

Control and Accuracy Report

for
Airborne Imaging's Lidar Library data set for the
Greater Toronto Area

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July 4, 2016

Contents

Introduction	1
Time Frame & Flight Parameters.....	1
Project Control	2
Ground Truthing.....	3

Appendix A Static Control Report	7
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Introduction

Airborne Imaging collected Lidar data over the Greater Toronto Area in 2014 and 2015. This report addresses:

- 1- The existing control the Lidar data set is based on.
- 2- Quantifying the expected accuracy for the entire data set.

Time Frame & Flight Parameters

The Lidar collection took place in the spring of 2014 and 2015 during the following dates: between April 20, 2014 and May 6, 2014 as well as between April 3, 2015 and April 25, 2015.

The LiDAR system utilized on this project was a Leica ALS70-HP, capable of laser pulse rates up to 500,000 Hz with Multiple Pulse in the Air (MPIA) technology. For this project the LiDAR data was acquired at an altitude of 800m AGL (Above Ground Level) with the laser pulse rate set at 300,000 Hz, resulting in a data set with an aggregate point density greater than 11 points per meter². The following details the flight parameters used:

Flight Height: 800 m AGL
Speed: 140 knots
Flightline Spacing: 350 m
Single Pass Swath width: 700 m
Overlap: 50%
Scan Angle or FOV: 50°
Scan Frequency: 47Hz
Scan Pulse Rate: 300 KHz
11 Points per Sq meter with overlap

Project Control

Airborne Imaging used one active control station (PWEL) and three additional existing control (70106, 61313 and 653196) in the geodetic network. The three existing control stations are all part of Ontario's MNR cosine network but only 61313 and 653196 are part of Natural Resources Canada's Geodetic Survey Division network.

A new station (A461) was established at the Buttonville airport and we also tied into a point previously used by Airborne Imaging (DVP1). Station A461 was used during flight operations and ground truth surveys.

The Geoid undulation model used throughout this project is HT2.0. All survey work on this project is therefore based on NAD83-CSRS horizontally and CGVD28 vertically.

The final least-squares adjustment was held fixed in three dimensions to stations PWEL and 61313 and also held fixed vertically to station 653196. The residuals at the existing control were very good, in the order of 1cm. For a map of the final adjusted coordinates, traverse overview, control sheets, traverse report and least-squares adjustment reports, see Appendix A.

Ground Truthing

Kinematic

One method of ground truthing carried out for this project is by vehicle mounted kinematic, where a GPS antenna is mounted on the roof of a vehicle and while driving on an open road, raw GPS observables are collected at one second intervals. GPS data is also collected from the closest base station and the raw data post-processed to obtain accuracies in the range of three centimeters vertically. When possible, we try to have ground truth over every flight line flown.

A comparison is made between the Lidar derived ground surface and the surveyed points on the road. The resulting accuracies on flat hard surfaces show excellent results with an RMS error of less than 5 cm. See table below for the final statistics on all the kinematic points.

Number of points	16,562
Average dz	+0.015
Minimum dz	-0.148
Maximum dz	+0.263
Average magnitude	0.033
Root mean square	0.042
Std deviation	0.039

For a statistical normal distribution, the accuracy at the 2-sigma confidence level (95% of the time) is the RMS value multiplied by 1.96, therefore **8.2 cm** vertical accuracy on the kinematic points.

Rapid Static

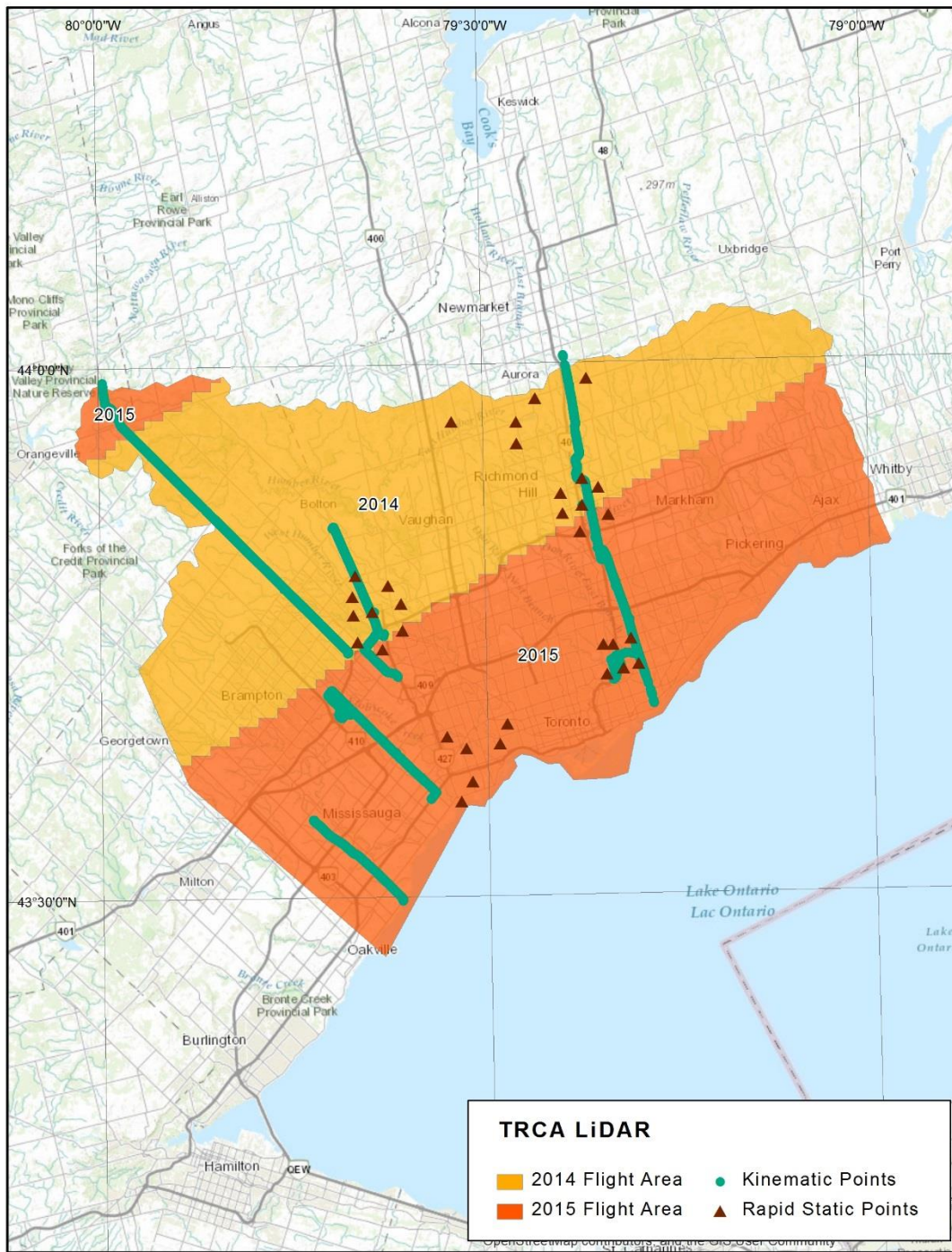
The second method of ground truthing carried out for this project is by rapid static GPS. Raw GPS observables are collected at a stationary point during ten to fifteen minutes on a flat hard surface. GPS data is also collected from the closest base station and the raw data post-processed to obtain accuracies in the range of one to two centimeters vertically.

