

## Layout Optimization – what are we optimizing and how?

30<sup>th</sup> January 2013



# Introduction

Layout optimization – working out where to place your turbines for best effect - is a complex, multi-disciplinary task.

Considerations are by turn (in no particular order):

- Geographical;
- Environmental;
- Political;
- Regulatory;
- Subjective;
- Aesthetic;
- Scientific;
- Commercial.
- ...

# What are we optimizing?

Within the constraints of the physical situation of the project and the regulations in effect at that location, we seek to optimise the following:

- Financial returns (high):
  - ✓ Energy yield (high)
  - ✓ Construction and running costs (low)
  - ✓ Tax and other incentives
- Local acceptance of the project (“good”).
- Environmental impact of the project (low).

An iterative process that may not have a single “best” solution.

## Fixed constraints to layout design - challenge

Generally fall under Acceptance and Environmental categories; factors not affected by the layout itself:

- **Physical:** Slopes, vegetation/fauna, land ownership, existing structures
- **Regulatory:** Typically, exclusion zones of fixed dimensions from some dwellings, roads, water bodies, electromagnetic communications, flight paths sites of archeological significance etc.
- **Expectation:** straight rows of turbines may be expected and fit in better with local land use patterns (along field boundaries, away from ploughing or other machinery such as Center-Pivot Irrigation systems); land owner X wants Y turbines on his land etc.

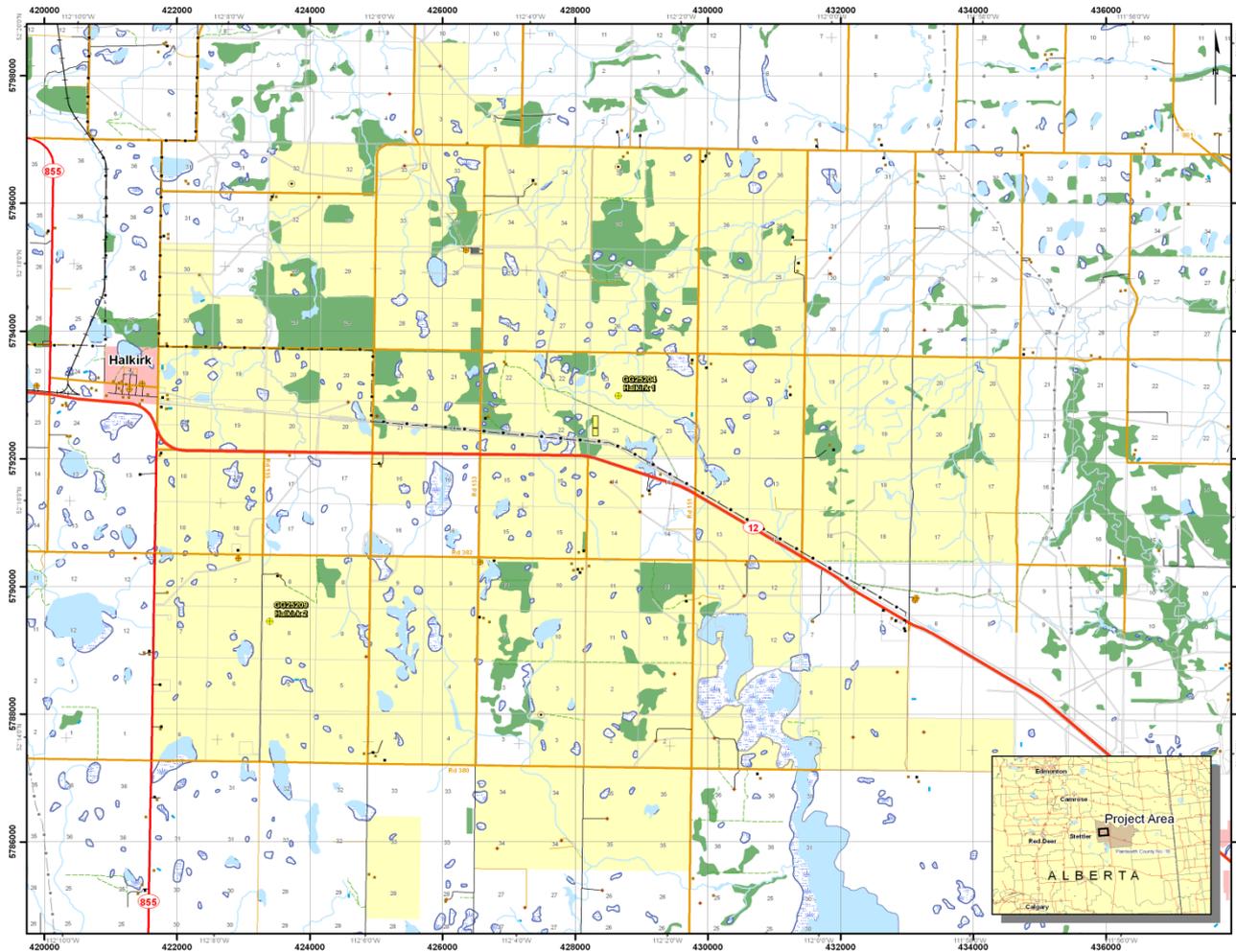
# Fixed constraints to layout design - approaches

Fairly straightforward

- Early-stage constraint mapping exercise;
- timely Environmental Impact study.

