Manaaki Whenua
Landcare Research

Reaching into the past

Deep learning and historic aerial imagery

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Manaaki Whenua Landcare Research

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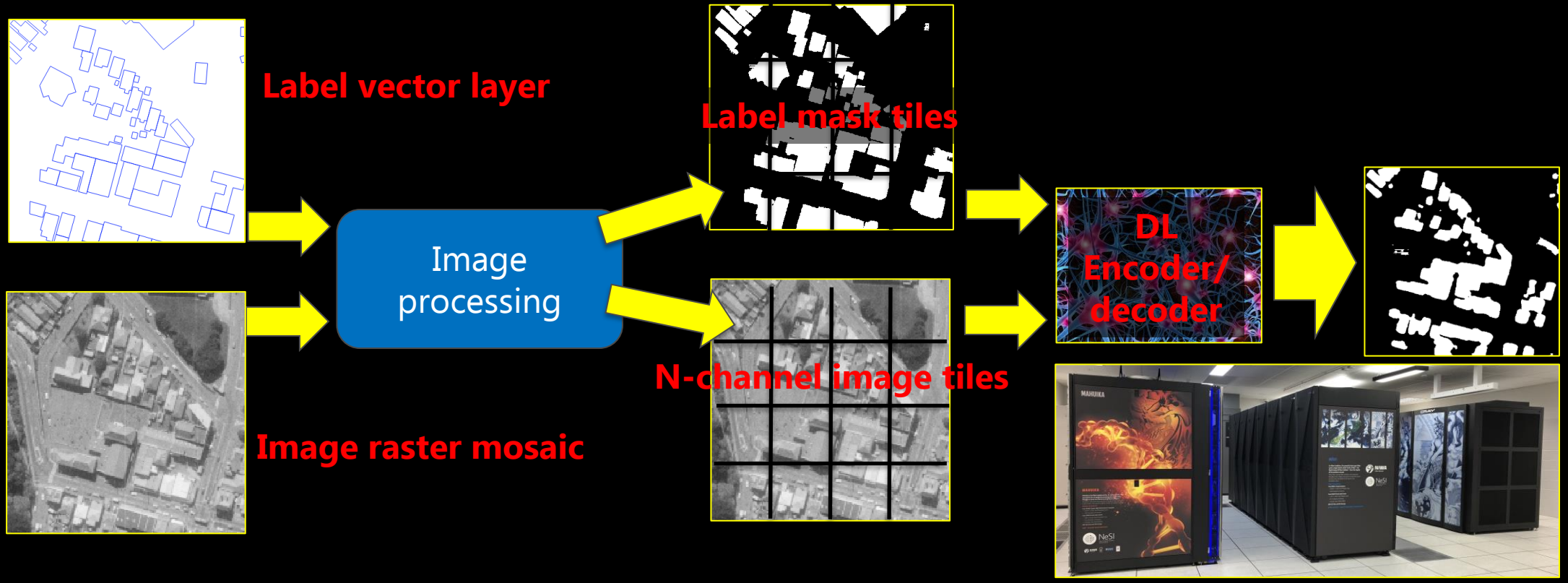
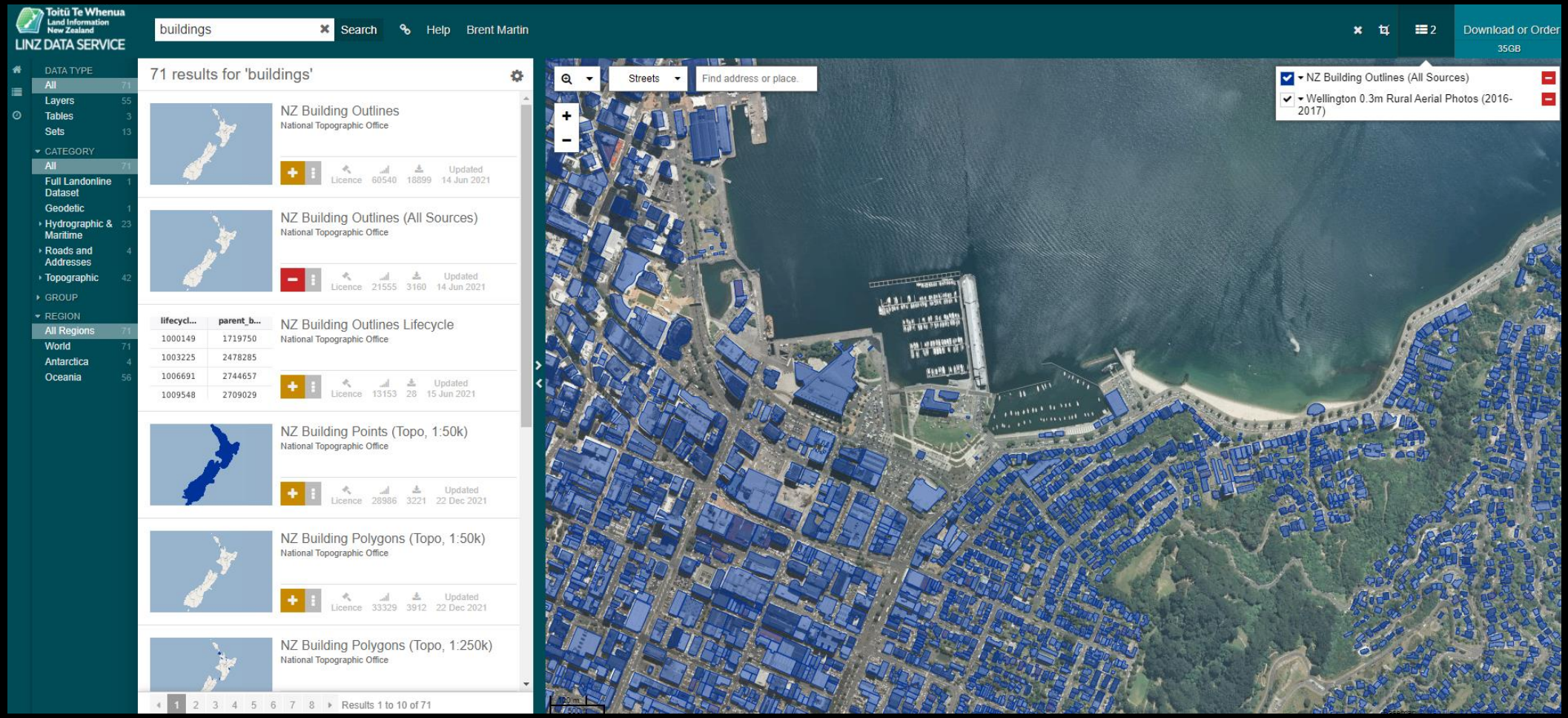
Goal: map urban built form change over time

