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SESSION 07 ALIGNING LAND USE PLANNING AND AGRICULTURAL PRACTICES WITH RIVER RESTORATION

Application of QUAL2K for estimation the effect of shading on water temperature regime of small streams in agricultural landscape

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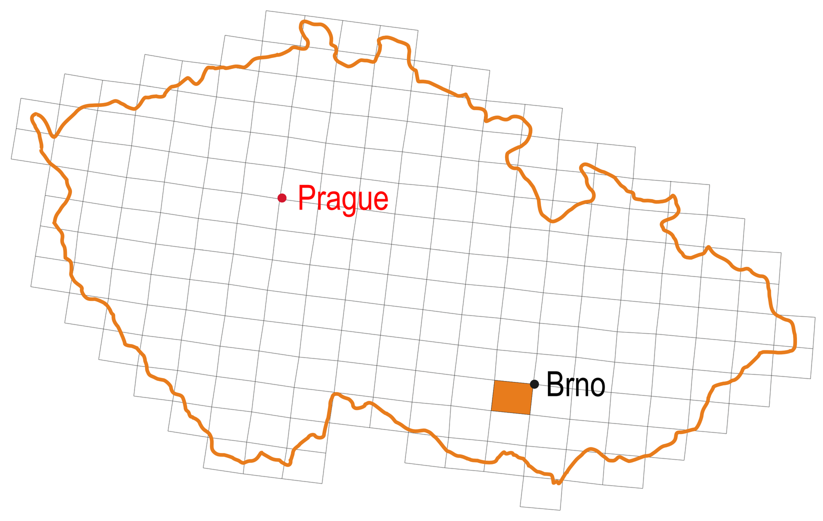


Fig. 1: Monitored locations since March 2008.

Introduction

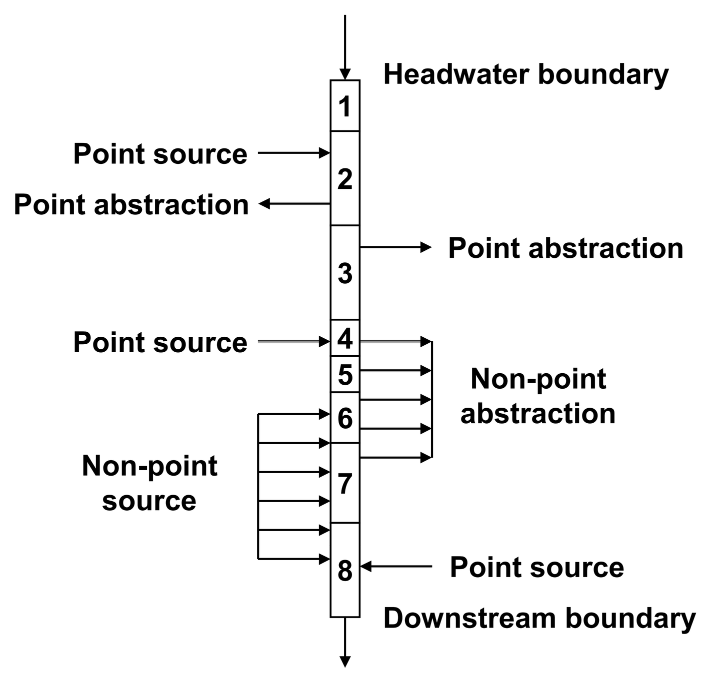
With the use of mathematical models and modern computer tools it has become an easy technique to study the dynamics of the river system. This paper describes and demonstrates the application of the water quality model QUAL2K on small streams near Brno city (Czech Republic). On these small streams the long term research has been focused on hydrogeomorphological degradation of stream channel as well as hydrochemical, hydrobiological and ecotoxicological properties of water and sediment. Since 2008 continuous monitoring of water temperature has been carried out (14 locations on Fig. 1), using data loggers installed in selected profiles (HOBO Water Temperature Pro v2 Data Logger). Based on the evaluation of the monitored environmental factors, the most suitable reaches for restoration were proposed.

QUAL2K simulates a dynamic diel heat budget and water quality kinetics for a one-dimensional, steady-flow systems. It represents a modernized version of the QUAL2E model. Numerical computations are programmed in Fortran 90 and MS Excel is used as the graphical user interface. All interface operations are programmed in VBA.

