figure 5.15: Position of point "Base station" from NRCan – PPP Service- May 2019



Figure 5.16 Field view of point Base station
## 6) Data Acquisition – GNSS survey in August 2019

Presented here are the precision GNSS survey reports for the August 2019 campaign (to the limits discussed above), as well as sample photos, of the MBR site targets (Figures 6.1 to 6.5). Information provided in these detailed reports include the latitude, longitude and altitude (both ellipsoidal and orthometric representing sea level) of the base of the antenna as installed on the target, the UTM zone, and the UTM Easting and Northing. Easting and Northing Planimetric positions are in NAD 83 CSRS.

For the purpose of the baseline processing between the base station and individual MB points, the base station position was set at the following values, which represent the average over time since 2017. Easting and Northing are set at 459390.920 metres and 5028226.526 metres, in UTM zone 18. Ellipsoidal height is set at 39.760 metres

-Unlike the January survey where two geoid models were used, this August survey applied CGVD 2013 only, the default model established few years ago and presently applied by most users, with a geoid variation of 32.33 m

This said, the change in geoid model has an impact mainly on the orthometric height estimation. Therefore the impact is minimal for this project since calculations are performed using ellipsoidal height.

Recall that during the summer of 2018, between the May and August surveys, the software used to calculate the orthometric height from the ellipsoïdal height was lightly modified. As a result, orthometric height are ~ 4 cm higher for the August 2018 survey onward. As well, MB-4 target was moved in early 2018. Therefore 3D positions differ from previous years.



Figure 6.1: Field views of GPS locations MBR-2 (left) and MBR-3 (right), August 2019.



Figure 6.2: Field views of GPS locations MBR-4 (left) and MBR-5 (right), August, 2019.



Figure 6.3: Field views of GPS locations MBR-6 (left) and MBR-7 (right) August, 2019.



Figure 6.4: Field views of GPS locations MBR-8 (left) and MBR-Base (right), August 2019.



Figure 6.5: Field views of GPS locations MBR-10 (left) and MBR-12 (right) (August 2019).

Table 6.1 to 6.9 report the acquisition detail of all points for the month of August 2019. Figures 6.6 to 6.16 report the position associated with each point.

Due to acquisition problem, no data were acquired for MBR-2 in August

Site :	MPD 2		2			
Installation Type		Antenn	ntenna reference point (ARP) in physical contact with top			
motaliation Type		face of plywood LIAV target. Plywood target bottom face in				
		physica	al contact with top of	nost		
		prijelee		p = = = = = = = = = = = = = = = = = = =		
Receiver (GNSS)		Ashtec	h ZXtreme CCRS # 2	2		
Antenna		Ashtec	h Chokering # 6910			
		ASH70	1945C M NONE (4	caract. between	M and None).	
Antenna height		0			,	
Battery		#2				
Acquisition start		2019 0	)8 19 16 h 51 mir	n. 30 sec.	(jour 231)	
Acquisition end		2019 0	08 20 14 h 17 mir	n 00 sec.		
Duration	21:25:3		25:30			
Acquisition interva	nterval 30 sec		seconds			
Raw GNSS files		0031.00	031.003			
Rinex files		0031.00	0N			
		0031.00	0031.000			
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
Geographic	45° 24' 36	61183"	-75° 31' 6 62076"	37 885	70.164	
Geographic	45 24 50.01165		-75 51 0.02070	07.000	70.104	
UTM	5028647.470		459426.444			
Error ellipse	.5 cm		1.0 cm			
@95%						
	±0.004m		±0.008m	±0.013m		

 Table 6.1:
 GNSS acquisition details of point MBR-3 – August 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028647.462	459426.444	37.891	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028647.473	459426.441	37.879	



# SCRS-PPP 2.26.1 (2019-05-31)



\_\_\_0031.000 1er jour Ashtech 2

Debut des donnees	Fin des données	Durée d	es observations	
2019-08-19 16:51:30.00	2019-08-20 14:17:00.00		21:25:30	
Heure de traitement		Туре	e de produits	
14:52:15 UTC 2019/08/23		RN	ICan rapide	
Observations	Fréquence		Mode	
Porteuse et pseudo-distance	Double		Statique	
Masque d'élévation	Données rejetées	Interva	lle des estimés	
7.5 degrés	0.04 %	:	30.00 sec	
Antenne	CPA au PRA	PR/	A au Repère	
ASH701945C_M NONE	L1 = 0.090 m L2 = 0.119 m	H:0.000m / I	E:0.000m / N:0.000n	
(CPA = centre de ph	ase de l'antenne; PRA = point de	e référence de l'anten	ne)	
Position	ns estimées pour	0031.000		
	Latitude (4p)	Longitudo (+o)	Altitude Ell	
NAD83/SCRS) (2019)	45º 24' 36 61182"	-75° 31' 6 82076"	37 885 m	
Sigmas(95%)	0.004 m	0.008 m	0.013 m	
A priori*	45° 24' 36 58117"	-75° 31' 6 68286"	43 918 m	
Position calculée – A priori	0.947 m	1.350 m	-6.033 m	
Altitude orthométrique CGVD2013 (CGG2013a)	Ellipse d'erreur 95% (mm) deml-grand axe: 10.264 mm deml-petit axe: 4.946 mm azimut du deml-grand axe: 93° 24' 33 N	.78" UTM (	Nord) Zone 18	
Altitude orthométrique CGVD2013 (CGG2013a) 70.164 m	Ellipse d'erreur 95% (mm) deml-grand axe: 10.264 mm deml-petit axe: 4.946 mm azimut du deml-grand axe: 93° 24' 33	.78" UTM ( 5028/ 4594	Nord) Zone 18 647.470 m (N) 126.444 m (E)	

Figure 6.6: Position of point MBR-3 from NRCan – PPP Service – August 2019

Site :	MBR-4		l.			
Installation Type		Antenna reference point (ARP) in physical contact with top				
		face of plywood UAV target. Plywood target bottom face in				
		physica	al contact with top of p	post.		
Receiver (GNSS)		Ashtec	h ZXtreme CCRS: #	2		
Antenna		Ashtec	h Chokering # 6910			
		ASH70	1945C_M NONE (4	caract. between	M and None).	
Antenna height		0	(See note above)			
Battery		#7	Endurance: ~	16 h		
Acquisition start		2019 0	08 20 14 h 37 min	. 00 sec.	(jour 232)	
Acquisition end		2019 0	)8 21 13 h 32 min	00 sec.		
Duration		22 h 5	22 h 55 m 00 sec.			
Acquisition interval 30		30 seco	30 seconds			
Raw GNSS files	Raw GNSS files SA		00.004			
Rinex files		0041.00N				
	-	0041.000				
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 37	.55869"	-75° 30' 58.20717"	37.412	69.688	
UTM	5028675.514		459609.512			
Error ellipse	.5 cm		1.0 cm			
@95%						
	±0.004m		±0.008m	±0.013m		

