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Paper 7505: Converting Digital Number Into Bathymetric Depth: A Case Study Over Coastal And Shallow Water Of Langkawi Island, Malaysia

Kelvin Tang Kang Wee
Biswajeet Pradhan

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Contents

Hydrographic Surveying …..

Hydrographic Surveying is defined as

"That branch of applied sciences which deals with the ***measurement*** *and* ***description*** *of the features of the* ***sea and coastal areas*** *for the primary purpose of navigation and all other marine purposes and activities, including –inter alia- offshore activities, research, protection of the environment, and prediction services."*

(IHO Pub. S32, 1994)

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- In strict sense, it is defined as the **surveying of a water area**.
- However, in modern usage it may include a wide variety of other objective such as **measurements of tides, current, gravity, earth magnetism and determination of the physical and chemical properties of water**.
- Nevertheless, the principle objective of most Hydrographic Surveying is to obtain basic data for bathymetric surveying projects and **compilation of nautical charts** with emphasis on the features that may affect **safe navigation**.

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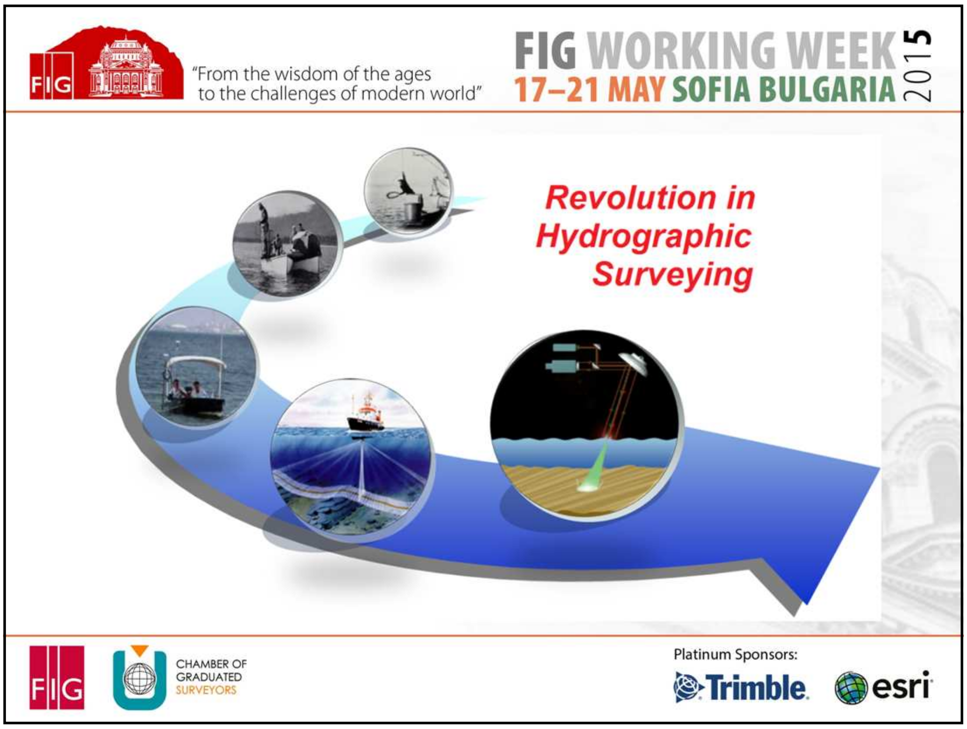
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Revolution in
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Surveying
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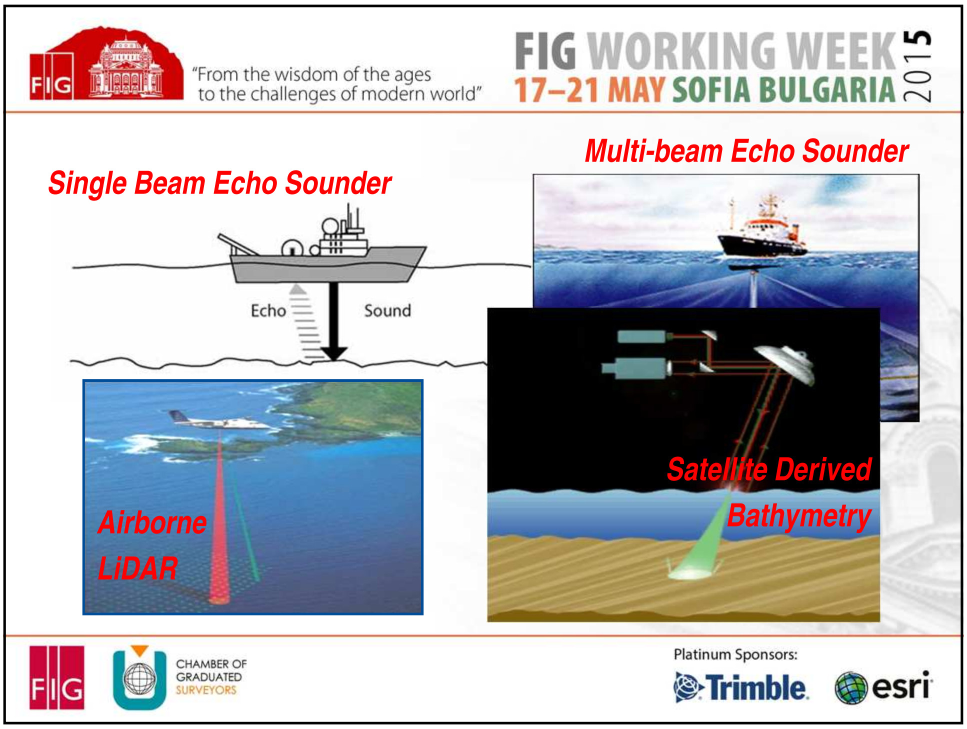
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Single Beam Echo Sounder
Echo
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Multi-beam Echo Sounder
Airborne
LiDAR
Satellite Derived
Bathymetry
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Problem statements