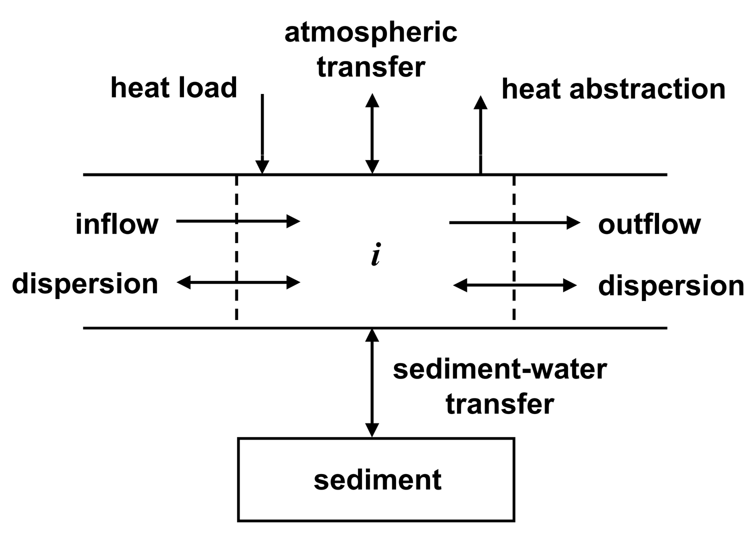
The available data provide a good base for case study for relatively new water quality model. Temperature of water influences physical, chemical and biological in-stream processes. The model was used to describe the effect of shading on small streams with engineered channel in the agricultural landscape, in some cases without accompanying vegetation. Model assesses the effect of shading (changed during potential streams restoration) on streams temperature regime.

QUAL2K model

QUAL2K simulates a stream as a set of interconnected segments. Water quality constituent values are computed for every segment which is defined as a stream reach with point and nonpoint inflow sources and withdrawals that drive changes in water quality. Each segment of the stream reach is modeled as having a trapezoidal channel shape. Water depth is calculated from steady flow in the segment using the Manning equation. Water mass balances are performed by QUAL2K for each segment to determine the discharge longitudinally throughout the stream reach.



**Example QUAL2K segments describing a river reach
(source: QUAL2Kw theory and documentation)**



**QUAL2K water-quality fluxes for model segments
(source: QUAL2Kw theory and documentation)**

QUAL2K can simulate a number of constituents including temperature, pH, carbonaceous biochemical demand, sediment oxygen demand, dissolved oxygen, organic nitrogen, ammonia nitrogen, nitrite and nitrate nitrogens, organic phosphorus, inorganic phosphorus, total nitrogen, total phosphorus, phytoplankton and bottom algae. All these components of the stream can the software use to model and track changes in the longitudinal profile of the stream, caused by changes in geomorphological conditions, flow rate, riparian vegetation and other factors, changed by stream restoration.

For the simulation of water temperature, a heat balance approach is used for description of the sources and sinks of heat for each model segment. The heat fluxes between water and the atmosphere include short- and long-wave solar radiation, shading and cloud cover attenuation, conduction, wind convection, evaporation, and condensation. The heat budget is calculated using a diurnal time scale. Mixing of water between adjacent segments is modeled through water movement from upstream to downstream and dispersive mixing at segment boundaries. Heat fluxes between water and sediment are also included in QUAL2K.

Experimental

As an example, the output from the model of small stream Leskava (Loc. 4 and 5, Fig. 2 and 3) is given, showing the temperature distribution in the longitudinal profile of the stream before and after the restoration. Leskava stream springs in the small wooded area, it flows alternately through urban and agricultural landscape. Stream channel has been engineered, incl. straightening in most of the river reaches. In Leskava stream watershed (21,2 km^2) fields (42 %) and development (40 %) prevail. The current shading of the stream is within the current state model (Fig. 6a) considered in the range of 15-80%, while within the model after potential stream improvement through mere extension of riparian vegetation (Fig. 6b) shading is considered in the range of 60-80%. Both models are based on the same atmospheric conditions, stream geomorphology, etc., difference is only in stream shading.