An example from our GIS team:

# Spatial Analysis Example (1/5) – Base Data



### Legend

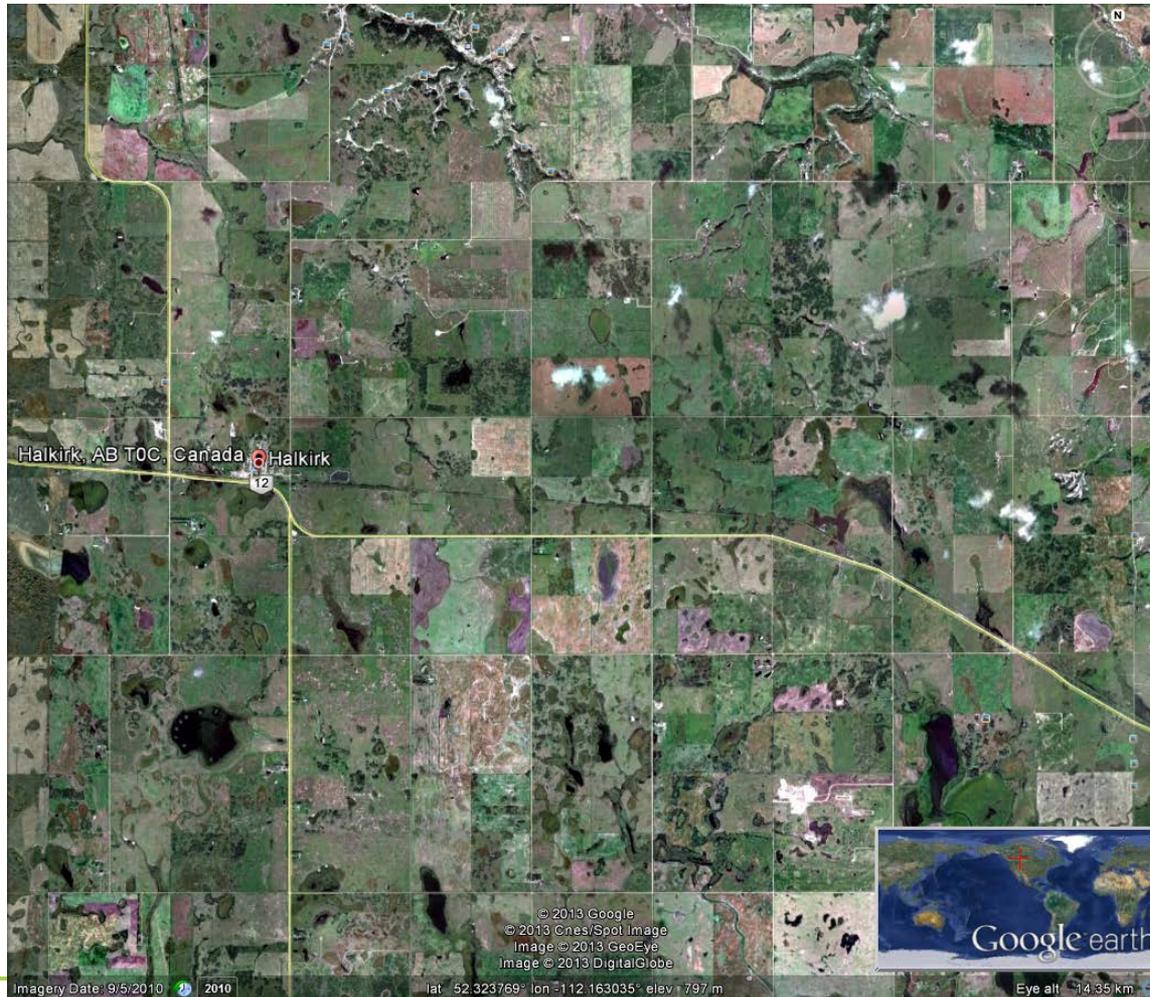
	Wind Turbine (100)		Non-Dwelling (200 m)
	Meteorological Tower		Dwelling On Site (256 m)
	Substation		Dwelling Off Site (640 m)
	Dwelling		Radiocommunication Tower (150 m)
	Other Building		Transmission Line (150 m)
	Radiocommunication Tower		Oil/Gas Pump (75 m)
	Wildlife Habitat		Oil/Gas Plant (150 m)
	Oil/Gas Pump		Pipeline (40 m)
	Transmission Line		Highway (200 m)
	Highway 12		Highway 12 (300 m)
	Road-Paved		Road (72 - 132 m)
	Road-Gravel		Trail (52 m)
	Road-Unimproved		Wildlife Habitat (500 - 1000 m)
	Truck-Trail		Archaeological Site
	Trail		Waterbody, Watercourse, Wetland and Liquid Depot (100 m)
	Pipeline		Geotechnical Constraint
	Stream / Ditch		Built-up Area (1000 m)
	Cadastral Limit (Property Line)		Cadastral Limit (Property Line - 52 m)
	Contour (interval: 10 m)		Right-of-way
	Built-up Area		Oil/Gas Plant
	Liquid Depot		Highway 12 (800 m)
	Vegetation		Radiocommunication Tower (1000 m)
	Wetland		Microwave Link
	Waterbody		Hallport (4000 m)
	Acquired Land		Coal Agreement

