# Organic Management Consultant Task 3
# Odour Mapping

PRESENTED TO
**Regional District of Okanagan-Similkameen**

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# EXECUTIVE SUMMARY

Tetra Tech EBA Inc. (Tetra Tech EBA) was retained by the Regional District of Okanagan-Similkameen (RDOS) to conduct odour mapping to assess potential odour impacts from developing organics processing facilities at eight publicly owned properties.

The RDOS is in the midst of revamping its solid waste management system and has been exploring enhancing its organics processing capabilities. Most recently, the RDOS has embarked on a multi-year project to develop an ‘apples to apples’ comparison between publicly and privately operated compost facilities.

This report builds on the findings from *Organic Management Consultant Task 1 – Site Assessment* and *Organic Management Consultant Task 2 – Feasibility Assessment*. The site information gathered from Task 1 and conceptual designs developed in Task 2 were used as inputs for the odour mapping exercise.

CALPUFF, an air dispersion modelling software system, was used for odour mapping. Scenarios were built using activity areas (e.g. receiving, composting, curing) for current operations at each site and each technology option from Task 2. The technology options included windrow, aerated static pile, covered aerated static pile, in-vessel composting, and anaerobic digestion. Emission factors based on Odour Units (OU), were assigned to odour generating areas according to the activity taking place.

One year of MM5 meteorological model data was used for odour modelling for all sites except for Summerland, where surface observations were used instead because MM5 was unable to resolve valley winds in the complex terrain. For MM5-based models, surface data from meteorological stations were used for wind field validation.

Odour maps were presented by site in three formats:

- Maximum Odour Concentrations – The maximum predicted 10-minute odour concentration at each receptor point over the course of the modelled year.
- Hourly Exceedances >1 OU – The number of hours over the course of the modelled year where an odour threshold of 1 OU was exceeded in a ten-minute averaged concentration.
- Hourly Exceedances >5 OU – The number of hours over the course of the modelled year where an odour threshold of 5 OU was exceeded in a ten-minute averaged concentration.

An analysis of the maximum odour concentration and hourly exceedances over 1 OU and 5 OU was conducted for the nearest receptor point to each site.

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| | Princeton Hayfield |
| | Keremeos Transfer Station |

# KEY TERMS, ACRONYMS & ABBREVIATIONS

| Acronyms/Abbreviations | Definition |
|---|---|
| BC | British Columbia |
| Green Waste | Leaf and Yard Waste |
| Ha | Hectare |
| OU | Odour Unit |
| MSW | Municipal Solid Waste |
| RDOS | Regional District of Okanagan-Similkameen |
| SWM | Solid Waste Management |
| Tetra Tech EBA | Tetra Tech EBA Inc. |

## LIMITATIONS OF REPORT

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The preparation of this feasibility study was carried out with assistance from the Green Municipal Fund, a Fund financed by the Government of Canada and administered by the Federation of Canadian Municipalities. Notwithstanding this support, the views expressed are the personal views of the authors, and the Federation of Canadian Municipalities and the Government of Canada accept no responsibility for them.

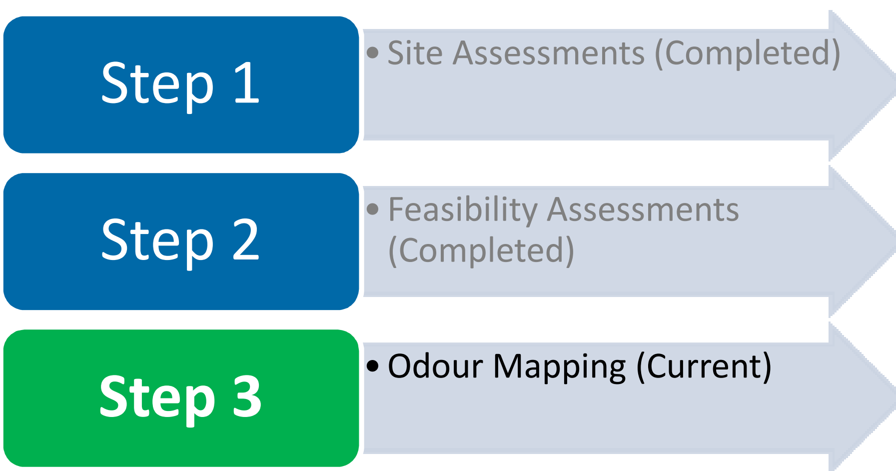
# 1.0 INTRODUCTION

Tetra Tech EBA Inc. (Tetra Tech EBA) was retained by the Regional District of Okanagan-Similkameen (RDOS) to conduct odour mapping to assess potential odour impacts from developing organics processing facilities at eight publicly owned properties.

The RDOS is in the midst of revamping its solid waste management system and has been exploring enhancing its organics processing capabilities. Organic waste refers to the biodegradable materials in the waste stream that are easy to break down by microorganisms. Organic waste generally includes food waste, leaf and yard waste (green waste), white wood, compostable paper, biosolids, agricultural waste, and slaughterhouse waste.

In 2010, the RDOS completed a Regional Organics Waste Management Strategy which looked at potential organics management options and their associated costs. In the same year, the RDOS began updating its Solid Waste Management (SWM) Plan which included calls for upgrading biosolids and yard waste composting practises and eventually banning landfill disposal of food waste. Most recently, the RDOS embarked on a multi-year project to develop an 'apples to apples' comparison between publically and privately operated compost facilities.

The feasibility study is being undertaken as a three step process as summarized below. Step 1 consisted of site assessments for nine (9) publically owned sites. During Step 1, Site Assessments – relevant information was collected, reviewed, and on each of the sites to help the RDOS with selecting sites that would be considered for Step 2 – Feasibility Assessments. Eight sites were selected for feasibility assessments. During Step 2, conceptual designs and associated capital and operating costs were developed for each site. Organics processing technologies included in Step 2 were aerated static pile, membrane covered aerated static pile, in-vessel composting, and anaerobic digestion. The conceptual design layouts were used as inputs for Step 3 – Odour Mapping to provide source emission areas.




# 2.0 METHODOLOGY

## 2.1 Modelling Software

CALPUFF, an air dispersion modelling software system, was used for odour mapping. It is a preferred odour transport model for the RDOS for its ability to handle air stagnation – a common occurrence during winter in the Okanagan and Similkameen valleys, which is responsible for 99% of odour complaints. CALPUFF is a Gaussian puff model that accounts for time- and space-varying meteorological conditions, different source configurations and contaminants and chemical transformations and contains algorithms for curved trajectories and terrain impingement found in complex terrain scenarios. CALPUFF contains a meteorological processor (CALMET) which produces a three-dimensional diagnostic wind field over the model domain, calculating slope and valley flows, terrain blocking and kinematic terrain effects (i.e., speed up over hills), and lake breeze circulation using inputs of real surface meteorological data and meso-scale meteorological model data.

## 2.2 Meteorology

As the RDOS is mainly comprised of complex valley and terrain influenced flows, a thorough meteorological data network was used to produce accurate mapping of potential odours on a local scale. MM5 meteorological data obtained from a third party company specializing in meteorological modelling (Lakes Environmental) was generally used as the input to CALMET for all sites except for Summerland. Due to the complex terrain surround Summerland, the MM5 model was unable to resolve the valley winds. Therefore, observations from local meteorological stations were used instead to build the model. For MM5-based models, hourly surface data from Environment Canada meteorological stations and British Columbia Ministry stations located within the regional district were used to for wind field validation.

Surface data was subjected to the substitution procedures described in British Columbia Ministry of Environment's guidelines entitled, "Guidelines for Air Quality Modelling in British Columbia". The most recent three years of data (2010–2012) was used to account for year-to-year variability. 1:50,000 scale digital terrain data at a grid resolution of approximately 20 m and 1:250,000 digital Land Cover Classification maps was obtained from GeoBase Canada's website. The meteorological grid size for each assessment was determined depending on site characteristics at a resolution which allows for definition of micro-scale flows (likely on the order of 100 m to 250 m).

## 2.3 Odour Units

The odour models were based on a unit measurement system called an Odour Unit (OU). An OU is a way of quantifying odours through the use of an odour panel that consists of a group of people with 'calibrated noses'. The definition of an OU is based on the proportion of odour panel members that can detect the smell of a substance. One OU represents the concentration of a particular substance when 50% of the odour panel can detect the odour. This is called the perception threshold[1]. At this point, although an odour may be detected, it is not distinct enough to be able to identify the type of odour.

The OU scale is based on dilutions, as shown in the following figure. As the number of OUs increase, more people can detect the odour, and the intensity of the odour increases. Five OU is considered a faint odour and ten OU is considered a distinct odour (the point when some people can identify the type of odour, or its potential source)[2].

[1] http://blog.odotech.com/odor-unit-perception-threshold

[2] Odours and VOCs: Measurement, Regulation and Control Techniques (2009). Kassel University Press.

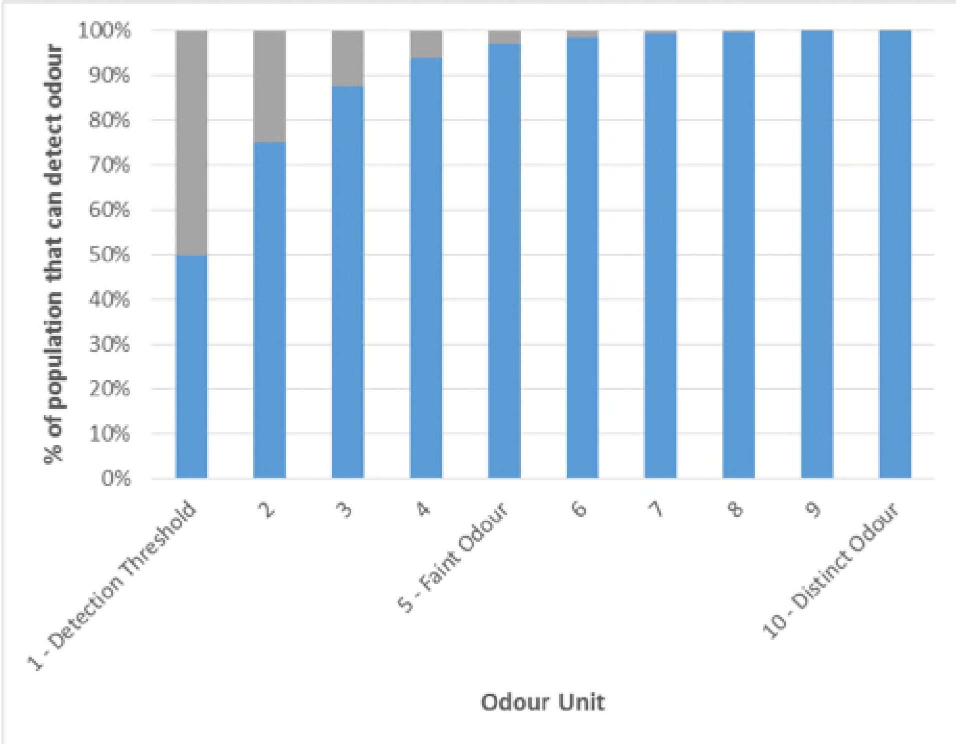



**Figure 2.1: Odour Unit Scale**

There are currently no guidelines for odour limits for composting facilities in British Columbia, however, some wastewater treatment facilities have imposed odour limits. For example, the standard in Metro Vancouver is no more than five OU at the property line. In other jurisdictions, the guideline is to have no detectable odour at the property line. At the Ogogrow facility in Vernon, BC, the limit is 50 OU at the property line.

## 2.4 Area Sources and Emission Factors

The site layouts from the *Organics Management Consultant Task 2 – Feasibility Assessment* report were used to define the boundaries of the odour sources for this modelling exercise. Areas that generate odours were assigned a specific emission factor (Table 2.1) according to the activity taking place (e.g. composting, curing, pile turning, etc.).

