INTRODUCTION TIDE TABLES

General theory

The fluctuating tidal heights and the changing of streams, both in direction and in speed, are mainly the result of the fluctuating gravitational forces of the Sun and the Moon on the water masses of the Earth. During New and Full Moon, the forces of the Sun and Moon reinforce each other resulting in spring tides. During the First and Last Quarter phases of the Moon, both forces are exerted at a right angle in respect to the other, creating neap tides. By performing a harmonic analysis on long series of tidal observations at a certain location, one can make tidal predictions for that location. These are called astronomical tides. These tidal heights in the tide tables of the HP33 and the digital tide tables of the HP33D-NLTides are published by the Hydrografic Service of the Royal Netherlands Navy.

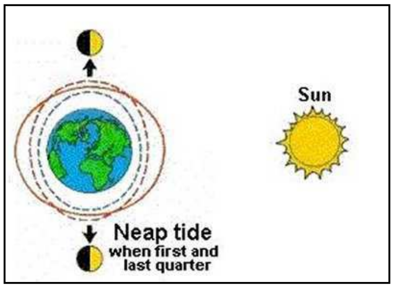


Figure 1

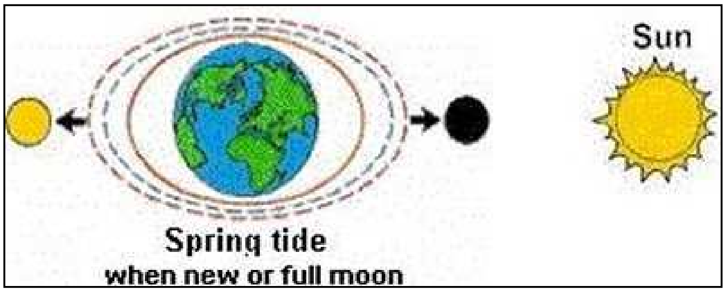


Figure 2

The tides originate in the Southern Ocean, surrounding Antarctica, where the water mass, and therefore also the tidal wave, propagates without interruption, between 55 and 65 degrees southern latitude. Via the Atlantic Ocean, the tidal wave moves with a speed of 400 knots to reach the Belgian and Netherlands coasts and propagates from South to North. The spring tides happen well over 2 days after Full and New Moon (from Katwijk to Texel about 3 days). Neap tides occur well over 2 days after the moments of First and Last Quarter (from Katwijk to Texel after about 3 days).

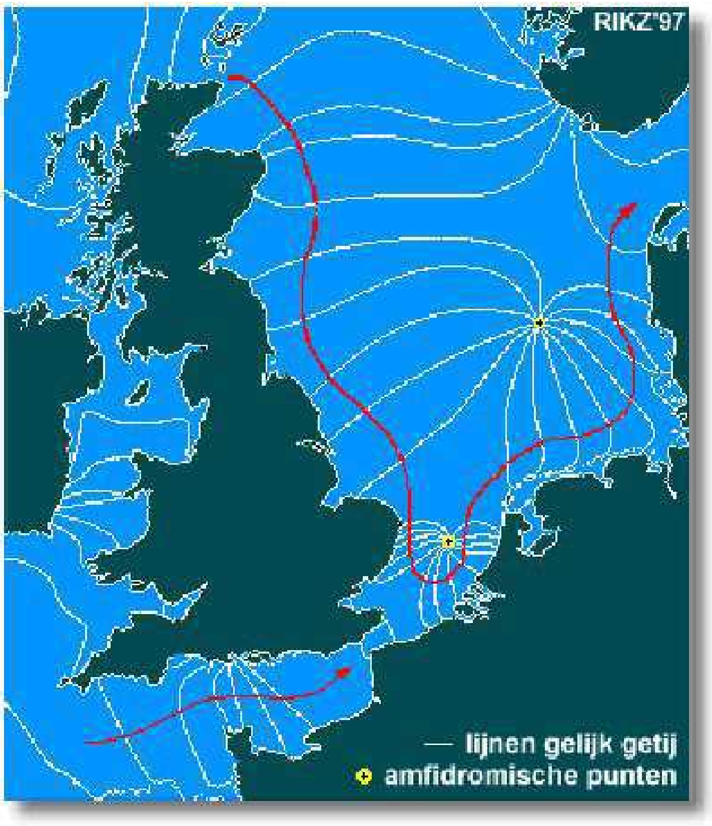


Figure 3

In the southern part of the North Sea, tidal waves rotate in a counterclockwise direction around two centres, called amphidromic points, situated at approximately 52º30'N - 003º03'E and 55º21'N - 005º40'E. When the co-tidal line of high water (the wave crest) is situated at one side of an amphidromic point, the co-tidal line of low water (the wave trough) is situated at the exact opposite side. In contrast to the horizontal tidal streams, vertical tidal movements rarely occur in amphidromic points.

