Comparative Accuracy Evaluation Between RTK (CORS) And PPK Aerial Surveying Approaches

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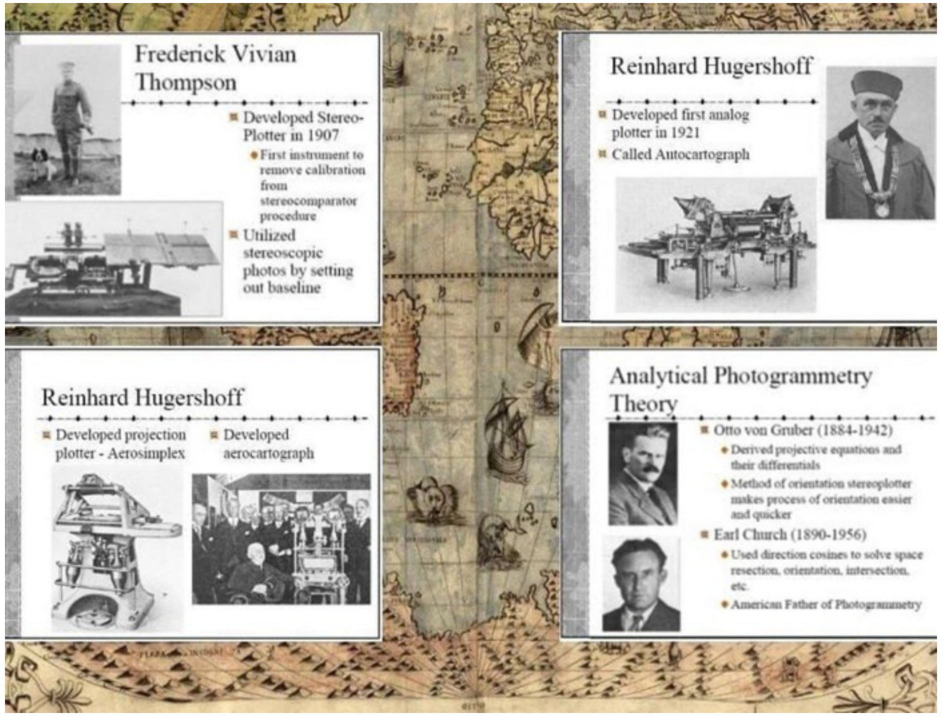
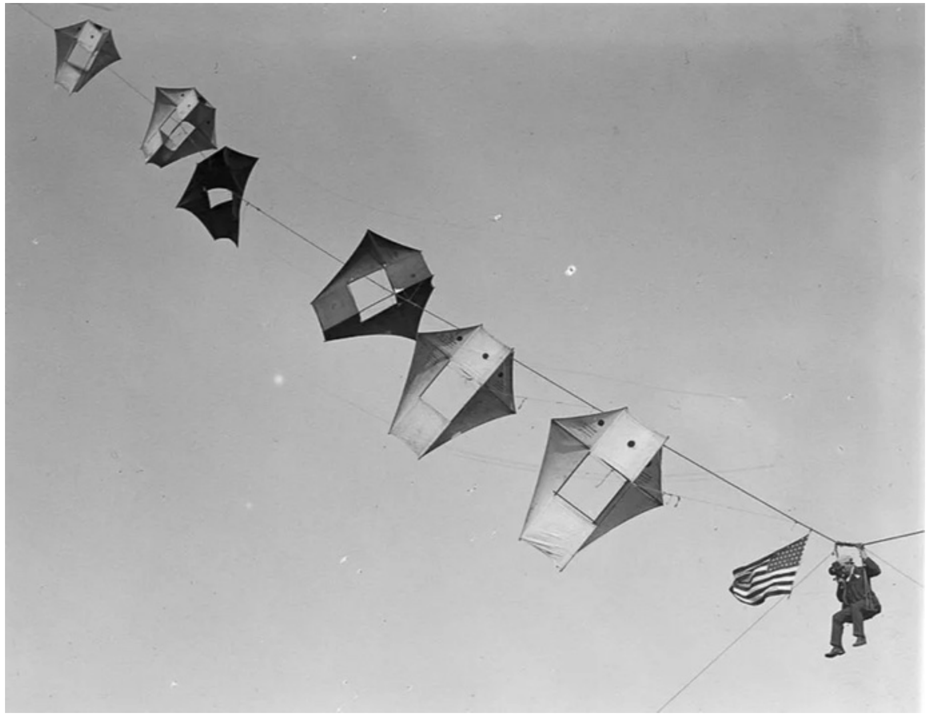
Content

Introduction to Aerial Mapping/Photogrammetry

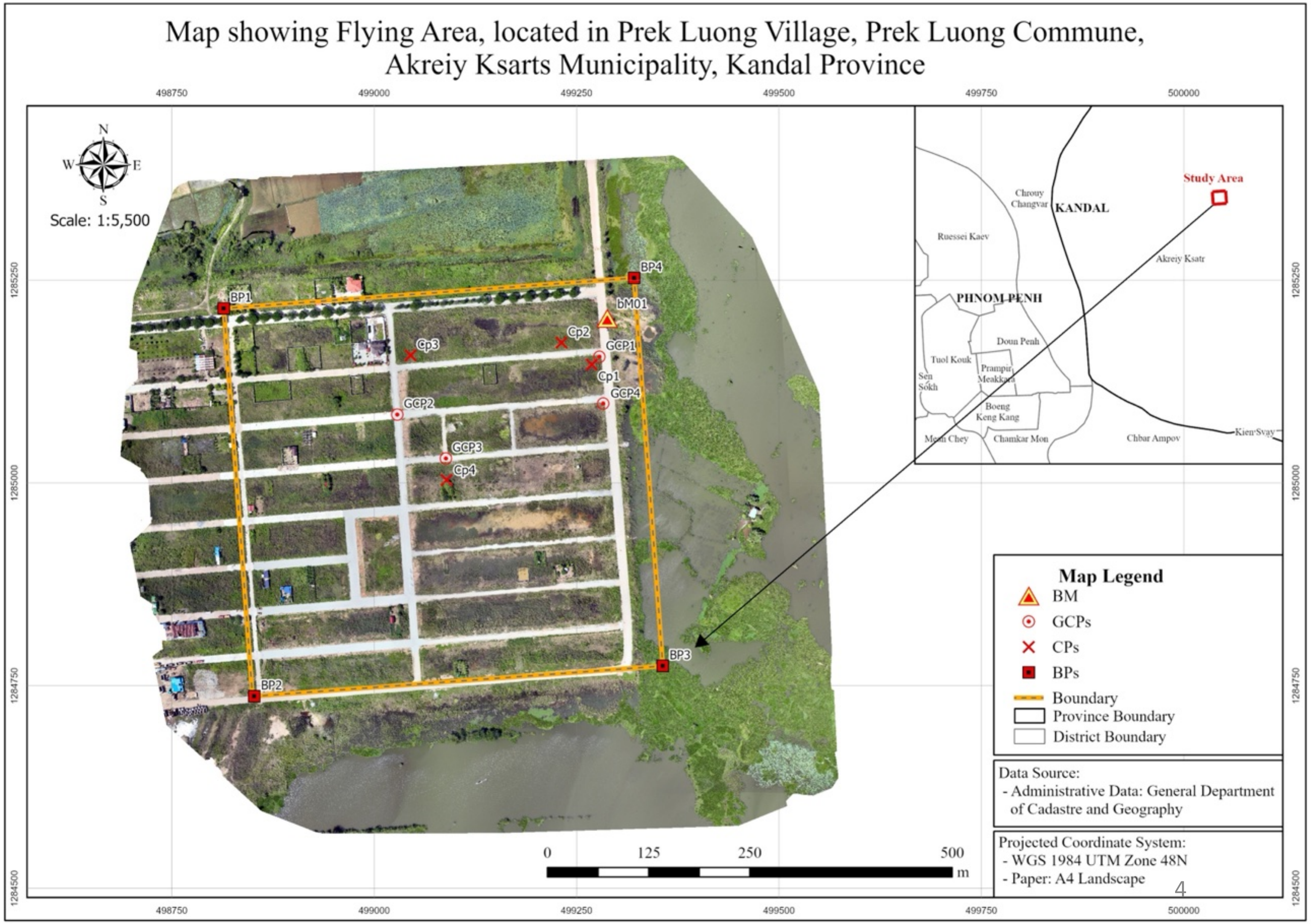
-In the 19th century, there was a glimpse of photogrammetry in human history.
- In 1849, Aimé Laussedat was named the “Father of Photogrammetry” as he initially used the terrestrial photograph for topographic map compilation.
- A year later, in 1958, Aimé Laussedat proved his successful experiment of aerial photography by using a string of kites and in 1862 by ballon. In 1864 the concept of using photograph for mapping was officially accepted by the Science Academy in Madrid City (Marky, nd).





