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Construction of Tidal Datums Based on Ellipsoid Using Spatial Interpolation

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Background and Purpose

- **Tidal Bench Marks are displayed in dots and laid only under tidal observation areas.**

※ Tidal bench marks in Korea are reference points that provide vertical datum

- **Height differences of tidal datums in each local area**
- **Getting the height information of a certain location without tidal bench mark**
- **Getting the height information by using GNSS without tidal observation**

- **Global trend of hydrography standard unification in an ellipsoid**

- **USA(V-Datum), UK(VORF): establishment of conversion system between tidal datum system and the ellipsoid**
- **2014 FIG publication No. 62: ellipsoid of tidal datums as official standard**
- **2016, IHO recommends to use the ellipsoid for observation standard of tidal and sea level**

Establishment of tidal datums in ellipsoid standard by using spatial interpolation

Method

- **Study Area**
  - Gyeong-gi Bay in Yellow Sea, Republic of Korea
  - Large differences in tides, irregular coastlines, diverse sea currents

<Dispersion of tidal bench marks>

- **Spatial Interpolation**
  - IDW(Inverse Distance Weighting), Kriging, Spline, Spline with Barrier
- **Experiment Data**
  - 67 tidal bench marks in 2016
  - Using the height from the ellipsoid level to local mean sea level
  - Spatial interpolation using ArcGIS Tool

- **Experiment of Parameter Selection**
  - **Repetition of cross validation that compares observed and expected values by using 67 tidal bench marks and excluding 1 each time**

<IDW>

Unit : cm

Power	RMSE
1	20.1379911
1.5	18.1539135
2	14.9404941
2.5	13.5309015
3	12.2002601
3.5	12.2959557
4	12.3266125

<Kriging>

Unit : cm

Parameter		RMSE
Ordinary	Spherical	9.7521530
	Circular	9.9383077
	Exponential	9.7523364
	Gaussian	10.0696171
	Linear	9.99108649
Universal	Linear with Linear drift	9.71221950
	Linear with Quadratic drift	12.1202543

<Spline>

Unit : cm

Parameter		RMSE
Regularized	0.1	20.137991
	0.2	14.940494
	0.3	12.200260
	0.4	12.026612
Tension	0.1	24.724587
	0.2	18.153913
	0.3	13.530901
	0.4	12.295955

<Spline with Barrier>

Unit : cm

Smoothing factor	RMSE
0.6	9.9445871
0.7	9.9104942
0.8	9.8945875
0.9	9.8050205
1.0	9.9023729

- **Spatial interpolation experiment and comparative validation (External verification)**
  - **Comparison between observed values after spatial interpolation**
  - **Excludes external verification results(7) among 67 tide bench marks**
    - ※ **External verification : verifies accuracy with unutilized points when modeling**

Unit : cm

Point	IDW	Kriging	Spline	Spline with Barrier
				
Deokjeokdo bukri	-15.19	0.89	0.76	-3.78
Jumun hang	-28.11	17.60	-19.02	-19.63
Incheon hang	-0.86	-4.74	0.29	-1.56
Palmido	-1.73	-7.68	5.47	-0.83
Pungdo hang	18.95	8.71	15.37	6.75
Gungpyeong hang	-10.32	0.89	-3.48	-4.58
Eoeundol hang	-8.03	-2.22	0.43	1.52
RMSE	14.90	8.22	9.57	8.21

- **Spatial interpolation experiment and comparative validation with observed value**
  - **Comparison between observed values after spatial interpolation using 67 tidal bench marks**

