DEMONSTRATION PROJECT

JICA PILOT PROJECT

ការផ្ទៀងផ្ទាត់ភាពត្រឹមត្រូវនៃការវាស់វែងព្រំដីជាមួយប្រព័ន្ធ Khmer GEONET

Accuracy Verification of Cadastral Survey with Khmer GEONET

JUNE 2024

អរុណា ថិចណូឡូជី
Aruna technology ltd.

Presentation Outline

I. Overview of the Demonstration Project

II. Work Performed

III. Use of Khmer GEONET

IV. Recommendation

V. Conclusion

I. Overview of the Demonstration Project

➢ **The main purpose of the pilot project is to demonstrate the accuracy of RTK survey by GNSS rover under field conditions.**

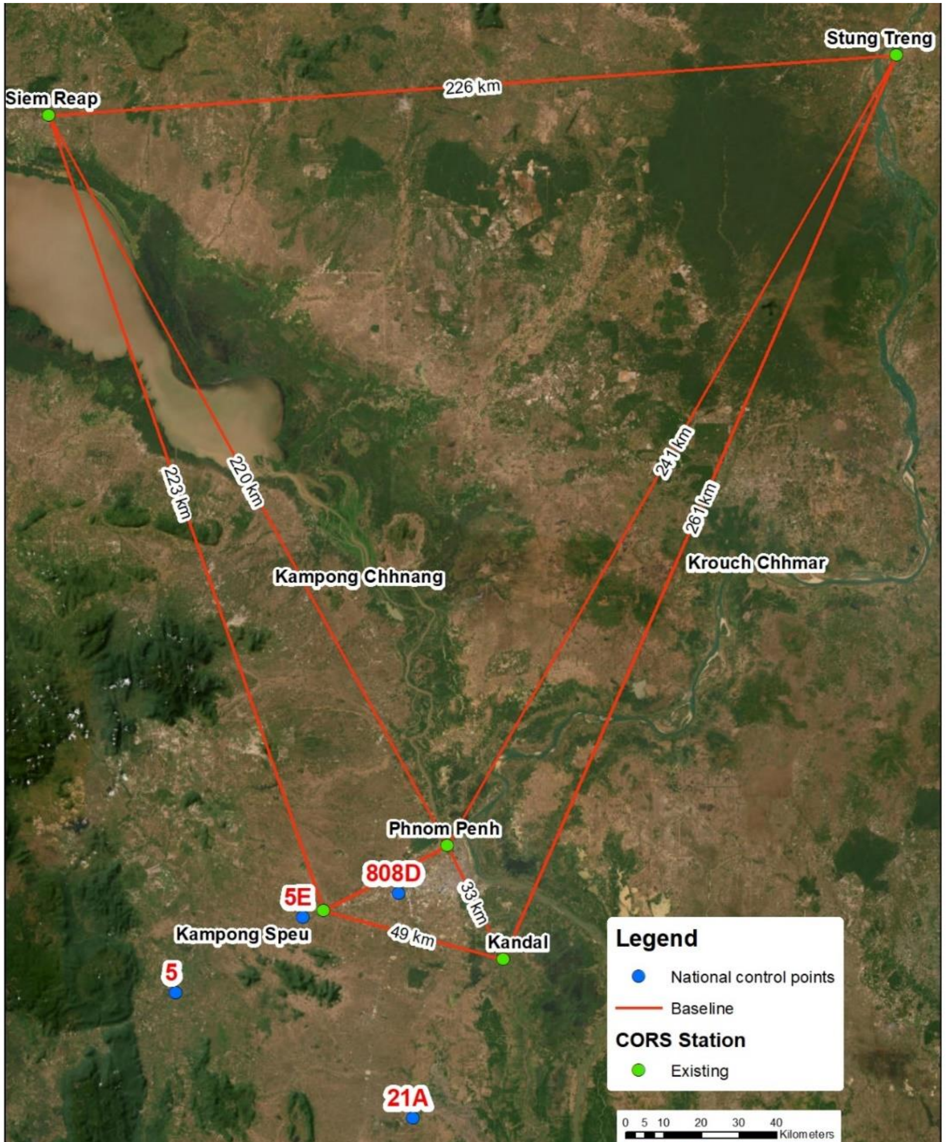
Accuracy can be measured in two main ways;

1) absolute accuracy in relation to known points and;
2) relative accuracy, or the variability of coordinates (X,Y and Z) over time.

➢ **Implementation Period**

1) Work at the site: JUL 2023 – SEP 2023
2) Reporting: SEP 2023 – NOV 2023

I. Overview of the Demonstration Project (Con.)



- Location of the demonstration project site

(1) In and around the three stations in Phnom Penh, Kandal, Kampong Speu and Takeo provinces

(2) Siem Reap Province; and

(3) Stung Treng Province

I. Overview of the Demonstration Project (Con.)

➢ This pilot project will focus on testing of absolute accuracy. The main parameters that will be tested are;

1) Comparison of accuracy when connected to the Network RTK vs. Single Station RTK

2) Comparison of accuracy of different makes and models of GNSS rover receiver

3) Comparison of accuracy under different Ionospheric conditions.

4) Determination of accuracy at longer distances from the nearest station e.g., 10, 20, 30, 40, 50, 70, 100 km

5) Determine the repeatability of measurements under field conditions by surveying the same temporary points, representing a cadastral boundary, on different days.

I. Overview of the Demonstration Project (Con.)

- The equipment listed below were used for the demonstration project.

No.	Make	Model	Frequencies	H Accuracy, RTK
1	Topcon	HiPer VR	3	5 mm + 0.5 ppm
2	Topcon	HiPer SR	2	10 mm + 0.8 ppm
3	Trimble	R10	3	8 mm + 1 ppm (Single) 8 mm + 0.5 ppm (Network)
4	Trimble	R8s	3	8 mm + 1 ppm (Single) 8 mm + 0.5 ppm (Network)
5	CHC	i80	3	8 mm + 1 ppm (Single) 8 mm + 0.5 ppm (Network)
6	SinoGNSS	T300 Plus	3	8 mm + 1 ppm (Single)
7	ZED-F9P		2	10 mm + 1 ppm (Single) (1km baseline) Manufacturer's note "ppm limited to baselines up to 20 km."

II. Work performed

- ➢ The Khmer GEONET system is able to broadcast both a Network RTK (NRTK) correction and a Single Station RTK (SSRTK).
- ➢ The NRTK correction for Khmer GEONET is set to Virtual Reference Station (VRS) mode.

Note: **Trimble Pivot Software and Hardware Alloy + ACR**

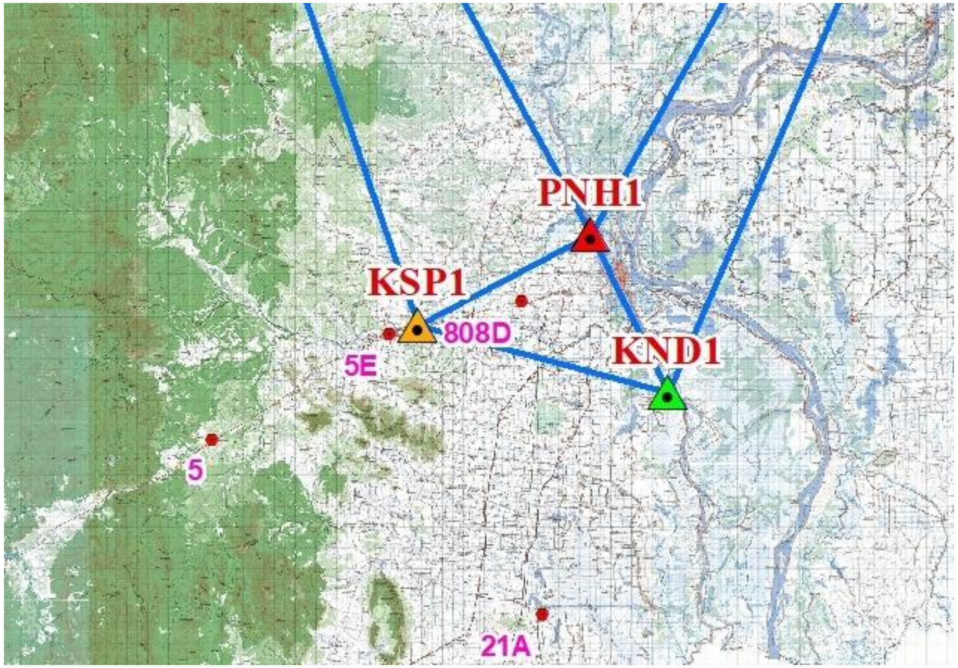
In summary the expectation is that the NRTK corrections (VRS), will

- Allow longer baselines between rover and reference station
- Be more accurate compared to SSRTK due to localized modeling of the tropospheric and Ionospheric
- Shorter initialization times compared to SSRTK

II. Work performed (Con.)

(1) Results of Network RTK vs. Single Station

National Control Point 5 about 44km from KSP CORS Station



Date: 30-07-2023

Receiver Model: Trimble R10

Survey Method: Continuous Topo; 1sec.

Number of observations: 478

Fix Type: RTK Fix

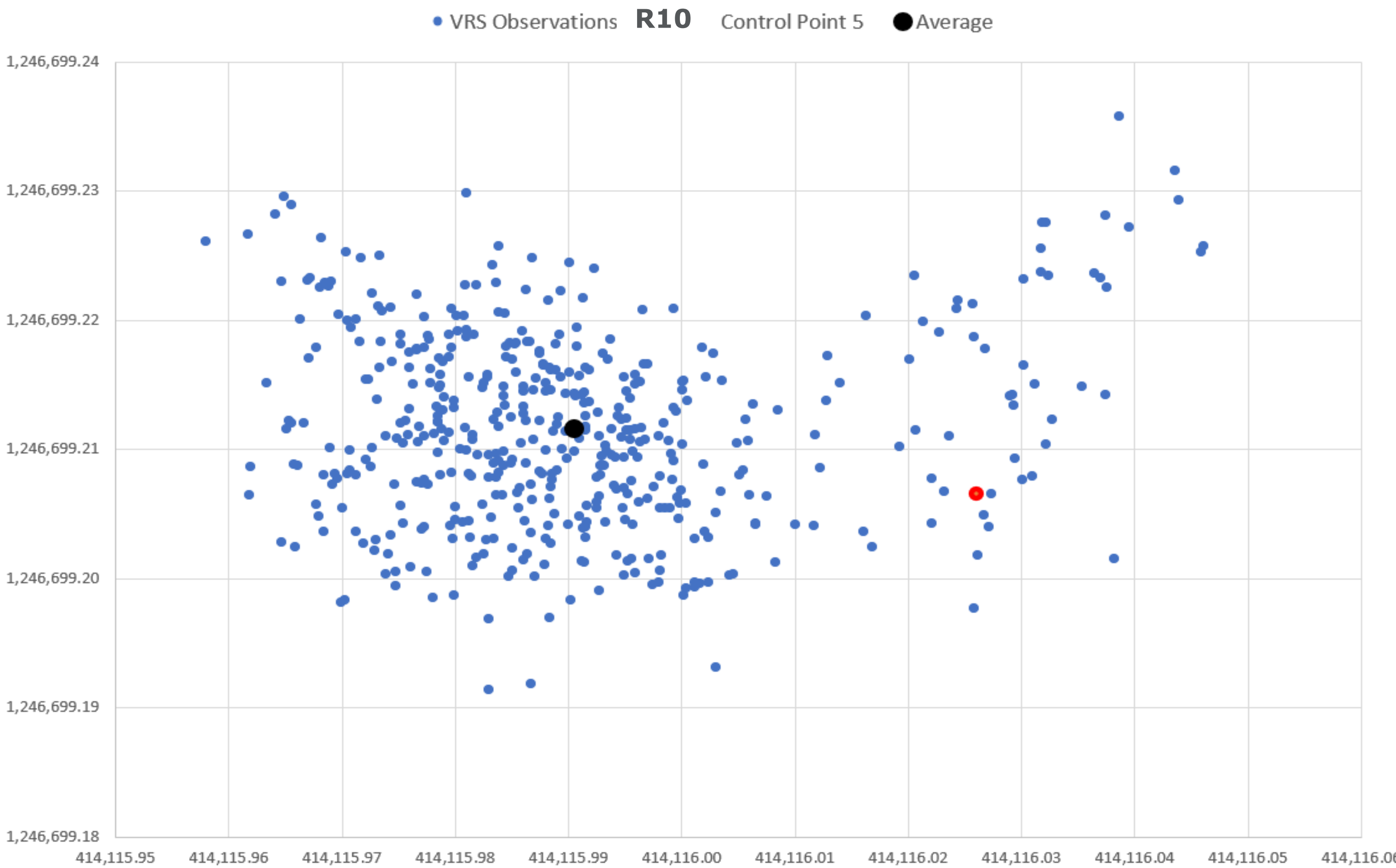
Mount Point: VRS

Average # of satellites: 14

II. Work performed (Con.)

(1) Results of Network RTK vs. Single Station RTK

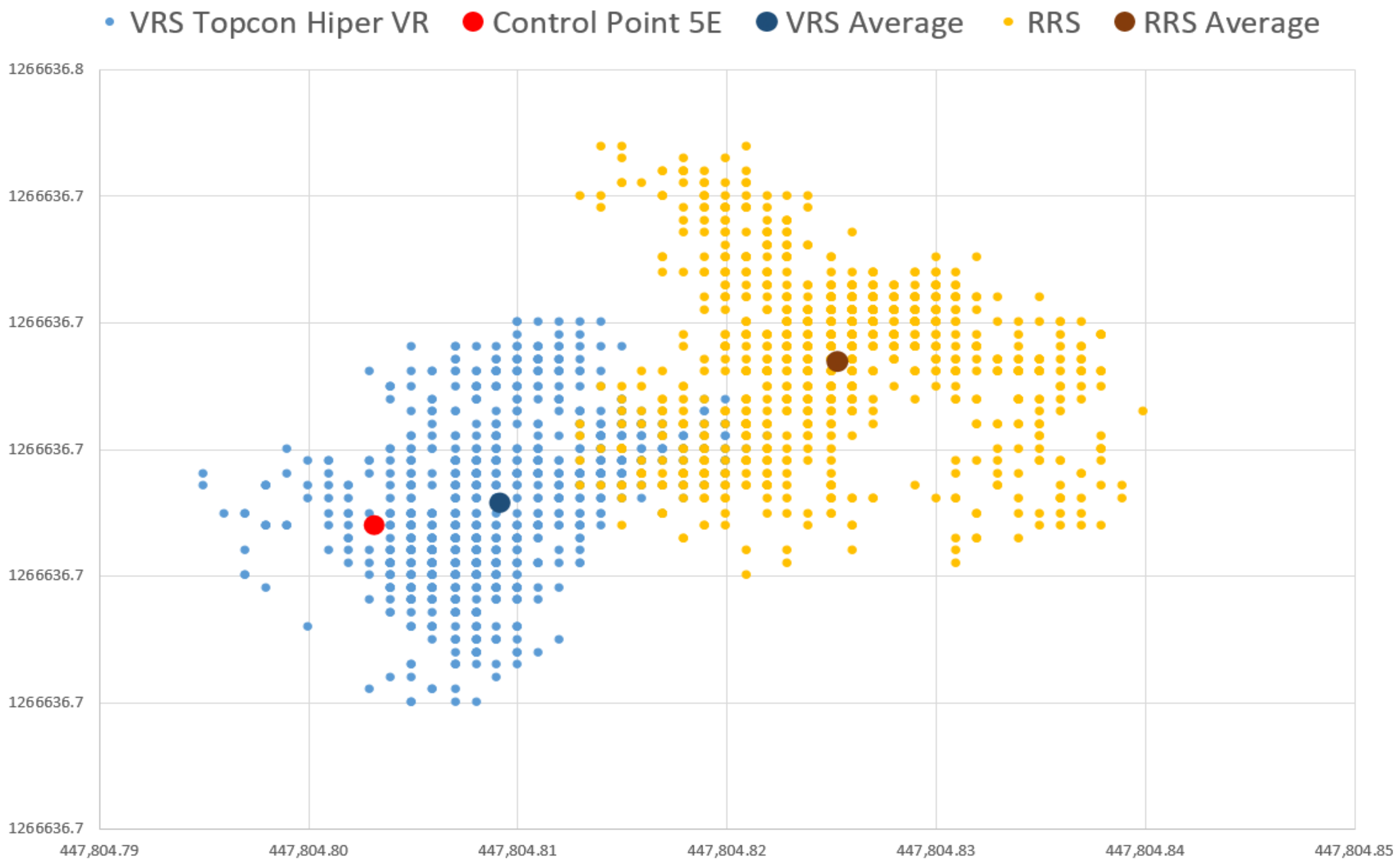
Horizontal coordinates of observation over known point 5 with R10 Receiver



II. Work performed (Con.)

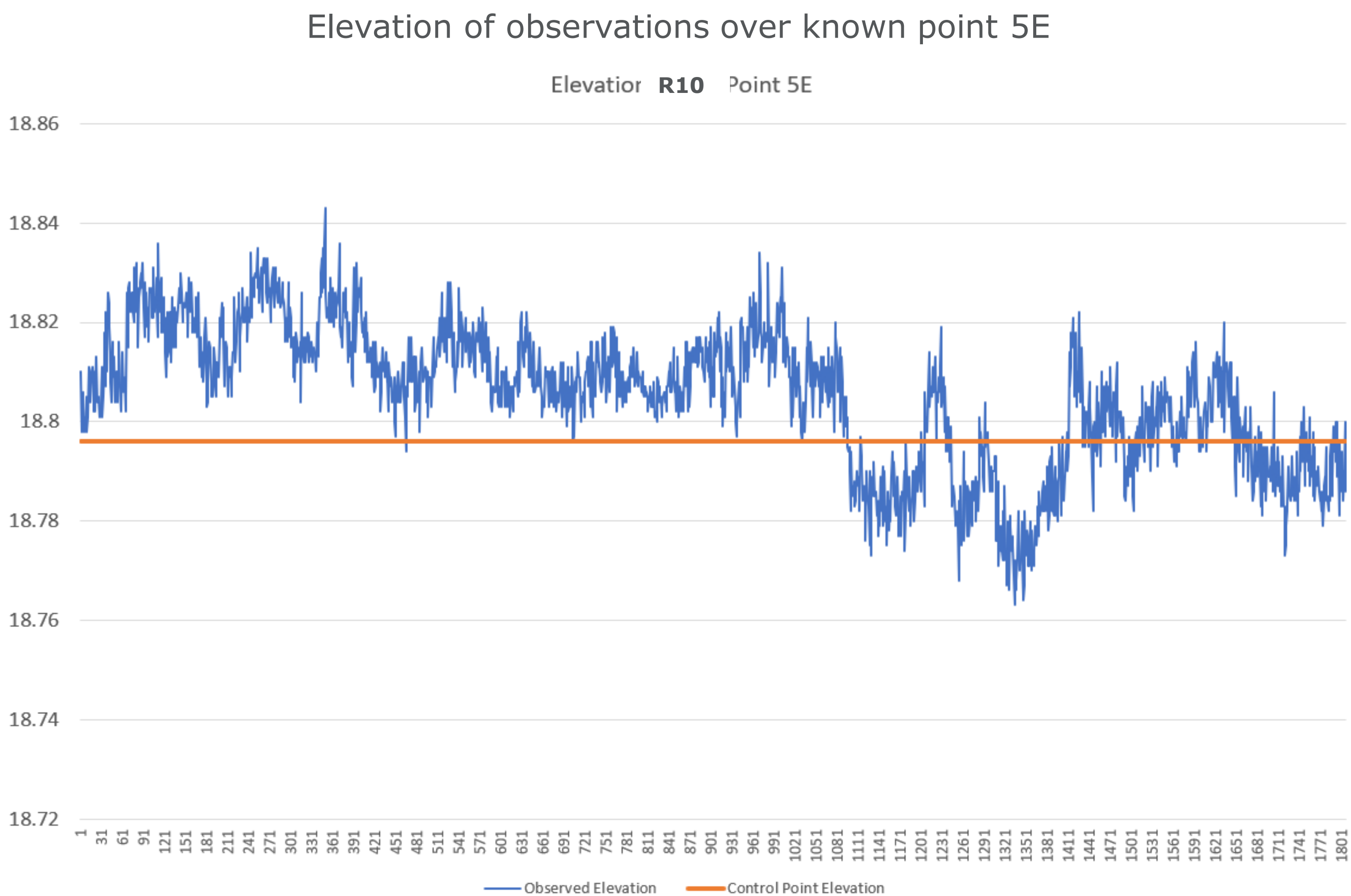
(1) Results of Network RTK vs. Single Station RTK

Horizontal coordinates of observation over known point 5E with Topcon Hiper VR Receiver



II. Work performed (Con.)

(1) Results of Network RTK vs. Single Station RTK



II. Work performed (Con.)

(1) Results of Network RTK vs. Single Station RTK

Comparison of observed coordinates vs known coordinate 5E with different receivers

	East	North	Δ East	Δ North	Linear
5E Known	**447804.8032**	**1266636.7141**			
R8s VRS Obs. Av.	447804.8113	1266636.7234	0.008	0.009	0.012
R8s RRS Obs. Av.	447804.8170	1266636.7203	0.014	0.006	0.015
Topcon Hiper VR VRS Obs. Av.	447804.8092	1266636.7158	0.006	0.002	0.006
Topcon Hiper VR RRS Obs. Av.	447804.8253	1266636.7270	0.022	0.013	0.026
CHC i80 VRS	447804.8209	1266636.711	0.018	-0.004	0.018
CHC i80 RRS	447804.7956	1266636.707	-0.008	-0.007	0.010
Sino 070 VRS	447804.8058	1266636.718	0.003	0.004	0.005
Sino 070 RRS	447804.8219	1266636.718	0.019	0.004	0.019
Trimble R10 VRS	447804.805	1266636.725	0.002	0.011	0.011
Trimble R10 RRS	447804.8931	1266636.698	0.090	-0.016	0.091
Topcon SR VRS	447804.8164	1266636.72	0.013	0.006	0.014
Topcon SR RRS	447804.8405	1266636.715	0.037	0.000	0.037

II. Work performed (Con.)

(1) Results of Network RTK vs. Single Station RTK

Comparison of observed coordinates vs known coordinate 808D with different receivers

	East	North	Δ East	Δ North	Linear
808D Known	**473113.1740**	**1272888.1020**			
R8s VRS Obs. Av.	473113.1817	1272888.1021	0.008	0.000	0.008
R8s RRS Obs. Av.	473113.1700	1272888.0927	-0.004	-0.009	0.010
Topcon Hiper VR VRS Obs. Av.	473113.1892	1272888.091	0.015	-0.011	0.019
Topcon Hiper VR RRS Obs. Av.	473113.2068	1272888.126	0.033	0.024	0.041
CHC i80 VRS	473113.151	1272888.072	-0.023	-0.030	0.038
CHC i80 RRS	473113.2506	1272888.022	0.077	-0.080	0.111
Sino 070 VRS	473113.1868	1272888.07	0.013	-0.032	0.034
Sino 070 RRS	473113.1774	1272888.084	0.003	-0.018	0.018
Trimble R10 VRS	473113.1899	1272888.101	0.016	-0.001	0.016
Trimble R10 RRS	473113.1347	1272887.53	-0.039	-0.572	0.573
Topcon SR VRS	473113.0545	1272888.056	-0.119	-0.046	0.128
Topcon SR RRS	473113.1398	1272888.056	-0.034	-0.046	0.058

II. Work performed (Con.)

(2) Comparison of accuracy of different makes and models of GNSS rover receiver

Although different manufacturers use different chips and technologies on board the receiver, the main factors affecting rover performance are;

1. The number of constellations tracked e.g. GPS, BeiDou, GLONASS

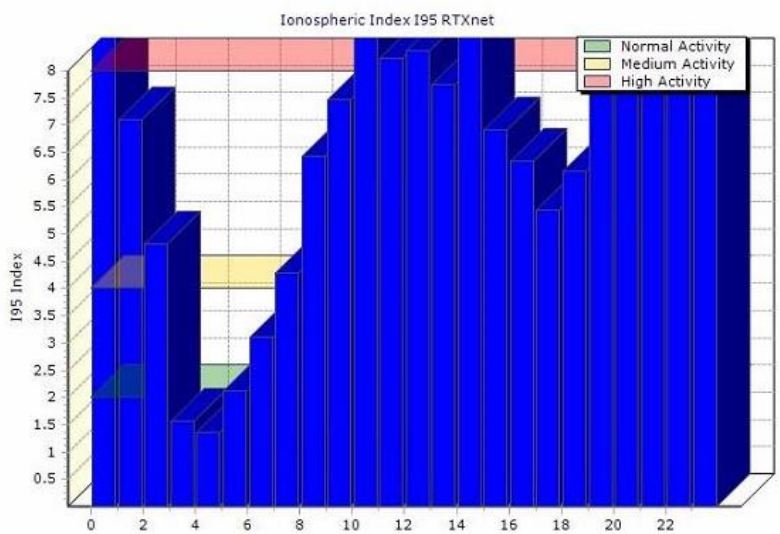
2. The frequencies tracked i.e. L1, L2, L5

Shows the specifications of the rover receivers utilized on this project.

Only two of the models were dual frequency; the Topcon HR and the ZED-F9P.

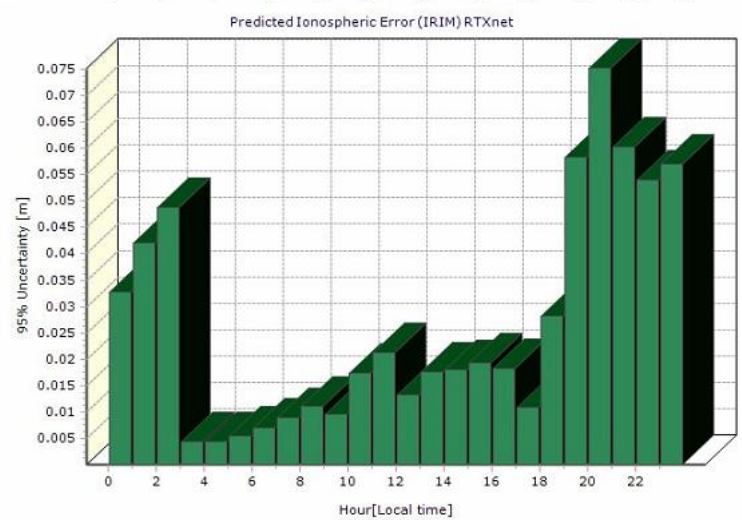
II. Work performed (Con.)

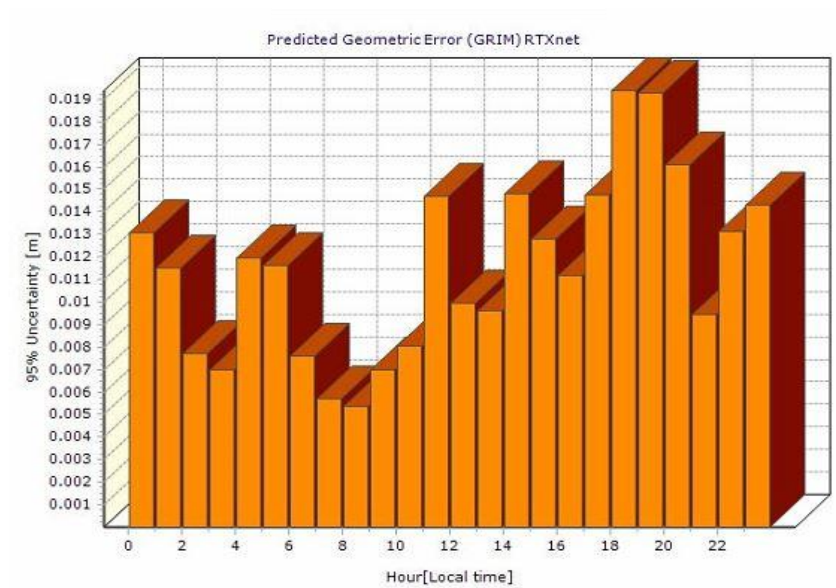
(3) Comparison of accuracy under different Ionospheric conditions



Trimble Pivot Platform includes powerful integratory monitoring functions to predict rover performance in the field.

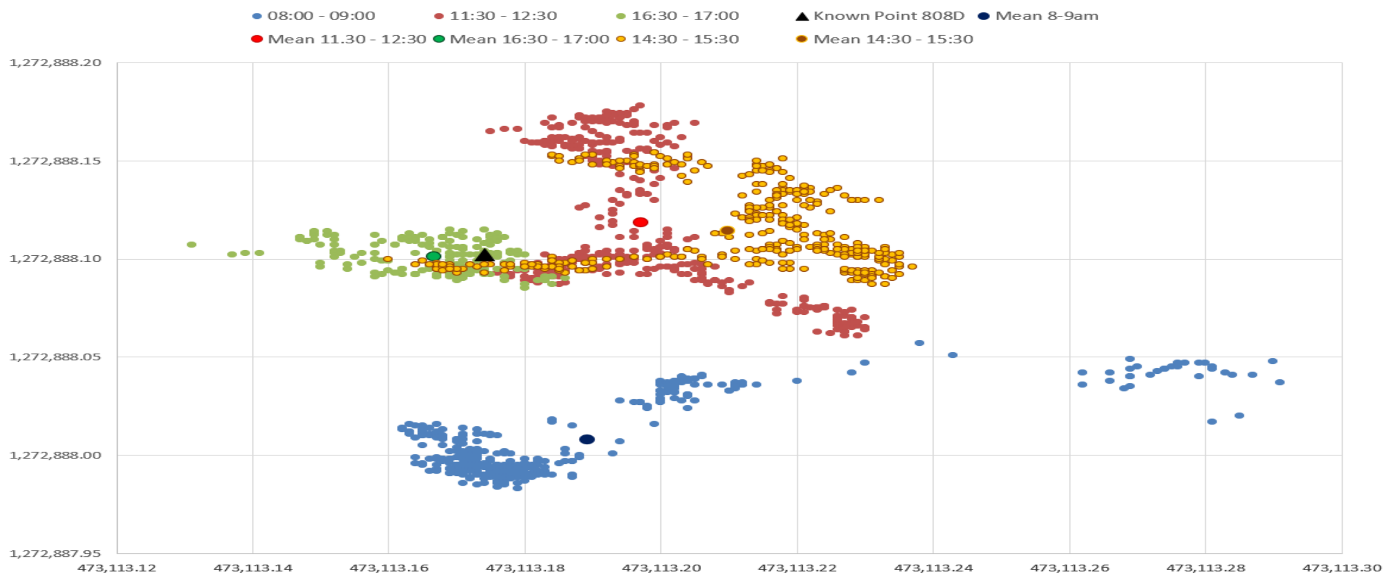
- ✓ It is a very useful tool to predict the rover performance.

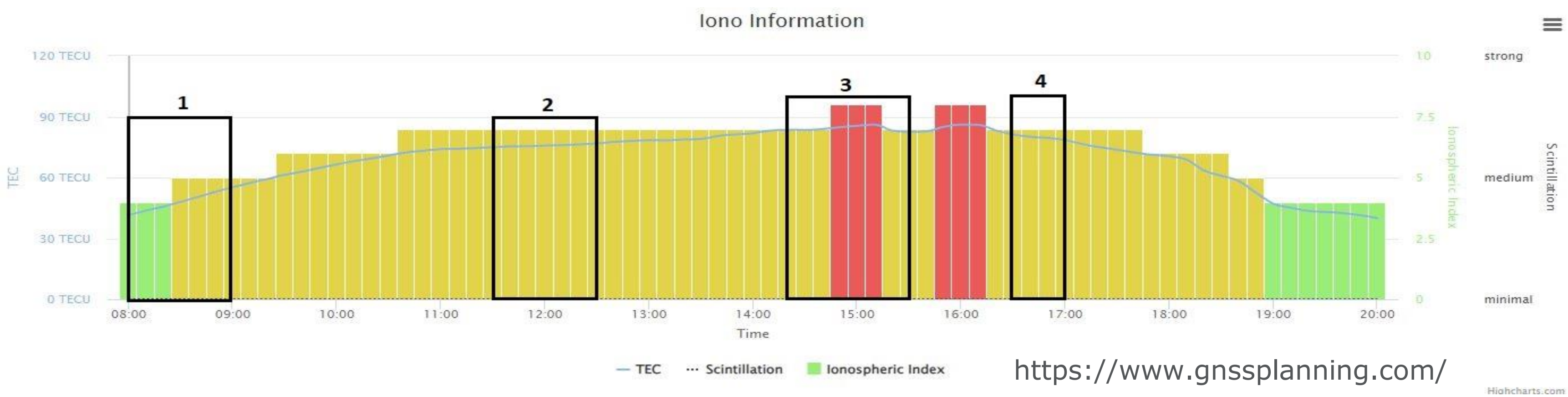




II. Work performed (Con.)

(3) Comparison of accuracy under different Ionospheric conditions





https://www.gnssplanning.com/

II. Work performed (Con.)

(3) Comparison of accuracy under different Ionospheric conditions

Sessions for observing under different ionospheric conditions

No	Session Time	I95	IRIM	GRIM	Δ to known point (m)
1	08:00 – 09:00	Medium	0.01	0.006	0.095
2	11:30 – 12:30	High	0.02	0.015	0.028
3	14:40 – 15:30	High	0.01	0.015	0.038
4	16:30 – 17:00	Medium	0.02	0.014	0.008

Ionospheric activity as measured by the I95 index varied from Medium (I95 > 4) and High (I95 > 8).

Note: Medium values relate to I95 values of > 4 and high values > 8

II. Work performed (Con.)

(4) Determination of accuracy at longer baseline distances from the nearest station

Fixing performance vs. baseline length for ZED-F9P GNSS receiver

Distance (km)	ZED-F9P	Trimble R10	Trimble R8s	SinoGNSS	CHC i80
10	100				
20	100	100	100	100	97
30	96				
40	85				
50	74	100	100	100	100
70	51				
100	3			100	

To determine the accuracy of longer baseline distances, two tests were devised;

1. A check of the fixing performance at different distances from the nearest CORS station; and
2. Calculate the accuracy of observed vs. known coordinates for different distances from the nearest CORS station.

II. Work performed (Con.)

(4) Determination of accuracy at longer baseline distances from the nearest station

Horizontal errors observed over known points at increasing distance

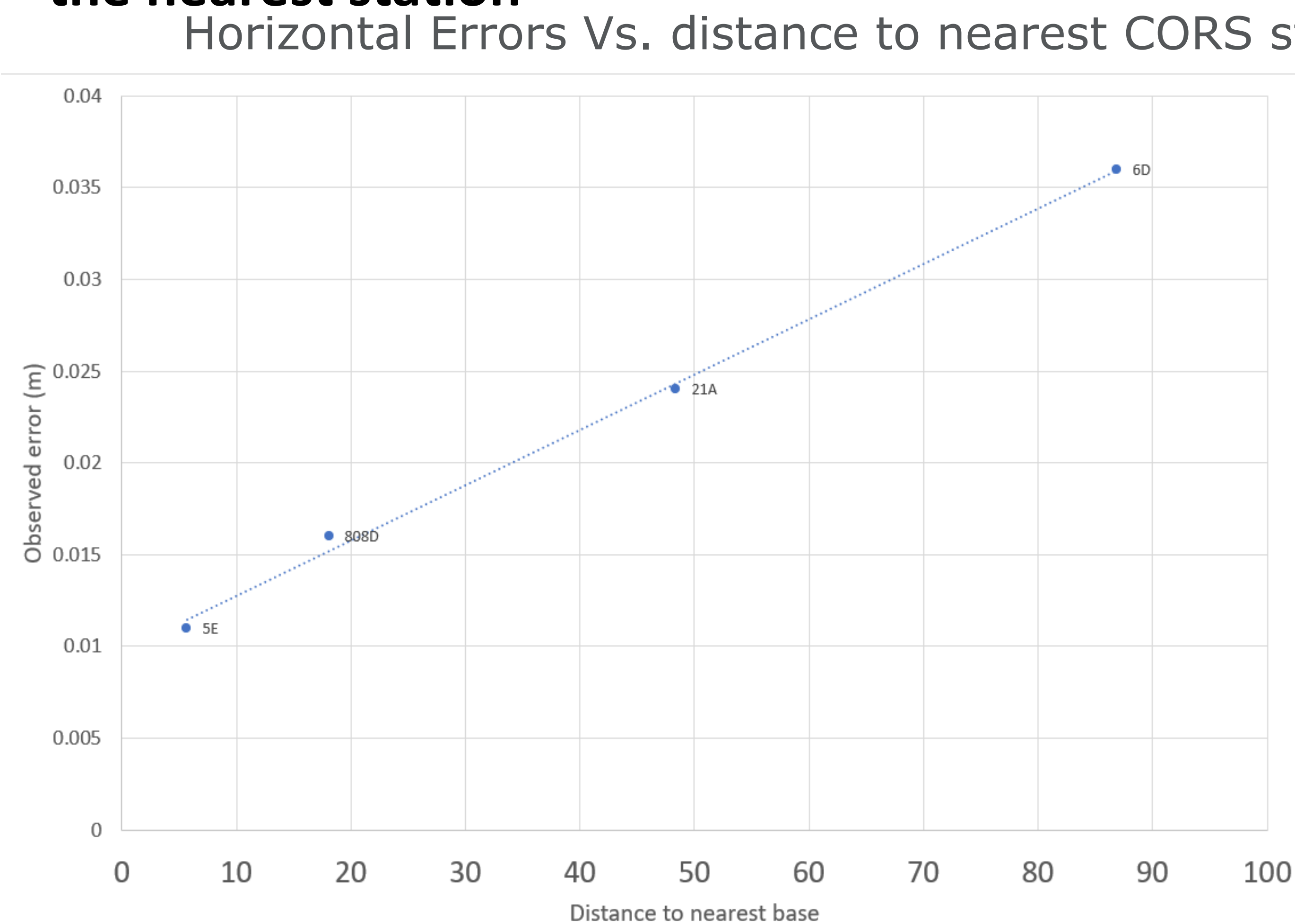
No.	Point ID	Nearest CORS Station	Distance to station (KM)	Δ East	Δ North	Linear	Date
1	5E	KSP	5.7	0.002	0.011	0.011	23/09
2	808D	PNH	18.1	0.016	-0.001	0.016	24/09
3	21A	KND	48.4	0.016	-0.018	0.024	21/09
4	6D	KNG	86.9	0.033	0.024	0.036	27/09

For the second set of checks, four known points were selected at increasing distance from the nearest CORS station and a Trimble R10 rover setup over each point. Observations were made for 5 minutes over each point and the results are given in Table above.

As you can see, the error is quite small and increasing linearly, even to a distance of 86 km from the nearest base station.

II. Work performed (Con.)

(4) Determination of accuracy at longer baseline distances from the nearest station



Based on the tests over four known points, it can be concluded the positioning accuracy of Khmer GEONET is high and increases linearly with distance from the nearest station. This means that the network correction is accurate reliable even at moderate distances (30 – 50 km).

II. Work performed (Con.)

(5) Determine the repeatability of measurements under field conditions

Two sites were selected for determining the repeatability of field measurements; 1 Location in Kandal Province and another location in Kampong Speu Province.

The procedure was as follows:

1. Setup tripod over 4 points
2. Measure 4 points in RTK mode
3. Repeat measure 3 times in succession

1. Move instrument to all points
2. Repeat steps 1-3

II. Work performed (Con.)

(5) Determine the repeatability of measurements under field conditions

Boundary Survey Scheme in Angk Snuol District

Boundary Survey Scheme in Phnum Sruoch District

II. Work performed (Con.)

(5) Determine the repeatability of measurements under field conditions

Name	Easting	Diff.	Northing	Diff.	Elev.	Diff.	Start Time	End Time
Boundary1-1	469533.742		1271519.702		7.027		7/31/2023 15:23	7/31/2023 15:23
Boundary1-2	469533.741	(0.001)	1271519.702	0.000	7.027	0.000	7/31/2023 15:23	7/31/2023 15:23
Boundary1-3	469533.739	(0.002)	1271519.702	-	7.024	(0.003)	7/31/2023 15:23	7/31/2023 15:23
Boundary2-1	469442.219		1271524.216		7.346		7/31/2023 15:52	7/31/2023 15:52
Boundary2-2	469442.218	(0.001)	1271524.216	0.000	7.343	(0.002)	7/31/2023 15:52	7/31/2023 15:52
Boundary2-3	469442.217	(0.001)	1271524.216	(0.000)	7.344	0.000	7/31/2023 15:52	7/31/2023 15:52
Boundary3-1	469427.044		1271415.808		7.266		7/31/2023 15:56	7/31/2023 15:56
Boundary3-2	469427.047	0.003	1271415.811	0.002	7.270	0.004	7/31/2023 15:56	7/31/2023 15:56
Boundary3-3	469427.045	(0.002)	1271415.81	(0.000)	7.266	(0.004)	7/31/2023 15:56	7/31/2023 15:56
Boundary4-1	469536.016		1271417.536		7.055		7/31/2023 16:15	7/31/2023 16:15
Boundary4-2	469536.016	(0.000)	1271417.533	(0.003)	7.054	(0.001)	7/31/2023 16:15	7/31/2023 16:15
Boundary4-3	469536.019	0.003	1271417.53	(0.003)	7.056	0.002	7/31/2023 16:15	7/31/2023 16:16
	Mean	(0.000)		(0.000)		0.000		
	Max	**0.003**		**0.003**		**0.004**		

Boundary Survey Results at Ank Snuol Site

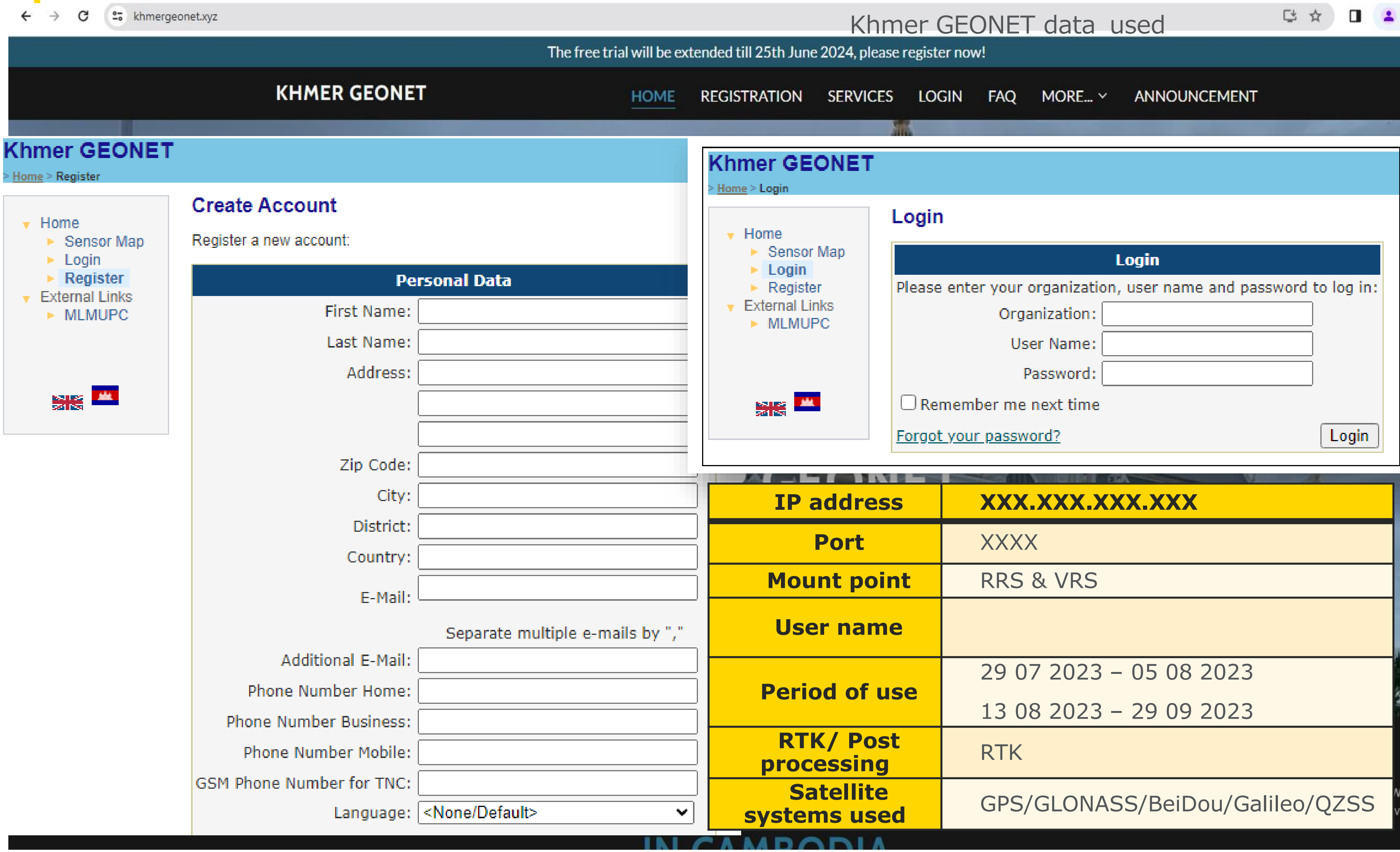
II. Work performed (Con.)

(5) Determine the repeatability of measurements under field conditions

Name	Easting	Diff.	Northing	Diff.	Elev.	Diff.	Start Time	End Time
Boundary1-1	434825.136		1261137.258		36.498		8/1/2023 11:00	8/1/2023 11:00
Boundary1-2	434825.135	-0.001	1261137.259	0.001	36.499	0.002	8/1/2023 11:00	8/1/2023 11:00
Boundary1-3	434825.131	-0.004	1261137.26	0.001	36.505	0.005	8/1/2023 11:00	8/1/2023 11:01
Boundary2-1	434876.952		1261035.41		36.3		8/1/2023 11:49	8/1/2023 11:49
Boundary2-2	434876.952	-	1261035.412	0.002	36.298	-0.002	8/1/2023 11:49	8/1/2023 11:49
Boundary2-3	434876.952	-0.001	1261035.411	-0.001	36.3	0.001	8/1/2023 11:49	8/1/2023 11:49
	Mean	**0**		**0**		**0**		
	Max	**0.004**		**0.002**		**0.005**		

Boundary Survey Results at Phnum Sruoch

III. Using Khmer GEONET



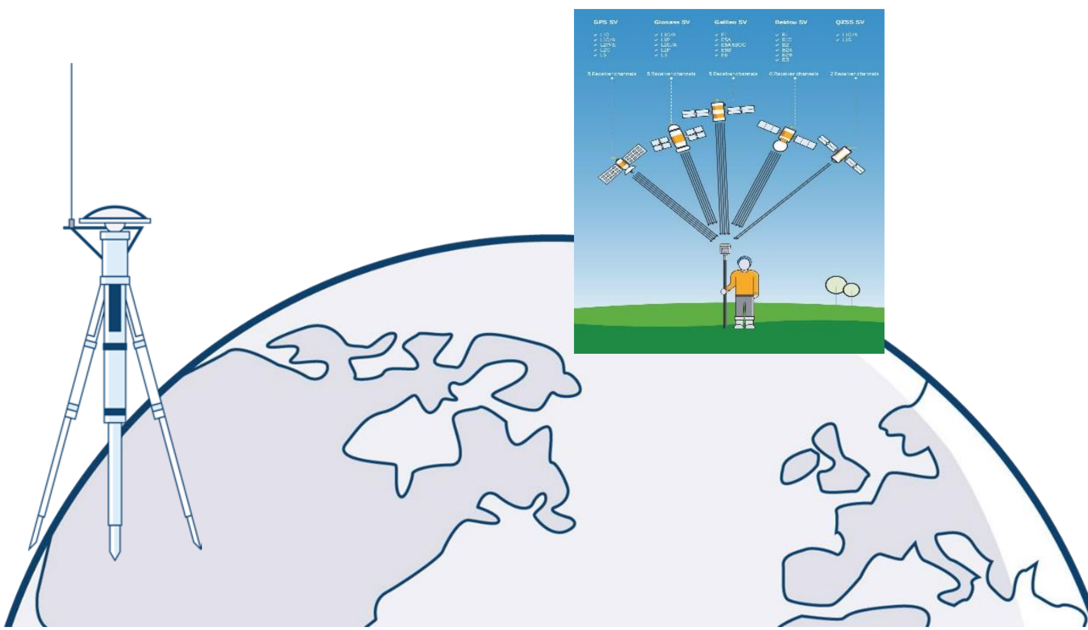
Khmer GEONET data used

IP address	**XXX.XXX.XXX.XXX**
Port	XXXX
Mount point	RRS & VRS
User name	
Period of use	29 07 2023 – 05 08 2023 13 08 2023 – 29 09 2023
RTK/ Post processing	RTK
Satellite systems used	GPS/GLONASS/BeiDou/Galileo/QZSS

III. Using Khmer GEONET (Con.)

Problems occurred and solutions

- No major problems were encountered with the Khmer GEONET network during the pilot project.
- No other related activities were performed during the pilot project.
- Based on the testing that we conducted, there are no outstanding issues to be resolved.



III. Using Khmer GEONET (Con.)

- **Good points using KhmerGEONET:** Based on the work conducted for this demonstration project would note the following positive points;

1. NRTK networks are more reliable than single base station networks, because even if a single station is offline, a correction signal can still be broadcast to rovers in that area.
2. NRTK networks are more accurate than single base solutions, particularly in their ability to model errors caused by ionospheric activity.
3. Khmer GEONET produces, precise, reliable network corrections that users can trust.
4. Khmer GEONET is based on open standards, meaning that all makes and models of GNSS rover receiver are supported, allowing access by a larger user base.

III. Using Khmer GEONET (Con.)

- **Good points using KhmerGEONET:**

5. The availability Khmer GEONET will reduce the cost and complexity for organizations who would otherwise have to operate their own base station. This will mean the wider adoption of GNSS positioning technologies over older surveying methods.

6. Khmer GEONET is based on an official, robust calculation of station coordinates, meaning that accuracy will be achieved and there will be a consistency between positioning by different organizations.

7. Khmer GEONET has proven to have a higher availability (uptime) than other base station infrastructure. This will mean that works can be completed in less time and for a lower cost.

III. Using Khmer GEONET (Con.)

➢ **Good points using KhmerGEONET:**

8. The availability of static data for download from Khmer GEONET is of great benefit for survey and engineering projects who need to establish control points on site.

9. Khmer GEONET has a large, active community and support is available to users who are learning the system or experiencing problems.

10. Khmer GEONET opens the possibility, for the first time, applications beyond land survey, including land and water navigation, precision agriculture, self-driving transportation to name a few.

IV. Recommendation

➢ **We would request the following points for improvement**;

1. Increased coverage in the country of Khmer GEONET
2. Guidance for users on the impact of ionospheric activity on survey accuracy, especially leading up to the solar maximum in July 2025.
3. Communication of periods of periods of highest solar activity on a daily basis
4. Practical guidance on how to manage/mitigate the impact on solar activity in the context of cadastral survey.

V. Conclusion

In conclusion, the results of the pilot project indicate that Khmer GEONET, with 5 stations is already providing a robust, reliable and acute correction to rovers in the field, operating under typical conditions.

With the expansion of the network to 99 stations, this reliability and robustness can be expected to increase, particularly in terms of redundancy and also for **Trimble Pivot** to model geometric error, the non-linear errors in the network and ionopheric error will consider how that might be impacting rover performance.

សូមអរគុណ

Report of JICA Pilot Project

(Utilize Khmer GEONET data in the construction project)

June 5 2024

IKEE PAVING SYSTEMS
TOPCON CORPORATION

JICA・Khmer GEONET Pilot project (Construction) in Cambodia

<u>Project Overview</u>

In this project, it was decided to evaluate the accuracy and workability of the conventional survey method for civil engineering construction and GNSS-based surveying using 3 cases.

1: Comparisons between Local RTK and N-RTK surveys (used Khmer GEONET)

2: Comparisons between the conventional survey (level survey) and GNSS survey (RTK survey by mmGPS)

3: Comparisons between Static survey and N-RTK(used Khmer GEONET)

IKEE [aiki:] PAVING SYSTEMS Cambodia

- The IPS was Established in 2015 (In Cambodia)
- VISION

Our construction company envisions pioneering innovation, sustainability, and efficiency in a developed country. Through cutting-edge technology, green practices, and a commitment to safety and quality, we aim to lead the industry while contributing to urban development and economic growth.

- Service:
  - Road Work Service and Consultation
  - Road and Pavement Construction
  - Road Stabilize Method Using Special Emulsion
  - Machinery Rental

Introduction of TOPCON (as of End/Mar 2024)

[aiki:] IKEE PAVING SYSTEMS

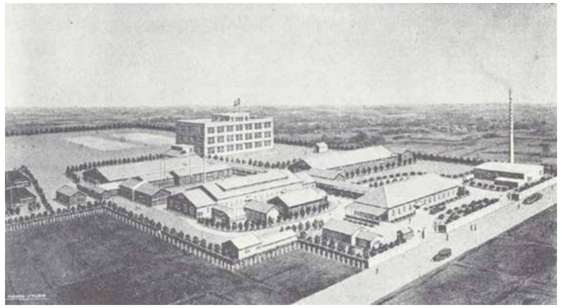
TOPCON

TOPCON

Net Sales	¥216B (Consolidation base) $1.44B (Consolidation base) ($1=¥150)
Number of Employee	5,556 (Consolidation base) (Japan staffs 30% only)
Number of Subsidiaries	64 (Equity method affiliate 6)

Head office at the time of establishment

Previously “Tokyo Optical Co., Ltd. “



Present

Established(1932)～1960’s | **1970’s-80’s** | **1990’s** | **2000’s～**

Pioneer of domestic optical instruments

A series of hit products with optomechatronics technology

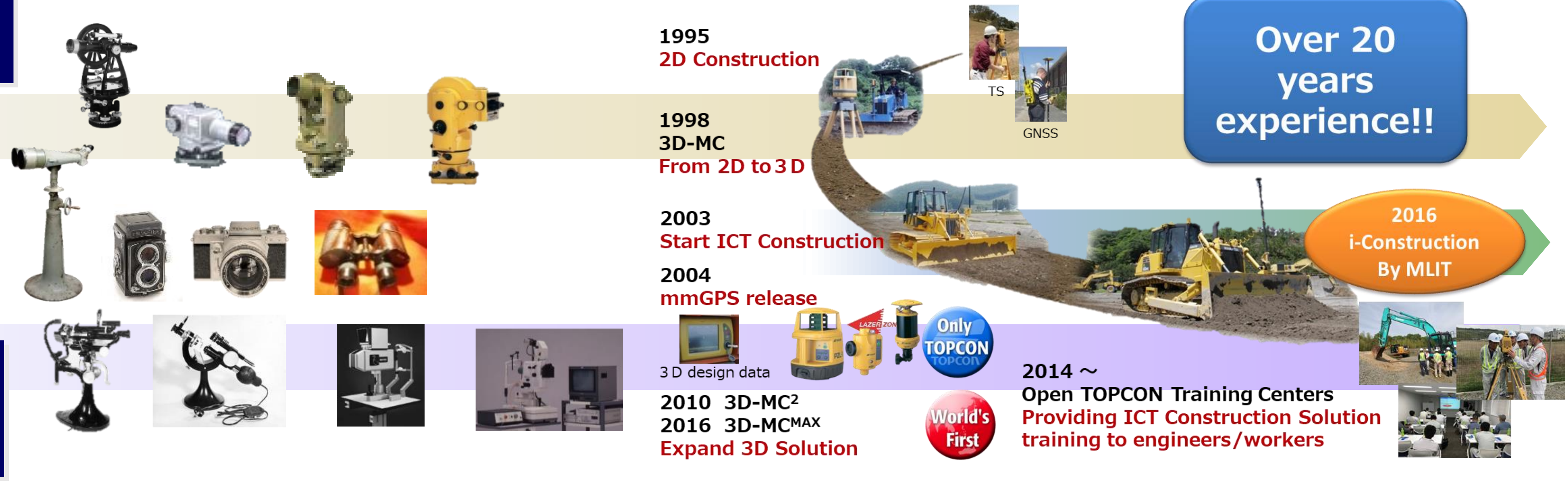
Expanding business with overseas’ M&A strategies

Acceleration of global investments

At the request from the former Imperial Army Ministry, K.Hattori & Co.(now Seiko Holdings Corp.) established Topcon in 1932.

Kintaro Hattori
Founder of Hattori Watch Shop (currently SEIKO HOLDINGS CORPORATION)

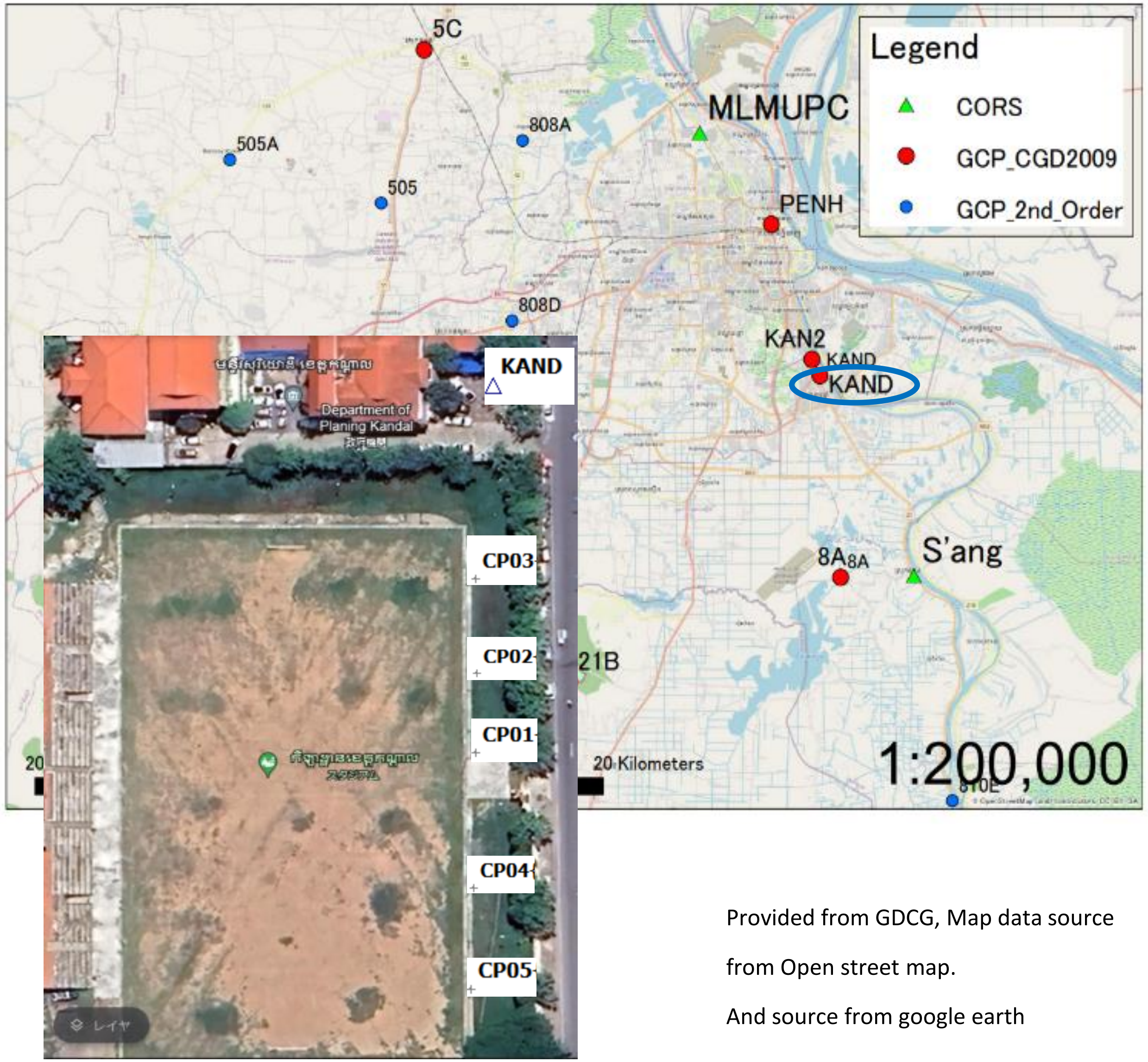
To achieve domestic production of surveying instruments



1: Comparisons between Local RTK and N-RTK surveys (used Khmer GEONET)

- It was decided to compare Local RTK and N-RTK (used Khmer GEONET) surveys using the First order Grand Control Point “KAND” located in Ta Khmau City, about 10 km south of Phnom Penh.

- RTK base point was established at the First order Grand Control Point KAND. Observation was performed at 5 points at a football pitch near the base point. The observation was performed by switching between Local RTK and N-RTK. (used Khmer GEONET)



Provided from GDCG, Map data source from Open street map. And source from google earth

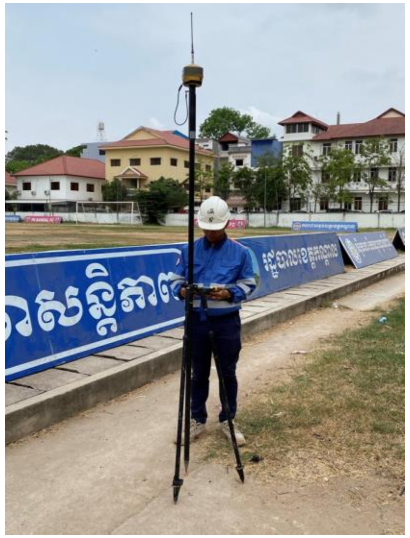
IKEE PAVING SYSTEMS TOPCON

1: Comparisons between Local RTK and N-RTK surveys (used Khmer GEONET)

Result

					RTK vs N-RTK		
		X	Y	H	△X	△Y	△H
RTK	CP01	1269085.567	494369.84	-3.754	0.013	-0.009	-0.057
	CP02	1269100.714	494369.331	-3.763	0.018	0.013	-0.013
	CP03	1269122.901	494369.271	-3.68	0.014	-0.003	-0.004
	CP04	1269070.061	494369.286	-3.77	0.012	0.002	-0.056
	CP05	1269047.824	494369.401	-3.818	0.005	0.004	-0.062
N-RTK	CP01	1269085.554	494369.849	-3.697			
	CP02	1269100.696	494369.318	-3.75			
	CP03	1269122.887	494369.274	-3.676			
	CP04	1269070.049	494369.284	-3.714			
	CP05	1269047.819	494369.397	-3.756			

⇒The average differences in accuracy between Local RTK survey using the locally established Grand Control Points and N-RTK survey (used Khmer GEONET) were 1.2 cm for X, 0.2 cm for Y, and -3.8 cm for H.

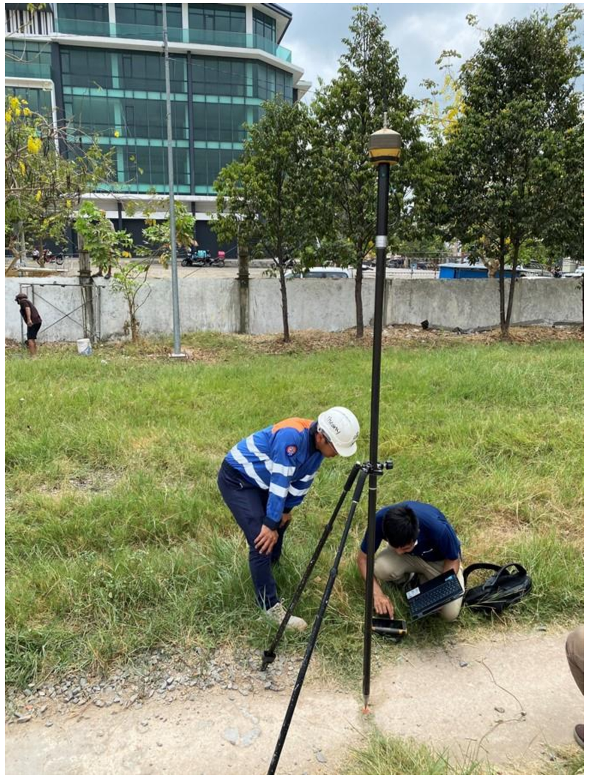


IKEE PAVING SYSTEMS TOPCON

1: Comparisons between Local RTK and N-RTK surveys (used Khmer GEONET)

- N-RTK survey（used Khmer GEONET） requires 20 minutes for observation, compared to 100 minutes for RTK survey, resulting in a 500% increase in productivity.

- N-RTK survey （used Khmer GEONET） requires 2 workers (or man-hours), compared to 3 for the RTK survey, resulting in a 150% increase in productivity.



	Look for & go to GCP	Set up base	Preparation of survey	surveying time	Number of Surveying staff	Working productivity
N-RTK	0mins	0mons	5mins	15mins	2 persons	◎
RTK	60mins	20mins	5mins	15mins	3 persons	○

2: Comparisons between the conventional survey (level survey) and GNSS survey (RTK survey by mmGPS)

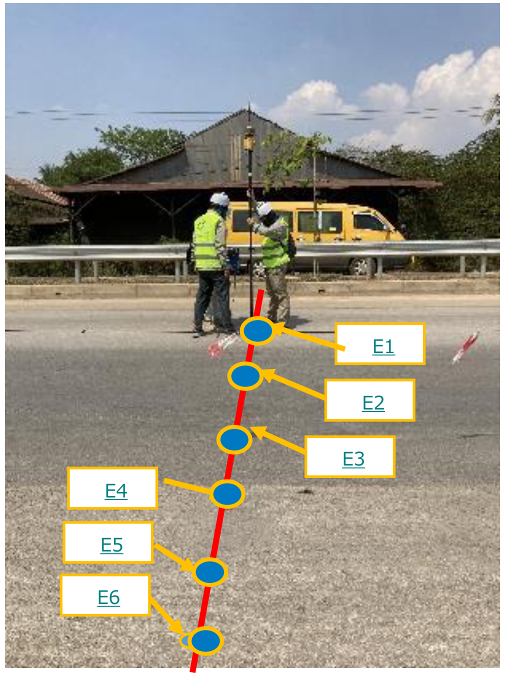
- Measurement site used for the selection of measurement areas were the JICA National Road No. 5 Improvement Project (in Phum Puk Chhma district in the suburbs of Battambang City).

- It was made to calculate coordinates of Grand Control Point (1 point) for base station of RTK survey and Grand Control Points (2 points) for set up laser transmitter by conducting Static survey at the site.

source from google map

2: Comparisons between the conventional survey (level survey) and GNSS survey (RTK survey by mmGPS)

- The cross-sections were provided with a pitch of 10 meters. Measurements were performed at 6 points per cross-section.
- Measurements were performed twice on the road surface previous and after the paved area. The pavement thickness was calculated from the height data.
- After measuring with the conventional method (level survey), the same point was measured with RTK (mmGPS) method.



Observation points for each cross-section

E1: A point 1.5 m from the center on the cross-section

E2: A point 2.35 m from the center on the cross-section

E3: A point 4.4 m from the center on the cross-section

E4: A point 5.75 m from the center on the cross-section

E5: A point 7.75 m from the center on the cross-section

E6: A point 9.0 m from the center on the cross-section

2: Comparisons between the conventional survey (level survey) and GNSS survey (RTK survey by mmGPS)

Result

Unit : m

STATION/Survey Result	E1			E2			E3		
	Paving thickness (Level) (m)	Paving thickness (mmGPS) (m)	Thickness reguation (over 0.045)(m)	Paving thickness (Level) (m)	Paving thickness (mmGPS) (m)	Thickness reguation (over 0.045)(m)	Paving thickness (Level) (m)	Paving thickness (mmGPS) (m)	Thickness reguation (over 0.045)(m)
281+820	0.053	0.051	0.045	0.053	0.052	0.045	0.057	0.055	0.045
281+830	0.057	0.049	0.045	0.059	0.051	0.045	0.063	0.051	0.045
281+840	0.061	0.049	0.045	0.055	0.052	0.045	0.061	0.056	0.045
281+850	0.054	0.046	0.045	0.063	0.052	0.045	0.066	0.055	0.045
281+860	0.059	0.045	0.045	0.063	0.052	0.045	0.064	0.056	0.045
281+870	0.058	0.053	0.045	0.063	0.059	0.045	0.065	0.058	0.045
281+880	0.051	0.052	0.045	0.058	0.055	0.045	0.061	0.058	0.045
281+890	0.045	0.054	0.045	0.054	0.056	0.045	0.055	0.058	0.045
281+900	0.049	0.053	0.045	0.053	0.052	0.045	0.051	0.054	0.045
281+910	0.052	0.057	0.045	0.056	0.062	0.045	0.050	0.059	0.045
281+920	0.051	0.060	0.045	0.056	0.060	0.045	0.050	0.058	0.045

STATION/Survey Result	E4			E5			E6		
	Paving thickness (Level) (m)	Paving thickness (mmGPS) (m)	Thickness reguation (over 0.045)(m)	Paving thickness (Level) (m)	Paving thickness (mmGPS) (m)	Thickness reguation (over 0.045)(m)	Paving thickness (Level) (m)	Paving thickness (mmGPS) (m)	Thickness reguation (over 0.045)(m)
281+820	0.058	0.053	0.045	0.062	0.051	0.045	0.052	0.064	0.045
281+830	0.063	0.052	0.045	0.053	0.055	0.045	0.062	0.059	0.045
281+840	0.061	0.056	0.045	0.059	0.054	0.045	0.062	0.059	0.045
281+850	0.059	0.051	0.045	0.053	0.046	0.045	0.045	0.045	0.045
281+860	0.061	0.057	0.045	0.053	0.050	0.045	0.052	0.051	0.045
281+870	0.066	0.059	0.045	0.060	0.060	0.045	0.055	0.054	0.045
281+880	0.069	0.060	0.045	0.053	0.055	0.045	0.056	0.058	0.045
281+890	0.056	0.059	0.045	0.054	0.054	0.045	0.061	0.063	0.045
281+900	0.052	0.054	0.045	0.051	0.048	0.045	0.066	0.062	0.045
281+910	0.054	0.059	0.045	0.054	0.060	0.045	0.051	0.060	0.045
281+920	0.052	0.055	0.045	0.049	0.056	0.045	0.054	0.064	0.045

⇒ The average observation difference of 66 observation points on all 11 cross-sections in the evaluation area was ±4 mm in accuracy, so it can be used for normal surveying even with GNSS survey method (mmGPS).

2: Comparisons between the conventional survey (level survey) and GNSS survey (RTK survey by mmGPS)

- The level survey requires 7 minutes for installation, compared to 20 for the RTK survey, resulting in a 35% decrease in productivity.
- Both the level survey and RTK survey require 5 minutes for observation per section, resulting in equivalent productivity, or 100%.
- The level survey requires 5 workers, compared to 2 for the RTK survey, resulting in a 250% increase in productivity.

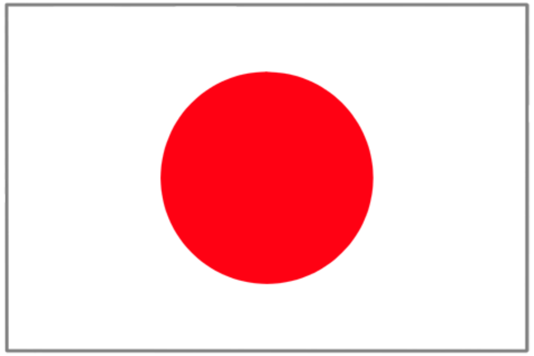
	See Bsck sight	Set up base	Preparation of survey	surveying time（1 cross section）	Number of Surveying staff	Working productivity
Level Survey	2mins	0mins	5mins	5mins	5 persons	○
RTK(mmGPS)	0mins	20mins	5mins	5mins	2 persons	◎

Conclusion

- It was understood that the use of N-RTK surveying using Khmer GEONET in the construction field is a highly productive surveying method that ensures the same level of measurement accuracy as conventional methods.

- With the expansion of the Khmer GEONET CORS network in Cambodia, anyone can use N-RTK anytime, anywhere, and we believe that the use of N-RTK will expand not only in the construction field, but also in the agriculture, transportation, and auto-mobile applications!

Thank you very much for your attention.
អរគុណច្រើនសម្រាប់ការយកចិត្តទុកដាក់របស់អ្នក។.



Provided from IKEE OAVING SYSTEMS, open ceremony of National road No.5

JC Group
Japan ⇆ Cambodia

Khmer GEONET Demonstration Project (Agri-Sector)

Feb-Aug2023

JC Agricultural Cooperatives Co., Ltd.

