

Protide

Probabilistic Tidal Window Determination

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Protide prototype

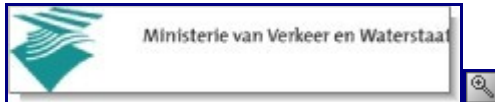
PROTIDE stands for 'PRobabilistic TIDal window Estimation'. It is a tidal window advice program, which will be used for determining tidal windows within the 'euro-maas-geul' and 'ijgeul'. A probabilistic safe passage will be stipulated taking into account the waterlevels, current (direction) and motion.

Prototype

PROTIDE is under development since 2007 and is in a prototype phase. The objective is to combine the state-of-the-art knowledge on probabilistic tidal window calculations and deliver a full application early in 2009.

Developers

[Dienst verkeer en scheepvaart
\(DVS\) - Ministerie van Verkeer, Charta Software
en Waterstaat](#)



Instructing party



Developer PROTIDE

[Amarcon](#)



Provider of the ship motion application OCTOPUS

Site layout

A brief description of which information can be found on this web site.

[Protide \(prototype\)](#)

Introducing.

[How to use Protide](#)

How to get a tidal window advice and what can be found under the 'Professional' tab.

- [Log in](#) Getting access to the functionality.
- [Getting an advice](#) The steps to take to get a tidal window advice, to approve the calculated advice and to view the details and data.

[Technical documentation](#)

How is the application constructed and which (mathematical) models are used.

- [Status of the application](#) What is already incorporated in the application and what will be done in the (near) future.
- [Calculation description](#) A description of the calculation method and used techniques.
- [Full calculation scheme](#) A detailed stepwise description of the calculation method.
- [Data](#) What kind of data is used.

[Support and feedback](#)

Questions raised and answers found.

[Project group](#)

The participating parties.

[Meetings](#)

Presentations, reports, schedule and all.

How to use Protide

The steps to take for trying the functionality of the Protide application are explained here. The first step is to [log in](#). That will give you access to the 'Professional' tab. Under this tab you will find a menu from which you can address the functionality. An overview of the menu:

[Data forecast](#)

For viewing the waterlevels, currents (direction) and motions that are recorded within the channels. This is the information the tidal window advices are based on.

[Request tidal window](#)

For submitting a new request regarding a tidal window advice.

[Status monitor](#)

For watching the progress and status of submitted requests, calculations and advices.

[Open activities](#)

For learning which requests must be submitted to get an advice and which advices must be evaluated and approved (or declined).

[Tidal window advice details](#)

For viewing the details of an advice. The state of the channel is sketched, starting at the estimated time of arrival up to 24 hours later.

[Documents](#)

For adding documents that might be useful to Protide.

Log in

To get access to the functionality of Protide you have to log in. You can do this by filling in one of the standard login profiles. Because certain functionality is permitted only to specific users, you will have different rights with each chosen profile. For example, you are allowed to view advice details as a pilot, but you are not allowed to submit a request.

An overview of the login information and permissions:

E-mail	Password	Submit request	View status	View and process open activities	Get details of an advice
Ship Master	Protide1	Yes	Yes	No	Yes
Pilot	Protide1	No	Yes	No	Yes
Port Authority	Protide1	Yes	Yes	Yes	Yes
Provider	Protide1	No	Yes	Yes	Yes

Getting an advice

In order to get an advice the following steps have to be taken:

1. A request for a tidal window is submitted. This is done by a 'Ship master' or a 'Port Authority'. Within the request the details of the ship and the journey are specified. For example the IMO number, width and length of the ship and the estimated time of arrival. [Request tidal window module](#)
2. Around the desired tide the 'Provider' delivers or has delivered data forecasts. These forecasts can be adjusted automatically or manually. [Data forecast module](#)
3. The 'Provider' or 'Port authority' starts the determination of a tidal window advice for a request. This gives a temporary or tentative advice. [Open activities module](#)
4. A tentative advice is then to be approved explicitly. [Open activities module](#)

During the process all relevant parties can view the status of the request ([Status monitor module](#)), the data forecasts ([Data forecast module](#)) and the advice details ([Tidal window advice details module](#)).

Technical documentation

When you want to know more about the technical background of the Protide application take a look at the following articles.

[Status of the application](#)

New versions of the Protide application will be released. Here you can see what is incorporated in the latest version and what will be added in the (near) future.

[Tidal window calculation method](#)

Here you can find out how the Protide application is build. What (mathematical) models it is based on and how we incorporated that.

[Data](#)

Here you can see what type of data is used within the Protide model.

Status of the application

During the project the functionality on this site will constantly be expanded.

Current functionality contains:

- *Data forecast*

Interested parties can view data forecasts entered by the provider that are used in tidal window calculations. We have a very detailed dataset for the period 15th of September up to the 15th of October 2007. This dataset is sufficient for testing and validating the model. For long term statistics (f.e. harbour down time or overlay percentages) the dataset is currently expanded to several years. This will be a less detailed set in terms of the number of forecast points along a channel or in time.

- *Request tidal window*

As a ship master, or as his representative, it is possible to add a request for a tidal window advice. The ship type and load type (bulk, ore or tanker) is now very simplified and others may seem over elaborate, because we are testing the use of the OCTOPUS model that calculates the ship motions. It is to be examined which fields are absolutely necessary and which are optional to prepare a tidal window advice.

- *Status Monitor*

All interested parties (ship master, agent, provider, port authority or pilots) can monitor current pending advice requests. For example, they can monitor whether the calculation has started or whether the determined advice is approved.