Table 6.2: GNSS acquisition details of point MBR-4 - August 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028675.507	459609.515	37.404	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028675.517	459609.511	37.403	



Figure 6.7: Position of point MBR-4 from NRCan - PPP Service- August 2019

Site :	MBR-		5		
Installation Type		Antenna reference point (ARP) in physical contact with top			
		face of plywood UAV target. Plywood target bottom face in			
		physica	l contact with top of p	oost.	
		. ,			
Receiver (GNSS)		Ashtech	n ZXtreme CCRS: #	4	
Antenna		Ashtech	h Chokering # 5875	1	
		ASH70	1945C_M NONE (4	caract. between	M and None).
Antenna height		0	(See note above)		
Battery					
Acquisition start		2019 0	8 19 15 h 50 min	. 30 sec.	(jour 231)
Acquisition end	2019 (		8 20 13 h 44 min	30 sec.	
Duration	21 h		21 h 54 m 00 sec.		
Acquisition interval	interval 30 se		30 seconds		
Raw GNSS files	ïles S_A		SA00.003		
Rinex files		0031.00N			
		0031.00O			
Position I	Latitude		Longitude	Ellipsoidal	Orthometric
established by				Height (m)	Height (m)
PPP					CGVD 2013
Geographic 4	45° 24' 28.	66392"	-75° 31' 12.69316"	37.085	69.367
UTM 5	5028403.051		459292.866		
Error ellipse	.5 cm		1.0 cm		
@95%					
E	±0.004 m		±0.008 m	±0.013 m	

 Table 6.3:
 GNSS acquisition details of point MBR-5- August 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028403.049	459292.868	37.090	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028403.059	459292.865	37.078	



Figure 6.8: Position of point MBR-5 from NRCan – PPP Service – August 2019

Site :	MRP		5		
Installation Type		Antenna reference point (ARP) in physical contact with top			
51		face of plywood LIAV target. Plywood target bottom face in			
		physica	al contact with top of r	nost	
		P			
Receiver (GNSS)		Trimble	e NetR-9 S/N 1205	CCRS: # 4	
Antenna		Ashtec	h Chokering 1125		
		ASH70	1945C_M NONE (4	caract. between	M and None).
Antenna height		0	(See note above)		
Battery		#4	Endurance:	>24 h < 33 h	1
Acquisition start		2019 0	08 19 16 h 01 min	. 30 sec.	(jour 232)
Acquisition end	2019		08 20 10 h 11 min	30 sec.	
Duration		18 h 10 m 00 sec.			
Acquisition interval		30 seconds (+ 1 & 10 sec.)			
Raw GNSS files	iles 12972		12972310C.t02		
Rinex files		12972310C.19n			
		12972310C.19o			
Position	Latitude		Longitude	Ellipsoidal	Orthometric
established by				Height (m)	Height (m)
PPP					CGVD 2013
Geographic	45° 24' 29	.38018"	-75° 31' 19.28295"	37.105	69.390
UTM	5028426 083		459149,766		
	5020720.000				
Error ellipse	.6 cm		1.1 cm		
@95%					
	±0.005 m		±0.009 m	±0.015 m	
L	L		I		I

Table 6.4: GNSS acquisition details of point MBR-6 – August 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028426.077	459149.772	37.118	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028426.088	459149.769	37.085	



Figure 6.9: Position of point MBR-6 from NRCan - PPP Service - August 2019

Site :		MBD 7	,			
Installation Type		Antenn	ntenna reference point (APD) in physical contact with top			
installation Type		face of	Antenna reference point (ARP) in physical contact with top			
			plywood OAV largel	nost		
		physica	ar contact with top of	post.		
Receiver (GNSS)		Ashtec	n ZXtreme # 4			
Antenna		Ashtec	h Chokering 58/5			
		ASH70	1945C_M NONE (4	caract. between	M and None).	
Antenna height		0	(See note above)			
Battery						
Acquisition start		2019 0	)8 20 13 h 58 mir	n. 30 sec.	(jour 232)	
Acquisition end	isition end 2019		08 21 05 h 44 mir	1 30 sec.		
Duration	on 15 h		5 h 46 m 00 sec.			
Acquisition interva	Acquisition interval 30 se		30 seconds			
Raw GNSS files		SA	SA00.004			
Rinex files		004	1.00N			
		004	0041.00O			
Position	Latitude	1	Longitude	Ellipsoidal	Orthometric	
established by			_	Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 27	.84179"	-75° 31' 7.93745"	38.269		
					70.549	
UTM	5028377.013		459396.079			
Error ellipse	.7 cm		1.1 cm			
@95%						
	±0.005 m		±0.009 m	±0.017m		
	I		I			

 Table 6.5:
 GNSS acquisition details of point MBR-7 – August 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028377.003	459396.081	38.256	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028377.015	459396.078	38.260	



Figure 6.10: Position of point MBR-7 from NRCan – PPP Service- August 2019.