The same comparison is made between the Lidar derived ground surface and the surveyed points on flat hard surfaces. The resulting accuracies are also excellent with an RMS error of less than 4 cm. See table below for the final statistics on all rapid static points.

Number of points	33
Average dz	-0.004
Minimum dz	-0.082
Maximum dz	+0.066
Average magnitude	0.031
Root mean square	0.038
Std deviation	0.039

The resulting vertical accuracy on the rapid static points is **7.5 cm** at the 2-sigma confidence level (95% of the time).

See next page for a map of the kinematic and rapid-static points over the Greater Toronto Area.



Appendix A

Static Control Report



NRCAN (NAD83CSRS) Static Control Report

- a.) Final Adjusted Coordinates
- b.) Traverse Overview
- c.) Control Sheets
- d.) Traverse Report
- e.) Minimally Constrained Network Adjustment
- f.) Fully Constrained Network Adjustment



a.) Final Adjusted Coordinates

Project: 1371_TRCA_FULL
 Program: GrafNet Version 8.40.3116
 Profile: Ali Network Summary
 Source: Network
 Datum: NAD83, (processing datum)
 Control IDs: FWEL, 653196, 61313
 Geoid: HT2_0-Canada.wpg (Absolute correction)

Map projection info:
 Defined grid: UTM, Zone 18

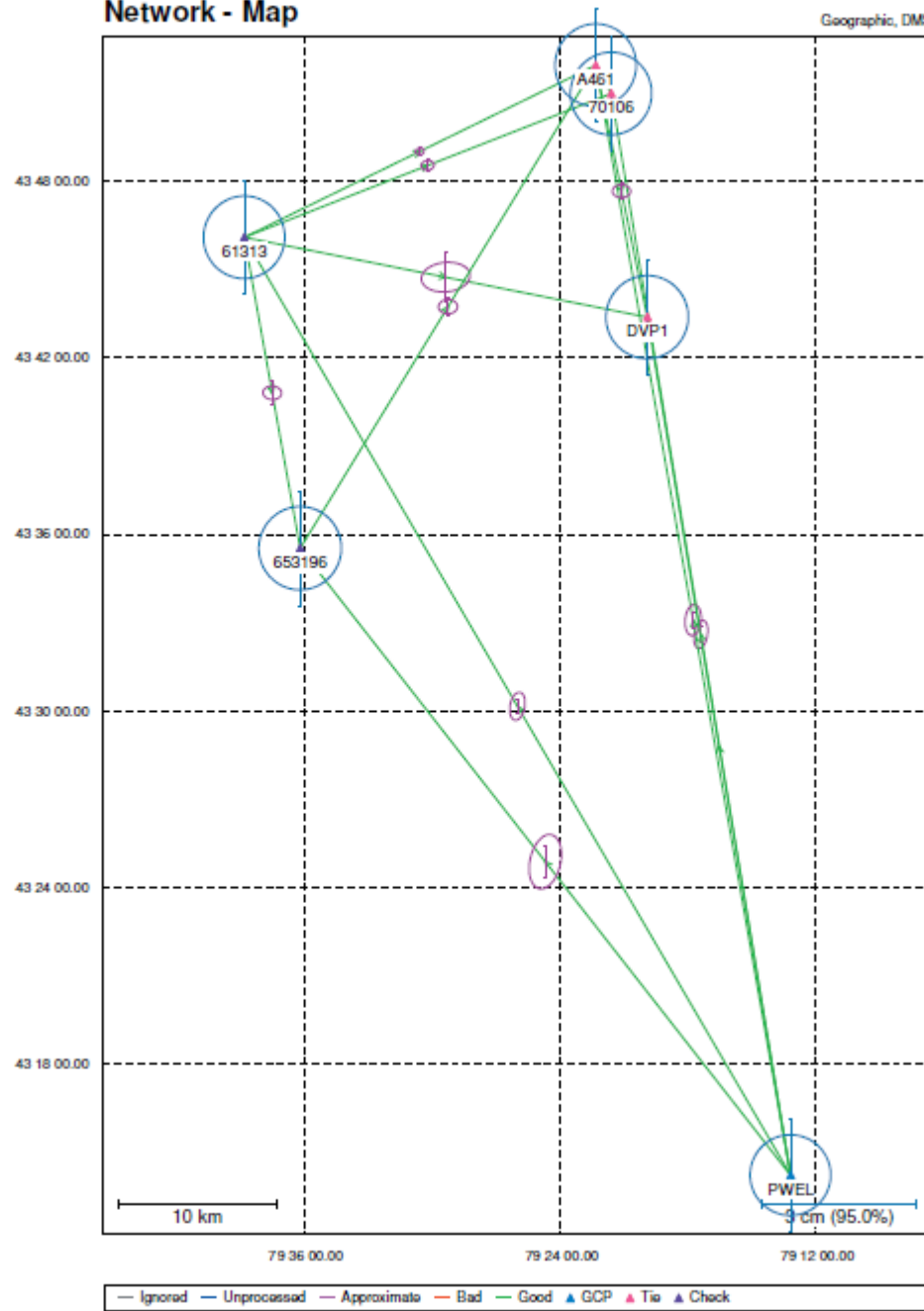
Station	Latitude (+/-D M S)	Longitude (+/-D M S)	H-ELL (m)	Undulation (m)	H-MSL (m)	Northing (m)	Easting (m)
61313	43 46 05.44812	-79 38 49.15723	154.971	-36.327	191.299	4856629.849	125966.314
653196	43 35 30.99772	-79 36 11.54776	92.610	-36.389	128.999	4836856.633	128401.953
70106	43 50 58.73917	-79 21 36.00850	147.191	-36.300	183.491	4864420.645	149545.266
AM61	43 51 56.75449	-79 22 19.64073	160.514	-36.287	196.801	4866262.241	148665.814
DVP1	43 43 22.50658	-79 19 54.47507	93.136	-36.392	129.527	4850224.326	151074.580
FWEL	43 14 12.20253	-79 13 10.77832	44.994	-36.039	81.033	4795753.934	157366.325