The vessel-based echo sounding methods applied nowadays constrained by limited ground coverage, difficulties to access shallow coastal water, labour intensive and high operating cost which significantly limits the frequent repetitions.

Due to the complicatedness in acquired the accurate and well-distributed spatial sounding data, a robust method of deriving the bathymetric data directly from the passive optically sensed satellite imagery would **enhance** the capability to map the seabed topography.

Objectives

- To study the **usability of satellite-derived bathymetric mapping** and **identify the appropriate channel** of Landsat 8 multispectral satellite data to be used in extracting bathymetric information.
- To **product bathymetry map** of the study area from multispectral Landsat 8 multispectral satellite image.
- To analyse remotely sensed data to provide an **accurate and cost-effective alternative** to the classical techniques for bathymetric mapping.

to map the coastal and shallow water areas in remote sensing and GIS environment

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Literature Review

- The **fundamental principle** of deriving sea bed information for bathymetric mapping using optical remote sensing is that **light** (visible wavelengths) which can **penetrate the water column** in various degrees.
- The **measured radiance** is closely related to the **incoming solar radiation**, **attenuation of radiation in and out of the atmosphere and water column**, **reflectance properties of the sea bed** as well as the **water depth**.

Satellite-Derived Bathymetry

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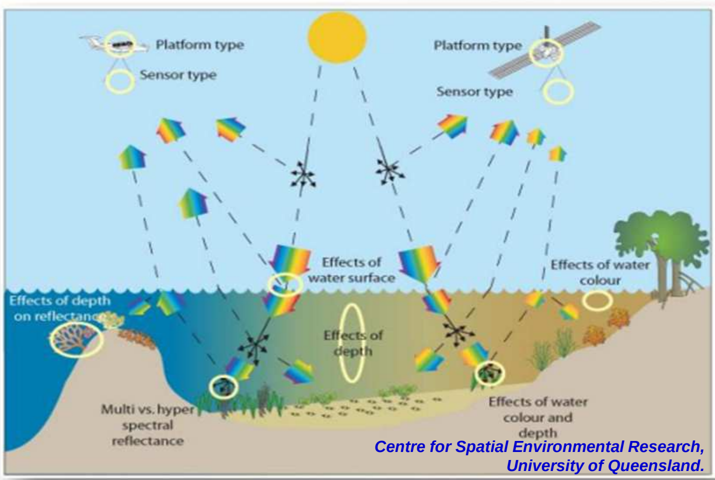

Centre for Spatial Environmental Research, University of Queensland.