Unit : cm

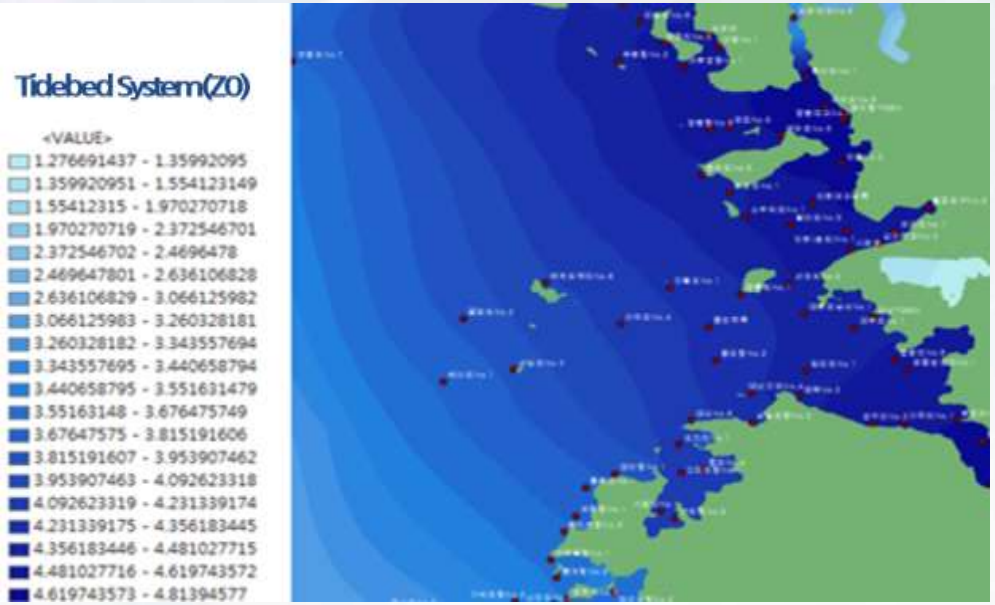
Point	IDW	Kriging	Spline	Spline with Barrier
				
North of Pungdo	12.84	-9.48	12.41	-12.51
South of Incheon Grand bridge	-13.17	-9.23	3.51	-6.12
RMSE	13.006	9.356	9.120	9.848

IHO STANDARDS FOR HYDROGRAPHIC SURVEYS (S-44)
5th Edition February 2008

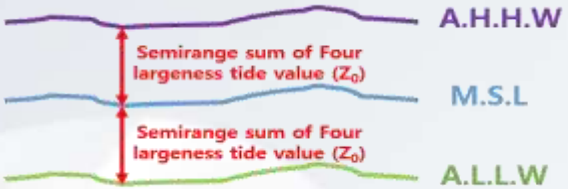
TABLE 1
Minimum Standards for Hydrographic Surveys
(To be read in conjunction with the full text set out in this document.)

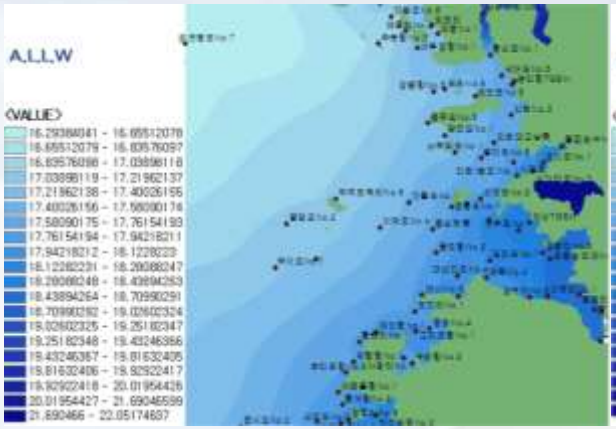
Reference	Order	Special	1a	1b	2
Chapter 1	**Description of areas.**	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under-keel clearance is less critical but *features* of concern to surface shipping may exist.	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.
Chapter 2	**Maximum allowable THU 95% *Confidence level***	2 metres	5 metres + 5% of depth	5 metres + 5% of depth	20 metres + 10% of depth
Para 3.2 and note 1	**Maximum allowable TVU 95% *Confidence level***	a = 0.25 metre b = 0.0075	a = 0.5 metre b = 0.013	a = 0.5 metre b = 0.013	a = 1.0 metre b = 0.023
Glossary and note 2	***Full Sea floor Search***	Required	Required	Not required	Not required
Para 2.1 Para 3.4 Para 3.5 and note 3	***Feature Detection***	Cubic *features* > 1 metre	Cubic *features* > 2 metres, in depths up to 40 metres; 10% of depth beyond 40 metres	Not Applicable	Not Applicable
Para 3.6 and note 4	**Recommended maximum Line Spacing**	Not defined as *full sea floor search* is required	Not defined as *full sea floor search* is required	3 x average depth or 25 metres, whichever is greater For bathymetric lidar a spot spacing of 5 x 5 metres	4 x average depth
Chapter 2 and note 5	**Positioning of fixed aids to navigation and topography significant to navigation. (95% *Confidence level*)**	2 metres	2 metres	2 metres	5 metres
Chapter 2 and note 5	**Positioning of the Coastline and topography less significant to navigation (95% *Confidence level*)**	10 metres	20 metres	20 metres	20 metres
Chapter 2 and note 5	**Mean position of floating aids to navigation (95% *Confidence level*)**	10 metres	10 metres	10 metres	20 metres