Emissions were assumed to occur homogeneously over the entirety of the area source. Some odour emissions (e.g. pile turning, pile moving, etc.) were assigned a diurnal variation based on the expected times of day the activity was to be performed (Table 2.1). Such activities are expected to occur daily at the facility over a one- to two-hour period, however since the activity may occur in the morning or in the afternoon, odour emissions were assumed in the model to occur between $10^{00}$ to $12^{00}$ – when vertical mixing is generally highest – and between $15^{00}$ to $17^{00}$ – when, during the winter, the mixing height is approaching its nighttime minimums, thus resulting in higher concentrations closer to the ground. This is a somewhat conservative approach since the activity may only be occurring over a single hour rather than four, may not take place every day, and peak odour emission would only occur during and immediately following the activity and decaying in the hour following.

Emission heights were either assigned a value of 3 m (assumed average height for piles) or 1 m (biofilters and other activities close to ground surface) depending on the activity occurring within the area source. Specific heights used for the various activity types are listed in Table 2.1.

### Table 2.1: Emission Factors

| Activity | Emission Factor (OU/m$^2$s) | Release Height (m) | Time of Day |
|---|---|---|---|
| Receiving area | 0.082 | 1 m | 24h |
| Receiving area biofilter | 69.40 | 1 m | 24h |
| Windrow composting (yard waste) | 0.2 | 3 m | 24h |
| Windrow composting (food and yard waste) | 1.4 | 3 m | 24h |
| Windrow pile turning and moving | 1.95 | 1 m | 10am-12pm<br>3pm-5pm |
| ASP composting | 0.2 | 3 m | 24h |
| ASP pile building | 0.44 | 3 m | 10am-12pm<br>3pm-5pm |
| ASP pile breakdown | 2 | 3 m | 10am-12pm<br>3pm-5pm |
| Covered ASP composting | 0.2 | 3 m | 24h |
| Covered ASP pile building | 0.44 | 3 m | 10am-12pm<br>3pm-5pm |
| Covered ASP pile breakdown | 0.47 | 3 m | 10am-12pm<br>3pm-5pm |
| In-vessel/anaerobic digestion vessel loading | 0.44 | 3 m | 10am-12pm<br>3pm-5pm |
| In-vessel/anaerobic digestion vessel loading | 2 | 3 m | 10am-12pm<br>3pm-5pm |
| Composting biofilter | 38.89 | 1 m | 24h |
| Curing (windrow food and yard waste) | 0.12 | 3 m | 24h |
| Curing (all other scenarios) | 0.11 | 3 m | 24h |
| Screening | 0.0081 | 3 m | 10am-12pm<br>3pm-5pm |
| Storage | 0.013 | 3 m | 24h |

# 3.0 RESULTS

## 3.1 Odour Mapping

Odour maps are presented in the reports for each site in Appendix B.

For each scenario, odour modelling results were presented as three different plots:

- Maximum Odour Concentrations – The maximum predicted 10-minute odour concentration at each receptor point over the course of the modelled year.
- Hourly Exceedances >1 OU – The number of hours over the course of the modelled year where an odour threshold of 1 OU was exceeded in a ten-minute averaged concentration.
- Hourly Exceedances >5 OU – The number of hours over the course of the modelled year where an odour threshold of 5 OU was exceeded in a ten-minute averaged concentration.

Note that for some scenarios, the odour model produced results that were below the thresholds displayed on the map scale (e.g. there were no points on the map that exceeded 1 OU). In those cases, odour maps were not presented as they would just appear as blank maps.

## 3.2 Nearest Receptor Analysis

Based on the three plots described in Section 3.1, an analysis of the odour conditions at the nearest receptor to each site was conducted. The results from this analysis are presented in Tables 3.1 to 3.3.

Analyses of the maximum odour, number of hours over 1 OU, and number of hours over 5 OU over the course of a year.

## Table 3.1: Maximum Odour Concentration at Nearest Receptor during the Modelled Year

| Site | Maximum Odour Concentration (OU) | | | | | |
|---|---|---|---|---|---|---|
| | Current Operations | Aerated Static Pile | Membrane Covered Aerated Static Pile | In-Vessel Composting | Anaerobic Digestion | Windrow Composting |
| **Individual Sites** | | | | | | |
| Campbell Mountain Landfill | 3 | 28 | 7.1 | 21 | 23 | N/A |
| Summerland Landfill | 0.3 | 5 | 1 | 5 | 3 | N/A |
| Okanagan Falls Landfill | 0 | 0.43 | 0.02 | 0.89 | N/A | N/A |
| Oliver Landfill | 2 | 94 | 21 | 80 | N/A | N/A |
| Osoyoos Landfill | 0.2 | 3.1 | 0.7 | 2.0 | N/A | N/A |
| Princeton Landfill | 0.05 | 7 | 0.2 | 5.3 | N/A | N/A |
| Princeton Hayfield | N/A | 5.2 | 0.15 | 3.9 | N/A | N/A |
| Keremeos Transfer Station | 0.01 | 6.8 | 0.13 | 6.3 | N/A | N/A |
| **Regional Facilities** | | | | | | |
| Campbell Mountain | N/A | 53 | 8.6 | 43 | 36 | N/A |
| Summerland | N/A | 22 | 5.1 | 18 | 16 | N/A |
| Summerland with RDCO Biosolids | N/A | 27 | 5.3 | 21 | 20 | N/A |
| Oliver | N/A | 238 | 101 | 190 | 225 | N/A |
| Osoyoos Windrow | N/A | N/A | N/A | N/A | N/A | 0.4 |

## Table 3.2: Number of Hours Exceeding 1 OU at Nearest Receptor during the Modelled Year

| Site | Hours Exceeding 1 OU | | | | | |
|---|---|---|---|---|---|---|
| | Current Operations | Aerated Static Pile | Membrane Covered Aerated Static Pile | In-Vessel Composting | Anaerobic Digestion | Windrow Composting |
| **Individual Sites** | | | | | | |
| Campbell Mountain Landfill | 7 | 480 | 95 | 408 | 440 | N/A |
| Summerland Landfill | 0 | 14 | 1 | 14 | 7 | N/A |
| Okanagan Falls Landfill | 0 | 0 | 0 | 0 | N/A | N/A |
| Oliver Landfill | 2 | 216 | 105 | 194 | N/A | N/A |
| Osoyoos Landfill | 0 | 20 | 0 | 9 | N/A | N/A |
| Princeton Landfill | 0 | 540 | 0 | 486 | N/A | N/A |
| Princeton Hayfield | N/A | 159 | 0 | 132 | N/A | N/A |
| Keremeos Transfer Station | 0 | 444 | 0 | 334 | N/A | N/A |
| **Regional Facilities** | | | | | | |
| Campbell Mountain | N/A | 515 | 45 | 398 | 397 | N/A |
| Summerland | N/A | 274 | 26 | 206 | 216 | N/A |
| Summerland with RDCO Biosolids | N/A | 276 | 22 | 192 | 186 | N/A |
| Oliver | N/A | 302 | 224 | 301 | 298 | N/A |
| Osoyoos Windrow | N/A | N/A | N/A | N/A | N/A | 0 |

**Table 3.3: Number of Hours Exceeding 5 OU at Nearest Receptor during the Modelled Year**

| Site | Hours Exceeding 5 OU | | | | | |
|---|---|---|---|---|---|---|
| | Current Operations | Aerated Static Pile | Membrane Covered Aerated Static Pile | In-Vessel Composting | Anaerobic Digestion | Windrow Composting |
| **Individual Sites** | | | | | | |
| Campbell Mountain Landfill | 0 | 49 | 4 | 27 | 35 | N/A |
| Summerland Landfill | 0 | 1 | 0 | 1 | 0 | N/A |
| Okanagan Falls Landfill | 0 | 0 | 0 | 0 | N/A | N/A |
| Oliver Landfill | 0 | 87 | 44 | 78 | N/A | N/A |
| Osoyoos Landfill | 0 | 0 | 0 | 0 | N/A | N/A |
| Princeton Landfill | 0 | 61 | 0 | 3 | N/A | N/A |
| Princeton Hayfield | N/A | 1 | 0 | 0 | N/A | N/A |
| Keremeos Transfer Station | 0 | 1 | 0 | 1 | N/A | N/A |
| **Regional Facilities** | | | | | | |
| Campbell Mountain | N/A | 127 | 1 | 70 | 53 | N/A |
| Summerland | N/A | 16 | 1 | 7 | 9 | N/A |
| Summerland with RDCO Biosolids | N/A | 19 | 1 | 12 | 5 | N/A |
| Oliver | N/A | 202 | 102 | 166 | 198 | N/A |
| Osoyoos Windrow | N/A | N/A | N/A | N/A | N/A | 0 |

## 3.3 Biofilter Effect

During the conceptual design phase, it was assumed that the composting biofilter would be made of a mixed medium consisting of a combination of finished compost, overs, and wood chip/bark mulch type materials. This is the most common practice for biofilter media in the Pacific Northwest. This type of biofilter is also the simplest design and lowest capital cost. However, it does not have as high of an odour treatment capability. As presented in Table 3.4, biofilters were the largest source of odour emissions in the odour mapping exercise.

## Table 3.4: Odour Emissions from Biofilters

| Site | % of Odour from Biofilters | | | | | |
|---|---|---|---|---|---|---|
| | Current Operations | Aerated Static Pile | Membrane Covered Aerated Static Pile | In-Vessel Composting | Anaerobic Digestion | Windrow Composting |
| **Individual Sites** | | | | | | |
| Campbell Mountain Landfill | N/A | 82% | N/A | 79% | 75% | N/A |
| Summerland Landfill | N/A | 77% | N/A | 72% | 67% | N/A |
| Okanagan Falls Landfill | N/A | 97% | N/A | 99% | N/A | N/A |
| Oliver Landfill | N/A | 85% | N/A | 82% | N/A | N/A |
| Osoyoos Landfill | N/A | 76% | N/A | 69% | N/A | N/A |
| Princeton Landfill | N/A | 98% | N/A | 99% | N/A | N/A |
| Princeton Hayfield | N/A | 98% | N/A | 99% | N/A | N/A |
| Keremeos Transfer Station | N/A | 98% | N/A | 99% | N/A | N/A |
| **Regional Facilities** | | | | | | |
| Campbell Mountain | N/A | 80% | N/A | 77% | 73% | N/A |
| Summerland | N/A | 80% | N/A | 77% | 73% | N/A |
| Summerland with RDCO Biosolids | N/A | 82% | N/A | 79% | 75% | N/A |
| Oliver | N/A | 75% | N/A | 71% | 67% | N/A |
| Osoyoos Windrow | N/A | N/A | N/A | N/A | N/A | N/A |

Examples of more advanced biofilter systems include additional treatment of odours (e.g. wet scrubbers) or engineered biofilter media. Wet scrubber-type systems are more common at composting operations in Ontario and at wastewater treatment plants (Photo 1) such as in Penticton, BC.

Through there are additional capital and operating costs associated with installing a BIOREM-type wet scrubber, this investment in odour control technology could result in potential cost savings for siting facilities or choosing a lower-cost technology, if the primary barrier to the lower cost options is odour.

**Photo 1: BIOREM biological removal system at the Penticton Wastewater Treatment Plant**

# 4.0 CONCLUSION

Odour mapping was conducted for eight sites identified by the RDOS for potential expansion of organics processing facilities for each service area as well as regional facilities. Together with the findings from *Organic Management Consultant Task 1 – Site Assessment* and *Organic Management Consultant Task 2 – Feasibility Assessment*, the results of this study can be used to help the RDOS determine suitable sites for organics processing facilities.

# 5.0 CLOSURE

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech EBA Inc.

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# APPENDIX A
## TETRA TECH EBA'S GENERAL CONDITIONS

# GENERAL CONDITIONS

## GEO-ENVIRONMENTAL REPORT

This report incorporates and is subject to these “General Conditions”.

### 1.1 USE OF REPORT AND OWNERSHIP

This report pertains to a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment.

This report and the assessments and recommendations contained in it are intended for the sole use of TETRA TECH’s client. TETRA TECH does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than TETRA TECH’s Client unless otherwise authorized in writing by TETRA TECH. Any unauthorized use of the report is at the sole risk of the user.

### 1.2 ALTERNATE REPORT FORMAT

Where TETRA TECH submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed TETRA TECH’s instruments of professional service); only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by TETRA TECH shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of TETRA TECH’s instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except TETRA TECH. The Client warrants that TETRA TECH’s instruments of professional service will be used only and exactly as submitted by TETRA TECH.