Satellite-Derived Bathymetry

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- The methods of extracting the sea bed information over clear shallow water from the satellite imagery was first addressed by **Lyzenga (1978)**, and later on was expended and further explore by **Benny and Dawson (1983)**, **Spitzer and Driks (1987)**, **Jupp (1988)**, **Philpot (1989)**, **Bierwirth (1993)**, **Maritorena et al. (1994)** and **Stumpf et al. (2003)**.
- Though remarkable efforts, a wide fusion of bathymetry retrieval algorithms have been developed as well as empirical models have been established to form the statistical relationship between image pixels values and water depth values.

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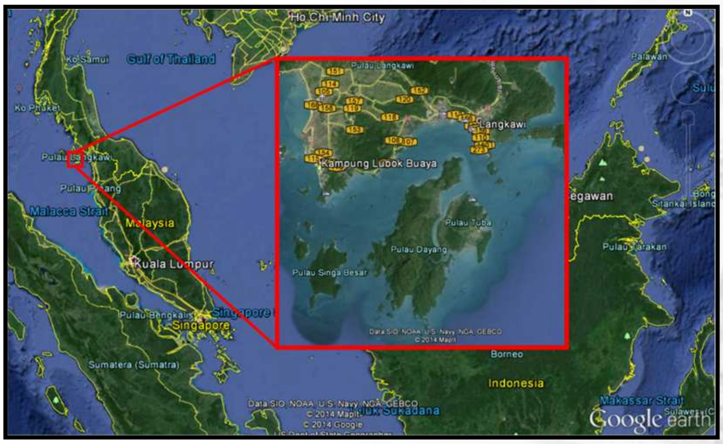
Study Area