Site :	Site :		8			
Installation Type		Antenna reference point (ARP) in physical contact with top				
		of vertion	of vertical steel rod coupler			
			I			
Receiver (GNSS)		Trimble	NetR-9 CCRS: # 7	# 0126		
Antenna		ASH70	1945C_M NONE (4	caract. between	M and None).	
Antenna height		0	(See note above)	# 5815		
		405-40	7 mm from base			
Battery						
Acquisition start		2019 08	8 19   15 h 29 min. 3	30 sec. (jo	our 232)	
Acquisition end		2019 08	2019 08 21 13 h 13 min 00 sec.			
Duration	Duration		45 h 43 m 30 sec.			
Acquisition interval 3		30 seconds + 1 & 10 seconds				
Raw GNSS files 01262		012623	10C.t02			
Rinex files		012623	01262310C.19O			
	-	012623	10C.19N & 19g 19h			
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 22	.68942"	-75° 31' 16.91602"	39.653	71.938	
UTM	5028219.274		459199.878			
Error ellipse	.3 cm		.5 cm			
@95%						
	±0.002 m		±0.004 m	±0.008 m		

 Table 6.6:
 GNSS acquisition details of point MBR-8 – August 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028219.270	459199.884	39.666	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028219.281	459199.880	39.656	



## SCRS-PPP 2.26.1 (2019-05-31)



#### 01262310C.19o MB-8

Fin des données

2019-08-21 13:13:00.00

Début des données 2019-08-19 15:29:30.00 Heure de traitement 18:12:54 UTC 2019/08/22 Observations Porteuse et pseudo-distance Masque d'élévation 7.5 degrés Antenne ASH701945C\_M NONE

Fréquence Double Données rejetées 0.02 % CPA au PRA

L1 = 0.090 m L2 = 0.119 m

Type de produits RNCan rapide Mode Statique Intervalle des estimés

Durée des observations

1 jour, 21:43:30

30.00 sec

PRA au Repère

H:0.000m / E:0.000m / N:0.000m

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

### Positions estimées pour 01262310C.19o





Figure 6.11: Position of point MBR-8 from NRCan – PPP Service – August 2019.



Figure 6.12 Field view of MBR-8– August 2019.

Site :		Base s	station			
Installation Type		Antenn	Antenna reference point (ARP) in physical contact with top			
		of verti	cal steel rod coupler.	, . <b>.</b>		
Receiver (GNSS)		Trimble	• Net-R9 #06 S/N 0	)352		
Antenna		Ashtec	h Chokering 36	70		
		ASH701945C_M NONE (4 caract. between M and None).			M and None).	
Antenna height		0	(See note above) (	Ref.: 502 mm f	rom base)	
Battery						
Acquisition start		2019 0	08 19 15 h 03 min	. 30 sec.	(jour 231)	
Acquisition end	2019 (		08 21 13 h 57 min	00 sec.		
Duration	46		46 h. 53 min. 30 sec.			
Acquisition interva	uisition interval		30 seconds			
Raw GNSS files	S files C		03522310C.t02			
Rinex files		035223	03522310C.19O 19N 19G 19H			
			-		-	
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by	(average	)	(average)	Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 22	.96421"	-75° 31' 8.13012"	39.756	72.037	
UTM	5028226.519		459390.920			
Error ellipse	.3 cm		.5 cm			
@95 %						
	±0.002m		±0.004m	±0.008m		

 Table 6.7: GNSS acquisition details of point "Base station" - August 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028226.515	459390.922	39.769	



Figure 6.13: Position of point "Base station" from NRCan – PPP Service- August 2019



Figure 6.14 Field view of point Base station

Site :		MBR-1	0			
Installation Type Red		Receive	Receiver in physical contact with concrete target (drone			
		target).	Centered on colors	junction.		
Receiver (GNSS)		Ashtecl	n Zxtreme A051427			
Antenna		Ashtecl	h Pinwheel ASH701	975.01A		
Antenna height		0 (c	concrete + washer + r	nut)		
Acquisition start		2019 0	8 20 13 h 12 min	. 00 sec.	(jour 232)	
Acquisition end		2019 0	8 21 13 h 06 min	00 sec.		
Duration		23 h. 54	3 h. 54 min. 00 sec			
Acquisition interval 30 sec		30 seco	30 seconds			
Raw GNSS files		SA	SA00.004			
Rinex files		004	0041.00N			
	1	004	1.000		1	
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 20	.56291"	-75° 31' 30.42099"	39.989	72.279	
UTM	5028155.559		458905.881			
Error ellipse	.6 cm		.98 cm			
@95 %						
	±0.005 m		±0.008 m	±0.017 m		

 Table 6.8: GNSS acquisition details of point MBR-10 August 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028155.546	458905.881	40.035	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028155.557	458905.877	40.034	



Figure 6.15: Position of point MBR-10 NRCan - PPP Service. August 2019

Site :	P		Point MB-12			
Installation Type		Receive	Receiver in physical contact with concrete target (drone			
		target).	target). Centered on colors junction.			
		<u> </u>				
Receiver (GNSS)		Ashtec	h Zxtreme A051427			
Antenna		Ashtec	h Pinwheel ASH701	975.01A		
Antenna height		0	Concrete + washer	+ nut		
Battery		12				
Acquisition start		2019 0	08 19 17 h 09 min	. 30 sec.	(jour 232)	
Acquisition end	2019		08 20 13 h 01 min	30 sec.		
Duration		19 h 52	19 h 52 min 00 sec.			
Acquisition interva	1	30 seconds				
Raw GNSS files		SA	SA00.003			
Rinex files		00	0031.00O			
		00	0031.00N			
Position	Latitude	•	Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 17	.86041"	-75° 31' 29.45307"	41.222	73.511	
UTM	5028072 (	)23	458926 378			
	0020072.020					
Error ellipse	5 cm		1.2 cm			
@95 %						
	±0.004 m		±0.009 m	±0.016 m		

 Table 6.9:
 GNSS acquisition details of point MBR-12 August 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028072.018	458926.379	41.218	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028072.029	458926.376	41.208	



Figure 6.16: Position of point MBR-12, from NRCan – PPP Service. August 2019

## 7) Data Acquisition – GNSS survey in December 2019

Presented here are the precision GNSS survey reports for the December 2019 campaign (to the limits discussed above), as well as sample photos, of the MBR site targets (Figures 7.1 to 7.5). Information provided in these detailed reports include the latitude, longitude and altitude (both ellipsoidal and orthometric representing sea level) of the base of the antenna as installed on the target, the UTM zone, and the UTM Easting and Northing. Planimetric positions are in NAD 83 CSRS.

For the purpose of the baseline processing between the base station and individual MB points, the base station position was set at the following values, which represent the average over time since 2017. Easting and Northing are set at 459390.920 metres and 5028226.526 metres, in UTM zone 18. Ellipsoidal height is set at 39.760 metres



Figure 7.1: Field views of GPS locations MBR-2 (left) and MBR-3 (right), December 2019.



Figure 7.2: Field views of GPS locations MBR-4 (left) and MBR-5 (right), December 2019.



Figure 7.3: Field views of GPS locations MBR-6 (left) and MBR-7 (right), December 2019.



