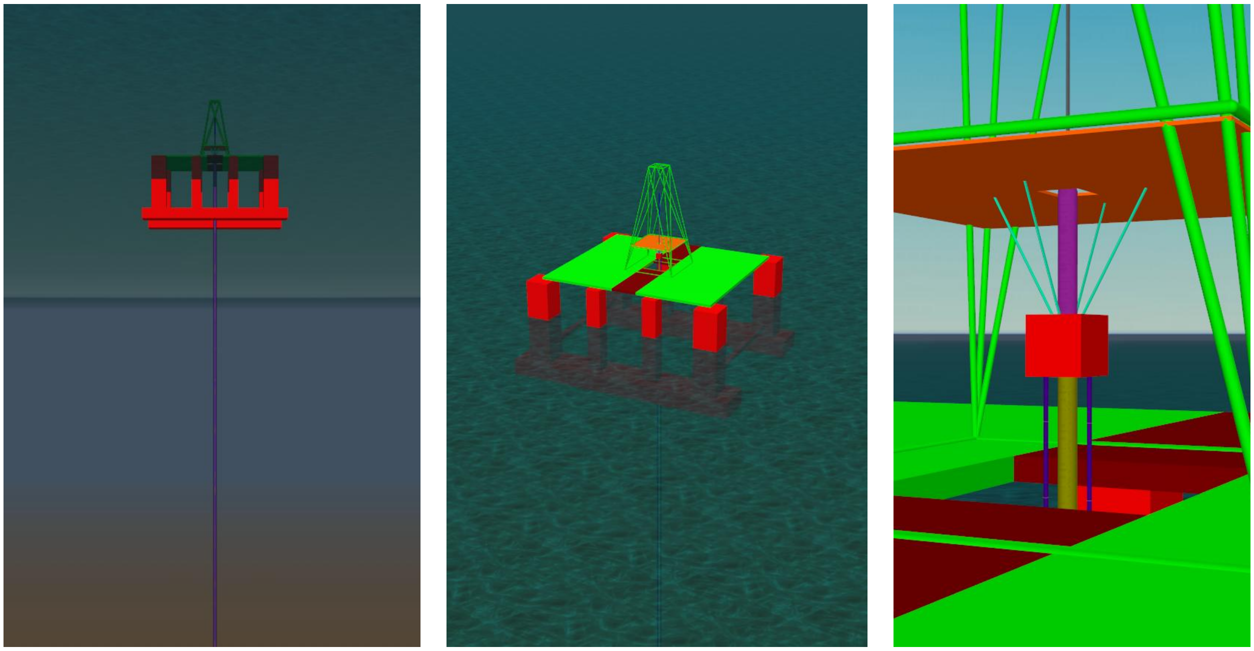
B01 Drilling riser



A tensioned drilling riser descends from a semi-submersible drilling vessel to a blow out preventer (BOP) on the seabed. A drill string is modelled running inside the riser down to the BOP and carries on into the casing below the seabed.

Building the model

The complete system is around 2000m long from top to bottom; therefore the model is easier to understand if viewed in sections, using workspaces. The file opens up with the default workspace loaded, which shows two shaded views of the semi-sub.

First load up the workspace *B01 Drilling riser top views.wrk*. This shows the topside part of the system, which has a drilling riser descending through the moonpool of a semi-sub, down to the seabed.

The semi-sub motion is represented by a vessel, named *Semisub*. The semi-sub shape could be defined by importing a .x, .obj or panel mesh file, or by adding shapes to the vessel, but in this case, it is represented by a wireframe. The main semi-sub shape (red part) has been specified on the *drawing* page of the *vessel type* data form (*8 column semisub*). The drill tower (green part) has been specified on the *drawing* page of the *vessel* data form for the *Semisub*.

This allows a general representation of the vessel to be stored with the vessel type (main shape) and then customised individually on the vessel page each time it is used (drill tower). It also allows the vessel and vessel type parts to be different colours. For an explanation of how the solid shape is filled in, see the example A05 Steel catenary riser systems or the Modelling, data and results | Vessels | Vessel types | Shaded drawing page of the OrcaFlex help.

