Delineation of watersheds in the Kulbäcksliden area.

Notes by Anneli Ågren 2021-11-24 who calculated these layers together with Koffi Dodji Noumonvi.

Watersheds were delineated by the following steps:

DEMs and Flow accumulation: For delineating watersheds, higher resolution DEM's is not always better. We model water flow based on the surface topography, but in mires the water movements don't always follow the topography. For ex, in high resolution DEMs the hummocks and hollows might act as "dams" and route the water in the wrong direction in the model, while the water actually drains perpendicular to these features and underneath the surface of the mire. So in order to "fix" these problems it can be better to aggregate the DEMs to a larger scale which smooths out this micro-topography. The trick is to not aggregate to too large pixels or work in too high resolution. The "optimum level" depend on the landscape type and is found by trial-and error and expert judgment (20 years' experience of hydrological GIS modeling and knowledge on the Swedish boreal landscape). Therefore we choose to not use the 0.5 M DEM available but instead the 2 m national Swedish DEM and also one DEM aggregated to 6 m resolution. Secondly the pre-processing step of the flow accumulation calculations is key. Here we used the Breach function in White Box Tools 2.0 to pre-process the DEM, which is superior to the more commonly used Fill function in ArcGIS Pro (Lidberg et al., 2017). There are many algorithms for modelling flow accumulation, but for delineating watershed we want to use a non-dispersive method, so flow accumulations were calculated using D8.

Weirs: A lot of effort was put into getting the accurate positioning of the weirs (see example from e-mail discussion below). To get the best placement of the outlet points we field-verified the positions using a combination of high accuracy GPS but also using a tablet (with GPS) in the field with a 0.5 m resolution DEM and a 6.5 cm resolution aerial photo as a reference to manually make sure that the positions of the weirs were accurate. For delineating watersheds the outlet pour points are usually snapped automatically to the highest flow accumulation. However, to have more control and not lose the high accuracy of the positioning, we instead edited to points manually to align with cells with high flow accumulation in the DEM's. Due to the good positioning from the start, points were only moved a maximum of 2 m to "manually snap to flow accumulation raster". The edited point's locations were saved in different shapefiles, each (containing a single point) for each of the catchments, and named after the catchment, as follows:

- Degerö_open_mire_18OutletFlowCompatibleSweref99TM.shp
- Hälsingfors_open_forest_61OutletFlowCompatibleSWEREF99TM.shp
- Hälsingfors_dense_forest_62OutletFlowCompatibleSWEREF99TM.shp
- Hälsingfors_open_mire_63OutletFlowCompatibleSWEREF99TM.shp
- Hålmyran_open_mire_64OutletFlowCompatibleSWEREF99TM.shp
- Stortjärn_open_mire_65OutletFlowCompatibleSWEREF99TM.shp
- Hälsingfors_Theroretical_whole_areaOutletFlowCompatibleSWEREFF99TM.shp

The number in each name is the ID of the site/outlet/weir. Note that one of the names does not have this ID (Hälsingfors_Theroretical_whole_areaOutletFlowCompatibleSWEREFF99TM.shp). This is because it is a theoretical large catchment containing roughly the area of all three Hälsingfors subcatchments (open mire catchment, dense forest catchment, open forest catchment+ a little extra area), there is not an actual weir there but was added if someone wants to display the entire Hälsingfors area on a map sometime.
The attribute table of each outlet shapefile contains the following field:

- Site = the site ID
- North = GPS Y coordinate (SWEREF99 TM coordinate system, EPSG 3006) of the weir in the field, measured with a RTK GPS. The Hälsingfors theoretical large catchment does not have a "North" value, as it is not a material point in the field, and has a value "0" for "North" in the attribute table.
- East = GPS X coordinate (SWEREF99 TM coordinate system, EPSG 3006) of the weir in the field, measured with a RTK GPS. The Hälsingfors theoretical large catchment does not an

