QUANTM

Changing Technologies

Optimizing Road and Rail Alignments
to meet
Cost and Environmental Constraints

Background

- Quantm is a spin-off from CSIRO, an Australian government research organisation.
- It was formed in 2000 to commercialise research that I had been engaged in for much of the previous decade.
- From 2000 to 2005 it was an independent company and operated as an ASP; during this period the software was converted from a laboratory prototype to a commercial product.
- Earlier this year Quantm was acquired by Trimble Navigation, a U.S. company that specialises in spatial technologies.

Software

- Quantm produces planning software optimises the alignments of roads and railways under scenarios that describe the cost structures and the social, environmental and engineering constraints that have to be met.
- The software consists of two parts:
  - Integrator – which is loaded on computers in the client's offices and allows the user to create the scenarios and review the results.
  - Pathfinder – which resides on a cluster of computers in Quantm's offices and undertakes the optimization.
- Communication between the two is via email or https.

Costs and Constraints

Determining the "best" way to get from A to B subject to:

- A cost regime for:
  - Earthworks
  - Structures
  - Land acquisition and clearing
- Constraints relating to zones:
  - Avoid
  - Different geometries, geologies or cost regimes
  - Altitude or construction requirements
  - Additional costs relating to length or area
- Constraints relating to linear features
  - Width
  - Vertical clearances
  - Type of construction

Deciding Goals

- Before we begin optimizing we need to decide what we are attempting and why.
- It is easy to assume that the goal is obvious and push ahead but we fail to understand the context our efforts will be wasted.
- Why planning rather than design?
- What is the planning process?
- What sorts of constraints are placed on routes? Quantitative? Qualitative?
- How is infrastructure costed?
- How are conflicting constraints handled?

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Planning vs Design

- Both planning and design have substantial subjective elements.
- In planning, the optimal alignment represents a balance between low cost and non-quantitative factors relating to impacts on the environment and the community.
- In design, the optimal alignment represents a balance between low cost and criteria that constitute good design.
- The criteria for an optimal design alignment varies too much between organizations to contemplate automating it and assumes we are stating with a good planning alignment.
- Instead we focus on producing good planning alignments and let designers amend them to meet their criteria.

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Planning Process

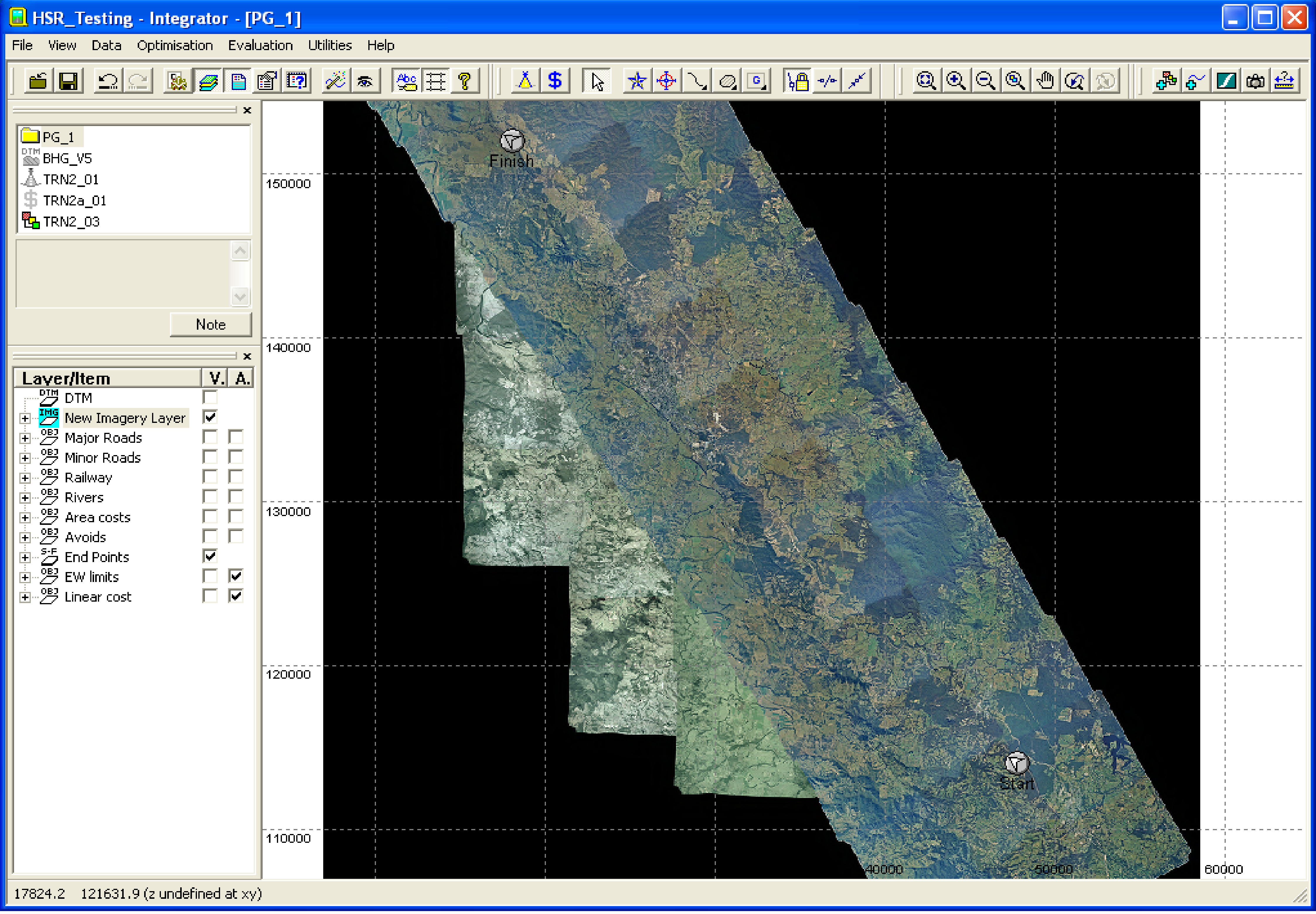
- Road planning has several key questions that are repeated until the answers remain unchanged:
  a) Is a road between A and B necessary/desirable?
  b) What capacity/standard should it be?
  c) What route should it take?
  d) What will it cost?
- Then, because accurate information about costs could have modified earlier decisions, questions a), b) and c) are repeated with cost information included.
- The coarser location of the road is determined by planners on the basis of environmental or social impacts.
- The finer placement is left to the designers because the detail from design provides more accurate estimates of cost.

