The effects of flood harvesting on fine sediment deposition in braided rivers

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Climate, Freshwater & Ocean Science

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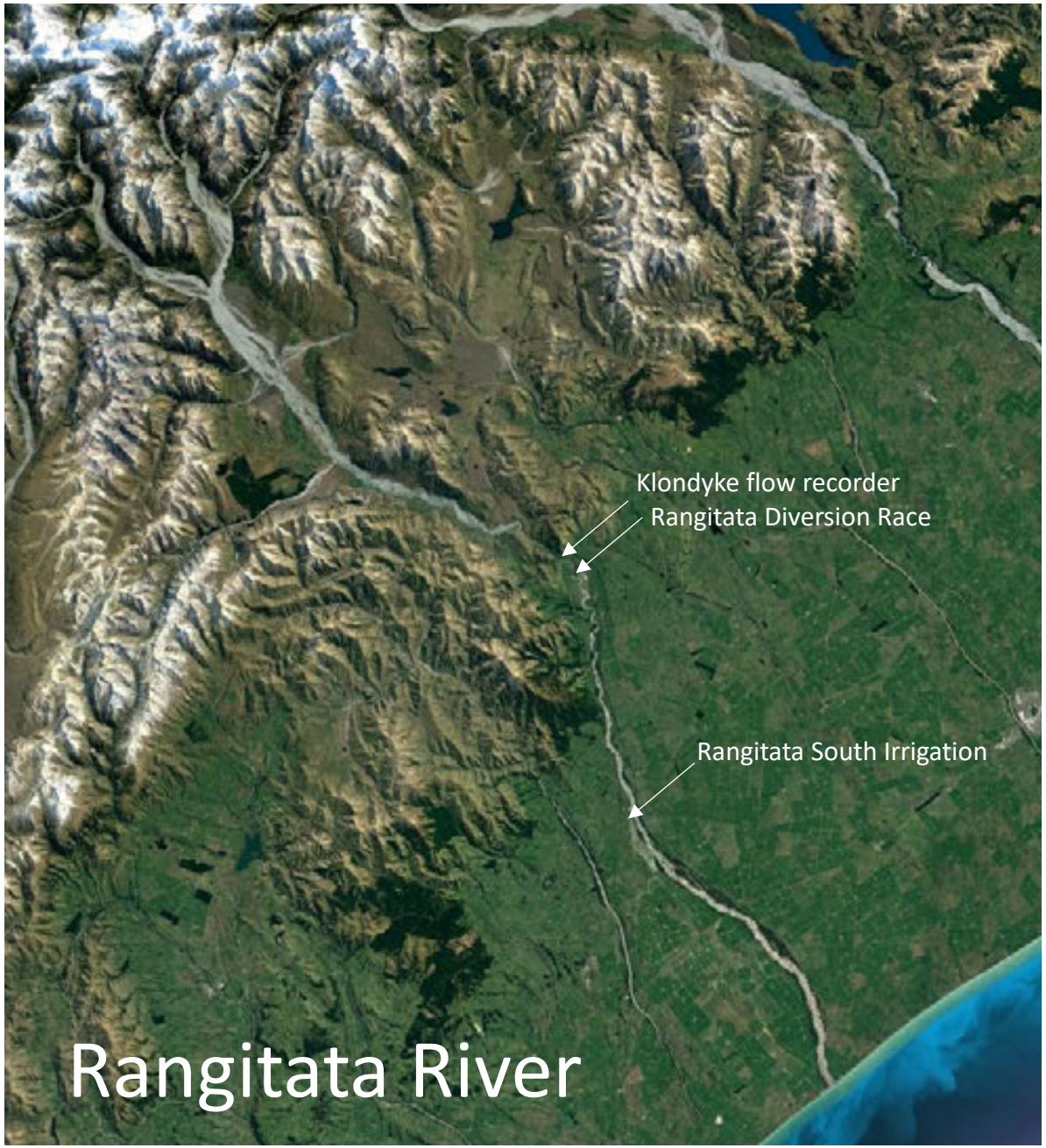
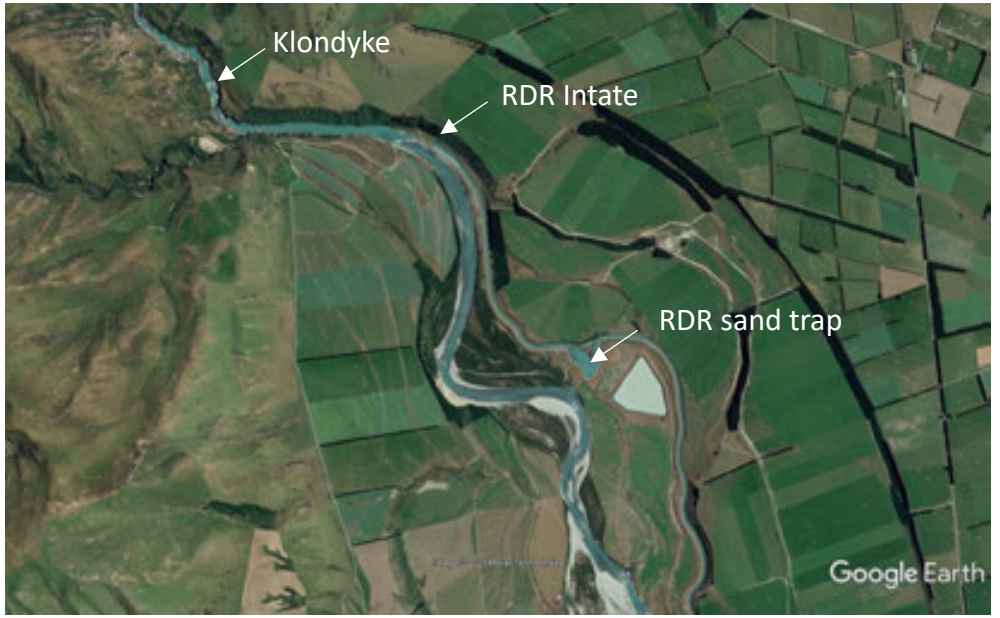
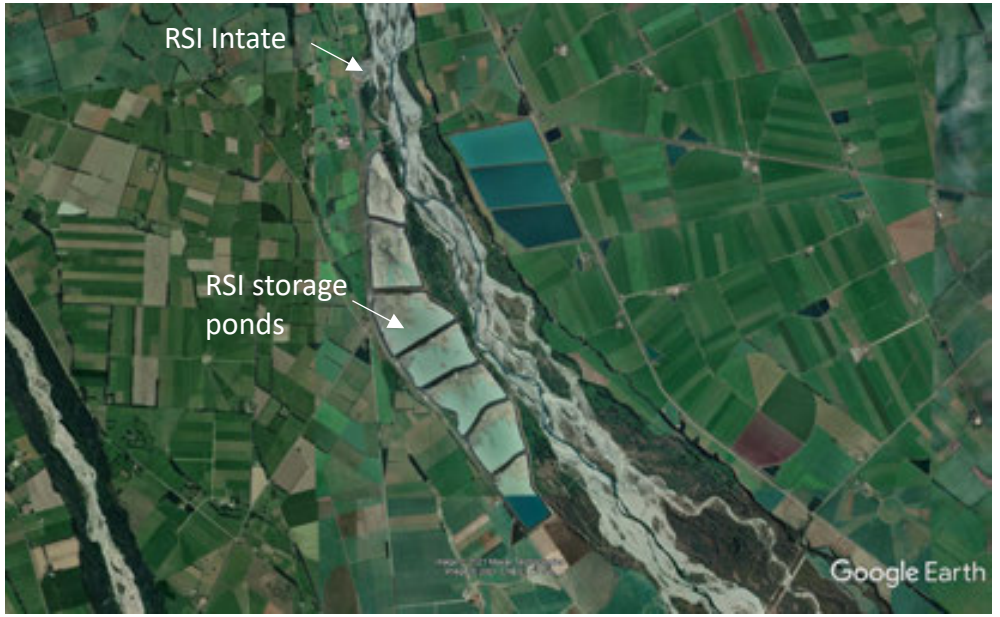
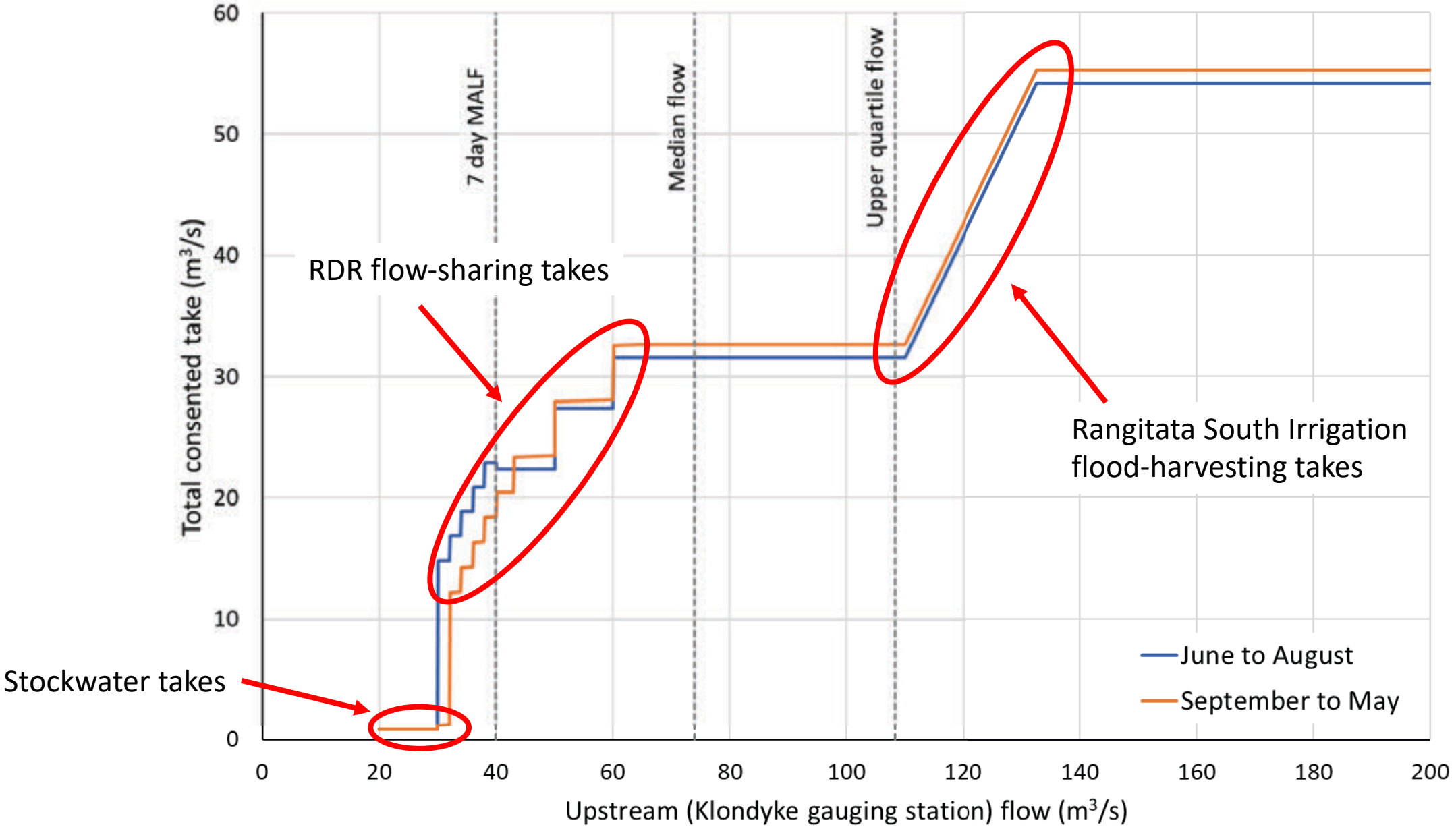
What do we mean by flood harvesting?

