Date	12 November 2012
Subject	Memo on PROTIDE harbor configuration options
Relevancy	Configuration of PROTIDE settings for Eemshaven/Emden
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PROTIDE harbor configuration

Introduction

PROTIDE - PRObabilistic TIdal window DEtermination - is a web-based application used to calculate tidal windows for channel and tidal bound ships. By combining individual ship dimensions and stability details, actual channel layout, up-to-date environmental forecasts and a state-of-the-art ship motion analysis engine, PROTIDE can maximize the accessibility of a harbor while minimizing the probability of channel bottom contact during harbor approach or departure.

PROTIDE is useful when harbor admittance is restricted by the channel depth, tidal influences and/or ship movements. Under these circumstances a harbor can use PROTIDE to optimize harbor accessibility (minimize downtime), guarantee a certain level of safety and minimize dredging costs.

To use the application the harbor should be configured in PROTIDE. This configuration means entering the harbor / channel layout, prediction data sources, ship types, calculation and safety settings, speed regimes and application authorization. This document discusses each of these subjects. Together with the available data template this document assists in the first step of implementing PROTIDE.

Harbor / channel layout

Tree structure

The destination or departure harbor is to be described in PROTIDE. A harbor is defined as a tree structure starting at sea, which can split into branches towards multiple berths. The visualization below shows this modeled harbor structure. Other layouts are modeled by using multiple harbors.
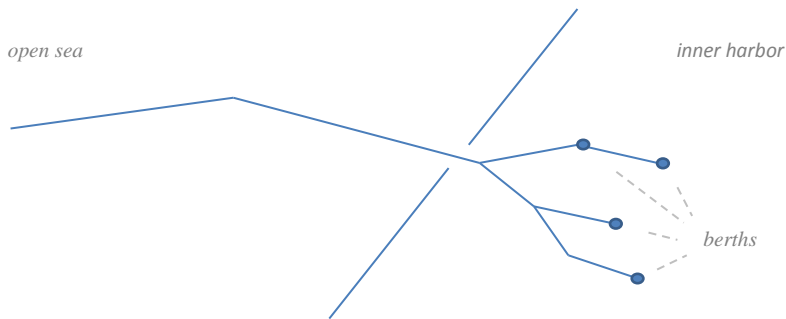
Figure 1 Channel layout tree structure

Channel definition

The channel is defined by channel positions (coordinates / kilometer position), berths (selection of channel positions), segments (links between positions) and their properties that define the depth and course/angle. Every change in depth or course should be modeled by a new segment. These segments present the intended design of the channel. Temporary changes in depth can be entered by adding temporal channel bottom elevations.

The channel depth can be entered with any reference level (for instance the mean sea level, lowest astronomical tide or local reference levels) in mind, as long as the water level predictions use the same reference level. We recommend using the mean sea level as reference. For the channel angle the course should be entered in degrees (0 is north and 90 is east).

The distances through the channel are constant and determined by fixed kilometer positions set per channel position. These kilometer positions are also used to couple environmental forecasts (water level, current and waves) to the channel. Kilometer positions in the open sea are positive and kilometer positions the inner area are negative. The kilometer position 0, the harbor entrance, is the location where cross current exclusions can be modeled.
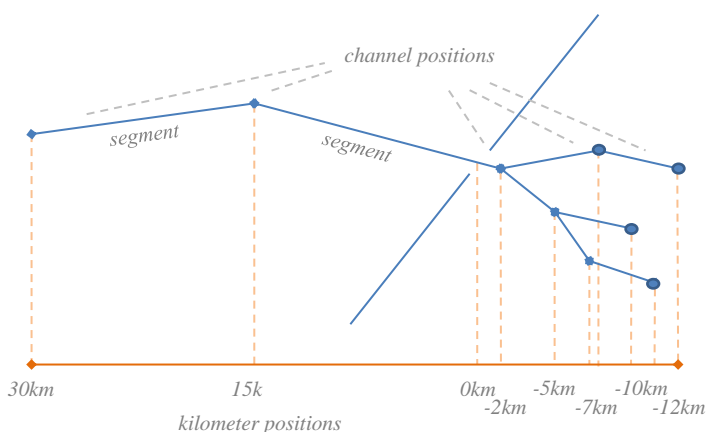