b.) Traverse Overview

Network - Map

Geographic, DMS





c.) Control Sheets

SITE IDENTIFICATION

Unique Number : 61313
Name : GORE
Established by : Geodetic Survey Division - Nrcan
Province : ON
Prov. Identifier : 00161313
NTS Map No : 030M13

STATION COORDINATES

Horizontal Datum : NAD83CSRS
Method : Global Positioning System
Latitude : N43° 46' 05.4481" +/- 0.002 m Std Dev. (68% confidence level)
Longitude : W79° 38' 49.1573" +/- 0.002 m Std Dev. (68% confidence level)
Ellipsoid Height : 154.98 m +/- 0.013 m Std Dev. (68% confidence level)
Geoid Separation (HTv2.0) : -36.328 m
Agency : Geodetic Survey Division - Nrcan
Adjustment Net : M01707
Coordinate Version No. : 3.0.1
Epoch : 1997.0
UTM : Zone = 17 Scale Factor = .9997 N = 4847015.15 m E = 608898.45 m
XYZ Coords. : X = 829093.27 m Y = -4538332.79 m Z = 4389634.27 m

Horizontal Datum : ITRF2008
Latitude : N43° 46' 5.4792"
Longitude : W 79° 38' 49.1697"
Ellipsoid Height : 153.85 m
Epoch : 1997.0
XYZ Coords. : X = 829092.73 m Y = -4538331.38 m Z = 4389634.18 m

VERTICAL DATA

Vertical Datum : CGVD28
Elevation : 189.7 m
Order : Adjusted Unclassified
Method : Differential
Adjustment Line : NOVA1961
Published Year : 1961

STATION MARKER INFORMATION AND LOCATION

Marker Type : Brass/Bronze Tablet Or Cap
Inspected in : 1992
Status : Good
Inspection Comments : None

Accessible by passenger car or light truck and a walk of less than 50 m

BRAMPTON

FROM THE INTER. OF HWY #7 AND HWY #50, PROCEED NE ALONG HWY #7 FOR APPROX 150 M, TURN NW ONTO HUNTINGTON RD AND DRIVE 70 M. THE STA IS LOC BEHIND A CHAIN LINK FENCE ON THE W SIDE OF HUNTINGTON RD, AND 15.5 M NW OF HYDRO POLE "5/8/1/9/202". MKD BY A GSC BRASS TABLET "STPD 61313", SET IN THE TOP OF A CONCRETE BLOCK, 10 CM ABOVE GRD LVL. A SIMILAR SUB-SURFACE MKR WAS PLACED IN A CONC BLOCK 1.4 M BELOW THE UPPER MKR. REF TO TWO STPD REF TABS. A IS 10.8 M W OF RD C/L AT NE COR OF FENCE. B IS AT THE SE COR OF FENCE 10.8 M W OF RD C/L AND 11.6 M NW OF HYDRO POLE. SURVEY SIGN POSTS WERE PLACED NEAR THE STA AND BOTH REF MKR. GSC FLAT BLUE SIGN POSTS WERE SET AT THE MAIN STA AND THE TWO REF.

REFERENCE STATIONS INFORMATION:

Reference name, Marker type, AZ/DIR/BRNG (DEG MIN SEC), (H)orizontal or (S)loped distance (m), and Diff. in elev. (cm)

REF A(61313A) BRASS/BRONZE TABLET OR CAP 31 13' 02 H 5.25
REF B(61313B) BRASS/BRONZE TABLET OR CAP 127 05' 59 H 4.86

HISTORICAL COORDINATES NOTE: Coordinates listed below are no longer maintained by GSD and should be verified with your provincial agency before use.