- Offline storage of mid-range flows (freshes and floods) in water storage reservoirs
- We need water for irrigation and stock water
- In many catchments baseflows are fully allocated
- Flood harvesting is seen as an ‘easy fix’ for water shortage issues
- Region wide offline storage is becoming more common
- The cummulative effects of flood harvesting on river physical characteristics (habitat) are currently not well understood


Klondyke flow recorder
Rangitata Diversion Race
Rangitata South Irrigation
Rangitata River


Klondyke
RDR Intate
RDR sand trap
Google Earth


RSI Intate
RSI storage ponds
Google Earth



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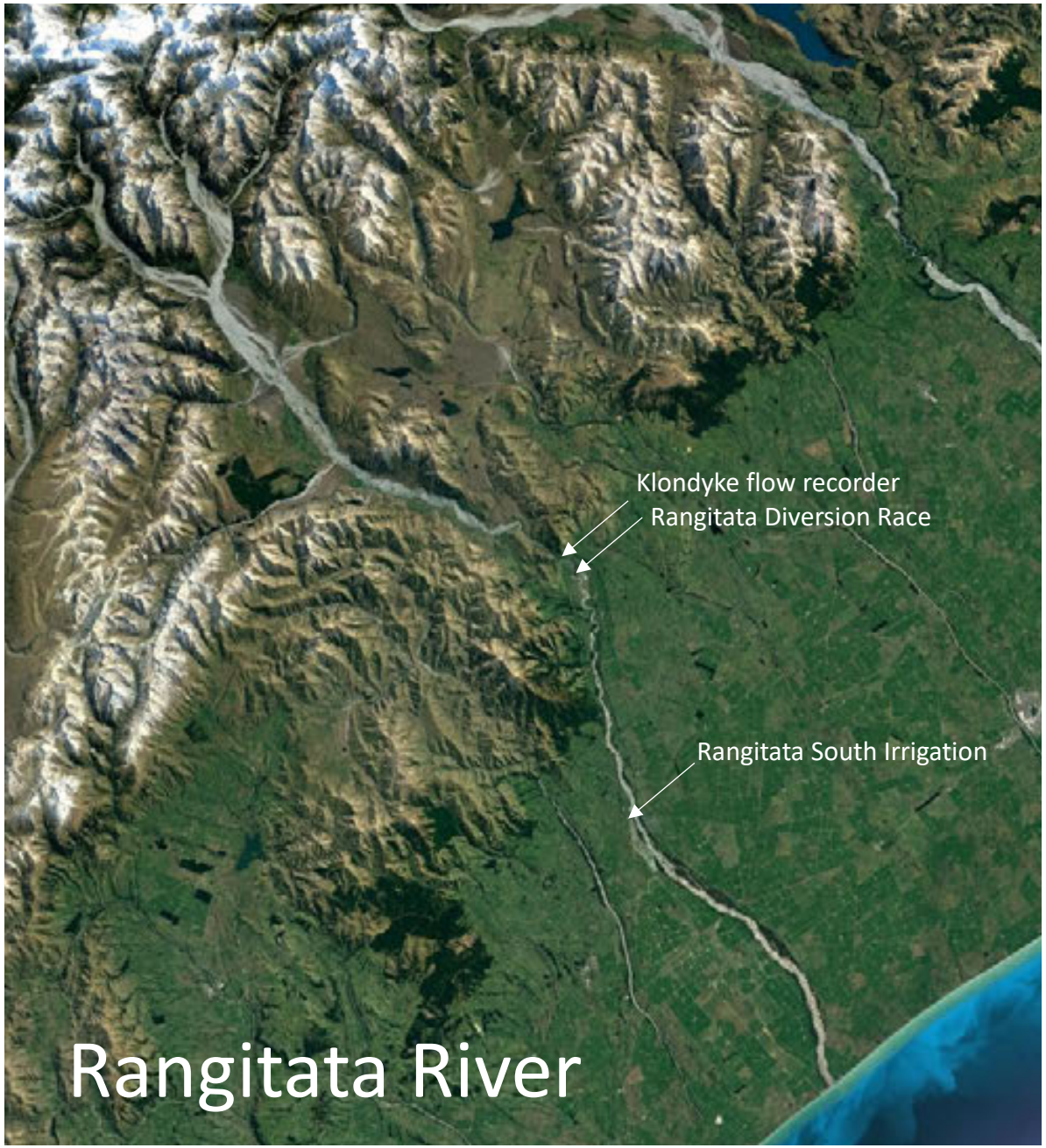

There are anecdotal reports that there is more fine sediment on the Rangitata riverbed

Questions

- Is there evidence in the field that the bed is getting finer?
- Where could all this fine sediment be coming from?
- Is this fine sediment sand or silt?
- Conceptually could flood harvesting cause fine sediment deposition?

