Cartography M.Sc.

Generalisation of heterogeneous topographic linear features to derive a German Alpine club map

Sifa Mawiyoo

24.09.2021

Outline

- Introduction
- Research Problem
- Research Objective
- Research Questions
- Literature Review
- Methodology and Implementation
- Results
- Discussion
- Conclusion

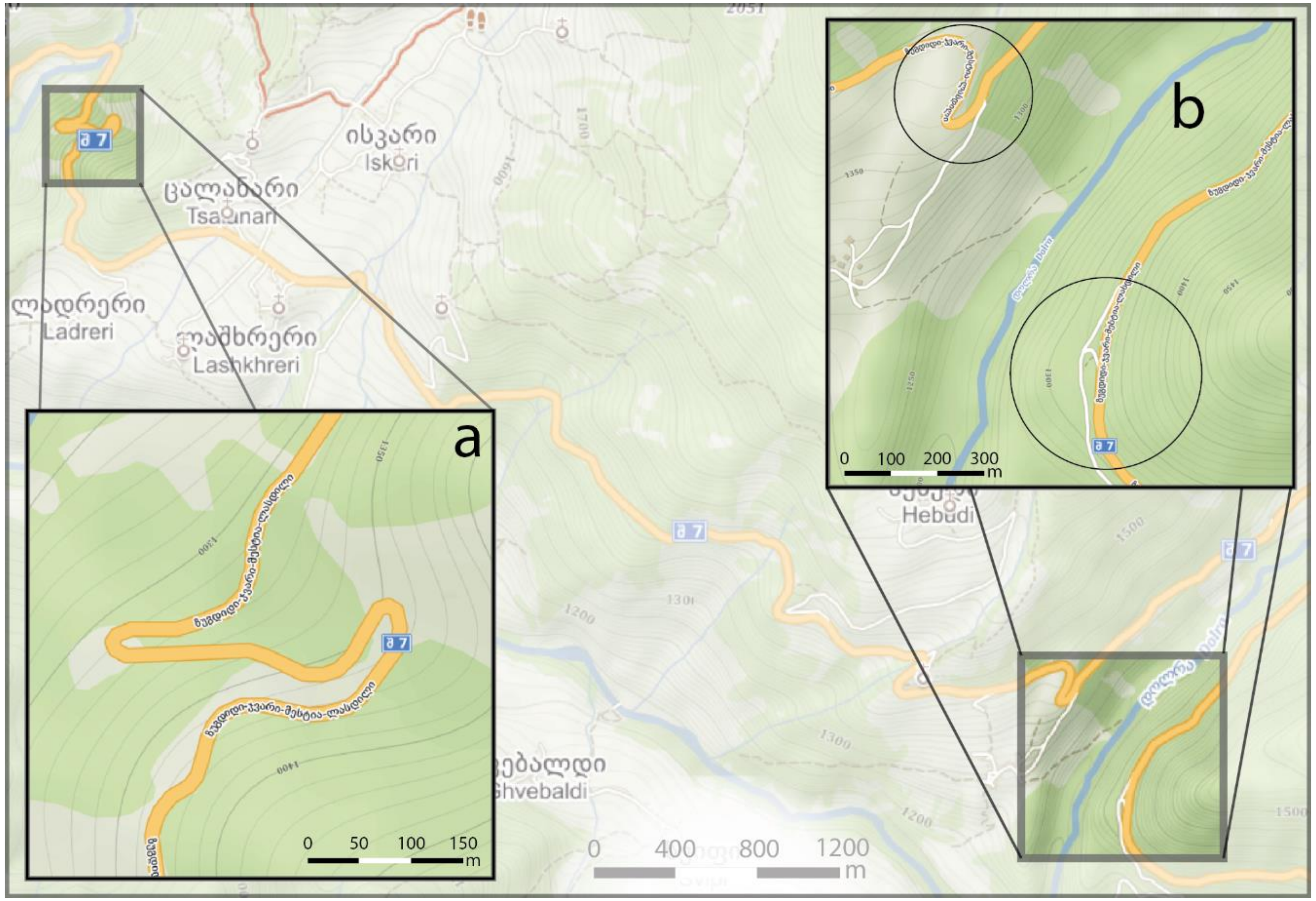
Introduction

- Thesis presents two models that support the generalisation of heterogeneous topographic linear features.
  - Study area: Ushba Mountains, Republic of Georgia
    - Source Datasets
      - » Open Street Map
        - Satellite images digitisation
        - GPS Field Data
      - » Global Digital Elevation Models
    - Target Scale is 1:33,000

"Generalisation aims to simplify representation of geographic data in the map production process"

- Ruas, 2008

Research Problem



Source: Mapy.cz 2020

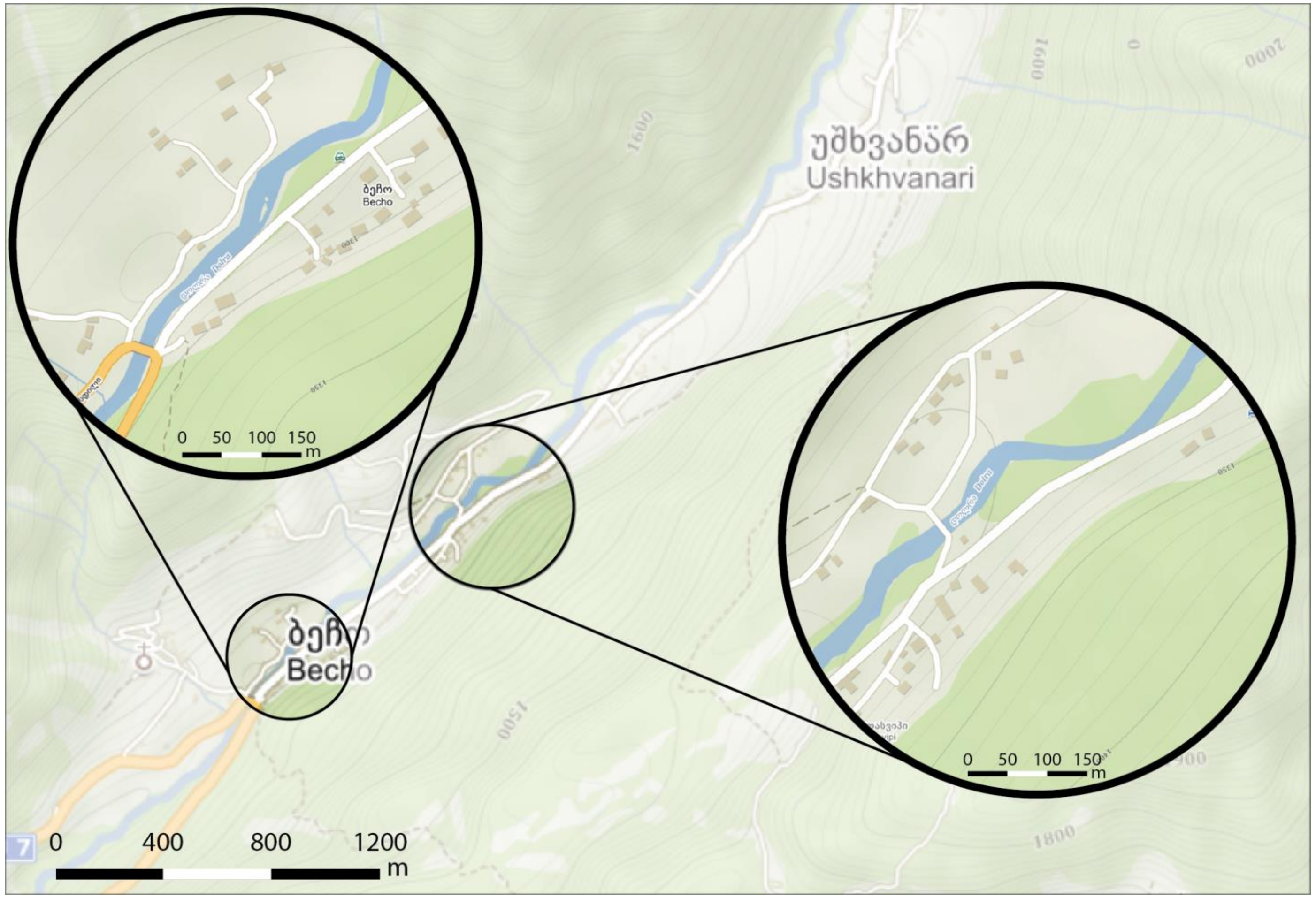
Ineffective generalisation results in coalescence conflicts

Shown here as (A) a feature overlapping itself (Self-overlapping)

Or (B) features of different road classes overlapping other features

Generalisation inefficiencies result in coalescence conflicts among and between features.

Research Problem



Source: Mapy.cz 2020

Ineffective generalisation results in coalescence conflicts

Shown here as:
Features of Different Types(Roads and Rivers) overlapping other features.