**Halkirk Wind Project**

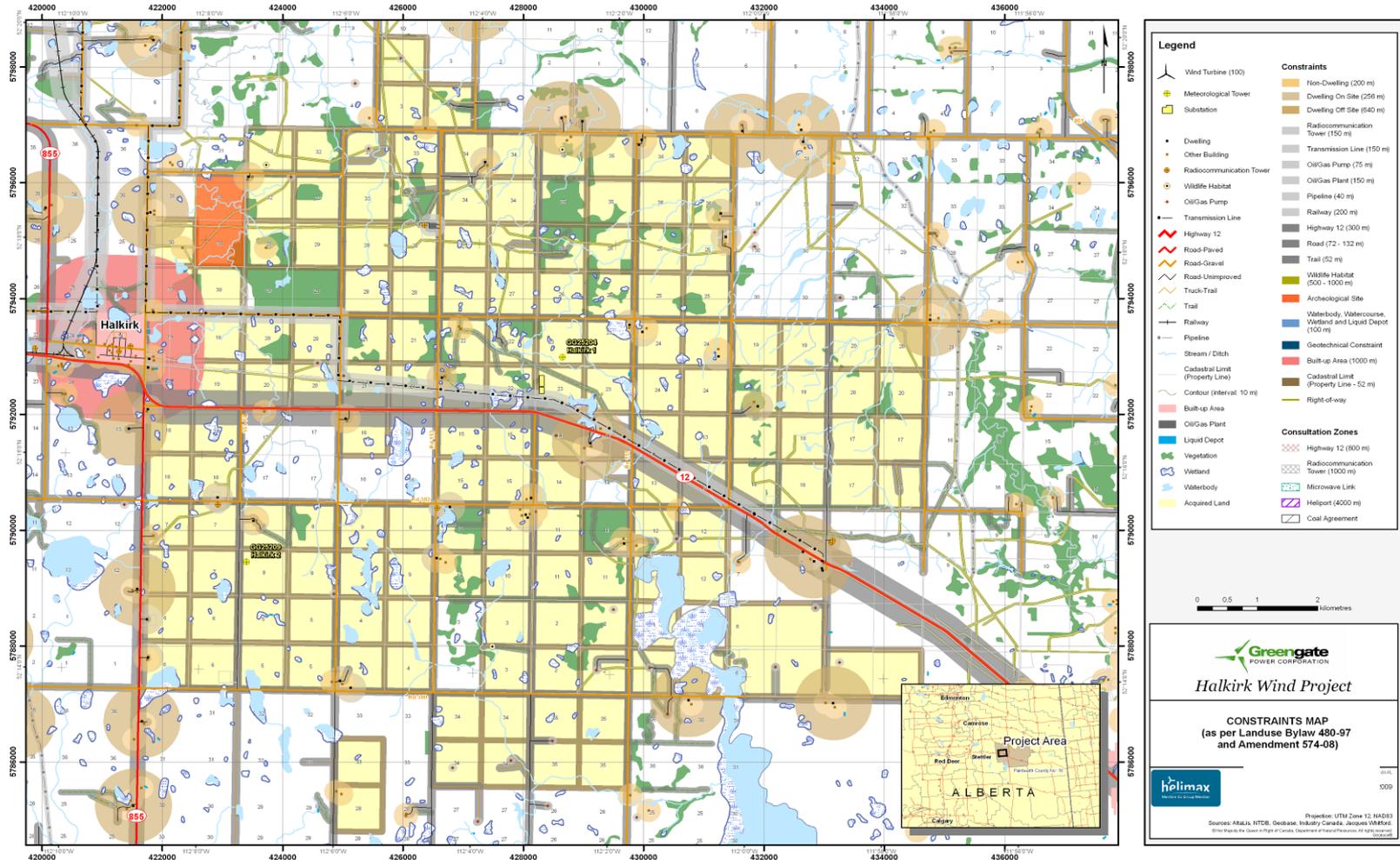
**CONSTRAINTS MAP**  
(as per Landuse Bylaw 480-97 and Amendment 574-08)

Projection: UTM Zone 12, NAD83  
Sources: Atlas, ITDB, Geodata, Industry Canada, Jacques Whitford, etc. Maps by Geomatics Canada, Department of Natural Resources, etc.

