Building with Nature

EcoShape

Interactive Dredge Planning Tool:

Setup and Guideline

Report title:	Interactive Dredge Planning Tool Setup and Guideline
Authors:	Wiebe de Boer, Ingrid Das, Roderik Hoekstra, Leon de Jongste, Robin Morelissen
Team	Wiebe de Boer (Deltares), Ingrid Das (Boskalis), Roderik Hoekstra (Deltares), Leon de Jongste (Witteveen+Bos), Bastien van Veen (Witteveen+Bos), Robin Morelissen (Deltares), Aleyda Ortega (MTI/IHC)
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Interactive Dredge Planning Tool

Prediction of species response to sedimentation and suspended sediments for managing dredging operations

Table of Contents

Acronyms and Abbreviations

BwN	Building with Nature
DMZ	Demilitarised zone (network outside firewall)
EDD	Eco-dynamic Development and Design
GUI	Graphical User Interface
IDT	Interactive Dredge Planning Tool
NEA	National Environment Agency
OBS	Optical Backscatter Sensor
PAR	Photosynthetically Available Radiation
SDWA	Singapore – Delft Water Alliance
SRC	Species Response Curve
SSC	Suspended Sediment Concentration
S-structure	Internal data (structure) used in IDT
TASS	Turbidity ASsessment Software
TSHD	Trailing Suction Hopper Dredger
UI	User Interface

1. Introduction

During dredging operations, fine sediments are released in the water column. These fines have a very low fall velocity and can therefore be transported over significant distances under influence of the ambient currents. The suspended fine sediments or deposition of this sediment may impact sensitive ecosystems (such as coral reefs and sea grass meadows) in the vicinity of the dredging operations.

Ecological impact criteria for dredging activities nowadays are typically fixed (turbidity) thresholds. Present thresholds for tropical areas are mostly estimated or copied from other (non-tropical) areas due to a lack of scientific research in this area. To obtain more location dependent and ecologically relevant criteria for different species of corals and seagrass, other research projects are carried out in the Building with Nature (BwN) and SDWA programs.

Instead of using arbitrary turbidity thresholds that are imposed in the vicinity of the dredging vessel, the BwN program introduced ecologically relevant indicators near the sensitive ecosystems for use in dredging projects. Therefore, the ecosystem responses under dredging-induced (and natural) stressors have been studied, in which the intensity and also the duration of the stressors are considered. The response of these species to different stress levels are summarised in so-called Species Response Curves (SRC's), of which a conceptual example is presented in Figure 1.1 below. These SRC's are determined in other BwN project and form input to the ecological impact assessment.

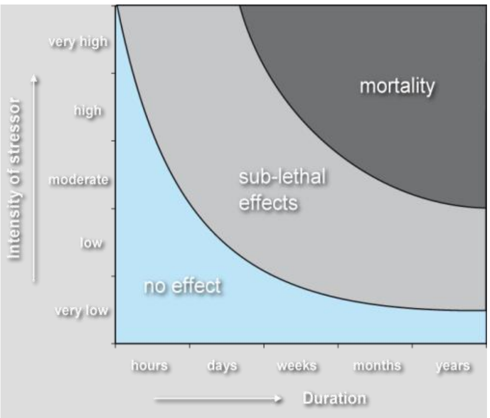

Figure 1.1 Example of Species Response Curve

In order to make practical use of this approach in dredging works, an adaptive dredging process can be used. In this approach, the expected stressors (suspended sediments → light attenuation and sedimentation) are being assessed with models and field measurements for the full trajectory from the dredging vessel to the ecological sensitive areas. Subsequently, the expected ecological response is assessed with the SRC's and if necessary, adaptations can be made to the dredging process to reduce ecological impacts. The effectiveness of this adaptation can then be assessed by means of the same models and/or monitoring and SRC's. This *conceptual model* of the adaptive dredging cycle is presented in the figure below.

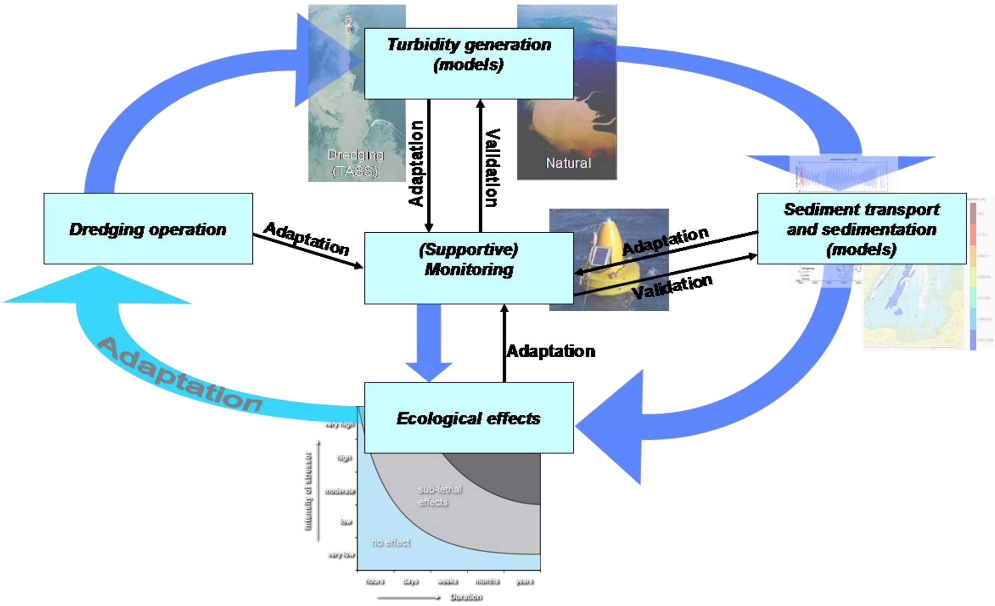

Figure 1.2 General layout of the adaptive dredging cycle (conceptual model).

In order to use this adaptive dredging cycle in practice (e.g. in the project design phase or managing the construction phase) by contractors, legislators or consultants, it needs to be available in an *operational* form. Therefore, an interactive *tool* is developed that can be applied in the planning phase of a dredging project, allowing the user to get a preliminary, rapid insight of the potential effects of a specific dredging operation, phase or project on the ecosystem surrounding the dredging site.

The prototype version of this *Interactive Dredge Planning Tool (IDT)* will serve as proof-of-concept and demonstration. This modularly set up tool allows for easy expansion in future with further developments and functionalities. The components that are embedded in the tool are graphically explained in the next section. The subsequent sections elaborate on which components are embedded in the prototype of the tool and which opportunities there are for future developments.

The set-up, assumptions, methods etc, in the development of the prototype dredge plume modelling tool will be included in these guidelines to facilitate the set up of such a tool for other applications or locations and as a basis for further development. The present development is aimed at an operational prototype Interactive Dredge Planning Tool applied for the Singapore region.

Note to readers
It is noted that the rapid-assessment Interactive Dredge Planning tool is developed as a flexible, modular and generic tool framework for this type of tools and that this framework can easily be adapted and extended and that the IDT can also be prepared for application in other geographical areas. However, in order to obtain a demonstrable tool, the prototype was applied to the Singapore region. This document therefore contains descriptions of the generic modules and functions of the tool, as well as some more specifics regarding the Singapore application of the tool. To facilitate the distinction between the generic parts and Singapore prototype-specific parts, these specific parts are placed in coloured text boxes.

1.1 General description of the Interactive Dredge Planning Tool

The Interactive Dredge Planning Tool (IDT) is able to perform a rapid assessment of the expected, initial ecological effects caused by interactively defined dredging operations. For this, the IDT makes use of rapid assessment dredge plume modelling, a database with hydrodynamic and background conditions and a database with ecological information; locations, species and species response information.

The IDT consists of a map platform (Google Earth), in which dredging operations can be defined in an easy way. Based on the defined dredging operations and selected background conditions, the resulting stresses at the ecological areas are determined into so-called *effect regimes*.

This modularly set up tool makes it possible to use any type of sediment (plume) dispersion model and ecological assessment that is suitable for the area of application. Furthermore, the definition of effect regimes is flexible and can be adapted to the amount of ecological response information available or applicable regulations in the area. The IDT platform is suitable for the presentation and communication of the rapid-assessment results to demonstrate the expected effects on ecology to different stakeholders. Furthermore, the IDT is suitable to perform easy sensitivity analyses on the rapid assessment results or for dredging design purposes (suitability maps).

The generic rapid-assessment framework of the tool is in fact usable for many more applications than the present dredge plume dispersion application. It can also be used to perform rapid assessments with other models for other purposes in an ecodynamic design process.

Figure 1.3: Example of the IDT user interface with the defined dredging operation (white line), maximum suspended sediment concentration footprint, and resulting ecological impact assessment (green and orange exclamation marks).

1.2 IDT components

The following components, schematized in a workflow diagram in Figure 1.4, are embedded in the tool. The diagram also indicates what kind of input is required from the user and what kind of output the tool provides.

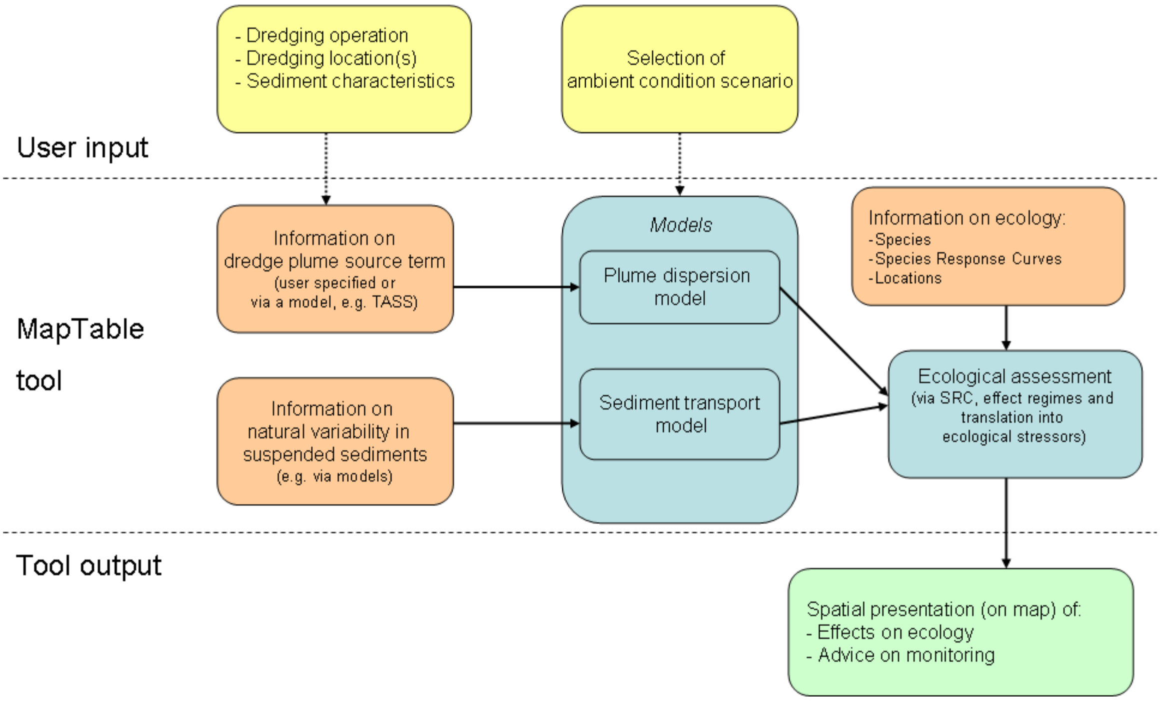

Figure 1.4: Workflow diagram of the IDT components

1.3 Functionality prototype version of the Interactive Dredge Planning Tool (IDT)

This section describes the general way of working of the prototype version of the IDT.

1. The user specifies the required input parameters of the dredging operation (location(s), schedule, sediment characteristics, spill rate, etc.) and selects the ambient conditions scenario (e.g. normal conditions, storm or a particular season). The location(s) of the dredging operation can be defined interactively, e.g. by drawing points or a polygon on the map (white line in Figure 1.6). In the prototype version of the tool, the sediment spill rate and characteristics of the dredging operation will be entered manually. For the prototype, the source terms are specified directly, i.e. in S(x,y,z,t) [kg/s]. This can be improved with a more detailed coupling to the dredging operations (via TASS model) at a later stage.

2. When the required input is given, hydrodynamic and sediment plume models embedded in the tool will rapidly assess the sediment plume dispersion in combination with the background sediment concentrations and determine the expected stresses (suspended sediment concentration (→ light attenuation) and sedimentation) at the locations with

sensitive species in the form of 'time series' at these locations. Furthermore, the 'foot print' of the dredge plume extent could also be presented for further reference (e.g. the area indicated by the contours in Figure 1.6).

3. The locations of the ecologically sensitive areas and species and associated Species Response Curves are included in a database in the tool (XML format, so it can easily be extended and edited). To be able to use the SRC in practical applications with the tool, it will be mapped onto a discrete number of *effect regimes*, distinguishing (initially 3, but this can be adapted to match the available ecological information or regulations) different timescales and (relative) intensity levels. In the ecological assessment module of the tool, the model results in ecologically sensitive areas which will be mapped to the same effect regimes to enable the assessment of either 'no effect', a 'sub-lethal' or a 'mortal effect' on the different species for the different timescales, see Figure 1.5.

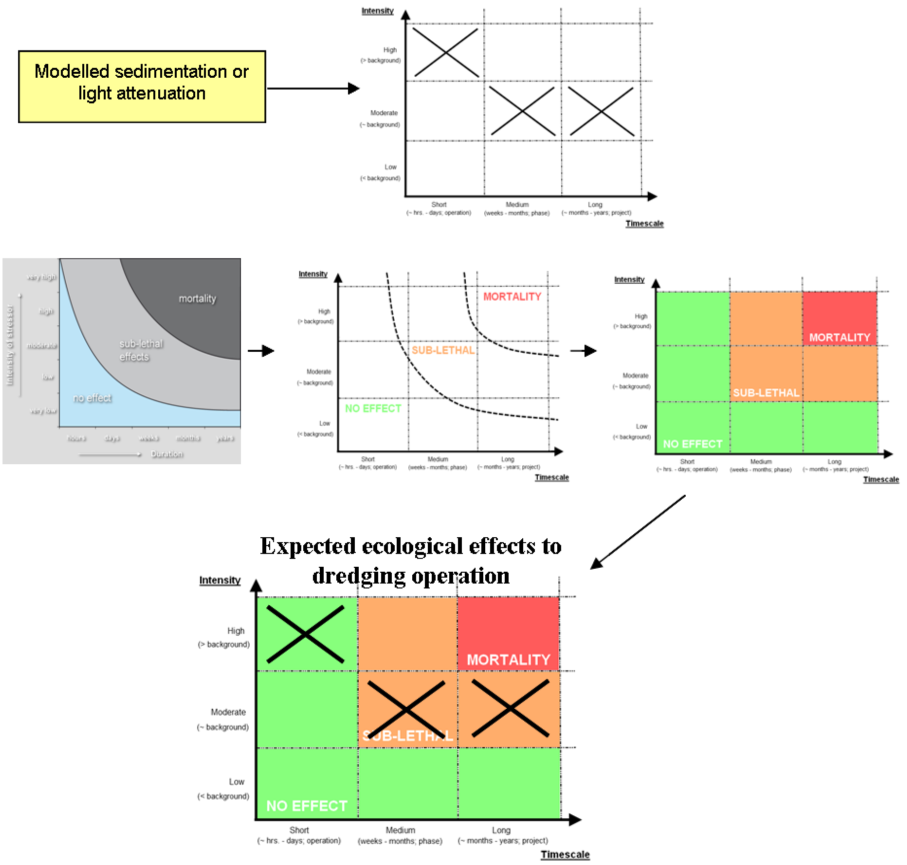

Figure 1.5: Mapping of model results and species response curves to effect regimes

4. The expected effects on the ecological areas, expressed in terms of the considered effect regimes, will show up in green (ok), orange (sub-lethal) or red (mortal) on the map, see Figure 1.5 and Figure 1.6. For each of the considered timescales for which an effect is expected, a monitoring advice can be provided by clicking on the highlighted ecological areas (markers) in the map. In the present prototype of the tool, the functional provision (in the software) for this monitoring advice is implemented, but since the actual descriptions are not fully available, these have not been included.