Research Problem

Source: Mapy.cz 2020

Disagreements / misalignments in topographically linked datasets.

Shows here as:
Misalignments between the contour lines and the position of the river.

Rivers should flow along the path of lowest elevation in the valley. “The Talweg”.

Research Objectives

1. Explore generalisation methodologies that can solve coalescence conflicts across the available linear features.

2. Explore generalisation operators to refine and optimise the content of the map from the source scale to the target scale.

3. Explore solutions to harmonise two heterogeneous datasets namely the contours and the river network.

4. To build a modelling solution that is fully or partially automated and capable of generating the improved generalised and cartographic results.

Research Questions

1. Which generalisation approach can be used to refine the network of linear features and optimally reduce the content load at the set scale for the target use case?

2. Which generalisation algorithms/approaches can be used to detect and resolve standard coalescence and self-coalescence conflicts?

3. What generalisation and spatial adjustment process can be used to harmonise topographical representations between contours and waterways from heterogeneous data sources?

Literature Review – Line feature generalisation

- Yan (2019), Highlighted road network selection algorithms for network generalisation including :
  - Semantic based algorithms - Using street type, rank order and importance
  - Graph based algorithms - Focusing on topological relationships and centrality
  - Stroke based algorithms – strokes of roads as important aspect for good continuation in dense urban centres
  - Hybrid Comprehensive approach - Combining metric, statistical, topological, thematic information and scale (micro, macro variations in the selection process.

Overall effect is to:

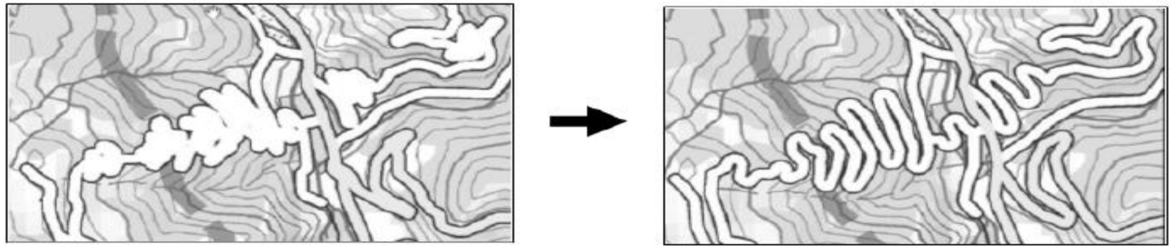
select or omit features,
reduce the quantity of features involved in the network

maintain connectivity between important places

make room for subsequent generalisation requirements

Literature Review - Line feature generalisation

- Agent Based Generalisation models works on identifying cartographic conflicts then applying a local specific transformation to features that are in continuous conflict automatically. (Gaffuri, 2007)

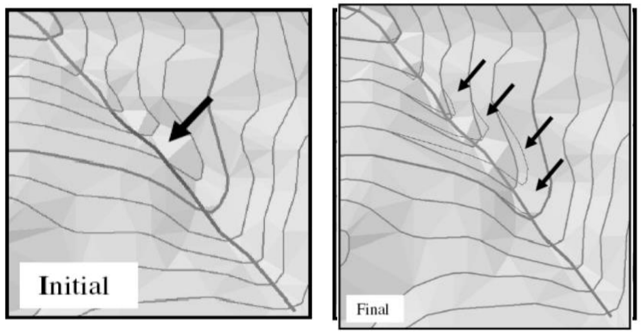


Example: Coalescence conflicts solved with the agent based generalisation approach by applying displacement operator to a line feature (Gaffuri, 2007).

- ***User-directed generalisation using an **optimised constraint** approach
  - Uses a ranking system & defined hierarchy to set the order in which features that are in conflict are adjusted for different scales. .

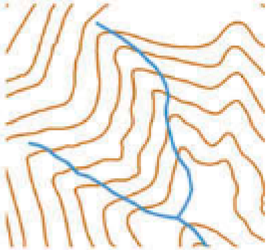
Literature Review – Contour & Waterway Matching

- Uses Spatial Constraint knowledge to detect and correct inconsistencies between contour and river network.
- Generalisation based on Agents and Elasticity Model (GAEL)
  - Parts of objects are considered based on:
    - Internal constraints (shape preservation)
    - External constraints (deformation requirements)
    - Resulting deformation (displacement of some parts of the object)

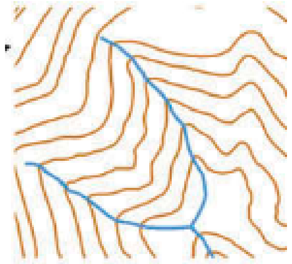


Example: Applying the GAEL Model to deform the relief using the hydrographic network. (Gaffuri, 2007)

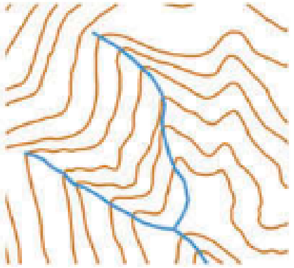
- ***Conflation of DEM's with Hydrographic lines
  - Uses spatial adjustment techniques to match positions of streams extracts in DEM data to reference hydrographic lines



Source Data



Rivers adjusted to contours



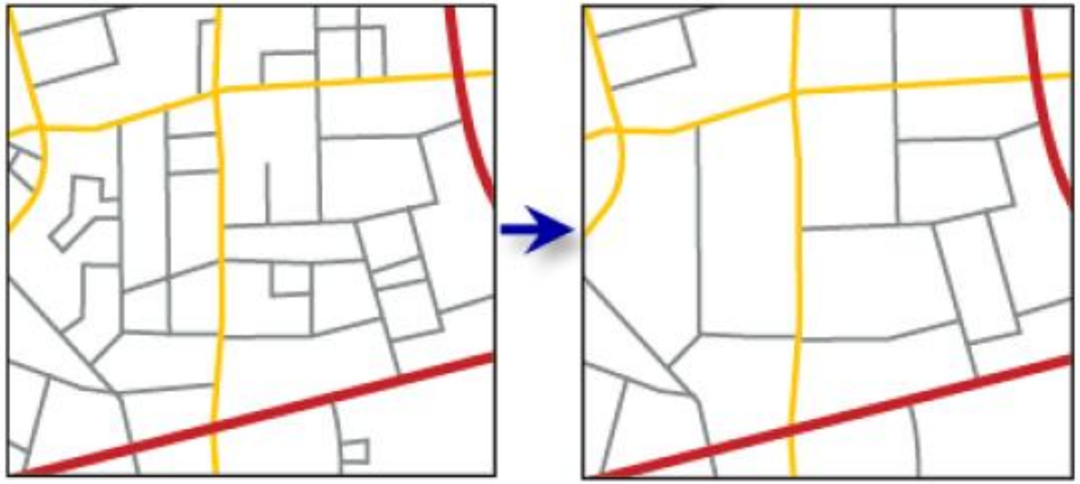
Contours adjusted to rivers

(Ai et al. 2014)

Methodology – Linear Feature Generalisation

Co-opts a series tools available in ArcGIS Pro for cartographic generalisation based on the optimised constraint approach

- **Network Generalisation** / Refinement is performed by:
  - Thin Roads network tool – Recommends line segments of omission based on a minimum distance threshold and selects line segments that are important for connectivity through .



