The drainage area plugin comes with two modules. The first module is called 'Surface penalty' and is used to identify features and setbacks on the grounds surface where development of SAGD surface facilities is not permitted. The second module is called 'SAGD drainage area optimization'. This module optimizes the locations of the drainage areas and surface pads subject to the user-inputted constraints and parameters. The surface created by the first module is a required input for the second module.

Surface Penalty

The user interface for the 'Surface penalty' module is shown in Figure 1. The 'Surface penalty' module can either create a new surface or it can edit an existing surface. This surface has elevation equal zero where surface development is not permitted and elevation greater than zero where surface development is permitted. If a new surface is created, the user must specify the name of the surface and the min, max, and inc for X and Y. If an existing surface is edited, the user must identify the surface to be edited.

The 'Surface penalty' module can use any combination of polylines, wells, and points to set the surface elevation to zero within the exclusion zones. For each object a radius is specified. Any location on the surface that falls within this distance of the object will be set to have elevation equal zero. This is illustrated for a 100m setback from river polylines in Figure 2. The areas surrounded in the magenta lines fall within 100m of the rivers (blue) and are therefore off-limits for surface development.

For polylines (typically used to represent rivers, lakes, roads, railways, pipelines, etc.) there is an option to 'Fill if closed'. If this option is selected, any surface location that falls within a closed polyline will be set to have elevation equal zero. An example is a polyline that represents the boundary of a lake. Selecting this option sets the surface elevations inside the lake boundary equal to zero.

When using the 'Edit existing' option, the module can be run iteratively without loss of the previous runs. Consider a scenario where the user has run the module for polylines representing roads and has flagged all locations within 200m as off-limits for surface development. The user now wishes to flag all locations within 100m of rivers as off-limits for surface development. With 'Edit existing' selected and the correct surface identified, the user can choose the polylines representing rivers and set the radius to 100m. When the module is run, the locations within 100m of rivers will be set to have elevation equal zero. The locations previously set to have elevation equal zero within 200m of roads will still have elevation equal zero. Now locations both within 100m of rivers and 200m of roads will have elevation equal zero therefore designating them as off-limits for surface development.

SAGD Drainage Area Optimization

The user interface for the drainage area optimization plugin is shown in Figure 3. The optimization is based on a number of surfaces. The required surfaces are a reservoir base, a reservoir gross thickness, and the previously discussed surface penalty surface. The optional surfaces are net thickness, porosity, oil saturation, recovery factor, and topography. When the porosity, oil saturation, and recovery factor surfaces are not used a global value must be specified. Another optional input is a bounding polygon. When this is used the drainage area and surface pad polygons must fall within the bounding polygon. There are many additional parameters in the tabs below. The parameters for each tab are discussed below.

Drainage Areas

The drainage areas tab is where the parameters relating to the size and features of the drainage areas are specified and is shown in Figure 3. The drainage area length relates to the dimension of the drainage area along the side parallel to the wells. In Figure 4 this is the distance from the heel to the toe. The drainage area width is the dimension of the drainage area perpendicular to the wells. The well spacing is the distance between adjacent wells. The target well length is the desired length of the horizontal wells. The user can specified some allowable variation from this length. The allowable change is specified as a percentage. The well length can change up to this fraction without any penalty. The minimum and maximum well length specify the limits on well length. A cost can be associated with these length of wells specified in units of thousands of barrels. This penalty function is illustrated in Figure 5 for a target well length of 1000m, allowable change of 10%, minimum well length of 750m, and maximum well length of 1250m. For well lengths between 900m and 1100m there is no penalty as these are within the allowable 10% range. For well lengths less than 900m the cost increases linearly up to 200,000 barrels for a well that is 750m long. For well lengths greater than 1100m the cost increases linearly up to 200,000 barrels for a well that is 1250m long. The penalty will be extrapolated for well lengths less than the minimum/greater than the maximum unless the 'Drop wells if below min/above max' option is selected. Selecting this option does not allow any wells with length less than the minimum or greater than the maximum.

To understand the minimum fraction effective parameter, the meaning of *ineffective* is given. A well is *ineffective* where it is below the base of the reservoir as illustrated in Figure 6. A well is effective where it is above the base of the reservoir. A well with an effective fraction less than the specified fraction is dropped.