Figure 1.6: Visualisation of dredge track (white line) and expected effects on ecology (green and orange exclamation marks

1.4 How to use - getting started requirements

The IDT is available in two different forms:

1. as a *stand-alone tool* locally installed on the user's PC, in order to be used for the planning of dredging operations;
2. as a *web-based tool*, to be used for demonstration and communication purposes.

For the first option, installation of the following software is required: Python, Pylons, the Matlab wrapper and Matlab. A tutorial on installing these components can be found on http://publicwiki.deltares.nl/display/OET/Your+own+web+application+-+Getting+started . The open-source code of the IDPT is included in the OpenEarth tools repository (see http://publicwiki.deltares.nl/display/OET/OpenEarth) and can be downloaded from there.

The second option is platform-independent and can be used on any computer with the latest version of Google Earth and either Mozilla or Google Chrome as browser. The Microsoft Internet Explorer browser experiences compatibility issues with regard to the Javascript parts on the web interface and therefore the tool cannot be used in this browser. The user can define a scenario and see the results on the OpenEarth Viewer (http://viewer.openearth.nl). The tool itself resides and runs on a remote computer that is in contact with the webpage.

Developing a case with the IDT
The set-up of the IDT is generic, such that this software can be used for any site or location. In the current research program of Building with Nature the tool has been applied to the Singapore coastal waters. Application at another location requires site-specific data, like:

- adaptation of the tool settings file, which includes settings regarding the geographical location of the tool application, references to the background conditions, model parameters, such as the dispersion coefficient, etc.;
- an ecological database with species response curves and locations of vulnerable ecosystems or species;
- a database with ambient hydrodynamic conditions. These hydrodynamic data are in the present implementation based on Delft3D-FLOW modelling results. These hydrodynamic conditions can be prepared by running a Delft3D-FLOW model with the on-line WAQ coupling activated. For convenience, a switch to activate this option has been implemented in the Delft Dashboard tool, which could be used to set up an initial Delft3D-

FLOW hydrodynamic model. For other use and more details, reference is made to the Delft3D-FLOW User Manual;
- a database with background sediment conditions (optional, if ecological criteria are used which include this).

The IDT-code is easily adaptable by experienced Matlab users, because of its modular set-up. If desired, modules can be replaced or added to the workflow and the behaviour and appearance of the tool can be changed. This flexibility is used, for instance, when making dredging suitability maps (based on a maximum specified effect) instead of assessing the effects of a specific dredging operation.

Advice and recommendations
The IDT is intended for rapid assessment of the effects of dredging activities on vulnerable coastal ecosystems. The first-order estimate of ecological effects it produces cannot replace more advanced analyses or detailed modelling. The usefulness of the results depends, among others, on the accuracy of the ecological database, the hydrodynamic and sediment background conditions and the dredge plume dispersion model. This means that the computed ecological effects need to be considered carefully, taking into account the possible uncertainty ranges associated with the complex nature of the chain of operations leading to the estimated ecological effects. Expert interpretation and explanation are essential for proper use.

1.5 Future developments

After completion of the initial version of the tool and the proof-of-concept, the tool was demonstrated and discussed with different envisaged users and stakeholders in a workshop organised in November 2011. Based on their input and already existing plans, the tool is extended and improved on various aspects.

Improvements that were collected during the first demonstration workshop of the IDT tool included:

- The option to produce so-called *dredge suitability maps* with the IDT. These maps show the maximum allowed spills within a specified area, in order to remain below a certain effect level and are very useful for dredge operation design purposes.
- Develop a link with Delft Dashboard to easily set-up initial hydrodynamic models for other areas than the Singapore demonstration case.
- Develop the IDT fully web-based. The prototype includes the web-based features developed for e.g. the Holland Coast nourishment tool, but also contains stand-alone (Matlab) features. It is considered useful if the IDT can be used in a web browser and has the same type of appearance as some other interactive tools developed within BwN.
- Development of a Show case showing where the IDT can be used within the dredging project (and by whom) and also indicating the different steps in the process of the dredging project, e.g. starting from no background information to gaining more and more data of the project area. The IDT could then demonstrate how the initial assessments could improve and change when more/better data and models become available.

Further ideas on future developments include:

- The Turbidity Assessment Software (TASS) model can be implemented (in a later version of the tool) to determine the sediment spill rates (i.e. source terms) as a result

of a certain dredging operation as a replacement of the manually entering of this information.
- Improvement on the underlying rapid assessment models; both in performance and accuracy, but observing the fact that this will remain an initial rapid-assessment tool to provide first indications and will not replace detailed modelling.
- Adjustment possibilities of the SRC/computed stresses to determine the sensitivity of the rapid-assessment result to the possible range of outcomes in the assessment.
- Validation of the IDT results against field measurements.

It is noted that apart from the above further improvements i.e the suitability maps, the show case, the link with Delft Dashboard and the fully web-based user interface have been realised in the last part of this project.

2. General design of the Tool

The Interactive Dredge Planning Tool (IDT) has been set up in a very modular way, so that it allows for easy extension and modification by other users and for other use. In the design process, this was considered an important aspect of the tool, also since the tool is available as open source software and further developments, extensions and fixes are very much encouraged. In general, the tool operates with so-called 'workflows', which are started and run independently from the user interface once all required user input has been collected from the user interface.

Furthermore, to make the tool (and more importantly, the tool's framework) flexible in use and set-up, the full tool behaviour and appearance is specified in a single settings XML file. In this XML file, the workflow is defined, as well as specific settings that are used in the different modules of the workflow. This way, different functionalities can easily be added to the workflow, or a substantially different workflow can easily be specified, while still using the generic tool framework. Furthermore, the appearance/definition of the graphical user interface (GUI) is specified in this settings file (also as XML). This makes it possible to use the tool framework for creating a very different tool and application, although some resemblance with an 'interactive map' would be obvious (but not required).

This flexible set-up has already been utilised in the presently implemented functionality of the tool where the tool can work in the 'forward' loop mode (i.e. starting from a specified dredging operation and determining its effects on ecology) or in 'reversed' loop mode, or *Dredge Suitability map* mode (i.e. starting from a maximum accepted effect regime/class and determining the maximum spill budgets in a user-defined area). In the latter case, the workflow needs some different modules and order of execution, which could easily be implemented in this framework.

As mentioned above, the IDT consists of a number of modules with specific functions. These modules are called by generic functions in the Matlab backbone of the tool framework and use the workflow specification in the settings file to call subsequent modules. The modules themselves consist of an 'interface' at the start and end of the module and a certain functionality in between. This could be the Delft3D-PART model (stand-alone and executed by Matlab) that is encapsulated in the module's interface, which writes the Delft3D-PART input file and reads the output files. An alternative could be that the functionality of a certain module is taken care of by Matlab functions, but still encapsulated within the interfaces. These interfaces make sure that the common data structure is read from the global memory and that its results are stored back in this memory.

Operation mode (or 'forward' loop mode)

The present IDT (forward loop) application consists of nine different modules, see Figure 2.1:

1. Graphical User Interface (GUI)
2. Matlab backbone
3. Dredge Input

Start workflow

4. Hydrodynamic and sediment background conditions (database)
5. Dredge plume dispersion
6. Ecology input: location of ecology and the associated species response curves (database)
7. Translation of increased turbidity and sedimentation into ecological stresses
8. Ecological assessment
9. Presentation module

End workflow

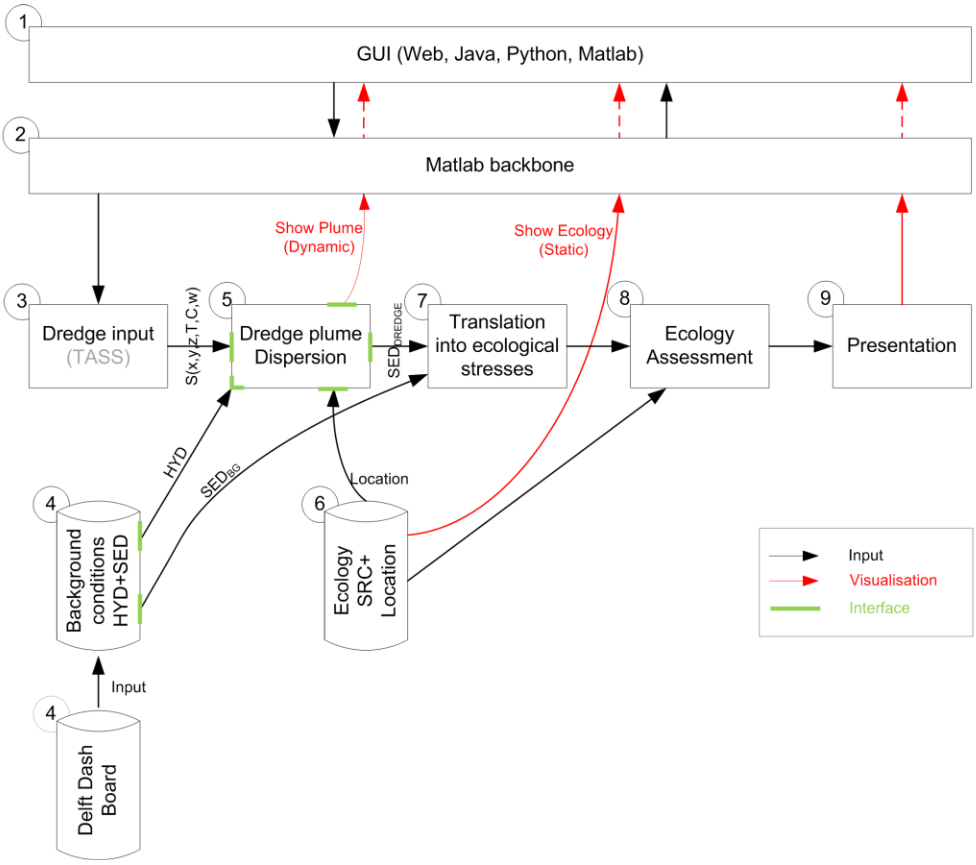

Figure 2.1: Workflow diagram of IDT tool modules

The sequence of these modules (Modules 4 – 9) forms the workflow in the tool. The other modules are not directly part of the workflow, but are supporting and take care of user input, visualisation and communication. The first module is the graphical user interface (GUI). The GUI contains a web-based part (JAVA script) with Google Earth as main feature for visualisation and presentation of the input and dredge plume, see Figure 2.2. The remaining parts of the GUI are built in Matlab in the prototype version of the tool, but are also made fully web-based (i.e. JAVA script) in the latest release of the IDT. The GUI is a relatively thin layer, in which the user specifies the required input data. Module 2 is the Matlab backbone, which will direct and connect all other modules. The communication between the Matlab backbone and the web-based part of the GUI is established in Python. In the fully web-based version of the tool, the communication between the GUI and the Matlab workflow is arranged via XML files (see Chapter 3).

The user-defined dredge input is, together with the hydrodynamic background conditions, the input for the dredge plume dispersion simulation. In the dredge plume dispersion module the actual dredge plume spreading is simulated with a rapid-assessment particle tracking model (Delft3D-PART). At the ecologically sensitive locations/areas (specified in the ecology database), time series of relevant abiotic parameters (in the present case suspended sediment concentrations and sedimentation rates) are extracted from the modelling simulations. These time series are translated into ecological stress time series, by translating the abiotic parameters to ecologically relevant stresses (i.e. light attenuation). The ecological stress time series are then mapped to the same effect regimes as where the species response curves have been mapped to (which are stored in the ecological database). From this mapping, the expected ecological effects become clear, which are subsequently presented as indicators in the ecological areas on the Google Earth map (via KML files), see Figure 2.2.

Figure 2.2: Visualisation of IDT assessment results in Google Earth via KML files

Suitability map mode (see also Chapter 12)

In addition to the ‘forward loop’ or ‘operation mode’ (i.e. starting from a specified dredging operation input towards the expected ecological effects), the IDT has been extended to be able to produce so-called ‘suitability maps’, which show the maximum allowed spill source in a certain area while remaining below a user-specified maximum ecological effect class. These maximum source terms at the different locations within the specified area represent the ‘spill budget’ that is allowed and a dredging suitability contour map is constructed for the specified dredging area. In Figure 2.3, an example output of the suitability model is presented and Chapter 12 describes this mode of the tool in more detail.

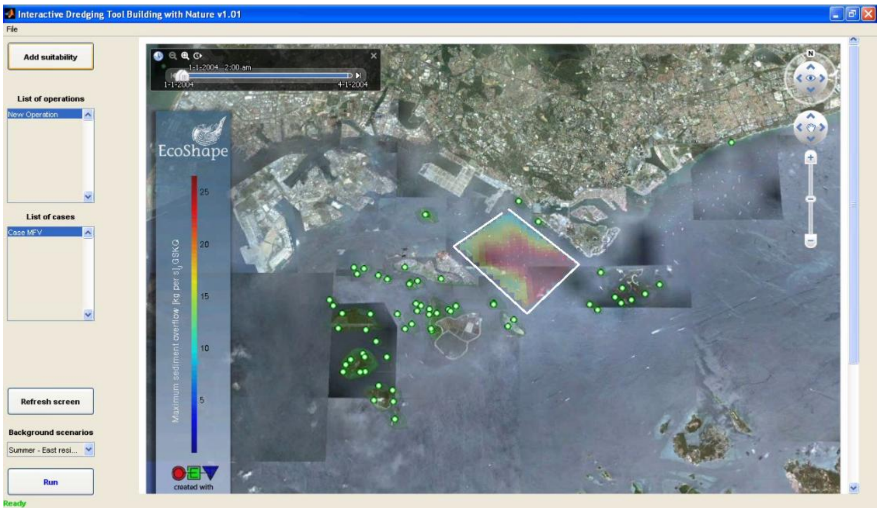

Figure 2.3 Example output of the Suitability map model of the IDT, indicating the maximum allowed spill budget (i.e. sediment source term) within the indicated area (in white) in order not to exceed a specified ecological effect class.

In the below chapters, the different modules of the IDT are described in terms of their functionality, interfaces, implementation and limitations and possible future improvements.

3. GUI (Module 1)

3.1 Functionality

The graphical user interface (GUI) is the interface in which the user can define the dredging operations, start the model to simulate the dredge plume scenario and view the plume dispersion including the effects on the ecology when the simulation has finished (see Figure 2.2). The implementation of the input fields of the GUI can be found in Chapter 5 – Dredge input. The tool can be used in three different ways, being:

- standalone;
- web based; and
- local host.

Each method requires internet access, because all of them use Google Earth for visualisation. Therefore the visual appearance of each method is similar. However, the technical implementation of the each GUI's is different and described here.

Standalone tool

The GUI of the standalone version of the tool consists of standard MATLAB GUI elements with a web application embedded into it. The web application is based on the OpenEarth Viewer (http://viewer.openearth.nl). Its main feature is a Google Earth interface that allows for insightful visualizations both in space and in time. In the IDT a very thin layer of the web application is used. For more information on the general set-up of the web application, the reader is referred to the user manual of the OpenEarth Viewer (http://publicwiki.deltares.nl/display/OET/Your+own+web+application+-+Getting+started).