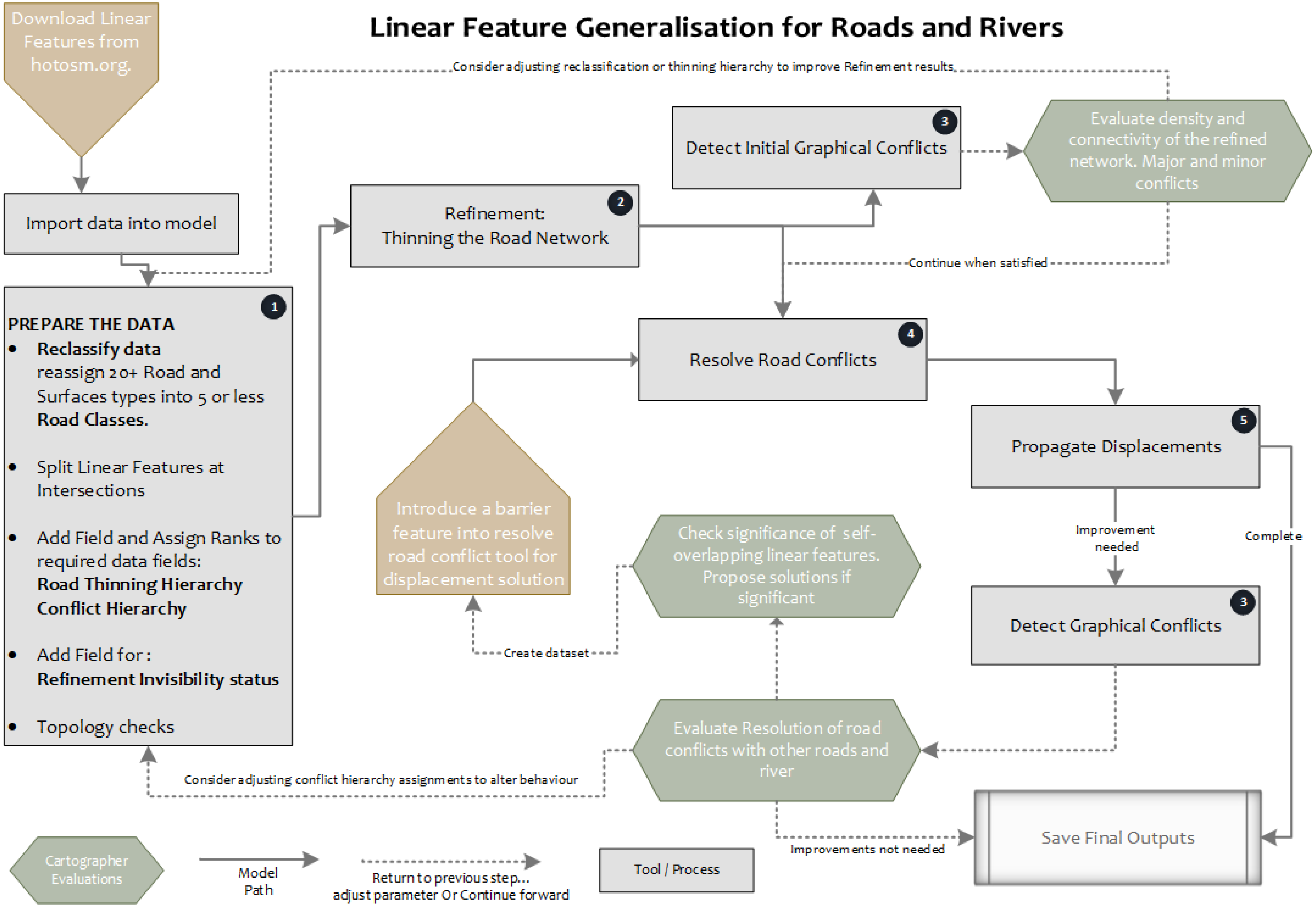
Elimination of insignificant road segments using Thin road network tool.
(Punt & Watkins, 2010)

Methodology – Linear Feature Generalisation

Co-opts a series tools in ArcGIS Pro for cartographic generalisation based on the optimised constraint approach

- **Conflict Detection and Resolution**
  - Graphical Conflict detection tool – Detects features in conflict with each other Overlapping features
  - Resolve Road Conflict tool – Calculates the displacement feature which contains the Direction and Distance a feature segment is required to move to resolve a conflict.
  - Propagate displacement tool – Implements the displacement of features while maintaining spatial relationships to other features.

Implementation – Linear Feature Generalisation



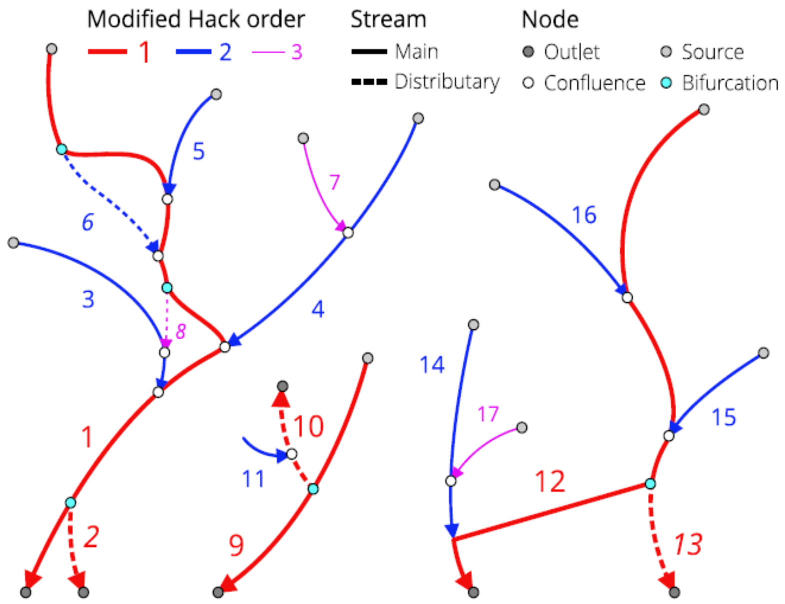
Summary of the Implemented Work Flow.

Highlights
- Data Preparation
- Cartographer Evaluations
- Self Overlapping conflicts

Methodology – DEM Conflation for Contour generation and river network matching.

Co-opts an Open source python toolbox for Conflation of DEM with reference hydrographic lines.

- Pre-Processing - Assigning Modified Hack Ordering of streams



Field Name	Definition	Application
ID	Unique identifier	
CONFL	ID of stream that current stream outflows to	Outlet is the end node of the stream with CONFL = -1 Confluence is the End node of stream with CONFL ≠ -1
BIFUR	ID of inflowing stream to the current stream	Source is the start node of stream with BIFUR = -1 Bifurcation is the start node of stream with BIFUR ≠ -1
ITER	Number of iterations during which a counterpart of the current stream should be extracted	If CONFL = -1 and BIFUR =-1 then ITER =1 Then corresponding streams are excluded from the list and iterations begin starting with i=2 and continues with i = i + 1
ORDER	Modified Stream Order	
TYPE	Stream type with respect to bifurcation process	If the BIFUR = -1 the type is a 'main' If the BIFUR ≠ - 1 the type is a 'distributary'

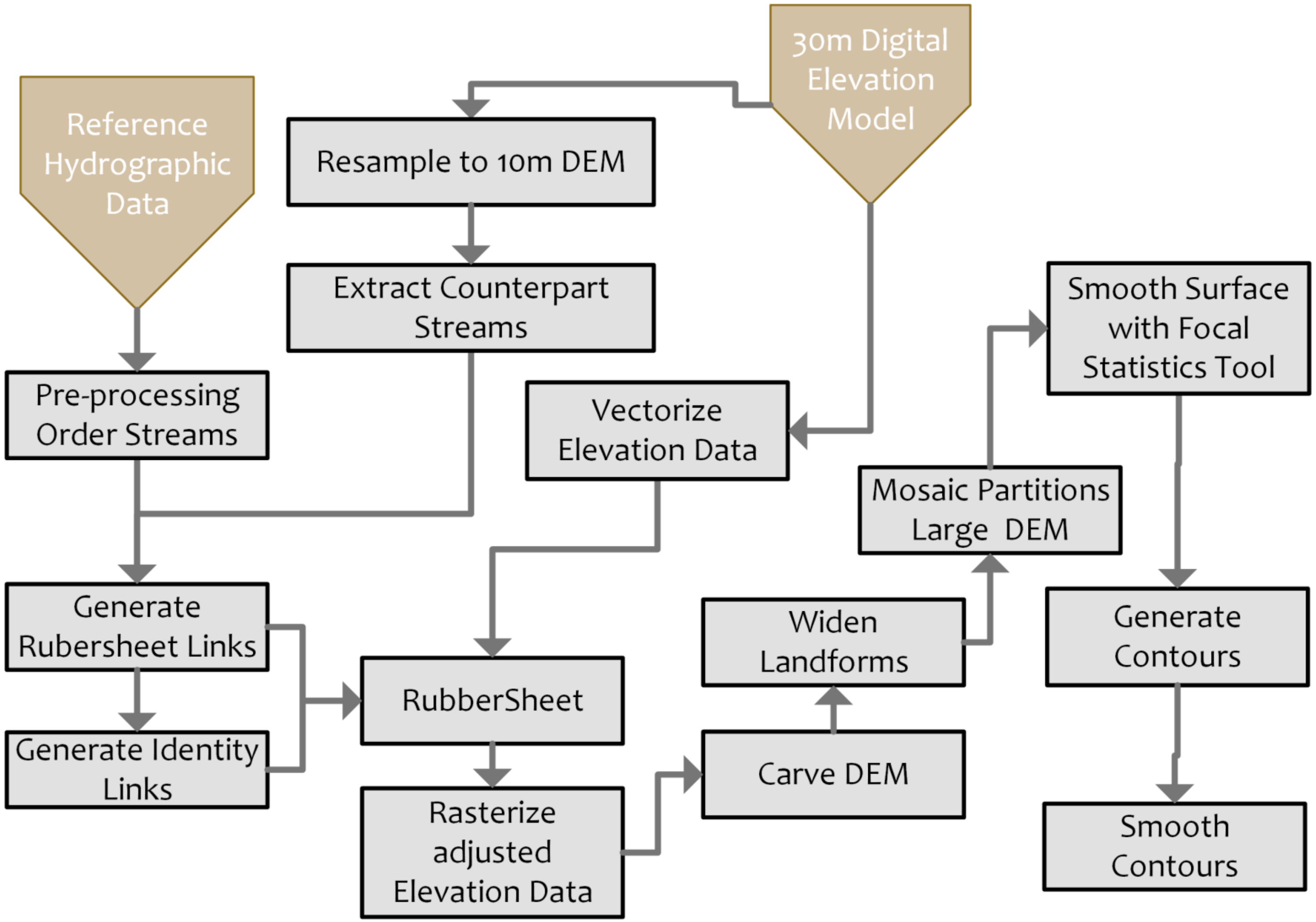
Methodology – DEM Conflation for Contour generation and river network matching.