- *Open activities*

After a tidal window request is made, the provider or port authority can start the calculations necessary to determine an advice. The advice can be based on several safety criteria:

1. Minimum UKC percentage
2. Minimum UKC minus squat percentage
3. Maximum bottom touch probability

All three criteria can be set and used in combination with each other. For example one could be satisfied with a UKC > 5% in combination with a bottom touch probability < 0.01%. In flat water (no waves), this would lead to a minimum of 5%

UKC and with significant vertical motion due to waves the probability criterion will kick in.

The calculation is done by finding the safe times to be at each location along the channel with a given speed towards the harbor. Safety is dependent of draught, channel depth, water level estimation, current estimation, wave height estimation, squat calculation, vertical motions analysis and finally the probability calculation. Because all these parameters are stochastic, the result is a probability distribution that a location is safe to be at a certain time. Finally we choose the 95% percentile of the resulting distribution is chosen to make sure we have a maximum type 1 error of 5%. The type 1 error is the chance that we consider the time / location to be safe for our ship, considering the safety criterion, but actually we were wrong. A port authority can evaluate the determined advice. If the advice is considered safe it can be approved, but if there are doubts, a port authority can request a recalculation by declining the determined advice.

- *Tidal window advice details*

As soon as a tidal window advice is available, all parties can view the results in detail. Some information about the request is given, for example the estimated time of arrival that was filled in. Some information about the calculation is given, for example the time the calculation was started and whether or not the advice is approved. And some information about the advice is given, for example the time the ship arrives at the harbor when following the advice. A time location diagram, a tide curve diagram, a cross current curve diagram and a bottom touch probability / UKC diagram are also given. These figures cover the time starting from the estimated time of arrival up to 24 hours later.

What is yet to come:

- *Parameter estimation and validation*

Finally some parameters in the model are to be estimated. This is planned for the safety indication parameters: cut-off chance (what is the maximum chance of a bottom collision at any time in the probability density function?) and single voyage chance (what is the maximum chance of a bottom collision for a single voyage). These are estimated in relation to long term statistics: estimated number of bottom collisions in 25 years and harbour statistics. The validation is done by calculating and comparing the actual tidal windows for requests that were issued in the period we have detailed data (15th of September up to the 15th of October 2007).

- *Better integration OCTOPUS model*

OCTOPUS is used to calculate possible vertical motion patterns that could occur during a channel voyage. Because many different circumstances are simulated a lot of calls are made to the OCTOPUS model, which is a major bottle neck. We are planning to discuss the way we use OCTOPUS with it's provider Amarcon to optimize the collaboration between PROTIDE and OCTOPUS.

Calculation description

During the development of the prototype a calculation method is figured out. This method is developed in cooperation between DVS (Ernst Bolt) and Charta Software (Marlies de Keizer, Peter-Jan Roes and Karsten Uil). The initial idea was to make a method based on the research of Ruud Bouw ('Admittance policy tidal bound ships'), which was a study to find a truly probabilistic methodology as an improvement on the currently used HARAP model. The main objectives:

1. Introduce a model that can be used real-time
2. Use actual forecast data instead of schematizations for water levels, swell and current
3. Use a continuous/actual data for the channel layout, channel depth reductions and ship dimensions
4. Use state-of-the art ship motion analysis
5. Analyse and use a safety criterion for each individual ship entrance

These objectives were analyzed in an initial feasibility study that resulted in a method reported on June 2007. The report can be downloaded in the [Meetings](#) section on this website.

The calculation determines the probability that a ship, going through a channel with a certain speed at a certain time and location, hits the bottom. The times and locations where the probability is smaller than a prescribed safety criterion are suitable for a navigational route.

The probability is determined in a number of steps:

1. The under keel clearance (UKC), the space between the bottom of the channel and the navigating ship in smooth water with squat reduction, is determined.
2. The motion (period and probability distribution of the significant vertical movement) as a result of the waves is determined.
3. The frequency of bottom touches, given the UKC and motion, is determined.
4. The probability of a bottom touch, given the frequency, is determined.

With this method the probability of a bottom touch at one location in the channel at one moment in time, can be determined.

[More information >>](#)

In order to get a tidal window advice we can apply the above method in a progressive scheme:

1. By applying a [search method](#), which searches for the locations and times where the probability of a bottom touch is just equal to the safety criterion, a time location diagram can be determined with possible navigational routes.
2. Next, the moments in time that the cross current is too strong at the entrance of the harbour are excluded.
3. The last step is determining a navigational route which, given a certain speed, is allowed and



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safe enough.

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P(bottom-touch)

The determination of the probability of a ship hitting the bottom at a certain location in a channel at a certain moment in time, can be divided into the steps below.

Under keel clearance (UKC)¹

The basic UKC is the UKC of a ship given the waterlevel, the draught of the ship and the squat².

1. *Water level*


The water level is determined from the water level forecasts for the depicted time and location. These levels are provided by HMCN (see [Project group](#)) at given times and locations. [Squared interpolation](#) is used when water levels are needed that are not within the forecasts. The forecast consists of a water level forecast and the error bandwidth (standard deviation). The actual water level is assumed to be distributed normally around the given forecast with the given standard deviation.

To incorporate the uncertainty in the waterlevel forecast we draw a number of times from the given water levels distribution function as a start for the next steps (squat and motion analysis). Currently we use about 100 trials per time location point, which results in about 300.000 to 500.000 trials in the whole time location diagram. It is to be examined if we can analytically determine the squat and UKC distributions given the water levels distribution.