Figure 7.4: Field views of GPS locations MBR-8 (left) and MBR-Base (right), (December 2019.



Figure 7.5: Field views of GPS locations MBR-10 (left) and MBR-12 (right), December 2019.

Table 7.1 to 7.12 report the acquisition detail of all 10 points for the month of December 2019. Figures 7.6 to 7.18 report the position associated with each point.

Site :		MBR-2	2			
Installation Type		Antenna reference point (ARP) in physical contact with top				
		face of plywood UAV target. Plywood target bottom face in				
		physica	physical contact with top of post.			
Receiver (GNSS)		Trimble NetR-9 s/n 1059 CCRS: # 1				
Antenna		Ashtec	h Chokering # 588	5		
		ASH70	1945C_M NONE (4	caract. between	M and None).	
Antenna height		0	(See note above)			
Battery						
Acquisition start	2019		2 17 15 h 54 mir	. 00 sec.	(jour 351)	
Acquisition end	2019		2 18 13 h 44 mir	30 sec.		
Duration	ion		21 h 50 m 30 sec.			
Acquisition interva	Acquisition interval		30 seconds + 1 sec 10 sec			
Raw GNSS files		105935	510c.t02			
Rinex files		105935	10593510c.19N			
	1	105935	10c.19O		1	
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 32	.82050"	-75° 31' 4.69521"	37.328	69.607	
UTM	5028530.201		459467.545			
Error ellipse	.6 cm		.9 cm			
@95%						
	±0.005m		±0.007m	±0.013m		

 Table 7.1:
 GNSS acquisition details of point MBR-2- December 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028530.199	459467.549	37.313	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028530.210	459467.545	37.312	



Figure 7.6: Position of point MBR-2 from NRCan – PPP Service – December 2019.

MBR-3	MBR-3			
Antenn	Antenna reference point (ARP) in physical contact with top			
face of	plywood UAV target	. Plywood targe	et bottom face in	
physica	al contact with top of	post.		
Trimble	Trimble NetR-9 s/n 1072 CCRS: # 2			
Ashtec	h Chokering # 5815			
ASH70	1945C_M NONE (4	caract. between	M and None).	
0	(See note above)			
2019 1	2 17 16 h 10 mir	n. 00 sec.	(jour 351)	
2019 1	12 18 15 h 05 mir	n 30 sec.		
22 h 5	22 h 55 m 30 sec.			
30 sec	30 seconds + 1 sec & 10 sec.			
107235	0723511C.t02			
107235	511C.19N			
107235	10723511C.19O			
tude	Longitude	Ellipsoidal	Orthometric	
		Height (m)	Height (m) CGVD 2013	
24' 36.61188"	-75° 31' 6.62064"	37.888		
			70.168	
647.471	459426.447			
<u>ו</u>	.9 cm			
)4m	±0.007m	±0.012m		
	MBR-3 Antenn face of physica Ashtec Ashtec Ashtec ASH70 0 2019 1 2019 1 22 h 5 30 seco 107235 107235 107235 tude	MBR-3         Antenna reference point (All face of plywood UAV target physical contact with top of         Trimble NetR-9 s/n 1072         Ashtech Chokering # 5815         ASH701945C_M NONE (4         0       (See note above)         2019 12 17       16 h 10 mir         2019 12 18       15 h 05 mir         22 h 55 m 30 sec.       30 seconds + 1 sec & 10 s         10723511C.102       10723511C.19N         10723511C.19N       10723511C.19O         tude       Longitude         647.471       459426.447         n       .9 cm         04m       ±0.007m	MBR-3         Antenna reference point (ARP) in physical of face of plywood UAV target. Plywood target physical contact with top of post.         Trimble NetR-9 s/n 1072 CCRS: # 2         Ashtech Chokering # 5815         ASH701945C_M NONE (4 caract. between 0 (See note above)         2019 12 17 16 h 10 min. 00 sec.         2019 12 17 16 h 10 min. 00 sec.         2019 12 18 15 h 05 min 30 sec.         2019 12 18 15 h 05 min 30 sec.         20 19 12 18 15 h 05 min 30 sec.         20 19 12 18 15 h 05 min 30 sec.         30 seconds + 1 sec & 10 sec.         10723511C.19N         10723511C.19N         10723511C.19O         tude       Longitude         Ellipsoidal Height (m)         e4' 36.61188"       -75° 31' 6.62064"         37.888       -75° 31' 6.62064"         1.9 cm	

 Table 7.2:
 GNSS acquisition details of point MBR-3 – December 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028647.465	459426.446	37.885	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028647.477	459426.442	37.883	



Figure 7.7: Position of point MBR-3 from NRCan – PPP Service – December 2019

Site :		MBR-4			
Installation Type		Antenn	Antenna reference point (ARP) in physical contact with top		
		face of	plywood UAV target.	Plywood targe	t bottom face in
		physica	al contact with top of p	post.	
		This po	pint is a new installa	tion for May a	nd August
		2018. F	Point is offset from pre	evious year mea	asurements.
Receiver (GNSS)		Trimble NetR-9 CCRS: # 3 S/N 1216			
Antenna		Ashtecl	h Chokering # 5850		
		ASH70	1945C_M NONE (4	caract. between	M and None).
Antenna height		0 (See note above)			
Battery					
Acquisition start	2019		2 17 16 h 28 min	. 30 sec.	(jour 351)
Acquisition end	2019 1		2 18 14 h 38 min	30 sec.	
Duration	22 h 1		10 m 00 sec.		
Acquisition interva		30 seco	econds + 1 sec. & 10 sec.		
Raw GNSS files		121635	10C.To2		
Rinex files		121635	12C.19N		
		121635	12C.19N		
Position	Latitude		Longitude	Ellipsoidal	Orthometric
established by PPP				Height (m)	Height (m) CGVD 2013
Geographic	45° 24' 37	.55859"	-75° 30' 58.20717"	37.419	69.695
UTM	5028675.511		459609.512		
Error ellipse	.5 cm		1 cm		
@95%					
	±0.004m		±0.007m	±0.012m	
L			•		

 Table 7.3:
 GNSS acquisition details of point MBR-4 - December 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028675.508	459609.516	37.413	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028675.519	459609.512	37.410	