Co-opts an Open source python toolbox for Conflation of DEM with reference hydrographic lines.

- Processing -
  - Defining and applying parameters for counterpart stream extractions
  - Conflation process
- Post Processing – Surface landform exaggeration and Contour generation.

Parameter	Definition	Application
Catch Radius (r)	Limits the maximum spatial deviation of a counterpart from its reference line	Minimum value = DEM Pixel size (R) Larger r values guarantee a counterpart will be extracted but finding flow line can be challenging if r value is close to R **Recommendation** catch radius is pixel size multiplied by positive integer value (k).
Minimum flow accumulation (a)	Defines lower limit of possible magnitudes of counterpart streams	Higher (a) value = more significant paths are identified as counterpart streams. too large an (a) value risks now matching counterpart being found. **Recommendation** the minimum flow accumulation (a) value is ≤ (k) integer value
Off stream Penalty (w)	Defines how strictly the least-cost counterpart will follow the drainage network defined by a	W value should be large enough to penalise algorithm from jumping from one stream to another while calculating the3 shorted path. **Recommendation** (w) is 10 times a positive integer value (m)
Maximum deviation	Maximum deviation distance of a counterpart stream from its possible reference line.	

Implementation – DEM Conflation for Contour generation and river network matching.

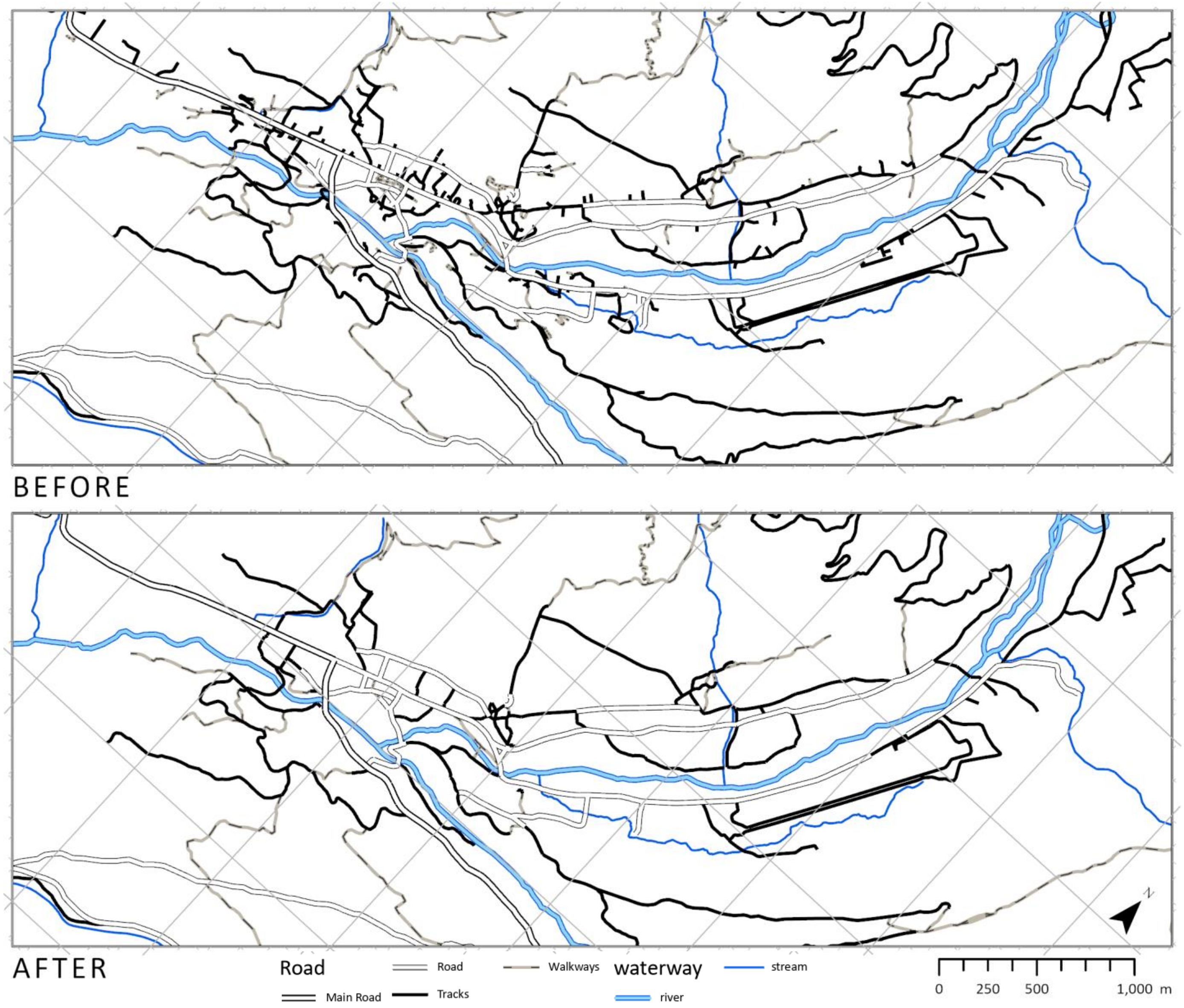


Summary of the implemented work flow.

Highlights.

- Resampling the DEM to 10X10m Grid sizes (Bilinear resampling)
- DEM smoothing with Focal statistics tool for smooth contours

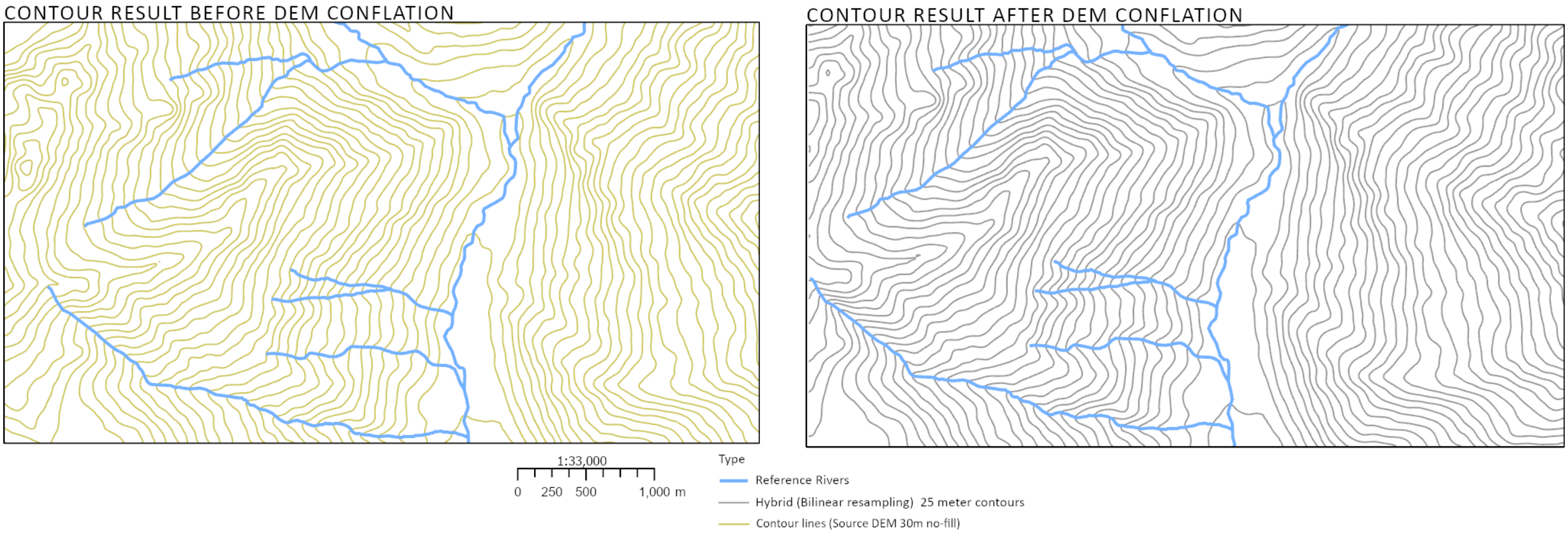
Results - Linear Feature Generalisation



Sample Area viewed before and after generalisation.

