Survey of Natural Boundaries using Drones

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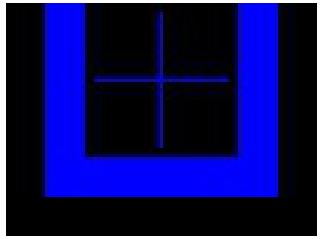
What is a Natural Boundary?

- A natural boundary “is no different from any other boundary on land insofar as defining the extent of property rights…” (I de Rijke, 2016)
- The natural boundary must be surveyed with a similar diligence as a conventional boundary between two survey posts. The boundary generally is harder to survey due to the ambiguity and subjective nature of “What defines the Natural Boundary being surveyed?”



How is a non-tidal water boundary to be located on Canada Lands?

- The National Standards for the Survey of Canada Lands (2014) set out that a water boundary is located “in keeping with provincial or territorial statute or custom”

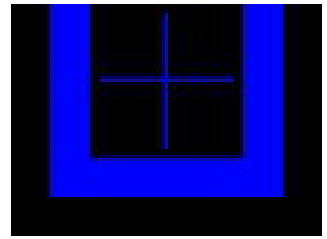
Dr. Ballantyne is his “Water Boundaries on Canada Lands: That Fuzzy Shadowland” continues:

For instance:

◆ In British Columbia, present natural boundary is used, which accords with the change in vegetation or soil owing to the continued presence of the water;

◆ In Ontario, water’s edge is used, which accords with water’s edge under non-extreme (freshet, storm) conditions; and

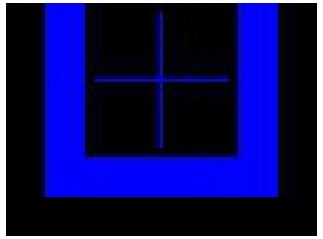
◆In the north (Yukon, NWT, Nunavut), ordinary high water mark is used as the limit or edge of the bed of a body of water.



How to Locate Tidal Boundaries on Canada Lands?

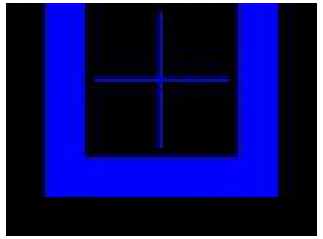
Dr. Ballantyne is his “Water Boundaries on Canada Lands: That Fuzzy Shadowland” continues:

- The boundary of the upland riparian parcel is the “high tide line” or mean high water mark (MHWM/OHWM) - the average of the high spring and high neap tides. Evidence of the MHWM might include the state of vegetation and the accumulation of drift-wood and debris; a practice “generally accepted and followed” by surveyors and endorsed by the courts as early as 1918 and as recently as 2010.
- Although vegetation might be persuasive, it is not conclusive. A vegetation line is often the result of freshets, and “there is a very distinct difference between freshet marks on a tidal river and high water mark.” The former is often a distinct line and should be ignored; the latter might be represented by a slight gravel ridge.