About US_JC Agricultural Cooperatives

JC Group

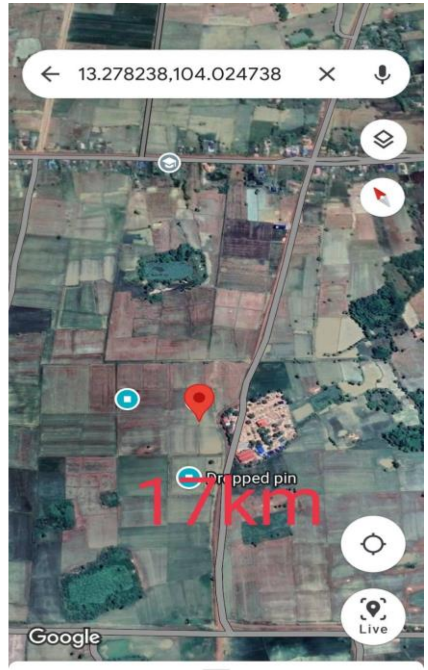
About Company

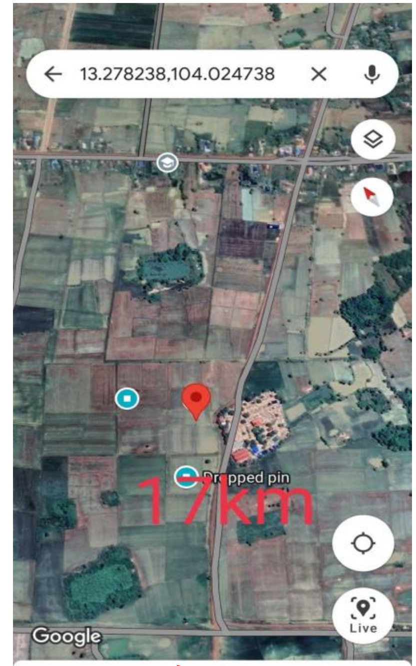
JC Agricultural cooperative co., Ltd.(JCAC) was registration since 21-November-2016

JCAC was founded for supporting local farmers in Cambodia, providing machinery service and smart-agri-solution.

Add: #21, Dang Kao Teab Village, Tul Ta Ek Sangkat, Battambang City, Battambang Province.

Our Scope_ Location of project





- Selected 3 sites according to the distance from CORS in SiemReap
- Comparison of RTK flight and GNSS flight (Non-RTK) at each site

Finding local farmers to collaborate

N	Customer Name	Customer Address	Disttance from CORS		Farm HA
			Range	Actual	
1	Mr.Sat Saem	Tropangron Village, Ampil Commune ,SPR city.	5km	5.82km	1.5
2	Ms.Khoeun Samnang	Trobangron Village, Ampil Commune ,SPR city.	5km	5km	1.5
3	Mr.Tol	Donnum Village ,Mean Chey commune Bakong district ,SRP.	10-15km	13km	1
4	Mr.Orl	Donnum Village ,Mean Chey commune Bakong district ,SRP.	10-15km	13km	2
5	Ms.Nhaoch	Donnum Village ,Mean Chey commune Bakong district ,SRP.	10-15km	13km	1
6	Mr.Chea	Lvea Village Tropangthom commune Bakong district ,SRP	17-20km	17km	2
7	Mr.Vanndy	Lvea Village Tropangthom commune Bakong district ,SRP	17-20km	17km	1
8	Mr.Than	Lvea Village Tropangthom commune Bakong district ,SRP	17-20km	17km	1

Machineries used for demonstration

DJI AgrasT10

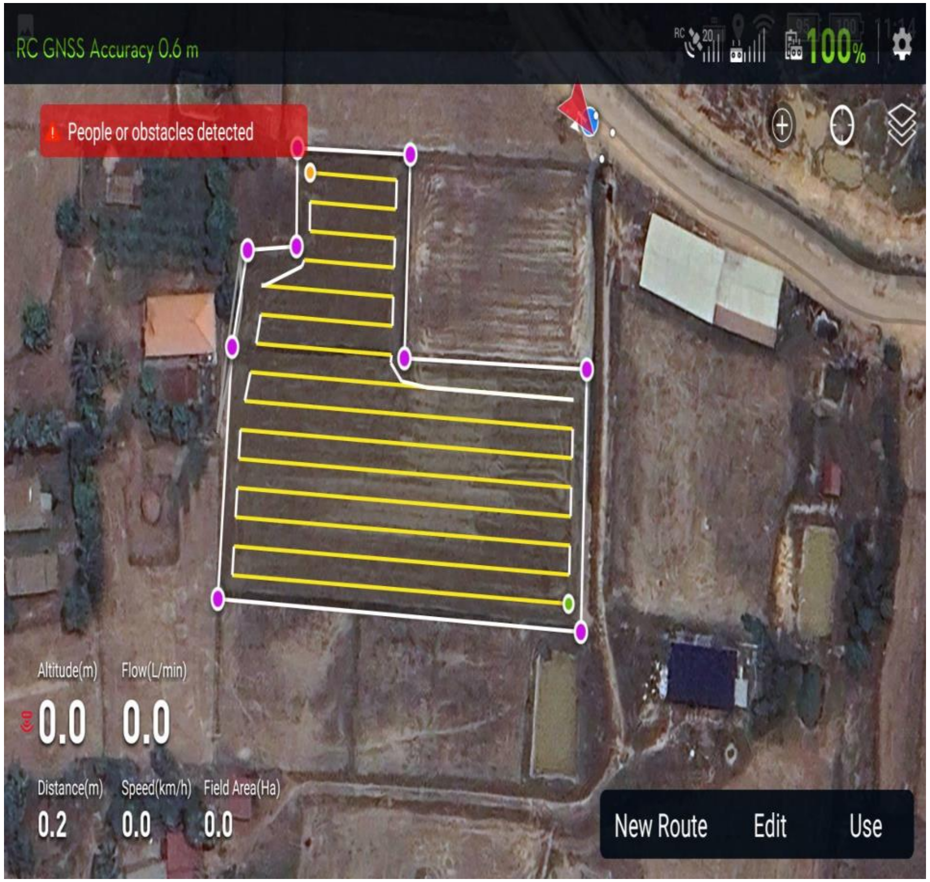
- Drone for spraying chemicals/fertilizer from above the farmland
- Sprayed free for local farmers who collaborate with us for this project

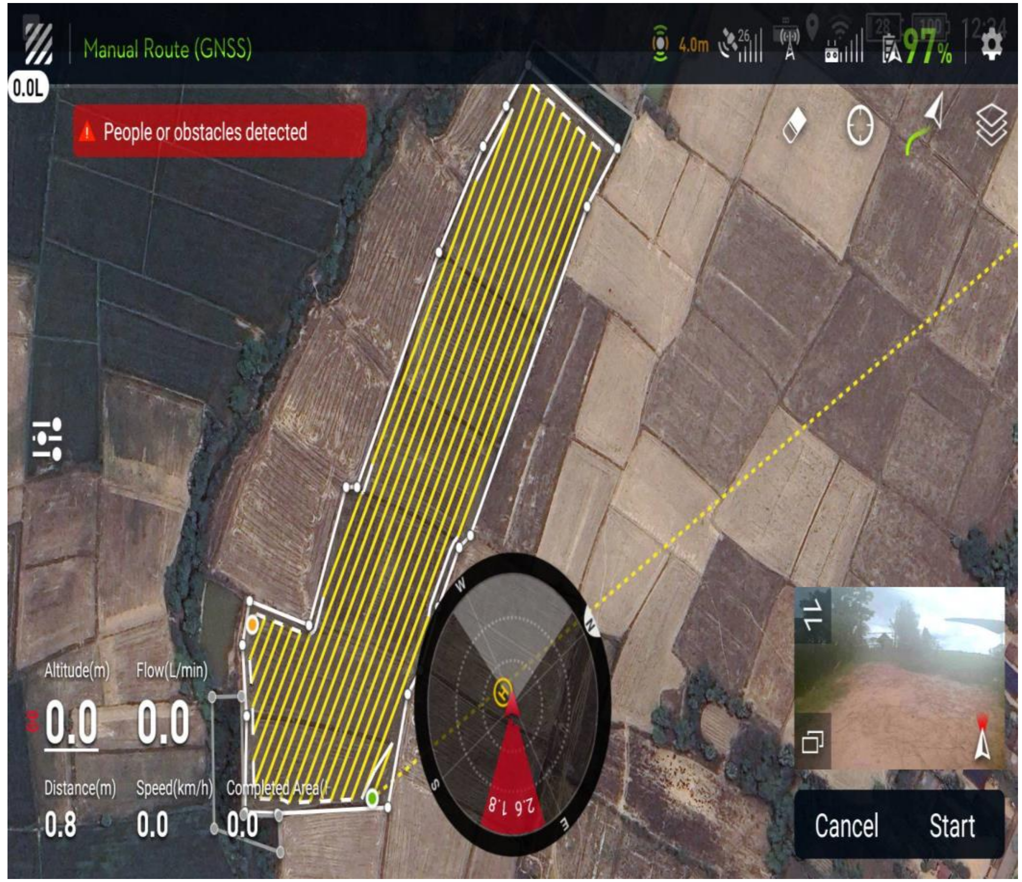
DJI Phantom4 RTK

- Drone for taking pictures
- Flight for standard deviation analysis

Spray Drone Flight

Auto-Flight-Plan for accurate spray

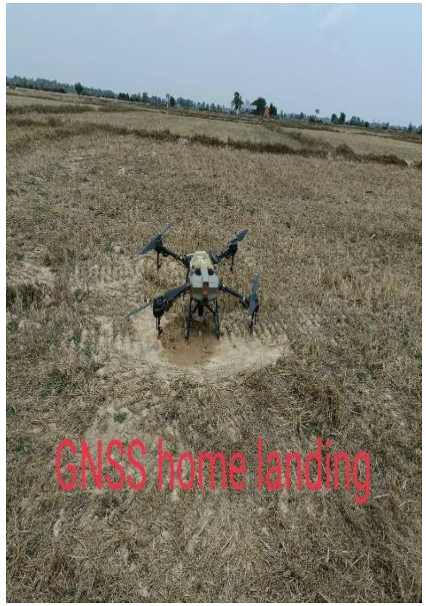




Difference between RTK and GNSS

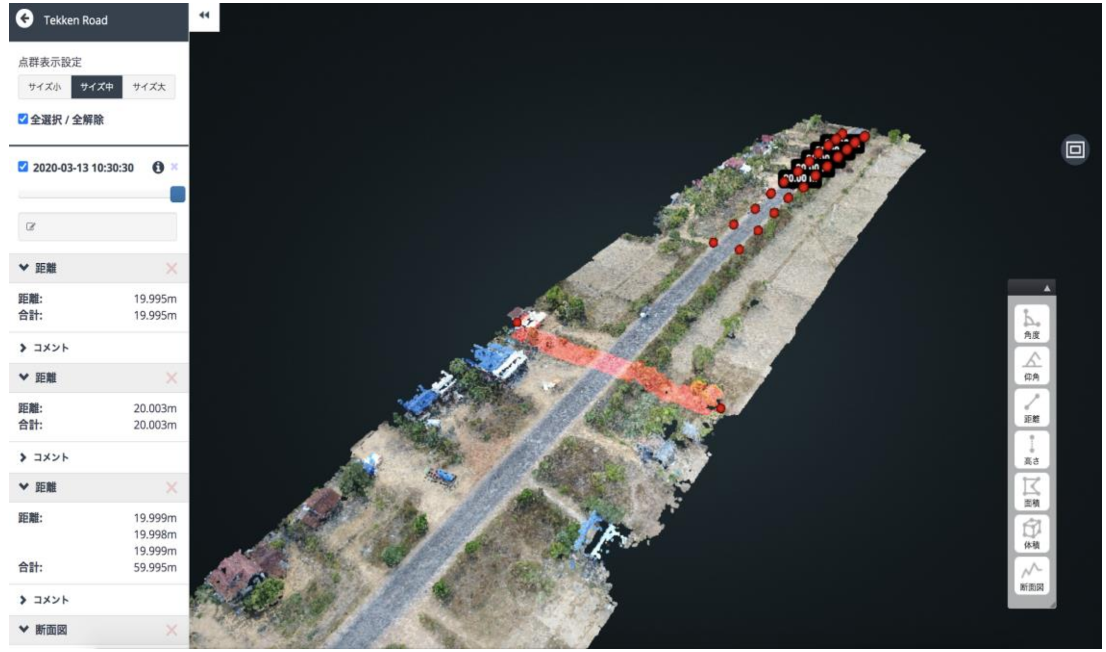
Landing by RTK Flight

Landing by GNSS Flight



KUMIKI for standard deviation analysis

JC Group



Note : Now introducing in Cambodia
supported by JICA Project

SkymatiX
Remote Sensing as a Service

Standard Deviation Analysis by KUMIKI

Distance fromCORS	Coordinate	Standard Deviation (m)		
		RTK	Non-RTK	Difference
12km	x	0.064	0.240	-0.176
	y	0.032	0.315	-0.283
	z	0.021	0.292	-0.271
17km	x	0.075	0.369	-0.294
	y	0.102	0.301	-0.199
	z	0.410	0.299	0.111

Drone Flight under KhmerGEONET
showed more accurate result than GNSS

Future Outlook

JC Group

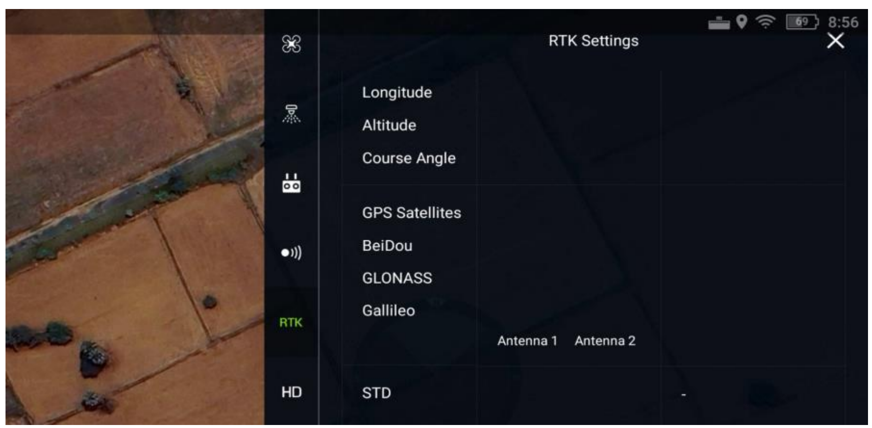
- RTK flight under Khmer GEONET shows more accuracy in coordinate information than GNSS(No-RTK) flight

- In Current operation custom, flight of spray-drone does not necessarily require accurate coordinate information

- But in the future, various "Smart-Agri-Solutions" which require accurate coordinate information will be introduced in Cambodia, and Khmer GEONET must be the necessary IT infrastructure
  - Self-drive/drive assistant service of tractor and harvester
  - Irrigation system with auto-water-adjusting function

Khmer GEONET Data Used

IP address	cgd09.khmergeonet.xyz
Port	2101
Mount point	RRS_RTCM32
User name	JCG
Period of use	16-Mar-2023 - 28-Mar-2023 11-April-2023– 24-May-2023 14-June-2023– 25-July-2023
RTK/ Post processing	Network RTK
Satellite systems used	GPS, BeiDou, GLONASS, Gallileo (picture of drone controller as below)



JC Group

Thank you for kind attention

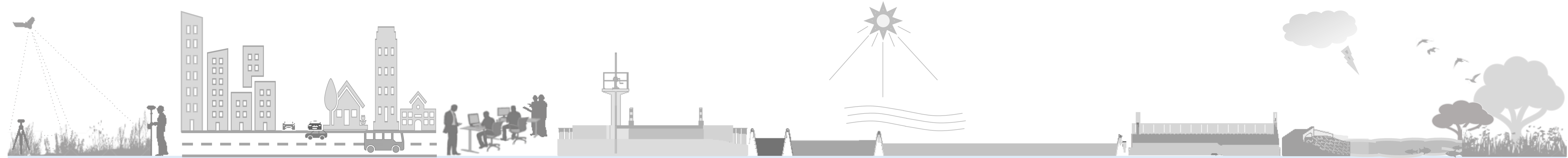
Project on Establishment of Continuously Operating Reference Station (CORS) for Land Management and Infrastructure Development

PLANNING PAPER OF THE DEMONSTRATION PROJECT FOR JICA PILOT PROJECT

KEY CONSULTANTS (CAMBODIA)

Assessment for the Efficiency and Accuracy of Khmer GEONET CORS Application for Flood Inundation Study in Siem Reap Town

jica



CONTENT:

I. BACKGROUND

- ABOUT US
- OBJECTIVE OF THE PROJECT

II. METHOD AND TOOLS

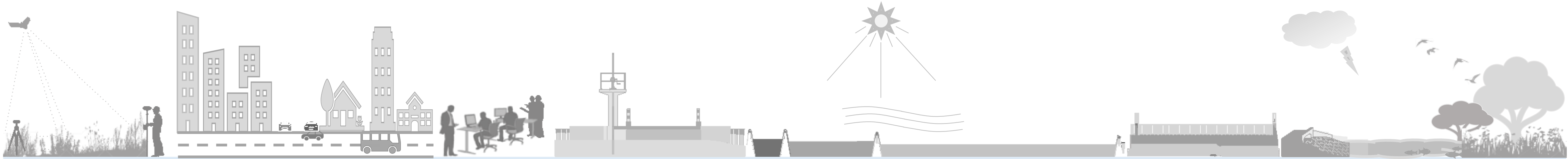
- STATIC SURVEY
- REAL TIME KENAMATIC SURVEY (RTK)
- DRONE SURVEY

III. FINDING AND DISCUSSION

- COMPARISION RESULT FROM KHMER GEONET VS NATIONAL BM ZERO GRADE
- EFFICIENCY OF USING KHMER GEONET

IV. APPLICATION FOR FLOOD INUNDATION STUDY IN SIEM REAP CITY

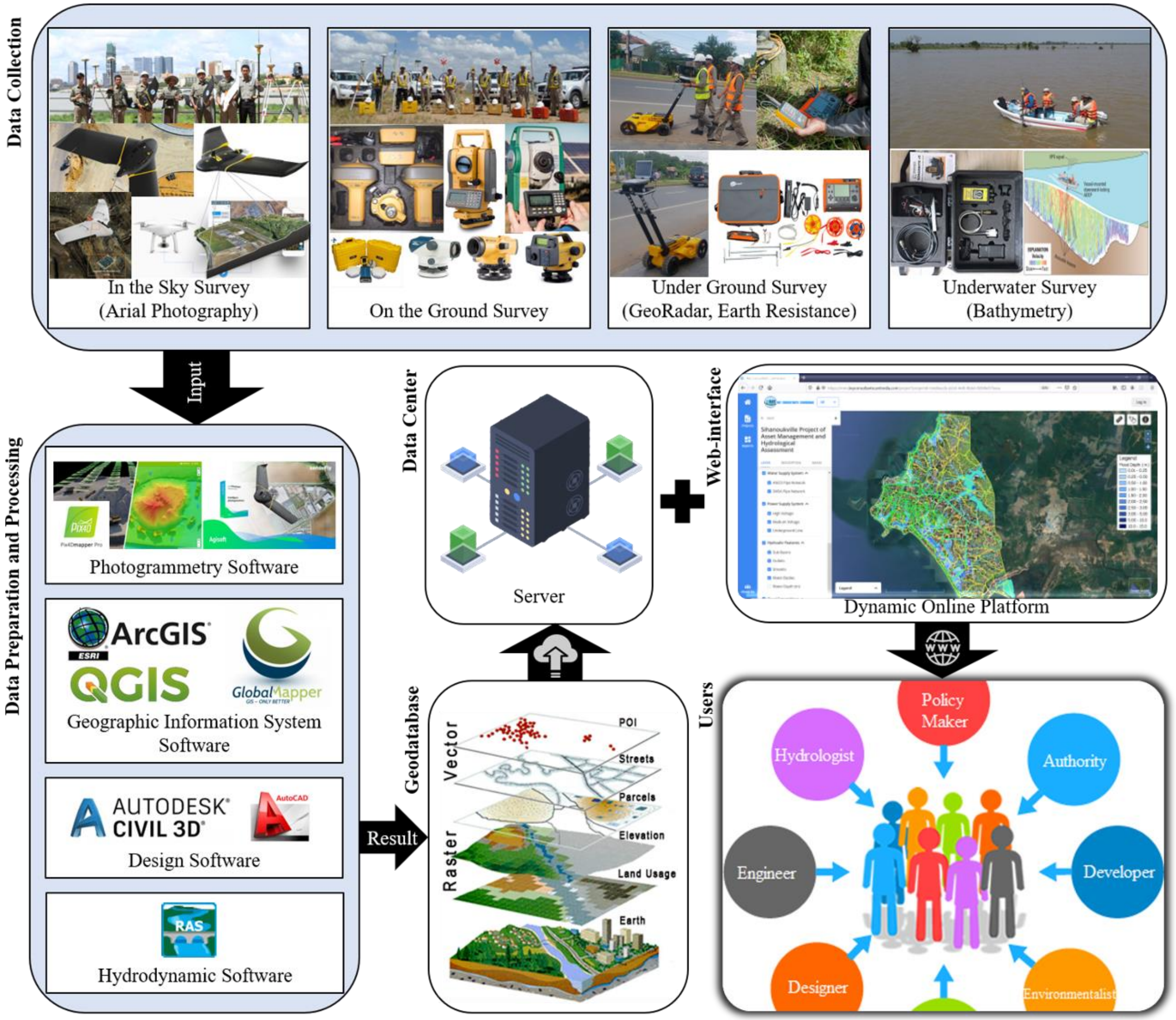
V. CONCLUSION

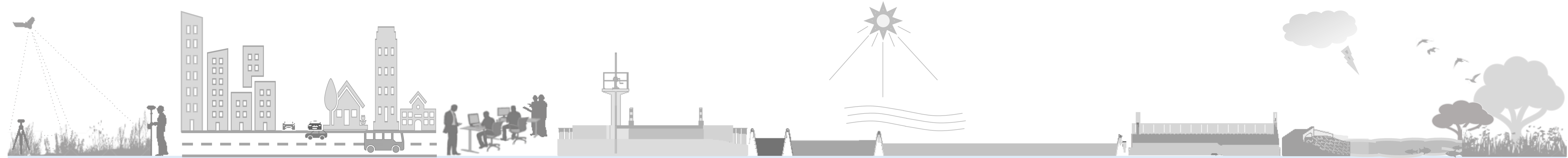


I. BACKGROUND

■ ABOUT US:

KEY CONSULTANTS (CAMBODIA) Ltd. is a Cambodian consulting firm with over 20 years of experience. KCC offers a wide range of services including Water Sanitation & Environment, **Topography and GIS**, Urban Planning and Design, Water Resources and Rural Infrastructure, and Social Economic and Institutional Development. Our team of professionals aims to provide clients with cost-effective solutions.





I. BACKGROUND

OBJECTIVE OF THE PROJECT

The study was aimed:

(i) To compare the advantages of using a CORS-connected unmanned aerial vehicle (UAV) versus the National BM zero-order control

(ii) To compare the coordinate data obtained from KHMER GEONET CORS SIE-1 and the coordinate data obtained from the National BM zero-order control and

(iii) To use the Digital Elevation Model (DEM) as the product from the CORS for flood study.

I. BACKGROUND

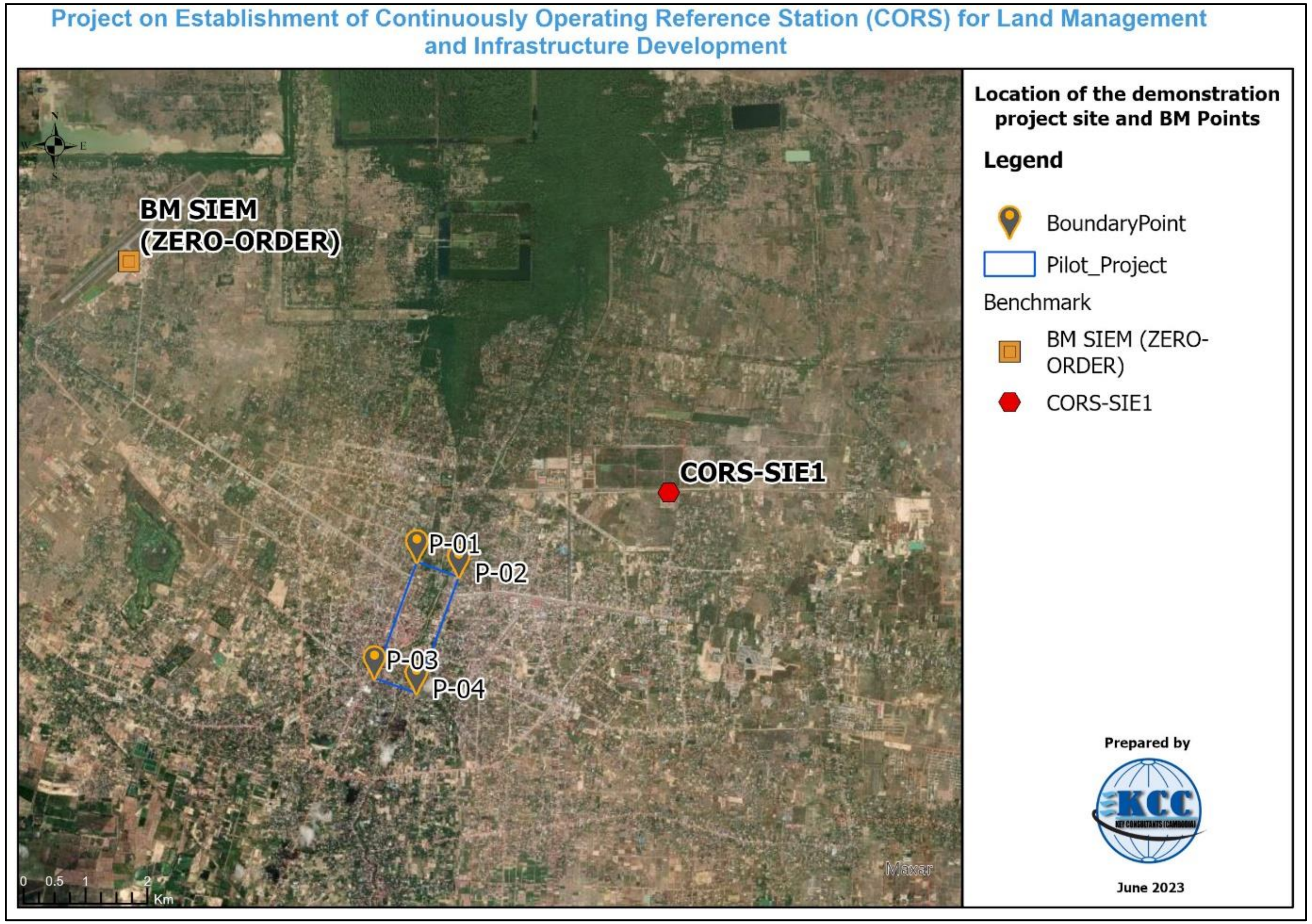
OBJECTIVE OF THE PROJECT

The study was aimed:

(i) To compare the advantages of using a CORS-connected unmanned aerial vehicle (UAV) versus the National BM zero-order control

(ii) To compare the coordinate data obtained from KHMER GEONET CORS SIE-1 and the coordinate data obtained from the National BM zero-order control and

(iii) To use the Digital Elevation Model (DEM) as the product from the CORS for flood study.



II. METHOD AND TOOLS

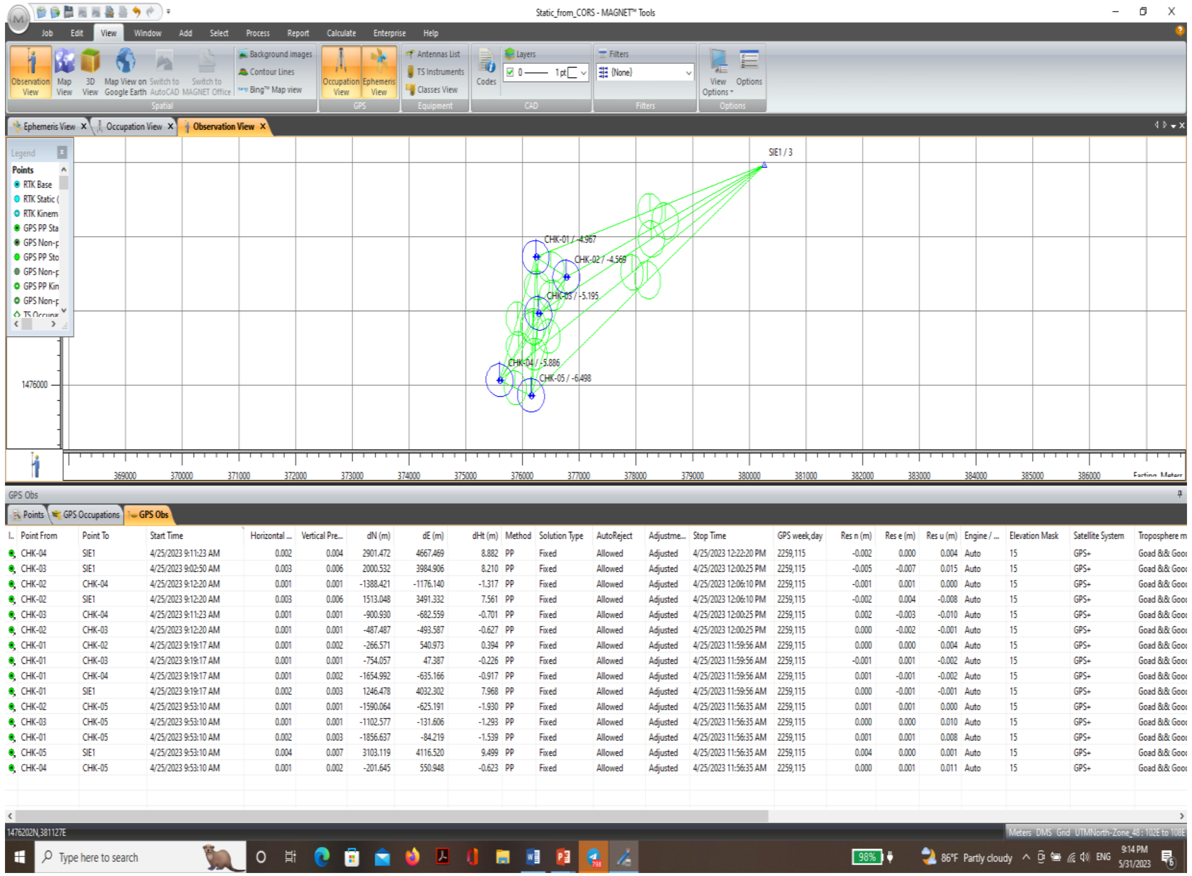
■ STATIC SURVEY

(i) Both of KHMER GOENET CORS SIE-1 and National BM Zero-order were used as Static Reference points

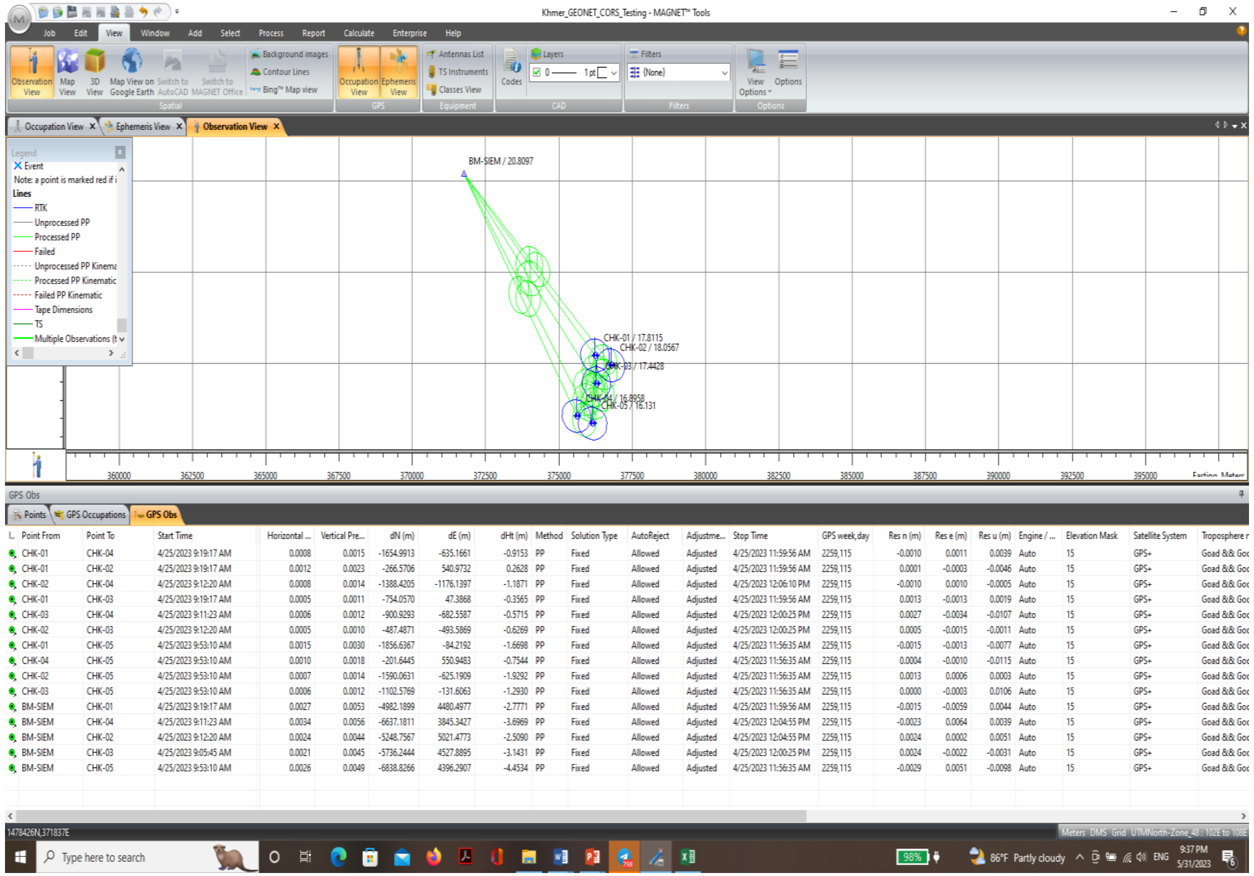
(ii) Five Ground Check Points were measured by using Static Survey and RTK Survey in order to compare the result from both Reference Stations.

II. METHOD AND TOOLS

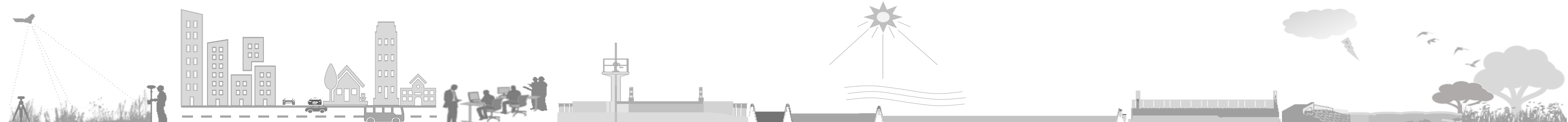
STATIC SURVEY



USING STATIC LOG FILE FROM KHMER GEONET TO CONDUCT STATIC POST PROCESSING IN MAGNET TOOLS



USING STATIC LOG FILE NATIONAL BM ZERO-ORDER TO CONDUCT STATIC POST PROCESSING IN MAGNET TOOLS



II. METHOD AND TOOLS

- **REAL TIME KENAMATIC SURVEY (RTK)**

(i) Several brands of GNSS rovers were used to connect to Khmer Geonet Cors such as CHC-i90, Sokkia GRX-3

(ii) The measurement was performed along river bank and river bed of the Siem Reap river in order to get coordinate and elevation of points of interest.

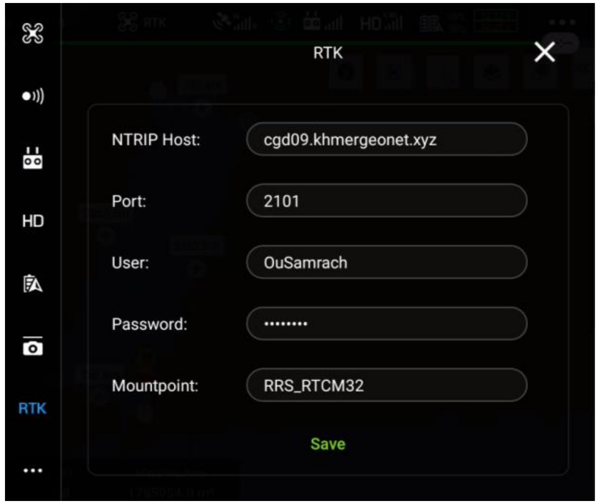
II. METHOD AND TOOLS

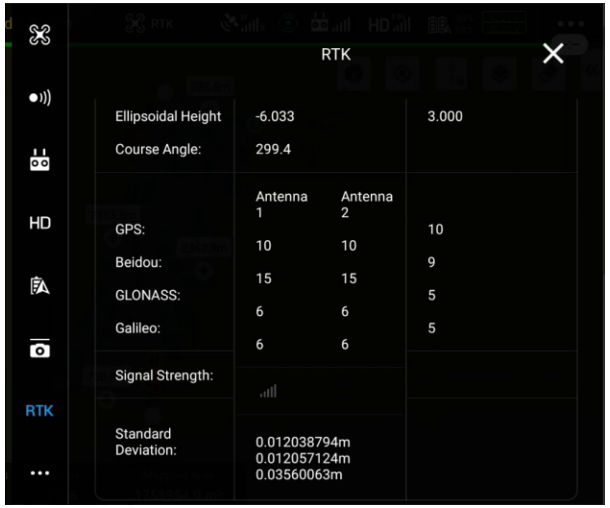
■ DRONE SURVEY

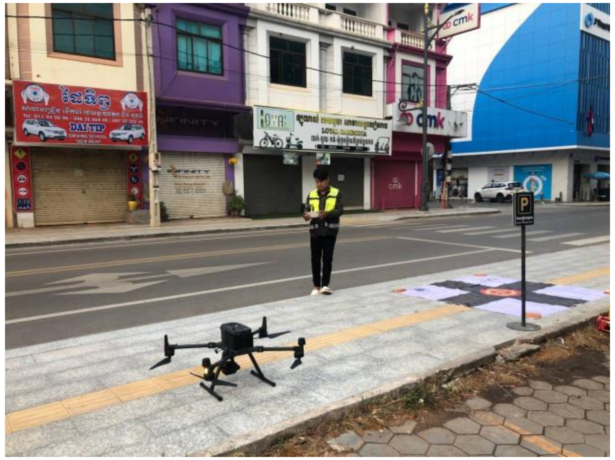
(i) Multi Rotor Drone (DJI M300 RTK) was used to conduct aerial photogrammetry with two different references (Khmer GEONET and National BM zero-order)

(ii) Pix4D Mapper software was assisted for images mosaic and DTM generation.

(iii) Coordinate of Ground Check Points were extracted from both Orthophoto images data set to compare its accuracy.







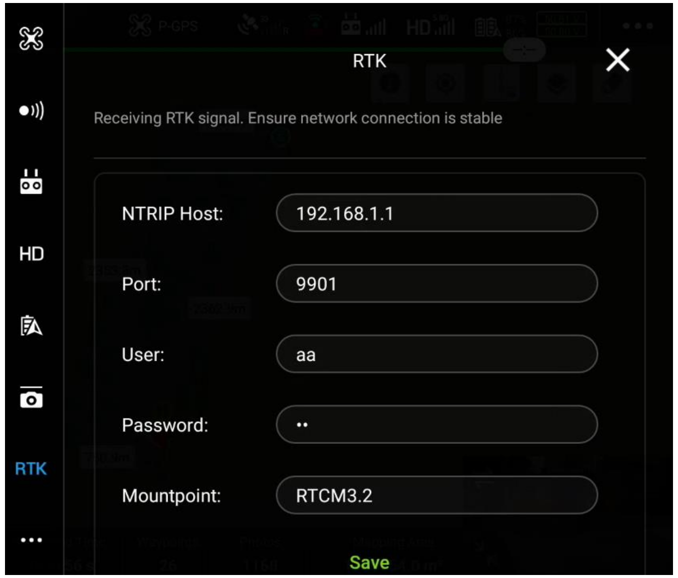
II. METHOD AND TOOLS

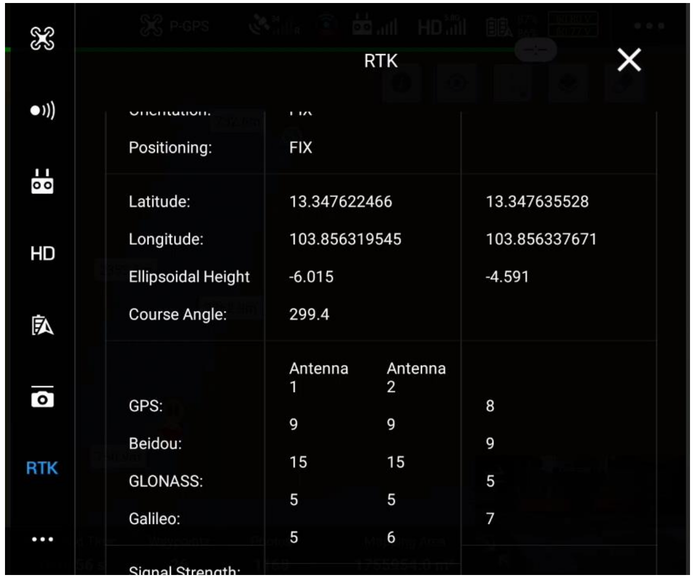
■ DRONE SURVEY

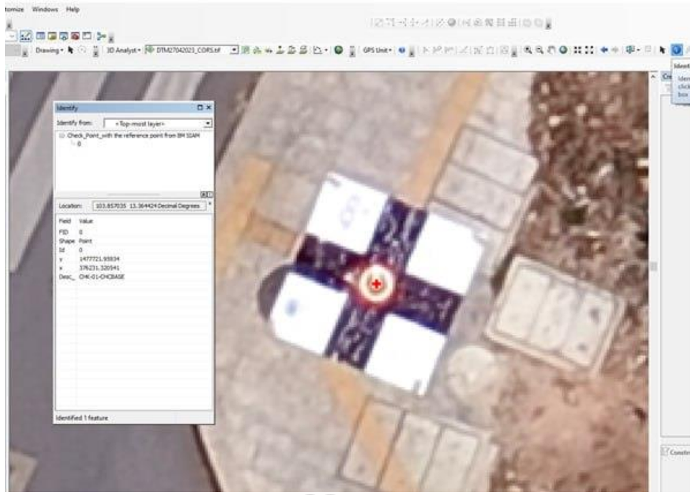
(i) Multi Rotor Drone (DJI M300 RTK) was used to conduct aerial photogrammetry with two different references (Khmer GEONET and National BM zero-order)

(ii) Pix4D Mapper software was assisted for images mosaic and DTM generation.

(iii) Coordinate of Ground Check Points were extracted from both Orthophoto images data set to compare its accuracy from GIS software.







III. FINDING AND DISCUSSION

CONDUCTED MEASUREMENT

Five data set (N, E, Z) of ground check points were acquired from different method of measurement

- Static Survey (Ref. point Khmer Geonet Cors)
- Static Survey (Ref. National BM Zero-Order)
- RTK (Ref. point Khmer Geonet Cors)
- Extracted from orthophoto image (Ref.point Khmer Geonet)
- Extracted from orthophoto image (Ref.point National BM Zero-order)

III. FINDING AND DISCUSSION

TABLE-1 COORDINATE DATA FROM STATIC SURVEY (REF. BM ZERO-ORDER)

STATIC SURVEY (REF.BM ZERO-ORDER)			
name	Northing	Easting	Ellip height
CHK-1	1477721.979	376231.393	-5.2034
CHK-2	1477455.407	376772.368	-4.9582
CHK-3	1476967.918	376278.781	-5.5722
CHK-4	1476066.983	375596.223	-6.1195
CHK-5	1475865.337	376147.175	-6.8843

TABLE-2 COORDINATE DATA FROM STATIC SURVEY (REF. KHMER GEONET CORS SIE-1)

STATIC SURVEY (KHMER GEONET CORS SIE-1)			
name	Northing	Easting	Ellip height
CHK-1	1477721.996	376231.396	-4.967
CHK-2	1477455.425	376772.369	-4.569
CHK-3	1476967.938	376278.784	-5.195
CHK-4	1476067.005	375596.228	-5.886
CHK-5	1475865.360	376147.178	-6.498

TABLE-3 COORDINATE DATA FROM RTK SURVEY (REF. KHMER GEONET CORS SIE-1)

RTK SURVEY (KHMER GEONET CORS SIE-1)			
name	Northing	Easting	Ellip height
CHK-1	1477721.990	376231.398	-4.979
CHK-2	1477455.439	376772.371	-4.665
CHK-3	1476067.006	375596.201	-5.857
CHK-4	1476967.935	376278.778	-5.310
CHK-5	1475865.332	376147.174	-6.627

TABLE-4 COORDINATE DATA EXTRACTED FROM DRONE IMAGERY (REF. BM ZERO-ORDER)

EXTRACTED FROM DRONE IMAGERY (REF. BM ZERO-ORDER)			
name	Northing	Easting	raster value
CHK-1	1477721.959	376231.321	-5.081
CHK-2	1477455.464	376772.432	-4.794
CHK-3	1476967.925	376278.767	-5.408
CHK-4	1475865.404	376147.216	-6.647
CHK-5	1476067.017	375596.192	-5.895

III. FINDING AND DISCUSSION

TABLE-5 COORDINATE DATA EXTRACTED FROM DRONE IMAGERY (REF. KHMER GEONET CORS SIE-1)

EXTRACTED FROM DRONE IMAGERY (KHMER GEONET CORS SIE-1)			
name	Northing	Easting	raster value
CHK-1	1477721.970	376231.355	-4.755
CHK-2	1477455.450	376772.381	-4.452
CHK-3	1476967.948	376278.736	-5.100
CHK-4	1475865.405	376147.184	-6.302
CHK-5	1476066.991	375596.204	-5.613

III. FINDING AND DISCUSSION

- **DISCUSSION:**

(i) Using Statistical analysis to find out the accuracy of the measurement from the above five different methods.

TABLE-6 COORDINATE CHECK POINT FROM FIVE DIFFERENT METHOD

Point	Method	Northing	Easting	Ellip. Height
CHK-1	1	1477721.979	376231.393	-5.203
	2	1477721.996	376231.396	-4.967
	3	1477721.990	376231.398	-4.979
	4	1477721.959	376231.321	-5.081
	5	1477721.970	376231.355	-4.755
CHK-2	1	1477455.407	376772.368	-4.958
	2	1477455.425	376772.369	-4.569
	3	1477455.439	376772.371	-4.665
	4	1477455.464	376772.432	-4.794
	5	1477455.450	376772.381	-4.452
CHK-3	1	1476967.918	376278.781	-5.572
	2	1476967.938	376278.784	-5.195
	3	1476967.935	376278.778	-5.310
	4	1476967.925	376278.767	-5.408
	5	1476967.948	376278.736	-5.100
CHK-4	1	1476066.983	375596.223	-6.120
	2	1476067.005	375596.228	-5.886
	3	1476067.006	375596.201	-5.857
	4	1476067.017	375596.192	-5.895
	5	1476066.991	375596.204	-6.302
CHK-5	1	1475865.337	376147.175	-6.884
	2	1475865.360	376147.178	-6.498
	3	1475865.332	376147.174	-6.627
	4	1475865.404	376147.216	-6.647
	5	1475865.405	376147.184	-6.302

III. FINDING AND DISCUSSION

- **DISCUSSION:**

(i) Using Statistical analysis to find out the accuracy of the measurement from the above five different methods.

TABLE-7 STATISTICAL ANALSIS FOR CHECK POINT-1 FROM FIVE DIFFERENT METHOD

Point	METHOD	Diff N	Diff E	RMSE_N	RMSE_E
CHK-1	Method-1	0.000061999774	0.020398799970	0.013308004	0.030405187
	Method-2	0.017261999892	0.023498800001		
	Method-3	0.011261999840	0.025498799980		
	Method-4	0.019398000091	0.051960200013		
	Method-5	0.009188000113	0.017436199996		
Mean		0.000000000140	0.000000000012		
Standar Deviation of Diff		0.014878801012	0.033994032189		
Paired T-Tests		0.000000020995	0.000000000766		
Correlation Analysis		0.920438638322			

TABLE-8 STATISTICAL ANALSIS FOR CHECK POINT-2 FROM FIVE DIFFERENT METHOD

Point	METHOD	Diff N	Diff E	RMSE_N	RMSE_E
CHK-2	Method-1	0.029908000259	0.015980400029	0.019642422	0.024428678
	Method-2	0.012008000165	0.015380400000		
	Method-3	0.001991999801	0.013380400022		
	Method-4	0.026651999680	0.047982599994		
	Method-5	0.013271999778	0.003241400002		
Mean		0.000000000233	0.000000000012		
Standar Deviation of Diff		0.021960895222	0.027312092423		
Paired T-Tests		0.000000023707	0.000000000953		
Correlation Analysis		0.880174441809			

III. FINDING AND DISCUSSION

- **DISCUSSION:**

(i) Using Statistical analysis to find out the accuracy of the measurement from the above five different methods.

TABLE-9 STATISTICAL ANALSIS FOR CHECK POINT-3 FROM FIVE DIFFERENT METHOD

Point	METHOD	Diff N	Diff E	RMSE_N	RMSE_E
CHK-3	Method-1	0.014926000033	0.012068200042	0.010585748	0.017737802
	Method-2	0.005274000112	0.014868200000		
	Method-3	0.002274000086	0.008868200006		
	Method-4	0.008085999871	0.002300799999		
	Method-5	0.015463999938	0.033503799990		
Mean		0.000000000047	0.000000000012		
Standar Deviation of Diff		0.011835226218	0.019831465461		
Paired T-Tests		0.000000008798	0.000000001313		
Correlation Analysis		0.918899458717			

TABLE-10 STATISTICAL ANALSIS FOR CHECK POINT-4 FROM FIVE DIFFERENT METHOD

Point	METHOD	Diff N	Diff E	RMSE_N	RMSE_E
CHK-4	Method-1	0.017786000157	0.013580399973	0.012209815	0.013597433
	Method-2	0.004613999743	0.018180399959		
	Method-3	0.005613999907	0.008819600043		
	Method-4	0.016963999951	0.017325600027		
	Method-5	0.009406000143	0.005615600036		
Mean		0.000000000140	0.000000000035		
Standar Deviation of Diff		0.013650988272	0.015202392337		
Paired T-Tests		0.000000022883	0.000000005137		

III. FINDING AND DISCUSSION

- **DISCUSSION:**

(i) Using Statistical analysis to find out the accuracy of the measurement from the above five different methods.

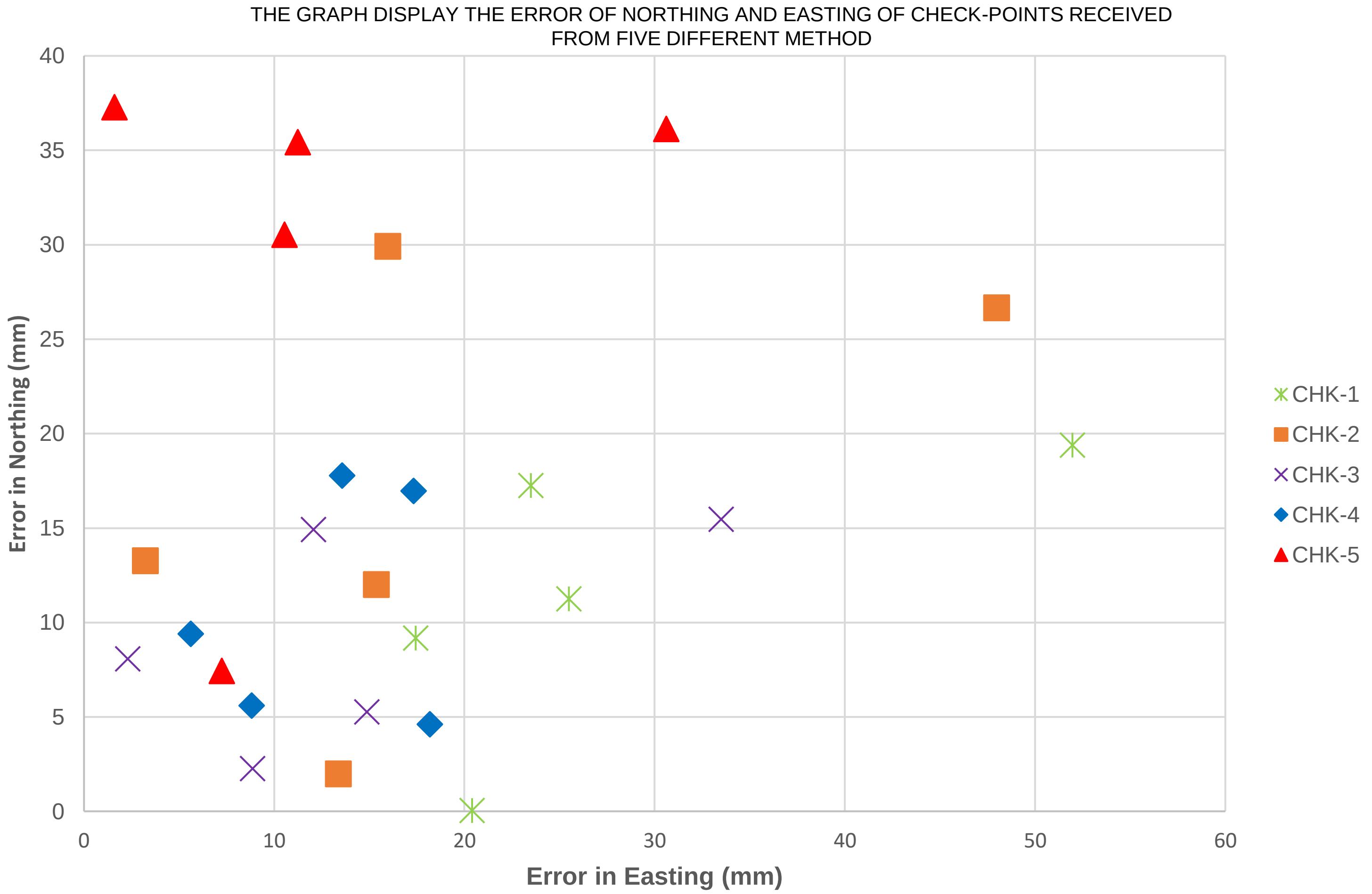
TABLE-11 STATISTICAL ANALSIS FOR CHECK POINT-5 FROM FIVE DIFFERENT METHOD

Point	METHOD	Diff N	Diff E	RMSE_N	RMSE_E
CHK-5	Method-1	0.030537999934	0.010540199932	0.031429967	0.015684311
	Method-2	0.007437999826	0.007240199891		
	Method-3	0.035437999992	0.011240199907		
	Method-4	0.036132000154	0.030619800091		
	Method-5	0.037282000063	0.001599199895		
Mean		0.000000000093	0.000000000093		
Standar Deviation of Diff		0.035139771231	0.017535592383		
Paired T-Tests		0.000000005926	0.000000011876		

III. FINDING AND DISCUSSION

- **DISCUSSION:**

(i) Using Statistical analysis to find out the accuracy of the measurement from the above five different methods.



III. FINDING AND DISCUSSION

- **EFFICIENCY OF USING KHMER GEONET:**

(i) Required budget was calculated for field data collection by two different method (Khmer Geonet Cors vs Conventional method

TABLE-12 COST EXPANCE USING CONVENTIONAL METHOD

No.	Description	Unit	Qty.	Approximate Amount (USD)
1	GNSS receiver	No	5	$5,580.00
2	GNSS receiver operator	person	5	
3	Leveling Instrument	No	2	
4	Leveling operator	person	6	
5	Leveling staff holder	person	4	
6	Transportation	No	1	

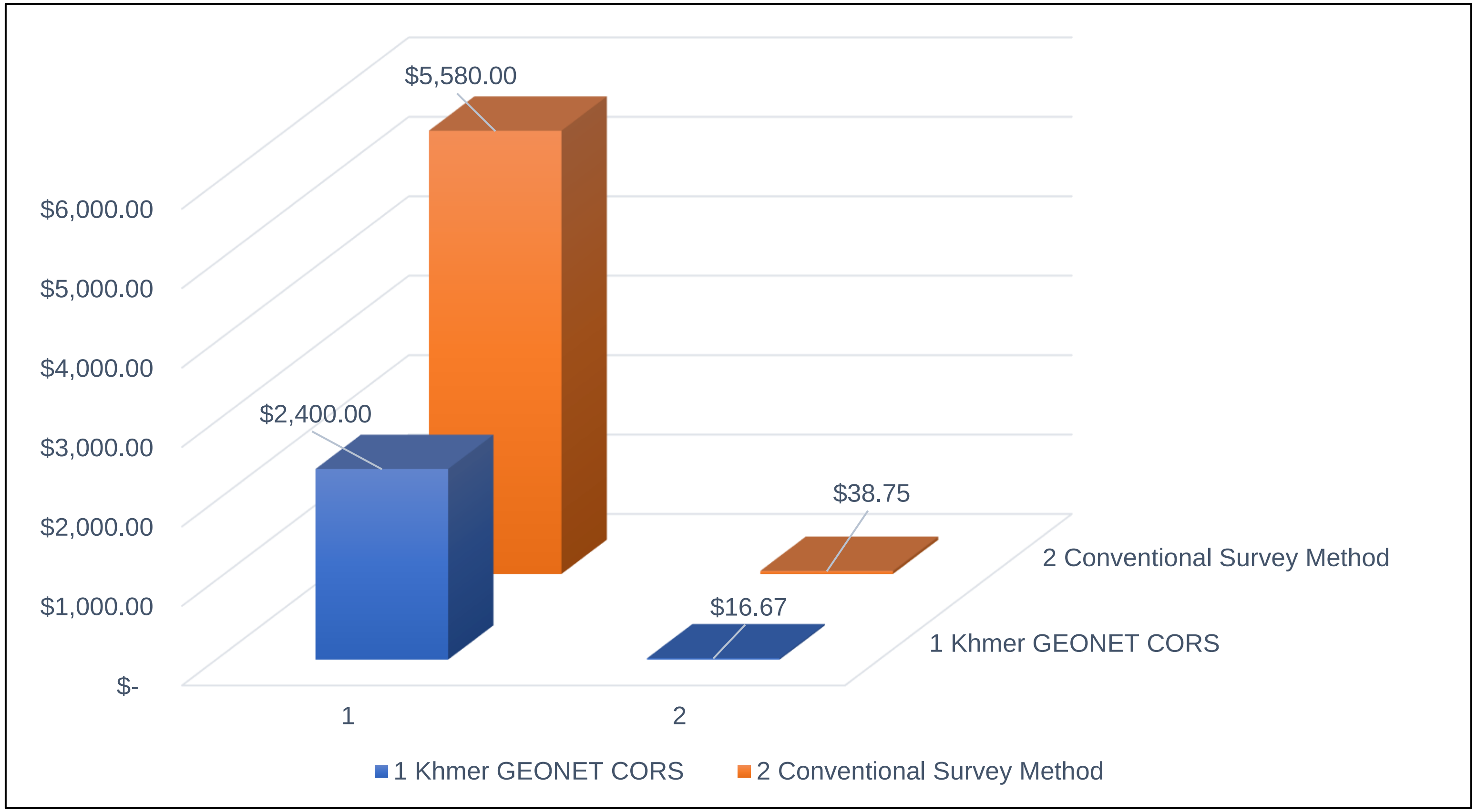
TABLE-13 COST EXPANCE USING KHMER GEONET CORS SIE-1

No.	Description	Unit	Qty.	Approximate Amount (USD)
1	GNSS receiver	No.	5.00	$ 2,400.00
2	GNSS receiver operator	person	5.00	
3	Transportation	No.	1.00	

III. FINDING AND DISCUSSION

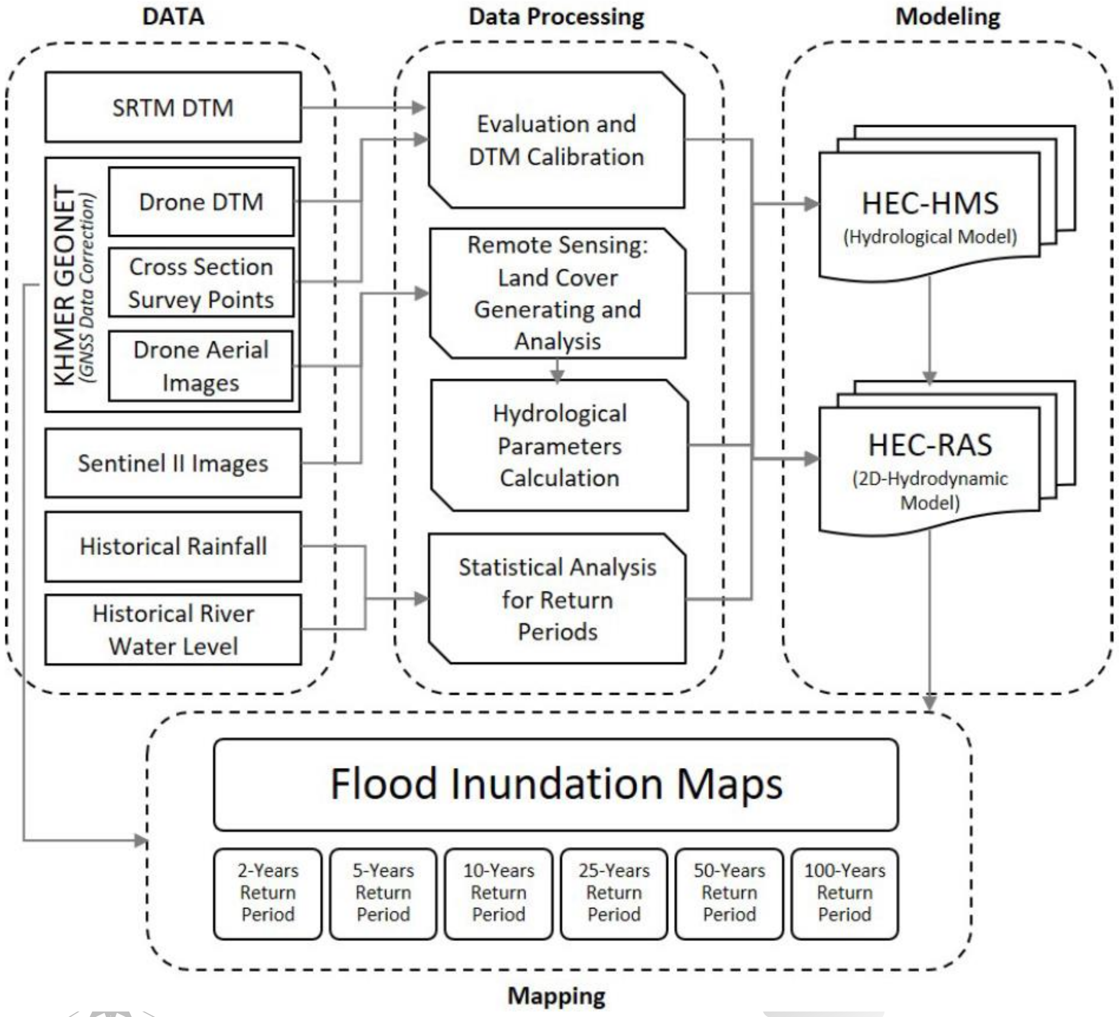
- **EFFICIENCY OF USING KHMER GEONET:**

(i) Required budget was calculated for field data collection by two different method (Khmer Geonet Cors vs Conventional method



IV. APPLICATION FOR FLOOD INUNDATION STUDY IN SIEM REAP CITY

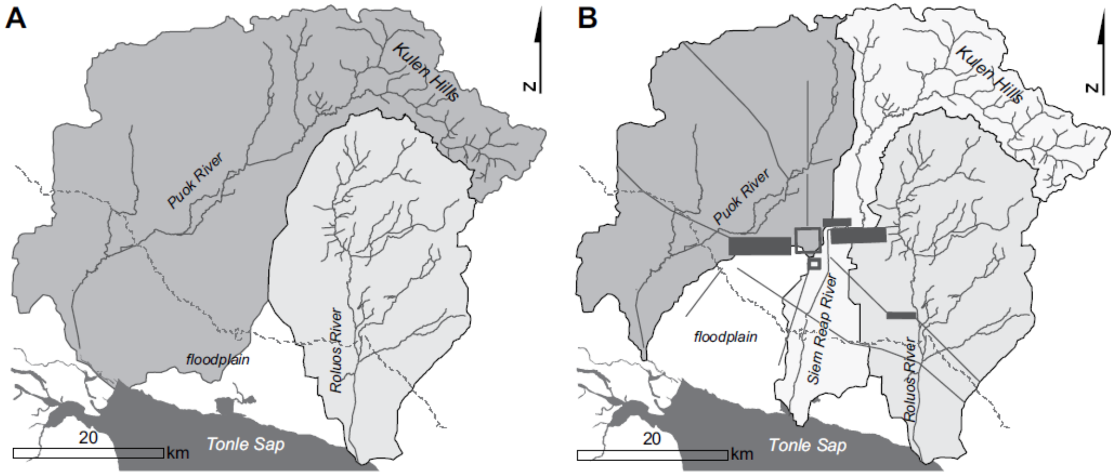
- Acquired accurate data from Khmer Geonet Cors plays as fundamental data for for representing the terrain characteristic of the focus area (a part of Siem Reap City).
- The precision of the data from the measurement is the key to make the flood inundation simulation appearance closed to the reality.

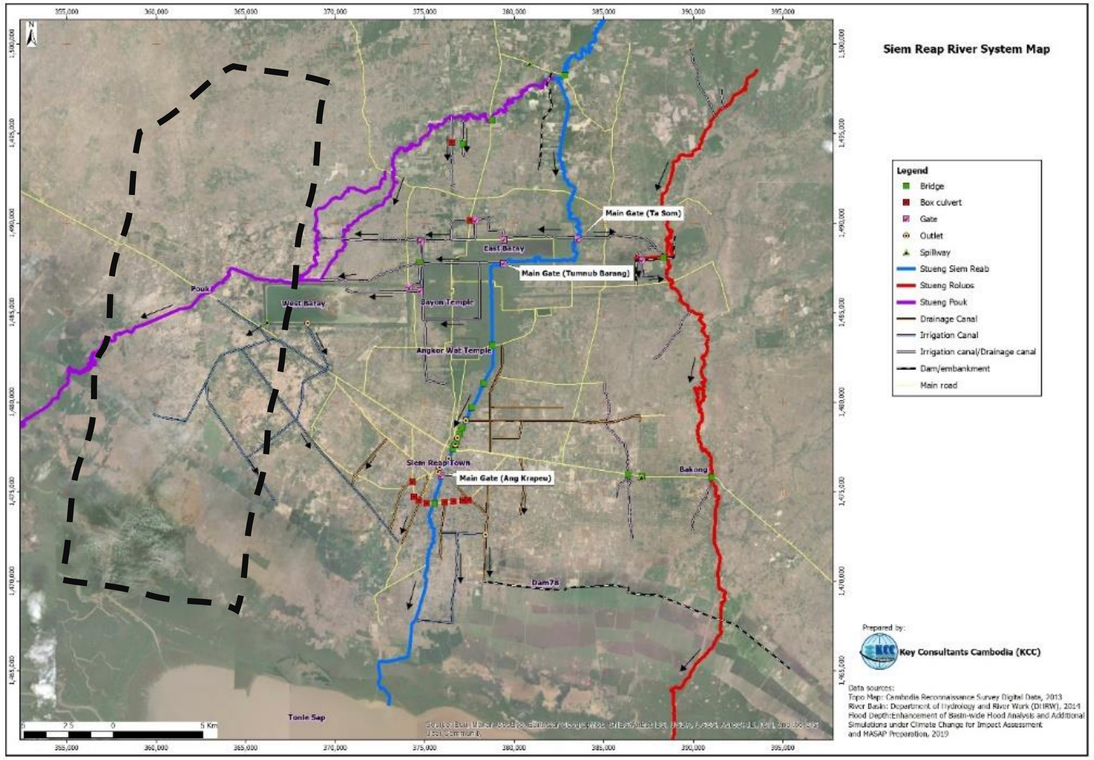


IV. APPLICATION FOR FLOOD INUNDATION STUDY IN SIEM REAP CITY

1. Hydrological Basin

- Siem Reap River is an artificial waterway which intercepted during 10th-11th CE; where the southerly Pouk branch from the Kulen Mountains (main river basin) to an offtake canal system in temple zone and through Siem Reap town.
- The evolution of the watersheds: (A) natural watersheds; and (B) present watersheds is shown in figure below

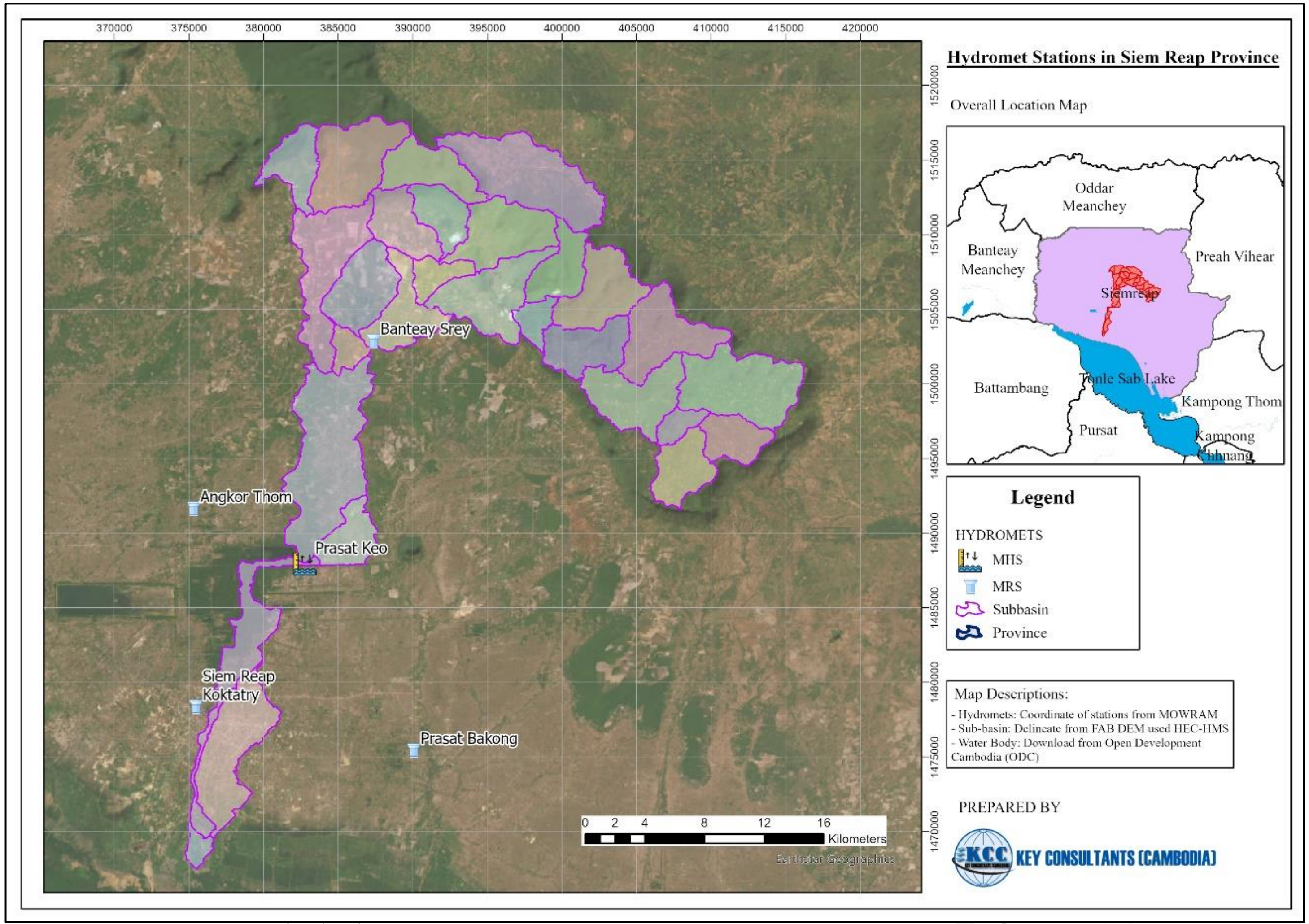




IV. APPLICATION FOR FLOOD INUNDATION STUDY IN SIEM REAP CITY

2. Secondary Data Collection and Numerical Analysis

- Hydrological is secondary data, where 18 ground stations exist in Siem Reap Province
- Above 83% hydromet stations within data range over 15-years are continuously recoding while the newly AWS station have been recording over 6 years long.
- There are four hydromet stations sited surrounding the project area and Siem Reap basin; where the stations at Prasat Keo, Banteay Srey, Prasat Bakong and the station in the town have been collected

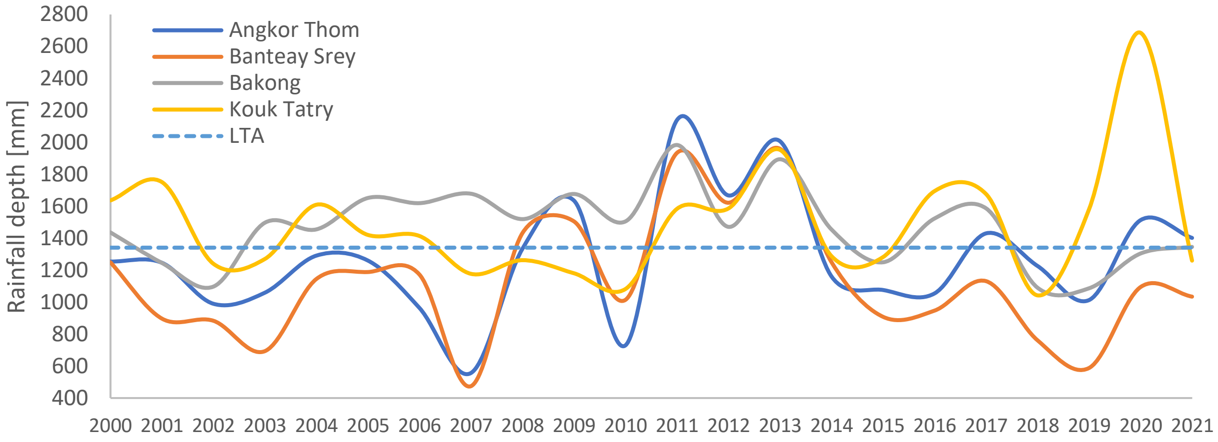


IV. APPLICATION FOR FLOOD INUNDATION STUDY IN SIEM REAP CITY

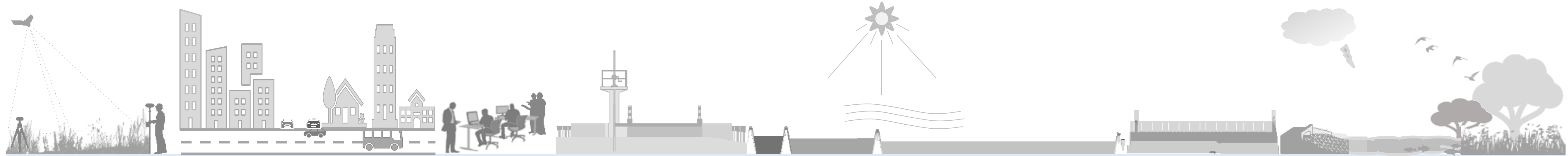
2. Secondary Data Collection and Numerical Analysis (cont.)

