LiDAR for River & Coastal Managers
1. Overview & applications

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The situation…

- Airborne LiDAR is a neat new technology for delivering high-density topography information really fast
- It's being used more & more by local authorities & clients (with big wallets)
- But it ain't cheap ($50k - $100s k)
- May be hard to justify for single purpose & client
- Developing technology delivering more & more information (bang for buck)
- Multiple uses = multiple clients = easier to justify

My aim…

- Tell you about the technology, my experience with it, & how it can be used in river (& coastal) managment

Outline

- LiDAR / ALS technology –
  - what it is
  - how it works
  - what information it captures
- Capabilities & specs
- Limitations & workarounds
- Applications
  - River & coastal flood modelling
  - Habitat modelling & mapping
  - River bed level monitoring
  - Coastal erosion monitoring
  - Gravel resource management
- Indicative costs & alternatives
- Pros & cons

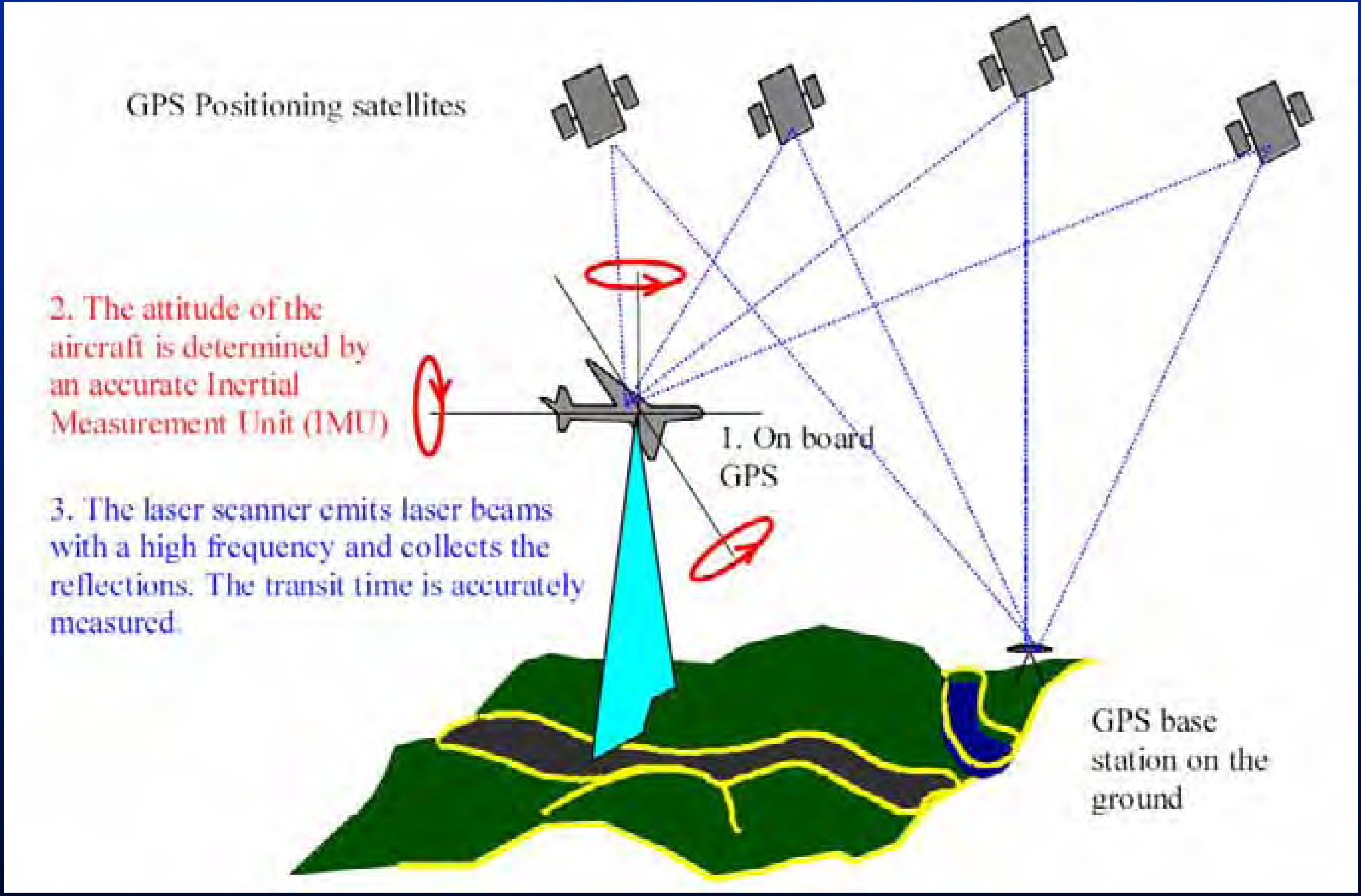
Airborne LiDAR / ALS
– what it is, what it does

- (Airborne) Light Detection And Ranging = Airborne Laser Scanning

- Have Terrestrial and Bathymetry systems

- Also have satellite and ground systems

How it works – terrestrial LiDAR



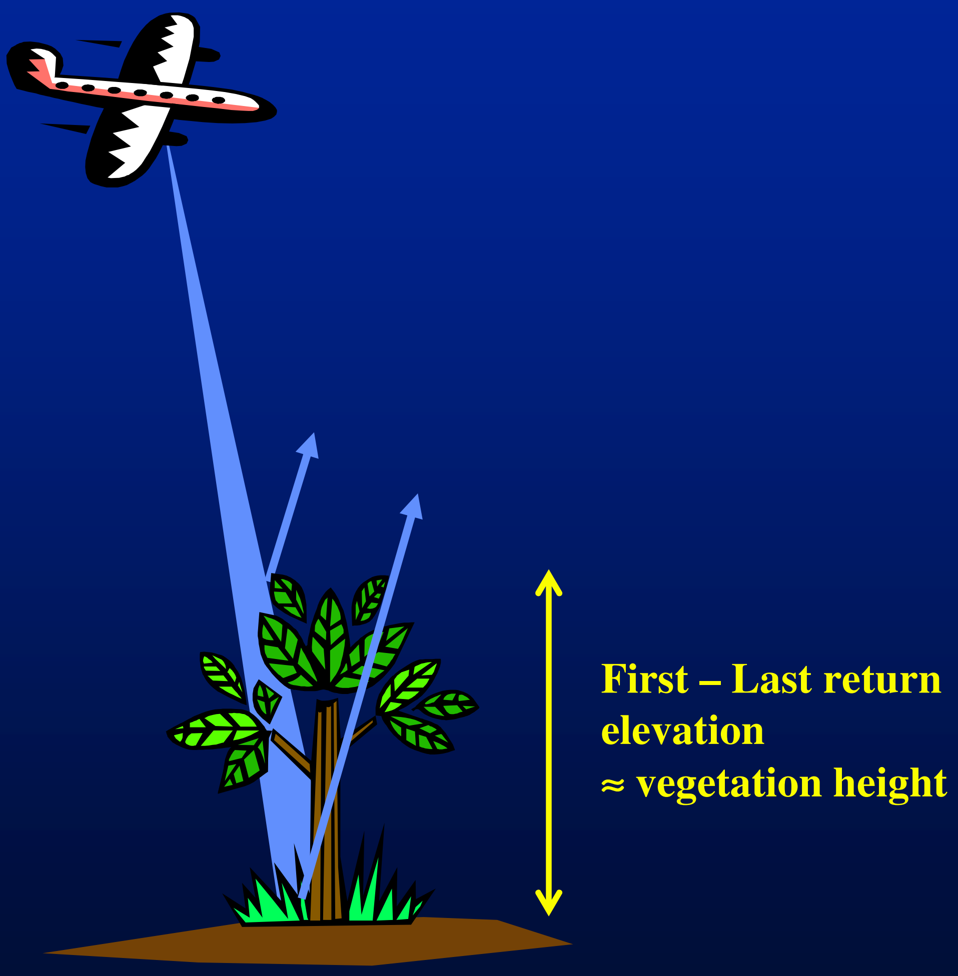
Graphic: AAMHatch

Terrestrial LiDAR - what it can deliver

First return pulse
Measures distance to the first object encountered .. in this case, the tree foliage

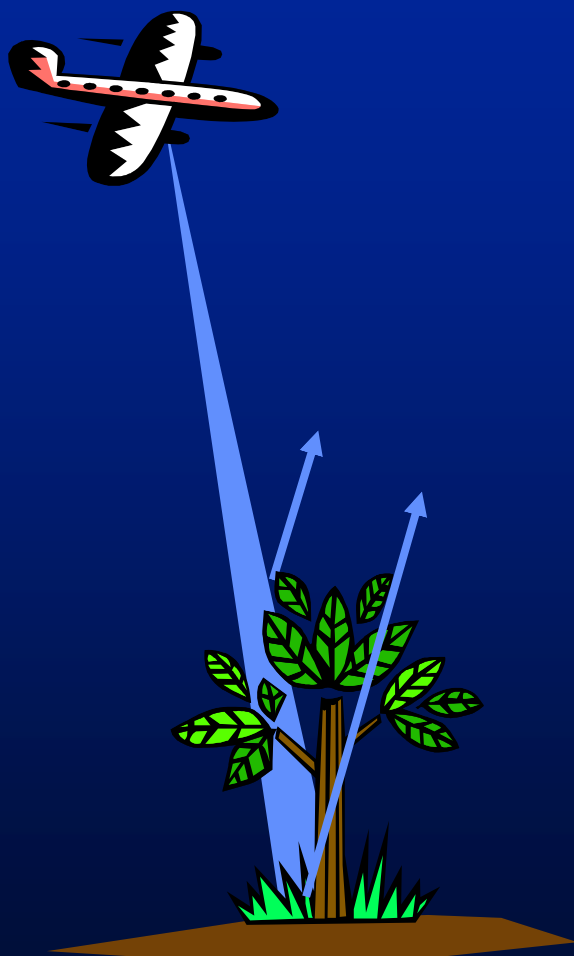
Last return pulse
Measures distance to the last object .. in this case, the ground