Horizontal Datum : NAD83
Method : Multiple Methods
Latitude : N43° 46' 05.45715"
Longitude : W79° 38' 49.15666"
UTM : Zone = 17 Scale Factor = .9997 N = 4847015.432 m E = 608898.457 m

Horizontal Datum : NAD27
Method : Triangulation - Trilateration
Latitude : N43° 46' 05.25100"
Longitude : W79° 38' 49.84300"
UTM : Zone = 17 Scale Factor = .9997 N = 4846792.916 m E = 608886.342 m

SITE IDENTIFICATION

Unique Number : 653196
Name : 650146
Established by : Topographical Survey Division - Nrcan
Province : ON
Prov. Identifier : 001653196
NTS Map No : 030M12

STATION COORDINATES

Horizontal Datum : NAD83
Method : Values should be checked with your provincial agency before use.
Latitude : N43° 35' 31.00647"
Longitude : W79° 36' 11.54861"
Agency : Geodetic Survey Division - Nrcan
Adjustment Net : MA90500
UTM : Zone = 17 Scale Factor = .9998 N = 4827500.580 m E = 612751.778 m

VERTICAL DATA

Vertical Datum : CGVD28
Elevation : 128.982 m
Order : First Order
Method : Differential
Adjustment Line : VA331
Published Year : 1965

STATION MARKER INFORMATION AND LOCATION

Marker Type : Permanent Agency Marker
Inspected in : 1965
Status : Good
Inspection Comments : None

LIMEHOUSE

HIGHWAY NO. 5 BRIDGE OVER C.P.R.Y., 0.5 KM SOUTHWEST OF CAWTHRA ROAD, TABLET IN TOP OF SIDEWALK ON NORTHWEST SIDE OF HIGHWAY, 3.7 M FROM NORTHEAST END OF BRIDGE, 1.8 M SOUTH OF CONCRETE END-POST, 90 CM FROM EDGE OF CURB. ESTABLISHED BY TOPOGRAPHICAL SURVEY.

HISTORICAL COORDINATES NOTE: Coordinates listed below are no longer maintained by GSD and should be verified with your provincial agency before use.

Horizontal Datum : NAD83
Method : Multiple Methods
Latitude : N43° 35' 31.00647"
Longitude : W79° 36' 11.54861"
UTM : Zone = 17 Scale Factor = .9998 N = 4827500.580 m E = 612751.778 m

Horizontal Datum : NAD27
Method : Electronic Traversing
Latitude : N43° 35' 30.79905"
Longitude : W79° 36' 12.24453"
UTM : Zone = 17 Scale Factor = .9998 N = 4827278.222 m E = 612739.505 m

SITE IDENTIFICATION

Unique Number : M023002
Name : PWEL RACS-GLCORS
Established by : Geodetic Survey Division - Nrcan
Province : ON
Prov. Identifier : PWEL
NTS Map No : 030M03

STATION COORDINATES

Horizontal Datum : NAD83CSRS
Method : Values Available In Another Datum
Latitude : N43° 14' 12.2027" +/- 0.006 m Std Dev. (68% confidence level)
Longitude : W79° 13' 10.7778" +/- 0.005 m Std Dev. (68% confidence level)
Ellipsoid Height : 44.99 m +/- 0.022 m Std Dev. (68% confidence level)
Geoid Separation (HTv2.0) : -36.040 m
Agency : Geodetic Survey Division - Nrcan
Adjustment Net : M10716
Coordinate Version No. : 4.0.2
Epoch : 2002.0
UTM : Zone = 17 Scale Factor = .9999 N = 4788641.74 m E = 644555.69 m
XYZ Coords. : X = 870505.90 m Y = -4571874.35 m Z = 4346729.16 m

Horizontal Datum : ITRF2008
Latitude : N43° 14' 12.2342"
Longitude : W 79° 13' 10.7935"
Ellipsoid Height : 43.84 m
Epoch : 2002.0
XYZ Coords. : X = 870505.27 m Y = -4571872.94 m Z = 4346729.08 m

VERTICAL DATA

None

STATION MARKER INFORMATION AND LOCATION

Marker Type : Self Centering Plate
Inspected in : 2002
Status : Good
Inspection Comments : None

PORT WELLER

THE GPS REFERENCE MARK CONSISTS OF A ALUMINUM PLATE WITH A FORCED CENTERING STAINLESS STEEL BOLT EMBEDDED ON TOP OF A 3.3 M HIGH, 15 CM DIAMETER ALUMINUM PILLAR, ANCHORED TO A 2.4 M SQUARE, 30.5 CM THICK CONCRETE PAD SUPPORTED BY A 6 M CONCRETE STILLING WELL LOCATED ON THE SHORE. THE CONCRETE PAD ALSO SUPPORTS A WATER LEVEL GAUGE.

HISTORICAL COORDINATES NOTE: Coordinates listed below are no longer maintained by GSD and should be verified with your provincial agency before use.

None



d.) Traverse Report

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*****
* GrafNet - GRAPHIC GPS NETWORK PROCESSING *
*          SOFTWARE PACKAGE                *
*                                          *
* TRAVERSE SOLUTION:                     *
*                                          *
* Copyright NovAtel Inc. (2012)          *
*                                          *
* Version: 8.40.3116                     *
*                                          *
* PROJECT: 1371_TRCA_Min                  *
*****

DATUM:  NAD83
GRID:   UTM, Zone 18
UNITS:  metres (see preferences to change)
GEOID:  C:\Programs\CommonFiles\WaypointGeoids\HT2_0-Canada.wpg

*****
STATIONS (STATUS):
*****

Station Type      HgtStatus      Result  Coordinates derived from...
61313   Check-3D   OK              Good    FWEL
653196  Check-V     OK              Good    FWEL
70106   Loop Tie   OK              Good    FWEL
A461    Loop Tie   OK              Good    FWEL
DVP1    Loop Tie   OK              Good    FWEL
FWEL     Control-3D OK              Pub (3D) (-)