- The long-term average (LTA) of annual rainfall at the four key stations were revealed by 1,300 mm and by 1,418 at Siem Reap station which are remarkable over 50% exceedance.

- A statistical analysis was made for this period by fitting the annual maxima with a Log Pearson III distribution on 21 years of daily rainfall records collected from the Siem Reap station, resulting in extreme daily rainfall



Return Period [year]	2	5	10	20	50	100	200
Daily Rainfall [mm/day]	92	136	168	200	244	279	316

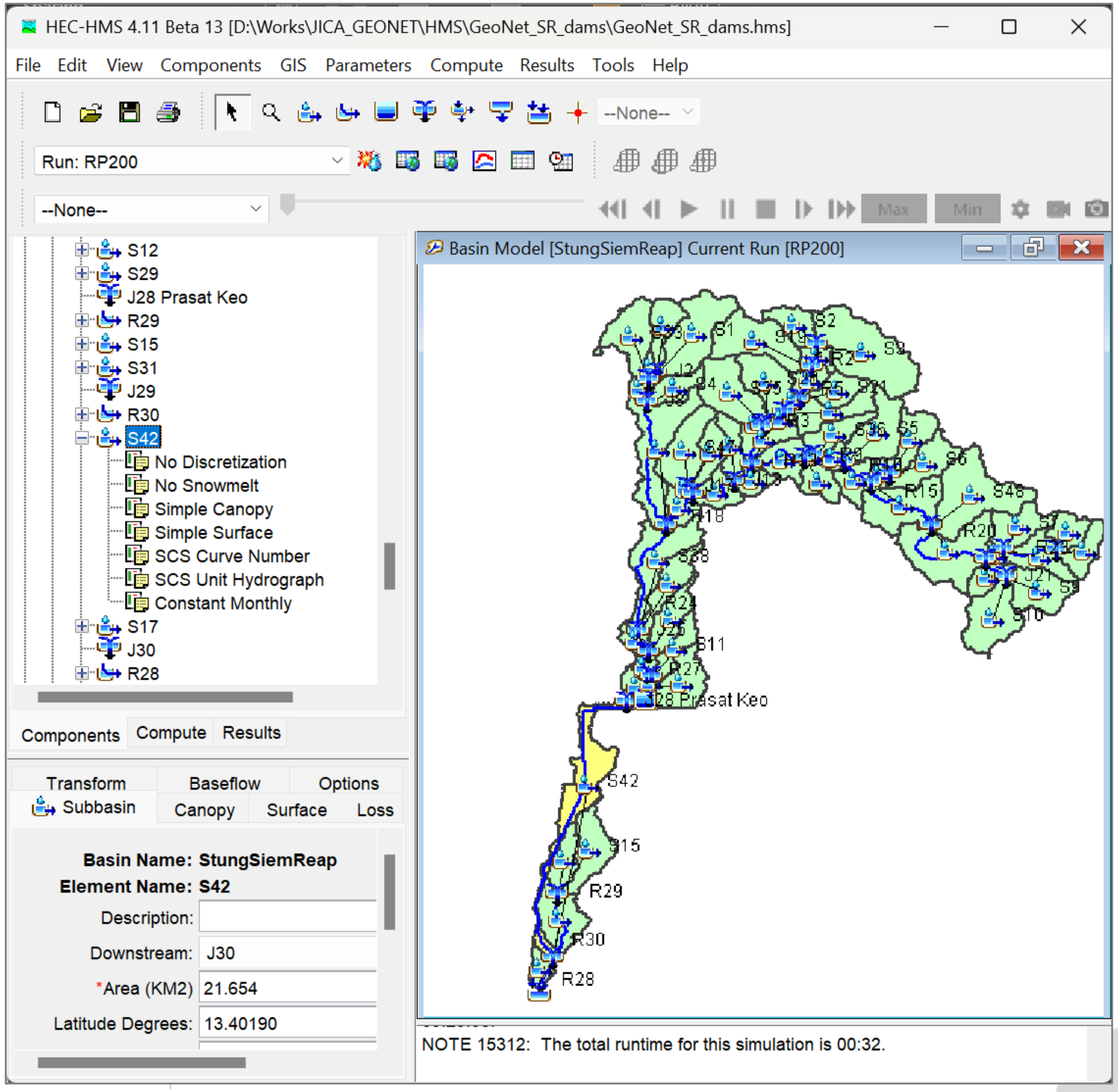


IV. APPLICATION FOR FLOOD INUNDATION STUDY IN SIEM REAP CITY

3. Hydrological Modeling Setup

Hydrological analysis was performed to understand the characteristics of surface hydrological process, and make an estimation for the surface hydrological situation in different amplitudes of meteorological events happened on a terrain.

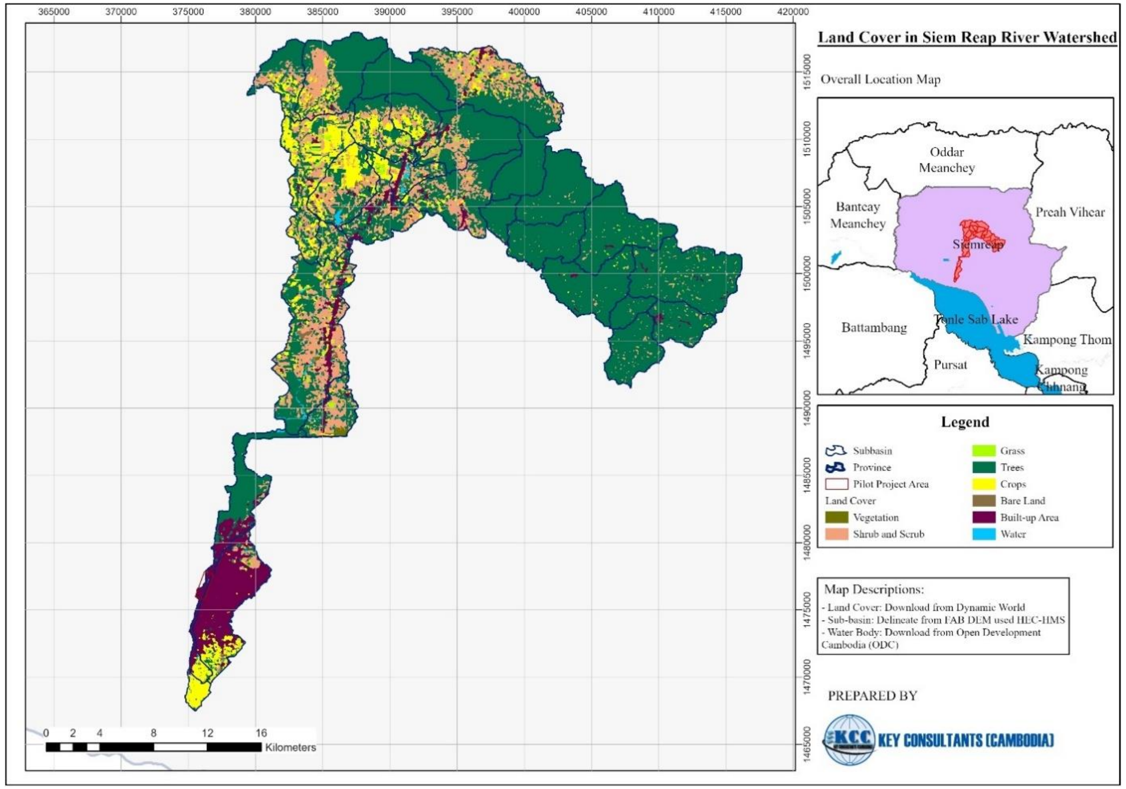
- Sketching from terrain to flow, HEC-HMS performed orders of works including:
  - Watershed delineation
  - Subbasins and reaches hydrologic method and parameters determination
  - Meteorological data input
  - Rainfall-Runoff simulations for calibration, validation and hydrograph production

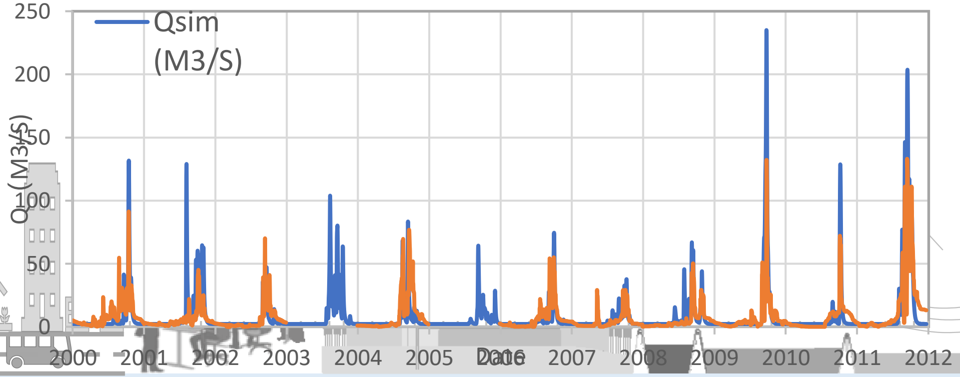


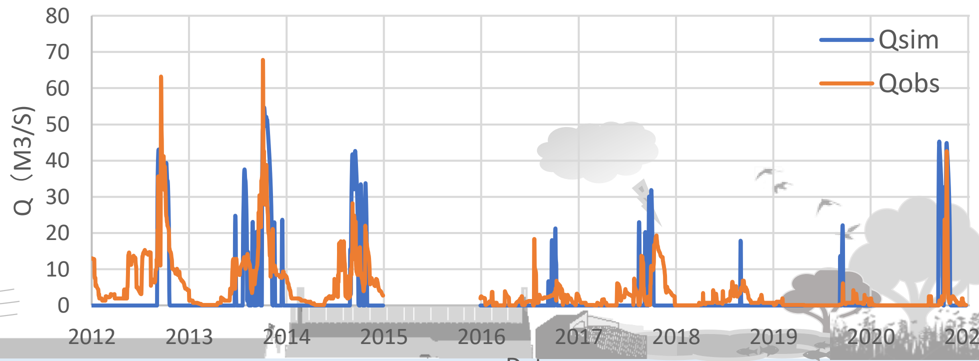
IV. APPLICATION FOR FLOOD INUNDATION STUDY IN SIEM REAP CITY

3. Hydrological Modeling Setup (Cont.)

- Land cover was used as second parameter beside rainfall for rainfall-runoff simulation
- Soil Conservation Service (SCS) method was derived from Land Cover and used in the Hydrological modeling setup.
- Control point at Prasat Keo with Stage and Discharge was used to calibrate the model
- Statistical model performance was used to test accuracy of the model setup and revealed good agreement from 2000-2012 and 2013-2021.
- Two phases were performed before and after Tasom Dam construction
- The result flow hydrograph of Hydrological model are used for Hydraulic Model



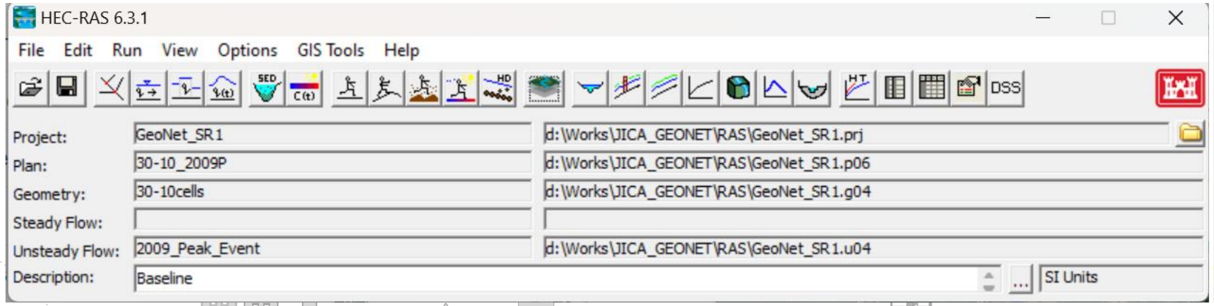


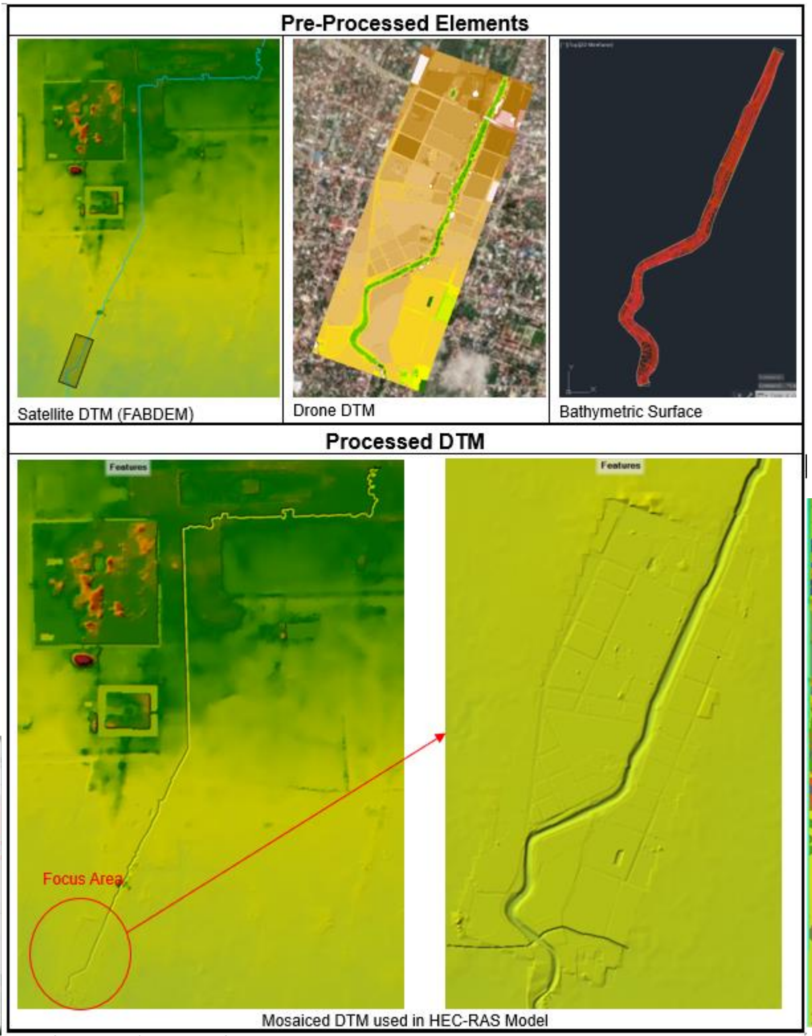


IV. APPLICATION FOR FLOOD INUNDATION STUDY IN SIEM REAP CITY

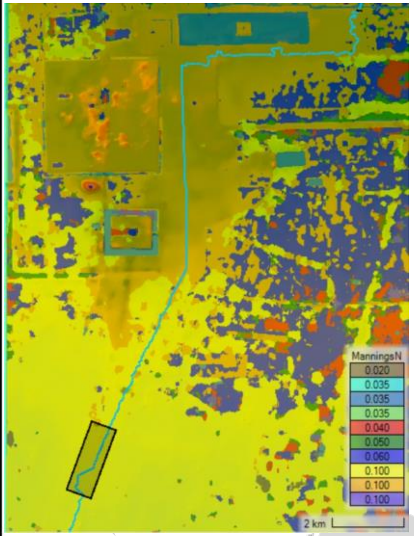
4. Hydrodynamic Model Setup

- The Hydrodynamic model of HEC-RAS, the 2D unsteady flow model was applied to generate overland flood.
- In this study, DTM from Global Terrain Data – FABDEM, Drone DTM and River Surface created from river cross section survey were mosaiced together to be terrain of the model. The river shape from Tasom Dam was modified assumedly along the digitized alignment until connecting to the bathymetric surveyed section.
- Inline structures along the river were taken into account in the model
- Land cover was used to assign roughness coefficient or Manning's value





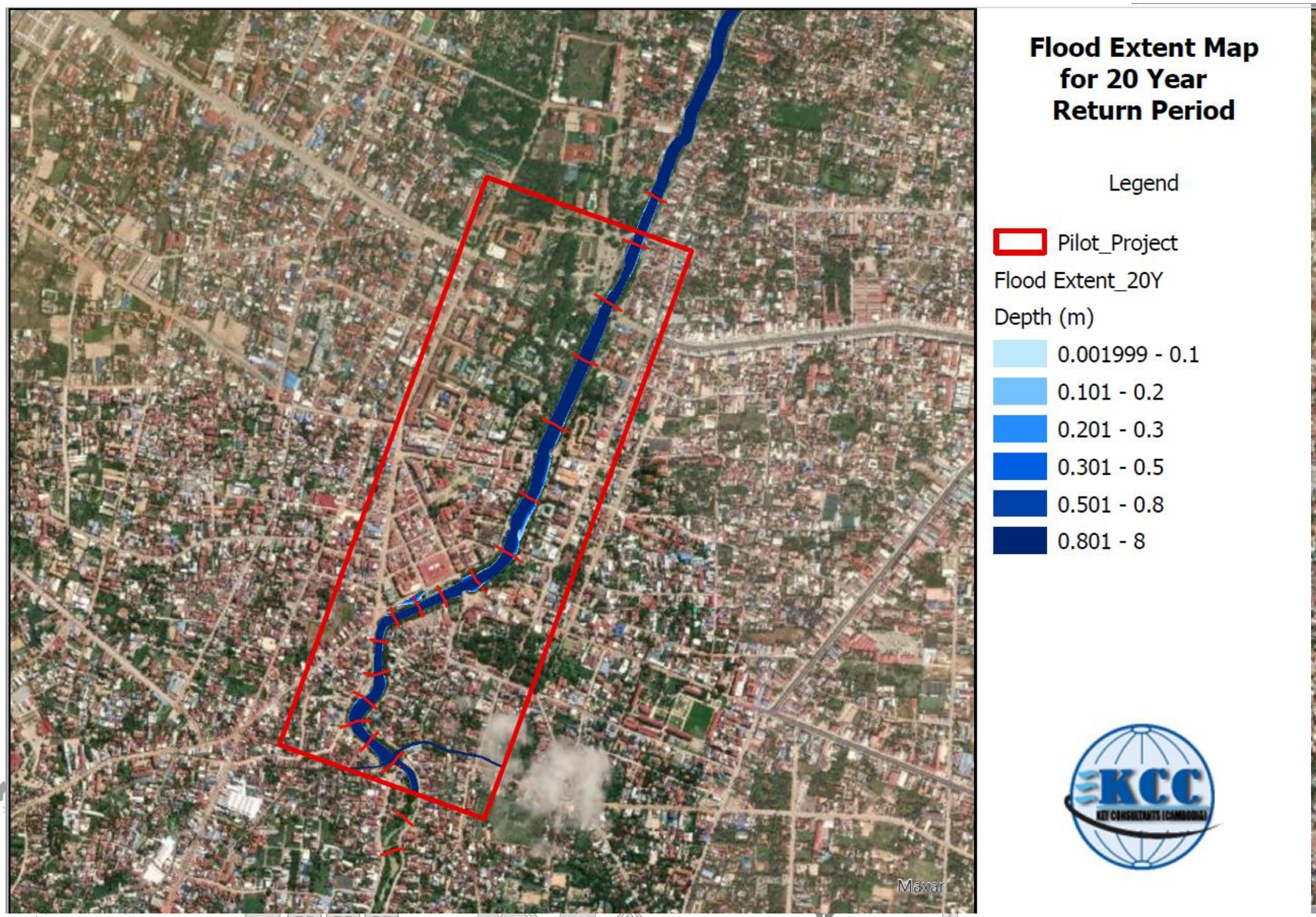
- Manning's value

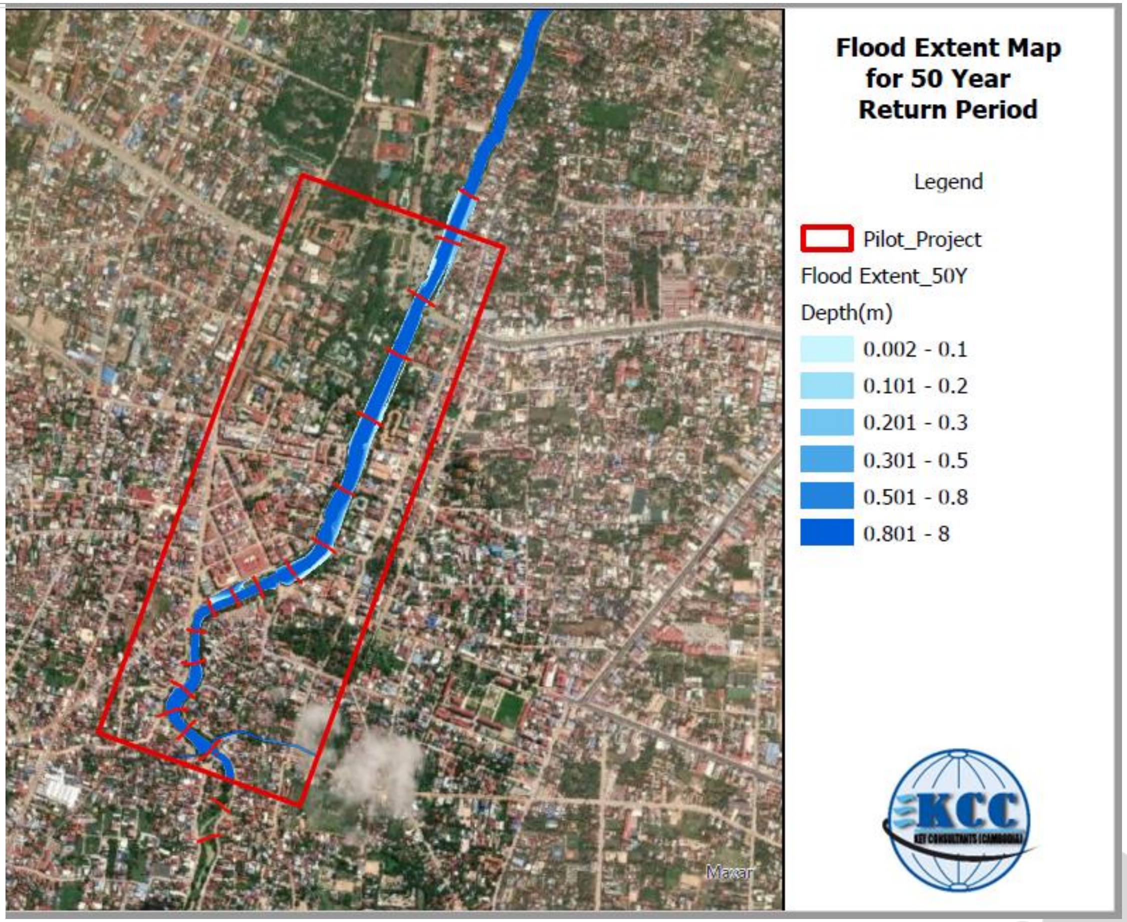


IV. APPLICATION FOR FLOOD INUNDATION STUDY IN SIEM REAP CITY

5. Flood Result

- The 20& 50 Year return period flood extent has slightly spilled over riverbank after improvement of the flood structure of the riverine.

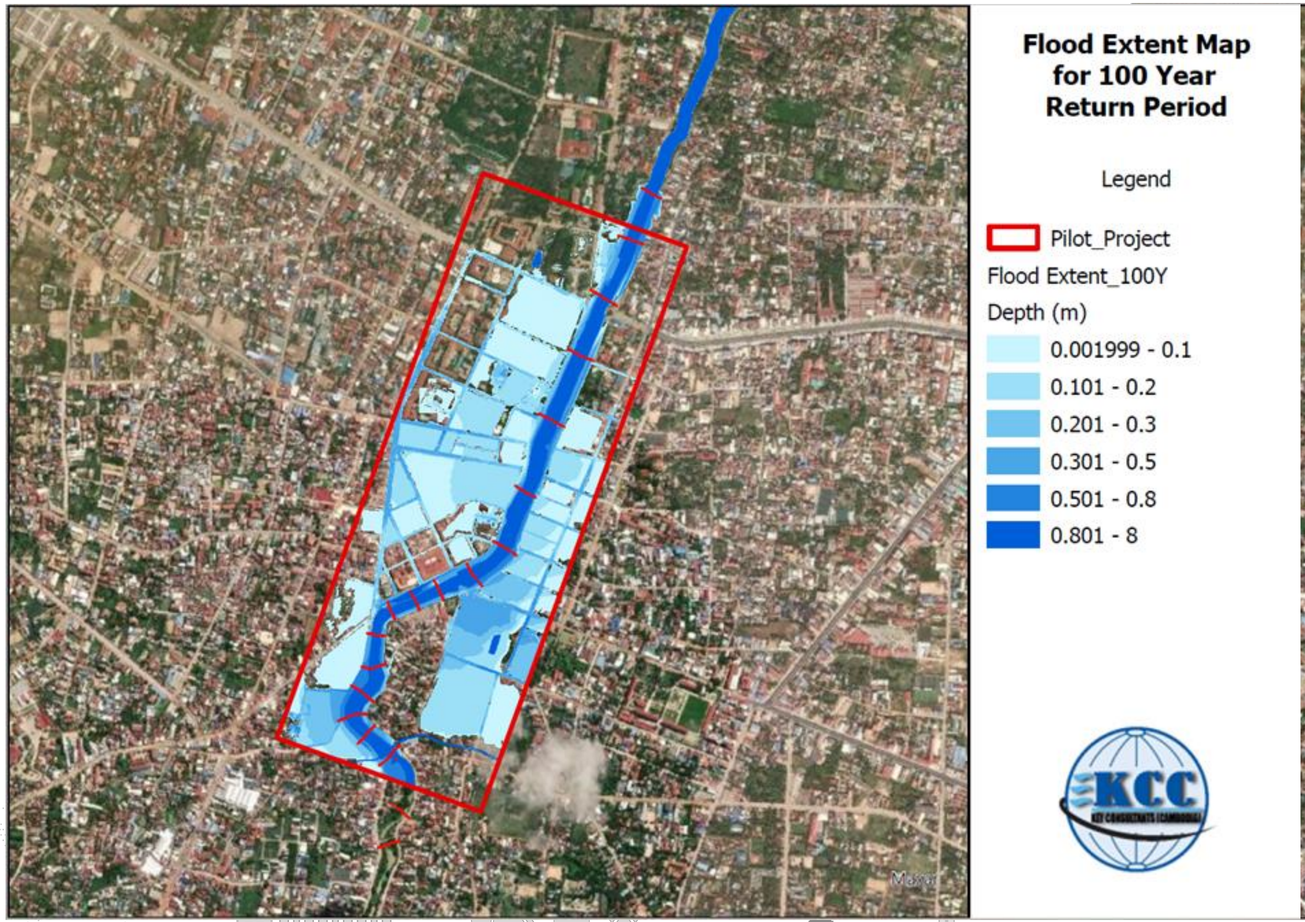


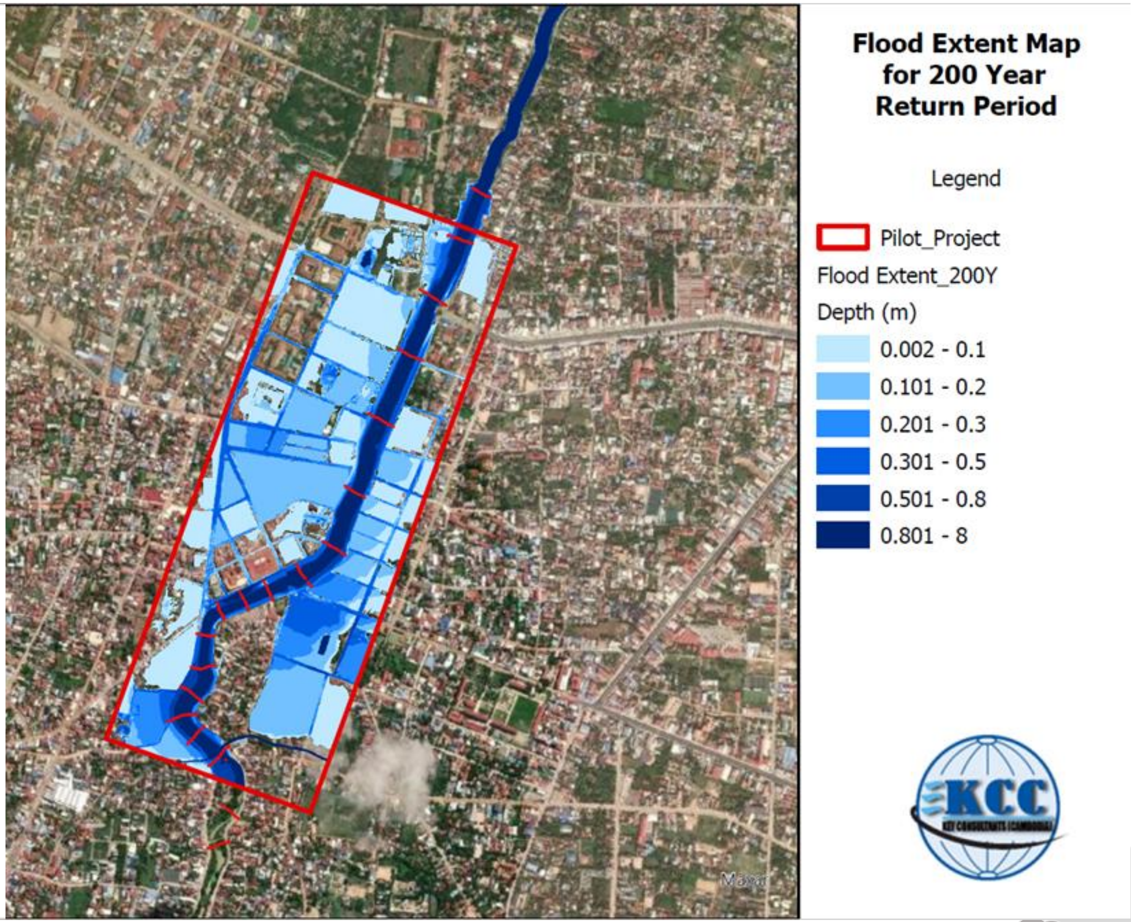


IV. APPLICATION FOR FLOOD INUNDATION STUDY IN SIEM REAP CITY

5. Flood Result

- The 100 and 200 Year return period flood extent were generated
- It's remarkable 100& 200 year return period, flooding spilled into the project area

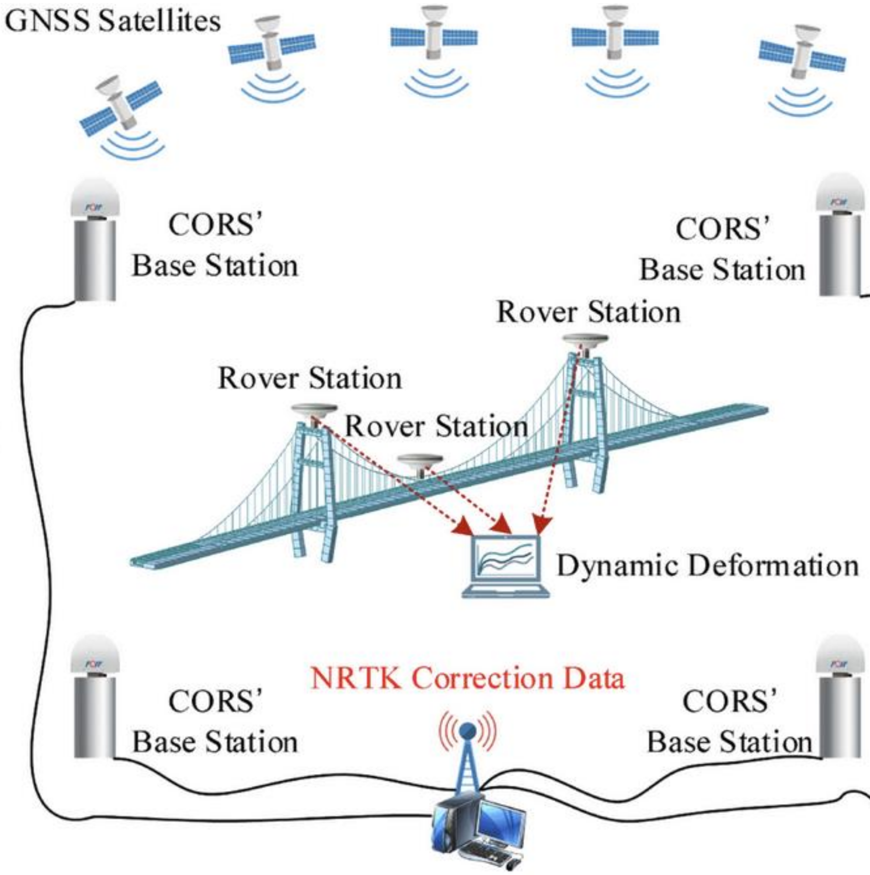


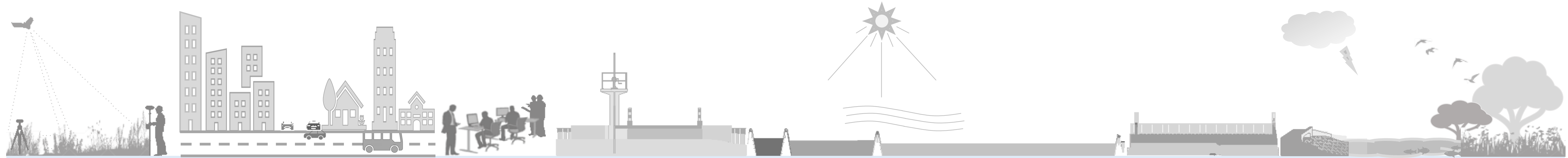


V. CONCLUSION

- KHMER GEONET CORS is able to provide centimeter level accuracy compared to the other methods
- KHMER GEONET CORS provides convenient and cost-effective method to conduct the land survey, drone survey.
- Users can instantly commence the measurement by just accessing to the Khmer Geonet Cors through Username and Password.
- A flood study in an urban area previously required extensive ground-based measurements over the study area, which resulted in exorbitant expenses. The advent of drone surveys and the current existence of Khmer Geonet Cors undoubtedly facilitate rapid access, precise data acquisition, and cost-effectiveness in generating digital terrain models (DTM) and aerial photographs, which are indispensable for flood modeling and analysis.
- In case in urgent situation of coming flood, quick DTM data from Khmer GEONET Cors reference survey for flood simulation will save the town from inundation since we can make flood control or prevention in advance on time.
- As soon as the Khmer Geonet service becomes nationwide, it is anticipated that it will provide significant assistance in the fields of agriculture, topographical surveying, land surveying, infrastructure management such as bridge deformation monitoring, and navigation as well.

V. CONCLUSION





THANK YOU!

រដ្ឋាករទឹកស្វយ័ត ក្រុងភ្នំពេញ

រ ទ ស ភ

PHNOM PENH WATER SUPPLY AUTHORITY

(PPWSA)

បទបង្ហាញប្រវត្តិនៃការប្រើប្រាស់ឧបករណ៍ជំនួយក្នុងការសិក្សាគម្រោង

Presentation On The History Of Using of assistive devices In Project Study Aids

មាតិការ

I. សាវតារ

❖ ប្រវត្តិ រ.ទ.ស.ភ

អំពីនាយកដ្ឋានផលិតកម្ម និងផ្គត់ផ្គង់ទឹក

(ABOUT WATER PRODUCTION AND SUPPLY DEPARTMENT)

- ស្ថិតក្រោមការដឹកនាំផ្ទាល់របស់អគ្គនាយក នៃរដ្ឋាករទឹកស្វយ័តក្រុងភ្នំពេញ។

➢ UNDER THE DIRECT SUPERVISION OF THE DIRECTOR GENERAL OF THE PHNOM PENH WATER SUPPLY AUTHORITY.

- សម្ថតភាពក្នុងការផលិតនិងផ្គត់ផ្គង់ទឹកស្អាតក្នុងឆ្នាំ ២០២១ ដល់ ២០៣០.

➢ ABILITY TO PRODUCE AND SUPPLY CLEAN WATER IN 2021 TO 2030

ទី១ រោងចក្របាក់ខែង (BAKHENG WTP)
- សម្ថតភាពផលិត (PRODUCTION CAPACITY/D)390,000 M3/D

ទី២ រោងចក្រ ជ្រោយចង្វារ CHROY CHANGWAR WTP
- សម្ថតភាពផលិត (PRODUCTION CAPACITY/D) 130,000 M3/D

ទី៣ រោងចក្រ ភូមិព្រែក (PHUM PREK WTP)
- សម្ថតភាពផលិត (PRODUCTION CAPACITY/D) 195,000 M3/D

ទី៤ រោងចក្រ ចំការមន (CHAMCAR MORN WTP)
- សម្ថតភាពផលិត (PRODUCTION CAPACITY/D) 52,000 M3/D

ទី៥ រោងចក្រ និរោធ (NIROTH WTP)
- សម្ថតភាពផលិត (PRODUCTION CAPACITY/D) 260,000 M3/D

ទី៦ រោងចក្រ តាខ្មៅ (TA KHMOA WTP)
- សម្ថតភាពផលិត (PRODUCTION CAPACITY/D) 30,000 M3/D

ទី៧ រោងចក្រ បឹងធំ (BOENG THOM WTP)
- សម្ថតភាពផលិត (PRODUCTION CAPACITY/D) 5,000 M3/D

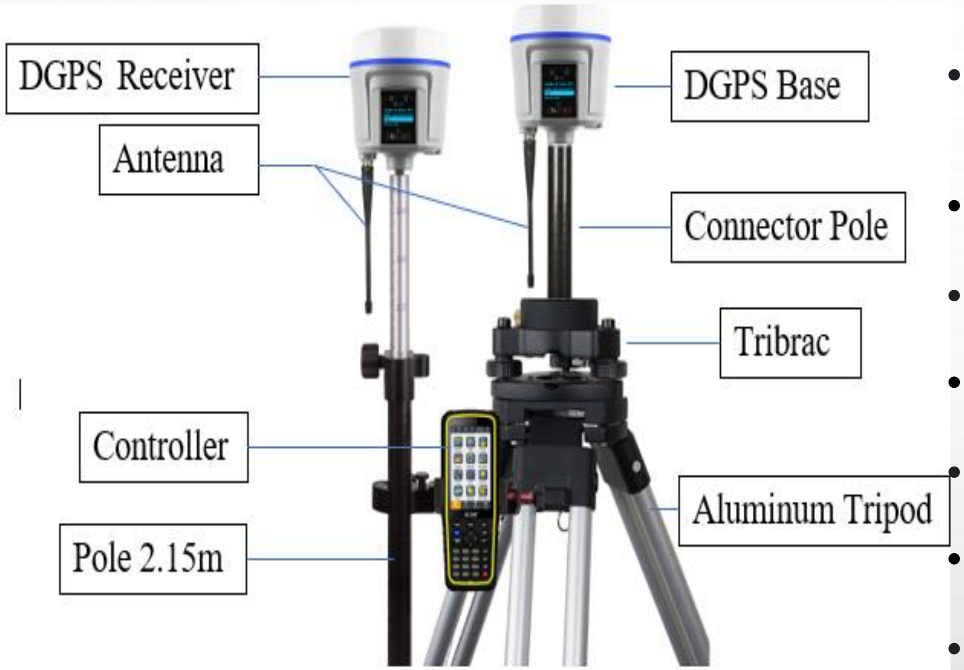
I. សាវតា

❖ ការប្រើប្រាស់ DGPS

- ការជ្រើសរើសក្នុងការប្រើសេវាកម្ម DGPS ធ្វើអោយការងាររបស់យើងប្រសើរឡើង នូវភាពជាក់លាក់និងត្រឹមត្រូវនៃទីតាំង GPS របស់យើង ព្រមទាំង សម្ថតភាពក្នុងការចាប់យកសញ្ញារបស់ទីតាំងច្បាស់លាស់និងមានភាពលំអៀងតិច។

- ➢ CHOOSING TO USE THE DGPS SERVICE IMPROVES OUR WORK WITH THE ACCURACY AND PRECISION OF OUR GPS LOCATIONS, AS WELL AS OUR ABILITY TO CAPTURE PRECISE LOCATION SIGNALS WITH LESS BIAS.

❖ ការប្រើប្រាស់ DGPS

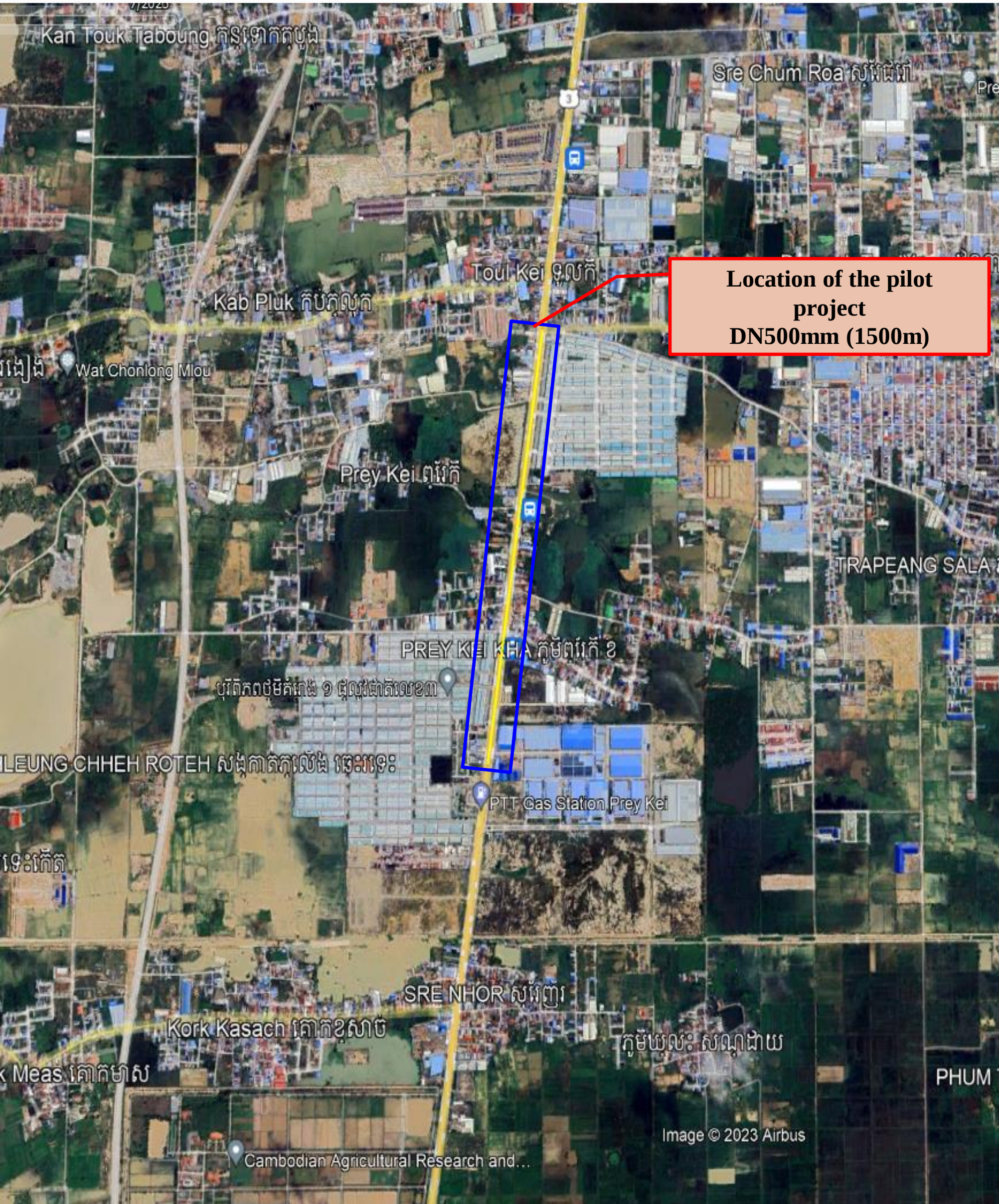


- ប្រើប្រាស់សំម្រាប់បង្កើតប្លង់មើលពីលើ ដែលត្រូវបានភ្ជាប់ជាមួយ នឹងប្លង់ពុះបណ្តោយ និងបង្ហាញពីទីតាំងដៅបំពង់។
- Used to create a top view plan that is associated with a longitudinal split plan to indicate the position of the pipe.
- ប្រើប្រាស់សំរាប់បង្កើតផែនទី, ផែនទីយោង ឬប្លង់ទីតាំង។
- Used to create maps, reference maps, or location maps.
- ប្រើសំរាប់ត្រួតពិនិត្យ និងកំណត់ទីតាំងផ្លូវ, បំពង់, លូ ,ខ្សែភ្លើង។
- Used to inspect and locate roads, pipes, drains, power lines.
- ប្រើសំរាប់ស្វែងរក ចំនុច ឬ ទីតាំងដែលមានស្រាប់ តាមរយៈប្រពន្ធ័GPS។
- Used to find existing points or locations through GPS.
- ប្រើសំរាប់វិភាគ និង បង្កើត រយះកំពស់ដី, ក្រឡាផ្ទៃ, និង មាឌដីចាក់បំពេញ។
- Used to analyze and create soil height, surface area, and fill volume.

❖ ការប្រើប្រាស់ DRONE DJI Phanthom 4 pro

- ប្រើប្រាស់សំម្រាប់បង្កើតប្លង់រូបភាពមើលពីលើ ដែលត្រូវបានភ្ជាប់ជាមួយចំណុចកូអរដោនេ។
- Used to create a top-level image layout that is associated with coordinates.
- ប្រើប្រាស់សំរាប់បង្កើតផែនទី, ផែនទីយោង ឬប្លង់ទីតាំង រូបភាពកាត់ទទឹងផ្លូវ។
- Used to create maps, reference maps, or location diagram of road map.
- ប្រើសំរាប់ត្រួតពិនិត្យ និងកំណត់ទីតាំងផ្លូវ, បំពង់, លូ និងស្ពានដី តាមរយៈរូបភាពប្លង់មើលពីលើ(Plan View)។
- Used to monitor and locate roads, pipelines, sewers and landscapes through Plan view
- ប្រើសម្រាប់វិភាគ និង វាស់ក្រឡាផ្ទៃ, ប្រវែងក្រោយពីយកទិន្នន័យពី Drone មកវិភាគក្នុង កម្មវិធី Pix4Dmapper នឹងបំឡែងទៅជា File KMZ,KML,DXF,Tif,PNG,JPG…។
- Used to analyze and measure area, length, after taking data from the drone to analyze in Pix4Dmapper will be converted to File KMZ, KML, DXF, Tif, PNG, JPG….
- ប្រើសម្រាប់ធ្វើជាទិន្នន័យ Contours ដោយបានមកពីរូបភាពប្លង់រូបភាពមើលពីលើ។
- Used for Contours data from the image layout view above.

បទពិសោធន៍ការងារ



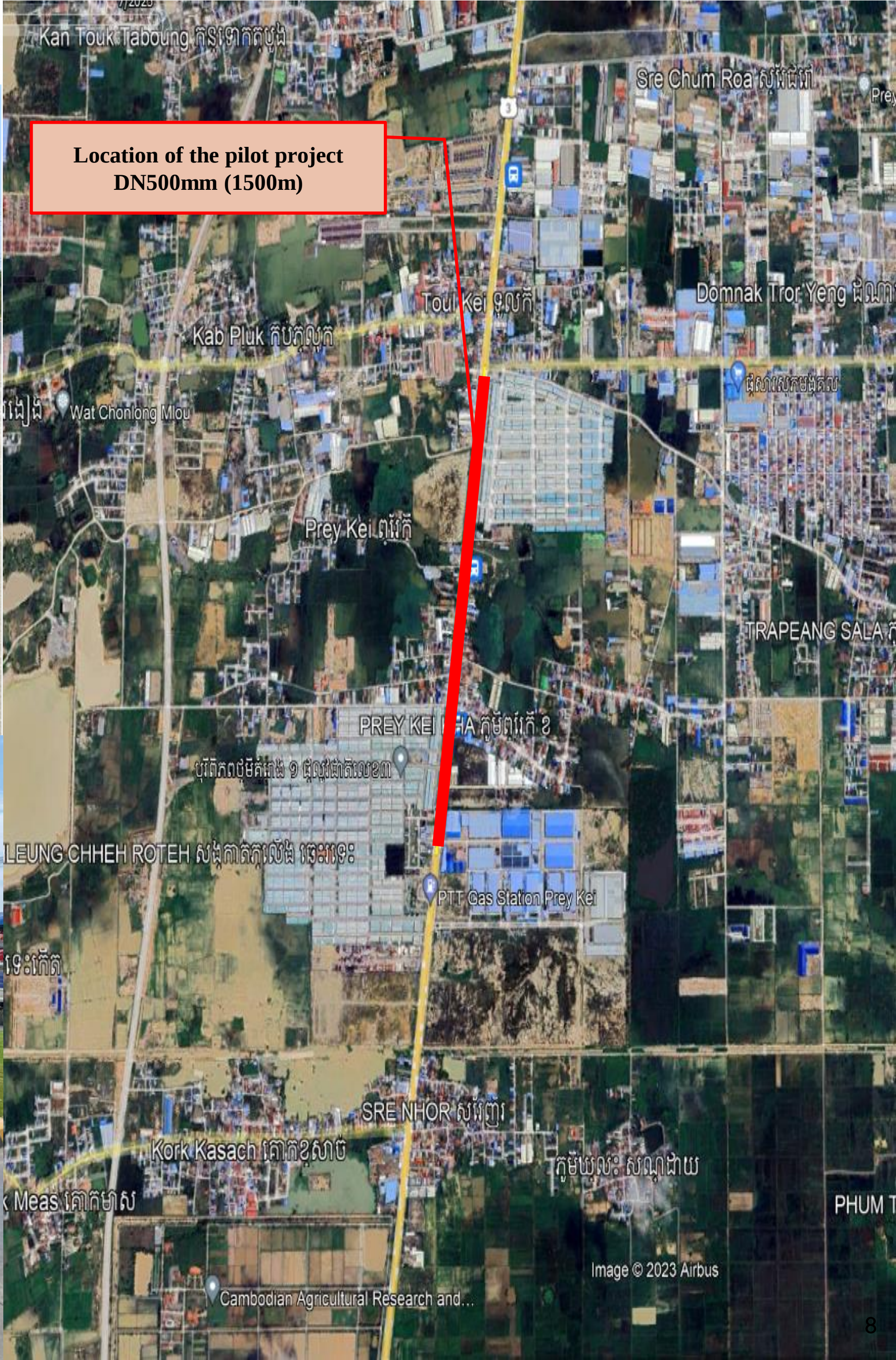
❖ **ការងារជាក់ស្តែងក្នុងការប្រើប្រាស់**

➢ ការងារចុះអនុវត្តលើគម្រោងដាក់បំពង់មេនៅផ្លូវNR-3

- គម្រោងនេះមានទីតាំងនៅរាជធានីភ្នំពេញ ហើយការសិក្សាប្លង់បំពង់មេនាំទឹកស្អាត DN500MM ដែលមានប្រវែង ១៥០០ម តាមបណ្តោយផ្លូវជាតិលេខ៣ នេះស្ថិតនៅខាងមុខបុរីពិភពថ្មី៣ កែងនិងផ្លូវ136DT សង្កាត់ភ្លើងឆេះរទេះ ខណ្ឌពោធិ៍សែនជ័យ។

- THE PROJECT IS LOCATED IN PHNOM PENH AND THE STUDY OF DN500MM WATER PIPELINE DESIGN WITH 1500M LENGTH ALONG NATIONAL ROAD 3 IS IN FRONT OF BOREY NEW WORLD III NR-3 CORNER STREET 136DT, SANGKAT PLEUNG CHEH ROTEH, KHAN POR DEN CHEY.

❖ ការប្រើប្រាស់ DGPS

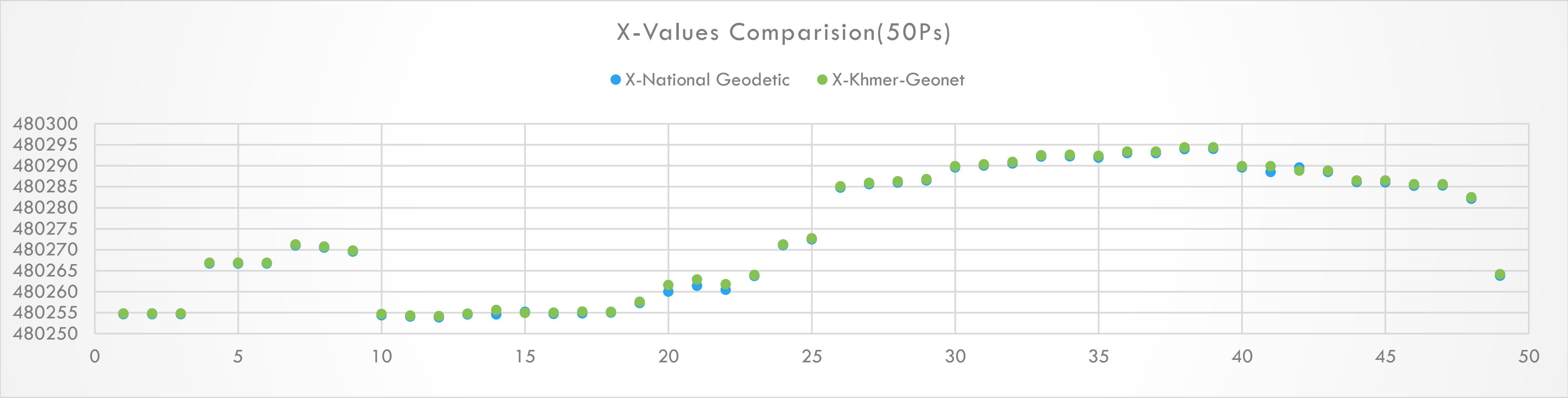


❖ ការប្រើប្រាស់ DGPS

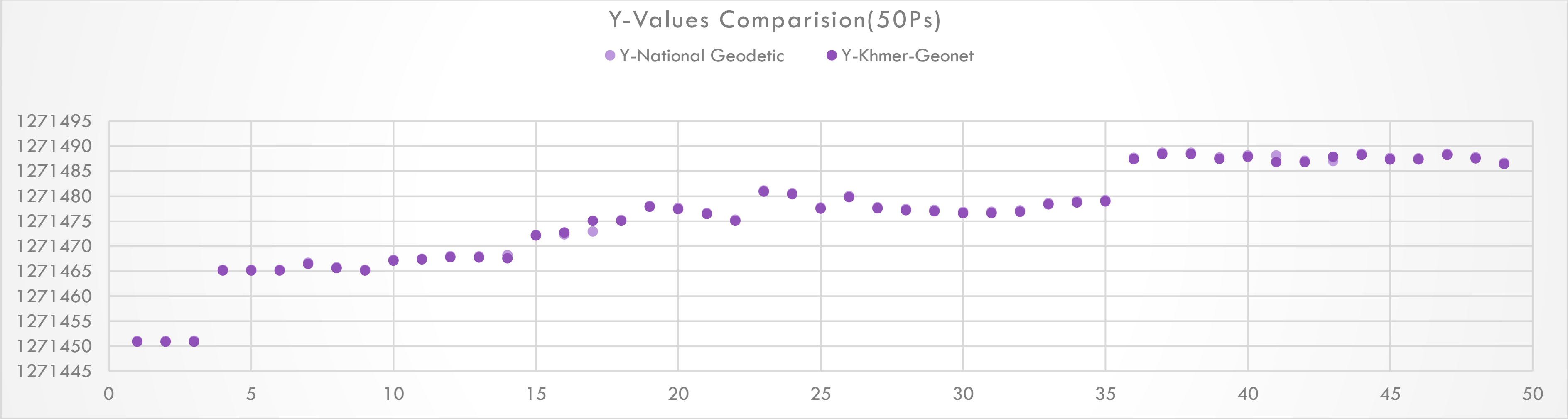
❖ ការប្រើប្រាស់ AUTO-LEVEL

IV. ប្រសិទ្ធភាពការងារ

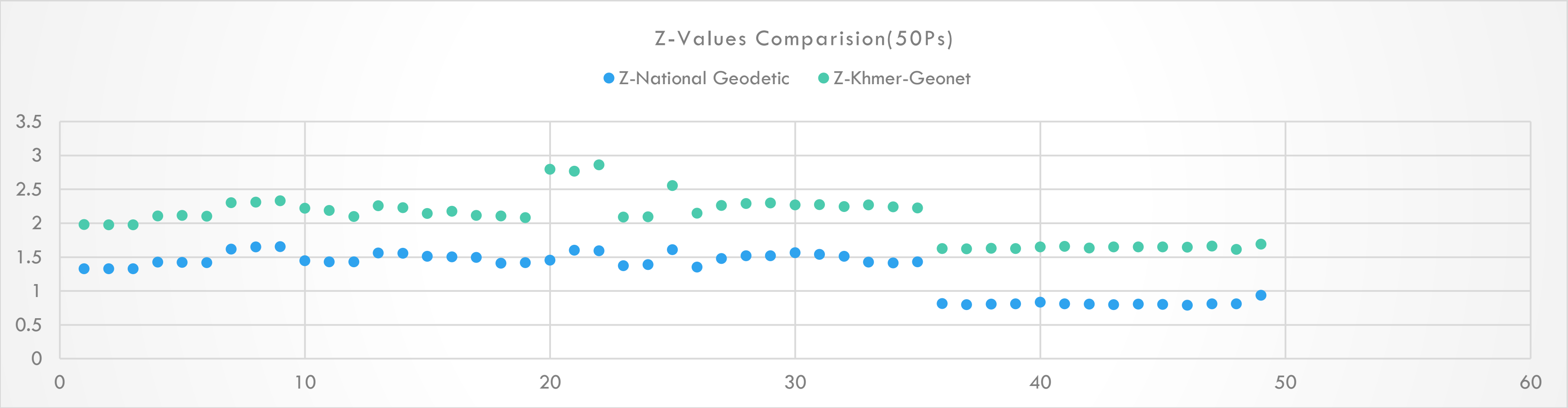
- Surveying projects the result of verification of accuracy degradation:
  - X-Valve (BM.J3, Manhole PPWSA, EDC Pole)



  - Y-Valve (BM.J3, Manhole PPWSA, EDC Pole)



Z-Valve (BM.J3, Manhole PPWSA, EDC Pole)



V. ការប្រៀបធៀប Core Jica Vs Core GCDC

Table 1.Comparison of Point GDPS

POINT	DIFFERENCE		
	Northing (m)	Easting (m)	Z (m)
BM.J3	0.188	-0.225	-0.652
Manhole PPWSA	0.245	-0.384	-0.811
EDC Pole	0.621	-0.551	-0.210

CONCLUSION

- គម្រោងនេះបានផ្តល់ការគាំទ្រផ្នែកបច្ចេកទេសសម្រាប់ការអភិវឌ្ឍន៍ និងប្រតិបត្តិការនៃ KHMER GEONET CORS
- THE PROJECT WILL PROVIDE TECHNICAL SUPPORT FOR THE DEVELOPMENT AND OPERATION OF KHMER GEONET CORS
- ការពង្រឹងសមត្ថភាពប្រតិបត្តិការ និងថែទាំមជ្ឈមណ្ឌលទិន្នន័យ
- STRENGTHENING THE OPERATION AND MAINTENANCE CAPABILITIES OF THE DATA CENTER
- លើកកម្ពស់ការប្រើប្រាស់ទិន្នន័យKHMER GEONET CORSដើម្បីបង្កើនប្រសិទ្ធភាពជាក់លាក់ខ្ពស់នៃសេវាកម្ម។
- PROMOTING THE UTILIZATION OF KHMER GEONET CORS DATA TO INCREASE THE EFFICIENCY OF SURVEYING BY HIGH-PRECISION POSITIONING SERVICE.
- រួមចំណែកមិនត្រឹមតែដល់ការអភិវឌ្ឍន៍ប្រកបដោយប្រសិទ្ធភាព និងការធ្វើបច្ចុប្បន្នភាពការសិក្សាគ្រោងប្រពន្ធ័ទឹកស្អាតប៉ុណ្ណោះទេ ប៉ុន្តែថែមទាំងវិស័យផ្សេងទៀតផងដែរ។
- THIS WILL CONTRIBUTE NOT ONLY TO THE EFFECTIVE DEVELOPMENT FOR THE STUDY OF WATER SUPPLY SCHEMES, BUT ALSO TO THE EFFECTIVE IMPLEMENTATION OF OTHER SECTORS AS WELL.

សូមអរគុណ !

Project on Establishment of Continuously Operating Reference Stations (CORS) for Land Management and Infrastructure Development

JICA Pilot Project

Demonstration project Implementation Report

January 2024

Aruna Technology Ltd., Royal University of Agriculture,

General Department of Cadastral and Geography, MLMUPC

Table of Contents

1. Overview of the demonstration project

1.1 Name of the demonstration project

EN: Accuracy Verification of Cadastral Survey with Khmer GEONET

KM: ការផ្ទៀងផ្ទាត់ភាពត្រឹមត្រូវនៃការវាស់វែងព្រំដី ជាមួយប្រព័ន្ធ Khmer GEONET

1.2 Background and purpose of the demonstration project

Cadastral boundary survey is one of the main survey activities of the MLMUPC and perhaps the largest single application for survey in Cambodia. The main purpose of the demonstration project is to test the performance of Khmer Geonet for cadastral boundary survey.

1.3 Brief description of the demonstration project

The main purpose of the pilot project is to demonstrate the accuracy of RTK survey by GNSS rover under field conditions. Accuracy can be measured in two main ways;

(1) absolute accuracy in relation to known points;

(2) relative accuracy, or the variability of coordinates (X,Y and Z) over time.

A considerable amount of testing has already been undertaken by the Pasco consultant team, therefore, this pilot project will focus on testing of absolute accuracy. The main parameters that will be tested are;

(1) Comparison of accuracy when connected to the Network RTK vs. Single Station RTK

(2) Comparison of accuracy of different makes and models of GNSS rover receiver

(3) Comparison of accuracy under different Ionospheric conditions.

(4) Determination of accuracy at longer distances from the nearest station e.g., 10, 20, 30, 40, 50, 70, 100 km

(5) Determine the repeatability of measurements under field conditions by surveying the same temporary points, representing a cadastral boundary, on different days.

1.4 Implementation period

Preparation: JUL 2023 – JUL 2023

Work at the site: JUL 2023 – SEP 2023

Reporting: SEP 2023 – NOV 2023

Table 1-1 Plan and actual of the schedule

Work Items/ Year & Month	2023						
	5	6	7	8	9	10	11
Sign a contract with Pasco							
Preparation of the pilot project							
Making a pilot project implementation plan							
Obtainment of necessary permits							
Performance of the Pilot Project							
Survey work in Phnom Penh, Kandal and Kampong Speu							
Survey work in Siem Reap							
Survey work in Stung Treng							
Additional work in Takeo, Kg. Chhnang, Kg. Thom and Kg. Cham							
Evaluation of Result							
Making final Report							
JICA seminar, Presentation material, Case study leaflet, Pilot project implementation report							
JICA seminar (postponed)							
Final deadline of Case study leaflet (promotion material)							
Final deadline of Pilot project implementation report							

1.5 Location of the demonstration project site

There were three project sites for implementing the demonstration project;

In and around the three stations in Phnom Penh, Kandal, Kampong Speu and Takeo provinces

Siem Reap Province; and

Stung Treng Province

The project sites are show in Figure 1-1 below. The known points selected for this project are detailed in Table 1-2 below.

Table 1-2 Summary of known points included in pilot project

No	Point ID	Easting	Northing	Height (Ellipsoid)	Nearest CORS Station	Distance to station (KM)
1	808D	473113.174	1272888.102	5.158	PNH	18.1
2	5E	447804.8032	1266636.7141	18.7966	KSP	5.7
3	5	414116.0260	1246699.2066	87.0256	KSP	44.7
4	21A	477047.9927	1213405.8972	-5.0353	KND	48.4
5	4A	440029.6343	1367524.8155	3.0156	KNG	27
6	6D	494316.7759	1435590.5539	9.8026	KNG	86.9

For all points except 808D, the coordinates were provided by the GDCG in the form of benchmark description cards (See Annex 1). For point 808D, supplied coordinates were not in the CGD09 coordinate system, so a static observation was made on the 24th September 2023 and the coordinates calculated using Trimble Business Center. The calculation can be found in Annex 2.

Figure 1-1 Location of the demonstration project site

1.6 Members

The members listed below performed the demonstration project.

Table 1-3 List of members

NO.	Name	Company/Organisation/Department/Title	Role
1	Paul Gager	Aruna Technology Ltd	Project Director
2	Sami Sivuth	Aruna Technology Ltd	Project Manager
3	Chan Yuthea	Aruna Technology Ltd	Surveying
4	Pav Rotha	Royal University of Agriculture	Support surveying
5	Sin Sotheany	General Department of Cadastral and Geography	Lead Surveying
6	Chin Chharom	General Department of Cadastral and Geography	Surveying
7	Kuch Jeudi	General Department of Cadastral and Geography	Surveying
8	Chea Saran	General Department of Cadastral and Geography	
9	Kandal, Kampong Speu, Siemreap, Stung Treng	Provincial Department of Land Management, Urban Planning, Construction and Cadastre (PDLMUPCC)	Support surveying

1.7 Equipment used for the demonstration project

The equipment listed below were used for the demonstration project.

Table 1-4 List of equipment used

No.	Make	Model	Frequencies	H Accuracy, RTK
1	Topcon	HiPer VR	3	5 mm + 0.5 ppm
2	Topcon	HiPer SR	2	10 mm + 0.8 ppm
3	Trimble	R12	3	8 mm + 1 ppm (Single) 8 mm + 0.5 ppm (Network)
4	Trimble	R8s	3	8 mm + 1 ppm (Single) 8 mm + 0.5 ppm (Network)
5	CHC	i80	3	8 mm + 1 ppm (Single) 8 mm + 0.5 ppm (Network)
6	SinoGNSS	T300 Plus	3	8 mm + 1 ppm (Single)
7	ZED-F9P		2	10 mm + 1 ppm (Single) (1km baseline) Manufacturer’s note “*ppm limited to baselines up to 20 km.*”

2. Details of the work

2.1 Work performed

2.1.1 Preparation

Once the contract was signed, the preparation phase of the project commenced in the last week of July 2023. This involved finalizing the fieldwork plan, allocating personal to perform assigned tasks and checking and preparing the equipment. A kick off meeting was held between all involved parties to inform them of the plan and to make final adjustments before mobilization to the field.

2.1.2 Implementation

The implementation of the project commenced in the last week of July 2023 and ran through to the end of October. The fieldwork was conducted by two teams, one of which was mobilized twice, since they were required to come back to Phnom Penh to provide inputs into other work programs.

2.1.3 Results

2.1.3.1 Comparison of accuracy of Network RTK vs. Single Station RTK

Purpose of test

The Khmer GEONET system is able to broadcast both a Network RTK (NRTK) correction and a Single Station RTK (SSRTK). The NRTK correction for Khmer GEONET is set to Virtual Reference Station (VRS) mode.

A virtual reference station is an imaginary, unoccupied reference station which is only a few meters from the RTK user. For this position, observation data are created from the data of surrounding reference stations as though they had been observed on that position by a GPS receiver. The concept of virtual reference stations (VRS) offers new possibilities. The principle is to interpolate the data of several reference stations in order to obtain the correction data for the rovers, which reduces the systematic influences of the RTK measurement decisively. Not only may the allowed distance between the reference station and the rover be increased, but also the reliability of the system is heightened. Should a reference station fail temporarily, for example, the correction data are computed with the surrounding reference stations. In addition, productivity is improved by clearly shorter initialization times.

Source: https://gisresources.com/virtual-reference-station/

Furthermore, the Network Processor module in Trimble Pivot will also create network specific atmospheric models:

The Network Processor module is one of the central calculation units of Trimble Pivot Platform. It is responsible for the creation of tropospheric and ionospheric models of *your reference station network. Trimble Pivot Platform generates corrections from these network models and transmits them to the rover in the field. Source: Trimble Pivot Help Documentation*

In summary the expectation is that the NRTK corrections (VRS), will

- Allow longer baselines between rover and reference station
- Be more accurate compared to SSRTK due to localized modeling of the tropospheric and ionospheric
- Shorter initialization times compared to SSRTK

Indeed, most manufacturers will express the accuracy of their receivers in terms of Single baseline and Network RTK, with the Network RTK method having a lower ppm value.

Table 2-1: Example manufacturer's specification for Rover receiver (Trimble R10)

REAL TIME KINEMATIC SURVEYING		
Single Baseline <30 km		
	Horizontal	8 mm + 1 ppm RMS
	Vertical	15 mm + 1 ppm RMS
Network RTK[3]		
	Horizontal	8 mm + 0.5 ppm RMS
	Vertical	15 mm + 0.5 ppm RMS

One other point to mention is that the current network of 5 stations in the Khmer GEONET is the minimum number required for NRTK/VRS and two stations are quite far north of the three near Phnom Penh. It could be expected that once the network is denser, the performance will improve.

