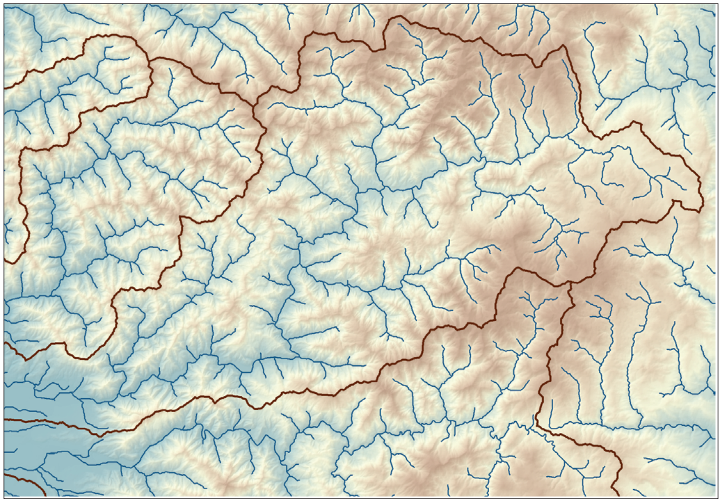
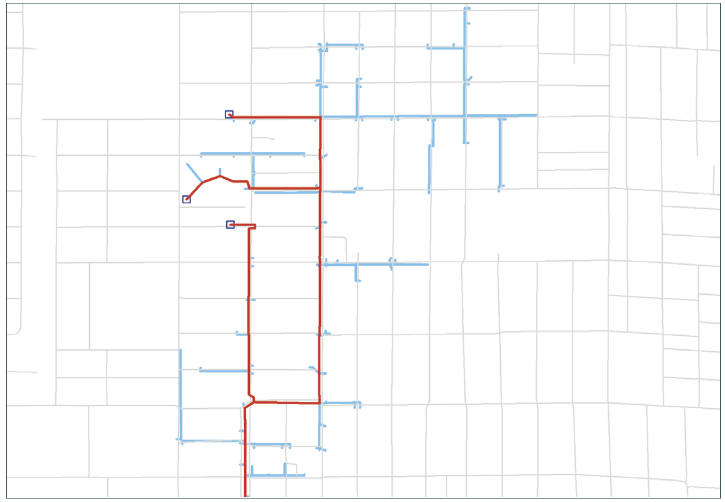
5 Modeling flow

Model flow to find out where things will accumulate, such as rainfall runoff or sediment loads, or to find the likely paths things will take, such as tracing a toxic material through a stormwater system.



Flow models were used to create the stream channels as well as the hydrologic basin boundaries (shown in red).



A flow model used to identify where motor oil dumped into a stormwater system will go. The oil was dumped into three inlets (blue boxes); the red lines show the pipes the oil will flow through. Street centerlines are also shown, in gray.

Flow is modeled either overland or over a network of features such as water pipes, electrical lines, or a stream system. With overland flow, you model the accumulation of water (or other substance) from across the surface of the study area, converging at a location—such as when modeling how much water will flow through the outlet of a watershed after a storm. Overland flow is modeled using raster data. With flow over a network, you model the flow upstream or downstream from an origin location through the pipes (or other elements of the network). Network flow is modeled over a geometric network.

To define the parameters of your model and choose the appropriate method, you need to first define the problem you're addressing and the information you need from the model. You also need to consider issues such as the behavior of the phenomenon you're modeling, the external influences on the flow, and the time period over which the flow occurs.

DEFINE THE PROBLEM

In addition to the broad goals of your model (where are the stream channels? where will the oil travel through the stormwater system?), you'll want to identify the specific information you need from the model. This will help you define the input and the parameters for the model.

Most flow models address some basic information that is usually at the heart of what you need to know:

- where the flow goes
- what it travels over or what the affected area is
- how far it travels
- how long it takes to get there

In the case of hydrologic flow, you can measure the flow volume. For example, you could model the volume of water reaching the outlet of a watershed during a rainstorm of given duration and intensity. You might also want to measure how much of something the flow carries with it, such as the amount of sediment carried by stormwater runoff.

If you're modeling flow over a network, you can find out what's connected to or affected by the flow. For example, you could model where there is likely to be flooding on streets that empty into a storm drain system if the drains back up. (The core of the model is the storm drain system, but the streets are connected to the drains and could be affected by a major storm if the drainage system is overloaded.)

WHAT INFLUENCES THE FLOW

External factors may be present—beyond the nature of the phenomenon itself—that influence the flow. You should identify these and quantify them to the extent possible, so they can be incorporated in your model.