Importance of Choice

- The alternative to seeking a unique solution, is to produce a selection of low cost alignments which meet the objective criteria, and allow planners (or the community) to select the alignment which represents the optimal balance between low cost and minimal adverse impacts and to customise that alignment if necessary.
- Thus the goal of optimization is not a single alignment but a selection that covers the principal corridors in the study area.
- Some corridors can be significantly more expensive than the best but they may need to be identified for legislative reasons.
- The cost of an alignment can change by up to 15% once the start of construction reveals the true nature of the geology. universal

Data

- Data can come from many sources and take many forms.
  - Aerial imagery
  - Photogrammetry
  - GIS
  - CAD
- It reduces to four basic categories:
  - Terrain
  - Geometric standards
  - Construction costs and standards
  - Geographic objects imposing constraints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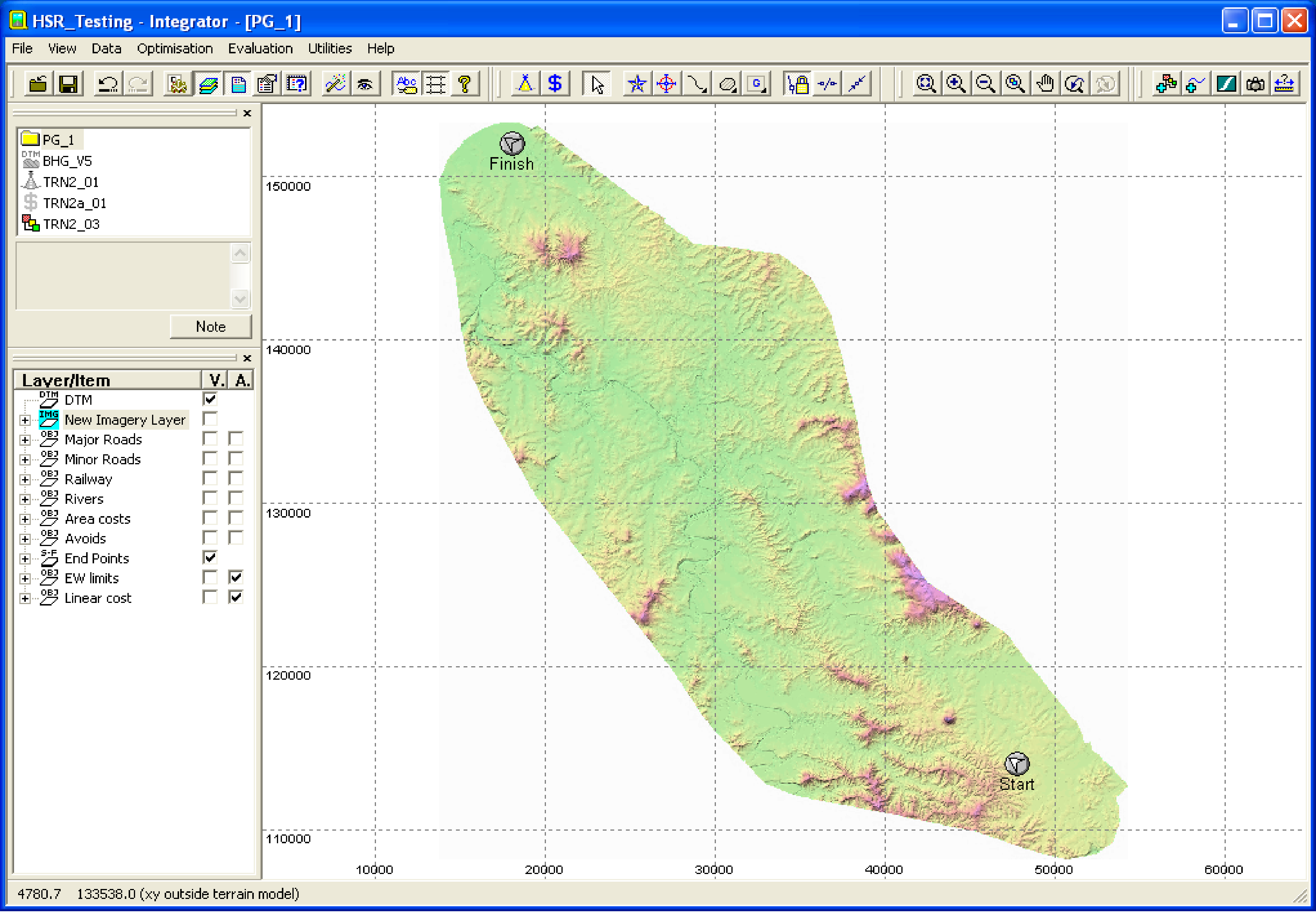
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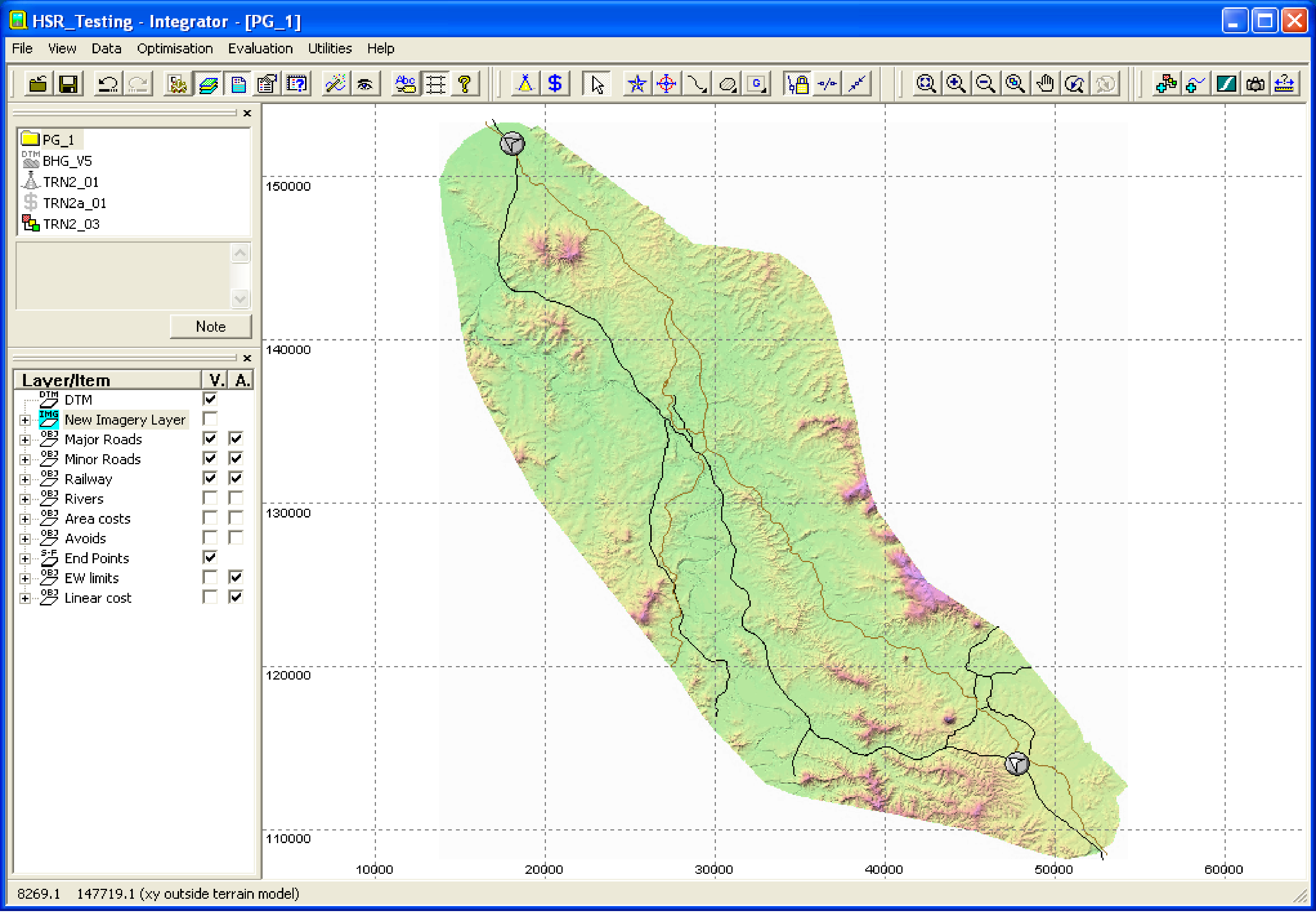
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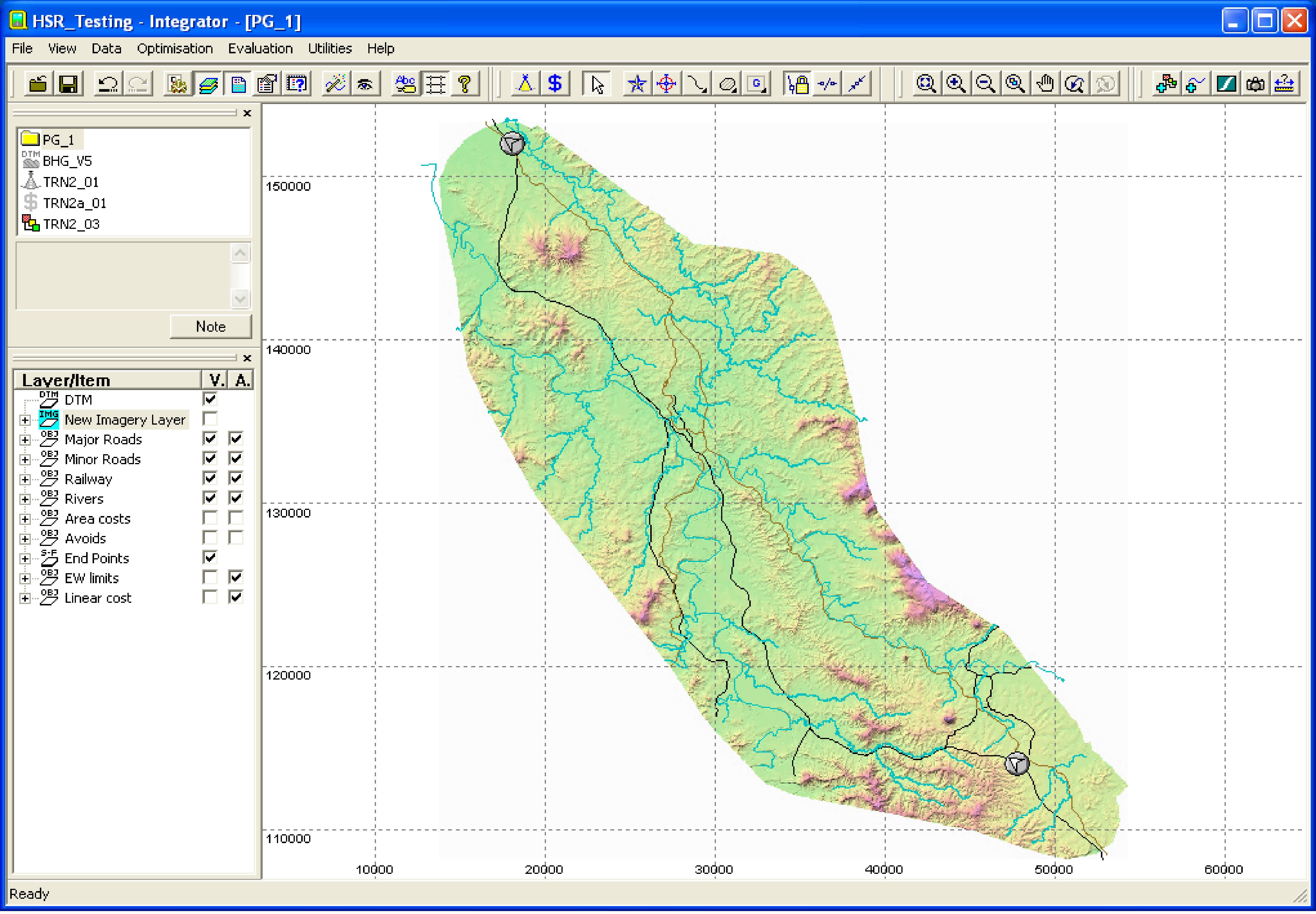

