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Modelling long distance gravity flow channel design and alignment

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Abstract: Conventional gravity flow channel design techniques have been traditionally undertaken by engineers using largely manual methods. These methods are very laborious, time consuming and expensive. Here we introduce the WaterRoute model (Petheram et al. 2021), a model that optimises channel alignment through dissected country by weighing up costs of route variations between cut and fill while avoiding the expense of extra channel distance.

Figure 1 illustrates the schematic flow of the WaterRoute model, which employs Dijkstra's algorithm (1959), a graph theory algorithm commonly used for finding the shortest paths in a weighted graph. The weights are expressed as a cost per metre ($/m) to construct a channel through a Digital Elevation Model (DEM) cell, and the graph theory tool sums the weights as it traverses cells to get from a starting point to an endpoint with the least accumulated cost.

The weight ($/m) to traverse any given cell is i) a function of the channel characteristics and ii) the elevation of the digital elevation model cell relative to the elevation that the channel bed needs to be to maintain the constant slope at as it passes through that cell. The former is a function of the channel dimensions (shape and peak discharge capacity), material through which the channel traverses (i.e. regolith, hard rock) and whether the channel needs to be lined (i.e. in sandy and loamy soils), while the latter informs the amount of cut and fill required for a channel of a specified geometry.

At each cell the model also determines if the channel requires cross-drainage infrastructure to traverse a drainage line. Cross drainage infrastructure is deemed necessary for cells along the channel alignment with a catchment area greater than 1 km2. Where a drainage line requires cross drainage infrastructure, instead of weighting the cell using the generic per metre channel cost surface described earlier, weighting is assigned based on the type, length and flow capacity of the required cross-drainage. Two types of cross drainage infrastructure: i) inverted siphons and ii) cross drains, were evaluated and costed at each cross-drainage location, and the more cost effective option selected, subject to certain conditions being met. Siphons, being a significant source of head loss, it is particularly important to be able to explicitly model their location and size.

Once an optimal alignment that minimises the overall cost of cut and fill is identified, the model refines the channel cost further. This refinement incorporates peak discharge losses, cross-drainage infrastructure, and linear features such as roads, fences, and bridges. The peak discharge capacity of the channel at a cell is calculated by subtracting the peak flow loss incurred within that cell from the capacity of the previous cell. The channel dimensions, and therefore the channel costs, are modified accordingly. Annual losses are calculated in a similar manner; however, they have no bearing on channel capacity dimensions, rather they are reported by the model to inform the gross area of demand that could potentially be supported by the diversion system.

The WaterRoute model was tested against conventional gravity flow channel design techniques independently undertaken for the proposed Elliot Main Channel Extension (EMCE) in north Queensland, later known as Water for Bowen in later investigations. This proposal, which dates back to the mid-1990's, involves a gravity flow channel from the Elliot main channel outfall on the Burdekin River to Euri Creek near Bowen, 94 km as the crow flies. Deriving the alignment and calculating the cost of the channel in the original Water for Bowen investigations took many person years of effort. The WaterRoute model was able to faithfully reproduce the proposed EMCE channel alignment and cross-drainage infrastructure with a higher degree of accuracy with less than half a day's person effort.

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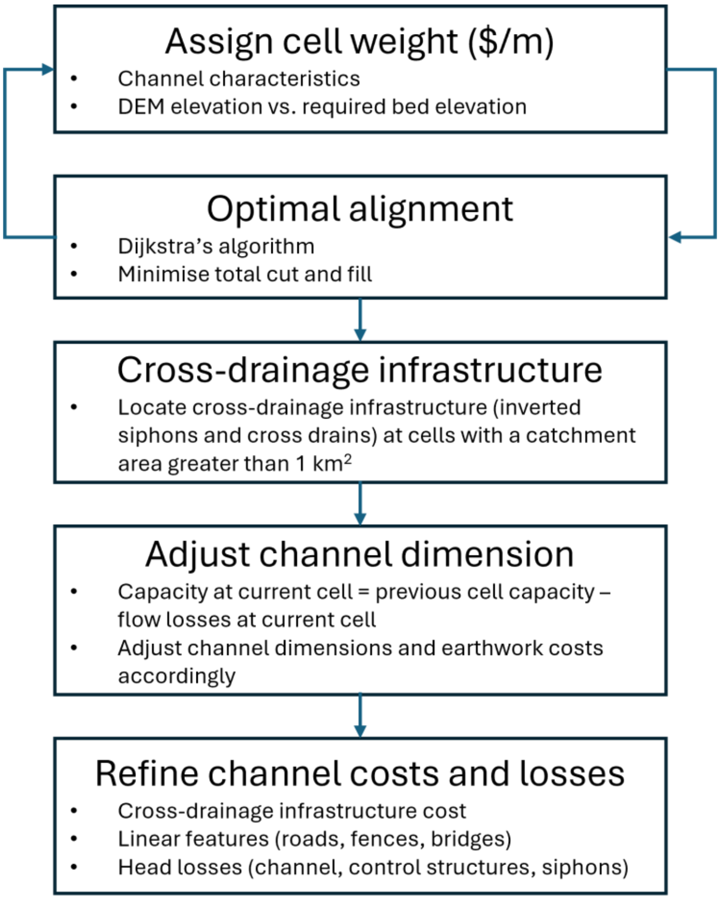

Figure 1. schematic flow chart of the WaterRoute model

Keywords: *Gravity flow channel, inter-basin water transfer, open channel*

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