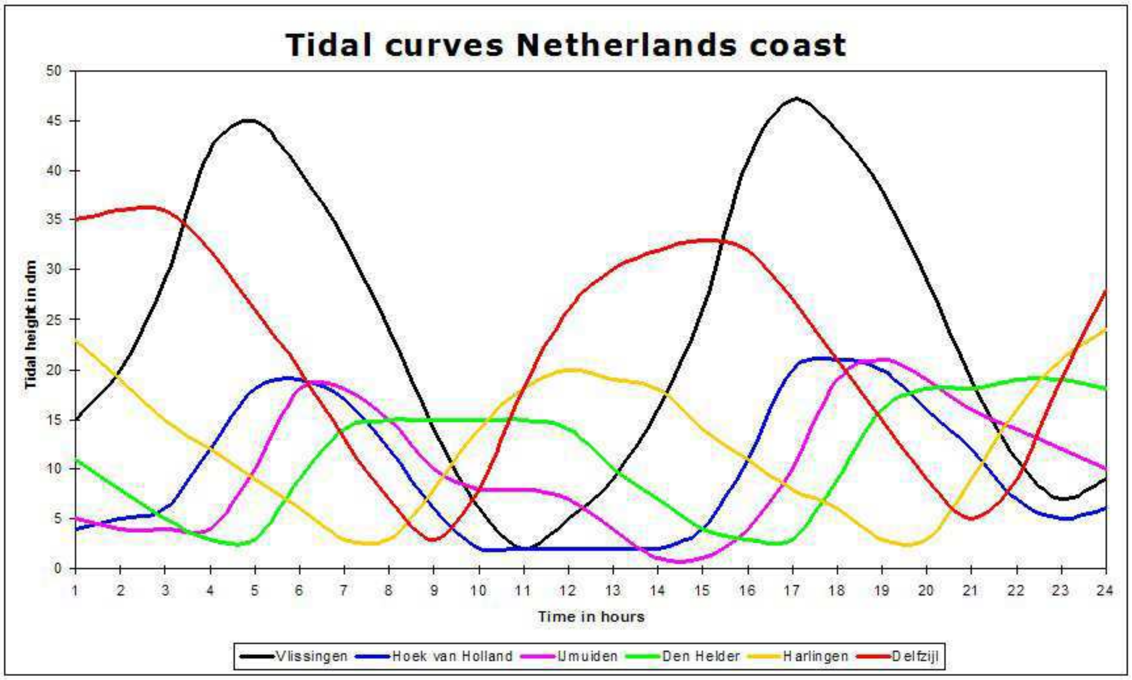


Figure 4*: tidal curves of Dutch tidal stations***.**

Chart Datum

Chart Datum (CD) is the plane of reference to which all charted depths and drying heights are related (see figure 5). In tidal areas, charts show the least depth of water found under normal meteorological conditions. It will vary from place to place in relation to the land survey datum or mean sea level.
The Chart Datum needs to meet the following conditions:
1. so low that the water level will seldom fall below the defined Chart Datum
2. not unrealistically low
3. contain gentle transitions from chart to chart and area to area with respect to the plane of reference.

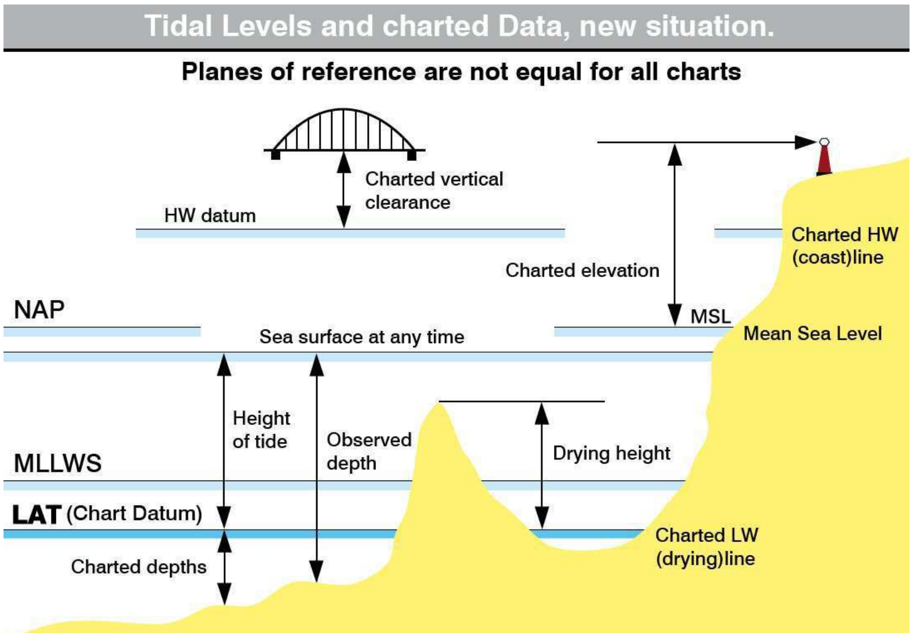


Figure 5

Lowest Astronomical Tide (LAT) LAT is the lowest tide level which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions. LAT is not the lowest level that can be reached. Storm surges may cause considerably lower water levels than LAT. About once a year a water level occurs that is 0,50 m below LAT. This mainly occurs on the eastern part of the North Sea. About 2 times a month a water level occurs that is 0,25 m below LAT.

In the HP33 all hourly heights are referenced to LAT except at the port of Rotterdam, Europahaven and Vlaardingen. The hourly heights of these ports are referenced to approximate LAT (ALAT). The values of ALAT correspond to those of Equivalent Low Water (OLW). OLW forms a fluent transition from LAT in Hoek van Holland to Equivalent Low River level (OLR) on the river Waal near Tiel. OLR is a local water level based on the Equivalent Low Discharge (OLA) at Lobith for stations on the Bovenrijn, the river IJssel, the river Waal up to Tiel, the river Lek, and the Benedenrijn.