The steam-oil interface angle is illustrated in Figure 7. It is the angle, θ, measured from horizontal to the interface between the steam and unproduced bitumen. The drainage radius is the horizontal distance that bitumen can flow to reach the producer well. The steam chamber roughness penalty relates to the variability in the thickness of the reservoir. Increasing this penalty will penalize a reservoir with variable thickness. This penalty has little effect on a reservoir with non-variable thickness. The target number of slots is the desired number of slots or well pairs to have in the drainage area. The optimization tries to achieve the desired number but is allowed to vary between the minimum and maximum number of slots.

Surface Pads

This tab specifies the size of the surface pad and location of the surface pad relative to the location of the drainage area. It is shown in Figure 8. The size of the surface pads is based on the number of slots or well pairs in each drainage area. The length of the surface pad is the dimension parallel to the wells while the width is the dimensions perpendicular. The length and width are specified for the minimum number of slots then the additional length/width are specified for additional slots. The location of the surface pad relative to the drainage area is specified by a target distance with an allowable range (min, max) as well as a lateral and rotational allowance.

Thief Zones

The thief zones tab allows the user to specify surfaces representing various aspects of the thief zone as well as parameters related to the thief zone. It is shown in Figure 9. There are five types of thief zone: bottom water, bottom lean, top water, top gas, and top lean. For the bottom water and bottom lean, the top and net thickness of each can be specified. For the top water, top gas, and top lean the bottom and net thickness of each can be specified. For the net thicknesses a discount factor must be specified.

Well Trajectory Optimization

Optimizing the well trajectory is optional and only done if the checkbox on this tab is checked (Figure 10). If well trajectory optimization is performed a number of parameters are required. The optimization is only performed on the portion of the well that is within the drainage area; it does not apply to the build-up portion of the well.

Maximum slope is specified in degrees. No portion of the well can be at an angle steeper than this. Maximum vertical offset relates to the vertical offset between the heel and hoe of the well. Injector height above producer is self-explanatory. Max height of producer above adjacent injector is illustrated in Figure 11. This is to prevent steam bypass from an injector to a neighboring producer. The minimum and maximum producer offsets above bottom water are self-explanatory as are the minimum and maximum bottom water thickness parameters. Only wells with effective fraction greater than the effective well length fraction for reporting are reported.

Drainage Area Optimization

The drainage area optimization requires a random number seed as random numbers are generated as part of the optimization (Figure 12). The number of initial iterations is the number of starting points to consider. For DA locking the user can choose to lock the best from the best pattern or to lock the best so far. They can also choose to lock after the maximum number of iterations or to lock on improvement. The max patterns to explore per iteration is the maximum number of patterns to try for each starting point. The importance of aerial conformance dials in how critical aerial conformance is ranging from 0 where it isn't used to 1 where it is the objective. The number of initial iterations and max patters to explore per iteration have the greatest control on run-time. Reduce these to run faster, increase to get better results.

Preferred Orientation

On the preferred orientation tab (Figure 13) the user chooses whether to use a preferred orientation surface and how strictly to follow the preferred orientation if it is used. The elevation of the preferred orientation surface must correspond to the preferred direction in degrees. Higher strictness makes the optimized result more closely follow the preferred orientation.

Costs

The costs tab stipulates supply and fixed costs. Supply cost is in barrels per barrel of bitumen. The fixed cost per DA and cost per well pair are specified in units of thousands of barrels of bitumen.

Reservoir Thickness

On the reservoir thickness tab a minimum thickness for recovery can be specified. This threshold can be applied to the gross or net thickness (if net thickness surface used). The user can choose to treat individual cells with thickness less than the minimum thickness as ineffective or the fraction of cells less than the thickness can be used.

Drilling

If a topography surface is used, drilling parameters can be specified on the drilling tab. The drilling parameters include limits on the spud angle, limits on the target build-rate, maximum dog-leg severity (degrees per 30m), minimum vertical to kick-off point, and number of build sections.

DA Locking

There may be already developed drainage areas around which additional drainage areas must be optimized. These drainage areas are considered locked and must be identified as such on the DA locking tab. The user simply selects which DA's are locked from the available polylines.