2. *Maximum squat*

The maximum squat is determined by the formula of Tuck-Taylor:

3.
$$F = \text{Froude-number} = \frac{v_s}{\sqrt{g \cdot h}}$$

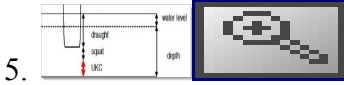
$$\text{squat} = \frac{F^2}{\sqrt{1-F^2}} \cdot \frac{v_s}{L_{pp}} \cdot C_{squat}$$


Where:

- $v(s)$: the speed of the ship
- g : acceleration due to gravity
- h : water level
- δ : water displacement
- $L(pp)$: length of the ship

4. *UKC calculation*

The UKC then follows from: depth + water level – draught - maximum squat



Motion

After determining the basic UKC and taking squat into account, the effect of the motion of the ship can be determined. This is done by calling the OCTOPUS program. This program uses a description of the ship under certain conditions (a compiled hydrodynamic database (?)) to create a RAO function (response amplitude operator). This function is then used to calculate the ships response under a variety of conditions that could occur at the desired time and location:


1. Depth / draught ratio ³
2. Ship heading
3. He10 ⁴
4. Possible wave spectra
5. Wave direction

For each response the maximum significant vertical motion and corresponding motion period is stored. These results are then grouped per depth / draught ratio, heading and wave height, which can then be used to estimate the vertical motion at any circumstance.

Frequency of bottom touches

By taking the responses calculated with OCTOPUS the frequency of the number of bottom touches is derived:

$$m_0 = \frac{1}{16} Z_s^2$$

$$\lambda = \frac{1}{T} \cdot e^{-\frac{KC^2}{2m_0}}$$


Where:

- m(0): 0th spectral moment of the ship movements
- KC: calculated basic UKC
- T: mean period of the ship movements
- lambda: frequency of bottom touches

Probability of bottom touches

Finally it is assumed that the bottom touches follow a Poisson distribution. From this the probability of the number of bottom touches during a navigational route, T(pas) can be derived:

$$P(\lambda \cdot T_{\text{max}} > 0) = 1 - e^{-\lambda \cdot T_{\text{max}}}$$


This probability can be used as the probability of hitting the bottom if during the whole navigational route the conditions (speed, water level and channel depth) stay the same.

Probability distribution analysis

By making draws out of the distribution of the water level forecast, the He10 expectation, the different possible wave spectra and a variance of the angle of incidence of the waves, we get an estimate of the probability density function chances that the the bottom is touched at one time at one location. We can use a test to analyze if the found bottom touch chances are significantly below the cut off safety criterion.

-
1. The space between the bottom of the channel and the navigating ship in smooth water.
 2. Increase of the draught of the ship because of the speed. As the water is pushed downward by the passing hull it accelerates and its pressure falls. The reduced pressure on the bottom of the boat sucks the boat slightly downward until the increased displacement counteracts the force generated by the reduced pressure.
 3. The ratio between the amount of water and the draught of the ship. For channel- and tide-bounded ships the value lies between 1.1 and 1.5.
 4. Height of the low frequency waves.

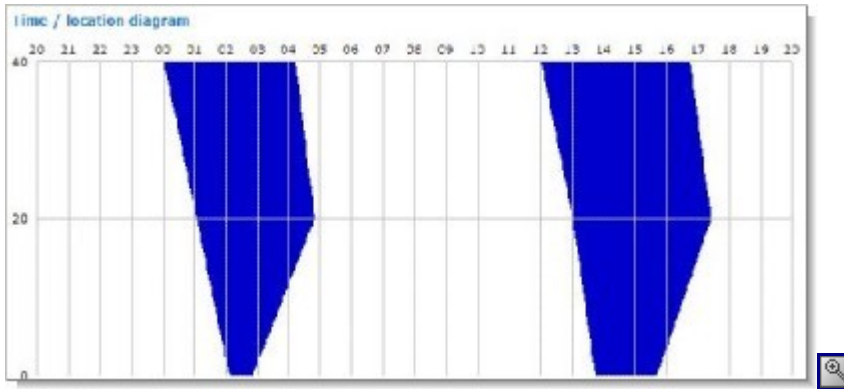
Calculation scheme

In order to get a tidal window advice we can apply the method for calculating the probability of a bottom touch in a progressive scheme. It consists of three steps which are explained below.

Step 1: Determining a time location diagram

The boundaries of the area within the time location diagram, that is safe for moving through, are given by the times and locations where the probability of hitting the bottom is just equal to the safety criterion. By searching for these extremes there is no need to calculate the probabilities for all times and locations, which makes it relatively efficient to determine the safe area within the time location diagram. A [zero point search method](#) is used for this purpose, which searches for safe time intervals for each kilometer point along the channel. The method is applied to [the probability calculation method](#).

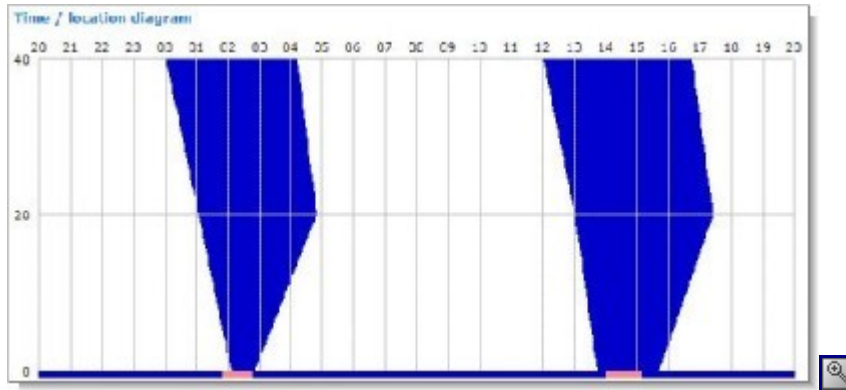
Resulting in



Step 2: Cross current exclusion

If, at some time, the cross current at the entrance of the harbour is too high (higher than a certain defined maximum), a ship can't go into the harbour. These times are excluded from the time location diagram.