Electronic files submitted by TETRA TECH have been prepared and submitted using specific software and hardware systems. TETRA TECH makes no representation about the compatibility of these files with the Client’s current or future software and hardware systems.

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In certain instances, the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by TETRA TECH in its reasonably exercised discretion.

### 1.4 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of the report, TETRA TECH may rely on information provided by persons other than the Client. While TETRA TECH endeavours to verify the accuracy of such information when instructed to do so by the Client, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

# APPENDIX B
## ODOUR MODELLING REPORTS

| | |
|---|---|
| Report 1 | Campbell Mountain Landfill |
| Report 2 | Summerland Landfill |
| Report 3 | Okanagan Falls Landfill |
| Report 4 | Oliver Landfill |
| Report 5 | Osoyoos Landfill |
| Report 6 | Princeton Landfill |
| Report 7 | Princeton Hayfield |
| Report 8 | Keremeos Transfer Station |

# CAMPBELL MOUNTAIN LANDFILL

# 1.0 INTRODUCTION

The following is a summary of model inputs and odour modelling results conducted for the purpose of assessing potential odour impacts from an organics management facility located at Campbell Mountain Landfill (hereafter referred to as the “Site”). Odour modelling was conducted using CALPUFF, an advanced air modelling software system recommended by the British Columbia Ministry of Environment (BC MOE).

# 2.0 MODEL INPUTS AND ASSUMPTIONS

## 2.1 Meteorology

The air dispersion model CALPUFF contains a diagnostic meteorological processor, CALMET, which creates a three-dimensional meteorological field over the spatial extent of the model. The data produced by CALMET is used by CALPUFF in its dispersion and plume transport calculations. Inputs to CALMET include the following:

- A geophysical grid, constructed using gridded terrain and land cover data (obtained from GeoGratis – Government of Canada); and
- A combination of prognostic (three-dimensional meso-scale model called MM5) meteorological data and hourly surface observations obtained from Environment Canada and BC MOE meteorological stations.

When CALMET is run in “no-observations” mode (using only MM5), the surface station observations provide a validation of the CALMET meteorology, in particular winds, to ensure representativeness. As MM5 is a meso-scale regional model, the grid used as input to CALMET is downscaled in three steps from a 32 km resolution grid to a 4 km grid and downscaled again within CALMET to the CALPUFF grid size (250 m). It is not expected that the meteorological time series in CALMET will exactly reproduce observed conditions on an hour by hour basis at any particular grid point; however, it is expected to be representative of the general conditions over a given year.

Table 2.1 summarizes the meteorological inputs to CALMET used in the Campbell Mountain Facility odour modelling and mapping exercise.

### Table 2.1: CALMET Inputs and Metadata

| Parameter | Usage |
|---|---|
| Surface Stations | None |
| Upper Air Soundings | None |
| Prognostic Data | 4 km resolution MM5 |
| Meteorological Grid | 12 km (east-west) x 15 km (north-south) at 250 $m^2$ |
| Grid Centrepoint | 313,500 m, 5,488,200 m, UTM Zone 11 |
| Vertical Cells (Cell Face Heights) | 10 (0 m, 20 m, 40 m, 80 m, 160 m, 320 m, 640 m, 1,200 m, 2,000 m, 3,000 m, 400 m) |
| Terrain Data | CDN DEM 15 min |
| Land Use Data | GeoBase Land Cover circa 2000-Vector |

As land cover characteristics over the modelling domain vary with season (e.g., albedo, Bowen ratio, etc.), seasonal CALMET files were created using the model's default seasonal geophysical properties for each land cover category contained within the geophysical grid. The date ranges assumed to define each season are listed in Table 2.2. Year-to-year variability will undoubtedly occur, however, this temporal approximation was used to simplify modelling based on Environment Canada 1981 – 2010 climate norms for the Okanagan-Similkameen region. The modelled year was 2012.

### Table 2.2: Geophysical Property Seasonality

| Season | Date Range |
|---|---|
| Winter | December 1 – February 28 (29) |
| Spring | March 1 – May 31 |
| Summer | June 1 – September 15 |
| Fall | September 15 – November 30 |

Figure 2.1 is a snapshot of the CALMET-modelled surface winds on June 13, 2012 at $3^{00}$ hrs. The time and date of the snapshot was selected to show an example of the easterly flow condition which is a common occurrence in both the modelled and observed data. Easterly winds tend to flow across Okanagan Lake north of Penticton and diverge as they meet terrain on the west side of the lake. The figure also shows the boundary of the site (green border) and the locations of Environment Canada (Penticton Airport) and BC MOE (Penticton RS, located near the Site) meteorological stations (dark green squares).

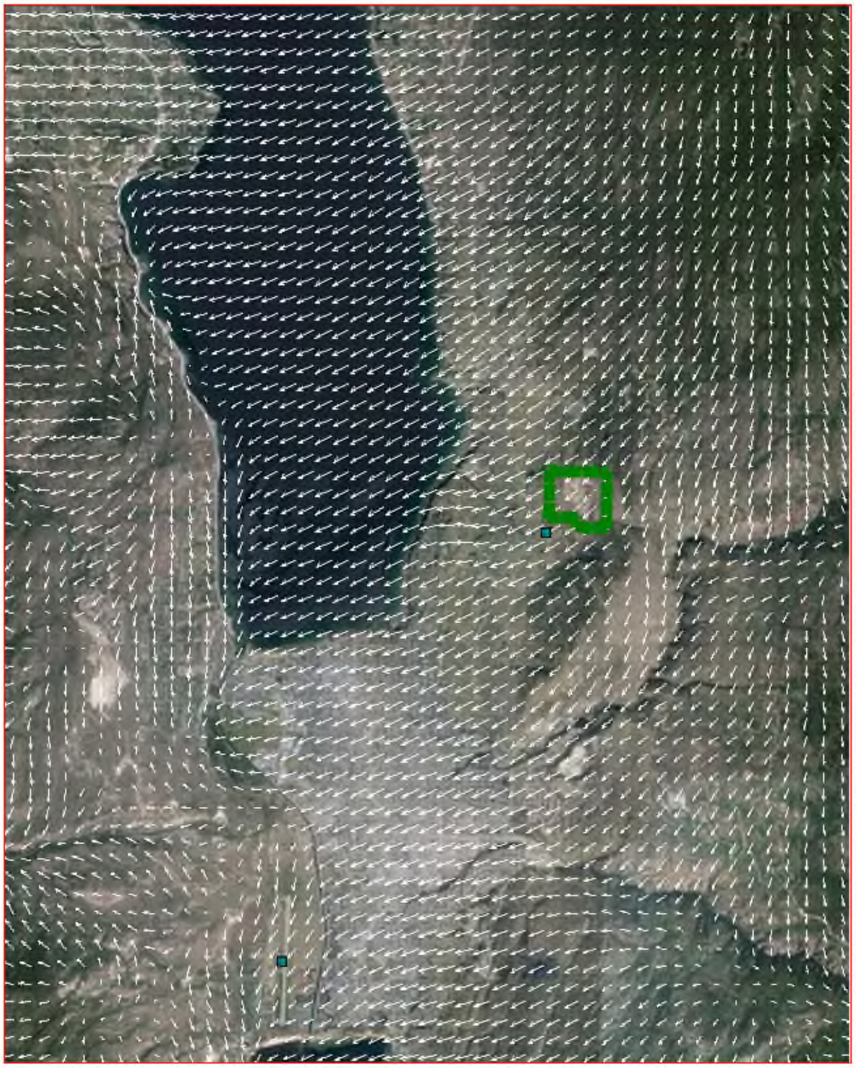

**Figure 2.1: CALMET-Modelled Wind Field – June 13, 2012, $3^{00}$ a.m.**

### 2.1.1 Meteorological Validations

#### 2.1.1.1 Winds

- *Wind flows primarily in the southwest from the facility*

Figure 2.2 shows a comparison of the CALMET-modelled winds (left) and the observed winds recorded at Ministry of Forests Lands and Natural Resource Operations (FLNRO) Penticton RS (49°31'6" N, 119°33'12" W, right). While CALMET under-predicts the frequency of wind speeds in the 12 to 14+ m/s range, particularly from the north, it does adequately reproduce the predominance of easterly downslope flows. Observed winds tend to come more-directly from the east (Figure 2.2, right), while CALMET predicts these easterly winds with a southerly or northerly component (Figure 2.2, left) due in part to the initial flow conditions contained in the grid cells at the resolution of the MM5 and in part to the terrain steering effects computed within CALMET due to the resolution of the terrain data. Despite the slight directional bias, overall the representation is adequate to predict odour concentrations downwind (west) of the facility. In actuality, there may be a higher occurrence of ground level odour impingements directly to the west, while the model would tend to initially carry the plume to the north or south more frequently, although plume transport away from the facility would ultimately be affected by the direction and strength of winds within the Okanagan Valley.


**Figure 2.2: Wind Rose Comparison: Modelled – Left vs. Observed at Penticton RS FLNRO – Right**

### 2.1.1.2 Mixing Height

- *Mixing height is lowest in the evening and during winter months*

The atmospheric mixing height can be defined as the top of the layer in the lower atmosphere, within which an emitted species, in this case odour, is readily mixed through turbulence and convective processes. Therefore, when the mixing height is low, higher ground-level concentrations will generally be predicted. Figure 2.3 are time series of modelled mixing heights extracted from CALMET over two distinct seasonal periods in 2012 at the location of the Penticton RS station. The top figure (red) plots a time series of mixing heights in the winter (between February 1 and 8), while the lower figure (blue) plots mixing heights in the summer (between July 1 and 8).

Seasonal contrast is strongly evident since there is reduced solar radiation, lower temperatures and snow cover, among other factors during the winter that results in generally lower mixing heights, and thus resulting in higher concentrations of odour. Both figures show the expected strong diurnal pattern, with mixing heights dropping quite close to the ground surface (~50 m as a default in CALMET) at night. When overnight mixing heights are higher, it is due to turbulence induced by higher wind speeds over uneven terrain.

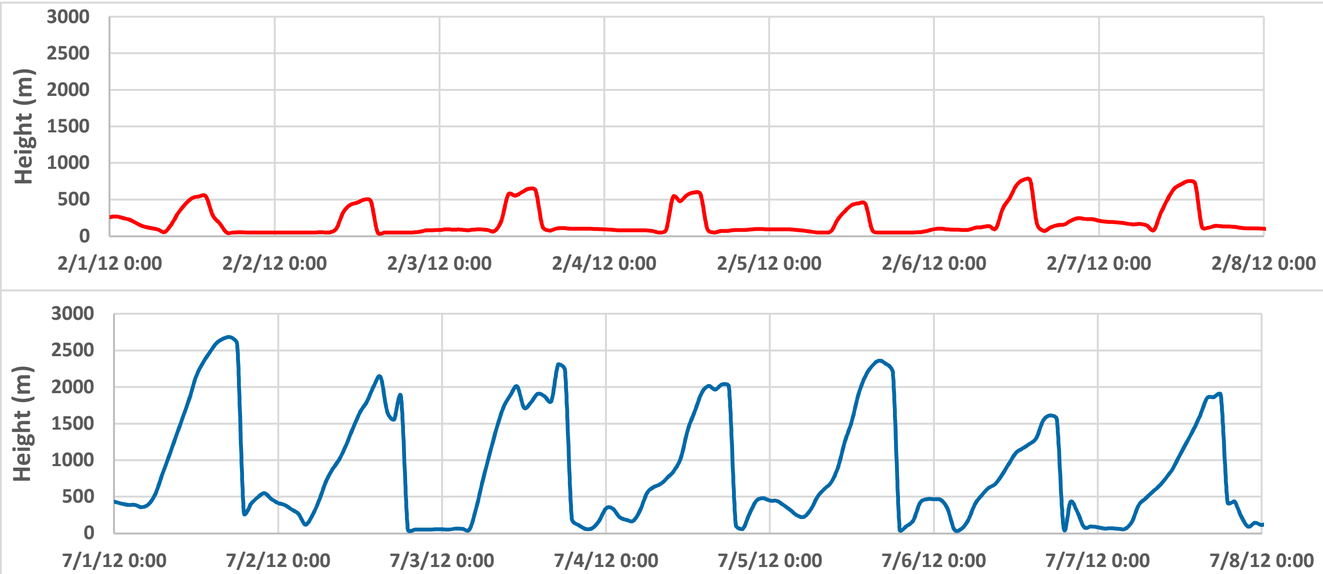


**Figure 2.3: CALMET-Modelled Mixing Heights for Winter (Red) and Summer (Blue)**

## 2.2 Area Sources and Emission Factors

The site layouts from the *Organics Management Consultant Task 2 – Feasibility Assessment* report for Campbell Mountain and Campbell Mountain Regional Facility were used to define the boundaries of the odour sources for this modelling analysis. Areas that generate odours were assigned a specific emission factor according to the activity taking place (e.g. composting, curing, pile turning, etc.). In the main report, Table 2.1 provides a description of the emission factors. The scenarios included for odour modelling are presented in Table 2.3.