Langkawi Island, Malaysia

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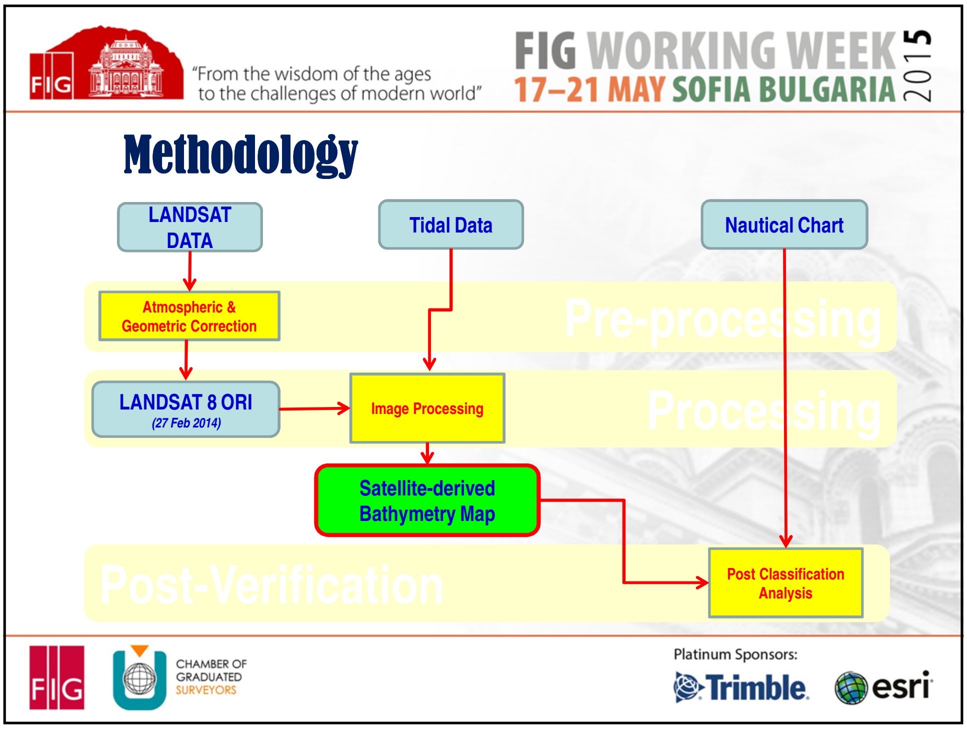
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Methodology
LANDSAT DATA
Tidal Data
Nautical Chart
Atmospheric & Geometric Correction
Pre-processing
LANDSAT 8 ORI
(27 Feb 2014)
Image Processing
Processing
Satellite-derived Bathymetry Map
Post-Verification
Post Classification Analysis
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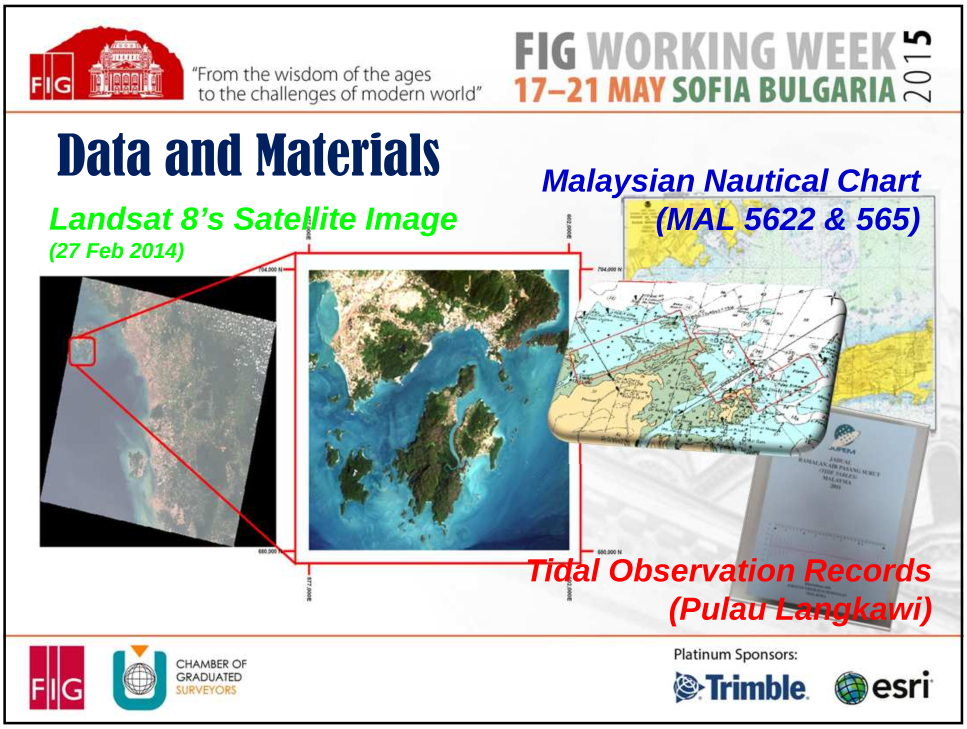
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Data and Materials
Landsat 8's Satellite Image
(27 Feb 2014)
Malaysian Nautical Chart
(MAL 5622 & 565)
Tidal Observation Records
(Pulau Langkawi)
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Procedure and Data Generation

- **Radiometric and Atmospheric Correction.**
- **Geometric Correction.**
- **Spatial Sub-setting**.
- **Deriving Satellite Bathymetry**.
- **Bathymetry Accuracy Assessment**

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Radiometric and Atmospheric Correction

- **Radiometric correction** allows us to **convert** the raw image digital value (DNs) to **spectral radiance (L_λ)** using the **Spectral Radiance Scaling Method's** equation:

$$L_\lambda = \left(\frac{Lmax_\lambda - Lmin_\lambda}{QCALmax - QCALmin}\right) * (QCAL - QCALmin) + Lmin_\lambda$$

- In order to generate the **reflectance** data, the spectral radiance values need to be converted into Top-of-Atmosphere **(ToA) reflectance value (P_λ)**.

$$P_\lambda' = M_\rho * Q_{cal} + A_\rho$$

$$P_\lambda = P_\lambda' / \cos\theta_{SZ} = P_\lambda' / \sin\theta_{SE}$$

(http://landsat.usgs.gov/Landsat8_Using_Product.php)

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Geometric Correction

- In this case, the selected Landsat 8 multispectral images of the study area was geo-referenced to the MAL Chart by selecting a sufficient number of Ground Control Points (GCPs) which were widely scattered throughout the area of study.
- A numbers of GCPs which were easily identifiable had been selected to conduct the 1st order polynomial wrapping function using the Nearest Neighbour re-sampling method