Obviously the GUI allows the user to trigger the model to start the simulation once all the required model input is provided. A DOS window will appear indicating the progress of the simulation. The presentation of the outcomes are visualised in the Google Earth viewer.

Web based

The web based version of the IDT contains a fully web-based GUI that can be approached from a web browser, at the website: http://viewer.openearth.nl. This website includes all web based tools developed within the Building with Nature research program. The GUI on the website is similar compared to the standalone GUI, but does not contain all functionality of the stand-alone version. Figure 3.1 shows two snapshots of the GUI of the web based tool. The main difference is that all input fields are in javascript code instead of Matlab. The interface on the website allows the user to define the input and output. The user defined in- and output on the website is stored in XML files on the FTP-server. The actual computation is done on an external Matlab computer. The XML files are used for the communication between the server and the Matlab computer.

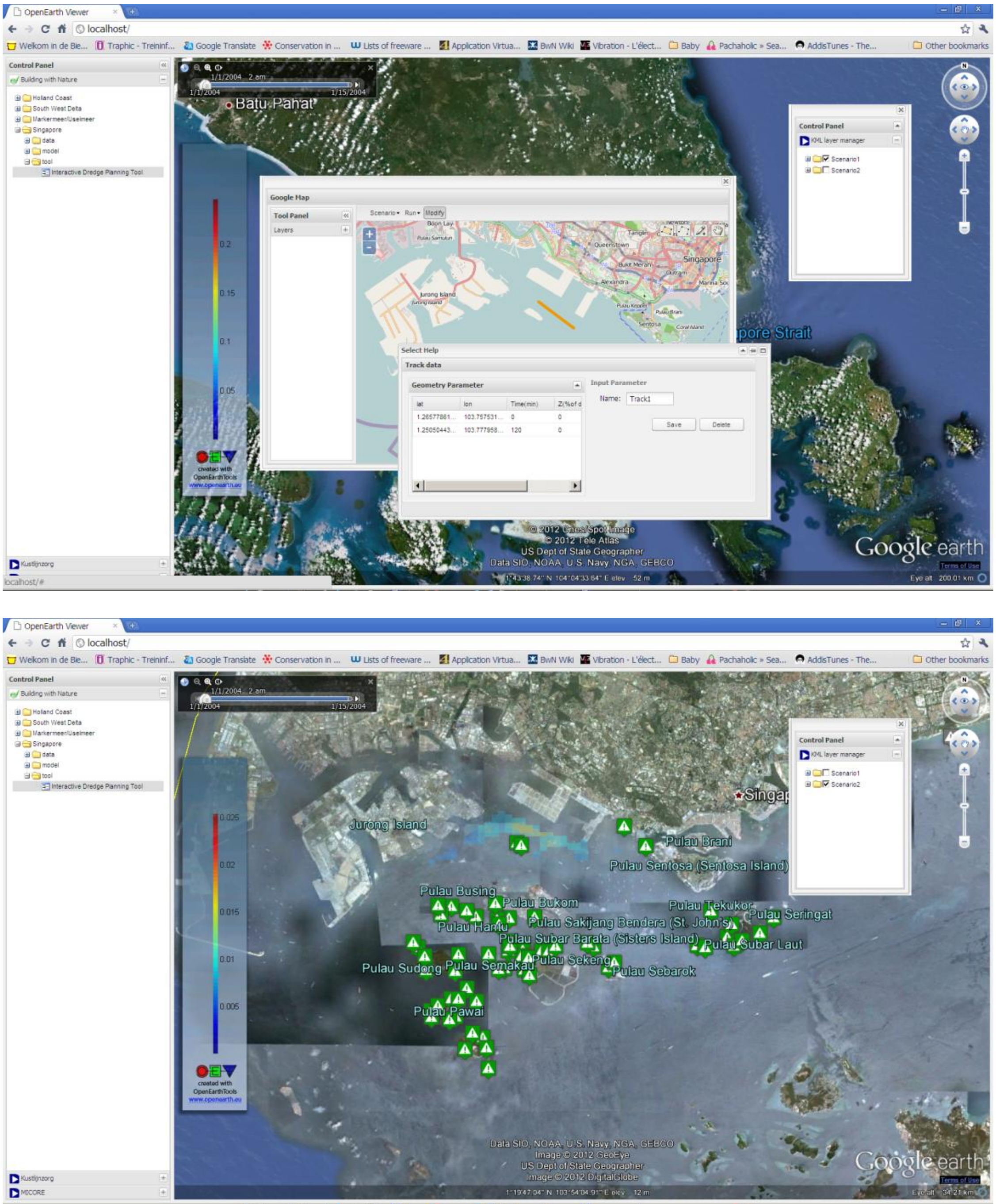

Figure 3.1: Two snapshots of the GUI of the web-based tool, showing an input field (upper) and the output (lower).

Local host

The local host version of the tool is similar to the web based version. The main difference is that the web and FTP server and the Matlab computer are on the local computer. This means that the in- and output files are stored locally and the simulations are performed local. This allows for more insight in the computations and the outcomes, i.e. the process of the tool computation can be tracked by the input and output files that are generated (which e.g. allows for more debugging when the tool is further developed). This installation option will most likely be used by advanced users and developers. It is noted that the tool code that is used for this option is the same as for the web-based installation.

Maptable

Both the standalone tool and the web-based version can be used on a suitable maptable (see Figure 3.2). For the stand alone tool several functionalities have been added to make the tool easily accessible on a maptable or touch screen. The GUI can be flipped (rotated 180 degrees) which is especially useful when operating the tool on a maptable surrounded by users. An on-screen keyboard (like on smart phones) is provided allowing users to operate the tool and specify required input details when using the tool on a maptable or touch screen without the presence of a physical keyboard.

Figure 3.2: Example of a maptable

Using the web based tool on a maptable requires Windows 7, because of the integrated touch screen support. The web-based version (http://viewer.openearth.nl) can be used easily by just going to the mentioned website on the maptable.

3.2 Interfaces

Standalone

The GUI links directly to the Matlab backbone, which facilitates the callbacks of the user interface controls (i.e. makes sure that the proper function is called upon a GUI operation by the user). The GUI operations that are supported by the Matlab backbone are:

In the File Menu:

- Load data – load previously saved IDT cases (*.mat-file)
- Save data – save IDT cases (*.mat-file)
- Edit settings – edit settings-file in text editor
- Reload settings – reload settings-file (to activate changes)
- Full reload – restart the web application
- Exit – exit the IDT

In the Main GUI:
- Add dredging operations – add a dredging operation by loading or clicking a dredging track
- Select/modify/delete operation – select operation by clicking an operation, modify operation specifications by double clicking an operation and delete by clicking right-mouse button
- Select/New/Copy/Rename/Delete case – select case by clicking a case, create new/make a copy/rename/delete case by clicking right-mouse button
- Refresh Screen – refresh the Google Earth window
- Flip Screen – flip the screen (for maptable applications)
- Select Background scenario – select the hydrodynamic conditions for the dredge plume dispersion
- Run – run the IDT (the type and order of operations that are performed upon pressing this button depend on the pre-defined workflow)

Furthermore, the Matlab backbone feeds visualizations back into the Google Earth interface of the GUI (by calling the *IDT_refresh* routine).

Web based
The web based version has very similar controls and functionality as the standalone version, although the design is slightly different. Where the standalone version communicates via Python or directly with the Matlab backbone, the web-based version uses input, output and status XML files on the web-server for this. The Matlab backbone functions (with a small shell function for the web-based execution) are executed by the Matlab weblistener functions on the computational nodes. The results of the tool's assessment are sent back to the web-server for visualisation. This process is described in more detail in the generic webtools document (De Boer, 2012).

3.3 Implementation

This section describes the implementation of the standalone and web-based versions of the IDPT. Furthermore, references to the installation manual for the standalone version are included.

Standalone
For running the standalone version on your pc, the following (free) software needs to be installed:
- Python;
- Pylons;
- Mlabwrap.

Installation guidelines for this software can be found on:
http://publicwiki.deltares.nl/display/OET/Your+own+web+application+-+Getting+started

To enable communication between MATLAB and the web application, the following items are important:
- MATLAB communicates to the web application using ActiveX control. This is used for refreshing the web application and fetching KML's (i.e. feedback from backbone in GUI);
- The web application communicates to MATLAB using a mlabwrapper. This wrapper allows a python based web application to call MATLAB functions. For more information on how to install the mlabwrapper, please have a look at the user manual of the OpenEarth Viewer http://publicwiki.deltares.nl/pages/viewpage.action?pageId=42401915);

- To ensure that the web application is communicating with the same MATLAB instance where the MATLAB GUI is running from, MATLAB needs to be made Automationserver. This enables the web application to manipulate data in the MATLAB workspace.

The main MATLAB function that is related to the GUI is *IDT_GUI.m*. This function builds the lay-out of the GUI. The MATLAB backbone facilitates the callbacks of the user interface controls in the GUI. This is discussed in Chapter 4.

Web based
Figure 3.3 shows a schematic overview of the infrastructure of the web-based tool. More information on the implementation of the (generic) web-based tools can be found in De Boer (2012).

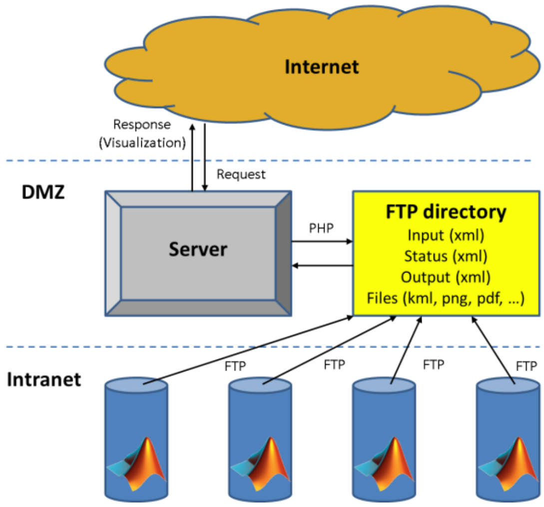

Figure 3.3: Schematic overview of the webtool infrastructure. DMZ means the demilitarised zone or the area open to the world (outside the firewalls) and PHP is the scripting language the web server uses to write the XML text files on the FTP directory.

Local host
For the implementation of the local host version of the tool, one needs to install a (Apache) web server and a FTP server on the local computer as well as Matlab. In general, the installation is very similar to the above web-based version and the same code is used.

3.4 Limitations and possible future improvements

Limitations of GUI:

- Due to the use of Google Earth for visualisation all versions of the IDT require access to the internet, this can be a limitation if internet is not stable or unavailable.
- The web-based version presently only works well in Google Chrome or Mozilla Firefox (i.e. not in Internet Explorer). Furthermore, due to the use of the Google Earth plugin, the standalone and web-based tools will presently only run under Microsoft Windows and Mac OS 10.4+ (since these operation systems are presently only supported by the Google Earth plugin).

4. Matlab backbone (Module 2)

4.1 Functionality

The MATLAB backbone is a set of (generic) MATLAB functions (located in the \Matlab\main directory) which facilitate the communication between the OpenEarth viewer and MATLAB GUI on the one hand and between the MATLAB GUI and underlying IDT modules on the other hand. Most of these functions are callbacks of the GUI elements, which make sure that the proper function is called upon a GUI operation by the user. The set-up of this set of functions is meant to be as generic as possible, so that they can be called from any module at any step in the workflow.

For the fully web-based version of the GUI, these only the backbone functions that take care of the workflow are used, supplemented with a number of web-related communication functions. In the web-based version, most of the GUI callbacks are programmed in Java script on the web page.

4.2 Interfaces

The MATLAB backbone has interfaces with all GUI controls (as described in Chapter 2) and all IDT modules (as shown in Figure 2.1). Every next module in the workflow is called through the MATLAB backbone by means of the *IDT_nextModuleInWorkflow* routine.

4.3 IDT settings XML file

The IDT settings XML file consists of different blocks with settings for the operation of the IDT. Below a summarised example of this settings file (for the suitability map mode) is presented:

```
<?xml version="1.0" encoding="ISO-8859-1"?>

<settings>

	<general>
	<!--General settings including the module name-->
		<EPSG>32648</EPSG>
		<webpath>..\webapp\</webpath>
		<screen>0</screen>
		<public>..\webapp\dredgingtool\public\</public>
		<weburl>http://127.0.0.1:5000</weburl>
		<datafile>si_data</datafile>
		<view>
			<lat>1.2904917</lat>
			<lon>103.85143</lon>
			<range>750000</range>
			<tilt>0</tilt>
		</view>
		<module>SuitabilityAnalysis</module>
	</general>

	<defaultvalues>
	…
	</defaultvalues>
```

```
<workflow>
        <module>
                <name>DredgingSuitabilitySpecs</name>
          <modulefunction>IDT_DredgingSuitabilitySpecs_Popup</modulefunction>
        </module>
        <module>
                <name>StartWorkflow</name>
                <modulefunction>startWorkFlow</modulefunction>
        </module>
        <module>
                <name>getOuputLocations</name>
                <modulefunction>IDT_getOutputLocations</modulefunction>
        </module>
        <module>
                <name>StartSuitabilityAnalysis</name>
                <modulefunction>IDT_startSuitabilityWorkflow</modulefunction>
        </module>
        <module>
                <name>DredgePlumeDispersion</name>
                <modulefunction>PART_dredgePlume</modulefunction>
        </module>
        <module>
                <name>Stresses</name>
                <modulefunction>IDT_Stresses</modulefunction>
        </module>
        <module>
                <name>AllowedDredging</name>
                <modulefunction>IDT_allowedDredging</modulefunction>
        </module>
        <module>
                <name>EndSuitabilityAnalysis</name>
                <modulefunction>IDT_endSuitabilityWorkflow</modulefunction>
        </module>
        <module>
                <name>SuitabilityVisualisation</name>
          <modulefunction>IDT_callSuitabilityVisualization</modulefunction>
        </module>
</workflow>

<backgroundconditions>
        <scenario>
                <name>Summer - East residual current</name>
                <dataType>COM</dataType>
                <dataLocation>d:\com-island.hyd</dataLocation>
                <refTime>2004-6-1</refTime>
                <dataPeriodStart>2004-6-1</dataPeriodStart>
                <dataPeriodEnd>2004-7-1</dataPeriodEnd>
                <lgaFile>d:\com-island.lga</lgaFile>
                <lgtFile>d:\com-island.lgt</lgtFile>
                <ccoFile>d:\com-island.cco</ccoFile>
                <volFile>d:\com-island.vol</volFile>
                <floFile>d:\com-island.flo</floFile>
                <wlkFile>d:\com-island.wlk</wlkFile>
        </scenario>
        …
</backgroundconditions>

<backgroundstresses>
        …
</backgroundstresses>
```

```
        <modulesettings>
               <module>
                      <modulefunction>PART_dredgePlume</modulefunction>
                      <runDir>d:\TEMP\idt</runDir>
                      <lgaFile>d:\com-island.lga</lgaFile>
                      <ccoFile>d:\com-island.cco</ccoFile>
                     <modelExecutable>c:\IDT\Matlab\DredgePlumeDispersion\delpar.exe
                     </modelExecutable>
                      <inputTemplate>PFL_basic.inp</inputTemplate>
                      <TimeStep>300</TimeStep>
                      <VertDisp>0.01</VertDisp>
                      <HorDiff>1</HorDiff>
                      <NumOfParts>200000</NumOfParts>
…
        <ecologydatabase>
        <file>c:\IDT\Matlab\EcologyDatabase\EcologyDatabase_SRC_Doorn2007.xml</file>
        </ecologydatabase>

        <GUI>
               <GUIType>Matlab</GUIType>
               <GUIBuildFunction>IDT_makeGUI</GUIBuildFunction>
               <Object>
                      <!--Map-->
                      <ObjectType>figure</ObjectType>
…
        </GUI>
</settings>
```

The different blocks in the settings file are discussed below.

