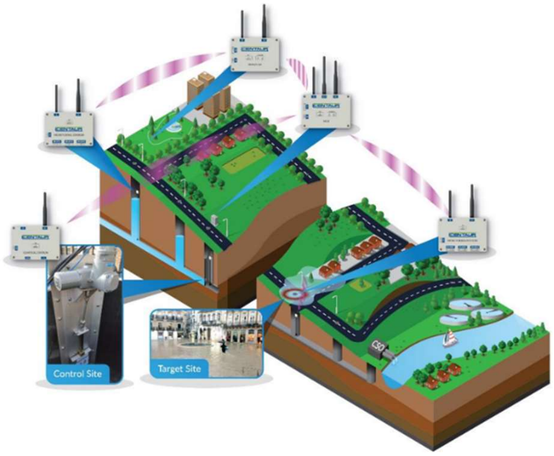
Modelling CENTAUR™ in InfoWorks ICM

With significant investment in overflow performance required to meet current and future environmental targets, as well as business plan objectives, the CENTAUR™ system will play a part in meeting this challenge. Here is how to model the system within industry standard software InfoWorks ICM.

What is CENTAUR™?

CENTAUR™ is an intelligent, autonomous, cost beneficial system installed into existing infrastructure to provide targeted management of CSO spill performance by **optimising existing storage** within sewerage network. The key benefits of the solution are:

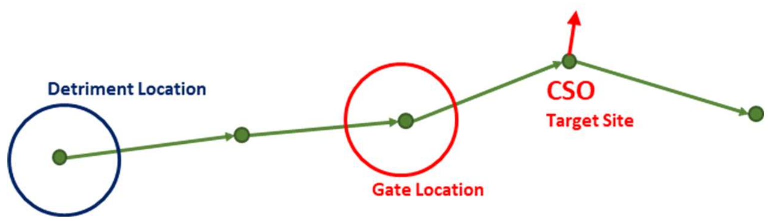


- Improves performance of **existing infrastructure**
- Reduces spill **frequency, duration and volume**
- **Cost Effective** – Significant saving over new storage
- **Fast deployment** (26 weeks from gate decision)
- **Easy maintenance** – known system components
- **Low carbon** intervention – No new concrete
- Part of **adaptive pathway** for catchment management

Our proprietary AI system manages flow control devices using a **SENSE-THINK-ACT** approach to optimise operation at the target overflow, enabling the reduction of spill frequency and duration.

What does a CENTAUR™ system look like?

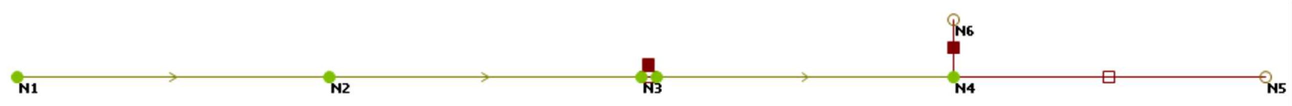
In its simplest instance, the system is a single actuated penstock installed upstream of a target location (in this example instance a CSO). The fuzzy logic AI controlling its operation is driven by level sensors at that target location, immediately upstream of the gate, and, additionally a third 'detriment' site upstream which supports system decision making.



This document provides an overview of modelling a simple single gate installation, considering the target CSO, the gate location and a supplementary upstream detriment location. It will explain how to add the network components, define starting values for the system and set up the CENTAUR™ RTC protocols to replicate system behaviour.

CENTAUR™ in InfoWorks ICM

Fuzzy Logic was added to the Real Time Control (RTC) module in v10.5 of ICM in to allow CENTAUR™ to be accurately represented within hydraulic models, ensuring that system behaviour in the model accurately reflects what would occur in the ground. Initial bugs were resolved in patch 10.5.2, so this is the earliest version of the software which should be used for CENTAUR™ system modelling. This application of CENTAUR™ can also be used within the ICM Live environment, enabling forecasted performance benefits to be replicated as part of building the business case for investment.



