Development of a CORS Network for the Turks and Caicos Islands (12451)

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1.0 Summary

Realizing an accurate, homogenous, reliable geodetic reference system for the Turks and Caicos Islands (TCI) is critical to the integrity of the geospatial information and land administration. This research aims to promote the adoption of uniform procedures for designing, installing, and operating Continuously Operating Reference Stations (CORS).

The delivery of a CORS Network is a paradigm shift from traditional passive ground survey control monuments (Directorate of Overseas Surveys) and the Autonomous Active Stations to a method that combines these marks with active CORS based on Global Navigation Satellite System (GNSS) technology. CORS will form an integral component of the nation's geospatial infrastructure in a geodetic context.

The primary purpose of geodetic CORS is to provide a reference frame and datum that can be defined, improved, and maintained for surveying, mapping, geoscience, and spatial datasets. This framework is significant as it is a reference for applications such as infrastructure development, asset management, resource and emergency management, automated machine control, intelligent transport systems, precision agriculture, environmental management, enforcement of planning guidelines, climate action, and research.

The completed research should outline TCI's recommended procedures for designing, installing, and operating CORS sites within the proposed Turks and Caicos Islands CORS Network framework. The proposed CORS should provide collocated stations between the national geodetic datum and the International Terrestrial Reference Framework (ITRF). The data from this CORS network should be available to the relevant national, regional, or international jurisdiction for national geodetic reference frame realization and improvement.

1.1 Background

The Turks and Caicos Islands are a group of islands in the North Atlantic Ocean and approximately 180 km north of the Dominican Republic. The territory has a total area of 950 km² (367 mi²) and a total coastline of 389 km (241.7 mi). The Turks and Caicos Islands are thus the 21st smallest country in the Americas, ranked 189th globally. The territory comprises six main islands (North Caicos, South Caicos, Middle Caicos, West Caicos, Providenciales and Grand Turk) and two Cays (Salt Cay & Ambergris Cay).

The previous realization of a spatial reference framework comprised active and passive systems. The active system was realized through three autonomous base stations in Providenciales (owned by UNAVCO), Grand Turk, and North Caicos, owned by TCIG. The geodetic receivers in Grand Turk and North Caicos were obsolete and non-functional. The passive network is accounted for by an infrastructure of monuments in all islands and cays referenced to the Directorate of Overseas Surveys (DOS). The passive network has lacked a time-series update since immemorial and is, therefore, fraught with errors. A consultant performed a transformation in 2007 to facilitate introducing a new system of reference. This new system was created from a plane rather than a geodetic survey.

The system created by the consultants in 2007 needed to address homogeneity, curvature or the projection to DOS planimetric coordinates. Instead, a coordinate transformation portal was created to transform coordinates from the 2007 system to DOS and vice versa. It is unknown if this portal operates on Block Shift, Molondensky, or Bursa Wolfe's mathematical models. Summarily, the TCI operates three systems of reference at once, none of which is up to date, precise or accurate enough to premise survey, albeit a general boundary system of registration in place.

The need for more clarity in applying Universal Transverse Mercator (UTM) Zones poses another threat where Middle Caicos features two UTM zones. The realities at work have compromised the integrity of the cadastre by introducing boundary errors and inaccuracies in the survey, which have translated to liability, unreliability in land information disseminated to stakeholders, lack of stakeholder confidence, delays in conveyance, inefficiencies in land administration and a lack of technical support for the other government ministries and departments.

The acquiesced perspective is the glaring need for a homogenous reference system, preferably realized from the International Terrestrial Reference Framework (ITRF) built to the standards of the National Geodetic Society (NGS) for Constantly Operating Reference Stations (CORS). This standard will facilitate annual time-series updates and international accreditation.

2.0 Introduction

According to Singh and Kumar (2019), the derivative solution from measurements gathered from a network of Continuously Operating Reference Stations (CORS) can achieve higher accuracy. The rationale is that the accuracy of the single reference station operating in autonomous mode with the Real Time Kinematic (RTK) positioning technique is significantly affected by an error budget, including satellite orbital errors and atmospheric biases. These errors are considered distant dependent and will propagate accordingly. A network-based (RTK) solution derived from a CORS network is considered superior. The undergirding condition is that CORS Network models and subsequently correct distance-dependent errors and biases. The corrections are then delivered to the user segment using the internet at a centimetre level of positional accuracy.