Approach: deep learning segmentation



- MWLR pipeline processes input data into image/label mask tile pairs for training/prediction
- Deep learning encoder-decoder network (Unet64) learns to generate mask tiles (512x512 pixels)
- Masks stitched back together (50% overlap)

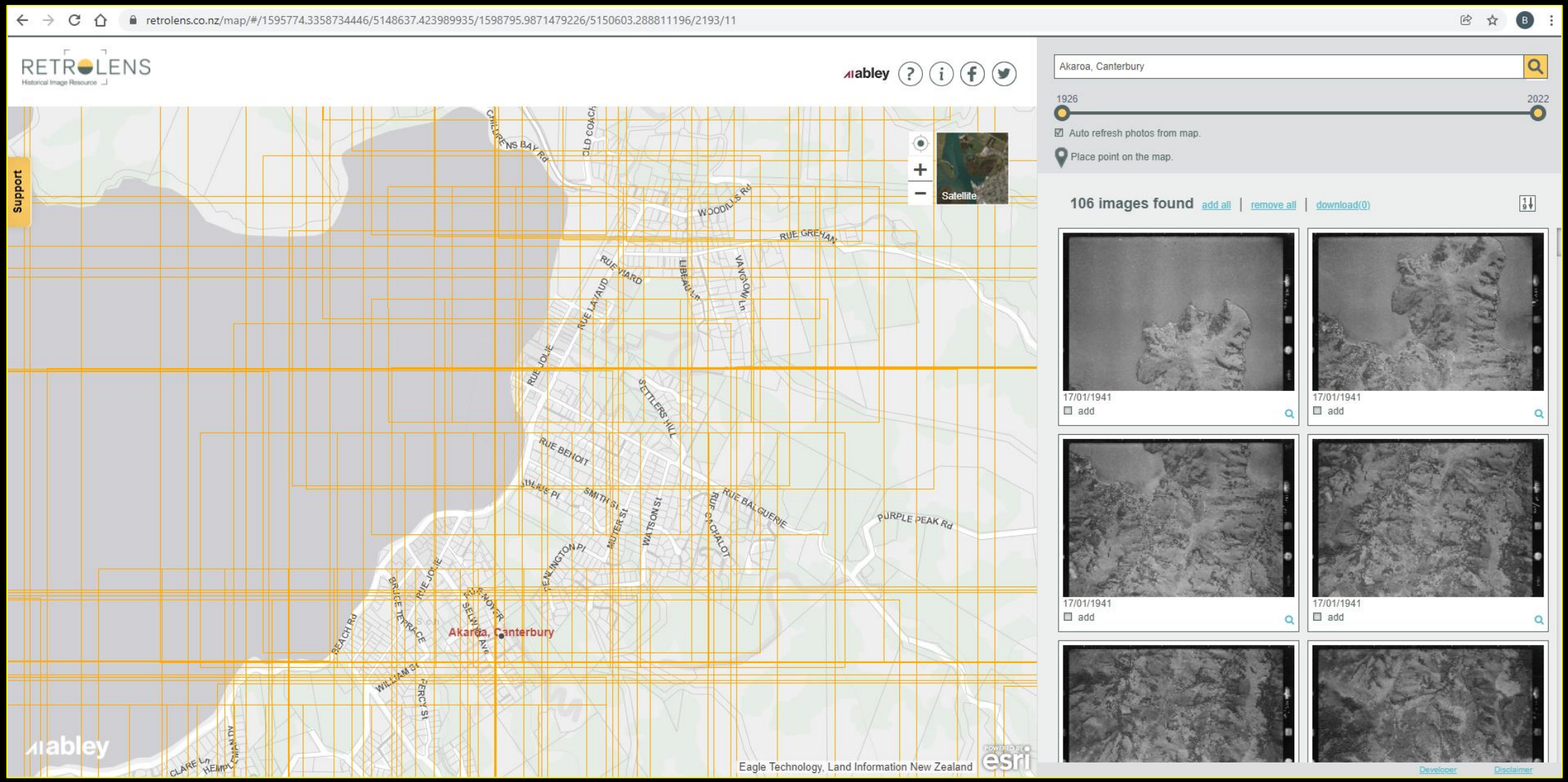
Training data: LINZ 2016



Imagery: 2016 0.3m aerial photos

Labels: NZ building outlines

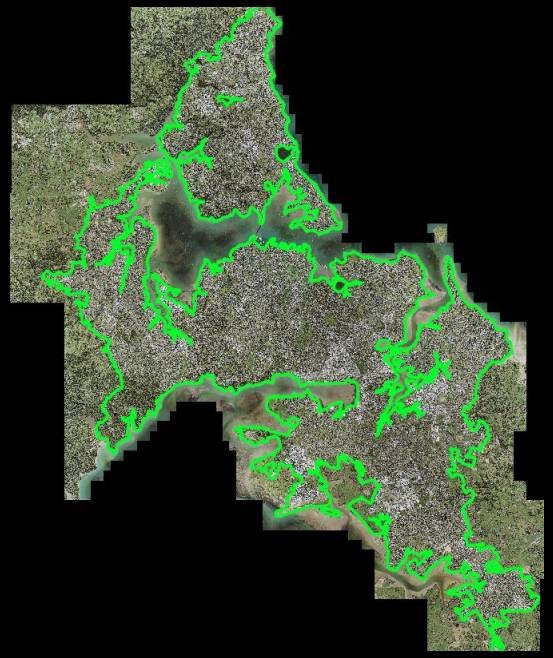
Historic imagery: Retrolens/LINZ