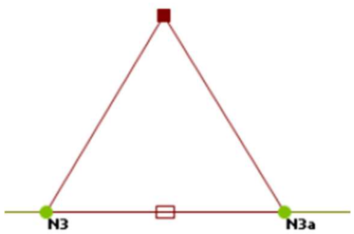
For the purposes of this guide, a simple test network is used where flows are generated at a subcatchment connected to N1, there is a CSO to protect at N4 and a gate is to be installed at N3. Within this demonstration network we will initially link two Level Monitoring Stations (LMS) at the CSO 'Target Site' (LMS1) and at upstream of the gate in the 'Control Manhole' N3 (LMS2).

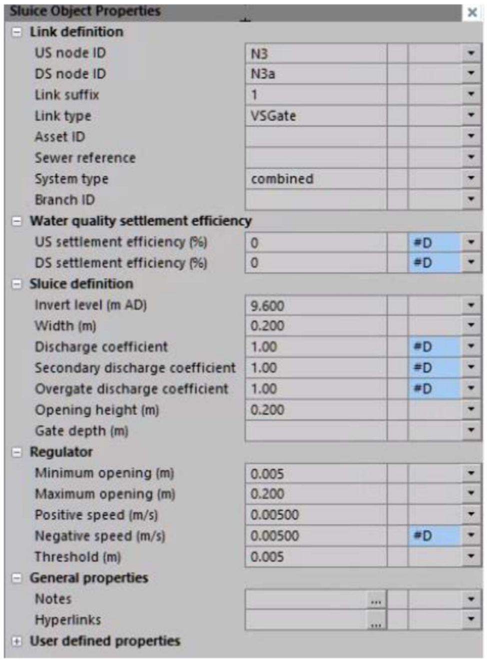
Modelling the CENTAUR™ Network

The CENTAUR™ system requires two control structures to be included within the network:

- **VS Gate** –Representing the actuated penstock (N3.1)
- **Weir** – Representing the overtopping route related to the detriment management level (N3.2)

To add a CENTAUR gate, firstly add a dummy node (node N3a in our example) immediately downstream of the manhole where the gate is to be installed/modelled (N3). Ensure that you do not impact the length of the downstream pipe (now N3a.1) if this is still flagged #D. You will then also need to ensure that the chamber area is split across the two nodes to reflect the storage available upstream of the gate. Between the gate manhole and the dummy manhole, add the Sluice as a VSGate and weir to represent the CENTAUR™ system components.





Sluice Object Properties

Link definition		
US node ID	N3	
DS node ID	N3a	
Link suffix	1	
Link type	VSGate	
Asset ID		
Sewer reference		
System type	combined	
Branch ID		
Water quality settlement efficiency		
US settlement efficiency (%)	0	#D
DS settlement efficiency (%)	0	#D
Sluice definition		
Invert level (m AD)	9.600	
Width (m)	0.200	
Discharge coefficient	1.00	#D
Secondary discharge coefficient	1.00	#D
Overgate discharge coefficient	1.00	#D
Opening height (m)	0.200	
Gate depth (m)		
Regulator		
Minimum opening (m)	0.005	
Maximum opening (m)	0.200	
Positive speed (m/s)	0.00500	
Negative speed (m/s)	0.00500	#D
Threshold (m)	0.005	
General properties		
Notes	...	
Hyperlinks	...	
User defined properties		

The VS Gate should be set up with the known information for the target location, in terms of invert level and pipe geometry. In this example the upstream invert of the pass forward pipe N3a.1 is the setting for the invert of the gate (9.6mAOD).

The width of the gate is reflective of the pipe geometry (in this example 0.2m) with the maximum opening height and maximum height set equivalent to the size of the gate. In the example the opening is 0.2m x 0.2m.