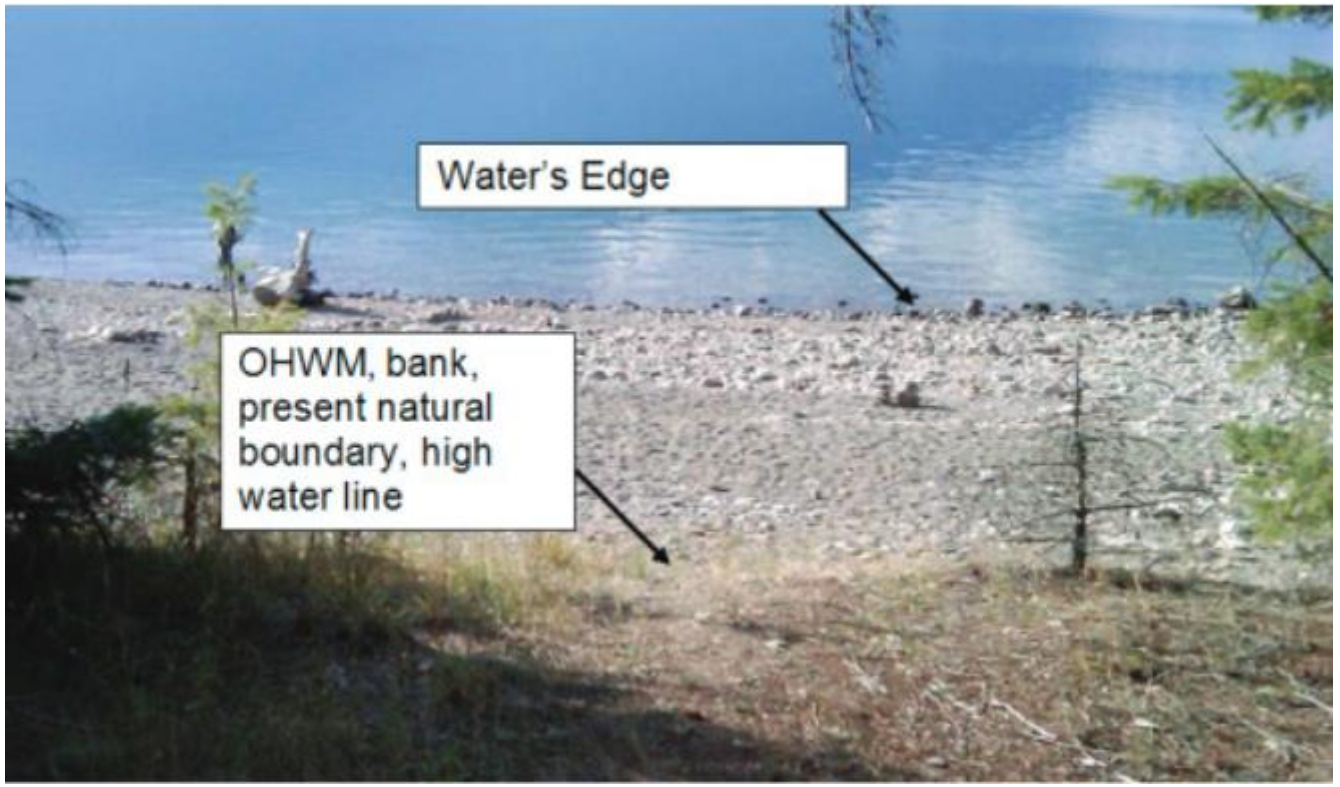


Defining the Natural Boundary

- Do we define the location of the boundary based on changes in vegetation? The location of logs and other debris, flotsam and jetsam pushed up the beach by the tide?
- Or can we use a tidal elevation?
- Or both?



Where is the Natural Boundary?



Or Here?

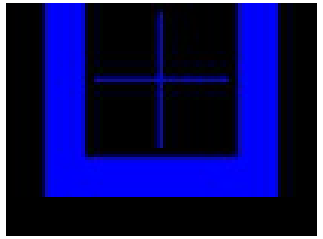
Photographs from Dr. Ballantyne “Water Boundaries on Canada Lands: That Fuzzy Shadowland”

Methods available to locate the Natural Boundary

On the ground:

- Conventional ties using total station
  - Radial ties
  - Offsets from traverse

- GNSS ties (RTK or Post Processed Kinematic)

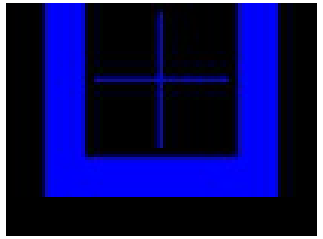


Methods available to locate the Natural Boundary

- Aerial Surveys:
  - GNSS equipment in a helicopter (post process kinematic)
  - Conventional Aerial Photographic interpretation

But Both of these methods give accuracy in the at best 5m range (which is sufficient for showing boundaries on 1:10,000 mapping or survey plans)

Prior to conducting a natural boundary survey using aerial methods, always gain permission first from the Surveyor General's office.



Toquana Indian Reserve No. 4

- The mapping in the **Tla'amin Final Agreement** defined the natural boundary of this parcel of a land as being the "highest extent of the tide"
- The Theodosa Inlet flows in to Theodosa Inlet which has a tidal range of around 3m