Figure 2 Channel positions, segments and kilometer positions

Channel path

PROTIDE assumes that all ships traverse the path between the start of the channel (the farthest point at sea relevant for the tidal window calculation) and selected berth. Because the channel is structured as a tree, there is always exactly one route possible between the start of the channel and each berth: the channel path. The selection of the berth determines the used channel, channel path and start of the channel.
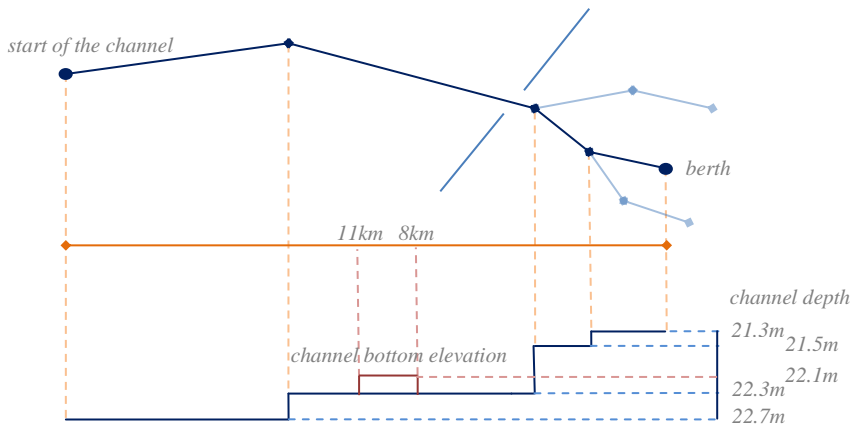

Figure 3 Channel path with depth and elevations

Positions used in tidal window calculations

The tidal window calculation traverses the channel path and determines the safety at each integer kilometer point, the (possibly fractional) end points plus the manually added significant positions. If specific fractional points along a route need special interest, then it is advised to add them as significant positions. These positions can be selected from available channel positions and should be part of the channel path (list of channel segments) used in the route.

Prediction data sources

Units

To perform tidal window calculations accurate environmental forecasts are necessary. These environmental forecasts should predict the expected water levels, (cross) currents and wave conditions for the relevant period and locations along the channel. We advise using small time steps (10 minutes up to 30 minutes) and at least two locations per unit and channel to enable interpolation to reduce possible intermediate errors. Extrapolation is not used, so it is recommended to add prediction locations close to the end points of the channel.

The water level is the expected water level in relation to the same reference level as the entered channel depth in meters. We recommend using the mean sea level as reference.
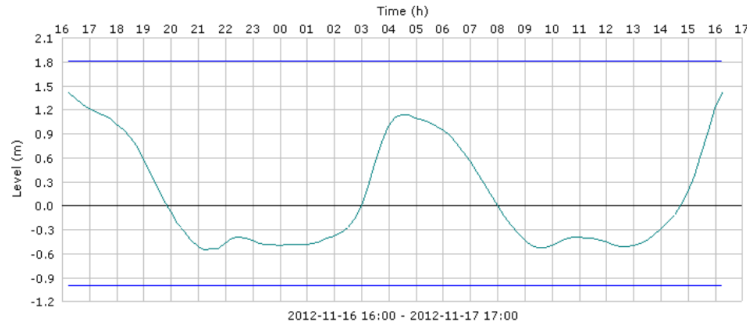
Figure 4 Example of water level data at one location

The current is a vector of water speed and water direction. The speed should be available in m/s and the direction in degrees (0 is north and 90 is east). A second option is to enter a water speed in X direction (east) and water speed in Y direction (north). This second option is converted to the same vector of water speed and direction in PROTIDE. If available it is possible to predict and use the cross current at kilometer 0 as a separate source.

Finally the wave conditions are to be predicted. There are two options: predict a full wave spectra or predict significant (Hm0) wave and swell heights (He10). The first option consists of predicting the energy level per frequency and direction per time step and location. This option has the beta status, but is to be preferred in the future. If the second option is used, then the predicted wave and swell heights are used to select possible spectra from an historical database. For this second option a locally relevant historical database should be constructed.

Data classification

Data classifications indicate the level of precision or authority of data sources. It is possible to make predictions per unit with multiple classifications. The "Order in calculation" property is used by PROTIDE to determine which prediction supersedes others in quality or relevancy.