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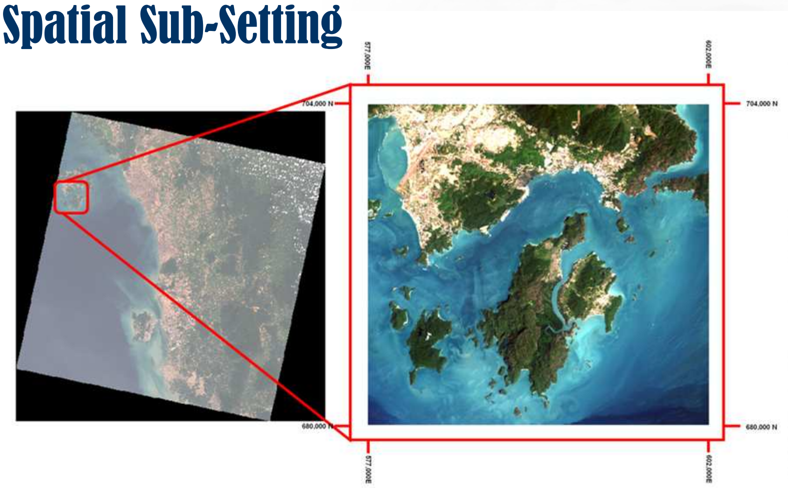
Spatial Sub-Setting



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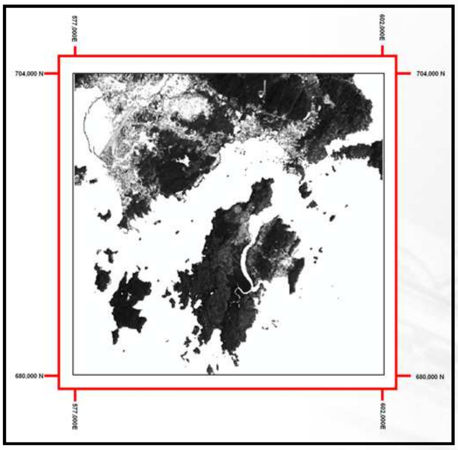

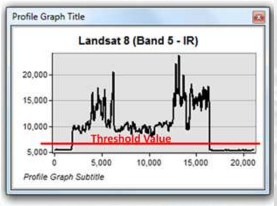

Dry Land Areas extracted from the Landsat 8 (Band 5)

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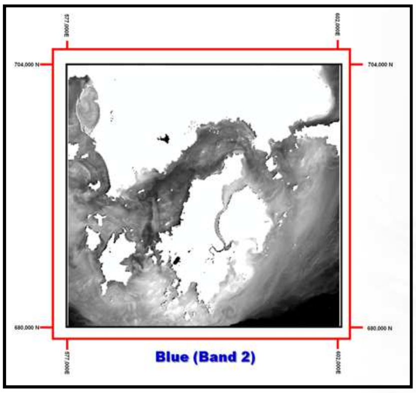

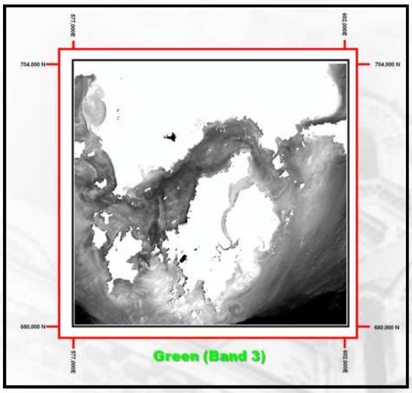

Extracted of Water Surface area

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Deriving Satellite Bathymetry

- An optically-derived bathymetry algorithm based on **ratio of two bands** was employed to produce bathymetric map.
- **Stumpf et al. (2003) model** to map the shallow water bathymetry of study area:

$$Z = m_1 * \left(\frac{\ln(nR_w(\lambda_i)}{\ln(nR_w(\lambda_j)} \right) - m_0$$

- The water depth was extracted using a the corrected reflectance dataset from **Band 2 (blue)** and **Band 3 (green)**.