The Turks and Caicos Islands CORS Network was conceptualized to support Land Administration and Registration. There is a need to premise all geospatial measurements on homogenous reference projects to harmonize spatial reference in the Cadastre and on the ground. Essentially, the ambition of harmonization between de jure and de facto was seen as the catalyst to reduce boundary disputes and the duration of the plan checking/ certification process and propel the lofty ambition of developing a Multi-Purpose Cadastre. The improved accuracy was seen as a game-changing element to standardize geospatial work and compilation of the Cadastre. The engagement of stakeholders over the project cycle has expanded the parentheses of value-added services that can be enhanced from the CORS Network.

According to Kun and Yong (2007), a CORS Network can adequately support the ambition of developing a Smart City as it can offer a real-time dynamic framework for geodetic control for the entire country and the region. With the agenda of disaster monitoring, prediction, prevention and response, a CORS Network can deliver positional accuracy and the real-time capability of making measurements. Geospatial information can be leveraged as a valuable resource in climate change adaptation and resilience strategy development, such as coastal monitoring, geotechnical analysis, sea level rise and physical planning outcomes. Immediately, a CORS Network can advance weather forecasting, emergency services, transportation, logistics, infrastructure management, utility management, agriculture and national security in the Turks and Caicos Islands.

3.0 Design of CORS Network

The Active Geodetic Network of the Turks and Caicos Islands incorporated seven active geodetic stations distributed across the islands. The hardware installed at the geodetic sites are the Trimble NETR9 Alloy GNSS Receiver and a Trimble Zephyr 3 Geodetic Antenna. The geodetic sites are as follows:

- ✓ Louise Garland-Thomas High School – Providenciales
- ✓ Gustavus Lightbourne Sports Complex – Providenciales
- ✓ Cecelia Gray-Gardiner Primary Health Clinic – North Caicos
- ✓ Alsada Hall-Malcolm Health Care Clinic – Middle Caicos
- ✓ Bambara Community Center – Middle Caicos
- ✓ District Commissioner’s Office – South Caicos
- ✓ Survey and Mapping Department – Grand Turk