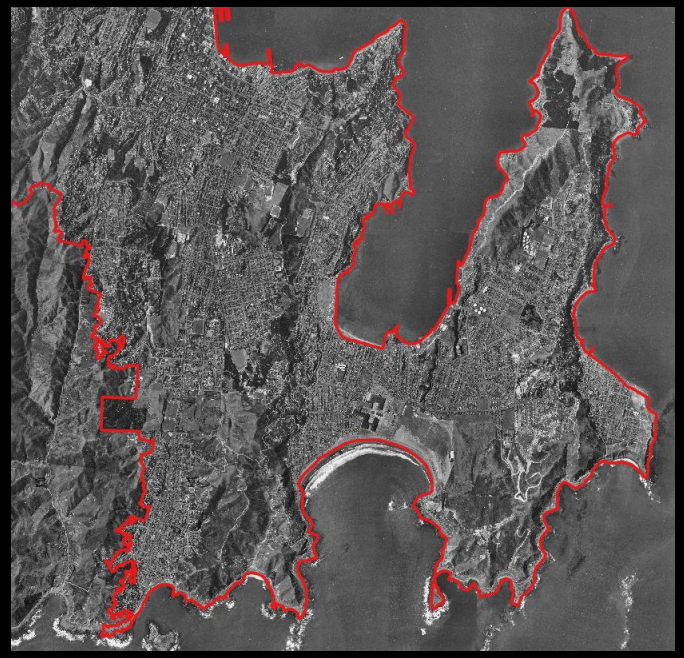


Challenges

How to train the network for all time periods and cities?

- Can a model trained on 2016 be used for historic B&W imagery?
- Can training transfer between cities?





Transfer between time periods

2016: excellent

1940: poor

2016 model fails to transfer to historic imagery

Issue: image quality

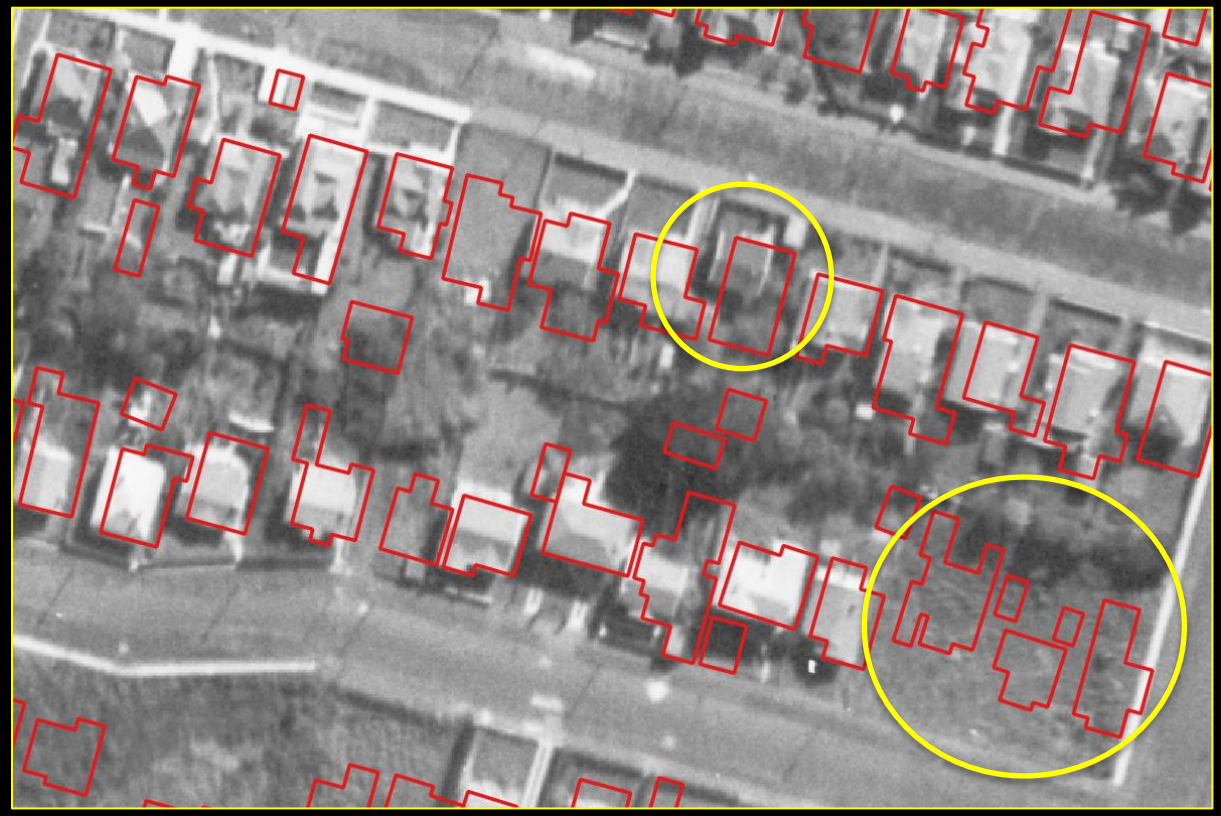
2016: digital
Standardised brightness/contrast
Minimal noise
Sharp focus
High spatial accuracy
Shadows