Figure 7.8: Position of point MBR-4 from NRCan – PPP Service- December 2019

Site :		MBR-5	5			
Installation Type		Antenna reference point (ARP) in physical contact with top				
		face of plywood UAV target. Plywood target bottom face in				
		physica	al contact with top of p	post.		
Receiver (GNSS)		Trimble NetR-9 S/N 1297 CCRS: # 4				
Antenna		Ashtech Chokering # 2735				
		ASH701945C_M NONE (4 caract. between M and None).				
Antenna height		0 (See note above)				
Battery						
Acquisition start		2019 1	2 17 15 h 07 min	. 30 sec.	(jour 351)	
Acquisition end		2019 12 18 14 h 12 min 30 sec.				
Duration		23 h 05m 30 sec.				
Acquisition interval		30 seconds + 1 sec , 10 sec.				
Raw GNSS files		12973510C.t02				
Rinex files		12973510C.19N				
	1	12973510C.10O				
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 28	.66401"	-75° 31' 12.69332"	37.107	69.390	
UTM	5028403.054		459292.863			
Error ellipse .5 cm			.9 cm			
@95%						
	±0.004 m		±0.007 m	±0.012 m		

Table 7.4: GNSS acquisition details of point MBR-5- December 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028403.051	459292.868	37.105	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028403.062	459292.864	37.102	



Figure 7.9: Position of point MBR-5 from NRCan – PPP Service – December 2019
Site :		MBR-6	5			
Installation Type		Antenna reference point (ARP) in physical contact with top				
51		face of	face of plywood UAV target. Plywood target bottom face in			
		physica	al contact with top of	post.		
Receiver (GNSS)		Trimble	e NetR-9 S/N 1205	CCRS: # 5		
Antenna		Ashtec	h Chokering 1125			
		ASH70	1945C_M NONE (4	caract. between	M and None).	
Antenna height		0	(See note above)			
Battery						
Acquisition start		2019 1	2 17 15 h 24 min	. 30 sec.	(jour 351)	
Acquisition end	d 20		2 18 12 h 30 min	30 sec.		
Duration	on		21 h 06 m. 30 sec.			
Acquisition interva	Acquisition interval		30 seconds + 1 sec & 10 sec.			
Raw GNSS files		120535	510C.t02			
Rinex files		12053510C.19N				
		120535	510C.19O			
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 29	.38043"	75° 31' 19.28266"	37.146	69.431	
UTM	5028426.090		459149.773			
Error ellipse	.6 cm		1. cm			
@95%						
	±0.005 m		±0.008 m	±0.013 m		

Table 7.5: GNSS acquisition details of point MBR-6 - December 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028426.087	459149.774	37.138	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028426.098	459149.770	37.137	



Figure 7.10: Position of point MBR-6 from NRCan - PPP Service - December 2019

Site :		MBR-7	,			
Installation Type		Antenn	Antenna reference point (ARP) in physical contact with top			
metallation Type		face of	plywood UAV target	Plywood targe	t bottom face in	
		physica	al contact with top of	nost		
		prijelee				
Receiver (GNSS)		Ashtecl	h ZXtreme CCRS: #	\$ 2		
Antenna		Ashtecl	h Chokering 6910			
		ASH70	1945C_M NONE (4	caract. between	M and None).	
Antenna height		0	(See note above)			
Battery						
Acquisition start		2019 1	2 17 16 h 52 mir	n. 00 sec.	(jour 351)	
Acquisition end		2019 1	2 18 14 h 38 mir	1 30 sec.		
Duration		21 h 40	21 h 46 m 30 sec.			
Acquisition interval		30 seconds				
Raw GNSS files		SA00.123				
Rinex files		1231.19N				
		123	1.190			
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 27	.84177"	-75° 31' 7.93677"	38.277	70.558	
UTM	5028377.012		459396.093			
Error ellipse	.6 cm		1.0 cm			
@95%						
	±0.005 m		±0.008 m	±0.014m		

Table 7.6: GNSS acquisition details of point MBR-7 – December 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028377.010	459396.099	38.273	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028377.021	459396.094	38.267	



Figure 7.11: Position of point MBR-7 from NRCan – PPP Service- December 2019.

Site :		MBR-8	3			
Installation Type		Antenna reference point (ARP) in physical contact with top				
		of vertic	cal steel rod coupler.			
		Tuinalala		0000.# 7		
Receiver (GNSS)		I rimble	NetR-9 5/N 0126	UCR5:# 7		
Antenna		ASILIZO	n Chokering 4202			
		ASHTUT945C_M NONE (4 caract. between M and None).				
Antenna height		0	(See note above)			
Battery		Out of p	oower		() 05()	
Acquisition start		2019 1	2 17 15 h 26 min	. 00 sec.	(jour 351)	
Acquisition end		2019 1	2019 12 18 03 h 56 min 30 sec.			
Duration		12 h 30 m 30 sec.				
Acquisition interval		30 seconds + 1 sec +10 sec.				
Raw GNSS files		0126351Ct02				
Rinex files		0126351C.18N				
		012635	1C.18O			
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 22	.68937"	-75° 31' 16.91602"	39.667	71.951	
UTM	5028219.2	72	459199.878			
Error ellipse	.5 cm		.9 cm			
@95%						
	±0.004 m		±0.007 m	±0.014 m		

 Table 7.7:
 GNSS acquisition details of point MBR-8 - December 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028219.270	459199.884	39.664	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
	5028219.281	459199.879	39.659	



Figure 7.12: Position of point MBR-8 from NRCan – PPP Service – December 2019.



Figure 7.13: Field view of MBR-8 – December 2019.

Site :		_				
la stallation Toma		Bases	station			
Installation Type		Antenn	a reference point (AR	(P) in physical (	contact with top	
		of vertic	cal steel rod coupler.			
Receiver (GNSS)		Trimble Net-R9 #06 S/N 0352				
Antenna		Ashtec	h Chokering 58	75		
		ASH70	1945C_M NONE (4	caract. between	M and None).	
Antenna height		0	(See note above)			
Battery						
Acquisition start		2019 1	2 17 15 h 00 min	. 30 sec.	(jour 351)	
Acquisition end	on end		2 18 14 h 21 min	30 sec.		
Duration	Duration		23 h. 21 min. 00 sec.			
Acquisition interva	Acquisition interval		30 seconds			
Raw GNSS files		035235	0352351C.t02			
Rinex files		0352351C.19O 19N 19G 19H				
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by	(average	)	(average)	Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 22.96418"		-75° 31' 8.12996"	39.766	72.047	
UTM	5028226.518		459390.923			
Error ellipse	.4 cm		.8 cm			
@95 %						
	±0.004m		±0.006m	±0.013m		
h			•			

Table 7.8: GNSS acquisition details of point "Base station" - December 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028226.515	459390.924	39.762	•



(lien pour la référence altimétrique)

\*(Position a priori initialisée à partir des coordonnées de l'en-tête du RINEX)

0,0,20200

Figure 7.14: Position of point "Base station" from NRCan - PPP Service- December 2019

0.999620 (point) 0.999614 (combiné)



Figure 7.15: Field view of Base station – December 2019.