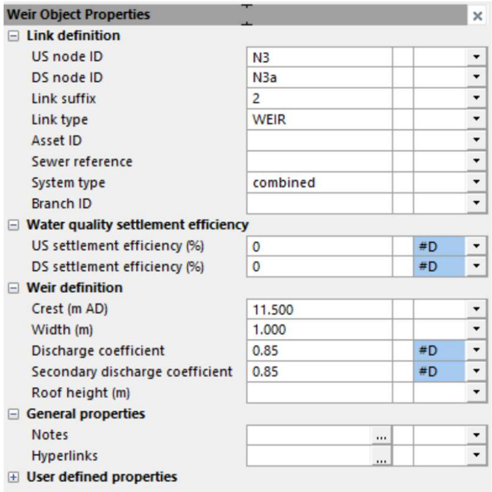
The boundaries which the CENTAUR™ system will act upon are defined within the additional *Regulator* properties where a minimum opening is set (it is recommended that the gate is initially tested without the ability for the system to fully close. The opening/closing speed of the gate is also initially set here, and initially should be set to 0.005m/s. These speeds can be altered at a later date, (although positive/negative should always be the same) as the speed can be defined within the actuator/penstock arrangements which are ultimately installed as part of the CENTAUR™ system. Please liaise with the Cura Terrae team should you wish further clarification on this.

Gate depth should not be populated and the threshold should be set to 0.005m. This is the minimum change in opening which the system will implement.

The weir is set up to protect the upstream network from detriment. The crest level is site specific for the gate location and the upstream network, but as a minimum on set up this should be at least 0.5m below ground level at the gate location.

In reality the chamber needs to house the gate arrangement and the actuator, so the weir level will be influenced by the chamber roof. If the manhole has been surveyed, this detail should be used to support setting the initial gate height.

The width of the weir should be set to the width/diameter of the chamber. If there is confidence in the chamber details, the roof height can also be set. The discharge coefficients should be set in line with client/industry standards based on a weir depth of ~100mm influencing head over the weir.



Weir Object Properties

Link definition		
US node ID	N3	
DS node ID	N3a	
Link suffix	2	
Link type	WEIR	
Asset ID		
Sewer reference		
System type	combined	
Branch ID		
Water quality settlement efficiency		
US settlement efficiency (%)	0	#D
DS settlement efficiency (%)	0	#D
Weir definition		
Crest (m AD)	11.500	
Width (m)	1.000	
Discharge coefficient	0.85	#D
Secondary discharge coefficient	0.85	#D
Roof height (m)		
General properties		
Notes	...	
Hyperlinks	...	
User defined properties		

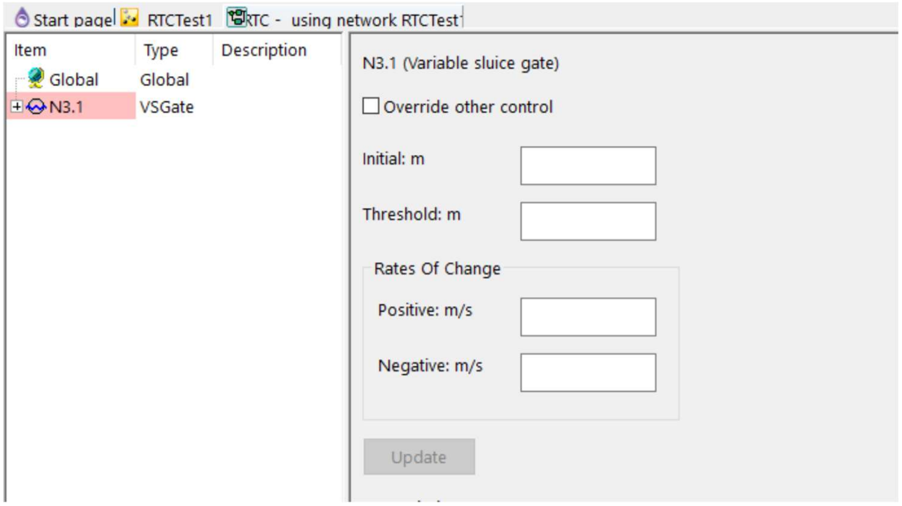
CENTAUR™ Control Set Up

Once the gate and weir are added, the CENTAUR™ control can be set up within the RTC module within InfoWorks ICM.. In order for a CENTAUR gate to be configured the following elements will need to be added:-

- A **Regulator** – The CENTAUR™ VS Gate (VS Gate N3.1)
- A **Range** for the Target Location (LMS1) set a the overflow chamber (Node N4)
- A **Range** for the Control Manhole (LMS2) immediately upstream of the gate (Node N3)
- A **Logic** to define under what conditions CENTAUR™ is active
- A **Controller** with relevant setpoints/parameters
- **Rules** to define the trigger for CENTAUR™ logic to activate

The first step is to open the RTC editor by selecting Grid windows /RTC editor from the Window menu, and adding a regulator, in our example the VS Gate N3.