During the calculation PROTIDE selects the best available classification (lowest order in calculation) per unit, time and location. By choosing the classification carefully, all kinds of override or fallback schemes can be implemented, depending on the availability of certain data sources. It is recommended to enter at least one long term available source (for instance astronomical predictions with a low priority classification) for each unit, to make sure PROTIDE has sufficient data to perform the calculations. Short term / high precision / authorized sources should be entered with a high priority classification (low order in calculation).

There are two special data classifications: manual override and manual extended. Both indicate data that is manually entered (or imported). This can be used when operators have better or more up-to-date knowledge available about the current circumstances or when other sources are not available for the period of interest. Data tagged with the manual override classification always has the highest priority (lowest order in calculation) and therefore overrides any other data source. Data tagged with

the manual extended classification has the lowest priority and therefore is only used in calculations when no other sources are available. This specific feature is mainly used when other sources have a limited available prediction time horizon and it needs to be extended for a specific calculation.
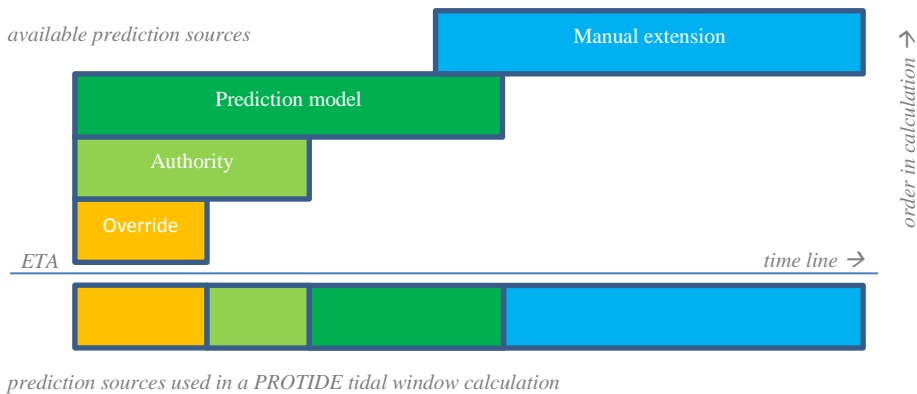

prediction sources used in a PROTIDE tidal window calculation

Figure 5 Used prediction sources in the "Order in calculation" starting at the Estimated Time of Arrival (ETA) for the relevant period

Data settings and predictions

The data settings are the starting point for the predictions in PROTIDE. By entering a setting, PROTIDE has knowledge on a type of prediction: unit, classification and channel position.

Actual predictions then refer to the data setting with the following fields: data settings, analysis date/time (the date/time the prediction was constructed), prediction date/time and value. There can be only one prediction per date/time for each data setting. When new predictions become available these will override the previously entered data. By adding transaction fields per prediction PROTIDE monitors changes in predictions.

MATROOS

For the Netherlands all prediction data PROTIDE now depends on the data availability in MATROOS (Multifunctional Access Tool foR Operational Oceandata Services) provided by Rijkswaterstaat. A web service is used to poll the MATROOS database for new data with 10 minute intervals. Per data setting that needs to be imported from PROTIDE a MATROOS data retrieval setting needs to be configured. This consists of entering the type of interface and the URL parameters. The interface can be "series" for data that is directly available in MATROOS for a specific location or "map2series" for data on a location not directly available, but can be constructed by interpolation from other results to a given coordinate. The URL parameters are dictated by MATROOS and contain information about the location (name or coordinates), source and unit. For 2D wave spectra it is expected that a OPeNDAP connection with MATROOS will be implemented.

Predictions used in tidal window calculations

A calculation tries to find tidal windows in a 24 hour period. The period starts at a given estimated time of arrival / departure and ends 24 hours later. Per unit all data settings are selected that contain valid predictions for the relevant channel and time interval. For each data setting a predictor is constructed

that can look up predictions from that single setting. These data setting predictors are grouped in location predictors that contain all data settings with equal kilometer positions. Per kilometer position the predictors are sorted by data classification. The visualization below shows the constructed result.
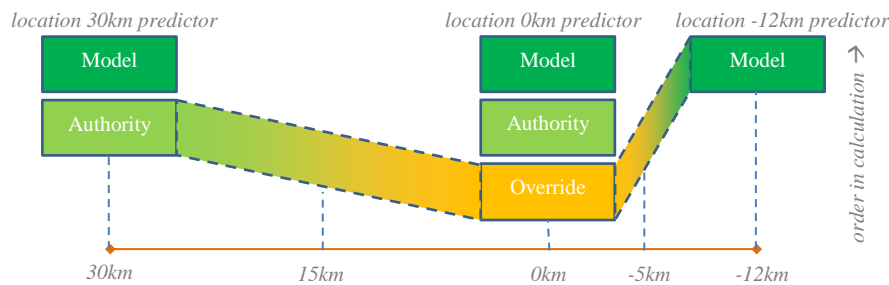

Figure 6 Combined sources per location predictor. Between location predictors interpolation is used.