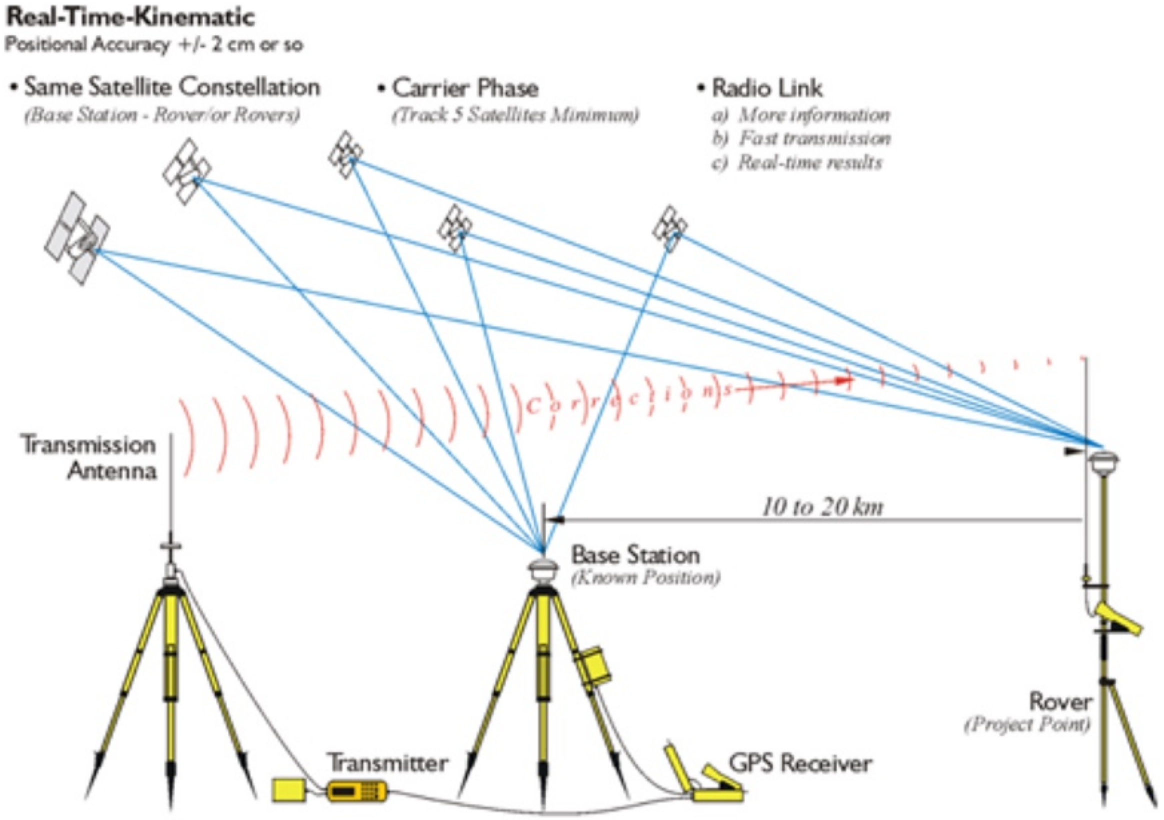
Study Area

- The surveying has been taking place at 7NG Area, Akreiy Ksatr Municipality, Kandal Province, covering 24.38 hectares of land.