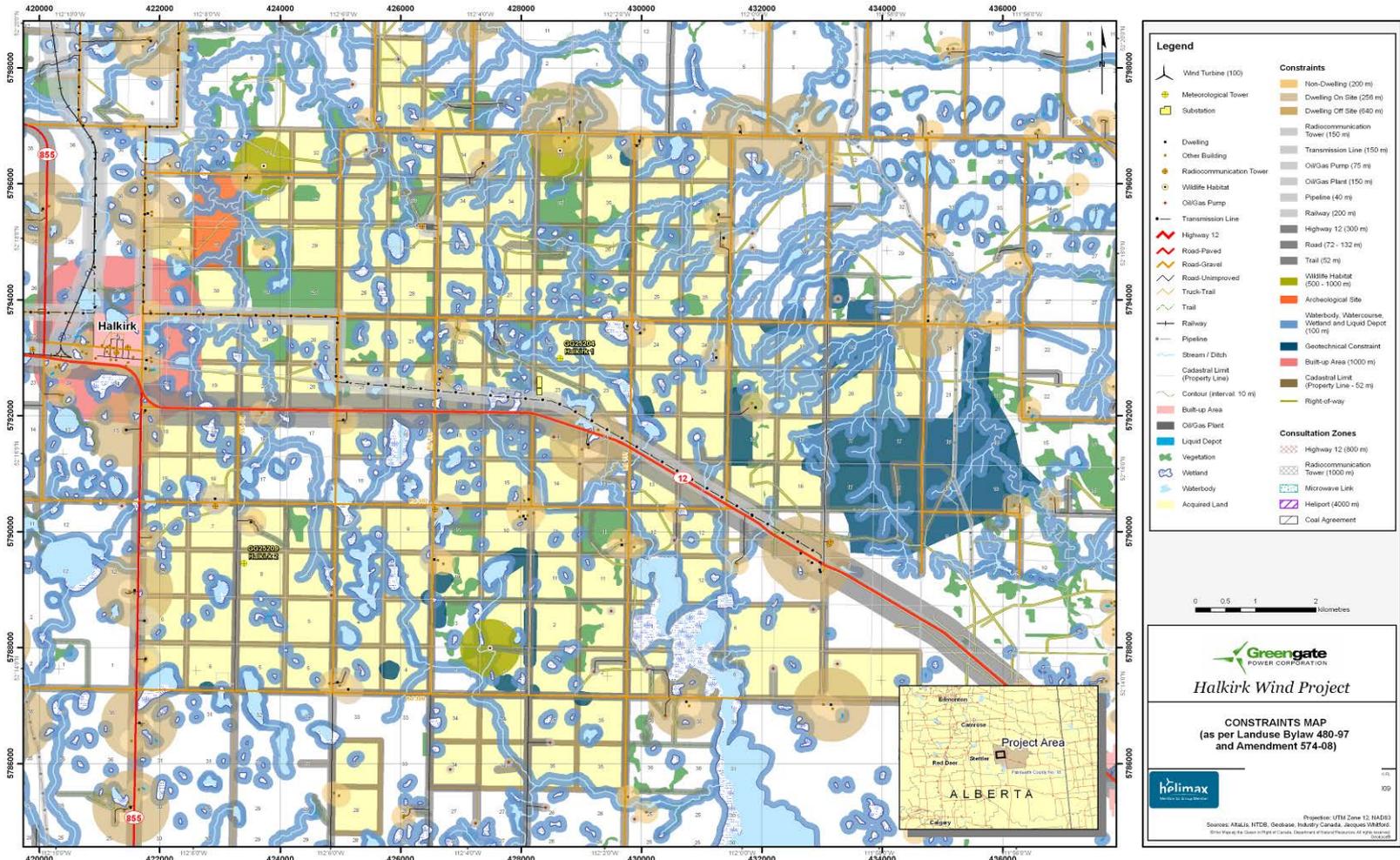
# Spatial Analysis Example(1a/5) - Photograph



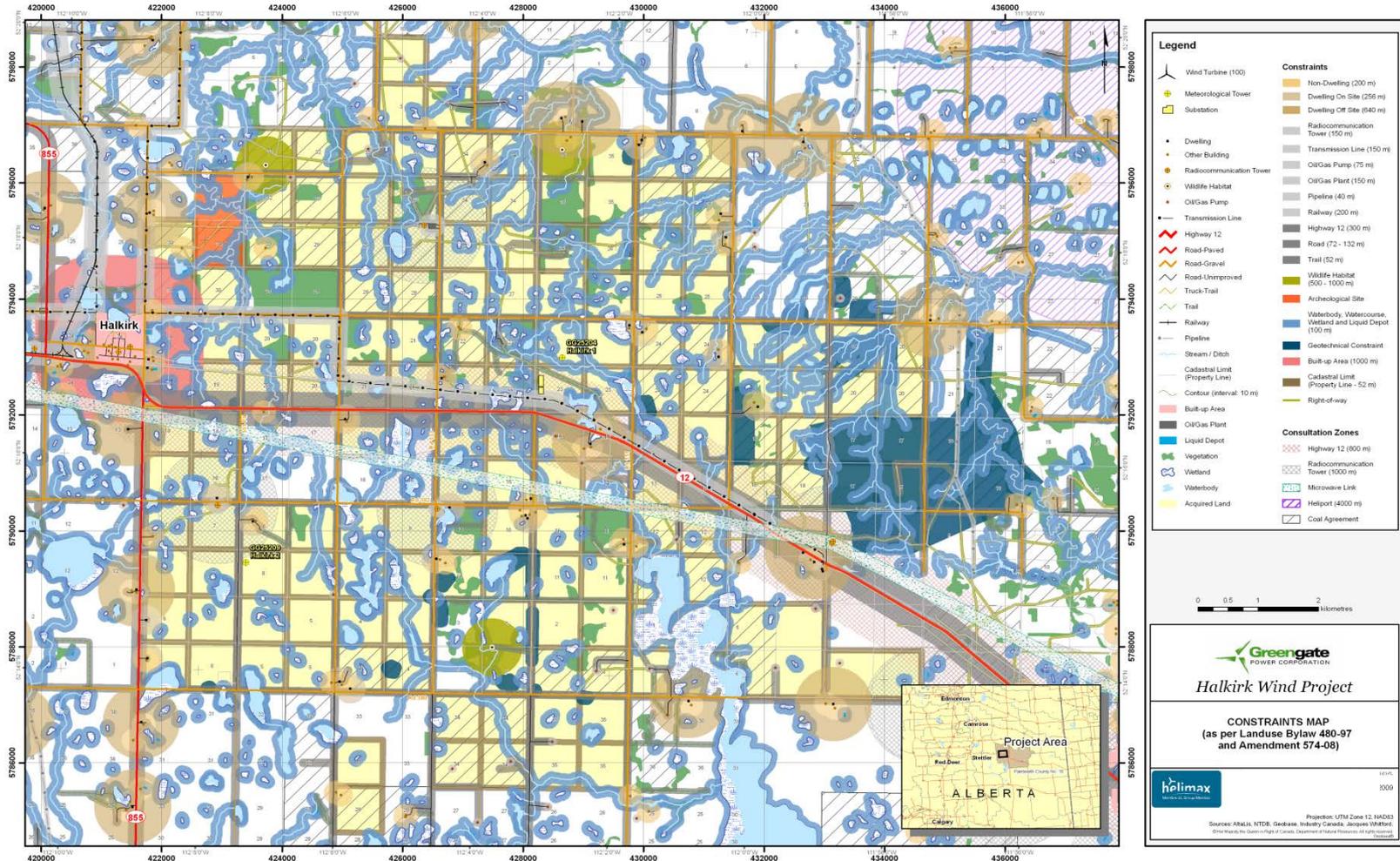
# Spatial Analysis Example (2/5) – Human constraints