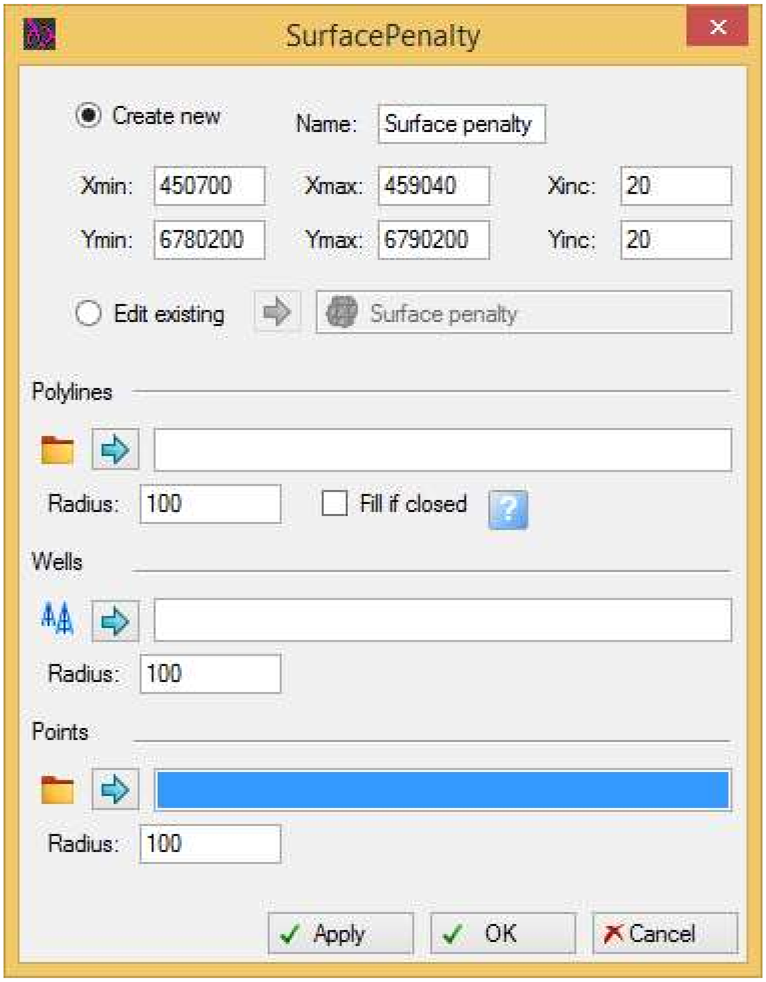

Figure 1: User interface for the 'Surface penalty' module.