Resulting in



Step 3: Tidal window advice

The last step concerns the actual determination of a tidal window advice. This is done by drawing an as wide as possible path from the start of the channel up to the berth, taking into account a given speed (which is the [resulting speed](#) from the fullmaneuvering speed of the ship and the speed of the current) and if needed a minimal width of a tidal window, through the safe area of the time location diagram. When it is possible to draw such a path, it is considered to be the advice.

Drawing the path is done by picking times of arrival at the entrance of the harbour with certain intervals (for example every 5 minutes). If the point of time and location is within the safe area a route is determined from the start of the channel to the berth, moving with the given speed and passing through this point. If the whole route is within the safe area it is added to the tidal window advice and the next point of time and location is taken.

If there are no routes found that completely fall within the safe area it is not possible to determine a tidal window advice for the given situation. The ship has to wait for the next tide and a new calculation must be made.

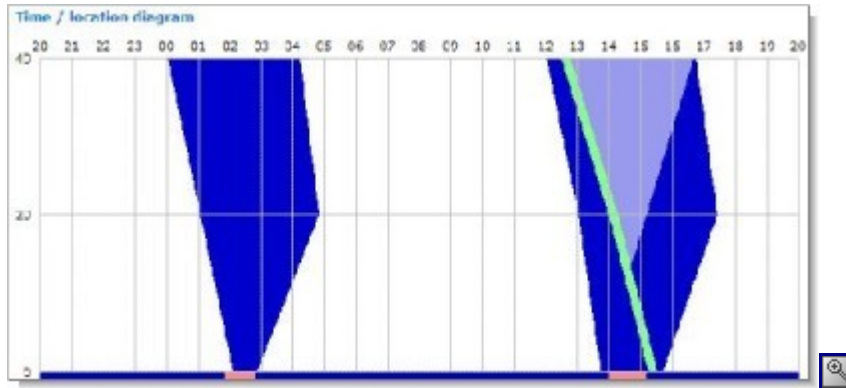
If a tidal window advice is determined it means that during the whole trip the probability of hitting the bottom is below the safety criterion. The realized risks of bottom touches can be sketched separately or a UKC picture can be drawn. Also the possibility for returning can be indicated (for now we assume that we can take the same time-location diagram for this return movement, but in fact we should use a different angle for the waves to get the right motion of the ship).

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Probabilistic Tidal Window Determination

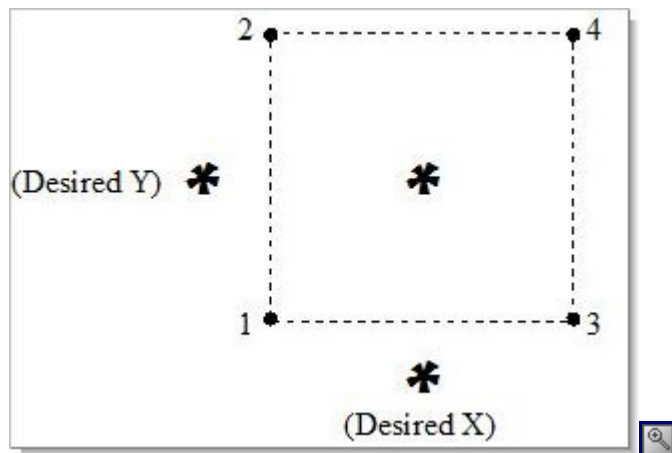
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Resulting in



Squared interpolation

Squared interpolation is used for finding the Z-value belonging to the point (Desired X, Desired Y), when four measure points around it are known:



To find the Desired Z, there are two possible methods:

1. First find the Z-value for the desired X over the vector 1->3 and over the vector 2->4 (Y is kept constant). Then interpolate the two results to find the Z value for the point (Desired X, Desired Y). This is result number one.
2. First find the Z-value for the desired Y over the vector 1->2 and over the vector 3->4 (X is kept constant). Then interpolate the two results to find the Z value for the point (Desired X, Desired Y). This is result number two.

The final result is the average of the results coming from the above two methods.

Bisection method

Zero-point or root finding

A zero-point search algorithm is used to find the edges of the time intervals when it would be safe for a ship to be at that point in channel at that time with the given speed. The function that we are analyzing is:

$$P_{safe} - P_{bottom-touch}(time, location)$$

The search method searches for the points where the above function evaluation changes sign. The method is called for a fixed location, so the only parameter is "time". The method is called bisection, but actually is a combination of a fixed step analysis and true bisection:

1. First with a fixed step size (30 minutes) the function is evaluated between the estimated time of arrival of the ship and 24 hours later. These 49 function evaluations and their results determine the discriminating power of the algorithm. Now we are interested in the function evaluations (times) where the result changed sign. Because (under the assumption of a continuous function) we know from the [intermediate value theorem](#) that there must be a root (time where the chance of touching the bottom is exactly equal to the safety criterion) between the two points.
2. Secondly we apply a [bisection algorithm](#) on the intervals where the sign flipped to find the root with more precision. The precision is set to 5 minutes, which makes the maximum error equal to 5 minutes and the average error is estimated to 2.25 minutes.