- Line feature network is generalised.
- Overlapping conflicts are corrected by the displacement operation.

Results - DEM Conflation for Contour generation and river network matching.

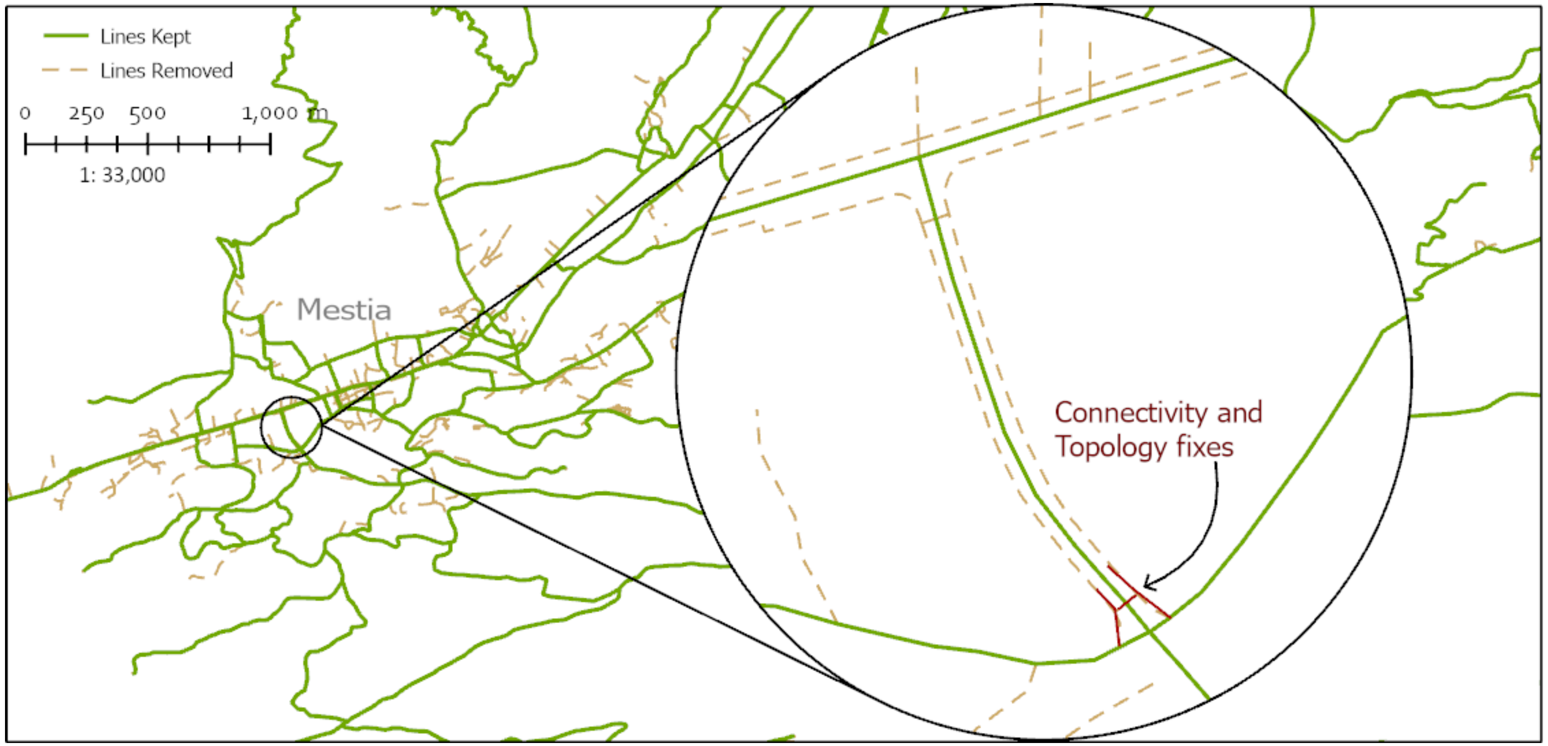


Sample contours comparing before and after conflation of the DEM.

- Improved alignment of the contours to the rivers course.

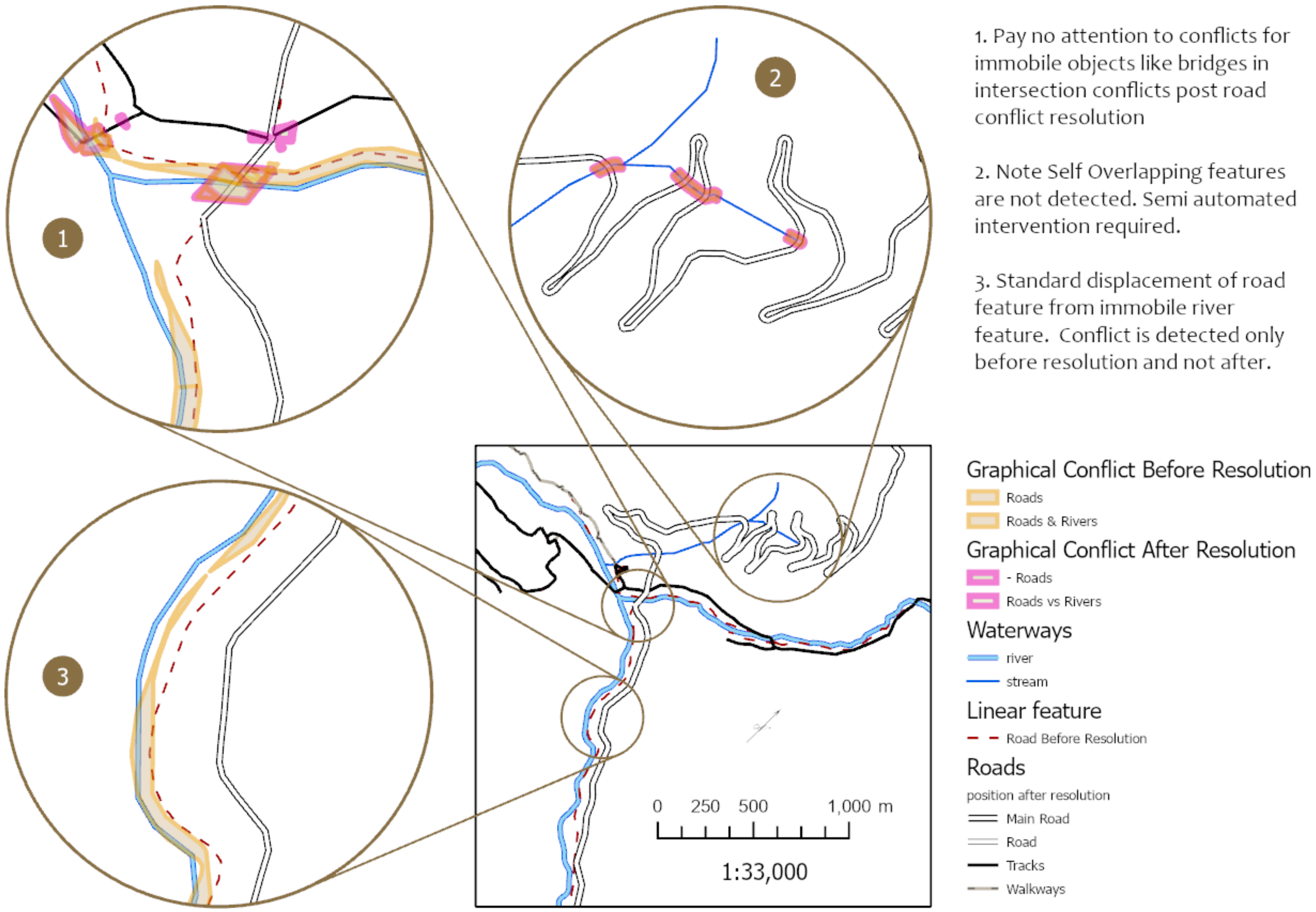
Discussion – Linear feature generalisation

- Network Generalisation
  Quality of the data and topology of the network features is crucial the best results, including removal of parallel features.



Discussion – Linear feature generalisation

- Conflict Detection and Resolution.
  - Detects features with coalescence conflicts with other features
  - Does not detect Self-Overlapping conflicts
  - Displacement only applied to conflicts between different features.