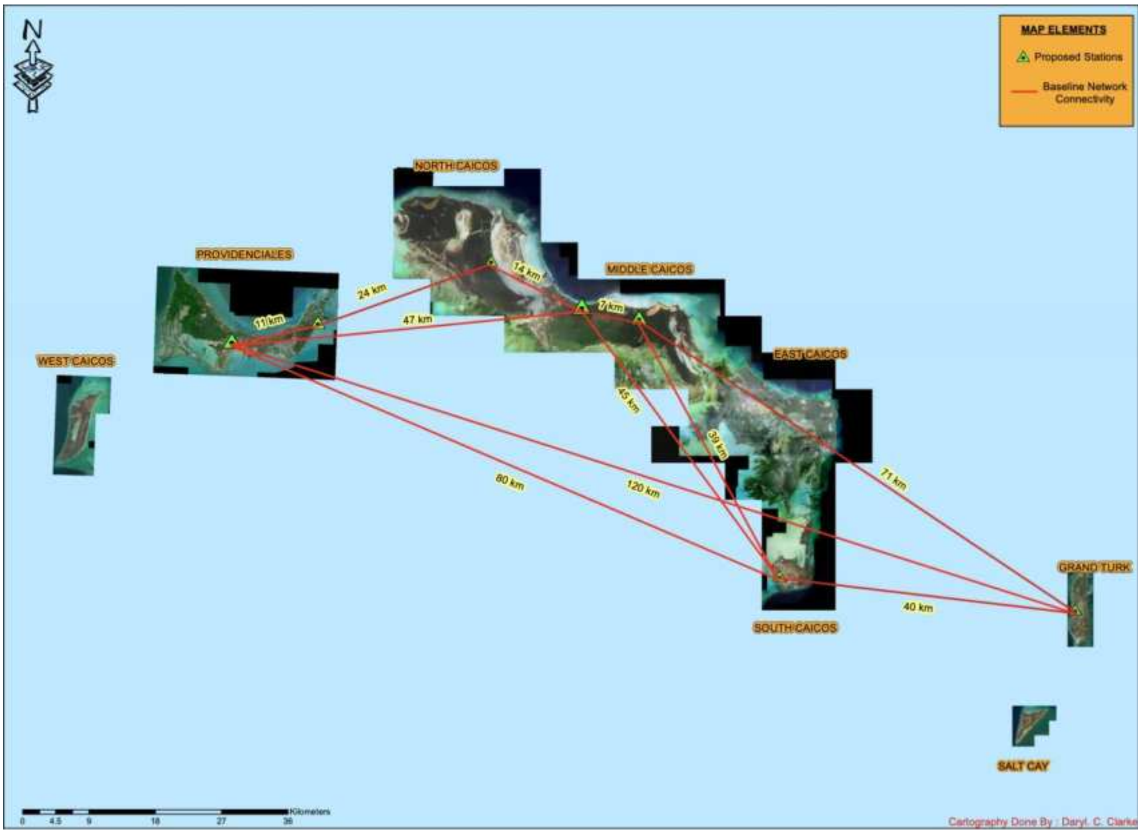

Figure 1.0 – Location of Geodetic Stations

According to NOAA (2006), geodetic sites are typically not perfect. However, it is prudent to design the network to avert degradation in the data quality. The islands' geographical location represents a fixed condition of nature; therefore, guidelines were adopted to facilitate the delivery of high-quality data from the geodetic equipment at each location. Certain items were factored in the design rubric of the network to deliver the optimal location of sites and optimal performance. These factors are:

- ✓ Proprietorship and Access to Sites
- ✓ Site Location & Structural Integrity of Buildings
- ✓ Satellite Visibility
- ✓ Data Quality & Degradation Factors
- ✓ Security & Safety
- ✓ Availability of Power and Communication Links System
- ✓ System Redundancy
- ✓ Network Density

3.1 Proprietorship of Sites

The Estate Department, through various stakeholder engagement sessions, expressed that potential sites would preferably be state-owned structures. The justifications for this preference include the tenure over which the site can be used in that the usage of the site will not be affected by the tenure of a lease agreement or the associated conditions. Retrofitting will become necessary to facilitate the geodetic and data infrastructure required at these sites, and this scope of work will need clearance from the proprietor. It may require renegotiated terms, which could be a protracted process.

Using a state-owned facility required clearance from the Estate Department, and the retrofitting elements required clearance from the Public Works Department. These clearances were easily attainable, which enabled an expeditious installation phase of the project. The facilities owned and operated by the Government of the Turks and Caicos Islands will allow easy access to facilitate maintenance and periodic inspection of the geodetic equipment. The maintenance plan for the CORS Network requires that all equipment be inspected every six months. A disaster management protocol also requires 24-hour access to the site and the provision of the contact details of the persons required to provide this access.

3.2 Site Location and Structural Integrity of Buildings

The initial conceptual design consideration was to install one Constantly Operating Reference Station (CORS) on each island to maximize the coverage of the territory. West Caicos was removed from the initial design due to a lack of internet. East Caicos is uninhabited, and Salt Cay is located within the operating radius of the Grand Turk CORS and has internet availability issues. This situation required that Providenciales and Middle Caicos would accommodate the additional CORS. These stations were to be spaced to maximize coverage of the entire territory.

The associated factor of having located suitable state-owned buildings that can facilitate complete coverage of the territory is the determination of the structural integrity of the buildings. Antennas required side mounting brackets to be fitted to load-bearing walls that offer "visibility" over all obstacles. Buildings slated for repair were removed from consideration to avoid removal of the equipment after the realization of the network. The Public Works Department was the partner responsible for providing structural clearance for buildings chosen in the initial list of potential sites. No geotechnical or geological parameters were considered, as no ground-based monuments were featured.

3.3 Site Visibility

Visibility sketches were prepared for each potential site to assess the site visibility based on a mask angle of 10°. According to NOAA (2006), the assessment should include potential obstructions and the likelihood of change in the antenna's surroundings. This principle led to the evaluation of the Development Order to assess future construction, site inspections to assess projected growth of trees, building expansions, and reflectors such as solar panels within a 30m radius of a potential site.

During this process, the mounting heights of antennas were determined from the minimal obstacle zone. The height was increased to ensure obstacles remained at 0° - 10° , the defined minimum obstacle zone. This iterative process aimed to maximize the obstruction-free zone to increase the possibility of receiving the greatest signal volume unaffected by multipath to the antenna. The rule of thumb is that the greater the volume and quality of the received signals, the more robust the positional most probable value will be.