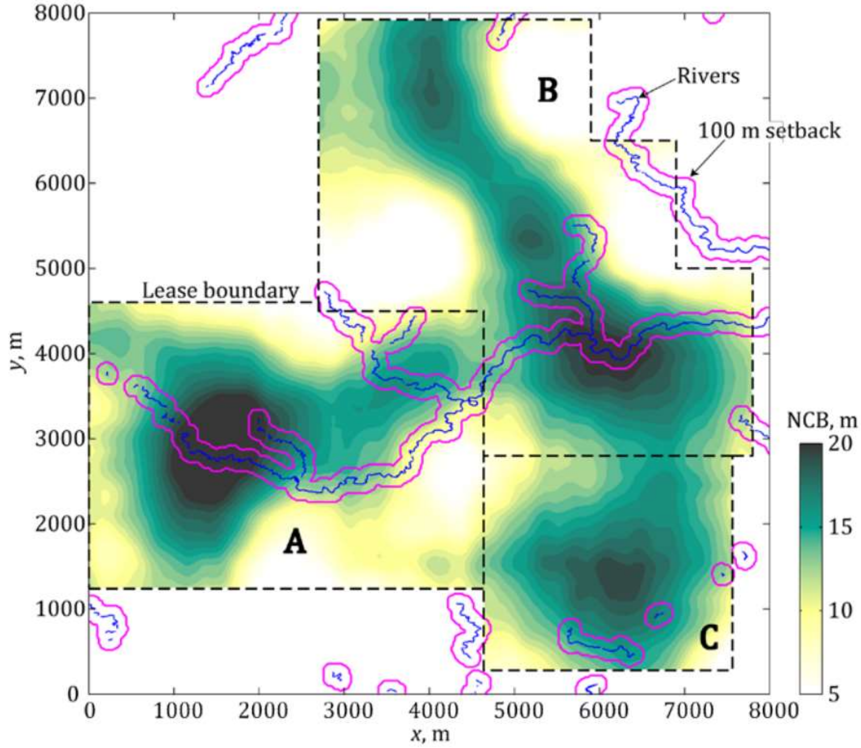

Figure 2: Illustration of 100m setback from rivers.

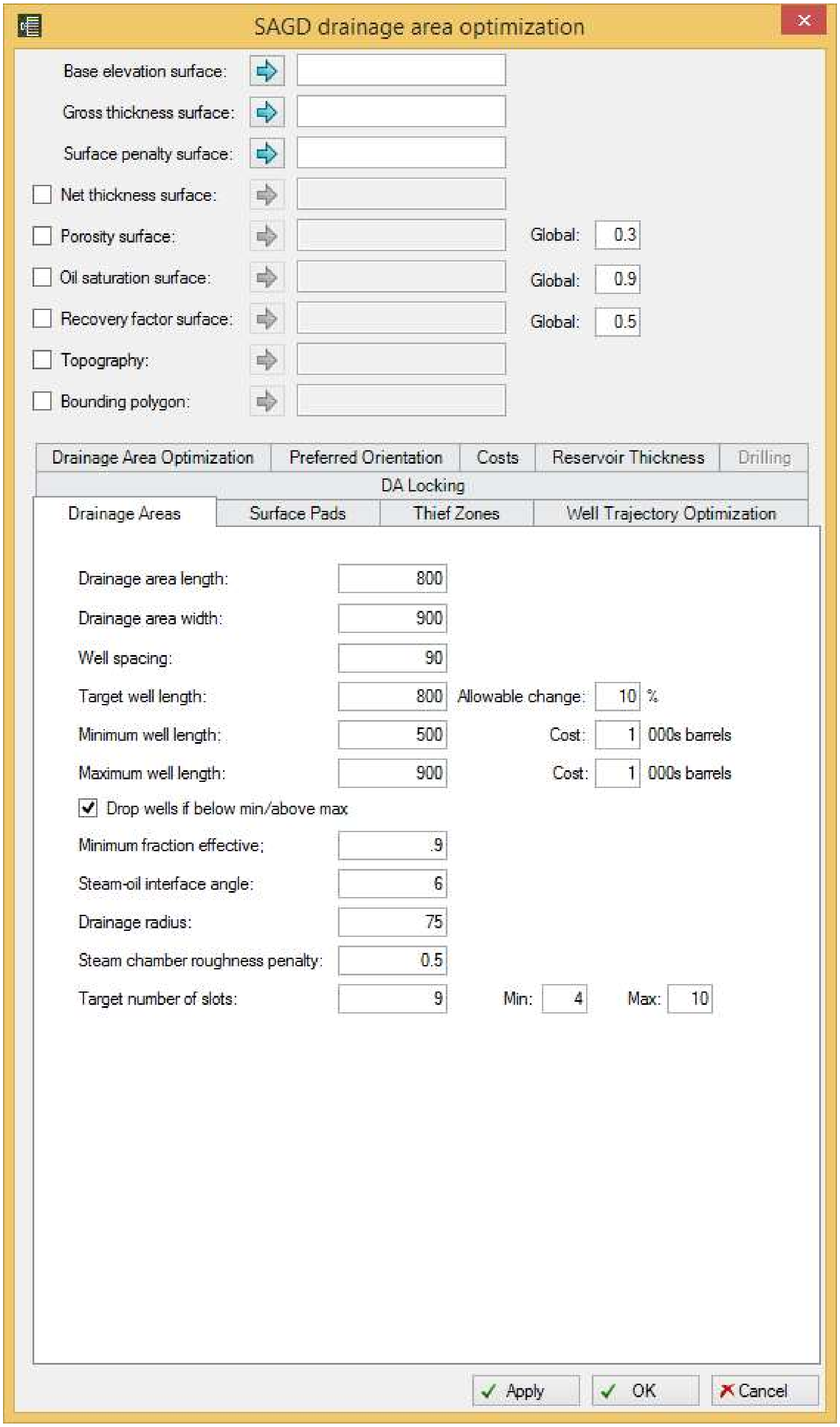

Figure 3: User interface for the SAGD drainage area optimization module.