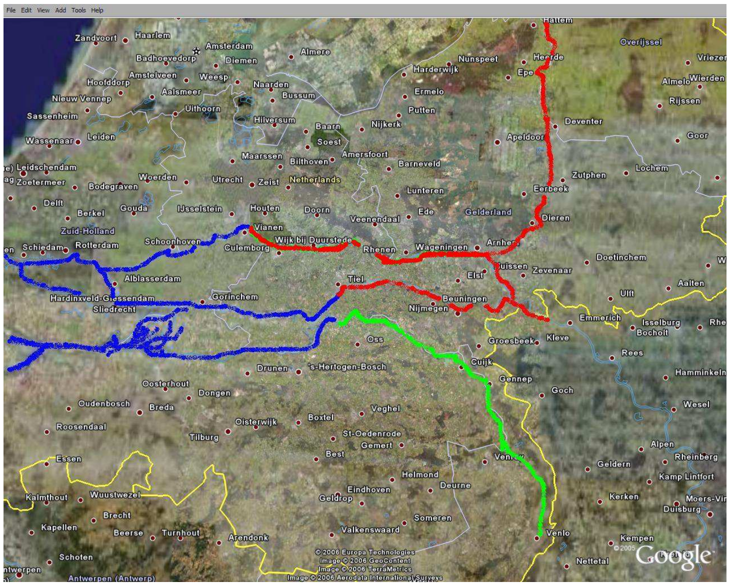


Figure 6

In figure 6 in blue the OLW area, in red the OLR and in green the local weir level. All levels are defined with reference to NAP and are as such comparable with each other.

Chart datum is mentioned on every paper chart and Electronic Navigational Chart (ENC). It is important to read and use the information in the legend. Chart Datum currently used by neighbouring countries: The United Kingdom Hydrographic Office (UKHO) uses ALAT. The German Hydrographic Service (BSH) and the Flemish Hydrographic Service use LAT.

For ports the predicted hourly height value can be used directly from the tide tables, if the charts are referenced to LAT.

In the Netherlands, heights on land are referenced to the Amsterdam Levelling Reference **(NAP)**. Along the coast, NAP equals MSL to within a decimeter. On the pages containing the tidal curves in the HP33 and in a supplementary table in the HP33D - NLTides, an indication of the difference between NAP and LAT / approximate LAT is provided. In many cases, the coastal authorities (harbour master, lock-keeper) provide the observed tide in NAP.

In the curve of Belgian station Zeebrugge, a line representing the Second General Levelling plane **(TAW)** is shown. This plane approximates the LAT plane.

Vertical Clearance

Highest Astronomical Tide (HAT) is the highest level that can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions. HAT is not the most extreme water level that can be reached. Storm surges may cause even considerable higher water levels. Vertical clearances are referenced to HAT. The Dutch national standards for waterways (RVW 2020) prescribes in standard H99 that at vertical clearances the daily observed water levels may only exceed the (agreed upon) local reference water level for a maximum of 1% of the total measurements annually. At locations with little variation in astronomical tide, HAT does not meet this standard. For these locations new reference water levels, that do meet the H99 standard, are determined. This apply to the stations Dordrecht, Harmsenbrug, Hartelbrug, Krimpen aan de Lek, Maassluis, Moerdijk, Rak Noord, Rotterdam, Rozenburgsesluis noordzijde, Rozenburgsesluis zuidzijde, Spijkenisse, Suurhoffbrug noordzijde, Tennesseehaven and Vlaardingen.

Tide tables HP33

The tidal height predictions in the HP33 are based on calculations by Rijkswaterstaat and Flemish Hydrography. The HP33 tide tables contain 17 Dutch and 1 Belgian locations. All hourly tidal heights are presented in dm, referenced to Chart Datum for a whole calendar year.

Tide tables HP33D – NLTides

The HP33D – NLTides is the digital version of the HP33 and is published on USB. The Netherlands Hydrographic Service (NLHS) issues the program HP33D - NLTides as an official equivalent of paper tide tables in accordance with SOLAS V/2.2 and V/19.2.1.5. It may replace traditional paper tide tables provided that appropriate back-up arrangements are available (for example a print facility or second installed version of the NLTides program). *NLTides* provides more ports than its paper equivalent HP33. *NLTides* uses the same prediction algorithms and Harmonic Constants for the Belgian and German ports as the UK Admiralty *TotalTide* program. The Dutch ports are predicted using the Dutch constants and algorithms as supplied by Rijkswaterstaat. Tidal heights are displayed clearly and concisely both in a graphical and tabular format. Tidal Stream rates are presented in a chart-based diagram. The tidal Stream rates are supplied by Rijkswaterstaat and the Port of Rotterdam.