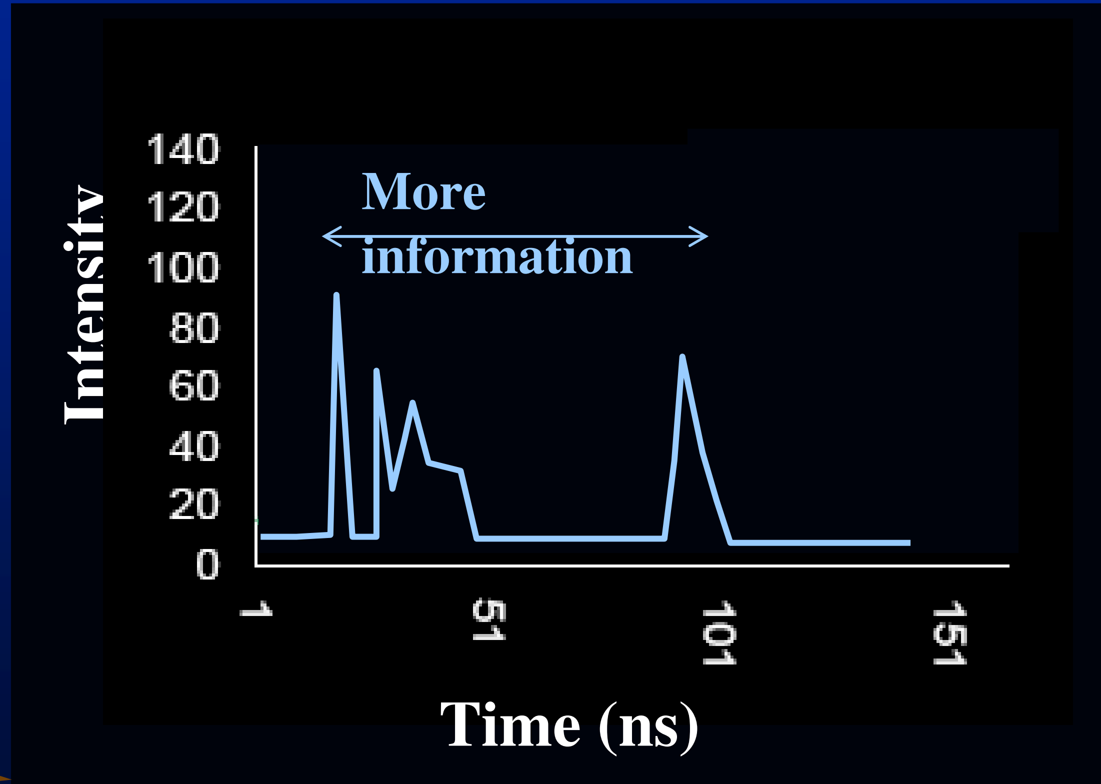
Also get intensity of the return pulses

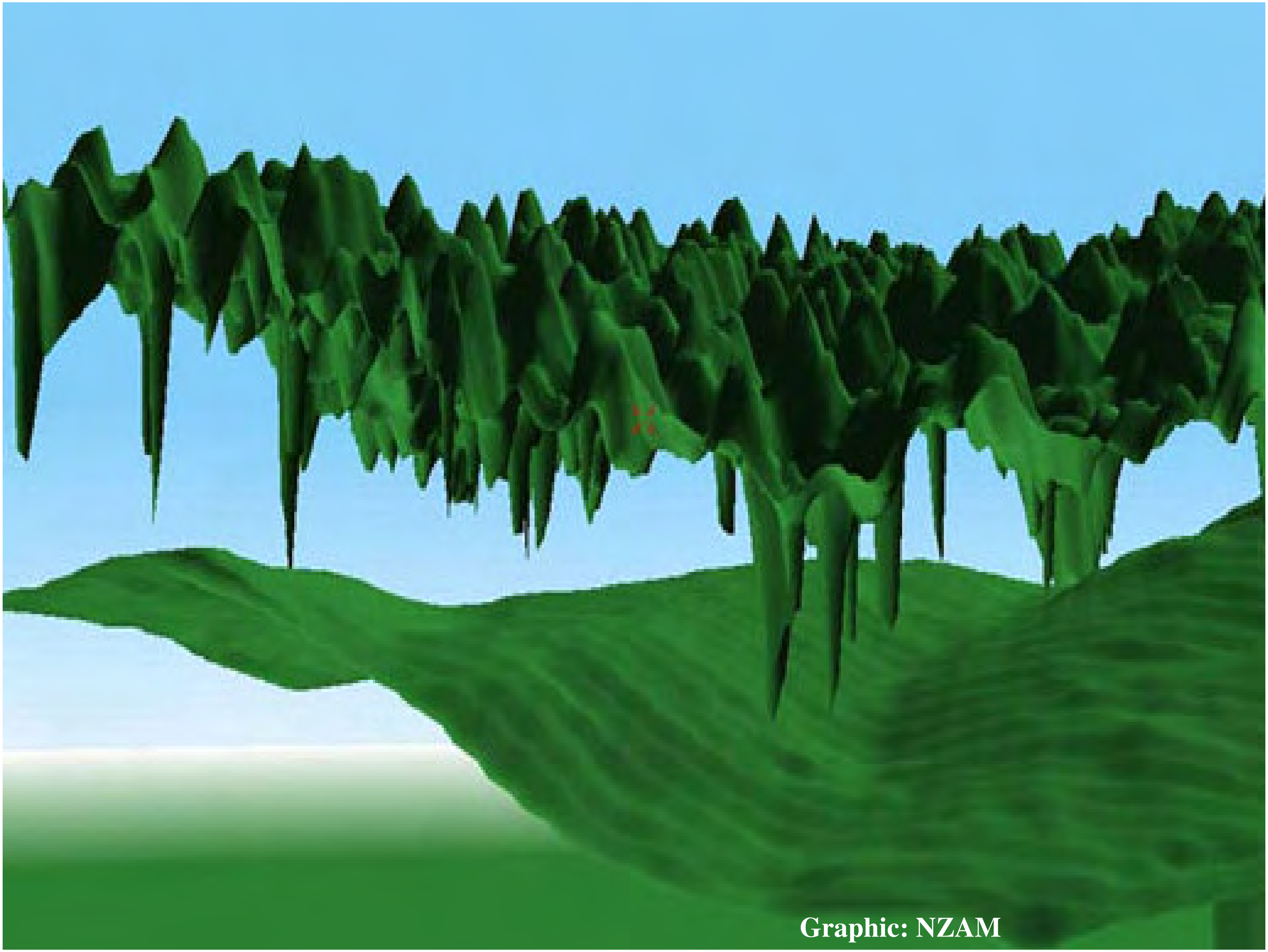


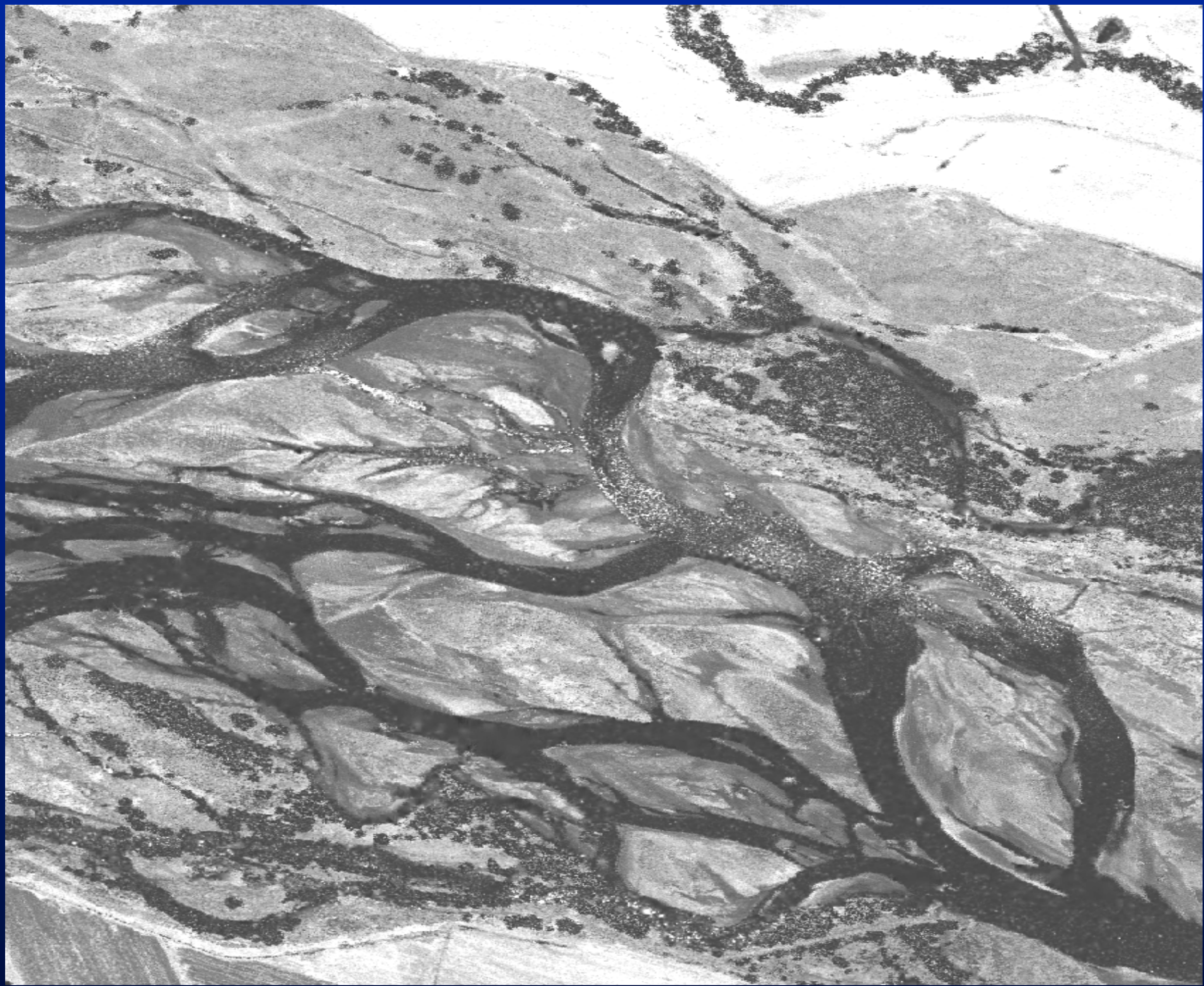
Terrestrial LiDAR – delivering more

Full waveform





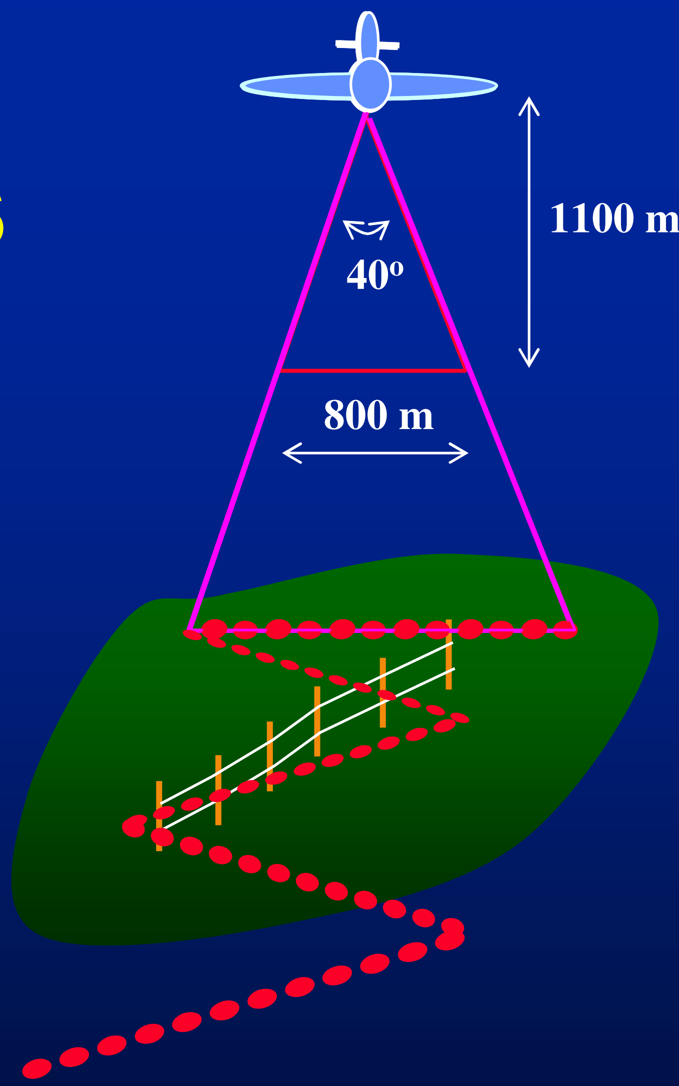

Graphic: NZAM



First-return intensity

User options

- Flying height: spatial density, accuracy
- Scan & pulse rate: spatial density
- Pulse width: foot print, precision
  chance of striking linear targets



Key stats of Terrrestrial LiDAR

- Fast:
  - ~ 200 million + points per hour
  - ~ 50 km^2/hr
- Accurate:
  - < 0.15 m vertical rms error (68% points in this range)
  - > 0.2 m horizontal rms error
- High spatial density:
  - Typically 1.5 m point spacing
- Surveys ground and above-ground features

Limitations

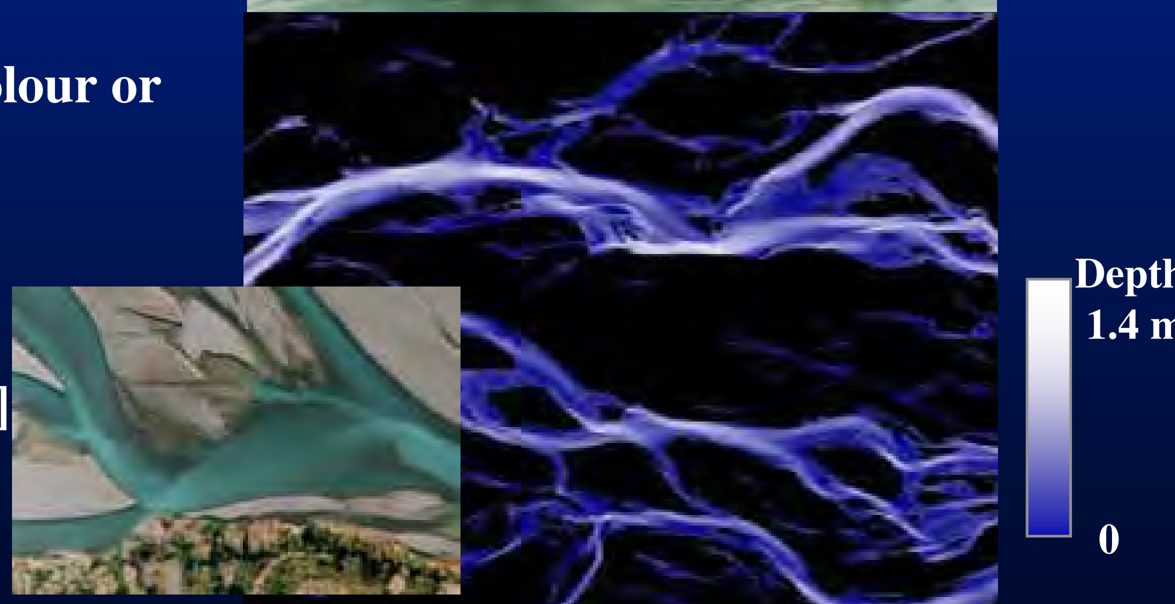
- Terrestrial LiDAR doesn’t penetrate water
- Thick vegetation canopy can prevent ground strikes (so helps to work in winter)
- Can’t operate in cloud/smoke
- Large start-up cost (unless shared)