Bisection

The essence of the bisection algorithm is dividing the interval in half and re-evaluating the function. This way we double the precision of our zero-point each function evaluation. The code below shows how the root is found to a certain precision in the interval:

```
[StartInterval.Parameter, EndInterval.Parameter]
```

of which we know that:

```
StartInterval.Result * EndInterval.Result < 0
```

```
while EndInterval.Parameter - StartInterval.Parameter > (Precision / 2) do
begin
  Middle := (EndInterval.Parameter + StartInterval.Parameter) / 2;
  MiddleFunctionValue := ContinuousFunction.Execute(Middle);
  if (StartInterval.Result * MiddleFunctionValue > 0) then
```

Protide

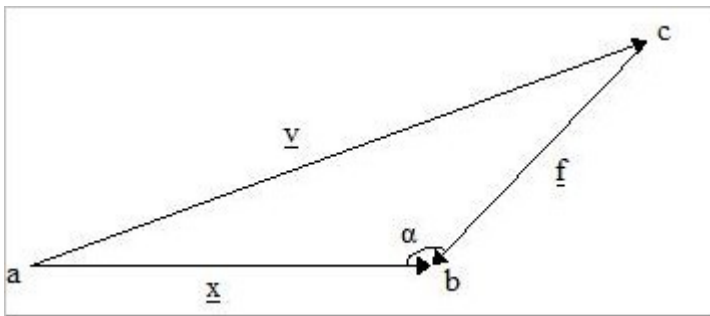
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```
begin
  StartInterval.Parameter := Middle;
  StartInterval.Result    := MiddleFunctionValue;
end
else
begin
  EndInterval.Parameter := Middle;
  EndInterval.Result    := MiddleFunctionValue;
end;
end;
Result := (StartInterval.Parameter + EndInterval.Parameter) / 2;
```

Resulting speed

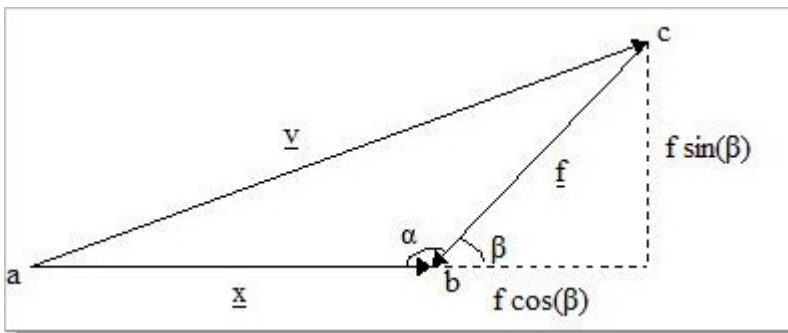
When a ship is moving towards the harbour with a certain speed in a certain direction, the real speed will be different because of the influence of the current.



- Given that you are navigating from point a to point c with fullmaneuvering speed \underline{y}
- The current is going from point c to point b with speed \underline{f}
- The angle with which the vectors cut each other of at point b is denoted α

Then we can determine the actual speed, \underline{x} , that the ship is moving with from point a to point b.

The first thing to do is split the vector from point c to point b in a horizontal and vertical part. Applying the sinus and cosinus functions you can determine the lengths of these new vectors.



Where $\beta = 2\pi - \alpha$

Applying pythagoras: $\underline{y}^2 = (\underline{x} + \underline{f} \cos(\beta))^2 + (\underline{f} \sin(\beta))^2$

This can be rewritten to:

- $\underline{x} = (\underline{y}^2 - (\underline{f} \sin(\beta))^2)^{1/2} - \underline{f} \cos(\beta)$
- $\underline{x} = -(\underline{y}^2 - (\underline{f} \sin(\beta))^2)^{1/2} - \underline{f} \cos(\beta)$

One of the two values above will be positive. This is the resulting speed \underline{x} .



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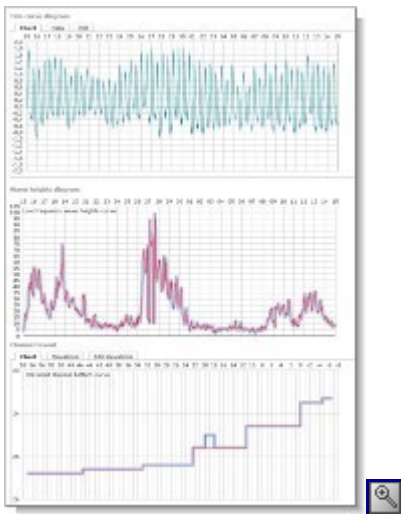
KvK: 24387981
BTW: NL8151.65.286.B01

Full calculation scheme

To calculate a tidal window a probabilistic methodology is used that simulates a set of possible conditions to determine exact times and locations that the probability of touching the bottom is below the safety criterion. Then a route is found through these "safe" moments to determine the tidal window advice.

After the tidal window calculation is started the following steps are performed:

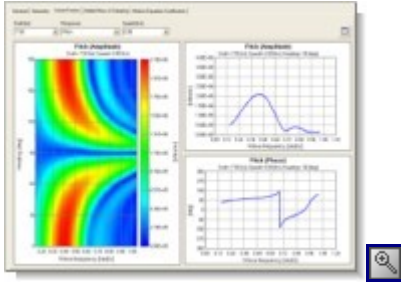
Find applicable measurements and forecasts of possible circumstances



All measurements and forecasts between the estimated time of arrival and the estimated time of arrival plus one day are retrieved from the database:

- water level estimation
- water level variation
- current direction
- current speed
- wave heights (He10)
- wave height variation
- channel depth
- channel bottom elevations
- channel heading / angle
- ship dimensions

Calculate possible vertical motions

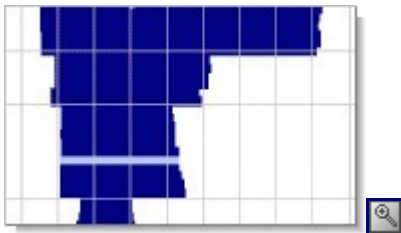


OCTOPUS (by Amarcon) is used to calculate the possible vertical motions that can occur for this ship under the estimated circumstances. This is done by:

- determining the wave height variation
- creating wave spectra files
- calculating the ship responses for different depth / draught ratios, headings, wave heights and wave directions

[Detailed vertical motion calculation documentation >>](#)

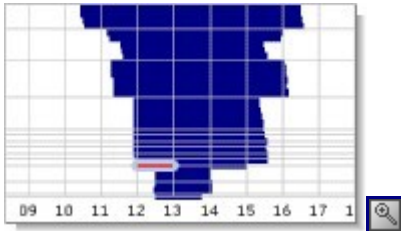
Calculate safe time location diagram



The next step in the tidal window calculation is the determination of the time intervals that the ship can be at each kilometer point with the given speed. This is done by finding exact times and the locations that the chance of touching the bottom is exactly equal to the maximum allowed criterion. These "roots" also determine the safe time intervals in the time location diagram.

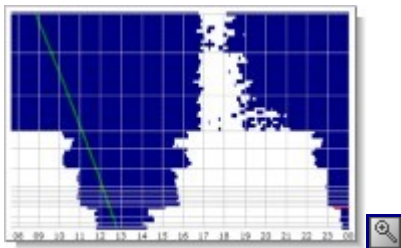
[Detailed safe time intervals calculation documentation >>](#)

Exclude times of excess cross current



The safe time intervals calculation only determines that at the given time the chance of touching the channel bottom is lower than the desired safety criterion. An extra criterion is the maximum allowed cross current on harbor entrance. This is set between about 0.4 and 0.6 m/s. The safe time intervals are trimmed, split or fully removed when the cross current is expected to be higher than this criterion.

