Modelling Source-to-Sink systems in New Zealand: The Waipaoa and Waitaki catchments.

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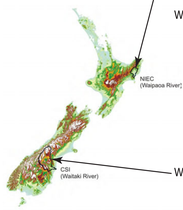
INTRODUCTION



Waipaoa Sedimentary System

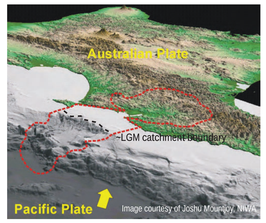
Deforested and steep hillslopes composed of weak mudstone and argillite lithologies
Vigorous maritime climate
One of the highest sediment yeilds on Earth
Mean annual suspended sediment yield of 6780 t km^{-2} yr^{-1}, compared with ~1000 t km^{-2} yr^{-1} prior to anthropogenic influences

We are using HydroTend to help us understand:

How the sediment flux has changed through time
1. From the Last Glacial Maxiumum to the presnt day
2. As a result of deforestation
3. Has the catchment reached saturation with respect to transporting sediment?

What records can we use to investigate the past climate/sediment signals?

How do events (storms and earthquakes) affect the sediment load?

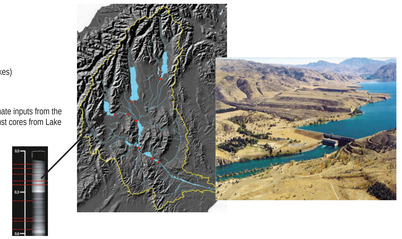


Waitaki Sedimentary System

Strong basement rocks
Infrequent but large earthquakes
Glacial processes
Strong sediment and water supply fluctuations
Low sediment yield (natural lakes and hydro dam lakes)

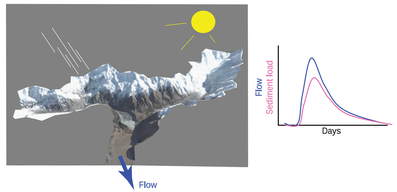
We are using HydroTrend to:

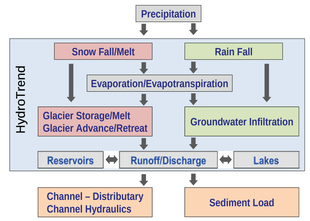
Model sediment input into the glacial likes using climate inputs from the past 80 years. Model results will be calibrated against cores from Lake Ohau.



HYDROTREND

Climate-driven hydrological model (Syviski et al., 1998)

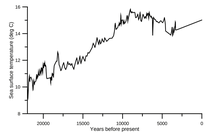




CLIMATE INPUT - WAIPAOA

Sea Surface Temperatures (SST)

Calculated from mid-shelf core, MD972121 (Carter et al., 2002)



Lake Tutira Core

Estimate 100 yearly average rainfall based on the storminess as shown by the thickness and number of storm layers

Lake Tutira catchment, Post-cyclone Bola, 1988

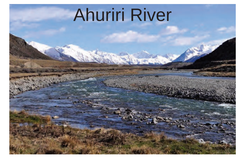
VEGETATION FACTOR INPUT - WAIPAOA

Present day
Waipaoa veg = 8, Sheep farming and forest clearance

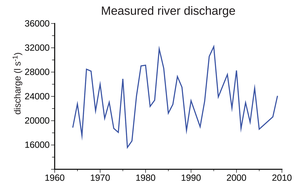
Pre-Anthropogenic Influences
Waipaoa veg = 1, Nearly 100% forest cover

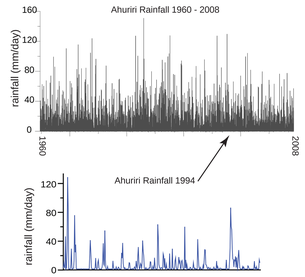
Last Glacial Maximum
Waipaoa veg ~ 4, grasses and shrubs dominate the landscape. Rivers carry significant bedload

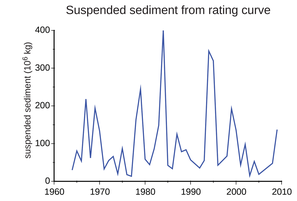
MODEL CONSTRAINTS WAITAKI



Validation Data from NIWA

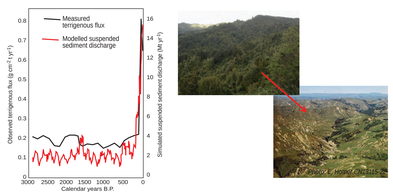






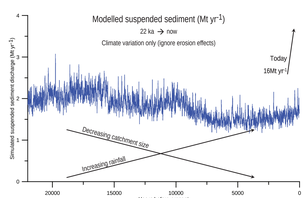
MODEL RESULTS, DISCUSSION AND IMPLICATIONS - WAIPAOA

Previous work - deforestation signal (Kettner et al. 2007)

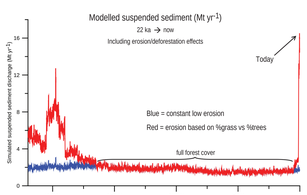


Model from Last Glacial Maximum (LGM, 22ka) to present day

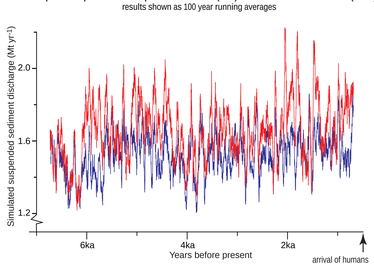
Model #1 - Ignores changes in vegetation cover and deforestation

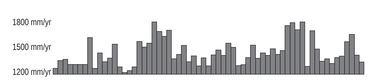


Model #1 - Includes changes in vegetation cover and deforestation



Precipitation proxies: comparison of SST (red) and Lake Tutira storms (blue)
results shown as 100 year running averages





Esimated rainfall from Lake Tutira in 100 year bins

Red = climate based on SST (temperature and precipitation)
Blue = climate based on SST (temperature) and Lake Tutira (precipitation)

Peaks in precipitation are matched by peaks in the blue predicted suspended sediment load

The overall pattern matches between the two records, for example, higher Q_{SS} around 5ka. The Tutira precipitation estimates are consistantly higher than the SST predictions.