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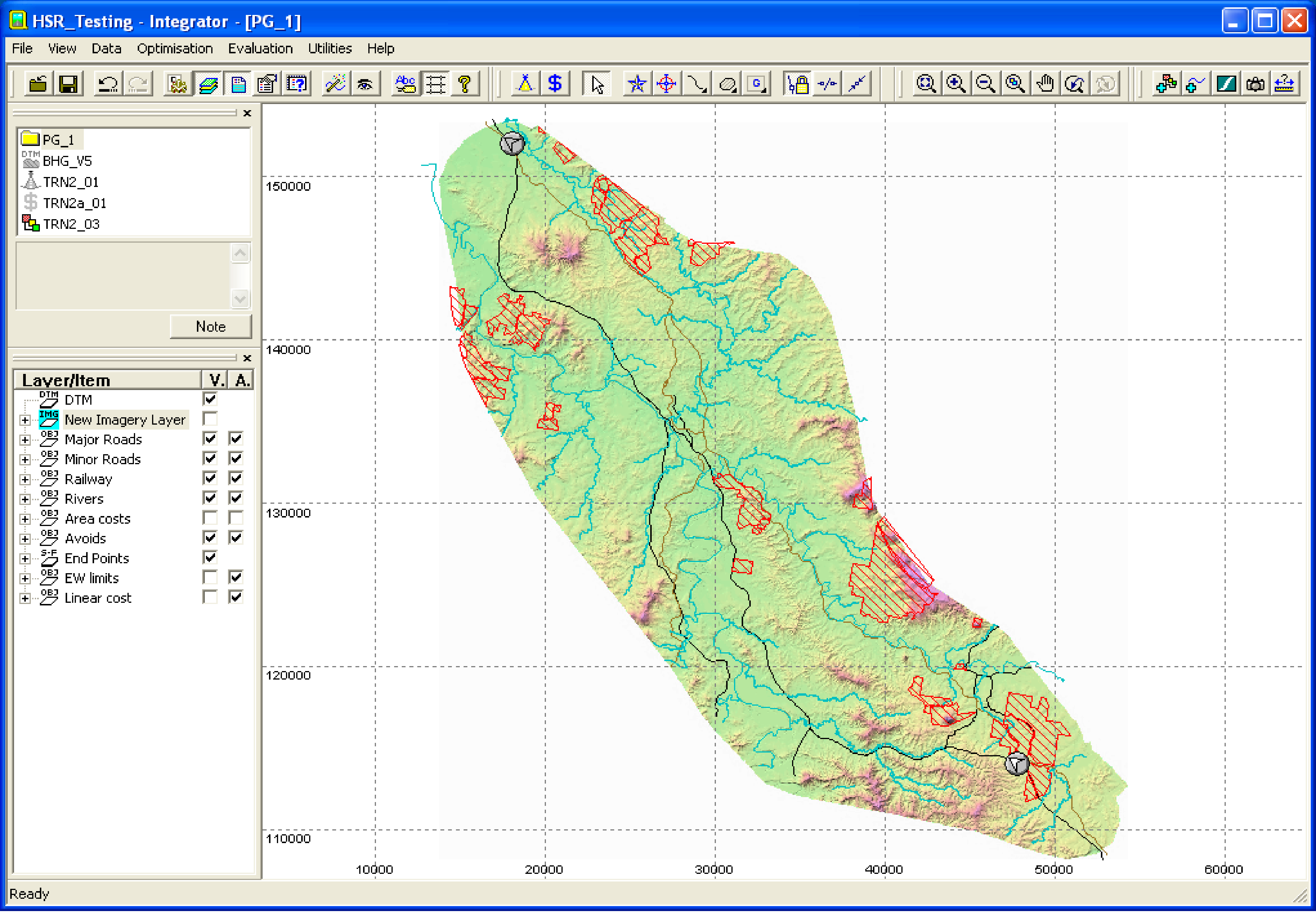
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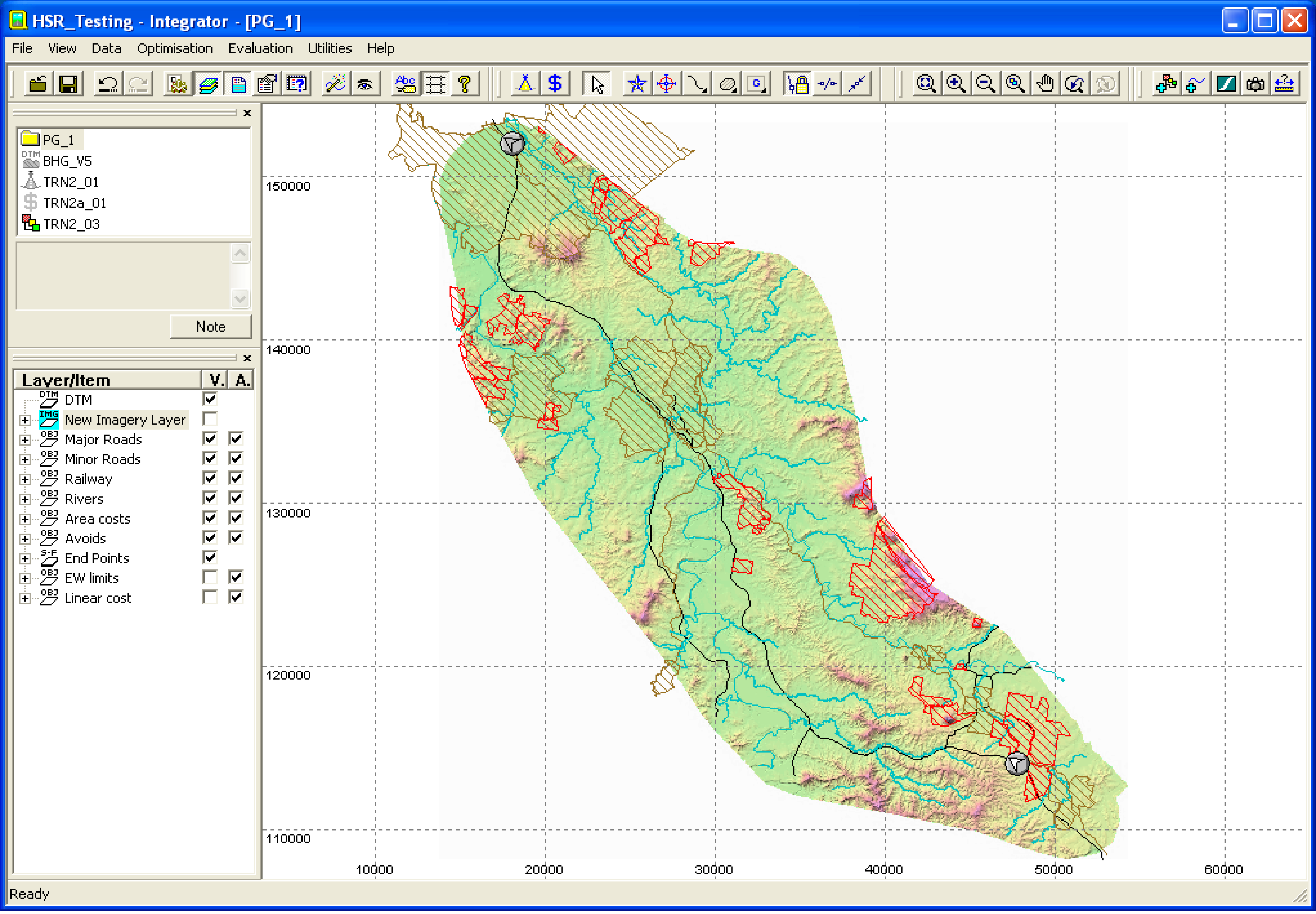