The moonpool edges are modelled as dummy lines *MP FWD*, *MP PORT*, *MP AFT* and *MP STBD* attached to the platform. You can see them in the current view as yellow lines around the moonpool edge. The dummy lines are there so that clearance information can be obtained between the riser and moonpool. The dummy lines need only have one segment, with both ends connected to the *Semisub* vessel. Their behaviour does not require any stiffness or other information, and they have negligible properties.

Clearance results are always reported between lines, so there is no need to turn clashing contact on for these lines if all you are interested in is whether they come into contact or not. Clash checking is only required if you want to show how the lines react as a result of contacting one another.

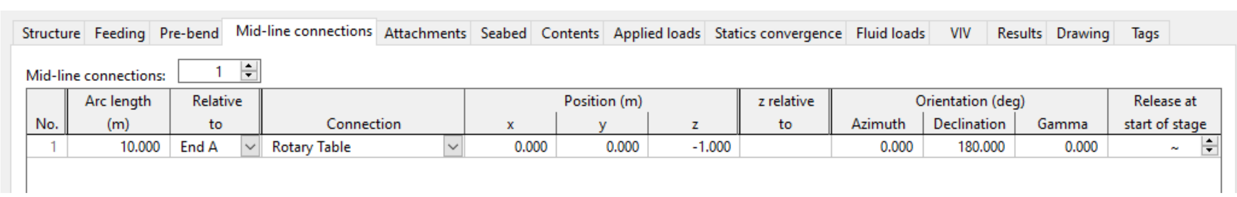
A series of *drawing* type shapes are used to model the deck structures. This means that the shapes have zero stiffness and are there for visualisation only.

At the very top of the screen the bottom of a winch, coloured blue, can be seen. This winch supports the drill string, which is the grey line seen passing through the upper deck before disappearing inside the riser. Open the *Drill string support* winch data form: the winch is set to keep a constant tension during the dynamic simulation by using the *specified tension change* option and setting its value to zero.

The rotary table is modelled using a constraint object. This provides the lateral restraint to the drill string.

Ensure that *view by groups* is selected from the model browser – right-mouse click in the *model browser* to find this option – and then find the object named *Rotary Table* within the *Semisub Group*.

Open the data form for this object and you'll see that the constraint is connected to the semisub and has one free degree of freedom in the local *z* direction. This means that anything connected to the constraint will only be able to move along this axis only i.e. there will be no lateral movement or rotation. In this case, a mid-line connection has been added to the *Drill String* line, and this has been connected to the constraint. The *mid-line connections* page of the *Drill String* line's data form is shown below:


Structure | Feeding | Pre-bend | Mid-line connections | Attachments | Seabed | Contents | Applied loads | Statics convergence | Fluid loads | VIV | Results | Drawing | Tags

Mid-line connections: 1

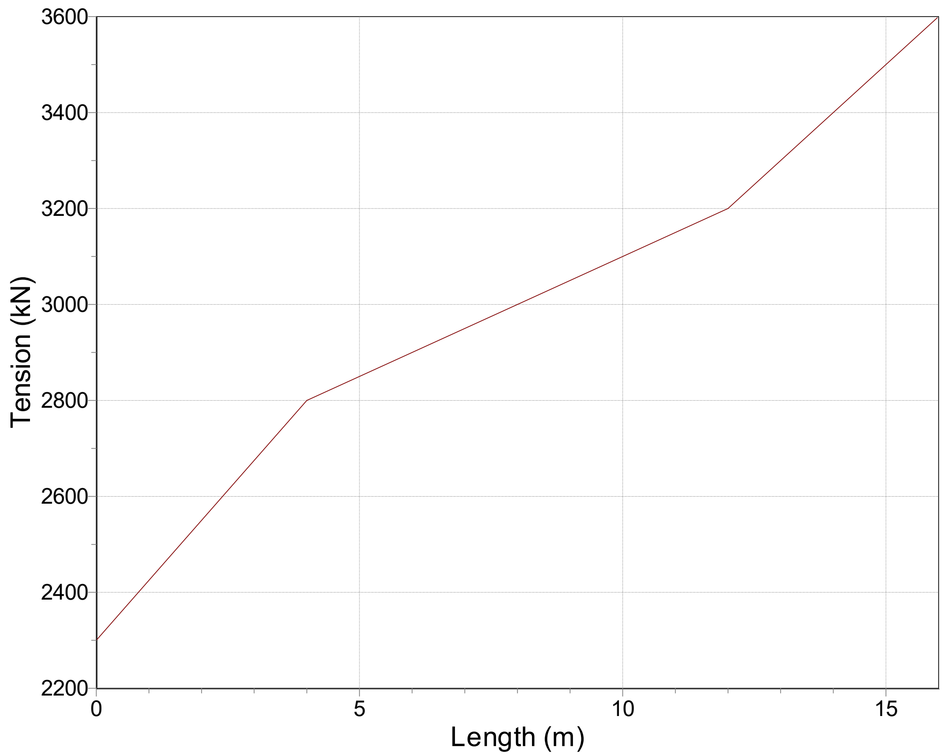
No.	Arc length (m)	Relative to	Connection	Position (m) x	Position (m) y	Position (m) z	z relative to	Orientation (deg) Azimuth	Orientation (deg) Declination	Orientation (deg) Gamma	Release at start of stage
1	10.000	End A	Rotary Table	0.000	0.000	-1.000		0.000	180.000	0.000	~