Calculate safe route



After the safe time intervals are determined and corrected for the cross current the algorithm tries to find a safe route with a desired minimum time window width. The algorithm starts at the first available safe time interval on the most restrictive kilometer position in the channel and then tries to reach the berth and start of the channel from there. The algorithm starts with a minimal time window width of 2 hours and on failure tightens the desired width.

[Detailed route calculation documentation>>](#)

Related articles

- [Vertical motions](#)
- [Safe time intervals](#)
- [Calculate route](#)

Vertical motions

OCTOPUS (by Amarcon) is used to calculate the vertical motions that can occur given the possible conditions.

A set of possible vertical motions is calculated given the ship and load characteristics and the given conditions and condition variations.

Input

- Ship characteristics: length, width, draught (front and back) metacentric height, free fluids correction, 6 motion points and speed
- 3 depth / draught ratios: 1.4, 1.2, 1.1
- 3 CHDB files (compiled hydrodynamic databases). One for each depth / draught ratio.
- Possible headings in the channel.
- Minimum and maximum forecasted wave heights (He10).
- 16860 historical measured wave spectra
- Wave direction distribution: N(mean, standard deviation)

Calculation method

determine wave height steps

Step size: $\text{Minimum}(10, (\text{maximum wave height} - \text{minimum wave height}) / 10\text{cm} + 1)$
 Create steps from minimum wave height to maximum wave height with step size

create wave files

for each wave height step:

- 1) select wave spectra corresponding to possible wave height bandwidth
- 2) randomly select number of desired possible wave spectra and create wave file

calculate ship responses

for each depth / draught ratio:

- 1) select chdb file
- 2) calculate RAO (chdb, ship dimensions)
- 3) for each heading (channel angle):
 - 1) for each wave height step:
 - 1) get wave file
 - 2) for each wave direction iteration:
 - 1) draw wave direction from N(mean, standard deviation)
 - 2) calculate vertical motion responses (heading, wavefile, wave

direction)

3) for each wave spectrum in the wave file:

1) store maximum vertical motion and corresponding motion

period

Output

These vertical motions are calculated for the given possible conditions during a channel passage. The responses are stored per: depth / draught ratio, heading and wave height.

At the moment a vertical motion analysis is needed during the tidal window calculation, one vertical motion is randomly selected from all the calculated responses with the correct depth / draught ratio, heading and wave height.

Safe time intervals

The determination of the time intervals that the ship can be at each kilometer point with the given speed. This is done by finding exact times and the locations that the chance of touching the bottom is exactly equal to the maximum allowed criterion. These "roots" also determine the safe time intervals in the time location diagram.

The safe time intervals are determined for each kilometer position. At each position the start and end times of the intervals are determined that it is safe to be at that position. This is done for the period starting at the estimated time of arrival (ETA) up to ETA plus one day.

for each kilometer position between start of the channel to the berth

Calculate roots of the bottom touch probability function with a bisection method on:

maximum bottom touch probability - $P(\text{bottom touch})$

for number the set number of iterations

$P(\text{bottom touch})$ per (time, location):

- 1) Draw water level from $N(\text{mean}, \text{standard deviation})$
- 2) Get channel depth
- 3) Get bottom elevation
- 4) Get channel heading (angle)
- 5) Calculate under keel clearance
- 6) Calculate Squat with the Tuck-Taylor formula
- 7) Draw wave height from $N(\text{mean}, \text{standard deviation})$
- 8) Draw possible random vertical motion
- 9) Calculate spectral moment and bottom touch frequency
- 10) Calculate $P(\text{bottom touch})$ as if the frequency would hold during a whole channel passage

Take the 95% $P(\text{bottom touch})$ percentile of the found percentages

Safe time intervals are found between the found roots

Calculate route

The objective is to find a route with a desired time window width. This is done by traversing the safe time intervals while taking into account the ship speed and the expected current speed and direction.

Pseudo code