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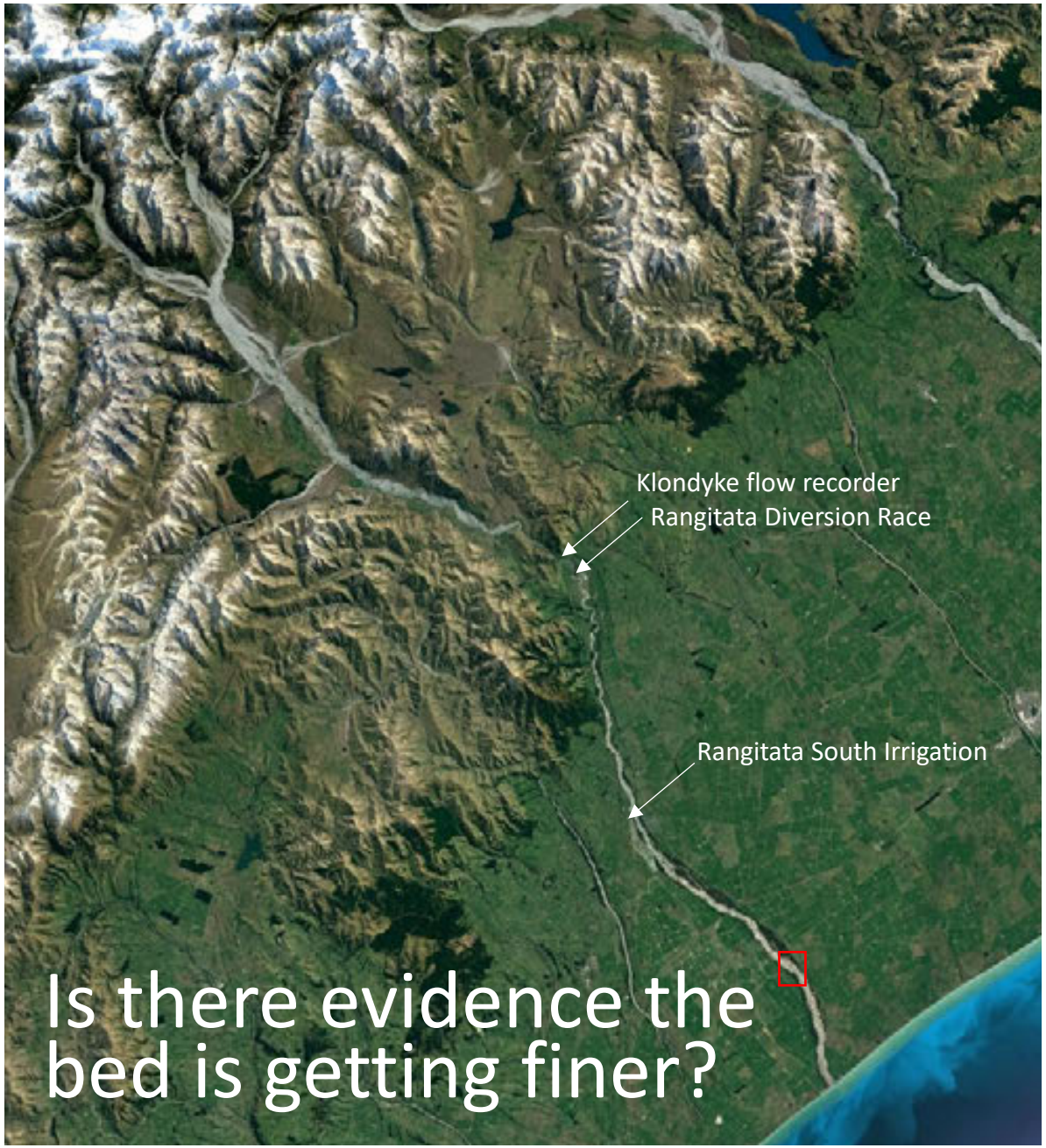
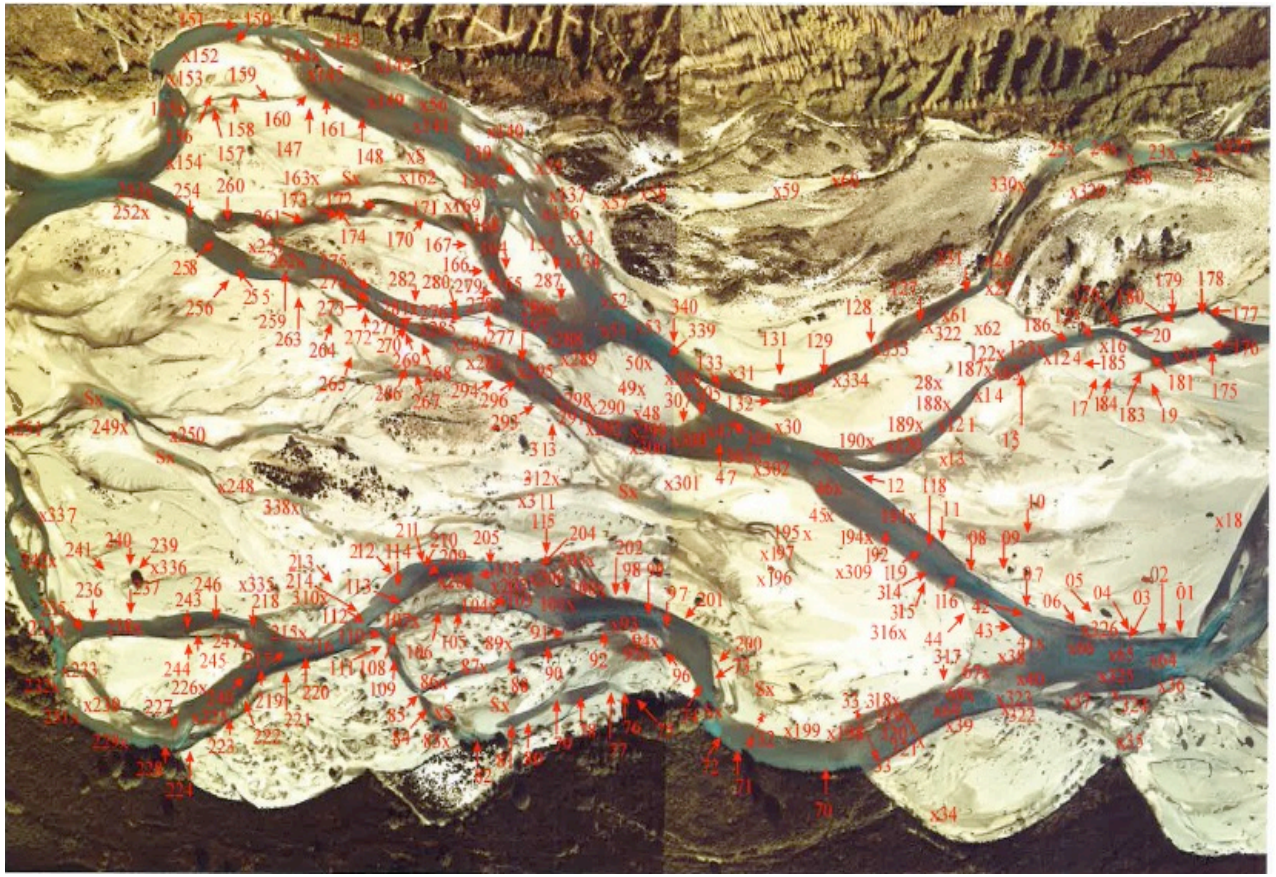


Is there evidence the bed is getting finer?

Bed sediment data from 2001

- 2001 Study aim: predict the effect of flow changes due to the Water Conservation Order on habitat availability for fish, birds and invertebrates (Duncan and Hicks, 2001)

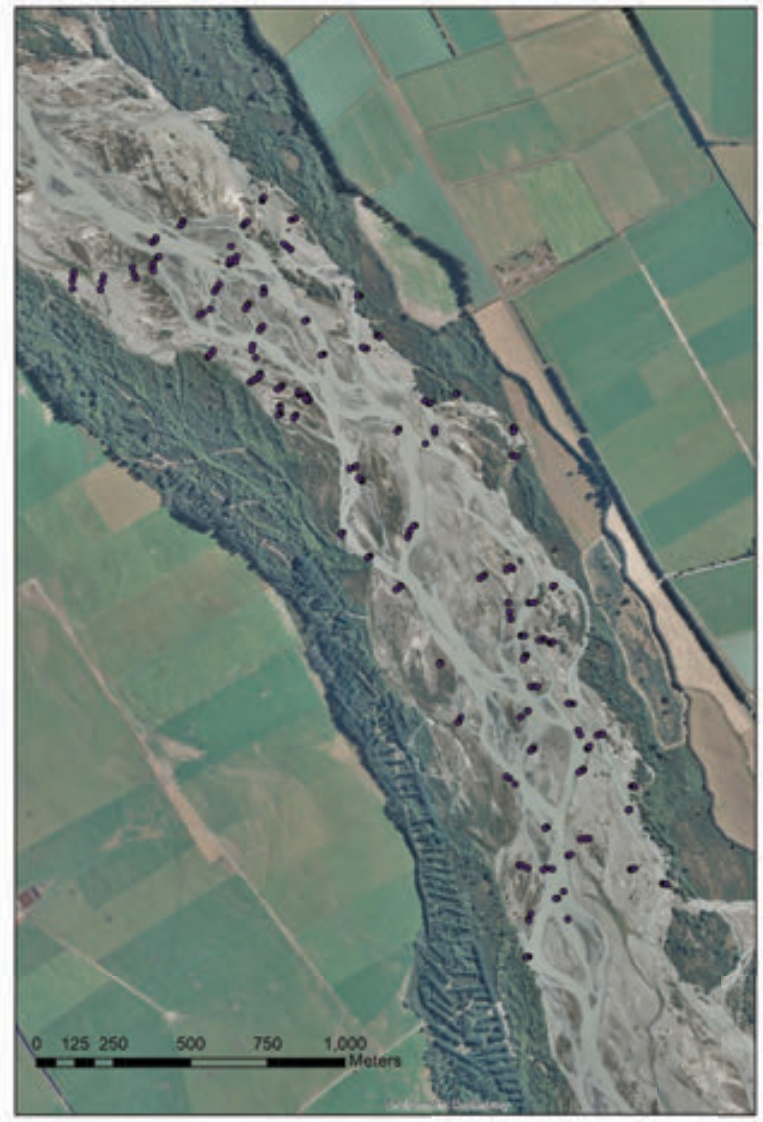
- Data collection included grain size distributions from the riverbed (Hudson 2001)
- Small Wolman samples (25-50 clasts measured) at each site.
- Large number of samples (338)
- Covering a wide range of meso habitats