### Table 2.3: Odour Modelling Scenarios

| Organics Processing Technology | Campbell Mountain | Campbell Mountain Regional Facility[1] |
|---|---|---|
| Current Composting Operations | √ | |
| Aerated Static Pile (ASP) | √ | √ |
| Membrane Covered Aerated Static Pile | √ | √ |
| In-Vessel Composting | √ | √ |
| Anaerobic Digestion (AD) | √ | √ |

[1] Campbell Mountain, Summerland, Oliver, and Osoyoos feedstocks combined.

Emissions were assumed to occur homogeneously over the entirety of the area source. Some odour emissions (e.g. pile turning, pile moving, etc.) were assigned a diurnal variation based on the expected times of day the activity is to be performed (Table 2.1 of the main report). Such activities are expected to occur daily at the Site over a one-to two-hour period; however, since the activity may occur at any time during the operational hours of the facility in the morning or in the afternoon, odour emissions were assumed in the model to occur between $10^{00}$ to $12^{00}$ – representing a time of day when vertical mixing is generally highest – and between $15^{00}$ to $17^{00}$ – when, during the winter, the mixing height is approaching its night time minimum, thus resulting in higher concentrations closer to the ground. This is a somewhat conservative approach since the activity may only be occurring over a portion of a single hour rather than four, may not take place every day, and peak odour emission would only occur during and immediately following the activity and decay in the hour following. It should be noted that odour emissions produced from pile building and moving are inconsequential compared to that produced from the biofilters which emit odour continuously.

Emission heights were either assigned a value of 3 m or 1 m depending on the activity occurring within the area source. Specific heights used for the various activity types are listed in Table 2.1 of the main report.

## 2.3 CALPUFF Settings and Assumptions

The CALPUFF model input settings were assigned with consideration to the recommendations in Table 9.7 of '*Recommended CALPUFF Input Group 2 Switch Settings*' in '*Guidelines for Air Quality Dispersion Modelling in British Columbia*'. Generally, default model settings were used. Since the area of interest is in the near-field (within 12 – 15 km of the source), dispersion coefficients were internally calculated using micrometeorological variables (MDISP = 2) based on estimates of the crosswind and vertical components of turbulence based on similarity theory and the land cover type. The probability distribution function (PDF) was used for dispersion under convective conditions (MPDF = 1) which explicitly accounts for the differences in the distribution and strengths of up and down drafts within the convective boundary layer, reporting the average between the two. By using these two settings, AERMOD-type dispersion is simulated (generally accepted as better-predicting in the near-field than CALPUFF), while also providing the benefit of a puff model and allowing for the effects of complex terrain.

The receptor grid spacing was 125 m at ground level over the entire grid. The simulations were to determine the general effects downwind from the facility, on the scale of kilometres, and therefore, did not consider building downwash – the drawdown of the odour plume downwind of facility buildings due to turbulence.

# 3.0 RESULTS

Since the time step of the meteorological data is one-hour, CALPUFF can only output one-hour averaged predictions of odour concentration. However, since odour perception is on a much shorter scale, an averaging time-scalar must be applied to assess shorter-term peak concentrations due to plume meandering within the hourly period. Hourly odour concentrations are scaled to a ten-minute averaging period using Equation 1.

$$Cp = Co * \left(\frac{t_o}{t_p}\right)^{0.28} \qquad (1)$$

Pursuant to Equation 1, $t_o$ is the 60 minute averaging time, $t_p$ is the short-term averaging time (10 minutes) and $C_o$ and $C_p$ are the respective peak concentrations (BC MOE). The scalar when converting from hourly to ten-minute average concentrations equates to 1.65.

## 3.1 Odour Units

An Odour Unit (OU) is a way of quantifying odours through the use of an odour panel that consists of a group of people with 'calibrated noses'. The definition of an OU is based on the proportion of odour panel members that can detect the smell of a substance. One OU represents the concentration of a particular substance when 50% of the odour panel can detect the odour. This is called the perception threshold[1]. At this point, although an odour may be detected, it is not distinct enough to be able to identify the type of odour.

[1] http://blog.odotech.com/odor-unit-perception-threshold.

The OU scale is based on dilutions, as shown in the following figure. As the number of OUs increase, more people can detect the odour, and the intensity of the odour increases. Five OU is considered a faint odour and ten OU is considered a distinct odour (the point when some people can identify the type of odour, or its potential source)[2].

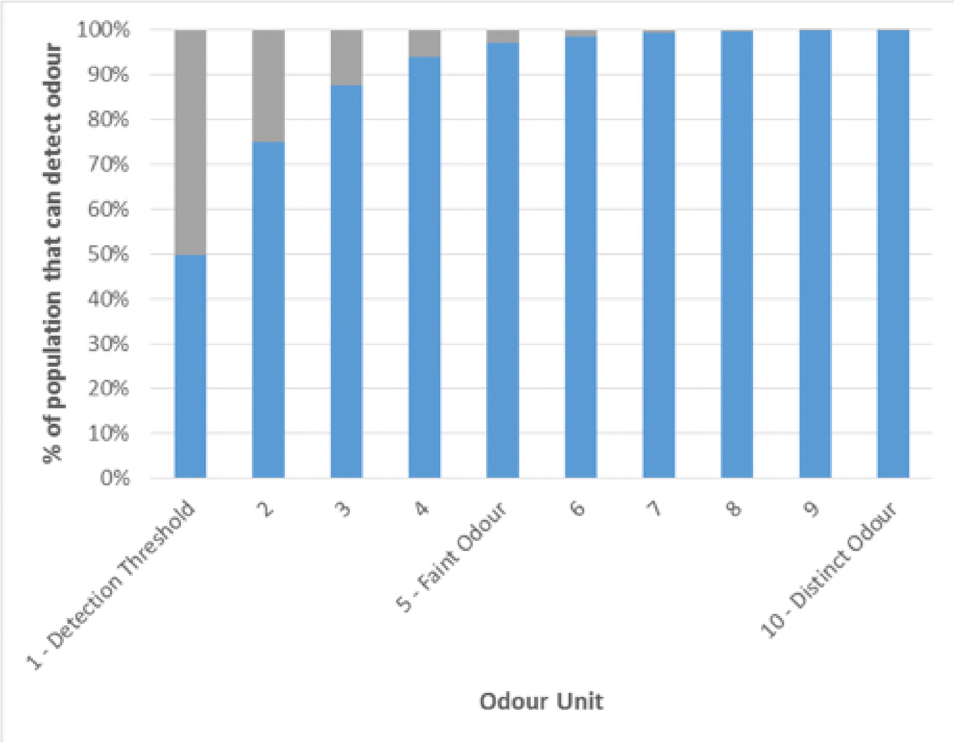


**Figure 3.1: Odour Unit Scale**

There are currently no guidelines for odour limits for composting facilities in British Columbia, however, some wastewater treatment facilities have imposed odour limits. For example, the standard in Metro Vancouver is no more than five OU at the property line. In other jurisdictions, the guideline is to have no detectable odour at the property line. At the Ogogrow facility in Vernon, BC, the limit is 50 OU at the property line.

## 3.2 Odour Maps

Odour maps are included as part of Appendix A. For each organics processing option listed in Section 2.2, odour modelling results are presented as three different plots:

- Maximum Odour Concentrations – The maximum predicted 10-minute odour concentration at each receptor point over the course of the modelled year. This is displayed as a contour plot showing the maximum predicted 10-minute averaged odour concentration at every ground level receptor point over the entire one-year simulation (8784 hours) as a blue gradient (light to dark). The 1 OU contour is white. The highest levels >10 OU are dark blue. The facility boundary is shown as a green outline.
- Hourly Exceedances >1 OU – The number of hours over the course of the modelled year where an odour threshold of 1 OU was exceeded in a ten-minute averaged concentration. This is displayed as a contour plot showing the number of times the predicted 10-minute odour concentration exceeded 1 OU over the modelled

[2] Odours and volatile organic compounds: Measurement, Regulation and Control Techniques (2009). Kassel University Press.

year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to 50% of the population being able to detect odour produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.

- Hourly Exceedances >5 OU – The number of hours over the course of the modelled year where an odour threshold of 5 OU was exceeded in a ten minute averaged concentration. This is displayed as a contour plot showing the number of times the predicted 10-minute odour concentration exceeded 5 OU over the modelled year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to when a faint odour is produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.

## 3.3 Results Summary

The odour maps presented in Appendix A show: (1) the magnitude and spatial extent of maximum ground level odour, and (2) the number of exceedances of odour detection thresholds for the technologies assessed. The membrane covered aerated static pile results had the least odour issues.

The following table summarizes the results of the odour mapping exercise based on the predicted maximum odour and number of hours of odour exceedances at a location 100 m south of the property boundary representing the resident that is closest in proximity to the Site (315578 m, 5488324 m, UTM Zone 11), Figure 3.2.

### Table 3.1: Results Summary based on Closest Receptor Point

| Scenario | Maximum Predicted 10-min Odour | Odour Exceedance >1 OU (hours per year) | Odour Exceedance >5 OU (hours per year) |
|---|---|---|---|
| **Campbell Mountain** | | | |
| Current Composting Operations | 3 OU | 7 | 0 |
| ASP | 28 OU | 480 | 49 |
| Membrane Covered Aerated Static Pile | 7.1 OU | 95 | 4 |
| In-Vessel Composting | 21 OU | 408 | 27 |
| AD | 23 OU | 440 | 35 |
| **Campbell Mountain Regional Facility** | | | |
| ASP | 53 OU | 515 | 127 |
| Membrane Covered Aerated Static Pile | 8.6 OU | 45 | 1 |
| In-Vessel Composting | 43 OU | 398 | 70 |
| AD | 36 OU | 397 | 53 |


**Figure 3.2: Location of Discrete Receptor (315578 m, 5488324 m, UTM Zone 11)**

### 3.3.1 Biofilter Effect

Similar to the odour maps shown in Appendix A, the Membrane Covered Aerated Static pile has the lowest odour emissions of the technologies as this type of operation does not use a biofilter. The greatest source of odour emissions can be attributed to the biofilters, as seen in Table 3.2.

### Table 3.2: Odour Emissions from Biofilters

| Scenario | % of Odour from Composting Biofilter |
|---|---|
| **Campbell Mountain** | |
| Current Composting Operations | N/A |
| ASP | 82% |
| Membrane Covered Aerated Static Pile | N/A |
| In-Vessel | 79% |
| AD | 75% |
| **Campbell Mountain Regional** | |
| ASP | 80% |
| Membrane Covered Aerated Static Pile | N/A |
| In-Vessel | 77% |
| AD | 73% |

# 4.0 DISCUSSION – METEOROLOGICAL DESCRIPTION OF EXCEEDANCES

## 4.1 Seasonality

As described in Section 2.1, the height of the mixing layer, the layer of air near the surface within which air parcels readily rise and turbulent mixing can occur, is a major factor in dispersing odour vertically away from the surface. Although several other meteorological factors affect dispersion as well (e.g. wind speed and direction, atmospheric stability, etc.), higher ground level concentrations generally occur when the mixing height drops closer to the surface. As Figure 2.3 illustrated, this occurs overnight as solar-induced vertical convection ceases, reducing the depth of the mixed layer. As well, in northern hemisphere mid-latitudes, daytime mixing heights are much lower during the winter than in the summer as solar intensity is diminished. This is even more enhanced within valleys where inversion conditions frequently develop.