General
General tool settings, such as local coordinate system, location of the tool application, directories, etc.

Default settings
Default settings to be used in the tool. Reference is made to the actual settings XML file for which settings to specify.

Workflow
The workflow is specified next in the IDT settings XML file, where the actual (Matlab) function name of the module is coupled to the workflow. When the workflow is started (i.e. via the ‘Run’ button in the IDT), the *IDT_nextModuleInWorkflow* routine will start the workflow below the ‘StartWorkflow’ notification in the workflow definition of the settings XML file and will run the modules below this specification subsequently.

Background conditions
Specification of the background condition scenarios. Different scenarios can be added for use in the simulation. In the above example, the use of Delft3D COM files is specified for the Delft3D-PART module, but if the model allows, different data sources can be used interchangeably.

Background stresses
Specified similarly as the background conditions, the background stresses (such as background suspended sediment and sedimentation) can be used in the assessment (if the (ecological) criteria require this).

Module settings
In this block, the settings for the different modules are specified (referenced to the module function as mentioned in the workflow specification). These settings are module (function) specific and can for example include certain settings for the Delft3D-PART model simulation (as shown above).

Ecology database
Specification of the ecology database XML file to use.

GUI
Definition of the GUI elements (objects) and with that the appearance of the GUI (in stand-alone mode).

The IDT settings file, and in particular the *workflow* and *GUI* blocks, makes it possible to define the operation and appearance of the tool via this single file. This has also been used to distinguish between the *operation mode* and *suitability map mode* of the tool, but it is noted that this tool framework can be used to create many different tools modularly and flexibly.

4.4 Implementation

All the MATLAB backbone functions can be found in the \Matlab\main directory. The web-based backbone functions are collected in the \Matlab\web directory (and some in the \Matlab directory itself). These routines are the core of the functioning of the IDT and are called by the GUI routines or routines in the workflow. Some of these routines are called directly by an action from the user in the GUI and others support the tool process without direct user intervention. Here the functionality of all these routines is briefly described:

IDT_init:
This is the start-up routine and it routine creates a MATLAB structure based on the file *settings.xml*, starts the web application, starts the GUI (by calling IDT_GUI), can start the On-screen keyboard (OSK), reads the ecology database, converts its content to KML and displays the result on the Google Earth window.

IDT_GUI:
This routine builds up the GUI based on the specifications in the settings XML file.

IDT_change_case:
This routine is called when the user selects another dredging case in the list box of available, pre-defined cases. Data associated with the selected dredging case can be modified using the GUI functionalities, hence dredging operation tracks and specifications.

IDT_deleteCase:
This routine deletes a dredging case (combination of different dredging operations) listed in the dredging cases list. The routine is called for by right-clicking a dredging case in the list and subsequently by clicking ‘delete’.

IDT_deleteOperation:
This routine deletes a dredging operation listed in the dredging operation list. It is called by right-clicking a dredging operation in the list and subsequently click ‘delete’.

IDT_edit_listbox:
This routine is called for when the user wants to check or edit a dredging operation listed in the dredging operation list box. It loads all the information of the dredging operation selected by the user and makes sure that changes are dealt with properly.

IDT_fill_case_listbox:
When starting up the tool, this routine fills the dredging case list box with all the available dredging cases.

IDT_fill_listbox:
When starting up the tool, this routine fills the dredging operation list box with all the available dredging operations.

IDT_flip_screen:
This routine is called for when clicking the ‘Flip screen’ button in the main GUI. The routine executes iRotate.exe, which is a freeware executable that flips the user’s screen (rotates 180 degrees).

IDT_full_reload:
This routine resets and reloads the entire tool functionality: all incorporated plugins, connected servers, tool settings and data related to user-defined dredging cases and operations.

IDT_loadData:
This routine is called for when the user wants to load predefined ‘cases’. The case information is stored in a *.mat file and appears in the list of ‘cases’ when loaded.

IDT_makeUniqueID:
This routine makes a unique identifier for a dredging operation, case or KML-file, mainly to overcome caching issues on the web server.

IDT_newCase:
This routine is called for when the user wants to create a new dredging case.

IDT_nextModuleInWorkflow:
This routine switches between different tool modules, distinguishing the different tool functionalities and operations. The tool is build based upon a series of modules of which the sequence is prescribed in the xml-settings file. Each chapter in this report is devoted to a module of the tool.

IDT_receptor:
This routine is called for when the user has drawn a dredging track in the Google Earth window. It saves the Google Earth view and passes the coordinates of the dredging operation to the dredging operation specification table.

IDT_refresh:
This routine is called for when the user wants to refresh the data that is presented in the Google Earth viewer.

IDT_reloadSettings:
This routine reloads the tool settings described in the xml settings file, to enable the user to work with the most up to date settings.

IDT_renameCase:
This routine is called for when the user wants to change the name of an existing case. Technically a new case is defined with all the information of the original case.

IDT_run:
This routine is called for when clicking on the button ‘Run’ in the main GUI. The routine IDT_nextModuleInWorkflow will firstly find the *StartWorkFlow* definition in the workflow block of the settings XML file and will run the modules below that subsequently.

IDT_saveData:
This routine is called for when the user wants to save ‘case’ information, by right-clicking on the casename in the list. The case information, describing the specifications of one or multiple dredging operation, is saved in a *.mat file.

IDT_setstatus:
This routine is called when the tool is switching from one operation or state to another, usually human-induced. It prescribes the actual tool status or operation at the bottom of the main GUI, for example when a simulation is running or when simulation output is being processed. For the web-based GUI, this function also contains an attempt to update the web GUI status (via the generic sendWebStatus command, which is part of the webListener toolbox) if run from a web GUI.

IDT_storeCurrentCase:
This routine stores the internal tool data, including settings and results (i.e. the ‘S’ data structure) of the current case in a Cases structure (to enable the IDT to deal with multiple cases).

The following functions are used for the web-based implementation of the IDT:

IDT_initWeb
The web-based tool can have different callbacks to the Matlab routines in addition to running the workflow (e.g. for loading and showing the ecology layer, initialising the web tool (i.e. sending the IDT specific settings, computing fall velocities, etc.). However, since these different tasks may be handles by different Matlab computers (i.e. nodes), each job requires an initialisation of the IDT on that node and loading of the settings.
The IDT_initWeb function initialises the IDT on the current Matlab node, adds relevant directories to the path, creates necessary directories in the local temporary directory on the node and reads the IDT (web) settings XML file (with the subroutine webIDT_readSettings). This function is a supporting function for web callbacks and is not a direct callback from the web.

webIDT_readSettings
Reads the *IDT_WEB_settings.xml* settings file and stores the content in the internal S structure[1]. This function is a supporting function for web callbacks and is not a direct callback from the web.

webIDT_ToolInitialise
This function is called directly from the web to retrieve the IDT specific settings required for the web GUI, including the default number of days to run the simulation and the background condition scenarios.

webIDT_loadEcoLayer
This function is called directly from the web to upload the ecology layer KML to the web to be shown as a supporting layer in the web GUI.

[1] The internal S structure contains the internal data of the tool and is used by all parts of the tool.

IDT_runWeb
This function is called directly from the web to run the IDT in operation mode based on the input specified in the web GUI. During execution, this routine will update the status on the web GUI. The resulting KML files will subsequently be uploaded to the web server and shown on the web GUI. In addition, this routine will store the results (internal IDT data, KMLs and supporting files) in a cache directory, so that these completed simulations can be retrieved in a later session to show again in the web GUI.

4.5 Limitations and possible future improvements

The flexible and generic set-up of the workflows and modular components allow for easy future developments of different tools based on the same Matlab backbone, including web-based tools. For these developments, it could be necessary to extend the backbone with additional functions to account for future functionalities. Due to the source code being open source, this is facilitated towards other developers.

Useful functionalities that are currently foreseen to be developed include:
- Storing and restoring of scenarios in the web-based GUI.
- User management for the web-based GUI so that users can easily keep their previous scenarios.
- Extension of web status updates with e.g. graphical representations of wait bars etc.
- Optimise uploading results to the web GUI.
- Possibly optimise code further on speed (although the modules typically take more time to run).

5. Dredge input (Module 3)

5.1 Functionality

The Dredging input module are the specifications of the dredging operation and the (estimated) soil characteristics of the dredged material, such as the dredging track, the release rate, the grain size distribution and fall velocity of the sediment. This input is given in a framework of user interface tables, which are visualised in the Graphical User Interface (GUI). After saving the data, it is stored in the internal data structure and used as input by the Dredge plume dispersion module (Module 5).

It is noted that this module is made in Matlab for the stand-alone version of the IDT, but that in the web-based GUI, this module is almost entirely made in Java script embedded in the web page. The below description mainly considers the Matlab implementation of this module, but the Java script implementation contains essentially the same functionality.

5.2 Interfaces

The Dredge input module needs input from:

- Matlab backbone which enable the links with the previous workflow and the next workflow (it is noted that this module is not part of the workflow after the workflow is started, but rather an input to the workflow); and
- For communication/visualisation purposes input from the GUI; the track indicated on the Google Earth map needs to be transferred to the table in the GUI.
- For the web-based GUI, all communication between the maps and user interface is done within Java script and no additional functions from the Matlab backbone are required. This module will write the data entered in the GUI in an input XML file to be run by a Matlab node.

The output of the Dredge input is used in the Dredge plume dispersion module. The user defined data is made readable and saved in the internal data structure (or as an XML file for the web-based GUI) as input for the Dredge plume dispersion module.

5.3 Implementation

This module contains various functions, which combined form the user interfaces for the specifications of the dredging operations for the stand-alone IDT. A short description of all scripts is given below.

IDT_SimpleInputGUI
This function creates the popup GUI of the Dredge specifications table for each Dredging operation. The in this popup, the Operation name (the default can be adjusted by user), the start and end of the dredging operation (in days), the time, location (x,y), the depth of release (Z in % of depth) and the release rate (kg/s) can be specified. The coordinates of the track are defined by the clicked track in the map. In this table the total time of the dredging operation is defined and the time it takes to sail from one defined point to another. The total cycle is repeated as many times as needed to fit the total time of the dredging operation. In this dredging cycle, also the sailing and discharging times need to be included/specified (as a zero discharge (S [kg/s]) to obtain a representative dredging cycle.

Additional functions such as Save (the dredge operation specification), Load (a dredge operation specification), Define sediment fractions, move row up (/\) in the table, copy row, delete row, move row down (\/) and Done to save the operation data. Each of these functions has an associated callback function which is specified in the IDT_SimpleInputGUI. See Figure

5.1 for an example of the popup user interface for the dredge specification of one dredging operation.

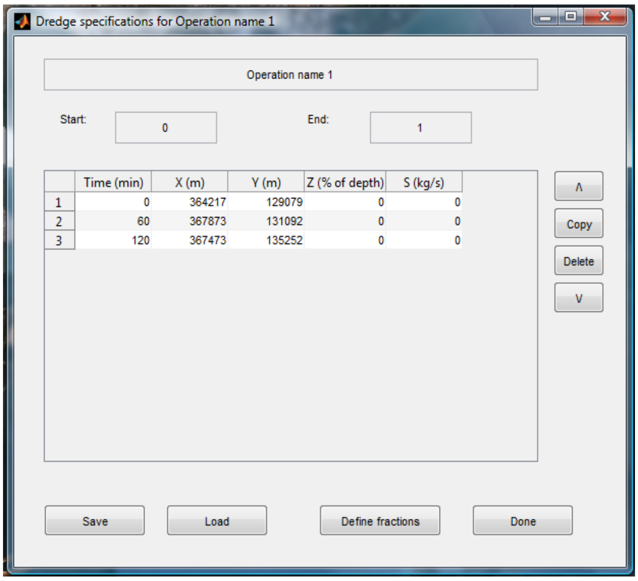

Figure 5.1: Dredge operation specification for one dredge operation

IDT_add_sed_specs

The IDT_add_sed_specs function creates the popup user interface for the specification of the sediment fractions of which the dredge spill consists. Three grain sizes (20, 40 and 63mu) are specified by default, including a distribution and the fall velocity (m/s) of that specific grain size, but these values can be altered by the user. The fall velocity can be user defined or computed by the tool based on the grain size. The fall velocity is computed using formulae for non-spherical particles (Van Rijn 1993). A distinction is made between small grain sizes d_{50} < 100 µm, which uses the Stokes Equation, and larger sediment particles (100 < d_{50} < 1000 µm) to compute the fall velocity. If the grain size is out of range for this method an error will occur. Up to five different grain sizes can be defined (per dredging operation)[2]. If the total percentage of the distribution does not equal 100% or if negative values are filled in for the distribution also an error will be given. There are save and load buttons to save the specified data or to load already saved data.

[2] It is noted that the grain size classes can vary per dredging operation, e.g. Operation 1 could have classes 10µ, 20µ and 30µ, while Operation 2 could have 30µ, 40µ, 50µ and 63µ. This would then result in a total of six classes for the assessment. For all dredging operations together up to 14 different grain sizes can be defined this way (limitation of Delft3D-PART).

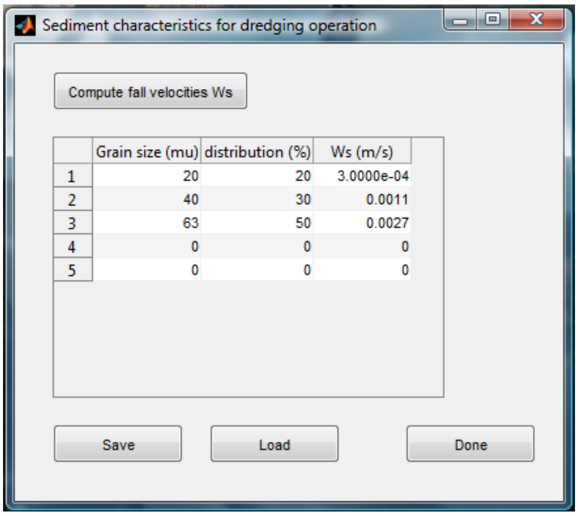

Figure 5.2: Pop-up user interface to define the sediment characteristics (grain size, distribution and fall velocity) for one dredging operation

IDT_createDredgingTimeseries
This function is to create the input for the Dredge Plume Dispersion module regarding the spill times and locations. The function will take the user specified data from the specified dredge operation and will repeat the dredge cycle as many times as required to fill the specified operation duration and will subsequently interpolate the operation on a one-minute time step grid. This interpolated operation time series will be used by the Dredge plume dispersion module to create input files for the (in this case) Delft3D-PART model. Also the defined sailing and discharge times will be taken into account in the time series as zero discharges.

IDT_DredgingOperationSpecs_callback
This callback function enables the user to define (i.e. click) a new dredge track on the Google Earth map or to load a track (i.e. coordinates)

IDT_loadtrack
If the user wishes to load a track (see IDT_DredgingOperationsSpecs_callback), this function will guide the user to select a file and get the track coordinates. The coordinates will be converted to the right type of coordinated and added to the structure.

IDT_writeTrackKML
This carry out the following tasks:
- Get track data from structure;
- Delete any previously existing track KML file;
- Write a new KML file with the new location (lat, lon) information (and a unique ID to allow the Google Earth plugin to refresh).

5.4 Limitations and possible future improvements

Some limitations of the present implementation include the necessity for the user to make an estimate of the sediment flux (discharge) of the dredging operation in kg/s, while this is commonly very hard to estimate up front. Furthermore, the possibilities to define dredging operations are relatively schematised (i.e. simplified), which could exclude more detailed specifications of the operations. This matches the initial character of the IDT rapid-assessment tool, but some improvements could be obtained by coupling the TASS dredging model to the IDT (see below).