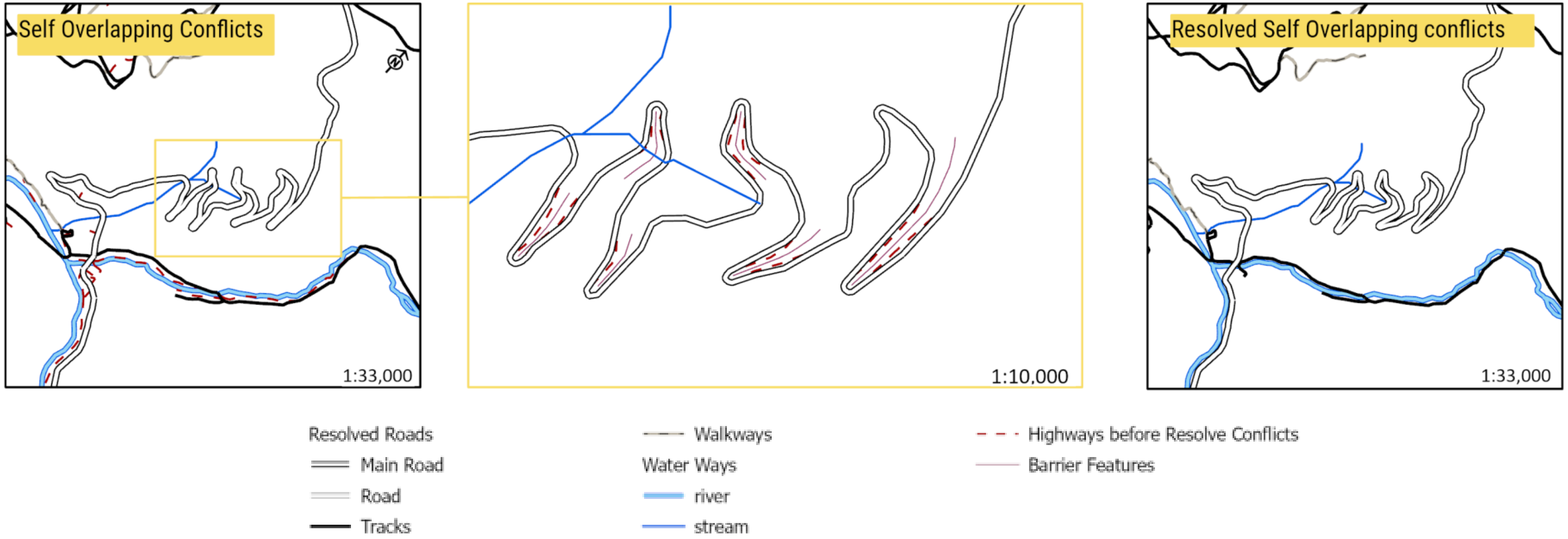


Discussion – Linear feature generalisation

- Conflict Detection and Resolution.
  - Detects features with coalescence conflicts with other features
  - Does not detect Self-Overlapping conflicts

Manual Intervention required

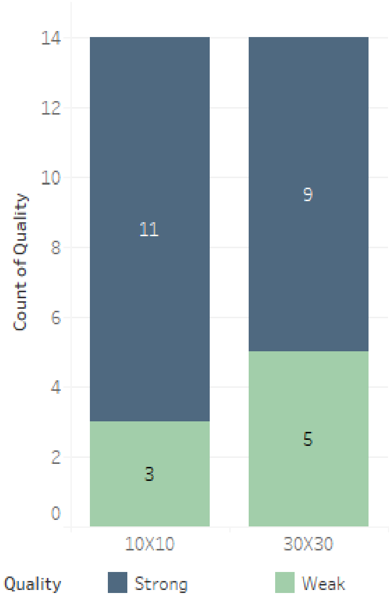
- User directed approach enabled additional components to be added to model i.e.
  – Barrier Features

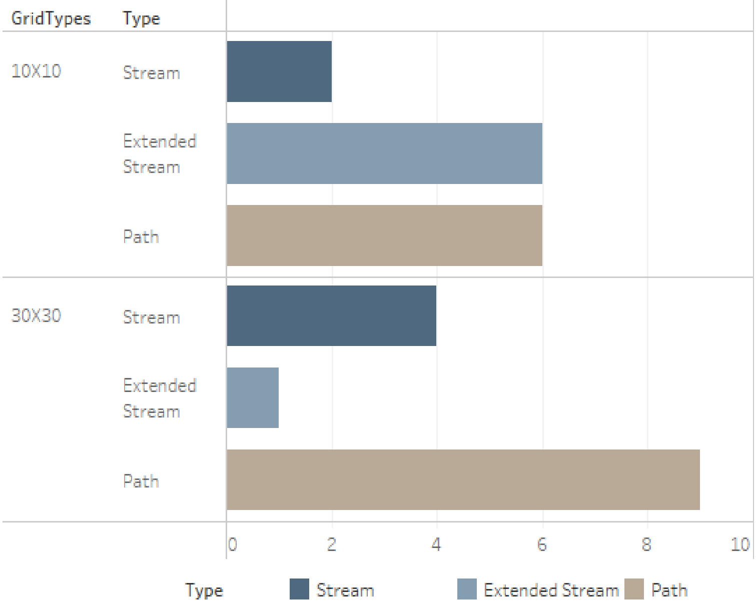


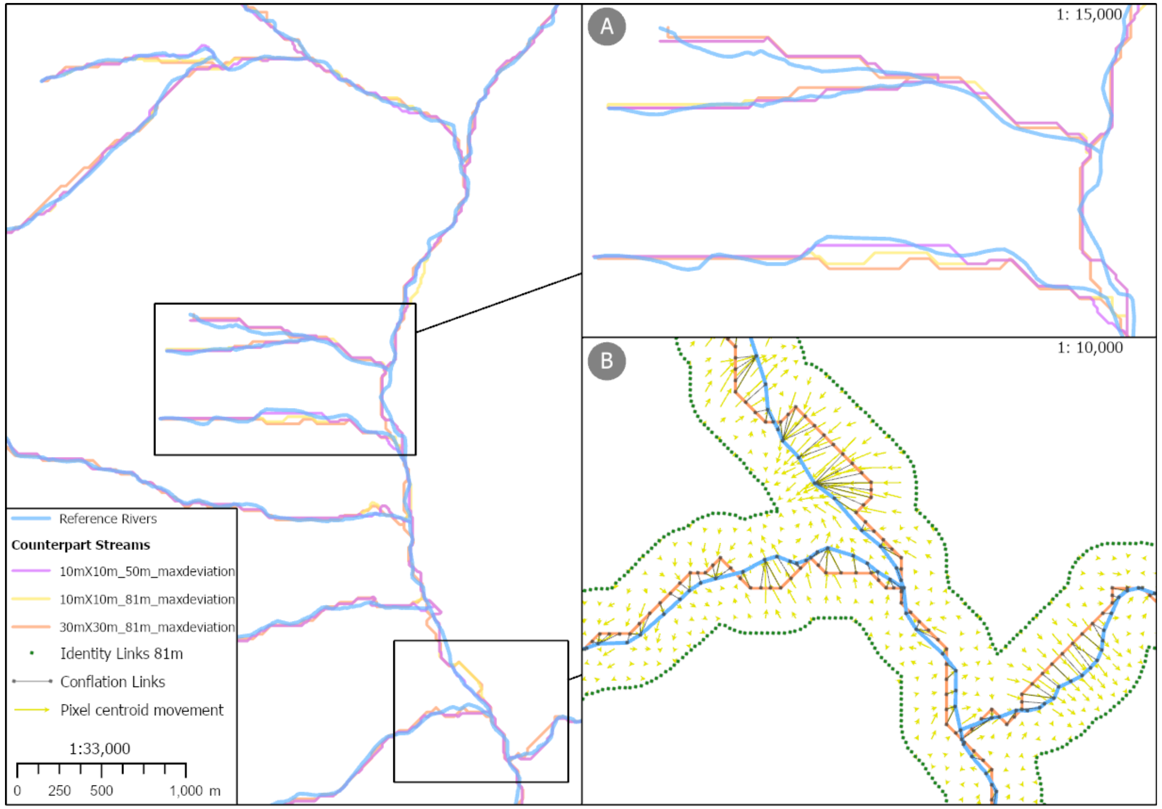
Discussion – Contour generation and River matching

Counterpart Extraction Evaluation

- Iteratively adjust parameters to improve extraction results.