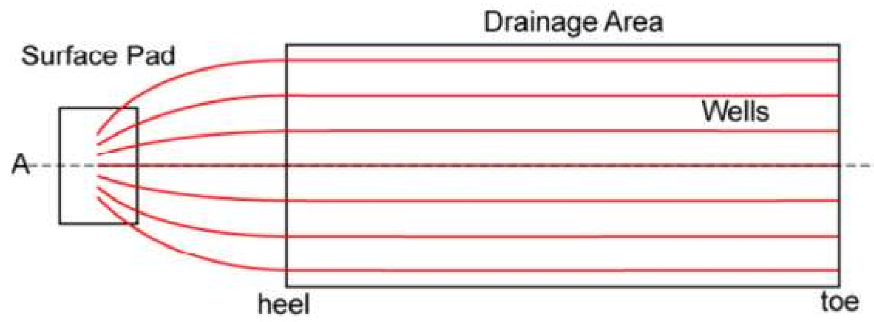

Figure 4: Illustration of a typical drainage area and surface pad layout.

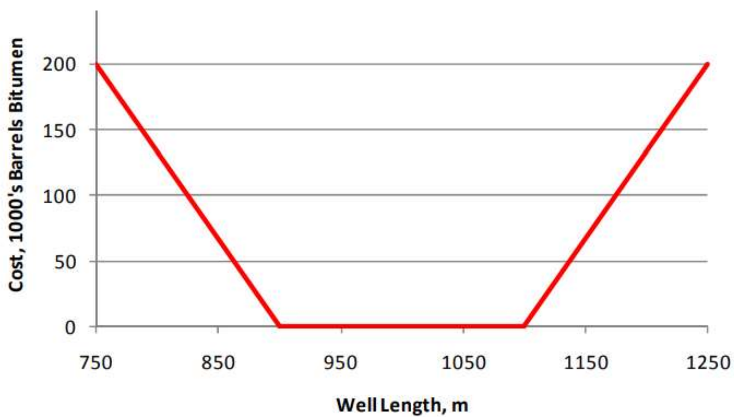

Figure 5: Illustration of the cost function for well lengths other than those specified.

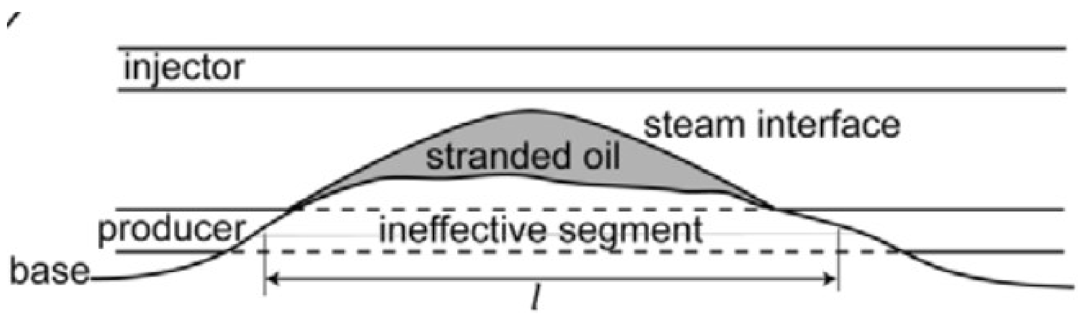

Figure 6: Illustration of ineffective segment of producer well.