2.1.3.2 Results of Network RTK vs. Single Station

National Control Point 5

National control point 5 is located in Treaeng Trayueng commune, Phnom Sruoch District, Kampong Speu province, about 44km from the Kampong Speu CORS Station, KSP. The control point is located close to a brick wall and there is also a building close the wall on the adjacent property (see Figure 2-1 below).

Figure 2-1: Trimble R10 receiver setup on national control point "5"

Several receivers were setup over this point to collect data for comparison. Data collect from the Trimble R8s is summarized as follows;

Date:	30-07-2023
Receiver Model:	Trimble R8s
Survey Method:	Continuous Topo (Recorded every 1 second)
Number of observations:	478
Fix Type:	RTK Fix
Mount Point:	VRS
Average # of satellites:	14

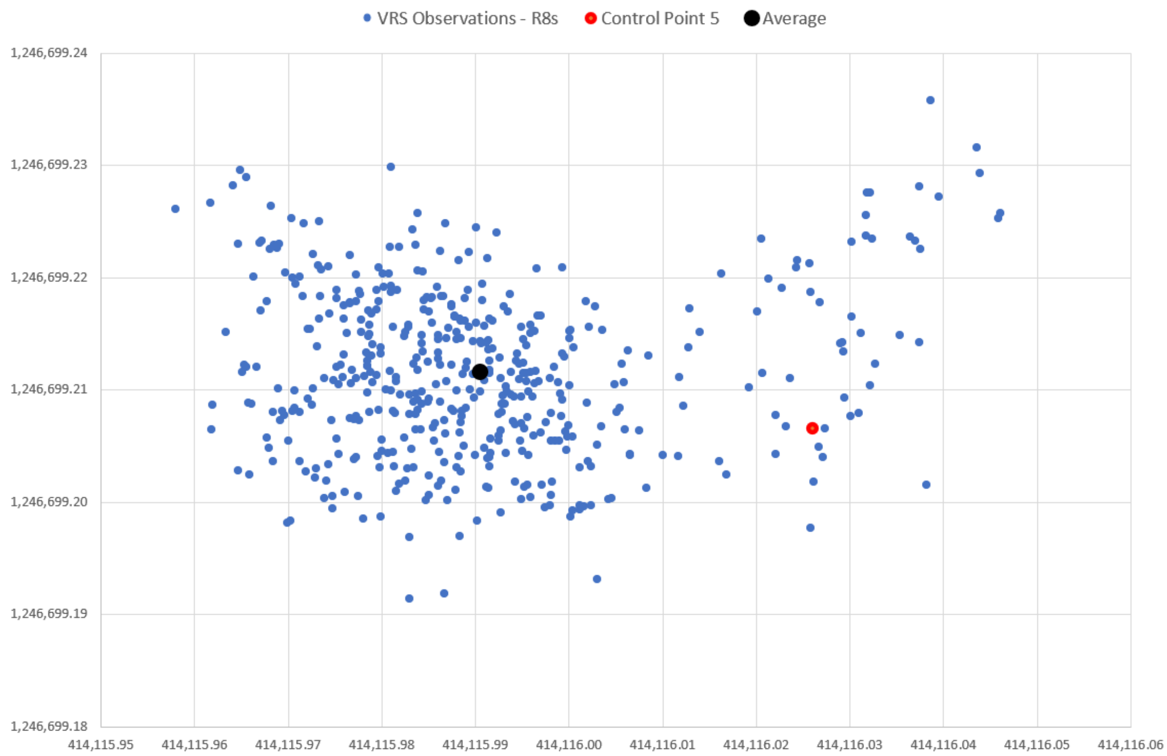


Figure 2-2: Horizontal coordinates of observation over known point 5 with R8s Receiver

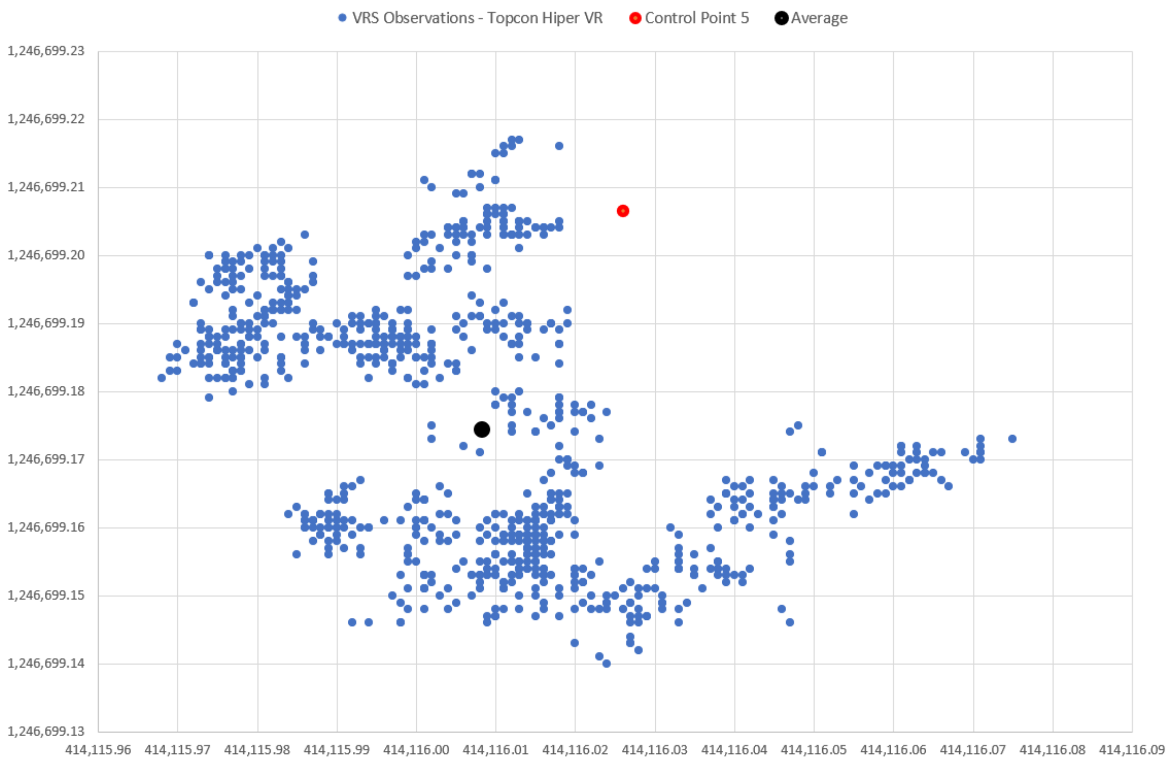


Figure 2-3: Horizontal coordinates of observation over known point 5 with Topcon Hiper VR Receiver

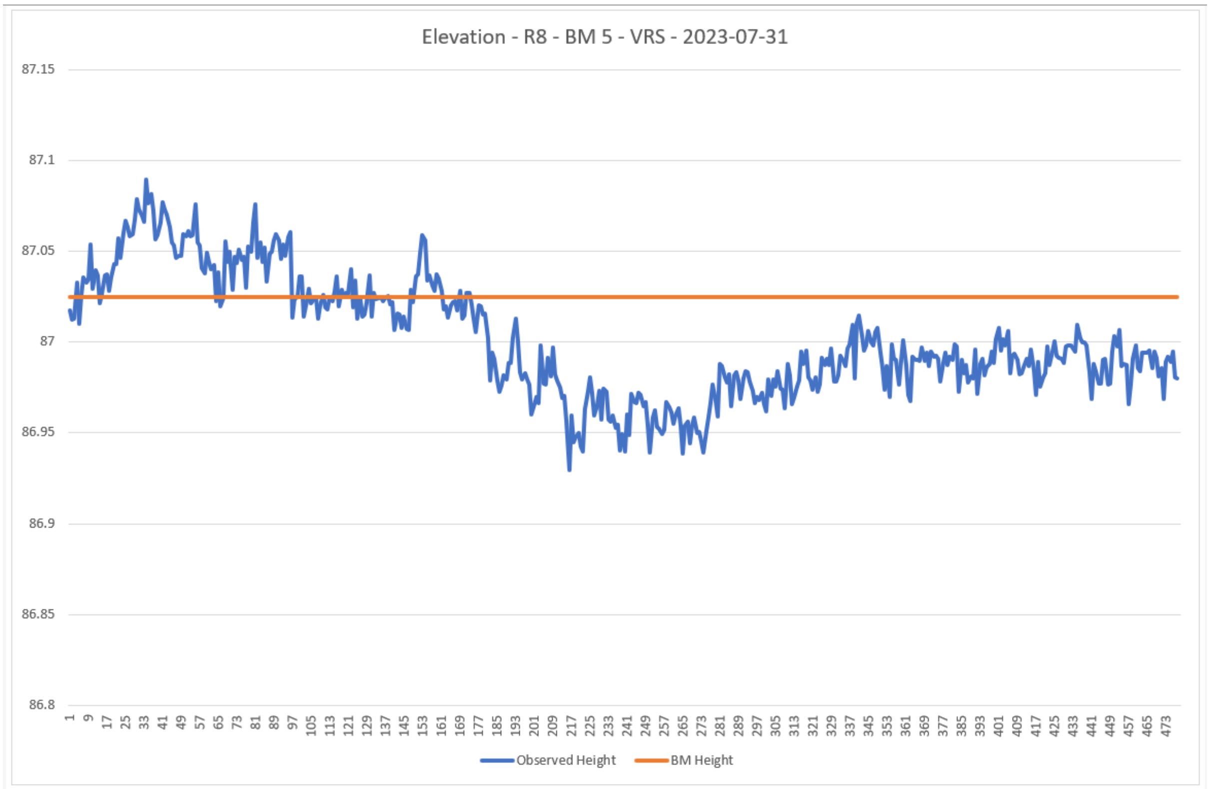


Figure 2-4: Elevation of observations over known point 5

As can be seen in Figure 2-2 and Figure 2-4, the observation data was about 4cm offset from the known coordinates on average and the observed elevation range from +60mm above control point elevation to -90mm below.

In conclusion, site conditions are far from ideal with significant obstruction to the sky. Even though an RTK Fix was achieved, the low number of satellites indicates weak geometry.

National Control Point 5E

National control point 5E is located in Chbar Mon commune, Chhbar Mon District, Kampong Speu province, about 5km from the Kampong Speu CORS Station, KSP.

Several receivers were setup over this point to collect data for comparison. Data collect from the Trimble R8s and Topcon Hiper VR is summarized as follows;

Date:	01-08-2023
Receiver Model:	Trimble R8s
Survey Method:	Continuous Topo (Recorded every 1 second)

Number of observations:	1807
Fix Type:	RTK Fix
Mount Point:	VRS
Average # of satellites:	16

Date:	30-07-2023
Receiver Model:	Trimble R8s
Survey Method:	Continuous Topo (Recorded every 1 second)
Number of observations:	478
Fix Type:	RTK Fix
Mount Point:	RRS
Average # of satellites:	14

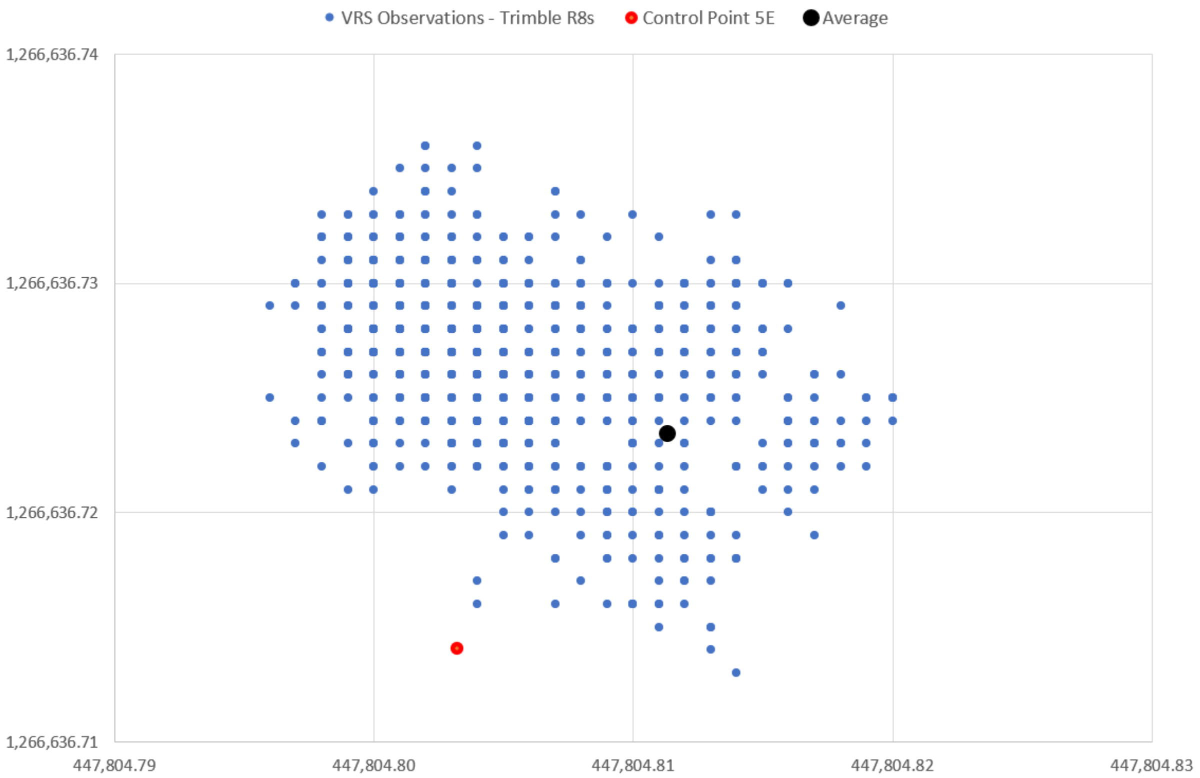


Figure 2-5: Horizontal coordinates of observation over known point 5E with R8s Receiver

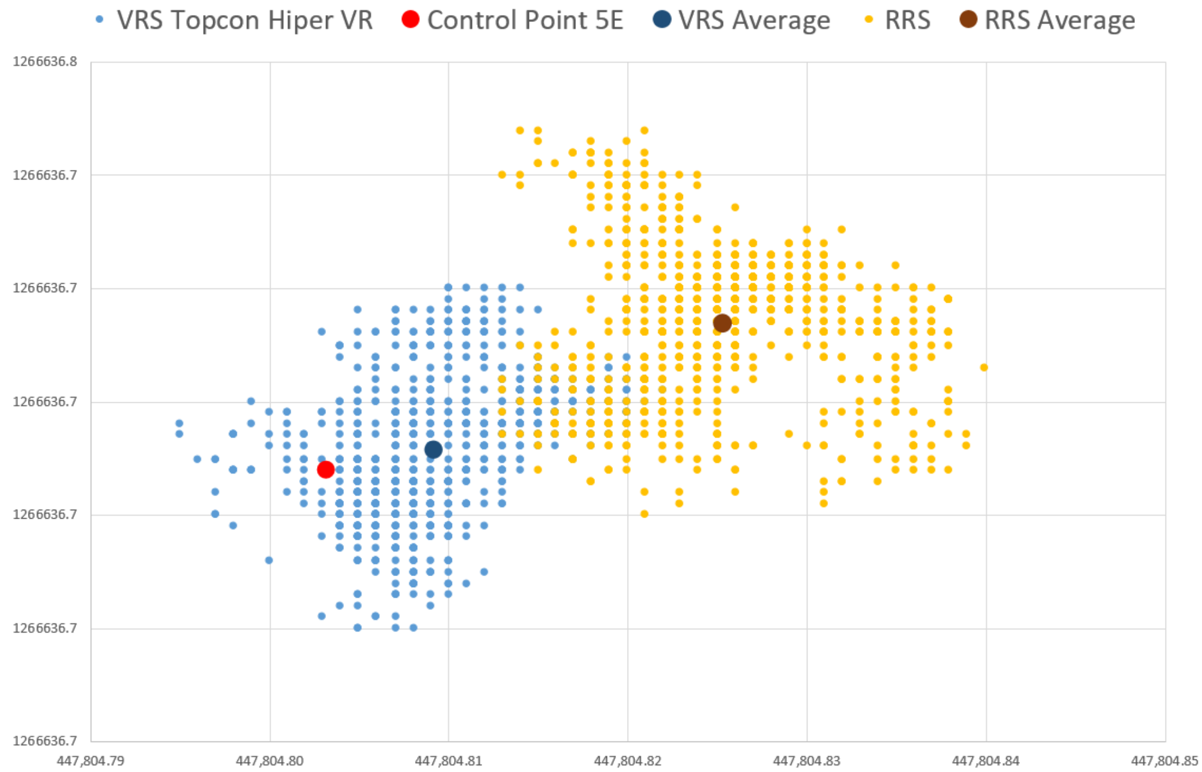


Figure 2-6: Horizontal coordinates of observation over known point 5E with Topcon Hiper VR Receiver

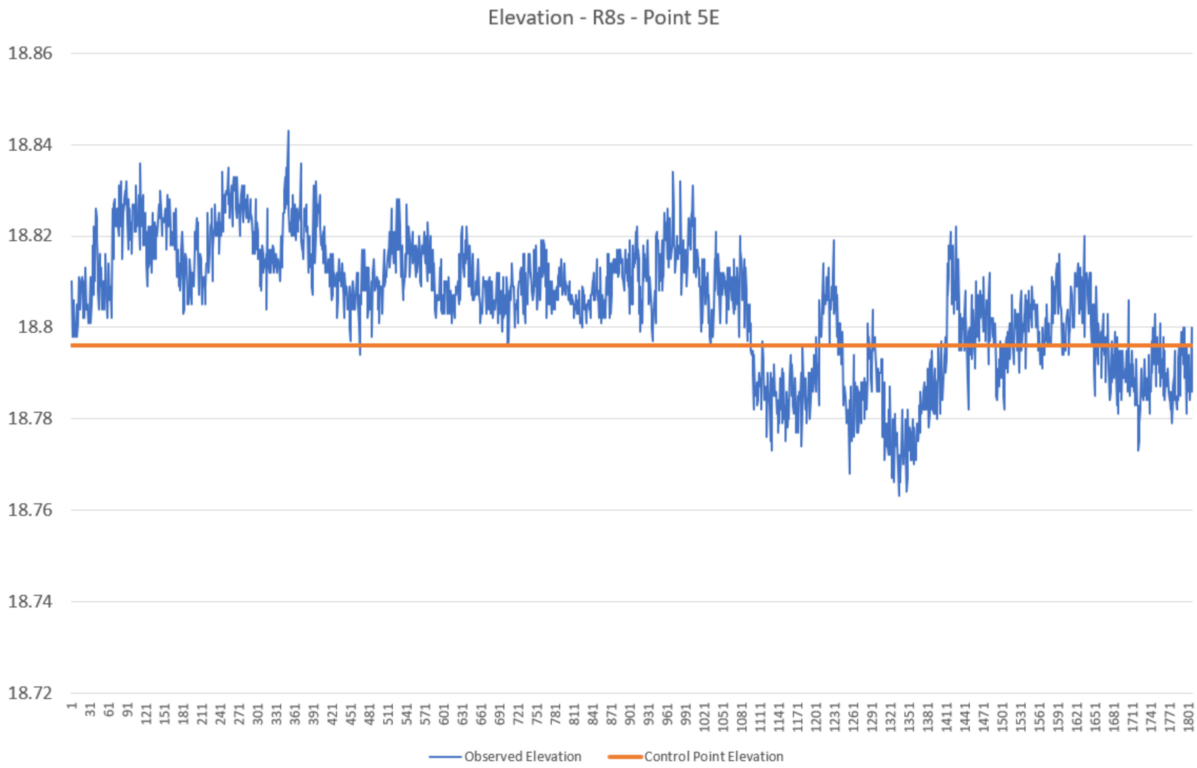


Figure 2-7: Elevation of observation over known point 5E with R8s Receiver

Table 2-2: Comparison of observed coordinates vs known coordinate 5E with different receivers

	East	North	Δ East	Δ North	Linear
5E Known	**447804.8032**	**1266636.7141**			
R8s VRS Obs. Av.	447804.8113	1266636.7234	0.008	0.009	0.012
R8s RRS Obs. Av.	447804.8170	1266636.7203	0.014	0.006	0.015
Topcon Hiper VR VRS Obs. Av.	447804.8092	1266636.7158	0.006	0.002	0.006
Topcon Hiper VR RRS Obs. Av.	447804.8253	1266636.7270	0.022	0.013	**0.026**
CHC i80 VRS	447804.8209	1266636.711	0.018	-0.004	0.018
CHC i80 RRS	447804.7956	1266636.707	-0.008	-0.007	0.010
Sino 070 VRS	447804.8058	1266636.718	0.003	0.004	0.005
Sino 070 RRS	447804.8219	1266636.718	0.019	0.004	0.019
Trimble R10 VRS	447804.805	1266636.725	0.002	0.011	0.011
Trimble R10 RRS	447804.8931	1266636.698	0.090	-0.016	0.091
Topcon SR VRS	447804.8164	1266636.72	0.013	0.006	0.014
Topcon SR RRS	447804.8405	1266636.715	0.037	0.000	**0.037**

Table 2-3: Comparison of observed coordinates vs known coordinate 808D with different receivers

	East	North	Δ East	Δ North	Linear
808D Known	**473113.1740**	**1272888.1020**			
R8s VRS Obs. Av.	473113.1817	1272888.1021	0.008	0.000	0.008
R8s RRS Obs. Av.	473113.1700	1272888.0927	-0.004	-0.009	0.010
Topcon Hiper VR VRS Obs. Av.	473113.1892	1272888.091	**0.015**	-0.011	0.019
Topcon Hiper VR RRS Obs. Av.	473113.2068	1272888.126	**0.033**	0.024	**0.041**
CHC i80 VRS	473113.151	1272888.072	**-0.023**	-0.030	**0.038**
CHC i80 RRS	473113.2506	1272888.022	0.077	-0.080	**0.111**
Sino 070 VRS	473113.1868	1272888.07	0.013	-0.032	**0.034**
Sino 070 RRS	473113.1774	1272888.084	0.003	-0.018	0.018
Trimble R10 VRS	473113.1899	1272888.101	0.016	-0.001	0.016
Trimble R10 RRS	473113.1347	1272887.53	-0.039	-0.572	**0.573**
Topcon SR VRS	473113.0545	1272888.056	-0.119	-0.046	**0.128**
Topcon SR RRS	473113.1398	1272888.056	-0.034	-0.046	0.058

Conclusion 1. Network RTK vs. Single Station RTK - Based on the observations made from the field data, it can be concluded that in almost all cases, connecting to the VRS mountpoint is more accurate than connecting to the Single station RTK.

National Control Point 808D

National control point 808D is located in Baek Chan commune, Angk Snuol District, Kandal province, about 18km from the Phnom Penh CORS Station, PNH.

Several receivers were setup over this point to collect data for comparison. Data collect from the Trimble R8s and Topcon Hiper VR is summarized as follows;

Date:	31-07-2023
Receiver Model:	Trimble R8s
Survey Method:	Continuous Topo (Recorded every 1 second)
Number of observations:	898
Fix Type:	RTK Fix
Mount Point:	VRS

Date:	31-07-2023
Receiver Model:	Trimble R8s
Survey Method:	Continuous Topo (Recorded every 1 second)
Number of observations:	901
Fix Type:	RTK Fix
Mount Point:	RRS

The observation data is presented in Figure 2-8 below and a comparison between the average VRS and RRS coordinates in

	EAST	NORTH	Diff X	Diff Y
Known Coordinates	473113.1740	1272888.1020		
Mean VRS Observation	473113.1817	1272888.1021	-0.007	0

Mean RRS Observation	473113.1700	1272888.0927	0.004	0.009

Table 2-4. It should be noted that although the average coordinates for the RRS observation was quite close to the mean coordinates, the scatter was larger than the VRS coordinates.

Table 2-4: Comparison of average VRS and RRS coordinates to control point coordinates.

	EAST	NORTH	Diff X	Diff Y
Known Coordinates	473113.1740	1272888.1020		
Mean VRS Observation	473113.1817	1272888.1021	-0.007	0
Mean RRS Observation	473113.1700	1272888.0927	0.004	0.009

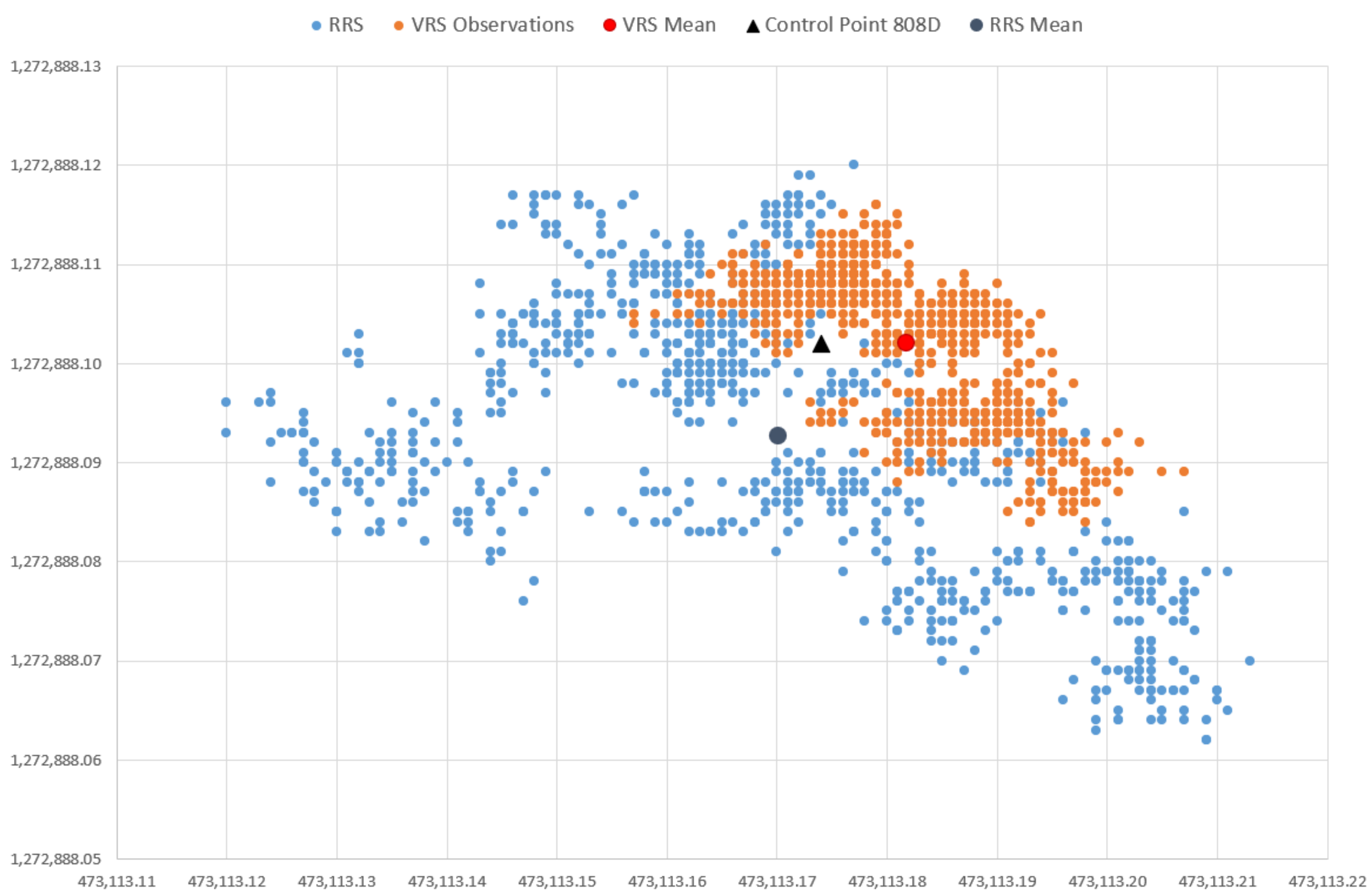


Figure 2-8: Comparison of Observations of RRS vs VRS over known point 808D with R8s receiver

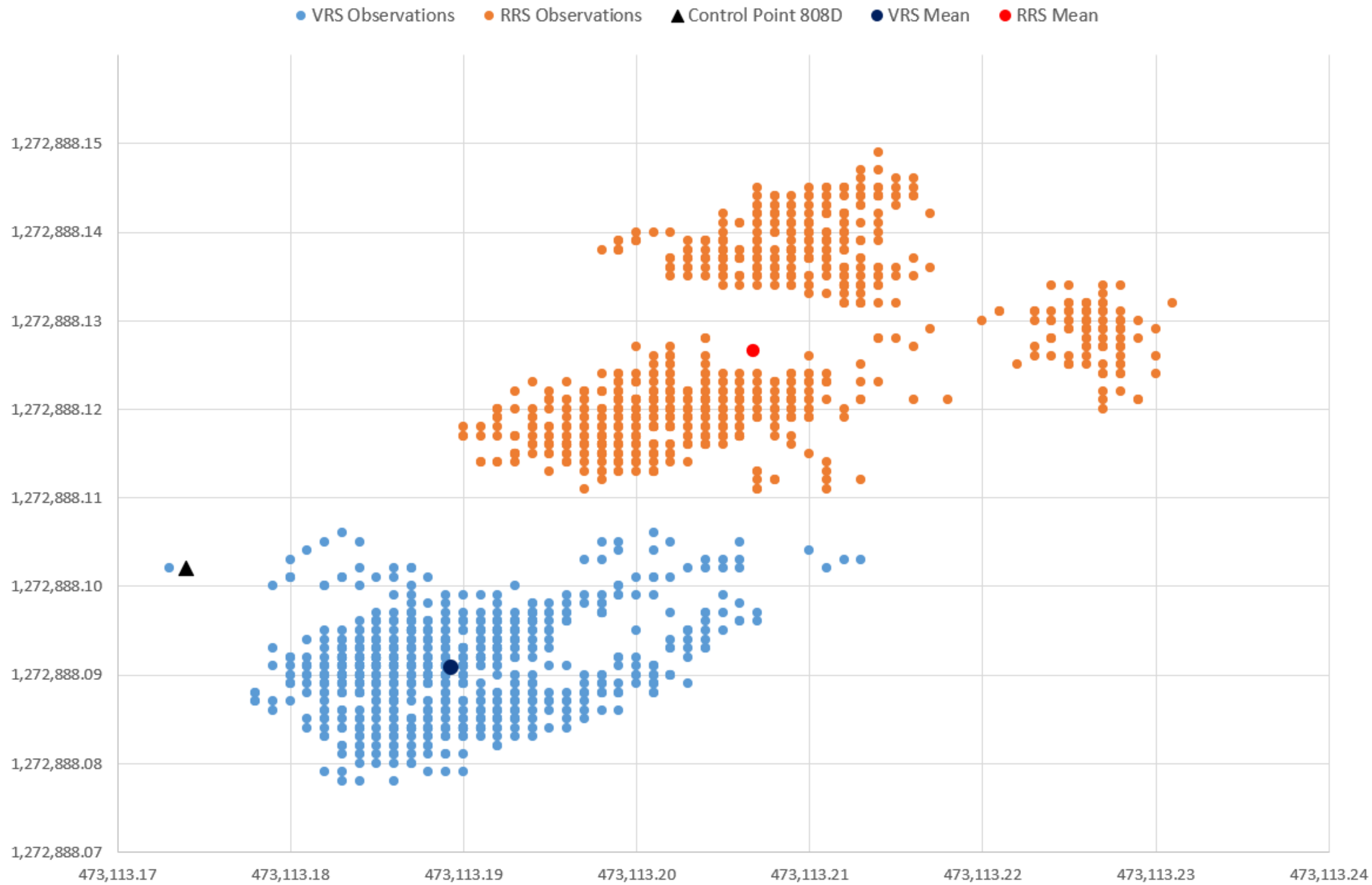


Figure 2-9: Comparison of Observations of RRS vs VRS over known point 808D with Topcon HiPer VR receiver

2.1.3.3 Comparison of accuracy of different makes and models of GNSS rover receiver

Although different manufacturers use different chips and technologies on board the receiver, the main factors affecting rover performance are;

1. The number of constellations tracked e.g. GPS, BeiDou, GLONASS
2. The frequencies tracked i.e. L1, L2, L5

Table 1-4 shows the specifications of the rover receivers utilized on this project. Only two of the models were dual frequency; the Topcon HR and the ZED-F9P.

2.1.3.4 Comparison of accuracy under different Ionospheric conditions

Background

Trimble Pivot Platform includes powerful integratory monitoring functions to predict rover performance in the field. From the Trimble Pivot Help:

> *In a reference station network the most critical error components are, first, the differential ionospheric residual error between the reference station network and the rover, i.e. the level of differential ionosphere the rover "sees" in the data, and, second, the geometric errors. If these effects are known, they can improve the RTK reliability and productivity of rovers working in a networking system. The Network Processor module removes the linear parts of these effects by applying ionospheric and geometric corrections to the raw data.*
>
> *Under disturbed ionospheric condition, ionospheric residuals cannot be considered as linear. The Network Processor module also describes the potential non-linear residual errors in the generated data stream transmitted to the user. This can also be considered as integrity monitoring for residual interpolation and ambiguity resolution in the network.* ***It is a very useful tool to predict the rover performance****.*
>
> *To find the non-linear residual errors, the Network Processor module omits one reference station from the interpolation that uses adjacent stations and then compares the interpolation results at that station with the real measurements. It computes the interpolation error separately for the ionospheric and the geometric contribution, and it provides a weighted RMS over all satellites.*
>
> *For stations at the border of a network, only extrapolations are possible. Therefore, the Network Processor module cannot provide the non-linear*

residuals. For example, for the stations A, B, and C in the figure below, no remaining residual errors can be estimated. Source: Trimble Pivot Help Manual

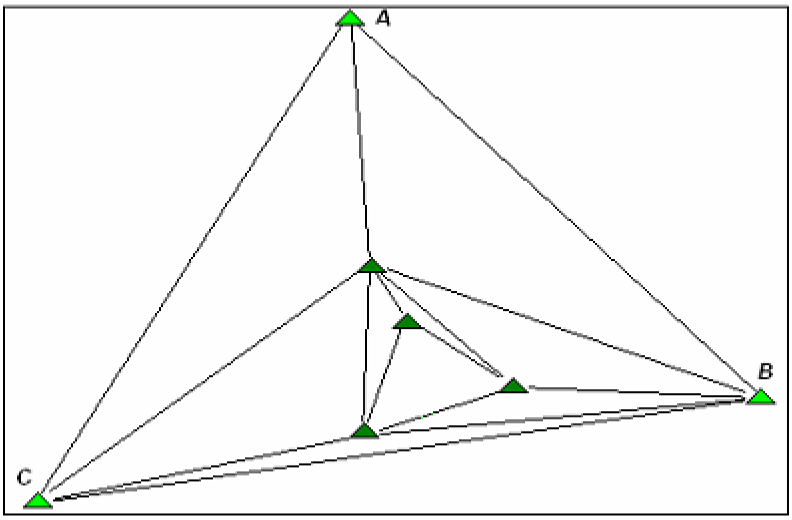


Figure 2-10: Diagram of example network and residual calculations

The Network Processor module creates a graphic overview on the predicted rover performance in terms of the Predicted Ionospheric Error (IRIM) and the Predicted Geometric Error (GRIM). For each hour of the day, it accumulates the RMS values of all network stations (except those stations building the edges of the network) for the ionospheric part as well as for the geometric part. It computes the 95% interpolation uncertainty value, where the worst 5% of the data are rejected. The highest then remaining value for the respective hour is displayed.

Conclusion 2. Predicting Rover Performance - Since the current Khmer GEONET only includes 5 stations, it could be expected that it is likely not possible to accurately calculate the non-linear residuals. However, once the network is expanded, this function of Trimble Pivot will be very important in understanding rover performance and communicating this information to users. This is especially true as we approach the solar maximum in July 2025, when ionospheric disturbance is expected to have a bigger impact on GNSS performance and accuracy.

To check the accuracy under different ionospheric conditions, observations were made on the 23rd September 2023 with the following session times.

Date:	23-09-2023
Receiver Model:	Trimble R12
Observation Period1:	08:00 – 09:00

Observation Period2:	11:30 – 16:00
Observation Period3:	16:30 – 17:00
Known Point:	808D

The ionospheric conditions reported by Trimble Pivot Platform are shown in the figures below. There are three main indicators of ionospheric conditions; Ionospheric Index (I95), Predicted Ionospheric Error (IRIM) and Predicted Geometric Error (GRIM).

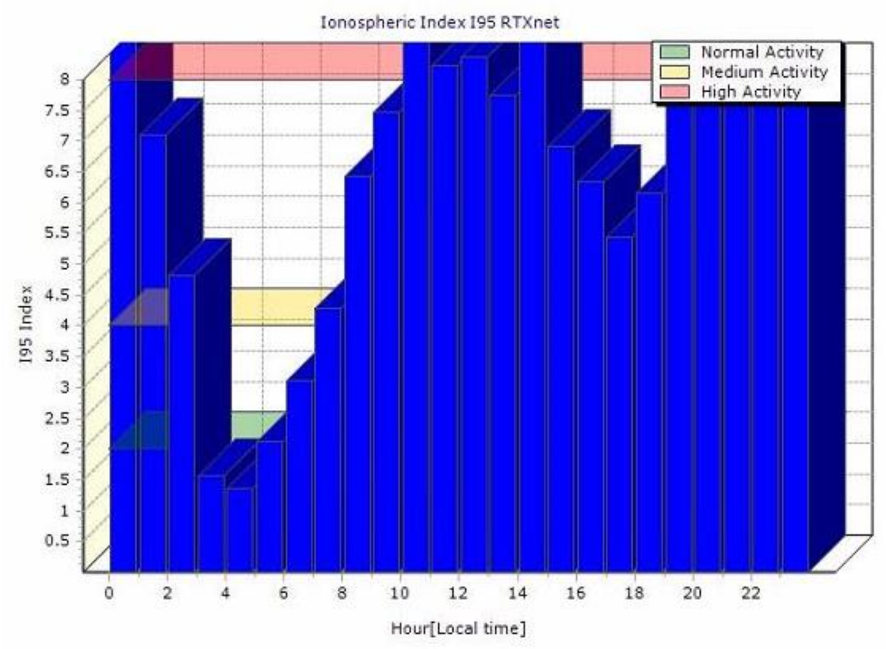


Figure 2-11: I95 Index on 23-09-2023

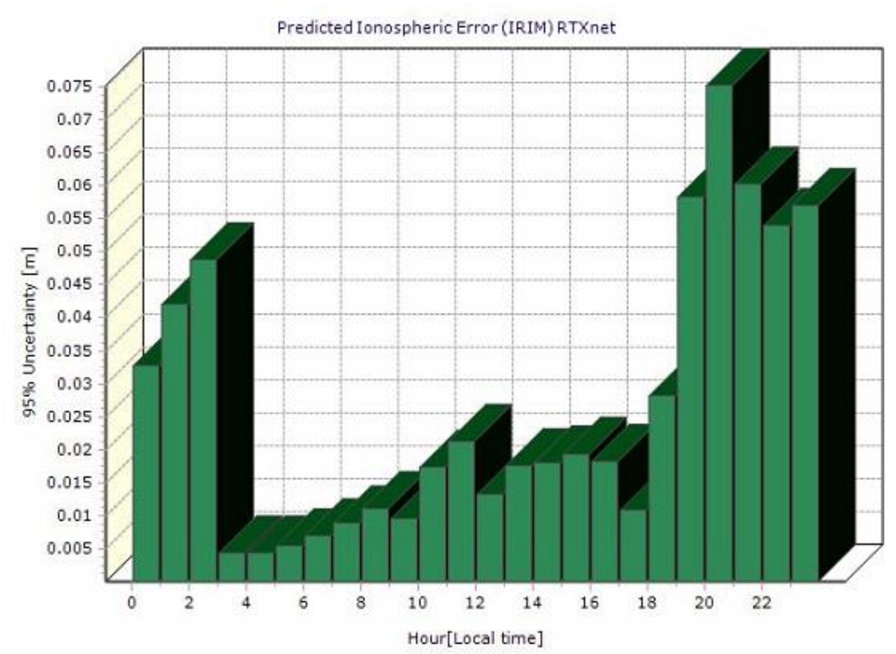


Figure 2-12: Predicted Ionospheric Error (IRIM) on 23-09-2023

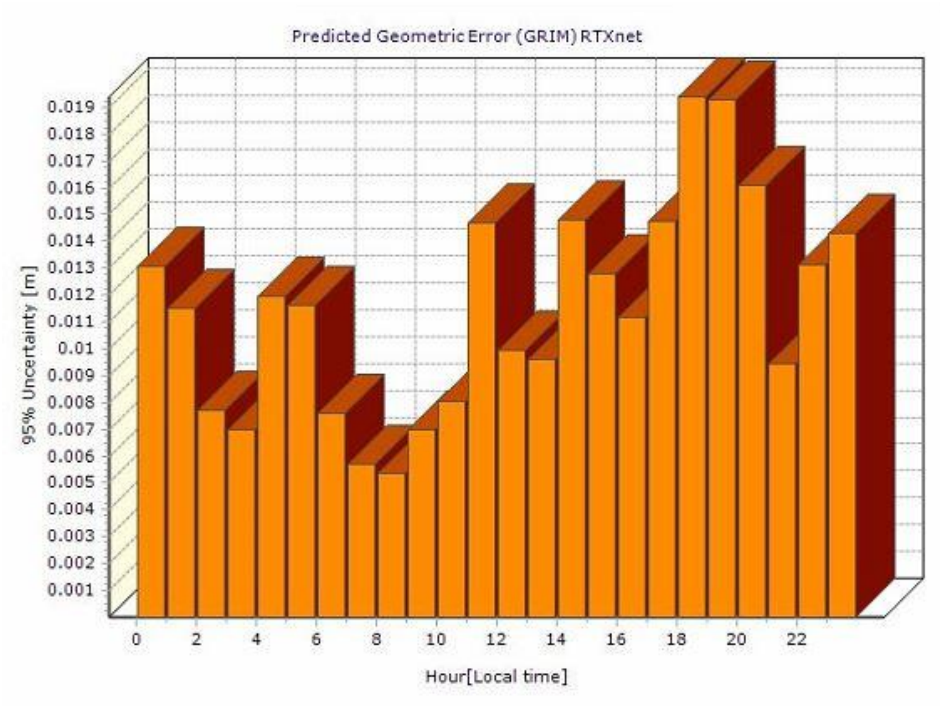


Figure 2-13: Predicted Geometric Error (GRIM) on 23-09-2023

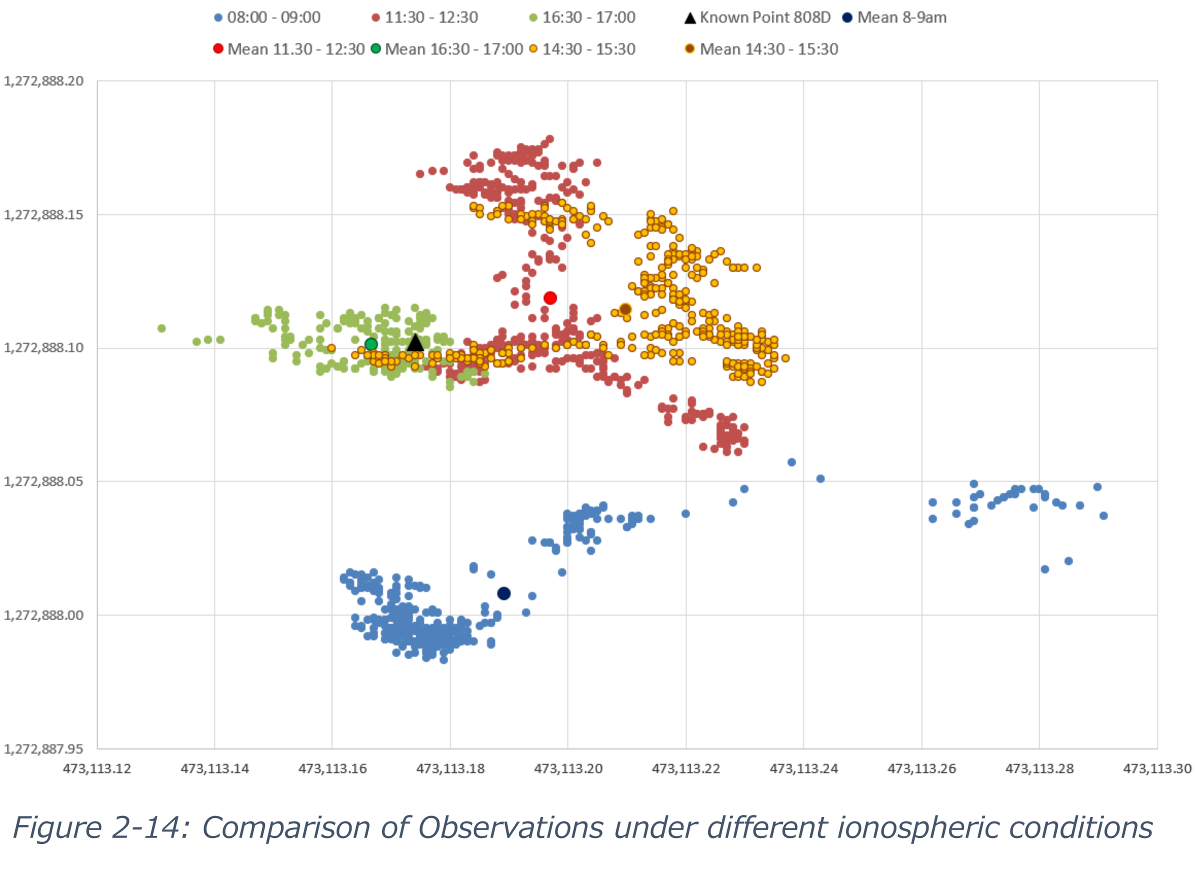


Figure 2-14: Comparison of Observations under different ionospheric conditions

The graph below shows the Ionospheric Index and Total Electron Count (TEC) as reported by https://www.gnssplanning.com/ for the time and location of field the observations.

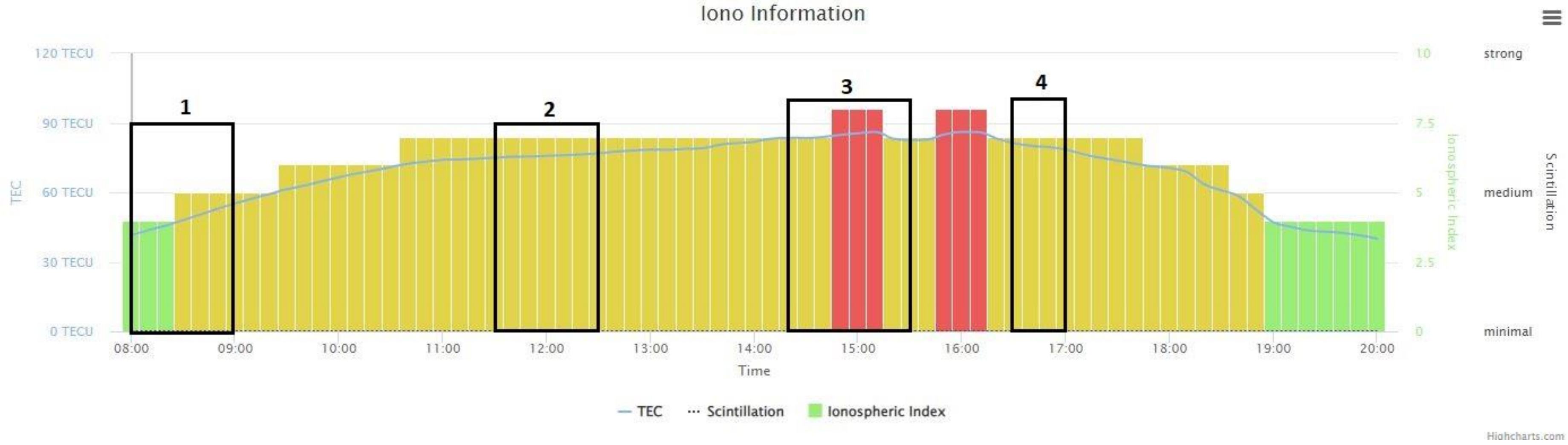


Figure 2-15: Ionospheric Conditions over time on 23-09-2023

A summary of the results of the observations over time are given in Table 2-5 below.

Table 2-5: Sessions for observing under different ionospheric conditions

No	Session Time	I95	IRIM	GRIM	Δ to known point (m)
1	08:00 – 09:00	Medium	0.01	0.006	0.095
2	11:30 – 12:30	**High**	0.02	0.015	0.028
3	14:40 – 15:30	**High**	0.01	0.015	0.038
4	16:30 – 17:00	Medium	0.02	0.014	0.008

Note: Medium values relate to I95 values of > 4 and high values > 8

From the figures and summary above it can be seen that there is no clear correlation between higher I95 values and larger errors. The largest error (0.095 m) was observed during a period of medium I95 activity as was the smallest error (0.008 m). For the two periods of high I95 activity, the error was not that high 0.028 and 0.38 respectively.

There is seemingly no strong correlation between the I95 value and the predicted Geometric (GRIM) errors, as reported by Trimble Pivot (Figure 2-11 to Figure 2-15).

Conclusion 3. Ionospheric activity as measured by the I95 index varied from Medium (I95 > 4) and High (I95 > 8). However, for the four observation periods on the date of observation, no clear correlation was found between the I95 index and the error observed over a known point. It is recommended that further investigation be conducted to understand the influence of high ionospheric activity.

2.1.3.5 Determination of accuracy at longer baseline distances from the nearest station

To determine the accuracy of longer baseline distances, two tests were devised;

1. A check of the fixing performance at different distances from the nearest CORS station; and
2. Calculate the accuracy of observed vs. known coordinates for different distances from the nearest CORS station.

Table 2-6 below shows the results of the checks of the fixing performance at different distances from the nearest CORS station. These observations were not over known points, but over temporary locations. All receivers permed well at all distances, except the ZED-F9P, which saw decreasing fixed performance with increased distance from the nearest base.

Table 2-6: Fixing performance vs. baseline length for ZED-F9P GNSS receiver

Distance (km)	ZED-F9P	Trimble R10	Trimble R8s	SinoGNSS	CHC i80
10	100				
20	100	100	100	100	97
30	96				
40	85				
50	74	100	100	100	100
70	51				
100	3			100	

For the second set of checks, four known points were selected at increasing distance from the nearest CORS station and a Trimble R10 rover setup over each point. Observations were made for 5 minutes over each point and the results are given in Table 2-7 and Figure 2-16 below. As you can see, the error is quite small and increasing linearly, even to a distance of 86 km from the nearest base station.

Table 2-7: Horizontal errors observed over known points at increasing distance

No.	Point ID	Nearest CORS Station	Distance to station (KM)	Δ East	Δ North	Linear	Date
1	5E	KSP	5.7	0.002	0.011	0.011	23/09
2	808D	PNH	18.1	0.016	-0.001	0.016	24/09
3	21A	KND	48.4	0.016	-0.018	0.024	21/09
4	6D	KNG	86.9	0.033	0.024	0.036	27/09

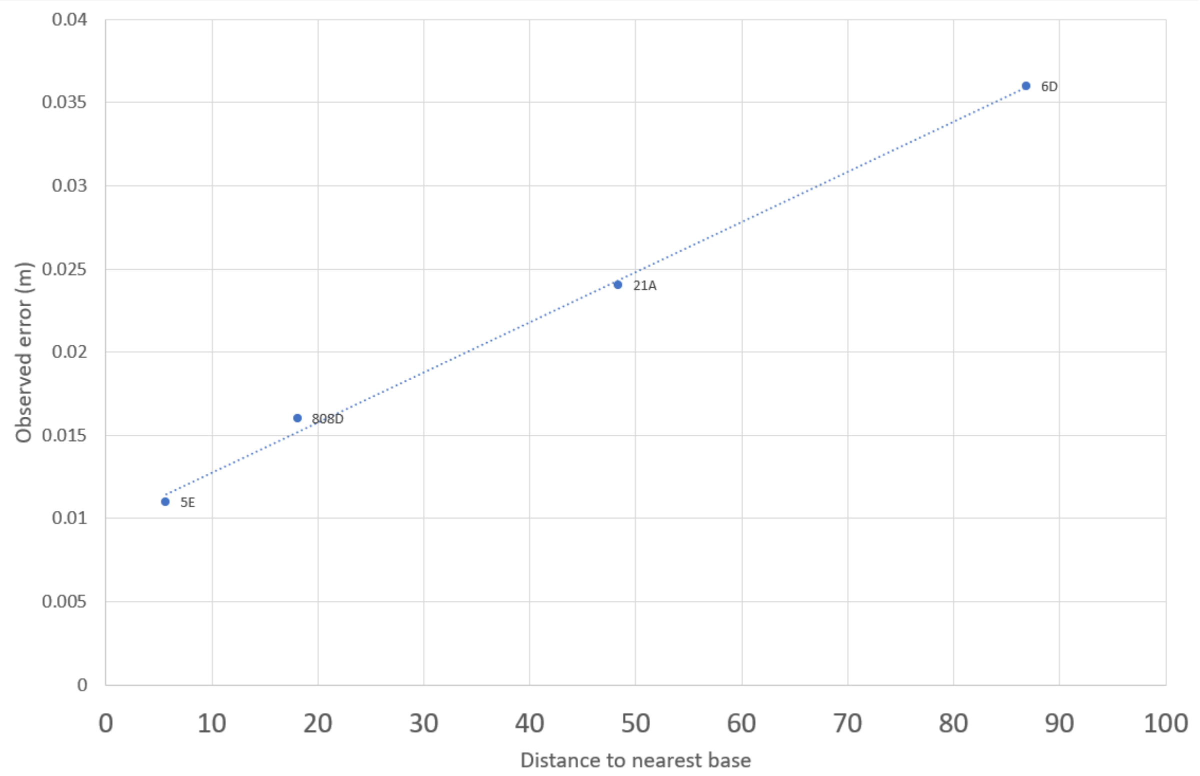


Figure 2-16: Horizontal Errors vs. distance to nearest CORS station

Conclusion 4. Based on the tests over four known points, it can be concluded the positioning accuracy of Khmer GEONET is high and increases linearly with distance from the nearest station. This means that the network correction is accurate reliable even at moderate distances (30 – 50 km).

2.1.3.6 Determine the repeatability of measurements under field conditions for cadastral survey.

Two sites were selected for determining the repeatability of field measurements; Location 1 at Prey Popel Village, Peuk Commune, Angk Snuol District, Kandal Province and location 2 at Anlong Thloeng Village, Moha Sang Commune, Phnum Sruoch District, Kampong Speu Province.

The procedure was as follows:

1. Setup tripod over point 1
2. Measure point in RTK mode
3. Repeat measure 3 times in succession
4. Move tripod to point 2
5. Repeat steps 1-3

Figure 2-17: Tripod Setup for boundary survey

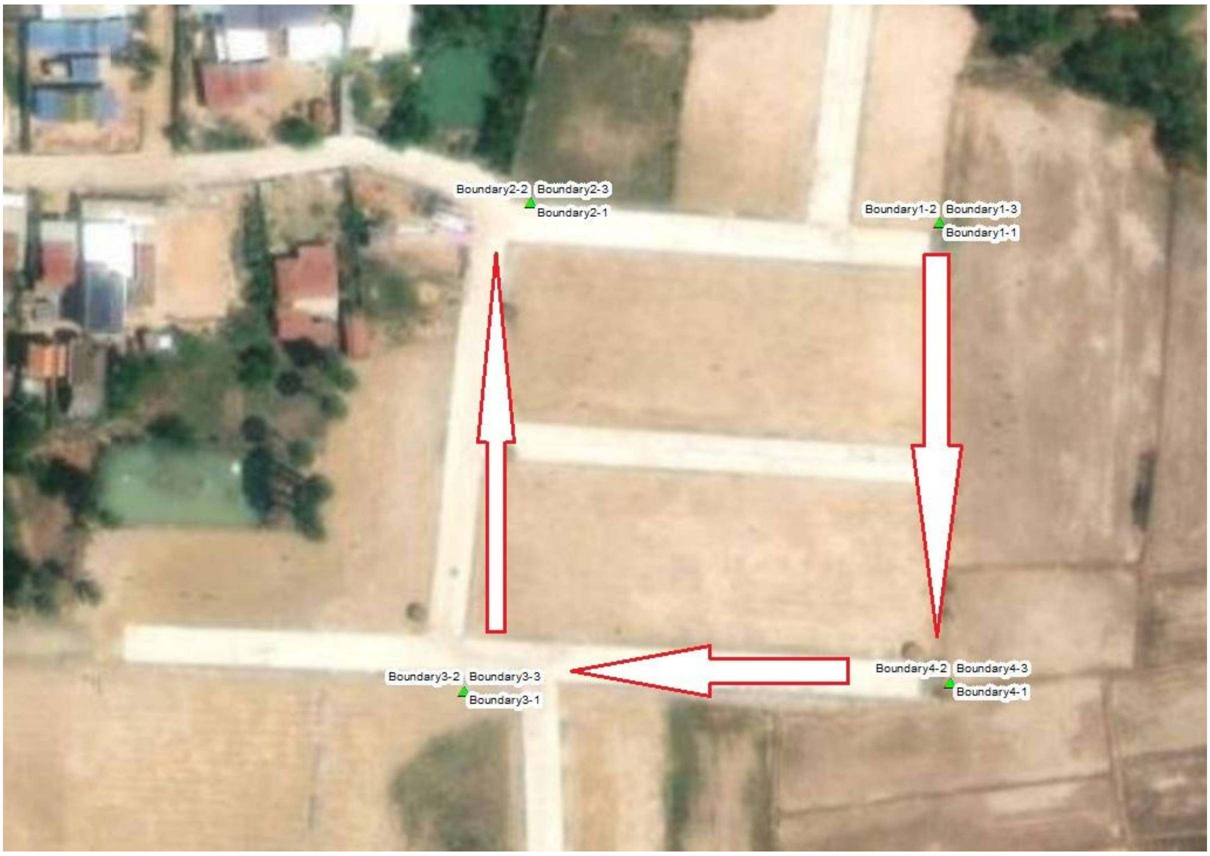


Figure 2-18: Boundary Survey Scheme in Angk Snuol District

Figure 2-19: Boundary Survey Scheme in Phnum Sruoch District

The results for the boundary survey are shown below for the CHCi80 receiver. It can be seen that the difference between measurements of the same point is very small, with a maximum difference of 3mm X, 2mm Y and 5mm Z across the two sites.

Table 2-8: Boundary Survey Results for CHC i80 receiver at Ank Snuol Site

Name	Easting	Diff.	Northing	Diff.	Elev.	Diff.	Start Time	End Time
Boundary1-1	469533.742		1271519.702		7.027		7/31/2023 15:23	7/31/2023 15:23
Boundary1-2	469533.741	(0.001)	1271519.702	0.000	7.027	0.000	7/31/2023 15:23	7/31/2023 15:23
Boundary1-3	469533.739	(0.002)	1271519.702	-	7.024	(0.003)	7/31/2023 15:23	7/31/2023 15:23
Boundary2-1	469442.219		1271524.216		7.346		7/31/2023 15:52	7/31/2023 15:52
Boundary2-2	469442.218	(0.001)	1271524.216	0.000	7.343	(0.002)	7/31/2023 15:52	7/31/2023 15:52
Boundary2-3	469442.217	(0.001)	1271524.216	(0.000)	7.344	0.000	7/31/2023 15:52	7/31/2023 15:52
Boundary3-1	469427.044		1271415.808		7.266		7/31/2023 15:56	7/31/2023 15:56
Boundary3-2	469427.047	0.003	1271415.811	0.002	7.270	0.004	7/31/2023 15:56	7/31/2023 15:56
Boundary3-3	469427.045	(0.002)	1271415.81	(0.000)	7.266	(0.004)	7/31/2023 15:56	7/31/2023 15:56
Boundary4-1	469536.016		1271417.536		7.055		7/31/2023 16:15	7/31/2023 16:15
Boundary4-2	469536.016	(0.000)	1271417.533	(0.003)	7.054	(0.001)	7/31/2023 16:15	7/31/2023 16:15
Boundary4-3	469536.019	0.003	1271417.53	(0.003)	7.056	0.002	7/31/2023 16:15	7/31/2023 16:16
	Mean	**(0.000)**		**(0.000)**		**0.000**		
	Max	**0.003**		**0.003**		**0.004**		

Table 2-9: Boundary Survey Results for CHC i80 receiver at Phnum Sruoch

Name	Easting	Diff.	Northing	Diff.	Elev.	Diff.	Start Time	End Time
Boundary1-1	434825.136		1261137.258		36.498		8/1/2023 11:00	8/1/2023 11:00
Boundary1-2	434825.135	(0.001)	1261137.259	0.001	36.499	0.002	8/1/2023 11:00	8/1/2023 11:00
Boundary1-3	434825.131	(0.004)	1261137.26	0.001	36.505	0.005	8/1/2023 11:00	8/1/2023 11:01
Boundary2-1	434876.952		1261035.41		36.300		8/1/2023 11:49	8/1/2023 11:49
Boundary2-2	434876.952	-	1261035.412	0.002	36.298	(0.002)	8/1/2023 11:49	8/1/2023 11:49
Boundary2-3	434876.952	(0.001)	1261035.411	(0.001)	36.300	0.001	8/1/2023 11:49	8/1/2023 11:49
	Mean	**(0.000)**		**(0.000)**		**0.000**		
	Max	**0.004**		**0.002**		**0.005**		

Conclusion 5. To simulate a real-world cadastral boundary survey, field tests were conducted to determine the repeatability of surveys of the same point on the same day. The results indicate the difference between repeated measures of the same point is very small, with a maximum of 4mm difference and an

average difference sub-mm. This demonstrates the robustness and reliability of Khmer GEONET for cadastral mapping purposes.

2.2 Use of KhmerGEONET

2.2.1 Details of the KhmerGEONET data used

Khmer GEONET was used as follows.

Table 2-10 Khmer GEONET data used

IP address	221.120.160.130
Port	2101
Mount point	RRS & VRS
User name	
Period of use	29 07 2023 – 05 08 2023 13 08 2023 – 29 09 2023
RTK/ Post processing	RTK
Satellite systems used	GPS/GLONASS/BeiDou/Galileo/QZSS

2.2.2 Problems occurred and solutions

No major problems were encountered with the Khmer GEONET network during the pilot project.

2.3 Other related activities

No other related activities were performed during the pilot project.

3. Way forward

3.1 Future outlook of the business using Khmer GEONET

To date, cadastral survey has relied on single GNSS base stations of unknown providence that are subject outages due to power or communication failure. With the expansion of Khmer GEONET, cadastral surveyors and others will have access to a low cost, accurate and reliable correction source. Because Khmer GEONET is maintained by the department with responsibility for positioning in Cambodia, the GDCG, users can trust that the positions are official and will allow them to integrate their maps and drawings with other agencies and organizations. The net result will be more projects delivered on time and with lower cost, more land parcels surveyed per year, the reduction or elimination of large positioning errors and general economic prosperity.

3.2 About KhmerGEONET

1) Good points using KhmerGEONET

The availability of NRTK for the first time in Cambodia is of great benefit to surveyors, particularly cadastral surveyors. Based on the work conducted for this demonstration project would note the following positive points;

1. NRTK networks are more reliable than single base station networks, because even if a single station is offline, a correction signal can still be broadcast to rovers in that area.
2. NRTK networks are more accurate than single base solutions, particularly in their ability to model errors caused by ionospheric activity.
3. Khmer GEONET produces, precise, reliable network corrections that users can trust.
4. Khmer GEONET is based on open standards, meaning that all makes and models of GNSS rover receiver are supported, allowing access by a larger user base.
5. The availability Khmer GEONET will reduce the cost and complexity for organizations who would otherwise have to operate their own base station. This will mean the wider adoption of GNSS positioning technologies over older surveying methods.
6. Khmer GEONET is based on an official, robust calculation of station coordinates, meaning that accuracy will be achieved and there will be a consistency between positioning by different organizations. Presently, other organizations use a range of national reference control points for GNSS positioning, with unknown accuracy.
7. Khmer GEONET has proven to have a higher availability (uptime) than other base station infrastructure. This will mean that works can be completed in less time and for a lower cost.

8. The availability of static data for download from Khmer GEONET is of great benefit for survey and engineering projects who need to establish control points on site.
9. Khmer GEONET has a large, active community with more than 1,300 registered users and more than 250 weekly active users and support is available to users who are learning the system or experiencing problems.
10. Khmer GEONET opens the possibility, for the first time, applications beyond land survey, including land and water navigation, precision agriculture, self-driving transportation to name a few.

2) Issues to be solved

Based on the testing that we conducted, there are no outstanding issues to be resolved. Of course, the current network of 5 stations has limited coverage, therefore can only be applied to cadastral survey within vicinity of this network. Expansion of the network to cover the whole country would be of great benefit to this activity, which is of national importance.

3) Request for improvement

We would request the following points for improvement;

1. Increased coverage in the country of Khmer GEONET
2. Guidance for users on the impact of ionospheric activity on survey accuracy, especially leading up to the solar maximum in July 2025.
3. Communication of periods of periods of highest solar activity on a daily basis
4. Practical guidance on how to manage/mitigate the impact on solar activity in the context of cadastral survey.

4. Conclusion

In conclusion, the results of the pilot project indicate that Khmer GEONET, with 5 stations is already providing a robust, reliable and acute correction to rovers in the field, operating under typical conditions. With the planned expansion of the network, this reliability and robustness can be expected to increase, particularly in terms of redundancy and also for Trimble Pivot to model the non-linear errors in the network and consider how that might be impacting rover performance.

One area that should receive close attention is the impact that ionospheric disturbance is having on network performance and how that impacts accuracy during peaks, which often happen each day.

Project on Establishment of Continuously Operating Reference Stations (CORS) for Land Management and Infrastructure Development

JICA Pilot Project

Demonstration project Imprementation Report

October 2023

IKEE PAVING SYSTEMS

TOPCON CORPORATION

TOPCON POSITIONING ASIA

Table of Contents

1. Overview of the demonstration project

1.1. Name of the demonstration project

EN: Utilize Khmer GEONET data in the construction project

KM: ការប្រើប្រាស់ទិន្នន័យ Khmer GEONET ក្នុងគម្រោងសាងសង់

1.2. Background and purpose of the demonstration project

The background behind the use of Khmer GEONET distribution data for civil engineering surveying was the establishment of five Continuously Operation Reference Stations (CORSs) in Cambodia and the start of Khmer GEONET operation.

In this project, it was decided to evaluate the accuracy and workability of the conventional survey method for civil engineering construction and GNSS-based surveying.

Accuracy comparisons were made between Static survey and N-RTK survey methods, and accuracy and workability comparisons were also made between N-RTK and RTK survey methods. This project objective was to use the evaluation and findings to provide information, including advice, on the use of N-RTK survey using Khmer GEONET provided data for future civil engineering surveys.

1.3. Brief description of the demonstration project

1: Comparisons of the civil engineering construction survey methods between the conventional survey (level survey) and GNSS survey (RTK survey by mmGPS).

• Accuracy comparisons were made between the conventional method (level survey) and GNSS survey method (mmGPS). The results showed that the average difference among the 66 observation points on 11 cross-sections in the assessment area was approximately ±4 mm in accuracy.

• In terms of workability, the operating time was the same for both the conventional method (level survey) and GNSS survey method (mmGPS). The conventional method required 5 workers while GNSS survey required only 2, less than half of that number.

2: The results of comparisons between Static survey and N-RTK survey showed that the fixed rate of the N-RTK survey was lower, and it was not possible to perform the accuracy comparison under this condition.

3: Comparisons between N-RTK and RTK surveys

• For accuracy, the average differences were 1.2 cm for X, 0.2 cm for Y, and -3.8 cm for H, which is generally acceptable when used as N-RTK survey. In terms of operating time and number of people, N-RTK survey resulted in higher productivity.

*Details are available in 2.1.3 "Results."

1.4. Implementation period

Preparation: Feb 2023 – Mar 2023

Work at the site: Mar. 2023 – Jun. 2023

Reporting: Jun. 2023 – Oct. 2023

Table 1-1 Planned schedule and actual schedule

Work Items/ Year & Month		Progress	2023											
			1	2	3	4	5	6	7	8	9	10	11	12
Sign a contract with Pasco	Plan	100.0%												
	Actual													
Preparation of the pilot project		**100.0%**												
Making a pilot project implementation plan	Plan	100.0%												
	Actual													
Export/import of equipment	Plan	100.0%												
	Actual													
Confrimed surveying area , set up GCP / confirmed current GCP points in the job site	Plan	100.0%												
	Actual													
	Plan	0.0%												
	Actual													
Performance of the Pilot Project		**100.0%**												
Test of N-RTK in Phnom Penh	Plan	100.0%												
	Actual													
Static & N-RTK survey from Siem Reap CORS Station	Plan	100.0%												
	Actual													
Milli-Meter GNSS Survey	Plan	100.0%												
	Actual													
Evaluation of Result	Plan	100.0%												
	Actual													
Making final Report	Plan	100.0%												
	Actual													
	Plan	0.0%												
	Actual													
JICA seminar, Presentation material, Case study leaflet, Pilot project implementation report														
JICA seminar								(Plan)						
Final deadline of Case study leaflet (promotion material)														
Final deadline of Pilot project implementation report														

1.5. Location of the demonstration project site

The project was carried out at the site of the National Road No. 5 Improvement Project in Phum Puk Chhma district, near Battambang City.

Address: Phum Puk Chhma, Cambodia

Location on route drawings: PK282 + 100 to PK281 + 300

Coordinates: X: 1443404.556, Y: 312330.616

(From the observation point results of Static survey near the implementation site.)

Figure 1-1 Location of the demonstration project site (Source from Google map)

Figure 1-2 Location of the demonstration project site

(Phum Puk Chhma, National Road 5 improvement project site)

1.6. Members

The members listed below performed the demonstration project.

Table 1-2 List of members

NO.	Name	Company/Organization	Role
1	Kazunori Miyamoto	IKEE Paving Systems	Project Manager
2	Bun Sereyvathanak	IKEE Paving Systems	Support field survey & data calculation
3	Seang Sotheany	IKEE Paving Systems	Support field survey & data calculation
4	Naoyuki Tamaki	TOPCON CORPORATION	Assistant Project Manager
5	Takashi Ogawa	TOPCON POSITIONING ASIA(THAILAND)	Prepare equipment
6	Koichiro Fuse	TOPCON POSITIONING ASIA	Support data calculation & evaluation
7	Shunichi Takahashi	TOPCON POSITIONING ASIA	Data calculation & evaluation
8	Soun Tivea	CAM-ES	Prepare equipment (import & export work) & Support field survey
9	Pauv Amrong	CAM-ES	Prepare equipment (import & export work) & Support field survey
10			

1.7. Equipment used for the demonstration project

The equipment listed below were used for the demonstration project.

