**SUPPLEMENTAL**

**Table S1.** Percent functional moat area relative to the total lake area measured by the manual tracing method and estimated by the semi-automated approaches for each image date. Maxar image catalog identification codes are included for each image used in this study.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Image date** | **Maxar catalog ID** | **Functional moat area (%)** | | |
| **Manual trace** | **NDWI approach** | **Supervised classification approach** |
| 1/10/2010 | 1030010003921200 | 5.67 |  |  |
| 1/28/2010 | 10300100040BE900 | 5.75 |  |  |
| 2/9/2011 | 1030010009319D00 | 13.42 |  |  |
| 1/20/2012 | 10300100102C1200 | 10.48 | 9.18 | 8.29 |
| 1/5/2013 | 103001001D381500 | 5.13 | 2.82 | 2.17 |
| 2/1/2014 | 103001002CCCEE00 | 12.82 |  |  |
| 1/21/2015 | 103001003ED2B400 | 5.80 | 3.94 | 3.91 |
| 1/23/2015 | 103001003CD3ED00 | 5.39 | 4.38 | 4.34 |
| 2/16/2015 | 103001003D133E00 | 6.30 | 4.22 | 3.93 |
| 1/25/2017 | 10300100648C3100 | 3.24 | 2.10 | 2.08 |
| 2/8/2017 | 10300100643A1400 | 3.60 | 0.34 | 0.34 |
| 2/14/2017 | 1030010063108000 | 3.50 | 0.93 | 0.82 |
| 12/2/2017 | 1030010074093000 | 0.13 | 0.00 | 0.04 |
| 1/19/2018 | 104001003769F800 | 3.23 |  |  |
| 12/11/2018 | 1030010089D13500 | 2.95 | 1.41 | 1.39 |
| 1/26/2019 | 10400100485D6900 | 9.06 |  |  |
| 12/3/2019 | 103001009FA0AE00 | 4.03 | 1.66 | 1.34 |
| 1/8/2021 | 10300100B308DD00 | 10.20 |  |  |
| 2/10/2022 | 10300100CD59D700 | 12.51 |  |  |

**Table S2.** Endmember data for the supervised classification-based semi-automated approach.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Wavelength** | **Sunlit Snow** | **Sunlit Open Water** | **Sunlit Soil** | **Sunlit Mat-Containing Stream Channels** | **Sunlit Blue Ice** | **Shadowed Soil** | **Shadowed Snow** |
| 0.427 | 0.5335731 | 0.0783754 | 0.0996233 | 0.0867999 | 0.3569888 | 0.0731834 | 0.2766301 |
| 0.478 | 0.5605644 | 0.0832198 | 0.1113727 | 0.0949302 | 0.3689195 | 0.0748258 | 0.2222964 |
| 0.546 | 0.5786975 | 0.0972665 | 0.1309051 | 0.1102986 | 0.3400344 | 0.0806482 | 0.1763622 |
| 0.608 | 0.5648832 | 0.0968985 | 0.1420555 | 0.1190836 | 0.2717045 | 0.0842259 | 0.1502182 |
| 0.659 | 0.5399275 | 0.0910590 | 0.1433709 | 0.1201415 | 0.2355455 | 0.0832440 | 0.1337971 |
| 0.724 | 0.4999251 | 0.0812708 | 0.1425238 | 0.1217812 | 0.2021495 | 0.0818702 | 0.1192002 |
| 0.831 | 0.4556860 | 0.0737524 | 0.1417669 | 0.1291174 | 0.1708665 | 0.0769210 | 0.1028850 |
| 0.908 | 0.3739899 | 0.0726320 | 0.1362682 | 0.1375241 | 0.1449925 | 0.0756288 | 0.0944652 |

**Table S3.** Summary of results of various semi-automated methods. Root mean square error (RMSE) values are in reference to the difference, in units of percent, between manually measured and predicted functional moat areas. Standard deviation (Std. Dev.) is also in reference to the error between the manually measured and predicted functional moat areas. All values correspond to the percent of the total lake area.

|  |  |  |  |
| --- | --- | --- | --- |
| **Method** | **Criteria** | **RMSE (%)** | **Std. Dev.** |
| Supervised classification | Open water | 2.19 | 0.95 |
| Open water + albedo parameter | 2.44 | 1.24 |
| Open water, blue ice, shadowed snow/ice | 5.57 | 3.63 |
| NDWI-based approach | | 1.96 | 0.87 |

**Table S4.** The percentage of true and false identifications of functional moat and not moat regions as produced by the supervised classification and NDWI-based semi-automated techniques. Displayed results based on 3 randomly selected sample images per technique. Percentages are relative to the corresponding manual measurements.