Fig. 2: Loc. 5, Leskava stream, 3. 7. 2014

Fig. 3: Loc. 5, Leskava stream, 3. 7. 2014

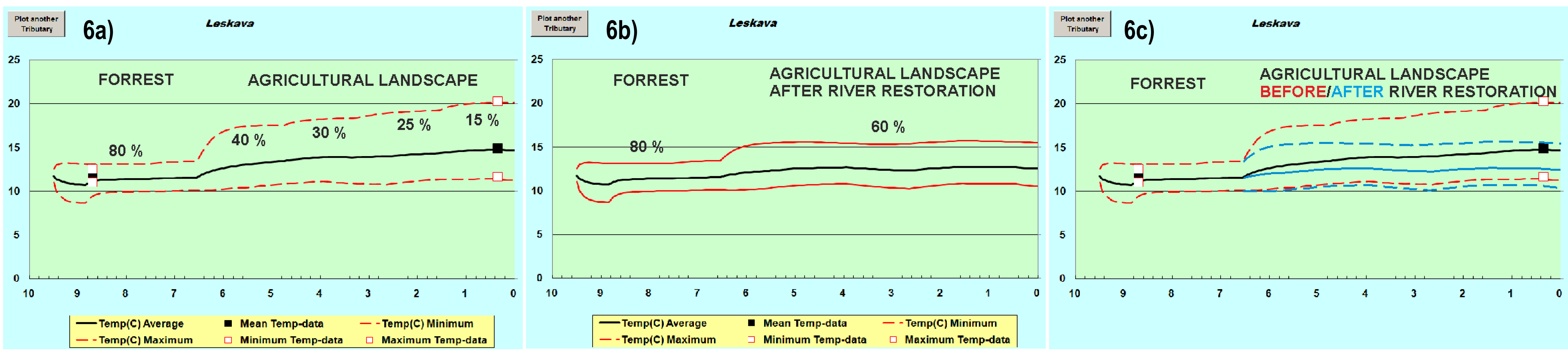


Fig. 6a-c: QUAL2K model output. Models of temperature regime of Leskava stream, June 1, 2014. Axe X: longitudinal profile of the stream [km], Axe Y: water temperature [°C]. 6a: Stream in current state, 6b: Stream after extension of riparian vegetation (change of shading), 6c: Combination of Fig.6a and Fig. 6b. Percentage values indicate shading of stream.

Conclusion

Water temperature influences physical, chemical and biological in-stream processes. Many factors like solubility of gases, viscosity, density and other properties of water depend on water temperature. These factors influence all biological processes, such as nutrient cycling and decomposition processes, including life cycles of organisms. Excessive water temperature reduces the solubility of oxygen and accelerates the process of bacterial decomposition, which can create conditions limiting the survival of some organisms in organically contaminated streams. High water temperature is a serious problem of streams with engineered channels. One of the effects of stream restoration is decrease of its water temperature.

The results in Fig. 6a-c represent modeling of temperature regime of a small stream in agricultural landscape. On this stream the effect of shading was evaluated comparing situation before and after extension of riparian vegetation. The model is designed for a typical summer day. During other seasons the effect of riparian vegetation on stream temperature will be lower. QUAL2K, of course, allows to model many others components, such as pH, carbonaceous biochemical demand, sediment oxygen demand, dissolved oxygen, nitrogen, phosphorus and others. These models can be used to display the current state of these components in the stream longitudinal profile by insertion geomorphological, hydrological and meteorological data into the QUAL2K software and subsequent model calibration. Another option is to use the software for modeling current state changes of a stream, e.g. either during the river restoration project design or after, before the project implementation.

This application of the QUAL2K software proved, that stream simulation or modelling is a common cost-effective way for water quality monitoring and predicting the future quality of rivers and streams.

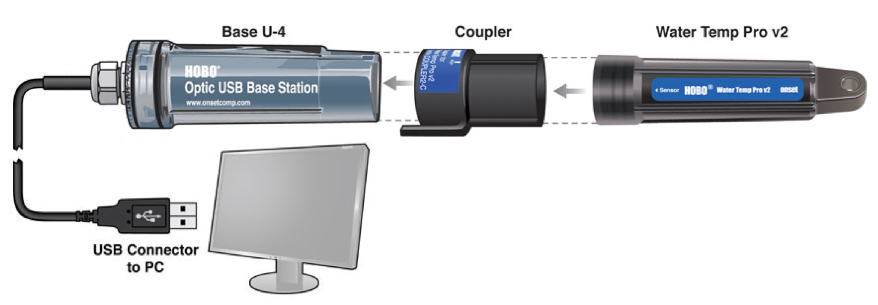


**Fig. 5: HOBO Water Temperature Pro v2 Data Logger, Optical Interface for data transfer
(source: http://www.onsetcomp.com)**

Fig. 4: Loc. 11, Bobrava stream, 3. 7. 2017, Logger

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