The riser also needs some lateral restraint, and a second constraint could be used here. However in this instance, it is modelled with a single segment line called *Riser Slip Joint* (coloured pink in the model). We have chosen to use the line method so that we can also include finite connection stiffness between the top of the slip joint and the vessel, which allows the slip joint some freedom to rotate about this point.

The slip joint line has a very low axial stiffness to allow axial motion of the nodes at each end but high bend stiffness to stop lateral motions. The bending stiffness is set similar to that of the riser itself. It could be argued that it needs to be stiffer.

The four tensioners, in the usual cruciform arrangement, are modelled using four *spring/damper* type links. In this case the *stiffness* for each link is non-linear, as shown by the plot below. The characteristics have been set to give a lesser axial stiffness from 4m to 12m link length, a stroke of ±4m. Beyond this range, the stiffness should increase, and we have chosen to double the stiffness.

The link *damping* is linear with velocity, but a non-linear option is also available).



The tensioner ring is modelled using a 6D buoy (visible as a red cube); the tensioner links and the slip joint all connect to it. The buoy has been given negligible properties, as its purpose here is simply to act as a connection point.

The riser (in yellow) and the choke and kill lines (purple) all connect to the tensioner ring as well. The choke and kill lines each have a line contact relationship defined with the riser, which enables the lines to be clamped to each other at specified locations. The first two clamps are visible in the current view, as thin orange rings around the choke and kill lines (open workspace *B01 Drilling riser tensioner detail.wrk* for a closer view).

These three lines extend all the way down to the seabed, where they terminate to the BOP. Open the workspace *B01 Drilling riser bottom views.wrk*. The blue cylindrical object is the BOP. The riser, choke and kill lines are all connected to another 6D buoy (red cube) with negligible properties, called *Flex Joint*. This ensures that the BOP sees appropriate total moments rather than individual ones.

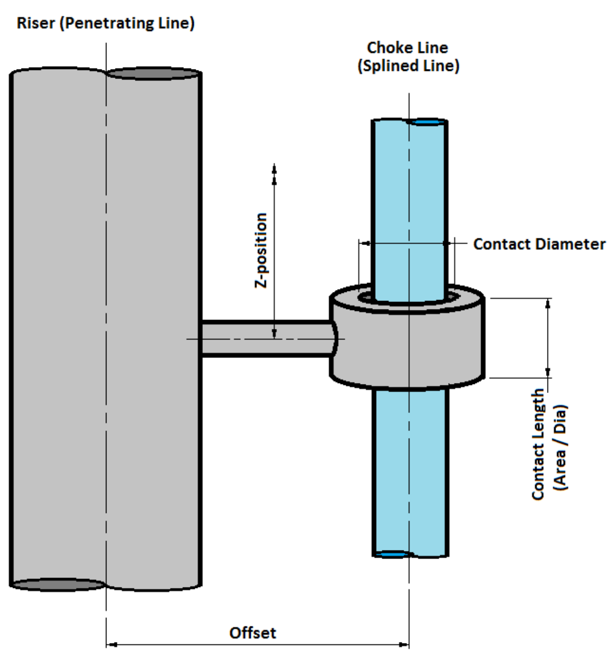
The flex joint itself is modelled by connecting this buoy to a length of line (the short thick red line visible in the top right-hand view) which has infinite connection stiffness at the buoy, but finite (non-zero) connection stiffness at its lower end. Note that this is one method of creating a flex joint, which is appropriate when the joint coincides with a line end. In OrcaFlex you can also create mid-line flex joints using the *flex joint* type of *attachment*: see the help page [Modelling, data and results | Lines | Attachments | Flex joints]() for further details.