Handling wetted channels

Wetted channel topography = Water surface topo (from LiDAR DEM) minus Water depth

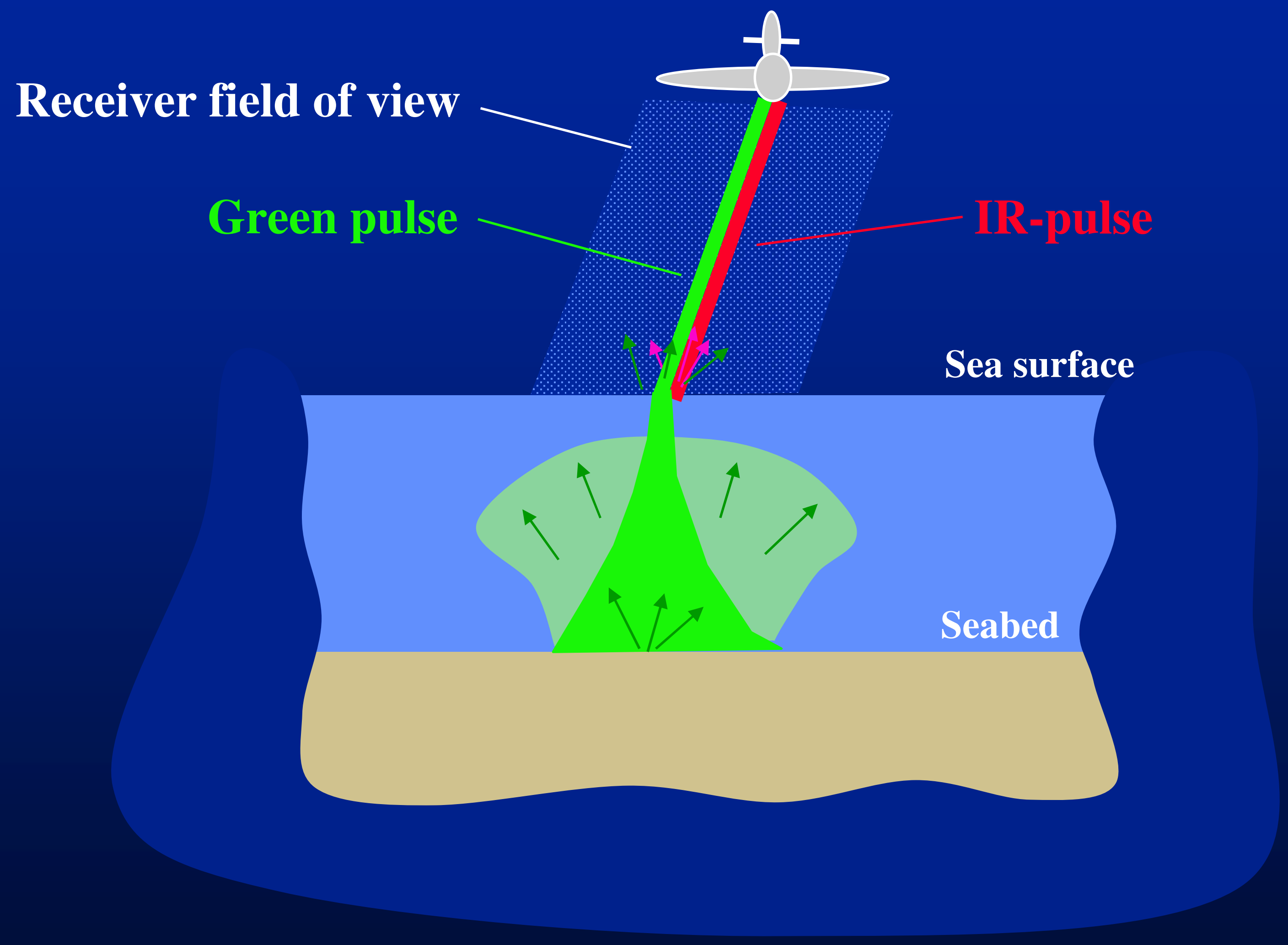
Water depth mapping by
-Boat with sounder & GPS
[Accuracy ~ 5 cm at-a-point]

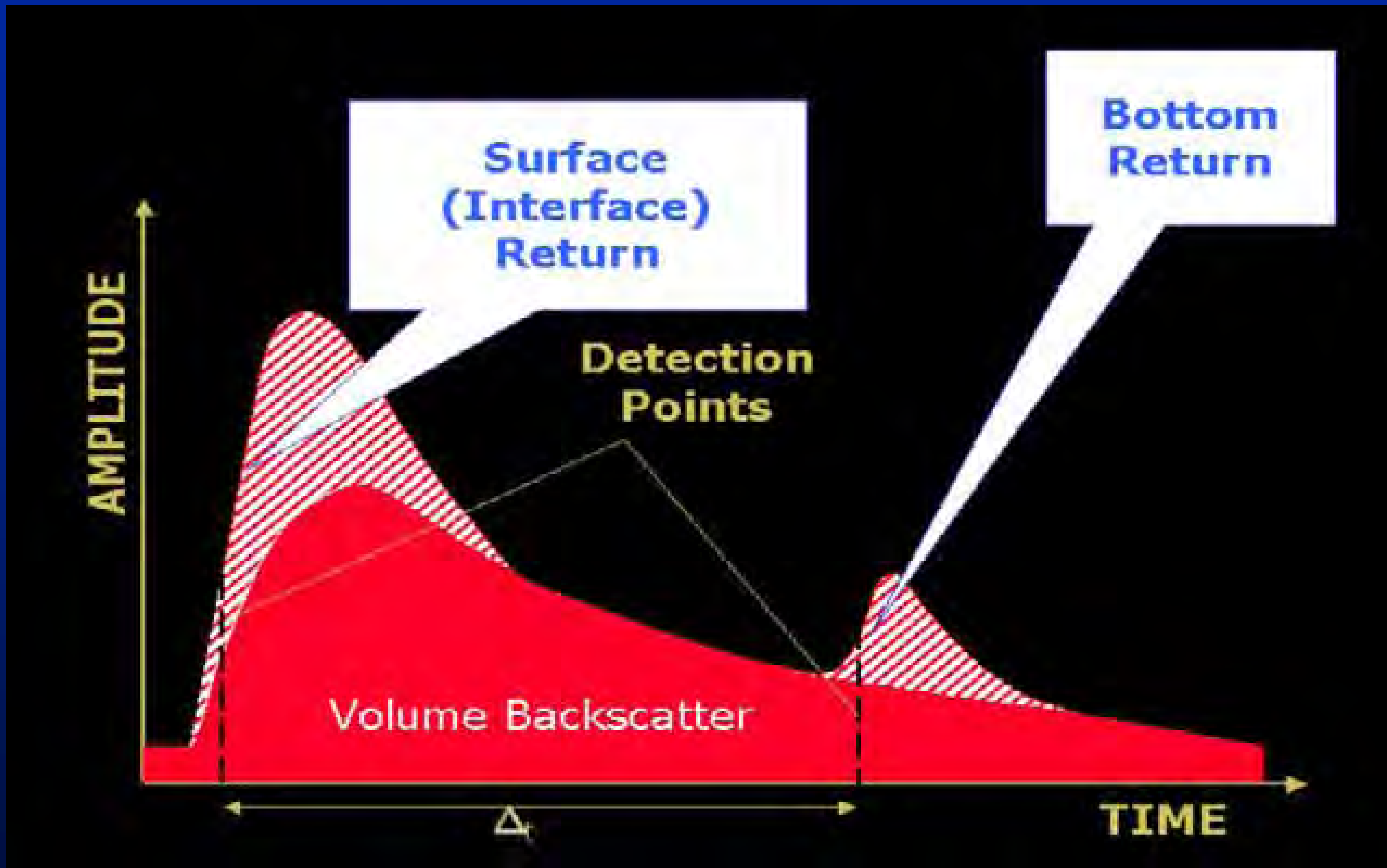
-Remote-sensing (water colour or multi-spectral imagery) calibrated with boat measurements
[Accuracy ~ 20-30 cm; depth limited by turbidity]



Waimakairir River

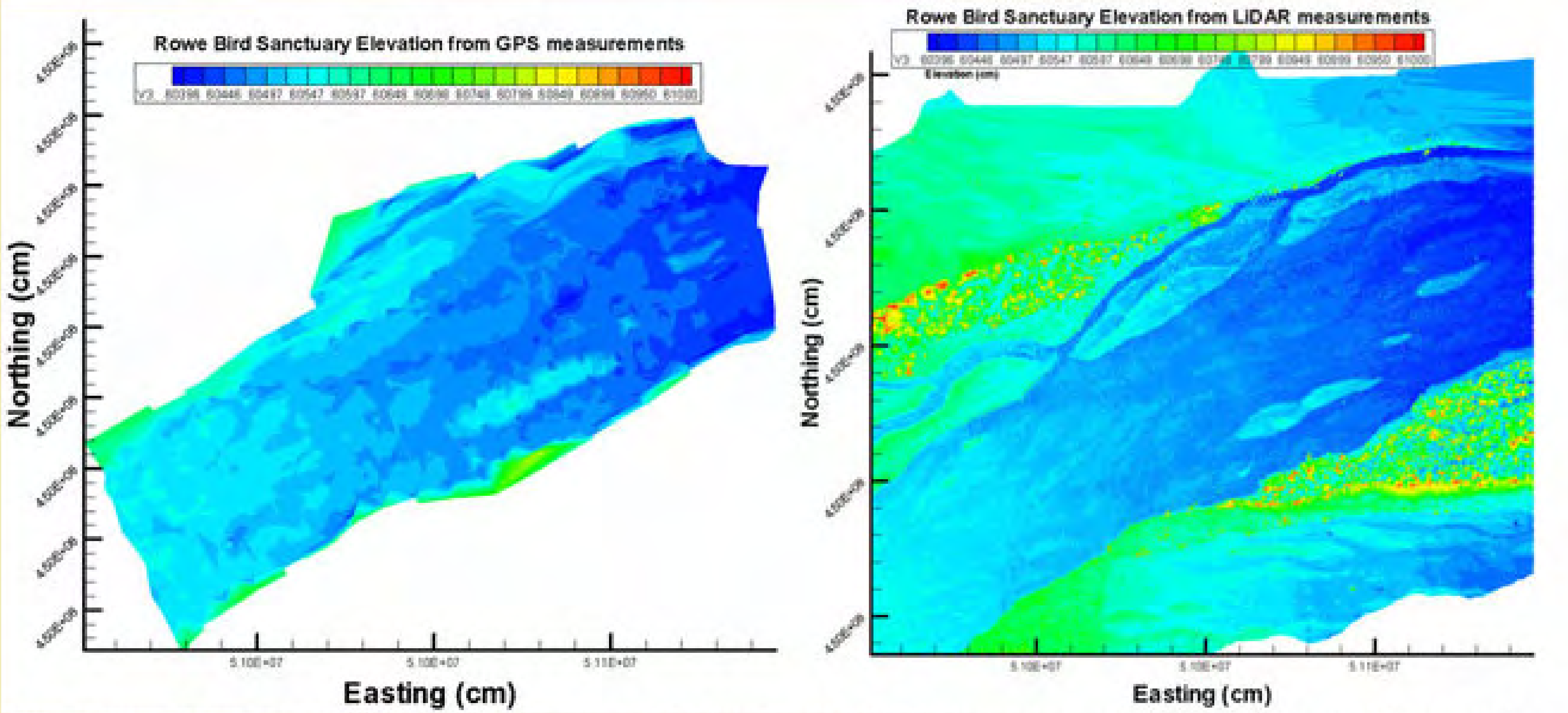
Bathymetry LiDAR





Bathymetry LiDAR waveform (Green)

Graphic: Guenther et al



Comparison of elevation maps from ground survey-grade GPS and aerial LiDAR measurements. The GPS data required three people wading the river over two days, whereas the LiDAR was collected over a few seconds. Note the improved resolution of channel features in the LiDAR map as compared with the map created by a TIN of the ground GPS data.

EAARL on the Platte River

Graphic: NASA/USGS

	Terrestrial (e.g. Optech 3100)	New Dual-mode (e.g. SHOALS-1000T, EAARL)	Bathymetry (e.g. SHOALS, LADS)
Energy	Low	Medium	High
Laser	Near IR	Green, near-IR	Green, near IR
Pulse rate	< 100 khz	1 khz / 10 khz	< 1 khz
Footprint	0.2 - 0.9 m on ground	~ 1 m	2-3 m on WS
Flying height	800-2200 m	200-400 m 300-700 m	200-500 m
Point spacing	~ <1-2 m	2-5 m	~ 5 m
Penetrates water	No	Yes to 0.2-50 m (2-3 x SD)	Yes to ~ 50 m
Vertical accuracy	~ 0.15 m	~0.25 m	~ 0.28 – 0.15 m

Applications

- River & coastal flood modelling
- Habitat modelling & mapping
- Bed level monitoring
- Gravel resource management
- Coastal erosion monitoring

Flood modelling example: Lower Waitaki River

Need ground topography and roughness

Approach for high-density topo surveys...