Table 1-3 List of equipment used

NO.	Name	Quantity	Remarks (specifications, usage, etc.)
1	TOPCON GNSS Receiver HiPerHR	2	GNSS Receiver
2	TOPCON GNSS Receiver HiPerVR	1	GNSS Receiver
3	TOPCON Field Controller FC-5000	1	Field computer
4	TOPCON Field Controller FC-6000	2	Field computer
5	TOPCON mmGPS Laser Transmitter	2	Surveying option equipment

NO.	Name	Quantity	Remarks (specifications, usage, etc.)
6	TOPCON mmGPS Laser Receiver	1	Surveying option equipment
7	GNSS External Battery & Tripod	3	Survey accessories
8	WIFI router	3	Data communication
9	TOPCON Magnet Tools (Calculation Software)	1	Calculation software

GNSS receiver HiPerHR

GNSS TECHNOLOGIES (SIGNAL TRACKING)	
GPS	L1 C/A, L1C, L1P(Y), L2P(Y), L2C, L5
GLONASS	L1 C/A, L1P, L2C/A, L2P, L3C
Galileo	E1, E5a, E5b, E5 AltBOC, E6
BeiDou	B1, B2, B3
IRNSS (NavIC)	SPS-L5
SBAS	WAAS/EGNOS/MSAS
QZSS	L1 C/A, L1C, L2C, L5, LEX
L-band	Yes
Universal Tracking Channels™	452 GNSS channels Vanguard Technology™ with Universal Tracking Channels™; 4 reserved for L-band
TILT™	Topcon Integrated Leveling Technology™
GNSS Antenna	Integrated Full wave Fence Antenna™ technology with internal ground plane
POSITIONING PERFORMANCE	
Precision Static	H: 3 mm + 0.1 ppm | V: 3.5 mm + 0.4 ppm
Static/Fast Static*	H: 3 mm + 0.3 ppm | V: 5 mm + 0.5 ppm
RTK	H: 5 mm + 0.5 ppm | V: 10 mm + 0.8 ppm
Code Differential GNSS	H: <0.4m | V: <0.6m
RTK, TILT Compensated	H: 1.3 mm/°Tilt; Tilt ≤ 10° | H: 1.8 mm/°Tilt; Tilt > 10° Maximum recommended angle for tilt compensation is 15°**
COMMUNICATIONS	
Internal Radio (Optional)	405-470 MHz UHF or FH915 spread spectrum Max Transmit Power: 1W Range: 5-7 km typical; 15 km in optimal conditions.***
Cellular	3.5G
LongLink™ Bluetooth	Up to 328.1 m / 1000 ft
WiFi	Yes
Bluetooth™	Yes
Connectors	1 Power, 1 Serial, 1 USB, 2 Connectors
DATA FORMAT AND MEMORY	
Data Output	TPS, RTCM, CMR/CMR+, NMEA, BINEX
Internal Memory	8 GB
Update Rate	Up to 20Hz
POWER	
External Power Supply	9.0 – 28.0 V DC
Battery	Internal: Li-ion 5,200 mAh, 3.7 V External: Li-ion 2,900 mAh, 7.2 V (Hot swappable)
Operating time with radio	Up to 9 hours with included batteries. *Refer to the operator's manual for more information*
HARDWARE	
Dimensions (W x H)	11.5 cm x 13.2 cm (4.53 in x 5.20 in)
Weight	1.172 kg (2.58 lb) with batteries
Ingress Protection	Dust and water IP67
Vibration	MIL-STD 810G
Drop	Survive 2m pole drop on concrete surface
Operating Temperature	-40° C to +65° C (-40° F to +149° F)
Humidity	100%

GNSS receiver HiPerVR

GNSS Tracking	
Channel Count	226 with Topcon's patented Universal Tracking Channels™ technology.
Signal	
GPS Signals	L1 C/A, L1C[†] L2C, L2P(Y), L5 [†]L1C when signal available.
GLONASS	L1 C/A, L1P, L2C/A, L2P, L3C[‡] [‡]L3C when signal available.
Galileo	E1/E5a/E5b/Alt-BOC
BeiDou/BDS	B1, B2
IRNSS	L5
SBAS	WAAS, EGNOS, MSAS, GAGAN (L1/L5[§]) [§]L5 when signal available.
L-band	TopNET Global D & C Corrections services
QZSS	L1 C/A, L1C, L1-SAIF, L2C, L5

Positioning Performance	
Static/ Fast Static	H: 3 mm + 0.4 ppm V: 5 mm + 0.5 ppm*
RTK	H: 5 mm + 0.5 ppm V: 10 mm + 0.8 ppm
RTK, TILT Compensated	H: 1.3 mm/°Tilt; Tilt ≤ 10° V: 1.8 mm/°Tilt; Tilt > 10° Maximum recommended angle for tilt compensation is 15°.**
DGPS	0.25 m HRMS
L-Band, D Corrections Service	H: < 0.1 m (95%) V: < 0.2 m (95%)
Operational Time	RX mode - 10hr TX mode 1W - 6hr *Use of external 12V battery is recommended when using HiPer VR with internal radio in transmit mode.*
Internal Radios	425-470 MHz UHF radio Max Transmit Power: 1W Range: 5-7 km typical; 15 km in optimal conditions.***
Memory	Internal Non-removable 8 GB SDHC
Environmental	Ingress Rating – IP67 Operating Temp – -40°C to 70°C Humidity – 100%, condensing Drop and Topple – 1.0 m drop to concrete. 2.0 m pole drop to concrete.
Dimensions	150 x 100 x 150 mm (w x h x d)
Weight	<1.15 kg

mmGPS Laser Transmitter LZ-T5

Operating range	
Zone radius	300 m (985 ft) *1
Zone width	+/-10° (5 m to 30 m), +/-5 m (30 m to 300 m)*
General accuracy	
Height accuracy	5 mm + 50 ppm X D (D: Horizontal distance [mm])*
	*When used in combination with the PZS-1
Channels	4
Laser	
Light source	Laser diode (invisible laser)
Laser class	Class 1
Auto leveling section	
Auto leveling range	+/-3°
Sensitivity of circular level	10 ft / 2 mm
Rotational speeds	600 rpm

Plumb beam	
Light source	Laser diode (visible laser)
Laser class	Class 2
Communication section	
Serial	One port, in compliance with RS-232C
Bluetooth	One port, v2.1 + EDR
Range	10 m (in controller communication)
Power source section	
Standard battery	Ni-MH battery pack BT-67Q
Charging time	Approx. 7 hours (using with Ad-11D/at +20°C (+68°F))
Operating time	Approx. 18 hours (at +20°C (+68°F))
Range of charging temperature	10 to 40°C
General	
Protection against water and dust	IP66 (based on the standard IEC60529)
Operating temperature	-20°C to +50°C (-4°F to +122°F)
Storable temperature range	-30°C to +60°C (-22°F to +140°F)
Dimensions	232(W) x 192(D) x 280(H) mm [9.1(W) x 7.8(D) x 11.0(H) in]
Weight	4.3 kg (9.5 lbs) (Ni-MH battery type: including BT-67Q)

mmGPS Laser Receiver PZS-1

Detective angle	
Horizontal	+/- 10°
Vertical	+/- 10°
Serial port	RS-232C
Power supply	BT-62Q
Continuous operating time at +20°C (+68°F)	Approx. 8 hours
Tripod screw	5/8 inch x 11 thread
Operating temperature	-20°C to +50°C (-4°F to +122°F)
Protection against water	IPX6 (Based on the standard IEC60529)
Dimensions	Approx. 170(W) x 86(D) x 144(H) mm
	Approx. [6.69(W) x 3.38(D) x 5.67(H) in]
Weight	Approx. 1 kg [2.2 lbs] (With battery)

Field Computer FC-5000 / FC-6000

Hardware	
CPU	Intel® Atom™ Z3745 Processor
OS	Windows® 10
Memory	4 GB LPDDR3 RAM, SD slot, user accessible
Display	7 in. Sharp screen, Wide XGA at 1280 x 800
GPS	Type: uBlox NEO M8M Accuracy: 2-5 m Channels: 72 Update Rate: 5 Hz
Camera	Rear: 8 megapixel with LED Illumination Front: 2 megapixel
Wireless Connectivity	
Bluetooth®	Long-range Bluetooth Smart Ready wireless technology, v4.0 +EDR, Class 1.5, BLE support
Wi-Fi	802.11 a/b/g/n 2.4 GHz and 5 GHz
Cellular (optional)	Internal GSM 4G LTE

Environmental	
Water/Dust Rating	IP68 certified
Operating Temp	-20ºC to 50ºC
Temperature Shock	MIL-STD 810G
MIL-STD 810G	Drop 4 ft. (1.2 m), vibration, humidity, tumble spec: 1,000 1.6 ft. / 0.5 m tumbles (2,000 drops)
Dimensions (l x w x h)	13.71 x 3.45 x 21.5 cm
Operating Time	Up to 15 hours (5 hours internal batteries, 10 hours with swappable batteries)

2. Details of the work

2.1. Work performed

2.1.1. Preparation

The following items were prepared for the National Road No. 5 Improvement Project in Phum Puk Chhma district in the suburbs of Battambang City.

[1]A plan was made to calculate coordinates of Grand Control Point (1 point) for base station of RTK survey and Grand Control Points (2 points) for set up laser transmitter by conducting Static survey at the site.

[2]A simultaneous observation program was prepared to perform Static survey (for [1]) and N-RTK survey simultaneously.

[3]Interviews were held on the conventional survey method with Tekken Corporation, the construction company involved in the National Road No. 5 project, to determine how to compare the conventional survey method with RTK survey (mmGPS) method.

[4]A method of comparing the accuracy and workability between the N-RTK and RTK surveys using locally established Grand Control Points was determined.

*However, the survey for the work described in [4] was carried out in another location. (See 2.1.2 “Implementation” for details.)

[5]The required mmGPS equipment was imported / exported smoothly.

The reason for importing the equipment was cited as “for use in JICA project,” and a simultaneous application was made to export the equipment about 3 months after import. The equipment was imported into Cambodia on a provisional import basis without delay.

Figure 2-1 [1] Image of Static survey (Source from Google Map)

Figure 2-2 [2] Image of RTK vs N-RTK (Source from Google Map)

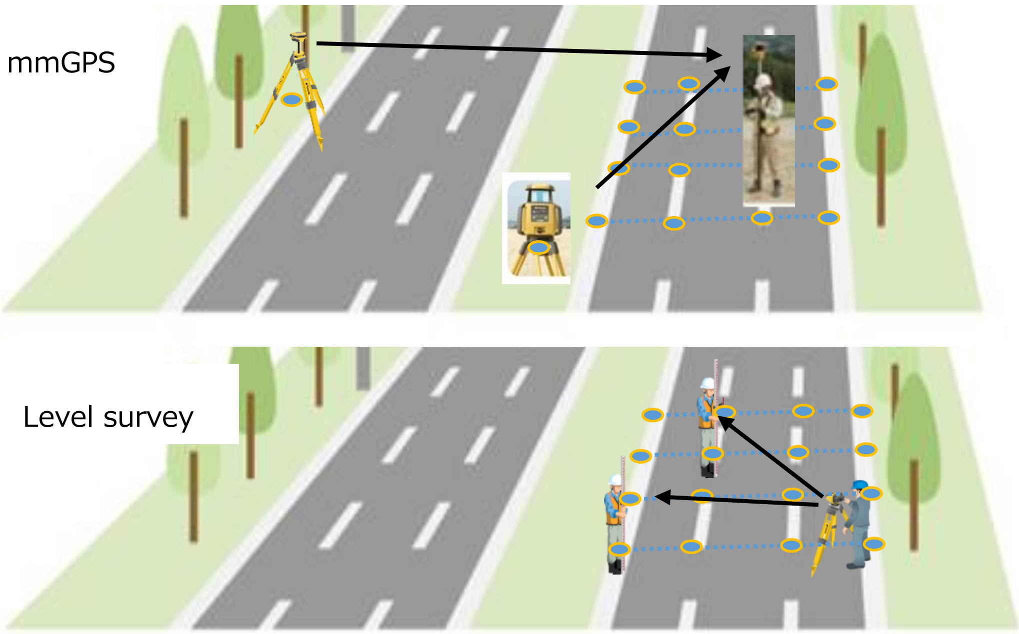


Figure 2-3 [3] Image of RTK (mmGPS)vs Level survey

Figure 2-4 Meeting for surveying plan with MLMUPC and GDCG

Figure 2-5 Meeting for surveying plan with Tekken JV

Figure 2-6 Meeting for surveying plan with Construction surveying team

2.1.2. Implementation

1: Conducting Static and N-RTK surveys on site

To obtain the coordinates of the three Grand Control Points (1 for the base station for the RTK survey and 2 for set up laser transmitters) for on-site measurement, 3 points were established on the site and Static survey was carried out. N-RTK survey was also conducted simultaneously.

As for the measurement technique, the survey was carried out under the following conditions and methods.

Receivers used: 3 GNSS receivers (TOPCON, HiPerHR and HiPerVR) in total.

Observation: 2 measurements were carried out simultaneously for Static survey and N-RTK survey.

Observation conditions: Continuous measurement was conducted at the same observation points for 10 hours.

For the observation span, data acquisition was performed once per second for both Static and N-RTK surveys.

Satellites used: GPS, GLONASS, QZSS, GALILEO, BEIDOU

N-RTK observation conditions: See 2.2.1 “Khmer GEONET data utilization” below.

Figure 2-7 Static Survey (Left: Survey for RTK base station / Right: Survey for set up mmGPS equipment)

The survey results are given in 2.1.3 “Results.”

2. Comparisons of accuracy and workability between N-RTK and RTK surveys using locally established Grand Control Points

The work was planned for this site on the National Road No. 5, but at a meeting with GDCG, it was found that there were no Grand Control Points near the site. As a result of that meeting, it was decided to conduct the survey in another location.

It was decided to compare N-RTK and RTK surveys using the First order Grand Control Point “KAND” located in Ta Khmau City, about 10 km south of Phnom Penh.

RTK base point was established at the First order Grand Control Point KAND. Observation was performed at 5 points at a football pitch near the base point. The observation was performed by switching between N-RTK and RTK surveys.

As for the measurement technique, the surveys were carried out under the following conditions and methods.

Receivers used: 2 GNSS receivers (TOPCON and HiPerHR) in total.

Observation: RTK and N-RTK surveys were conducted.

Observation conditions: RTK and N-RTK surveys were conducted once each. Observation was performed once per second for a total of 10 seconds, and the average value was recorded.

Satellites used: GPS, GLONASS, QZSS, GALILEO, BEIDOU

N-RTK observation conditions: See 2.2.1 “Khmer GEONET data utilization” below.

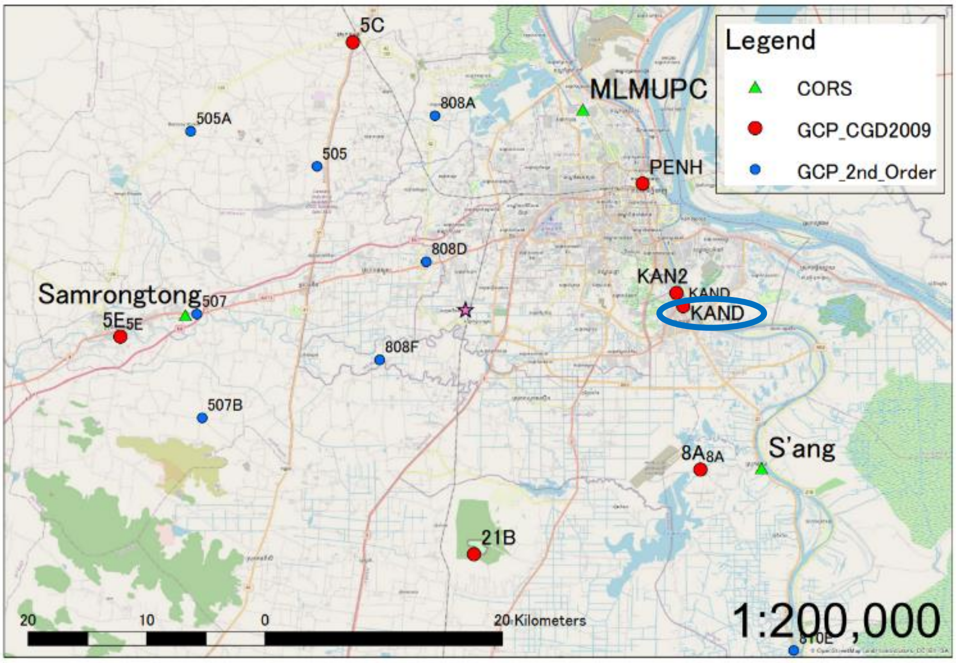


Figure 2-8 Location MAP for N-RTK vs RTK in Ta Khmau city

(Provided from GDCG, Map data source from Open street map)

Figure 2-9 Comparison of N-RTK vs RTK survey (Pictures are setting for RTK)

Figure 2-10 Comparison of N-RTK survey vs RTK survey

(Pictures are collecting data on survey points)

Comparisons of workability and the survey results are given in 2.1.3 “Results.”

3. Comparisons between the conventional and GNSS (mmGPS) survey methods in the road improvement project

RTK survey (mmGPS) was conducted using the Grand Control Points established according to Item 1 under 2.1.2. "Implementation of static survey."

• Measurement was performed within an observation range of 300m from the route PK271 + 700 to PK282 + 000. (The evaluation was conducted within a total range of 100 m from the point where the laser transmitter set up to just fore and back the 50-m mark (PK281 + 820 to 920).)

• The cross-sections were provided with a pitch of 10 meters. Measurements were performed at 7 points per cross-section. (The 7th point was not used for accuracy evaluation because it was outside the road surface.)

• Measurements were performed twice on the road surface previous and after the paved area. The pavement thickness was calculated from the height data.

• After measuring with the conventional method (level survey), the same point was measured with RTK (mmGPS) method.

• RTK (mmGPS) measurement was performed once per second for a total of 10 seconds at each measurement point, and the average value was recorded.

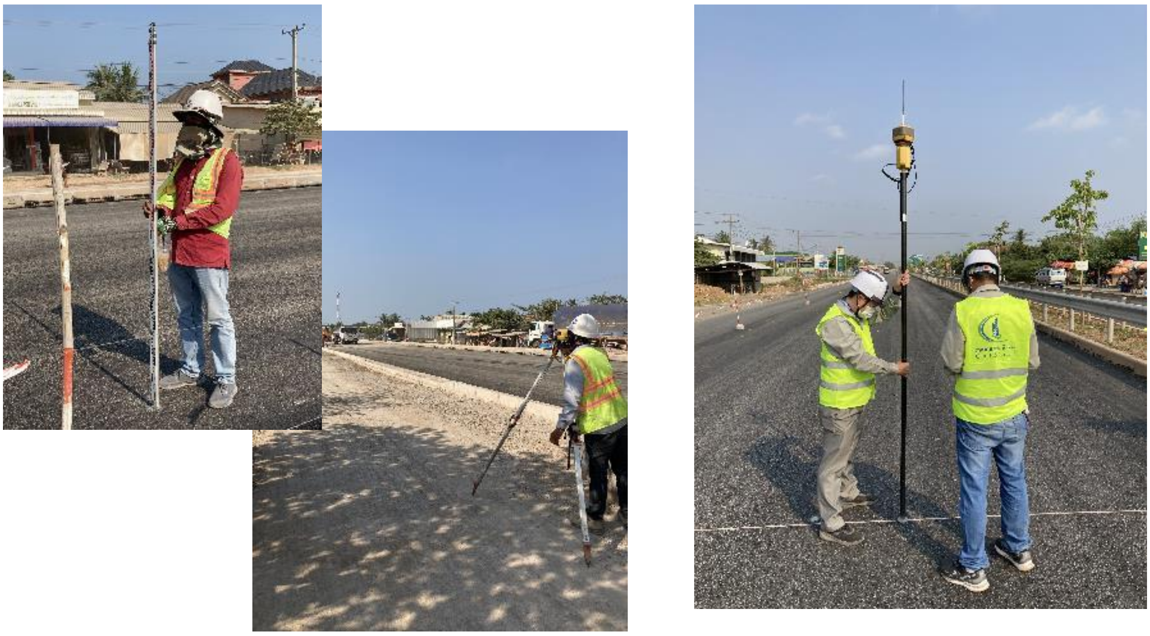


Figure 2-11 Comparison of level survey vs RTK (mmGPS) survey

The survey results are given in 2.1.3 "Results."

2.1.3.Results

1: Results of Static and N-RTK surveys

1-1: The calculation results of Static survey were as follows.

Table 2-1 Calculation result of static survey

	X	Y	H	Lat	Lon	H
GB-01(RTK Base)	1443404.556	312330.616	12.581	13° 03′ 03.23271″	103° 16′ 09.39916″	12.581
LT-01(Laser Transmitter set position)	1443856.412	312348.876	14.505	13° 03′ 08.56841″	103° 16′ 09.96809″	14.505
LT-02(Sub Laser Transmitter set Position)	1443577.281	312337.881	14.515	13° 03′ 08.85457″	103° 16′ 09.60114″	14.515

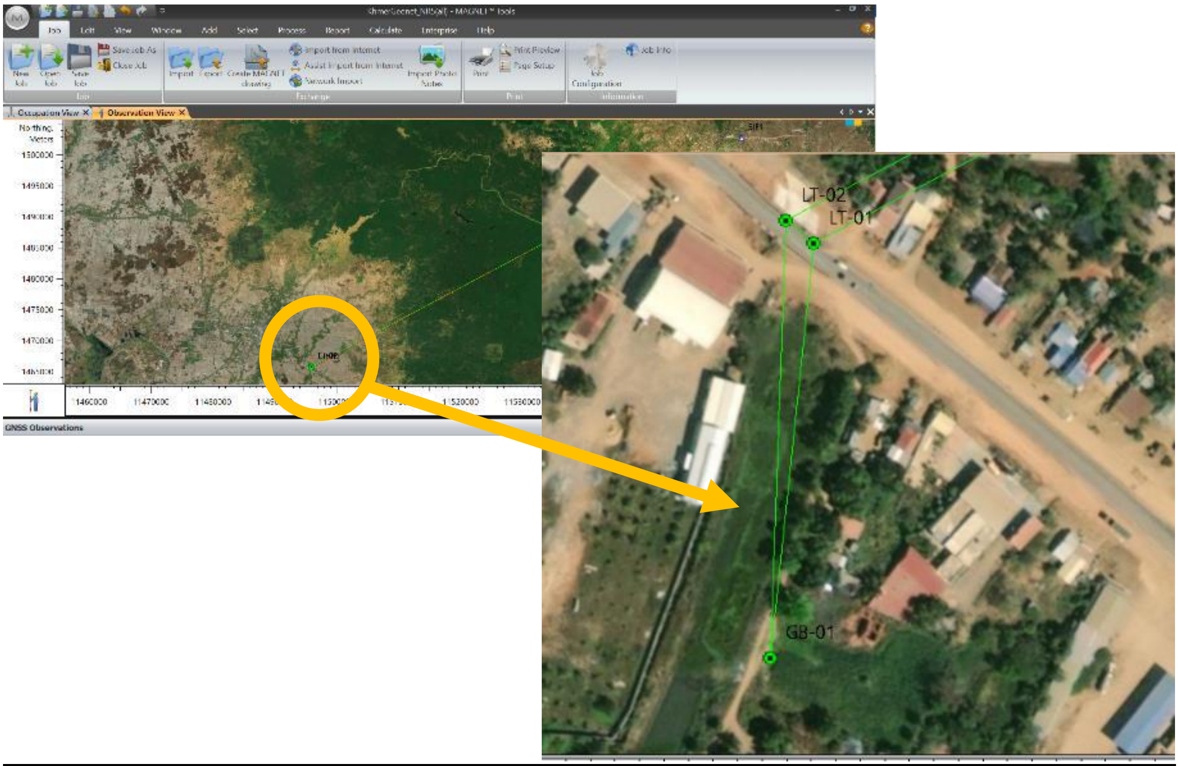


Figure 2-12 Static calculation by survey office software (TOPCON Magnet Office)

1-2: Differences between Static and N-RTK surveys

The positioning results of N-RTK survey were as follows:

GB-01 (Grand Control Point for the RTK base station)

Table 2-2 Results of N-RTK survey (GB-01)

	Data	%
Autonomous	15,700	62.3
DGPS	0	0.0
Float	5,564	22.1
Fixed	2,581	10.2
Miss Fixed	1,355	5.4
Total	25,200	100.0

N-RTK survey accounted for 10% of the total observation time, and normal observation was not performed.

LT-01 (Grand Control Point for laser transmitter)

Table 2-3 Results of N-RTK survey (LT-01)

	Data	%
Autonomous	0	0.0
DGPS	0	0.0
Float	8,934	35.5
Fixed	1,696	6.7
Mis Fixed	14,570	57.8
Total	25,200	100.0

N-RTK survey accounted for 10% or less of the total observation time, and normal observation was not performed.

LT-02 (Sub-Grand Control Point for laser transmitter)

Table 2-4 Results of N-RTK survey (LT-02)

	Data	%
Autonomous	481	1.9
DGPS	0	0.0
Float	23,597	93.6
Fixed	126	0.5
Mis Fixed	996	4.0
Total	25,200	100.0

N-RTK survey accounted for 10% or less of the total observation time, and normal observation was not performed.

Results and discussion of Static and N-RTK surveys

- It was not possible to perform a difference comparison between Static and N-RTK surveys because the fixed rates of N-RTK measurements at all 3 points were low and the measurements were not performed successfully. (See the red boxes in Tables 2-2 to 2-4.)
- The distance to the nearest CORS from the observation point was about 75 km, which was the probable cause of the failure to perform successful measurements in N-RTK survey. (Generally, the observable range is within about 30 km from the observation point to the nearest CORS.) When conducting N-RTK survey (or RTK survey), it is necessary to perform measurement within a 30km radius of an existing CORS or to establish a base point for RTK at the site to conduct RTK survey.

2: Comparisons of accuracy and workability between N-RTK and RTK surveys using locally established Grand Control Points

2-1: The comparison results of the accuracy between N-RTK and RTK surveys using the locally established Grand Control Points were as follows.

Table 2-5 Differences of N-RTK survey vs RTK survey

					RTK vs N-RTK		
		X	Y	H	△X	△Y	△H
RTK	CP01	1269085.567	494369.84	-3.754	0.013	-0.009	-0.057
	CP02	1269100.714	494369.331	-3.763	0.018	0.013	-0.013
	CP03	1269122.901	494369.271	-3.68	0.014	-0.003	-0.004
	CP04	1269070.061	494369.286	-3.77	0.012	0.002	-0.056
	CP05	1269047.824	494369.401	-3.818	0.005	0.004	-0.062
N-RTK	CP01	1269085.554	494369.849	-3.697			
	CP02	1269100.696	494369.318	-3.75			
	CP03	1269122.887	494369.274	-3.676			
	CP04	1269070.049	494369.284	-3.714			
	CP05	1269047.819	494369.397	-3.756			

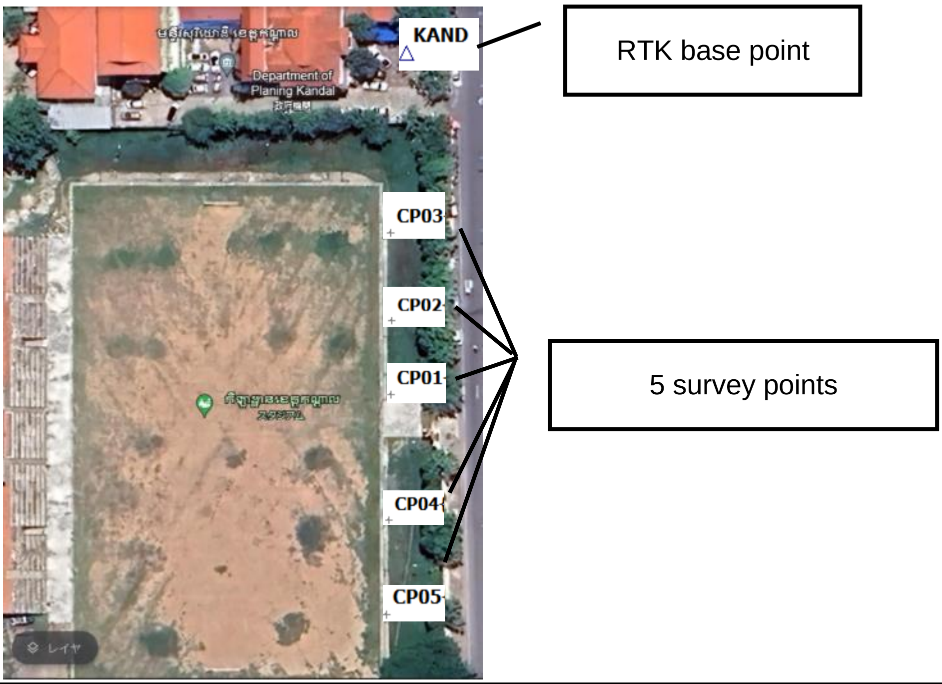


Figure 2-13 Location of N-RTK survey vs RTK survey

2-2: The results of comparisons of workability between N-RTK and RTK surveys using the locally established Grand Control Points were as follows.

Table 2-6 Comparison list of N-RTK survey vs RTK survey

	Look for & go to GCP	Set up base	Preparation of survey	surveying time	Number of Surveying staff	Working productivity
N-RTK	0mins	0mons	5mins	15mins	2 persons	◎
RTK	60mins	20mins	5mins	15mins	3 persons	○

Consideration of comparison results of accuracy and workability between N-RTK survey and RTK survey using locally established Grand Control Points

- The average differences in accuracy between N-RTK survey and RTK survey using the locally established Grand Control Points were 1.2 cm for X, 0.2 cm for Y, and -3.8 cm for H, which were generally acceptable and comparable for N-RTK surveys.

- In terms of workability, N-RTK survey differs from the RTK survey using the locally established Grand Control Points. N-RTK survey requires no base station and makes it possible to start observation by creating a connection with the Khmer GEONET. This means that N-RTK survey can be conducted in less time than RTK survey. It also requires fewer workers and man-hours.

  N-RTK survey requires 20 minutes for observation, compared to 100 for RTK survey, resulting in a 500% increase in productivity.

N-RTK survey requires 2 workers (or man-hours), compared to 3 for the RTK survey, resulting in a 150% increase in productivity.

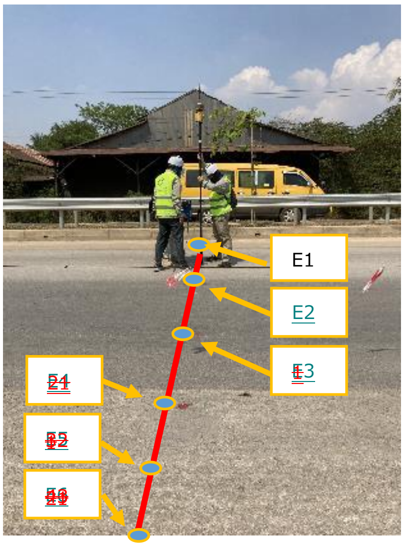
3. Comparisons between the conventional and GNSS (mmGPS) survey methods in the road improvement project

3-1: Accuracy comparisons between the conventional survey (level survey) and GNSS survey (mmGPS)

Accuracy comparisons were performed between the conventional survey method (level survey) and GNSS survey (mmGPS) method.

The pavement thickness values measured by the conventional level survey (road surface heights previous and after the paved area are measured to calculate the pavement thickness) were used as reference values to compare with the values observed by GNSS survey (mmGPS).

Measurement was performed within an observation range of 300 m from the route PK271 + 700 to PK282 + 000. A comparative evaluation was conducted within a total range of 100 m from the point where the laser transmitter of the mmGPS was set up to just fore and back the 50-m mark (PK281 + 820 to 920).



Observation points for each cross-section

E1: A point 1.5 m from the center on the cross-section

E2: A point 2.35 m from the center on the cross-section

E3: A point 4.4 m from the center on the cross-section

E4: A point 5.75 m from the center on the cross-section

E5: A point 7.75 m from the center on the cross-section

E6: A point 9.0 m from the center on the cross-section

Figure 2-14 Survey for thickness of survey (mmGPS)

Table 2-7: Paving thickness data of E1 to E6 (PK281 + 820 to PK281 + 920) 100 m

STATION/Survey Result	E1			E2			E3		
	Paving thickness (Level) (m)	Paving thickness (mmGPS) (m)	Thickness reguation (over 0.045)(m)	Paving thickness (Level) (m)	Paving thickness (mmGPS) (m)	Thickness reguation (over 0.045)(m)	Paving thickness (Level) (m)	Paving thickness (mmGPS) (m)	Thickness reguation (over 0.045)(m)
281+820	0.053	0.051	0.045	0.053	0.052	0.045	0.057	0.055	0.045
281+830	0.057	0.049	0.045	0.059	0.051	0.045	0.063	0.051	0.045
281+840	0.061	0.049	0.045	0.055	0.052	0.045	0.061	0.056	0.045
281+850	0.054	0.046	0.045	0.063	0.052	0.045	0.066	0.055	0.045
281+860	0.059	0.045	0.045	0.063	0.052	0.045	0.064	0.056	0.045
281+870	0.058	0.053	0.045	0.063	0.059	0.045	0.065	0.058	0.045
281+880	0.051	0.052	0.045	0.058	0.055	0.045	0.061	0.058	0.045
281+890	0.045	0.054	0.045	0.054	0.056	0.045	0.055	0.058	0.045
281+900	0.049	0.053	0.045	0.053	0.052	0.045	0.051	0.054	0.045
281+910	0.052	0.057	0.045	0.056	0.062	0.045	0.050	0.059	0.045
281+920	0.051	0.060	0.045	0.056	0.060	0.045	0.050	0.058	0.045

STATION/Survey Result	E4			E5			E6		
	Paving thickness (Level) (m)	Paving thickness (mmGPS) (m)	Thickness reguation (over 0.045)(m)	Paving thickness (Level) (m)	Paving thickness (mmGPS) (m)	Thickness reguation (over 0.045)(m)	Paving thickness (Level) (m)	Paving thickness (mmGPS) (m)	Thickness reguation (over 0.045)(m)
281+820	0.058	0.053	0.045	0.062	0.051	0.045	0.052	0.064	0.045
281+830	0.063	0.052	0.045	0.053	0.055	0.045	0.062	0.059	0.045
281+840	0.061	0.056	0.045	0.059	0.054	0.045	0.062	0.059	0.045
281+850	0.059	0.051	0.045	0.053	0.046	0.045	0.045	0.045	0.045
281+860	0.061	0.057	0.045	0.053	0.050	0.045	0.052	0.051	0.045
281+870	0.066	0.059	0.045	0.060	0.060	0.045	0.055	0.054	0.045
281+880	0.069	0.060	0.045	0.053	0.055	0.045	0.056	0.058	0.045
281+890	0.056	0.059	0.045	0.054	0.054	0.045	0.061	0.063	0.045
281+900	0.052	0.054	0.045	0.051	0.048	0.045	0.066	0.062	0.045
281+910	0.054	0.059	0.045	0.054	0.060	0.045	0.051	0.060	0.045
281+920	0.052	0.055	0.045	0.049	0.056	0.045	0.054	0.064	0.045

3-2: Comparisons of workability between the conventional survey (level survey) and RTK survey (mmGPS)

Workability comparisons were performed between the conventional survey method (level survey) and RTK survey (mmGPS) method.

Table 2-8 Comparison list of level survey vs RTK (mmGPS) survey

	See Bsck sight	Set up base	Preparation of survey	surveying time (1 cross section)	Number of Surveying staff	Working productivity
Level Survey	2mins	0mins	5mins	5mins	5 persons	○
RTK(mmGPS)	0mins	20mins	5mins	5mins	2 persons	◎

Consideration of comparison results of accuracy and workability between the conventional survey and RTK survey (mmGPS) in the road improvement project

• Comparison of the measured layer thickness values for the accuracy of the conventional survey (level survey) and GNSS survey (mmGPS).

The average observation difference of 66 observation points on all 11 cross-sections in the evaluation area was ±4 mm in accuracy, so it can be used for normal surveying even with GNSS survey method (mmGPS).

• Workability comparisons were performed between the conventional survey (level survey) and RTK survey (mmGPS). The results showed that while RTK survey (mmGPS) takes longer to set up, the measurement time is the same as the conventional survey, and it requires fewer surveyors.

The level survey requires 7 minutes for installation, compared to 20 for the RTK survey, resulting in a 35% decrease in productivity.

Both the level survey and RTK survey require 5 minutes for observation per section, resulting in equivalent productivity, or 100%.

The level survey requires 5 workers, compared to 2 for the RTK survey, resulting in a 250% increase in productivity.

*The conventional survey (level survey) only records the height, but the RTK survey (mmGPS) uses three-dimensional coordinates. On-site workers had positive commented about the use of RTK survey because the 3 dimensional data can be used at the site in various ways, such as to confirm the location of survey points.

2.2. Use of Khmer GEONET

2.2.1. Details of the Khmer GEONET data used

Khmer GEONET was used as follows.

Table 2-9 Khmer GEONET data used

IP address	221.120.160.130
Port	2101
Mount point	VRS_RTCM32
User name	TOPCON
Period of use	Mar17, 2023 – Mar 17, 2023 (Test) Mar 22, 2023 – Mar 28, 2023 Mar 31, 2023 – Mar 31, 2023
RTK / Post processing	Both RTK & post processing used
Satellite systems used	GPS, GLONASS, QZSS, GALILEO, BEIDOU

2.2.2. Problems occurred and solutions

Date and time of problem: 9:00 to 11:30 on March 24, 2023

Description of problem: The Khmer GEONET server froze, and corrected data for N-RTK surveying could not be accessed, preventing the start of surveying.

Solution: The server was restored through user support recovery work, and survey work was resumed.

2.3. Other related activities

1) Training in Japan

Representatives of Cambodian government-affiliated organizations came to Japan to obtain a deeper understanding of CORSs usage and operation. They visited Topcon's Training Center and received training on using data from CORS such as GNSS and ICT Construction.

Training date: August 15, 2023

Training site: Topcon Kanto Training Center

Training objective: For participants to understand the importance of the operation and use of CORSs and the distribution of stable CORS data.

Demonstrations of GNSS surveying and ICT construction system were conducted. The validity of real-time data was verified.

Training participants: A total of 10 representatives from Cambodian government-affiliated organizations including MLMUPC, LMUPCC, and GDCG

Training content

Training content for Sessions 1 & 2: Demonstrations in the field

VRS survey demonstrations to show the accuracy of distributed data.

Demonstrations of ICT construction (Excavator/Dozer) to show the productivity improvements from ICT construction (semi-automated construction)

Figure 2-15 GNSS and ICT Construction Training at the TOPCON Kanto Training Center

Using CORS data from Japan, we taught the participants that using CORSs can result in greater efficiency not only in surveying but also in the construction field, and that the CORS data can be used in various fields.

*Training was also provided in Japan in November 2022, but its content is not covered in this report as it was prior to the signing of this project contract.

3. Way forward

3.1. Future outlook of the business using Khmer GEONET

IKEE PAVING SYSTEMS

We are engaged in construction work locally in Cambodia with a focus on infrastructure construction. Being able to use real-time, high-precision positional information for on-site surveying and construction will make it possible to survey and confirm the exact location regardless of the worker's technical ability, allowing us to prevent mistakes before they can occur and enabling highly productive construction. We would like to use the real-time data from Khmer GEONET for any projects within the applicable range.

TOPCON CORPORATION

Through this JICA pilot project (surveying), we demonstrated how GNSS (mmGPS) can be used at construction sites to improve the surveying efficiency and the productivity of N-RTK surveys using real-time data from Khmer GEONET.

We would like to educate local users in Cambodia about the benefits of using real-time data from Khmer GEONET in N-RTK surveys and other activities to improve the efficiency of surveying using GNSS at construction sites.

3.2. About Khmer GEONET

1) Benefits of using Khmer GEONET

It is very significant that the Khmer GEONET data distribution has made real-time, high-precision position corrected information available anytime and for anyone to use.

2) Issues to be solved

At this point, 5 CORSs have already been established in Cambodia, but the utilization range is limited. Real-time surveying using Khmer GEONET is only available in the neighboring areas of these stations.

It is desirable to expand the utilization range by adding CORSs in consideration of future utilization in the surveying and construction fields.

3) Requests for improvement

As previously noted in 2.2.2 “Problems occurred and solutions,” there was an issue where the server frozed during use and it was not possible to conduct N-RTK survey. The server needs to operate stably.

As described in 3.2.2. “Issues in use,” the usable area for N-RTK surveys is limited. The area of availability in Cambodia should be expanded.

4. Conclusion

Activities related to civil engineering and construction surveying were carried out as a pilot project to utilize high-precision positioning data.

During the activity period, we contributed by sharing observation information using 5 CORSs in Cambodia and ensuring the stable operation of Khmer GEONET as part of the pilot project.

For users of high-precision positioning data, what is most important is that stable measurement is possible and the data is available *anytime*, *anywhere*, for *anyone* to use.

We hope that the data measurements and the recommendations provided through this civil engineering and construction survey will be useful in the future.

Finally, the sites used for the selection of measurement areas were the JICA National Road No. 5 Improvement Project (sections: Battambang to Thlea Ma'am and Sri Sophorn to Poipet / Phase II). On November 22, 2023, government officials and construction representatives from both Cambodia and Japan gathered at the site for an opening ceremony, and service began at the site.

We would like to express our congratulations to the government-affiliated organizations of Cambodia and Japan for the successful opening ceremony, and we would like to thank JICA and Tekken Corporation, who provided the site, for their cooperation in the demonstration experiment at the site.

Figure 3-1 Opening ceremony for National Road No. 5 in Kampong Chhnang Province

End of Report

Project on Establishment of Continuously Operating Reference Stations (CORS) for Land Management and Infrastructure Development

JICA Pilot Project

Demonstration project Implementation Report

October 2023

JC Agricultural Cooperatives Co.,Ltd.

Table of Contents

1. Overview of the demonstration project

1.1. Name of the demonstration project

EN: Accuracy Verification of Agri-Drone auto flight for spraying fertilizer and chemicals

KM: ផ្ទៀងផ្ទាត់ភាពត្រឹមត្រូវនៃការហោះហើរស្វ័យប្រវត្តិ Agri-Drone សម្រាប់បាញ់ថ្នាំជី និងសារធាតុថ្នាំគីមី.

1.2. Background and purpose of the demonstration project

Currently many local farmers are starting to make use of an auto-flight drone for spraying fertilizer and chemicals using GPS data in Cambodia.
But under GNNS flight, without RTK network service, we assume the drone will not be able to fly accurately. Especially when spraying chemicals on farms by drone, inaccurate drone flight might lead to damage to other farm land, or even health damage to people who stay near the spraying spot.
Our demonstration project analyses the difference of accuracy between RTK flight and Non-RTK flight, and confirms if RTK flight would work for more accurate and safer agricultural chemical spray by drone.

1.3. Brief description of the demonstration project

Purpose：

Analysis of accuracy difference between RTK and Non-RTK flight by chemical-spraying drone

Contents :

Comparison of actual drone flight, under RTK(Khmer GEONET) and Non-RTK, and coordinate data (X and Y) difference analysis

Result :

The difference of RTK and Non-RTK flight of the drone could not be felt physically nor visibly by the drone operator. But we could confirm difference by coordinate data, RTK flight was more accurate than Non-RTK flight

1.4. Implementation period

Preparation : Feb 2023 – Mar 2023

Work at the site :Mar 2023 – Aug 2023

Reporting : Aug 2023 – Sep 2023

Table 1-1 Plan and actual of the schedule

Work Items/ Year & Month		Progress	2022								
			2	1	2	3	4	5	6	7	8
Sign a contract with Pasco	Plan	100.0%									
	Actual										
Preparation of the pilot project		**18.8%**									
Making a pilot project implementation plan	Plan	25.0%									
	Actual										
Export/import of equipment	Plan	0.0%									
	Actual										
Obtainment of necessary permits	Plan	50.0%									
	Actual										
	Plan	0.0%									
	Actual										
Performance of the Pilot Project		**12.4%**									
Gathering and selectiong the local farmers collaborating for pilot project	Plan	30.0%									
	Actual										
Drone flight with/without KHMER GEONET(Dry season / Rainy season)	Plan	7.0%									
	Actual										
Analysing the differece of drone flight accuracy between with/without KHMER GEONET	Plan	0.0%									
	Actual										
Regular communication with SSCA (State Secretaria of Civil Aviation) and APSARA Authority for drone flight rule	Plan	50.0%									
	Actual										
Summarizing the result of analysis and creating report	Plan	0.0%									
	Actual										
	Plan	0.0%									
	Actual										
	Plan	0.0%									
	Actual										

1.5. Location of the demonstration project site

Address:

5km: https://maps.app.goo.gl/6w33f1qxp5HXLFcW7

12km: https://maps.app.goo.gl/WvNxUXjuxsVavXwL9

17km: https://maps.app.goo.gl/CnLTPgkCyjEXPi9B6

Coordinates:

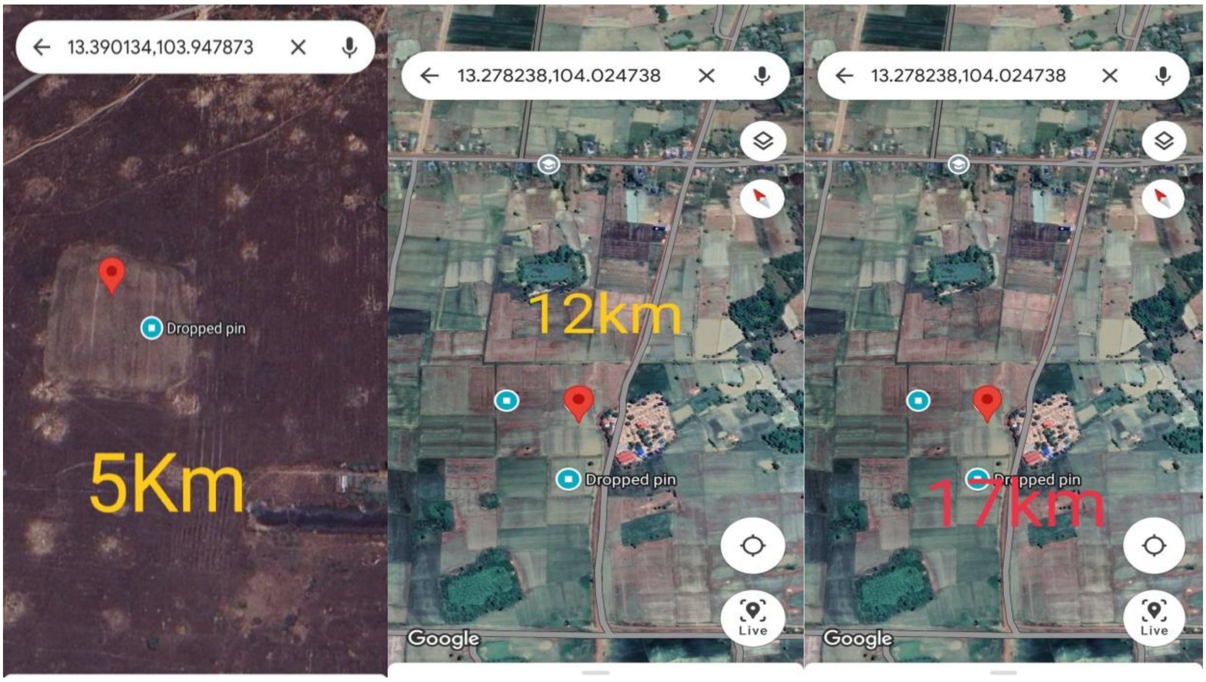


Figure 1-1 Location of the demonstration project site

1.6. Members

The members listed below performed the demonstration project.

Table 1-2 List of members

NO.	Name	Company/Organisation	Role
1	Ko Honam(Mr.)	JC Agricultural Cooperatives Co.,Ltd. / President CEO	Project Manager
2	Nourn Kunthy(Ms.)	JC Agricultural Cooperatives Co.,Ltd. / Smart-Agri-Service Dept. Manager	Drone & Software Operator
3	Chheing Samphors (Ms.)	JC Agricultural Cooperatives Co.,Ltd. / Smart-Agri-Service Dept. Assistant	Drone & Software Operator
4	Yoeurt Kimhak(Mr.)	JC Agricultural Cooperatives Co.,Ltd. / Mechanic Department Manager	Mechanic / Driver
5	Pay Chanthan(Mr.)	JC Agricultural Cooperatives Co.,Ltd. / Mechanic Department Assistant	Mechanic / Driver
6	Noriko Yamaguchi (Ms.)	JC Agricultural Cooperatives Co.,Ltd. / SeamReap Dept. Manager	Manager in Siem Reap
7	Thor Phalkun(Ms.)	C Agricultural Cooperatives Co.,Ltd. / SeamReap Dept. Assistant	Translator in Siem Reap (negotiation with farmers)
8	Lach Phina(Ms.)	JC Agricultural Cooperatives Co.,Ltd. / SeamReap Dept. Assistant	Translator in Siem Reap (negotiation with farmers)
9	Rouen Chhaneary (Ms.)	JC Leadings Co.,Ltd. / Translator	Translator in Phnom Penh (discussion with governmental institution/officers)

1.7. Equipment used for the demonstration project

The equipment listed below were used for the demonstration project.

Table 1-3 List of equipment used

NO.	Name	Quantity	Remarks (specifications, usage, etc.)
1	DJI Agras T10	1	Spray chemicals/fertilizer on farm land -GNSS receiver：D-RTK Technology
2	DJI Phantom4RTK	1	Take picture of farm land -GNSS receiver：D-RTK Technology

2. Details of the work

2.1. Work performed:

We selected 3 location in difference distance from CORS to farm land in order to analyze the accuracy of Network RTK by Khmer GEONET in each distance, assuming it more accurate if closer to CORS
- 5km /10-13km / 17-20km

We found and negotiated with several farmers in each location, and gathered some farmers who collaborate with our project, with promise that we will make free spray drone (fertilizer and chemicals) on their farm land in return to their collaboration.
We conducted drone flight by RTK(with Khmer GEONET) and Non-RTK mode, and confirmed difference operator feels physically and visibly.
Also we used “KUMIKI” system to analyze the coordinate date difference with each coordinate data we can derive from pictures taken by drone.

2.1.1.Preparation

<Equipment>
We prepared 2 drones as below;
1.Drone for spraying fertilizer/chemicals : DJI AgrasT10

2.Drone for taking pictures : DJI Phantom4 RTK

We have both above as our own stock, so no importing.

Figure 2-1 Left: AgrasT10 / Right: Phantom4RTK

<Arrangement of the site>

We searched chief of village in each distance (5km/10-12km/17km from CORS) and asked him to find the farmer who can collaborate with us.

We gathered 8 farmers who agreed collaboration.

Table 2-1 : Information of local farmers collaborated

N	Customer Name	Customer Address	Disttance from CORS		Farm HA
			Range	Actual	
1	Mr.Sat Saem	Tropangron Village, Ampil Commune ,SPR city.	5km	5.82km	1.5
2	Ms.Khoeun Samnang	Trobangron Village, Ampil Commune ,SPR city.	5km	5km	1.5
3	Mr.Tol	Donnum Village ,Mean Chey commune Bakong district ,SRP.	10-15km	13km	1
4	Mr.Orl	Donnum Village ,Mean Chey commune Bakong district ,SRP.	10-15km	13km	2
5	Ms.Nhaoch	Donnum Village ,Mean Chey commune Bakong district ,SRP.	10-15km	13km	1
6	Mr.Chea	Lvea Village Tropangthom commune Bakong district ,SRP	17-20km	17km	2
7	Mr.Vanndy	Lvea Village Tropangthom commune Bakong district ,SRP	17-20km	17km	1
8	Mr.Than	Lvea Village Tropangthom commune Bakong district ,SRP	17-20km	17km	1

<Necessary Permission>

1. SSCA (State Secretariat of Civil Aviation)
   SSCA is the governmental department which takes in charge of formal regulation of civil aviation in Cambodia.
   We had meeting with SSCA on 14th Mar 2023, and confirmed that we don't have to get permission of drone flight lower than 100m height, except the area close to Angkor Heritage where APSARA authority controls

2. APSARA Authority (Authority for the Protection of the Site and Management of the Region of Angkor)
   APSARA Authority is the organization for the protection and management of the Region of Angkor.
   We officially requested APSARA Authority for permission of drone flight in each location.
   APSARA authority sent official letter to us telling the location 5km from CORS is included in coverage of APSARA Authority management, so they did not allow flight in the 5km location.

Kingdom of Cambodia,
Nation, Religion, King

APSARA Authority
A P S A R A

Inform

Mr. NUON KUNTHY, Head of Donation, JC Agricultural Collection Co., Ltd.

Subject: Case request for testing the use of agricultural drones to help spray weeds and fertilizers on farmers' fields In Trapeang Run Village, Ampil

References Commune, Prasat Bakong District, Siem Reap Province.

I would like to inform the President that the APSARA Authority cannot allow the use of agricultural drones to spray weeds and fertilizers on the land of two farmers in Trapeang Run village, Ampil commune, Prasat district. Bakong, Siem Reap Province, from May to August 2023, as the proposed site is located in the Angkor resort area, where all uses are prohibited and should not be located in the World Heritage Site for chemical testing. Which can lead to various negative side effects.

Please be informed accordingly, Mr. Chairman. Please accept, Sir, the assurances of my highest consideration.

17/6 (Panchasak BE 2567, Siem Reap, 1st 1% of the National Assembly in 2023

(..Yik Chandarath

Copy
- Department of Temple Preservation and Anthropology
- Department of Public Order
- Department of Tourism and Culture Development
- Department of Water Management, Forestry and Infrastructure - Angkor Heritage Protection Police Unit
- Tourist Police Unit
- Documents - Chronology

APSARA National Authority

Figure 2-2 : Official Letter from APSARA authority

2.1.2.Implementation

【Monthly Implementation Detail】

MARCH2023

<Gathering Farmers>

Period/Date : 1st Mar 2023 – 20th Mar 2023

We visited several local farmers who live/have their farm land in the location 5km/10-15km/17-20km

We found and negotiated with some farmers, and could get agreement for collaboration as below;
2 farmers at 5Km point

3 farmers at 10-15km point

3 farmers at 17-20km point.

<Drone Flight>

1 .

Date:16-Mar-2023

Detail: Compare RTK flight and Non-RTK flight, which one is good for spray chemicals and liquid fertilizer for farmer 10km -15km

2.

Date:28-Mar-2023

Detail: Compare RTK flight and Non-RTK flight, which one is good for spray chemicals and liquid fertilizer for farmer 17km-20km.
But we couldn't connect with RTK due to the weakness of internet radio.

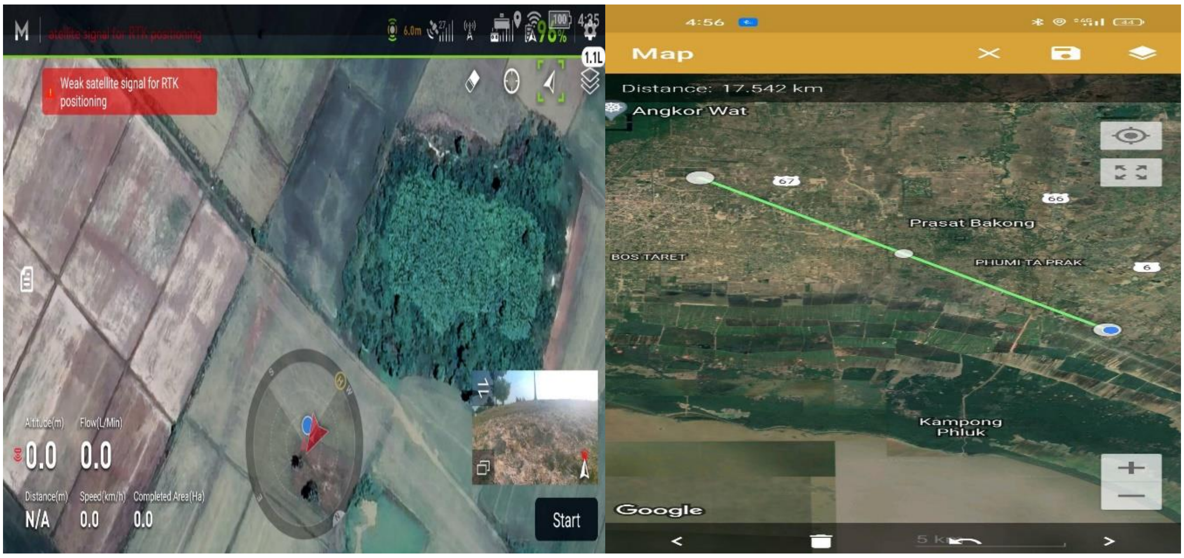


Figure 2-3 Screenshot of drone controller during flight (just for reference)

<Other implementation>

Date 14Mar2023

Communication with SSCA

We confirmed if we need to apply permission to SSCA for each drone flight.
SSCA told us if the flight lower than 100m, not necessary to ask for permission. SSCA added that when we fly in Siem Reap close to any heritage, we should confirm APSARA Authority if any procedure necessary.

Date 29Mar2023

Communication with APSARA Authority

APSARA Authority
have 2 farmer and 5km from CORs but this location control by APSARA authority, so the APSARA said if we want to fly the drone that location we have to make the request letter send to their manager for approval and sign

Figure 2-4 : Location 5km from CORS

April2023

<Drone Flight>

1 .
Date:11-April-2023

Detail: We still try to compare Non-RTK and RTK flight to find different point.

2.
Date :20230426

Detail: We have the plan go to flight but the farmer said we can't go because the farmers have to prepare farm (cut tree that have in farm).

<Other implementation>
Find new farmer :3 old farmers that we got before 17km to 20km can't connect with RTK, So we have to find more new farmers.

Figure 2-5 Location 17km from CORS

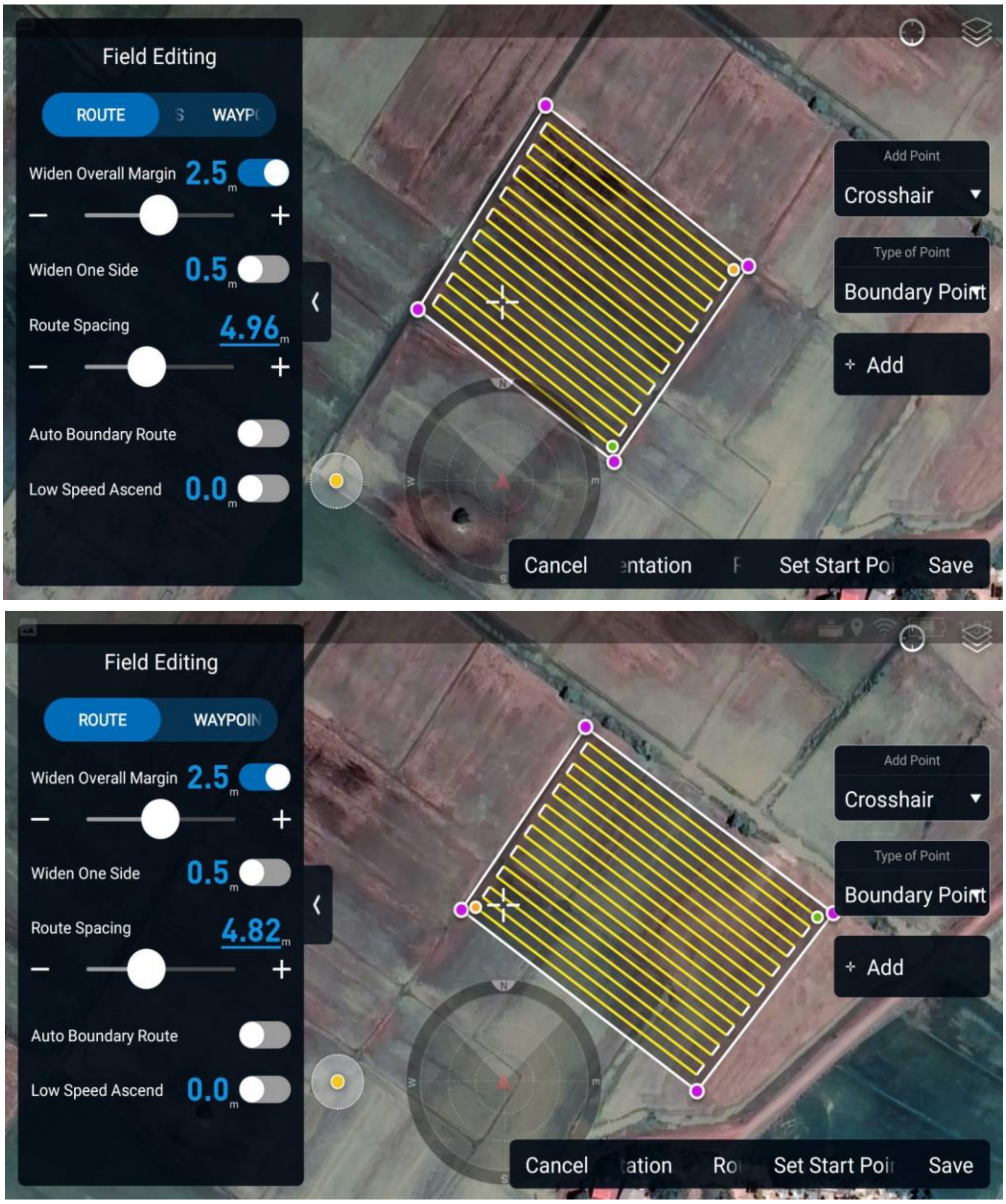


Figure 2-6 Screenshot of drone controller during flight (just for reference)

MAY2023

<Drone Flight>

1. Date: 20230510

Detail: We went to flight 17km from CORs, but when we arrived the location and start flight our controller have problem. It can't turn on. We have to go back and send the controller of drone spray to phnom penh for fixing.

2.Date: 24-May-2023

Detail: We try to flight three customers 17km from CORS but we can't find the different point.

5km from CORS: After we prepare request letter for flight the drone send to The APSARA authority. We got reply letter and they said they not allow all drone flight in the apsara location and they also said we should not use Apsara location for flight the drone.

Figure 2-7 : Location 5km from CORS

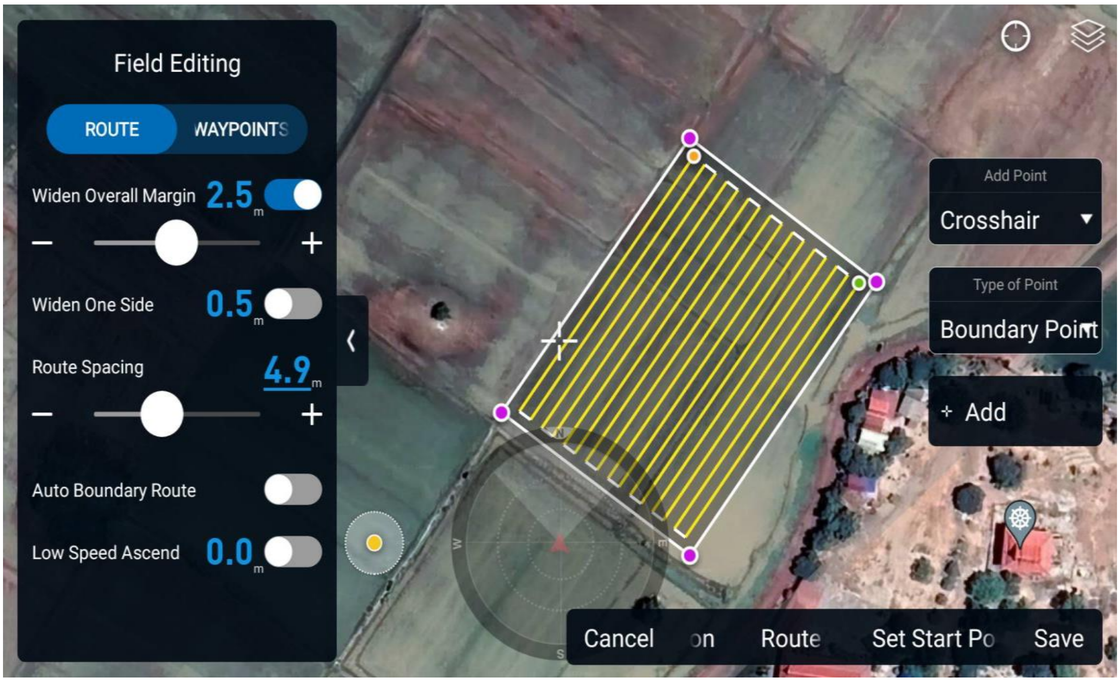


Figure 2-8 Screenshot of drone controller during flight (just for reference)

JUNE2023
<Drone Flight>

We conducted 3flights NON-RTK and RTK flight for spray chemicals (weed killer)

Date 2023/6/14

. Mr.Tol's farm: We confirmed and compared RTK and NON-RTK flight a bit different only return home.

Date 20230619

. **Mr.Orl's farm**: We tried watching by video and by eyes if any change between RTK flight and NON-RTK flight, but we could not recognized any difference.

Date 20230626

. **Mr.Ms.Nhaoch's farm: The** same as above**,** NON-RTK flight and RTK flight looked same by sight (eye).

Figure 2-9 Screenshot of drone controller during flight (just for reference)

Figure 2-10：Screenshot of auto flight plan

JULY2023

Date: 2023-July-11

We conducted 3flights NON-RTK and RTK flight for spray liquid fertilizer

.Mr.Chea's farm: We confirmed and compared RTK and NON-RTK flight but we didn’t see different point both are still the same.

Date: 2023-July-17

.Mr.Vandy's farm: We confirmed and compared RTK and NON-RTK flight this time RTK fast connecting with our drone and for spray liquid fertilizer not different.

Date: 2023-July-25

.Mr.Than's farm: We try to compare RTK and NON-RTK flight but we cannot find good point and different point from both (RTK and NON-RTK flight). Reaction from farmer: They are really happy when JCAC flight drone for them without charge service from them.

Figure 2-11 : Mr.Than’s farm

Figure 2-12：Screenshot of auto flight plan

【Physical and Visible Difference of accuracy between RTK and Non-RTK flight】

We conducted comparison of RTK flight and Non-RTK flight several times throughout this project.

But visibly, it seems difficult to let drone operate feel the difference during the flight. Just by watching the drone flight, operator could not recognize the difference of flight accuracy, speed, and any other movement.

RTK flight after drone flight finish it will come back home automatically the same Non-RTK but we don't need to use manually the drone will auto landing by itself and the same place before flight this is the good point that we see with RTK flight.

When flight finishes (goes through the flight plan), the drone automatically come back to the landing point.

When landing at the point, operator could recognize the RTK flight drone was more accurate than Non-RTK flight.

In Non-RTK flight, the drone landed at the point strayed larger from the planned landing point than the drone in RTK flight.

Figure 2-13 RKT flight：Departure and Landing point

Figure 2-14 Non-RKT flight：Departure and Landing point

【Coordination Data Difference of accuracy between RTK and Non-RTK flight】

The difference of RTK flight and Non-RTK flight was difficult to recognize physically and visibly by drone operator. Even though we could recognize the landing point difference, the difference was not so large and would not be the matter for drone operating farmers.

So additionally, we conducted the "coordination data difference analysis", making use of the pictures taken by drone during flight.

The analysis compares "map coordinate information included in the pictures" and #coordinate information which drone figured out".

The KUMIKI system, developed by SkymatiX Inc.(Japanese company) can issue the difference automatically by uploading the pictures into their cloud-analysis system. This system is used in another JICA project whose counterpart is MPWT(Ministry of Public Works and Transportation) / DPWT(Department of Public Works and Transportation), for improvement of drone survey for infrastructure civil work.

Table 2-2 Standard deviation difference analysis by KUMIKI

Distance fromCORS	Coordinate	Standard Deviation (m)		
		RTK	Non-RTK	Difference
12km	x	0.064	0.240	-0.176
	y	0.032	0.315	-0.283
	z	0.021	0.292	-0.271
17km	x	0.075	0.369	-0.294
	y	0.102	0.301	-0.199
	z	0.410	0.299	0.111

In terms of the coordinate date difference, we could recognize the big difference of accuracy between RTK flight and Non-RTK flight.

In 12km, the standard deviation was several cm for RTK, and several tens of cm for Non-RTK.

In 17km, the accuracy of RTK also becomes worse (in y and z coordinate). This implies that the further from CORS, the less accuracy of coordinate.

<For Reference ：Report issued by KUMIKI >

We attach the part of report picture, which shows standard deviation.

Table 2-3：KUMIKI Report RTK flight (12km from CORS)

KUMIKI

RTK / 12km

外部パラメータ

GPS誤差	X方向誤差(m)	Y方向誤差(m)	Z方向誤差(m)
平均値	-0.001	0.000	-0.001
標準偏差	0.064	0.032	0.021
RMSE	0.064	0.032	0.021

撮影位置の相対的な誤差です。

<annotation>

GPS error	X error (m)	Y error (m)	Z error (m)
Average	-0.001	0.0000	-0.001
Standard Deviation	0.064	0.032	0.021
RMSE	0.064	0.032	0.021

Relative error of picture spot

Table 2-4:KUMIKI Report_Non-RTK flight (12km from CORS)

KUMIKI

Non-RTK / 12km

外部パラメータ

GPS誤差	X方向誤差(m)	Y方向誤差(m)	Z方向誤差(m)
平均値	-0.008	0.012	-0.013
標準偏差	0.240	0.315	0.292
RMSE	0.241	0.315	0.292

撮影位置の相対的な誤差です。

<annotation>

GPS error	X error (m)	Y error (m)	Z error (m)
Average	-0.008	0.012	-0.013
Standard Deviation	0.240	0.315	0.292
RMSE	0.241	0.315	0.292

Relative error of picture spot

Table 2-5：KUMIKI Report_RTK flight (17km from CORS)

KUMIKI

RTK / 17km

外部パラメータ

GPS誤差	X方向誤差(m)	Y方向誤差(m)	Z方向誤差(m)
平均値	-0.002	0.003	-0.018
標準偏差	0.075	0.102	0.410
RMSE	0.075	0.102	0.411

撮影位置の相対的な誤差です。

<annotation>

GPS error	X error (m)	Y error (m)	Z error (m)
Average	-0.002	0.003	-0.018
Standard Deviation	0.075	0.102	0.410
RMSE	0.075	0.102	0.411

Relative error of picture spot

Table 2-6：KUMIKI Report_Non-RTK flight (17km from CORS)

KUMIKI

Non-RTK / 17km

外部パラメータ

GPS誤差	X方向誤差(m)	Y方向誤差(m)	Z方向誤差(m)
平均値	-0.029	-0.009	0.009
標準偏差	0.369	0.301	0.299
RMSE	0.370	0.301	0.299

撮影位置の相対的な誤差です。

<annotation>

GPS error	X error (m)	Y error (m)	Z error (m)
Average	-0.029	-0.009	0.009
Standard Deviation	0.369	0.301	0.299
RMSE	0.370	0.301	0.299

Relative error of picture spot

2.1.3. Results

By technical accuracy difference analysis making use of coordinate information, we could recognize the accuracy of RTK flight comparing to Non-RTK flight.

Nevertheless, drone operator could not feel the difference physically and visibly. Therefore, in the current situation of agricultural drone usage by local farmers, it will be difficult to induce local farmers to join KhmerGEONET because there will be no change in efficiency (manpower, time, etc).

About detail explanation and photos, refer to 2.1.1 Implementation, in paragraph below.

【Physical and Visible Difference of accuracy between RTK and Non-RTK flight 】

【Coordination Data Difference of accuracy between RTK and Non-RTK flight 】

2.2. Use of KhmerGEONET

2.2.1. Details of the Khmer GEONET data used

Khmer GEONET was used as follows.

Table 2-7 KhmerGEONET data used

IP address	**cgd09.khmergeonet.xyz**
Port	**2101**
Mount point	**RRS_RTCM32**
User name	**JCG**
Period of use	**16-Mar-2023 - 28-Mar-2023** **11-April-2023– 24-May-2023** **14-June-2023– 25-July-2023**
RTK/ Post processing	**Network RTK**
Satellite systems used	**GPS, BeiDou, GLONASS, Gallileo** **(picture of drone controller as below)**

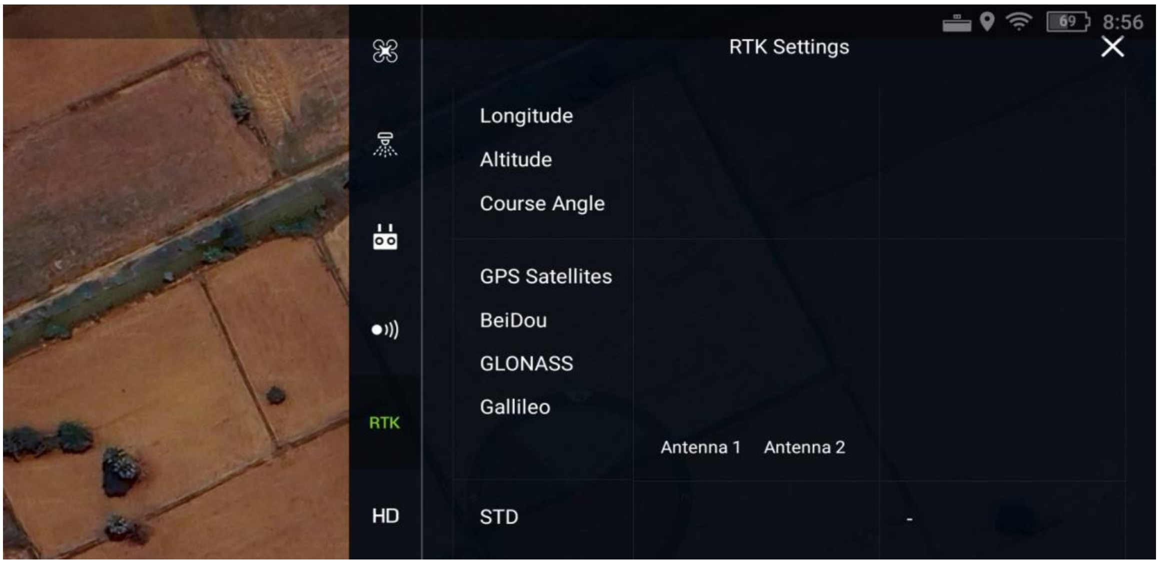


Figure 2-15 Screenshot of Drone Controller showing GNSS used for flight

2.2.2. Problems occured and solutions

In the location far from the center of the city, internet radio becomes weaker and it becomes more difficult to let drone connect to KhmerGEONET.