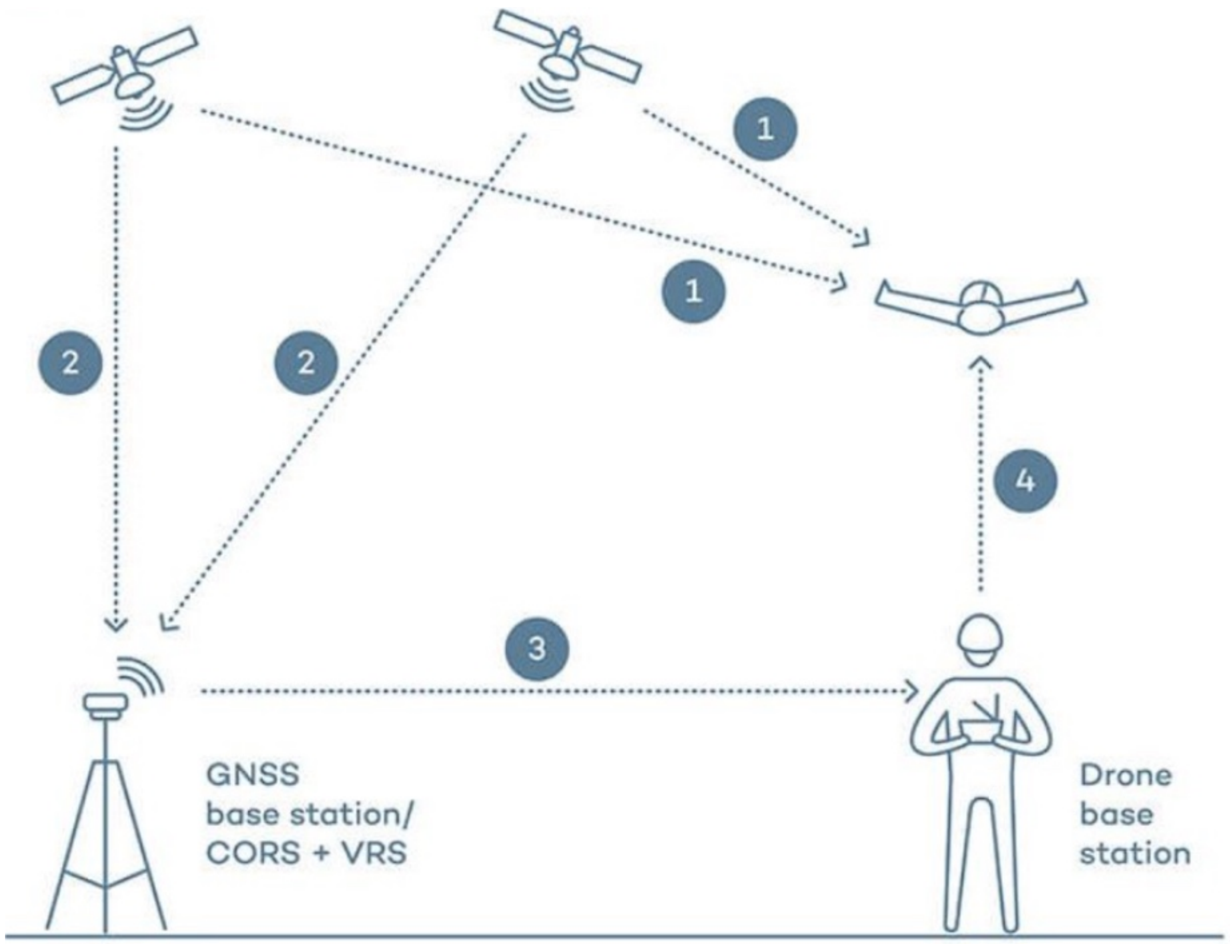


Surveying Methods

- Real-Time Kinematic (RTK)



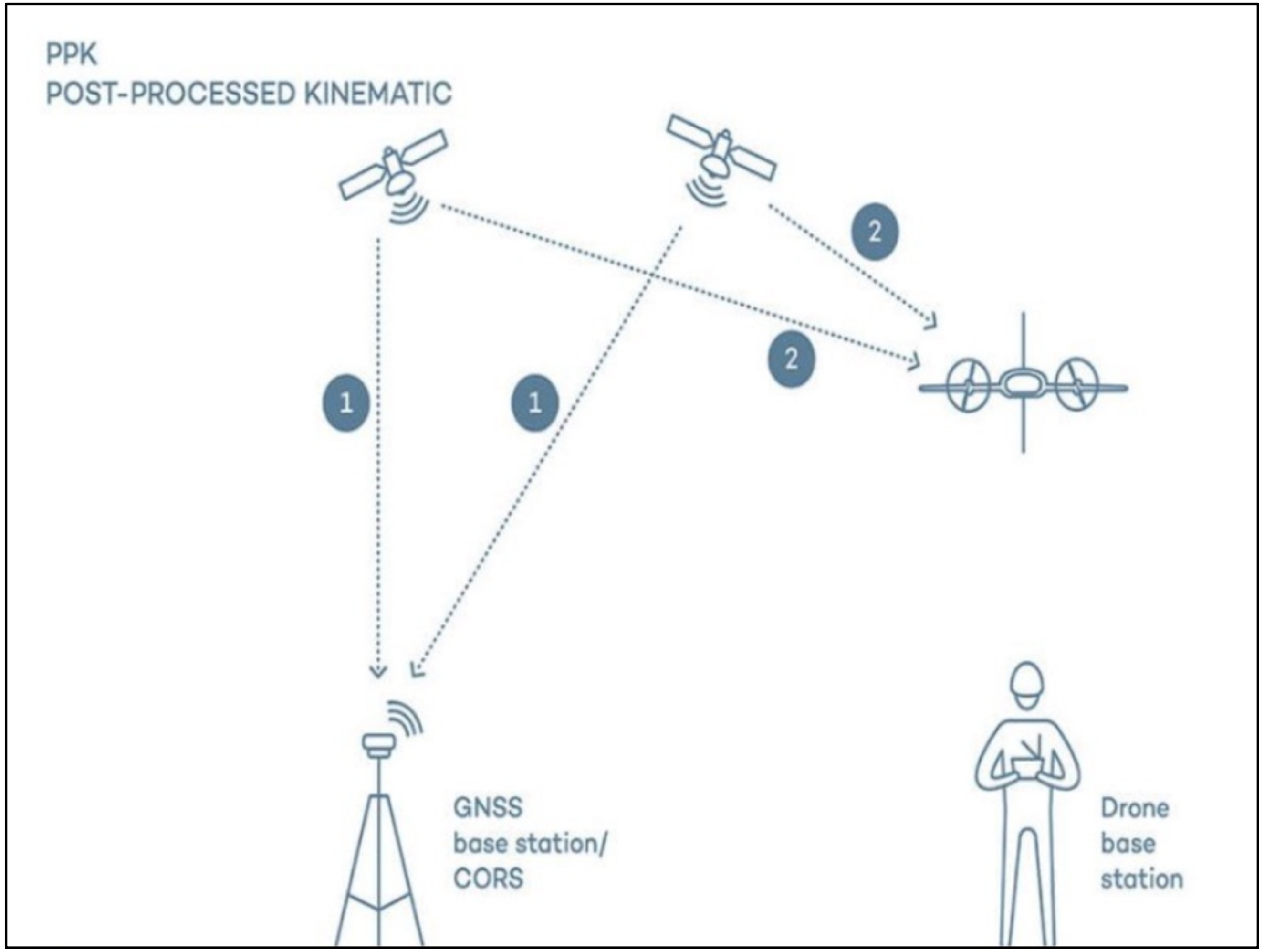
Source: GPS for Land Surveyors



Source: Jacob Stoner (2025)

Surveying Methods (Cont)