New bed sediment data 2019 & 2020

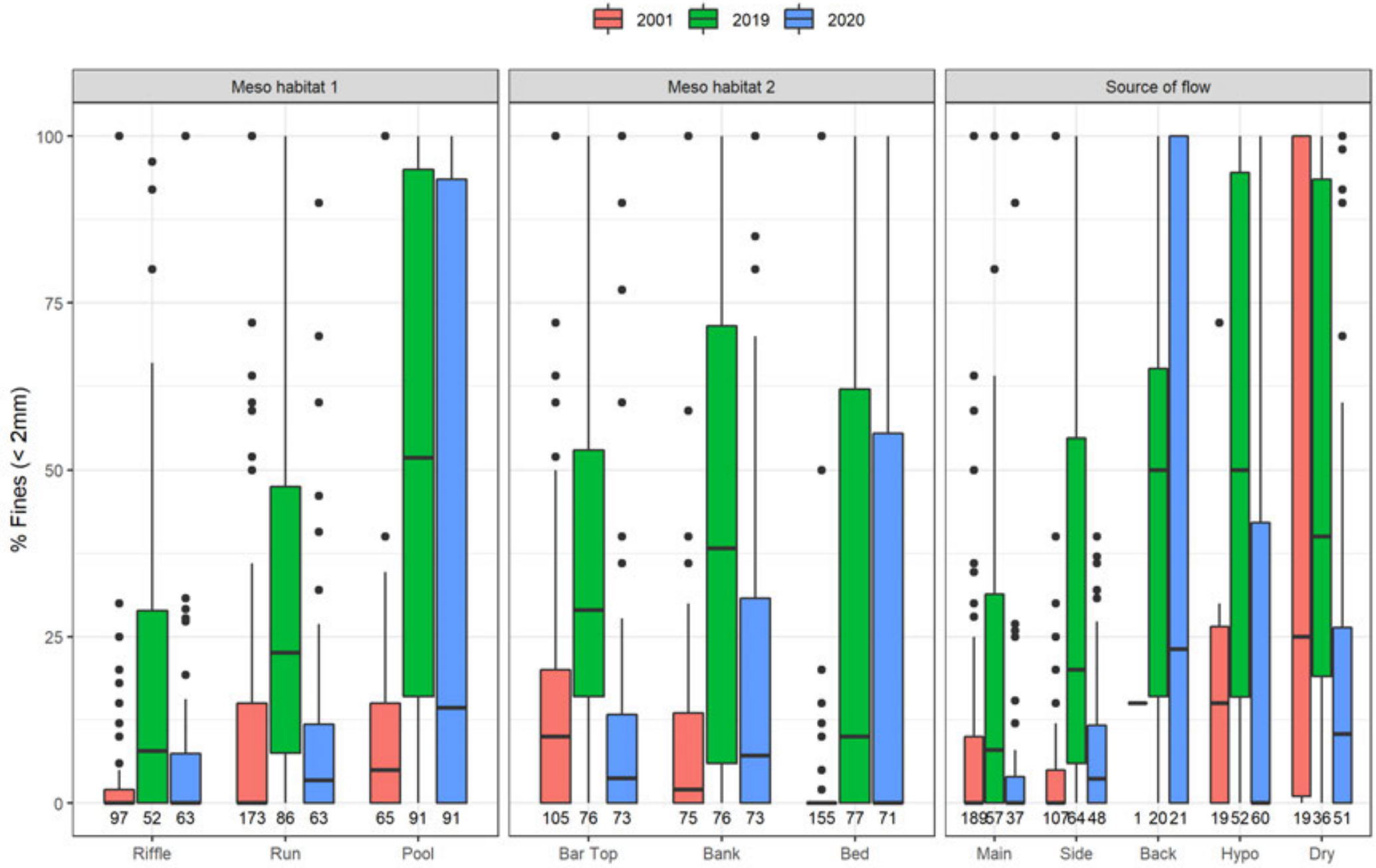
- 2019-2020 Study aim: collect new bed sediment data that is comparable with 2001 data and compare

- Small Wolman samples (25-50 clasts measured) at each site.
- Large number of samples (2019 – 229, 2020 - 217)
- Covering a wide range of meso habitats (depositional environments)
  - Pools, riffles and runs
  - Main braids, side braids, backwaters, hyporheic seeps and dry bars
  - Bed, bank and bar top
  - Aim to replicate 2019 proportions