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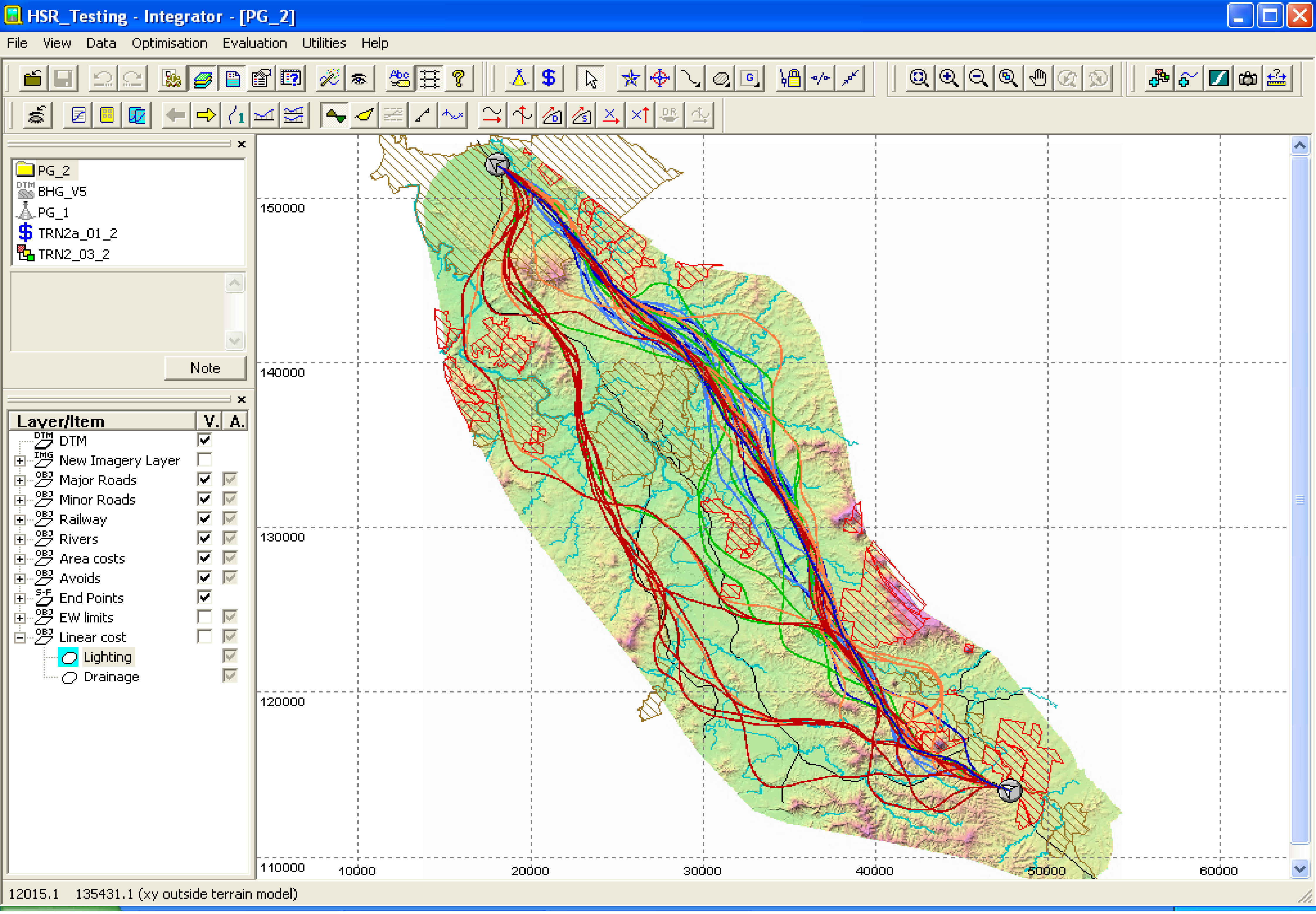
Important Issues