1980: film
Flat contrast
Grainy
Moderate focus
Moderate spatial accuracy
Short shadows

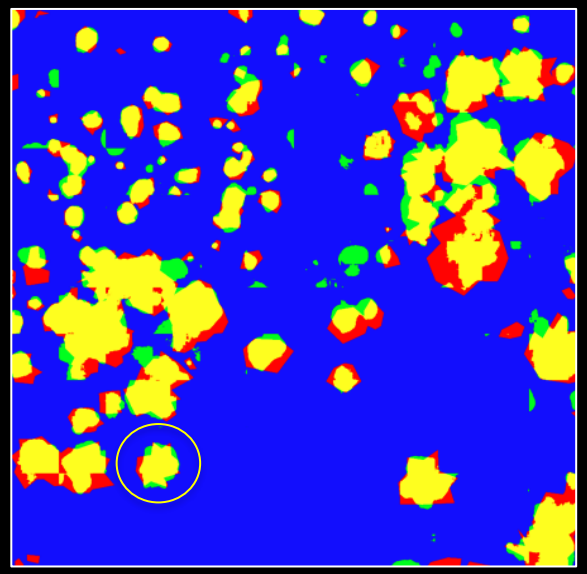
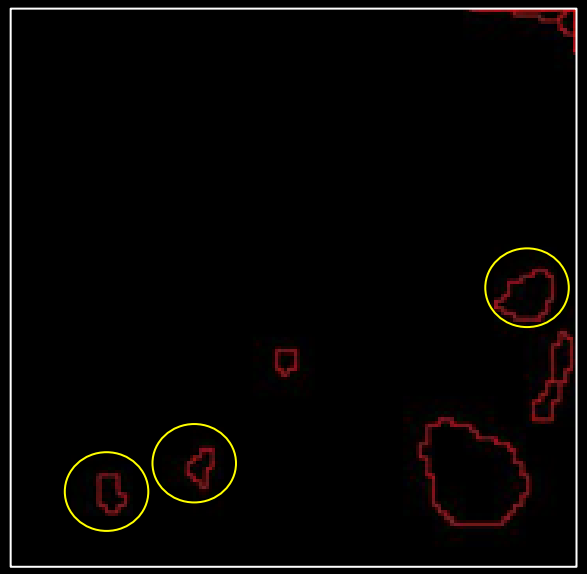
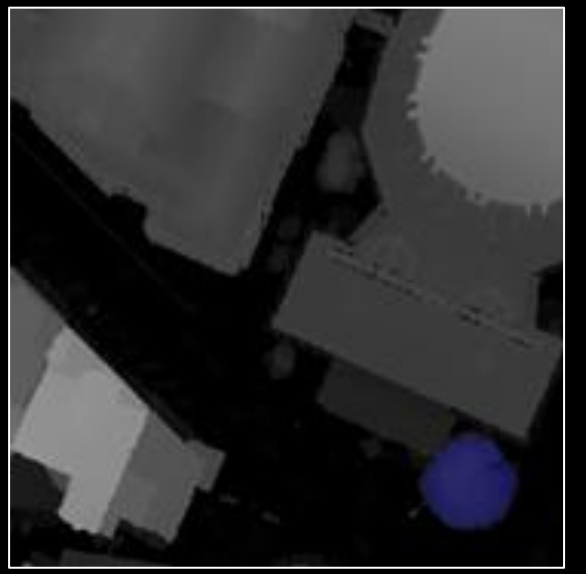
1940: film
Variable brightness/contrast
Grainy
Variable/poor focus
Spatial distortion/displacement
Long shadows