Dry riverbed

Wetted channels

Hydro-survey

LIDAR

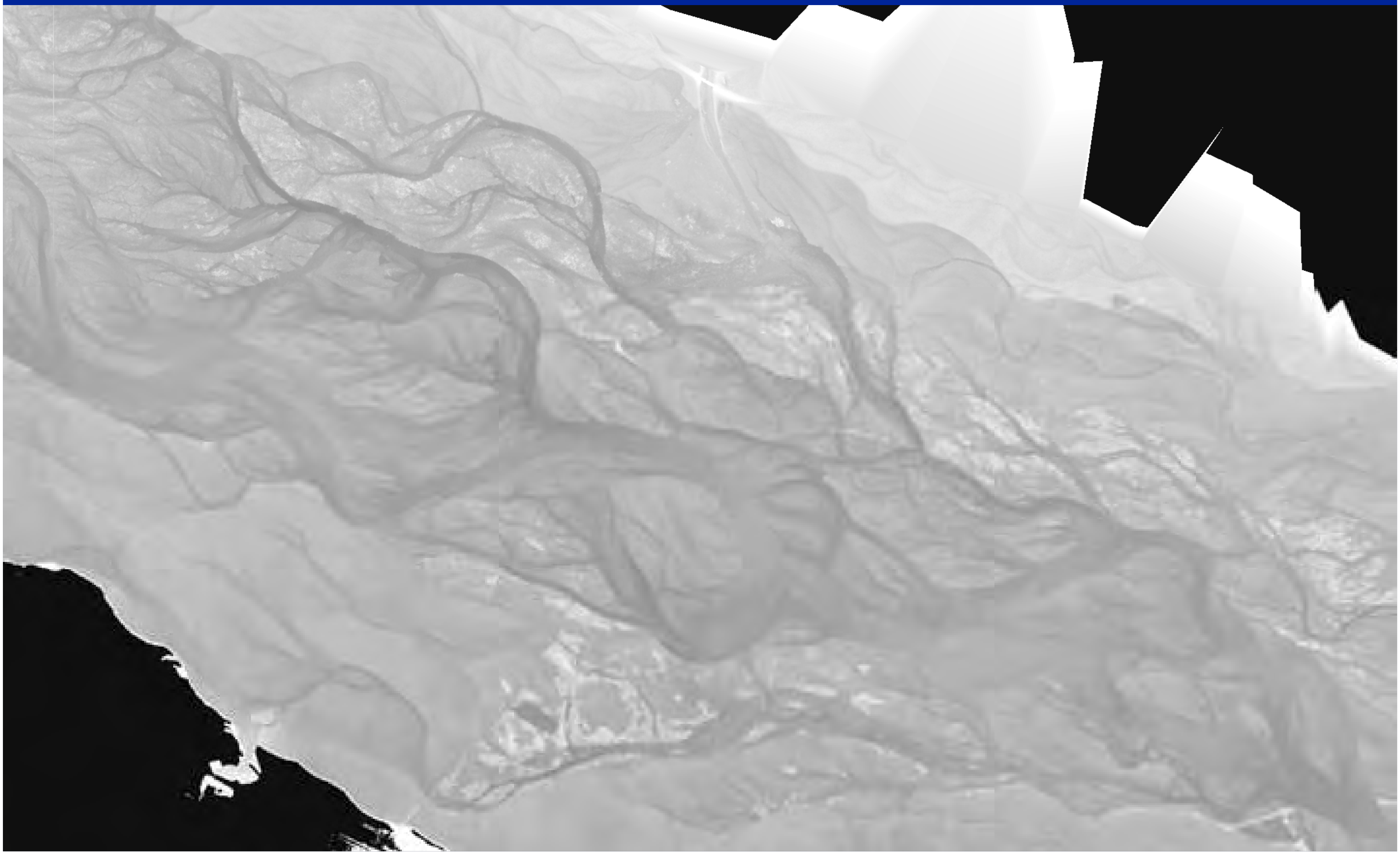
Water-surface model

Depth Mapping from MS imagery

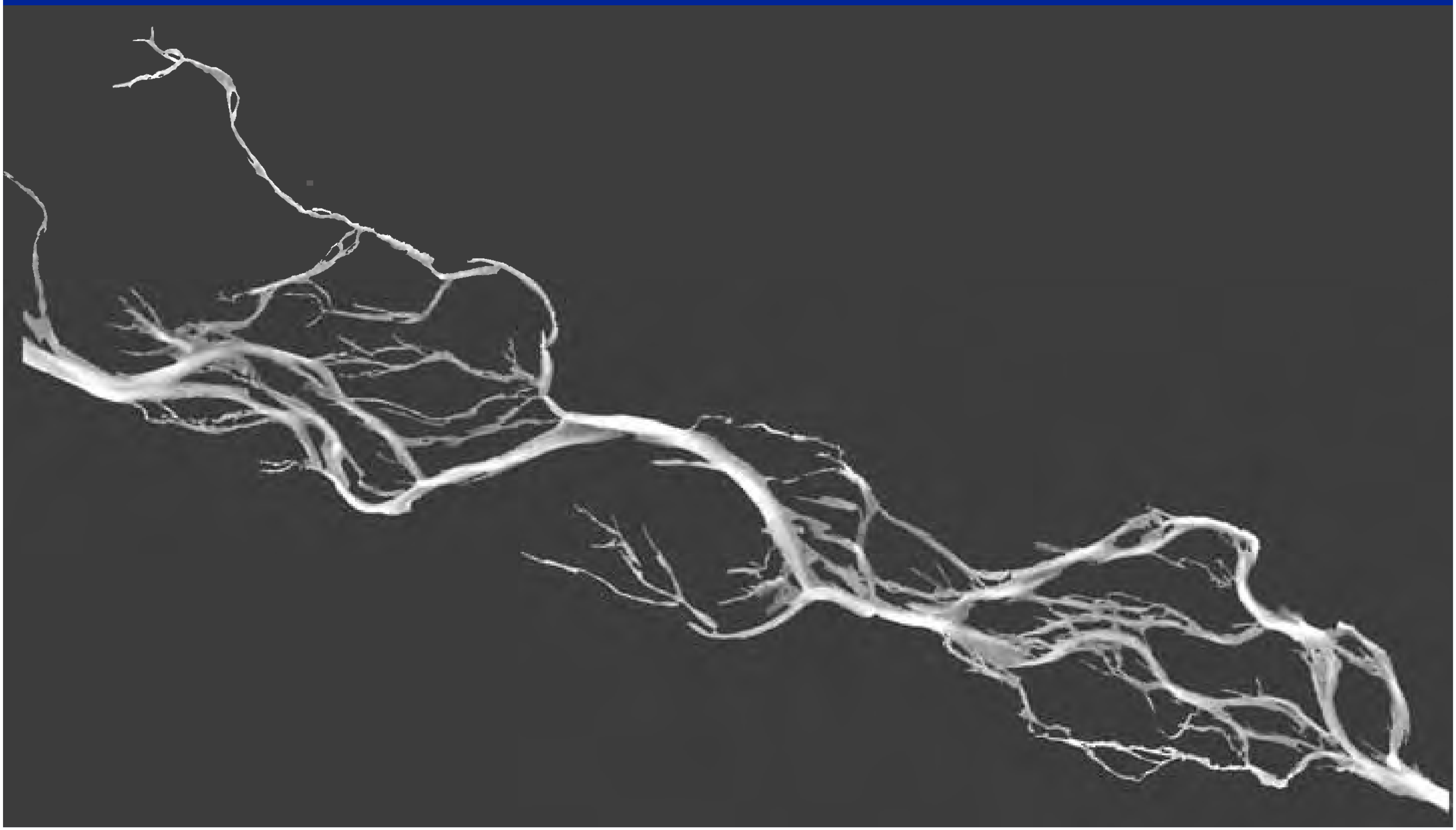
Vege filtering & editing

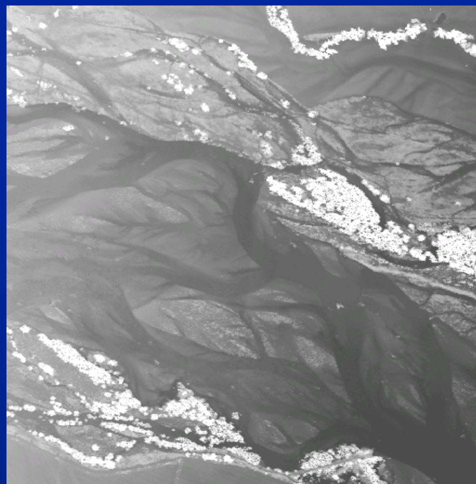
DEM of whole river bed

Ground DEM from ALS (last return, numerical veg filter)



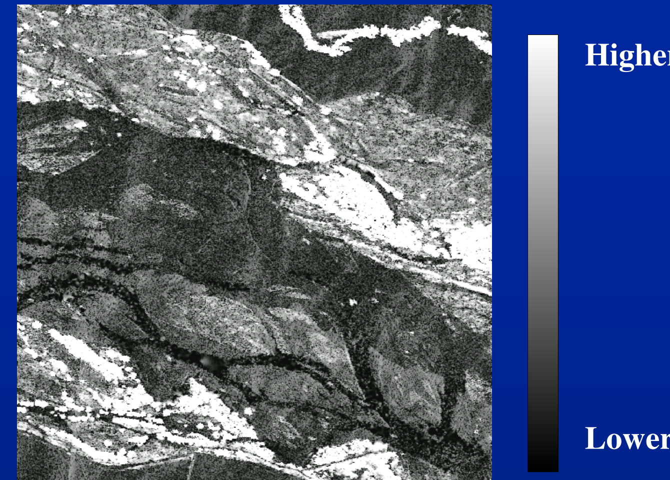
Depth Map from multi-spectral imagery



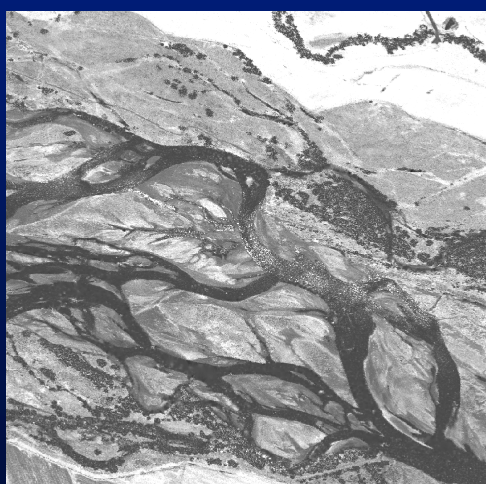


First return elevation

Last return elevation

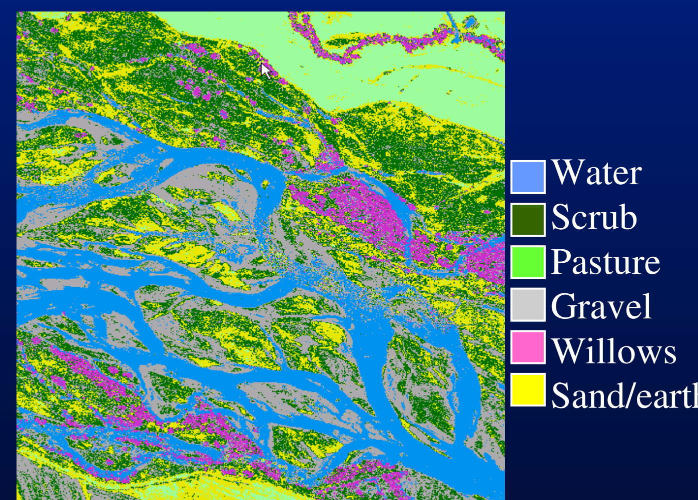


Elevation difference (~ veg height)