*****
STATIONS (COORDINATES):
*****

Station      Latitude      Longitude      Grid-E      Grid-N      EllHgt      OrthoHgt
              (D M S)          (D M S)          (m)          (m)          (m)          (m)
61313      43 46 05.44821  -79 38 49.15651  125966.330  4856629.850  154.971  191.298
653196     43 35 30.99791 -79 36 11.54689  128401.973  4836856.638  92.612  129.001
70106      43 50 58.73944 -79 21 36.00794  149545.279  4864420.653  147.182  183.482
A461       43 51 56.75468 -79 22 19.63993  148665.832  4866262.246  160.516  196.803
DVP1       43 43 22.50663 -79 19 54.47523  151074.577  4850224.328  93.114  129.505
FWEL       43 14 12.20270 -79 13 10.77780  157366.337  4795753.939  44.990  81.029

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 LOOP, CHECK & DUPLICATE TIES:

Name/Session	Type	Result	DEast (m)	DNorth (m)	DHeight (m)
POINT 61313	CheckPnt	Good	0.0176	0.0033	-0.0090
FWEL to 61313 (2)	Duplicate	Good	0.0060	-0.0027	0.0025
POINT 653196	CheckPnt	Good	(-)	(-)	0.0192
61313 to 653196	LoopTie	Good	0.0039	0.0029	0.0069
61313 to 70106	LoopTie	Good	-0.0032	0.0058	-0.0101
FWEL to A461 (2)	Duplicate	Good	0.0179	0.0011	0.0140
61313 to A461	LoopTie	Good	0.0019	0.0027	0.0016
61313 to A461 (2)	Duplicate	Good	-0.0008	0.0066	0.0039
61313 to A461 (3)	Duplicate	Good	0.0017	0.0057	-0.0028
653196 to A461	LoopTie	Good	-0.0016	-0.0014	0.0012
70106 to A461	LoopTie	Good	0.0064	-0.0029	0.0135
70106 to A461 (2)	Duplicate	Good	0.0050	-0.0023	0.0102
61313 to DVP1 (2)	Duplicate	Good	-0.0186	0.0004	-0.0210
61313 to DVP1	LoopTie	Good	-0.0246	-0.0008	-0.0303
A461 to DVP1	LoopTie	Good	-0.0210	-0.0102	-0.0241
A461 to DVP1 (2)	Duplicate	Good	-0.0209	-0.0018	-0.0261
			-----	-----	-----
RMS (tie points)			0.0128	0.0043	0.0153
RMS (check points)			0.0176	0.0033	0.0150
			=====	=====	=====



e.) Minimally Constrained Network
Adjustment

```

*****
* NETWORK - WEIGHTED GPS NETWORK ADJUSTMENT *
* *
* (c) Copyright NovAtel Inc., (2012) *
* *
* Version: 8.40.3116 *
* *
* FILE: 1371_TRCA_Min.net *
*****

DATUM: 'NAD83'
SCALE_FACTOR: 1.7820
CONFIDENCE LEVEL: 95.00 % (Scale factor is 2.4479)

*****
INPUT CONTROL/CHECK POINTS
*****

STA_ID TYPE -- LATITUDE -- -- LONGITUDE -- ELLHGT - HZ-SD V-SD
61313 CHK-3D 43 46 05.44810 -79 38 49.15730 154.980
653196 CHK-VT 92.593
FWEL GCP-3D 43 14 12.20270 -79 13 10.77780 44.990 0.00780 0.02200

*****
INPUT VECTORS
*****

SESSION NAME VECTOR(m) ----- Covariance (m) [unscaled] -----
DX/DY/DZ standard deviations in brackets
61313 to 653196 (1) 5899.9070 1.6305e-006 (0.0013)
-12622.1895 -6.2485e-007 1.0666e-005 (0.0033)
-14204.3960 5.5516e-007 -7.7034e-006 1.1222e-005 (0.0033)

61313 to 70106 (1) 21563.2613 9.4853e-007 (0.0010)
10373.9215 -4.8477e-007 3.5105e-006 (0.0019)
6527.1545 3.3088e-007 -2.2883e-006 4.0508e-006 (0.0020)

61313 to A461 (1) 20378.3775 4.6817e-007 (0.0007)
11404.0171 -2.7716e-007 1.7590e-006 (0.0013)
7827.5300 1.8145e-007 -1.0173e-006 1.6674e-006 (0.0013)

61313 to A461 (2) 20378.3804 2.0396e-006 (0.0014)
11404.0165 -1.1537e-006 6.7005e-006 (0.0026)
7827.5256 6.8122e-007 -4.4908e-006 8.0053e-006 (0.0028)

61313 to A461 (3) 20378.3786 1.6663e-006 (0.0013)
11404.0119 -9.7277e-007 6.4285e-006 (0.0025)
7827.5309 7.2633e-007 -3.9346e-006 6.8187e-006 (0.0026)

61313 to DVP1 (1) 25588.5894 8.5275e-006 (0.0029)
1256.2375 -3.3785e-006 3.5769e-005 (0.0060)
-3675.7777 2.6813e-006 -3.4023e-005 7.4638e-005 (0.0086)

61313 to DVP1 (2) 25588.5824 2.5444e-006 (0.0016)
1256.2422 -1.7618e-006 1.1948e-005 (0.0035)
-3675.7851 1.1745e-006 -6.2965e-006 8.3704e-006 (0.0029)