In general, farm lands are located in province, far from the city. Internet radio weakness in province could be the big issue for easy usage of KhmerGEONET.

The solutions depend on the improvement of internet coverage in province.

2.3. Other related activities

- Study about network RTK mechanism and Khmer GEONET
- Meeting with General Department of Cadastre and Geography in Sieam Reap, confirming the location of CORS.
- Several manager class meeting in Japan and Cambodia
- Made contract for KUMIKI system usage for compensation.
- Free drone service of spraying fertilizer/chemicals for farmers who collaborated with us for this project.

3. Way forward

3.1. Future outlook of the business using KhmerGEONET

In terms of agricultural usage to which KhmerGONET might affect, drone for spraying fertilizer/chemicals (“spray drone” hereafter) will be the only existing IT solution currently.
There are some other IT solutions/software services for local farmers using internet, but we could not recognize any other solutions/services which require more accurate coordinate information than current GNSS(without RTK).

And even for the spray drone, we confirmed that it would be difficult to let drone operator (assuming local farmers who own and use spray drone) feel the difference of efficiency (such as accuracy of drone flight, reducing manpower, time-saving,etc) in RTK flight comparing to Non-RTK flight physically and visibly.

But we confirmed that RTK flight shows more accuracy in coordinate information than No-RTK flight. Therefore, in case that any other IT solutions/software services for agriculture, which requires more coordinate accuracy, was introduced and prevailed in Cambodia, KhmerGEONET would work for it.

Possible IT solutions/software services for agriculture as above, which is called “Smart-Agriculture Solutions”, will be as below
- Self-drive/drive assistant service of tractor and harvester
- Irrigation system with auto-water-adjusting function

Smart-Agriculture Solutions as above surely increase efficiency (reducing man power, saving time), which may induce local farmers to join Khmer GEONET with payment.

3.2. About KhmerGEONET

1) Good points using KhmerGEONET

In terms of coordinate information, standard deviation of RTK flight under KhmerGEONET shows much better accuracy than Non-RTK flight.

2) Issues to be solved

In terms of spray drone usage for agriculture, internet coverage issues would be the most difficult thing.
Farm lands are often located in province far from city, and internet radio is very weak in those area.
Improvement of internet coverage in province must be necessary.

3) Request for improvement

In terms of agriculture sector, necessary improvement would be expansion of smart-agri-solution variety and internet coverage, not the improvement of KhemrGEONET service quality.

We confirmed the accuracy of coordinate by KhmerGEONET. Therefore, we expect the introduction of more sophisticated smart-agri-solution which require the accuracy of KhmerGEONET in Cambodia in the future.

4. Conclusion

We could recognize the accuracy of RTK flight comparing to Non-RTK flight by technical accuracy difference analysis making use of coordinate information.

Nevertheless, drone operator could not feel the physical and visible difference between RTK flight and Non-RTK flight.
This means currently it is difficult to let drone operator, who we assume is the local farmers using drone for spraying fertilizer/chemicals, feel any improvement of efficiency such as reducing manpower, saving time, etc.

In case more sophisticated smart-agri-solutions which requires more accurate coordinate information, such as autonomous driving of tractor/harvester, auto-irrigation system, etc are introduced and prevailed in Cambodia in the future, the demand for Khmer GEONET in agricultural sector will expand practically.

Project on Establishment of Continuously Operating Reference Stations (CORS) for Land Management and Infrastructure Development

JICA Pilot Project Demonstration Project Implementation Report

June 2023

Key Consultants (Cambodia)

Table of Contents

1 Overview of the demonstration project

1.1 Name of the demonstration project

Flood Inundation Study in Siem Reap Town Using Khmer GEONET

1.2 Background and purpose of the demonstration project

Under the Ministry of Land Management, Urban Planning, and Construction, the General Department of Cadastral and Geography (GDCG) has been providing Continuously Operated Reference Station (CORS) service in Cambodia, known as Khmer GEONET. Internet-connected Khmer GEONET provides correct dataset for registered GNSS users to attain few centimeter-level precisions around the CORS.

Khmer GEONET currently operates five continuously operational reference stations in Phnom Penh, Kandal, Kampong Speu, Siem Reap, and Stung Streng under the technical support and cooperation of JICA having started in early of 2021. Users are able to have freely access to the service where the station signal are covering until October 26, 2023.

The objective of this assignment is to demonstrate the functionality of CORS, its accuracy, limitation observation to the GNSS rover, as well as the advantages of using Khmer GENONET CORS in land surveying, mapping and drone survey.

Prior to the official introduction of the service, efficiency and accuracy are by far the most crucial factors. In light of this, JICA, via PASCO Corporation, has awarded the contract to Key Consultants (Cambodia) as an independent local consultant firm to conduct study and evaluate the capability and effectiveness of the established CORS, named "SIE-1", located in Siem Reap province.

The study is aimed to (i) compare the advantages of using a CORS-connected unmanned aerial vehicle (UAV) versus the National BM zero-order control and (ii) to compare the coordinate data obtained from Khmer GEONET CORS SIE-1 and the coordinate data obtained from the National BM zero-order control and (iii) to use the Digital Elevation Model (DEM) as the product from the CORS for flood study.

1.3 Brief description of the demonstration project

SIE-1 CORE is located in Siem Reap; was established in front of administrative offices of Siem Reap province and selected to use for the study and evaluate its functionality.

In addition to make data even useful, the study utilized raster DTM obtained from drone photogrammetry software to model a flood extension map over the study area. The map obviously extended from the bridge that is located at the AMANSARA hotel all the way down to the water gate that is currently in place.

Khmer GEONET is an internet-connected service that provides its consumers with numerous benefits in the disciplines of land surveying, engineering surveying, and mapping. The system is capable of providing users with centimeter-level accuracy, which is required for engineering surveying tasks such as site setting out, road boundary setting, canal boundary setting out, topographical map surveying, etc. In addition, the system reduces the number of GNSS receivers typically required at least two GNSS receivers for measuring by the user. By registering with Khmer GEONET and purchasing a GNSS receiver, users of Khmer GEONET can save thousands of dollars on their initial investment budget. Then, they can conduct measurements in the surveying. Moreover, Khmer GEONET can effectively reduce the time-consuming process of data collection. By not requiring their own RTK base station, users can save time in the field and begin working immediately upon connecting to the Khmer GEONET where they are standing nearby. Additionally, the user can obtain the GPS Rinex file from the Khmer GEONET if post-processing is required.

In contracts, the conventional method or traditional RTK method requires more sources to operate. Users are required to purchase at least two GNSS receivers, one of which serves as the base station and the other as a rover, resulting in a significant initial investment cost. In addition, users must spend more time in the field setting up the base station and have a great deal of work to do, such as delivering the GNSS receiver base and rover, the GPS antenna, and the battery, resulting in a substantial expenditure on transportation and labor. In addition, antenna-based RTK restricts measurement. The user is discouraged from taking measurements beyond 20 kilometers from the base station.

The result is shown that, the horizontal and vertical data accuracy varied from millimeters to centimeters as a consequence of measurements made at five measurement checkpoints using various reference stations and techniques. The outcome demonstrates the usefulness and efficiency of doing thorough surveys and mapping utilizing Khmer GEONET CORS across the target region. There is a little discrepancy of acquired data between Khmer GEONET CORS data and National BM zero-order data.

Flooding result also revealed the goodness of the CORS, as the model was setup within the combination of free source DTM within low resolution of 30m for basinwide of Siem Reap River. The flood assessment found also the details of flood extent over the pilot area, in which; the result will help the local authority or the municipality to prepare for any development. However, the pilot area of detailed information or the surveyed area from the topographical data was not covered entire of the municipality.

It would be useful to have more topographic data covering the whole city, where urban expansion will be taking place in the near future. As the Siem Reap town is lying along the river; river flood might occur due to uncertainty of climate and rainfall. The study of flood assessment within the wide area of topographical data will be helpful to improve and protect the town from any disastrous due to the change of human being and natural.

Preparation : Apr 2023 – Jun 2023

Work at the site : 23 April 2023 – 28 April 2023

Work Processing

Reporting : 05 May 2023 – 30 June 2023

Table 1-1 Plan and actual of the schedule

No.	Work Items/ Year & Month		Progress	2023											
				1	2	3	4	5	6	7	8	9	10	11	12
1	**Sign a contract with Pasco**	Plan	100%												
		Actual													
	Preparation of the pilot project		**100%**												
2	Desk study Data collection (Hydrology Team)	Plan	100%												
		Actual													
3	Hydrological Analysis (Hydrology Team)	Plan	100%												
		Actual													
4	Conducted drone fly (Drone Aerial Photographic Team)	Plan	100%												
		Actual													
5	Cross section survey of Siem Reap River and Checkpoints (Topography Survey Team)	Plan	100%												
		Actual													
6	Image Processing (Drone Aerial Photographic & Topography Survey Team)	Plan	100%												
		Actual													
7	Report and Mapping	Plan	100%												
		Actual													

1.4 Location of the demonstration project site

The project site is located in the center of Siem Reap town where Siem Reap River is also compounded in the study boundary. The boundary has an area of 144ha with approximate of 2km length stretching along the river downward to Ang Krapeu head structure and the upper boundary is in Royal Independence Gardens.

It's clearly seen the boundary of the study shown in T**able 1-2** below.

Table 1-2 Project boundary positioning

Point	Positioning	E (m)	N (m)
P-01	Top Left	376,197	1,477,849
P-02	Top Right	376,874	1,477,605
P-03	Bottom Left	375,512	1,475,973
P-04	Bottom Right	376,189	1,475,729
CORS SIE-1	Point	380,263	1,478,968
SIEM (ZERO-ORDER)	Point	371,550	1,482,704

Khmer GEONET CORS SIE-1 is located approximately of 6km from the project site; while another zero-order BM was installed in 1997 located inside the Siem Reap international airport is about 8km from the site were used in this study. Location of the site demonstration and the BM-points are illustrated in the **Figure 1-1** below; while the description card of national BM zero-order in the airport is shown in **Figure 1-2**.

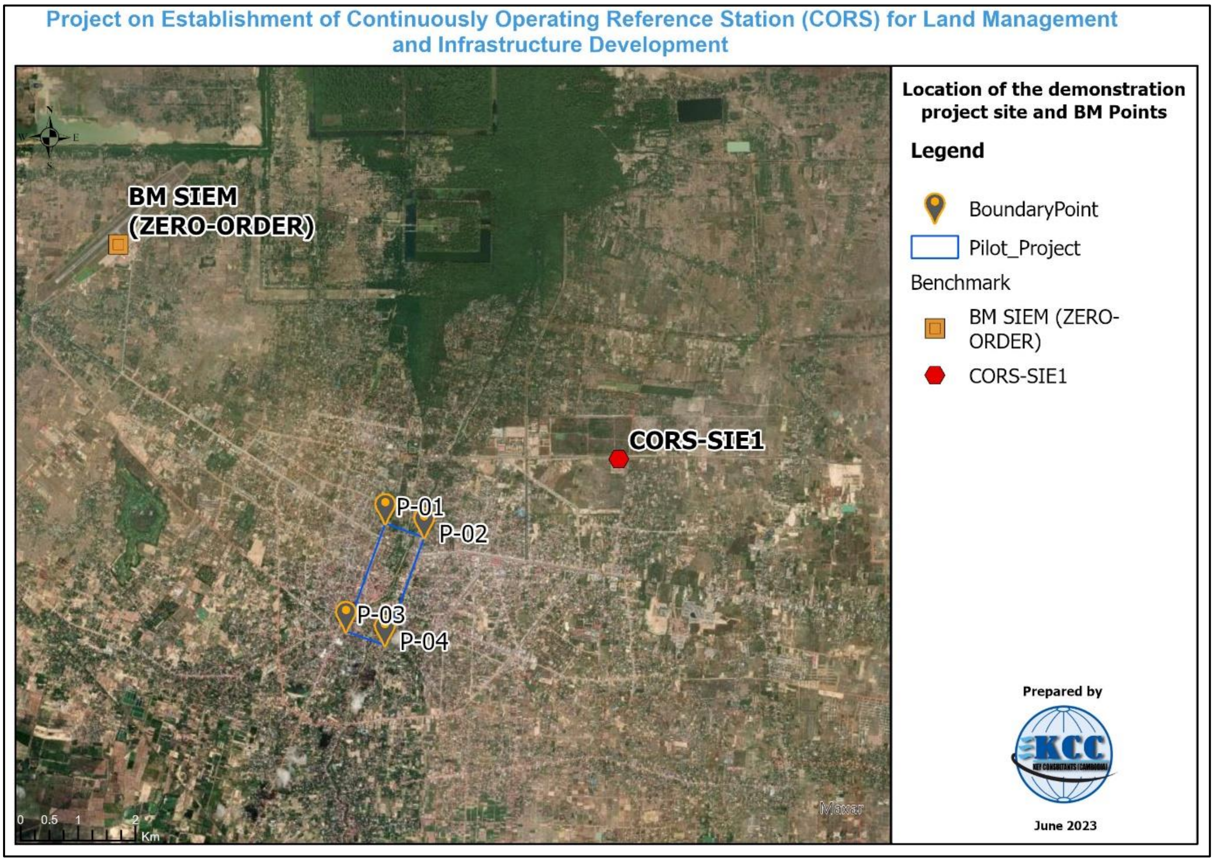


Figure 1-1 Location of the demonstration project site and BM-points

Network in: Siem Reap **Installation Date: 1997**

SIEM

District: Puok **Commune:** **Village:**

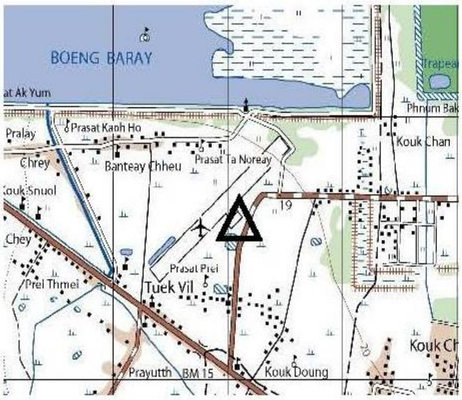
Place: Siem Reap Airport

Reference Frame: ITRF2005

Project: UTM Zone 48 North Ellipsoid GRS 80

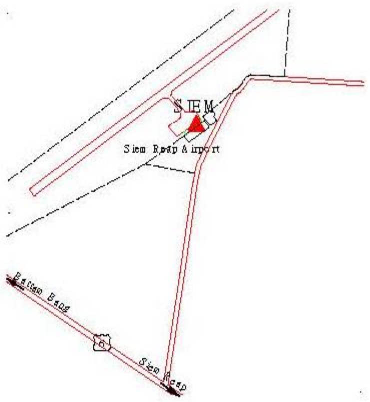
Latitude	**N 13° 24' 33.39281"**	**N** (x)	**1482704.1854m**
Longitude	**E 103° 48' 55.60495"**	**E** (y)	**371750.8732m**
Height (ellip.)	**-2.2052m**	**epoch**	2009.56

1/100,000 (5735)

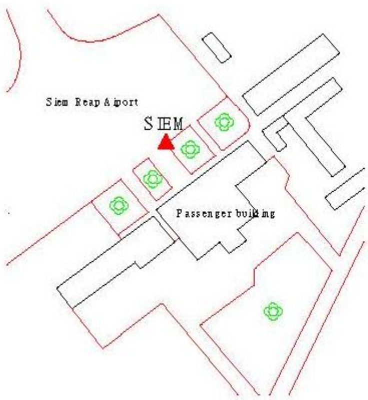


Photo

Route Sketch



Delineation



NOTE

The control point was installed in reinforced concrete square which is high 0.2m from the ground. GDCG, code number, and the date of construction were written on its top, and copper center mark was installed in its center.

Figure 1-2 Description Card of National BM Zero-order

1.5 Members

Two teams were deployed in the study; in which topographical survey team was led the team and accompanied with Hydrological team to conduct flood study by using the product such digital elevation generated from drone and ground survey. The deployment teams are described in the **Table 1-3** below.

Table 1-3 List of members

NO.	Name	Company/Organization	Role
1	Mr.Prak Chamrouen	Key Consultants (Cambodia)	Head department of GIS and Topographical Survey
2	Mr.Chan Thanin	Key Consultants (Cambodia)	Civil Engineer/Topo Team Leader
3	Mr.Sam Kosal	Key Consultants (Cambodia)	Civil Engineer/Cad & GIS operator
4	Mr.Vet Layveng	Key Consultants (Cambodia)	Geology Engineer/Cad & GIS operator
5	Mr. Kim Techor	Key Consultants (Cambodia)	Rural Engineer/Cad & GIS operator
6	Mr. Uk Samseiha	Key Consultants (Cambodia)	Head department of Hydrology and Modeling
7	Mr. Seak Sothearith	Key Consultants (Cambodia)	Hydraulic Engineer

1.6 Equipment used for the demonstration project

Four major equipment were deployed in the study such as UAV model eBeeX and DJI Matrice drone; receiver and boat to conduct both ground and water depth of the river. Each equipment is listed in **Table 1-4** below with its functionality and specification.

Table 1-4 List of equipment used

No.	Name	Qty.	Remarks (specifications, usage, etc.)
1	UAV models eBee X RTK 	01	• Fully autonomous navigation including take-off and landing and automatic control of the on-board camera • Wingspan: 116cm • Weight (incl. supplied camera & battery):1.1 - 1.4kg depending on depending on camera and battery • Cameras: senseFly S.O.D.A. 3D • Automatic 3D flight planning: eMotion 3 • Cruise speed: 40-110 km/h • Max. flight time: Standard: 60 minutes / Endurance Extension: 90min • Max. flight range: Standard: 47 km / Endurance Extension: 95 km

No.	Name	Qty.	Remarks (specifications, usage, etc.)
2	DJI Matrice M300 RTK 	01	• Dimensions: Unfolded, propellers excluded, 810×670×430 mm (L×W×H) Folded, propellers included, 430×420×430 mm (L×W×H) • Diagonal Wheelbase: 895 mm • Weight (with single downward gimbal) Approx. 3.6 kg (without batteries) Approx. 6.3 kg (with two TB60 batteries) • Single Gimbal Damper's Max Payload: 930g • Max Takeoff Weight: 9 kg • Operating Frequency: 2.4000-2.4835 GHz 5.725-5.850 GHz • RTK Positioning Accuracy • When RTK enabled and fixed: • 1 cm+1 ppm (Horizontal) • 1.5 cm + 1 ppm (Vertical)
3	GNSS receiver models Sokkia GRX-3 	02	• GNSS Tracking: 226 with patented Universal Tracking Channels technology • GPS signal: L1 C/A, L1C', L2C, L2P(Y), L5, L1C when signal available • GLONASS signal: L1 C/A, L1P, L2C/A, L2P, L3C', L3C when signal available • Galileo signal: E1/E5a/E5b/Alt-BOC • BeiDou/BDS signal: B1, B2 • IRNSS signal: L5 • SBAS signal: WAAS, EGNOS, MSAS, GAGAN (L1/L5') • L-band signal: TopNET Global D&C Correction services • QZSS signal: L1 C/A, L1C, L1-SAIF, L2C, L5 • Static/Fast static: H 3mm +0.4ppm, V 5mm + 0.5ppm • RTK: H 5mm+0.5ppm; V 10mm+0.8ppm • Internal Radios: 425-470MHz UHF radio, Max transmit power 1w, Range 5-7km
4	GNSS receiver models CHC i90 pro	04	• GPS signal: L1C, L1C/A, L2E, L5 • Channels: 336 channels • GLONASS signal: L1C/A, L2 C/A, L3 CDMA • Galileo signal: E1, E5a, E5b, EAltBOC, E6 • BeiDou singal: B1, B2, B3 • SBAS signal: L1C/A, L5 • QZSS signal: L1 C/A, S1 SAF, L2C, L5, LEX

No.	Name	Qty.	Remarks (specifications, usage, etc.)
			• IRNSS signal: L5 • L-BAND signal: RTX • RTK: H 8mm+1ppm RMS; V 15mm+1ppm RMS • PPK: H 2.5mm+1ppm RMS; V 5mm+0.5ppm RMS Static: H 2.5mm+0.5ppm RMS; V 5mm+0.5ppm RMS Network modem: • Integrated 4G modem, LTE (FDD): B1, B2, B3, B4, B5, B7, B8, B20 • DC-HSPA+/HSPA+/HSPA/UMTS • B1, B2, B5, B8 • EDGE/GPRS/GSM • 850/900/1800/1900MHz • UHF Radio: • Standard Internal Rx/Tx: 410-470MHz • Transmit Power: 0.5W to 2W • Protocol: CHC, Transparent, TT450, SATEL3AS • Link rate: 9600 bps to 19200 bps • Range: 5km under optimal conditions • Data formats: • RTCM2x, RTCM 3x, CMR, CMR+ • SCMRX input and output • HCN, HRC, RINEX 2.11, 3.02 • NMEA 0183 output • NTRIP Client, NRTIP Caster.

2 Details of the work

2.1 Work performed

2.1.1 Preparation

Prior to implementing the work, some necessary tasks had been initially prepared in the following steps:

- The UAV firmware and flight control software were verified to be up-to-date; the memory space was purged of all previous data, the UAV was pre-connected to Khmer GEONET using an activated username and password, and the UAV battery and charger were inspected for functionality. The body, swing, propeller, and wind tube of the UAV were inspected and affirmed to be free of fractures, defects, etc;
- GNSS receiver firmware, and GNSS's control device firmware were confirmed up-to-date, GNSS receiver were pre-connected to Khmer GEONET via provided username and password;
- The outboard engine was serviced by draining the machine oil and gear oil and then refilling them;
- The fiberglass boat's bottom was examined to make sure no cracks had formed.
- Site reconnaissance had been observed the following day the team arrived Siem Reap city;
- The proposed UAV take-off and landing locations were inspected for obstruction objects such as structures, tall trees, telecommunication antennas;
- Since the study area was a sensitive area, the permission letter was requested from GDCG. The GDCG, on the other hand, was not able to issue the letter prior to implementing the work on time. However, due to the better coordination between GDCG and Provincial Department of Land Management, Urban Planning and Construction, the Siem Reap provincial administrative and relevant officers were officially notified;
- Inline structures and site condition were observed, in which hydrological characteristic were identified in associated available dataset from relevant establishment and satellite data;
- Secondary data such rainfall, flow dataset was obtained from the Provincial Department of Water resources and Metrology and used to conduct numerical and statical analysis before input into Hydrological model;
- The product from topographical survey associated with hydrological result were input together into hydrodynamic model to conduct flood inundation modeling and flood mapping to difference scenarios and return period were prepared accordingly;

2.1.2 Implementation

Photogrammetry survey was used to generate three-dimensional point clouds from the specialized drone camera; in which the DEM was generated by using Pix4D mapper application; the interface of the application is shown in **Figure 2-1**.

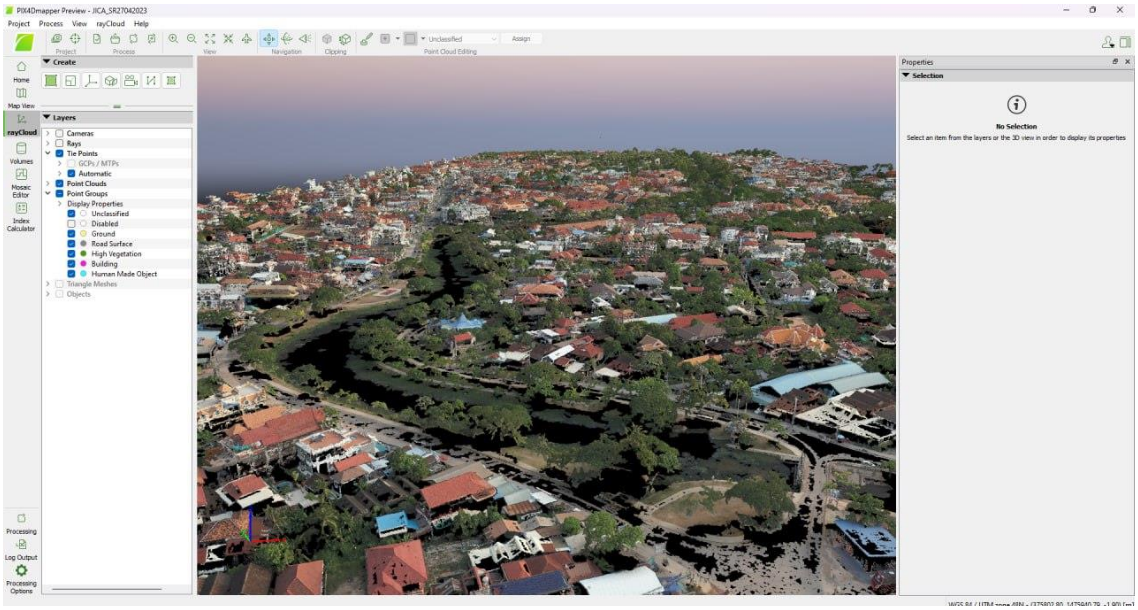


Figure 2-1 Three-dimensional point cloud obtained from drone camera and constructed in Pix4D mapper software

Drone imagery couldn't reach to the underneath of the water surface, however; river bathymetric or river cross-section in-situ the study area has been surveyed along the defined 2km alignment of Siem Reap River to construct an interpolated surface of the river bank and river bed elevation by using GNSS receiver. The bathymetric survey activity is shown in **Figure 2-2.**

Figure 2-2 River bathymetric surveying activity

As indicated in the objective of the study; a major task was to compare the differential and beneficiary of utilizing an unmanned aerial vehicle connected with Khmer GEONET CORS and the National BM zero-order control. Observing the coordinate data obtained from Khmer GEONET CORS SIE1 and from the National BM zero-order control were discussed in the section below.

In order to evaluate the accuracy retrieved from Khmer GEONET CORS; five checked-points on the ground were used to observe its values (N, E, Z). Five ground checked-points used for this project are CHK-01, CHK-02, CHK-03, CHK-04, and CHK-05 by utilizing GNSS receivers.

Five-time measurements were performed at each of the examined points.

a. The 1st measurement was performed by using Static Survey, setting up GNSS receivers on CHK-01, CHK-02, CHK-03, CHK-04, and CHK-05 with a minimum observation duration of two hours respectively. The satellite elevation mask was set to 10 degrees from the horizontal axis; and the data recording interval was 01 second.
   Raw GPS files known as Receiver Independent Exchange Format (RINEX) were collected from receivers of these control points once the observation finished; the RINEX file at reference station CORS SIE1 at the current time was acquired by Khmer GEONET.
b. The 2nd measurement was also performed by using Static Survey, setting up GNSS receivers on checked-points and on the national BM-SIAM zero-took three hours in observation.
c. The 3rd measurement was performed by using Real Time Kinematic Survey (RTK) by connecting GNSS receiver to the Khmer GEONET CORS SIE1 with the distance approximately of 6km.
d. The 4th and 5th measurements, in which the coordinate of checked points were obtained directly from drone imagery, are shown in the figure 2.3 – 2.7. Raw images were obtained from DJI M300 RTK and the image mosaic was processed in Pix4D Mapper. The Khmer GEONET CORS SIE1 and the National BM zero-order base stations were utilized in order to compare their respective results.

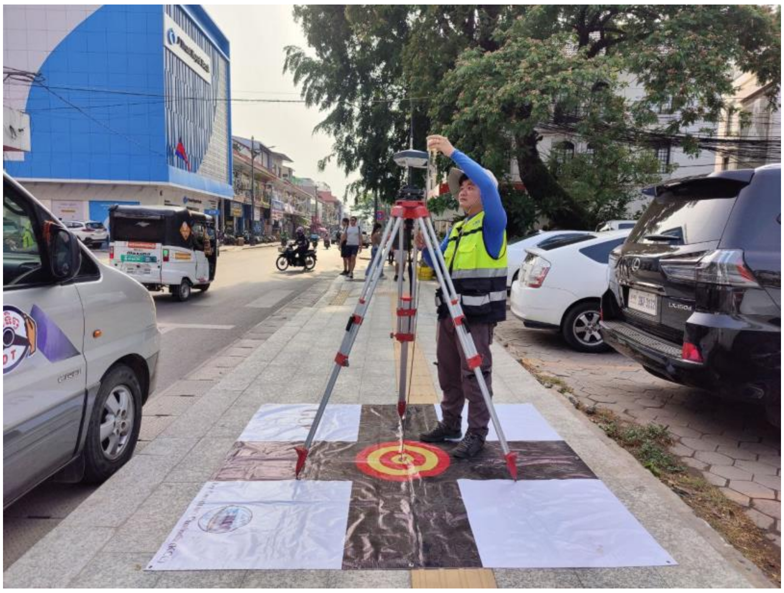
As mentioned in the above section, the drone camera sensor could not reach to the riverbed elevation. Furthermore, a specialized sensor was needed. However, the river cross-section survey was performed by utilizing an RTK survey and linked to Khmer GEONET CORS SIE1 with the following configuration:

- Protocol: NRTIP
- Data link: PDA network or Internet-Connected Device
- Domain/IP: cgd09.khmerGEONET.xyz
- Port:2101
- Mount point: RRS_RTCM32

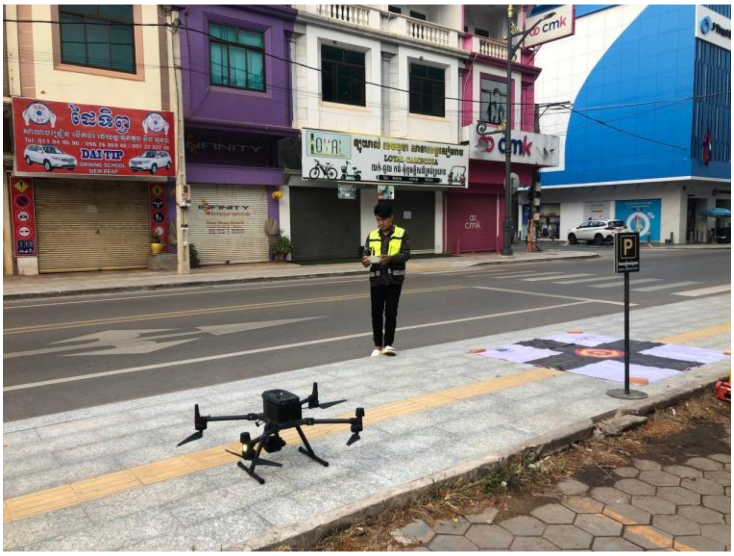
The following activities shown in the **Table 2-1** are the activities in setting up of Static survey at each checked-points by using GNSS receivers and drone flight preparation connecting to CORS SIE1 and Checked-point 3.

Table 2-1 Activity performed in setting up static and drone survey

Detailed of activities performed	
Static Survey was carried out on the ground checked-point CHK-01 Starting Time: 9:19AM – 12.00PM (UTC+7) GNSS receiver with dual frequency models CHC-i90 pro	
Static Survey was carrying out on the ground checked-point CHK-02. Starting Time: 9:13AM-12:02PM (UTC+7) GNSS receiver with dual frequency models Sokkia GRX-3	

Static Survey was carrying out on the ground checked-point CHK-03 Starting Time: 9:03AM – 12:02PM (UTC+7) GNSS receiver with dual frequency models Sokkia GRX-3	
Static Survey was carrying out on the ground check-point CHK-04 Starting Time: 9:10AM – 12:00PM (UTC+7) GNSS receiver with dual frequency models CHC-i90pro	
Static Survey was carrying out on the ground checked-point CHK-05 Starting Time: 9:10AM – 12:00PM (UTC+7) GNSS receiver with dual frequency models Sokkia GRX-3	

Static Survey was carrying out on the National BM SIEM zero-order Starting Time: 9:10AM – 12:00PM (UTM+7) GNSS receiver with dual frequency models CHC-i90pro.	
Multi rotors drone models DJI M300 RTK received the correction data from ground base receiver CHC-i90pro. The connection parameter: NRTIP host: 192.168.1.1 Port: 9901 Mountpoint: RTCM3.2 Satellite used: GPS 8, Beidou 9, Glonass 5, Galileo 7 Note: The GNSS receiver was installed on CHK-03, and its coordinate received from static survey with BM SIEM as the reference station.	

Multi rotors drone models DJI M300 RTK received the correction data from Khmer GEONET CORS SIE-1 NTRIP host: cgd09.khmerGEONET.xyz Port: 2101 Mountpoint: RRS_RTCM3.2 Satellite used: GPS 10, Beidou 9, Glonass 5, Galileo 5	
Khmer GEONET CORS SIE-1 located in front of Administration center of Siem Reap.	

2.1.3 Topographical surveyed data processing

RINEX files have been imported into MAGNET Tools Ver.4.3.2.0 software to conduct data processing and network adjustment. Some parameters had been configured prior to processing the data:

a. Coordinate System: Projection UTM Zone 48N: 102E to 108E, Datum: WGS1984
b. Confidence level was set to 95%
c. Least Squares Formula had been used to compute Traverse Adjustment
d. Satellite filter angle was set to 10 degrees
e. Traverse Distance Precision was obtained from the Horizontal Control Network Standard in Federal Geodetic Control Committee (FGCC) as shown in **Table 2-2**. The Third-order, class II has been chosen.

Table 2-2 Distance accuracy Standard (FGCC)

Classification	Minimum distance accuracy
First-order	1:100,000
Second-order, Class-I	1:50,000
Second-order, Class-II	1:20,000
Third-order, Class-I	1:10,000
Third-order, Class-II	1:5,000

A distance accuracy calculate the value of 1:a that computed from a minimally constrained, correctly weight, least squares adjustments by:

$$a = d/s$$

Where:

- **a**: is a distance accuracy denominator
- **s**: is propagated standard deviation of distance between survey points obtained from the least square adjustment
- **d**: is horizontal between survey points
- Static horizontal precision was set to 0.02m
- Horizontal Tolerance for loop closure precision was set to 0.03m

Pix4D Mapper, a photogrammetry application, was used to mosaic the images. RTK-based drone model (DJI Matrice 300 RTK) was used to capture the images over the study area at a flying altitude of 270m; the image resolution was captured by 3cm pixels; the image side and front overlap was set to 80%; and the speed of the drone to capture the images was 15 m/s.

The final DTM was generated by using ArcMap's break line feature to combine the DTM retrieved from Pix4D with data from a ground survey.

The **Figure 2-3 to 2-7** depict the locations of ground checkpoints CHK-01, CHK-02, CHK-03, CHK-04, and CHK-05 that were initially placed on the ground prior to flying the drone. The locations were discovered at the open sky, at the visible place where the drone's camera could capture the clear images from top view. The coordinate data (N, E) was extracted from high-resolution aerial photograph using the **Identify tools of ArcMap software.**

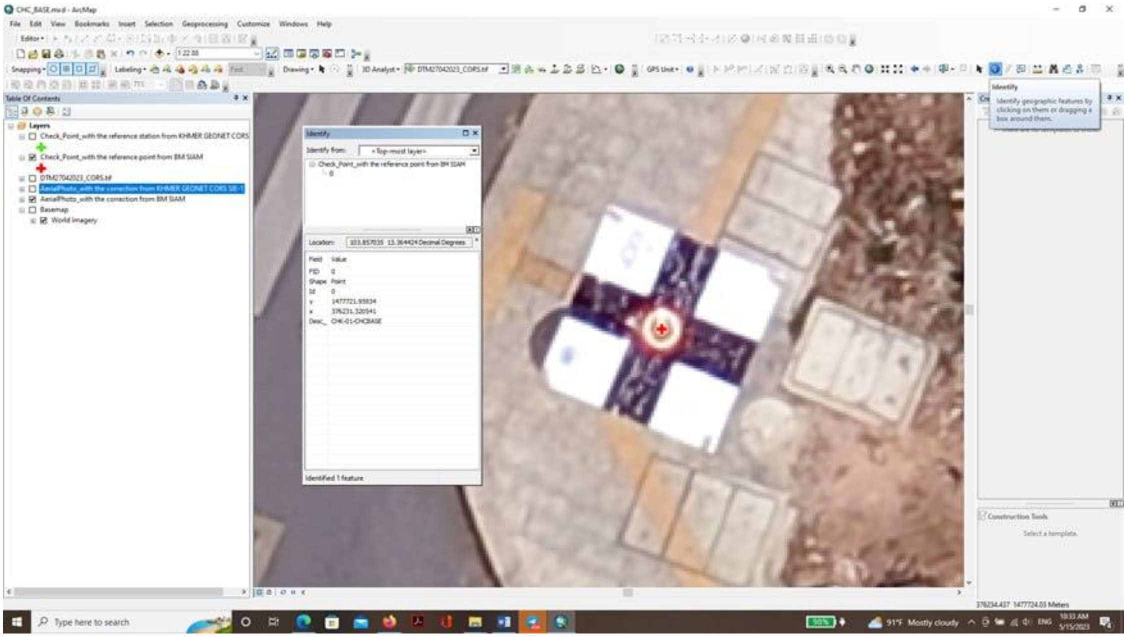


Figure 2-3 The coordinate data of CHK-01 was obtained from drone imagery

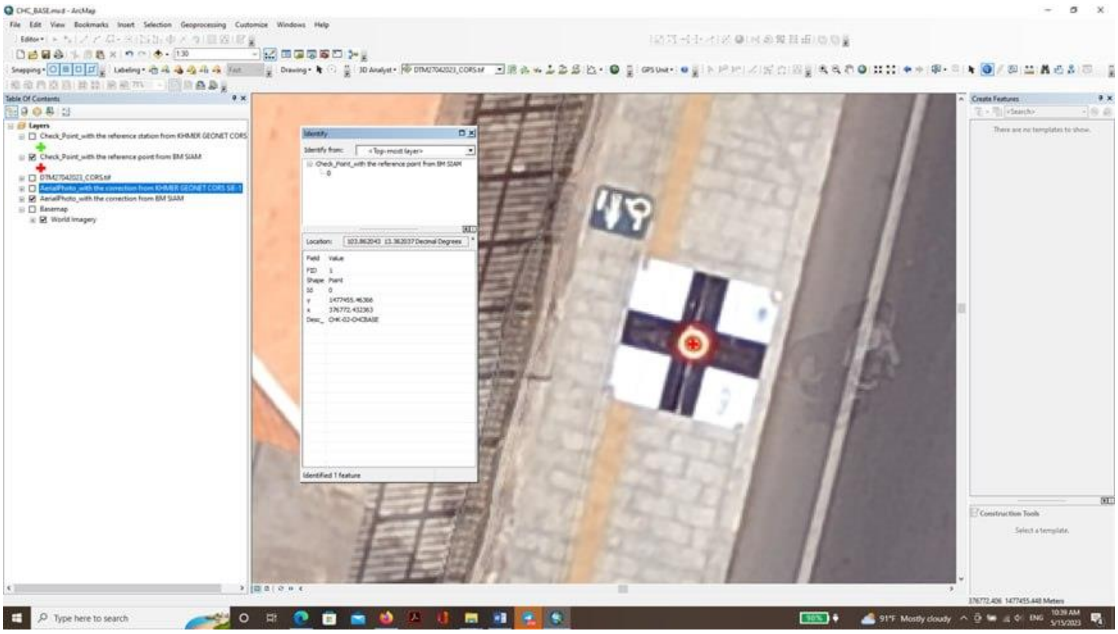


Figure 2-4 The coordinate data of CHK-02 was obtained from drone imagery

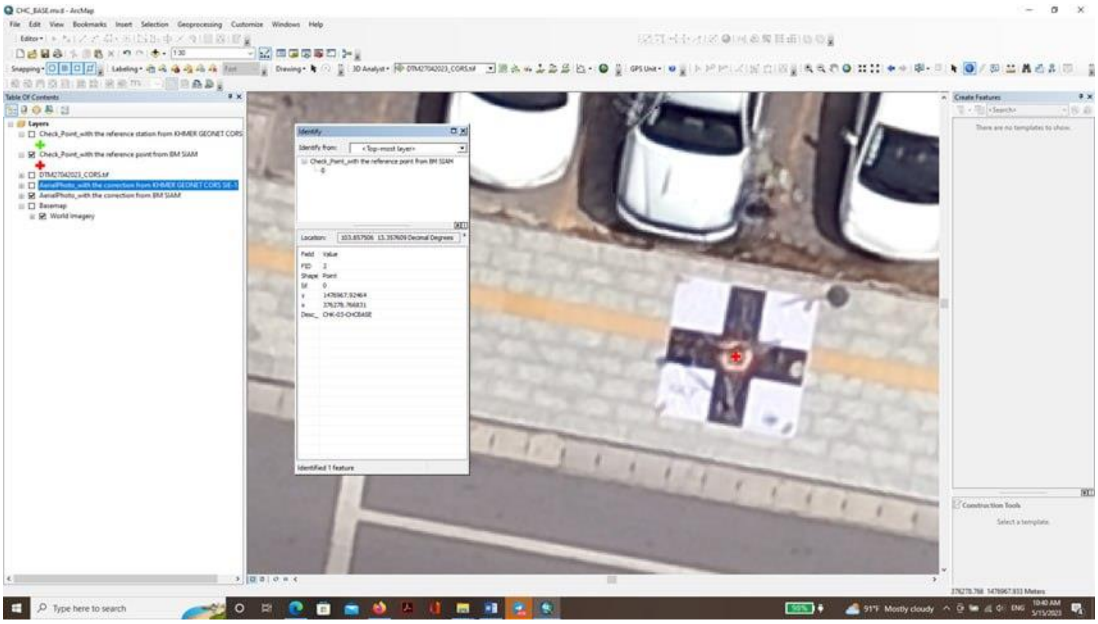


Figure 2-5 The coordinate data of CHK-03 was obtained from drone imagery

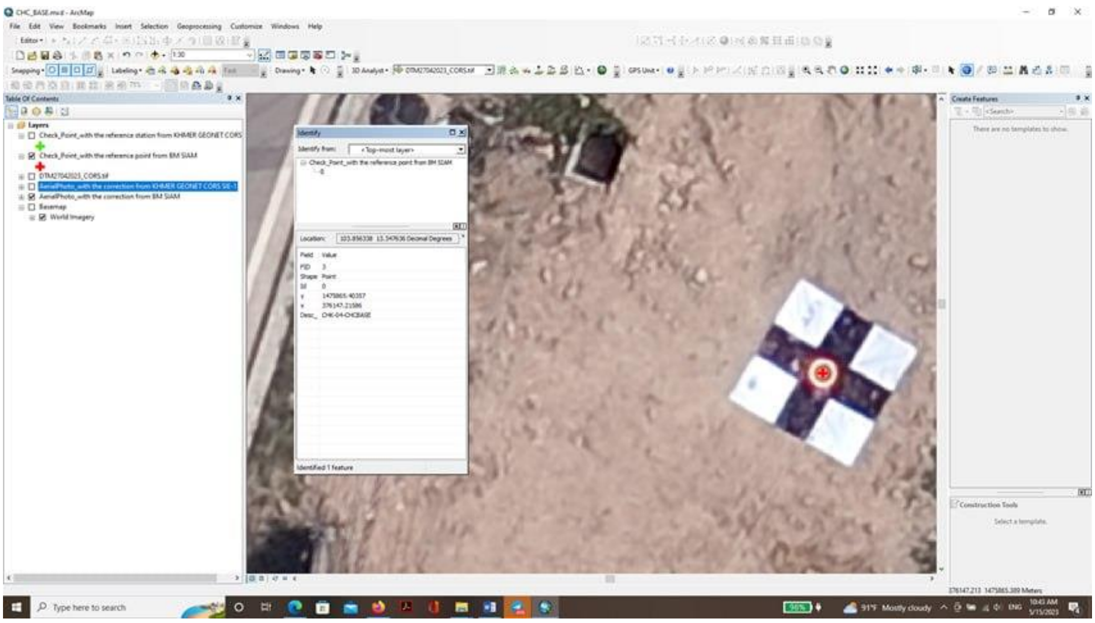


Figure 2-6 The coordinate data of CHK-04 was obtained from drone imagery

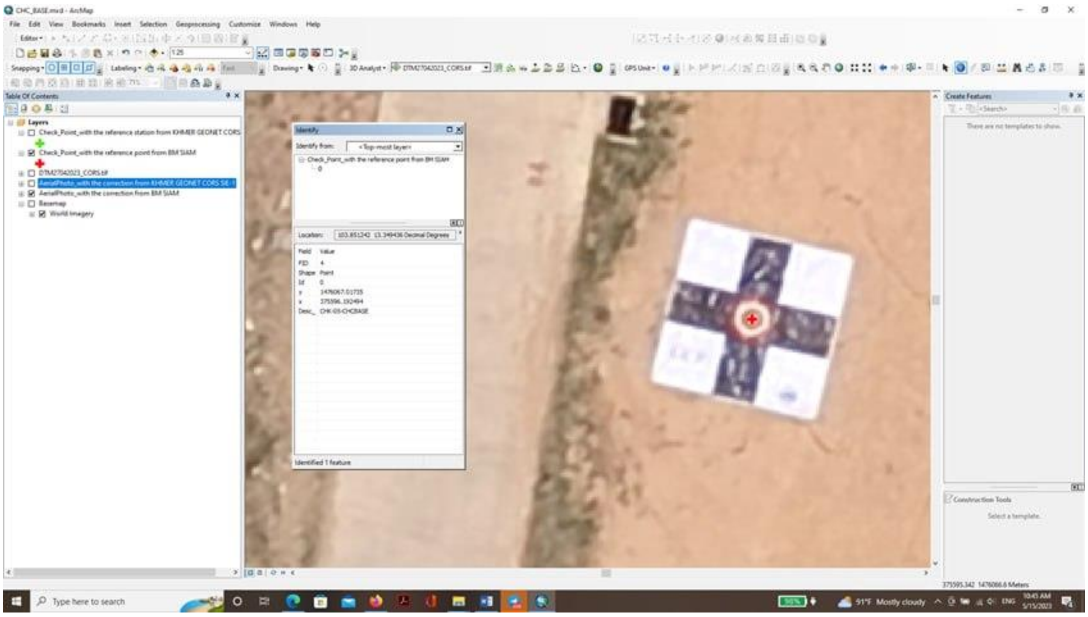


Figure 2-7 The coordinate data of CHK-05 was obtained from drone imagery

The elevations of ground checkpoints (ellipsoid height), on the other hand; were extracted from the final improved Raster DTM using **Extract Values to Points ArcMap** as illustrated in **Figure 2-8**.

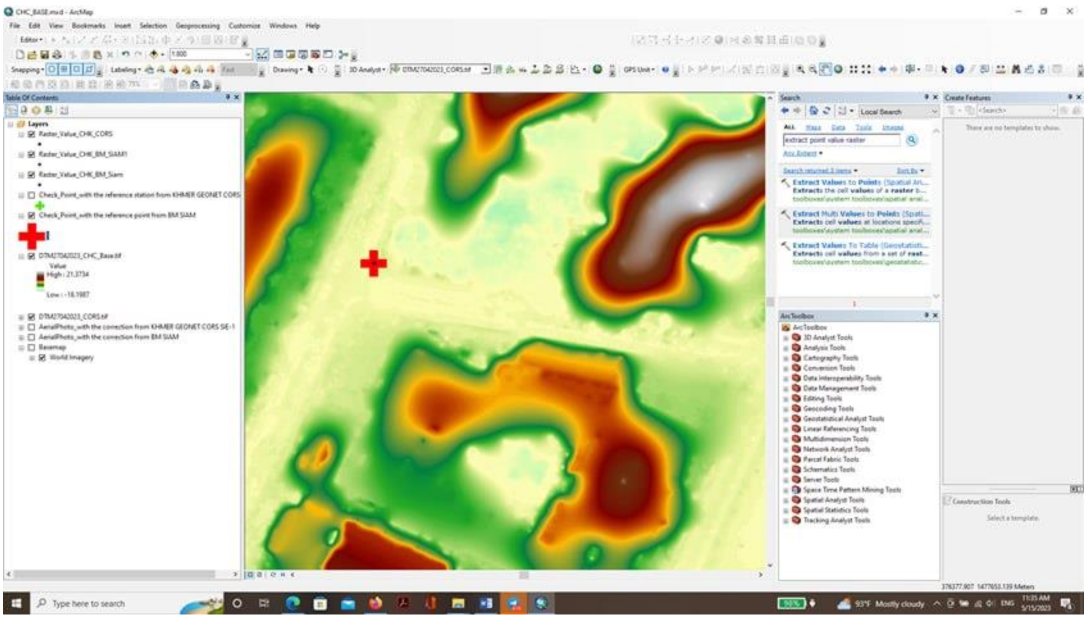


Figure 2-8 The elevation of ground checked points (ellipsoid height) were extracted from raster DTM using ***Extract Value to Point***

2.2 Surveyed Results

2.2.1 Northing and Easting comparison

In the analysis step, the accuracy assessment of the Khmer GEONET CORS was conducted by comparing the coordinate of the 5-ground checkpoints obtained from the static survey at the national BM zero-order (SIAM) with the coordinate determined by static survey measured from Khmer GEONET CORS.

Table 2-3 and 2-4 show the differences of horizontal and vertical RMS for the 5 checkpoints. The analysis of goodness fit test between the static survey from Khmer GEONET CORS SIE1 and the static survey from BM SIAM have shown that the discrepancies of the Northing and Easting shown in **Figure 2-9 to 2** with a few mm difference with the standard deviation of 0.01106m and mean of -0.01456m respectively. In contrast, the error of elevation was revealed by 20-30cm and the **Figure 2-11** and **Table 2-5** show the difference of elevation (ellipsoid height) of checkpoints.

Table 2-3 Static observation from Khmer GEONET CORS SIE1

STATIC OBSERVATION FROM KHMER GENOET CORS SIE1												
Name	**dN (m)**	**dE (m)**	**dHt (m)**	**Horz RMS**	**Vert RMS**	**Distance (m)**	**Duration**	**Solution Type**	**GPS Satellites**	**GLONASS Satellites**	**Status**	**RMS(m)**
CKH-02−CKH-03	-487.487	-493.587	-0.627	0.001	0.001	693.884	1:48:05	Fixed	7	7	Adjusted	0.001
CKH-02−CKH-05	-1590.064	-625.191	-1.93	0.001	0.001	1708.917	1:03:25	Fixed	7	6	Adjusted	0.002
CKH-02−SIE1	1513.048	3491.332	7.561	0.003	0.006	3805.925	1:53:50	Fixed	7	8	Adjusted	0.007
CKH-02−CKH-04	-1388.421	-1176.14	-1.317	0.001	0.001	1820.002	1:53:50	Fixed	7	8	Adjusted	0.002
CKH-02−CKH-01	266.571	-540.973	-0.394	0.001	0.002	603.213	1:40:39	Fixed	7	7	Adjusted	0.003
CKH-03−CKH-05	-1102.577	-131.606	-1.293	0.001	0.001	1110.637	1:03:25	Fixed	7	6	Adjusted	0.001
CKH-03−SIE1	2000.532	3984.906	8.21	0.003	0.006	4459.852	1:57:35	Fixed	7	7	Adjusted	0.007
CKH-03−CKH-04	-900.93	-682.559	-0.701	0.001	0.001	1130.529	1:49:02	Fixed	7	7	Adjusted	0.001
CKH-03−CKH-01	754.057	-47.387	0.226	0.001	0.001	755.703	1:40:39	Fixed	7	7	Adjusted	0.001
CKH-05−SIE1	3103.119	4116.52	9.499	0.004	0.007	5156.226	1:03:25	Fixed	7	6	Adjusted	0.008
CKH-05−CKH-04	201.645	-550.948	0.623	0.001	0.002	586.812	1:03:25	Fixed	7	6	Adjusted	0.002
CKH-05−CKH-01	1856.637	84.219	1.539	0.002	0.003	1858.936	1:03:25	Fixed	7	6	Adjusted	0.003
SIE1−CKH-04	-2901.472	-4667.469	-8.882	0.002	0.004	5496.99	1:10:57	Fixed	7	8	Adjusted	0.004
SIE1−CKH-01	-1246.478	-4032.302	-7.968	0.002	0.003	4221.486	1:40:39	Fixed	7	7	Adjusted	0.004

Table 2-4 Static observation from National BM Siam

STATIC OBSERVATION FROM NATIONAL BM (SIAM) ZERO-ORDER												
Name	**dN (m)**	**dE (m)**	**dHt (m)**	**Horz RMS**	**Vert RMS**	**Distance (m)**	**Duration**	**Solution Type**	**GPS Satellites**	**GLONASS Satellites**	**Status**	**RMS(m)**
BM-SIEM−CKH-01	-4982.208	4480.514	-2.777	0.003	0.005	6701.891	2:40:39	Fixed	7	7	Adjusted	0.0059
BM-SIEM−CKH-02	-5248.776	5021.495	-2.509	0.002	0.004	7265.414	2:52:35	Fixed	7	8	Adjusted	0.005
BM-SIEM−CKH-03	-5736.265	4527.906	-3.143	0.002	0.005	7309.447	2:54:40	Fixed	7	7	Adjusted	0.005
BM-SIEM−CKH-04	-6637.205	3845.357	-3.697	0.003	0.006	7672.200	2:53:32	Fixed	7	8	Adjusted	0.0065
BM-SIEM−CKH-05	-6838.851	4396.307	-4.454	0.003	0.005	8131.653	2:03:25	Fixed	7	7	Adjusted	0.0056
CKH-01−CKH-02	-266.5716	540.975	0.263	0.001	0.002	603.213	2:40:39	Fixed	7	7	Adjusted	0.0026
CKH-01−CKH-03	-754.0597	47.387	-0.357	0.001	0.001	755.703	2:40:39	Fixed	7	7	Adjusted	0.0012
CKH-01−CKH-04	-1654.997	-635.168	-0.916	0.001	0.002	1773.062	2:40:39	Fixed	7	7	Adjusted	0.0017
CKH-01−CKH-05	-1856.643	-84.220	-1.670	0.002	0.003	1858.937	2:03:25	Fixed	7	6	Adjusted	0.0034
CKH-02−CKH-03	-487.4889	-493.589	-0.627	0.001	0.001	693.884	2:48:05	Fixed	7	7	Adjusted	0.0011
CKH-02−CKH-04	-1388.426	-1176.144	-1.188	0.001	0.001	1820.002	2:53:50	Fixed	7	8	Adjusted	0.0016
CKH-02−CKH-05	-1590.069	-625.193	-1.930	0.001	0.001	1708.917	2:03:25	Fixed	7	6	Adjusted	0.0016
CKH-03−CKH-04	-900.9326	-682.561	-0.572	0.001	0.001	1130.529	2:49:02	Fixed	7	7	Adjusted	0.0014
CKH-03−CKH-05	-1102.581	-131.607	-1.293	0.001	0.001	1110.637	2:03:25	Fixed	7	6	Adjusted	0.0013
CKH-04−CKH-05	-201.6452	550.950	-0.754	0.001	0.002	586.812	2:03:25	Fixed	7	6	Adjusted	0.0021

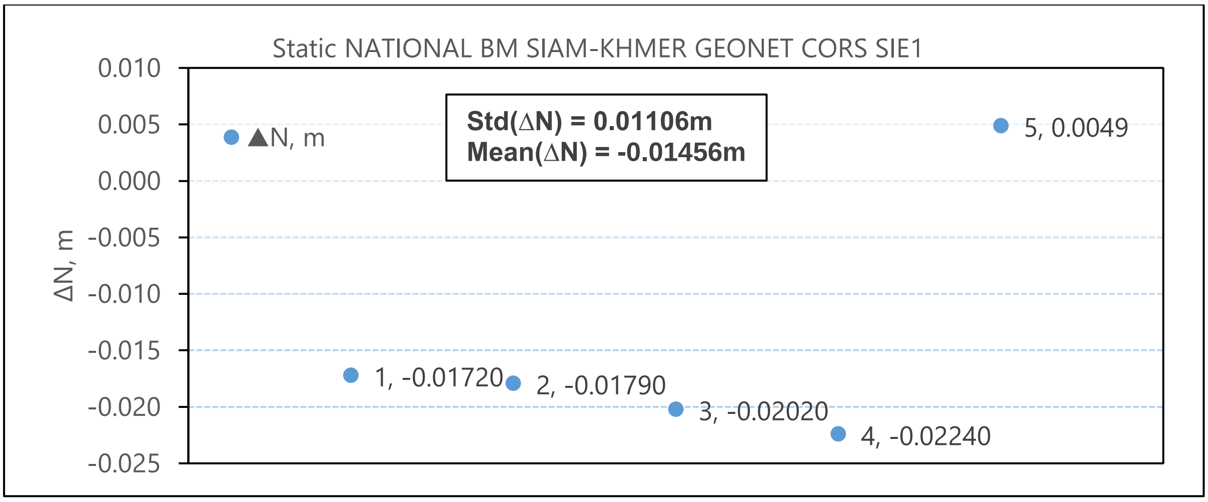


Figure 2-9 The difference of Northing data of Checkpoint

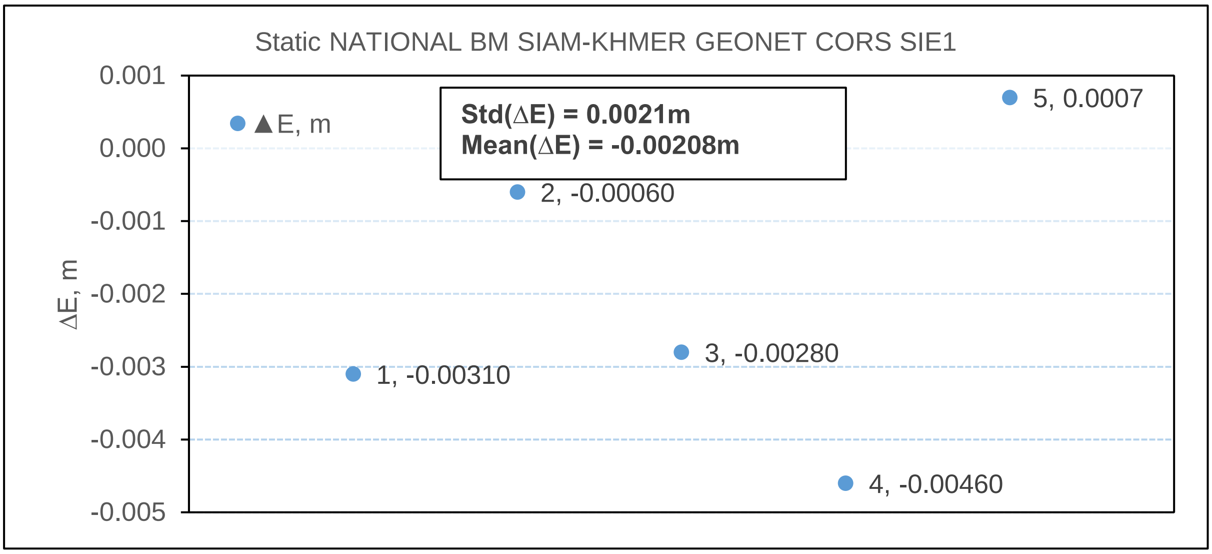


Figure 2-10 The difference of Easting data of checkpoint

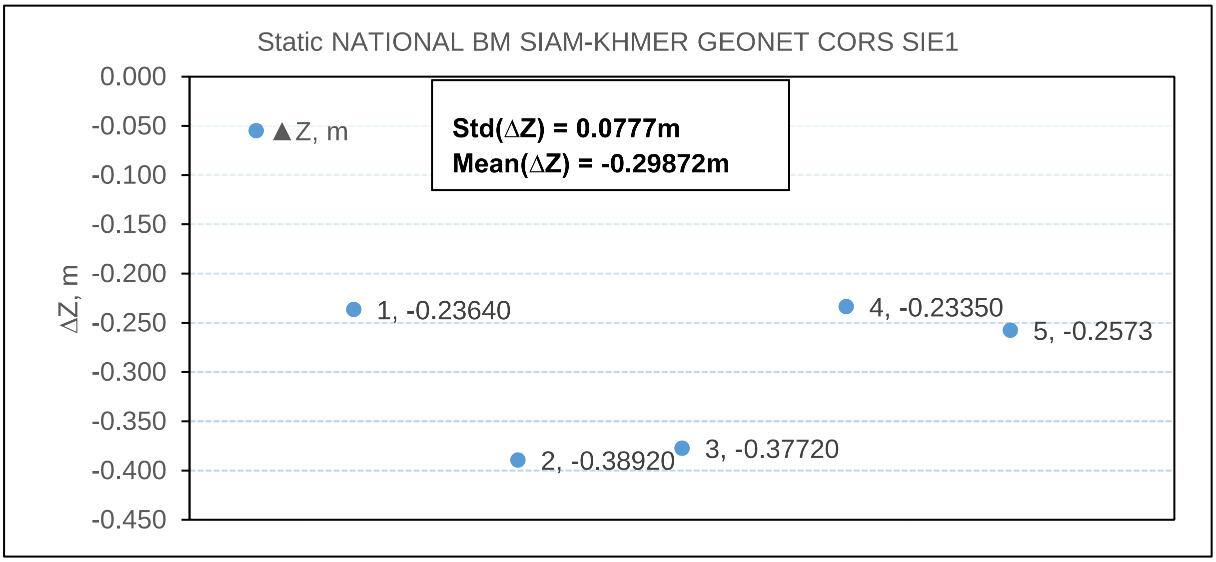


Figure 2-11 The difference of elevation (ellipsoid height) of checkpoints

Table 2-5 Comparison of Static survey for CORS Vs National BM (Airport)

POINT	DIFFERENCE		
	Northing (m)	Easting (m)	Z (m)
CKH−01	-0.0172	-0.0031	-0.2364
CKH−02	-0.0179	-0.0006	-0.3892
CKH−03	-0.0202	-0.0028	-0.3772
CKH−04	-0.0224	-0.0046	-0.2335
CKH−05	0.0049	0.0007	-0.2573
Mean	-0.0146	-0.0021	-0.2987
Standard Deviation	0.0111	0.0021	0.0778

At the examined points, the comparison of data from the Khmer GEONET CORS RTK and the National BM SIEM static survey was also observed. In **Figures 2-12** and **2-13**; in which the differences of northing and easting data range from a few millimeters respectively; while elevation data range from 22-39cm as seen in **Figure 2-14** and **Table 2-6** below.

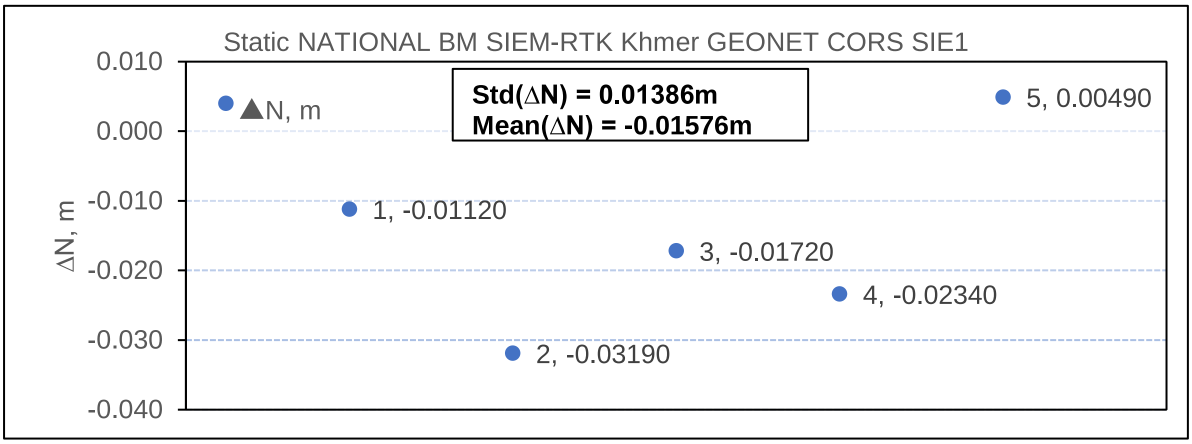


Figure 2-12 The difference of Northing data getting from BM SIEM and Khmer GEONET CORS

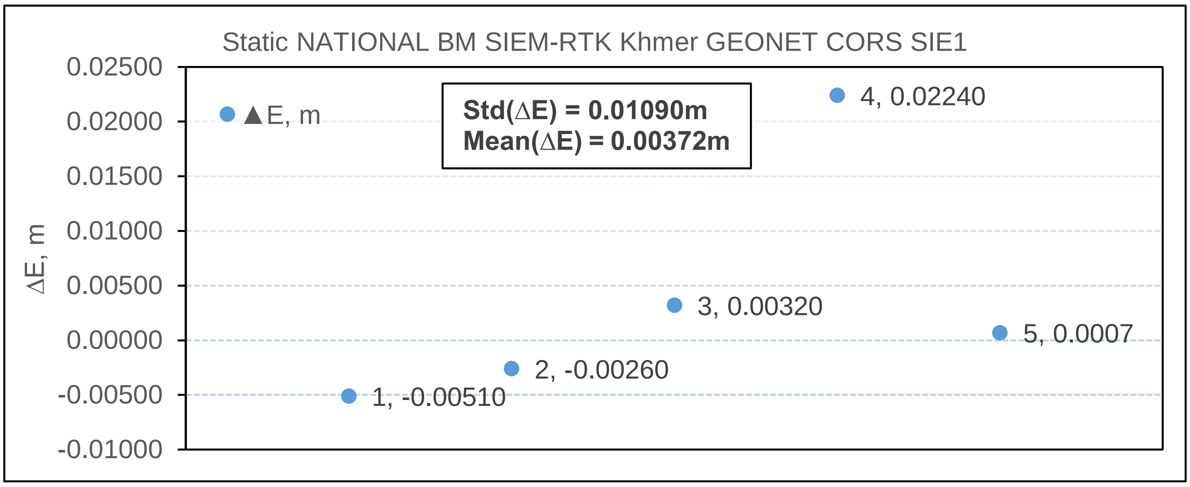


Figure 2-13 The difference of Easting data getting from BM SIEM and Khmer GEONET CORS

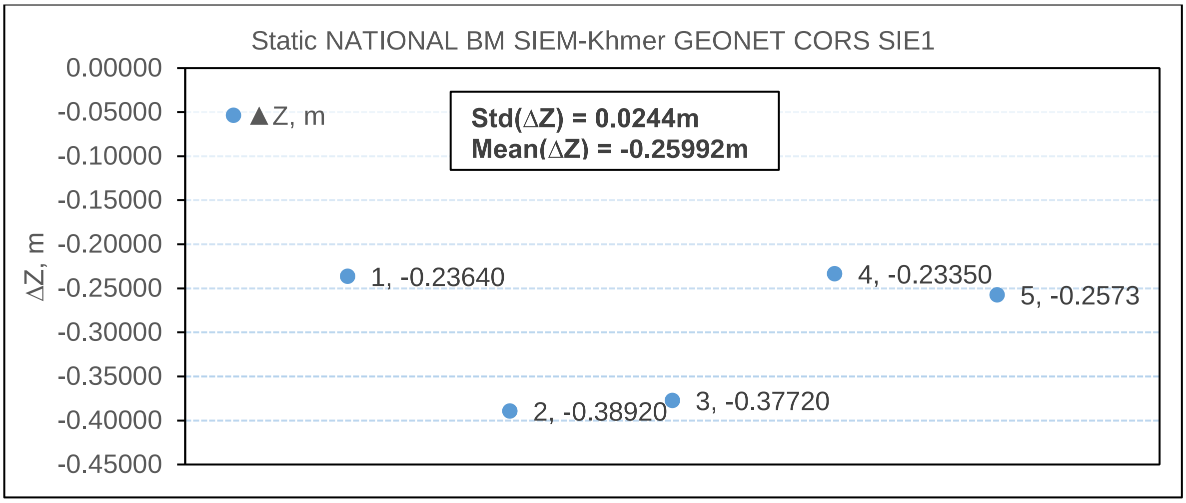


Figure 2-14 The difference elevation (ellipsoid height) of BM SIEM and Khmer GEONET CORS SIE1

Table 2-6 Comparison of RTK Survey Vs Static Survey (CORS)

POINT	DIFFERENCE		
	Northing (m)	**Easting (m)**	**Z (m)**
CKH−01	-0.0112	-0.0051	-0.2244
CKH−02	-0.0319	-0.0026	-0.2932
CKH−03	-0.0172	0.0032	-0.2622
CKH−04	-0.0234	0.0224	-0.2625
CKH−05	0.0049	0.0007	-0.2573
Mean	-0.0158	0.0037	-0.2599
Standard Deviation	0.0139	0.0109	0.0244

Comparing data from drone imagery with two different reference stations at Khmer GEONET CORS SIE1 and National BM SIEM was the final step in determining the checkpoints' accuracy. The **Figure 2-15** demonstrates that the variance in Northing and Easting data extends from a few millimeters to 2.6 centimeters. On the other hand, **Figure 2-16** depicts an Easting difference between 1 cm and 5 cm, whereas **Figure 2-17** and **Table 2-7** show an elevation difference between 23 cm and 38 cm.

