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TECHNICAL BRIEF

South African Rivers

Accurately measuring the relationship between organisms and local hydraulic variables

Developing Hydraulic Modelling Tools for Ecological Studies

The need for ecohydraulic modelling tools

The ecological response to catchment river management and river rehabilitation measures is determined largely by the relationship between organisms and local hydraulic variables. The most important habitat variables include water depth and water velocity. Easily accessible tools are needed to predict hydraulic habitat and substrate characteristics, and to interpret these in ways which would address the requirements of South African ecological studies, such as impact assessments and Ecological Reserve determinations. Research with an ecohydraulic modelling focus has been undertaken in order to make such tools available. This research included:

- Reviewing previous studies in the area of ecohydraulic modelling in order to clarify local requirements and assess the suitability of existing models to meet these requirements;
- Developing tools for eco-hydraulic assessments and packaging these appropriately for applications such as Reserve determination and the planning and design of river rehabilitation measures; and
- Applying, verifying and demonstrating the tools developed in laboratory and field case studies, so as to enable them to reliably predict local impacts, such as those of upstream water resources developments that modify discharges and thereby impact on local habitat-defining hydraulic conditions.

Establishing information and hydraulic model requirements

The extensive review of ecohydraulic research yielded an understanding of the types of hydraulic information required during ecological studies, and the relationship between these information types and the various types of hydraulic model. The types of hydraulic information considered included stage-discharge curves and cross-section information, lateral velocity distributions as well as frequency and spatial distributions.

Hydraulic models were broadly categorised as:

- **Deterministic hydraulic models**, which may be one, two or three-dimensional, according to the number of directions of motion considered. 1D models are useful for predicting combinations of stage and corresponding discharge; 2D models predict spatial distributions of hydraulic variables;
- **Empirical Frequency distribution models**, which predict frequency distributions of hydraulic variables;
- **Simplified models**, which predict hydraulic variables in specific situations for which appropriate relationships may be defined; and
- **Lateral distribution tools**, which predict the distribution of velocity across a cross-section based on cross-section characteristics, water surface elevation and discharge.

Use of deterministic hydraulic models

Selection and evaluation

Based on a review of relevant model characteristics, the 1D HEC-RAS model and 2D (River2D) model were selected for further investigation from a large number of available models, mainly to develop recommendations regarding inputs and parameters required for their use. Model predictions were evaluated against measured data for particular river sites.

Hydraulic resistance

Hydraulic resistance is the major parameter used in 1D models, and is also very important for 2D models. The proposed prediction methods (for both bed roughness and vegetation resistance) were applied to predict stage-discharge data for a site on the Letaba River. Two hydraulic resistance assessment tools have been developed:

- A *Guide to Hydraulic Characteristics of South African Rivers*
- *Simple resistance conversion functions,* for converting between different resistance coefficients.

Topographic data

A main input to 2D hydraulic models is topographic data. Since precise determination of positions and sizes of many features is unnecessary, a preliminary but potentially valuable tool for rapid, approximate generation of topography of

specified features has been developed, specifically for use with River2D.

Interpolation

Spatially explicit hydraulic data, whether measured or modelled, must invariably be interpolated to enable a full depiction of hydraulic conditions. Generally, interpolation by triangulation is recommended, since it produces the most realistic results and requires little time to perform. The R2D bed module of River2D incorporates appropriate software and can be recommended for performing this triangulation.

Ecological interpretation

In ecological studies, hydraulic data needs to be interpreted in ways which will be meaningful to ecologists. The following assist in interpretation:

- ***Habitat Classes*** are combinations of conditions that must be met in a particular area in order for this area to be suitable for specified organisms. Conditions generally comprise a specified range of velocity magnitudes, and/or a specified range of depths, and/or other specified non-flow dependent habitat characteristics. For fish, existing habitat classes are recommended but for invertebrates, new habitat classes are being proposed.
- ***Behaviour-based Models*** attempt to deal with the complexity of spatial variation in hydraulics and ecology. The method proposed, supported by two worked examples, is an attempt to state spatial variations of ecological relevance in ways which can be predicted by hydraulic analysis.

Empirical frequency distribution models and HABFLO

The developed HABitat-FLOw simulation software (HABFLO) incorporates two published velocity frequency distribution models and also a suite of associated tools deemed useful for eco-hydraulic studies. The reason for developing this software is to provide a working model that automates the prediction of habitat-type abundance and composition, for fish and macro-invertebrates.

Simplified, rule-based hydraulic model

Existing simplified models generally cannot satisfy the needs of eco-hydraulic studies of rivers. A new development within this project is the preliminary development and description of a rule-based model. This is a new type of simplified model which aims to predict how hydraulic variables (particularly velocity) are distributed through an area in which the average values have been predicted using a conventional hydraulic model.

Lateral distribution tools

Lateral distributions of velocity across a section can be predicted by several methods, namely through: enhancing outputs of 1D models such as HEC-RAS; using a 2D model to model a surveyed cross-section as a prismatic 2D area; and, developing analytical methods appropriate for certain situations.

Model for sand scour from cobble beds

Based on laboratory experiments, a model for sand scour from cobble beds is proposed. Despite generally good predictions of measured scour, this tool is based on very limited data and can therefore only be considered a rough preliminary method, still requiring further development.

Conclusion

The suite of tools presented includes both new and existing methods for the analysis and interpretation of hydraulic information. This suite of tools is expected to cover the hydraulic modelling requirements of most ecological studies. All hydraulic information is described in terms of depth and velocity, and their distributions.

Case studies serve to illustrate the use of and verify the various tools proposed. Documented applications at different levels of assessment of ecological water requirements ensure that the tools, with the exception of some still under development, can be adopted for national use.

The products of this research comprise substrate maintenance models and manuals and hydraulics models and manuals, as well as the ***Guide to Hydraulic Characteristics of South African Rivers***.

The tools presented should be used only by practitioners with a background in hydraulics. This would include civil engineers with practical eco-hydraulics experience, or anyone with equivalent knowledge.

Tools that require further development are the rule-based hydraulic model, the topography generator and the sand scour model. In addition, the updating of the manual ***Guide to Hydraulic Characteristics of South African Rivers***, as new data and photographs become available, would also be valuable.

Further reading:

Hydraulic Modelling for Ecological Studies for South African Rivers (**Report No: 1508/1/07**).
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