Another tool that is further developed within Building with Nature is the ‘Turbidity assessment model’ (TASS). This tool calculates, based on the dredging cycle and equipment (hopper size, type, sediment characteristics, operation modes, etc. see also the TASS manual), the overflow and the dynamic and passive plume. These latter two are based on a constant current flow. The calculation of the overflow terms and the dynamic plume could serve as input into the IDT, thereby replacing the current Dredge Input module. The input (source term) generated by the TASS model is more comprehensive than the current Dredge Input module. The coupling of TASS to the IDT is foreseen as a future development of the IDT.

6. Background conditions (Module 4)

6.1 Functionality

The background conditions are the ambient hydrodynamic conditions and the sediment concentrations in the area that is covered by the (Delft3D-PART) model domain. Delft3D-PART simulates particle transport processes by means of a particle tracking method, using pre-simulated hydrodynamics from a Delft3D-FLOW model application (run outside IDT). The dredge plume dispersion is simulated based on a schematised sediment source term reflecting the initial sediment plume due to dredge spill and dispersed by hydrodynamic forcing. Background sediment conditions are also pre-computed and included in the background conditions database.

For the Singapore application, the background conditions are pre-simulated with the Delft3D-FLOW module and available for different periods of the year, to account for the intra-annual variability of residual currents affecting the hydrodynamics and background sediment concentrations. In fact, the presently available background conditions for the Singapore application cover a full year, of which one-month sub-periods are specified in the IDT settings file (and therefore other periods could be added without rerunning the Delft3D-FLOW simulations). The user can choose one out of the available background condition scenarios to force the PART model with, each effectively covering a period of a month. One scenario is for a period with residual currents directed eastward (Summer), one intermediate scenario without residual currents (Intermediate) and a scenario with a westerly residual current (Winter) (van Maren, 2011).

It is noted that other geographical areas will require the set-up of a hydrodynamic model or the use of another existing model.

6.2 Interfaces

The hydrodynamic conditions used directly in the Delft3D-PART model simulation (i.e. there is no intermediate Matlab interface in the use of the present background condition files, which are Delft3D COM (NEFIS) files). However, different data sources could be used (as well as different (dispersion) models), but this could require the development of an interface between the data and the sediment dispersion model (in this case Delft3D-PART).

When the model simulation has finished, the total suspended sediment concentration can be determined as a combined result of the PART simulation results and the pre-simulated background sediment conditions in the database (if available).

The background sediment concentration is used for the ecology assessment. The background sediment concentrations, together with the sediment concentration resulting from the dredging activities, are translated into ecological stresses in the module Translation into ecological stresses (Module 9).

6.3 Implementation

The present implementation of the background conditions uses the proprietary files of the open source Delft3D (COM files). However, as mentioned, other data formats/sources could be used flexibly, but could require a dedicated interface. In the present implementation, the hydrodynamic results are described in a <*.hyd> file and the corresponding data is given in the associated grid files (<*.lga>, <*.lgt>, <*.cco>), volumes file (<*.vol>) and flows file (<*.flo>). For each of the three background condition scenarios, these above mentioned files are available prescribing the hydrodynamics in the PART model domain. Depending on the user-defined simulation time frame (in terms of days relative to the starting day of the period covered by the different hydrodynamic scenarios), the hydrodynamics are extracted from the database by the Delft3D-PART model simulation.

6.4 Limitations and possible future improvements

The present implementation only includes the proprietary Delft3D files for use in the Delft3D-PART model. Future developments could include the use of other data sources (e.g. netCDF) for use in a particle tracking model (e.g. Delft3D-PART). The tool's structure is suitable for such modular extension, but developments would need to be made to Delft3D-PART, as this model does not yet use other file formats for input.

The Delft3D-PART model does not yet use spherical coordinates (will be implemented as part of the integration of Delft3D-PART and Delft3D-WAQ in about one year from now) and therefore, the background condition files need to be converted (once) to a metrical coordinate system. This will be updated in the near future. Nevertheless, conversion routines are available to convert the coordinates in the background condition files (*.CCO file) from spherical to UTM coordinates.

The total suspended sediment concentration at a location is the sum of dredging induced SSC and the ambient SSC (i.e. by combining the PART model results (dredge plume dispersion) and the pre-simulated background/ambient sediment concentrations). Interactions between non-linear effects such as density currents and hindered settling are not accounted for. This therefore result in a first order sediment dispersion simulation, but this linear approach also enables the scaling of the magnitude of the dispersion computation results for use in the computation of dredge suitability maps (see Chapter 12).

At the moment of writing the functionality is included to use the background sediment concentrations, however the background sediment condition data (sedimentation and suspended concentrations) are not included in the database yet. In addition, the ecological criteria presently in use (see Modules 6 and 7) only consider excess sediment concentrations (following Van Doorn-Groen (2007)) (i.e. in addition to the background levels) and sedimentation rates and therefore do not yet need these background data. If more comprehensive ecological criteria are available, which depend on e.g. absolute (total) sediment concentrations rather than excess concentrations, this background data could be added easily.

7. Dredge plume dispersion (Module 5)

7.1 Functionality

The dredge plume dispersion module computes the actual dredge plume dispersion using a particle tracking model. Delft3D-PART is selected as a suitable far field plume dispersion model. Delft3D-PART is the particle tracking module of Delft3D and is mostly used for the simulation of mid-field water quality and oil spills. The Part module simulates transport and simple water quality processes by means of a particle tracking method using (2 or 3 dimensional) flow data from the FLOW module, in this case the Singapore model (Van Maren, 2011)

A large advantage of the Delft3D-PART module is that it is not limited by the spatial resolution of the hydrodynamic database; it is a Langrangian, sub-grid particle tracking model. Thus, relatively high plume details can be resolved with spatially coarse hydrodynamic information. A computational time-costly refinement of the grid is therefore not required. The model calculates a dynamic concentration distribution by following the tracks of thousands of particles in time. Delft3D-PART is a random walk particle tracking model, which is based on the principle that the movement of dissolved (or particulate) substances in water can be described by a limited (large) number of discrete particles that are subject to advection due to the currents and by horizontal and vertical dispersion. The movement of the particles consists therefore of two elements. For each time-step, the first step is the advection movement due to the shear stresses from currents (on the bed) and wind (on the water surface). The second step is the random walk step in which the size and direction of the movement is a random process but is related to the horizontal and vertical dispersion. For more information about the conceptual model of Delft3D-PART see the manual of Delft3D-PART (Deltares, 2011).

7.2 Interfaces

In order to run the Delft3D-PART model as part of the IDT, interfaces were developed on both the input and output side of the PART model. These interfaces were developed in Matlab and are described in more detail below.

Input

On the input side, the Dredge plume dispersion module has interfaces with Dredge input module (Module 3), Hydrodynamic background conditions (Module 4) and the ecological database in the form of the locations of the ecological areas (Module 6).

The Dredge input module provides the input for the Dredge plume dispersion module regarding the dredging operations. Thus the location of the dredging operation, the dredging cycle, duration, the release rate, the particle size distribution, etc.

The hydrodynamic background conditions provide the hydrodynamic forcing for the plume dispersion calculation. In the present set-up of the tool, the hydrodynamic background conditions are saved in a database and originate from the Singapore model (Van Maren 2011). Other models can be used (e.g. for other areas) to generate the hydrodynamic background conditions e.g. from a model generated with Delft Dashboard. For the present implementation with Delft3D-PART, these hydrodynamic background conditions however need to be made with Delft3D-FLOW. Please note that when the IDT is applied to other areas, an ecological database of that area is also necessary in order to carry out the ecological assessments.

Output
The output locations of the Dredge plume dispersion module are based on the location of the ecology, because here the relevant output to determine the effect on the ecology is required. The output generated by the Dredge plume dispersion module are time series of the suspended sediment concentration (SSC in kg/m^3) at the defined output locations and the sedimentation (mg/m^2) at these locations. These time series need to be translated into ecological stresses (matching with the ecological criteria) which are required to perform the ecology assessment. This translation is done in Module 7 (Translation into ecological stresses).

Furthermore, the maximum dredging-induced suspended sediment concentration footprint computed by the dredge plume dispersion module over the full simulation period is prepared and presented in the Google Earth environment (GUI).

7.3 Implementation

The structure of the Dredge plume dispersion module is 1) to prepare the input, 2) to run the simulation and 3) to generate output. All required input and settings for the Delft3D-PART simulation are defined in the input file (.inp file). In this file also the locations and time steps of the output are defined.

The settings that can be specified by the user for the dredge plume dispersion module are defined in the Dredge input (Module 3) and from the IDT settings XML file (static settings). A Delft3D-PART input file template is available with keywords that are replaced by the various settings by the interface routines. The basic input file of PART including keywords can be seen in Table 7.1. The keywords can be recognised by the percentages.

The input file contains all settings of the simulation, such as start time and end time, time step, dumping location, sediment characteristics, etc. Here also the hydrodynamic background conditions are indicated by referring to the .hyd file. The location of the .hyd file and the other required files from the hydrodynamic database are specified in the IDT settings file. The scenarios which can be specified in the GUI gather the data from the above mentioned files for the simulation period.

Delft3D-PART requires two input files. One is the .inp file, which is described above and in which all the settings of the simulation are defined. The other input file is the .mdp file which refers to the required input files related to the background conditions. In the latter file also the output files that need to be created are defined.

The Matlab function *PART_dredgeplume.m* (i.e. the module interface) replaces the keywords in the copied basic input file with the settings for the simulation defined in the settings file. For the settings which require more than 1 block in the input file (such as the release locations and times), new blocks are inserted in the input file.

For each substance, representing one user defined particle size, new blocks are inserted in the input file. More than one dredging operation can be defined in the GUI. The different dredging operations can have (partly) the same particles. If a particle size is used in more than one dredging operation, it needs to written in the input file only once. Therefore only unique names will be written in the input file.

After the insertion of the substances new blocks are inserted for the release location of the particles. The sediment discharges are defined as so-called 'instantaneous releases' in the Delft3D-PART model input file. In this case all particles used for this release will be released at once, at the specified location and time. Therefore at every time step of the simulation that a dredging operation is taking place a instantaneous release will be defined and a new block will be inserted into the input file. The user defines the release rate in kg/s. PART requires the total kg released for each instantaneous release (i.e. per time step). Therefore the total mass of all releases is determined for each time step in the PART simulation. This is divided over the total of release, so the kg for each release is obtained.

The locations of the releases are determined by the user-defined dredging track. This track is divided into specific locations for each 10 minutes. These locations are the release locations. Hereafter the fall velocity for each substance is inserted in the input file.

Once the input files have been fully created, the actual Delft3D-PART simulation starts. This will take some time depending on e.g. the processing power of the computation PC, the simulation period, the amount of particles used and the time step of the simulation.

While running, Delft3D-PART will create some output files, such as the .his file. This file contains the suspended sediment concentration (SSC) and the sedimentation in the predefined output locations.

The *IDT_getOutputLocations* function determines relevant locations for the generation of time series output of the plume dispersion model, based on the areas defined in the ecology database. Based on the polygons defined in the ecology database and in comparison with the underlying hydrodynamic (output) grid, the cells in which output is required are determined. In fact, this (relatively time-consuming) determination of the output locations is done once as a separate step in the workflow, which makes the suitability map mode of the IDT more efficient.

The script *IDT_monitorPARTRun* shows the progress of the simulation in the GUI for the convenience of the user and collects the Delft3D-PART map output during the simulation to allow for a shorter run time.

Table 7.1: Template Delft3D-PART input file (.inp file) including keywords

```
'V3.66.00        ' ; please, don't change this line

''
''
''
'T0: 2004.01.01 00:00:00 (scu =       ls)'

;                       Hydrodynamics file (*.hyd)
'%dataLocation%'; name of *hyd file
;

;                       Numerical parameters
; Type of model: 1 - tracer (basic module)
;                       2 - (obsolete option)
;                       3 - red tide model
;                       4 - oil model
;                       5 - (obsolete option)
     1     0     0     1  ; type of model        tracks(0/1)    extra output      sed/erosion(0/1)
     1    %TimeStep%               ; num. scheme          time_step(s)   (0=flow time step)
     0   1.00      %VertDisp%       ; vert. disp option(*)   scale        disp_coeff.(m2/s)
                        ; (*) 0=constant 1=depth averaged



;                       Substances
 %NUMBER_SUBSTANCES%   ; no_of_substances
 '%NAME_SUBSTANCE1%'

;                       Particles
```

```
   %NumOfParts%  ; number of particles

;                          Physical parameters
              0.02 ; roughness [m]
              %HorDiff% ; a coeff. in hor. diff. D = a*t^b
              0.01 ; b coeff. in hor. diff. D = a*t^b
                 1 ; wind_drag (%)
              1024 ; density of water (kg/m3)

;                          Wind_parameters
  2
; dd hh mm ss        speed(m/s)   direction(degr.)

  %StartDayOfSim%  0  0  0          0.000        0.000
  %EndDayOfSim%  0  0  0          0.000        0.000

;                          Model specific parameters
    0 ; number of model specific parameters

;                          Timers
;yyyy mm dd hh mm ss
         %StartDayOfSim%  0  0  0      ;simulation start time
         %EndDayOfSim%  0  0  0      ;simulation stop time
         1  0  0  0      ;DELWAQ take over time
         %StartDayOfSim%  0  0  0      ;map file start time
         %EndDayOfSim%  0  0  0      ;map file stop time
         0  0 %MapTimeStep_Min%  0      ;map file time step
         %StartDayOfSim%  0  0  0      ;his file start time
         %EndDayOfSim%  0  0  0      ;his file stop time
         0  0 %HisTimeStep_Min%  0      ;his file time step
 %ReferenceDate%      ;reference date for output

;                          Observation points
    XX
;                               x-coordinate          y-coordinate
   'NAME'                   X-COORDINATE    Y-COORDINATE

;                          Output parameters
;Zoom grid output method
 1
; dd hh mm ss        recovery(-) (for scaling of output)
 %StartDayOfSim% 0 0 0  1
;                          Zoom grid output parameters
       0.00         100.00  ; x-start(m)              x-end(m)
       0.00         100.00  ; y-start(m)              y-end(m)
        100          100  ; grid cells in x dir(-)  grid cells in y dir(-)
;                   Instantaneous releases
  %NUMBER_RELEASES%  ; number of instantaneous releases

'%NAME_RELEASE1%'
     %StartDayofRelease%  %StartHourofRelease%  %StartMinofRelease%  0                              ; release time (dd
hh mm ss)
     %x_coord%     %y_coord%        %depth_release% ; x-coord(m)     y-coord(m)      depth under surface(%)
             0         %Radius_release%                 ; option for release radius      radius[m]
                                    ; (0=user-defined radius;1=formula Fay-Hoult)
         %Perc_part%                          ; perc. of total particles(%)
;released mass(kg)
      0.000       ; %NAME_SUBSTANCE1%

;                          Continuous releases
  0  ; number of continuous releases
;                          User defined releases
  0
;                          Decay rates
  0
;dd hh mm ss          decay rates (1/day)
;
;   %StartDayOfSim%  0  0  0          0.0        0.0
;  %EndDayOfSim%  0  0  0          0.0        0.0
```

```
;
;                    Settling velocities
; Generalized settling formula
        0.0000  ; exponent for c(-)
             1  ; grid refinement factor for accurate settling(-)

; Settling tables
          2  ; table dimension
; %NAME_SUBSTANCE1%
; dd hh mm ss      A0[m/s]    A1[m/s]   Period[h]    Phase[h]   Vmin[m/s]   Vmax[m/s]
%StartDayOfSim%  0  0  0       %FALL_VEL1%      0.000      0.000      0.000      0.000      %FALL_VEL1%
%EndDayOfSim%  0  0  0        %FALL_VEL1%      0.000      0.000      0.000      0.000      %FALL_VEL1%

;Sediment/erosion parameters
    %CritShearSed% ; Critical shear stress for sedimentation (Pa)
    %CritShearEro% ; Critical shear stress for erosion (Pa)
    %Chezy% ; Chezy coefficient (m1/2/s)
```

After (and during) the simulation, the time series and map results are collected and stored in the internal data structure in the IDT (S structure)[1] for subsequent visualisation and assessments in the next modules of the workflow.