```

15

653196 to A461 (1)	14478.4691	1.8813e-006 (0.0014)
	24026.2119	-4.8249e-007 7.9037e-006 (0.0028)
	22031.9225	3.4575e-007 -5.5227e-006 9.7780e-006 (0.0031)
70106 to A461 (1)	-1184.8853	3.3776e-007 (0.0006)
	1030.0964	-1.4380e-007 1.1662e-006 (0.0011)
	1300.3742	7.9291e-008 -8.5044e-007 1.5638e-006 (0.0013)
70106 to A461 (2)	-1184.8834	1.3954e-007 (0.0004)
	1030.0939	-7.3343e-008 6.5223e-007 (0.0008)
	1300.3761	4.7590e-008 -3.5351e-007 5.2632e-007 (0.0007)
A461 to DVP1 (1)	5210.2047	1.6241e-006 (0.0013)
	-10147.7704	-7.8193e-007 7.0738e-006 (0.0027)
	-11503.3084	4.7006e-007 -3.8137e-006 6.6316e-006 (0.0026)
A461 to DVP1 (2)	5210.2058	1.8159e-006 (0.0013)
	-10147.7775	-1.1845e-006 8.8201e-006 (0.0030)
	-11503.3130	7.3320e-007 -4.5556e-006 6.1506e-006 (0.0025)
FWEL to 61313 (1)	-41412.6193	7.9298e-006 (0.0028)
	33541.5757	-1.7669e-006 6.6749e-006 (0.0026)
	42905.1060	9.9258e-007 -2.9392e-006 3.4532e-006 (0.0019)
FWEL to 61313 (2)	-41412.6258	9.8913e-006 (0.0031)
	33541.5783	-5.1896e-007 8.7201e-006 (0.0030)
	42905.1063	1.2468e-007 -3.7502e-006 4.4343e-006 (0.0021)
FWEL to 653196 (1)	-35512.7078	3.2155e-005 (0.0057)
	20919.3840	-1.2498e-005 3.0183e-005 (0.0055)
	28700.7168	7.8919e-006 -1.1969e-005 1.2300e-005 (0.0035)
FWEL to 70106 (1)	-19849.3631	8.0724e-006 (0.0028)
	43915.5077	-1.7678e-006 5.6586e-006 (0.0024)
	49432.2576	1.1277e-006 -2.7121e-006 3.0567e-006 (0.0017)
FWEL to A461 (2)	-21034.2593	1.1359e-005 (0.0034)
	44945.5997	-2.3000e-006 5.9544e-006 (0.0024)
	50732.6286	1.3877e-006 -2.9885e-006 3.7897e-006 (0.0019)
FWEL to A461 (3)	-21034.2400	9.3600e-006 (0.0031)
	44945.5938	-8.1224e-007 6.3834e-006 (0.0025)
	50732.6392	8.9983e-007 -2.6795e-006 3.7985e-006 (0.0019)
FWEL to DVP1 (1)	-15824.0580	3.3434e-004 (0.0183)
	34797.8297	-9.8410e-005 8.6533e-005 (0.0093)
	39229.3068	4.6641e-005 -3.4247e-005 3.8428e-005 (0.0062)

 OUTPUT VECTOR RESIDUALS (East, North, Height - Local Level)

SESSION NAME	-- RE -- (m)	-- RN -- (m)	-- RH -- (m)	- PFM -	DIST - (km)	STD - (m)
61313 to 653196 (1)	0.0003	-0.0004	0.0051	0.257	19.9	0.0065
61313 to 70106 (1)	0.0005	-0.0001	-0.0010	0.046	24.8	0.0039
61313 to A461 (1)	0.0002	-0.0009	-0.0003	0.039	24.6	0.0026
61313 to A461 (2)	-0.0025	0.0030	0.0019	0.179	24.6	0.0055
61313 to A461 (3)	0.0000	0.0022	-0.0048	0.214	24.6	0.0052
61313 to DVP1 (1)	-0.0051	0.0002	-0.0086	0.388	25.9	0.0146
61313 to DVP1 (2)	0.0009	0.0014	0.0007	0.070	25.9	0.0064
653196 to A461 (1)	0.0003	-0.0017	0.0011	0.057	35.7	0.0059
70106 to A461 (1)	0.0010	-0.0006	0.0024	1.323	2.0	0.0023
70106 to A461 (2)	-0.0004	-0.0000	-0.0009	0.488	2.0	0.0015
A461 to DVP1 (1)	0.0001	-0.0056	-0.0005	0.347	16.2	0.0052
A461 to DVP1 (2)	0.0003	0.0027	-0.0024	0.227	16.2	0.0055
FWEL to 61313 (1)	-0.0038	0.0027	-0.0042	0.092	68.4	0.0057
FWEL to 61313 (2)	0.0022	-0.0000	-0.0017	0.040	68.4	0.0064
FWEL to 653196 (1)	-0.0074	-0.0005	-0.0060	0.190	50.2	0.0115
FWEL to 70106 (1)	-0.0002	-0.0030	0.0049	0.084	69.0	0.0055
FWEL to A461 (2)	0.0124	0.0004	0.0078	0.207	71.0	0.0061
FWEL to A461 (3)	-0.0055	-0.0008	-0.0062	0.117	71.0	0.0059
FWEL to DVP1 (1)	0.0157	0.0038	0.0174	0.434	54.8	0.0286

RMS	0.0053	0.0022	0.0058			

\$ - This session is flagged as a 3-sigma outlier

 CHECK POINT RESIDUALS (East, North, Height - Local Level)

STA. NAME	-- RE -- (m)	-- RN -- (m)	-- RH -- (m)
61313	0.0138	0.0060	-0.0132
653196			0.0132

RMS	0.0138	0.0060	0.0132

 CONTROL POINT RESIDUALS (ADJUSTMENT MADE)