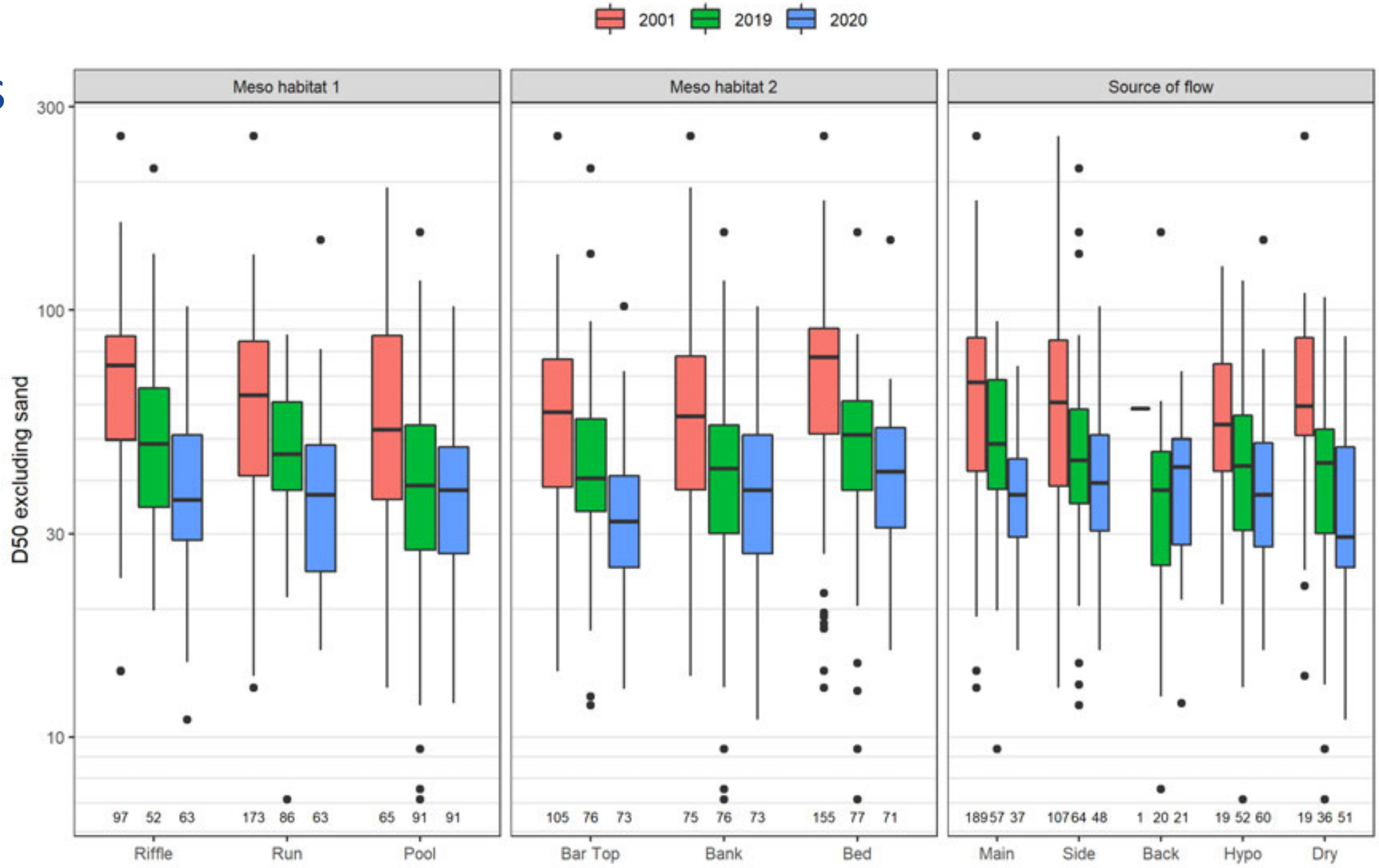
Results

Proportion of fine sediment on the bed and how that varies spatially



Results

Median grainsize (ignoring sand) and how that varies spatially



Where could the fine sediment be coming from?

Suspended sediment monitoring at Klondyke

Aim – to measure SSC and to understand the range of sizes of suspended sediment being carried at different discharges

We Installed:

- Turbidity sensor (observator) – measures finer suspended sediment
- Acoustic sensor (LISST-ABS) – measures coarser suspended sediment

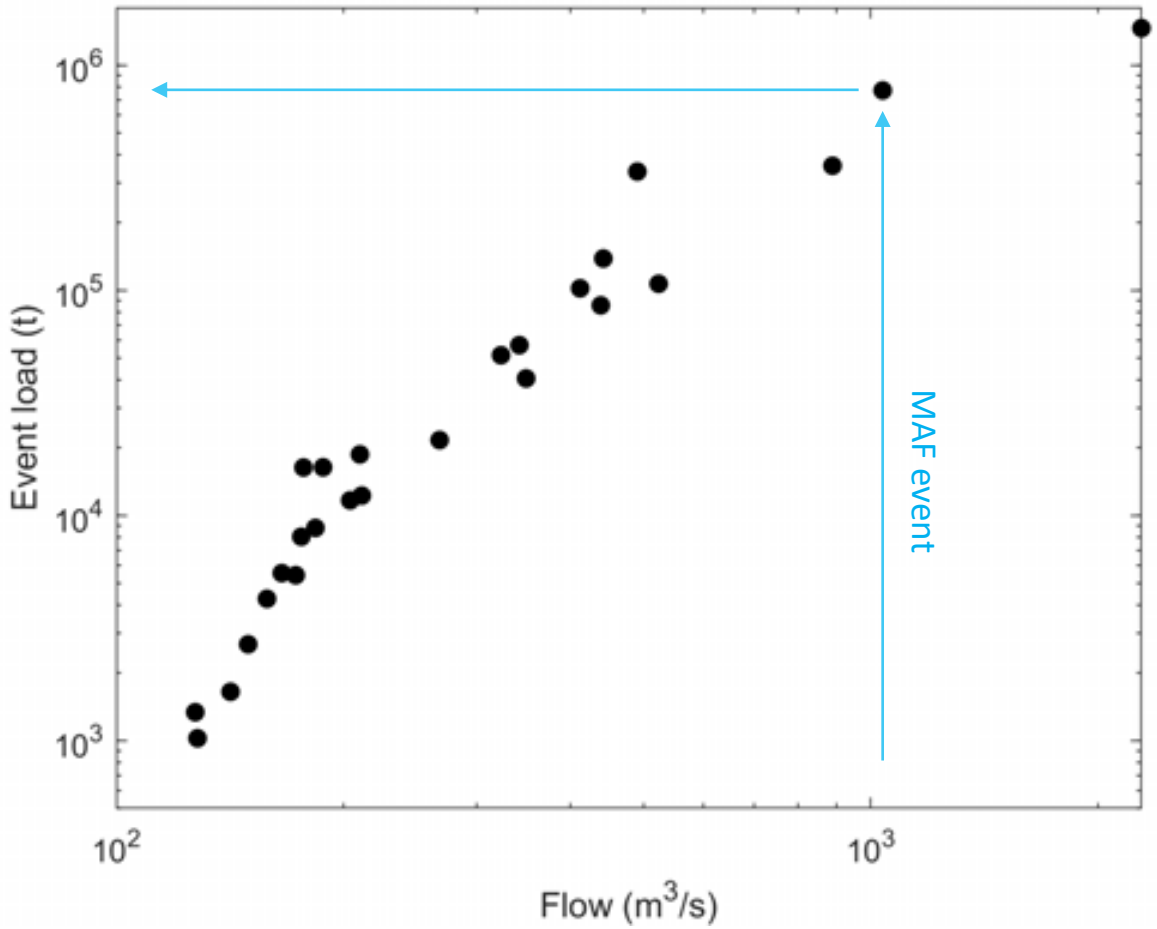
These provide continuous measurement of surrogates for suspended sediment

We also carry out flood gaugings to calibrate sensors

Rangitata River suspended sediment loads

Our sediment monitoring at Klondyke site shows:

- In an event the size of mean annual flood (Q_{max}=1050 m^3/s in December 2019), 772,000 t of suspended sediment was transported downstream.
- This equals to more than 38,000 dump trucks (with 20 t load) during 100 hr flood!