In the simulation, the semi-sub's *primary motion* has been set to *prescribed*, making it move with a constant speed in the vessel's x-direction. Run the replay (*Ctrl+R*) and you can see the effect of the flex joint, preventing the moment from being transmitted from the riser to the casing. The casing line extends down through the BOP and into the seabed. Its lower end can be seen in the left-hand model view; it is the lowest point in the model.

The drill string is modelled inside the riser and casing. Click on the *Riser Group* in the model browser and select *Ctrl+H* to hide the contents of this group. The grey drill string is now visible. Ideally the drill string should be modelled as a continuous line, extending from the winch on the semi-sub right down to the drill head. However, in this model, we have split it into two lines (*Drill String* and *Drill String Below BOP*) joined by a further 6D buoy (*Drill String Connection*) visible as a pale blue cube. The reason for this will be explained below.

Finally at the bottom end of the drill string we have added a 3D buoy (*DHA*) visible as a blue dot to add some mass to represent the drill head assembly.

Make the *Riser Group* visible again (*Ctrl+H* in the model browser) and open the *line contact data* form, located towards the top of the model browser. The line contact relationships for the choke and kill lines (as discussed earlier) are defined here, on the *relationships* page. The riser restraint goes around the choke and kill lines, like a collar (see sketch below). The *penetrator locations* page shows where those collars are, and their offset from the riser centreline.



Offset 'Around' Line Contact Relationship

Here we have also defined the relationships for the drill string lines; the upper and lower sections of drill string are located *Inside* the riser and casing respectively. Containment is enabled for these relationships – this means that the inner line is shielded by the outer line, so it doesn't see any environmental loading. The inner line sees fluid loads from the outer line's contents.

The line contact model in OrcaFlex only allows you to have one line inside two other lines if they both have contents that are *free flooding*. In this case, the riser and the casing line contents are both mud (i.e. not free flooding), and this is the reason why the drill string has been split into two sections. Torsion needs to be included for any lines identified as the *splined line* in a line contact relationship, and for both lines if the relationship type is *around*.

Contact stiffnesses for the line contact relationships have been set so that they are high enough to restrain correctly, but not so high that they cause rattle. Note that line *contact* is different to line *clashing*, therefore we do not need to turn on *clash checking* for these lines. For more information about the different contact models in OrcaFlex, please refer to our Modelling Contact Guide, which can be downloaded from the Papers and technical notes page of the Orcina website.

The casing line has a P-y model, which means that there is no normal resistance from the seabed, but there is lateral resistance. Open the *Casing* line data form (in the riser group) to see that the P-y *Model1* is specified at the top of the form. Click on the *P-y models...* button at the bottom of the form to see the input data.

The lower drill string (which is inside the casing) does not have a p-y model, so it would usually see a huge normal reaction force from the seabed, which would push it upwards. In this model however, the drill string is shielded from contact with the seabed by means of the *containment enabled* part of the line contact model. Containment shields the inner line from environmental fluid forces as well as from contact with elastic solids or the seabed.

Results

Open the workspace *B01 Drilling riser top views.wrk* again and look at the motion of the slip joint and tensioners when you replay the animation.

Open the results workspace *B01 Drilling riser tensioner.wrk*. This brings up results graphs showing the tension time histories of the four links and the effective tension in the riser.

Open the results workspace *B01 Drilling riser clearance.wrk*. Look at the *line clearance* range graphs for the riser. The graphs show the overall clearance to each of the dummy lines representing the moonpool edge. These results account for the line *contact diameter*. Minimum clearance is just less than 4 m to the aft edge.