- *Mixing layer height affects vertical dispersion of odour.*
- *Mixing layer height decreases in the evening and overnight.*
- *Mixing layer heights are typically much lower in the winter.*

Figure 4.1 shows a plot of 1 OU exceedances during a three month period in summer 2012 (June 1 to August 31, left) a plot of 1 OU exceedances over a three-month period in fall/winter 2012 (October 1 to December 31, right) for the Anaerobic Digestion configuration. The seasonality is quite evident with a higher frequency of occurrences in the winter months, particularly over Okanagan Lake where mixing heights are generally lower than over land due to ground heating differences and lower ground friction (less turbulence).

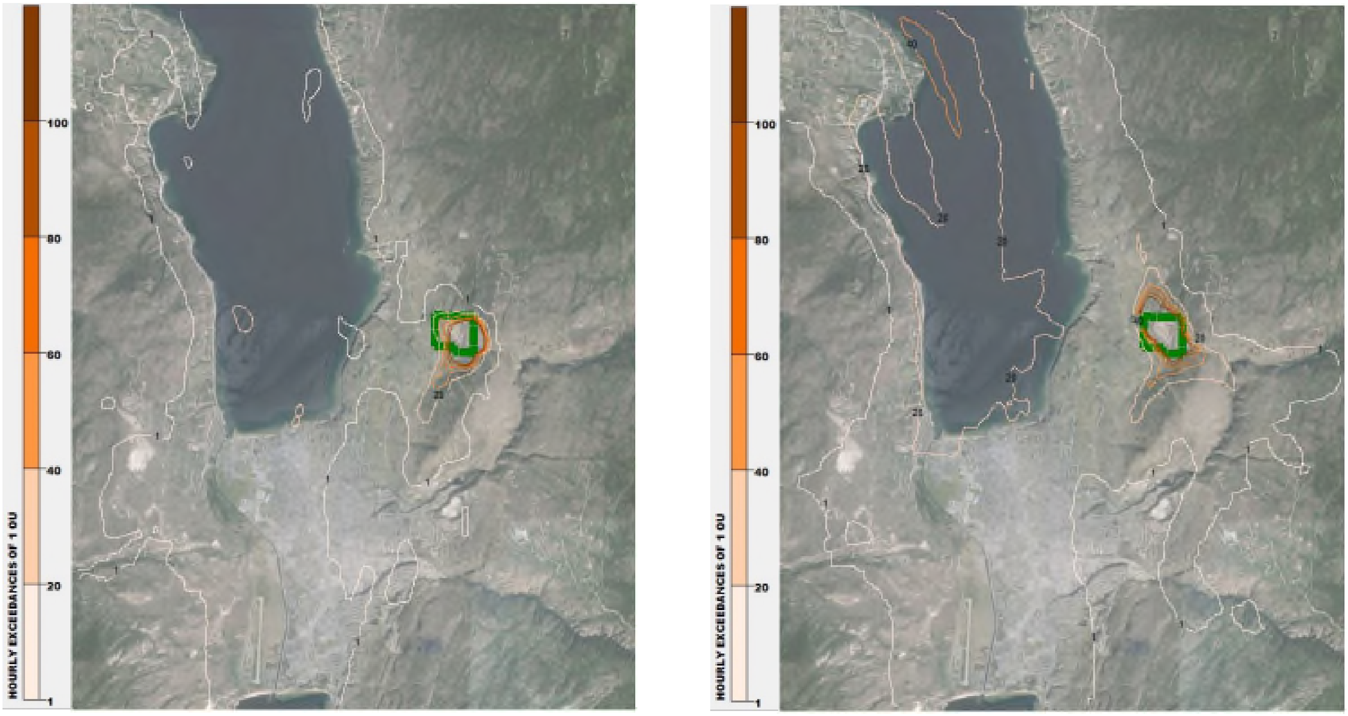


**Figure 4.1: Summer (June to August, left) and Winter (October to December, right) Exceedances of 1 OU (AD)**

## 4.2 Diurnal Variations (Day/Night)

Figure 4.2 shows a time series plot of mixing height (blue) and predicted ground level concentration (orange) over the period November 1 to 8 at a residential location just southwest of Okanagan Lake, 310625 easting, 5486825 northing, Zone 11 (See Figures 4.3 through 4.6).

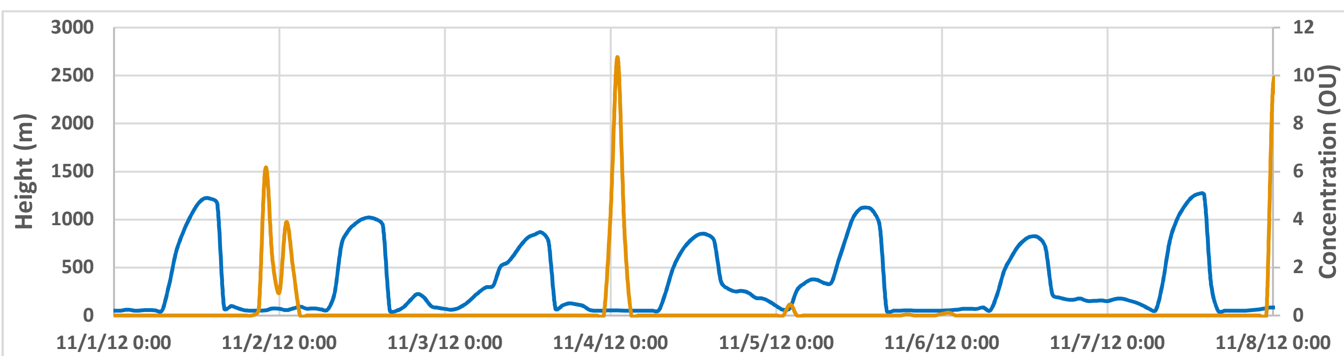


**Figure 4.2: CALMET Mixing Height and Predicted Ground Level Concentration at 310625, 5486825 (November 1 to 8)**

The figure shows several spikes in predicted concentrations, all occurring at night when the mixing height is low and atmospheric conditions are most stable. However, winds (both speed and direction) are also a factor since emissions were modelled as a constant rate during non-working hours and the spike only occurs occasionally.

Figures 4.3 through 4.6 are hourly snapshots of the odour plume (pink shaded represents the 1 OU contour, dark purple is 0.5 OU; blue through green increasing from 1 OU), the modelled wind field (shown as white arrows in the direction of flow with the length of the arrow representing faster wind speeds) and the modelled mixing height (as shaded and labelled contours; purple representing a mixing height below 100 m) on November 3 and 4 from 22$^{00}$ hrs through 1$^{00}$ hrs, respectively. The location of interest (310625 m, 5486825 m, UTM Zone 11) is marked as a red circle just southwest of Okanagan Lake.

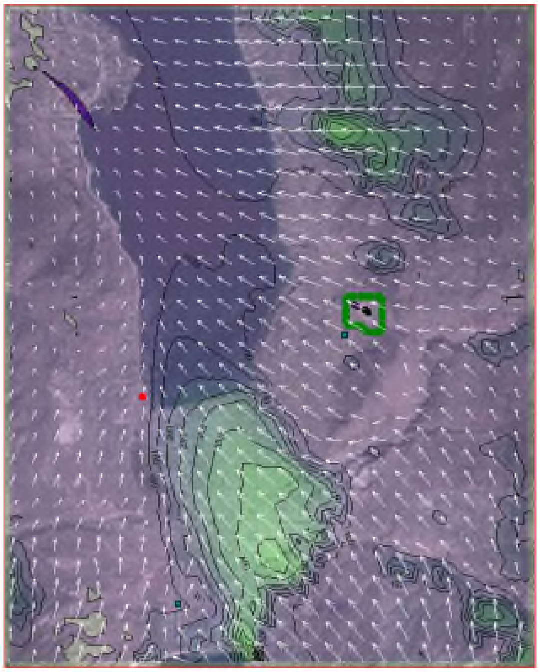

**Figure 4.3: November 3 21$^{00}$ hrs**

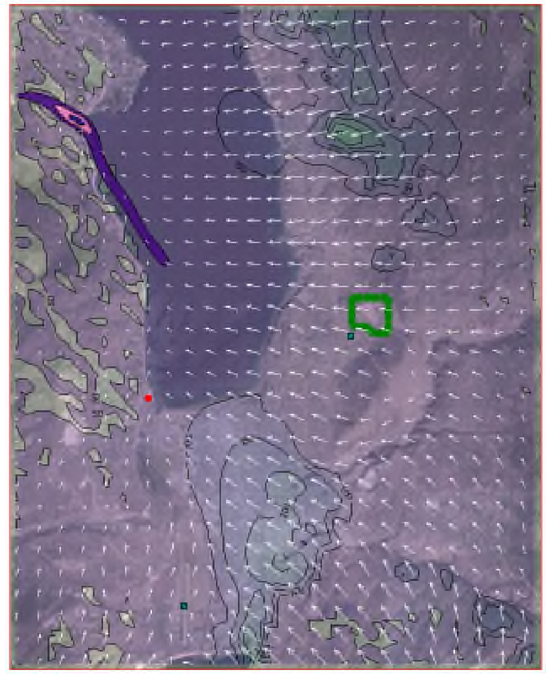

**Figure 4.4: November 3 22$^{00}$ hrs**

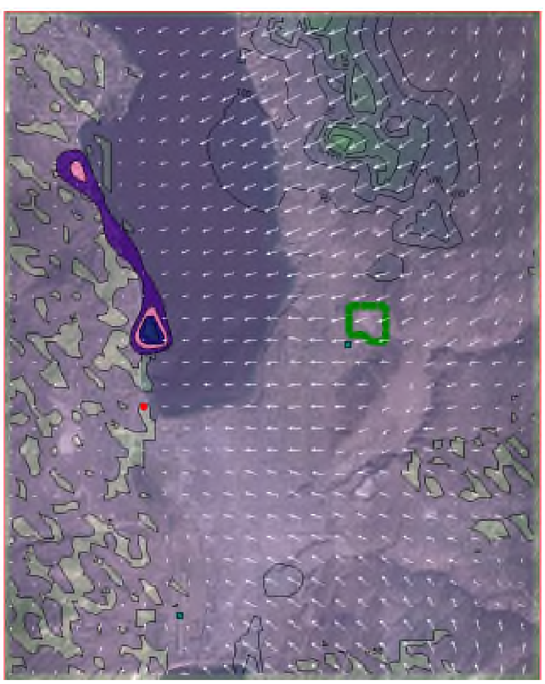

**Figure 4.5: November 3 23$^{00}$ hrs**

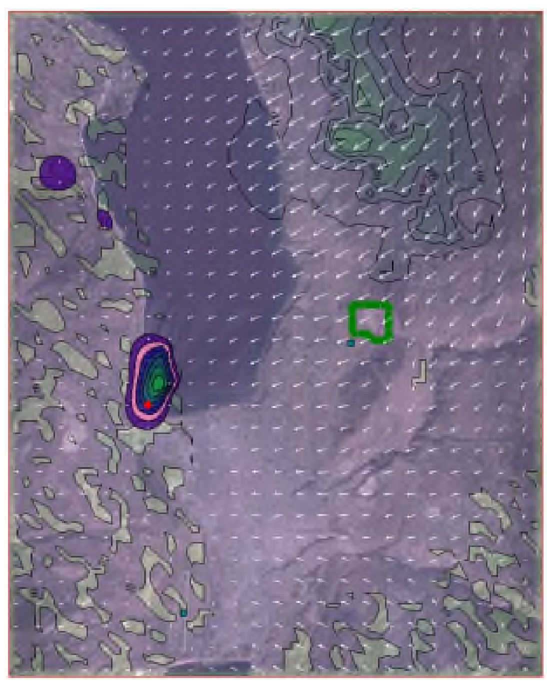

**Figure 4.6: November 4 0$^{00}$ hrs**

The figures show the transport of an odour plume over the four hours leading up to the maximum which occurred at $1^{00}$ hrs. The overall wind condition shows valley convergence, with easterly and southerly winds flowing into the valley near Penticton. The purple colour covering the majority of the maps is indicative of a low mixing height over the valley floor. In Figure 4.3, mixing heights are higher (shaded green) over the city and north of the facility on the lee side of the predominant north-easterly wind due to turbulence induced by buildings and uneven terrain, respectively. Figure 4.3 also represents the time of day when mixing heights are approaching the daily minimum. Prior to this hour, and evidenced in the pattern of the hourly (ten-minute) averaged concentration, the odour plume is mixed readily, hence there is little evidence of the odour plume beyond the facility (the model output cut-off is 0.5 OU – dark purple). As mixing heights fall and the atmosphere becomes more stable, we begin to see odour concentrations near the surface on the west side of the lake, blocked by terrain (Figures 4.4 and 4.5). As winds shift, the plume moves towards Penticton, resulting in an exceedance at the selected grid point (Figure 4.6). As described briefly in Section 2.0, this is a common flow condition as predicted by CALMET.