"East" value, as it is not a material point in the field, and has a value "0" for "East" in the attribute table.
- Elevation = the elevation above sea level of the weir in the field, measured with a RTK GPS. The Hälsingfors theoretical large catchment does not an "Elevation" value, as it is not a material point in the field, and has a value "0" for "Elevation" in the attribute table.
- Details = the long name for each catchment
- POINT_X = the computed X coordinate (SWEREF99 TM coordinate system, EPSG 3006) of the point, i.e. the flow compatible point being described in this section.
- POINT_Y = the computed Y coordinate (SWEREF99 TM coordinate system, EPSG 3006) of the point, i.e. the flow compatible point being described in this section.

The following table summarizes the attributes of all the previous outlets. Note that the "Catchment area (ha)" column is not part of the outlets attribute table, but is representing the catchment area calculated from the watersheds mentioned later. These areas can be found in the attribute table of the watershed shapefiles, under the column name "Shape_Area". They have been gathered in the same outlets table in this description document for convenience.

Table: Outlets attributes, and catchment area

Site	North	East	Elevation	Details	POINT_X (m)	POINT_Y (m)	Catchment area (ha)
18	7125894.565	720584.499	262.002	Degero	720584.025	7125906.187	272.93
61	7121929.972	721223.135	286.098	Halsingfors open forest	721223.135	7121929.972	11.88
62	7121892.99	721107.458	287.561	Halsingfors dense forest	721106.708	7121890.938	13.66
63	7122318.711	721118.113	289.246	Halsingfors open mire	721117.897	7122314.771	64.83
64	7123109.814	722094.648	282.477	Halmyran	722094.648	7123109.814	33.11
65	7124609.905	722022.177	266.848	Stortjarn	722021.918	7124607.897	29.64
Halsingfors_large	-	-	-	Halsingfors including all 3 sites	721109.930	7121873.295	106.92

Watershed delineation: First, two different watershed delineations were calculated for each catchment (by Anneli Ågren, using the method above based on 2 m and 6 m resolution DEM). In most places the delineation suggested the same border with either DEM resolutions, but in some locations different methods gave fairly different results. In these places we had a group discussion with some key persons working in the Kulbäckslidens area (Mats Nilsson, Matthias Peichl, Koffi Dodji Noumonvi, Joshua Ratcliffe) to discuss what we believe is the truth based on expert knowledge from the field, DEMs of different resolutions, including the hillshade of the 0.5 m DEM and high resolution aerial photos (6.5 cm resolution). We also compared with previous delineations in ArcGIS using Fill as preprocessing step. The border between Degerö and Stortjärn as well as Hålmyran and Hälsingfors was manually edited by Koffi based on our best estimate of the watershed boundaries from the different sources into one "optimal" watershed delineation for each site. These are now the official watershed boundaries for the Kulbäcksliden area and are named:

- Degerö_open_mire_18CatchmentSweref99TM.shp
- Hälsingfors_open_forest_61CatchmentSWEREF99TM.shp
- Hälsingfors_dense_forest_62CatchmentSWEREF99TM.shp
- Hälsingfors_open_mire_63CatchmentSWEREF99TM.shp
- Hålmyran_open_mire_64CatchmentSWEREF99TM.shp
- Stortjärn_open_mire_65CatchmentSWEREF99TM.shp
- Hälsingfors_Theroretical_whole_areaCatchmentSWEREFF99TM.shp

Here are two maps, showing the location of all the different catchments and their outlets. The two maps are similar with the only difference of the DEM (2 m resolution) or orthophoto (6.5 cm resolution) as basemap.