3.4 Data Quality and Degradation Factors

Two Trimble R12i GNSS Receivers were used in the Static Survey Technique to collect data at each site. The number of satellites, Position Dilution of Precision (PDOP), and Geometric Dilution of Precision (GDOP) values were examined to assess each site's signal strength and quality. In addition to signal strength and quality, the sources of signal interference were considered in selecting sites. Sites within 30 meters of radio stations, cellular transmission infrastructure, RADAR and high-voltage sites were considered less than ideal. This type of interference can result in noise and loss of lock and can render sites inoperable. These sources of interference were noted in the inspection reports, so the final sites were not chosen close to these elements.

3.5 Safety and Security

The costs associated with procuring equipment and implementing the CORS Network represented a significant capital expenditure by the Turks and Caicos Islands Government (TCIG). This reality required that sites offer additional protection from theft, vandalism and misuse. Sites chosen were fenced with security personnel and surveillance capabilities. The geodetic receiver, modem, and backup battery were all placed in ventilated storage racks with keyed access. These storage racks were located out of the regular functions of the building in which they were housed, typically with other data infrastructure with notification stickers of warning and contact details for the Survey and Mapping Department.

Another element was a disaster management protocol for each station whereby hazards such as hurricanes or fire were considered. Fire extinguishers were located within three meters of each storage rack, and areas with concrete slab roofing were selected wherever possible.

3.6 Availability of Power and Communication Links

A primary requirement at each CORS is a power supply. This condition was created from an alternating current supply from the state network, a standby generator with an automatic transfer switch (Existing at the Location) and an uninterruptible power supply (UPS) with at least 24 operating hours. The operational capacity of the system to serve the user segment, in addition to being monitored for quality control and management, will depend on the availability of the Public Static Internet Protocol (IP) Address at each station and the server.

All geodetic stations were uniquely named based on location to facilitate data retrieval and monitoring. The data transfer process will be achieved using Internet File Transfer Protocol

(FTP). The receivers store data in the Receiver Independent Exchange (RINEX) file format with the associated GNSS time (UTC), Julian Day, and the base directory associated with the location. This data will be retrievable hourly. The server will facilitate access to the stored data by officers of the Survey and Mapping Department, who will be assigned the administrative privilege. This data will be saved in the American Standard Code for Information Interchange (ASCII) Format.

The server will also facilitate remote access through the LogMeIn Application, which operates through a Virtual Private Network (VPN) tunnel. Janssen et al. (2011) articulated that this tunnel allows secure and direct access to CORS receivers through a firewall. The Digitization E-Government Technology and Innovation (DETI) Department has provided the firewalls for the server. This remote access will be needed for maintenance, such as installing firmware updates. The Trimble Pivot Platform will facilitate all the operations of the network.

3.7 Network Density

The economic reality of the Survey and Mapping Department was a significant determinant in the network's density, as the funding available could accommodate a network of seven base stations and a control center. The land area to be covered and the proposed user segment were also factors considered. The user needs assessment conducted by the Survey and Mapping Department through various stakeholder engagement sessions indicated that an accurate realization of a homogenous datum was required in addition to real-time positioning services.

According to Haasdyk et al. (2011), the real-time requirement necessitated a mechanism for integrity monitoring, redundancy, reliability and service continuity. Singh and Kumar (2019) articulated that current network RTK software typically requires a maximum inter-CORS distance of 70 Km. Wang et al. (2010) stated the consequences of exceeding the 70 – 90 Km inter-CORS distance. The maximum distance between stations is 120 km, and the shortest is 7 km. However, the maximum baseline linking islands is 40 Km. In the event of consecutive stations being inoperable, the stations at the extremities of the network would exceed the postulate of Wang et al. (2010).

Feng and Li (2008) predicted that the use of GNSS, which will feature modernization and new constellations, should deliver 2-cm level Network Real-Time Kinematic (NRTK) accuracy derived from inter-CORS distances in the range of 140-180 Km. The current state of GNSS now includes modernized GPS, GLONASS, Galileo and BeiDou constellations, which should enable, under extreme conditions, the delivery of 2-cm level accuracy.

3.8 Tiered Hierarchy

Rizos (2007) introduced the concept of a tiered hierarchy of permanent GNSS reference stations. Tier 1 stations formulate a network which contributes to a global geodesy agenda. Tier 2 stations provide primary geodetic infrastructure for datum definition and control on a national basis. Tier 3 stations are secondary state or private GNSS networks, typically established for positioning services. The TCI case study offers elements of Tier 2 and 3 hierarchies. GNSS Chokring Antennas is typical of a Tier 2 Network, whereas the antennas mounted on buildings can be considered a Tier 3 Network.