Site :		MBR-1	10			
Installation Type Antenn		Antenn	na in physical contact with concrete target (drone			
		target).	Centered on colors	junction.		
Receiver (GNSS)		Ashtec	h ZXtreme CCRS # 4			
Antenna		TRM57	971.00			
Antenna height		0				
Acquisition start		2019 1	2 17 19 h 09 min	. 30 sec.	(jour 351)	
Acquisition end		2019 1	2 18 13 h 46 min	30 sec.		
Duration		21 h. 3	7 min. 00 sec			
Acquisition interva		30 seco	30 seconds			
Raw GNSS files		SA	SA00.123			
Rinex files		1231V2.19O .19N				
	1		1	-	-	
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 20	.56244"	-75° 31' 30.42099"	40.043	72.333	
UTM	5028155.545		458905.881	1		
Error ellipse	.6 cm		1.0 cm			
@95 %						
	±0.005 m		±0.008 m	±0.016 m		
established by PPP Geographic UTM Error ellipse @95 %	45° 24' 20 5028155.5 .6 cm ±0.005 m	.56244"	-75° 31' 30.42099" 458905.881 1.0 cm ±0.008 m	40.043 ±0.016 m	Height (m)           CGVD 2013           72.333	

Table 7.9: GNSS acquisition details of point MBR-10 December 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028155.542	458905.884	40.074	

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028155.553	458905.879	40.068	



Figure 7.16: Position of point MBR-10 from NRCan – PPP Service. December 2019

Site :		MBR-1	I2 –Session A			
Installation Type		Receiver in physical contact with concrete target (drone				
		target).	Centered on colors	junction.		
Receiver (GNSS)		GENEC	Q SX Blue CCRS	# 1		
Antenna						
Antenna height		.070				
Acquisition start		2019 1	2 17 16 h 30 min	. 22 sec.	(jour 351)	
Acquisition end		2019 1	19 12 17 23 h 59 min 59 sec.			
Duration	07 h 2		h 29 min 370 sec.			
Acquisition interva	val 1 seco		conds			
Raw GNSS files		86113	11351GF.sth			
Rinex files		86113	51GF. 19G .19N .1	90		
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 17	.85982"	-75° 31' 29.45362"	41.242	73.531	
итм	5028072.0	005	458926.366			
Error ellipse	.7 cm		1.1 cm			
@95 %						
	±0.006 m		±0.009 m	±0.019 m		
	1					

 Table 7.10:
 GNSS acquisition details of point MBR-12 December 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	Not calculated	Not calculated	Not calculated	file corrupted

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	Not calculated	Not calculated	Not calculated	file corrupted



Figure 7.17: Position of point MBR-12 Session –A from NRCan – PPP Service. December 2019

Site :		MBR-1	12 –Session B			
Installation Type		Receiver in physical contact with concrete target (drone				
		target).	Centered on colors	junction.		
Receiver (GNSS)	Receiver (GNSS)		Q SX Blue CCRS	# 1		
Antenna						
Antenna height		.070				
Acquisition start		2019 1	12 18 00 h 00 min	. 00 sec.	(jour 352)	
Acquisition end	Acquisition end		2019 12 18 13 h 54 min 14 sec.			
Duration		13 h 54 min 14 sec.				
Acquisition interva	Acquisition interval		1 seconds			
Raw GNSS files		86113	61135200.sth			
Rinex files		86113	5200. 19G .19N .19	0		
Position	Latitude		Longitude	Ellipsoidal	Orthometric	
established by				Height (m)	Height (m)	
PPP					CGVD 2013	
Geographic	45° 24' 17	.85994"	-75° 31' 29.45362"	41.230	73.519	
UTM	5028072 (	009	458926 366			
	2020072.0					
Error ellipse	.5 cm		0.9 cm			
@95 %						
	±0.004 m		±0.007 m	±0.014 m		
	1					

 Table 7.11:
 GNSS acquisition details of point MBR-12 December 2019

Position established by baseline-NRC	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028072.011	458926.375	41.235	•

Position established by baseline-Base	Latitude	Longitude	Ellipsoidal Height (m)	Orthometric Height (m)
UTM	5028072.022	458926.370	41.252	•



Figure 7.18: Position of point MBR-12 Session –B from NRCan – PPP Service. December 2019

orthing	Easting	Ellip H.	Ortho H.	
5028072.005	458926.366	41.242	73.531	
5028072.009	458926.366	41.230	73.519	
5028072.007	458926.366	41.236	73.525	

Table 7.12: Average position of point MBR-12 December 2019 from PPP

### 8) Vertical movement of points through time established using various methods.

As the Mer Bleue Peatland is a relatively flat site with significant microtopography, specific attention was given to potential causes of height variations of individual survey points related to the research boardwalk. Such vertical motion can be estimated from three different methods: Precision Point Processing (PPP), baseline processing using the Natural Resources Canada (NRCan) CACS station located 9 km away, and baseline processing using the installed MBR Base Station located ~150 meters away from the peatland, on upper dry ground as discussed above.

The baseline height trend from the MBR Base Station located close to the peatland would represent the altimetric movement of the site in relation to its close surrounding. For example, a lowering trend would indicate that the site is getting lower in relation to the surrounding upper ground, perhaps caused by moisture variations within the peatland.

The baseline height trend from the NRCan CACS station located 9 km away would represent the altimetric movement of the point in relation to its remote surrounding and may reflect a regional altimetric trend. A lowering temporal trend indicates that the point is getting lower in relation to the CACS station.

Finally, it should be noted that the PPP processing system does not use a baseline for comparison. It uses precise ephemeris and GNSS clock information to estimate the position and height of the target. A height trend from PPP processing represents the altimetric alteration of the point for reasons which could be related to seasonal changes in the environment.

