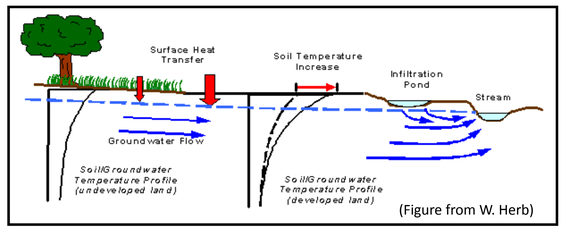
Heating of shallow groundwater from a paved surface: A coldwater stream protection problem

Craig Taylor* & Heinz Stefan – St. Anthony Falls Laboratory

Overview

Coldwater streams often provide habitat for trout and are often threatened when urban development encroaches into the watershed. The threats are related to changes in hydrology and rising water temperatures. The water source for many coldwater streams is groundwater from shallow aquifers.

Surface cover affects ground surface temperatures and, hence, the temperatures below the surface. A network of roads, driveways and parking lots constructed in a new urban development creates areas with substantially higher mean ground surface temperatures in summer than is typical for undeveloped or agricultural (vegetated) land. These surface areas heat the soil and the shallow groundwater below by conduction.

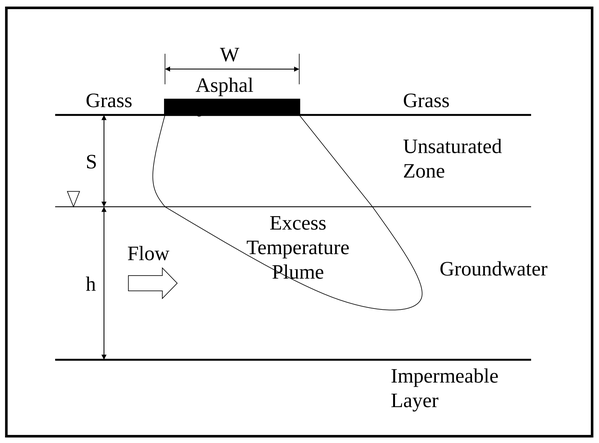


(Figure from W. Herb)

Objective

In this study we address the question **"What horizontal distance is required downstream from a paved surface such that the shallow groundwater does not significantly feel the presence of the warmer surface?"**

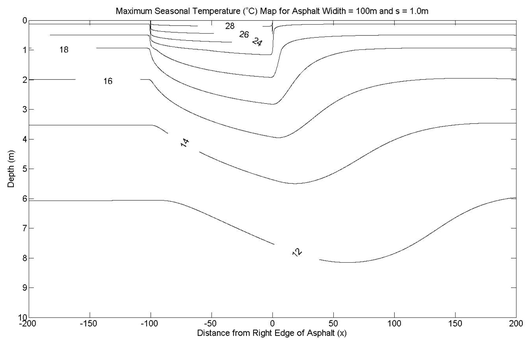
To determine this distance, we consider the case of a single asphalt strip (e.g. a road or parking lot) bordered on each side by a large vegetated (grass) surface. The higher surface temperature of the asphalt strip causes a warmer temperature plume to form. The plume originates from the asphalt strip then penetrates into the groundwater where it is swept downstream under the adjacent grass surface. To quantify the heating of the groundwater due to the asphalt strip, we introduce the concept of an excess temperature.



The excess temperature is the maximum temperature difference throughout the season between the local temperature with the asphalt strip and the local temperature without the asphalt strip.

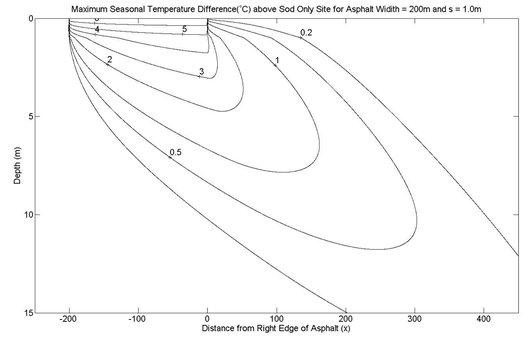
Simulations

Simulations were run to generate "virtual case-studies." Cases were explored for a range of site parameters: asphalt width, depth to groundwater table, groundwater velocity, vadose zone thermal diffusivity, and groundwater thermal diffusivity.



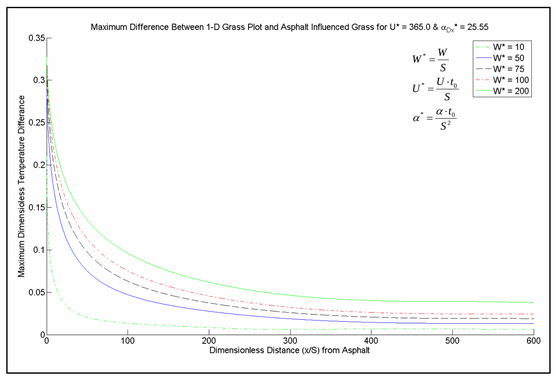
Example of seasonal maximum temperature below an asphalt strip bounded on both sides by grass.

A comparison of the site with and without an asphalt strip generates an excess temperature.



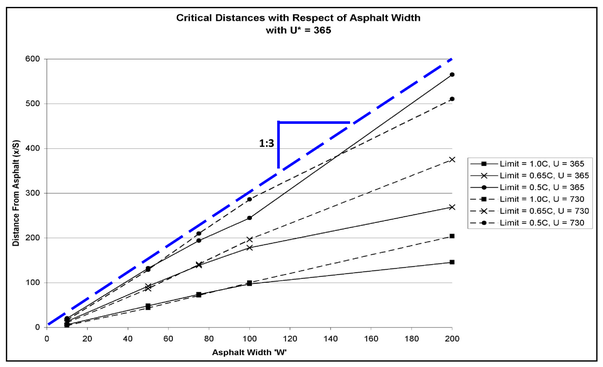
Example of an excess temperature plume below an asphalt strip bounded on both sides by grass.

Recording the maximum excess temperature at any depth reveals the thermal impact for different scenarios.



Example of maximum excess temperature at any depth, recorded for a range of asphalt widths (with all other parameters fixed). (S = Distance from ground surface to water table.)

Recording the distance at which the maximum excess temperature drops below a critical value reveals the influence of asphalt width on the required buffer distance.



Influence of asphalt width on the distance required for maximum excess temperature to drop below a given critical temperature. (Recorded for two different velocities.)

Conclusions

- Cool baseflow is a key component for maintaining many cold-water stream temperatures.
- Changes in surface type cause heat plume in the groundwater.
- Goal is to determine the distance downstream at which the presents of an asphalt strip is no longer felt.
  - Run simulations to develop virtual case studies.
  - Run for a range site parameters
- The length of thermal plume increases with increasing asphalt surface width.
- ***Necessary buffer distance between asphalt strip and coldwater stream ~3 x Pavement Width.***
  - The necessary buffer distance can be reduced by conducting a site specific model; however, three times the pavement width is a good general rule.

*E-mail: tayl0423@umn.edu