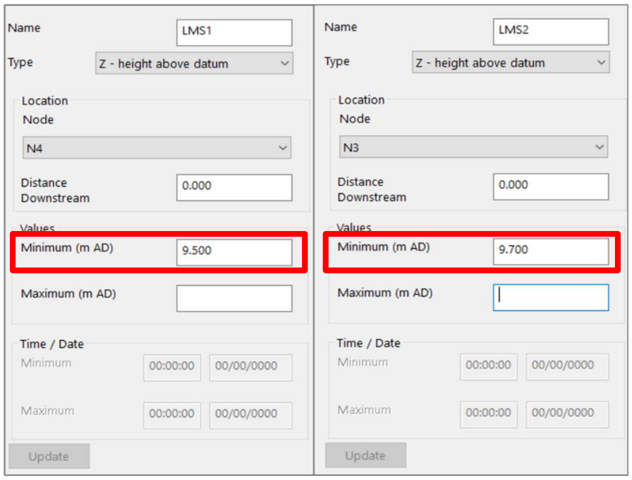
As you have set the settings directly in the gate itself, the options here can be left blank and the 'override other control' box unchecked. All other elements within the CENTUAR™ logic will be added to that regulator.



Setting Ranges

The next step is to add the two ranges for LMS1 and LMS2 relating to the target location and the control manhole respectively. Both ranges are set to type 'Z – Height above datum'. Both then have minimum values in mAOD applied. These minimum values define with the CENTAUR™ logic will become active and start to manage flow through the gate and mobilise storage within the upstream network.

The value at the 'Target Location' LMS1, (the CSO chamber), is usually the primary setting for activating the CENTAUR™ system. This means that the minimum range value applied should be the level at which which CENTAUR first comes into effect. This should be set at an appropriate value below the crest level of the overflow to ensure the system is active in sufficient time to influence performance. This value will be entirely site specific.



Note - The gate will usually be open and only start controlling flow once these certain trigger thresholds are breached for the monitoring locations.

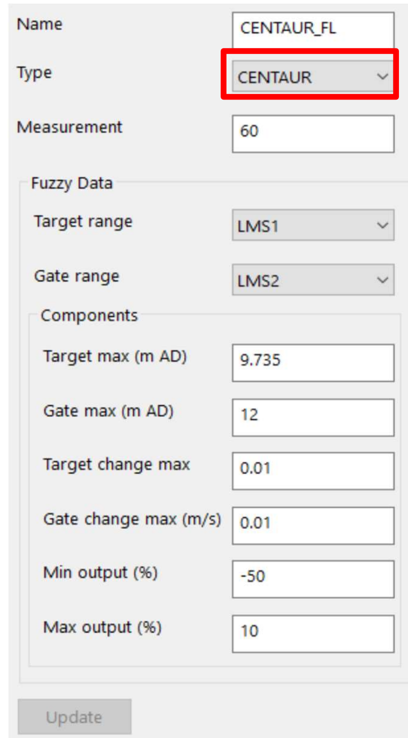
The value at LMS2, just upstream of the gate, is set above the peak dry weather flow depth to prevent control under dry weather conditions (unless this is the desired outcome). Again, this will be site specific in terms of the actual value and should be looked at in conjunction with the values at LMS1 to determine the action of the system and network detriment objectives.

Logic

The logic is used to define that when CENTAUR™ becomes active, based on the minimum values in the LMS1 and LMS2 range variables. This logic is set up as an **OR** basis, i.e. whichever of LMS1 or LMS2 minimum values is satisfied first. In the example this is named **CENACTIVE**.

Controller

The controller is the device to control the regulator (VS Gate) in order to achieve the defined set point. The critical aspect here is the **Type CENTAUR**. This will enact the logic developed in the system to replicate the behaviour of the onsite system.