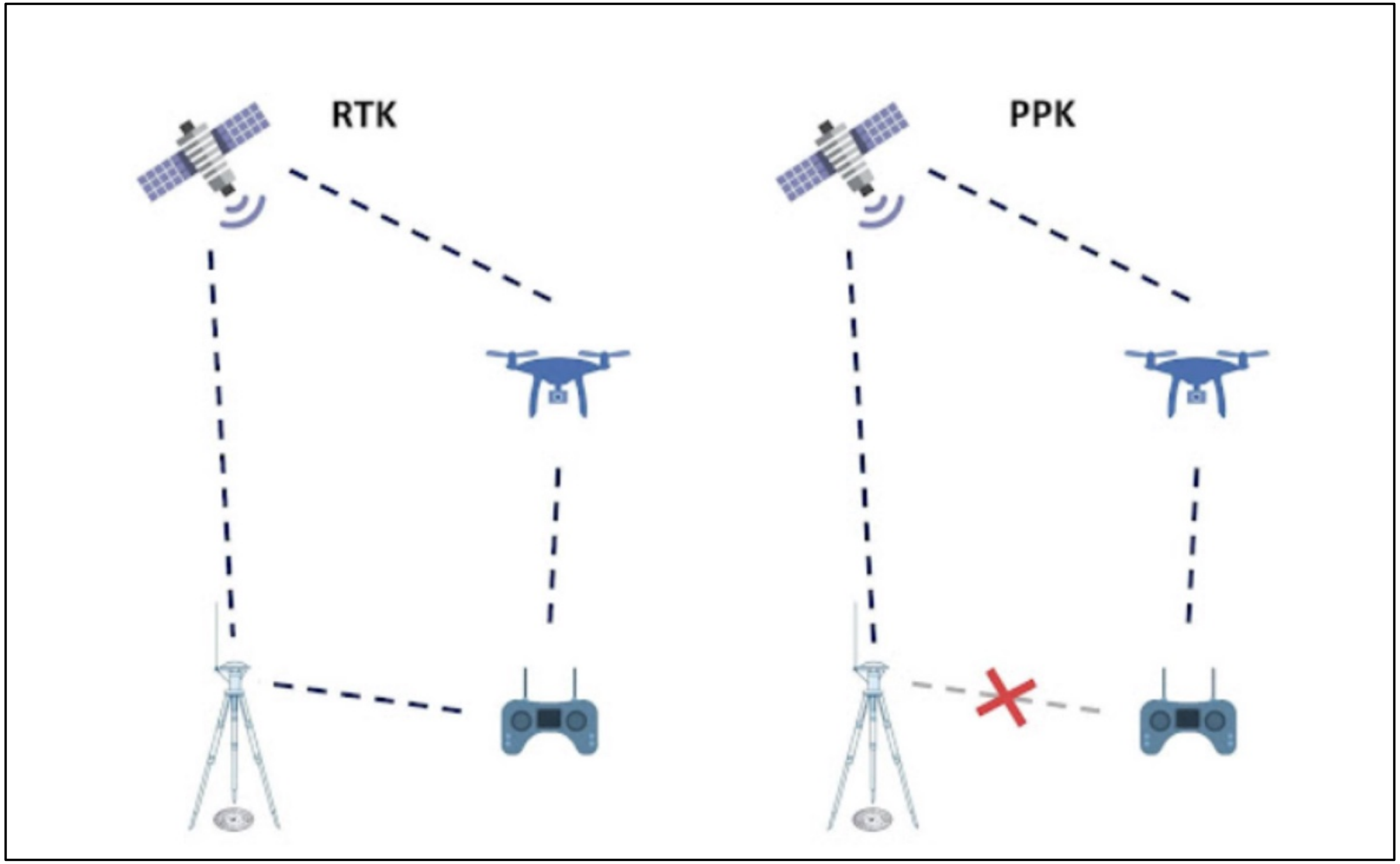
- Post-Processed Kinematic (PPK)



Source: Jacob Stoner (2025)

Surveying Methods (Cont)

- Overall, what is the distinction between RTK and PPK?



Source: DronEng Drones and Engineering (2024)

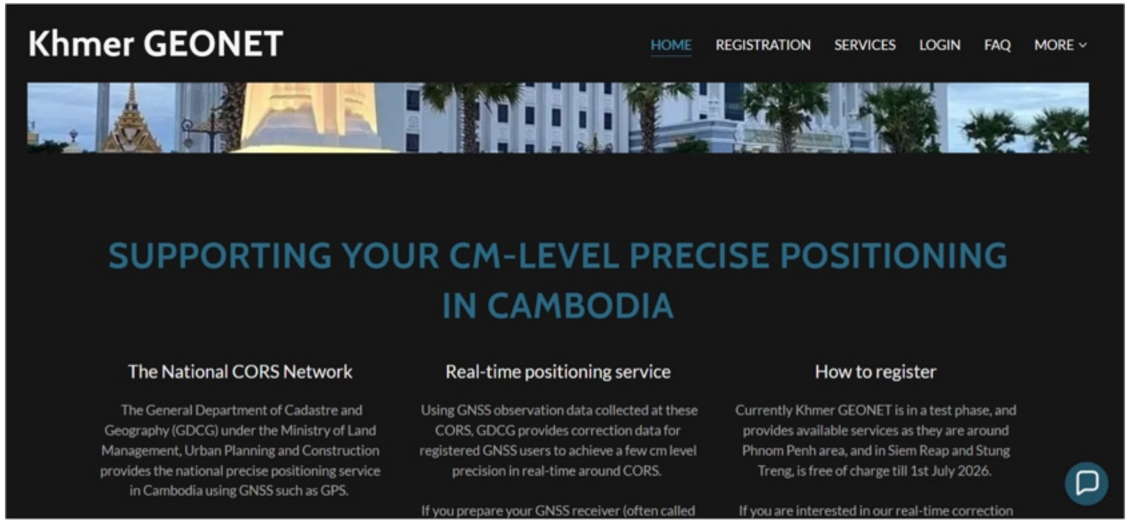
Surveying Equipment

- UAV: DJI M350 RTK Enterprise with L2 Sensor
- DGPS: Trimble R8s
- CORS: Khmer GEONET