- Data consistency
  - The centreline of the streams in the example are sometimes 7 or 8 m above the land.
- Level of detail
  - 15,000 points defining the boundary of a zone.
  - Every building in the study area.
- Constraint consistency
  - Overlapping zones specifying different geologies
- The existence of feasible alignments
  - Avoid zones prevent any complying alignment

Handling Subjective Issues

There are two basic strategies that can be followed:

- Quantify the subjective aspects and incorporate the resulting values in an objective function. However:
  - While it may be possible to allocate a monetary value to each square metre of a National Park based on the impact that the alienation of that square metre would have, it is more difficult to value the impact of the alignment on the contiguity of the Park.
  - Any interested party that disagrees will contest the values assigned to the subjective factors.
- Produce multiple alignments and choose between them on subjective grounds. If an environmental conflict exists, investigate the costs of avoiding the sensitive area completely. If this is considered excessive, investigate compromises.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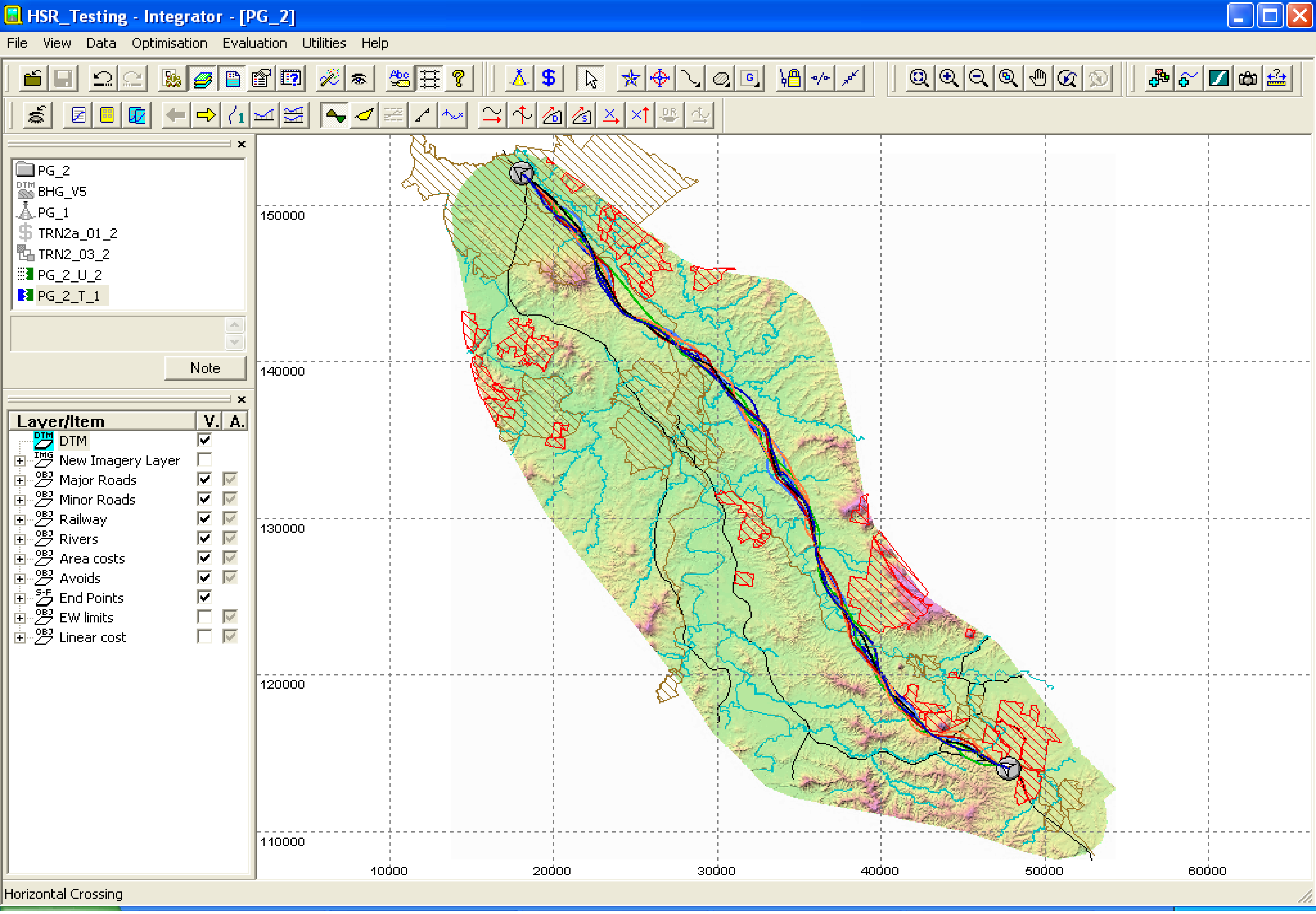
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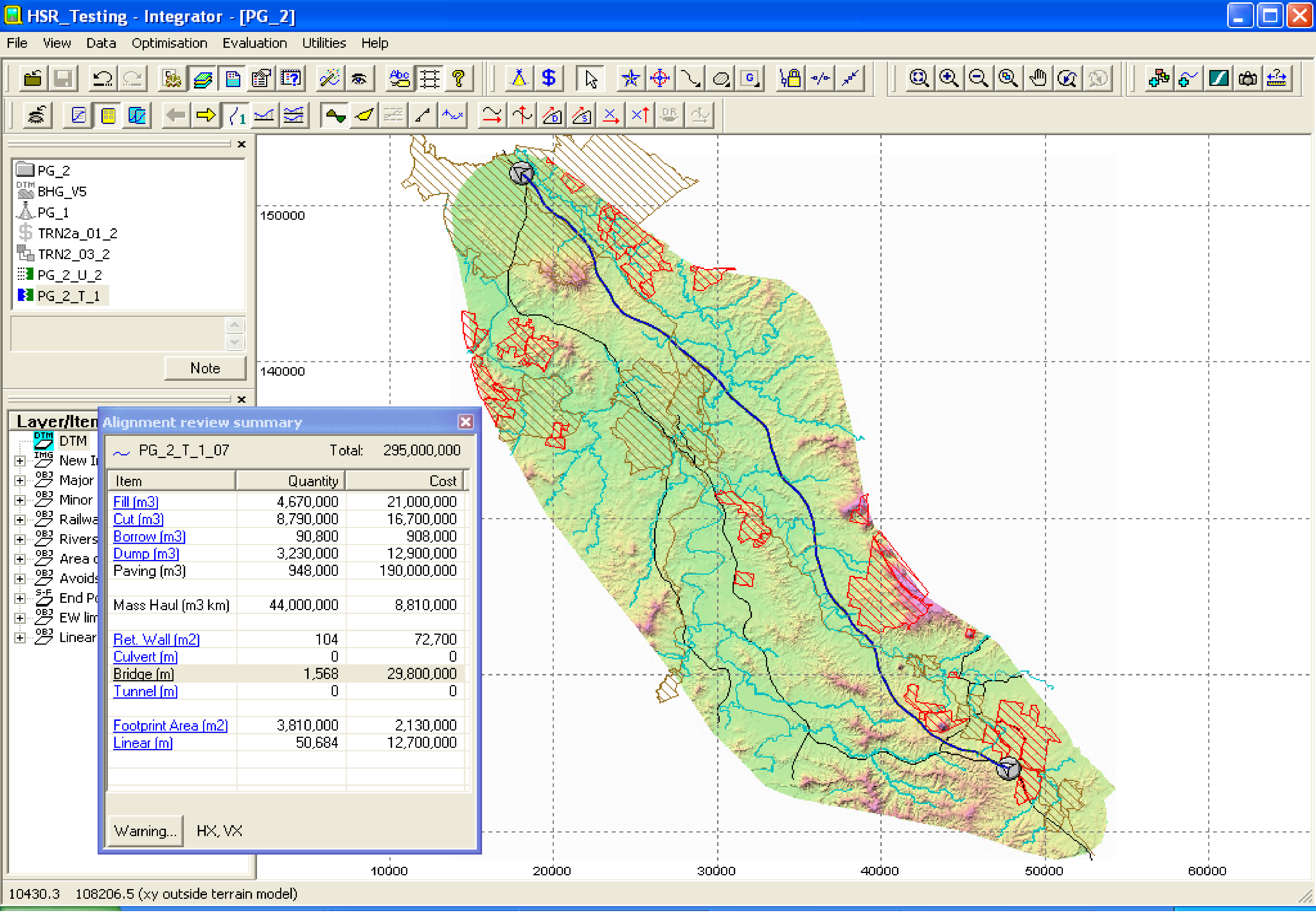
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Borrow (m3) 90,800 908,000
Dump (m3) 3,230,000 12,900,000
Paving (m3) 948,000 190,000,000
Mass Haul (m3 km) 44,000,000 8,810,000
Ret. Wall (m2) 104 72,700
Culvert (m) 0 0
Bridge (m) 1,568 29,800,000
Tunnel (m) 0 0
Footprint Area (m2) 3,810,000 2,130,000
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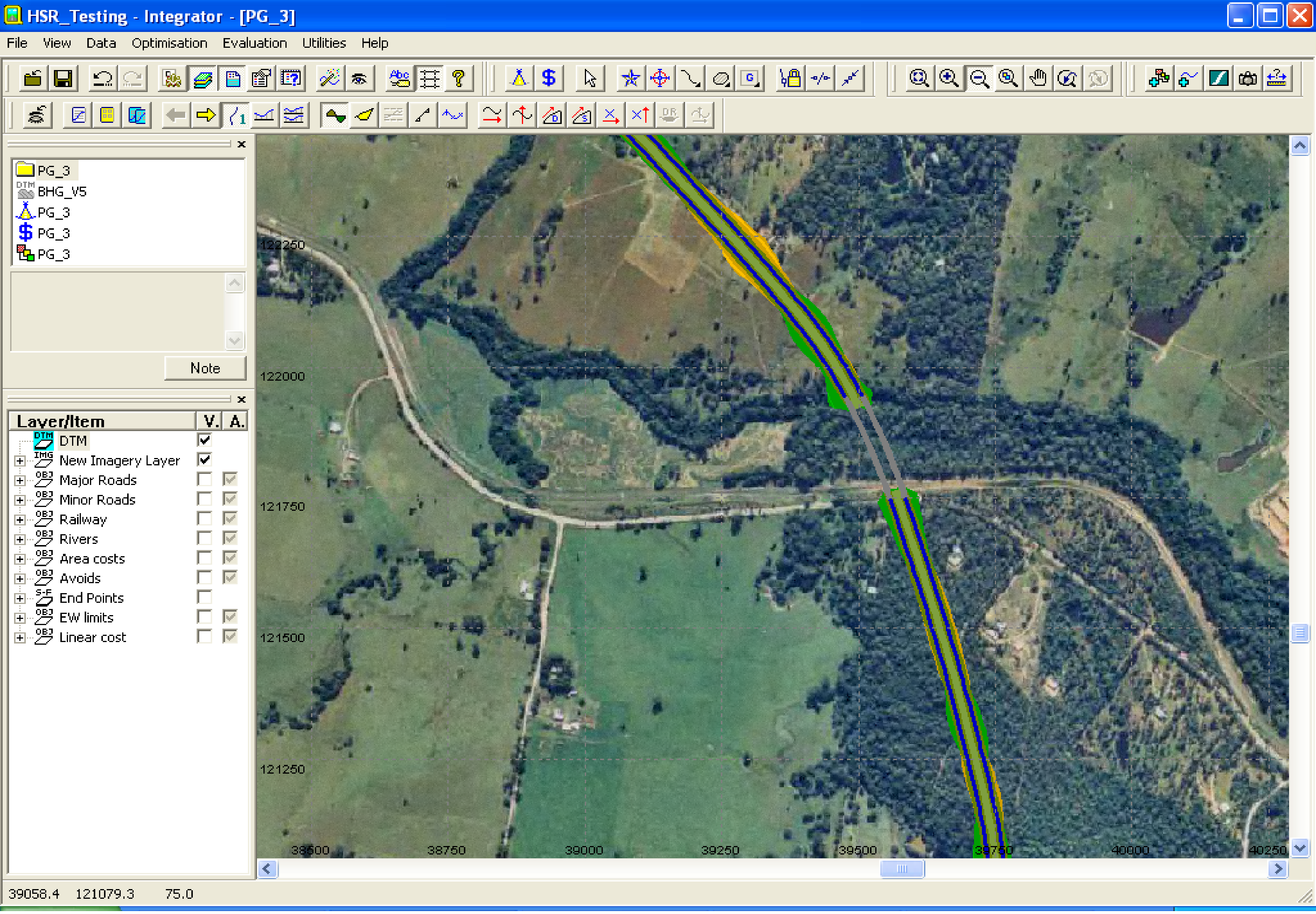
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Planning and Subjectivity