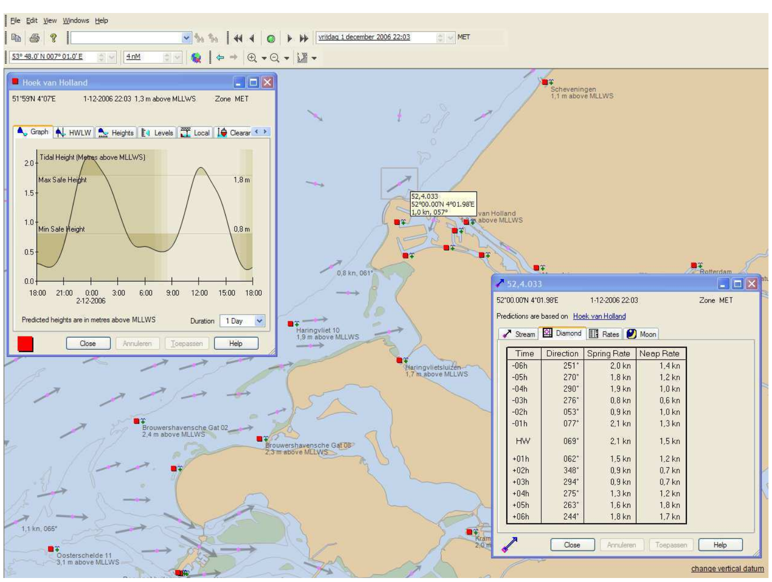
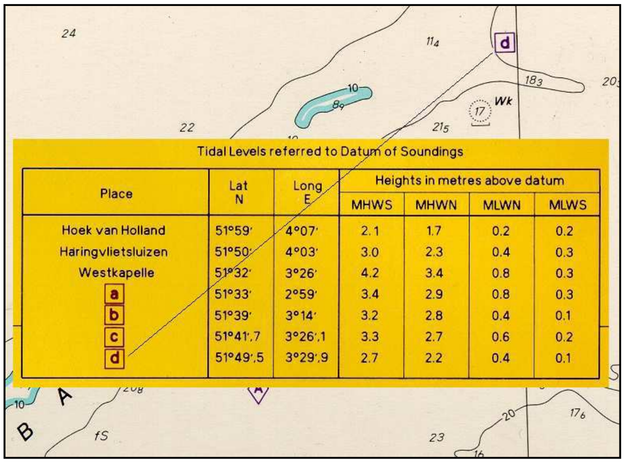


Figure 7

Tidal height data in the chart

Tidal height information is also presented on paper charts, by means of a tide table that connects tidal height information with certain location on the chart. Some tables contain information of tide stations along the coast. Next to the geographical location the following information is presented:


Tidal Levels referred to Datum of Soundings

Place	Lat N	Long E	Heights in metres above datum			
			MHWS	MHWN	MLWN	MLWS
Hoek van Holland	51°59′	4°07′	2.1	1.7	0.2	0.2
Haringvlietsluizen	51°50′	4°03′	3.0	2.3	0.4	0.3
Westkapelle	51°32′	3°26′	4.2	3.4	0.8	0.3
a	51°33′	2°59′	3.4	2.9	0.8	0.3
b	51°39′	3°14′	3.2	2.8	0.4	0.1
c	51°41′.7	3°26′.1	3.3	2.7	0.6	0.2
d	51°49′.5	3°29′.9	2.7	2.2	0.4	0.1

Figure 8

Mean High Water Spring (MHWS)
Mean High Water Neap (MHWN)
Mean Low Water Neap (MLWN)
Mean Low Water Spring (MLWS).

All values refer to chart datum.

Influence of meteorological circumstances

Considerable differences may exist between predicted tidal heights (as presented in the HP33 and NLTides) and observed tidal heights as illustrated in figure 9. These differences are nearly always due to meteorological conditions, which are only predictable for a short period of time. An onshore breeze usually causes higher water levels and earlier times of high and low waters. Offshore winds tend to cause an opposite effect. The atmospheric pressure also has an influence on the water level. The higher the pressure, the lower the water level and vice versa.

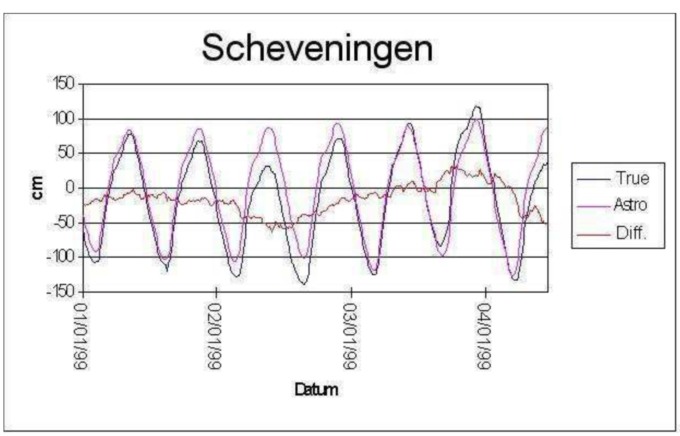


Figure 9

LAT is not the lowest water level that can be reached. Storm surges may cause considerably lower levels than LAT to occur. About once a year a water level occurs which is 0,50 m below LAT. This mainly occurs on the eastern part of the North Sea. About twice a month a water level occurs which is 0,25 m below LAT.

Cautions

- The moment of LW Hoek van Holland is difficult to determine because of the double low water.
- Near Den Helder, it is difficult to determine the moment of HW because of the double high water in that area, Harlingen is a good reference port for stream calculations.
- LAT is not the lowest water level that can be reached. Storm surges may cause considerably lower levels than LAT to occur.