```
desired route width = 8 x time location granularity (2 hours)
while no route found and desired route width >= minimal route width (15 minutes)
  find most critical kilometer point and first safe time

  //first try to reach berth starting at this point:
  while berth not reached
    if time is not safe for at least desired route width
      get next safe time for this kilometer point
      find next time location point with the given speed

  //next try to reach start of the channel:
  while start channel is not reached
    if time is not safe for at least desired route width
      get next safe time for this kilometer point
      find previous time location point with the given speed

  if route is found
    calculate bottom touch probability and save route
  else
    half desired route width
```

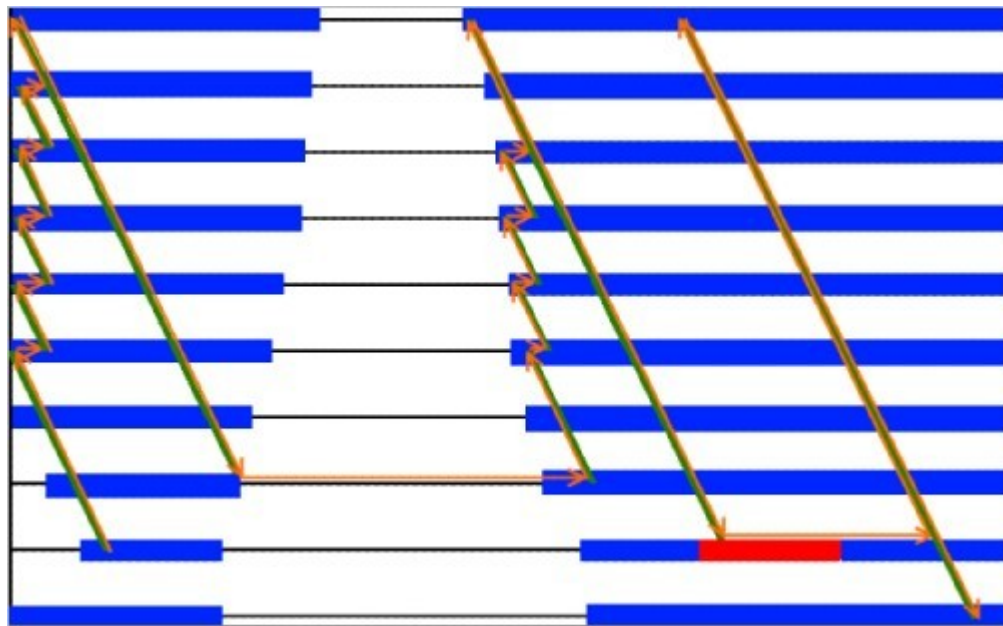
Algorithm visualization

The visualization shows the (orange) traversal from the most critical (narrow) safe time interval up to the start of the channel. Each time the next step in the traversal was not feasible, the algorithm shifts to the first available safe time (with the desired width). If a traversal is possible from start channel to berth, without shifts, then this is the tidal window advise.

Protide

Probabilistic Tidal Window Determination

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Data

For Protide to produce results we need data with regard to the water in the channels (Euro-Maasgeul and IJgeul). That is, we need:

- Water level
- Current
- Current direction
- Wave observation

For each channel there should be at least two positions for which we have this data during across time.

The supplied data can be divided according to the period of time. We have short term data and long term data.

Short term

The short term comprises the period 15 september 2007 till 15 october 2007. For this period we have data available per half hour. With respect to time there is enough data.

With respect to the channel positions there is also enough data available. Per kilometer point we have water levels for the Euro-Maasgeul as well as for the IJgeul. The current and current direction are given for the same kilometer points. The wave observations are indeed given per channel, but because the variation in waves across the positions in the channel will not influence the model too much, the same wave observation will be used for all kilometer points in one channel.

Long term

The long term comprises the period 1 january 2004 up to 31 december 2007. For this period we have data available for every ten minutes. With respect to time there is enough data.

With respect to the channel positions there is enough data available for the Euro-Maasgeul. For the IJgeul the data is extended.

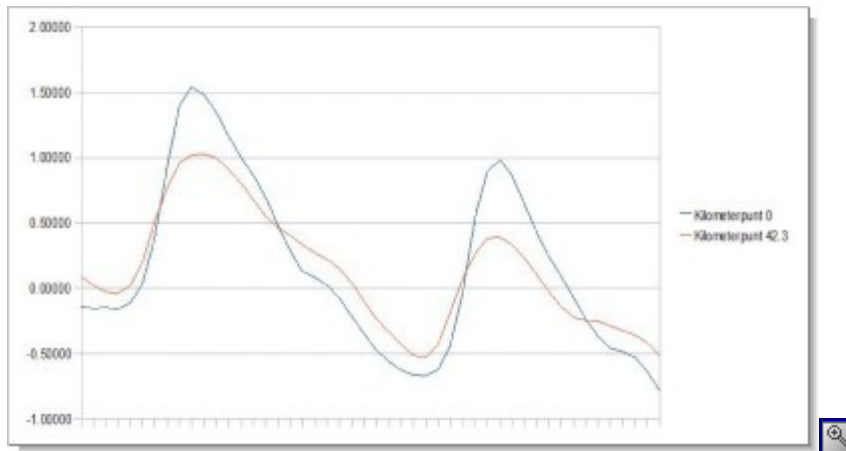
Water levels

The water levels within the Euro-Maasgeul are given for two positions: Europlatform (kilometer point 57) and Hoek van Holland (kilometer point 0). This is enough to be able to run the Protide model and it forms the basis for the rest of the long term data (see 'Current, direction and wave observation' below).

The water levels within the IJgeul are only given for IJmuiden (kilometer position 0). This is extended with water levels for the start of the channel (kilometer point 42.3), which are deducted from the tide-

curves in the short term data.

A tide-curve reflects the course of the waterlevels at a certain position during a day. For kilometer point 0 and 42.3 this looks like the following on september the 15th:



Both curves move around the same level during one tide. Only for kilometer point 0 the water levels decrease and increase faster compared to kilometer point 42.3. We will use this property to imitate the data for kilometer point 42.3: we will scale the data given for kilometer point 0.

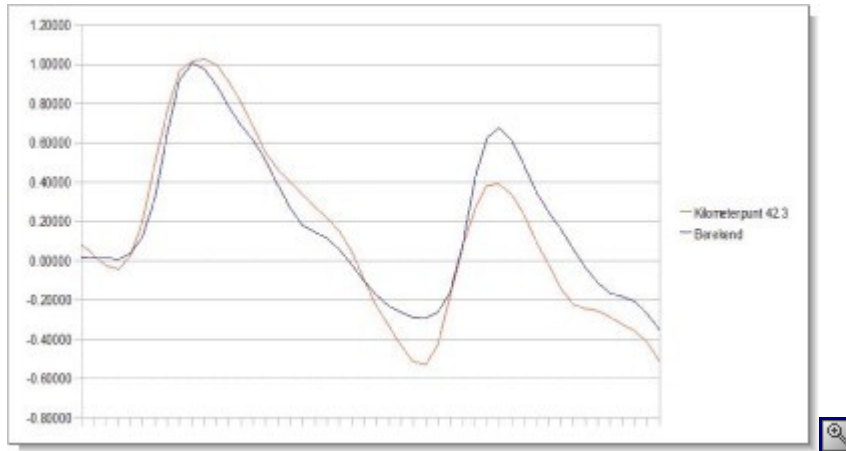
In essence we compare the levels of the minima and maxima for the two kilometer points. Where we use the following definitions:

- Tide impact: the difference between the maximum and minimum water level during a tide
- Middle: the level around which the curves move. This is the middle level between the minimum and the maximum, or the minimum plus half the tide impact
- Scale: the proportion between the tide impacts for the two kilometer points

Imitating the water levels then comes down to:

1. $\text{middle} = \text{minimum}(0) + 0.5 * \text{tideimpact}(0)$
2. $\text{scale} = \text{tideimpact}(42.3) / \text{tideimpact}(0)$
3. $\text{waterlevel}(42.3) = \text{middle} + (\text{waterlevel}(0) - \text{middle}) * \text{scale}$

The difference between the imitated and real data for kilometer point 42.3 is:



By applying the above method to all days within the short term data we can get a feeling about the scale between the two kilometer points.

