Establishing and Updating Vertical Datum for Land and Hydrographic Surveying in Dubai Emirate

Mustafa Mohammed Baqer
Head of Hydrographic Unit
Geodesy & Hydrographic Section
Survey Department
Dubai Municipality
Email: MMBAQER@dm.gov.ae

What is Vertical Datum?

A vertical datum is a base measurement point to which all elevations are referred.

A precise vertical datum is required for all kind of surveys. Without a common datum it may have different elevations values for the same location.
The vertical datum needs to be updated periodically because of the geologic changes to the surface of the earth due to the subsidence and uplift or gradual changes in sea level.

All Surveyors/Cartographers/GIS users are defining points in terms of X,Y,Z /E,N,H/ Lat. Long. H, which are the Geo-spatial factors.

Generally in the era of Global Navigation Satellite System (GNSS), defining a Horizontal position is easy. But defining a precise vertical reference level (Z) is complicated.

Traditionally the horizontal reference level taken for the land surveying is referred to MSL or Reference Ellipsoid and for Hydrographic Surveying the reference level is the Chart Datum, which is more or less close to the Lowest Astronomical Tide Level.
Why to update Vertical datum

For transferring accurate vertical level to near shore & offshore constructions
For updating Land/Offshore Geoid Models
Creating numerical modeling for tide and tidal streams
For revising coastal boundary lines (coastline and shore line)
For precise surveying
For updating Dubai Virtual Reference System (a real time RTK DGPS system, now being converted to a GNSS System)

This paper explains the details of sea level change and the necessity to update the vertical datum of Dubai Emirate with respect to the tidal variations and other factors.
Topics of Discussion

- Various definitions of Height
- Tides
- Need to measure the water levels?
- Measuring water levels
- Status of Dubai Tidal-Met stations
- Analysis and Prediction of water level
- Application of water level / vertical datum
- Future Plans for updating water levels.
- Conclusion

Orthometric Height (H)

Height from the geoid to the Earth’s surface

Usually derived from leveling using spirit levels

Frequently called “height above mean sea level”

e.g. The Height of Mount Everest is “8848 meters”
Ellipsoidal Height ($h$)

- Height from the Ellipsoid to the Earth’s surface
- WGS -84 ellipsoid is used by GPS
- To convert ellipsoidal height to orthometric height one needs gravity measurements

What is TIDE?

The tide is the regular rising and falling of the ocean's surface caused by changes in gravitational forces external to the Earth.
How does gravitational force generate Tide?

The Moon's gravity imparts tremendous energy to earth, making raising of water level throughout the global oceans.

How water level can be measured:
- In-Shore Tide Gauge
- Manual Measurement (Tide Gauges)
- Pressure Transducers
- Acoustic Transducers
- RADAR
- RTK DGPS
- Off-Shore Tide Gauge
- Offshore Buoy with ADCP/Pressure Sensors
- Satellite Altimetry
Why Tide Gauges are needed in the “Age of Satellite Altimetry”?

- Altimeters need to be calibrated using tide gauges
- Continuity in reading and low cost. The altimeter record may have lots of data gaps
- Continuous mean sea level (MSL) records for a long duration are needed for water rise studies
- Accuracy of the Altimeters in the coastal area are not precise.

Why to measure Tides?

1- To establish a unique vertical reference (Z)
2- To define the coastal boundary
3- To design inshore/offshore structures
4- For coastal monitoring
5- For geoid modeling for VRS
6- For safe navigation on the Sea
To monitor the sea level variation and its effects over the near shore and offshore manmade islands and to transfer a precise vertical datum to offshore islands.

Various Tide levels and Chart Datum

Tidal Definitions:
Diagramatic illustration of the terminology of tidal heights in metres.
GEOID Determination by MSL and Gravity Metering

For Defining a precise geoid precise Orthometric heights from a vertical datum is required

Why do we study GEOID?
The easy explanation is this - by using the geoid model and GPS, we can determine elevations faster and cheaper.

Construction projects can be completed faster and for less cost - so, we all benefit.

Who use GEOID?
Anyone who wishes to use GPS to determine elevations above Mean sea level will definitely need to use the Geoid.
History of Dubai Vertical datum

- In 1954, first vertical datum was established in Dubai by the Royal British Navy with reference to the Lowest Water.
- In 1978, first national bench mark was established by M/s. Halcrow in Port Rashid with reference to lowest water.
- In 2004, Dubai Municipality had established five tidal-meteorological stations along the coastal area to finalize the discrepancies existed between different datum.
- In 2011, Dubai started construction of a series of permanent tidal stations along the coastal area of Dubai to update the vertical datum. The first one will be completed this year.

In 2003 the Geodesy and hydrographic Survey Section of Dubai Municipality had decided to establish a unique vertical Datum in Dubai.