Use of tide tables

Each tide station in the HP33 is accompanied by a diagram showing the mean tidal curves at springs and neaps for that location.

Figure 10 depicts an example in the use of the HP33 tide tables when planning a tidal flat passage. The same information can be found in HP33 – NLTides. The data used in the example below does not refer to data in this edition of the HP33.

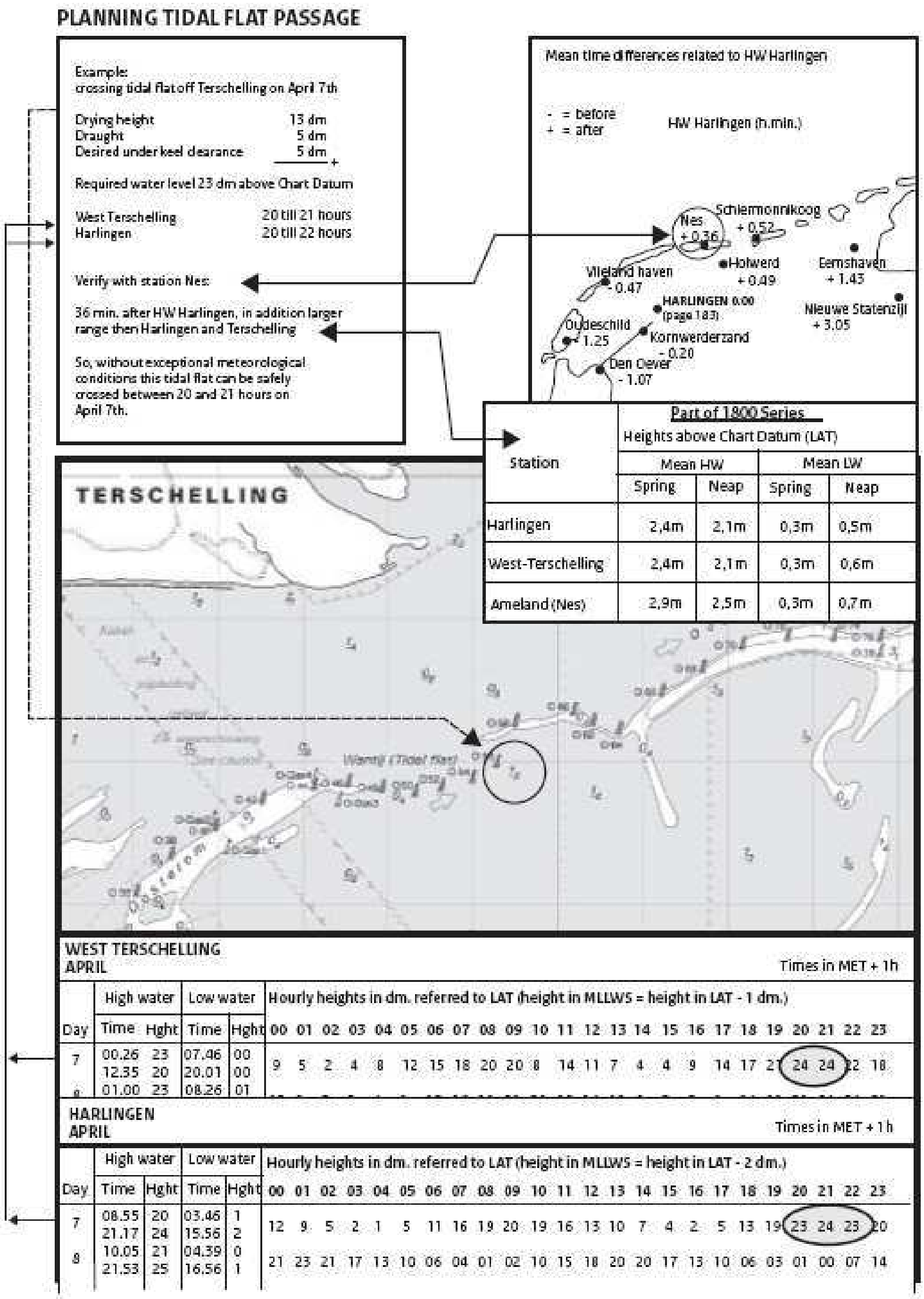


Figure 10

INTRODUCTION STREAM ATLASES

HP33 Tidal stream data

The stream data is based on tidal models developed by Rijkswaterstaat and Havenbedrijf Rotterdam N.V.. Using a mathematical model, the stream information becomes more coherent and provides flexibility to changes, like harbour extensions and the construction of artificial islands. Measurements near the most important harbours, Waddenzee and Delta area show that the models agree well with the actual stream rate and direction. The tidal streams are calculated based upon an average mean neap tide and mean spring tide during average weather conditions (wind south-west force 3 to 4 Beaufort).

HP33 Stroomatlas

The two digits in the front end of the arrow provide the mean stream rate in tenths of a knot (1 knot = 1 nautical mile per hour = 1852 (m) / 3600 (s) = 0.514 (m/s)) at spring tides. The two digits in the rear end of the arrow provide the mean rate in tenths of a knot at neap tides. The centre of the arrow is the position of the model value. Influenced by wind, the stream rate and direction can variate substantially. To allow for a quick impression of the distribution of the different rates, the arrows are shown in different colors as shown in the legend of the individual stream atlases.