DJI M350 RTK Enterprise

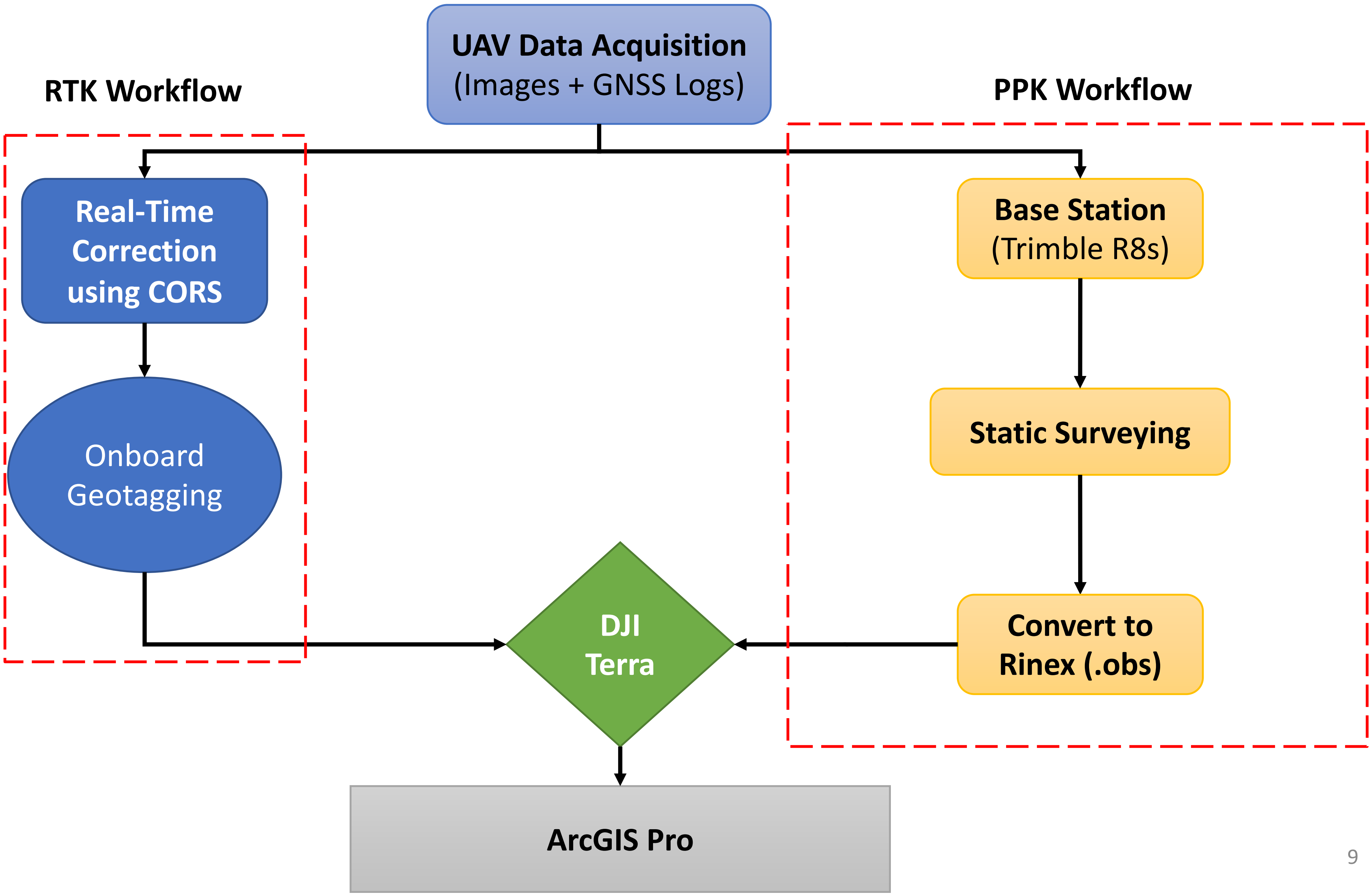
Trimble R8s

DJI Zenmuse L2



CORS

Diagram Workflow



Data Acquisition

Base Setup

Base Static Surveying

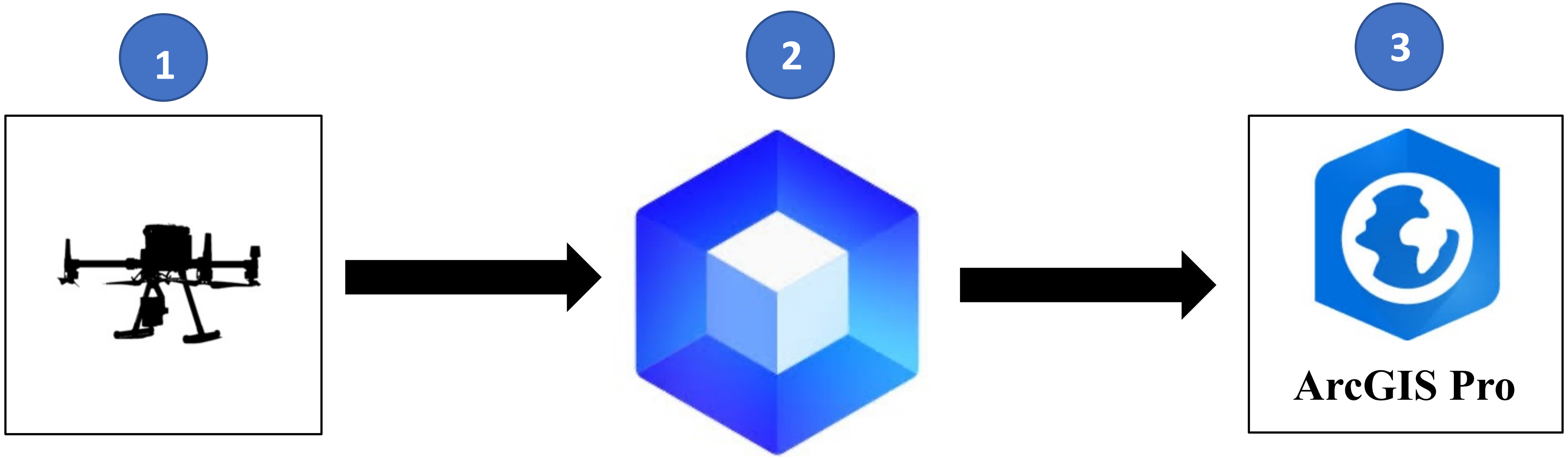
Drone Setup

GCPs&CPs Surveying

Data Processing

- Real-Time Kinematic (RTK)

With the RTK method, users can obtain accurately georeferenced drone data that can be processed in DJI Terra without concerns about uncorrected positional errors by following these simple steps.



DATA from DJI M350 RTK

Image Processing
DJI Terra

Visualizing/ Analysis

Data Processing (Cont)

- Post Processing Kinematic (PPK)

Unlike RTK, the PPK workflow requires an additional processing step, where GNSS data from the drone and the static base station are combined to generate corrected geotagged photos.

1

DATA from DJI M350 RTK

2

Require Post-Processed file (.obs)