7.4 Limitations and possible future improvements

Limitations of the present Delft3D-PART approach

Several possible future improvements are identified for the plume dispersion module. Most of the possible future improvements are related to the generation of output of the plume dispersion model. As described above the running of the model is not grid depended. However, the output of the model is 'mapped' onto a grid (the hydrodynamic Delft3D-FLOW or a separately defined Delft3D-PART zoom grid), in order to define the suspended sediment concentration and sedimentation in a certain area, or grid cell. In the basic simulation this is mapped onto the hydrodynamic grid. However, the hydrodynamic grid cell size can be quite large (grid cells in order of 200-500m) and therefore the output is mapped on these large grid cells. By creating a local, in the area of interest, finer grid the output can be mapped on this grid. This makes the output more accurate. This function already exists within the PART model and is called the 'zoom grid'. However, this is not yet included in the Interactive Dredge Planning Tool. This functionality could be improved by the possibility to define several areas of interest for more detailed output instead of one, which would be a development in Delft3D-PART.

Another interesting option for improvement is to map the output onto a 3D grid. This has no impact on the simulation itself, because the simulation of the particle tracks is already in 3D, even when 2D hydrodynamic forcing data is used. By mapping the output also on a 3D grid the concentration at different depths can be generated as output (also even with 2D hydrodynamic forcing data). Thereby the impact on the ecology, which is also present at different depths, can be estimated more accurately, i.e. if a depth-dependent relation for SSC to light attenuation is available.

In the present implementation, only sedimentation is considered and no resuspension of deposited material, by specifying the 'Critical shear stress for erosion (Pa)' in the settings XML file.

Another plume dispersion model (or other type of model for a different application of the tool framework) can be easily implemented due to the modular setup of the tool. For this, a model-specific interface needs to be written, but after this, the module can easily be included or replaced in the workflow.

8. Ecology database (Module 6)

8.1 Functionality

The ecology database module is used for the provision of data of the sensitive ecology needed for the ecology assessment. The ecology database contains three main parts:

1. Stressor: a list of the relevant stresses on ecology. At this moment Suspended Sediment Concentration (SSC) and sedimentation are included. Others, for example light attenuation and temperature can also be included if the relation between the modelled parameters and the stressors are known (which can then be included in the tool's workflow). For a stressor like temperature, also a temperature model needs to be used (presently not used);
2. Species: the characteristics of each species, especially Species Response Curves for the relevant stresses;
3. Locations: the coordinates of areas where sensitive ecology is present and the occurring species.

Table 8.1 gives an overview of the ecology database and a description per keyword.

Table 8.1: Overview of ecology database

level 1	level 2	level 3	description
Stressor			external stimulus that can be a stress for certain species
	Name		name of a stressor
	TranslationFunction		name of a Matlab function which will translate modelled (often abiotic) parameters into ecological stresses
Species	NameSpecies		name of the species
	IndexSpecies		index of the species (for internal book keeping)
	DescriptionSpecies		reference to a website with a description of each species
	SRC		Species Response Curve (SRC)
		Stressor	Stressor to which the SRC applies
		IndexStressor	index of the stressor (for internal book keeping)
		AssessmentFunction	name of a Matlab function which will assess the ecological effect
		TransformationMethod	name of a Matlab function which will transform the stressor time series into an intensity (e.g. a certain percentile relevant to ecological response)
		TimeScaleRow	time scale axis matching to the response matrix (horizontal axis)
		TimeScaleRowString	string of time scale axis
		TimeScaleRowHeader	header of time scale axis
		IntensityColumn	stressor intensity axis matching to the response matrix (vertical

			axis)
		IntensityColumnString	string of stressor intensity axis
		IntensityColumnHeader	header of stressor intensity axis
		ResponseMatrix	ecological effect as function of time scale and intensity (unique characteristic of a species, depends on healthy / history of a species)
Locations			coordinates are specified of each point / polygon / area, coordinate system is defined in the settings file
	NameLocation		unique name of location
	DescriptionLocation		reference to html file with a description of each location
	x		x-coordinates
	y		y-coordinates
	RelativeDepth		Relative depth of the ecology in the water column (for future use for assessments depending on depth)
	IndexSpecies		index of occurring species at this specific location (for internal book keeping)

The ecological areas in the database can be visualised in the IDT and will show as green, transparent patches (polygons) on the map indicating the different areas and a indicator label (green point) that, when clicked, shows possible additional information about the area. The figure below shows an example of these ecological areas presented on the IDT map.

Figure 8.1: Example presentation of ecological areas from the database on the IDT map. Green transparent patches indicate the ecological area, the green points are indicators of each area that, when clicked, can show additional information about the area.

8.2 Interfaces

The ecology database module has interfaces with various modules:

- Presentation module:
  when a user starts the Interactive Dredge Planning Tool, the locations with sensitive ecology are shown on the map.
- Dredge plume dispersion module:
  The output locations of the dredge dispersion module are based on the locations of the sensitive (ecological) receivers, which are specified in the ecology database.
- Translation into ecological stresses:
  the ecology database defines for each stress type which Matlab function should be used to transform the time series of (abiotic) model output to ecologically relevant stresses (e.g. suspended sediment concentration into light attenuation).
- Ecology assessment module:
  the ecology assessment module needs information about the characteristics of occurring species. The species response curves contain important information for this assessment. The computed stressor intensity will be mapped on the species response curve in this assessment to determine the ecological effects.

8.3 Implementation

The ecological database is specified in a xml-file which is located in the folder *EcologyDatabase*. Users can edit this file with a text editor. The settings file refers to this xml-file, for instance to *EcologyDatabase_SRC_Doorn2007.xml*.

> The information in the ecology database is specific for the area of application of the IDT and the database for the prototype IDT application (e.g. *EcologyDatabase_SRC_Doorn2007.xml*) is specific for the Singapore region. For other geographical areas, another database (XML file) needs to be prepared with locally relevant (ecologically) sensitive areas, stressors and response information.

An example of an empty ecological database can be found in Table 8.2.

Table 8.2: XML-file structure of (empty) ecological database

```
<EcologyDatabase>

  <Stressor>
          <Name> string </Name>
          <TranslationFunction> string </TranslationFunction>
  </Stressor>

  <Species>
          <NameSpecies> string </NameSpecies>
          <IndexSpecies></IndexSpecies>
          <DescriptionSpecies> string </DescriptionSpecies>
          <SRC>
            <Stressor> string </Stressor>
            <IndexStressor> integer </IndexStressor>
            <AssessmentFunction> string </AssessmentFunction>
            <TransformationMethod> string </TransformationMethod>
```

```
            <TimeScaleRow>
            row vector with N elements
            </TimeScaleRow>
            <TimeScaleRowString> string with N words </TimeScaleRowString>
            <TimeScaleRowHeader> string </TimeScaleRowHeader>
            <IntensityColumn>
            column vector with M elements
            </IntensityColumn>
            <IntensityColumnString> string with M words </IntensityColumnString>
            <IntensityColumnHeader> string </IntensityColumnHeader>
            <ResponseMatrix>
            M x N matrix
            </ResponseMatrix>
          </SRC>
 </Species>

 <Locations>
   <NameLocation> string </NameLocation>
   <DescriptionLocation> string </DescriptionLocation>
   <y> row vector with K elements </y>
   <x> row vector with K elements </x>
   <RelativeDepth> double between 0 and 1 </RelativeDepth>
   <IndexSpecies> integer </IndexSpecies>
 </Locations>

</EcologyDatabase>
```

The ecology database can be read by Matlab with *IDT_readEcologyDatabase.m* which is located in the folder *EcologyAssessment*. This Matlab function reads the XML-file and transforms the ecology data into a Matlab structure.

8.4 Limitations and possible future improvements

Possible future improvements of the ecology input module are:

- to join format standards for ecological databases, such as defined in the OpenEarth developments;
- to create the possibility to load ecological data from possible ecological databases at other locations in the world to extend the application range of the tool.

9. Translation into ecological stresses (Module 7)

9.1 Functionality

This module translates the output of the dredge plume dispersion module into ecological stressor parameters. This translation is required to assess the impact of the dredging plume on the ecology. Two types of translation are accommodated for, these are:

1. the transformation of multiple time series to one time series per area where ecology is located (in each ecological area, time series are collected at all model grid cells that fall within the area and therefore result in multiple time series per area);
2. the transformation of suspended sediment concentration (SSC) given by the PART module into the ecological stressor light attenuation.

The first translation is implemented in the current version of the IDT. The second is described here, but not yet fully implemented in the IDT.

As a starting point for the Singapore application of the IDT, the ecological assessment method of Doorn-Groen (2007) (see Chapter 10 – Ecology assessment) is used, which is the present practice used in the Singapore region. This method does not use a direct ecological stressor like light attenuation, but has based the ecological effect assessment directly on suspended sediment concentrations and sedimentation rates and therefore does not use this second type of translation. This assessment method is based on modelling and uses suspended sediment concentrations to assess the ecological impact.

However, to fully assess the effect on the sensitive receptors, ecology relevant parameters, such as light attenuation are required. For further development of this tool the translation between SSC and light attenuation is already developed and implemented in the tool. Whenever a different assessment method is used, based on the sensitive receptors and developed using field monitoring and lab experiments the translation between SSC and light attenuation may be required.

The following types of ecological stressors are implemented in the IDT:

- Suspended sediment concentration;
- Light attenuation; and
- Sedimentation rate.

9.2 Interfaces

The translation module needs input from the dredge plume dispersion module. The dredge plume dispersion module simulates the suspended sediment concentration and sedimentation due to dredging activities. The output of this module is time series of (depth-averaged) suspended sediment concentration and sedimentation at several locations in each area of sensitive ecology defined in the ecology database.

The output of the translation module will be used in the ecology assessment module. The translation module will provide the time series of ecological stressor intensity and duration per species, per type of stressor and per ecological area.

9.3 Implementation

The translation module is located in the folder *Stresses* and can be run by *IDT_Stresses.m*. This Matlab function calls a transformation of multiple time series to one 'maximum' time series per area and a transformation of this resulting time series into light attenuation.

1. Transformation of multiple time series per ecological area
   The dredge plume dispersion module gives output data at multiple output locations per ecology area (within a polygon, see Figure 8.1). As mentioned above, the model output time series for all model grid cells within each area are collected. The function *IDT_createSingleTSForEcoPolygon.m* transforms these multiple time series into one maximum time series per polygon(/ecological area). This time series can be assessed with the ecological thresholds, as described in Chapter 10 – Ecological assessment. The present implementation combines the various time series from an ecological area (i.e. several locations in this area based on the model grid cell sizes in this area) to a 'maximum' time series, which means that for each time step, the maximum suspended sediment concentration and sedimentation of all locations for that time step is used to construct the resulting time series.

2. Transformation into ecological stresses
   Two types of transformations are available in the IDT, being SSC to light attenuation and the cumulative sedimentation at the location of ecological receptors.

<u>Suspended sediment concentration to light attenuation:</u>
It is noted that the translation of the suspended sediment concentrations into light attenuation depends on different factors (as described below) and is therefore location specific. The modular set-up of the IDT allows for the easy use and implementation of a different location specific translation function. In the below description is focused on the implementation of a translation function from suspended sediment concentrations to light attenuation for the Singapore prototype application of the IDT. Similar approaches could be followed for other areas, but the location specifics need to be taken into account.

For the translation of suspended sediment concentrations (based on instantaneous sediment concentrations) into the ecological stressor light attenuation, field data is used of an experiment employed in the Singapore region (Sin et al. 2012, Sin 2013 and Ong and Sin 2012), aiming at developing a generic relation between attenuation of photo synthetically available radiation (PAR) and the light attenuation factors as a function of the depth.

The Lambert-Beer equation is used to estimate the attenuation coefficient (K_D) from vertical profiles of down-welling irradiance as a function of depth (z):

$$K_D = \frac{\ln\left(\frac{I_0}{I_z}\right)}{z}$$

I_0 = PAR at surface
I_z = PAR at depth z

The attenuation coefficient K_D is derived from the data obtained in the field experiment, measuring PAR at the depth of the corals. PAR at surface is obtained from the National Environment Agency (NEA) in Singapore.

It is generally acknowledged that the attenuation coefficient K_D can be further decomposed into partial attenuation coefficients accounting for contributions due to clear water itself (Kw), chlorophyll (Kc), sediments (Kssc) and organics (Ko). Application of multiple regression techniques indicated strong relations between calculated Kd and all the independent variables in the model. The non-linear relationship modelled on SSC resulted in a correlation (R^2) of 0.75. For more numeric results reference is made to the Data Analysis Report (Sin et al. 2012, Sin 2013 and Ong and Sin 2012).

PAR measurements have been executed at three different sites in the Singapore region (Raffles Lighthouse, Kusu, Hantu). Parallel to the PAR measurements, turbidity measurements are executed and transformed into SSC by the use of an OBS calibration curve. Comparing the calculated K_D with the turbidity and SSC clearly reflects the different sites showing a significant spatial and temporal variation.

The results based on the field data and the subsequent analysis of Sin (2012) will be implemented as an initial model to translate SSC into light attenuation. The translation model will be updated in a later stage when a full year's dataset will be available. It is noted that the K_D will be location specific and that this will need to be assessed for different locations (within and outside the Singapore region) for an accurate application of this module in the IDT.

<u>Sedimentation:</u>
The sedimentation rate is based on the cumulative sedimentation (totalSedimentation) by function *IDT_SSC2Sedimentation.m*.

9.4 Limitations and possible future improvements

Regarding the translation of the SSC into the light attenuation, the following shortcomings of the present implemented translation model can be noted:

- The present implementation of the translation module from suspended sediment concentrations towards light attenuation is in its first development stages and could be updated when the complete field data analysis becomes available and when ecological response data becomes available based on light attenuation. It is noted that the IDT tool caters for easy implementation of this translation and stressor, but that sufficient (and site specific) data and information are required for the proper use of this stressor.
- Field data and subsequent translation model is site specific and therefore not globally representative. At a new location this translation model should be developed using field data.
- Surface PAR data, purchased from the NEA is not site specific, referring to the three different sites in the Singapore regions. The K_D might be miscalculated by providing incorrect reference PAR at the surface of each site.
- Water depths for the K_D calculations are not yet accurately derived. Site specific water depths need to be derived.
- The dataset used for the preliminary analysis does not cover a full year yet. The translation model therefore might not be representative for every season.
- For the calculation of the (total) light attenuation the ambient background suspended sediment concentration (and sedimentation) are also required. At this moment these are not included in the hydrodynamic background dataset and therefore not yet incorporated.
- The present implementation combines the various time series from an ecological area (i.e. several locations in this area based on the model grid cell sizes (the Delft3D-FLOW model grid or a separately defined Delft3D-PART 'zoom grid') in this area) to a 'maximum' time series, which means that for each time step, the maximum suspended

sediment concentration and sedimentation of all locations for that time step is used to construct the resulting time series. The ecological relevance of this assumption needs to be validated against ecological field data.

10. Assessment of ecological effects (Module 8)

10.1 Functionality

The ecology assessment module translates the simulated stresses into effects on sensitive ecology. It gives an assessment of the expected ecological response due to dredging activities.