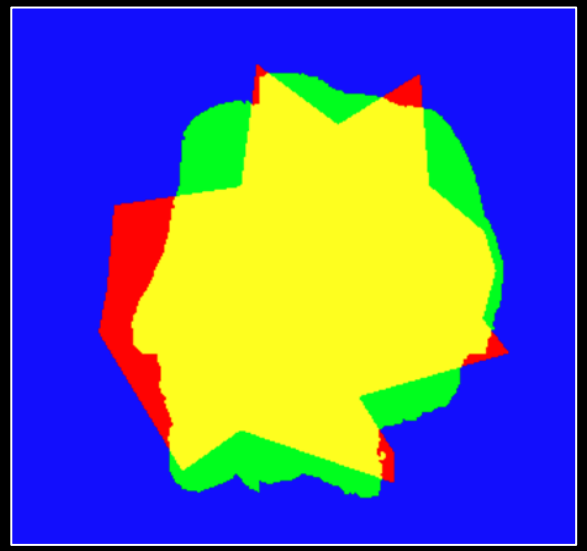
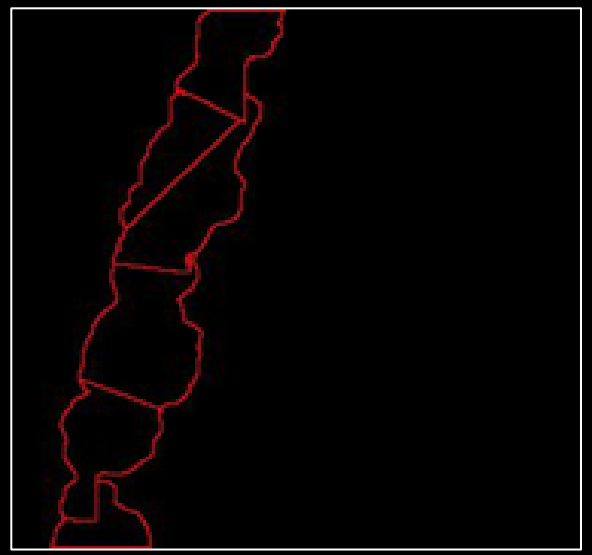
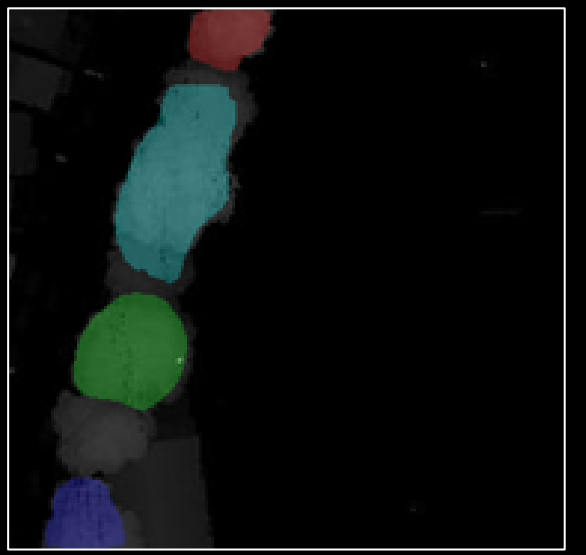
Solution: imperfect learning

- Train model on historic imagery but *current* labels?
  - Buildings may have been built, demolished or modified
  - Image may be displaced because of distortion issues
- Select tiles with "reasonable" match
  - What is "reasonable"?
  - Enough tiles?