Image Processing
DJI Terra

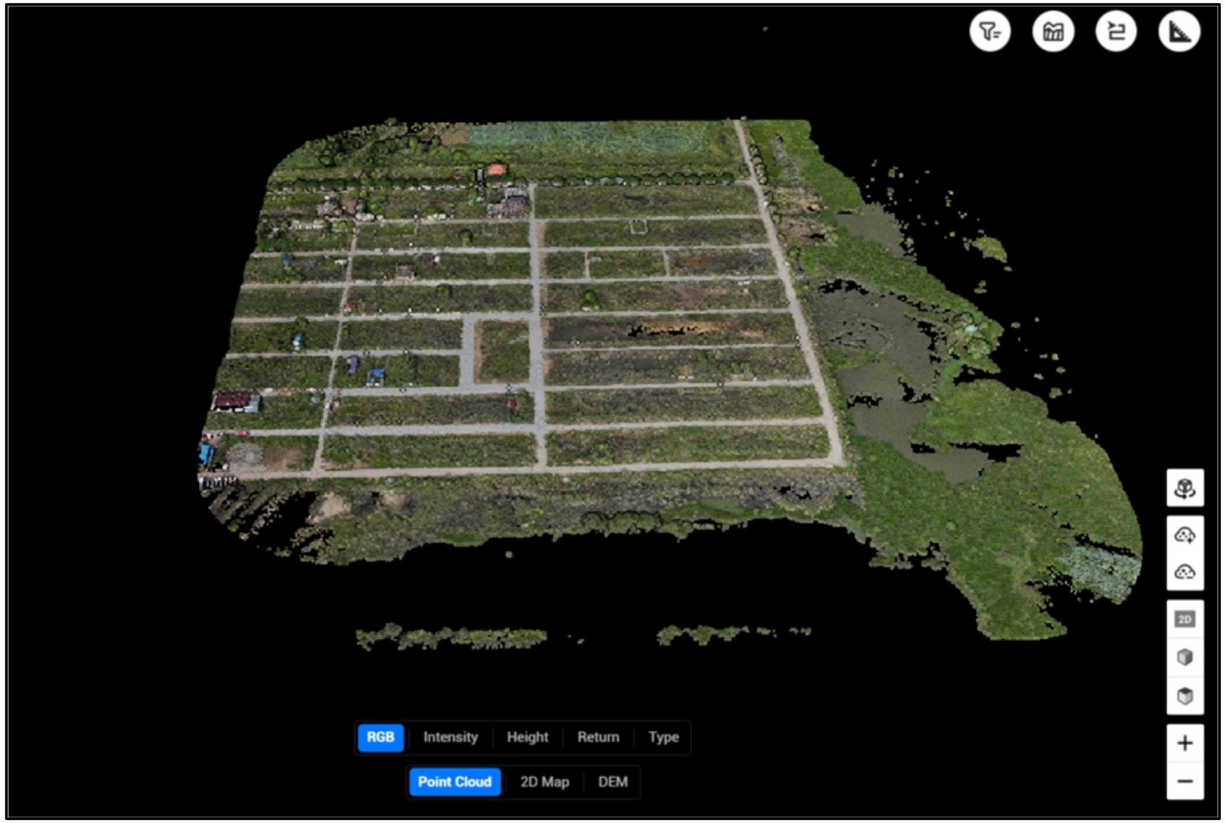
ArcGIS Pro

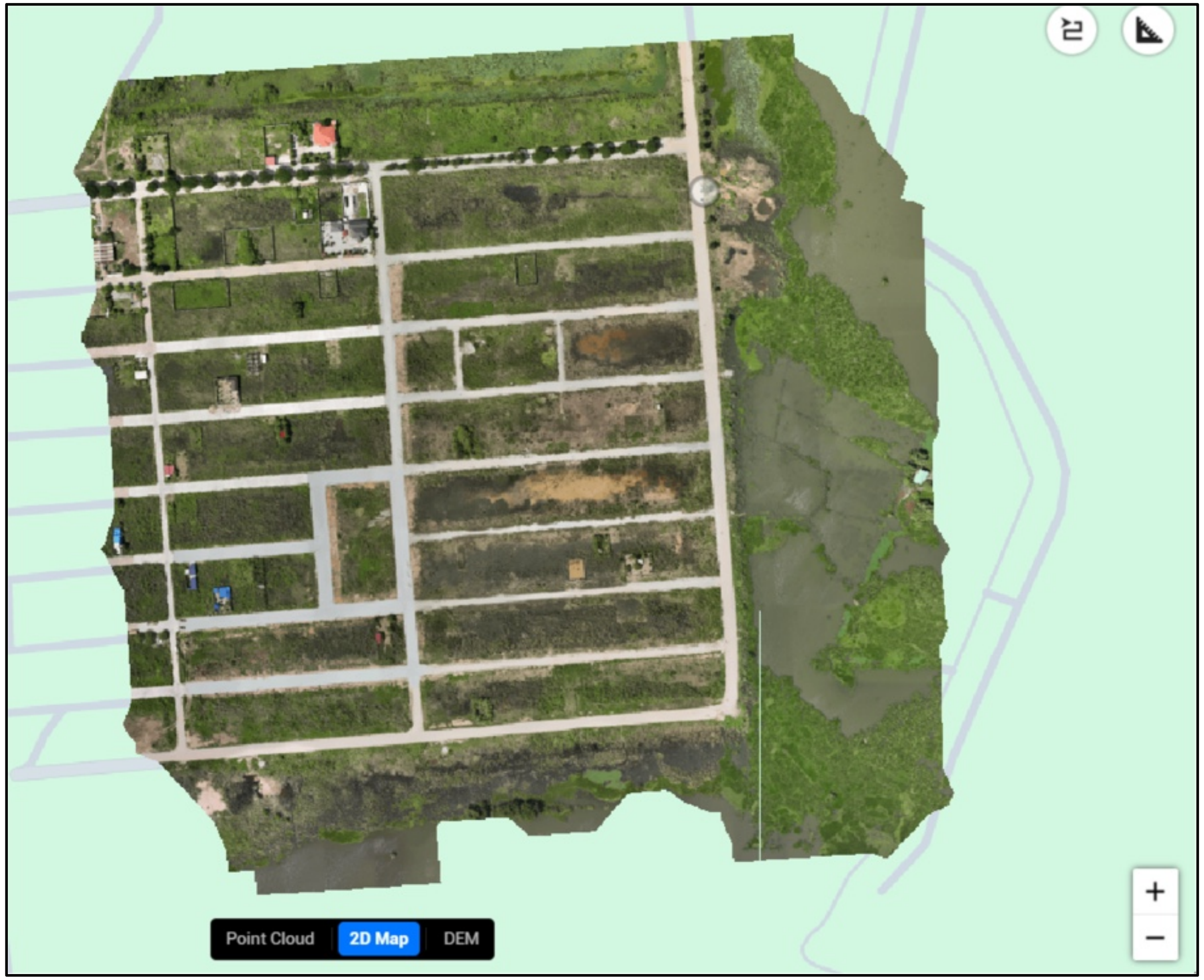
3

Visualizing/ Analysis

Findings

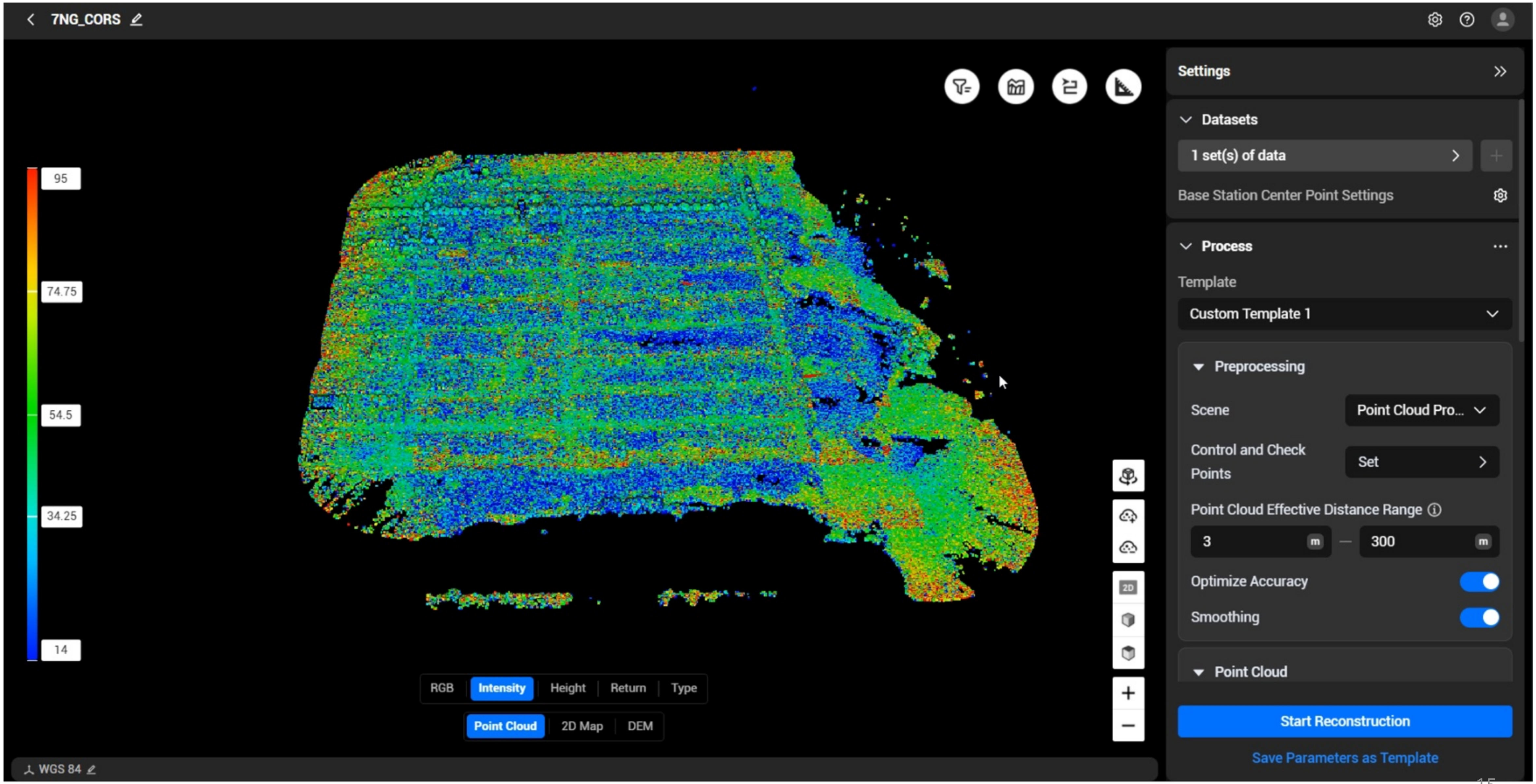
- LiDAR Products: Point Cloud, 2D Map, and DEM