When a prediction is needed during the tidal window calculation the unit predictor is asked to give a prediction for a time and location. The unit predictor finds the two location predictors that represent the closest kilometer positions and request a prediction for the specific time. Per location predictor the first data settings predictor that can produce a prediction is used to make a location specific prediction for the requested time with the highest classification. Finally the location specific predictions are interpolated towards the requested location.

Ship types

Hulls

PROTIDE supports a list of ship types for which a hull database is available. These types and hulls are supplied and used by Amarcon B.V.. There are about 50 different ship types and 120 unique hulls. When configuring PROTIDE a selection of hulls from the database should be selected, which are relevant for the harbor. If necessary new hulls are to be added to the database.

Ship types in tidal window calculations

A tidal window request contains a ship type plus the individual ship dimensions length, width and dead weight. Based on the type and given dimensions the ship motion calculator (OCTOPUS by Amarcon B.V.) selects the most appropriate hull and scales it to meet the dimensions of the individual ship.

Calculation and safety settings

Calculation settings

The calculation of a tidal window consists of the determination of possible ship motions, the construction of a safe time/location diagram and finally the route calculation. Each step has certain settings that need to be set before calculations can be performed.

Ship motion analysis

The possible ship motions are determined as a pre-process step in the tidal window calculation. This is done by loading the specific ship parameters, calculating the response amplitude operator and determining the responses in possible water and wave conditions. The ship motions are analyzed per different course (channel segment angle), for five (preset) depth draft ratios and possible combinations of predicted swell- and wave heights.
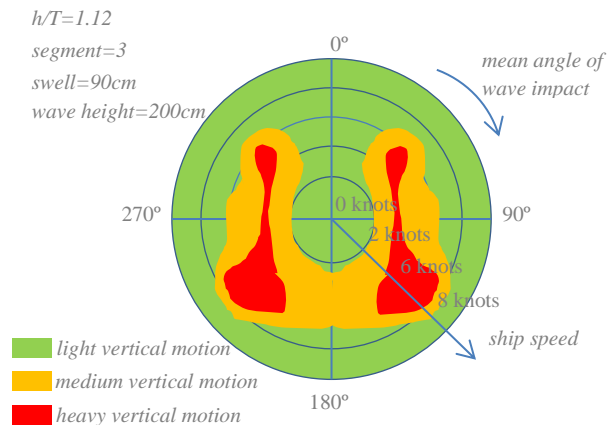

Figure 7 Vertical motions per angle of wave impact and ship speed.

The available settings determine the possible wave spectra (the amount of spectra to select per swell/wave combination) and wave direction (average direction / standard deviation / spread).

Safe time / location diagram

PROTIDE performs a Monte Carlo simulation to repeatedly draw the possible circumstances at a time/location and calculating the necessary statistics to be able to determine if a time/location is safe for the specific ship with a given speed and course. These statistics are compared to a set cut-off criterion. The safe time intervals at the 0-km position (harbor entrance) are reduced by possible cross current exclusions.

The settings contain:

- The number of iterations per time location point: higher means more stability in results, but longer calculation times.
- The granularity (the time steps) taken in the time / location diagram between points: the time interval we find small enough not to investigate any further for possible unsafe moments.
- The precision: the precision up-to a which a safe - not safe boundary is to be investigated.
- The safety cut-off criterion: the cut off value of the minimum under keel clearance (absolute/relative), minimum under keel clearance after squat reduction (absolute/relative) and / or maximum bottom touch probability. A combination of criteria is possible to model different strategies per kilometer position or ship draft. The safety cut-off criteria can be defined "as is", and are coupled to kilometer positions and ship drafts via the cut-off steps.
- Empirical reliability: the fraction of the simulation that needs to be taken into account to determine if a time/location is safe. A 95% reliability means that we can skip 5% of the outliers.