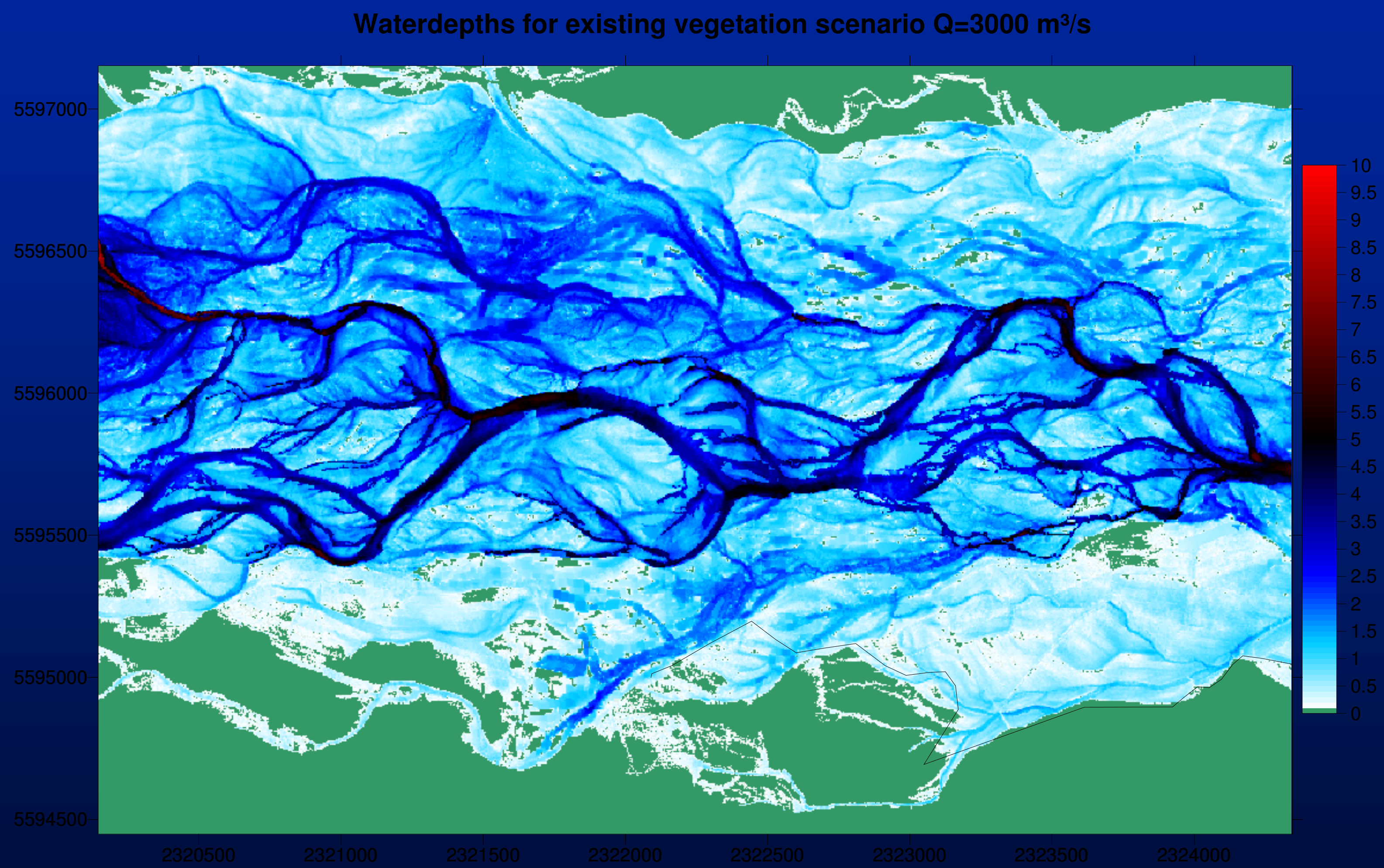
First-return intensity

Photograph Waitaki River

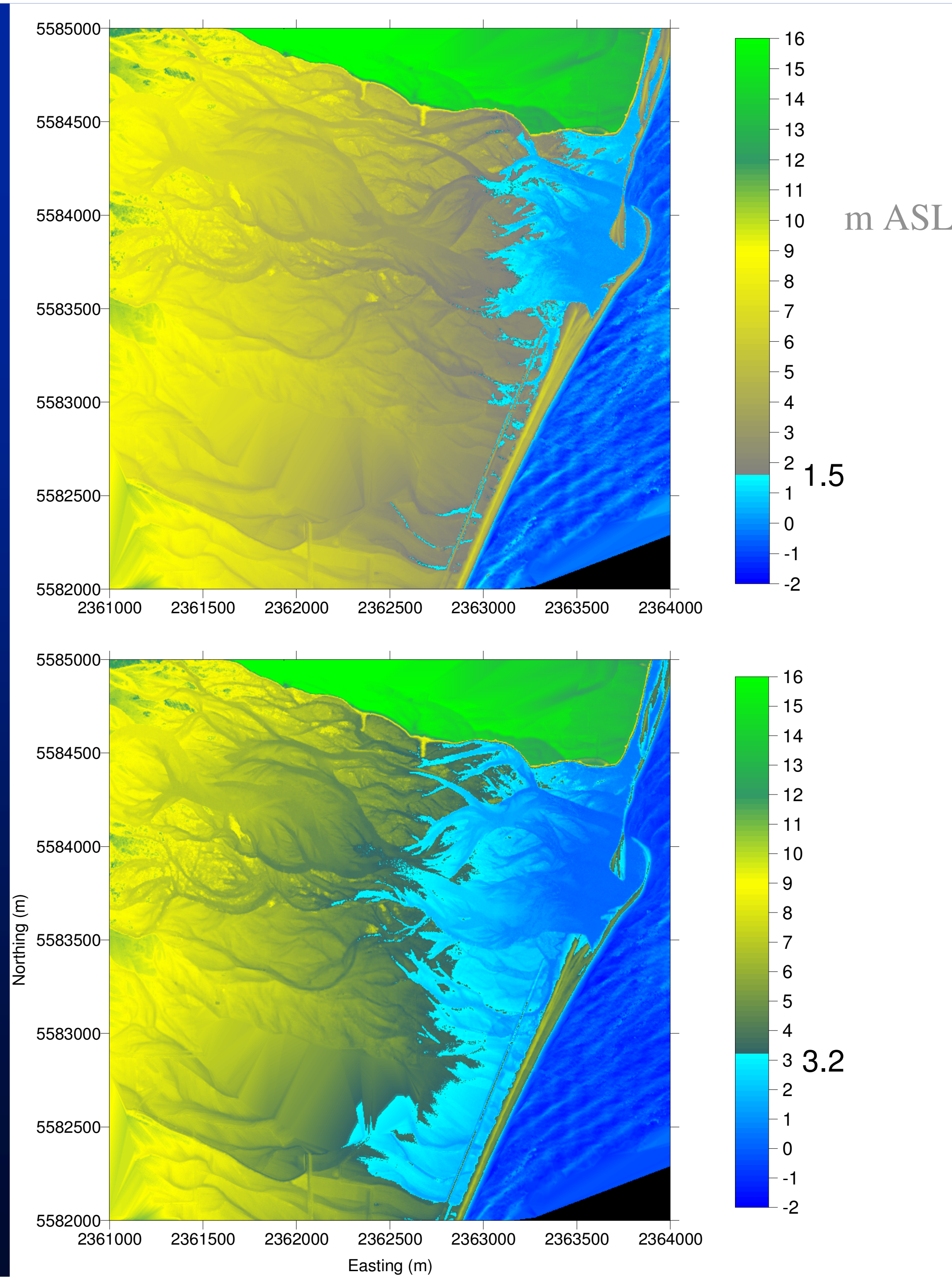


Ground classification for roughness

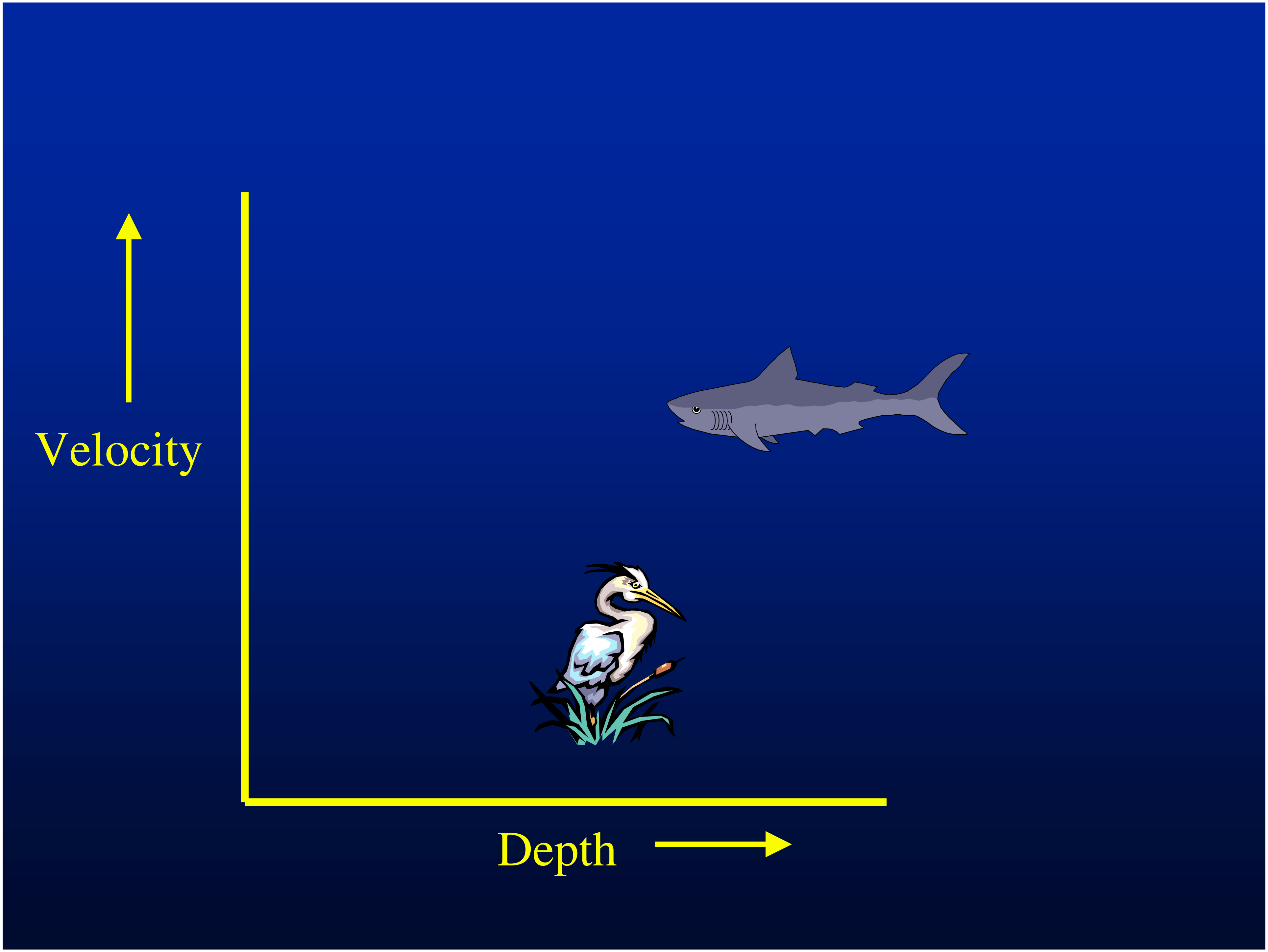
Flood modelling example: Lower Waitaki River