Named CENTAUR_FL in our example, the Fuzzy Data Target Range is set to the Target Overflow manhole (LMS1) and the Gate range to the Control Manhole (LMS2). The target max is set to the overflow crest level.

The 'Measurement' (interval) is measured in seconds and is representative of the control interval on the gate. It should be a multiple of the simulation timestep. This measurement interval should not usually be less than 60 seconds, which is the default value.

The values for 'Target max' and 'Gate max' are again site specific, but are defining key levels within the process.

- Target Max – This is the level that CENTAUR™ is protecting and in this instance is the crest level at the overflow.
- Gate Max – This is the maximum level that the system is looking to achieve behind the gate. There is then the mechanical protection of the weir overtop within the system.

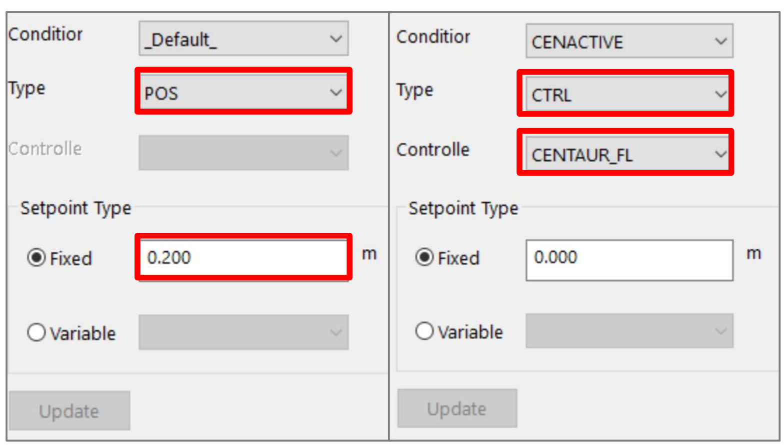
Target change max and gate change max are scaling parameters for the rate of change in water level, they should usually be left at the default values of 0.01 m/s.

Min output and Max Output are scaling parameters for the change in gate position on each control cycle. **The default values of Min output = -50 and Max output = 10 should always be used with Controller Type CENTAUR™.** These are fundamentally speed parameters effectively relating to slow open, quick close.

Rules

There are two rules which need to be added to define CENTAUR™ operation:

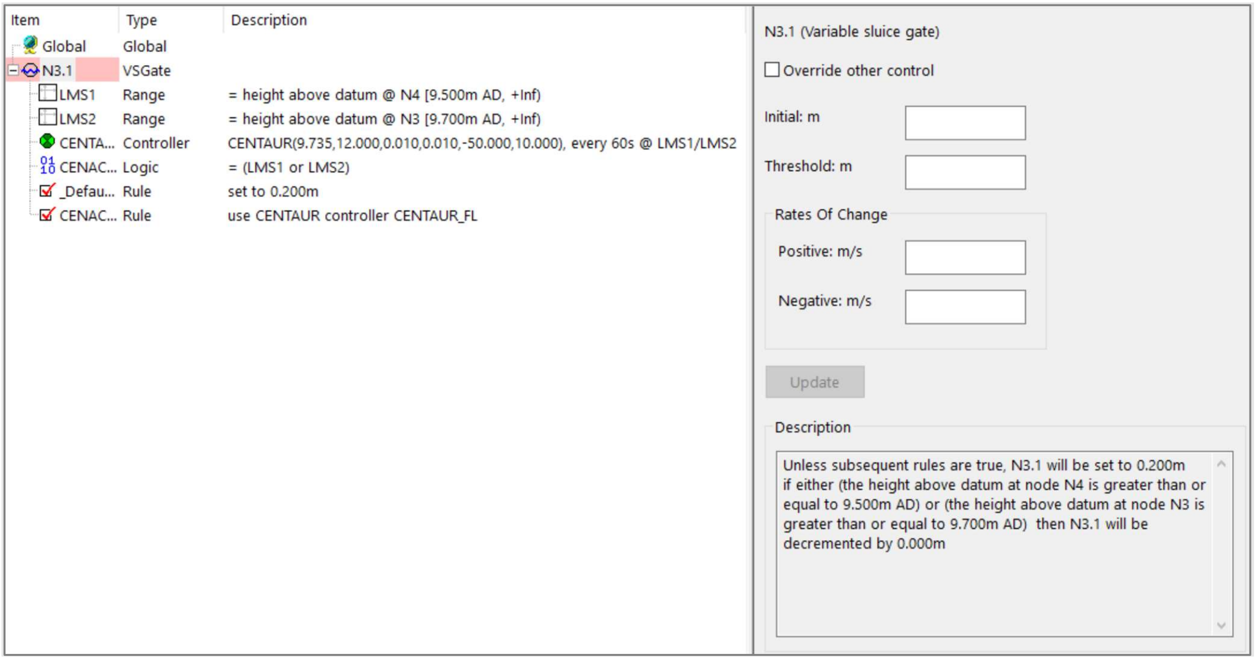
- **_Default_** - This sets when the CENTAUR™ system is not active and the gate is fully open. This is set to Type POS (a fixed setpoint)at the fully open position of the gate (0.2m in our example network)
- **CENACTIVE** -The second rule is Type CTRL (Control) and uses the CENTAUR™ controller set up earlier. The value in the Setpoint Type box is not used, so leave this as 0 m.