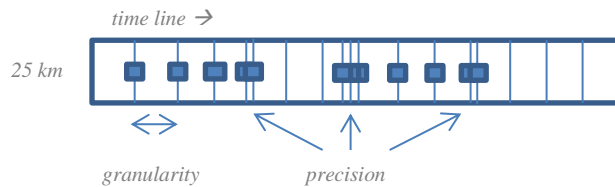- The maximum cross current in m/s at the harbor entrance. This can be specified for different ship depths.

time line →

25 km

granularity   *precision*

Figure 8 The visualization of the granularity and the precision for one kilometer position in the time / location diagram.

Route finding

Through an available safe time/location diagram a route is found from the start of the channel (at sea) up to the selected berth that only passes safe time segments. The first possible route with the preferred route width determines the tidal window. If there isn't any route possible with the preferred route width, then the width is iteratively reduced by 50% until there is a route possible or the time/location granularity is reached. Hence, the settings relevant for the route finding are the preferred route width and the previously mentioned time/location granularity.

Speed regimes

Speed

A different speed at a time/location gives a different safety analysis, because it changes the ship motion characteristics and squat. Also the speed determines the time needed to traverse the successive kilometer intervals and effects the tidal window width. PROTIDE works with "GPS" speeds (speed over the ground), which are corrected for currents to determine the actual course and speed through the water.

Regimes

A speed regime is defined as a set of speeds per kilometer trajectory. These speed regime values contain a low kilometer position, high kilometer position and a speed in knots. The lower bound is inclusive. A speed regime should cover the whole channel and inner harbor area. It therefore advised to define speed regimes for all positions between a high positive kilometer position (for instance +100km) and a low (negative) kilometer position (for instance -100km). Connecting speed regime values should have equal low and high kilometer position to be sure the segments are contiguous.

Typically a harbor (or berth) uses several speed regimes to analyze possible changes in accessibility and to give pilots insight in the effect of possible changes of speeds during a channel voyage.
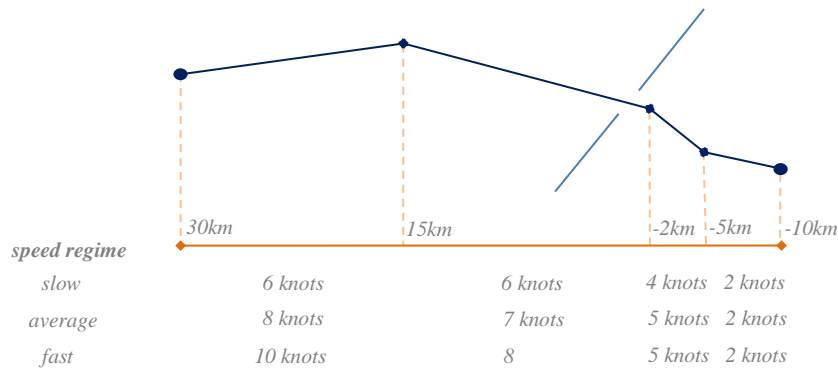
Figure 9 Example of three different speed regimes.

Application authorization

Users

PROTIDE is a web application where each user needs to register with an e-mail address and password. Via an e-mail validation the PROTIDE account is validated. It is advisable to give each user their own account, to be able to monitor usage, give users explicit rights and prevent users whom leave their employer still have access and rights in PROTIDE.

Rights

To use PROTIDE users can get assigned specific rights. There are six categories of users:

1. Registered (and activated) user: all registered users can post support requests and view / analyze data (water level, currents, et cetera).
2. Shipmaster: ship masters can request new tidal windows and view approved advices for their own request.
3. Pilots: pilots can view all approved (Approved indicatively or Approved definitely) advices.
4. Port authority: the port authority can request new tidal windows, view all requests and advices, start calculation and judge tentative advices.
5. Provider: a provider has all rights within the PROTIDE functionality. This is equal to the Port authority plus the possibility to add and edit data (Manual predictions).
6. Administrator: Next to registered users, the 4 specific PROTIDE roles, there is one super-user category: the administrator. The administrator has full access and is only used by the software host to manage the application and deliver support to users. Also changes to all settings can only be done by an administrator.

Next to the different user rolls, users get assigned a specific harbor. This restricts users from viewing and participating in other regions then their own channel / harbor. It is possible to assign multiple harbors / channels to users.