

**Tidal and Water Level Working Group**  
(27-29 April 2010 – Stavanger, Norway)

Paper for Consideration by TWLWG

**Definitions of MSL and relevance of IHO TRs to non-tidal waters**

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<b>Submitted by:</b>	Finland
<b>Executive summary:</b>	This paper analyses the current IHO definitions for vertical Chart Datums and proposals for revision of IHO Chart Datum Definitions.
<b>Related documents:</b>	None
<b>Related projects:</b>	BSHC ChartDatumWG

**1. Introduction/Discussion**

Immediately after TWLWG1 a discussion was raised about definitions for the “2.8.1.1 EU-INSPIRE Specification on Coordinate Reference Systems – Guidelines.” The first drafts were quite inadequate. The final version in September 2009 is not in contradiction to IHO regulations and practices. However, the text included to these specifications

*“For depth values of the sea floor in marine areas with an appreciable tidal range, the use of the Lowest Astronomical Tide [IHO] is already mandated by Technical Resolution A2.5 of the International Hydrographic Organisation (IHO). In marine areas without an appreciable tidal range, in open oceans and effectively in waters deeper than 200m tide is not measured since it has no significant impact on the accuracy of the sounding.”*

This description is only a source of numerous questions outside the tidal areas. NOTE: the abbreviation (IHO/LAT). This specification does not recognize inland waters at all. And depths are used also on those areas, too. Not the height contours related to general vertical Datum.

The author had a possibility to meet TWLWG Chairman Stephen Gill in NOAA on 2<sup>nd</sup> of December 2009. In our brief discussion the Chairman proposed that I should make a proposal for the changes to IHO regulations, required by the new MSL/geodetic datum definitions and circulate those in good time before the TWLWG meeting. I apologize that unfortunately, due to our organization developments I have not been able to draft my proposals until now.

**1.1 The definition of MSL**

**The real system** definition of MSL would require the following fundamental theoretical definitions

- Shall the MSL definition be related
  - o to geometric distance from the Earth centre
  - o certain gravity potential level

- the true ocean level including the global rise effect of the oceans
- to the nearby earth crust
- In all cases the realization of the MSL would require practical advices how to eliminate the apparent geophysical effects from the observations before the final calculation of MSL.
- This includes the necessary recommendation for the length of the time series. 20 years might be the requirement for an acceptable time series. In the Baltic Sea area there exists a clearly observed 15 year regular period. The origin of this is most probably the global meteorological NAO-effect. (North Atlantic Oscillation).
- The postglacial land uplift, where it exists, causes difficulties. The apparent mean sea level decreases, the channels become shallower and shallower. The nautical chart production has to react to the fact that navigation environment has changed and has become more dangerous.
- The epoch should be mentioned together with the MSL realization (The mid-epoch of the timeserie?). Or could the MSL be a linear function of time (in years) in case this dependency can be solved with sufficient reliability.

It is a simple fact that with only one tide gauge it is impossible to create a realization of mean sea level, which would be independent on those other geophysical effects. One is able only to tell that the mean value of time series between to named epochs is solved and realised with a fixed marker on the earth crust.

It is also evident that these same geophysical effects have an influence to LAT definitions, but in that case the tidal effects are more dominant.

The author sees that the main difference between LAT and MSL definitions is the different navigation practices between the two marine areas. In my understanding, these have never been studied thoroughly, but I might expect that the minimum underkeel clearances over the charted shoals are significantly narrower on non-tidal areas compared to tidal areas. The other significant difference between these two is that if the master of the ship wants some 30 cm more underkeel clearance on tidal areas, he is required only to wait one or two hours more before unmooring. In the Baltic Sea area he has to be prepared to wait for two weeks.

On non-tidal and shallow coast the main issue is the following

- there is a scale or gauge in the harbour area and a shoal (hard bottom - dredged bedrock) in the channel or fairway leading to that port.
- what is the vertical elevation difference between the zero of this scale and the level of the shoal.
- water level is much easier to take into account, it can be read from the scale and it is practically the same over the shoal and normally it does not even change significantly during the travel from the port to the shoal.