In the high precision world of GNSS height estimation, it must be noted that there already exists an apparent seasonality in the height estimation (Ferland R., 2000). Figure 8.1 and Table 8.1 illustrate, based on PPP, the seasonality height movement of the NRCan CACS station, which is physically very stable through time. Further discussion on the fine height variations are beyond the scope of this document, however any change of vertical position uniformly by all GNSS targets (including the Base Station) of less than 5 cm over several weeks would be considered a within-experimental design uncertainty, and not due to a vertical upheaval of the entire Mer Bleue Research Boardwalk and surrounding region. Relative vertical change between points however could still indicate motion within the peatland.



Figure 8.1: Seasonal variation in height of the NRC-CACS station, 2019 (Source: NRCan GSD)

Date of survey	Latitude	Longitude	Vertical
23 January 2019	-0.005	-0.001	-0.006
24 January 2019	-0.000	0.002	0.018
25 January 2019	-0.002	-0.002	-0.005
29 May 2019	-0.003	0.001	-0.003
30 May 2019	-0.002	-0.001	-0.002
31 May 2019	-0.005	-0.001	0.002
18 August 2019	-0.005	-0.003	0.014
21 August 2019	0.000	0.003	-0.005
17 December 2019	-0.002	-0.005	0.002
18 December 2019	-0.004	-0.005	-0.003

Table 8.1: Seasonal variation of NRC CACS station at time of survey (in metres)

Source: Geodetic Survey Division, RNCan 2019

Note that on January 24 the CACS station reported an elevation .018 m. above its reference. This can be tracked on the altimetric values of MB-Base and MB-8, since these two points were acquired in January 23 and 24. Also, it is reflected on points acquired on the 24 January i.e. MB4, MB-7.

## 9) Altimetric Trends

Most of the high precision GPS target points at MBR show a similar behaviour in a way that derived point altimetry movement is more stable when estimated using the NRCan and the Base Station methods (The PPP method provides more varied results). In all three methods, the MBR target points in the peatland appear to shift in the same manner as the more stable Base Station points, indicating that this apparent motion is due more to the hardware and processing methodology rather than actual motion of the Mer Bleue Peatland. As well, the Base Station and the NRCan CACS station provide similar results. This confirms the advantage of using a Base Station type method in determining vertical position, either a CACS station or a local base station when there is no CACS station in the vicinity.

Figures 9.1 to 9.9 illustrate the altimetric trend of each point throughout the survey period. Time scale is similar for all graphs.



Figure 9.1: Altimetric trend estimation of MBR-2 in 2016-2017-2018-2019 using various methods



Figure 9.2: Altimetric trend estimation of MBR-3 in 2016-2017-2018-2019 using various methods



Figure 9.3:. Altimetric trend estimation of MBR-4 in 2016-2017-2018-2019 using various methods



Figure 9.4: Altimetric trend estimation of MBR-5 in 2016-2017-2018 using various methods



Figure 9.5: Altimetric trend estimation of MBR-6 in 2016-2017-2018-2019 using various methods



Figure 9.6: Altimetric trend estimation of MBR-7 in 2016-2017-2018 using various methods



Figure 9.7: Altimetric trend estimation of MBR-8 in 2016-2017-2018-2019 using various methods



Figure 9.8: Altimetric trend estimation of MBR-12 in 2019 using various methods



Figure 9.9: Altimetric trend estimation of "Base" in 2016-2017-2018 using various methods

Figures 9.10 to 9.16 illustrate the height movement of each point through the 2016-2019 survey period, in relation to the Base Station. So far, this appears to provide a robust representation of vertical motion within the Mer Bleue Bog, featuring trends between the stable Base Station and the individual sites. These trends are in the order of 5-30 mm throughout the years, therefore very minimal and close to the limit of detectability previously discussed. Time scale is similar for all graphs.



Figure 9.10: Vertical motion of MBR-2 normalized to the MBR Base Station height.



Figure 9.11: Vertical motion of MBR-3 normalized to the MBR Base Station height.



Figure 9.12: Vertical motion of MBR-4 normalized to the MBR Base Station height



Figure 9.13: Vertical motion of MBR-5 normalized to the MBR Base Station height.



Figure 9.14:. Vertical motion of MBR-6 normalized to the MBR Base Station height.



Figure 9.15: Vertical motion of MBR-7 normalized to the MBR Base Station height.



Figure 9.16: Vertical motion of MBR-8 normalized to the MBR Base Station height.

Finally, researchers were wondering about the effect of soil freeze/thaw potentially creating an up-down movement. To obtain a first order estimation of such movement, tests were performed on Base station and MBR-8. Measurements were made of the distance between the top of the steel pipe which is a 50 cm pipe hammered in the ground (therefore mobile with frost), and the top of the ground rod hammered 6 metres down the ground and therefore not moving with frost (Figure 9.17). The results are shown on Table 9.1 and reveal no vertical movement. Snow and grass likely provide soil insulation. More details on the set up of these two points on pages 37-39.



Figure 9.17 Field view of Base station (left) and MBR-8 (right) in May

Date	Base Station	MBR-8
	"A" distance	"A" distance
Jan 2019	500	405 mm
May	502	401
August	502	406
December	502	407

	Table 9.1	Soil vertical	movement	throughou	it the v	ear
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# 10) Precision of positioning using Stop & Go approach January

During the January survey, an experiment was undertaken to estimate the precision of positioning of drone targets using a Stop & Go approach, and using a lightweight, low cost, single frequency GNSS receiver (Figure 10.1)

The Stop&Go approach implies that the operator in the field carries the receiver and the antenna, and travels from one drone target to another making sure the lock to the GNSS satellites is maintained. The data recording is continuously activated at 1 second interval. Once over a target, the operator stops for a short period of time (3-10 minutes) without moving as illustrated in Figures 10.2 to 10.5. An alternate method could be using a collapsible pole to make walking easier, and a level to ensure the pole is kept vertical for the time period on the target

The acquired dataset is then processed through phase differential in kinematic mode. Once the process is completed, the next step is to extract the points corresponding to the time interval the operator was standing over the target, and compute the average 3D position.

In order to increase the agility of the approach, the receiver, to be carried, was chosen to be easy to operate, since all components are within a single enclosure i.e. antenna, receiver, battery and recorder.

Operationally, the purpose of the experiment was to test the feasibility of using agile and low cost approach to acquire multiple drone target position in an easy and short survey time.