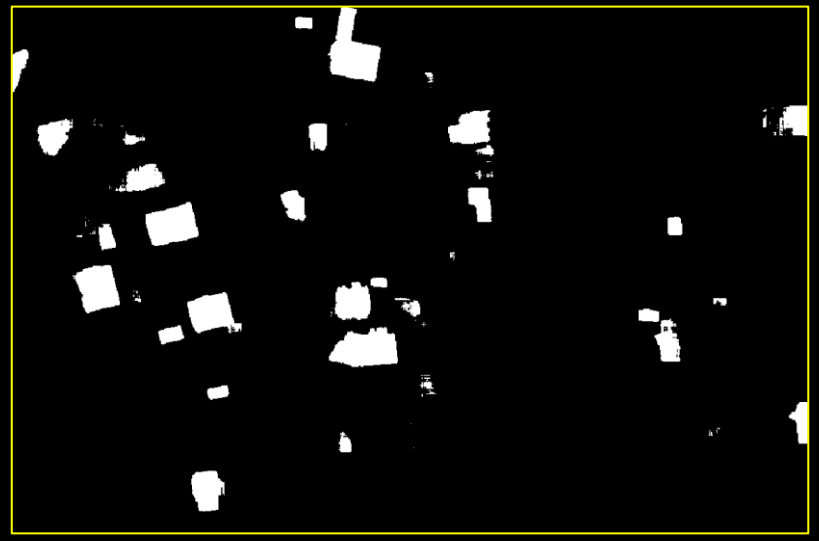
Segmentation label quality tolerance

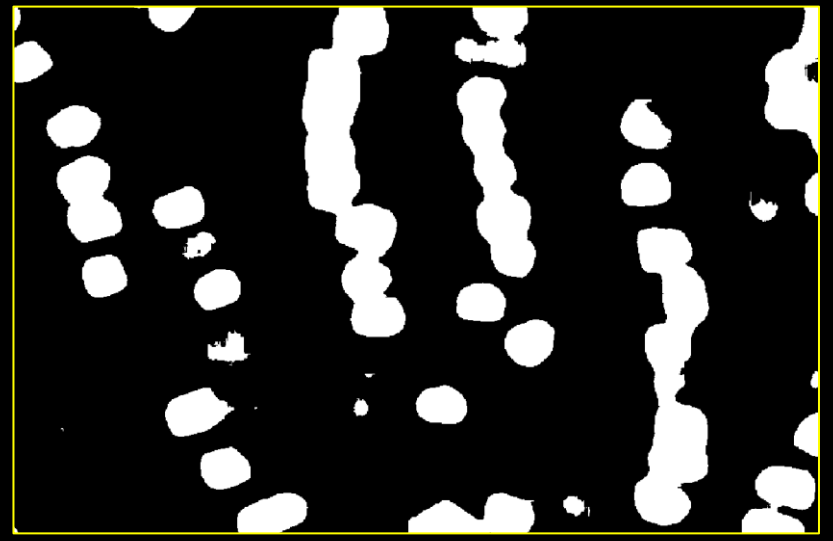




Imperfect training results: 1940

Wellington: 1940 image



2016-based mask

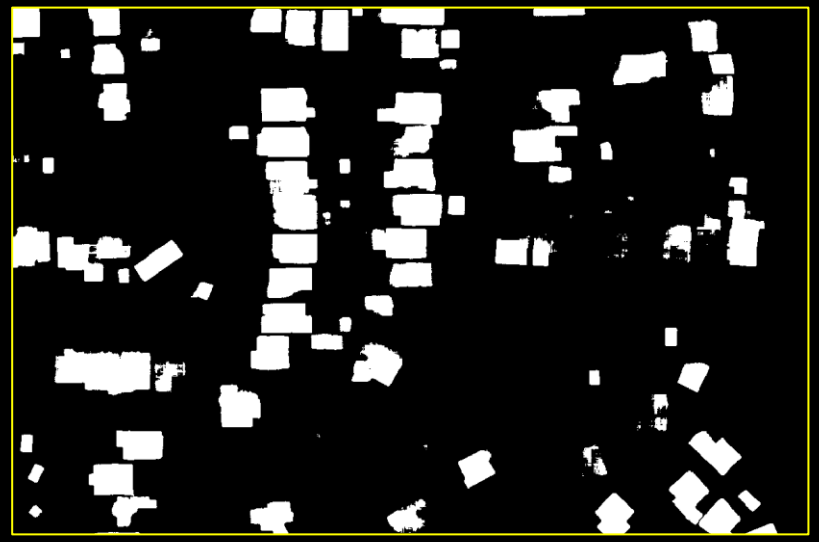


1940 imperfect data mask

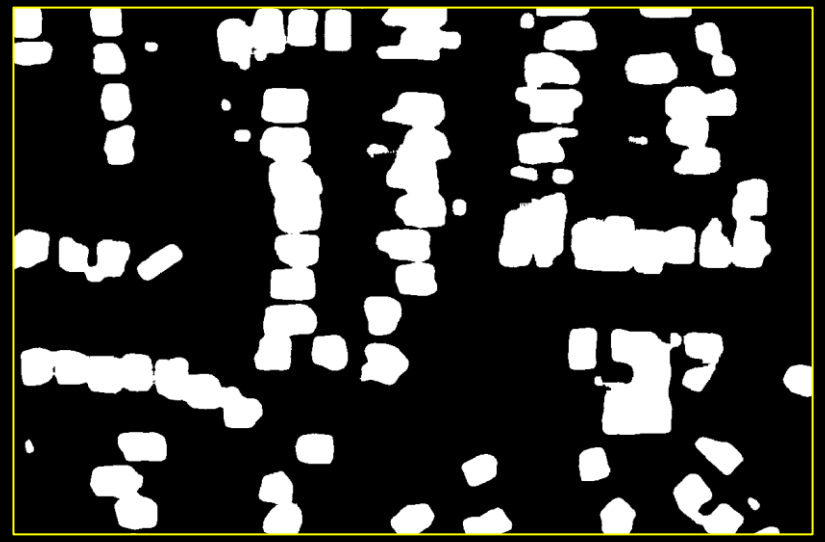
Training on 1940s imagery with imperfect data significantly improved

Imperfect training results: 1980

Wellington: 1980 image



2016-based mask

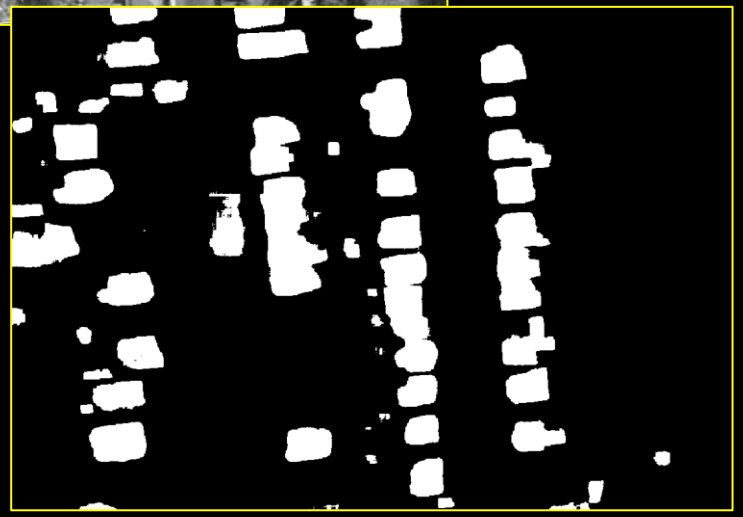


1980 imperfect data mask

1980: significantly improved recall but reduced shape precision

City transfer: Wellington to Auckland

1980



1940

Wellington models transfer well to Auckland

Final model configuration

- Combined model: trains one model on all training data:
  - 2016: all cities
  - 1980: Wellington and Hamilton
  - 1940: Wellington only (insufficient data for Hamilton)

City/year	1940	1980	2016
Wellington	Combined	Wgtn 1980	Wgtn 2016
Auckland	Combined	Wgtn 1980	Auckland 2016
Hamilton	Combined	Combined	Hamilton 2016