In summary one comes to the conclusion that MSL, although being quite simple in theory, is difficult to realize within sufficient accuracy in practice and tend to vary during the time. Could it be replaced with something else, which would save the general impression of mean sea level, but would have more accurate realization for surveying and charting purposes on larger areas? In practice a national or international geodetic vertical reference frame could serve as a realization. Geodetic levelling networks have been useful throughout time for understanding the variations of sea level and especially for knowing the land uplift effect. On the other hand the height values of a geodetic height system have normally the zero height selected so that it represents the approximate mean sea level on the coastline.

## 1.2 The applications of the MSL in practice

The practices in the Northern Europe show that although the Chart Datum is called MSL, it deviates in practice in almost all cases from the best realization of MSL on that coastal area which is presented on chart.

In Finland and in Sweden the Chart Datum is tied to the MSL observed on the nearest tide gauge (mareograph). But it is tied on a certain epoch. Now, when the land uplift continuously changes the location of the shoreline, the charted depths are always deeper than the true depth related to the present (theoretical) MSL. (Or one has to select the epoch of MSL from the future).

The water level observations in Kronstadt (outside St.Petersburg) have been the origin of height measurements in Russia and the former Soviet Union. The Baltic Height System BK77 was established in 1970:s The geodetic levelling network based on this height definition covered the eastern coast of the Baltic Sea even to the shoreline of former DDR.

BK77 zero is quite close to the MSL of the eastern tip of the Gulf of Finland and the land uplift has almost no effect in St.Petersburg and on the eastern coast of the Baltic Sea. However this geodetic height system with zero value in Kronstadt represented the MSL through the whole coast. (Poland was an exception). I have understood that this National Height System of Russia is the reference of nautical charts also on other non-tidal Russian coasts (White Sea, Black Sea?).

In Denmark the National Height System DVR90 has its zero level as the mean of all sea level observations around the Danish coast. This is maybe the most accurate realization of MSL for larger areas of all. I have understood that by the Danish law the Chart Datum for Danish non-tidal waters is DVR90. The principle is clear although one could also say that the Chart Datum is MSL.

For the German Baltic Sea coast and for the Polish coast one may only say that the Chart Datum is based on the geodetic height system, which is of course close to MSL.

Outside Northern Europe one may find one different application of MSL. The only one which author knows is for the Great lakes in USA-Canada. These lakes have a natural mean height, but Chart Datum is defined to be 30 cm (1 foot?) below the mean water level.

### **1.3 The Low Water and High Water levels**

On non-tidal waters these extremities are always irregular and cannot be predicted in long run. The calculation of LW and HW requires certain rules. In all the observation period should be several years but the short time intervals have a meaning also. In IHO M-3 A2.5 it is recommended to adopt lower/upper 94-100 percentile of observations. But what is the observable, instant observation, mean value of 6 minutes/one hour/six hours/one day. There might be several practices for the recording intervals and especially in the storage of long time series on non-tidal observations. Therefore, in my understanding, the definition of LW/HW in A2.5 is not unambiguous. The IHO regulations do not say anything of the application and use of LW. HW is referred in A2.5.2 b "*It is further resolved that a HW datum be used for vertical clearances in non-tidal waters.*" However the text in S-4 B-380.1 does not mention HW for non-tidal waters and allow the use of MSL as a reference to vertical clearances. (S-4 Edition 3.007 December 2009).

### **1.4 The common navigation practice on non-tidal waters**

It is in my understanding that before the IHO regulations related to MSL are changed or even clarified, a common understanding for the basic rules should be created.