Findings (Cont)

Findings (Cont)



Findings (Cont)

- The accuracy of the two methods is measured through the RMSE value. The smaller the value is, the accurate it will be.
- According to the ASPRS (2024), the formula can be followed:

$$\mathrm{RMSE_X} = \sqrt{\frac{1}{n}(X_{i(map)} - X_{i(surveyed)})^2} \quad (1)$$

$$\mathrm{RMSE_Y} = \sqrt{\frac{1}{n}(Y_{i(map)} - Y_{i(surveyed)})^2} \quad (2)$$

$$\mathrm{RMSE_Z} = \sqrt{\frac{1}{n}(Z_{i(map)} - Z_{i(surveyed)})^2} \quad (3)$$

$$\mathrm{RMSE_H} = \sqrt{RMSE_X{}^2 + RMSE_Y{}^2} \quad (4)$$

$$\mathrm{RMSE_T} = \sqrt{RMSE_H{}^2 + RMSE_Z{}^2} \quad (5)$$

Where $RMSE_X$, $RMSE_Y$, and $RMSE_Z$ are the root mean square errors in X, Y, and Z axes, respectively. $RMSE_H$ is the horizontal positional error, while $RMSE_T$ is the overall positional error. $X_{i\ (map)}$, $Y_{i\ (map)}$, and $Z_{i\ (map)}$ are the coordinates derived from the orthomosaic image. In contrast, $X_{i\ (surveyed)}$, $Y_{i\ surveyed)}$, and $Z_{i\ (surveyed)}$ are the coordinates obtained from DGPS surveying.

Findings (Cont)

Horizontal and Vertical Accuracy - PPK

Selected Camera Model

L2_12.3_5280x3956 (RGB) Edit...

Enabled	Image	Group	Latitude [degree]	Longitude [degree]	Altitude [m]	Accuracy Horz [m]	Accuracy Vert [m]	Omega [degree]	Phi [degree]	Kappa [degree]
☑	DJI_2025101712...	group1	11.62650098	104.99412780	198.077	0.006	0.018	180.00000	0.00000	-95.09882
☑	DJI_2025101712...	group1	11.62647280	104.99373051	198.180	0.006	0.018	180.00000	0.00000	-95.09873
☑	DJI_2025101712...	group1	11.62644692	104.99334683	198.182	0.006	0.018	180.00000	0.00000	-95.09866
☑	DJI_2025101712...	group1	11.62642015	104.99295632	198.148	0.006	0.018	180.00000	0.00000	-95.09858
☑	DJI_2025101712...	group1	11.62639356	104.99256938	198.120	0.006	0.018	180.00000	0.00000	-95.09850
☑	DJI_2025101712...	group1	11.62636757	104.99218491	198.144	0.006	0.018	180.00000	0.00000	-95.09842
☑	DJI_2025101712...	group1	11.62634169	104.99180055	198.147	0.006	0.018	180.00000	0.00000	-95.09835
☑	DJI_2025101712...	group1	11.62631515	104.99141358	198.149	0.007	0.019	180.00000	0.00000	-95.09827
☑	DJI_2025101712...	group1	11.62628767	104.99102649	198.171	0.007	0.019	180.00000	0.00000	-95.19819
☑	DJI_2025101712...	group1	11.62626130	104.99063500	198.207	0.007	0.019	180.00000	0.00000	-95.19811

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Findings (Cont)

Absolute Geolocation Variance
and Relative Geolocation Variance - PPK

Absolute Geolocation Variance

Min Error [m]	Max Error [m]	Geolocation Error X [%]	Geolocation Error Y [%]	Geolocation Error Z [%]
-	-0.01	0.00	0.00	0.00
-0.01	-0.01	0.00	0.00	0.00
-0.01	-0.01	0.00	0.00	0.74
-0.01	-0.01	0.00	0.00	6.62
-0.01	-0.00	0.00	0.00	11.76
-0.00	0.00	47.06	49.26	30.88
0.00	0.00	52.94	50.74	28.68
0.00	0.01	0.00	0.00	16.18
0.01	0.01	0.00	0.00	5.15
0.01	0.01	0.00	0.00	0.00
0.01	0.01	0.00	0.00	0.00
0.01	-	0.00	0.00	0.00
Mean [m]		-0.000000	-0.000001	0.000027
Sigma [m]		0.000179	0.000168	0.003542
RMS Error [m]		0.000179	0.000168	0.003542

Min Error and Max Error represent geolocation error intervals between -1.5 and 1.5 times the maximum accuracy of all the images. Columns X, Y, Z show the percentage of images with geolocation errors within the predefined error intervals. The geolocation error is the difference between the initial and computed image positions. Note that the image geolocation errors do not correspond to the accuracy of the observed 3D points.

Relative Geolocation Variance

Relative Geolocation Error	Images X [%]	Images Y [%]	Images Z [%]
[-1.00, 1.00]	100.00	100.00	100.00
[-2.00, 2.00]	100.00	100.00	100.00
[-3.00, 3.00]	100.00	100.00	100.00
Mean of Geolocation Accuracy [m]	0.003339	0.003339	0.009292
Sigma of Geolocation Accuracy [m]	0.000062	0.000062	0.000398

Images X, Y, Z represent the percentage of images with a relative geolocation error in X, Y, Z

Findings (Cont)

Horizontal and Vertical Accuracy – RTK (CORS)

Selected Camera Model

L2_12.3_5280x3956 (RGB)

Edit...

Enabled	Image	Group	Latitude [degree]	Longitude [degree]	Altitude [m]	Accuracy Horz [m]	Accuracy Vert [m]	Omega [degree]	Phi [degree]	Kappa [degree]
	DJI_2025101713...	group1	11.62648206	104.99412489	197.956	0.011	0.022	180.00000	0.00000	-95.09881
	DJI_2025101713...	group1	11.62645414	104.99372358	198.069	0.010	0.021	180.00000	0.00000	-94.89874
	DJI_2025101713...	group1	11.62642742	104.99333406	198.086	0.010	0.020	180.00000	0.00000	-94.79866
	DJI_2025101713...	group1	11.62640075	104.99294869	198.037	0.010	0.020	180.00000	0.00000	-94.79858
	DJI_2025101713...	group1	11.62637456	104.99255847	198.035	0.010	0.020	180.00000	0.00000	-94.79850
	DJI_2025101713...	group1	11.62634767	104.99216650	198.018	0.010	0.020	180.00000	0.00000	-94.79842
	DJI_2025101713...	group1	11.62632092	104.99177928	198.018	0.009	0.019	180.00000	0.00000	-94.79835
	DJI_2025101713...	group1	11.62629442	104.99138836	198.019	0.009	0.019	180.00000	0.00000	-94.79827
	DJI_2025101713...	group1	11.62626744	104.99099703	198.031	0.009	0.019	180.00000	0.00000	-94.79819
	DJI_2025101713...	group1	11.62624125	104.99060903	198.067	0.009	0.019	180.00000	0.00000	-94.79811