- Many planning issues are contentious and political.
  - What value that can be placed keeping a freeway out of sight from a scenic lookout?
  - What is the social cost of land acquisition?
  - What is the environmental impact of intruding into a national Park.
- Subjectivity means that it is highly unlikely that an alignment will be accepted as optimal by everyone.

Method of Optimization

Quantm uses stochastic optimisation. This provides:

- Robustness and Extensibility
  - The model works with a large range of data sets and accommodates new types of constraints without major rewrites.
- Speed
  - Stochastic optimisation is fast compared with conventional methods.
- Variable Focus
  - A study may begin with crude data, and add detail as the increasing focus justifies the cost of collecting the data.
- Choice
  - Multiple solutions allow planners to balance objective costs and subjective assessments.
- Reliability
  - The system explores the whole study area and consistently produces low cost alignments that are unbiased by preconceptions.

Pros and Cons

- Construction costs can be as much as 20 or 30% less those produced by conventional means (depending in the terrain).
- They are produced in a fraction of the time required by conventional methods.
- Alignments are curvilinear (ie no straights) which disturbs some designers/surveyors. However,
  - They are a good starting point for design although several % of the saving may be lost.
  - We are looking at optimizing geometric alignments.
  - Computer controlled earthmoving equipment has no problems with curvilinear alignments.