The Boundary to be Mapped

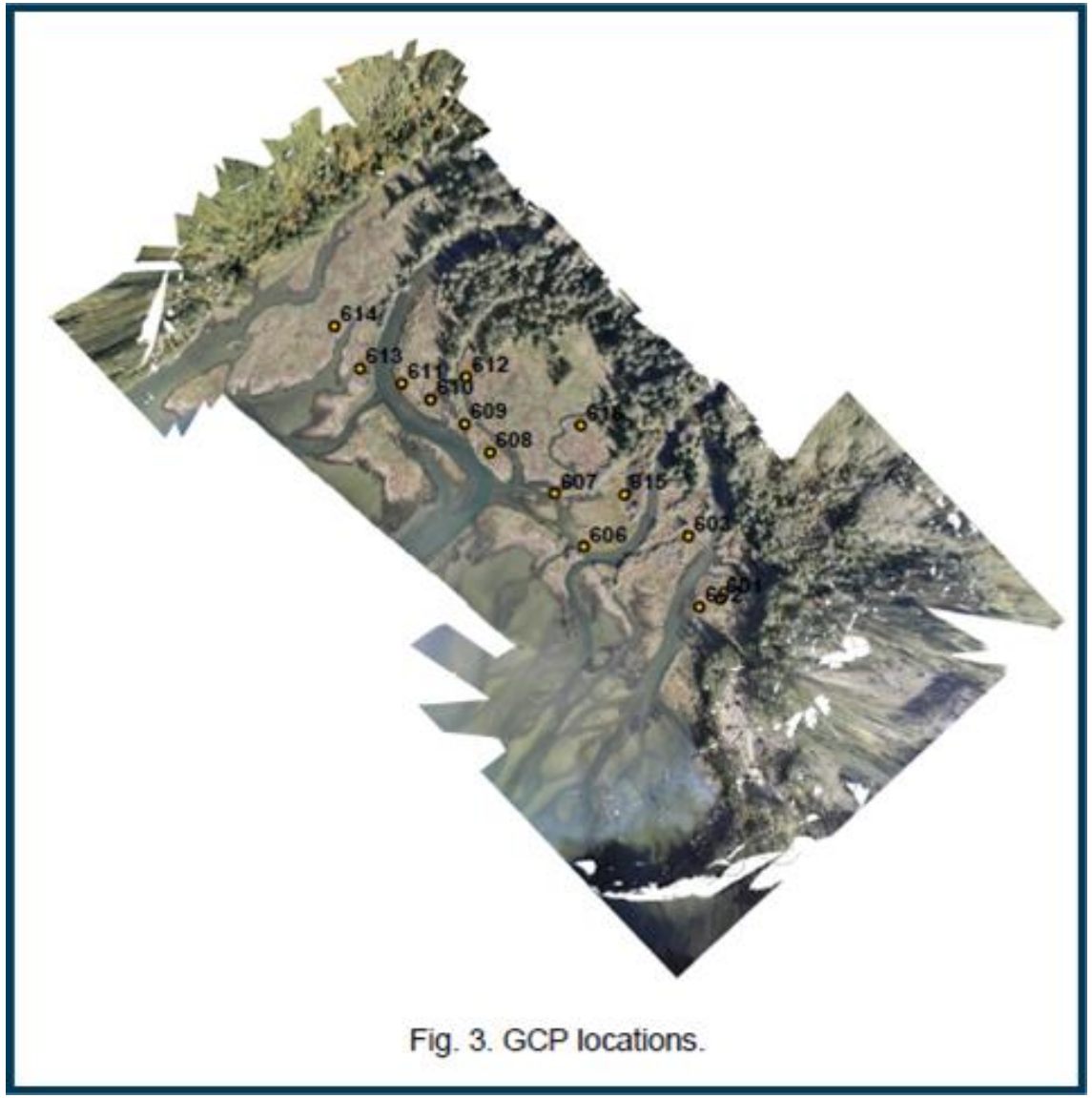
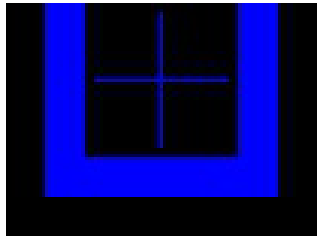


Fig. 3. GCP locations.

Issues at Theodosa Inlet

- There was approximately 3 km of Natural Boundary to be surveyed at the time of the highest tide. For best accuracy the survey would have to be completed within ½ hour of high tide
- Many of the islands were not accessible with our boat due to shallow channels of the Theodosa River and too deep to wade to with equipment



Using the “Underdrone”

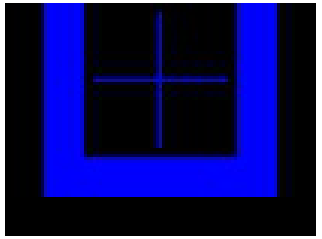
Pre-Flight Setup

(1) Pre-plan the area to be surveyed on Google Earth and design flight path to cover entire area with necessary photograph overlap

(2) Set targets over site and tie to GPS network

(3) Pray the grizzley bears don't play with the targets (not totally successful)

(4) Use GPS to tie in some areas of the
Natural Boundary at highest limit of tide
for checks on photographic interpretation later



Flight Day

- Flight had to be planned to be at time of highest tide
- Best time to fly is on a windless, sunny day near noon for the least amount of shadows, so we had to delay the flight for a few days for optimum conditions

Flight Path and Photograph Locations

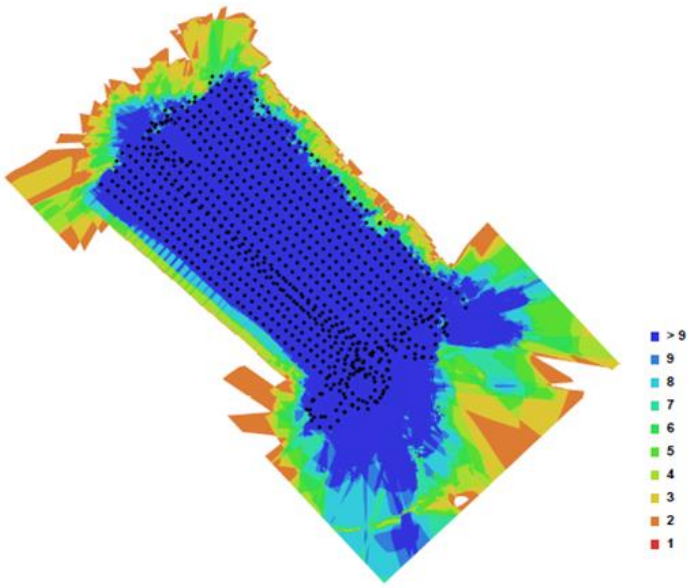
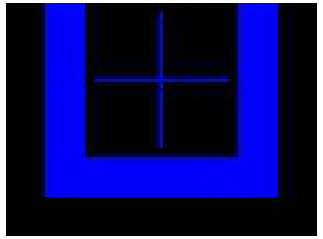