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Bathymetry Accuracy Assessment

- In this case, the geo-referenced MALs were being used to conduct the accuracy assessment of the satellite-derived bathymetric data. **50 depths** ranged from -0.5 to 20.8m were adopted from the MALs.
- The extracted water depth points were used for further modal calibration and data verification. **Root Mean Square Error (RMSE) Test** was used to evaluate the satellite-derived bathymetry accuracy.
- The **correlation coefficient (r^2)** based on the regression model between the satellite-derived bathymetric data and bathymetric data extracted from MALs were examined.

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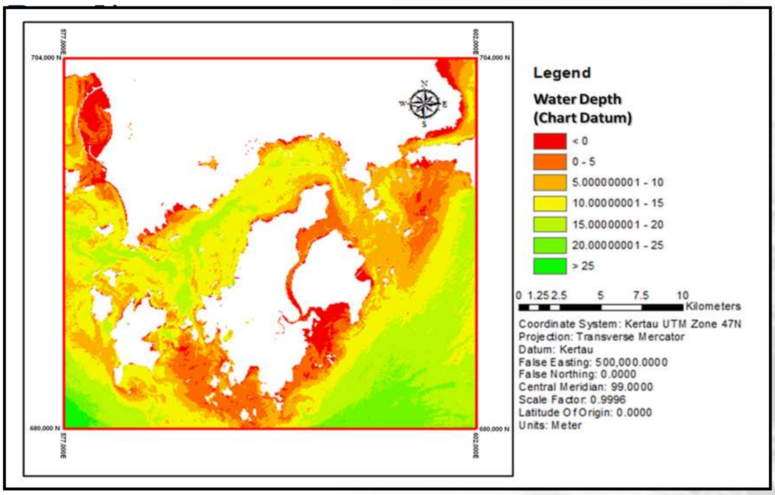

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Results & Discussions

- Based on the data quality assessment done across the checking area, the uncertainties were ranged from **-3.18m to 3.76m**.
- Apparently, the **highest RMSE** recorded was of **3.758m**, while the **lowest RMSE** was of **0.024m**.
- **Total RMSE** calculated based on the endorsed 50 reference points was **1.521m**.

No.	Easting (E)	Northing (N)	Checking Depth (m)	Estimated Depth (m)	Uncertainty (m)	RMSE (m)
1	642,810.29	605,012.85	-0.50	0.20524753	-0.71	0.705
2	643,158.22	604,794.57	-0.40	0.72823155	-1.13	1.128
3	644,284.02	604,676.83	-0.20	-1.65553204	1.46	1.456
4	644,108.54	604,904.87	-0.10	-1.80660283	1.71	1.707
5	643,922.87	604,770.76	0.40	-0.15392479	0.55	0.554
6	644,051.53	605,142.48	0.60	0.09846657	0.50	0.502
7	644,828.21	604,418.04	0.90	1.60978118	-0.71	0.710
8	643,526.45	604,703.79	1.10	1.61342144	-0.51	0.513
9	642,694.09	605,314.42	1.40	0.93208611	0.47	0.468
10	645,103.37	604,487.89	3.40	3.69868371	-0.30	0.299
11	644,225.10	605,332.98	3.40	4.36970497	-0.97	0.970
12	643,516.01	605,690.69	3.60	5.26217538	-1.66	1.662
13	643,937.23	605,642.01	3.90	5.36774292	-1.47	1.468
14	646,724.89	603,328.49	5.00	7.16481794	-2.16	2.165
15	643,344.56	605,942.58	5.00	8.07488294	-3.07	3.075
16	644,532.95	605,404.38	5.50	5.37563015	0.12	0.124
17	646,288.71	604,822.32	5.60	6.45314711	-0.85	0.853
18	645,477.30	604,869.98	5.70	6.95125602	-1.25	1.251
19	646,796.85	603,715.84	6.30	6.95368286	-0.65	0.654
20	645,152.08	605,539.31	6.30	8.70100766	-2.40	2.401
21	644,595.51	606,073.81	6.70	9.87681164	-3.18	3.177
22	646,484.04	604,672.86	7.50	5.03405242	2.47	2.466
23	646,178.64	604,917.57	7.60	10.3033288	-2.70	2.703
24	644,946.88	606,323.58	7.80	6.61392526	1.19	1.186
25	645,376.57	606,317.23	8.00	9.55828889	-1.56	1.558
26	647,448.79	603,601.54	8.00	9.84344259	-1.84	1.843
27	645,962.88	606,387.08	8.60	5.34408123	3.26	3.256
28	646,490.87	605,160.96	8.80	6.91424671	1.89	1.886
29	649,156.34	604,766.79	10.00	6.24201203	3.76	3.758
30	647,075.38	604,651.70	10.40	12.3236731	-1.92	1.924
31	646,513.22	606,433.65	11.20	12.1914103	-0.99	0.991
32	646,807.44	606,037.83	11.40	10.7626082	0.64	0.637
34	649,991.10	605,015.50	11.80	12.7744586	-0.97	0.974
35	649,770.78	605,375.31	11.80	12.7744586	-0.97	0.974
33	647,186.73	605,372.63	11.80	13.8713903	-2.07	2.071
36	649,499.84	605,760.54	12.20	10.6685682	1.53	1.531
37	649,305.11	605,019.71	12.30	14.3021544	-2.00	2.002
38	650,206.73	604,148.99	12.50	10.3997957	2.10	2.100
39	649,281.82	605,527.71	13.00	9.825848	3.17	3.174
40	647,390.46	606,124.04	14.40	14.8591142	-0.46	0.459
41	647,988.42	606,153.15	14.50	15.4081867	-0.91	0.908
42	647,857.23	604,998.30	14.90	11.8486191	3.05	3.051
43	648,816.56	605,512.86	15.70	15.9311707	-0.23	0.231
44	647,880.59	605,502.31	16.60	16.5378807	0.06	0.062
45	650,012.08	603,597.31	17.60	17.6244983	-0.02	0.024
46	649,834.28	604,153.99	18.00	14.5612195	3.44	3.439
47	648,813.92	606,057.90	18.50	18.9574402	-0.46	0.457
48	649,575.70	604,610.69	19.60	18.5333499	1.07	1.067
49	648,354.65	605,049.90	19.70	16.7429487	2.96	2.957
50	648,419.69	605,557.83	20.00	17.4697873	2.53	2.530