STA. NAME	-- RE -- (m)	-- RN -- (m)	-- RH -- (m)
FWEL	-0.0000	-0.0000	0.0000

RMS	0.0000	0.0000	0.0000

 OUTPUT STATION COORDINATES (LAT/LONG/HT)

STA_ID	-- LATITUDE --	-- LONGITUDE --	- ELLHGT -
61313	43 46 05.44829	-79 38 49.15668	154.9668
653196	43 35 30.99789	-79 36 11.54722	92.6062
70106	43 50 58.73934	-79 21 36.00795	147.1868
A461	43 51 56.75466	-79 22 19.64018	160.5100
DVP1	43 43 22.50675	-79 19 54.47453	93.1314
FWEL	43 14 12.20270	-79 13 10.77780	44.9900

 OUTPUT VARIANCE/COVARIANCE

STA_ID	SE/SN/SUP	2 ----- CK matrix (m)----- (95.00 %) (not scaled by confidence level) (m) (ECEF, XYZ cartesian)		
61313	0.0195	7.1855e-005		
	0.0192	-4.1864e-005	2.8026e-004	
	0.0541	3.9859e-005	-2.0872e-004	2.6105e-004
653196	0.0197	7.3102e-005		
	0.0195	-4.2365e-005	2.8583e-004	
	0.0545	4.0302e-005	-2.1209e-004	2.6616e-004
70106	0.0195	7.1882e-005		
	0.0192	-4.1883e-005	2.8022e-004	
	0.0541	3.9893e-005	-2.0872e-004	2.6106e-004
A461	0.0195	7.1818e-005		
	0.0192	-4.1845e-005	2.7996e-004	
	0.0540	3.9869e-005	-2.0857e-004	2.6084e-004
DVP1	0.0197	7.2801e-005		
	0.0195	-4.2412e-005	2.8419e-004	
	0.0544	4.0218e-005	-2.1079e-004	2.6420e-004
FWEL	0.0191	6.8698e-005		
	0.0191	-4.1268e-005	2.7758e-004	
	0.0539	3.9500e-005	-2.0745e-004	2.5941e-004

 VARIANCE FACTOR = 0.9989

Note: Values < 1.0 indicate statistics are pessimistic, while
 values > 1.0 indicate optimistic statistics. Entering this
 value as the network adjustment scale factor will bring
 variance factor to one.