The mean sea level is something, which is understandable for the mariner and even for all. The mariner must be aware that the instant water level may vary to positive and negative directions. The only possible way to receive this information is the shore-based automated or manned radio broadcasts. For these broadcasts it is essential that the water level info is referred to the Chart Datum. The Chart Datum need not to be exactly MSL, but the impression of mean sea level shall be maintained. During the navigation situation the knowledge of extreme values of water level is not essential for the mariner, except in that case when vertical clearances are measured from HW datum. Now when it is mandatory for the mariner always to know the instant water level, it might be easier for him, if the vertical clearances and simply all the vertical measures were given related to the same Chart Datum. If for instance a HW datum were used for vertical clearances, the difference of CD and HW should always be printed on chart.

## 2. A proposal for renewing the Chart Datum regulations

The Nautical Charts which follow the IHO regulations are used in three different types of marine environments. This will easily lead and has also led to certain misunderstandings both for mariners who sail from one environment to another and especially for the cartographer, who sometimes is obliged to update chart information even for charts which are for the other environment he is used to.

Therefore we should consider the presentation of all these cases and the different solutions for Chart Datum inside one clear regulation. My draft proposals for the amended beginning of A2.5 is the following

For sea areas where the tide has a significant effect

- a) It is resolved that the Lowest Astronomical Tide (LAT), or (other LW level) as closely equivalent to this level as is practically acceptable to Hydrographic Offices, be adopted as chart datum. Alternatively the differences between LAT and national chart datums may be specified on nautical documents. If low water levels in a specific area frequently deviate from LAT, chart datum may be adapted accordingly.
- b) The datum for tide predictions shall be the same as chart datum (datum for sounding reduction).
- c) It is resolved that Highest Astronomical Tide (HAT) be adopted as the datum for vertical clearances where tides have an appreciable effect on the water level. Alternatively the differences between HAT and national datums for vertical clearances may be specified on nautical documents. If high water levels in a specific area frequently deviate from HAT, the datum for vertical clearances may be adapted accordingly.
- d) It is resolved that heights on shore, including elevations of lights, should be referred to a HW datum. The datum used should be clearly stated on all charts.

For sea areas where the tide has not a significant effect but are connected to ocean so that the long time variations of the ocean level are reflected

It is resolved that all vertical information should be referred to one Chart Datum which shall be reasonably close to MSL (mean sea level). This Chart Datum may be

- an observed local MSL based on long series of water level observations
- or a well-defined geodetic vertical datum with the same zero value for heights as used in land survey applications of this datum. (In case this zero value deviates significantly from the local MSL, another height value of this scale may be selected to Chart Datum. *May be this is not needed*).
- The name of the Chart Datum shall be printed on charts. If the Chart Datum is not MSL the local difference of MSL and the Chart Datum shall be given too.
- If some other vertical datums are used i.e. HW for vertical clearances, the difference of these related to CD shall be printed on chart.
- (The same CD is mandatory for broadcasting the water level info for mariners).

For other separate water areas where the sea level variations have no effect (lakes, rivers)

It is resolved that two levels, the low water level LW and the high water level HW shall be determined based on the local circumstances. These shall be expressed as height values in a well known geodetic datum. If such datum is not available, these levels shall be given as heights on a local fixed scale. LW shall be used as Chart Datum and HW shall be the Datum for vertical clearances.

If the changes of water level are not significant during the navigational season it is possible to use only one selected level as the Chart Datum for all vertical information.

The importance of correct water level information have to be noted also. This is related to agenda items 4/4 and 4/3, too.

### **3. Justifications and Impacts**

Exact and feasible definitions for terms related to water level on non-tidal areas have a great importance for the safety of navigation, especially when there seems to exist a clear tendency to accept narrower under keel clearances compared with tidal areas.

I suppose that these proposals will raise discussion. Do we really need to build up the whole scheme of CD and vertical information from the beginning? In my understanding this is necessary for developing such a working environment to non-tidal areas, where misunderstandings and lack of proper information cannot endanger the safety of navigation.

I am prepared to explain and clarify my analysis and proposals at the TWLWG meeting.

### **4. Actions required by TWLWG**

The TWLWG2 meeting is invited

- to take note on this information and
  - to agree on further actions regarding to the definition of "mean sea level" as proposed in Chapter 2
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