Table 4.1 lists the number of 1 OU exceedances at the location of interest occurring during the night and during the day. The diurnal pattern related to mixing height is quite evident.

### Table 4.1: Diurnal Pattern to Predicted 1 OU Exceedance (at 310625 m, 5486825 m, Zone 11)

| | $22^{00}$ – $4^{00}$ | $8^{00}$ – $16^{00}$ |
|---|---|---|
| Number of Predicted Exceedances | 54 | 0 |

Overall, this shows that odour impingements away from the facility occur when the mixing height is low (night time, winter) and the prevailing winds carry the plume towards populated areas. Generally, exceedances of the 1 OU detection threshold occur at night.

This summary describes the conditions at one location. The temporal distribution could be different at other locations based on the prevalent meteorological conditions, however it can be assumed that the majority of odour issues at any point tend to occur at night.

# APPENDIX A

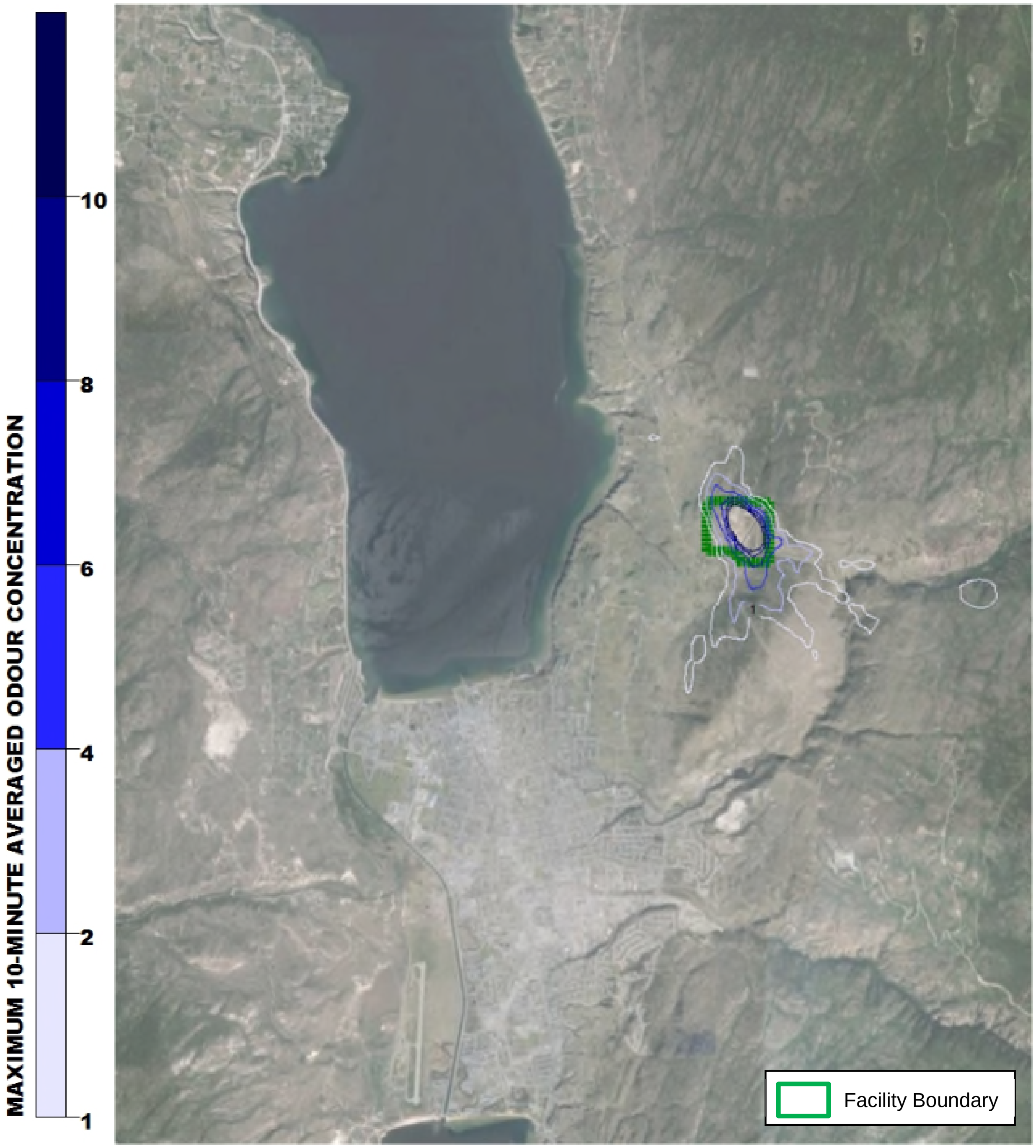


**Figure 1: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Current Composting Operations)**

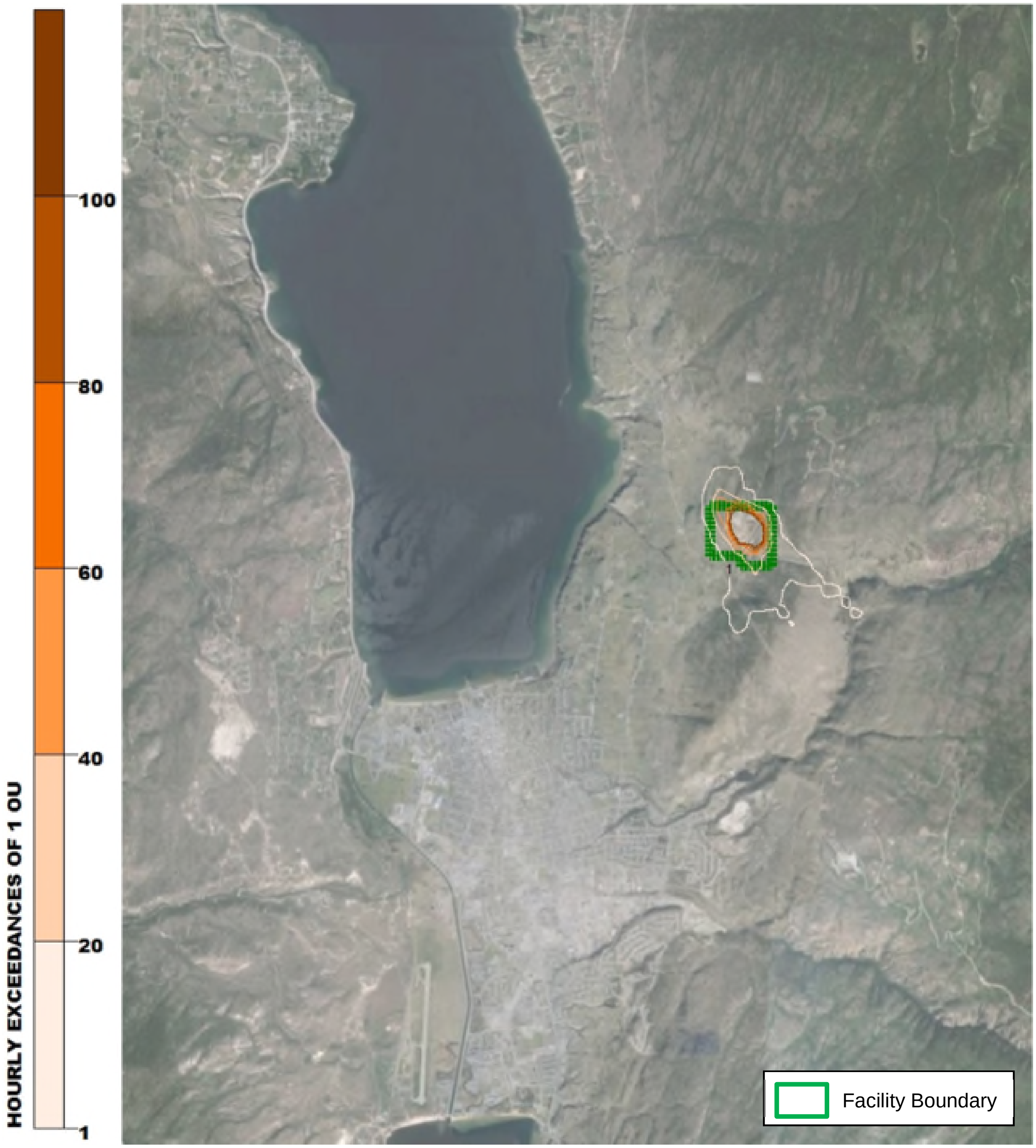


**Figure 2: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Current Composting Operations)**

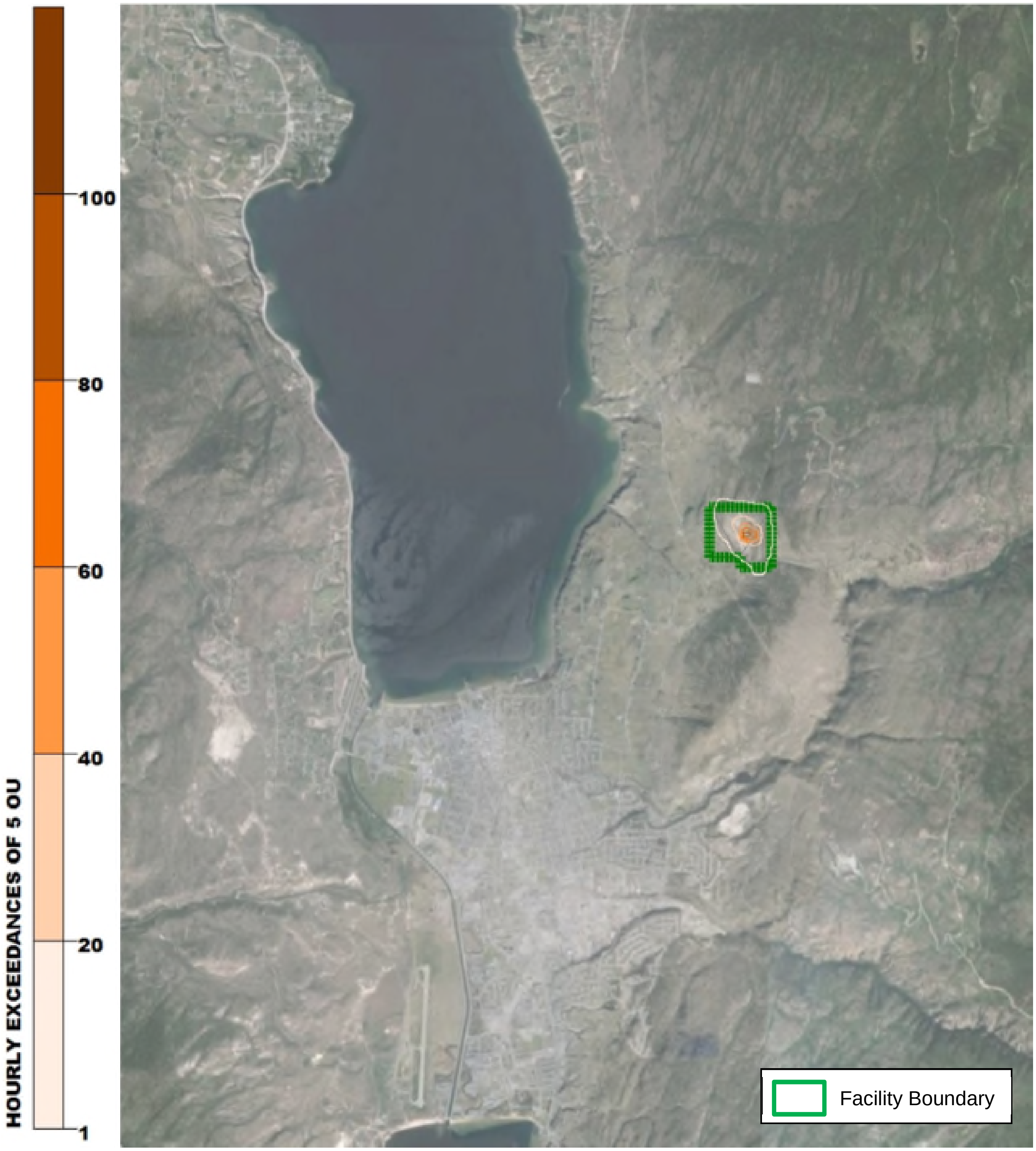


**Figure 3: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (Current Composting Operations)**

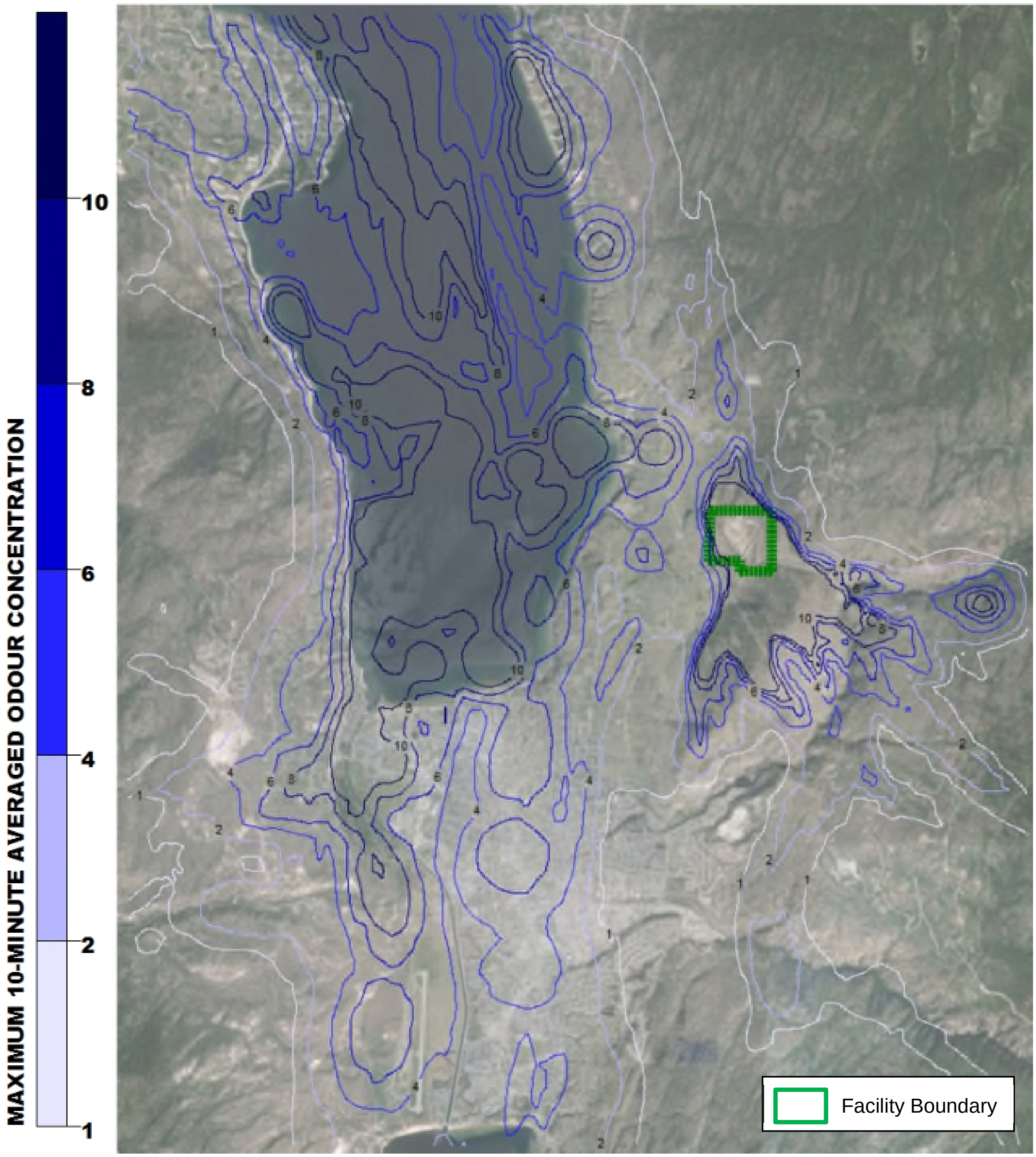