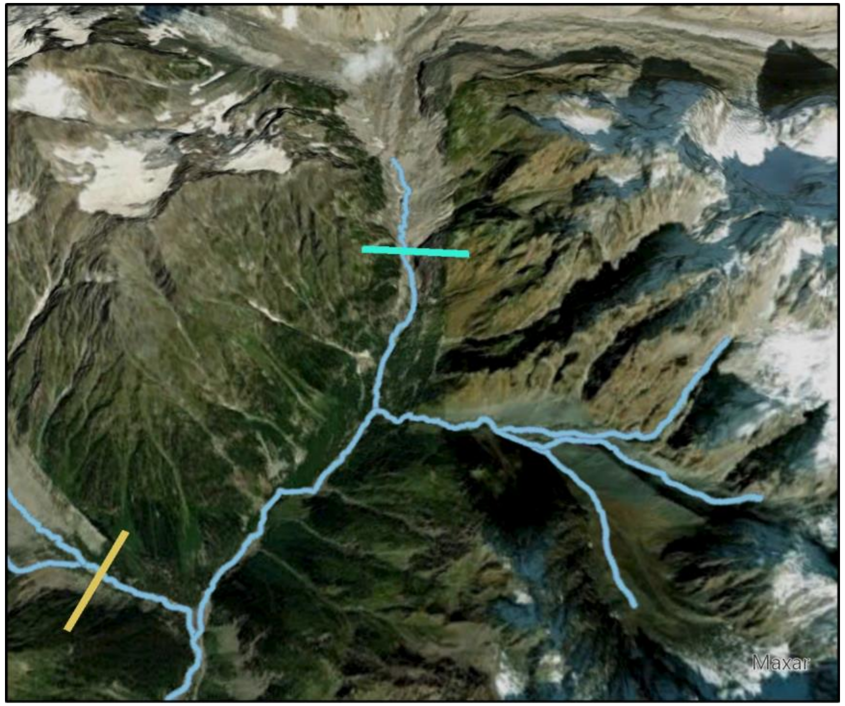




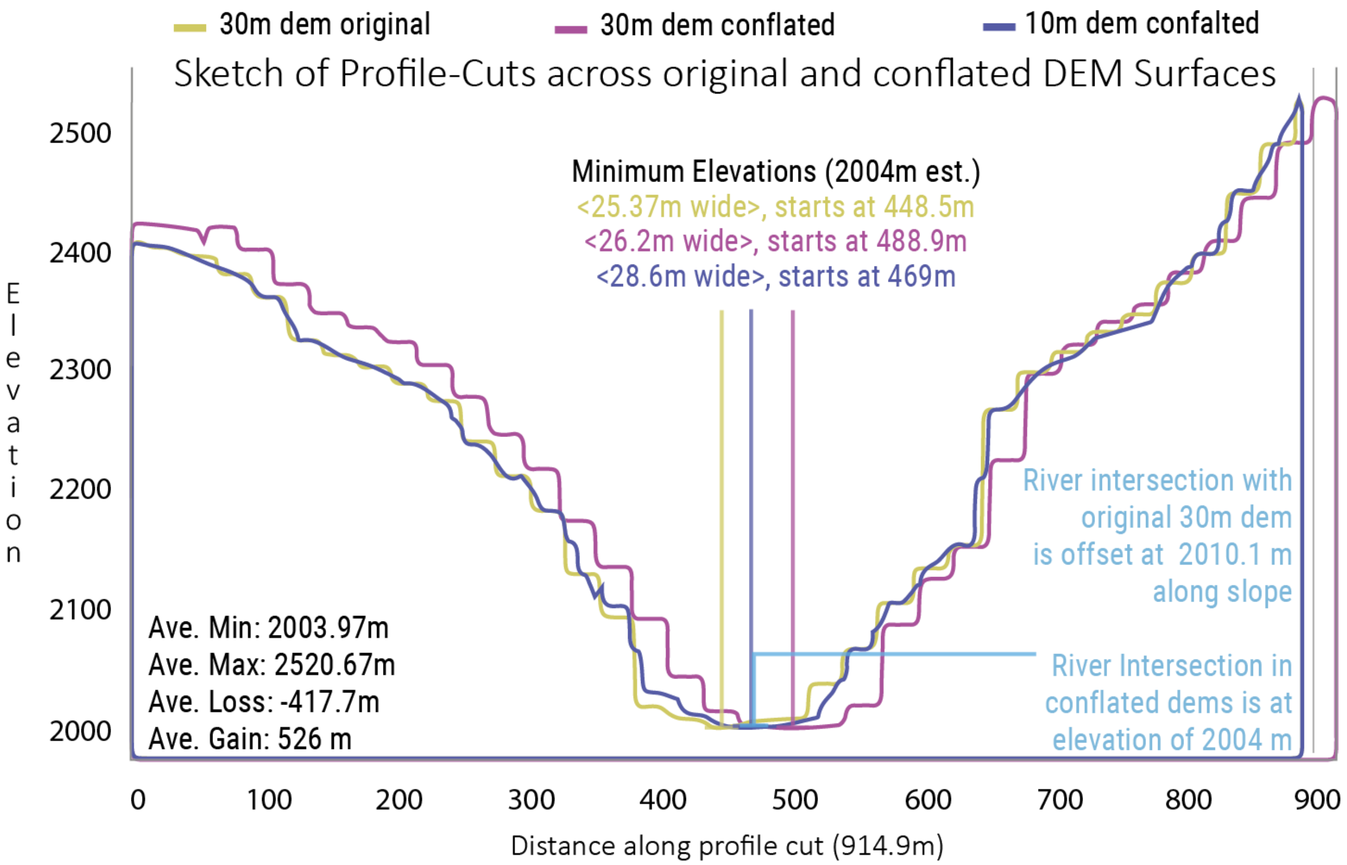


Discussion – Contour generation and River matching

Profile Cut Comparison across all DEM models.



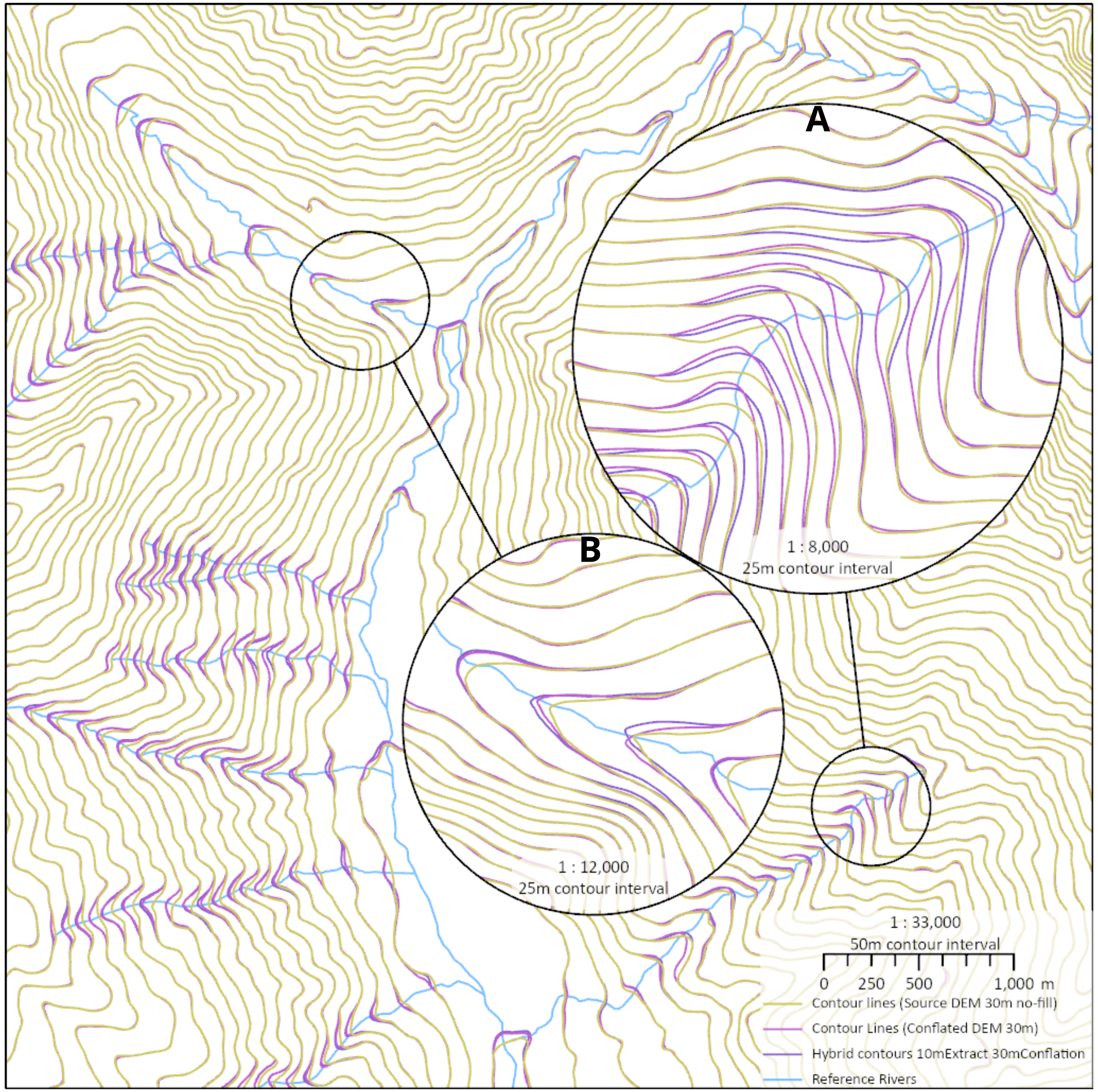
Sampled Profile Cut



Discussion – Contour generation and River matching

Contour Results comparing contours from:

- The source 30m DEM
- Conflated 30m DEM
- Hybrid – Combined 10M DEM
  Counterpart extraction
  with conflated 30m DEM



A) Improved result with hybrid approach.