Time references

The tidal streams are given at hourly intervals commencing 6 hours before and ending 6 hours after the time of high water at a standard port (except at Den Helder, where the moment of low water is used). The hours are mentioned on each chart. For the times of HW (LW for Den Helder) at the station used, reference is made to the tide tables in the HP33.

Rising and falling water

On the charts, the areas with rising water at mean tide are depicted in the color blue, and are separated from the white areas with falling water by blue co-tidal lines of high or low water.

Coast Pilot (HP1)

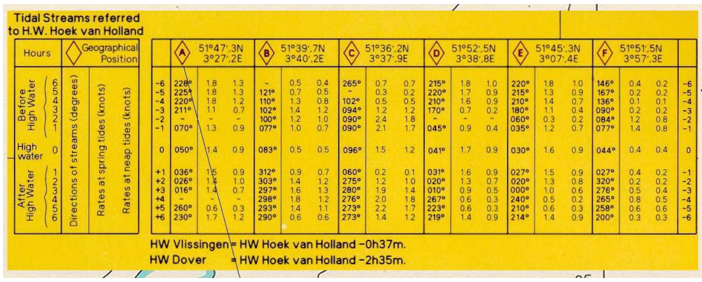
It is not possible to depict local characteristics correctly on the charts. For further particulars of tidal streams in separate fairways, reference is made to the Netherlands Coast Pilot (HP 1).

HP33D – NLTides Tidal Stream data

In the HP33D – NLTides a stream arrow indicates the following information:

- The tidal streams are given at hourly intervals from 6 hours before- to 6 hours after the time of high water at a standard port (except at Den Helder, where the moment of low water is used)
- stream rate and direction
- phase of the moon.

Tidal stream data in the chart



Tidal Streams referred to H.W. Hoek van Holland

Hours	A 51°47'.3N 3°27'.2E			B 51°39'.7N 3°40'.2E			C 51°36'.2N 3°37'.9E			D 51°52'.5N 3°38'.8E			E 51°45'.3N 3°07'.4E			F 51°51'.5N 3°57'.3E			
	Directions of streams (degrees)	Rates at spring tides (knots)	Rates at neap tides (knots)																
Before High Water 6 (-6)	228°	1.8	1.3	-	0.5	0.4	265°	0.7	0.7	215°	1.8	1.0	220°	1.8	1.0	146°	0.4	0.2	-6
5 (-5)	225°	1.8	1.3	121°	0.7	0.5	-	0.3	0.2	220°	1.7	0.9	215°	1.3	0.9	167°	0.2	0.2	-5
4 (-4)	220°	1.8	1.2	110°	1.3	0.8	102°	0.5	0.5	210°	1.6	0.9	210°	1.4	0.7	136°	0.1	0.1	-4
3 (-3)	211°	1.1	0.7	102°	1.4	1.2	094°	1.2	1.2	170°	0.7	0.2	180°	1.1	0.4	090°	0.2	0.2	-3
2 (-2)	-	-	-	100°	1.2	1.0	090°	2.4	1.8	-	-	-	060°	0.3	0.2	084°	1.2	0.8	-2
1 (-1)	070°	1.3	0.9	077°	1.0	0.7	090°	2.1	1.7	045°	0.9	0.4	035°	1.2	0.7	077°	1.4	0.8	-1
High water 0 (0)	050°	1.4	0.9	083°	0.5	0.5	096°	1.5	1.2	041°	1.7	0.9	030°	1.6	0.9	044°	0.4	0.4	0
After High Water 1 (+1)	036°	1.5	0.9	312°	0.9	0.7	060°	0.2	0.1	031°	1.6	0.9	027°	1.5	0.9	027°	0.4	0.2	-1
2 (+2)	026°	1.4	1.0	303°	1.4	1.2	275°	1.2	1.0	020°	1.3	0.7	020°	1.3	0.8	320°	0.2	0.2	-2
3 (+3)	016°	1.4	0.7	297°	1.6	1.3	280°	1.9	1.4	010°	0.9	0.5	000°	1.0	0.6	276°	0.5	0.4	-3
4 (+4)	-	-	-	298°	1.8	1.2	276°	2.0	1.8	267°	0.6	0.3	240°	0.5	0.2	265°	0.8	0.5	-4
5 (+5)	260°	0.6	0.3	293°	1.4	1.1	273°	2.2	1.7	223°	0.6	0.3	210°	0.6	0.3	258°	0.6	0.6	-5
6 (+6)	230°	1.7	1.2	290°	0.6	0.6	273°	1.4	1.2	219°	1.4	0.9	214°	1.4	0.9	200°	0.3	0.3	-6

HW Vlissingen = HW Hoek van Holland -0h37m.
HW Dover = HW Hoek van Holland -2h35m.

Figure 11

In nautical charts the predicted tidal streams are presented in a stream table for certain positions (see figure 11). Unlike vertical tidal information such a stream table only has limited general value. The rates and directions presented are only valid for that location, and have limited value for the streams in the vicinity of the location. For more detailed tidal stream information see the HP33 and HP33D - NLTides. When using the HP33 it is recommended to use the largest scale stream chart of an area. That way the relation between the area concerned and the reference station is optimised. The difference in travelling time during springs and neaps between two locations far apart, can mount up to over an hour. Therefore it is advised not to use a different reference station than the one presented on the largest scale chart of the relevant area, e.g. if exact times of turning of the tidal streams are required.