AuScope (2011) articulates that the specifications for Tier 2 sites should include weather stations capable of high-precision monitoring. The Cecelia Gray-Gardiner Primary Health Clinic (North Caicos), Alsada Hall-Malcolm Health Care Clinic (Middle Caicos) and the Bambara Community Center (Middle Caicos) included weather stations capable of monitoring by data telemetry. These weather stations fall in the Department of Disaster Management and Emergencies (DDME) remit and are not yet operational. The weather infrastructure was a factor in choosing these sites to utilize the meteorological data eventually. The network will initially be without a vertical control component.

The discrepancies found in the network of benchmarks, the dynamism of mean sea level due to climate change, and the lack of funding to re-establish a vertical datum collectively filtered into this decision. The ambition is to develop a geoid model from gravity measurements to undergird the realization of a vertical datum. The system server offers scalability to incorporate additional stations in the future, data telemetry from weather stations, and a vertical datum. Developing a Tier 2 Network is the logical direction with these other elements.

4.0 System Architecture

The Active Geodetic Network of the Turks and Caicos Islands (TCI) is being built on the provision of a control station housing a Server operating the Trimble Pivot Software located at the Digitization E-Government Technology and Innovation (DETI) Department and seven CORS utilizing geodetic receivers, chokring antennas, data infrastructure, firmware, lightening protection and power equipment. The system is designed to provide an optimized performance and reliability of this RTK network. It will offer superior coverage and connectivity to unlimited users with the accuracy afforded by reliable corrections and post-processed data to users within the zone of coverage compared to the previous autonomous base stations operated.

4.1 Server and Software Packages

The Trimble Pivot Software Package offers a robust management and monitoring system that suits the technical realities and ambitions of the Survey and Mapping Department and, more importantly, falls within the financial reality of the department. Utilizing user-friendly applications to enable and perform critical functions was considered advantageous. The foremost requirement of all systems designed and implemented by the Survey and Mapping

Department is to automate the entire system ideally. The Trimble Online Processing App enables automated online processing and delivery of field data. The Online Processing App also provides a scalable architecture to accommodate the lofty ambitions of the Survey and Mapping Department, including the network's densification.

Measurement systems necessitate redundancy and independent checking, and systems of reference require integrity monitoring. The Trimble Integrity Manager App is designed to monitor GNSS reference station dynamics through diagnostic tools and alerting options. The objective of integrity monitoring is to detect whether observed points move beyond a certain threshold over time and to understand the movement trend to trigger a response mechanism and enable users to respond appropriately. This application offers a solution for post-processed and real-time monitoring of CORS.

The availability of real-time corrections to distance-dependent errors is essentially the crux of the objective to deliver centimetre-level accuracy in the RTK technique. The Trimble Pivot RTX App performs absolute position estimation and coordinates integrity monitoring in real-time mode using the Trimble RTX technology. This correction technology generates and delivers precise satellite correction accuracy at the centimeter level anywhere on or near the earth’s surface, consequently guaranteeing worldwide coverage.

The network will be free for all users. However, the management of user accounts will be essential to streamline services. The Trimble Accounting App will allow the Survey and Mapping Department to manage user subscriptions and review usage information, making it easy to administer support services. This process facilitates the Survey and Mapping Department to provide access to the user segment under given terms and conditions for specified time intervals. The ultimate goal is to achieve integrity and accuracy in the service delivery and bill subscribers for the service.

4.2 Receiver and Antenna

The Trimble Alloy NetR9 Receiver integrates the latest multi-frequency GNSS technology into a specialized processing and communication framework. This receiver was procured because it can be integrated into a scalable network. This receiver can accept signals from all constellations (GPS, GLONASS, Galileo & BeiDou) while facilitating an active data transmission between users and the system. This receiver facilitates data storage, post-processing, network solutions and single-base solutions. This versatility is critical to the success of the service. The onboard integrated battery provides over 15 hours of operation. It contains 8 GB onboard storage with external USB drive support.