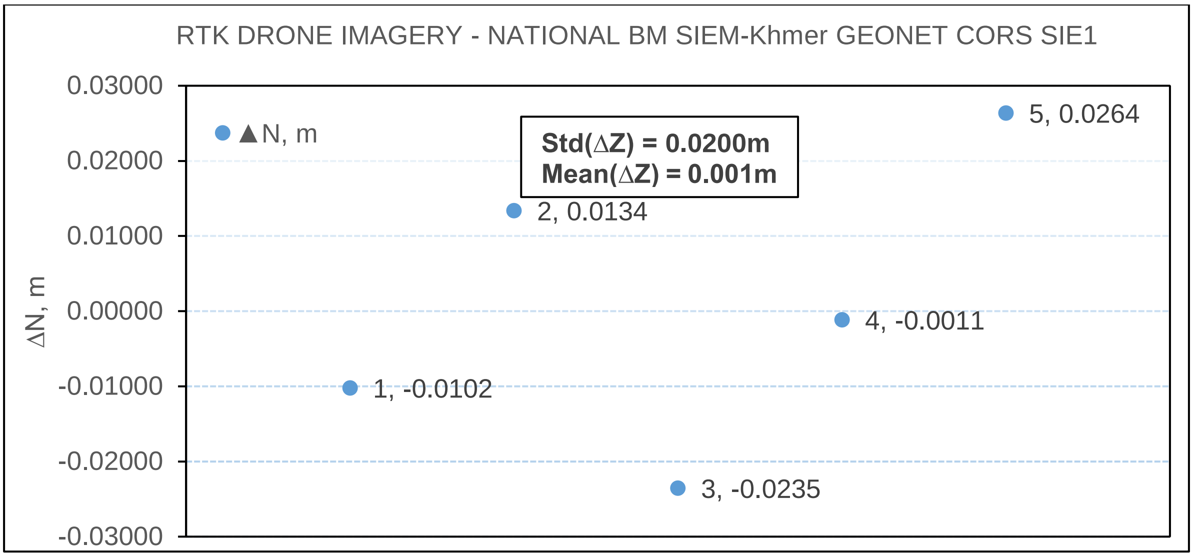


Figure 2-15, the difference of Northing from drone imagery

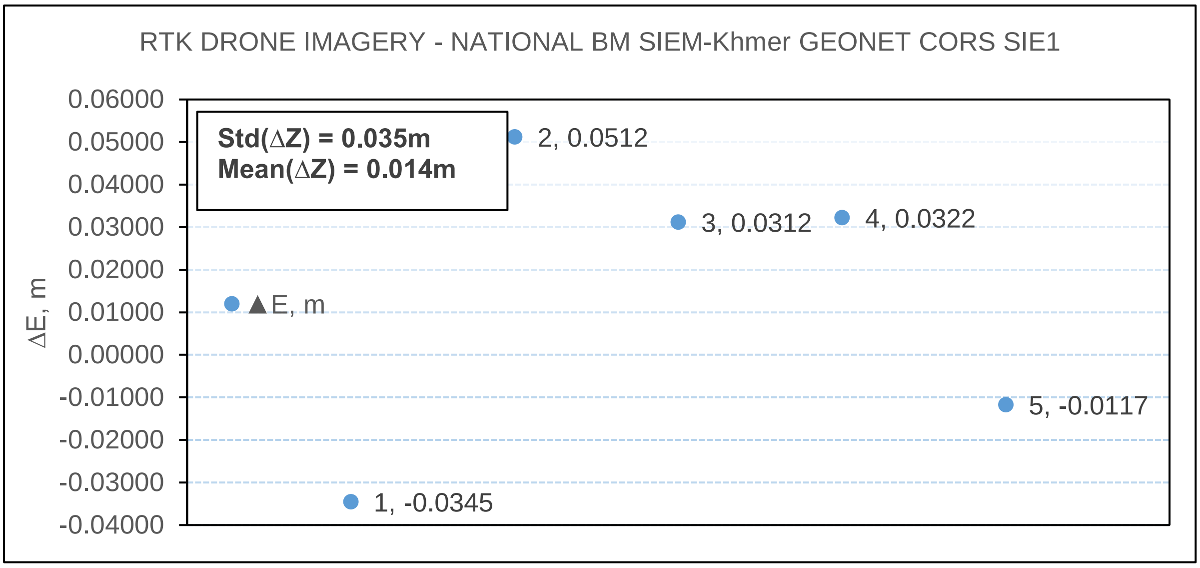


Figure 2-16, the difference of Easting from drone imagery

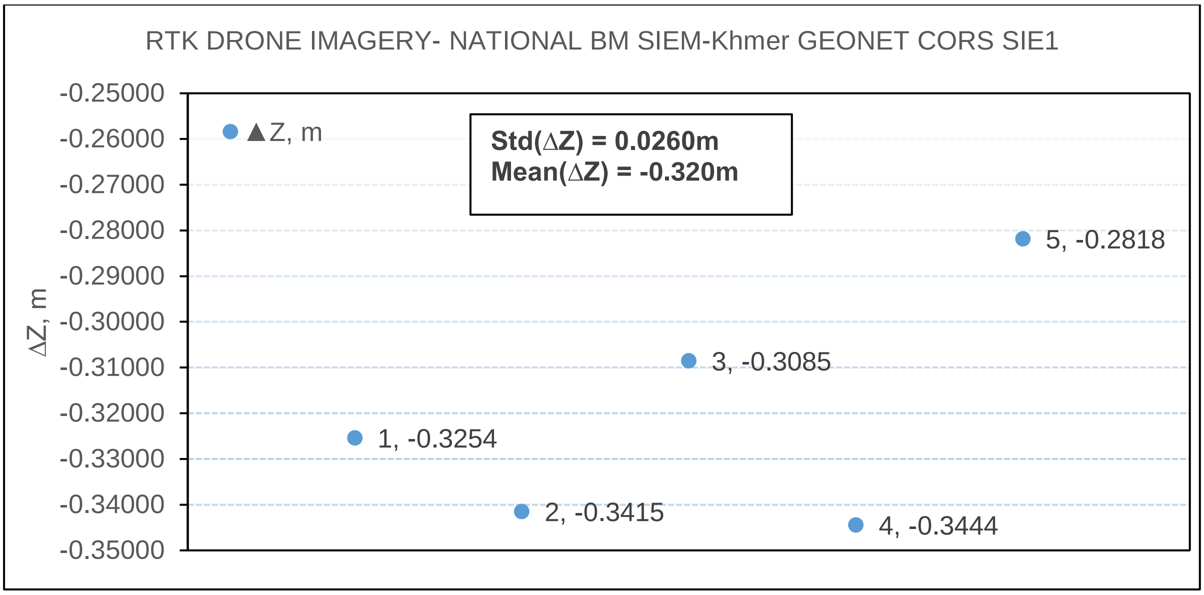


Figure 2-17, the difference of elevation from drone imagery

Table 2-7 Comparison of DTM (Drone RTK base CORS) Vs DTM (Drone RTK base National BM)

POINT	**DIFFERENCE**		
	Northing (m)	**Easting (m)**	**Z (m)**
CKH−01	-0.0102	-0.0345	-0.3254
CKH−02	0.0134	0.0512	-0.3415
CKH−03	-0.0235	0.0312	-0.3085
CKH−04	-0.0011	0.0322	-0.3444
CKH−05	0.0264	-0.0117	-0.2818
Mean	0.0010	0.0137	-0.3203
Standard Deviation	0.0196	0.0355	0.0259

2.2.2 Survey Cost Benefits

Understanding of cost expenditure of surveying by using ground National BM and the CORS will facilitate the work progress. The cost estimation to the uses of each typical of benchmark is discussed in the following section.

As discussed in the above section; in which the Khmer GEONET CORS and National BM were used and analyze of its accuracy of data acquisition and time consuming in connecting the benchmark.

It's clearly understood that; the project must include at least one static point and links to National BM in order to operate RTK drones while using National BM as a reference base.

In Cambodia, there is only one zero-order BMs available and connected to the Asia-Pacific GPS network found in Siem Reap International Airport; while one of first-order BM is available in each province.

Accessing to the firs-order BM faced challenges due to it’s lengthy to the study area; it’s important to have more CORS stations to facilitate in any development related to ground measurement.

The RTK is required to capture coordinate data in the field, many temporary benchmarks (TBMs) must also be established in the project area. Conventional RTK, which employs a single base station and transmits corrections to rovers via the UHF radio frequency has limited about distance. The length of the observation should be less than 20 kilometers, or the accuracy gets poor. This enables the surveyors to develop more efficient plan for transferring coordinate data from the national BM to the project area, a process that typically involves static surveying, which incurs additional costs, time, equipment, main power, transportation, etc.

On the other hand, Khmer GEONET CORS stations can be used in a wide range of applications, including land surveying, construction, engineering, and mapping. The high-precision GNSS information can be used to create detailed maps, survey land. Khmer GEONET CORS provide effectiveness and work efficiency by reducing time-consuming and cost. CORS which stands for Continuously Operating Reference Station are designed to operate continuously, 24hours a day, seven days a week, providing real-time GNSS information to users. The GNSS data collected by the CORS station is processed and transmitted to users via the internet, allowing them to access high-precision positioning information from anywhere, at any time.

Table 2-5 indicates that the work required for conventional survey, and six typical of actions are to be carried out for the surveying progress. It’s noticed that, number of operator and equipment receivers requires more manpower to operate; which revealed of time consuming and cost expenditure for these labor works.

Conventional surveying requires two steps: (i) coordinate data are transferred from the national ground BM to ground checkpoints by using static survey, and then (ii) the cross-section is completed by using RTK survey. Prior to conducting the RTK survey, the static survey created multiple RTK base station. Typically, RTK transmits the correction to the rover via UHF radio frequency; however, interference from any UHF radio frequency can cause a delay in determining the rover's precise position. In addition, operating with RTK drones requires an RTK base. Consequently, more resources were required to complete the operation. The distance between the national BM and our study area was also a concern, as more hours of static observation were required to improve the accuracy of GPS network processing. On top of that, RTK bases typically require one GNSS operator to standby to avoid any lost, unintentionally damaged, or relocated its position by humans.

The cost expenditure by using numbers of operator and time consuming for conventional method is provided in **Table 2-5** for 144 hectares of ground survey. The cost is depended on various condition; such weather, site accessibility, site condition and collaborative of the local authority.

Table 2-8 Approximate cost of using conventional survey

No.	Description	Unit	Qty.	Approximate Amount (USD)
1	GNSS receiver	No	5	$5,580.00
2	GNSS receiver operator	person	5	
3	Leveling Instrument	No	2	
4	Leveling operator	person	6	
5	Leveling staff holder	person	4	
6	Transportation	No	1	

In contrast, in **Table 2-6** has shown the cost expenditure of the completion of topographical surveying work for 144 hectares of ground survey by connecting to Khmer GEONET CORS. There are only three actions to conduct the survey as described in the table; in which; number of operators are minimized to operate with different equipment in the surveying task.

The GNSS receivers are similarity used to carry out the static survey which was done in conventional method; while the GNSS raw data are to be obtained from Khmer GEONET CORS. Additionally, the RTK survey to measure any river cross-section are simultaneously conducted without waiting for any completion of the static survey. RTK drone is easily connected and quickly received the correction data from Khmer GEONET CORS via the provisional of username and password. The working duration by using the CORS consumed less effort and cost expense are decreased, however; the cost is depended on various condition; such weather, site accessibility, site condition and collaborative of the local authority.

Table 2-9 Approximate cost of using Khmer GEONET CORS

No.	Description	Unit	Qty.	Approximate Amount (USD)
1	GNSS receiver	No.	5.00	$ 2,400.00
2	GNSS receiver operator	person	5.00	
3	Transportation	No.	1.00	

Comparison of both survey methodologies; the usage of Khmer GEONET CORS spends by half of conventional method by reducing operators and timing. As per unit of hectare area; using the CORS will cost approximately US$ 17/ha while conventional method will cost close to 40US$/ha. The cost expense for topographical data collection is mainly depended on the sites condition, and timing of each project areas nonetheless. The comparison of the cost estimation for both methods is illustrated in Figure 2-18, in which, the cost as per hectare area is shown.

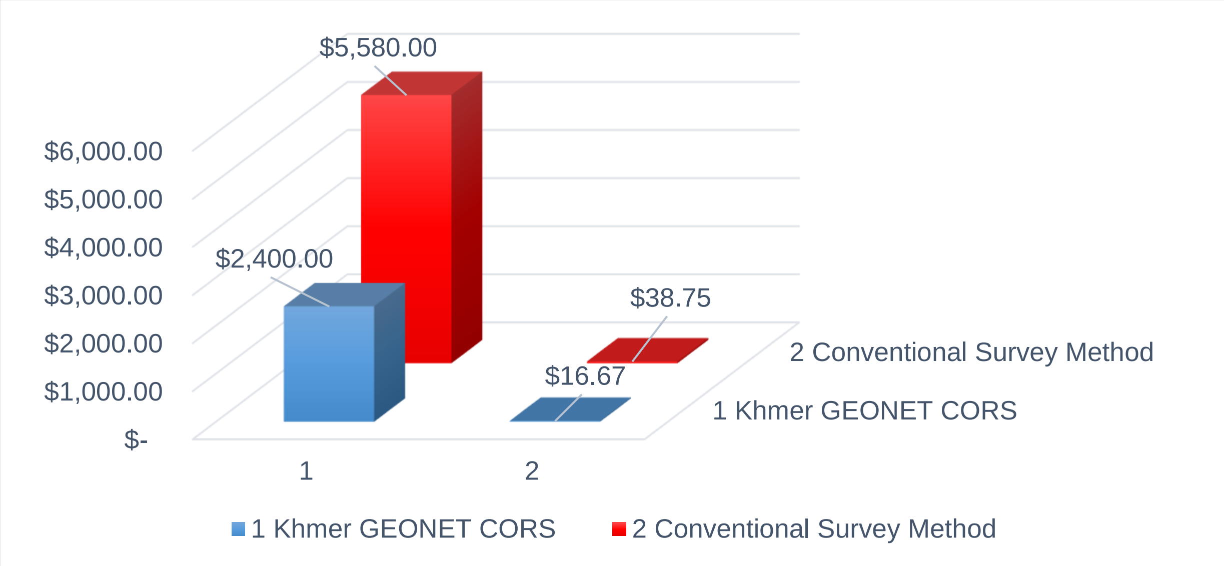


Figure 2-18, the estimate of the comparison cost between KhmerGEONET vs Conventional Survey Method

2.3 Use of Khmer GEONET

To gain access to Khmer GEONET, our team was required to register with a username and password. Khmer GEONET certified the account activation via the email address providing during registration. The RINEX static log file at the current session was requested from our team to the Khmer GEONET, once the post processing is needed.

In the field, we were required to select the correct mount point and remain within its service area, otherwise, the CORS correction would not be accurate. Currently, there are five Khmer GEONET CORSs, three of which are network CORS and two of which are standalone CORS functions. The measurements were typically carried out between 8a.m-12p.m, 2p.m-5p.m.

2.3.1 Details of the Khmer GEONET data used

The details of Khmer GEONET data used are described as the following.

Table 2-10 Khmer GEONET data used

IP address	cgd09.khmerGEONET.xyz
Port	2101
Mount point	RRS_RTCM3.2
User name	OuSamrach
Period of use	25 April 2023 – 30 April 2023
RTK/ Post processing	Real Time Kinematic, Static Survey
Satellite systems used	GPS, Glonass, Beidou, Galileo,

2.3.2 Problems occurred and solutions

The position of the rovers got fixed quickly without any delay, however; problem encounter was found when the rover was placed under the tree branches or near the building wall. To take over this problem, the operator should wait at least 5 minutes to get fully connecting to the CORS and fixed position.

2.4 Applicable of Khmer GEONET for urban flood assessment

Hydrological analysis is an essential work representing the natural phenomenon of water in the watershed of study area. It provides discharges which would flow across the study area depending on its magnitudes caused by different rainfall intensity. An accuracy and validated of input data such DTM is quite crucial to present the reliable of the model result; in which the result of vulnerable area due to flood potential was discussed below.

The result using the Khmer GEONET was used to equip in the hydrodynamic model by combining with other parameters; where the flood depth and inundation area reflected to difference event or extreme probability in the study area.

To produce flood inundation, performed hydrological analysis by using HEC-HMS model with the inputs of available and surveyed DTM dataset to create basinwide of Siem Reap River are required.

The following schematic of Figure 2-20 describes the procedure of flood assessment; in which the dataset from the result using the Khmer GEONET product is the primary input to assess the potential of inundation area.

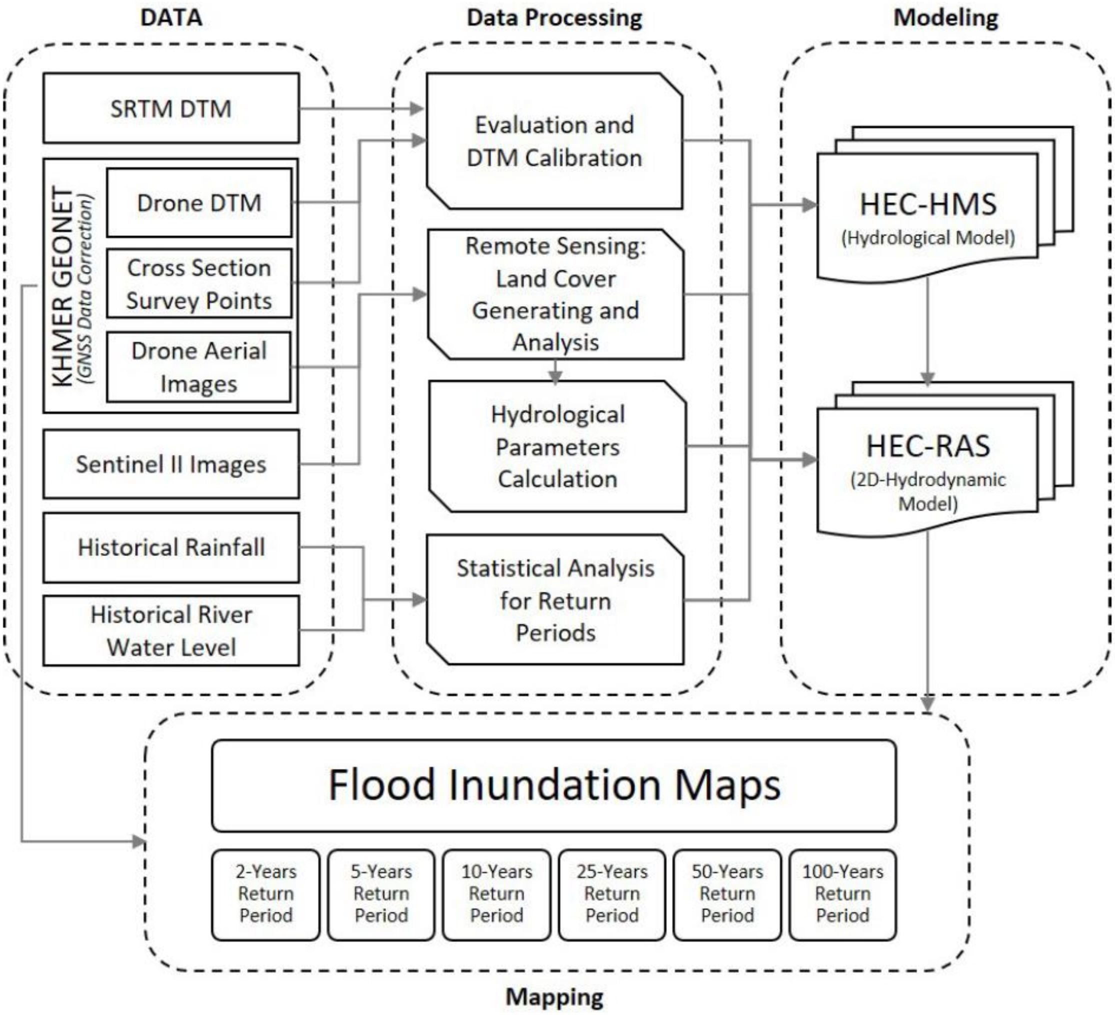


Figure 2-19 Flow chart of Flood indication assessment

2.4.1 Hydrological modeling

The dataset of Khmer GEONET CORS combined with the available digital elevation model were used to delineate rainfall catchment over the Siem Reap River.

To delineate the watershed, the combination of the Khmer GEONET CORSs and Digital Terrain Model (DTM) with the correction of bathymetric survey and the DTM clipping from Global Terrain Data – FABDEM (A 30 m global map of elevation with forests and buildings removed) for the study area was used. Using the built-in GIS tools in HEC-HMS to process the watershed delineation; in which Siem Reap River basin was delineated within the area of 537km^2 shown in Figure 2-21 which is stretching from Kulen mountain to the Tonlesap lake as downstream boundary of Siem Reap River basin.

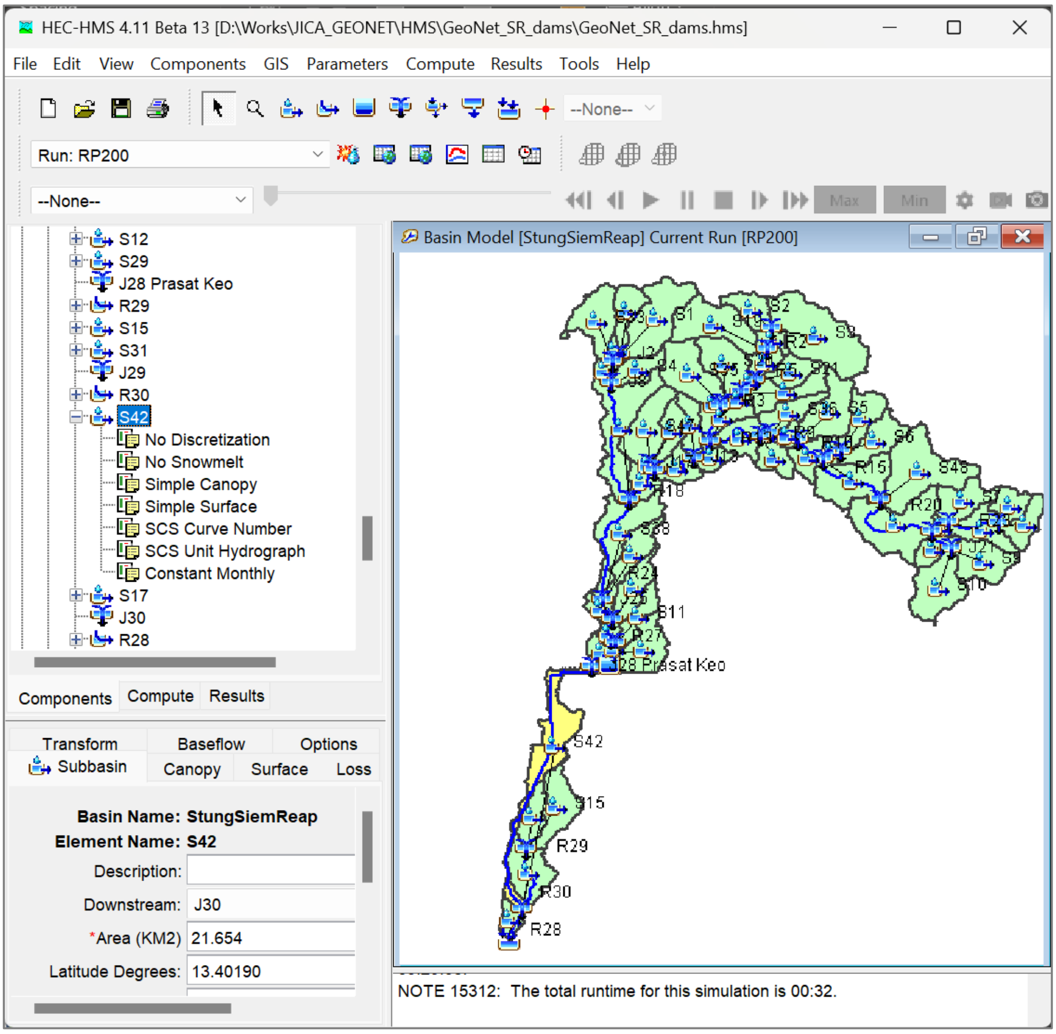


Figure 2-20 Siem Reap River basin and sub catchment

Siem Reap River is an artificial waterway which intercepted during 10th-11th CE[1]; where the southerly Pouk branch from the Kulen Mountains (main river basin) to an offtake canal system in temple zone and through Siem Reap town. Siem Reap River currently feeds water to ancient reservoirs such Baray and Moats. The water level is crucially conserved to maintain the foundation of ancient temple.

Several structures were observed at particular spots of Siem Reap river; it's clearly understood that there was only one head structure called Tum Nub Barang built over decades before 2012 and functioning to discharge water into temple area and minimize flood in the town.

Ta Som head structure, a new head structure was built and has been operating since 2013. The structure was built to evacuate potential of flow water from the huge river basin from Kulen mountain and navigate flow into major temple.

[1] *Water management in Angkor: Human impacts on hydrology and sediment transport, Kummu, 2009*

The primary result of the hydrologic model; in which simulated flow at a gauge was used to calibrate the model for long-term time series from the year 2000-2012. The calibrated result was observed on the goodness and fit test before input into hydrodynamic model. The graphic below shows the comparison of flow discharging at a stage gauge in Siem Reap River for 2000-2012.

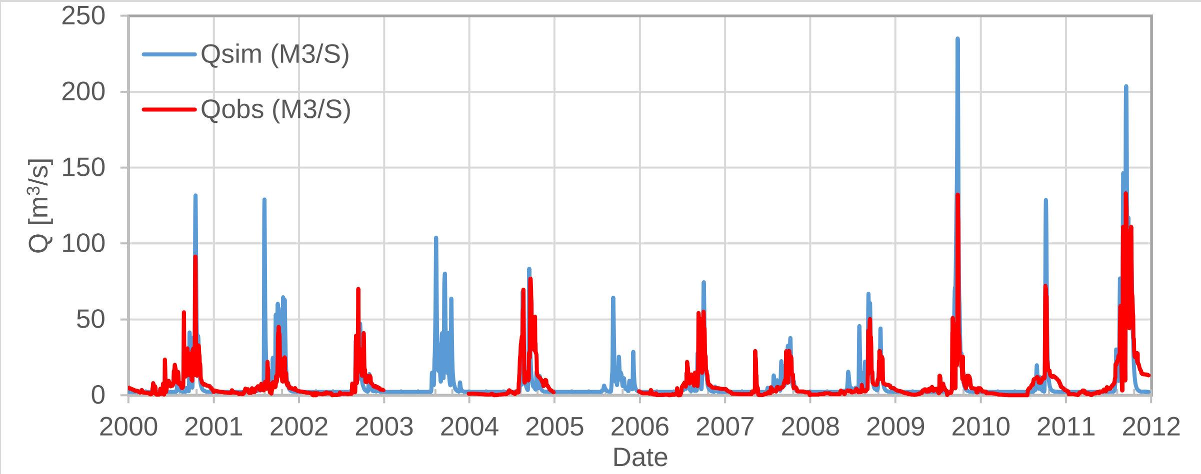


Figure 2-21 Comparison flow of staging gauge in Siem Reap River, 2000-2012

After Ta Som head structure was built and functioned; river flood potential was observed to have significantly decreased. However, urban flood in the city still occurred due to insufficient of urban infrastructure such urban drainage. The graph below shows the comparison result of gauging station and used as validated result from the hydrologic model and to be used for flooding assessment.

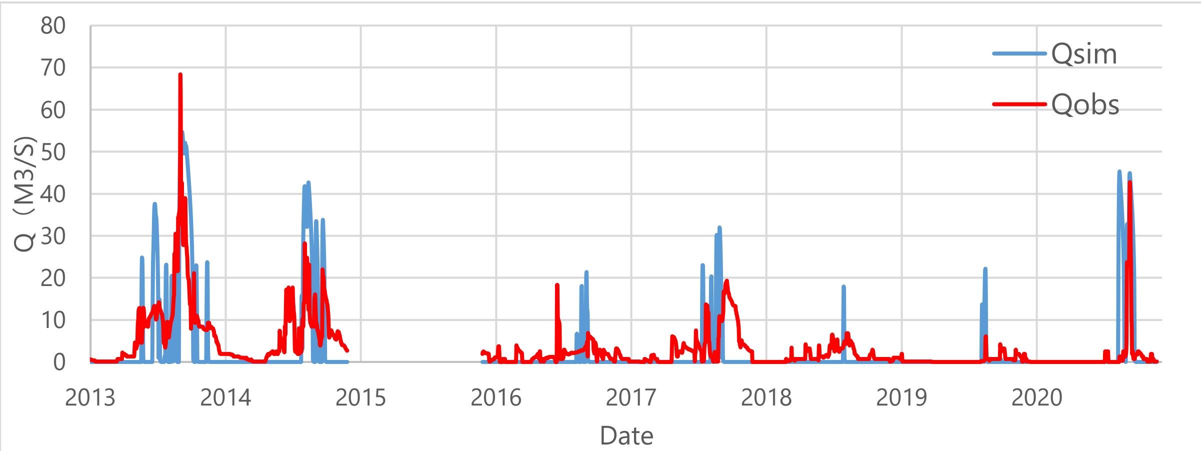


Figure 2-22 Comparison flow of staging gauge in Siem Reap River, 2013-2021

2.4.2 Hydrodynamic model

The 2D unsteady flow model was applied to generate overland flood. The most significant challenge for the hydrodynamic models is the availability of suitable digital elevation models (DEM) or digital terrain models (DTM). The DEM/DTM can be representing land surface feature in the study area. It provides information on surface elevations of the riverbed and the flood plain. The accuracy and scale of the DEM directly impact to land elevation surface used in the hydrodynamic model. Also, DTM or digital surface model can provide details of the terrain necessary for applying hydrodynamic modeling.

Table 2-11 Data requirement and input for Hydrodynamic model

Data Input	Parameter	Unit
DEM	Digital Elevation/Topography	Meter
Land Cover	Manning Roughness Coefficient	Dimensionless
Boundary Condition	Flow Hydrograph	Cubic meter per second

In this study, DTM from Global Terrain Data – FABDEM as mentioned in section above, Drone DTM and River Surface created from river cross section survey were mosaiced together to be terrain of the model. The river shape from Tasom Dam was modified assumedly along the digitized alignment until connecting to the bathymetric surveyed section. This modification simply assumed the river section as a trapezoidal with bottom width of 20m, side slope of 3:1 and upstream invert elevation of 20m.

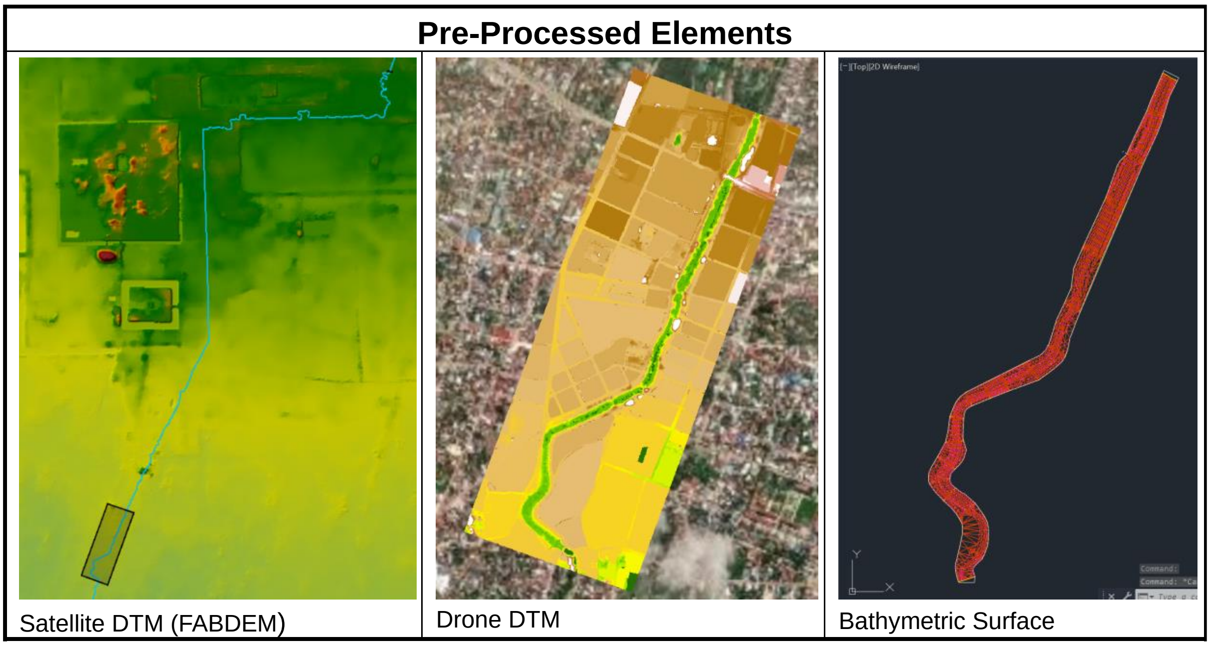


Figure 2-23 Pre-processing of improvement DTM

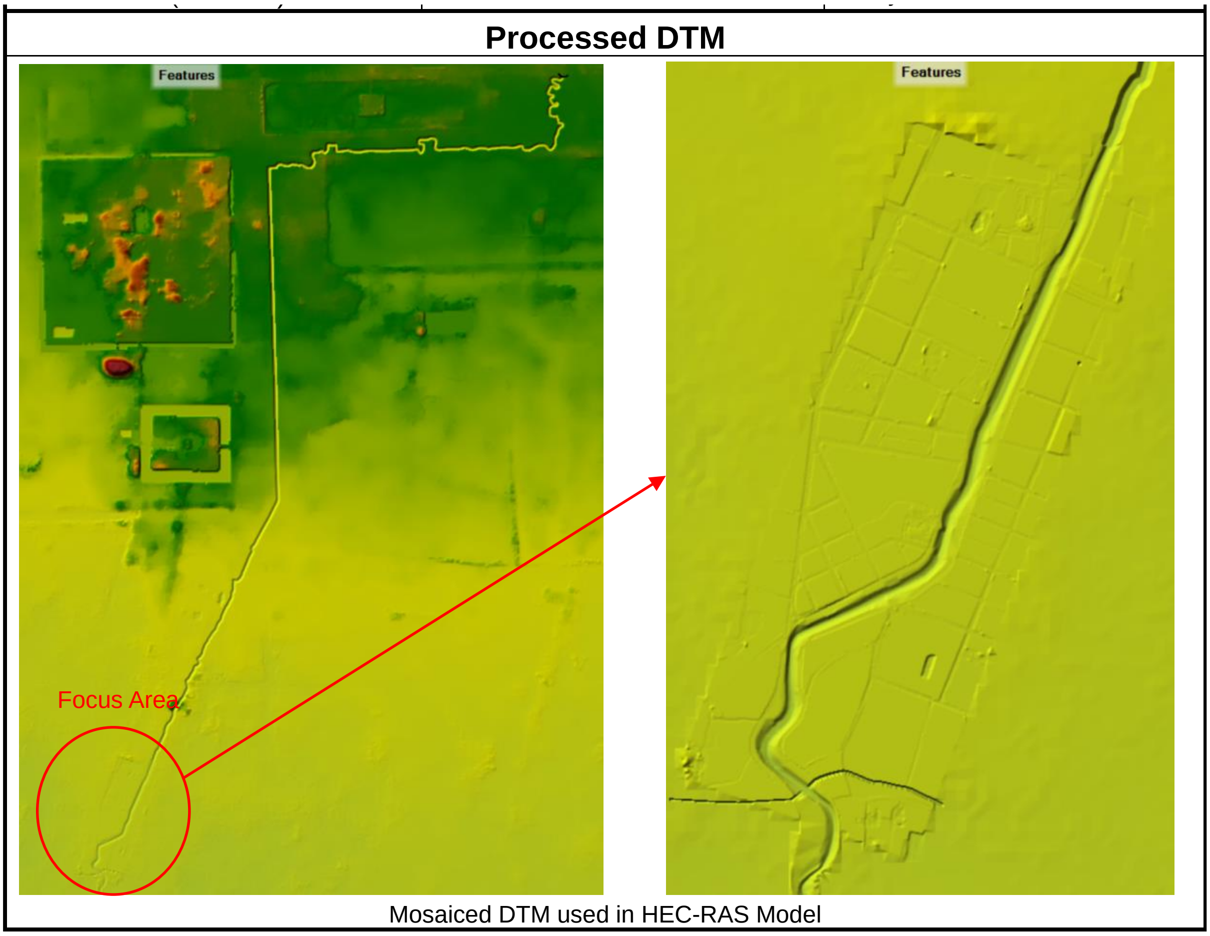


Figure 2-24 The post processing of improvement DTM

2.4.3 Inundation result

Once the river geometric, inflow and floodplain were prepared, result unsteady flow simulation was done chronologically to convey flood routing from the hydrological outfall to the downstream of the study area. GIS aids were required to symbolize the inundation area from the result of RAS-mapper.

It's revealed its accuracy of the surveyed DTM has more relatively high precision compared to the available DTM of FAB which is similar to other sources DTM such a free access of SRTM with lower resolution of 30m.

According to simulation result within the input of extreme event; the river flood is able to reach to the river bank within the return period of 50-year. However, for the return period extreme event of 100-year and 200-year return period; flooding is spilled from the river flow.

The flood extends for 50, 100, and 200 are illustrated in Figure 2-25 to 2-27. It's clearly seen for the study area; the free access of DTM has lower accuracy of elevation with less detailed information of floodplain.

To have more detail and precise of inundation depth for urban development and planning; having citywide of ground topographical data is quite important.

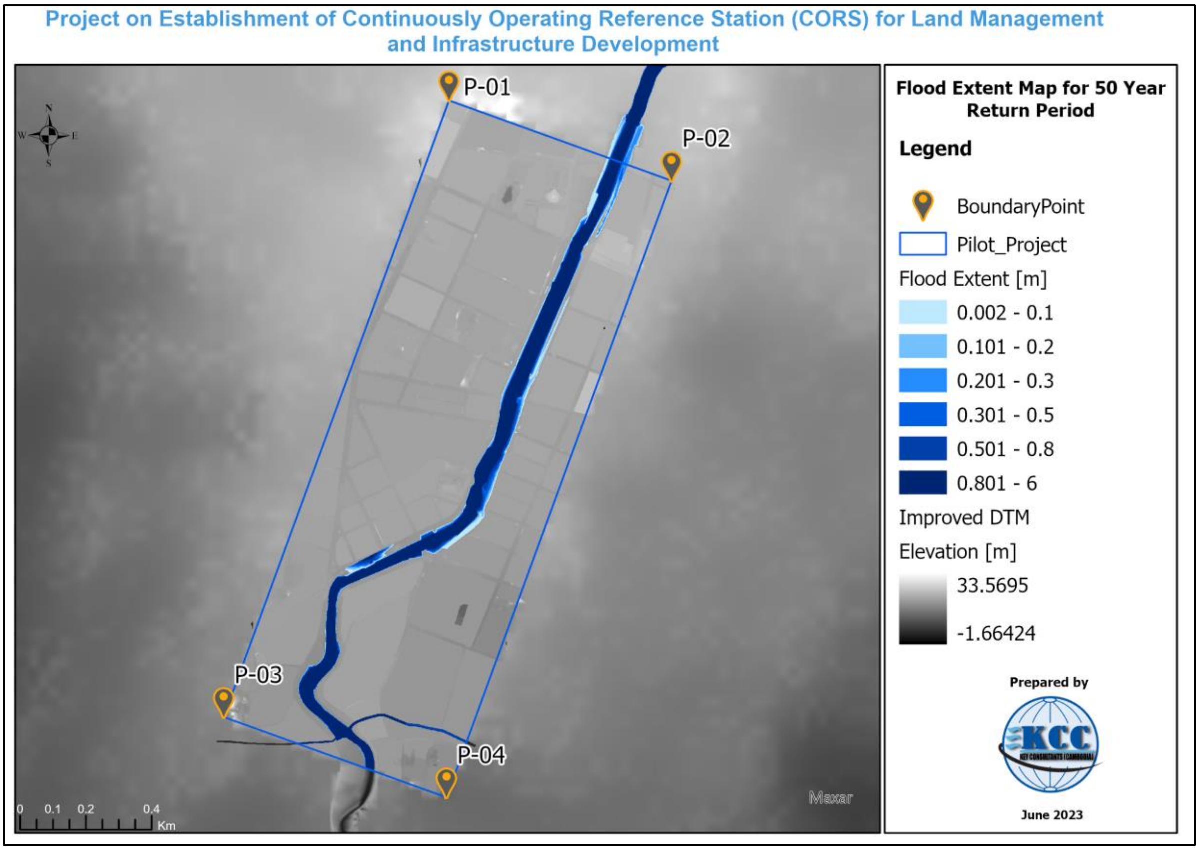


Figure 2-25 Flood extent map for 50-year return period

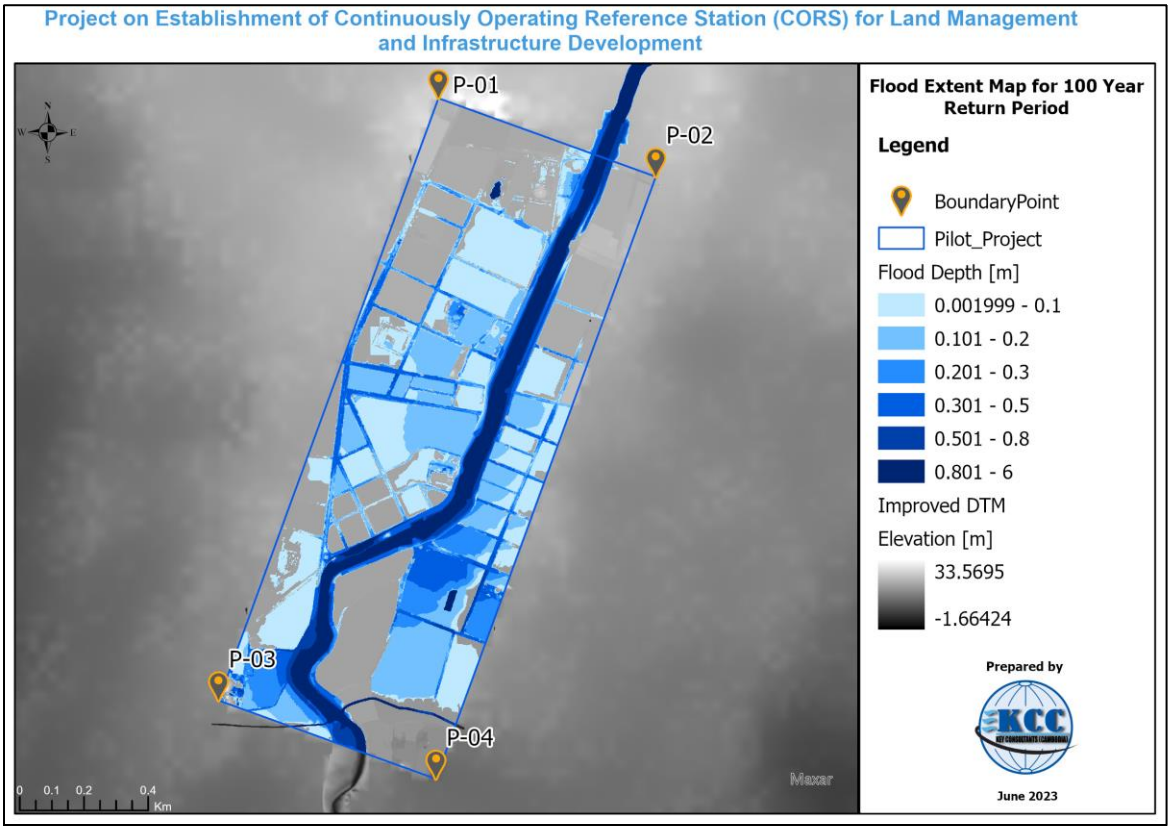


Figure 2-26 Flood extent map for 100-year return period

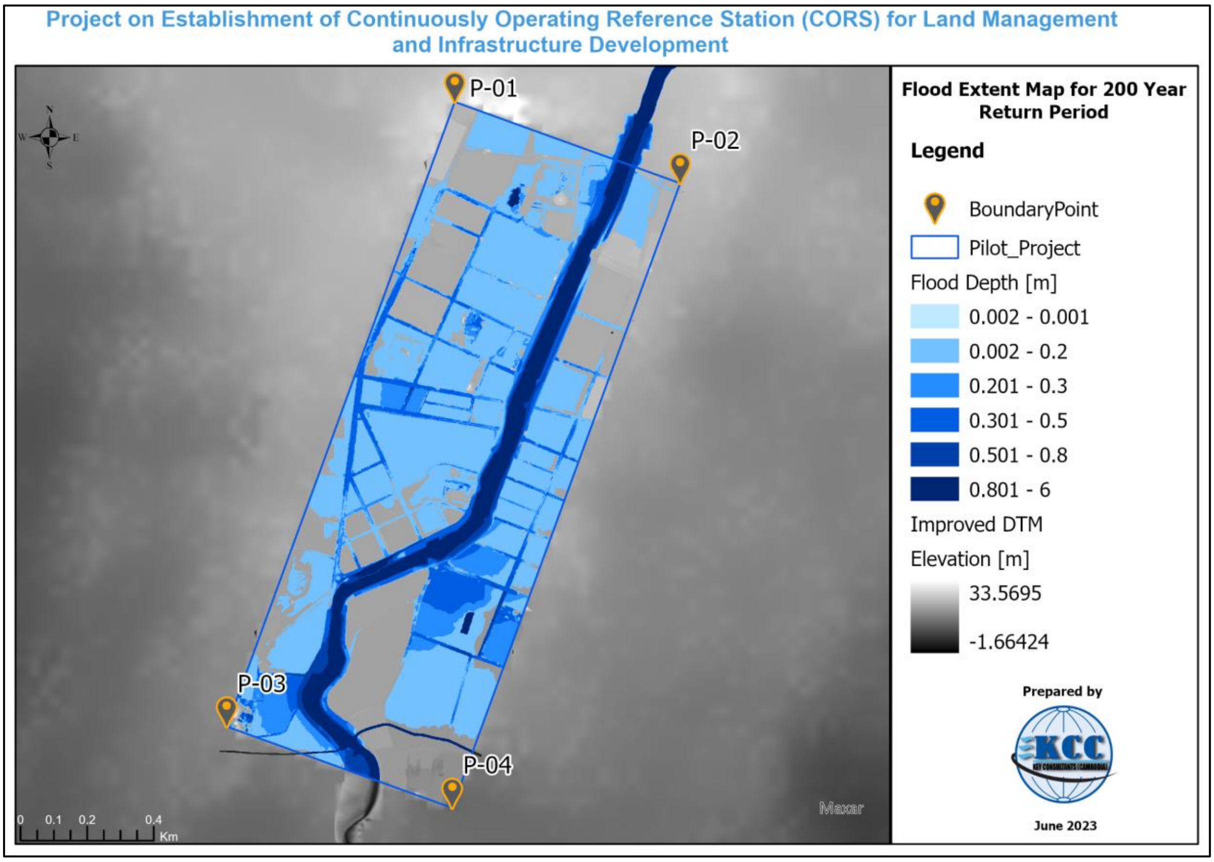


Figure 2-27 Flood extent map for 200-year return period

2.4.4 Conclusion of flood simulation

To get flood result, there are two major steps in which two hydrologic models were used. A primary hydrological model for rainfall and runoff calculation was prepared for setting up the river basin and to generate flow hydrograph within difference magnitudes for the input of the secondary hydrodynamic model.

The major requirement data to be used for hydrological model setup are rainfall, stage water level, landuse or landcover and additional inline structures are also input into the model.

As resulted from the hydrologic model, flow hydrograph is used for hydrodynamic model. The digital elevation model (DEM) is the primary parameter to be used and setup 2D unsteady flow; while land cover is used for roughness surface flow. The reliable result of inundation is depended on the accuracy of available DEM. In the study, the DEM was generated from the KHMER GEONET CORS and combined with the extensive area from free sources DEM are used to prepare flood modeling.

The flood result has shown goodness of the detail inundated information in the study area. For future investment or development, however, the topographical area such production from KHMER GEONET CORS is required to cover the city and it will assist the governor to have proper planning and aware of any exceedance flood.

3 Way forward

3.1 Future outlook of the business using Khmer GEONET

We plan to implement the technologies which we used for the demonstration project in our business in the following way:

- Use Khmer GEONET as the reference station to establish Temporary Bench Mark (TBM). As demonstrate above, Khmer GEONET could provide the result as better as the National BM.
- Around Phnom Penh Area, we may use Khmer GEONET for engineering surveying such as canal alignment setting out, road alignment setting out, or bathymetric survey for some areas of TonleSap river and Mekong River located nearby Phnom Penh City.
- Additionally, we may use Khmer GEONET as our reference station, once the photogrammetry survey is required. For a project in Phnom Penh or nearby Phnom Penh, in Siem Reap town or Stueng Streng town. Khmer GEONET is ideal for our reference station.

In spite of this, Khmer GEONET service coverage remains a major concern as we implement our work. Currently, service is only available within a 20-kilometer radius of Phnom Penh, a 20-kilometer radius of CORS in Siem Reap town, and a 20-kilometer radius of CORS in Steung Streng province. This restriction will be our greatest challenge. We are unable to utilize the service to the extent that we desired. In addition, the signal strength of the internet service is still our concerns when using Khmer GEONET. In Cambodia, the internet connection is only reliable in the major cities and towns; it may not be stable in remote areas or even some areas close to the cities.

3.2 About Khmer GEONET

a. Good points using Khmer GEONET

There are so many good points provided by Khmer GEONET. The 1st was time consumption. As Khmer GEONET just required an internet connection and a username and password to access the CORS, our team was able to get right to work. while implementing through National BM included extra steps including setting up temporary points in the study area, which took more time. Second, Khmer GEONET matched the precision offered by the National BM in terms of accuracy.

b. Issues to be solved

There were no issues encountered during the execution of this project. Within the study area, the signal strength from Khmer GEONET CORS was strong, and the CORS correction was very rapid. Nonetheless, the study location was chosen in the downtown area of Siem Reap, where 4TE signals are extremely stable, so there were no issues with the connection. It is difficult to demonstrate that the service still remains high-quality when users reside in areas with weak Internet connectivity or when they are located some distance from the CORS.

c. Request for improvement

In terms of service extensibility, there are some areas that require development despite its current benefits. The limitation of the service should to be expanded by establishing additional CORS throughout the country, and those CORS should be function as the network CORS that is able to provide a correction via VRS mode (Visual Reference Station). As a result of data sharing between additional base stations, the network is evidently able to provide rovers with even more accurate correction. On the top of that, with network CORS, users could be automatically connected from the closest CORS where they are staying.

Additionally, the users support should be enhanced. Currently, in order to obtain the static log file, users must contact the supporter directly via social media platforms such as Telegram, which can be an inconvenient process. Khmer GEONET should implement a web-based interface that enables users to upload their static log files into the system and receive a comprehensive processing report. This kind of service is provided by AUSOS (Online GPS Processing Service) under the Australian government through Geoscience Australia. Users can submit dual-frequency geodetic-quality GPS RINEX data to the GPS data processing system, and the submission report will be sent back the users. In case, this service could be provided by Khmer GONET. We strongly believe that the GNSS's users will change their mind instead of using conventional method to this service in the future.

In addition, final correction geoid model should be finalized and put on the service as soon as possible. As this model play important role of providing an accurate orthometric height (MSL) to the rovers and is necessarily required in land surveying work.

4 Conclusion

In the study, we demonstrated that Khmer GEONET CORS is capable of delivering a more accurate surveying and mapping result. With the accuracy ranges between few mm to few centimeters in horizontal as proved above, this outcome is suitable with land surveying work including engineering surveying, cadastral surveying, hydrographic surveying as well. Furthermore, once Khmer GEONET has completed its geoid correction model for Cambodia, which will enhance the accuracy of its elevation in the near future despite the issue with elevation accuracy found in this study. Additionally, the study demonstrates that Khmer GEONET CORS provides superior data correction for all GNSS products. RTK Drone, DJI Matrix 300, CHC-i90 Pro, and Sokkia GRX-3 are prime examples; all the receivers got their positions fixed quickly within seconds from the CORS. Working hours and costs were also discussed. It took two days to obtain topographical survey data from the field using Khmer GEONET CORS, resulting in a decrease in cost, whereas it took four and a half days with National BM, resulting in an increase in cost to conduct the work.

Within an urban development, accessing to ground topography is quite necessary for road, drainage improvement and riverbank protection. The study also revealed the goodness of the production by using ground topography as the result connecting from the Khmer GEONET CORS. As discussion in post processing and result, getting high quality of ground data such Digital Terrain Model, which was required less timing to process. The process will lead the local authority and government who has capabilities of modeling and development design to prepare and plan in timely manner to develop for sustainable of urban infrastructure.

In the near future, it is strongly believed that the trend of using Khmer GEONET will have gradually increased by the time that the service area is widely expanded and its correction geoid model (MSL) is ready to be put on the service.

Project on Establishment of Continuously Operating Reference Stations (CORS) for Land Management and Infrastructure Development

JICA Pilot Project

Demonstration project Implementation Report

June 2024

PHNOM PENH WATER SUPPLY AUTHORITY

(PPWSA)

Table of Contents

1. Overview of the demonstration project

1.1. Name of the demonstration project

EN: Transmission Main DN500mm on National Road 3 (NR3)

Extension project water services

KM: Length of Project 350m (ប្រវែងរបស់គម្រោង ៣៥០.ម) , (Km: 0+000 to 0+350)

1.2. Background and purpose of the demonstration project

Overall Plan View

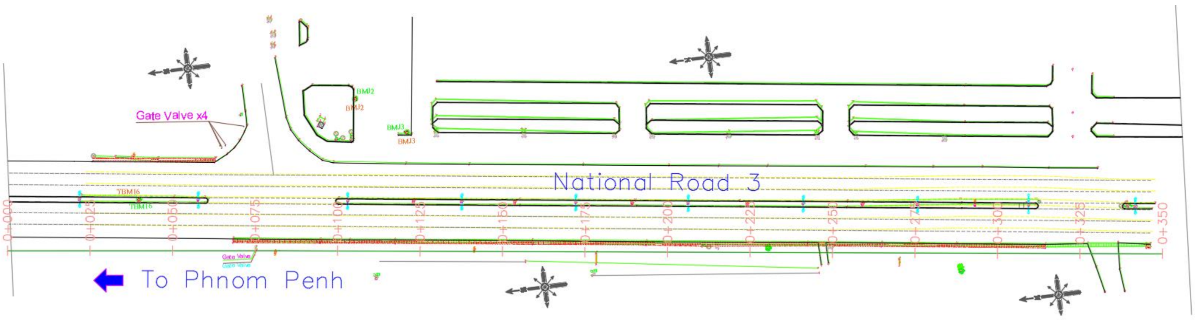


Figure 1-1 Overall Plan View

The General Department of Cadastral and Geography (GDCG), which is part of the Ministry of Land Management, Urban Planning, and Construction, has been offering the Khmer GEONET Continuously Operated Reference Station (CORS) service in Cambodia. For registered GNSS users to achieve a few centimetre-level precisions near the CORS, the appropriate dataset is made available through the internet-connected Khmer GEONET.

With the technical assistance and cooperation of JICA, which began in early 2021, Khmer GEONET presently runs five continuously operating reference stations in Phnom Penh, Kandal, Kampong Speu, Siem Reap, and Stung Streng. As long as the station signals are visible, users can access the service without restriction until June 26, 2024.

This assignment's goal is to demonstrate CORS' functioning, accuracy, and limitations observation to the GNSS rover, as well as the benefits of using Khmer GENONET CORS for mapping, road drainage alignment, subterranean obstacle detection, and drone surveying.

The purpose of the study is to (i) examine the benefits of adopting a CORS-connected system and (ii) compare the coordinate data produced from the National BM zero-order control with the coordinate data obtained from Khmer GEONET CORS PNH-1.

1.3. Brief description of the demonstration project

This project is location on National Road 3 (NR3) Phleung Chheh Roteh Commune Por Sen Chey District Phnom Penh City.

PNH-1 CORE is located in Phnom Penh; was established in front of Ministry of Land Management, Urban Planning and Construction and selected to use for the study and evaluate its functionality.

A web-based service called Khmer GEONET offers its users a variety of advantages in the fields of mapping, engineering surveying, and land surveying. For engineering surveying jobs like site laying out, setting out road and canal boundaries, surveying topographical maps, etc., the system may provide users with centimetre-level accuracy. Additionally, the system decreases the requirement for GNSS receivers, which is normally at least two GNSS receivers for user measurement. Users of Khmer GEONET can save thousands of dollars on their initial investment budget by signing up with Khmer GEONET and buying a GNSS receiver. They can then use the surveyor to take measurements. Additionally, Khmer GEONET can speed up the laborious process of data collection.

The conclusion of measurements taken at two measurement checkpoints using various reference stations and procedures is that the horizontal and vertical data accuracy varied from millimetres to centimetres. The results show the value and effectiveness of conducting detailed investigations and mapping using Khmer GEONET CORS throughout the target area. The data gathered for Khmer GEONET CORS and National BM zero-order differ slightly from one another.

1.4. Implementation period

We had preparation: April 2023 – June 2023

Work at the site: May 2023 – June 2023

Reporting: Aug 2023 – Sep 2023

Table 1-1 Table of the scheduling

No/Date	Starting Date	Working Date	Remark
Preparation	April 2023	June 2023	
Site actual	May 2023	June 2023	
Reporting	Aug 2023	Sep 2023	

Table 1-2 Plan and actual of the schedule

Work Items/ Year & Month		Progress	2023											
			1	2	3	4	5	6	7	8	9	10	11	12
Sign a contract with Pasco	Plan	100.0%												
	Actual													
Preparation of the pilot project		**100.0%**												
Making a pilot project implementation plan	Plan	100.0%												
	Actual													
Export/import of equipment	Plan	100.0%												
	Actual													
Obtainment of necessary permits	Plan	100.0%												
	Actual													
Performance of the Pilot Project		**80.0%**												
Survey Field	Plan	100.0%												
	Actual													
Drawing	Plan	100.0%												
	Actual													
Resurvey and Spot check	Plan	100.0%												
	Actual													
Report	Plan	20.0%												
	Actual													
JICA seminar, Presentation material, Case study leaflet, Pilot project implementation report														
JICA seminar									(Plan)					
Final deadline of Case study leaflet (promotion material)														
Final deadline of Pilot project implementation report														

1.5. Location of the demonstration project site

The project's location is in Phnom Penh, which is also included within the research's study boundary. The boundary is approximately 350 meters long and covers an area of 3.5 hectares along National Road Number 3. at the intersection of route 136DT and National route Number 03 in Phleung Chheh Roteh Commune, Por Sen Chey District, Phnom Penh City, in front of Borey New World III. Please see Figure 1-1 and the coordination below:

Coordinates:

Start project (E:480271.248,N:1271466.44)

End project (E:480203.622, N:1271229.698)

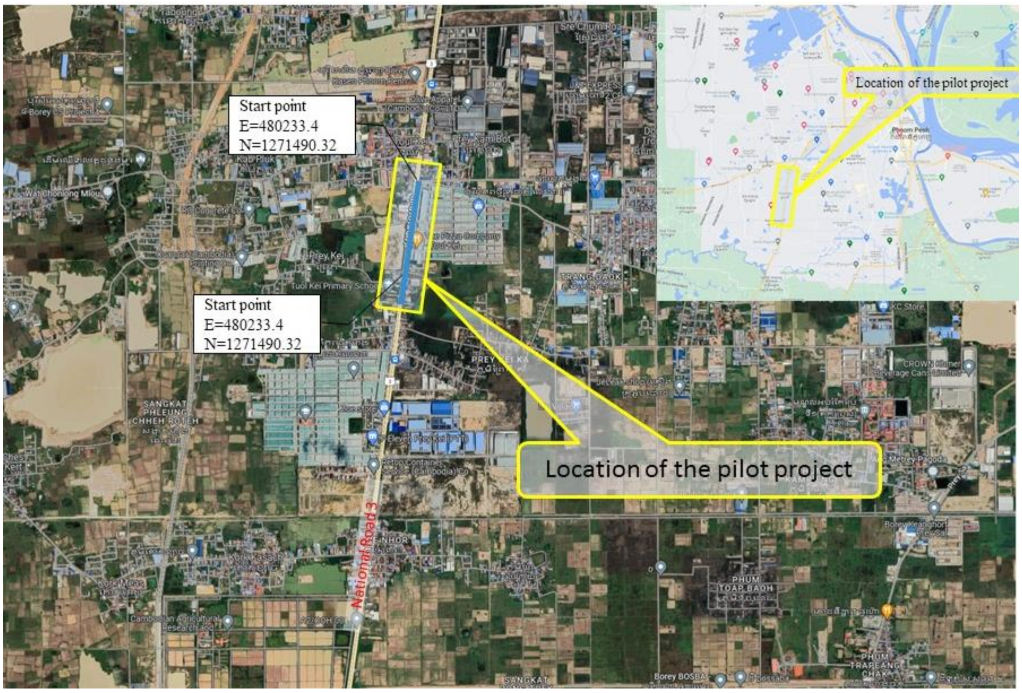


Figure 1-2 Location of the demonstration project site

Khmer GEONET PNH-1 is located approximately of 15.5km from the project site.

1.6. Members

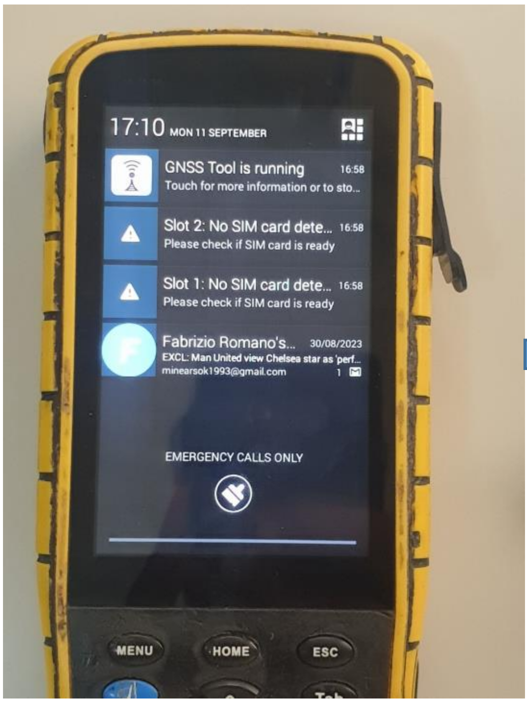
In the study, two teams were dispatched, with Team 01 and Team 02 leading the topographical survey team utilizing two GNSS receivers on opposite sides of the road. Tables 1-3 below include descriptions of the deployment teams.

Table 1-3 List of members

NO.	Name	Company/Organisation	Role
1	Mr.Chhang Kimyi	PPWSA	Project Manager
2	Mr. Sear Reachsey	PPWSA	Engineer Drawing
3	Mr. Sear Pisen	PPWSA	Engineer Drawing
4	Mr Pheng Daro	PPWSA	Engineer Drawing
5	Mr. Phorn Tola	PPWSA	Surveyor
6	Mr. Chhun Karona	PPWSA	Surveyor
7	Mr. Im Sokly	PPWSA	Surveyor
8	Mr. Chan Cheanrothana	PPWSA	Safety Quard
9	Mr. Sok Chanly	PPWSA	Safety Quard
10	Mr. Phor Lyvichearavuth	PPWSA	Safety Quard

1.7. Equipment used for the demonstration project

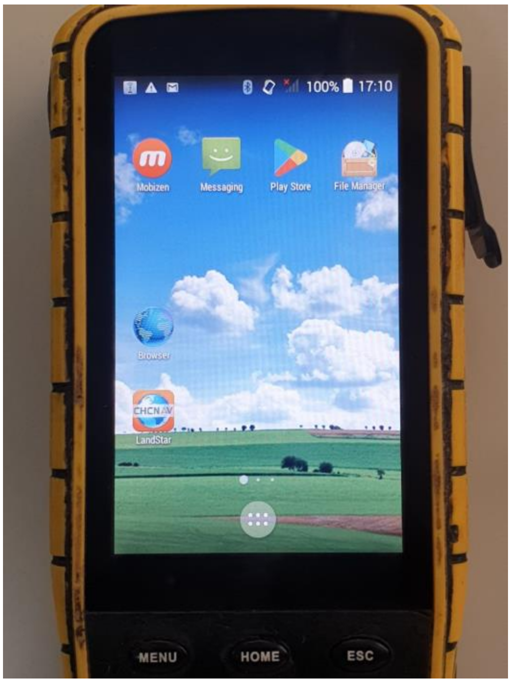
The attach photos step by step within the detail below

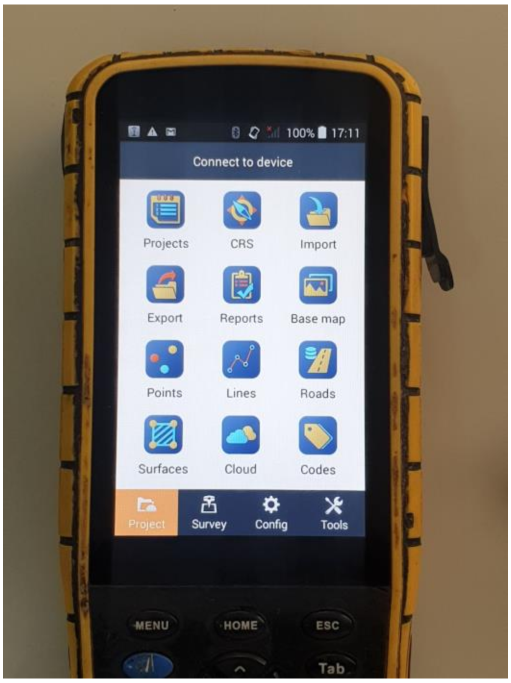


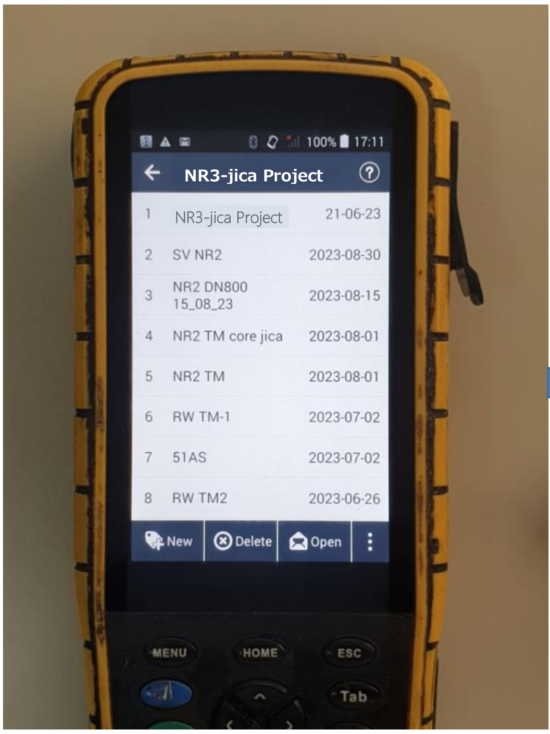
Connect Wi-Fi on Device

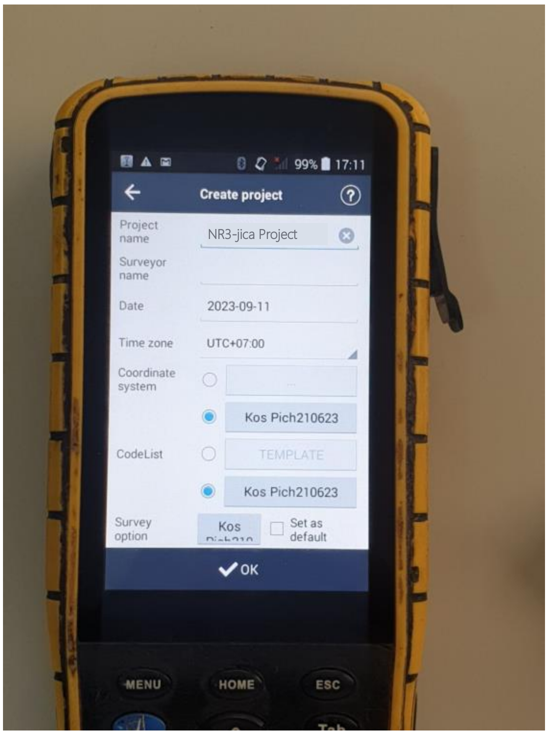
Open LandStart7

Select Project



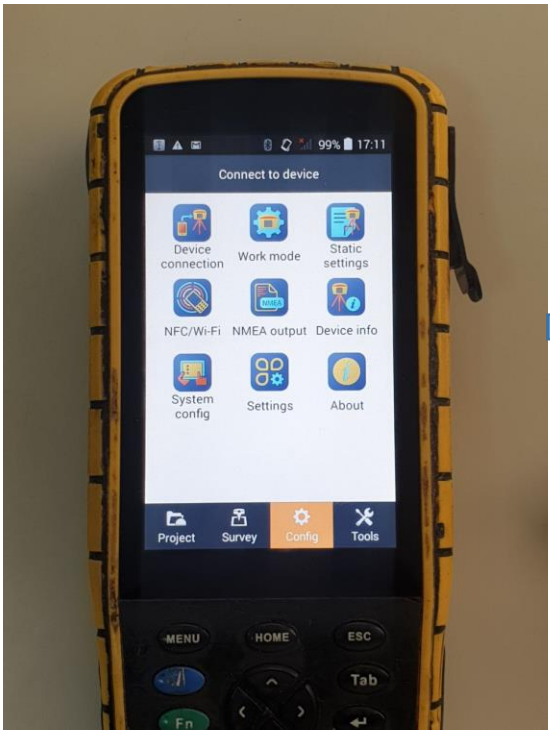


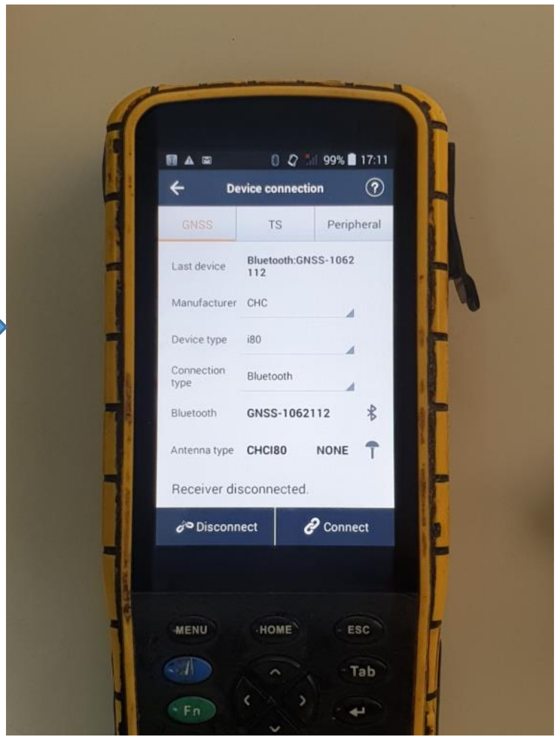




Create Project

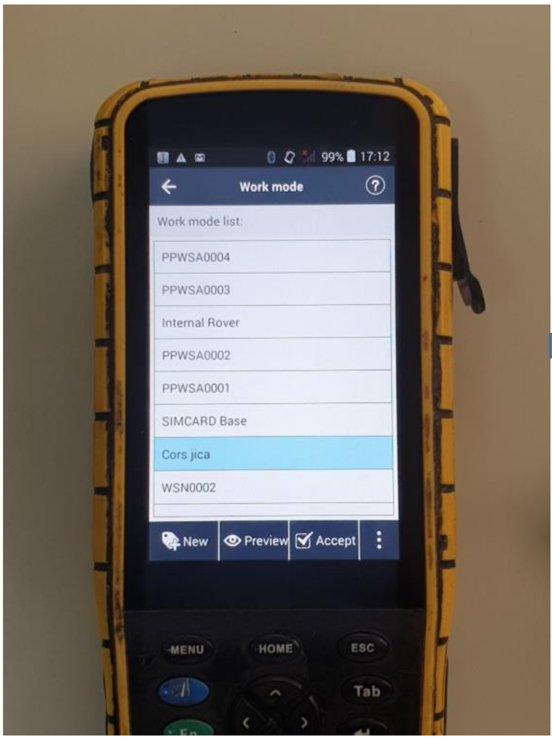
Select Zone

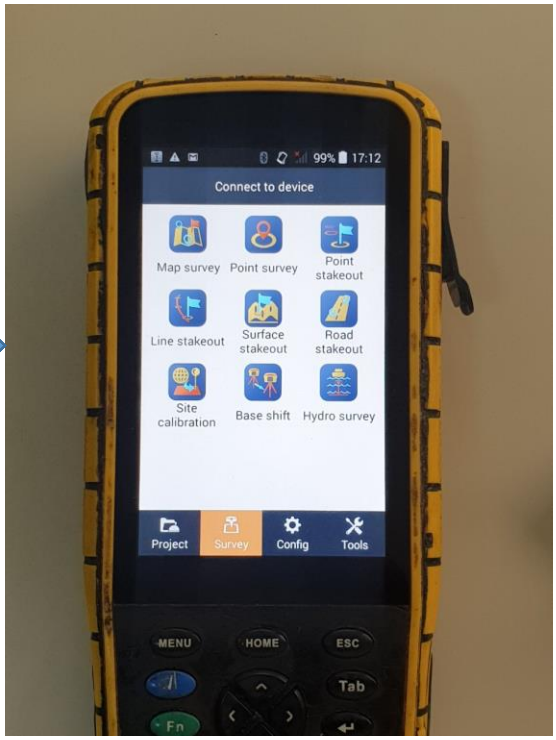




Select Config

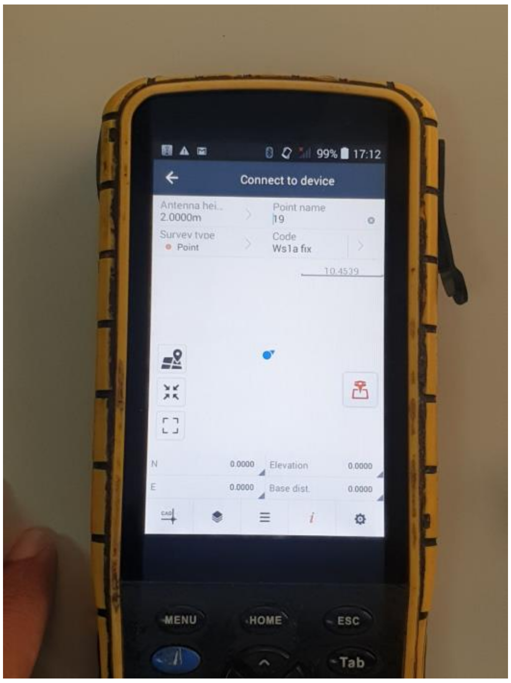
Find and Select code Receiver





Select Cors Jica (PNH-1)

Select Survey and Map survey



Waiting Device to Fix and Get Points

The Each equipment is listed in Table 1-4 below with its functionality and specification.