Influence of meteorological circumstances

The influence of meteorological conditions on the horizontal water movement is difficult to determine, in particular distant weather conditions (e.g. off the Norwegian coast) may affect the horizontal water movement near the Dutch coast. The principal meteorological conditions that affect the predicted tidal streams are wind fields and, to a lesser extent, air pressure differences at sea. Conditions that lead to a rise of sea level in the southern part of the North Sea will cause a water movement from the North Sea towards the English Channel. On the other hand, conditions that lead to a fall of sea level in the southern part of the North Sea will cause a water movement from the English Channel towards the North Sea. The influence of these movements on the tidal streams results in an increase in duration and strength in one direction and a decrease in duration and strength in the opposite direction. After the meteorological disturbance has ceased to exist, it takes some time before the tidal streams have become normal again. In general, wind increases or decreases the rates of tidal streams dependent on the directions of the wind and streams. To determine the effect of wind in open sea, the following rule of thumb applies: a current of 2% of the wind velocity should be applied to the tidal streams. As an example, a wind of 40 knots generates a current of 0.8 knot. The wind-generated current is about 10° veered with respect to the direction of the wind. For example, wind from the north-west generally generates a current to the direction south-by south-east.

Depth contours and low-tide elevations

Low tide elevations are shown in the color green. The shape of such areas is not in accordance with the actual state of the tide elevation.

Cautions

- This atlas shows averages of the tidal streams, in direction and rate. There is a lot of variety in the circumstances, which may cause severe deviations from averages. Therefore, tidal streams can never be predicted with absolute certainty.
- Depending on position and local bottom properties (e.g., channels, sand waves etc.), deviations in both direction and rate of the tidal stream may occur, especially at greater depths. This may have a notable effect on deep draught vessels. Unlike general expectations, the mean neap rates may be higher than the mean spring rates in some channels; this depends on their cross-sections in areas that lie above the momentary water level.
- In areas with banks, the tidal stream flows through the channels. The direction of the stream follows the bearings of the banks. After sufficient flooding, the tidal stream will cross the banks.
- For the tidal rivers, the only important directions are upstream and downstream. Near basins, docks, secondary waterways, and similar waters, the tidal stream pattern may be complicated. During extremely high Rhine-discharges of more than 6000 m3/s at Lobith, the Haringvliet sluices will be fully opened; in that case, it is impossible to keep the discharge through the Nieuwe Waterweg at a constant level. During sluicing, strong currents may occur in the vicinity of the Haringvliet sluices.
- At IJmuiden, a sea-going current occurs in the Buitenspuikanaal and North of the Noordersluis, during sluicing or pumping. This may hinder ships with a draught less than 5 metre, because the speed of the water layer 0 – 5 metre below the surface amounts to 1 knot during sluicing. Below this layer, hardly any current occurs. During pumping, the rates are about 50% less.
- At IJmuiden, due to the salt water/fresh water exchange, a northerly or southerly current occurs in the buitentoeleidingskanalen to the Noordersluis, Zeesluis IJmuiden and the Middensluis. These transverse currents can possibly set ships away.
- Double high water off Zeegat van Texel.
  The charts for 3, 4 and 5 hours after LW Den Helder illustrate the double high water off Zeegat van Texel; the area concerned is shown in blue shading In the northern part of this area, the second tide is higher than the first; in the southern part, the first tide is higher than the second; in the middle of this area, the high water remains approximately constant during that time.
- Stream rates in the stream atlas 'B' (Western Scheldt/Eastern Scheldt) are subject to changes. In the Western Scheldt, in particular its secondary fairways, stream rates alteration may appear as a result of dredging work and natural migration of channels.
- Platen van Ossenisse (Western Scheldt).
  During strong spring tides a very strong tidal stream (2.5 to 5 knots) may cross the Zuidergat. This tidal cross-stream occurs during high water levels of 5.53 m LAT (+2.70 m NAP) or higher, from 20 minutes before HW Hansweert to 60 minutes after HW Hansweert, and runs between the 51 and 53 buoys from the Eastern part of Platen van Ossenisse (north of Hoek van Ossenisse) in the direction of the North-West entrance of the Schaar van Valkenisse. At the same time, a western tidal cross stream runs between the 53 and 55 buoys towards the outlet area of the Schaar van Ossenisse. The tidal cross stream can also occur during less developed spring tides which, due to storm surging, result in a waterlevel at Hansweert of > 6.08 m LAT (+3.25 m NAP). Shipping is kept informed by the local traffic center (through shipping messages) about the tidal cross-stream.
- Middelgat – Overloop van Hansweert (Western Scheldt).
  During strong spring tides a strong tidal stream (measured to 2.7 knots) out of the Middelgat crosses the Overloop van Hansweert (between the 40A and 40B buoys.) This tidal cross-stream occurs from 1 hour before HW Hansweert to HW Hansweert.
- Tidal flats of the Waddenzee.
  In the Waddenzee the tidal stream pattern is complicated in tidal flat areas, flood streams from separate tidal inlets meet each other continuously, resulting in local

lower stream rates. This causes a comparatively high sedimentation rate in these tidal flat areas; tidal flats usually stretch meandering between coast and island.