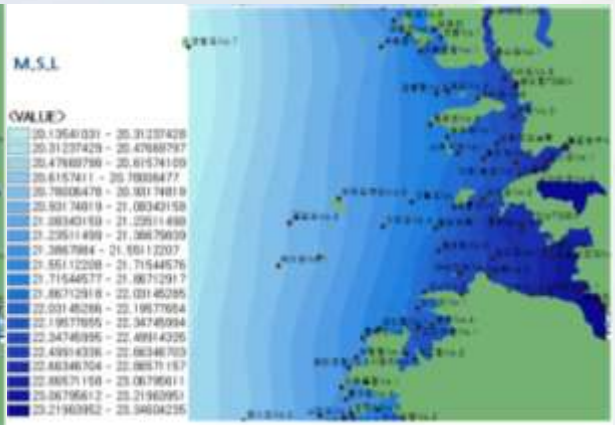
- **Tidebed System (KHOA, Korea Hydrographic and Oceanographic Agency)**
- **Information database of tidal features(harmonic constants, nonharmonic constants) and datum level in sea grids**
- **Computation of Semirange sum of four largeness tide value(Z_0 : M2,S2,K1,O1) of experiment area**

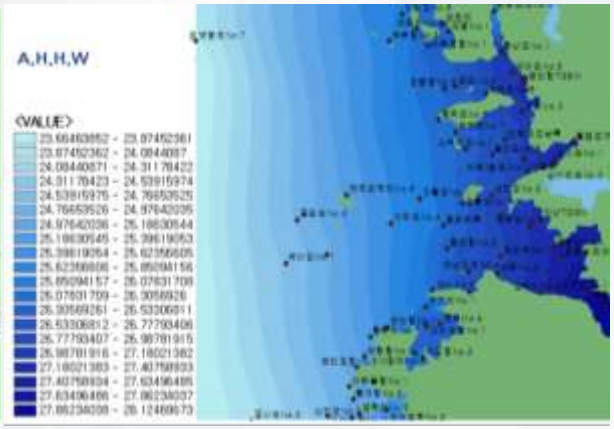


- **Construction of Tidal Datums**
  - M.S.L – Semirange sum of four largeness tide value (Z_0) = A.L.L.W
  - M.S.L + Semirange sum of four largeness tide value(Z_0) = A.H.H.W









Unit : m

	Observed value (A.L.L.W)	Forecasted Value (A.L.L.W)	Observed Value (A.H.H.W)	Forecasted value (A.H.H.W)
Gungpyeong hang	18.3842	18.3992	27.3982	27.4054
Deokjeokdo bukri	17.0583	17.1125	25.3063	25.2649
Eoeundol hang	17.8332	17.8283	24.9592	24.9691
Incheon hang	17.7835	17.7147	27.0535	27.1265
Jumun hang	16.8761	16.8872	25.7861	25.7802
Palmido	17.6079	17.6136	26.6859	26.6905
Pungdo hang	17.8375	17.8493	26.4395	26.4404
North of Pungdo	17.5720	17.6211	26.8000	26.7631
South of Incheon Grand bridge	17.6430	17.6188	26.1310	26.1594
RMSE		0.03529		0.03235

Conclusion

- **Conclusion**
  - **Proper parameter selection is needed since the expected results vary depending on parameter**
  - **Spline with Barrier(Minimum curvature) is considered as the best spatial interpolation**
  - **Spatial interpolation can be performed considering the Special Reference of minimum standard for hydrographic surveys of IHO and coast-lines**
  - **Height information is achievable through GNSS survey without tidal observation**

  * **Combined with the ship's draft, it is possible to build dynamic e-navigations.**

- **Further study**
  - **Characteristics of marine physical for more precise spatial interpolation**
  - **Establishment of tidal datums in open sea areas by using satellite altimeter or GNSS Buoy**

Thank you

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