Fig. 1. Camera locations and image overlap.

Number of images:	837	Camera stations:	809
Flying altitude:	107.129 m	Tie-points:	98640
Ground resolution:	0.0228969 m/pix	Projections:	696828
Coverage area:	0.805353 sq km	Error:	1.32678 pix

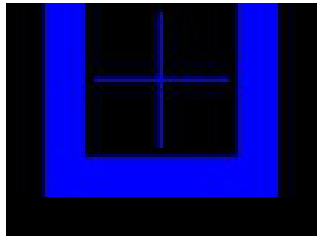
Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
NX1000	5472 x 3648	unknown	unknown	No

Table. 1. Cameras.



The overlapping photographs

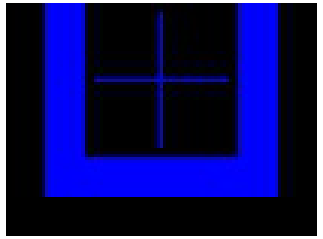
Overlapping photographs



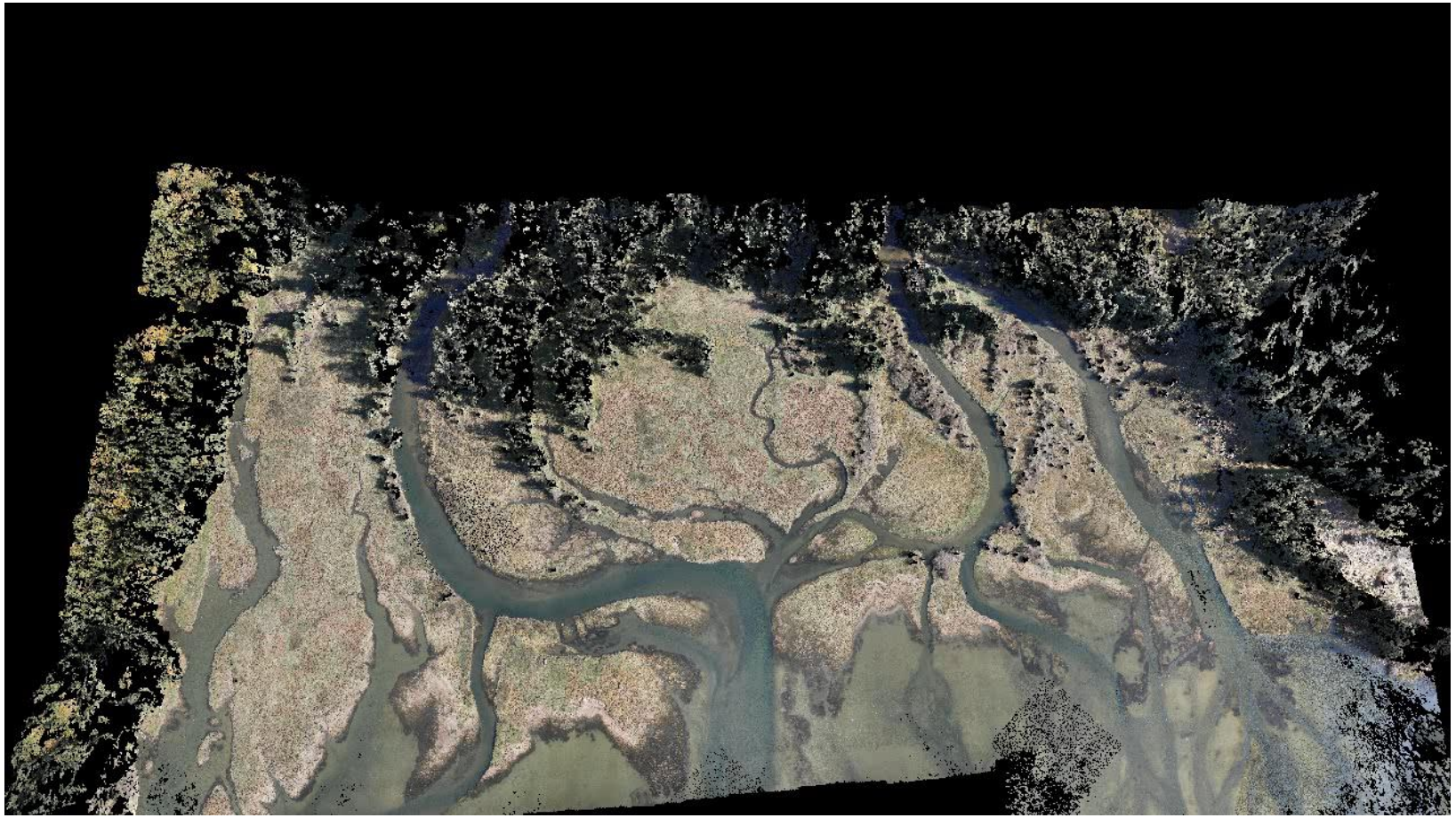
Post Processing the Photography

Agisoft PhotoScan

Agisoft PhotoScan is a stand-alone software product that performs photogrammetric processing of digital images and generates 3D spatial data



Hours of processing later……



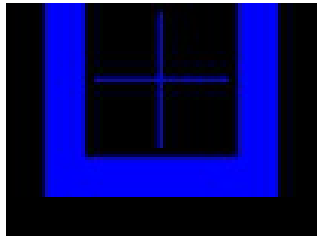
Results of Control Point Calibration

Label	X error (m)	Y error (m)	Z error (m)	Error (m)	Projections	Error (pix)
601	0.002326	-0.005604	0.009787	0.011515	21	0.261388
602	0.003077	-0.008616	-0.008568	0.012535	23	0.292704
603	-0.008787	0.010848	-0.003333	0.014353	26	0.128974