f.) Fully Constrained Network
Adjustment

```

*****
* NETWORK - WEIGHTED GPS NETWORK ADJUSTMENT *
* *
* (c) Copyright NovAtel Inc., (2012) *
* *
* Version: 8.40.3116 *
* *
* FILE: 1371_TRCA_FULL.net *
*****

DATUM: 'NAD83'
SCALE_FACTOR: 2.0042
CONFIDENCE LEVEL: 95.00 % (Scale factor is 2.4479)

*****
INPUT CONTROL/CHECK POINTS
*****

STA_ID TYPE -- LATITUDE -- -- LONGITUDE -- ELLHGT - HZ-SD V-SD
61313 GCP-3D 43 46 05.44810 -79 38 49.15730 154.980 0.00280 0.01300
653196 GCP-VT 92.593 0.02000
FWEL GCP-3D 43 14 12.20270 -79 13 10.77780 44.990 0.00780 0.02200

*****
INPUT VECTORS
*****

SESSION NAME VECTOR(m) ----- Covariance (m) [unscaled] -----
DX/DY/DZ standard deviations in brackets
61313 to 653196 (1) 5899.9070 1.6305e-006 (0.0013)
-12622.1895 -6.2485e-007 1.0666e-005 (0.0033)
-14204.3960 5.5516e-007 -7.7054e-006 1.1222e-005 (0.0033)

61313 to 70106 (1) 21563.2613 9.4853e-007 (0.0010)
10373.9215 -4.8477e-007 3.5105e-006 (0.0019)
6527.1545 3.3088e-007 -2.2883e-006 4.0508e-006 (0.0020)

61313 to A461 (1) 20378.3775 4.6817e-007 (0.0007)
11404.0171 -2.7716e-007 1.7590e-006 (0.0013)
7827.5300 1.8145e-007 -1.0173e-006 1.6674e-006 (0.0013)

61313 to A461 (2) 20378.3804 2.0396e-006 (0.0014)
11404.0165 -1.1537e-006 6.7005e-006 (0.0026)
7827.5256 6.8122e-007 -4.4908e-006 8.0053e-006 (0.0028)

61313 to A461 (3) 20378.3786 1.6663e-006 (0.0013)
11404.0119 -9.7277e-007 6.4285e-006 (0.0025)
7827.5309 7.2633e-007 -3.9346e-006 6.8187e-006 (0.0026)

61313 to DVP1 (1) 25588.5894 8.5275e-006 (0.0029)
1256.2375 -3.3785e-006 3.5769e-005 (0.0060)
-3675.7777 2.6813e-006 -3.4023e-005 7.4638e-005 (0.0086)

61313 to DVP1 (2) 25588.5824 2.5444e-006 (0.0016)
1256.2422 -1.7618e-006 1.1948e-005 (0.0035)
-3675.7851 1.1745e-006 -6.2965e-006 8.3704e-006 (0.0029)

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653196 to A461 (1)	14478.4691	1.8813e-006 (0.0014)
	24026.2119	-4.8249e-007 7.9037e-006 (0.0028)
	22031.9225	3.4575e-007 -5.5227e-006 9.7780e-006 (0.0031)
70106 to A461 (1)	-1184.8853	3.3776e-007 (0.0006)
	1030.0964	-1.4380e-007 1.1662e-006 (0.0011)
	1300.3742	7.9291e-008 -8.5044e-007 1.5638e-006 (0.0013)
70106 to A461 (2)	-1184.8834	1.3954e-007 (0.0004)
	1030.0939	-7.3343e-008 6.5223e-007 (0.0008)
	1300.3761	4.7590e-008 -3.5351e-007 5.2632e-007 (0.0007)
A461 to DVP1 (1)	5210.2047	1.6241e-006 (0.0013)
	-10147.7704	-7.8193e-007 7.0738e-006 (0.0027)
	-11503.3084	4.7006e-007 -3.8137e-006 6.6316e-006 (0.0026)
A461 to DVP1 (2)	5210.2058	1.8159e-006 (0.0013)
	-10147.7775	-1.1845e-006 8.8201e-006 (0.0030)
	-11503.3130	7.3320e-007 -4.5556e-006 6.1506e-006 (0.0025)
FWEL to 61313 (1)	-41412.6193	7.9298e-006 (0.0028)
	33541.5757	-1.7669e-006 6.6749e-006 (0.0026)
	42905.1060	9.9258e-007 -2.9392e-006 3.4532e-006 (0.0019)
FWEL to 61313 (2)	-41412.6258	9.8913e-006 (0.0031)
	33541.5783	-5.1896e-007 8.7201e-006 (0.0030)
	42905.1063	1.2468e-007 -3.7502e-006 4.4343e-006 (0.0021)
FWEL to 653196 (1)	-35512.7078	3.2155e-005 (0.0057)
	20919.3840	-1.2498e-005 3.0183e-005 (0.0055)
	28700.7168	7.8919e-006 -1.1969e-005 1.2300e-005 (0.0035)
FWEL to 70106 (1)	-19849.3631	8.0724e-006 (0.0028)
	43915.5077	-1.7678e-006 5.6586e-006 (0.0024)
	49432.2576	1.1277e-006 -2.7121e-006 3.0567e-006 (0.0017)
FWEL to A461 (2)	-21034.2593	1.1359e-005 (0.0034)
	44945.5997	-2.3000e-006 5.9544e-006 (0.0024)
	50732.6286	1.3877e-006 -2.9885e-006 3.7897e-006 (0.0019)
FWEL to A461 (3)	-21034.2400	9.3600e-006 (0.0031)
	44945.5938	-8.1224e-007 6.3834e-006 (0.0025)
	50732.6392	8.9983e-007 -2.6795e-006 3.7985e-006 (0.0019)
FWEL to DVP1 (1)	-15824.0580	3.3434e-004 (0.0183)
	34797.8297	-9.8410e-005 8.6533e-005 (0.0093)
	39229.3068	4.6641e-005 -3.4247e-005 3.8428e-005 (0.0062)

 OUTPUT VECTOR RESIDUALS (East, North, Height - Local Level)

SESSION NAME	-- RE -- (m)	-- RN -- (m)	-- RH -- (m)	- PPM -	DIST - (km)	STD - (m)
61313 to 653196 (1)	0.0004	-0.0004	0.0045	0.228	19.9	0.0069
61313 to 70106 (1)	0.0005	-0.0000	-0.0011	0.049	24.8	0.0041
61313 to A461 (1)	0.0002	-0.0008	-0.0004	0.039	24.6	0.0028
61313 to A461 (2)	-0.0025	0.0031	0.0019	0.178	24.6	0.0058
61313 to A461 (3)	0.0001	0.0022	-0.0049	0.217	24.6	0.0055
61313 to DVP1 (1)	-0.0051	0.0002	-0.0087	0.389	25.9	0.0154
61313 to DVP1 (2)	0.0009	0.0015	0.0006	0.070	25.9	0.0068
653196 to A461 (1)	0.0002	-0.0017	0.0016	0.065	35.7	0.0063
70106 to A461 (1)	0.0010	-0.0006	0.0024	1.321	2.0	0.0025
70106 to A461 (2)	-0.0004	-0.0000	-0.0009	0.489	2.0	0.0016
A461 to DVP1 (1)	0.0001	-0.0056	-0.0005	0.348	16.2	0.0055
A461 to DVP1 (2)	0.0003	0.0027	-0.0024	0.226	16.2	0.0058
FWEL to 61313 (1)	-0.0044	0.0027	-0.0042	0.097	68.4	0.0060
FWEL to 61313 (2)	0.0016	-0.0000	-0.0016	0.033	68.4	0.0068
FWEL to 653196 (1)	-0.0080	-0.0005	-0.0066	0.206	50.2	0.0122
FWEL to 70106 (1)	-0.0007	-0.0030	0.0049	0.084	69.0	0.0058
FWEL to A461 (2)	0.0118	0.0004	0.0078	0.200	71.0	0.0065
FWEL to A461 (3)	-0.0061	-0.0008	-0.0062	0.123	71.0	0.0063
FWEL to DVP1 (1)	0.0151	0.0038	0.0174	0.427	54.8	0.0303

RMS	0.0053	0.0022	0.0058			

\$ - This session is flagged as a 3-sigma outlier

 CONTROL POINT RESIDUALS (ADJUSTMENT MADE)

STA. NAME	-- RE -- (m)	-- RN -- (m)	-- RH -- (m)
61313	0.0015	0.0007	-0.0088
653196			0.0170
FWEL	-0.0117	-0.0052	0.0044

RMS	0.0084	0.0037	0.0114

 OUTPUT STATION COORDINATES (LAT/LONG/HT)

STA_ID	-- LATITUDE --	-- LONGITUDE --	- ELLHGT -
61313	43 46 05.44812	-79 38 49.15723	154.9712
653196	43 35 30.99772	-79 36 11.54776	92.6101
70106	43 50 58.73917	-79 21 36.00850	147.1911
A461	43 51 56.75449	-79 22 19.64073	160.5143
DVP1	43 43 22.50658	-79 19 54.47507	93.1357
FWEL	43 14 12.20253	-79 13 10.77832	44.9944