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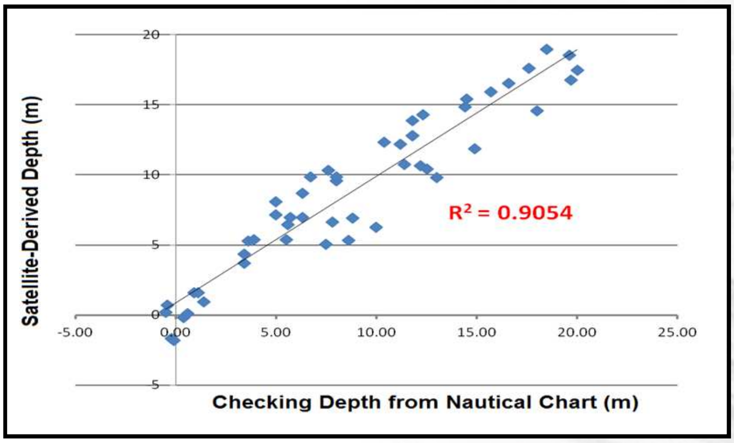
Results & Discussions



Correlation Coefficient (r^2) between Satellite-Derived Depth and Endorsed Depth

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Conclusions and Major Findings

The study was carried out to evaluate the use of satellite-derived bathymetry to map the coastal and shallow water areas in remote sensing and GIS environment. In the completion of this study, the following **research objectives were successfully achieved**:

1. To check the usability of satellite-derived bathymetric mapping and to identify the appropriate channels of Landsat 8 multispectral satellite data to be used in extracting bathymetry information.
2. To produce bathymetry map of the study area from Landsat 8 multispectral satellite image.
3. To analysis of remotely sensed data to provide an accurate and cost-effective alternative to the classical techniques for bathymetric mapping.

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Conclusions and Major Findings

Although this study had indicated that the satellite-derived bathymetry method is able to map the shallow water, nonetheless, it is still **not recommended** to be the replacement for conventional vessel-based sonar sounding surveys.

Perhaps, the satellite-derived bathymetry can be an **alternative method** and **reconnaissance tool** in facilitating the increasingly demand of hydrographic surveying activities around the coastal region as well as the remote shallow water areas.

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