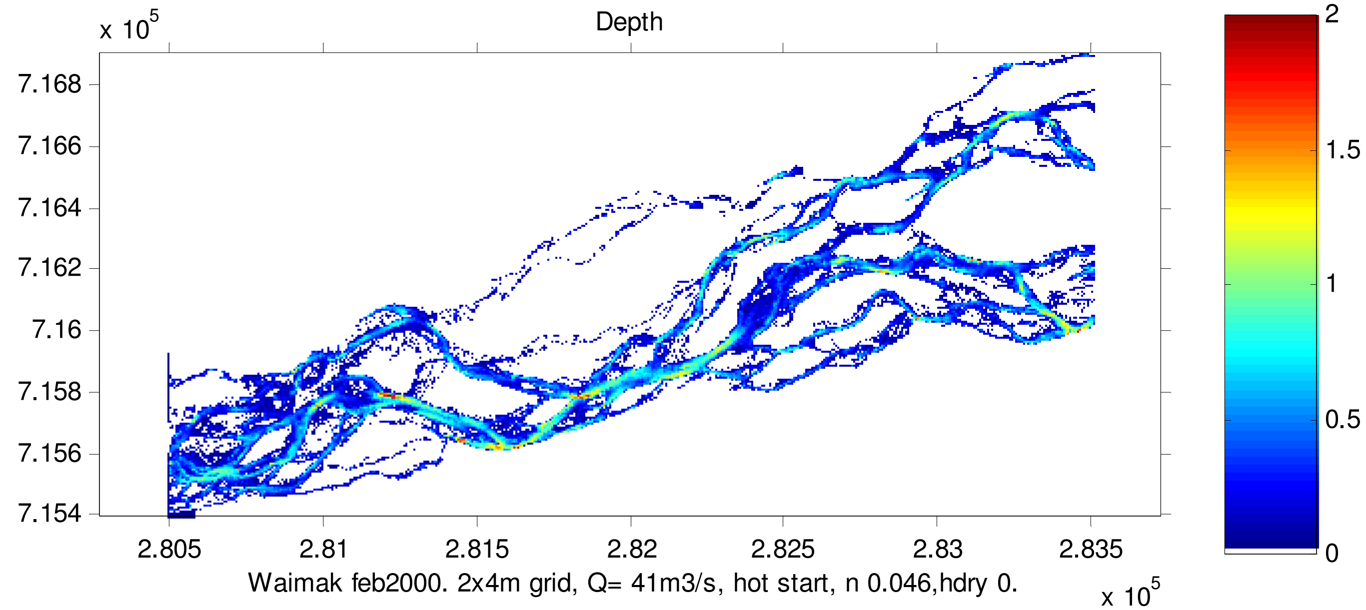
Estuary flooding



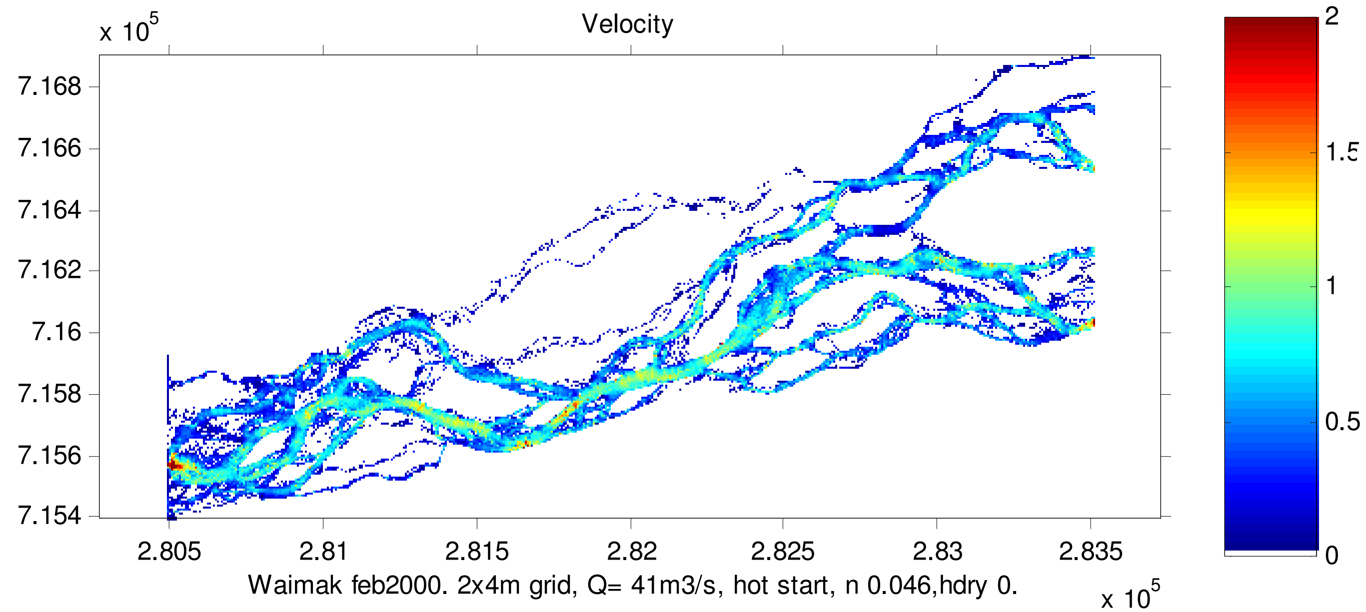
Habitat modelling & mapping


Velocity
Depth

Flow = 41 m^3/s

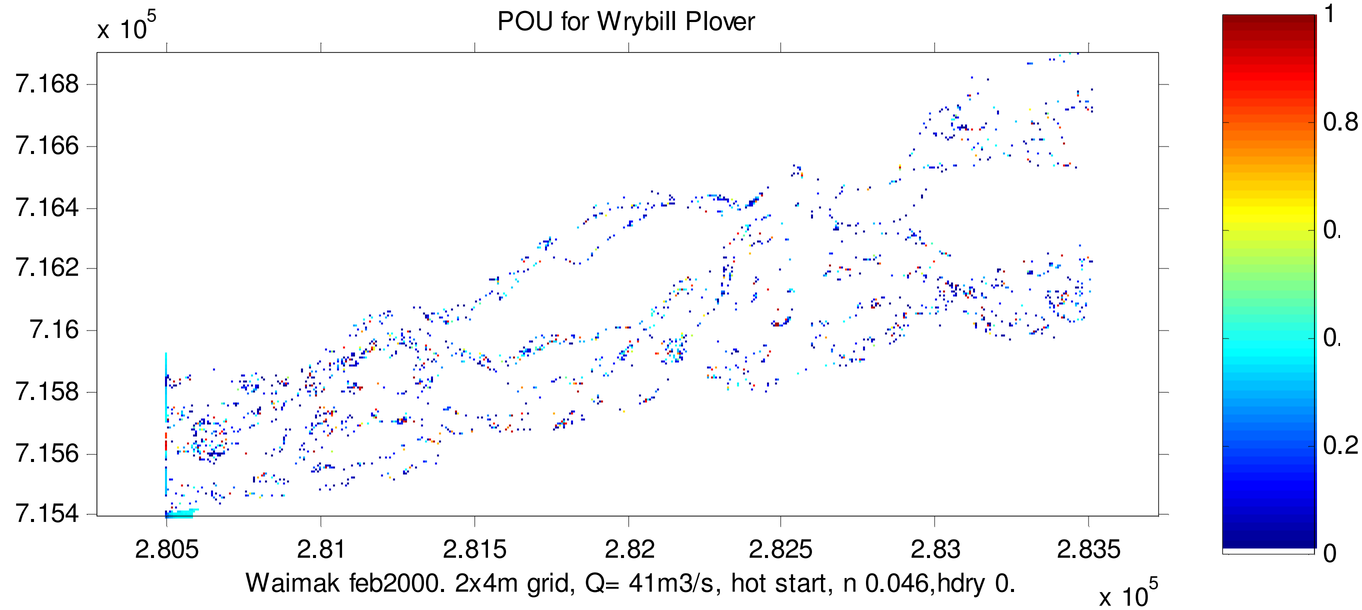


Depth (m)

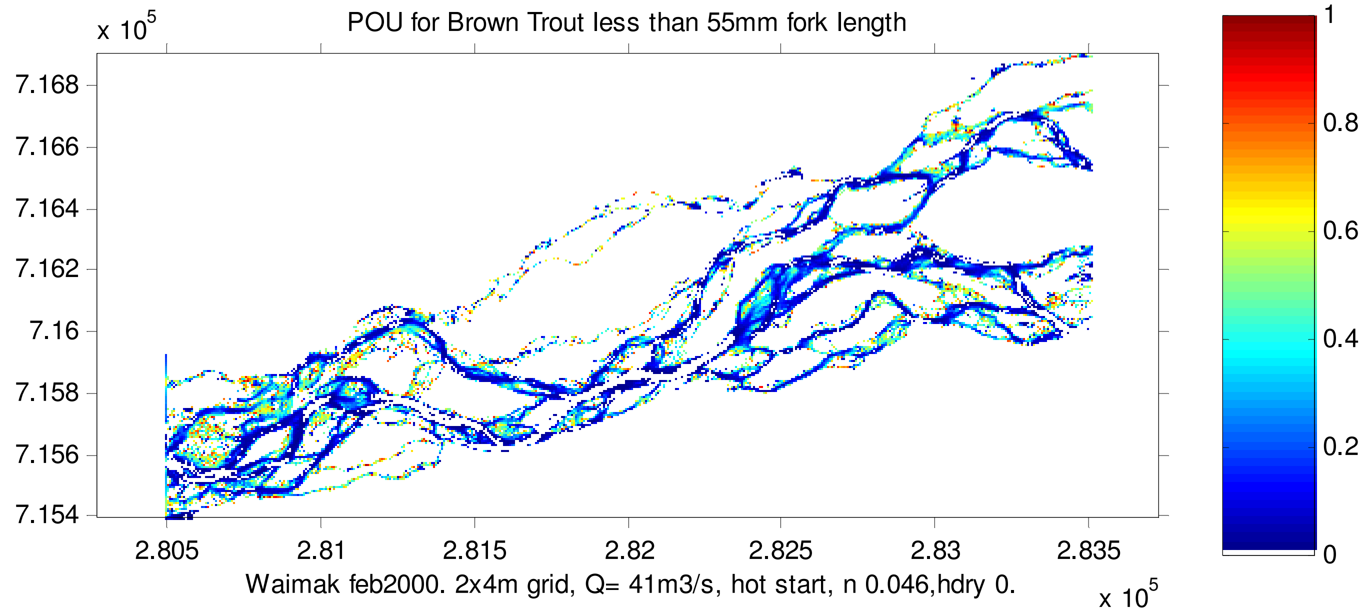


Velocity (m/s)