The present implementation in the Interactive Dredge Planning Tool consists of the assessment method of Van Doorn - Groen (2007), which is specific to Singapore. However, the set-up of this module is also suitable to flexibly implement other assessment methods. It is also noted that for other geographical areas, other assessment methods and criteria and are likely to be required. In addition to ecological criteria, also non-ecological criteria (e.g. operational or political criteria) can be added to the IDT tool in a similar way.

10.2 Interfaces

The ecology assessment module needs data from several modules:

- Ecology input module:
  The ecology database provides species response curves for specific species at specific locations. The simulated stresses can be projected on these species response curves, resulting in an expected ecological effect.
- Translation into ecological stresses:
  The translation module provides time series of the intensity of stresses and background stresses, which are used as input for the assessment.

Output of the ecology assessment module will be used by the presentation module, which shows the results of ecological assessment on the Google Earth interface. The following type of output can be distinguished for each location, stressor and species:

- the expected stressor intensity corresponding to a certain time scale;
- the ecological effect, which is the result of this stressor intensity.

10.3 Implementation

The ecology assessment module has two main purposes:

1. Providing a combination of a stress intensity level and a related duration.
2. Mapping of this combination of a stress intensity level and a related duration on a species response curve which results in an ecological effect.

These analyses are called with the Matlab function *IDT_callEffectOnEcology.m.*

The ecology database contains a reference to the name of the ecology assessment method. Different ecology assessment method can be used for different stresses and different species.

Table 10.1 provides an overview of the implemented Matlab functions, which transform time series of a stress level into an ecological effect.

Table 10.1 Overview of implementation of Van Doorn - Groen

Species	Stressor	Matlab function
corals	suspended sediment concentration	*IDT_SRC_Doorn2007_coral_ssc.m*
corals	sedimentation	*IDT_SRC_Doorn2007_coral_sedimentation.m*
seagrass	suspended sediment concentration	*IDT_SRC_Doorn2007_seagrass_ssc.m*
seagrass	sedimentation	*IDT_SRC_Doorn2007_seagrass_sedimentation.m*

The Interactive Dredge Planning Tool gives a first estimate of the possible effect on ecology of dredging activities in a limited number of *effect regimes*, matching the rapid-assessment character of the tool. Table 10.2 shows the translation of the impact categories of Van Doorn - Groen (2007) into three effect regimes in the Interactive Dredge Planning Tool.

Table 10.2 Implementation of Van Doorn - Groen in Interactive Dredge Planning Tool

Severity	Definition (excess concentration) (according to Van Doorn - Groen 2007)	Effect regimes IDT
No Impact	Excess Suspended Sediment Concentration > 5 mg/l for less than 5% of the time	level 1 - no effect (green)
Slight Impact	Excess Suspended Sediment Concentration > 5 mg/l for less than 20% of the time Excess Suspended Sediment Concentration > 10 mg/l for less than 5% of the time	level 1 - no effect (green)
Minor Impact	Excess Suspended Sediment Concentration > 5 mg/l for more than 20% of the time Excess Suspended Sediment Concentration > 10 mg/l for less than 20% of the time	level 2 - sub-lethal effect (orange)
Moderate Impact	Excess Suspended Sediment Concentration > 10 mg/l for more than 20% of the time Excess Suspended Sediment Concentration > 25 mg/l for more than 5% of the time	level 2 - sub-lethal effect (orange)
Major Impact	Excess Suspended Sediment Concentration > 25 mg/l for more than 20% of the time Excess Suspended Sediment Concentration > 100 mg/l for more than 1% of the time	level 3 - mortality (red)

10.4 Limitations and possible future improvements

The following items are limitations of the presently implemented ecology assessment method of Van Doorn - Groen (2007):

- Only a percentage of the total duration that a stress may occur is given, while the total duration is not clearly defined. From personal communication it was learned that this duration could be as short as 12 – 24 hours, depending on the receptor. Nevertheless, in the method of Van Doorn – Groen (2007) and also in the IDT, the length of the simulation assessment is used as the 'duration';
- There is no distinction of cumulative stress events;
- There are no spatial varying and season-dependent background conditions, i.e. only excess stresses (SSC and sedimentation);
- The current condition of the ecological community has not been taken into account.

The Interactive Dredge Planning Tool can be improved by the development of a new ecology assessment method which includes:

- time-varying stresses
- the frequency of 'events'
- the consecutive events (cumulative effects)
- spatial varying and season-dependent background stresses
- the history of community (healthy versus stressed situation)
- sedimentation rate and light attenuation as stressors

A new ecology assessment method needs to be based on site-specific observations of field experiments and laboratory experiments in area of application of the tool.

11. Presentation (Module 9)

11.1 Functionality

The presentation module visualizes the results of the ecological assessment. It does so by visualising “ecological effect matrices”, which map the ecological effects (based on Van Doorn – Groen (2007)), and icons that indicate the effect regime for the different areas, species and stress types (see also Chapter 10). The ecological effect matrices and icons are subsequently incorporated in a KML file in order to visualize the results in Google Earth. This way, the information of the ecological assessment is distributed to the end users.

11.2 Interfaces

The presentation module needs input from the ecological database (species, SRC’s, stressors and locations – Chapter 8) and the ecological assessment module (intensities and effects – Chapter 10).

The output of the presentation module goes directly through the Matlab backbone to the Google Earth interface. In the web-based version of the tool, the KML files are uploaded to the web server.

11.3 Implementation

The presentation module consists of three Matlab routines:

- IDT_plotEcoEffectMatrix
- IDT_ecoresults_to_KML
- IDT_refresh

<u>IDT_plotEcoEffectMatrix</u>

The *IDT_plotEcoEffectMatrix* function plots the ecological effect matrices based on the SRC’s and the intensities obtained from the ecological assessment for each stress time scale if relevant (note that the present implementation of the species response according to Van Doorn-Groen (2007) does not consider different time scales). It does so by looping through the ecological assessment results for all species-stressor combinations. The *IDT_plotEcoEffectMatrix* function results in a number of figures (see the example in Figure 11.1.a). These figures are saved on the local server, so that they can be accessed by the web application or later uploaded to the web server.

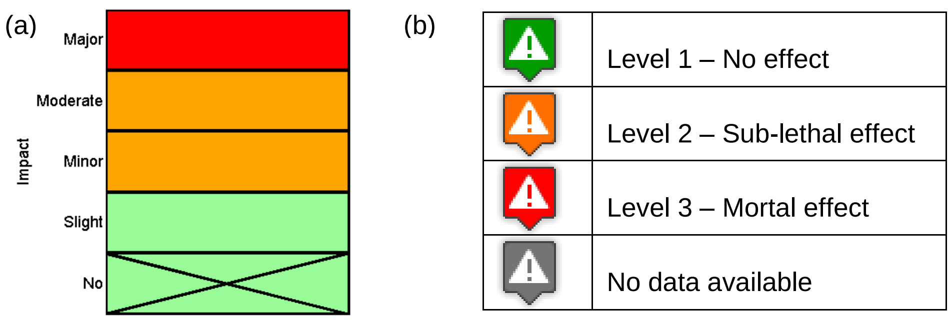

Figure 11.1: (a) Example ecological effect matrix and (b) KML-icons for different ecological effect regimes

IDT_ecoresults_to_KML

The *IDT_ecoresults_to_KML* function links the results of the ecological assessment module to the locations specified in the ecological database and to the ecological effect matrix (as described above) and to a corresponding KML-icon. Figure 11.1.b gives an overview of the KML-icons and the corresponding effect regimes from the ecological assessment. For each location and for each species the effects for each stressor (in terms of ecological effect matrices) are incorporated in a KML text balloon (see Figure 11.2), which is presented on the Google Earth map. The type of KML-icon is based on the worst ecological effect regime for the two different species (i.e. the maximum effect).

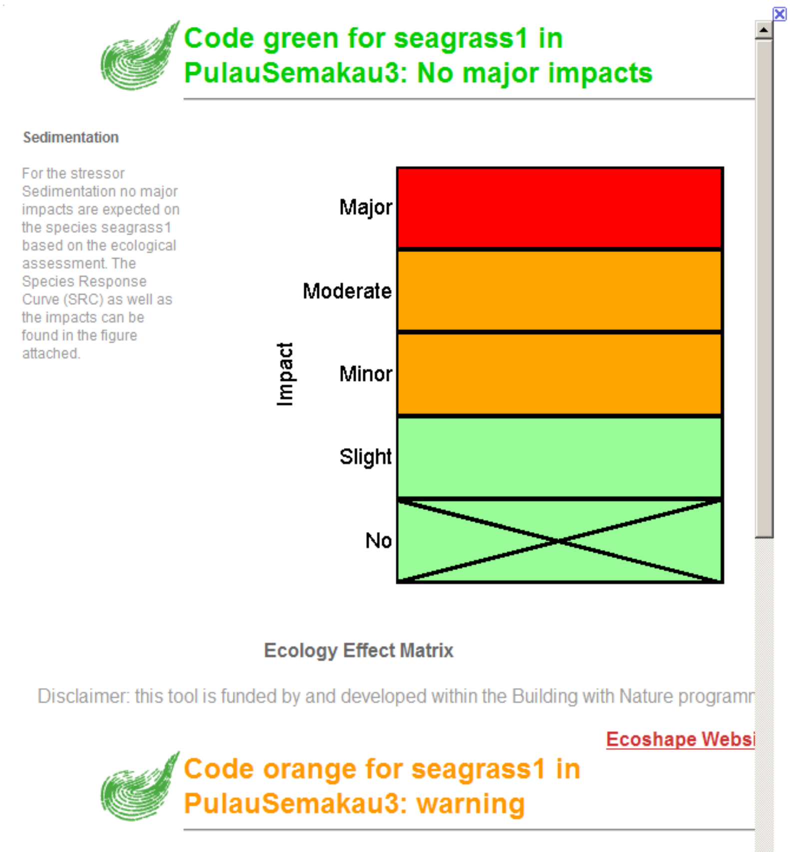

Figure 11.2: Example of a KML text-balloon with ecological effect matrix

IDT_refresh

The *IDT_refresh* function belongs to the Matlab backbone and ensures that the KML output of the *IDT_ecoresults_to_KML* is shown in the Google Earth window. The Google Earth window shows the icons for all locations and all species. By clicking the icons, a text balloon pops-up containing the ecological effect matrices (see Figure 11.3). In the web-based version of the tool, this function has no effect, since the web server awaits the output XML file and will present the KML files in this XML file on the Google Earth map as soon as the output XML becomes available.

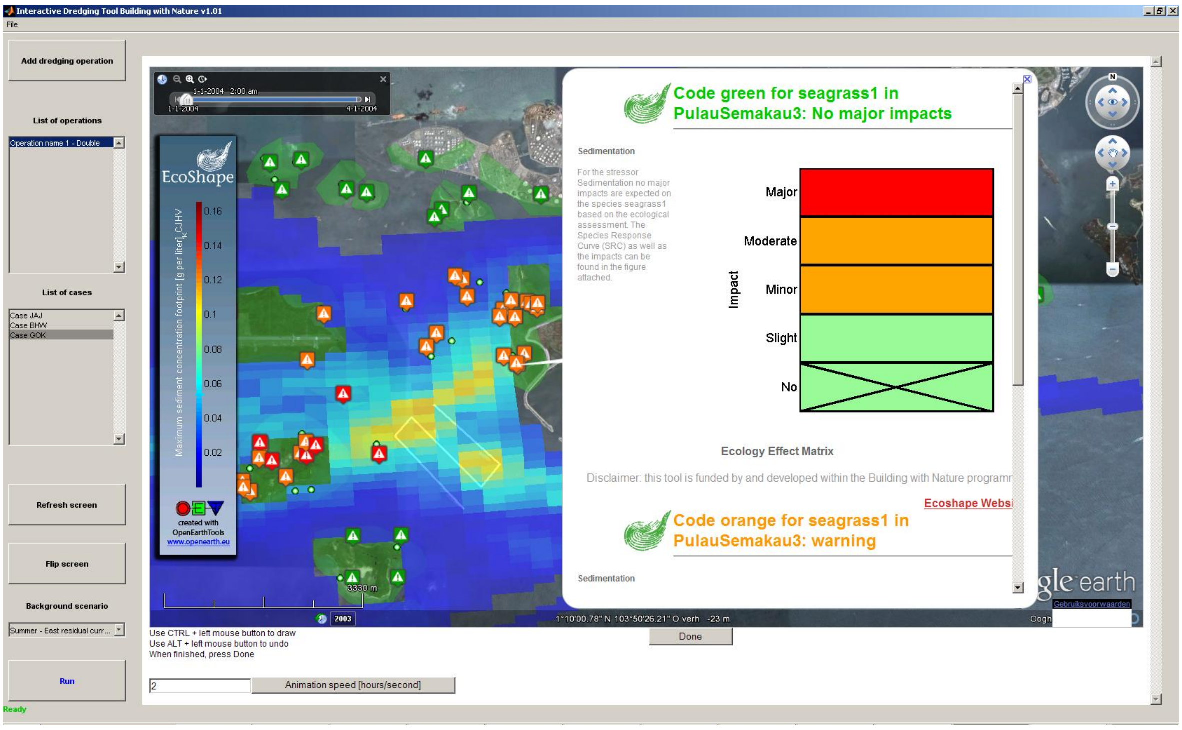

Figure 11.3: Ecological visualization in Google Earth window

11.4 Limitations and possible future improvements

The presentation module has the following limitations:

- Visualizations are based on Google Earth formats and conventions, which makes them dependent on the Google Earth software
- The colour of the KML-icons is only based on the worst ecological effect regime for a species at a specific location, implying that the effects of only one stressor are visible at first sight

The presentation module has the following possible future improvements:

- The generation of ecological effect matrices and KMLs tends to be rather slow. Future developments may aim at speeding up this process.
- The image size of the ecological effect matrix is hard-coded and not dependent on the screen resolution. This can be made more flexible. Nevertheless, the present dimensions of this image is suitable for typical screen resolutions in use nowadays.

12. Development of Suitability maps

12.1 Introduction

In addition to the 'forward loop' or 'operation mode' (i.e. starting from a specified dredging operation input towards the expected ecological effects), the IDT has been extended to be able to produce so-called 'suitability maps', which show the maximum allowed spill source in a certain area while remaining below a user-specified maximum ecological effect class.

For this functionality, the workflow was adapted to include a loop to carry out several dredge plume dispersion simulations for all possible locations within the specified dredging area based on a single discharge (see Figure 12.1). These locations within the specified dredging area are determined by the tool based on the area extent and user-specified number of locations within this area to be assessed.