Table 1-4 List of equipment used

NO.	Name	Q'ty	Remarks (specifications, usage, etc.)
01	GNSS receiver models CHC i80 "DGPS (Brand CHC)"	2sets	• 220 channels with simultaneously tracked satellite signals GPS: L1C/A, L1C, L2C, L2E, L5 GLONASS: L1C/A,L1P, L2C/A, L2P, L3 SBAS: WAAS, EGNOS, MSAS Galileo: E1, E5A, E5B (test) BeiDou: B1, B2 (optional) Performance specifications(1) • Real Time Kinematics (RTK) Horizontal: 8 mm + 1 ppm RMS Vertical: 15 mm + 1 ppm RMS Initialization time: typically < 5 s Initialization reliability: typically > 99.9% • Rapid Static Horizontal: 5 mm + 1 ppm RMS Vertical: 10 mm + 1 ppm RMS • Post Processing Static Horizontal: 2.5 mm + 0.5 ppm RMS Vertical: 3.5 mm + 0.5 ppm RMS Baseline Length: ≤ 300 km Electrical • Power consumption: 3.2 W • Li-ion battery capacity: 6600 mAh / 7.4 V • Battery life: typical 12 hours in RTK mode • External power: 12 ~ 36 VDC • Auto switch between battery and external power Communications • 1x UHF antenna port • 1x 7-pin LEMO port, for power supply, data download, and USB update • 1X 7-pin serial port, for power supply and correction output • Integrated GSM/GPRS modem, supporting HSPA/HSPA+ and 4G (optional) network WCDMA 850/900/1700/1900/2100 EDGE/GPRS/GSM 850/900/1800/1900 • Multimode Bluetooth® completely compatible with Android, Windows Mobile, IOS and Win7/Win8 OS • Wi-Fi, 802.11 B/G/N, supporting AP, 150 m(2) distance, 108 Mbps • Interface: 1x power button, 1x FN button, 1x LCD display • CHC radio modem internal Rx: 430-450/450-470 MHz • Optional radio modem (3) : Internal Rx/Tx: 403-473 MHz External Tx DL5: 1W - 20W adjustable • Protocols: RTCM2.1, RTCM2.3, RTCM3.0, RTCM3.1, CMR, CMR+ input and output

NO.	Name	Q'ty	Remarks (specifications, usage, etc.)
			NMEA0183 output RINEX and HCN outputs for GNSS raw data NTRIP • Data Storage: 16/32 G, extended up to 64G HCN, RINEX GPS device mounts as a USB external hard drive Physical • Size (HxD): 140 x 124 mm (5.5 x 4.9 in) • Weight: 1.5 kg with battery (53 oz) • Operating temperature: -45 °C to +75 °C (-49°F to 167°F) • Storage temperature: -50 °C to +85°C (-58°F to 185°F) • Humidity: 100% condensation • Waterproof and dust proof: IP67 - protected from temporary immersion to depth of 1 meter, floats • Shock: survives a 3-meter drop on to concrete (1) Accuracy and reliability specifications may be affected by multipath, satellite geometry and atmospheric conditions. Performances assume minimum of 5 satellites, follow up of recommended general GPS practices. (2) Wi-Fi working distance would be affected by obstacles, magnetic field or electric field. (3) UHF type approvals are country specific.

2. Details of the work

2.1. Work performed

2.1.1. Preparation

Some relevant activities had been initially planned in the following steps before the job was implemented:

- The firmware of the GNSS receiver and its control device were confirmed to be up-to-date, and the GNSS receiver was already linked to Khmer GEONET using the given username and password.

- Gets point on site have 2 teams, on either side of the road (The time is connected Device ready). We are gotten point on manhole box optic cable box, line road (concrete or asphalt, sidewalk Karola) curb Electric Light pano sign tree home BM EDC and Gate Valve⋯⋯.

- Export point project gate on site than we did draft point line on the computer work on official.

The equipment needs for the implement project:

Table 2-1 The equipment needs

Nº	Descriptions	Quantities	Remarks
01	Car	1 car	Include with Diesel
02	DGPS CHC i80	2 sets	
03	Hummer	2 pcs	
04	Nail of BM	10 pcs	
05	Fibber Measuring Tape 100m	1 pc	
06	Measure Hand 10m	2 pcs	
07	Sika Anchor Fix	1 set	Made BM references
08	Red Spray	2 cans	
09	White Safety Helmet	6 pcs	
10	White Safety Glove	6 sets	
11	Safety Clothing	6 pcs	
12	Safety Eyewear	6 pcs	
13	Mass Protection	6 pcs	
14	Safety Shoes	6 sets	
15	Drilling Machine 18V Bosch	1 set	

16	Traffic Cone	2 pcs	
17	Other		

2.1.2. Implementation

We had been starting for site surveying and inspection since May 2023 till June 2023 for our work.

- We start get the point for complete data on site in the project, next time they are export data report CSV file to PC after this check report error and verify. For design plan view at office. And after determining if there is a lack of data, we will research and collect additional data as needed on site again.

- The Fist measurement was completed using Real Time Kinematic Survey (RTK), which involved connecting a GNSS receiver over a roughly 15.5-kilometer distance to the Khmer GEONET CORS PNH-1.

As noted in the section above, the survey was carried out using an RTK survey and connected to Khmer GEONET CORS PNH-1 in the manner described below:

- Protocol: NRTIP
- Data link: PDA network or Internet-Connected Device
- Domain/IP: cgd09.khmerGEONET.xyz
- Port:2101
- Mount point: RRS_RTCM32

Figure 2-1 Report of site Survey on NR3

The following activities shown in Table 2-1 are the activities in setting up the RTK survey at each checked point by using GNSS receiver preparation connecting to CORS PNH-1 and checked BMj-1.

Table 2-2 Activity performed in setting up

Detailed of activities performed	
Khmer GEONET CORS PNH-1 located in front of Ministry of Land Management, Urban Planning and Construction. CORS Phnom Penh **PNH100KHM** **CGD09/ITRF2005 (Epoch 2009.56)** X: -1603672.132 m Y: 6038739.374 m Z: 1277314.715 m **Lat/Long** 11 37 47.14065 N 104 52 20.71325 E **Height (m):** Geoid (EGM 2008): -13.036 Ellipsoid Height: 2.707 Orthometric Height: 15.743 **WGS 84/UTM Zone 48** **Coordinates:** 1285617.021 N 486093.120 E	
Base receiver CHC-i80. The connection parameter: NRTIP host: 192.168.1.1 Port: 9901 Mountpoint: RTCM3.2 Satellite used: GPS 8, Beidou 9, Glonass 5, Galileo 7 Note: The GNSS receiver was installed on BM-j3, and its coordinate received from survey with BM as the reference station.	

2.1.3. Result

After implementing this project, we obtained the results of the Khmer GEONET ratio and the National Geodetic Control Points for X and Y were not significantly different, we were able to accept that. Khmer GEONET and National Geodetic Control Points There are differences for Z, but we think this is due to differences in height reference systems

Surveying projects the result of verification of accuracy degradation:

Table 2-3 X-Values (BM, Manhole PPWSA, EDC Pole for 50Ps) of National Geodetic Control Points (NGCT)Vs Khmer Geonet CORS

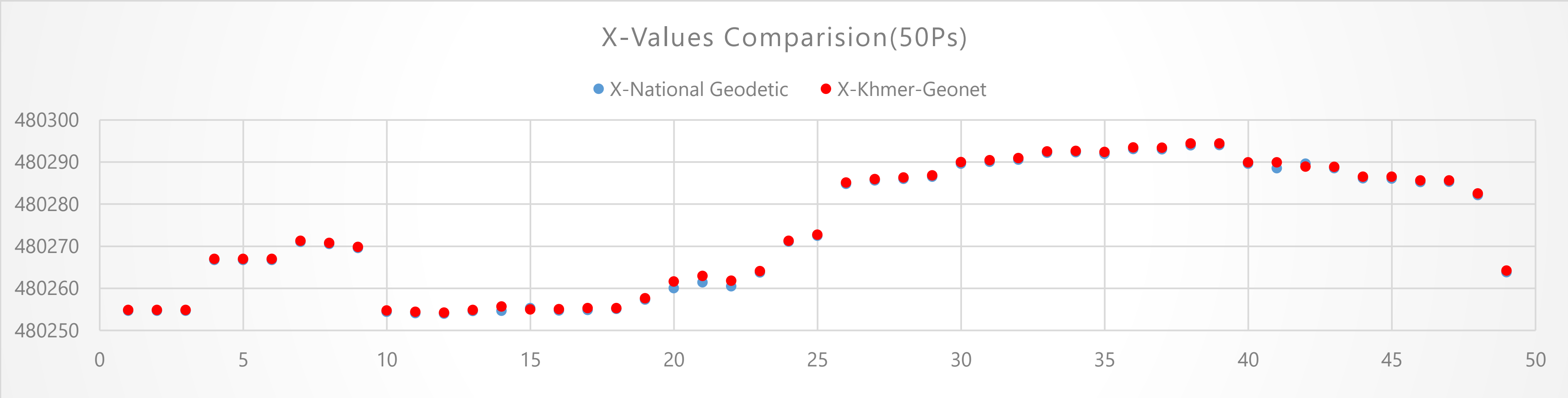


Table 2-4 Y-Values (BM. Manhole PPWSA, EDC Pole for 50Ps) of National Geodetic Control Points (NGCT)Vs Khmer Geonet CORS

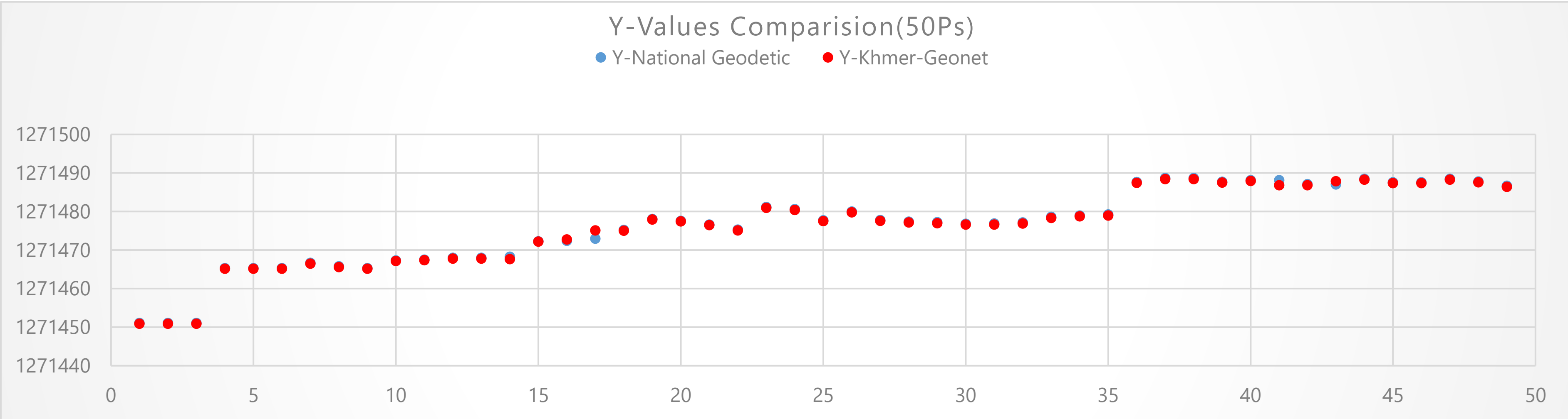


Table 2-5 Z-Values (BM. Manhole PPWSA, EDC Pole for 50Ps) of National Geodetic Control Points (NGCT)Vs Khmer Geonet CORS

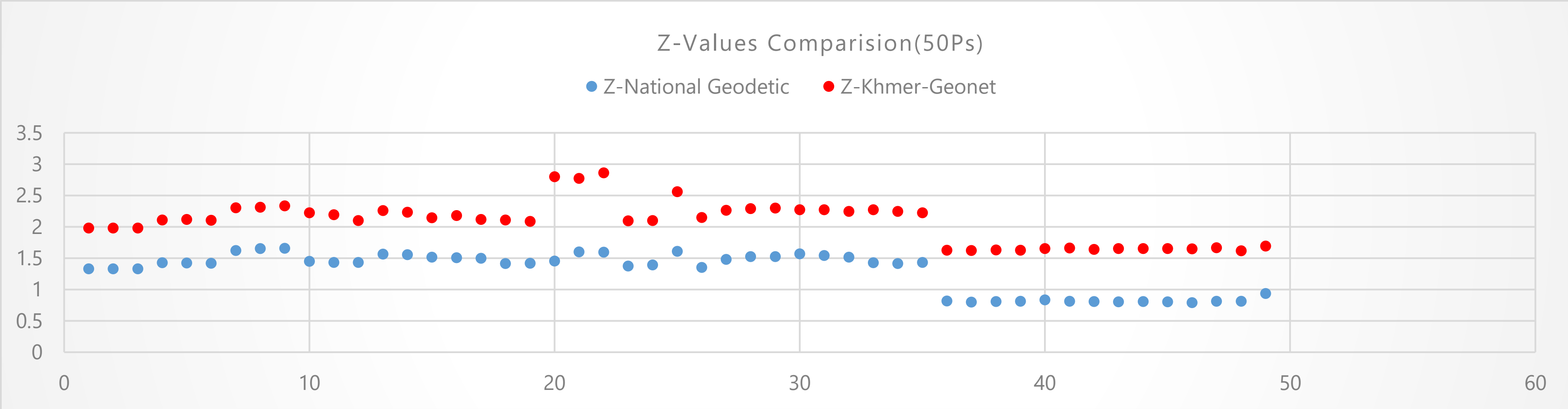
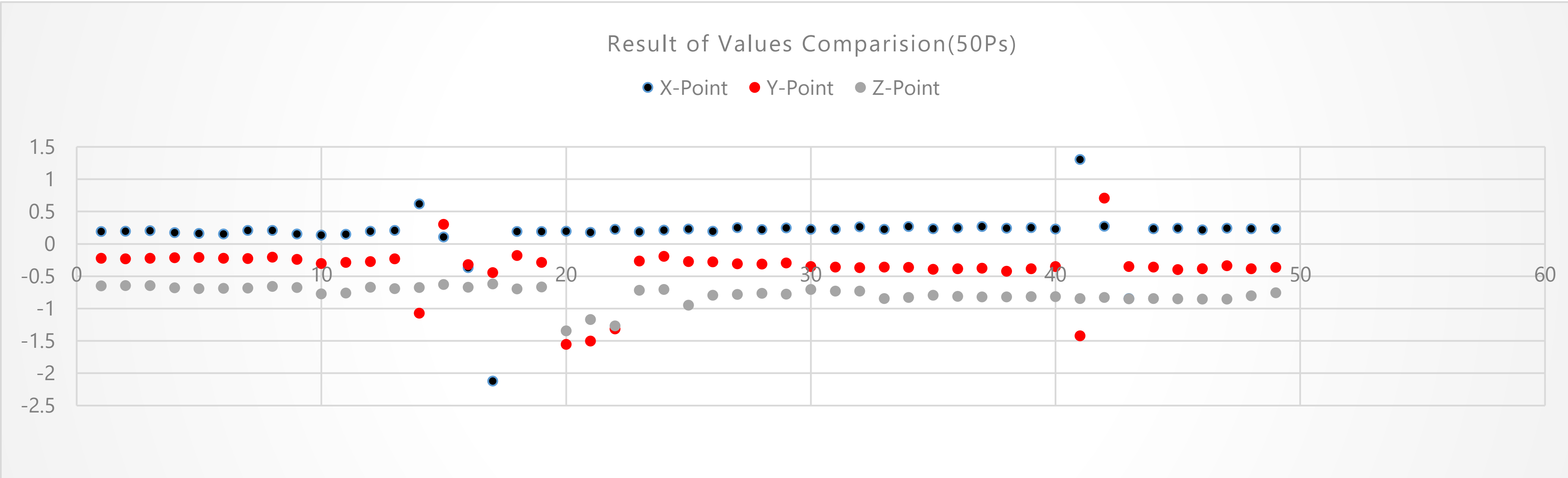


Table 2-6 Comparison of Point between National Geodetic Control Points(NGCP) and Khmer-Geonet CORS



2.2. Use of Khmer GEONET

2.2.1. Details of the KhmerGEONET data used

This is the key points of **Khmer GEONET** was used as follows.

Table 2-7 Khmer GEONET data used

IP address	cgd09.khmergeonet.xyz
Port	2101
Mount point	RTCM3.2
User name	
Period of use	21 April 2023 – 22 April 2023 16 May 2023 – 19 May 2023 06 June 2023 – 06 June 2023
RTK/ Post processing	Real Time Kinematic, Static Survey
Satellite systems used	GPS, Glonass, Beidou, Galileo,

2.2.2. Problems occured and solutions

In the field, we were required to select the correct mount point and remain within its service area; otherwise, the **CORS** correction would not be accurate. Currently, there are five **Khmer GEONET,** three of which are network **CORS** and two of which are single **CORS** functions.

Occurred:

- Situation: The weather is hot on field approximates times (11:00am to 03:00pm) Temperature 30C° to 35C°. Sometime the weather has a lot of cloudy gloomy sky.
- Location: Private or Line Optic Cable has a lot of high building and under high tree.
- Time: Encountered any problems when using **Khmer GEONET** connecting device a satellite is low show not fix (single, float). Good satellite (15/35).
- Solved: Shutdown, restart rover and reconnect.
- The position of the rovers got fixed quickly without any delay, however; problem encounter was found when the rover was placed under the tree branches or near the building wall. To take over this problem, the operator should wait at least 5 minutes to get fully connecting to the **CORS** and fixed position.

3. Way forward

3.1. Future outlook of the business using Khmer GEONET

For this implement project we had found the **Khmer GEONET** reference network has several advantages over traditional **CORS** systems. One of the most importance is its high level of accuracy. **Khmer GEONET** reference network uses high-precision **CORS** receivers and antennas, which are able to provide accurate positioning information to within a few centimeters. This level of accuracy is essential for many applications, such as surveying and mapping, construction, and transportation.

Khmer GEONET reference network also provides a wide coverage area. The network of reference stations is strategically placed throughout a specific area, which allows users to access accurate positioning information from almost anywhere within that area. This is particularly useful for industries such as construction, where accurate positioning information is needed for large projects that cover a wide area.

Finally, **Khmer GEONET** reference network is relatively cost-effective. The system is operated by government agencies and private companies, which means that users do not have to invest in expensive equipment or pay for costly data subscriptions. This makes **CORS** reference network an affordable option for many industries.

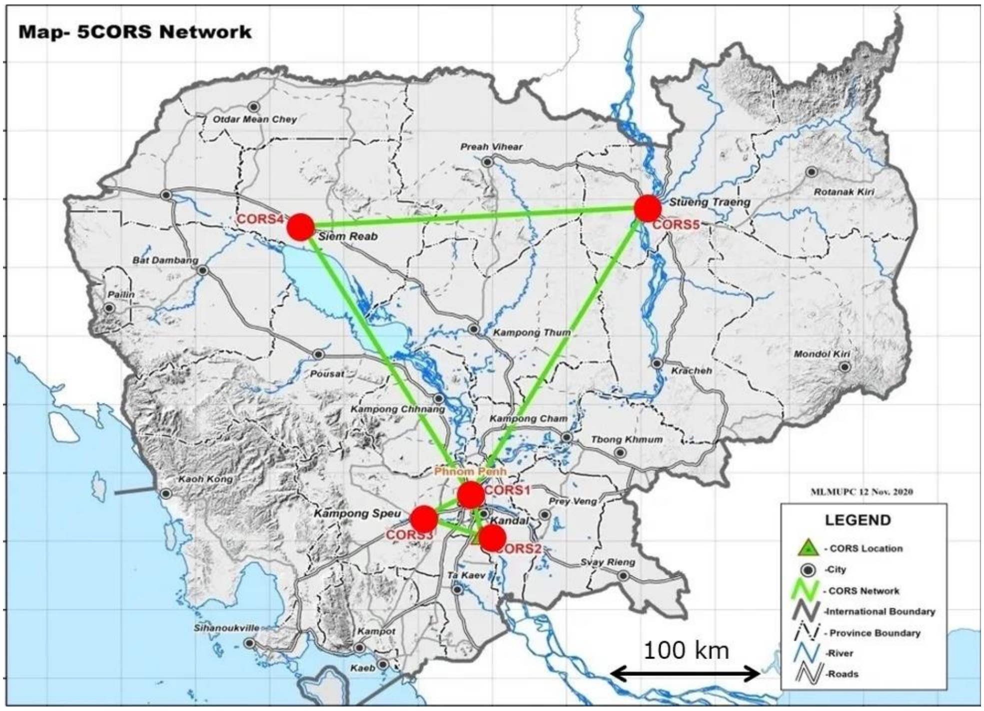


Figure 3-1 Map of 5CORS Network

3.2. About Khmer GEONET

1) Good points using Khmer GEONET

For easy connection to a device, satellite 8/32 get points are available. There are so many good points provided by **Khmer GEONET**. The first was time consumption. Our team was able to get started immediately away since **Khmer GEONET** only needed an internet connection and a login and password to access the CORS, but installing through National BM required additional processes, including establishing up temporary points in the research region, which took more time. Second, **Khmer GEONET's** accuracy matched that of the National BM's precision.

2) Issues to be solved

In the implementation of our project, there are also some issues caused by the internet that occurred during the implementation. This uncertainty has led us to spend more time on implementation and verification. There are two issues. First, it could be caused by internet used with CORE factors, secondly when users practiced in areas with weak Internet, but for the user's practicing we already deal with that. The most important thing is we would like to expand the scope internet of **CORS** to refine all available data accurately and precisely as more as possible.

However, Cambodia is developing in almost all areas, such as infrastructure, irrigation systems, water supply, and location applications that require further capacity building in addition to progress in this area.

3) Request for improvement

In our opinion, the improvement of **Khmer GEONET** should be installed in the **CORS** substitution network soon at another province project. It greatly improves the frequency and number of satellites on the field. We have needed more users for operations and support work.

Based on of implementation project that we done on National Road 3 above, it shows us that the implementation process is highly efficient, data retrieval is clear and fast. At the same time of getting new results, we also have the challenges mentioned above. So, what we insist on and what we should address is the issue of expanding the scope of access to data in Widespread use. The most improvement of **Khmer GEONET** should be installed in the core substitution network soon at another province project. It greatly improves the frequency and number of satellites on the field. We have needed more users for operations and support work.

4. Conclution

In short of the project **Khmer GEONET** is considered one of the most accurate ways. The range of operation of every particular system in case of best performance given by **Khmer GEONET.** The most importance of **Khmer GEONET** over to the advantages of user, helps our team to survey more area and more precisely with the greater accuracy. With these added advantages and features, the gathered data helps the team to prepare Detailed Project Report better and more accurate than before.

We also hope that in the near future, all the developments of **Khmer GEONET** will have a wider scope, whether in the city or in the provinces and can facilitate the development of key areas where demand is weak.

5. Reference Data

Table 5-1 Table of site implementation 300Ps

No	National Geodetic Control Point				Khmer Geonet				Error			Dec
	North	East	Ele	Solution	North	East	Ele	Solution	North	East	Ele	
1	1271451.035	480254.611	1.3258	Fix	1271450.847	480254.836	1.97804	Fix	0.188	-0.225	-0.65224	BM.J3
2	1271451.039	480254.605	1.3288	Fix	1271450.845	480254.836	1.97709	Fix	0.194	-0.231	-0.64829	BM.J3
3	1271451.049	480254.612	1.3293	Fix	1271450.846	480254.834	1.9767	Fix	0.203	-0.222	-0.6474	BM.J3
4	1271465.271	480266.701	1.4264	Fix	1271465.099	480266.918	2.10467	Fix	0.172	-0.217	-0.67827	BM.J2
5	1271465.255	480266.708	1.421	Fix	1271465.097	480266.918	2.1141	Fix	0.158	-0.21	-0.6931	BM.J2
6	1271465.253	480266.696	1.4159	Fix	1271465.1	480266.918	2.10284	Fix	0.153	-0.222	-0.68694	BM.J2
7	1271466.648	480271.019	1.617	Fix	1271466.44	480271.248	2.30033	Fix	0.208	-0.229	-0.68333	Curb
8	1271465.759	480270.514	1.6495	Fix	1271465.551	480270.719	2.30891	Fix	0.208	-0.205	-0.65941	Curb
9	1271465.256	480269.565	1.6529	Fix	1271465.103	480269.805	2.33009	Fix	0.153	-0.24	-0.67719	Curb
10	1271467.223	480254.396	1.4464	Fix	1271467.09	480254.702	2.22166	Fix	0.133	-0.306	-0.77526	Curb
11	1271467.453	480254.053	1.4296	Fix	1271467.307	480254.342	2.1893	Fix	0.146	-0.289	-0.7597	Curb
12	1271467.945	480253.904	1.4279	Fix	1271467.751	480254.178	2.09924	Fix	0.194	-0.274	-0.67134	Curb
13	1271467.917	480254.558	1.5618	Fix	1271467.708	480254.789	2.25561	Fix	0.209	-0.231	-0.69381	Sign
14	1271468.184	480254.593	1.5539	Fix	1271467.567	480255.664	2.22797	Fix	0.617	-1.071	-0.67407	Sign
16	1271472.24	480255.227	1.5121	Fix	1271472.135	480254.926	2.14245	Fix	0.105	0.301	-0.63035	Sign
17	1271472.33	480254.691	1.5045	Fix	1271472.699	480255.013	2.17556	Fix	-0.369	-0.322	-0.67106	Sign
18	1271472.896	480254.793	1.4955	Fix	1271475.017	480255.239	2.11558	Fix	-2.121	-0.446	-0.62008	Curb
19	1271475.203	480255.042	1.4094	Fix	1271475.011	480255.225	2.10584	Fix	0.192	-0.183	-0.69644	Curb
20	1271478.031	480257.302	1.4153	Fix	1271477.842	480257.588	2.08306	Fix	0.189	-0.286	-0.66776	Curb
21	1271477.558	480260.007	1.452	Fix	1271477.363	480261.562	2.79647	Fix	0.195	-1.555	-1.34447	Ft-EDC
22	1271476.574	480261.385	1.5986	Fix	1271476.398	480262.888	2.769	Fix	0.176	-1.503	-1.1704	Ft- EDC
23	1271475.244	480260.451	1.5921	Fix	1271475.02	480261.766	2.86018	Fix	0.224	-1.315	-1.26808	Ft- EDC

24	1271481.088	480263.748	1.3706	Fix	1271480.902	480264.015	2.09135	Fix	0.186	-0.267	-0.72075	Curb
25	1271480.579	480271.061	1.3902	Fix	1271480.368	480271.257	2.09603	Fix	0.211	-0.196	-0.70583	Curb
26	1271477.684	480272.439	1.6077	Fix	1271477.456	480272.713	2.5563	Fix	0.228	-0.274	-0.9486	Curb
27	1271479.959	480284.787	1.3509	Fix	1271479.765	480285.068	2.14594	Fix	0.194	-0.281	-0.79504	Curb
28	1271477.762	480285.609	1.4795	Fix	1271477.514	480285.92	2.26242	Fix	0.248	-0.311	-0.78292	Curb
29	1271477.355	480285.985	1.5208	Fix	1271477.136	480286.299	2.28832	Fix	0.219	-0.314	-0.76752	Curb
30	1271477.187	480286.485	1.5199	Fix	1271476.941	480286.783	2.29685	Fix	0.246	-0.298	-0.77695	Curb
31	1271476.783	480289.575	1.5651	Fix	1271476.558	480289.925	2.27029	Fix	0.225	-0.35	-0.70519	Curb
32	1271476.818	480290.006	1.5398	Fix	1271476.595	480290.368	2.27165	Fix	0.223	-0.362	-0.73185	Curb
33	1271477.11	480290.506	1.5116	Fix	1271476.847	480290.875	2.2442	Fix	0.263	-0.369	-0.7326	Curb
34	1271478.541	480292.143	1.4237	Fix	1271478.315	480292.503	2.27026	Fix	0.226	-0.36	-0.84656	Curb
35	1271478.941	480292.259	1.4134	Fix	1271478.675	480292.623	2.24116	Fix	0.266	-0.364	-0.82776	Curb
36	1271479.169	480291.935	1.4293	Fix	1271478.937	480292.328	2.22319	Fix	0.232	-0.393	-0.79389	Curb
37	1271487.626	480293.017	0.8137	Fix	1271487.381	480293.401	1.62512	Fix	0.245	-0.384	-0.81142	MH-PPWSA
38	1271488.628	480292.997	0.797	Fix	1271488.363	480293.374	1.62007	Fix	0.265	-0.377	-0.82307	MH-PPWSA
39	1271488.63	480293.932	0.8045	Fix	1271488.391	480294.358	1.62717	Fix	0.239	-0.426	-0.82267	MH-PPWSA
40	1271487.679	480294.015	0.8086	Fix	1271487.428	480294.4	1.62412	Fix	0.251	-0.385	-0.81552	MH-PPWSA
41	1271488.082	480289.558	0.8329	Fix	1271487.852	480289.912	1.64881	Fix	0.23	-0.354	-0.81591	MH-PPWSA
42	1271488.093	480288.491	0.8108	Fix	1271486.79	480289.913	1.6585	Fix	1.303	-1.422	-0.8477	MH-PPWSA
43	1271487.024	480289.553	0.805	Fix	1271486.754	480288.845	1.63526	Fix	0.27	0.708	-0.83026	MH-PPWSA
44	1271486.973	480288.478	0.7986	Fix	1271487.819	480288.83	1.64941	Fix	-0.846	-0.352	-0.85081	MH-PPWSA
45	1271488.445	480286.121	0.8036	Fix	1271488.214	480286.482	1.6508	Fix	0.231	-0.361	-0.8472	MH-PPWSA
46	1271487.561	480286.054	0.7992	Fix	1271487.322	480286.453	1.64936	Fix	0.239	-0.399	-0.85016	MH-PPWSA
47	1271487.541	480285.2	0.7891	Fix	1271487.327	480285.584	1.64528	Fix	0.214	-0.384	-0.85618	MH-PPWSA
48	1271488.443	480285.252	0.8079	Fix	1271488.201	480285.591	1.66327	Fix	0.242	-0.339	-0.85537	MH-PPWSA
49	1271487.745	480282.108	0.8111	Fix	1271487.513	480282.493	1.61363	Fix	0.232	-0.385	-0.80253	RC
50	1271486.615	480263.796	0.9347	Fix	1271486.383	480264.161	1.69161	Fix	0.232	-0.365	-0.75691	AR
51	1271485.728	480259.941	0.9753	Fix	1271485.481	480260.294	1.72041	Fix	0.247	-0.353	-0.74511	AR
52	1271483.753	480256.391	1.0289	Fix	1271483.479	480256.76	1.75423	Fix	0.274	-0.369	-0.72533	AR

53	1271480.865	480252.864	1.0979	Fix	1271480.601	480253.207	1.81567	Fix	0.264	-0.343	-0.71777	AR
54	1271477.361	480249.579	1.1432	Fix	1271477.116	480249.913	1.88422	Fix	0.245	-0.334	-0.74102	AR
55	1271474.193	480248.385	1.1318	Fix	1271473.935	480248.764	1.89127	Fix	0.258	-0.379	-0.75947	AR
56	1271452.339	480245.284	1.0991	Fix	1271452.136	480245.663	1.92743	Fix	0.203	-0.379	-0.82833	AR
57	1271453.677	480254.31	1.6801	Fix	1271453.47	480254.692	2.49539	Fix	0.207	-0.382	-0.81529	Karola
58	1271449.609	480253.777	1.6132	Fix	1271449.376	480254.134	2.46037	Fix	0.233	-0.357	-0.84717	Karola
59	1271433.289	480242.768	0.8841	Fix	1271433.13	480243.084	1.80795	Fix	0.159	-0.316	-0.92385	AR
60	1271399.056	480238.31	0.8805	Fix	1271398.877	480238.608	1.83609	Fix	0.179	-0.298	-0.95559	AR
61	1271373.308	480234.9	0.8572	Fix	1271373.135	480235.213	1.86338	Fix	0.173	-0.313	-1.00618	AR
62	1271358.37	480232.962	0.8646	Fix	1271358.198	480233.257	1.83728	Fix	0.172	-0.295	-0.97268	AR
63	1271343.721	480231.095	0.8382	Fix	1271343.545	480231.328	1.52875	Fix	0.176	-0.233	-0.69055	AR
64	1271314.233	480227.245	0.8374	Fix	1271314.034	480227.482	1.51405	Fix	0.199	-0.237	-0.67665	AR
65	1271293.984	480224.556	0.8242	Fix	1271293.772	480224.78	1.52176	Fix	0.212	-0.224	-0.69756	AR
66	1271279.103	480222.695	0.8032	Fix	1271278.919	480222.943	1.53252	Fix	0.184	-0.248	-0.72932	AR
67	1271259.208	480219.906	0.8473	Fix	1271259.024	480220.123	1.58066	Fix	0.184	-0.217	-0.73336	AR
68	1271244.556	480218.042	0.8699	Fix	1271244.331	480218.231	1.55902	Fix	0.225	-0.189	-0.68912	AR
69	1271238.596	480226.836	0.9131	Fix	1271238.403	480227.124	1.6477	Fix	0.193	-0.288	-0.7346	Curb
70	1271243.589	480227.471	0.9218	Fix	1271243.363	480227.69	1.65416	Fix	0.226	-0.219	-0.73236	Curb
71	1271245.005	480229.393	1.019	Fix	1271244.827	480229.648	1.67631	Fix	0.178	-0.255	-0.65731	Curb
72	1271244.911	480230.125	0.9729	Fix	1271244.689	480230.341	1.71011	Fix	0.222	-0.216	-0.73721	Curb
73	1271243.135	480231.572	1.0139	Fix	1271242.937	480231.764	1.71515	Fix	0.198	-0.192	-0.70125	Curb
74	1271238.443	480230.876	1.042	Fix	1271238.23	480231.107	1.77528	Fix	0.213	-0.231	-0.73328	Curb
75	1271237.141	480238.558	0.9707	Fix	1271236.934	480238.758	1.72237	Fix	0.207	-0.2	-0.75167	Curb
76	1271242.294	480239.201	0.934	Fix	1271242.097	480239.489	1.65961	Fix	0.197	-0.288	-0.72561	Curb
77	1271243.442	480240.742	0.8718	Fix	1271243.237	480241.03	1.66736	Fix	0.205	-0.288	-0.79556	Curb
78	1271242.688	480246.22	0.9845	Fix	1271242.469	480246.604	1.72713	Fix	0.219	-0.384	-0.74263	Curb
79	1271248.375	480248.413	0.9591	Fix	1271248.208	480248.698	1.62715	Fix	0.167	-0.285	-0.66805	CR
80	1271250.041	480235.458	0.9948	Fix	1271249.848	480235.658	1.74566	Fix	0.193	-0.2	-0.75086	CR
81	1271250.92	480228.251	0.8047	Fix	1271250.728	480228.476	1.51222	Fix	0.192	-0.225	-0.70752	CR

82	1271258.223	480229.318	0.9037	Fix	1271258.028	480229.549	1.58872	Fix	0.195	-0.231	-0.68502	Curb
83	1271256.699	480230.64	0.9933	Fix	1271256.485	480230.881	1.63786	Fix	0.214	-0.241	-0.64456	Curb
84	1271256.492	480232.204	0.9946	Fix	1271256.293	480232.45	1.66016	Fix	0.199	-0.246	-0.66556	Curb
85	1271257.872	480233.582	1.1439	Fix	1271257.684	480233.806	1.87336	Fix	0.188	-0.224	-0.72946	Curb
86	1271255.919	480237.488	0.9945	Fix	1271255.755	480237.737	1.75089	Fix	0.164	-0.249	-0.75639	Curb
87	1271256.704	480238.402	0.9947	Fix	1271256.517	480238.633	1.68014	Fix	0.187	-0.231	-0.68544	Curb
88	1271254.177	480250.423	0.9862	Fix	1271253.971	480250.67	1.7584	Fix	0.206	-0.247	-0.7722	Curb
89	1271254.758	480245.982	0.972	Fix	1271254.557	480246.232	1.71348	Fix	0.201	-0.25	-0.74148	Curb
90	1271255.408	480245.06	0.9532	Fix	1271255.187	480245.292	1.62563	Fix	0.221	-0.232	-0.67243	Curb
91	1271256.742	480244.574	1.0228	Fix	1271256.536	480244.81	1.72235	Fix	0.206	-0.236	-0.69955	Curb
92	1271281.229	480247.841	1.0379	Fix	1271281.051	480248.068	1.65896	Fix	0.178	-0.227	-0.62106	Curb
93	1271282.302	480241.788	0.9499	Fix	1271282.143	480242.055	1.76238	Fix	0.159	-0.267	-0.81248	Curb
94	1271282.71	480236.817	1.1727	Fix	1271282.542	480237.038	1.97037	Fix	0.168	-0.221	-0.79767	Curb
95	1271283.324	480232.635	0.8676	Fix	1271283.128	480232.862	1.69713	Fix	0.196	-0.227	-0.82953	Curb
96	1271288.896	480233.219	0.7519	Fix	1271288.675	480233.481	1.49592	Fix	0.221	-0.262	-0.74402	MH
97	1271289.049	480231.773	0.7619	Fix	1271288.847	480231.972	1.44986	Fix	0.202	-0.199	-0.68796	MH
98	1271290.124	480231.886	0.7435	Fix	1271289.945	480232.085	1.44971	Fix	0.179	-0.199	-0.70621	MH
99	1271289.943	480233.339	0.7427	Fix	1271289.733	480233.575	1.41648	Fix	0.21	-0.236	-0.67378	MH
100	1271315.36	480236.695	0.8053	Fix	1271315.492	480237.829	2.30317	Fix	-0.132	-1.134	-1.49787	MH
101	1271315.485	480235.736	0.8094	Fix	1271315.612	480236.875	2.29639	Fix	-0.127	-1.139	-1.48699	MH
102	1271316.467	480235.872	0.7759	Fix	1271316.579	480237.008	2.26226	Fix	-0.112	-1.136	-1.48636	MH
103	1271316.337	480236.817	0.7783	Fix	1271316.468	480237.944	2.28151	Fix	-0.131	-1.127	-1.50321	MH
104	1271316.537	480237.072	0.9323	Fix	1271316.654	480238.201	2.46374	Fix	-0.117	-1.129	-1.53144	Curb
105	1271317.669	480238.74	0.9858	Fix	1271317.812	480239.896	2.52081	Fix	-0.143	-1.156	-1.53501	Curb
106	1271317.485	480240.181	1.0315	Fix	1271317.624	480241.312	2.56711	Fix	-0.139	-1.131	-1.53561	Curb
107	1271315.867	480241.235	1.1927	Fix	1271315.996	480242.372	2.69942	Fix	-0.129	-1.137	-1.50672	Curb
108	1271316.929	480244.901	1.0797	Fix	1271317.044	480246.062	2.5994	Fix	-0.115	-1.161	-1.5197	Curb
109	1271315.355	480246.163	0.9959	Fix	1271315.5	480247.315	2.52521	Fix	-0.145	-1.152	-1.52931	Curb
110	1271326.492	480247.633	0.975	Fix	1271326.584	480248.938	3.13811	Fix	-0.092	-1.305	-2.16311	Curb

111	1271324.999	480245.503	1.0624	Fix	1271325.09	480246.803	3.2546	Fix	-0.091	-1.3	-2.1922	Curb
112	1271326.877	480242.664	1.1375	Fix	1271326.966	480244.006	3.23557	Fix	-0.089	-1.342	-2.09807	Curb
113	1271325.578	480241.293	0.9546	Fix	1271325.66	480242.634	3.11372	Fix	-0.082	-1.341	-2.15912	Curb
114	1271325.8	480239.629	0.9207	Fix	1271325.853	480240.981	3.06639	Fix	-0.053	-1.352	-2.14569	Curb
115	1271327.505	480238.492	0.8971	Fix	1271327.563	480239.835	2.97626	Fix	-0.058	-1.343	-2.07916	Curb
116	1271326.95	480238.294	0.7558	Fix	1271327.006	480239.619	2.82411	Fix	-0.056	-1.325	-2.06831	MH
117	1271327.148	480237.214	0.7479	Fix	1271327.212	480238.547	2.81393	Fix	-0.064	-1.333	-2.06603	MH
118	1271328.258	480237.376	0.7385	Fix	1271328.299	480238.715	2.79923	Fix	-0.041	-1.339	-2.06073	MH
119	1271328.076	480238.446	0.7414	Fix	1271328.139	480239.823	2.77195	Fix	-0.063	-1.377	-2.03055	MH
120	1271353.764	480241.841	0.749	Fix	1271353.845	480243.157	2.68223	Fix	-0.081	-1.316	-1.93323	MH
121	1271353.899	480240.973	0.8562	Fix	1271353.553	480241.253	1.49035	Fix	0.346	-0.28	-0.63415	MH
122	1271355.009	480241.107	0.9786	Fix	1271354.643	480241.419	1.48823	Fix	0.366	-0.312	-0.50963	MH
123	1271354.891	480241.878	0.79	Fix	1271354.551	480242.305	1.42333	Fix	0.34	-0.427	-0.63333	MH
124	1271376.7	480244.805	0.7803	Fix	1271376.507	480245.044	1.47988	Fix	0.193	-0.239	-0.69958	MH
125	1271376.787	480243.727	0.7603	Fix	1271376.603	480243.948	1.47579	Fix	0.184	-0.221	-0.71549	MH
126	1271377.909	480243.849	0.7762	Fix	1271377.735	480244.068	1.46595	Fix	0.174	-0.219	-0.68975	MH
127	1271377.829	480244.987	0.779	Fix	1271377.61	480245.224	1.49733	Fix	0.219	-0.237	-0.71833	MH
128	1271377.241	480245.082	0.951	Fix	1271377.011	480245.322	1.69761	Fix	0.23	-0.24	-0.74661	Curb
129	1271378.729	480246.969	0.993	Fix	1271378.509	480247.189	1.73787	Fix	0.22	-0.22	-0.74487	Curb
130	1271378.583	480248.095	0.9638	Fix	1271378.346	480248.297	1.72669	Fix	0.237	-0.202	-0.76289	Curb
131	1271376.924	480249.233	1.1677	Fix	1271376.699	480249.462	1.911	Fix	0.225	-0.229	-0.7433	Curb
132	1271377.945	480253.079	1.0207	Fix	1271378.172	480254.1	1.83625	Fix	-0.227	-1.021	-0.81555	Curb
133	1271376.586	480254.219	0.9853	Fix	1271376.828	480255.231	1.78674	Fix	-0.242	-1.012	-0.80144	Curb
134	1271386.928	480255.652	0.9705	Fix	1271386.733	480255.86	1.6435	Fix	0.195	-0.208	-0.673	Curb
135	1271386.081	480254.059	0.9782	Fix	1271385.875	480254.275	1.70198	Fix	0.206	-0.216	-0.72378	Curb
136	1271388.106	480250.754	1.1511	Fix	1271387.85	480251.073	2.13295	Fix	0.256	-0.319	-0.98185	Curb
137	1271386.617	480249.176	0.9414	Fix	1271386.374	480249.524	1.93632	Fix	0.243	-0.348	-0.99492	Curb
138	1271386.837	480247.302	0.9259	Fix	1271386.649	480247.54	1.60689	Fix	0.188	-0.238	-0.68099	Curb
139	1271388.035	480246.476	0.919	Fix	1271387.83	480246.688	1.61967	Fix	0.205	-0.212	-0.70067	Curb

140	1271388.096	480246.287	0.7556	Fix	1271387.887	480246.508	1.48458	Fix	0.209	-0.221	-0.72898	Curb
141	1271388.243	480245.401	0.7649	Fix	1271388.052	480245.626	1.47498	Fix	0.191	-0.225	-0.71008	Curb
142	1271389.134	480245.566	0.7598	Fix	1271388.945	480245.783	1.45514	Fix	0.189	-0.217	-0.69534	Curb
143	1271389.01	480246.43	0.761	Fix	1271388.8	480246.649	1.46686	Fix	0.21	-0.219	-0.70586	Curb
144	1271415.107	480249.844	0.772	Fix	1271415.034	480251.235	1.1518	Fix	0.073	-1.391	-0.3798	Curb
145	1271415.259	480248.791	0.8033	Fix	1271415.214	480250.193	1.19829	Fix	0.045	-1.402	-0.39499	Curb
146	1271416.239	480250.046	0.811	Fix	1271416.152	480251.439	1.22855	Fix	0.087	-1.393	-0.41755	Curb
147	1271416.394	480248.959	0.7991	Fix	1271416.345	480250.355	1.2032	Fix	0.049	-1.396	-0.4041	Curb
148	1271441.476	480253.264	0.8198	Fix	1271441.374	480254.702	1.22112	Fix	0.102	-1.438	-0.40132	Curb
149	1271441.637	480252.257	0.8255	Fix	1271441.503	480253.65	1.23671	Fix	0.134	-1.393	-0.41121	Curb
150	1271442.724	480252.368	0.7986	Fix	1271442.596	480253.792	1.24178	Fix	0.128	-1.424	-0.44318	Curb
151	1271442.549	480253.447	0.8166	Fix	1271442.436	480254.89	1.23114	Fix	0.113	-1.443	-0.41454	Curb
152	1271441.583	480253.496	0.9459	Fix	1271441.76	480254.615	1.78498	Fix	-0.177	-1.119	-0.83908	Curb
153	1271442.916	480255.125	0.9296	Fix	1271443.099	480256.197	1.81535	Fix	-0.183	-1.072	-0.88575	Curb
154	1271442.844	480256.546	0.9749	Fix	1271443.023	480257.622	1.81546	Fix	-0.179	-1.076	-0.84056	Curb
155	1271441.14	480257.699	1.1133	Fix	1271441.345	480258.809	1.97811	Fix	-0.205	-1.11	-0.86481	Curb
156	1271442.122	480261.54	0.9932	Fix	1271442.307	480262.598	1.78364	Fix	-0.185	-1.058	-0.79044	Curb
157	1271440.671	480262.694	0.9142	Fix	1271440.876	480263.764	1.74632	Fix	-0.205	-1.07	-0.83212	Curb
158	1271440.008	480268.949	0.9735	Fix	1271439.789	480269.132	1.6927	Fix	0.219	-0.183	-0.7192	Curb
159	1271500.401	480225.139	1.1651	Fix	1271500.302	480226.125	2.89804	Fix	0.099	-0.986	-1.73294	GV
160	1271507.073	480229.278	0.9081	Fix	1271506.834	480229.578	1.72132	Fix	0.239	-0.3	-0.81322	AR
161	1271507.335	480228.185	0.8948	Fix	1271507.097	480228.492	1.77583	Fix	0.238	-0.307	-0.88103	DG
162	1271495.05	480223.58	1.0942	Fix	1271494.83	480223.796	1.78308	Fix	0.22	-0.216	-0.68888	Pano
163	1271481.145	480224.715	0.8343	Fix	1271480.939	480224.96	1.53091	Fix	0.206	-0.245	-0.69661	DG
164	1271480.95	480225.764	0.8758	Fix	1271480.738	480225.984	1.52953	Fix	0.212	-0.22	-0.65373	AR
165	1271472.404	480223.598	0.868	Fix	1271472.161	480223.846	1.53352	Fix	0.243	-0.248	-0.66552	DG
166	1271472.193	480224.61	0.8684	Fix	1271471.953	480224.852	1.56088	Fix	0.24	-0.242	-0.69248	AR
167	1271465.727	480212.332	1.3323	Fix	1271465.512	480212.649	2.05314	Fix	0.215	-0.317	-0.72084	EDC
168	1271465.298	480212.224	1.2218	Fix	1271465.104	480212.563	2.02445	Fix	0.194	-0.339	-0.80265	EDC

169	1271465.399	480211.69	1.3315	Fix	1271465.094	480212.037	2.17869	Fix	0.305	-0.347	-0.84719	EDC
170	1271465.792	480211.744	1.2304	Fix	1271465.528	480212.086	2.14597	Fix	0.264	-0.342	-0.91557	EDC
171	1271458.643	480221.865	0.8425	Fix	1271458.482	480222.059	1.60772	Fix	0.161	-0.194	-0.76522	DG
172	1271458.502	480222.9	0.8717	Fix	1271458.335	480223.119	1.63243	Fix	0.167	-0.219	-0.76073	AR
173	1271435.099	480216.814	1.1727	Fix	1271434.898	480217.098	1.98897	Fix	0.201	-0.284	-0.81627	Pano
174	1271417.399	480216.415	0.8315	Fix	1271417.284	480216.734	1.7072	Fix	0.115	-0.319	-0.8757	DG
175	1271417.229	480217.457	0.8566	Fix	1271417.092	480217.765	1.72098	Fix	0.137	-0.308	-0.86438	AR
176	1271420.055	480211.374	1.3138	Fix	1271419.926	480211.613	2.0893	Fix	0.129	-0.239	-0.7755	Home
177	1271398.914	480208.067	1.1775	Fix	1271398.727	480208.279	1.81697	Fix	0.187	-0.212	-0.63947	Pano
178	1271398.517	480211.405	1.0971	Fix	1271398.275	480211.568	1.67903	Fix	0.242	-0.163	-0.58193	Pano
179	1271400.508	480204.688	1.3021	Fix	1271399.887	480205.239	1.5122	Fix	0.621	-0.551	-0.2101	EDC
180	1271383.084	480211.913	0.7781	Fix	1271382.91	480212.26	1.68913	Fix	0.174	-0.347	-0.91103	DG
181	1271382.976	480212.863	0.7962	Fix	1271382.805	480213.207	1.70006	Fix	0.171	-0.344	-0.90386	DG
182	1271366.43	480209.412	0.9266	Fix	1271366.297	480209.743	1.77305	Fix	0.133	-0.331	-0.84645	Sign
183	1271362.191	480209.01	0.8056	Fix	1271362.07	480209.785	2.8227	Fix	0.121	-0.775	-2.0171	MH
184	1271361.418	480208.904	0.7841	Fix	1271361.298	480209.687	2.80611	Fix	0.12	-0.783	-2.02201	MH
185	1271361.51	480208.126	0.8347	Fix	1271361.388	480208.894	2.85236	Fix	0.122	-0.768	-2.01766	MH
186	1271362.314	480208.287	0.845	Fix	1271362.172	480209.072	2.83905	Fix	0.142	-0.785	-1.99405	MH
187	1271346.583	480206.329	0.8841	Float	1271346.459	480206.682	1.58248	Fix	0.124	-0.353	-0.69838	Tree
188	1271334.631	480205.537	0.815	Fix	1271334.423	480205.752	1.4771	Fix	0.208	-0.215	-0.6621	DG
189	1271334.545	480206.581	0.8182	Fix	1271334.326	480206.803	1.49051	Fix	0.219	-0.222	-0.67231	AR
190	1271328.388	480204.713	0.8527	Fix	1271328.177	480204.938	1.56158	Fix	0.211	-0.225	-0.70888	MH
191	1271327.259	480204.562	0.8195	Fix	1271327.047	480204.803	1.55528	Fix	0.212	-0.241	-0.73578	MH
192	1271327.372	480203.721	0.9005	Fix	1271327.186	480203.979	1.63941	Fix	0.186	-0.258	-0.73891	MH
193	1271328.447	480203.918	0.9194	Fix	1271328.261	480204.164	1.6398	Fix	0.186	-0.246	-0.7204	MH
194	1271329.049	480202.816	0.9968	Fix	1271328.849	480203.077	1.71227	Fix	0.2	-0.261	-0.71547	Road
195	1271329.068	480199.186	1.1017	Fix	1271328.828	480199.427	1.74569	Fix	0.24	-0.241	-0.64399	Road
196	1271331.226	480198.988	1.0251	Fix	1271331.024	480199.224	1.67503	Fix	0.202	-0.236	-0.64993	Road
197	1271331.309	480202.294	0.9744	Fix	1271331.097	480202.55	1.64738	Fix	0.212	-0.256	-0.67298	Road

198	1271332.196	480196.982	1.2541	Fix	1271332.408	480198.479	3.13237	Fix	-0.212	-1.497	-1.87827	Home
199	1271312.411	480202.609	0.8127	Fix	1271312.19	480202.84	1.43835	Fix	0.221	-0.231	-0.62565	DG
200	1271312.207	480203.666	0.8128	Fix	1271311.998	480203.889	1.479	Fix	0.209	-0.223	-0.6662	AR
201	1271307.569	480198.123	1.0135	Fix	1271307.315	480198.395	1.71603	Fix	0.254	-0.272	-0.70253	Pano
202	1271307.773	480196.076	1.003	Fix	1271307.482	480196.854	2.69807	Fix	0.291	-0.778	-1.69507	Pano
203	1271289.911	480199.632	0.7896	Fix	1271289.703	480199.849	1.43424	Fix	0.208	-0.217	-0.64464	DG
204	1271289.751	480200.589	0.8246	Fix	1271289.547	480200.823	1.4715	Fix	0.204	-0.234	-0.6469	AR
205	1271289.351	480192.225	1.9478	Fix	1271289.4	480193.495	1.65285	Fix	-0.049	-1.27	0.29495	Tree
206	1271263.218	480196.008	0.7759	Fix	1271263.01	480196.232	1.40691	Fix	0.208	-0.224	-0.63101	DG
207	1271263.034	480197.078	0.8256	Fix	1271262.849	480197.308	1.45251	Fix	0.185	-0.23	-0.62691	AR
208	1271250.385	480195.684	0.8141	Fix	1271250.203	480195.889	1.47726	Fix	0.182	-0.205	-0.66316	AR
209	1271248.628	480188.281	1.1841	Fix	1271248.434	480188.478	1.83444	Fix	0.194	-0.197	-0.65034	Road
210	1271246.972	480180.443	1.2965	Fix	1271246.806	480180.617	1.9557	Fix	0.166	-0.174	-0.6592	Road
211	1271240.984	480179.86	1.2858	Fix	1271240.793	480180.077	1.95666	Fix	0.191	-0.217	-0.67086	Road
212	1271241.652	480186.707	1.2559	Fix	1271241.444	480186.935	1.90902	Fix	0.208	-0.228	-0.65312	Road
213	1271241.205	480194.808	0.9273	Fix	1271241.025	480195.039	1.6543	Fix	0.18	-0.231	-0.727	Road
214	1271232.904	480192.071	0.7576	Fix	1271232.799	480192.403	1.5112	Fix	0.105	-0.332	-0.7536	DG
215	1271232.875	480192.335	0.8042	Fix	1271232.776	480192.65	1.49575	Fix	0.099	-0.315	-0.69155	DG
216	1271232.794	480193.352	0.7786	Fix	1271232.67	480193.634	1.51171	Fix	0.124	-0.282	-0.73311	DG
217	1271231.475	480193.183	0.7813	Fix	1271231.373	480193.478	1.47055	Fix	0.102	-0.295	-0.68925	DG
218	1271231.715	480191.894	0.7703	Fix	1271231.579	480192.202	1.46664	Fix	0.136	-0.308	-0.69634	DG
219	1271229.698	480203.622	1.2785	Fix	1271229.549	480203.853	1.98326	Fix	0.149	-0.231	-0.70476	Curb
220	1271228.573	480205.251	1.3292	Fix	1271228.376	480205.51	2.05425	Fix	0.197	-0.259	-0.72505	Curb
221	1271234.499	480205.283	1.6031	Fix	1271234.298	480205.537	2.19572	Fix	0.201	-0.254	-0.59262	EL
222	1271234.764	480205.31	1.5751	Fix	1271234.583	480205.539	2.23336	Fix	0.181	-0.229	-0.65826	EL
223	1271234.802	480205.027	1.5584	Fix	1271234.611	480205.274	2.18068	Fix	0.191	-0.247	-0.62228	EL
224	1271234.5	480205.008	1.5285	Fix	1271234.315	480205.201	2.24062	Fix	0.185	-0.193	-0.71212	EL
225	1271237.178	480205.762	1.7884	Fix	1271236.992	480206.799	3.92337	Fix	0.186	-1.037	-2.13497	Ts
226	1271236.615	480205.561	1.5015	Fix	1271236.569	480205.872	2.14897	Fix	0.046	-0.311	-0.64747	Ts

227	1271236.651	480205.274	1.4604	Fix	1271236.544	480205.626	2.11127	Fix	0.107	-0.352	-0.65087	Ts
228	1271236.906	480205.364	1.4485	Fix	1271236.939	480206.514	3.63121	Fix	-0.033	-1.15	-2.18271	Ts
229	1271237.806	480204.644	1.3156	Fix	1271237.625	480204.905	2.07137	Fix	0.181	-0.261	-0.75577	Curb
230	1271238.485	480205.568	1.322	Fix	1271238.277	480205.766	2.02016	Fix	0.208	-0.198	-0.69816	Curb
231	1271237.585	480206.443	1.323	Fix	1271237.426	480206.652	2.03591	Fix	0.159	-0.209	-0.71291	Curb
232	1271264.56	480209.925	1.3182	Fix	1271264.146	480211.103	2.24565	Fix	0.414	-1.178	-0.92745	Curb
233	1271263.727	480208.953	1.3213	Fix	1271263.287	480210.154	2.22752	Fix	0.44	-1.201	-0.90622	Curb
234	1271264.812	480208.143	1.334	Fix	1271264.279	480209.178	2.39226	Fix	0.533	-1.035	-1.05826	Curb
235	1271266.555	480209.133	1.5879	Fix	1271266.361	480209.363	2.25558	Fix	0.194	-0.23	-0.66768	EL
236	1271266.856	480209.155	1.6109	Fix	1271267.156	480210.339	2.07256	Fix	-0.3	-1.184	-0.46166	EL
237	1271266.756	480209.437	1.5534	Fix	1271266.382	480210.624	2.42601	Fix	0.374	-1.187	-0.87261	EL
238	1271266.508	480209.407	1.5908	Fix	1271266.674	480210.615	3.90979	Fix	-0.166	-1.208	-2.31899	EL
239	1271282.642	480211.25	1.6482	Fix	1271282.615	480212.662	1.8086	Fix	0.027	-1.412	-0.1604	Pano
240	1271282.956	480211.288	1.6261	Fix	1271282.796	480211.551	2.24275	Fix	0.16	-0.263	-0.61665	Pano
241	1271282.928	480211.58	1.6503	Fix	1271282.743	480211.8	2.2971	Fix	0.185	-0.22	-0.6468	Pano
242	1271282.631	480211.539	1.6372	Fix	1271282.574	480211.876	2.45669	Fix	0.057	-0.337	-0.81949	Pano
243	1271286.585	480212.859	1.3608	Fix	1271286.794	480213.981	1.83922	Fix	-0.209	-1.122	-0.47842	Curb
244	1271286.817	480211.034	1.3641	Fix	1271287.04	480212.175	1.84142	Fix	-0.223	-1.141	-0.47732	Curb
245	1271299.932	480213.524	1.5362	Fix	1271299.751	480213.749	2.27928	Fix	0.181	-0.225	-0.74308	EL
246	1271300.24	480213.544	1.5471	Fix	1271300.044	480213.76	2.28717	Fix	0.196	-0.216	-0.74007	EL
247	1271300.247	480213.878	1.5452	Fix	1271300.005	480214.065	2.28392	Fix	0.242	-0.187	-0.73872	EL
248	1271299.896	480213.781	1.5718	Fix	1271299.72	480214.03	2.26541	Fix	0.176	-0.249	-0.69361	EL
249	1271316.405	480215.723	1.559	Fix	1271316.195	480215.939	2.326	Fix	0.21	-0.216	-0.767	Pano
250	1271316.812	480215.775	1.6098	Fix	1271316.614	480215.988	2.28865	Fix	0.198	-0.213	-0.67885	Pano
251	1271316.798	480216.171	1.6256	Fix	1271316.57	480216.588	2.01487	Fix	0.228	-0.417	-0.38927	Pano
252	1271316.334	480216.138	1.654	Fix	1271316.184	480216.375	2.26952	Fix	0.15	-0.237	-0.61552	Pano
253	1271321.382	480215.556	1.396	Fix	1271321.178	480215.844	2.16756	Fix	0.204	-0.288	-0.77156	Curb
254	1271320.984	480217.433	1.3695	Fix	1271320.793	480217.664	2.08161	Fix	0.191	-0.231	-0.71211	Curb
255	1271334.317	480218.092	1.4954	Fix	1271334.031	480218.349	2.35333	Fix	0.286	-0.257	-0.85793	EL

256	1271334.602	480218.112	1.5062	Fix	1271334.338	480218.358	2.35543	Fix	0.264	-0.246	-0.84923	EL
257	1271334.575	480218.406	1.4554	Fix	1271334.317	480218.674	2.37193	Fix	0.258	-0.268	-0.91653	EL
258	1271334.27	480218.383	1.4747	Fix	1271334.006	480218.624	2.36578	Fix	0.264	-0.241	-0.89108	EL
259	1271351.102	480220.186	1.6173	Fix	1271350.851	480220.465	2.45933	Fix	0.251	-0.279	-0.84203	Pano
260	1271351.469	480220.237	1.6493	Fix	1271351.295	480220.443	2.28835	Fix	0.174	-0.206	-0.63905	Pano
261	1271351.429	480220.577	1.6057	Fix	1271351.269	480220.823	2.31431	Fix	0.16	-0.246	-0.70861	Pano
262	1271351.066	480220.569	1.6193	Fix	1271350.849	480220.809	2.26344	Fix	0.217	-0.24	-0.64414	Pano
263	1271353.4	480221.609	1.3414	Fix	1271353.22	480221.835	2.04142	Fix	0.18	-0.226	-0.70002	Curb
264	1271353.443	480219.795	1.3649	Fix	1271353.245	480220.014	2.03495	Fix	0.198	-0.219	-0.67005	Curb
265	1271368.873	480222.594	1.5273	Fix	1271368.686	480222.826	2.21799	Fix	0.187	-0.232	-0.69069	EL
266	1271369.157	480222.636	1.5039	Fix	1271368.978	480222.864	2.2189	Fix	0.179	-0.228	-0.715	EL
267	1271369.101	480222.952	1.5213	Fix	1271368.936	480223.155	2.21698	Fix	0.165	-0.203	-0.69568	EL
268	1271368.792	480222.906	1.5121	Fix	1271368.644	480223.117	2.14292	Fix	0.148	-0.211	-0.63082	EL
269	1271385.64	480224.687	1.5627	Fix	1271385.468	480224.914	2.26431	Fix	0.172	-0.227	-0.70161	Pano
270	1271386.095	480224.697	1.5202	Fix	1271385.905	480224.949	2.23795	Fix	0.19	-0.252	-0.71775	Pano
271	1271386.09	480225.166	1.5065	Fix	1271385.893	480225.418	2.29373	Fix	0.197	-0.252	-0.78723	Pano
272	1271385.6	480225.127	1.5224	Fix	1271384.676	480225.638	3.41088	Fix	0.924	-0.511	-1.88848	Pano
273	1271384.837	480225.748	1.3303	Fix	1271384.634	480225.976	2.04732	Fix	0.203	-0.228	-0.71702	Curb
274	1271384.616	480223.901	1.3155	Fix	1271384.439	480224.117	2.05528	Fix	0.177	-0.216	-0.73978	Curb
275	1271402.677	480227.019	1.599	Fix	1271402.444	480227.258	2.38479	Fix	0.233	-0.239	-0.78579	EL
276	1271402.991	480227.047	1.5787	Fix	1271402.729	480227.301	2.40291	Fix	0.262	-0.254	-0.82421	EL
277	1271402.908	480227.356	1.578	Fix	1271402.698	480227.594	2.369	Fix	0.21	-0.238	-0.791	EL
278	1271402.609	480227.348	1.586	Fix	1271402.401	480227.577	2.33284	Fix	0.208	-0.229	-0.74684	EL
279	1271419.676	480228.477	1.3786	Fix	1271419.449	480228.732	2.13113	Fix	0.227	-0.255	-0.75253	Curb
280	1271419.495	480230.28	1.3564	Fix	1271419.296	480230.522	2.13753	Fix	0.199	-0.242	-0.78113	Curb
281	1271420.931	480229.276	1.5918	Fix	1271420.749	480229.499	2.32862	Fix	0.182	-0.223	-0.73682	Pano
282	1271421.409	480229.312	1.5822	Fix	1271421.211	480229.647	2.52587	Fix	0.198	-0.335	-0.94367	Pano
283	1271421.334	480229.823	1.5688	Fix	1271421.135	480230.093	2.37652	Fix	0.199	-0.27	-0.80772	Pano
284	1271420.849	480229.725	1.5798	Fix	1271420.634	480229.984	2.32784	Fix	0.215	-0.259	-0.74804	Pano

285	1271436.9	480231.512	1.6893	Fix	1271436.648	480231.745	2.44259	Fix	0.252	-0.233	-0.75329	EL
286	1271437.197	480231.544	1.6139	Fix	1271436.991	480231.782	2.3281	Fix	0.206	-0.238	-0.7142	EL
287	1271437.153	480231.853	1.6313	Fix	1271436.941	480232.097	2.37735	Fix	0.212	-0.244	-0.74605	EL
288	1271436.829	480231.809	1.6283	Fix	1271436.652	480232.052	2.28396	Fix	0.177	-0.243	-0.65566	EL
289	1271451.289	480233.461	1.6346	Fix	1271451.092	480233.721	2.37269	Fix	0.197	-0.26	-0.73809	Pano
290	1271451.786	480233.484	1.6188	Fix	1271451.575	480233.749	2.28452	Fix	0.211	-0.265	-0.66572	Pano
291	1271451.697	480233.995	1.5914	Fix	1271451.503	480234.246	2.33546	Fix	0.194	-0.251	-0.74406	Pano
292	1271451.228	480233.935	1.7043	Fix	1271451.057	480234.134	2.14146	Fix	0.171	-0.199	-0.43716	Pano
293	1271471.188	480236.024	1.6705	Fix	1271471.013	480236.272	2.23025	Fix	0.175	-0.248	-0.55975	EL
294	1271471.488	480236.069	1.6746	Fix	1271471.29	480236.306	2.31632	Fix	0.198	-0.237	-0.64172	EL
295	1271471.468	480236.389	1.6501	Fix	1271470.9	480236.655	2.22628	Fix	0.568	-0.266	-0.57618	EL
296	1271471.146	480236.322	1.699	Fix	1271470.941	480236.571	2.48224	Fix	0.205	-0.249	-0.78324	EL
297	1271471.446	480235.308	1.4293	Fix	1271471.302	480235.535	2.01167	Fix	0.144	-0.227	-0.58237	Curb
298	1271471.237	480237.107	1.4443	Fix	1271470.974	480237.394	2.19467	Fix	0.263	-0.287	-0.75037	Curb
299	1271474.172	480235.696	1.4498	Fix	1271473.972	480235.92	2.19953	Fix	0.2	-0.224	-0.74973	Curb
300	1271474.907	480236.749	1.4475	Fix	1271474.685	480237.028	2.19391	Fix	0.222	-0.279	-0.74641	Curb
301	1271473.867	480237.436	1.3875	Fix	1271473.599	480237.71	2.03044	Fix	0.268	-0.274	-0.64294	Curb
302	1271514.076	480242.721	1.4409	Fix	1271513.888	480242.99	2.06553	Fix	0.188	-0.269	-0.62463	Curb
303	1271513.217	480241.765	1.476	Fix	1271512.995	480242.041	2.19679	Fix	0.222	-0.276	-0.72079	Curb
304	1271514.345	480241.007	1.4018	Fix	1271514.147	480241.262	2.07251	Fix	0.198	-0.255	-0.67071	Curb
305	1271516.113	480241.973	1.6696	Fix	1271515.829	480242.273	2.53202	Fix	0.284	-0.3	-0.86242	EL
306	1271516.376	480242	1.6542	Fix	1271516.15	480242.226	2.24628	Fix	0.226	-0.226	-0.59208	EL
307	1271516.307	480242.312	1.6537	Fix	1271516.136	480242.567	2.22867	Fix	0.171	-0.255	-0.57497	EL
308	1271516.036	480242.297	1.5808	Fix	1271515.845	480242.468	2.22095	Fix	0.191	-0.171	-0.64015	EL
309	1271523.69	480242.237	1.4411	Fix	1271523.469	480242.496	2.02843	Fix	0.221	-0.259	-0.58733	Curb
310	1271523.332	480244.01	1.4465	Fix	1271523.09	480244.375	2.14848	Fix	0.242	-0.365	-0.70198	Curb
311	1271533.998	480244.47	1.5465	Fix	1271533.779	480244.811	2.1082	Fix	0.219	-0.341	-0.5617	TBM16
312	1271551.767	480245.941	1.4878	Fix	1271551.582	480246.234	2.1091	Fix	0.185	-0.293	-0.6213	Curb
313	1271551.547	480247.73	1.4464	Fix	1271551.037	480248.267	2.1107	Fix	0.51	-0.537	-0.6643	Curb

b	1271552.038	480247.025	1.6968	Fix	1271551.788	480247.244	2.09789	Fix	0.25	-0.219	-0.40109	EL
315	1271551.649	480247.074	1.699	Fix	1271551.518	480247.194	2.26951	Fix	0.131	-0.12	-0.57051	EL
316	1271551.717	480246.671	1.6789	Fix	1271551.539	480246.938	2.34573	Fix	0.178	-0.267	-0.66683	EL
317	1271552.07	480246.72	1.6569	Fix	1271551.825	480246.987	2.29647	Fix	0.245	-0.267	-0.63957	EL
318	1271546.473	480257.751	0.905	Fix	1271545.99	480259.463	2.23318	Fix	0.483	-1.712	-1.32818	AR
319	1271546.201	480258.842	0.902	Fix	1271545.943	480259.137	2.27422	Fix	0.258	-0.295	-1.37222	DG
320	1271539.438	480258.277	0.9636	Fix	1271539.224	480258.604	1.93344	Fix	0.214	-0.327	-0.96984	Home
321	1271534.691	480257.492	1.0868	Fix	1271534.506	480257.836	1.7174	Fix	0.185	-0.344	-0.6306	Home
322	1271533.931	480257.922	1.0282	Fix	1271533.743	480258.166	1.72157	Fix	0.188	-0.244	-0.69337	Pano
323	1271527.008	480255.258	0.9727	Fix	1271526.725	480255.56	1.74646	Fix	0.283	-0.302	-0.77376	AR
324	1271526.783	480256.274	1.018	Fix	1271526.503	480256.6	1.78926	Fix	0.28	-0.326	-0.77126	DG
325	1271509.768	480252.988	0.953	Fix	1271509.494	480253.267	1.7946	Fix	0.274	-0.279	-0.8416	AR
326	1271509.533	480254.065	0.9603	Fix	1271509.294	480254.378	1.83148	Fix	0.239	-0.313	-0.87118	DG
327	1271505.797	480254.937	0.9242	Fix	1271505.54	480255.183	1.76287	Fix	0.257	-0.246	-0.83867	AR
328	1271503.331	480256.611	0.8619	Fix	1271503.074	480256.859	1.86085	Fix	0.257	-0.248	-0.99895	AR
329	1271501.521	480258.471	0.8621	Fix	1271501.307	480258.776	1.75974	Fix	0.214	-0.305	-0.89764	AR
330	1271499.806	480260.862	0.8017	Fix	1271499.575	480261.139	1.65098	Fix	0.231	-0.277	-0.84928	AR
331	1271498.733	480262.771	0.7769	Fix	1271498.511	480263.073	1.63701	Fix	0.222	-0.302	-0.86011	AR
332	1271498.661	480267.018	0.7236	Fix	1271498.447	480267.373	1.70647	Fix	0.214	-0.355	-0.98287	AR
333	1271498.697	480274.912	0.8408	Fix	1271498.451	480275.235	1.60109	Fix	0.246	-0.323	-0.76029	AR
334	1271500.315	480266.262	1.0827	Fix	1271500.031	480266.52	1.73593	Fix	0.284	-0.258	-0.65323	EDC pole