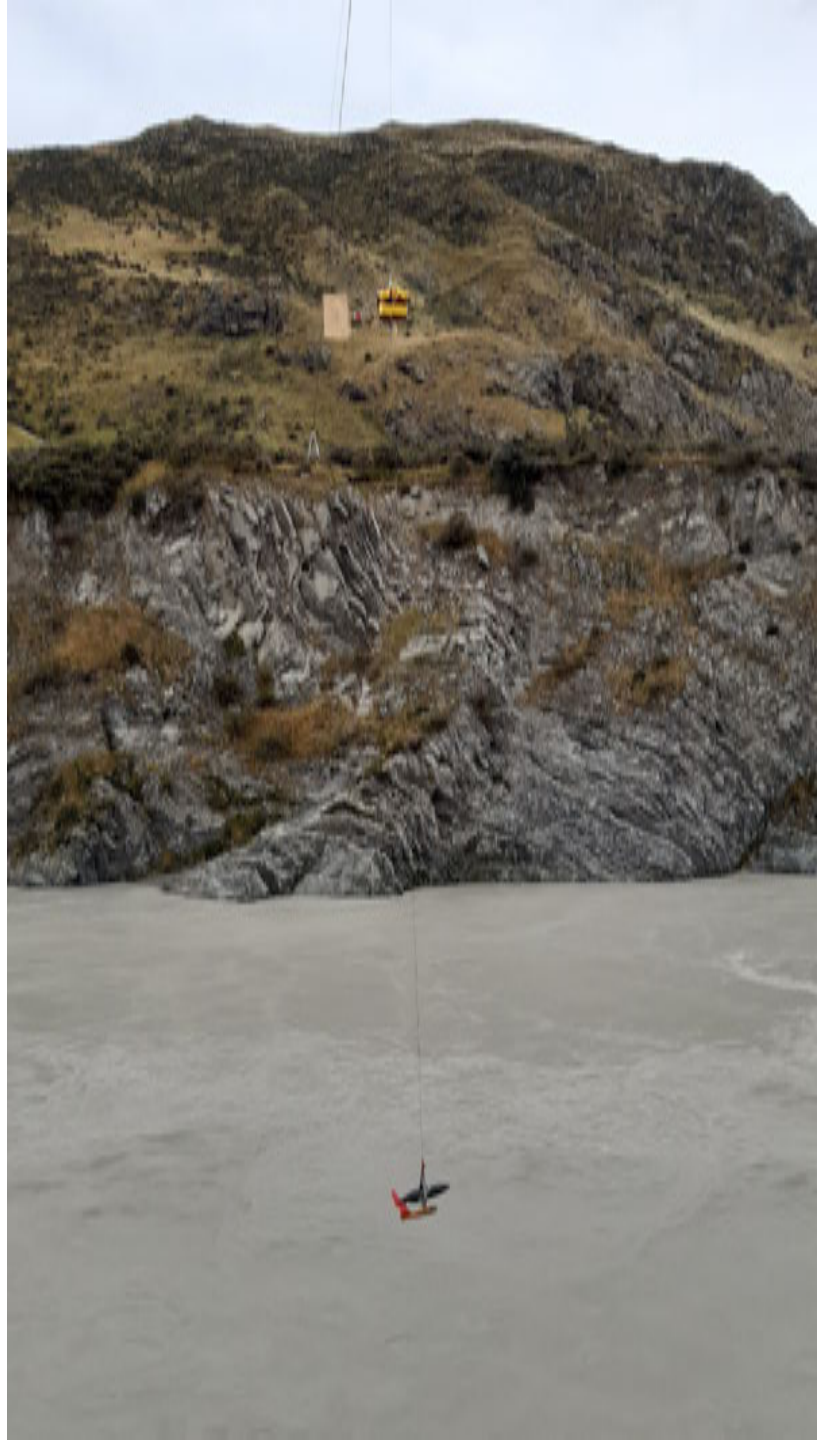


How much of that suspended sediment is silt vs sand?