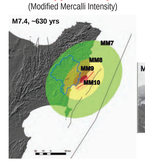
LGM to present day suspended sediment load in the Waipaoa

Today the Waipaoa River carries more sediment than at anytime during the past 22ka, including the LGM. At LGM the watershed was larger, the climate was colder and drier and the vegetation a mixture of grasses and shrubs. These factors combine to give a predicted suspended sediment load that was approximately a third to a half of what it is now.

Larger watershed → higher discharge and higher suspended sediment load
Colder climate → reduced weathering and availablity of material to be eroded
Drier climate → less water to transport material to the ocean
LGM vegetation → native grasses and shrubs leave the landscape more vunerable to erosion than full forest cover but less vunerable than today's situation of ~95% deforestation, short introduced grasses and sheep farming.

What would be the sediment response to a large earthquake in the Waipaoa catchment?

Strong ground shaking
(Modified Mercalli Intensity)

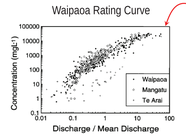


Return times of strong ground shaking

Catchment	MM7	MM8	MM9	MM10
Waipaoa	130	620	10,000	-

Litchfield et al. (2009)

Waipaoa Rating Curve



Hicks et al. (2000)

Bending over of rating curve at high discharge suggests the system is transport-limited not supply-limited.

Is the system capable of transporting more sediment if an earthquake loosened the hillslope material?

Taiwan - the rivers can carry a lot more sediment than usual following a large earthquake

e.g. Choshui River, Western Taiwan

Q_{SS} (average) ~ 40 Mt yr^{-1}
Q_{SS} (post-ChiChi) ~ 200 Mt yr^{-1}
(Milliman, WPGM 2010).

BUT - Taiwan rivers are not as modified as the Waipaoa River:

Have the anthropogenic modifications to the Waipaoa River saturated it?

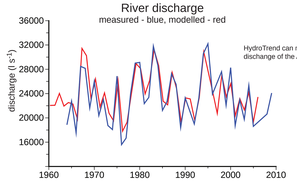
L. Homer CN13115

Haiti, following the January 2010 earthquake, may provide some insight.

PRELIMINARY MODEL RESULTS AND FUTURE WORK - WAITAKI

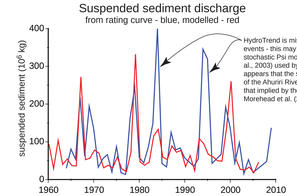
Comparison of model and validation data

River discharge
measured - blue, modelled - red



HydroTrend can model the river discharge of the Ahuriri River well.

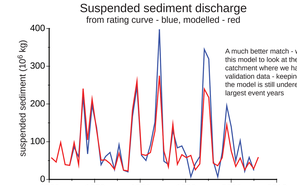
Suspended sediment discharge
from rating curve - blue, modelled - red



HydroTrend is missing some large events - this may be because of the stochastic Psi model (Morehead et al., 2003) used by HydroTrend. It appears that the sediment response of the Ahuriri River is more uniform that implied by the Psi model of Morehead et al. (2003).

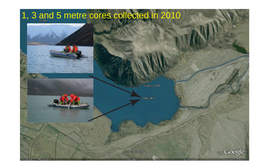
Modify HydroTrend - use specific rating curve from validation data, C ~ 3.02, remove daily variability in rating curve due to Psi model. Rerun HydroTrend.

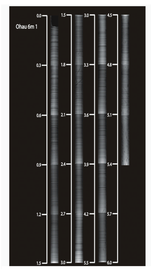
Suspended sediment discharge
from rating curve - blue, modelled - red



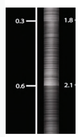
A much better match - we will then use this model to look at the Ohau catchment where we have no validation data - keeping in mind that the model is still underestimating the largest event years

Lake Ohau - coupling HydroTrend and Sedflux



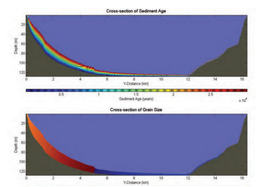


X-radiographs of Ohau 6m. The lightening of the images towards the bottom of each 0.3m set is an artifact of the imaging process. Depth scale in metres.



Light and dark layers: Do these represent seasonal layers or event layers?

Cores collected by Marcus Vandergoes, Richard Levy and Jamie Howarth.



Preliminary 2D sedflux models of Lake Ohau.

These models have a constant sediment source. Next, we will run the following models:

1 - seasonal variable sediment source
2 - use HydroTrend models, calibrated to the Ahuriri River catchment and using as input daily temperature and rainfall measurements over the past 60 years.
3 - Reconstruct the bathymetry of Lake Ohau back to 16ky, based on detailed studies of moraines.
4 - Extend HydroTrend models back to 16ky using paleoclimate estimates from nearby sites such as Boundary Stream Tarn (Vandergoes et al., 2008)
5 - Run all models using 3D sedflux