- In the Waddenzee lengthy periods with easterly winds may cause considerable water level reductions and shifts in tidal stream patterns.
- Deviations from the Waddenzee tidal stream atlases may occur after a number of years after publication. This is the result of ever changing channels in this area.
- Maasgeul.
  Because of the construction of Maasvlakte 2, current patterns in and near the Maasgeul have changed. Changes are most noticeable during flood tide. The flood current follows the new coastal line in a northerly direction and diverts, in the vicinity of buoy MV N, in an easterly direction. In the Maasgeul the cross current, during flood tide, decreases near buoy MV N. The rate of decrease is more gradual than in the old situation. During flood tide, the depth averaged stream rates are comparable to the old situation until one hour after high water at Hoek van Holland. After that time, stream rates and directions differ from the old situation, north of Maasvlakte 2. The turn of the flood tide near the harbour entrance starts slightly earlier than in the old situation.

  A remarkable change is a counter stream, which occurs after high water, between the MV-N buoy and the port entrance and just North of the new coastline of Maasvlakte 2. Seaward of the port entrance, the east-going flood stream partly bears off in a southern direction and continues in a western direction, directly under the new coastline of Maasvlakte 2. In the vicinity of MV-N, the counter stream merges with the north-going flood stream. The strength of the counter stream varies with tide, wind and river discharge. Effects of the counter current may be encountered until the Maasgeul. The counter stream is most dominant during spring tide.

  During ebb tide, the tidal stream bears off in a western direction in the vicinity of the port entrance and follows the new coastal line. No further changes of any significance have been reported during ebb tide.

The use of stream atlases

The example in figure 12 shows how to use the tidal stream data found in the HP33. The shown calculations are executed automatically in the HP33D – NLTides.

Location	Texelstroom East of Oudeschild
Date	23 October 2021
Time	07:16 Local Time

Question: calculate the stream rate and direction.

Answer:
In the tables with hourly heights Harlingen one can determine the present time to be 5 hours before HW Harlingen. The stream chart concerned depicts a NE going tidal stream with a rate of 1.0 kts at neap and 2.1 kts at spring tides. In the tables, New Moon occurs at October 20th. Along the coasts of Belgium and the Netherlands, spring tides occur well over two to three days after Full- and New Moon. October 23rd corresponds with spring tide, so the rate is 2.1 kts.

Resume:

- Determine which atlas covers the area concerned and which reference station is involved;
- Look up the nearest time of HW in the table "Hourly heights in dm referred to LAT" ;
- Determine the direction and rates of the stream at neap and spring tides from the stream chart concerned, or interpolate between two stream maps;
- Determine, whether the neap or spring rate value is to be used, or an interpolation has to be performed. Use the tide tables for this purpose.

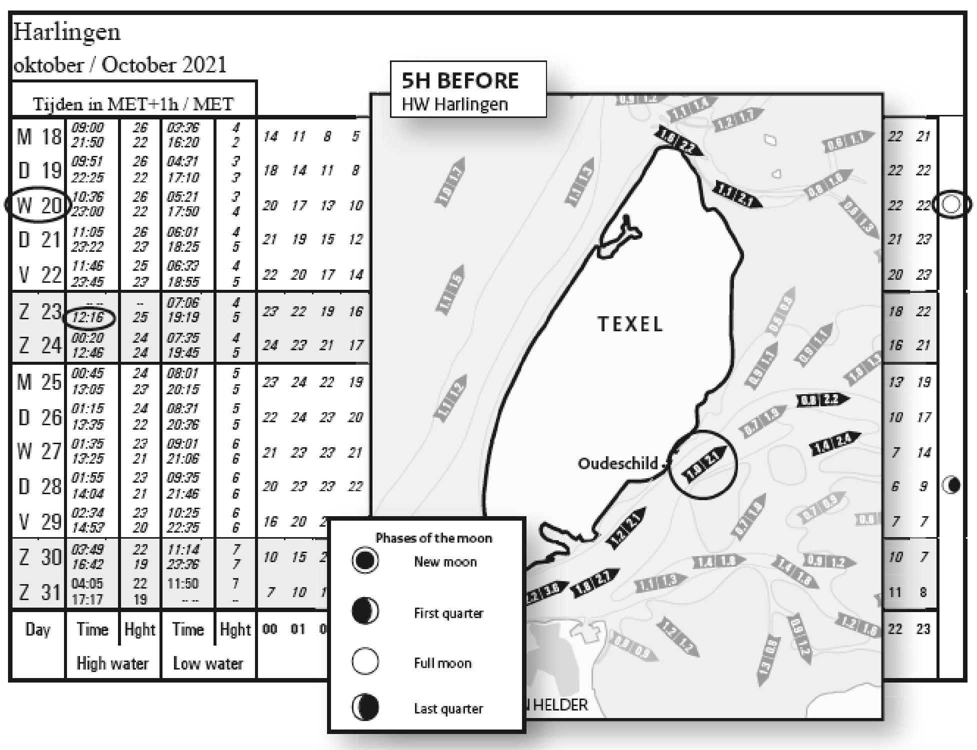


Figure 12