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Findings (Cont)

Absolute Geolocation Variance and Relative Geolocation Variance – RTK (CORS)

Absolute Geolocation Variance

Min Error [m]	Max Error [m]	Geolocation Error X [%]	Geolocation Error Y [%]	Geolocation Error Z [%]
-	-0.03	0.00	0.00	0.00
-0.03	-0.03	0.00	0.00	0.00
-0.03	-0.02	0.00	0.00	1.48
-0.02	-0.01	0.00	0.00	2.22
-0.01	-0.01	0.00	0.00	14.07
-0.01	0.00	56.30	56.30	28.89
0.00	0.01	43.70	43.70	33.33
0.01	0.01	0.00	0.00	17.78
0.01	0.02	0.00	0.00	1.48
0.02	0.03	0.00	0.00	0.00
0.03	0.03	0.00	0.00	0.74
0.03	-	0.00	0.00	0.00
Mean [m]		-0.000003	0.000002	0.000063
Sigma [m]		0.001023	0.001068	0.008013
RMS Error [m]		0.001023	0.001068	0.008013

Min Error and Max Error represent geolocation error intervals between -1.5 and 1.5 times the maximum accuracy of all the images. Columns X, Y, Z show the percentage of images with geolocation errors within the predefined error intervals. The geolocation error is the difference between the initial and computed image positions. Note that the image geolocation errors do not correspond to the accuracy of the observed 3D points.

Relative Geolocation Variance

Relative Geolocation Error	Images X [%]	Images Y [%]	Images Z [%]
[-1.00, 1.00]	100.00	100.00	97.04
[-2.00, 2.00]	100.00	100.00	100.00
[-3.00, 3.00]	100.00	100.00	100.00
Mean of Geolocation Accuracy [m]	0.009075	0.009075	0.018315
Sigma of Geolocation Accuracy [m]	0.000414	0.000414	0.000920

Findings (Cont)

- The accuracy of the two methods is measured through the RMSE value. The smaller the value is, the accurate it will be.

Surveying Method	RMSE X (m)	RMSE Y (m)	RMSE Z (m)
PPK	0.000179	0.000168	0.000168
RTK-CORS	0.001023	0.001068	0.008013

Findings (Cont)

Accuracy Statistics of the UAV-derived and Surveyed Points (GCPs and CPs) - PPK									
Poit ID	Orthomosaic-derived Values			Surveyed GCPs/CPs Values			Residual Error		
	Easting - E (m)	Northing - Y (m)	Easting - Z (m)	Easting - E (m)	Northing - Y (m)	Easting - Z (m)	ΔE (m)	ΔY (m)	ΔZ (m)
GCP1	499278.172	1285155.602	10.283	499278.201	1285155.567	10.287	-0.029	0.035	-0.004
GCP2	499028.548	1285084.208	10.225	499028.552	1285084.245	10.228	-0.004	-0.038	-0.003
GCP3	499088.598	1285030.259	10.073	499088.579	1285030.141	10.078	0.018	0.118	-0.005
GCP4	499282.931	1285097.819	9.998	499282.919	1285097.881	10.010	0.012	-0.062	-0.012
					Sum		-0.003	0.053	-0.024
					Mean Error (m)		-0.0008	0.0133	-0.0060
					Standard Deviation (m)		0.0212	0.0808	0.0041
					RMSE (H,V) (m)		0.0735		0.0070
					RMSETotal (m)		**0.074**		
CP1	499268.815	1285146.080	9.765	499268.849	1285145.831	9.768	-0.034	0.248	-0.003
CP2	499231.449	1285172.915	9.651	499231.539	1285172.929	9.656	-0.090	-0.014	-0.005
CP3	499045.188	1285157.192	9.474	499045.171	1285157.199	9.581	0.017	-0.007	-0.107
CP4	499089.435	1285003.397	9.759	499089.542	1285003.412	9.762	-0.107	-0.015	-0.003
					Sum		-0.106	0.227	-0.115
					Mean Error (m)		0.027	0.057	-0.029
					Standard Deviation (m)		0.0566	0.1304	0.0517
					RMSE (H,V) (m)		0.1443		0.0536
					RMSETotal (m)		**0.1539**		

Findings (Cont)

Accuracy Statistics of the UAV-derived and Surveyed Points (GCPs and CPs) - RTK (CORS)									
Poit ID	Orthomosaic-derived Values			Surveyed GCPs/CPs Values			Residual Error		
	Easting - E (m)	Northing - Y (m)	Easting - Z (m)	Easting - E (m)	Northing - Y (m)	Easting - Z (m)	ΔE (m)	ΔY (m)	ΔZ (m)
GCP1	499278.108	1285155.673	10.444	499278.201	1285155.567	10.287	-0.093	0.106	0.157
GCP2	499028.688	1285084.139	10.535	499028.552	1285084.245	10.228	0.135	-0.106	0.307
GCP3	499088.590	1285030.248	10.317	499088.579	1285030.141	10.078	0.011	0.107	0.239
GCP4	499282.976	1285097.829	10.221	499282.919	1285097.881	10.010	0.057	-0.052	0.211
					Sum		0.110	0.055	0.916
					Mean Error (m)		0.0275	0.0139	0.2289
					Standard Deviation (m)		0.0954	0.1094	0.0625
					RMSE (H,V) (m)		0.1295		0.2352
					RMSETotal (m)		**0.2685**		
CP1	499268.878	1285145.680	9.790	499268.849	1285145.831	9.768	0.029	-0.151	0.022
CP2	499231.600	1285172.800	9.780	499231.539	1285172.929	9.656	0.061	-0.129	0.124
CP3	499045.230	1285157.107	9.585	499045.171	1285157.199	9.581	0.059	-0.092	0.004
CP4	499089.650	1285003.550	9.778	499089.542	1285003.412	9.762	0.108	0.138	0.016
					Sum		0.257	-0.234	0.166
					Mean Error (m)		0.064	-0.058	0.041
					Standard Deviation (m)		0.0326	0.1332	0.0555
					RMSE (H,V) (m)		0.1472		0.0635
					RMSETotal (m)		**0.1603**		

Conclusion

- The RMSE Total values obtained from PPK are smaller than the RMSE Total values obtained from RTK (CORS). These values were obtained from the coordinates of surveyed points (GCPs and CPs).
- Therefore, PPK yields better results than RTK, as evidenced by the accuracy indicators.
- For challenging and low-internet connection areas, PPK is an appropriate method to adopt.

Conclusion (Cont)

Criteria	**RTK (Real-Time Kinematic)**	**PPK (Post-Processing Kinematic)**
Accuracy	High, but depends on real-time signal	Very high and more consistent
Workflow Speed	Faster, immediate geotagging	Slower due to post-processing
Reliability	Can fail with signal loss	Highly reliable, independent of live signal
Connectivity Required	Yes (NTRIP/Base Radio)	No live connection required
Field Requirements	Strong mobile/radio coverage	Base station setup + logging
Best Use Cases	Quick surveys with good signal	High-precision surveys or challenging environments
Extra Software Needed	No	Yes
Risk of Position Errors	Medium (if signal unstable)	Low (post-processed corrections)

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Thank you for your attention!