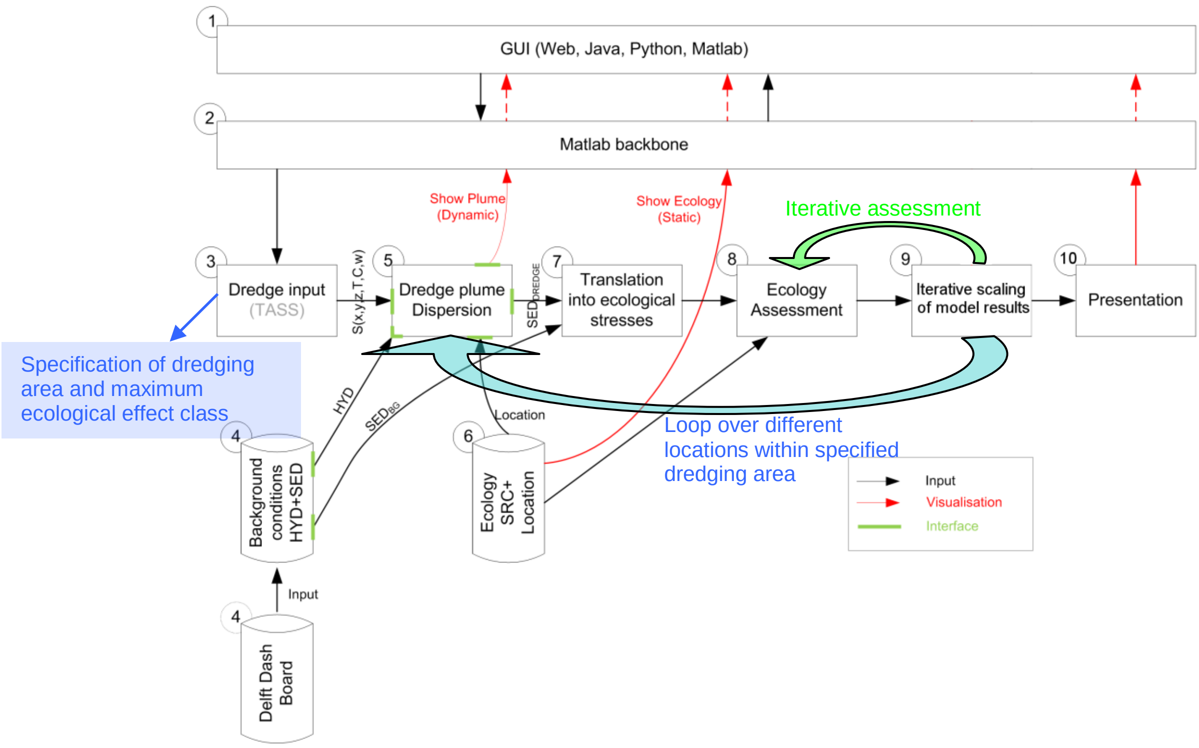

Figure 12.1: Workflow diagram of IDT tool modules in suitability map mode

Since the present implementation of the dredge plume dispersion modelling only contains *linear* processes (i.e. no resuspension processes, sediment induced density currents, etc) the dispersion modelling results (spatial and temporal distribution of the suspended sediment concentrations and sedimentation) can be 'scaled' with respect to the sediment source term. For example, in this modelling approach, the computed maximum suspended sediment concentration footprint is completely relative to the source term and the expected sediment concentrations at a certain location and time can be considered as a percentage from the initial source term. The sediment concentrations and sedimentation can therefore be 'scaled' up and down in relation to the (unit) source term to determine which source term magnitudes are expected to result in an exceedance of the user-defined effect class.

The (unit) source dredging terms of these simulations are therefore subsequently iteratively ‘scaled’ and tested against the resulting ecological effects to find the maximum source term for each location that remains within the specified maximum ecological effect class. This is done in an iterative loop for each location (green loop in Figure 12.1 ‘Iterative assessment’). Subsequently, this is done for the next locations in the specified dredging area via the blue loop in Figure 12.1 ‘Loop over different locations within specified dredging area’.

These computed maximum source terms at the different locations within the specified area represent the ‘spill budget’ that is allowed and a dredging suitability contour map is constructed for the specified dredging area. In Figure 12.2, an example output of the suitability model is presented.

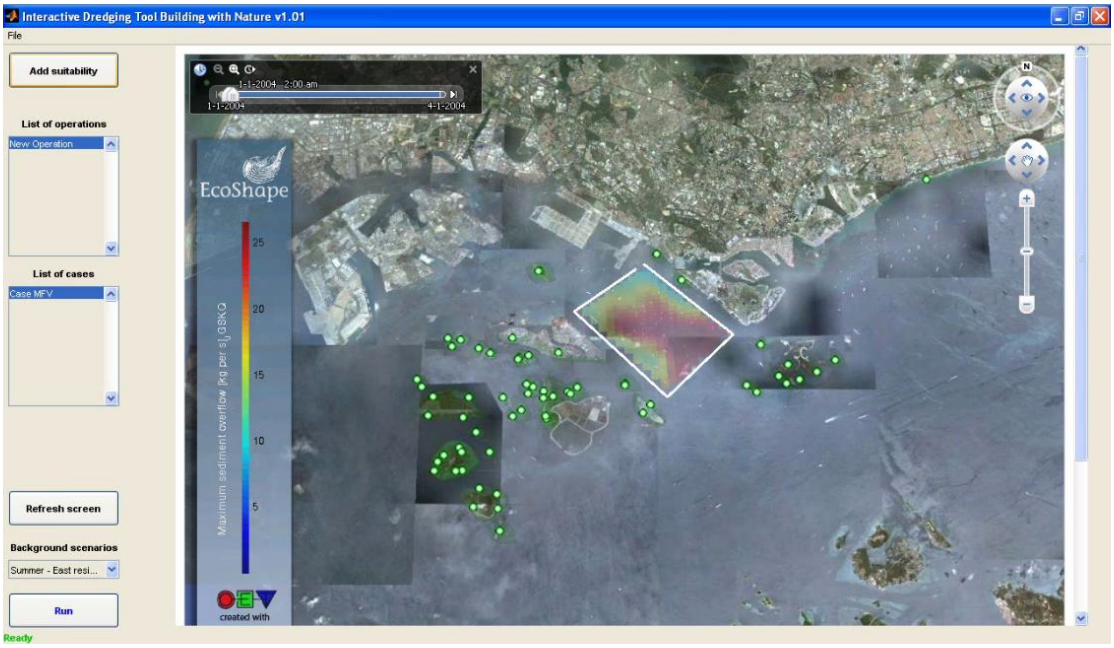

Figure 12.2 Example output of the Suitability map model of the IDT, indicating the maximum allowed spill budget (i.e. sediment source term) within the indicated area (in white) in order not to exceed a specified ecological effect class.

This chapter describes in short the suitability map functionality and implementation.

12.2 Implementation

The suitability map mode of the IDT tool makes use of the same modules as the operation mode of the tool. In addition, some modules have been added to allow for the looping through several simulations and the iterative assessment towards the maximum acceptable spill amount (see Figure 12.1). The suitability map mode of the tool in general performs the following steps:

- The user specifies the dredging area for investigation, the background conditions to use and the maximum allowed ecological effect class per species and stressor
- The tool automatically defines various spill locations within the dredging area (up to a number specified by the user)

- The tool simulates a plume dispersal for each possible spill location with the same:
  - Hydrodynamic forcing
  - Dredging spill (sediment source term)
- The tool translates the simulation results to the maximum allowed spill throughout the dredging area by linearly scaling the results of the simulations up to a level that still just falls within the maximum allowed ecological effect class. This is done by an iterative scaling process and ecological effects assessment, i.e. the green loop in Figure 12.1 ‘Iterative assessment’). The scaling of the modelling results makes use of the relative modelling results compared to the initial source term (percentage of source concentration), which is valid due to the linear modelling approach in the present implementation. This way, the plume dispersion simulation only has to be performed once for each location in the dredging area, which makes the suitability map assessment very efficient. Obviously, this approach is only valid in this schematised, linear modelling approach, which does not contain all physical details of a full, detailed modelling assessment, but this approach does allow for an efficient initial assessment of the expected dredging suitability.
- The maximum allowed spill amounts are visualised as contours on the Google Earth map

This suitability map mode of the tool is in essence a different *behaviour* than the operation mode of the IDT. Also, the GUI has a different appearance, but has similar elements. This different behaviour and different appearance is specified in the settings XML file. For the standalone version, also the GUI appearance and functionality is specified in this file, for the web-based version, an additional ‘tool’ GUI is created.

The specifications of the suitability map analysis are entered after clicking the area on the Google Earth map in the input screen shown below.

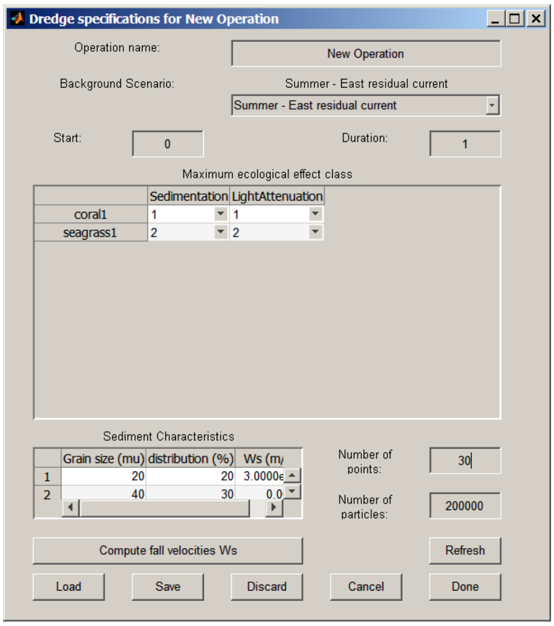

Figure 12.3 Input screen suitability map analysis

Most fields resemble the operation mode of the IDT and are self explanatory. The “Number of points” field defines the number of locations selected by the tool in the suitability analysis. For each of these points, a simulation is carried out.

After the simulations are completed, the results are scaled and analysed into a contour map in the defined area, indicating the maximum allowed spill amounts varying over the indicated area.

12.3 Limitations and possible future improvements

The present implementation of the suitability map mode assumes the following:

- Each simulation (i.e. for each location) consist of a single, fixed location instead of a track
- The spill is assumed continuous during the simulation (i.e. no cycle)
- The suitability map mode is presently designed to assess direct, short-term effects and therefore typically uses short simulations (few days), instead of e.g. a full spring-neap cycle (also because it is less likely that the spill location will be fixed for such long time in case of e.g. a hopper).
- The suitability map is presently based on a single concurrent operation.

Future improvements could consist of the extension of the functionality regarding the above items (e.g. use dredge operations/tracks rather than a single location, use of multiple concurrent operations in this analysis, etc.). Furthermore, possible performance improvements could be made (i.e. faster computational times, parallel computing etc.) if relevant. Any future developments should be coordinated with the eventual end-users to match the functionality to their needs.

13. Lessons Learned

In this chapter, the lessons learned in the development and use of the IDT tool are summarised. These lessons learned focus on the technical lessons in the development of this tool, but also on the development process and available user experiences.

SWOT analysis

These lessons are derived from a workshop session on 22 December 2011 involving Ecoshape Partners. The overview has been updated on 1 March 2012 and 21 June 2012.

Strengths	**Weaknesses**
• Applicable to full cycle from source to effect • Tool usable as Operation-based AND Impact-based (Reverse cycle) • Rapid-assessment • Easy visualization for communication purposes • Generic method • Predictions of impact • Modular and flexible set-up • The graphical output is understandable to a lay audience • Tailor-made (site-specific databases) • Insights into the ecosystem and its response	• Limited accuracy (rapid-assessment tool) • Difficult to validate full cycle • SRC not completely generic (location & species specific) • Time consuming to collect ecological data • For each ‘new’ area a new database with ambient conditions need to be set-up using modelling
Opportunities	**Threats**
• Standard method/approach (generic) • Optimisation of the monitoring program (for adaptive management) • Helps to create awareness • Stimulates sharing knowledge • Interactive • Can be used to make the process operational and transparent • Enables active stakeholder participation • Provides information about ecosystems • Inclusion of different types of criteria, e.g. ecological, institutional, operational, industrial, etc.	• Garbage in = garbage out (use any model with care) • Uncertainties in the far-field spreading of plumes • Uncertainties in physical parameters, such as the sediment characteristics • Uncertainty propagation in the computational process • Other stressors (natural or human-induced) • A tool this comprehensive may create false expectations • Difficult to determine

13.1 Technical Lessons Learned

Lessons learned setting up a MapTable tool

- Setting up a database with unknown data requires a generic approach. Ecological data was not yet available at the start of the project. However, this did not impose any problems, due to the generic approach of the setup of the database.
- Using separate modules makes the backbone of the MapTable tool and the data transfer more generic. For instance, modules can be replaced in the future without adapting the backbone of the tool.
- Using separate modules makes it easier for people to work independently on the tool.
- Using settings files makes the MapTable tool easier adaptable.

Some lessons learned Delft3D-PART - Dredge Plume Dispersion Modelling

- By using a closed boundary the particles will be reflected. In case of an open boundary the particles will leave the domain and never return. Therefore it is necessary to have a sufficiently large model domain to capture the full relevant extent of the plume;
- In the area of interest the grid size on which the Delft3D-PART results are projected should be small enough (e.g. <100-200 meter) to obtain a realistic value for the suspended sediment concentrations. It is noted that Delft3D-PART is a langrangian sub-grid model, but in order to derive the sediment concentrations, control volumes (i.e. a grid) is required. This grid can be the Delft3D-FLOW grid (by default) or a separately defined Delft3D-PART 'zoom grid';
- The concentration in an observation point is given as cell averaged of the grid cell it is in. If an observation point is located within the zoom grid, the output concentrations provided are the zoom grid cell averaged concentrations;
- The time scale of simulations is usually limited to a few weeks, in order to simulate accurately using a large number of particles;
- The number of particles needed for an accurate solution would be ideally 100 particles in one grid cell, implying a deviation of 1% (99% accuracy);
- If the bed shear stress at any location is greater than the critical shear stress for erosion, all deposited particles at that location will be returned in the water column instantaneously. This gives a 'sudden' plume which is not desired. Therefore it is advised to exclude erosion by choosing a high threshold for the critical shear stress for erosion;
- When using a large fall velocity there is an artefact in the module that the particles will 'bounce' at the bed and return in the water column, while they should stay at the bed. To reduce this difficulty all settings should be chosen realistically;
- Vertical dispersion is around 10^{-3} m2/s for low current velocities and a non-stratified model. In case of high current velocities the vertical dispersion can be increased to 10^{-2} m2/s. This value can be specified in the IDT settings file;
- Horizontal diffusion increases in about a day from 0.01 m2/s to 1m2/s, depending of the size of the grid. At first the plume is concentrated, later on it will become larger with as consequence more horizontal diffusion.

13.2 Lessons Learned development process

- Keep stakeholders pro-actively informed, also if these stakeholders are not pro-actively involved to keep monitoring their requirements and if the product (i.e. IDT tool) still meets these requirements.
- The use of a modular software design in a programming language that many development team members are familiar with, hugely expedites the development process, since modules can be developed in parallel.
- Making individual team members responsible for their own module development stimulates the involvement and motivation of the team members

13.3 Lessons Learned user experience

- Based on the comments gained during the Building with Nature conference, the attendees commented that they were impressed by the appearance and the possibilities of the prototype tool and found this development very interesting. Also the suitability map mode was found to be useful.
- In particular from a communication perspective, the tool is considered to be potentially very useful and powerful, specifically for communication with the community (e.g. living close to the project area, public). It was mentioned that the local community can have a very large influence on the progress of a construction project and a tool such as this could improve the communication with them substantially.
- It was also requested if such tool could be developed in a similar manner for other aspects, such as swimmer safety at the Sand Engine; and this is obviously possible in an efficient way based on the flexible framework that is developed in this project.
- The attendees quickly realised that the ‘weakest link’ in the tool would be the ecological criteria and assessment of the ecological effects, mainly fed by the ecological response data available (or actually not available).
- Some attendees had doubts about the applicability of rapid-assessment tools in general. The results of such tools generally provide an indication only, while in many cases more than just an indication is required. These cases require detailed modelling which is not rapid-assessment. Nevertheless, a rapid-assessment tool could also provide insight in the necessity of detailed modelling or other approaches in an early stage of the project design. It is noted however, that this prototype tool development should be regarded as a proof-of-concept and technique which could be used in many ways and for many applications in different dredging project phases and that it could be useful to support these phases in addition to more traditional approaches (and not so much replace other assessments or detailed modelling). In particular, during project execution and monitoring, this tool set-up, and the possibility to easily combine results with measurements in a Google Earth map environment, can be very useful.

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