606	0.012230	0.013924	0.006677	0.019698	35	0.124127
607	-0.004383	-0.006510	-0.001420	0.007976	29	0.108739
608	0.003375	0.016043	0.009432	0.018914	28	0.233553
609	0.018091	-0.011422	-0.017984	0.027949	28	0.277882
611	-0.000278	0.014804	-0.002720	0.015054	23	0.194654
612	-0.004126	0.010464	0.009592	0.014783	21	0.204829
613	-0.003367	-0.014814	0.002294	0.015365	26	0.128941
614	-0.001763	0.001247	-0.000031	0.002159	24	0.183836
615	0.000588	-0.010558	-0.004508	0.011495	19	0.111337
616	-0.017055	-0.009901	0.000602	0.019730	24	0.175465
Total	**0.008423**	**0.011117**	**0.007669**	**0.015917**	**327**	**0.194573**

Label	X error (m)	Y error (m)	Z error (m)	Error (m)	Projections	Error (pix)
610	7.295069	15.428124	-0.208093	17.067171	23	0.352649
Total	**7.295069**	**15.428124**	**0.208093**	**17.067171**	**23**	**0.352649**

Table. 3. Check points.

We are pretty sure this was the result of a grizzly bear ……..



Results of the Camera Calibration

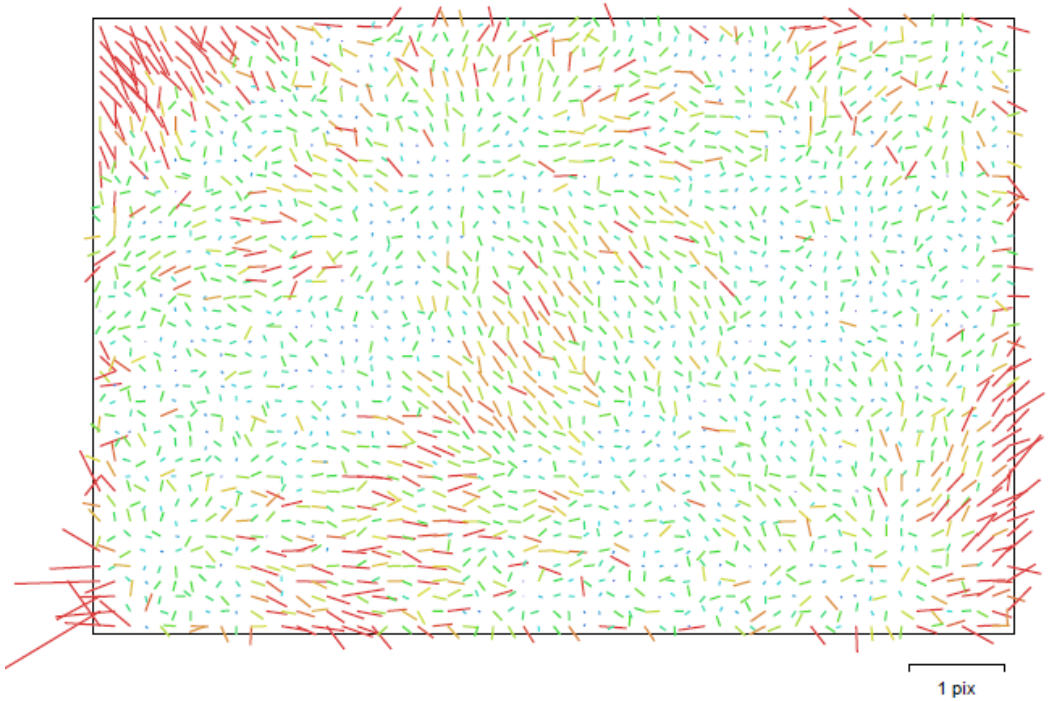
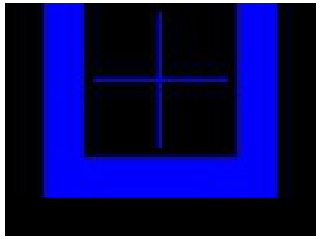