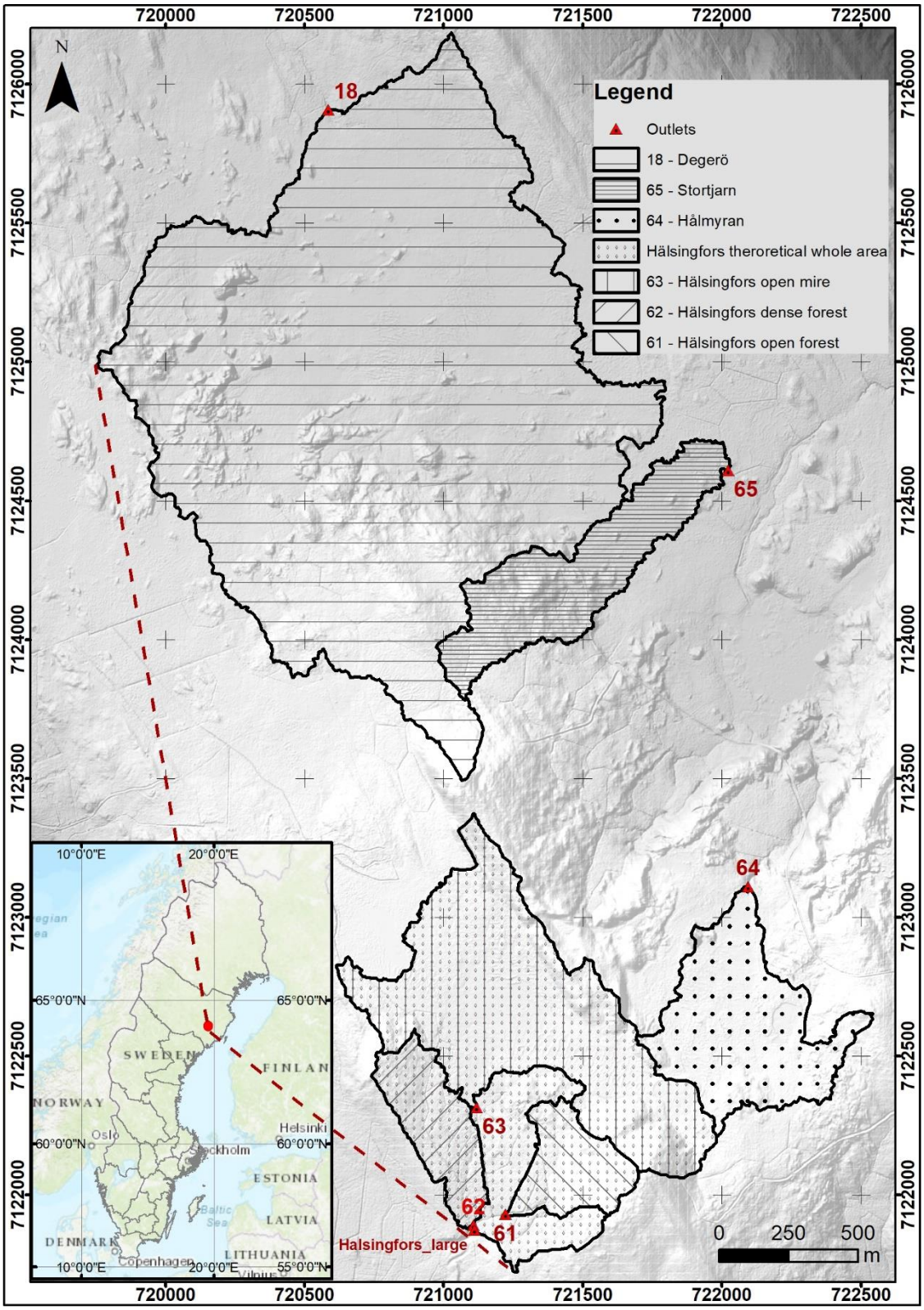


Figure 1: Catchments and outlets of the Kulbäcksliden research infrastructure, with a 2 m resolution DEM as basemap.