The Trimble Zephyr 3 Geodetic antenna utilizes the Trimble Stealth ground plane to function optimally in areas with high multi-path interference. Weather-resistant materials and a low-profile design protect it. This antenna is recommended for less-than-ideal sites because it provides excellent multipath rejection in a cost-effective design.

5.0 Benefits of CORS Network

Realizing a datum for horizontal positioning without the strictures associated with a passive geodetic network is a significant advancement in the geospatial industry. In this paradigm, cm-level positional accuracy can be derived using a CORS Network that will expand the geospatial possibilities of the Turks and Caicos Islands.

5.1 Improved Accuracy

The seven base stations represent a less-than-dense network, but based on the economic reality, it is a reasonable genesis along the continuum of a national reference system. A more densified reference framework ultimately offers shorter baselines, equating to improved accuracy. This Active Geodetic Network will model ionospheric effects on the satellite signals to provide corrections to the users via a virtual base to deliver enhanced precision and accuracy.

5.2 Versatility in Positional Solutions

The network offers the versatility of network and single-base solutions. The less accurate single base option can offer sub-centimeter level accuracy. The system provides users with a post-processing option where the network administrator can download Receiver Independent Exchange (RINEX) format files and provide users with data previously collected. This feature is particularly useful for Post-Processed Kinematic activities such as Unmanned Aerial Vehicles (UAV) Surveys.

5.3 Cost Effectiveness and Efficiency Savings

The time and cost savings represent an essential benefit of the network. Singh and Kumar (2019) opined on the reality of utilizing less equipment to attain corrected data to compute positions at centimeter-level accuracy. One dual-frequency survey-grade GNSS receiver with internet access can deliver such positional accuracy. The need to establish a base station or occupy one will be dispensed with, as there will be no need for a local base station. The system will eliminate the need for permanent autonomous base stations operated by surveyors contrary to the legislation and eliminate the need for semi-permanent bases (base and rover array) operated generally by SMD staff and other surveyors.

The nuances associated with using a local base station will be removed from the job costing and duration. The typical need of personnel to attend to or secure the equipment, the need to ensure “line of sight” of radio connection and exceeding the baseline length are all removed from consideration. The cost of procuring an additional GNSS receiver is significant, and the time to establish and occupy a base station can significantly increase the cost of deliverables and work scheduling.

5.4 Homogeneity and Accuracy

The reality of operating multiple passive and active geodetic networks on various reference systems introduced inconsistencies in geospatial measurement and transformation of coordinates, which translated to boundary disputes, registration errors and liability to the Turks and Caicos Islands Government. The CORS Network will standardize measurements because one reference system will underpin all geospatial endeavours. This new paradigm will facilitate corrections from one network to the roving user segment. This homogeneity will ensure that coordinate accuracy is maintained throughout the CORS Network. The fact that stations are within the inter-CORS distances, even over large distances, accuracy will be maintained.

5.5 Time Series Updates

The computation of the coordinates of each station will be referenced to the International Terrestrial Reference Framework (ITRF). The ITRF will be used to re-compute the coordinates of each station annually to maintain accuracy using this global reference framework. The ITRF platform will provide a premise to develop integrity monitoring capabilities to undergird quality assurance. This agenda is also consistent with the ambition of the Survey and Mapping Department of the Turks and Caicos Islands to upgrade the network to a Tier 2 Network. Eventually, this network should be included in a regional and global network used for deformation monitoring (variations in geopotential) and scientific research in plate tectonics (intra and inter-plate movement). Altamimi et al. (2011) state that modern geodetic datums use reference systems aligned with ITRF. The aim is to become consistent with the stringent monumentation specifications to contribute to regional and global geodesy.

5.6 Equipment Tracking

The Trimble Pivot Portal can use active communication (bi-directional) to accurately locate and illustrate the position of all users at any epoch. Each user will be registered via a user account with the information stored about the equipment (make, model, serial #). This may be used to monitor state operations and operators and to provide technical support to the user segment where a single base solution is required versus a network solution.

5.7 Quality Control & Integrity Monitoring

The system will offer integrity monitoring capabilities and status notifications. This will be realized by base station data stored in a central server operating as master control, which will provide monitoring of each base station, and users will be notified as to the health status of each station. The loss of connectivity to one station will not render the network inoperable. The Trimble Online Processing App will allow the user segment to upload field data to the web-based service to receive a post-processed solution. This option is advantageous where limited or no real-time corrections are available. The postprocessed option can be used to provide an independent check whenever necessary. The Integrity Manager App is designed to monitor GNSS reference station dynamics through diagnostic tools and alerts. These tools and alerts include Total network monitoring, Customized alarms, Real-time and post-processed motion detection and regular movement checks.