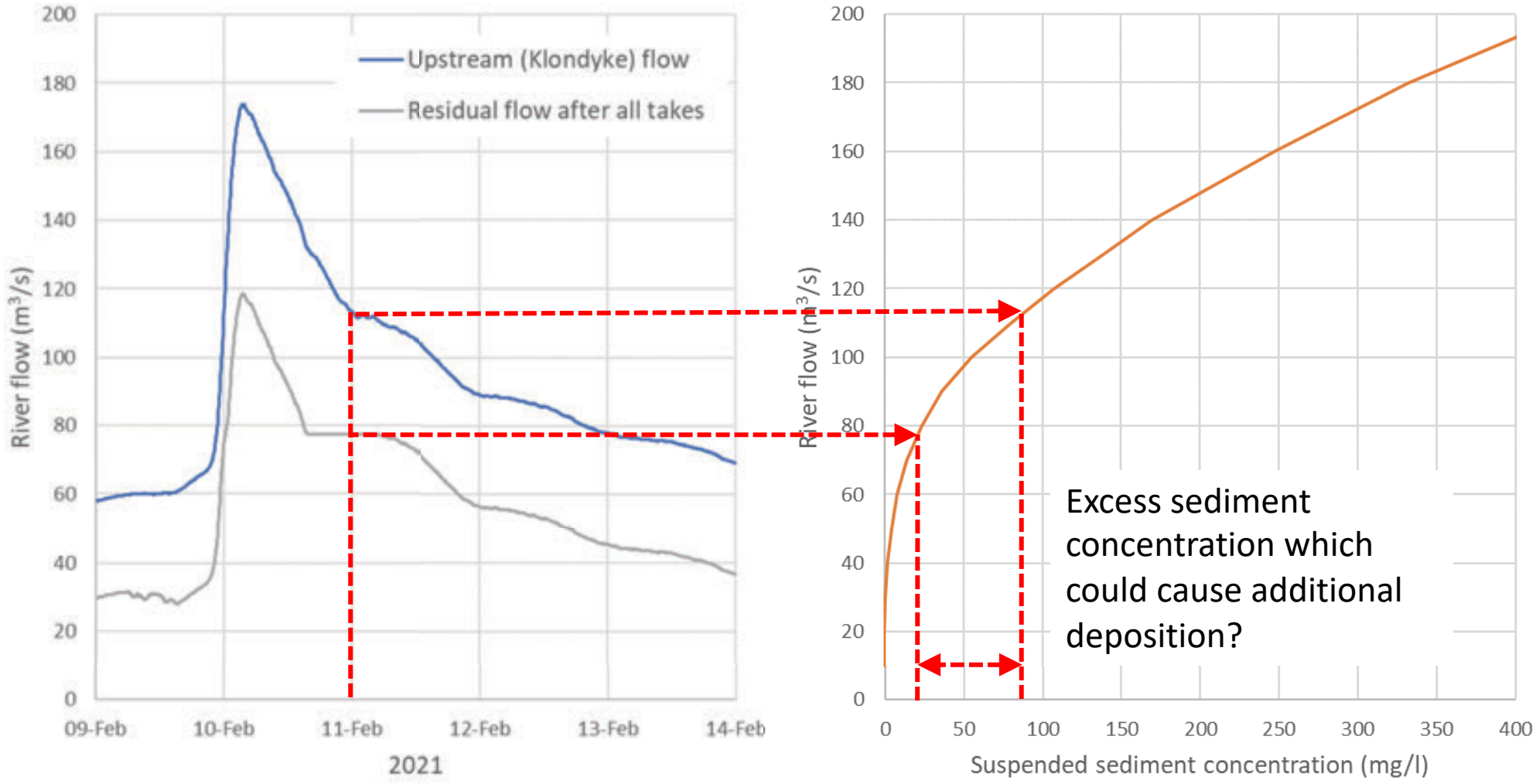
Flood gauging results

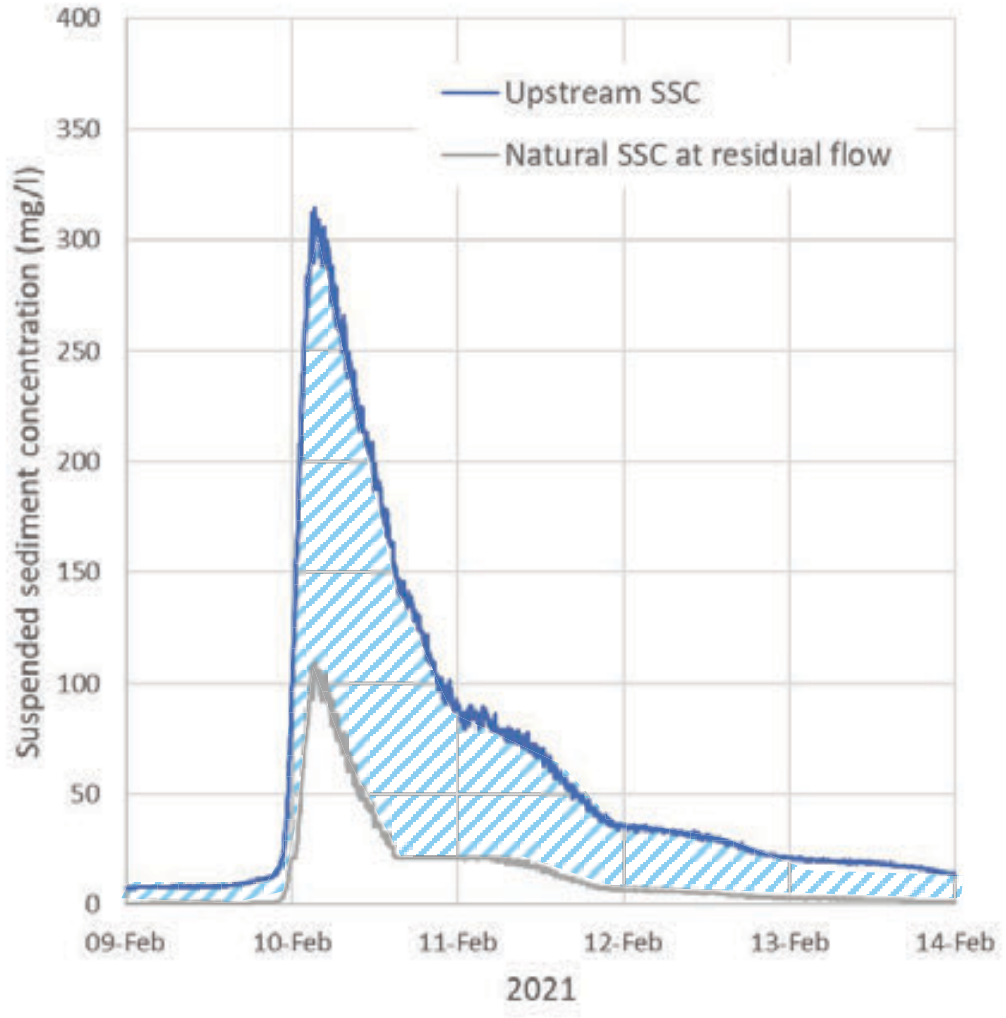
- Particle size data for suspended sediments was measured during a flood on 20 January 2021

- Gauged at two times during the flood event
  - 1st sediment gauging at 183 m^3/s: 39% sand (>62 micron)
  - 2nd sediment gauging at 164 m^3/s: 50% sand (>62 micron) on average throughout the cross section



Could flood harvesting cause fine sediment deposition?





- Potential for significant deposition?
- But excess concentration is a mixture of sand and silt…

Preliminary estimates:

Average annual suspended sediment load at Klondyke:	
Sand (t/yr)	349,507
Silt (t/yr)	815,516
Total (t/yr)	1,165,023

Assuming 30% of total load is sand

Excess sand load downstream of all existing takes*:	
Excess sand load due to change in flow (t/yr)	122,850
Sand input from RDR sand trap (t/yr)	33,898
Total excess sand (t/yr)	156,748
Proportion of total Klondyke sand load	45%

*Includes the effects of existing RDR consents as well as all other consented takes. Numbers assume full consented flow rates are extracted, irrespective of demand, this is a conservative assumption.

Take home messages

Is there evidence in the field that the bed is getting finer?

- Yes, considerably more fine sediment but varying over time (time since flood)
- This fine sediment is everywhere but predominantly low energy environments
- Median grain size is also getting finer (even ignoring sand)

Where could all this fine sediment be coming from?

- Suspended sediment load in the Rangitata is VERY high (Surface samples 7000 mg/l)

Is this fine sediment sand or silt?

- There's a mixture of size fractions being transported, the mix varies within an event and sand proportion is significant (40-50% of SSC)
- what is getting deposited is predominantly sand

Conceptually could flood harvesting cause fine sediment deposition?

- Yes, flood harvesting reduces the fine sediment transport capacity during high flows which has potential to cause significant fine sediment deposition (mostly sand)

Implications and other findings

- Flood harvesting is perhaps not such ‘easy’ fix for water shortage issues

- Habitats are changing in the Rangitata (and likely in other rivers with flood harvesting)

- Ecologically, sand is perhaps less of a concern than silt, but still a concern
  - Implications for feeding, nesting, spawning habitat
  - Implications for weed establishment

Suspended sediment loads for a given flow are higher (x3) in summer than in winter (we assume because of snow effects).

- Climate change could increase fine sediment deposition

Next steps

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- Collect more bed sediment data after a long period of no floods
- Gauge another flood
- 2D reach scale modelling:
  - Fine sediment deposition modelling - how do different flood harvesting scenarios impact the the pattern of fine sediment deposition on the falling limb of events?
  - Morphodynamic modelling – how does flood harvesting impact morphological adjustment (changes in topography and median grain size) over ~20 year timescale?

PhD student, Justin Rogers

- Catchment scale modelling:
  - How do effects get propagated downstream?
  - Are some reaches more vulnerable than others?

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