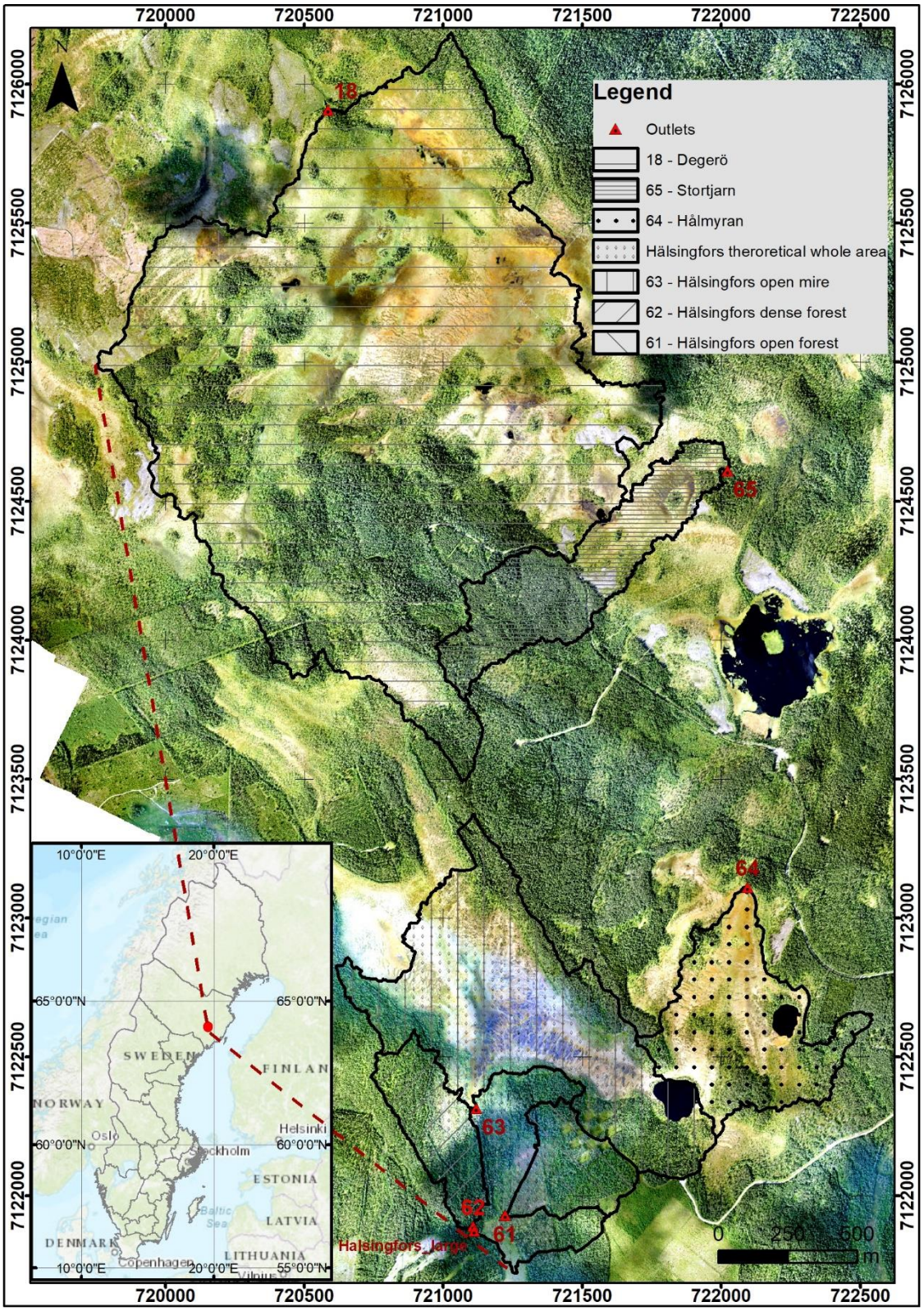


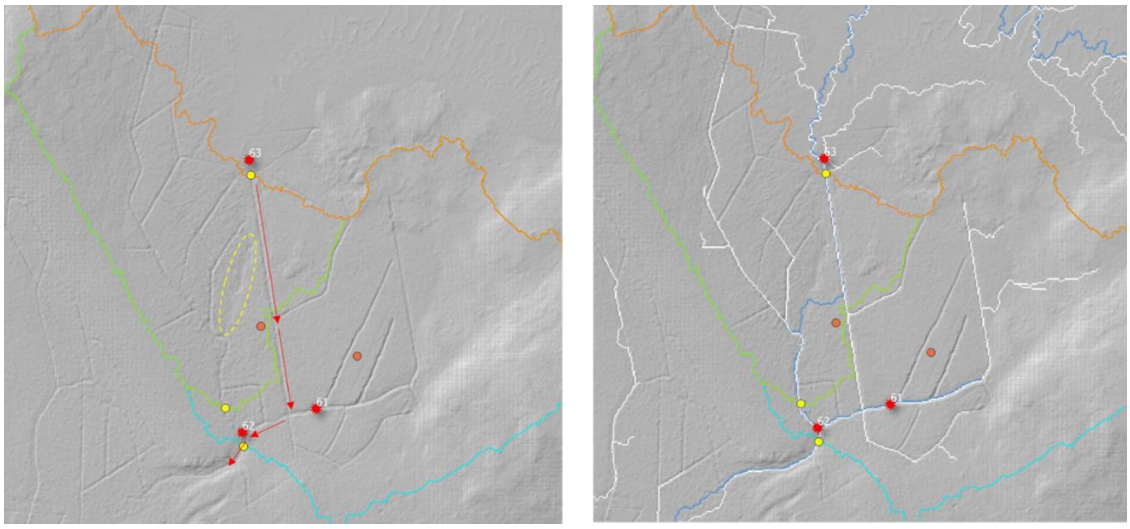
Figure 2: Catchments and outlets of the Kulbäcksliden research infrastructure, with a 6.5 cm resolution orthophoto as basemap.

Example of field verification Weirs – Hälsingfors. (Email from Koffi, after field visit with Joshua)

Hello everyone,
I was out in the field with Joss on Saturday as planned. I had the tablet of Anneli on which I put some maps, and can safely say the following:

- The weir locations given by Rowan were checked and are consistent with their locations in the field
- The previous delineation was based on a wrong stream model
- Things look exactly as they are on the DEM (see screenshots below, more details after)
- The streams that Anneli modelled are correct (white lines), and what was used before (blue line) is wrong in some aspects.

Details: So, with Joss, we walked from weir 63, down along the red arrows (we walked also up from 62, but no need to mention here), checking if there is any possibility that any water coming from weir 63 is possibly deviated somewhere toward the west, as indicated on the blue stream line. We found out that the main ditch going down from 63 (the white line until the insertion between 61 and 62) is perfectly functioning, and is quite deep (even down to 2 meters in some places), and there is a consistent water flow inside even now.
Nowhere to the west could we see any possibility of deviation of this water. The deviation showed by the blue line (previously used streams information) is not even to be seen in the field. The place where there is a natural depression (possibly a former natural stream) is the yellow dashed ellipse that I marked on the left image. Even that one does not come close to the main ditch. It is starting 10 to 15 meters away from the main ditch, and connects to the other ditches going down to 62.
In conclusion, any interpretations of the DOC measurements should also take these into account these, because 63, 62 (remember that the 62 is upstream of the merging point of the ditch coming from north and the one coming from East) and 61 cannot be considered connected. They are rather 3 more or less distinct (of course, this is when ignoring the underground flow which is important in such wetlands). So, with Anneli, as we "decided" last time, there will be one open mire catchment (outlet at 63), one dense forest catchment (outlet at 62), one open forest catchment (outlet at 61), and then one theoretical large catchment (outlet a bit south of 62, which would include all 3 previous subcatchments).



Thank you all, and have a nice week.
Koffi

Reference:

Lidberg, W., Nilsson, M., Lundmark, T., Agren, A.M., 2017. Evaluating preprocessing methods of digital elevation models for hydrological modelling. Hydrol Process 31(26), 4660-4668.