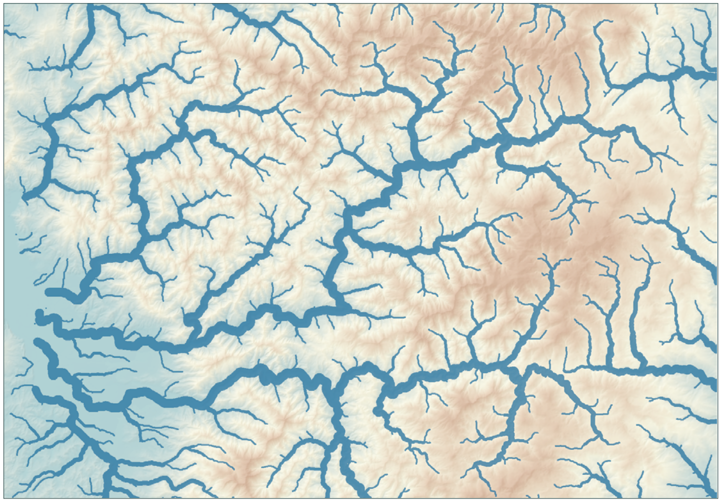
What the phenomenon travels over, or through, will influence where it flows, to some extent, but even more so, the rate at which it flows. Water will travel more quickly over exposed rock than through a wetland; stormwater will travel more quickly through pipes that are on steep slopes than it does through pipes that are on gentle slopes.

OVER WHAT TIME PERIOD

Flow inherently occurs over some length of elapsed time. Identifying or defining the time period will help you set the bounds of your model and identify the input data you need.

The flow event could be essentially instantaneous, such as when a power transformer goes out, or it could develop over a longer period (hours or days, such as with a rainstorm). In the latter case, your model will likely show the maximum flow over the course of the entire event.

Flow accumulation models are primarily used in hydrologic analysis to determine where water flows and accumulates on a terrain surface. This allows you to define stream channels and hydrologic basins and to measure the amount of rainfall runoff that will accumulate at a given downstream point (such as the outlet of a watershed) as well as how long it will take to travel there. Similarly, you can measure the accumulation of a substance carried by the flow, such as a pollutant or suspended soil particles resulting from erosion. Such analyses are useful in environmental planning, forestry, and wildlife biology, as well as in hydrology.



Streamflow layer created using a flow accumulation model and displayed with shaded relief.

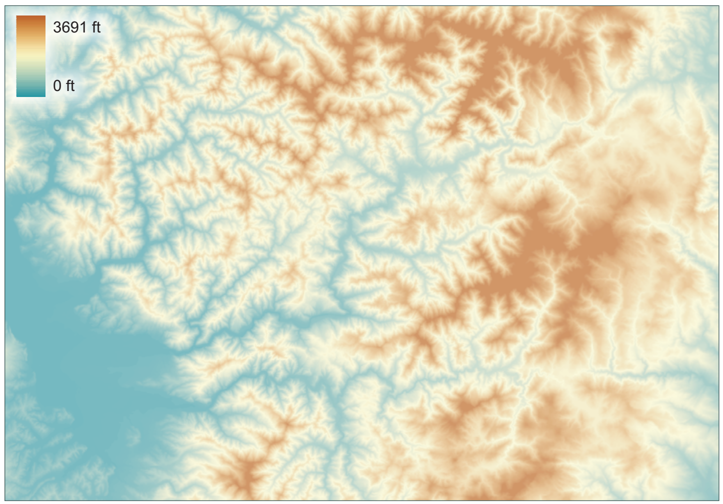
The various flow accumulation models all depend on a flow direction surface, which models how water—or another substance—flows across the raster surface, from cell to cell, following the steepest downhill paths. (The flow direction surface is in turn created from an elevation surface.) Once you've created the flow direction surface, you can create a model to obtain the results required for your analysis: delineating drainage channels, delineating drainage basin boundaries, calculating flow volume, or calculating travel time through the drainage system.

The steps for modeling flow accumulation over a surface are:

1. Obtain the elevation surface
2. Create the flow direction surface
3. Create the required output
4. Evaluate the results

OBTAIN THE ELEVATION SURFACE

Modeling flow accumulation requires an elevation surface, such as a digital elevation model (DEM). For most applications, you'll want to obtain the finest resolution DEM available to ensure that the results are accurate. If your study area is at the county or regional level, a DEM with a cell size of 10 meters or 30 meters will suffice. If you're studying a specific watershed, you may want to use even finer-resolution data if it's available.



Modeling flow accumulation starts with an elevation surface.

Preparing the elevation surface

Most publicly available digital elevation models (that is, those available from government agencies such as the USGS), are fine for making maps, for deriving data such as slope and aspect, or for modeling general movement such as a path or corridor. However, to delineate drainage channels or drainage basin boundaries, your elevation surface will likely require additional processing to produce acceptable results. This is because anomalies in the surface can interrupt the downhill flow, which causes errors in the flow direction surface when it's created (as described in the next section). You'll want to identify and fix errors in the surface that can prevent stream channel segments from connecting or that cause basin boundaries to cross stream channels.

Quite often, these errors are in the form of sinks—a cell (or group of cells) surrounded by cells of higher elevation.

Sink cells (dark brown) with the elevation surface.

If there is a sink in a stream channel, for example, the flow will travel into the cell (or cells) but will not travel out, thus creating a break in the stream.

Sinks can be identified and "filled" using tools in the GIS. The cell value is changed to be equal to the value of the surrounding cell with the lowest elevation value, so water no longer accumulates in the cell, but rather flows across it as it's supposed to.