In the first phase, DM established five Tidal-Met stations in the Coastal area of Dubai and started collecting water levels at two minutes interval.
The reasons for establishing 5 Tidal Stations

- Defining an accurate vertical datum
- Determination the Mean Sea Level, HAT, LAT
- Prediction the Water level
- Launching the Real time data to users
- Storm Surges Detection
- Establishment of Warning System in case of Abnormal High water

All the stations are located inside the Harbours or Basins
The Survey Department of Dubai Municipality has deployed an offshore buoy fitted with meteorological sensors and an ADCP (Acoustic Doppler Current Profiler) in the offshore area of Dubai Emirate for updating the vertical datum in the offshore area considering the massive construction taking place in the offshore area of Dubai. The WAVESCAN buoy is a wave directional buoy measuring waves, meteorological and other environmental parameters.

The buoy is equipped with a sophisticated array of sensors which report half hourly data as:

1. Wind speed and direction
2. Atmospheric pressure and humidity
3. Significant wave height and period
4. Air and Sea temperature
5. Sea water quality parameters
FIG Working Week 2011
Bridging the Gap between Cultures
Marrakech, Morocco, 18-22 May 2011
Tide Analysis and Its Results

<table>
<thead>
<tr>
<th>Month</th>
<th>MSL</th>
<th>Correction</th>
<th>Corrected Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>1.06</td>
<td>0</td>
<td>0.97</td>
</tr>
<tr>
<td>Feb</td>
<td>1.05</td>
<td>0.1</td>
<td>1.06</td>
</tr>
<tr>
<td>Mar</td>
<td>1.06</td>
<td>0.2</td>
<td>1.07</td>
</tr>
<tr>
<td>Apr</td>
<td>1.12</td>
<td>0</td>
<td>1.12</td>
</tr>
<tr>
<td>May</td>
<td>1.19</td>
<td>0.1</td>
<td>1.18</td>
</tr>
<tr>
<td>Jun</td>
<td>1.23</td>
<td>0.1</td>
<td>1.22</td>
</tr>
<tr>
<td>Jul</td>
<td>1.29</td>
<td>-0.2</td>
<td>1.27</td>
</tr>
<tr>
<td>Aug</td>
<td>1.31</td>
<td>-0.1</td>
<td>1.29</td>
</tr>
<tr>
<td>Sep</td>
<td>1.33</td>
<td>-0.1</td>
<td>1.31</td>
</tr>
<tr>
<td>Oct</td>
<td>1.33</td>
<td>0</td>
<td>1.33</td>
</tr>
<tr>
<td>Nov</td>
<td>1.39</td>
<td>0</td>
<td>1.39</td>
</tr>
<tr>
<td>Dec</td>
<td>1.03</td>
<td>0</td>
<td>1.03</td>
</tr>
</tbody>
</table>

Average=1.16m

Constituents Dubai Municipality (2009)

<table>
<thead>
<tr>
<th>Name</th>
<th>MSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sa</td>
<td>0.0809</td>
</tr>
<tr>
<td>Ssa</td>
<td>0.0330</td>
</tr>
<tr>
<td>Hm</td>
<td>0.0668</td>
</tr>
<tr>
<td>Hv</td>
<td>0.0648</td>
</tr>
<tr>
<td>D1</td>
<td>0.1709</td>
</tr>
<tr>
<td>K1</td>
<td>0.2471</td>
</tr>
<tr>
<td>H2</td>
<td>0.4645</td>
</tr>
<tr>
<td>S2</td>
<td>0.1770</td>
</tr>
<tr>
<td>Z0</td>
<td>1.1119</td>
</tr>
</tbody>
</table>

Based on one and five years data from Umm Sequim station

Water Levels computed at each Station

<table>
<thead>
<tr>
<th>Location</th>
<th>LAT</th>
<th>RLLW</th>
<th>MSLm</th>
<th>MSLm</th>
<th>MLWm</th>
<th>HTLw</th>
<th>HATm</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Umm Suqeim</td>
<td>-0.16</td>
<td>+0.43</td>
<td>+0.78</td>
<td>+1.11</td>
<td>+1.32</td>
<td>+1.66</td>
<td>+2.30</td>
<td>2006-2009</td>
</tr>
</tbody>
</table>

MSL of UMM Sequim Station calculated for 2010

Details of Vertical datum

- LAT = -0.20m
- HAT = 2.20m
- MSL = 1.08m (Based on DMD)
- MSL = 1.02m (Based on Admiralty Tide Table)

- HDJA = ACD = 0.06m (Reference to Dubai Municipality Measurements) - 1989
- DMD = PRD = HD (at port Rashid) = 0.0m
- DMD = PRD = HD (at port Rashid) = 0.0m
- LAT = 0.06m

Publishing Dubai Tide Table
By updating of our precise vertical datum, we are able to perform

1-Modelling the level of water (Offshore)
2-Preparing accurate Co-Tidal charts
3-Calibration of Satellite Altimeters readings in our region
4-Determination of Offshore Geoid model
5-Prediction of offshore water levels
6-Monitoring offshore constructions
7-Environmental Investigations

Conclusion

Use of proper vertical elevation is required in surveying & mapping especially for overlaying the bathymetric data and land survey data.
Progress towards a unique vertical reference for whole UAE is going on.
We are sharing the information regarding a precise vertical datum with other line departments especially with the GIS Dept. for ocean modeling.
THE DEMAND FOR SYSTEMATIC AND PRECISE VERTICAL DATUM IS INCREASING