But before we do that we first divide the days into so-called astroclasses. Because the tide impacts can differ a lot over the days we want to differentiate the scale a bit. We do this by assigning each day to a class according to the following rules:

- If the tide impact at kilometer point 0 is larger than 190 cm, the day falls into astroclass 1
- If the tide impact at kilometer point 0 is larger than 140 cm and smaller than 190 cm, the day falls into astroclass 2
- If the tide impact at kilometer point 0 is smaller than 140 cm, the day falls into astroclass 3

Now for each astroclass the mean scale is determined.

The goal was to extend the long term data. For each day in this period we determine the tide impact for kilometer point 0 (IJmuiden). With this we decide which astroclass it belongs to (based on the rules above). Next we determine the middle for kilometer point 0 according to formula (1), we take the mean scale determined from the short term data for the specific astroclass and we apply formula (3).

Current, direction and wave observation

Just as with the short term data the wave observations are only given per channel. Again, for each kilometer point in one channel we use the same value.

The current and direction are also only given per channel now. Because the effect of variation in the current across positions in the channel for the long term is not too big, the same value is taken for each kilometer point in one channel.

Support and feedback

When things are not working properly or not clear, or if you have any feedback, post a message and we will process it.

**** You have to be logged in to be able to post a message ****

When you are logged in, then on several places the following icon is shown:



. When you click the icon, the options you have are opened like replying or commenting on an article / message, posting a message or sending a page by email.

Messages

Editing forecast

Created by Protide Port Authority on 2008-03-11 13:48:48

At this moment, of the forecast data only water level can be adjusted. Should be possible for cross current and swell as well, I suppose.

Editing

Created by [Karsten Uil](#) on 2008-04-04 11:56:34

This is correctly noticed. All data in the forecast are to be made editable. Also, each edit will be saved to make it possible to analyze them and maybe improve the forecast automatically.

Because the current project focuses on the calculation method, the user interface is not improved (except where necessary). In the next phases we will come back to these points.

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Project group

The companies participating in the project are:

Company name	Function within project
Charta Software	Developer of the Protide web application
Dienst Verkeer en Scheepvaart	Instructing party
Haven Amsterdam	Information provider
Havenbedrijf Rotterdam	Information provider
Hydro Meteo Centrum Noordzee	Current tidal window and data provider
Rijkswaterstaat Noordzee	Information provider
Loodswezen Amsterdam-IJmond	Information provider
Loodswezen Rotterdam-Rijnmond	Information provider
Amarcon	Provider of the ship motion application OCTOPUS

Meetings

Topics discussed in a meeting and written down in a report, presentations given in a meeting and any other information that comes from a meeting, as well as an overview of meetings are presented here.

Related information

Date	Description	Document
26 June 2007	Documentation user oriented feasibility study	Strategisch en technisch ontwerp Protide.pdf
26 June 2007	Final presentation user oriented feasibility study	Charta - Protide eindpresentatie.pps
16 April 2007	First feedback moment presentation	Charta - Protide.pps

A meeting overview for the previous and coming period

Date	Type of meeting
10 June 2008	New release: bug fixes
2 June 2008	New release: full prototype with vertical motion calculation, different possible channels, bottom touch probability calculation (based on channel depth, ship draught, ship type, estimated water level, heading, wave height, wave spectrum, wave direction, etc)
27 March 2008	New release: performance increase (10.000 keel clearance calculations per second), introduced variance of forecasts in calculation, uses 95% percentile on resulting UKC distribution
19 March 2008	Discussion recent data delivery and first (usable) motion application release
8 February 2008	First calculation method released
19 November 2007	OCTOPUS presentation Amarcon
30 October 2007	Data request at HMCN
10 October 2007	Workshop at Marin
10 October	Kick-off calculation method study



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2007

26 June 2007 Final presentation user oriented feasibility study

25 May 2007 User feedback moment

16 April 2007 User feedback moment

26 January
2007 Kick-off user oriented feasibility study