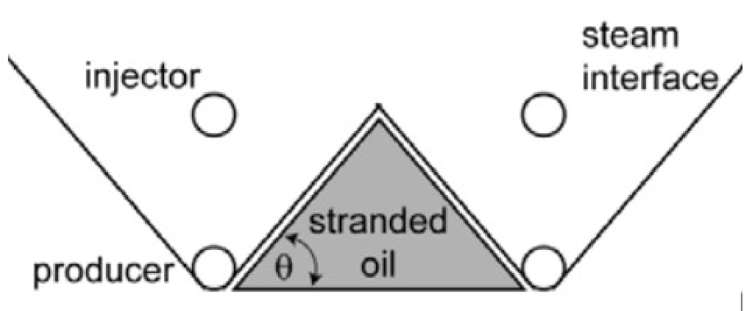

Figure 7: Illustration of steam-oil interface angle.

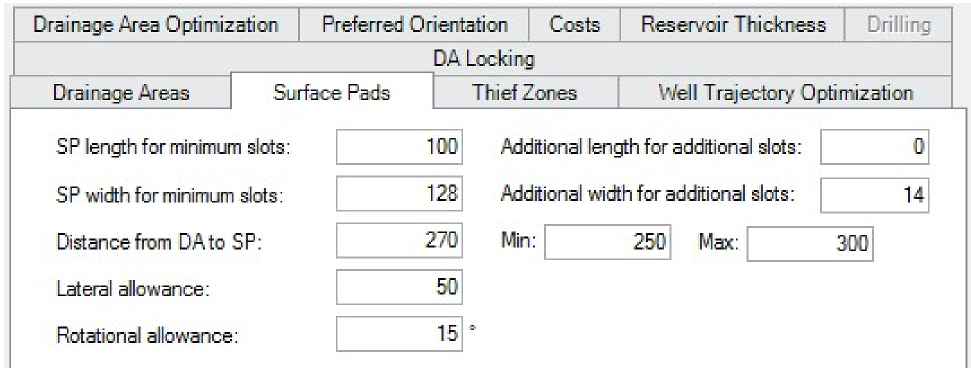

Figure 8: Surface pads tab in the drainage area optimization user interface.