Figure 10.1. Illustration of the size of the low cost and versatile GNSS receiver used.

Operationally, the receiver illustrated in figure 10.1 was attached onto a specially designed rack, attached as a backpack to a volunteer. The Base station was used as a verification point



Figure 10.2 Location of validation point in Mer Bleue (base station - known point)



Figure 10.3 Low cost GPS is attached to the rack. No belly pack required.

The low cost, lightweight, receiver was activated for 15 minutes before the beginning of the survey to solve some GNSS ambiguities. The team member then walked around, and stopped, without moving, over the base station (point) for five minutes. After five minutes, she moved away. Then the rack was attached to a second team member, and the operation was repeated. The receiver was recording during all that time. Caution was used to not bend over and stay as straight as possible since this type of movement would have the effect of losing GNSS lock to satellite, thus compromising the positioning accuracy.



Figure 10.4 First team member standing over the known point for 5 minutes



Figure 10.5 Second team member standing over the known point for 5 minutes

Following are the details and results of the experiment:

-Receiver started at 10:54:07

-Receiver started recording at 10:58:07

-Data were recorded at 1 second interval

-First trial – standing still over known point from 11:15:00 to 11:19:20

-Second trial – standing still over known point from 11: 22: 47 to 11:26:56

-Data were processes in single frequency using Baseline phase differential with NRC Base station located 9 km away.

Table 10.1 shows the comparison between the true position of the reference point and its estimated position from Stop & Go approach.

I II					
Trial	Average		Standard deviation		
	Easting	Northing	Easting	Northing	Height <sup>2</sup>
Trial -1	459390.926	5028226.535	.020	.023	.007
Trial -2	459390.927	5028226.559	.021	.009	.006
True position <sup>1</sup>	459390.920	50282326.526	.003	.006	

Table 10.1 Comparative results using Stop & Go approach

<sup>1</sup>: True position established from repeated surveys using dual frequency receivers, 24 hours acquisitions and PPP processing.

<sup>2:</sup> Height uncertainty does not include the measurement of the antenna height from the ground. This value may vary by a few centimeters depending on how the operator stands naturally.

In conclusion, this experiment demonstrated that the Stop & go method, can be an effective method to locate with precision, multiple points used as drone targets, and is especially well suited for northern applications **if**:

**-If** there is a reference station in the vicinity. This reference station can be established by the user or be a government station. Tests have shown that a reference station at 25 km did not show any loss in precision using single frequency observations.

**-If** the receiver is activated at least 15 minutes before the beginning of the survey to allow the resolution of ambiguities.

**-if** the operator can stand still for five minutes over a point, and record the start/stop time.

**-if** the operator remembers to not bend over during transit, to prevent losing the lock to satellites.

and if the operator posture remains stable over time.

## 11) Conclusion and Future Considerations

Reference target sites were located with precision using dual frequency GNSS receivers running in static mode for an extended time of acquisition. These targets are well marked on the ground such that they could be used for several years for the geocoding of airborne imagery.

A permanent station was set using a ground rod in an open area located on solid ground at the fringe of the bog. This permanent rod station can continue to be used as a fine GNSS positioning method by using the short baseline differential processing technique.

For future GNSS precision surveys, improvements can be incorporated into the project Standard Operating Procedure.

- The Base Station and MBR-8 will be the primary source of information to monitor the height variation of the posts located in the bog.
- In the short baseline processing, the vertical component of the 3D vector will be used to monitor height variation. To do so, the 3 components of the Earth Centric Earth Fixed reference frame will be converted in East-West and altimetric components.
- In view of existing and future satellite mission data processing, the weather information could be collected for each survey such as: temperature, pressure, wind direction and intensity, and sky condition.

#### 12) Related Publications

This document is one of many documents related to the use of Unmanned Aerial Vehicle imagery for snow and wetland monitoring. GNSS 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.

- Prévost, C., White, H.P., 2019. Mer Bleue, Ontario, Arctic Surrogate Study Site Project – 2018 - GPS survey report; Geomatics Canada, Open file 46, 93 pages, https://doi.org/10.4095/314595
- Prévost, C., White, H.P., 2017. Mer Bleue, Ontario, Arctic Surrogate Study Site Project – 2016 - GPS Survey Report; Geomatics Canada, Open file 36, 161 pages, doi:10.4095/304278
- Prévost, C., White, H.P., 2016. Mer Bleue, Ontario, Arctic Surrogate Study Site Project – 2015 - GPS Survey Report; Geomatics Canada, Open file 29, 59 pages, doi:10.4095/299442
- 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; Géomatique Canada, Dossier public 26, 67 pages. doi:10.4095/299047
- Prévost, C., Fernandes, R., and Canisius, F., 2016. 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, Geomatics Canada, Open file 27, 42 pages, doi:10.4095/299101
- Prévost, C., R. Fernandes, A. Langlois, X. Gervais-Gosselin, D. Kramer, 2018. Relevé GPS de cibles de référence au site test de Quinte, Ontario, dans le cadre du projet d'évaluation de l'épaisseur de neige par aéronef sans pilote; Géomatique Canada, Dossier public GC-40, 59 pages, doi:10.4095/308409
- Fernandes, R.A., F. Canisius, S. Leblanc, M. Maloley, S. Oakes, C. Prévost, C. Schmidt, 2017. Assessment of UAV-based photogrammetry for snow-depth mapping: data collection and processing, Geomatics Canada Open File 32, 50 pages, doi.org/10.4095/300553
- 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)/zxtreme/Manuals/630845-01-Post-ProcessSurveying.pdf
- Natural Resources Canada, Precision Positioning System (PPP) Tools and Applications. http://www.NRCan.gc.ca/earth-sciences/geomatics/geodeticreference-systems/tools-applications/10925
- Natural ressources Canada, Geodetic reference system, Canadian Active Control System (CACS). http://www.rncan.gc.ca/sciences-terre/geomatique/ systemes-reference-geodesique/donnees/10924#cacs
- Trimble NetR9 GNSS Reference Receiver User Guide , Ver. 4.15, May 2010, http://toolik.alaska.edu/gis/gps/images/gpsbase/NetR8\_UserGuide.pdf

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http://ashgps.com/mirror/master/GNSS%20Solutions/manuals/English/ GNSSSolutions\_RM\_F\_en.pdf 13) Bibliography

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