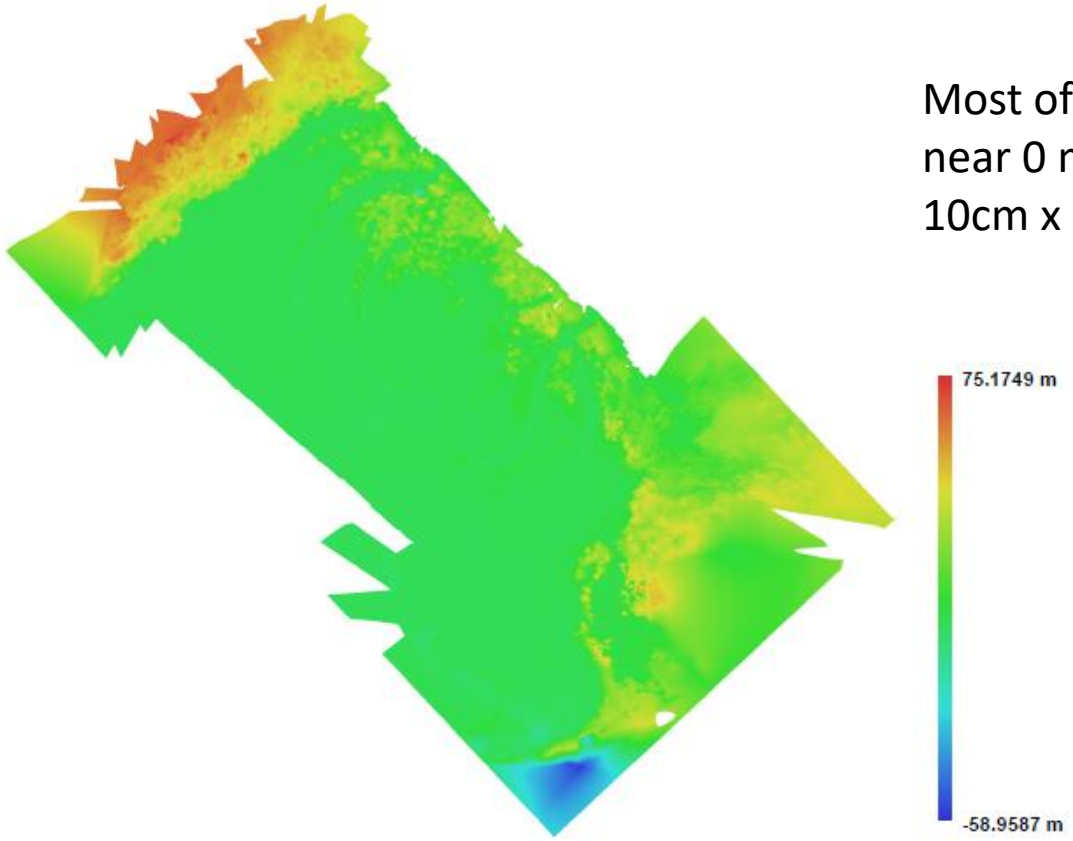
Fig. 2. Image residuals for NX1000 .

NX1000

Type:	Frame	K1:	-0.0647377
Fx:	4348.75	K2:	0.0820532
Fy:	4346.02	K3:	-0.0335404
Cx:	2756.28	K4:	0
Cy:	1861.39	P1:	0.000462201
Skew:	-0.0898075	P2:	-0.000280564