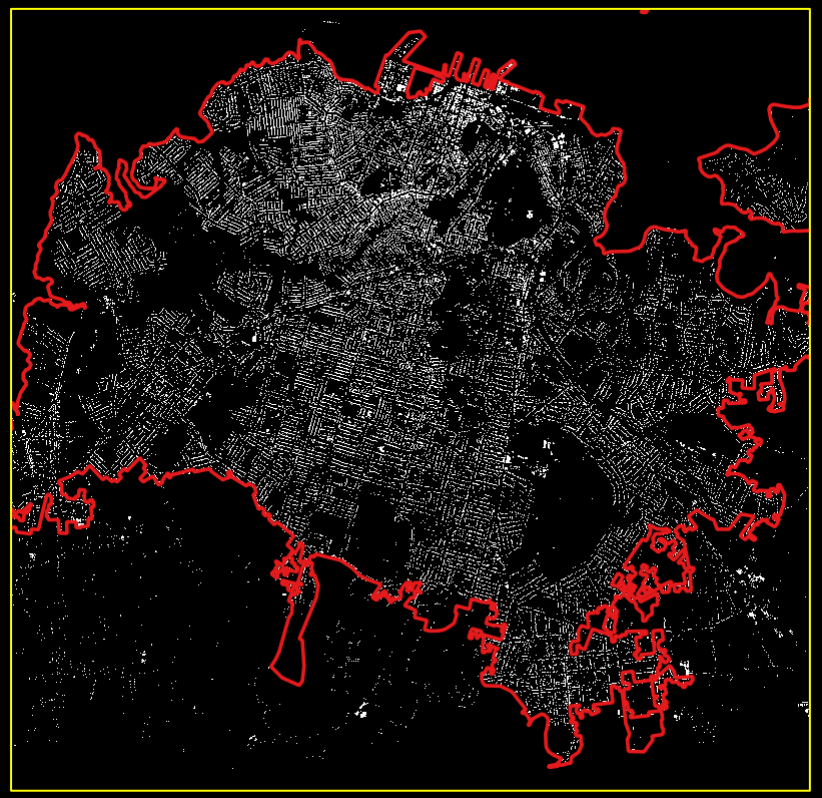
Hamilton

1940

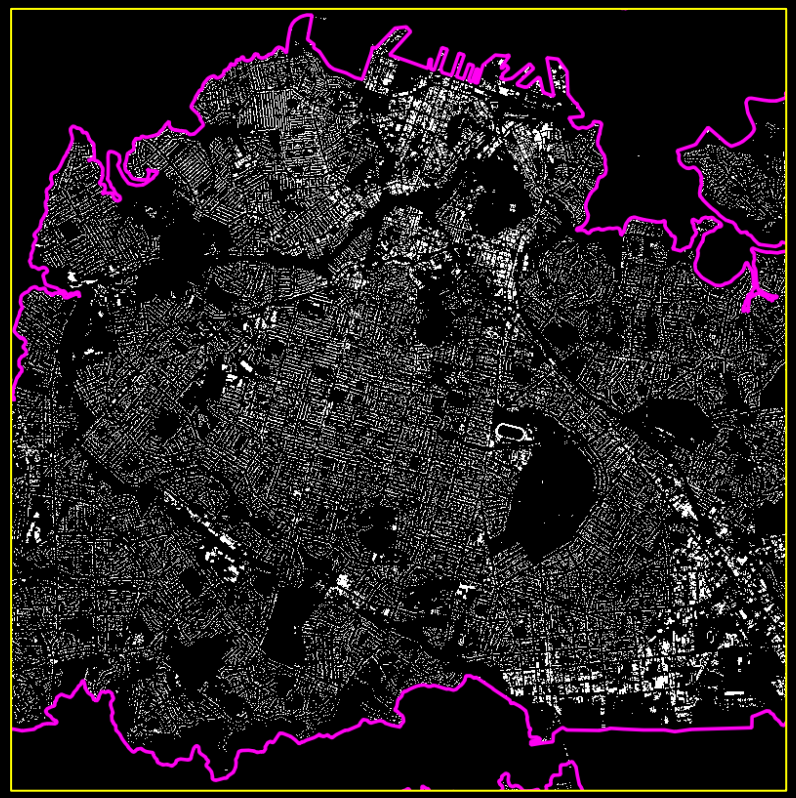
1980

2016

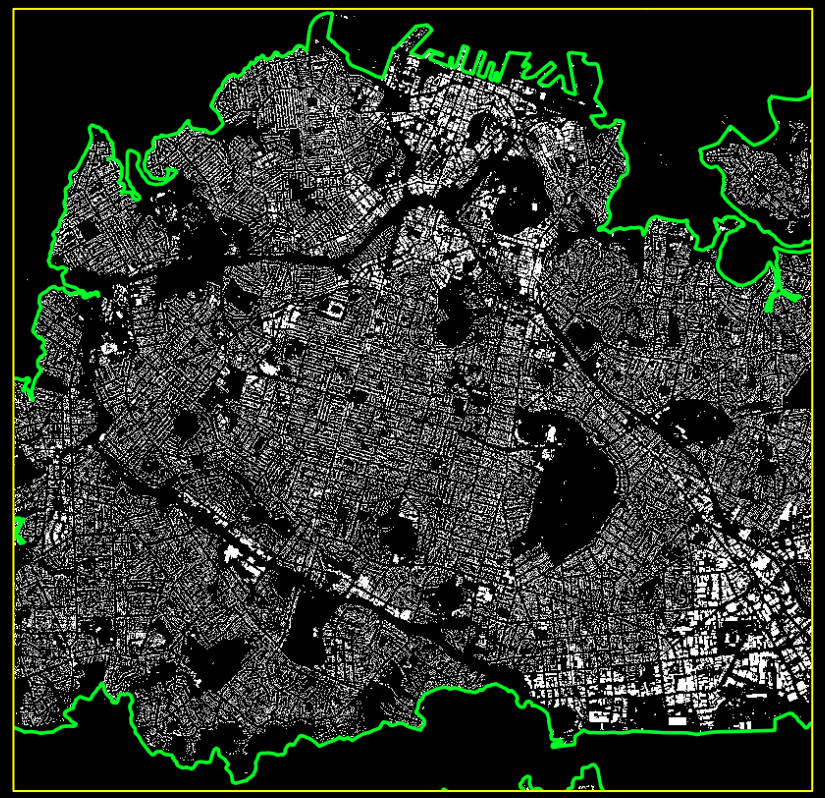
Auckland



1940



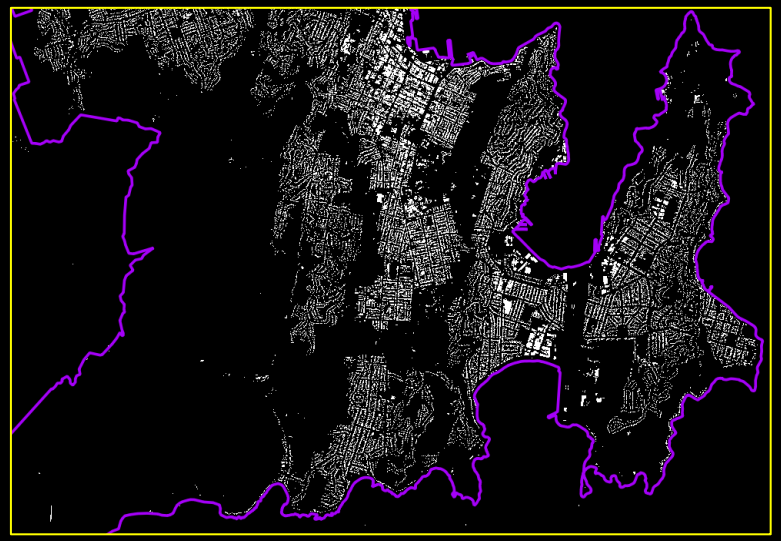
1980



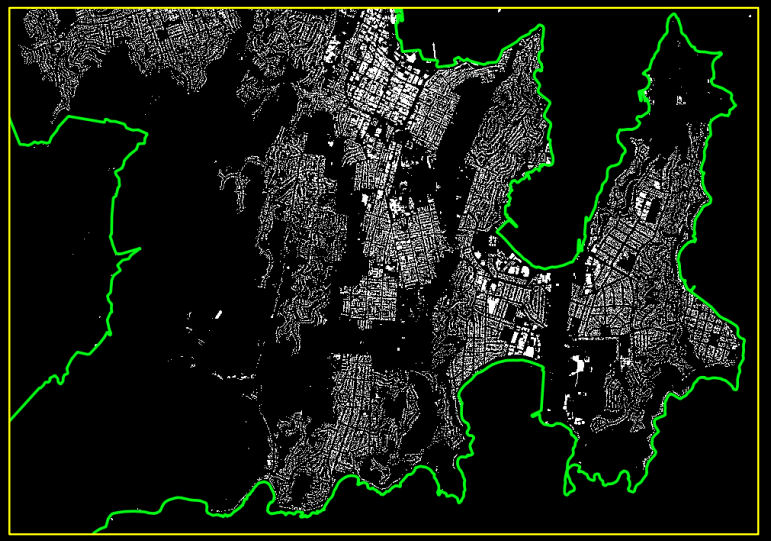
2016

Wellington and Hutt City

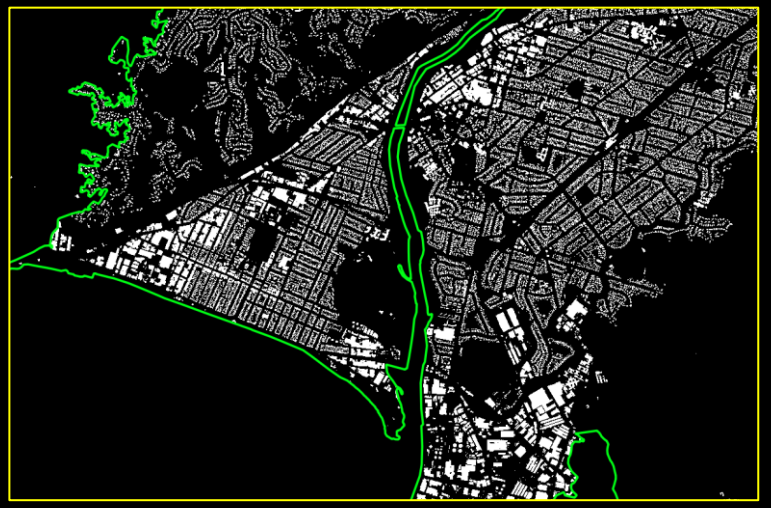
1940



1980



2016



Conclusions and further work

- Deep learning can be used to infer buildings from historic imagery
- Historic aerial imagery is challenging because of quality issues
- Models transfer well across cities, less well across time
- Imperfect training labels can yield usable results

Further research:

- Image standardisation
- Improved image registration
- Manual label generation/correction
- Increased training set sizes (e.g. do all of New Zealand)

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Questions?