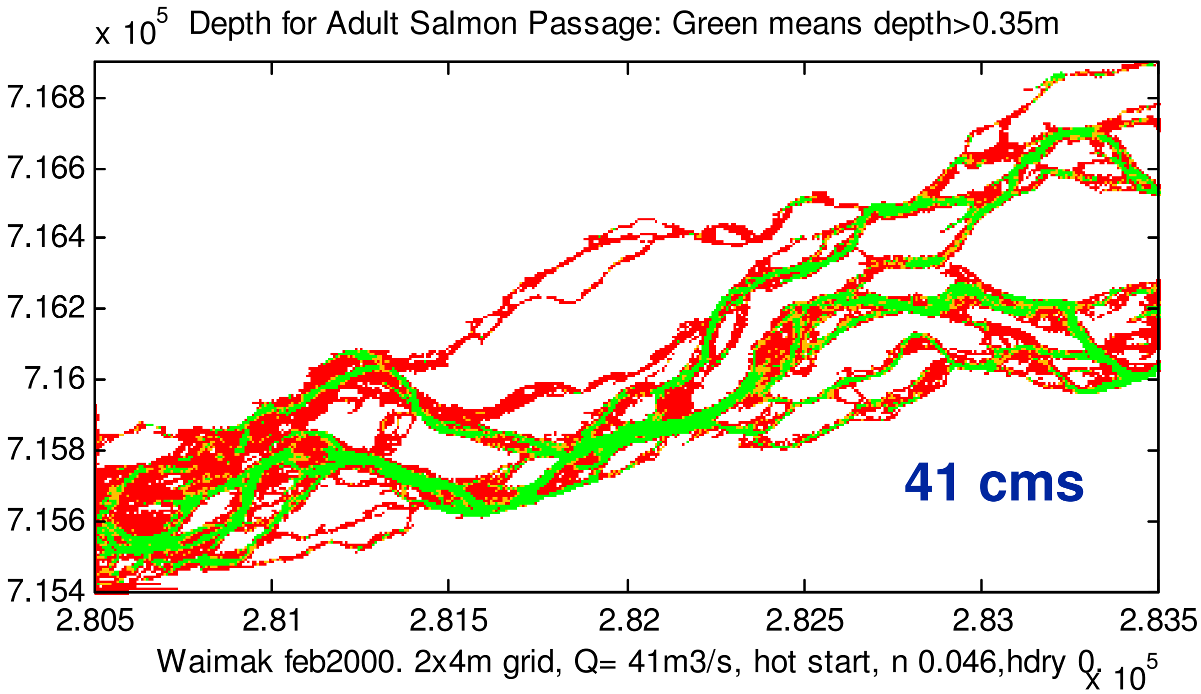
Flow = 41 m^3/s

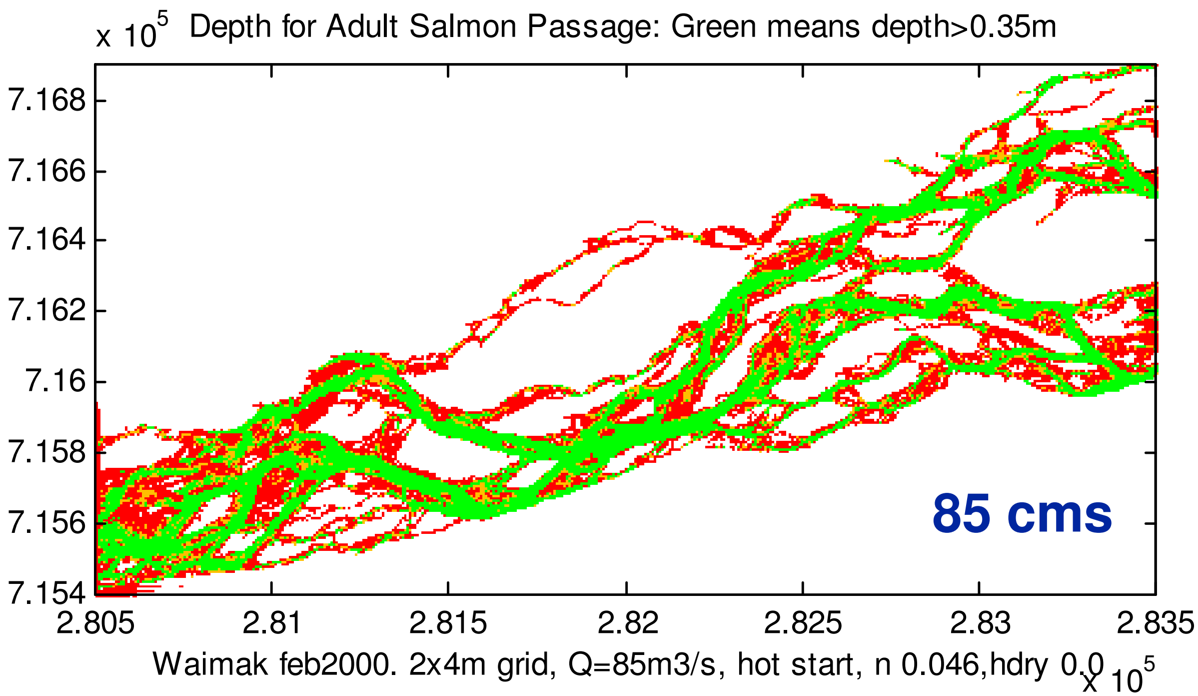


Suitability *Wrybill Plover*



Suitability *Small Trout*





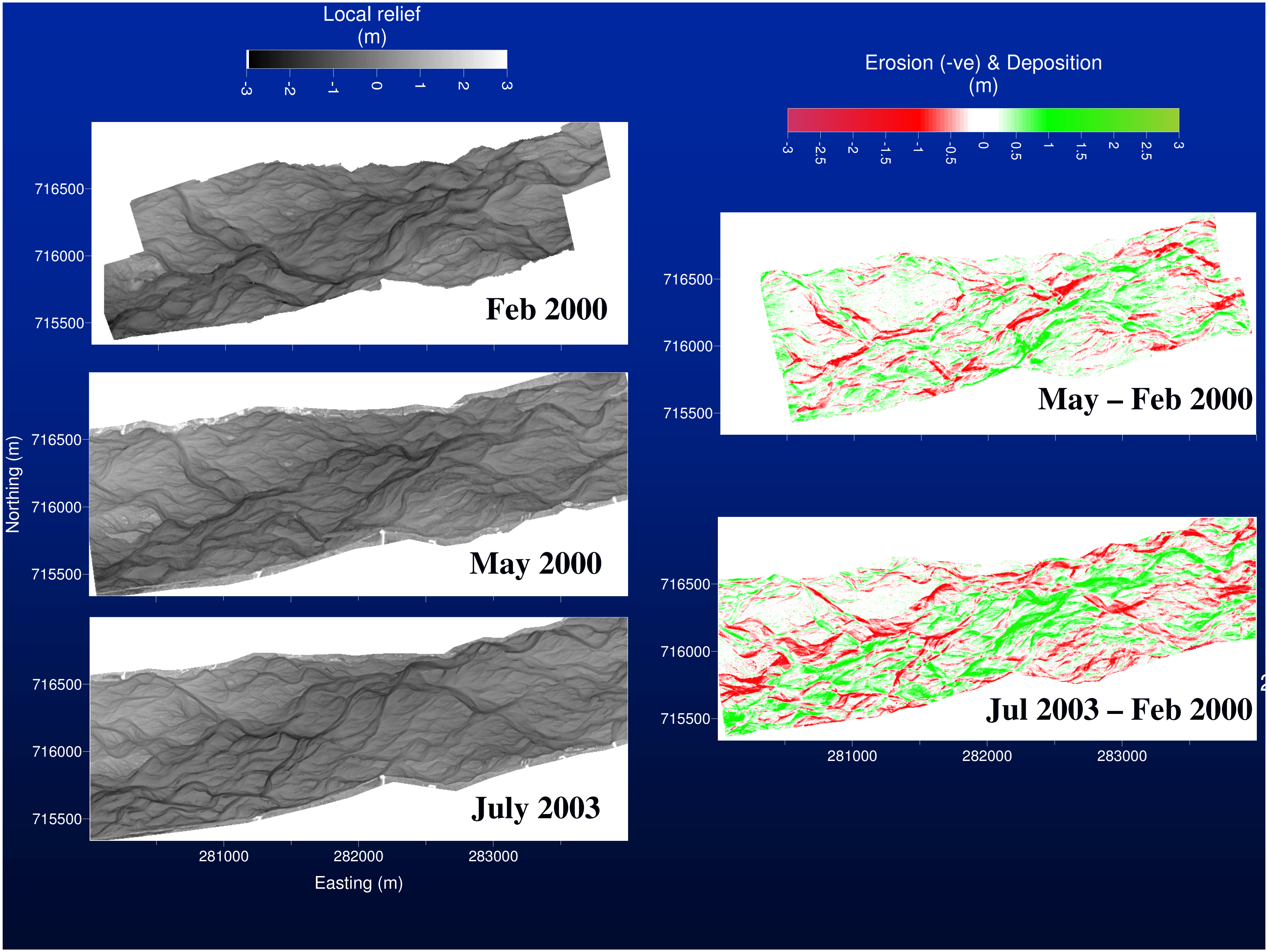
Salmon passage

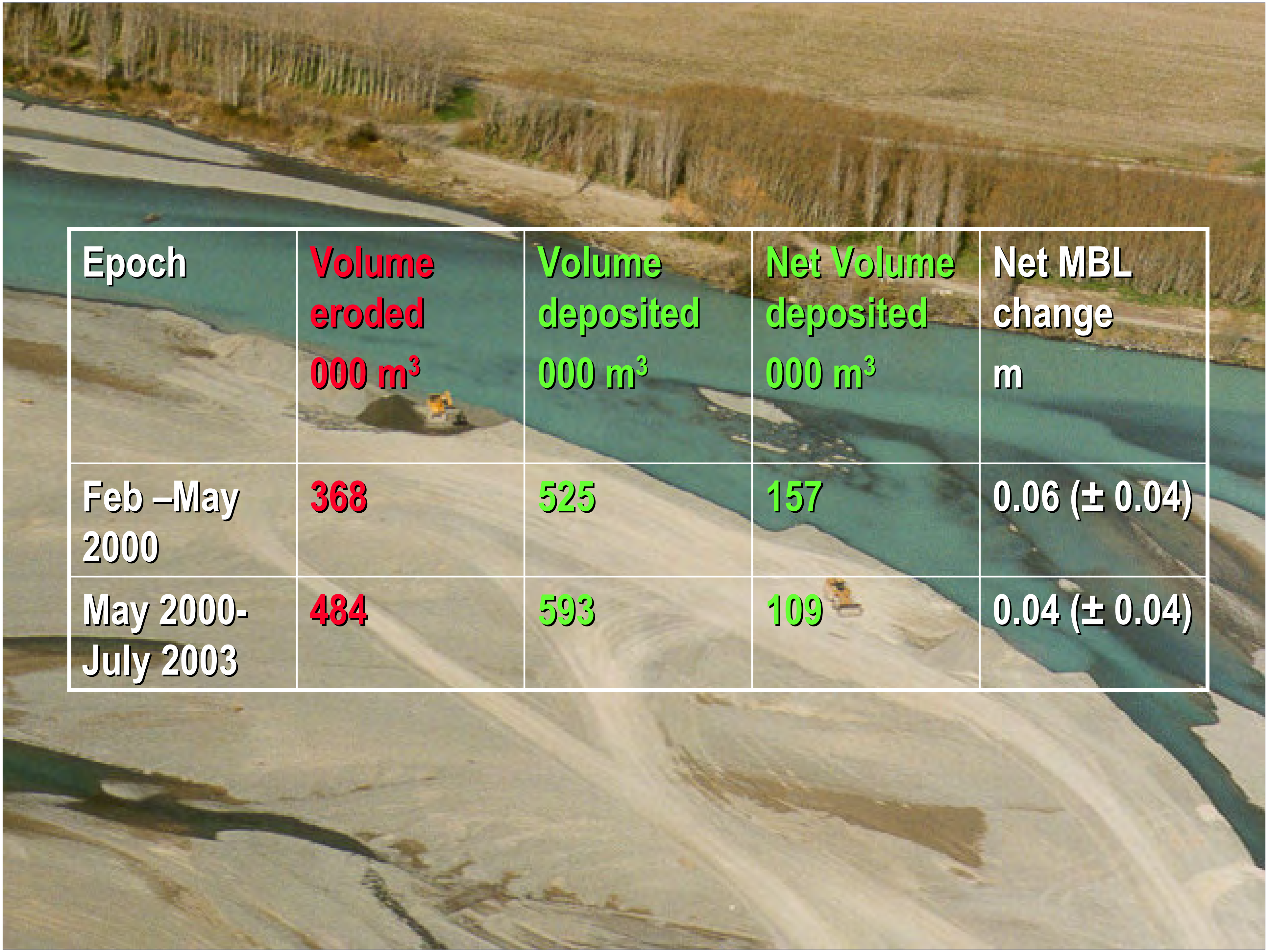
< 0.35 m

> 0.35 m

Bed–level monitoring

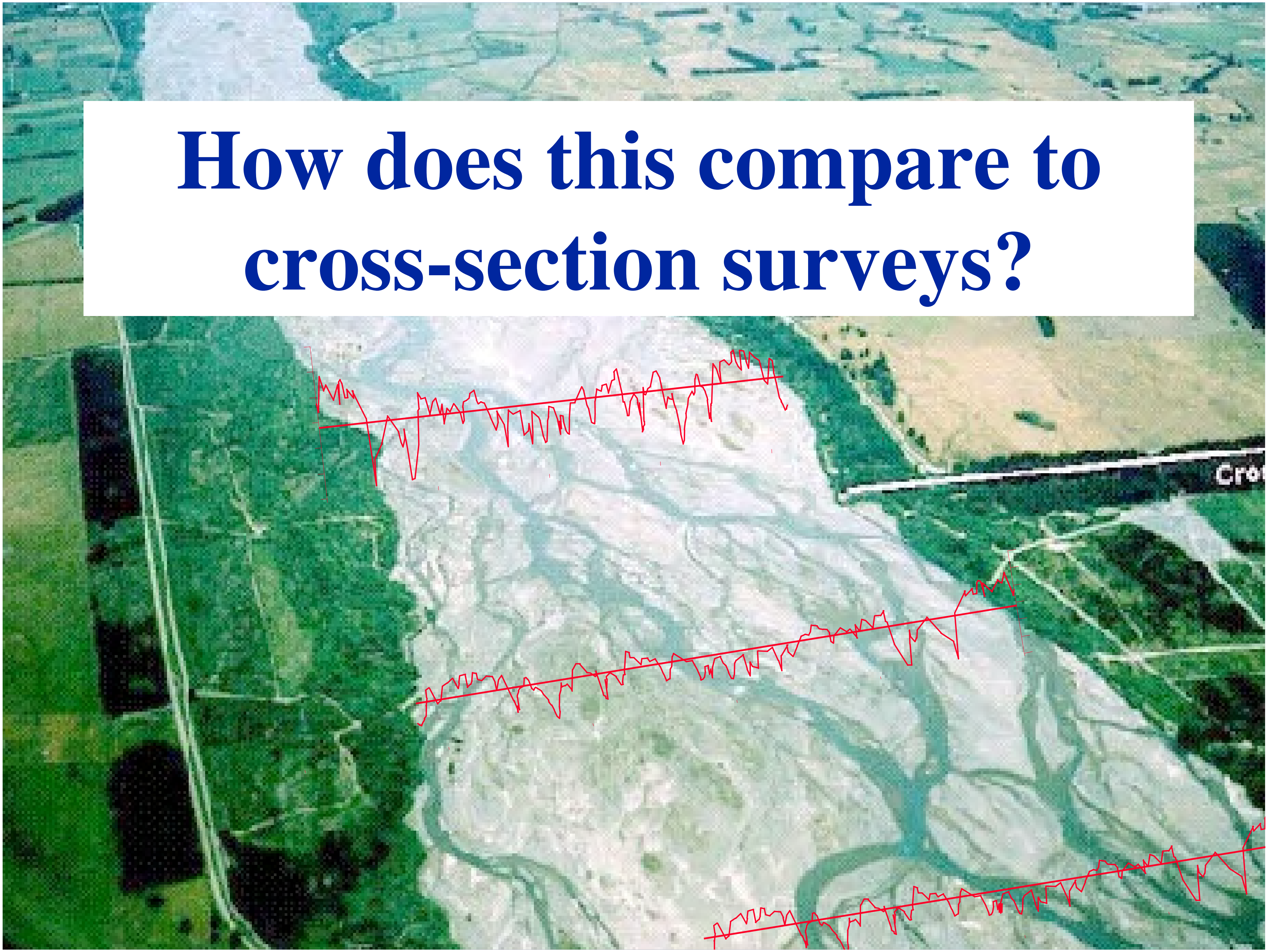
- **Flood conveyance**
- **Gravel resource management**
- **Bedload transport rates**


Local relief
(m)
-3
-2
-1
0
1
2
3
Erosion (-ve) & Deposition
(m)
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
Feb 2000
May 2000
July 2003
May – Feb 2000
Jul 2003 – Feb 2000
716500
716000
715500
281000
282000
283000
Northing (m)
Easting (m)