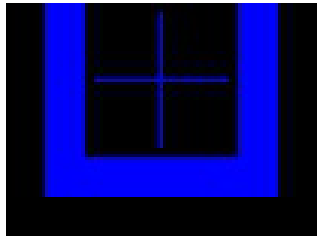
And a digital terrain model was created



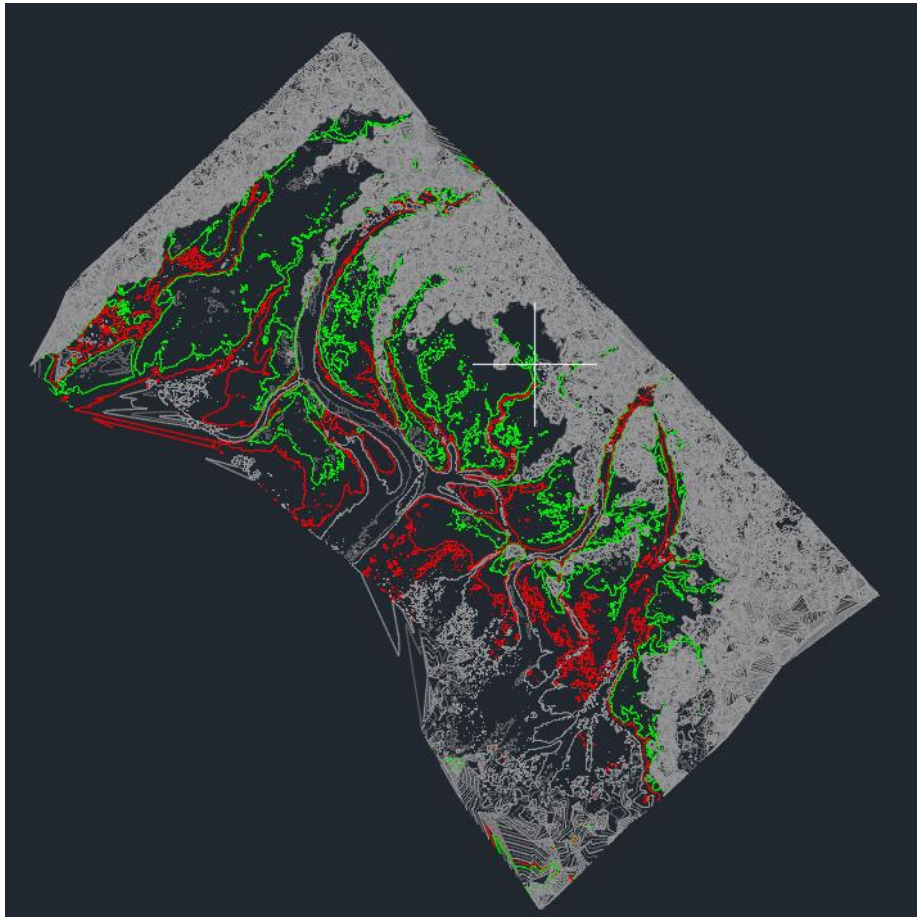
Most of the ground was
near 0 m elevation derived on a
10cm x 10cm grid

Fig. 4. Reconstructed digital elevation model.

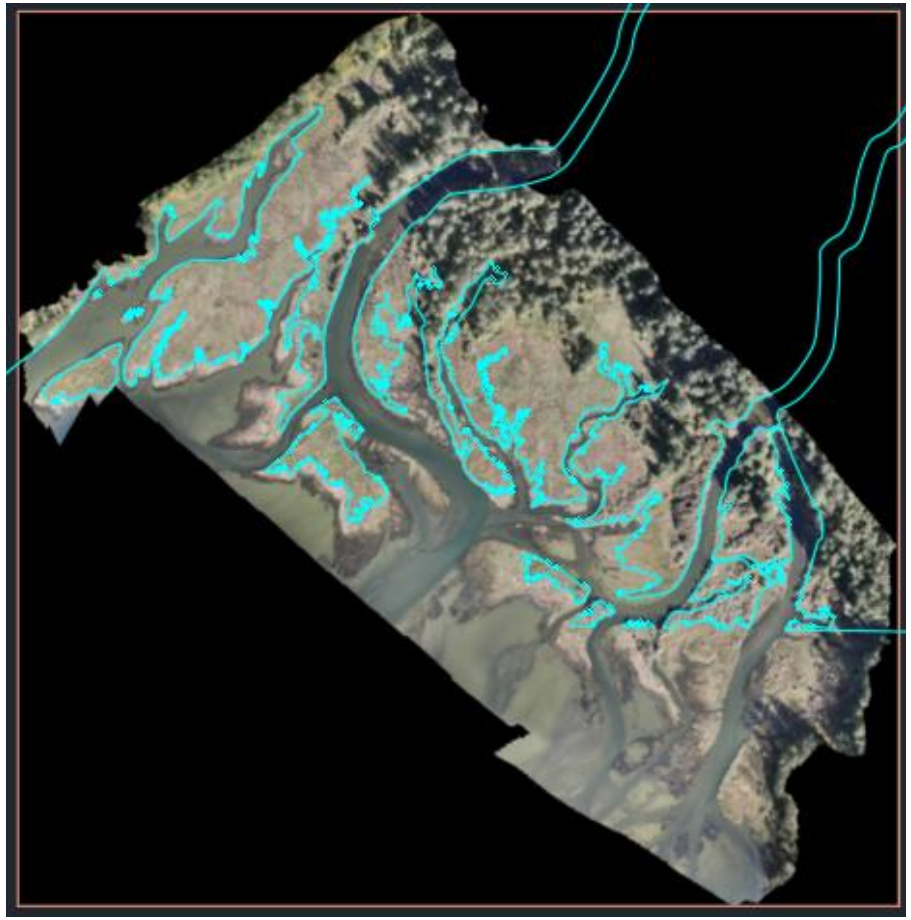
Resolution:	0.0915875 m/pix
Point density:	119.214 points per sq m