5.8 Challenges of CORS Network

The challenges in designing, implementing, and operating the Turks and Caicos Islands CORS Network will be similar to those of global case studies. The constraint in design due to geography is a reality of nature. The lack of support components such as a vertical datum is a work in progress, and the perennial internet-related issues of the territory will be alleviated in time.

5.9 GNSS-Based Vertical Control

Janssen et al. (2011) articulated that it is typical for countries to use an approximation of the orthometric height system referenced to the geoid. The ambition of the Turks and Caicos Islands is similar in that a geoid model is being considered to be developed and adopted for orthometric height determination. The transfer of heights will be done by the following mathematical model:

$$H = h - N$$

Where H is Orthometric Height, h is Ellipsoidal Height, and N is Geoid / Ellipsoid separation

The accuracy of the CORS-derived orthometric heights will be based on the absolute N values, as the rover will propagate inaccuracies in the N value. The accuracy in the determination of N values will be paramount in the development of a geoid model.

5.10 Public Static Internet Protocol Address

A Public Static Internet Protocol (IP) Address, which is manually configured to the geodetic equipment, will be necessary to provide access to the network. The challenge the Internet Service Provider (ISP) has is network coverage, whereby no network infrastructure is located where potential sites are identified. The Survey and Mapping Department relied on the Digitization E-Governance and Technology Innovation (DETI) Department to liaise with the ISP to deliver this critical component. The need for this intervention was to avoid duplication of the data infrastructure needed as multiple state agencies occupy buildings; therefore, elements of the data infrastructure can be used by various departments. The DETI has engaged one ISP to provide each CORS's Public Static IP Address. However, this item is outstanding.

6.0 Implementation of CORS Network

The implementation phase of the CORS Network of the Turks and Caicos Islands required the installation of the data infrastructure and the geodetic equipment at the selected sites. All equipment was procured and configured to be installed. The installation phase would feature the expertise of the consultant and the Survey and Mapping Department staff. All geodetic equipment has been installed in addition to the server and associated software. The single requirement is the provision of the Public Static IP Address at each CORS.

6.1 Coordination of CORS

The International Terrestrial Reference Framework (ITRF) will be used to coordinate CORS, and the Trimble Business Center Software will execute all computations/ adjustments. The data will be processed from international stations in the Caribbean region. Precise ephemerides from the International GNSS Service (IGS) will be used to post-process the data for greater accuracy and as an independent check. Data will be processed in 24-hour blocks and compared as a precision metric. The final coordinates will be referenced to the ITRF and used as the premise to compute the corrections to be delivered to the system users (Miller et al., 2007).

No vertical coordinates for stations will be computed because of the lack of an accurately defined vertical datum. The ambition is to satisfy this requirement later using a geoid model. The precision and accuracy of the network will be tested with “known points” of the passive network. A control point will be selected on each island and coordinated using the system daily for five (5) days. A comparative analysis will assess the differences in latitude, longitude, northings and eastings.

6.2 Access to CORS

All users will need a dual frequency GNSS receiver with Global System for Mobile (GSM) Communication coverage. The network will be accessible by Public Static Internet Protocol (IP) Addresses. All users will be within the recommended 30-50 Km baseline. The configuration of the network will facilitate all users based on baseline requirements. The Trimble Pivot Software will enable all users to connect to the network via a Public Static IP Address. Users can benefit from a network solution with access to three CORS, or positioning can be derived from a single base solution.

7.0 Conclusion

The Turks and Caicos Islands CORS Network comprises cutting-edge GNSS equipment, software, firmware and communication infrastructure. The stakeholders, including the Authorized Surveyors, all operate Dual Frequency GNSS Receivers, so as soon as the network is in operation, they can seamlessly transition to this infrastructure. The proliferation of Unmanned Aerial Vehicles (UAV) with Real-time Kinematic and Post-processed Kinematic functions will be able to optimize their capabilities in this paradigm. The agendas, which include hydrography, geodesy, photogrammetry, Geographic Information Systems (GIS) and populating the Cadastre, will be advanced using an accurate, homogenous and user-friendly reference platform.