These are the final elements that need to be added to the regulator within the RTC editor to make the CENTAUR™ system operational within the model. All elements can then be altered and customised to achieve the desired performance at the target overflow.

Completed CENTAUR™ RTC

Below you can see the completed CENTAUR™RTC system acting on the VS Gate at N3.1.



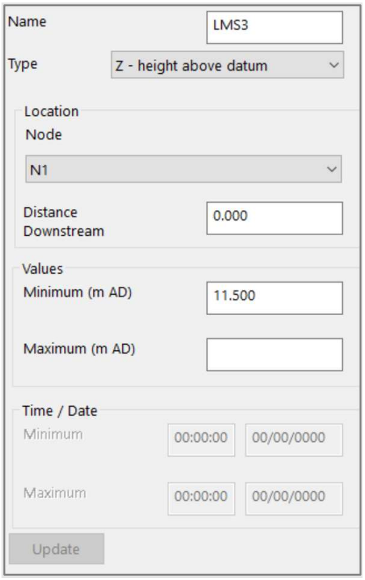
With the gate added to the network, the long section of our dummy network displays the control structures that have been added and when a simulation has been run with runoff contribution within the network triggering activation of the CENTAUR™ system, the behaviour of the gate is clearly visible, mobilising the storage in the upstream network and controlling flow through the target overflow

Adding additional Control – LMS3 as the Detriment Location

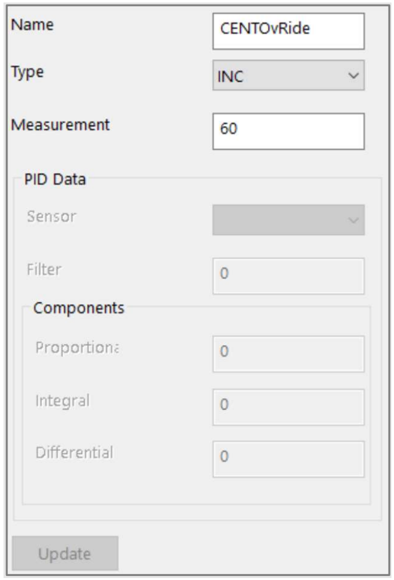
In its standard operation, CENTAUR™ assumes the weir associated with the gate controls the maximum water level at all upstream points. However there are instances where there are additional upstream overflows or low spots where no detriment is desired within the operation of the CENTAUR™ system. This can be achieved within the network by connecting an additional depth sensor to the network, and within ICM it is achieved by adding additional RTC elements to support an additional control location called the detriment location (LMS3). In our model example this location is at node M1.

In our example we can assume a critical level is being approached if node N1 reaches 11.5 m. An additional **Range** is therefore added, termed LMS3 of type Z – height above datum , setting a minimum water level at N1 of 11.5 m. An additional controller can then be added (CENTOvRide), which will override CENTAUR™. This is an incremental controller (INC) which should usually operate on the same time frequency as the CENTAUR™ controller. Finally the override rule is added, in this case, it opens the gate by 0.02 m for each period where the LMS3 range is true.