The contour based on the measured height of tide was created:

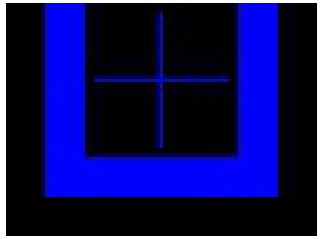


And overlaid on the photography

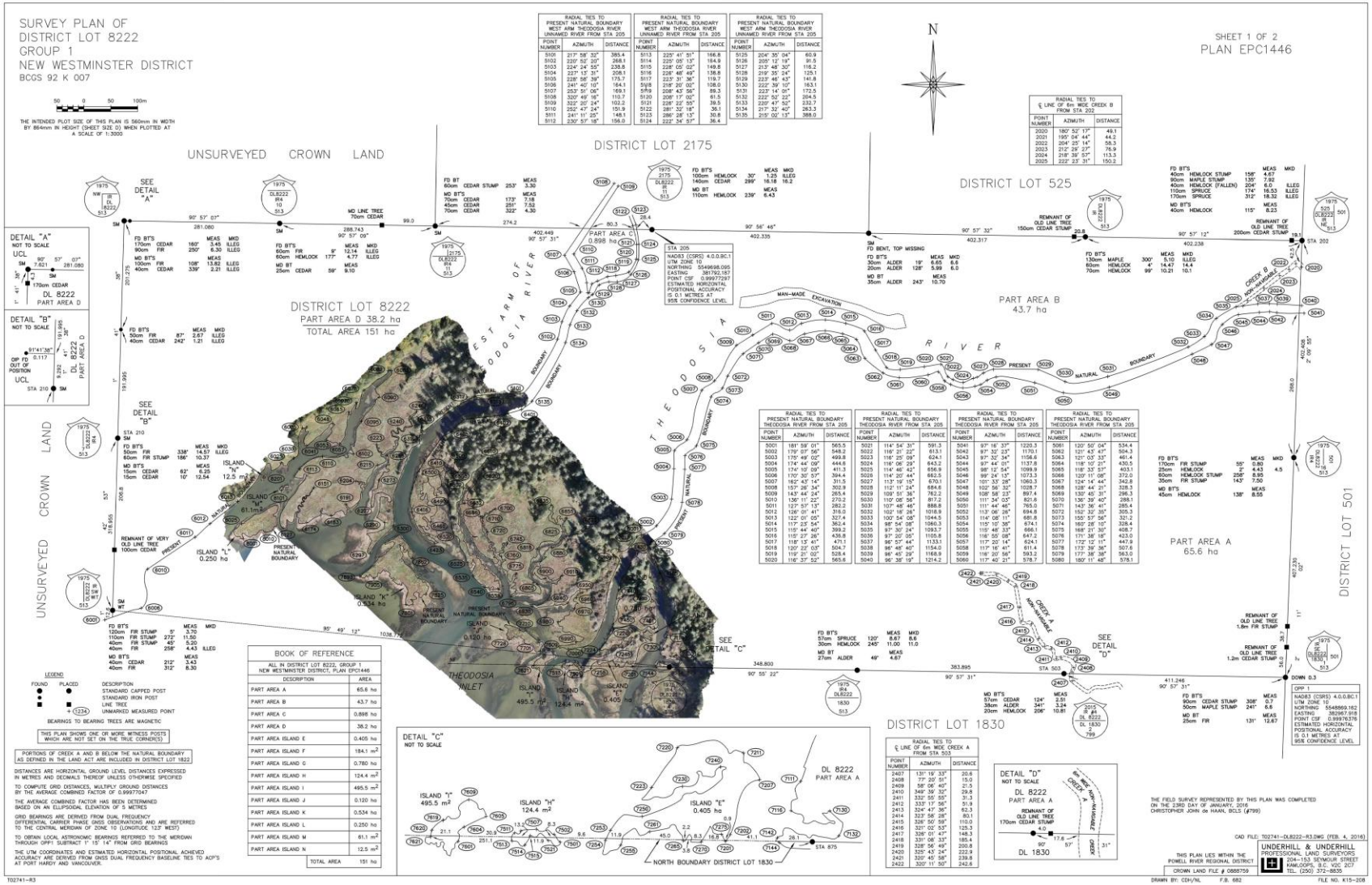


And checked against:

- Change in vegetation (upland v. water based) seen in photography
- Field ties of changes in vegetation (upland v. water based)
- Elevation measured in the field in various locations



And the survey was completed….



Thank you

- For further information

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