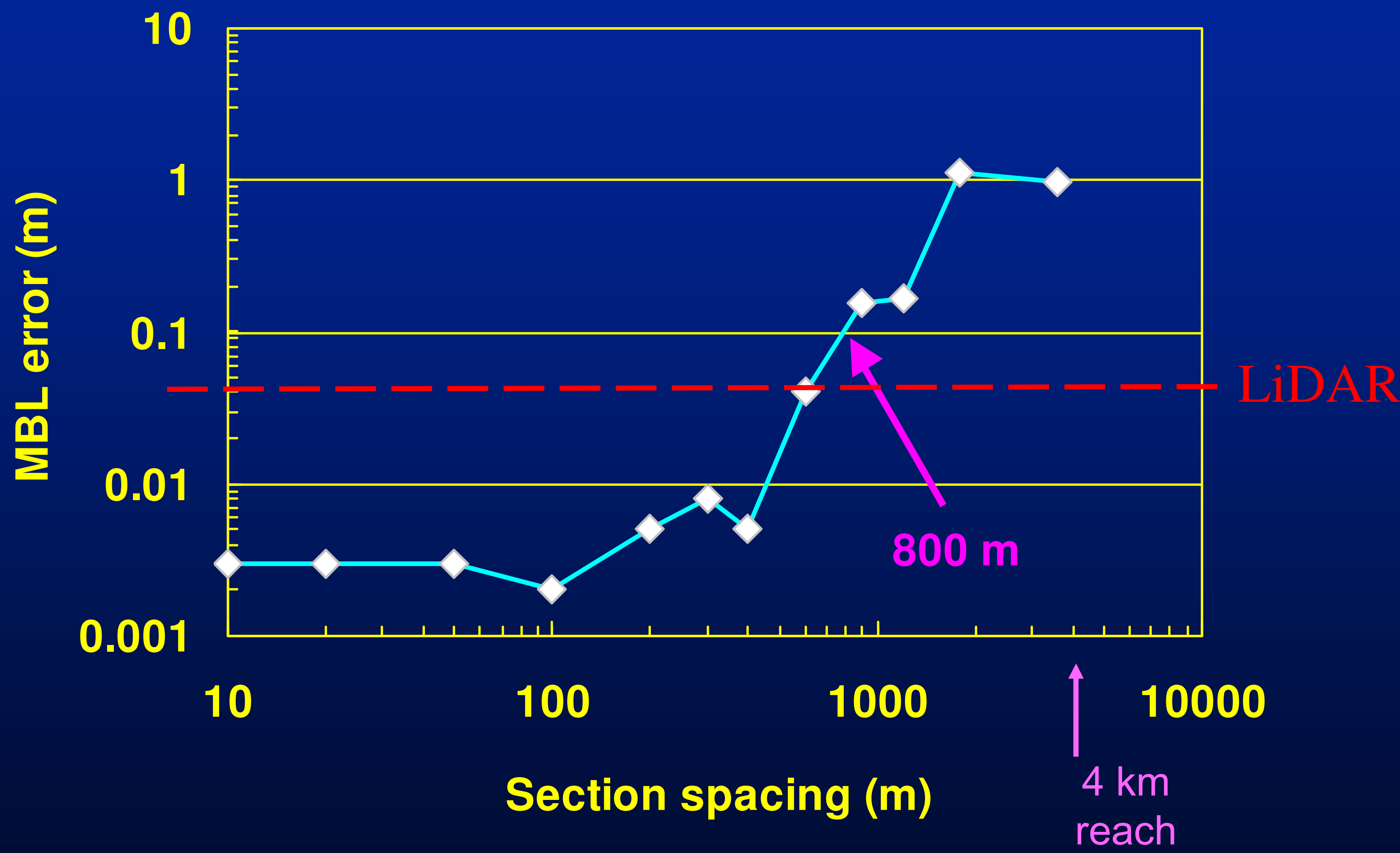


Epoch	Volume eroded 000 m^3	Volume deposited 000 m^3	Net Volume deposited 000 m^3	Net MBL change m
Feb –May 2000	368	525	157	0.06 (± 0.04)
May 2000-July 2003	484	593	109	0.04 (± 0.04)

How does this compare to cross-section surveys?



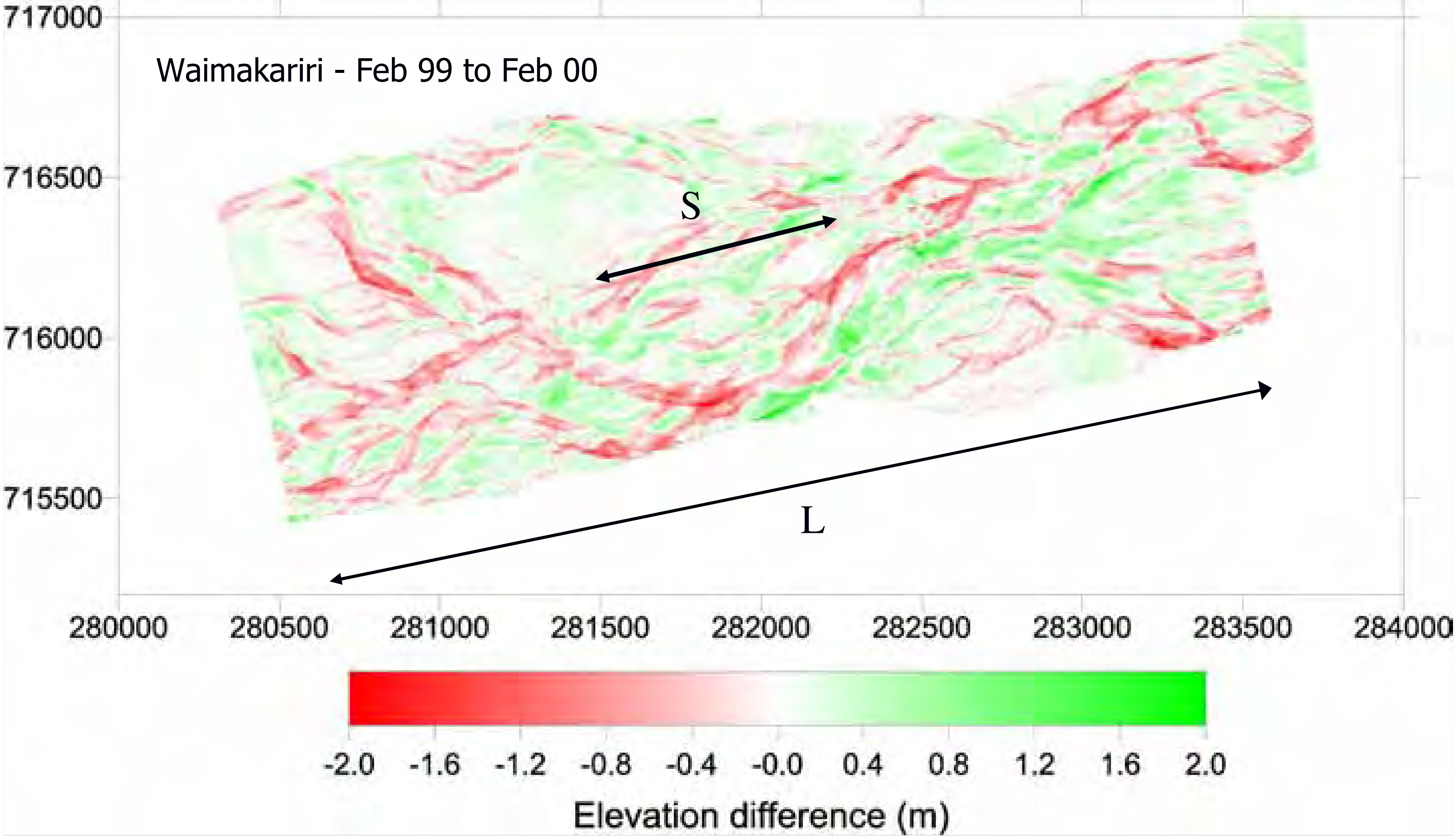
Sampling error in reach MBL vs section spacing
(Waimakariri at Crossbank)



Bedload transport rate

Bedload flux = (Σ(eroded volume)/L).s / ΔT

or Σ(fill volume)



Feb 1999 – Feb 2000

Bedload flux = (Σ(eroded volume)/L)·s / ΔT

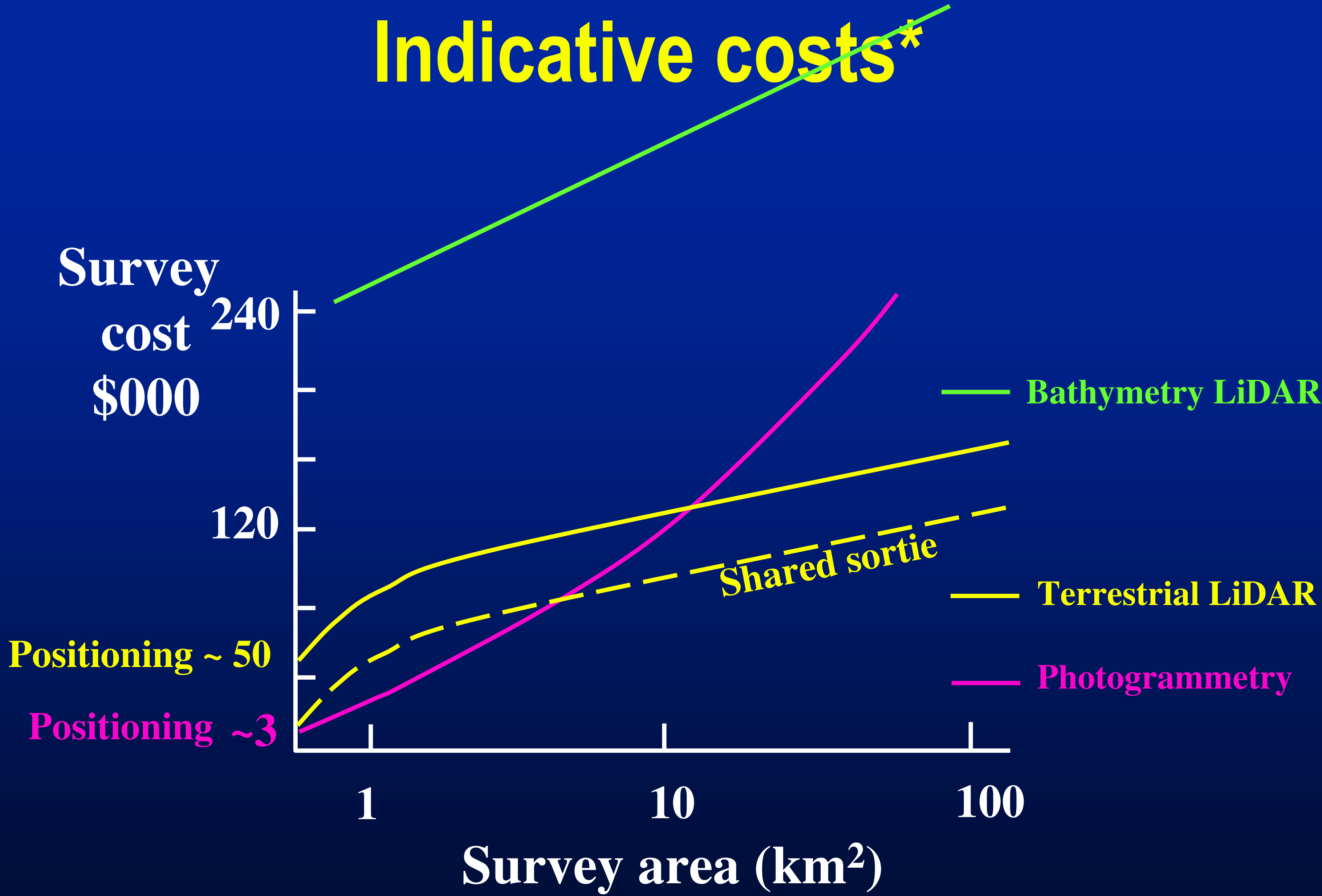
Bedload= (496,000)/3000)·500 / 1 = 83,000 m^3/yr

Indicative Costs* ($NZ)

	Terrestrial	Dual (topo + bathymetry
Positioning	$50k or less	$250k
Operational (per daily sortie)	$70k	$70k + $50k standby
Operational (per hectare)	<$12	?

* These are estimates only and do not necessarily reflect current or future charges by operators

Indicative costs*



* These are estimates only and do not necessarily reflect current or future charges by operators

Conclusions: Advantages/disadvantages of LiDAR

- **Advantages**
  - Hi spatial density
  - Very good vertical accuracy simultaneously and consistently
  - Multiple information, all co-georeferenced
  - ‘Penetrates” vegetation
  - Synoptic
  - Fast acquisition & processing
  - Multiple uses
  - Backward compatible with ground surveys
  - There is a bathymetry solution
  - Opportunities for cost-sharing with multi-client, multi-purpose sorties
- **Disadvantages**
  - Upfront cost (particularly for bathymetry systems)
  - On call availability (now a NZ based operator)
  - Environmental constraints (won’t work with cloud, smoke, fog)
  - Can’t deal with dense vegetation canopy (but what can?)