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | TRUE | FALSE |
|  |  |
| Supervised Classification | Moat | **95.2 ± 6.5 %** | **4.8 ± 6.5 %** |
| No Moat | **96.5 ± 1.5 %** | **3.5 ± 1.5 %** |
| NDWI | Moat | **92.8 ± 4.5 %** | **7.2 ± 4.5 %** |
| No Moat | **96.5 ± 1.9 %** | **3.5 ± 1.9 %** |

**Table S5.** Confusion matrices showing the percentage of true and false positives (moat predicted and manually measured or not measured, respectively) and true and false negatives (no moat predicted and manually measured or not measured, respectively) produced by the supervised classification (top matrix) and NDWI-based (bottom matrix) semi-automated techniques. Comparisons were directly done between shapefiles of moat/non-moat regions estimated by each semi-automated technique and measured by the manual traces, and were bounded to only areas falling within +2 and -4 m elevation relative to the lake level falling closest to the sampling dates. Calculations based on comparisons between 3 randomly selected sampling dates.

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | Supervised Classification | |
|  |  | Moat | No Moat |
| Manual Measurements | Moat | **10.2 % (7.4 %)** | **3.1 % (1.4 %)** |
| No Moat | **0.5 % (0.6 %)** | **86.2 % (7.3 %)** |
|  |  |  |  |
|  |  |  |  |
|  |  | NDWI | |
|  |  | Moat | No Moat |
| Manual Measurements | Moat | **5.8 % (1.9 %)** | **3.3 % (1.7 %)** |
| No Moat | **0.4 % (0.2 %)** | **90.5 % (3.0 %)** |

**Table S6.** Predicted verses measured percent functional moat area for each image date. Note that the 2013 and 2021 samples (bolded) show the largest offset between the predicted and measured values, and that the imagery for both was collected in early January. % TLA = percent functional moat area relative to the total lake area.

|  |  |  |  |
| --- | --- | --- | --- |
| Year | Date | Moat Measured (% TLA) | Moat Predicted (% TLA) |
| 2010 | 1/10/2010 | 5.67 | 4.45 |
| 2010 | 1/28/2010 | 5.75 | 4.99 |
| 2011 | 2/9/2011 | 13.4 | 13.4 |
| 2012 | 1/20/2012 | 10.5 | 11.3 |
| **2013** | **1/5/2013** | **5.13** | **7.15** |
| 2014 | 2/1/2014 | 12.8 | 13.5 |
| 2015 | 1/21/2015 | 5.8 | 5.36 |
| 2015 | 1/23/2015 | 5.39 | 5.36 |
| 2015 | 2/16/2015 | 6.3 | 5.36 |
| 2017 | 1/25/2017 | 3.24 | 4.12 |
| 2017 | 2/8/2017 | 3.6 | 4.14 |
| 2017 | 2/14/2017 | 3.5 | 4.14 |
| 2018 | 1/19/2018 | 3.23 | 4.42 |
| 2019 | 12/11/2018 | 2.95 | 3.28 |
| 2019 | 1/26/2019 | 9.06 | 8.49 |
| **2021** | **1/8/2021** | **10.2** | **7.33** |
| 2022 | 2/10/2022 | 12.5 | 11.6 |

A graph showing the amount of meat in the same order

Description automatically generated with medium confidence

**Figure S1.** The numerical difference (*i.e.* the percentage relative to the total lake area), between the semi-automated method based functional moat area estimates and the manually derived percent functional moat area measurements. NDWI data is in magenta and supervised classification data is in blue. Note that both approaches consistently underestimated moat area, but there was no correlation between the measured moat area and the degree of underestimation by the semi-automated approaches.

**Figure S2.** The number of degree days above 3°C prior to January 31 each austral summer. The 2001-2002 “flood year” data is highlighted red.