COBRN

An Abstract of the Development and Implementation of the City of Bellevue Reference Network

Project Objective:

A primary purpose of the City of Bellevue Land Survey Division is to locate, preserve, maintain and report existing survey monuments within the City and surrounding vicinity, and then correlate these monument positions within a local network. This network is further to be:

- referenced to NAD83 (2011) / Washington Coordinate System;
- monitored regularly for control point integrity (quality control), and;
- adjusted as necessary and migrated to GIS.

This document describes the progression of how this objective has been accomplished through the development of **BELNET** as referenced to the NGS HARN control (a Passive/Static framework), and now transitioning to **COBRN** being referenced to NGS CORS control (an Active/Real time framework). **COBRN** *(pronounced cōe-brin)* is the acronym for the *City of Bellevue Reference Network* which represents our current network.

Background:

Historically, the survey monuments controlling the Public Land Survey System (PLSS) in this area of King County have been referenced to the predecessor of the NGS, the USC&GS (1927) datum. This Federal network was extended by a local survey defined as King County Aerial Survey (KCAS), circa 1930's. The KCAS network, datum and its ground control were the survey basis of all land development and platting in Bellevue. The 1927 datum was later adjusted to the earth centered ellipsoid of NAD83/86 and again to NAD83 (1991) with the advancement of GPS technology.

In the early 1990's, the Survey Division embarked on a comprehensive program to replace the KCAS basis within the City. The PLSS monuments were occupied and measured resulting in current values being referenced to the NAD83 (1991) system. This was the origin of **BELNET** and remained the primary network for 25 years.

The Survey Division recognized in 2016 the undertaking of the NGS to replace their fixed static network (HARN) with a Continuously Operating Reference System (CORS) framework. The NGS is no longer going to maintain, occupy, or measure their control mark infrastructure thereby abandoning the Passive/Static model. In turn their control network in the future will only include marks occupied by CORS GPS receivers which are constantly acquiring, monitoring and broadcasting data. The data and mark information is published through the NGS web site. By definition, this is an Active/Real Time model.

Contrary to the NGS priority, the Survey Division determined that to best serve the primary objective mentioned above, we must continue to maintain a passive/static network model. That is, the City remains committed to protecting and maintaining the physical positions of survey monuments. Therefore, after evaluating the usefulness and benefits of transitioning to a real-time framework, we made the decision in 2017 to develop a hybrid datum. This datum solution would apply CORS values to our primary control file, but then in turn fix these values within the network adjustment. The significant advantage of adopting a CORS reference system is the ability to efficiently monitor control point movement and integrity, thereby allowing us to quickly respond to changes as necessary. This is the origin of **COBRN**.

Design:

BELNET: This network established three (3) primary control base stations around the city, i.e. *CITY, FIRE & SUMM*. Each of these base stations are occupied by survey grade GPS receivers and antenna which continuously stream and store data on our secure servers. The base stations were positioned by post processing GPS baselines to seven (7) nearby passive NGS HARN control stations [1.]. The baselines connecting the NGS HARN to our three base stations were remeasured only at times of either (a) antenna equipment change, or (b) NGS readjustment. This results in coordinate positions of our primary control being fixed and held for several years without monitoring any movement of the HARN stations. All measurement data (GPS vectors & ground traverse) of the subsequent localized projects were then tied directly or indirectly to three base stations.

[1.] *AVI2, HAFF, MEAD, MERC, OVER, PT_B & FUNK*

COBRN: This design required selecting five (5) CORS stations [2.] well beyond our local jurisdictional boundaries to capture a broader sampling of atmospheric conditions which mitigates network accuracy. Also included were five (5) CORS [3.] stations localized to Bellevue for the purpose of correlating corrections propagated by the Washington State Reference Network (WSRN). NGS Advisor Mark Armstrong provided valuable guidance in selection criteria of CORS marks, training in OPUS Projects baseline processing and adjustment together with review our test environment data results.

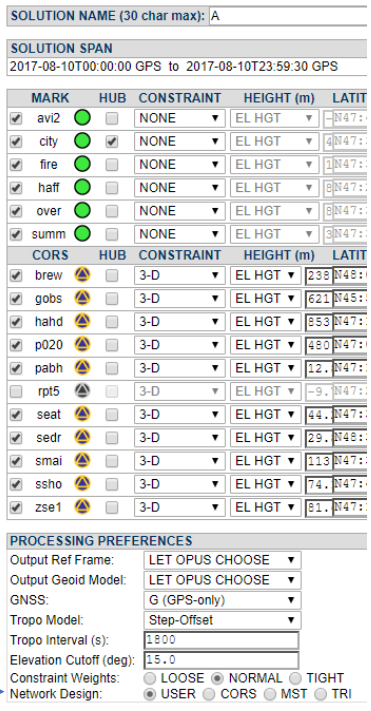
[2.] *BREW, GOBS, PABH, P020 & SEDR*

[3.] *HAHD, SEAT, SMAI, SSHO & ZSE1*

Implementation:

Our trial testing included measurement sessions and OPUS processing in December 2016, February 2017 and August 2017. We found that reliable positioning and baseline processing between the three base stations could be achieved by acquiring satellite data over three separate 24 hour sessions. As well, in order to preserve all of the historic GPS vectors connecting the network to the HARN stations, it was necessary to occupy each station for two separate 6 hour sessions. These HARN sessions were scheduled to coincide with the base station sessions. It should be noted here that station FUNK was no longer accessible and therefore not used in this trial.

The data was processed in OPUS Projects by holding all 10 CORS marks as "Constrained - 3D" and processing the 3 base stations and the collected HARN sessions as "Constrained – None". In each of the sessions being processed, one of the base stations was toggled as a "HUB" following a USER Network Design. The sessions were then adjusted in OPUS Projects as "Fully Constrained" and a report generated providing station results and uncertainties.



The final results supported our presumption there was indeed a shift in the NGS HARN positions from their published values. Armstrong advised this control had not been occupied and measured in over twenty years and movement was to be expected. We found the shift to be consistently South 0.03' and West 0.10' of the published values.

The last step was replacing the StarNet input file *Primary Control (NAD83 2011).dat* which contains the former fixed **BELNET** values of published HARN and base stations, with the *Primary Control CORS_date.dat* file which contains the new **COBRN** values from OPUS. Again, these new OPUS values remain fixed in the StarNet adjustment.

```
# MicroSurvey STAR*NET-PRO Version 7.1.0.5

.Units  Meters
.Sep    -
.3D

# HORIZONTAL DATUM:  NAD83(2011) - EPOCH 2010.00
# BASE STATION DATA DERIVED BY OPUS-PROJECTS ADJUSTMENT REPORT 9-21-2017

PH  CITY     47-36-51.07446  122-11-29.27092   46.144   ! ! !
PH  FIRE     47-37-02.70318  122-07-31.73351  122.050   ! ! !
PH  SUMM     47-33-15.26143  122-07-56.21939  336.653   ! ! !


# HARN STATION DATA DERIVED BY OPUS-PROJECTS ADJUSTMENT REPORT 9-21-2017

PH  AVI2     47-41-08.45240  122-14-56.79474 -15.983 ! ! !
PH  HAFF     47-29-05.28395  122-10-34.36054  80.883 ! ! !
PH  MEAD     47-31-10.05470  121-48-00.45018 108.356 ! ! !
PH  MERC     47-37-38.02138  122-13-09.72057  62.535 ! ! !
PH  OVER     47-38-09.93954  122-08-30.58114  89.030 ! ! !
PH  PT_B     47-34-16.91240  122-16-38.09458 -17.098 ! ! !

# POINT FUNK HAS BEEN DESTROYED OR NO LONGER ACCESSIBLE.
#PH FUNK     47-44-17.85066  121-59-08.54612  13.715 ! ! !

```

The StarNet results report confirmed that network strength and point integrity had been maintained through the control file transition. The Chi-Square Test, Residuals and Error Propagation at 95% confidence were all consistent between the **BELNET** adjustment and **COBRN** in StarNet. As a back test, we also compared the coordinate values of over 3100 network points in MS Excel between a recent **BELNET** adjustment and the current **COBRN** adjustment. This yielded similar deltas (South 0.01' and West 0.10') as those reported in the OPUS report with no apparent outliers. This concluded our test environment and we adopted the August 2017 OPUS values as our fixed control for future StarNet adjusted localized projects.

MONITORING:

As stated earlier, although the **COBRN** network remains a fixed passive/static framework, its significant feature is that integrity of the control point file can be monitored very easily. Rather than waiting several years between occupied measurables, we now have the capacity to view NGS CORS station condition and values online, download data to process with our base stations or simply check real-time data with any point in our network.

Moving forward, our intended plan is to regularly monitor the project control on a scheduled annual basis, probably in August. With anticipated clear visibility and favorable atmospheric conditions, we expect reliable results in the summer months. The monitoring workflow will include timed sessions consistent with the August 2017 project and OPUS Projects processing and adjustment. Based on the OPUS results report, we can determine if the fixed values in the StarNet control file will need to be modified.

Prepared, February 2018

The survey staff participating in the **COBRN** project:

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Together with Mark Armstrong, PLS and Lynn Call, PLS (former Survey Division Mgr.), we also appreciate the advice and contribution received from Gavin Schrock, PLS and Larry Signani, PLS.