The benefits are immediate and cross-cutting all built and natural environment sectors. These include homogeneity, cost-effectiveness, accuracy, integrity monitoring and ease of use. The perennial challenge is providing reliable internet service to enable service continuity to the user segment. The ambitions are lofty but realistic. These include transitioning to a Tier 2 CORS Network to contribute to regional and global geodesy. The vision is to comply with the rubric of the International GNSS Society (IGS) to have a station being adopted as an international reference station. This will guarantee the determination of the velocities of this station, which can logically serve as the premise for a time series update for all stations.

References

Altamimi, Z., Collilieux, X., and Metiver, L. (2011). An Improved Solution of the International Terrestrial Reference Frame. *Journal of Geodesy*, 85(8), 457-473.

AuScope (2011). An organization for a national earth science infrastructure program. http:/www.auscope.org.au/

Feng, Y., and Li, B. (2008). A Benefit of Multiple Carrier GNSS Signals: Regional Scale Network-Based RTK with Doubled Inter-Station Distances. *Journal of Spatial Science,* 53(1), 135-147.

Haasdyk, J., Roberts, C., and Janssen, V. (2010). Automated Monitoring of CORSnet-SW using the Bernese Software. *Proceedings of XXIV FIG International Congress 2010, Sydney, Australia,* 11-16 April, p.19.

Janssen, V., Haasdyk, J., McElroy, S. and Kinslyside, D. (2011). Technical Challenges Faced by CORS Network Operators: Experiences from New South Wales, Australia. International Journal of Geoinformatics, Volume 7, Number 3, September, pp. 23-33.

Miller, K.M., Leong, T., and Clarke, S. (2007). A new geodetic infrastructure for Trinidad and Tobago.

NOAA (2006). Guidelines for New and Existing Continuously Operating Reference Stations (CORS). National Geodetic Survey National Ocean Survey, NOAA, Silver Spring, MD 20910.
http://geodesy.noaa.gov/CORS/Establish Operate CORS.shtml

Rizos, C. (2007). Alternatives to current GPS-RTK Services & Some Applications for CORS Infrastructure and Operations. *GPS Solutions* 11(3), 151-158.

Singh, S.K., and Kumar, D. (2019). Continuously Operating Reference Stations (CORS) GNSS Network Challenges and Benefits in Indian Context. *FIG Working Week*. Geospatial information for a smarter life and environmental resilience, Hanoi, Vietnam.

Wang, C., Feng, Y., Higgins, M. and Cowie, B. (2010). Assessment of Commercial Network RTK user Positioning Performance over Long Inter-Station Distances. *Journal of Global Positioning Systems,* 9(1), 78-79.

Biographical Data

Wayneworth G. Hamilton earned a Bachelor of Science Degree with First Class Honours in Surveying and Geographic Information Sciences and a Master of Science Degree in Built Environment, majoring in Construction Management from the University of Technology, Jamaica, in 2012 and 2015, respectively.

Wayneworth is a recipient of the coveted Laurence Neufville Award (2015) for the best academic performance and best research thesis at the post-graduate level, titled: Performance Evaluation of a Central Wastewater Treatment Plant in Jamaica (Case Study of Soapberry). Additionally, Wayneworth has been awarded the prestigious University of Technology, Jamaica 60th Anniversary Outstanding Alumni Award for Service to University and Country (2019).

Wayneworth has over 25 years of experience in land surveying in Jamaica. He attained the professional status of Commissioned Land Surveyor in Jamaica in 2016 and operated his consultancy as a Geo-Information Management Consultant and Project Manager. He has lectured at the University of Technology, Jamaica, in the School of Building and Land Management at the associate and baccalaureate levels in the Land Surveying and Geographic Information Sciences and the graduate level in the Master of Science in Built Environment Programme from 2016 to 2021.

Wayneworth has a keen interest in research, publications, and media. He was a columnist in the Western Mirror with his impactful and educational column titled "Your Land & You" and his YouTube channel titled "Kicking It With The Pros".

Wayneworth is a member of the Land Surveyors Association of Jamaica and a member of the Kiwanis Club of Montego Freeport, where he served as secretary and a Justice of the Peace in the Parish of Saint James, Jamaica. Wayneworth G. Hamilton is a transformational leader with vision and interpersonal skills to inspire and engender growth and development. He has assumed the role of Director of Survey and Mapping in the Turks and Caicos Islands since November 1, 2022.

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