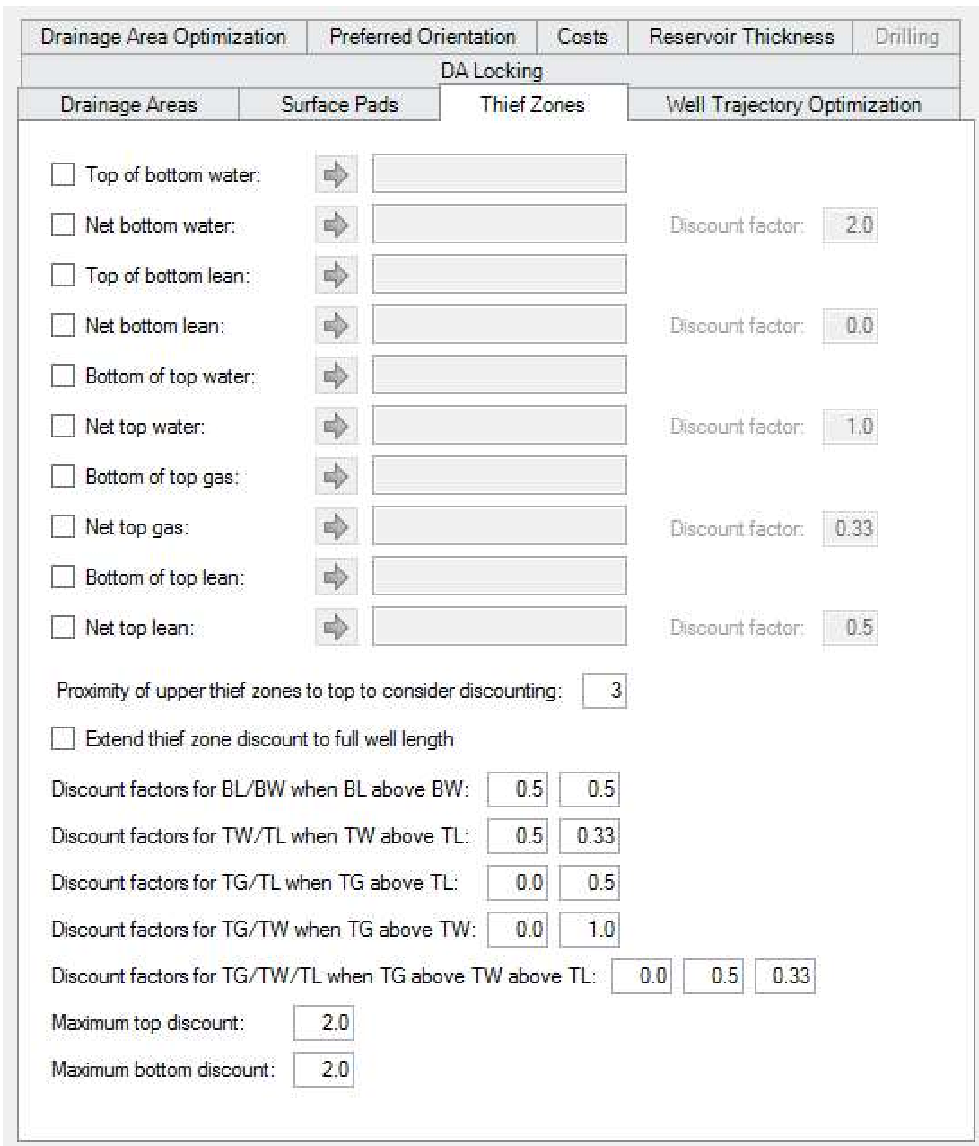

Figure 9: Thief zones tab in the drainage area optimization user interface.