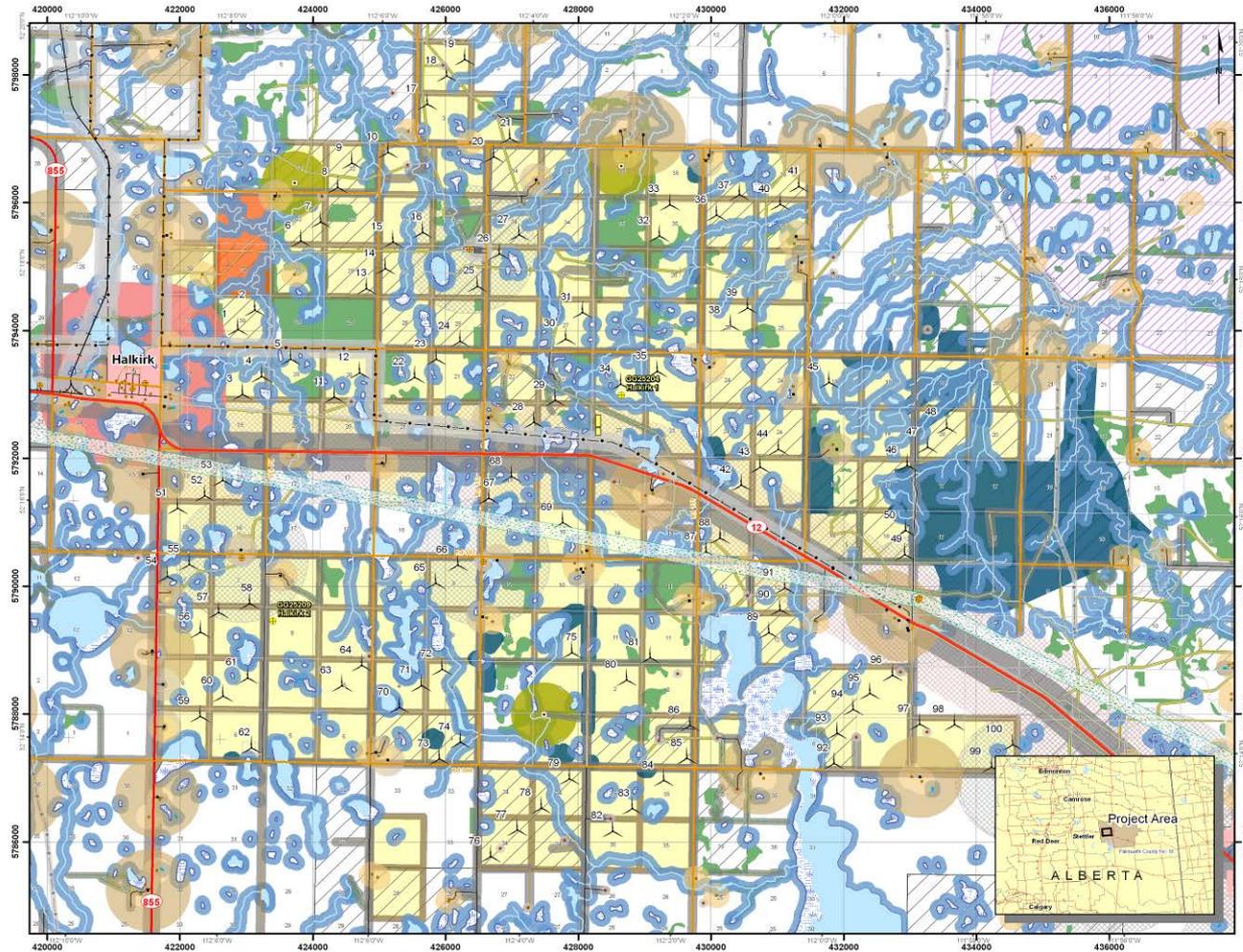
# Spatial Analysis Example (3/5) – Biophysical constraints