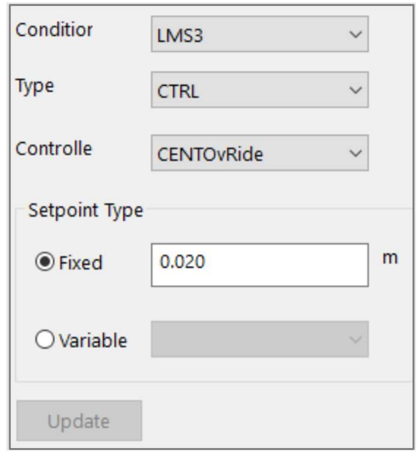
CENTAUR®



Range

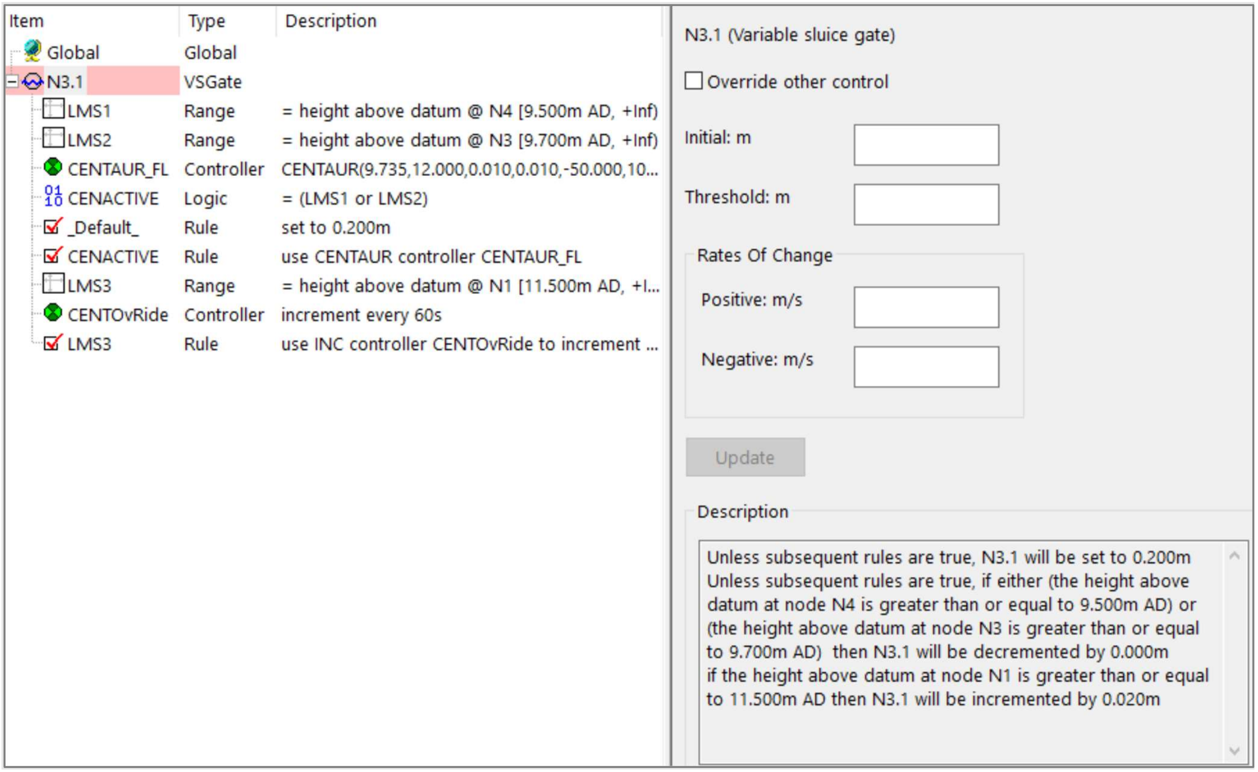


Controller



Rule

Together these three elements generate the additional element of the CENTAUR™ system to open the gate when thresholds at the detriment location are reached. The full RTC can now be seen below.



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