B) Limited suitability for large scale maps

Conclusions

1. This research shows that user directed generalisation using and optimised constraint based approach was able simplify and refine the road network using the Thin road network tool.

2. In combination with the resolve road conflicts tool and propagate displacement. the approach can also solve coalescence conflicts by making line adjustments / displacements for conflicting features.
   - Additional data inputs ie. Through the use of Barrier features are needed to solve self coalescence conflicts.
   - It's a flexible approach and can be extended to polygon based line features such as river banks.

Conclusions

3. Conflation of DEM surfaces to Reference hydrographic lines can be used to harmonise topographic representations between contours and waterways from heterogenous data sources.
   - There are scale limitations and dependencies that will influence the success of this approach. Therefore it should be limited to small scale maps.
   - Computationally challenging to implement for large areas and fine resolution DEMs (Roughly 1000X1000 pixel limit)
4. Using generalisation tools from ArcGIS and the Python toolbox for conflation a model for generalisation of linear features has been implemented.

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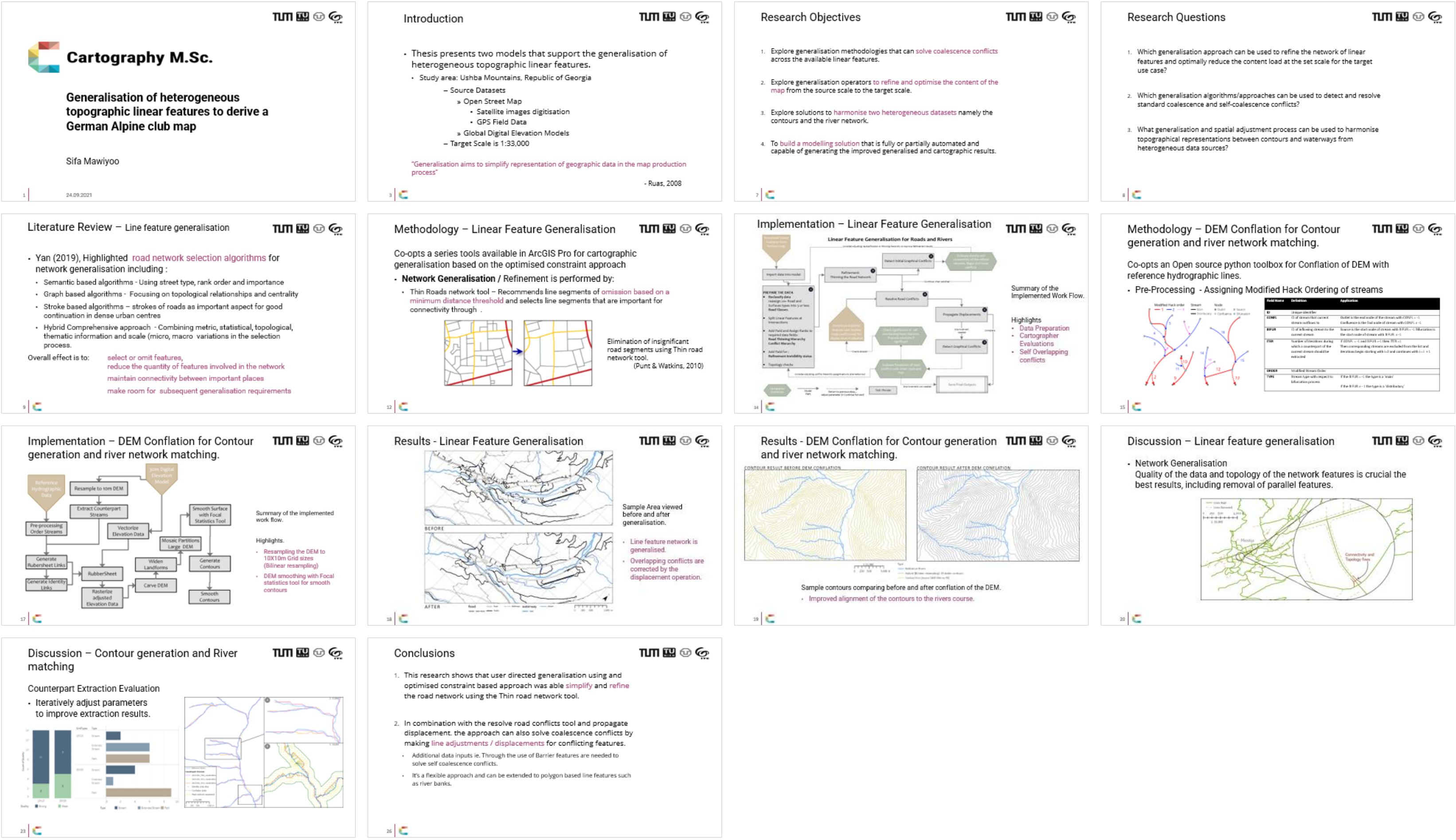
Questions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Discussion – Contour generation and River matching
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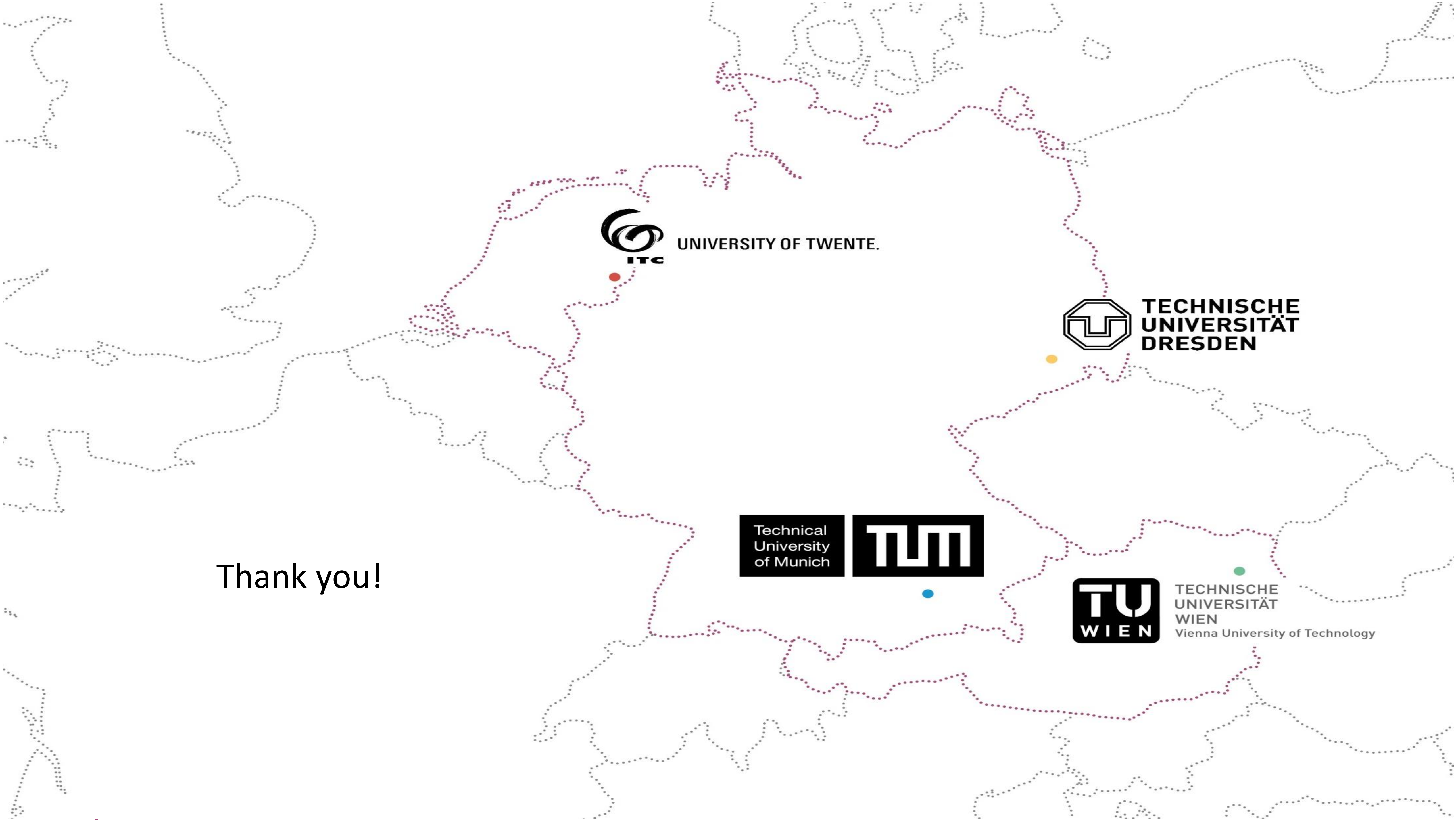
Thank you!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