# Spatial Analysis Example (4/5) – Consultation zones



# Spatial Analysis Example (5/5) – Layout!



**Legend**

<ul style="list-style-type: none"> <li> Wind Turbine (100)</li> <li> Meteorological Tower</li> <li> Substation</li> <li> Dwelling</li> <li> Other Building</li> <li> Radiocommunication Tower</li> <li> Wildlife Habitat</li> <li> Oil/Gas Pump</li> <li> Transmission Line</li> <li> Highway 12</li> <li> Road-Paved</li> <li> Road-Gravel</li> <li> Road-Unimproved</li> <li> Truck-Trail</li> <li> Trail</li> <li> Railway</li> <li> Pipeline</li> <li> Steam / Ditch</li> <li> Cadastral Limit (Property Line)</li> <li> Contour (Interval: 10 m)</li> <li> Built-up Area</li> <li> Oil/Gas Plant</li> <li> Liquid Depot</li> <li> Vegetation</li> <li> Wetland</li> <li> Waterbody</li> <li> Acquired Land</li> </ul>	<p><b>Constraints</b></p> <ul style="list-style-type: none"> <li> Non-Dwelling (200 m)</li> <li> Dwelling On Site (255 m)</li> <li> Dwelling Off Site (640 m)</li> <li> Radiocommunication Tower (150 m)</li> <li> Transmission Line (150 m)</li> <li> Oil/Gas Pump (75 m)</li> <li> Oil/Gas Plant (150 m)</li> <li> Pipeline (40 m)</li> <li> Railway (200 m)</li> <li> Highway 12 (300 m)</li> <li> Road (72 - 132 m)</li> <li> Trail (52 m)</li> <li> Wildlife Habitat (500 - 1000 m)</li> <li> Archeological Site</li> <li> Waterbody, Watercourse, Wetland and Liquid Depot (100 m)</li> <li> Geotechnical Constraint</li> <li> Built-up Area (1000 m)</li> <li> Cadastral Limit (Property Line - 52 m)</li> </ul> <p><b>Consultation Zones</b></p> <ul style="list-style-type: none"> <li> Highway 12 (800 m)</li> <li> Radiocommunication Tower (1000 m)</li> <li> Microwave Link</li> <li> Heliport (4000 m)</li> <li> Coal Agreement</li> </ul>
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0 0.5 1 2 Kilometres

**Halkirk Wind Project**

**CONSTRAINTS MAP**  
(as per Landuse Bylaw 480-97 and Amendment 574-08)

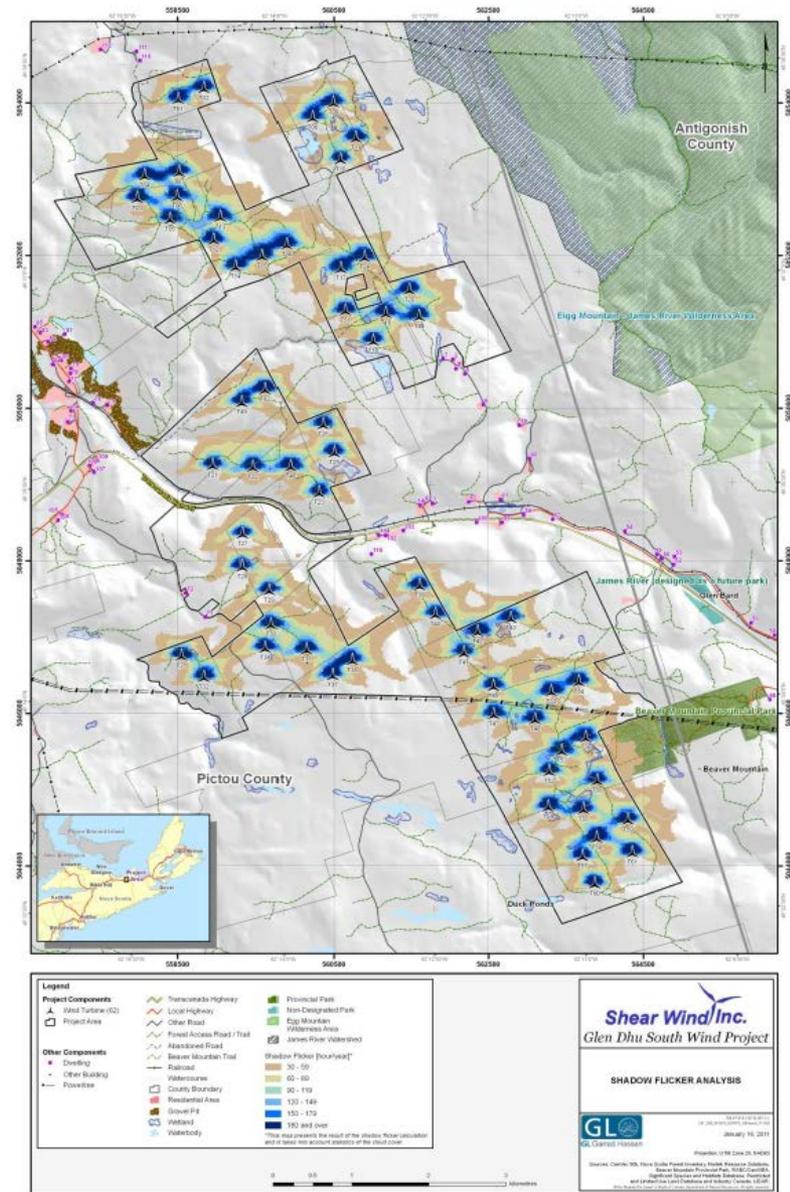
Prepared: UTM Zone 12, NAD83  
 Sources: ATLAS, NTCB, Geobase, Industry Canada, Jacques Villeneuve  
 Other Maps: the Queen's Institute of Canada, Department of Natural Resources. All rights reserved.



