BEDLOAD TRANSPORT MODELLING FOR RIVER CHANNEL IMPROVEMENTS

A valuable addition to a river improvement modelling study

Many of New Zealand's rivers carry gravel bedloads and present management challenges both in flood mitigation and in controlling gravel budgets. Improvements to river channels carried out for flood mitigation will generally have some effect on transport of the gravel bedload. Any resulting changes in bed levels can in turn affect flood levels, possibly diminishing the effect of the channel improvements over time. The Sediment Transport (ST) module in MIKE 11 is able to estimate these effects.

HOW CHANNEL WORKS AFFECT RIVER BED LEVELS

Improvements to river channels carried out for flood mitigation will generally have some effect on transport of the gravel bedload. Many of New Zealand's rivers carry gravel bedloads and present management challenges both in flood mitigation and in controlling gravel budgets. The gravel resource is often in demand as building and roading aggregate, and gravel extraction lowers the flood risk. However, too much extraction can cause undermining of bridge piers, stopbanks and other infrastructure. Any resulting changes in bed levels can in turn affect flood levels, possibly diminishing the effect of the channel improvements over time. The MIKE 11 ST module is able to estimate these effects.

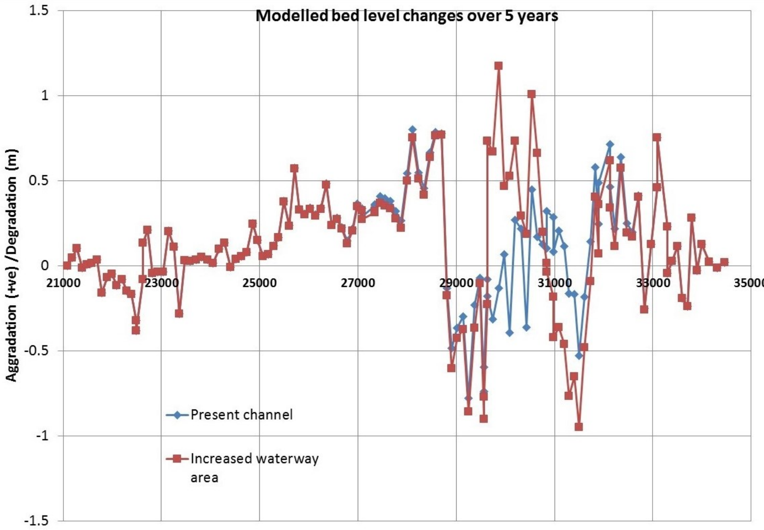

Figure 1: Modelled bed level changes over five years; existing cross-sections vs. with the flood mitigation option.

CLIENTS

- River management authorities
- River engineering consultants
- Central government environmental agencies
- Gravel extraction companies

CHALLENGE

- Determining how river channel works carried out for flood mitigation will affect gravel transport and bed levels
- Determining whether flood mitigation benefit might be lost over the years
- Budget, timeline and available data may not allow a full sediment transport study

SOLUTION

The application of MIKE 11's Sediment Transport module to a MIKE 11 model used for flood analysis.

VALUE

- Information can be provided to the client at the options stage, showing the extent of loss of the flood level gains over a typical five-year period
- The modelling can also provide an indication of the annual gravel extraction needed to avoid this loss

Image credits: Banner and Figure 1: Modelled bed level changes © DHI

A rigorous estimate of bed level changes requires measured gravel clast size, sediment loads from tributary streams, and any gravel extraction. Such an investigation would also require calibration against observed bed level changes and the observed flow hydrograph.

However, an indication of possible effects is easy and quick to obtain if a MIKE 11 model has already been assembled for the flood analysis. Using an uncalibrated model and assumed clast sizes, bed level changes with the present channel can be modelled and compared with those with the proposed channel modifications.

A significant difference between the two may then indicate that more rigorous investigation into the mobile-bed processes is warranted.