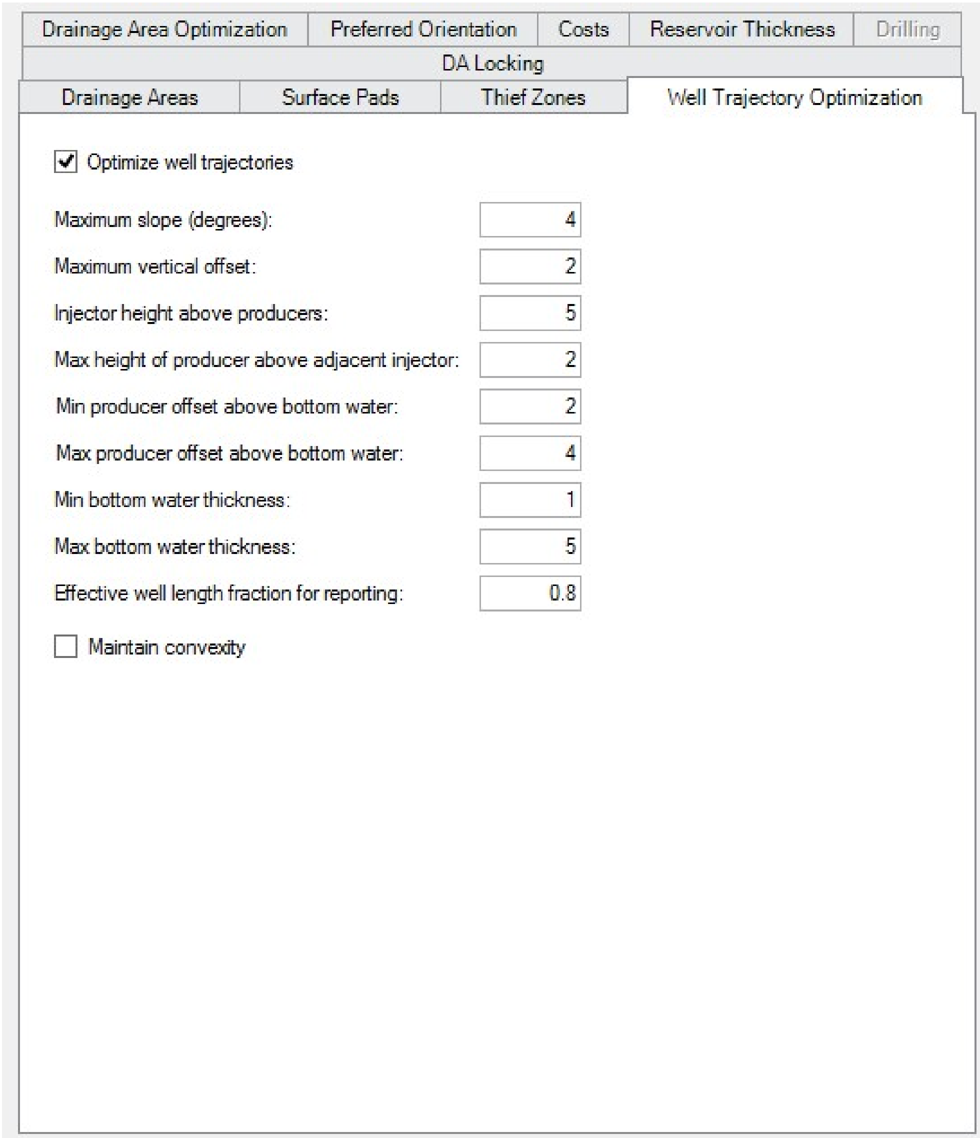

Figure 10: Well trajectory optimization tab in the drainage area optimization user interface.

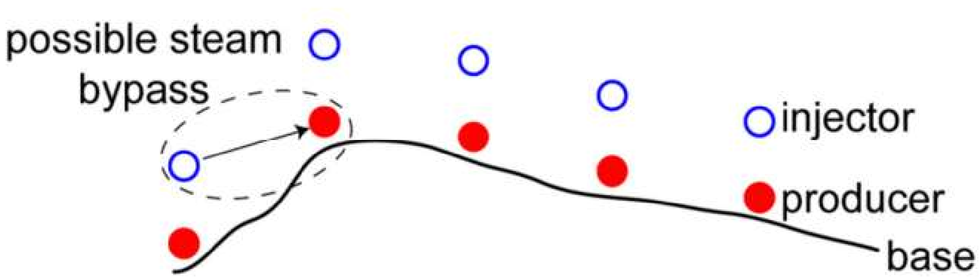

Figure 11: Illustration of vertical offset of producer above adjacent injector.

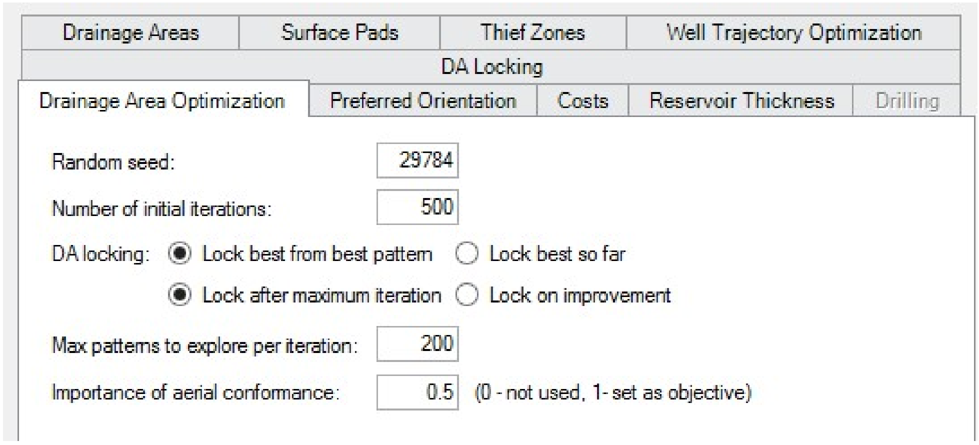

Figure 12: Drainage area optimization tab in the drainage area optimization user interface.

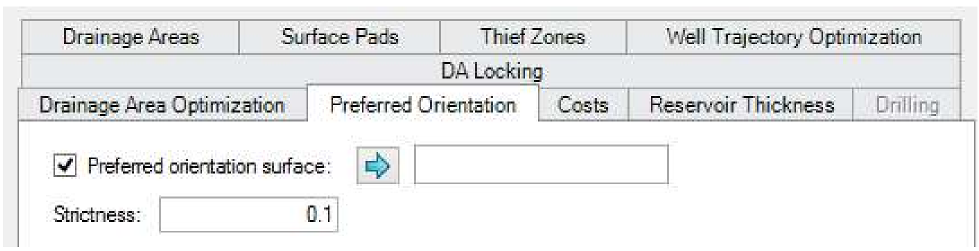

Figure 13: Preferred orientation tab in the drainage area optimization user interface.