# Layout-dependent factors - approaches

- Early stage assessments of these factors with various turbine and layout options under consideration to check for compliance with relevant regulations;
- Monitor ongoing changes to the applicable regulations during the project development process up to final approval.
- Local engagement;

Make conservative assumptions at the early stages to try to avoid forced changes later on – layout changes may involve penalties.



# Financial aspects of layout optimization - challenge

Relevant to the “Yield/Financial Returns” and “Construction and Running costs” categories above.

- For the same number of turbines, a more spread-out layout could offer higher yields through lower wake losses owing to more widely-spaced turbines and more potential to use the “best” bits of terrain in the area.

**But..** More widely spread turbines require longer access roads and cabling, which implies increased costs:

- Construction;
- Maintenance;
- Compensation to land owner.

# Financial aspects of layout optimization - approaches

A full financial optimization would be highly involved:

- Highly detailed cost information (both fixed and layout-dependent)
- Optimal BOP design and costing
- Yield and revenue for full life cycle

.. and for this to be calculated for each iteration

- Computational optimization possible with some simplification
- Apply experience-based estimates for construction and maintenance costs with reasonably design assumptions to assess the relative benefits of a layout.

## Layout Yield optimization - challenge

In light of fixed and layout-dependent factors and constraints, and local wind climate, position required number of turbines to maximize topographic advantages whilst minimizing energy loss and elevated turbulence levels from wakes, thus achieving maximum energy output.

- Accurate knowledge of wind resource and its variation across the site
- Turbine suitability

# Layout Yield optimization - approaches

- Good wind measurements – sufficient and representative
- Accurate flow modelling
- Address turbine suitability through simple spacing principles etc. at this stage (detailed load calculation necessary at some point)

Computational optimization – iterative layout revisions to maximise yield.

- Useful if you have a fairly constraint-free area in fairly simple terrain with good measurements and reliable flow modelling.

Manual layout design

- Depending on other constraints, layout may be effectively fixed.
- May wish to compare with computational results as a check

# Layout Yield optimization – flow modelling example

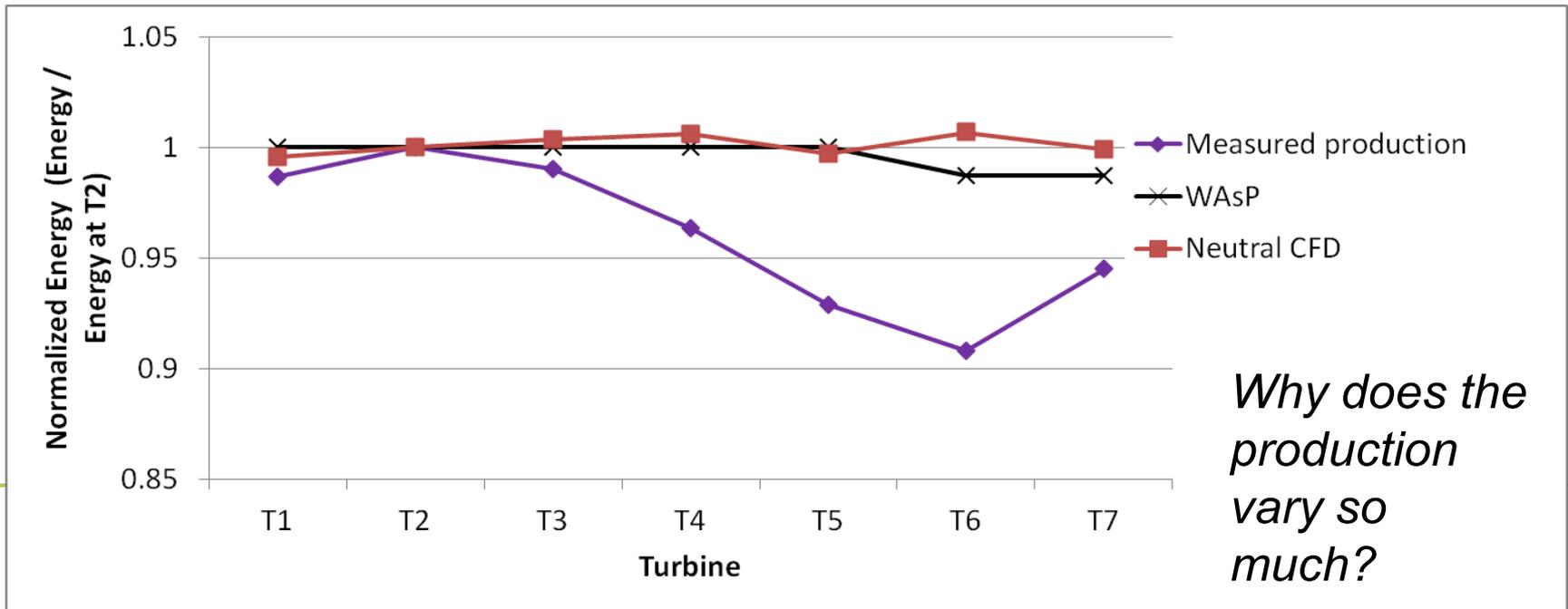
Research suggests that stable atmospheric conditions:

- Exhibit significantly different flows from neutral or unstable conditions;
- Are poorly modelled by WAsP or CFD assuming neutral conditions

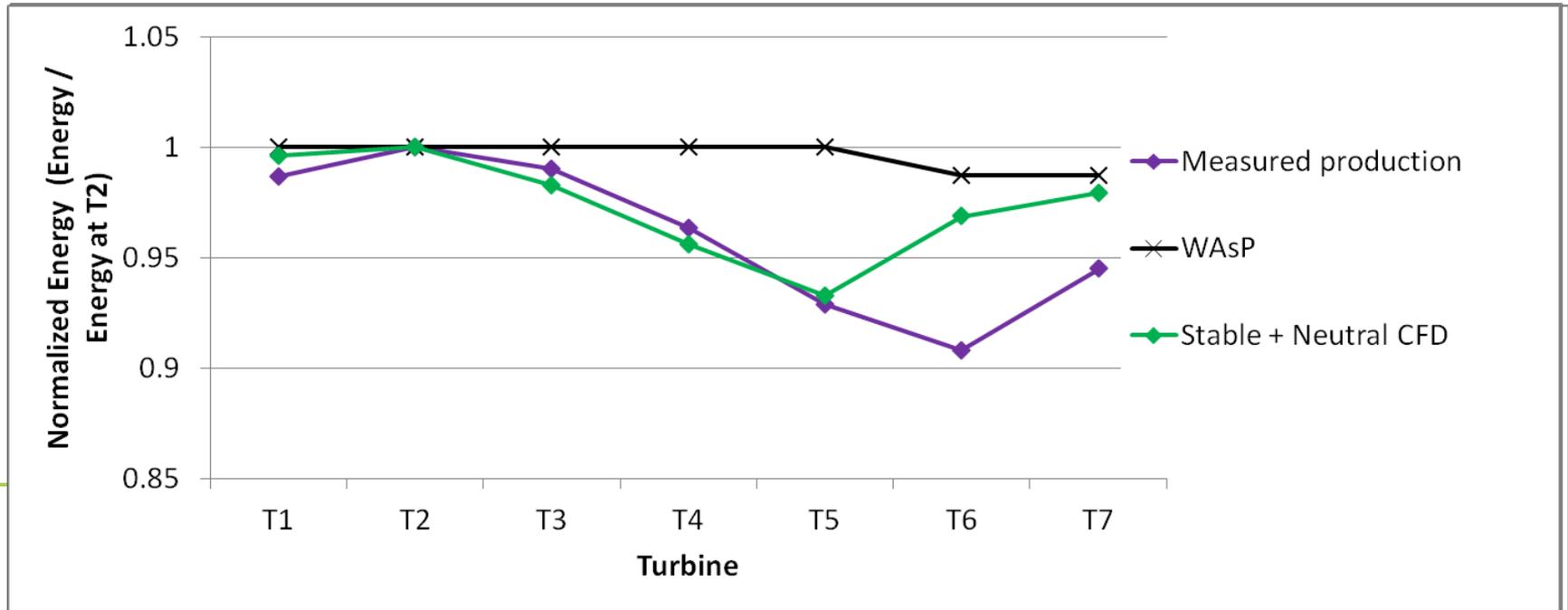
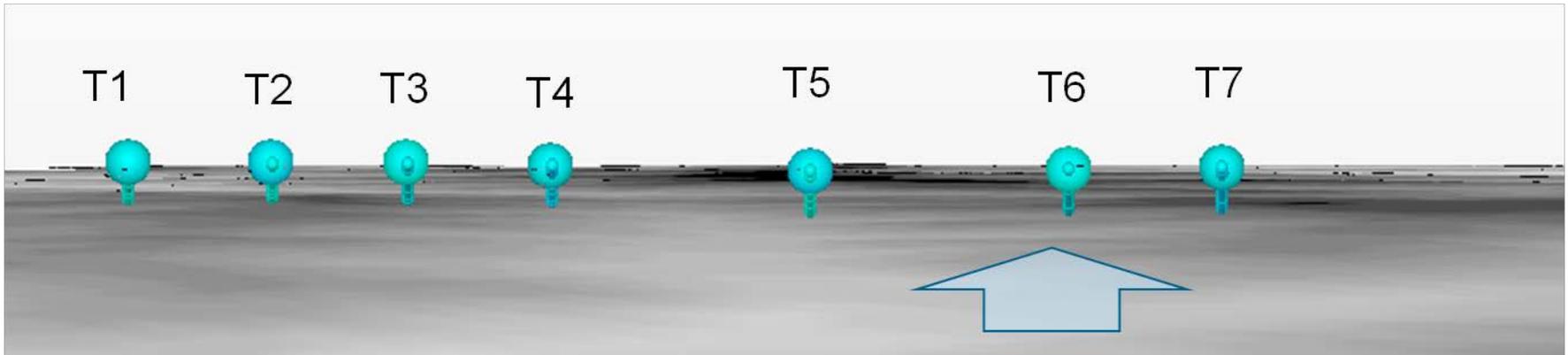
GL GH continues to develop our STAR-CCM+ CFD system, and the difficulties in modelling stable conditions were investigated.

- Turbulence, shear or temperature lapse rate used as proxies for stability.
- Modelling results validated against wind measurements and wind farm production data

# A “flat” site in the US Northern Plains



# Results with Buoyancy term





**Thank you!**

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