EXAMPLE: A HIGH-ENERGY NEW ZEALAND RIVER

Figure 1 shows the effect of a flood mitigation proposal ('increased waterway area') to widen the channel of the 1.15 km reach between chainages 29700 m and 30850 m. Indicative gravel clast sizes were available from previous studies. Although an estimated 50,000 m^3 of gravel is extracted annually, this has not been modelled.

The simulation utilised in MIKE 11 ST covers a 5-year period typical of the long term flow regime. Bedload was computed using a formula developed for gravel-bed rivers in Japan.

Figure 1 shows the bed level changes at the end of five years, aggradation and degradation in different locations of up to a metre. Caution is needed in interpreting the changes predicted with the present river bed. However, with no gravel extraction modelled, the predicted aggradation upstream of chainage 29700 m is expected. Consequently, the ongoing gravel extraction will be keeping the bed lower than it would otherwise be.

The most significant feature of this graph is the different pattern of bed change that occurs within the reach of increased waterway area. The additional conveyance provided by the channel works is gradually reduced by aggradation due to lower flow velocities there.

Relative to the existing bed, the 'increased waterway area' bed between the bridges aggrades by up to 1.3 m, mostly within the first year. Downstream of chainage 30850 m there is relative degradation, which progresses downstream, due to the channel being starved of gravel from upstream. Upstream of chainage 29700 m there is modest degradation.

Do these changes matter? The stage-flow rating at any cross-section can be examined to show both the immediate benefit of the channel improvement and how subsequent bed changes have affected this (Figure 2). At flood flows exceeding 900 m^3/s, the river stage is reduced by 0.5 m by the proposed channel improvements. After four years of bed changes in response to gravel transport, 0.15m of this improvement (30%) is lost.

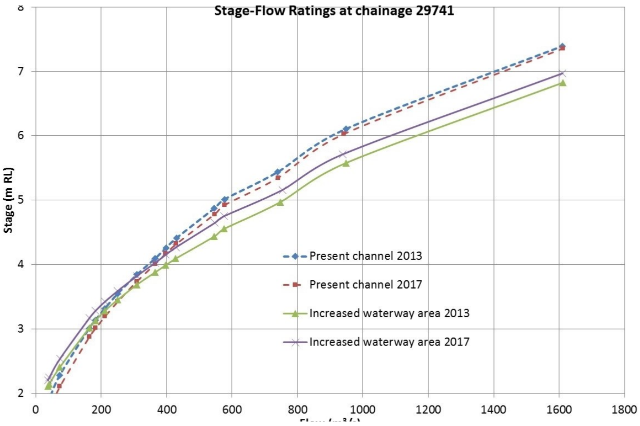

Figure 2: Computed stage-flow ratings at chainage 29741 m, for the present and 'increased waterway area' river channels and showing changes over four years.

HOW THESE RESULTS MIGHT BE USED

These model results should be regarded as indicative. They may be used to decide whether the issues need further attention, rather than to provide definitive and quantitative results.

First, one must decide whether the modelled changes over time are enough of a concern to warrant further investigation. If so, the results should be confirmed by more rigorous bedload transport modelling.

Further simulations with a calibrated MIKE 11 ST model would help decision making.

There are at least two alternative solutions worth considering:

- A partial loss of the flood risk improvements may be satisfactory, and the project still economically viable. Running the model for a yet longer period would indicate the 'final' flood level-flow rating, and might then confirm a favourable cost-benefit ratio for the proposed improvements.
- Increasing gravel extraction upstream of chainage 29700 m might be considered to minimise the aggradation between the bridges. An additional 8500 m^3/year would need to be extracted, this being the difference in computed annual bedload within the improved 1.15 km reach. This would however cause some degradation downstream of chainage 30850 m. Further simulations would determine the various longer-term effects on bed levels and water levels.

Image credits: Figure 2 Computed stage-flow ratings @ DHI