**Figure 4: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (ASP)**

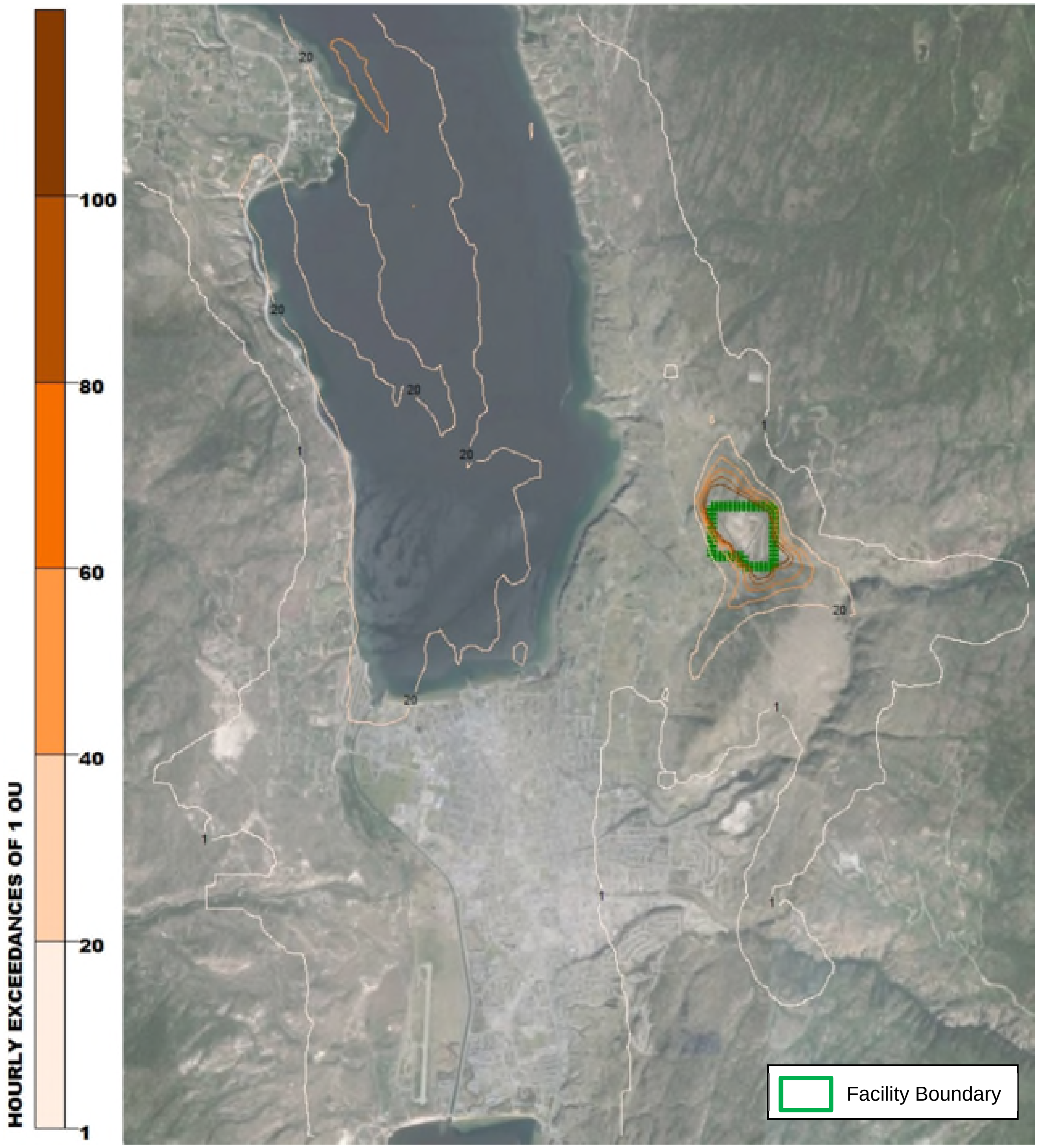


**Figure 5: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (ASP)**

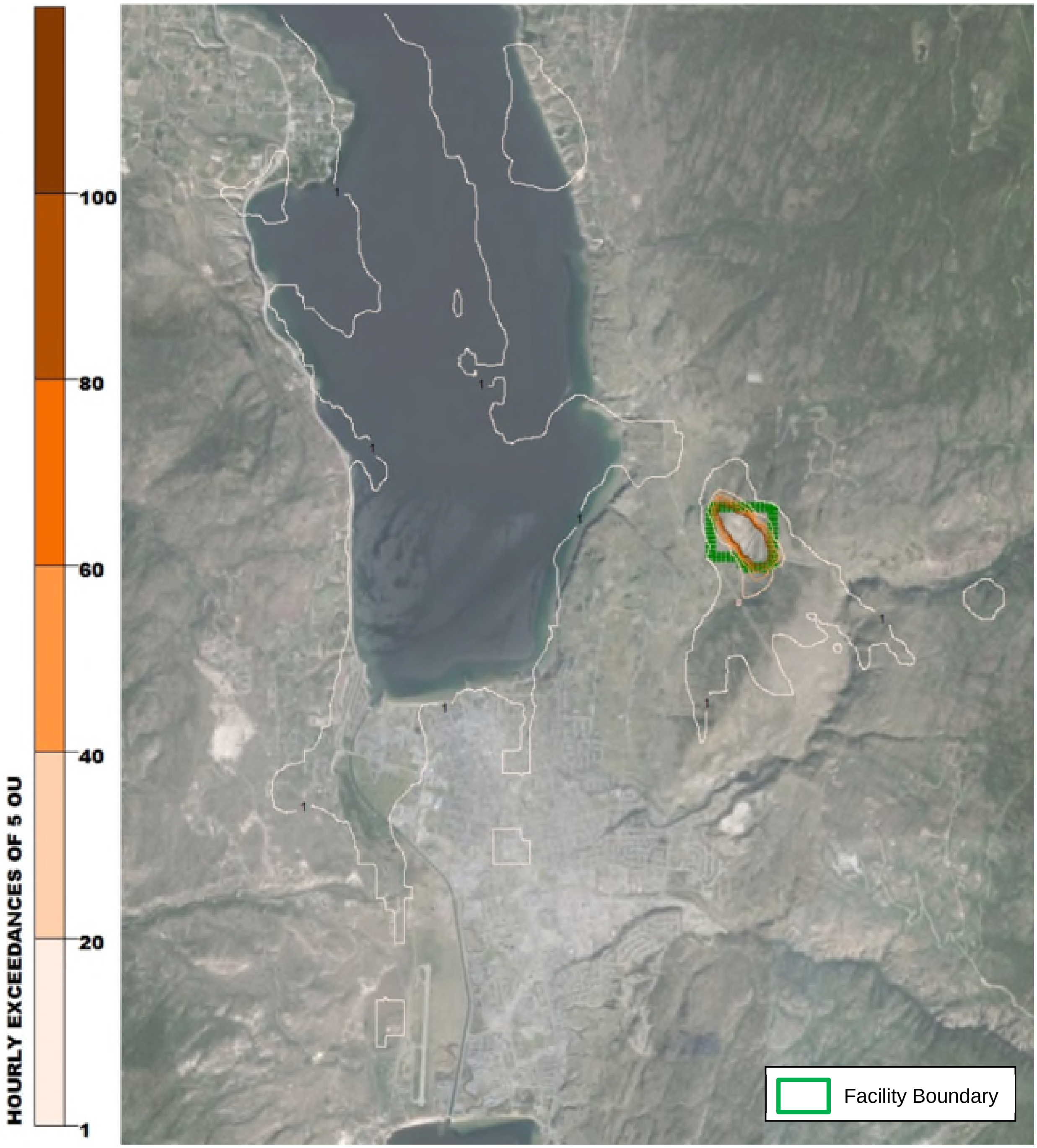


**Figure 6: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (ASP)**

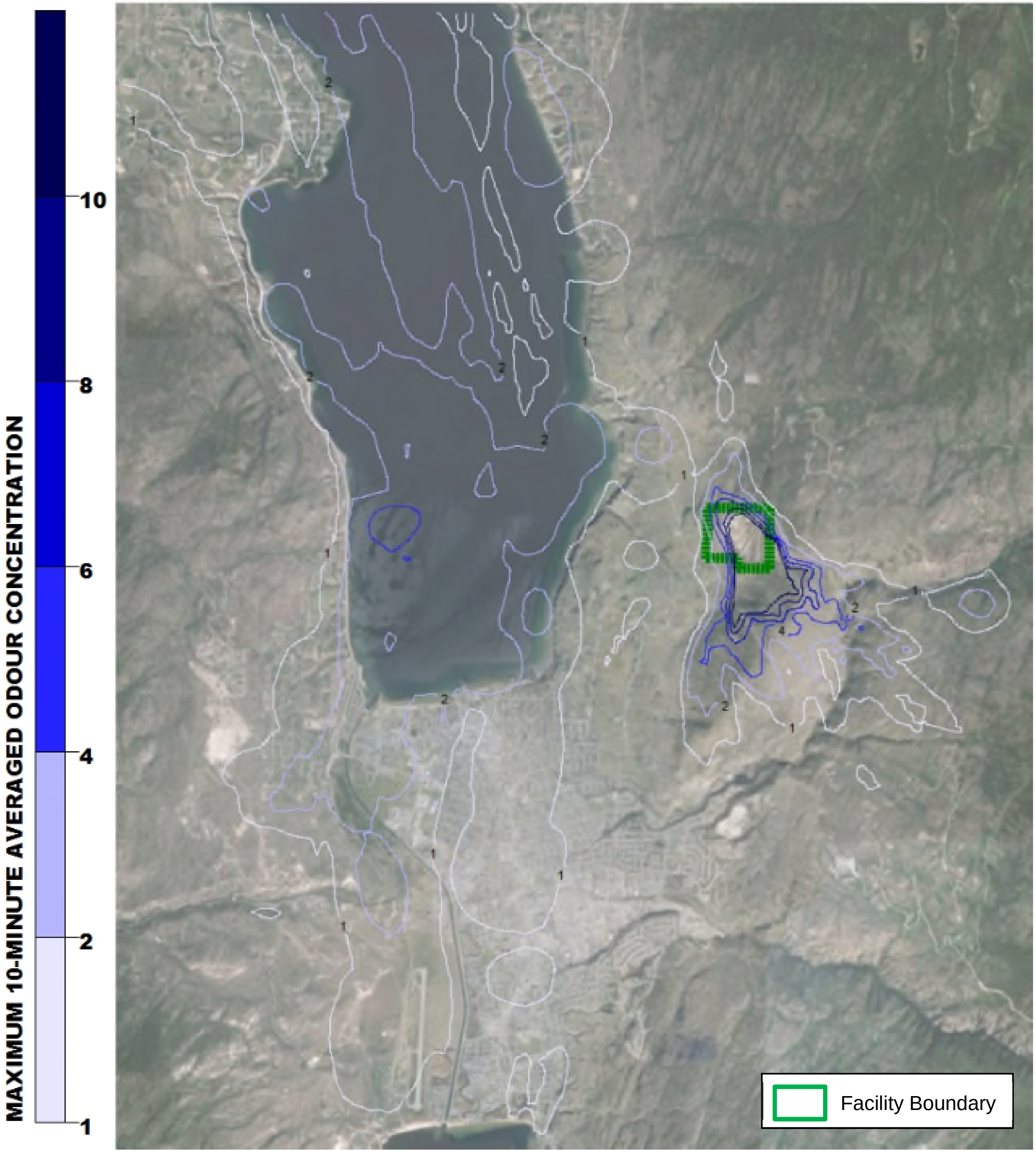


**Figure 7: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Covered ASP)**

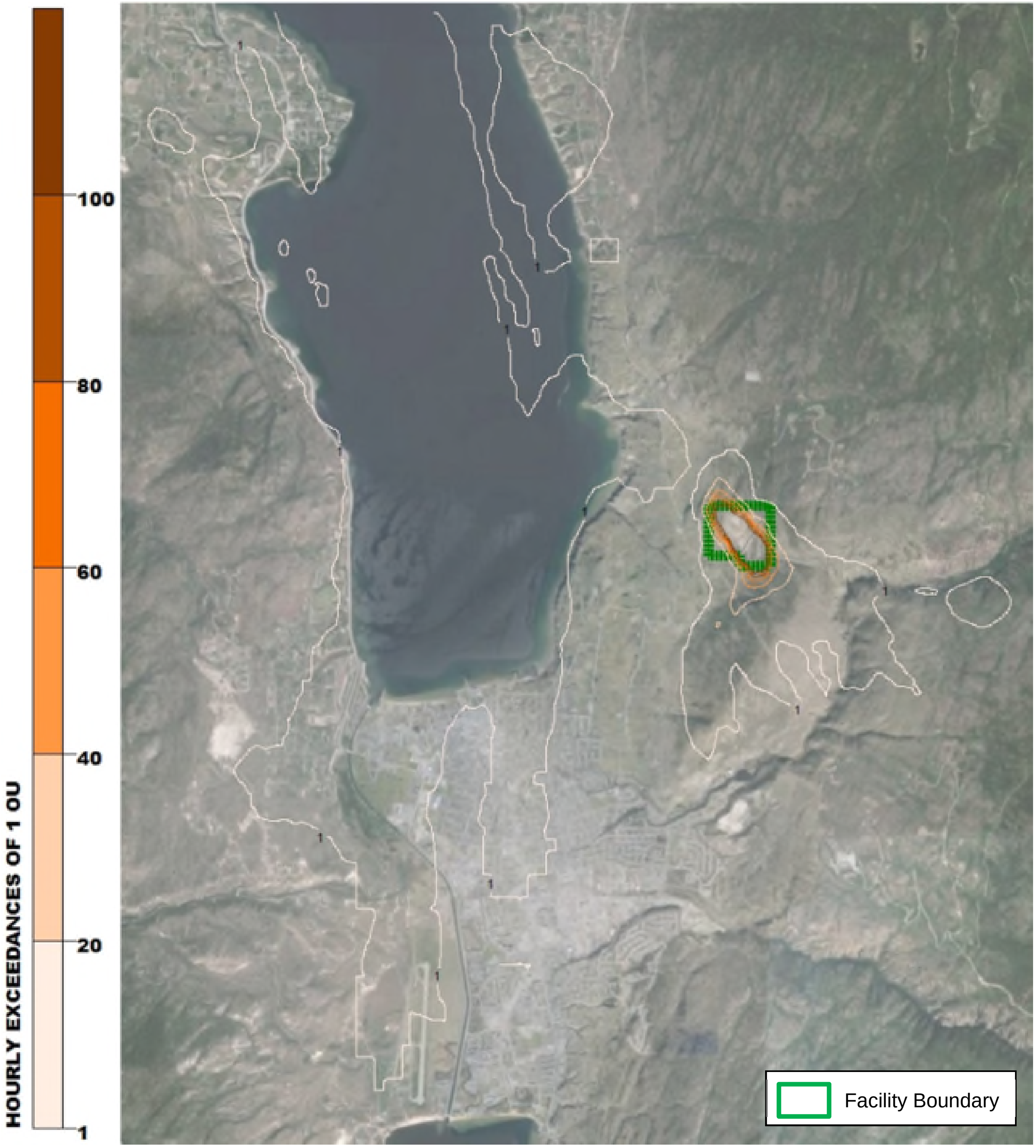


**Figure 8: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Covered ASP)**

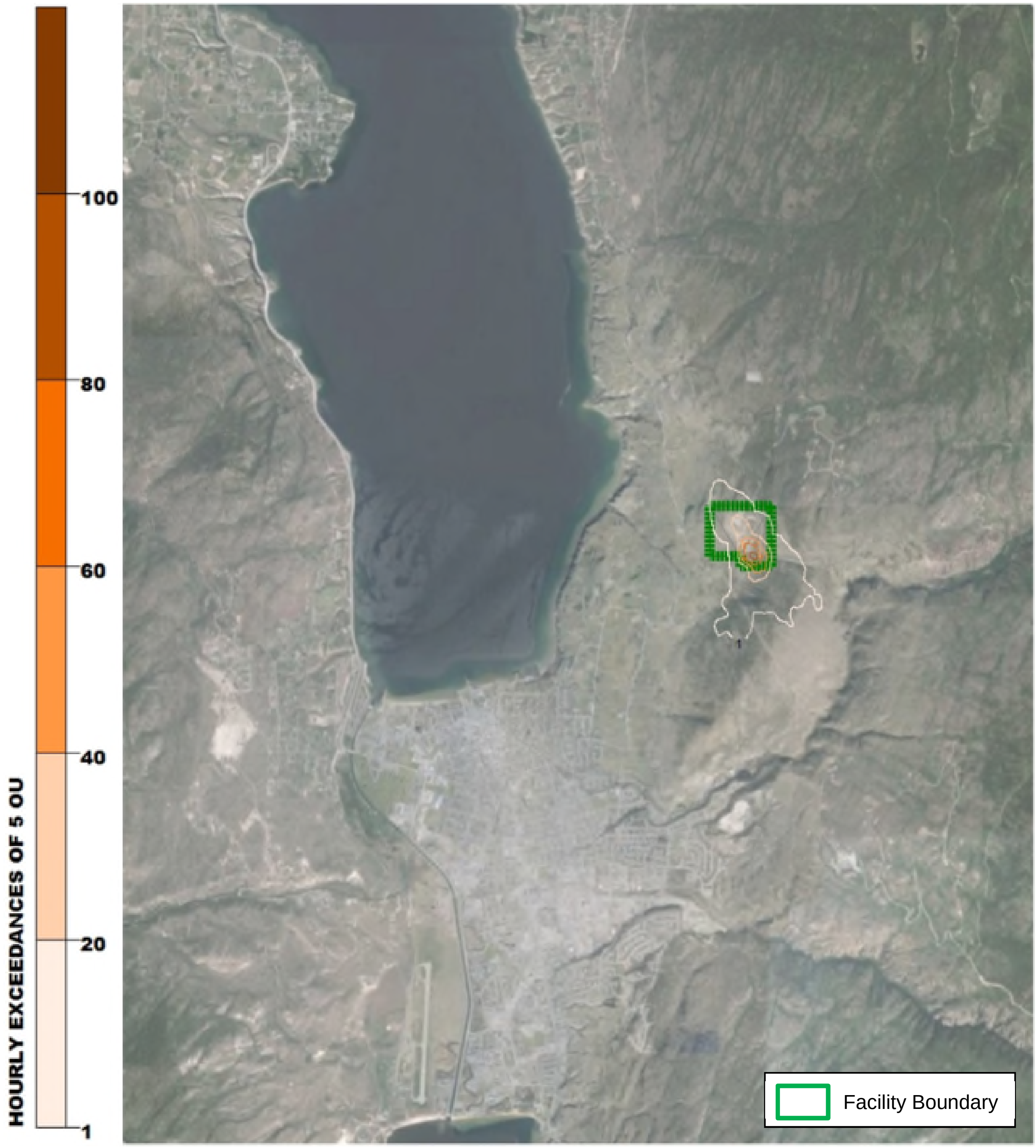


**Figure 9: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (Covered ASP)**

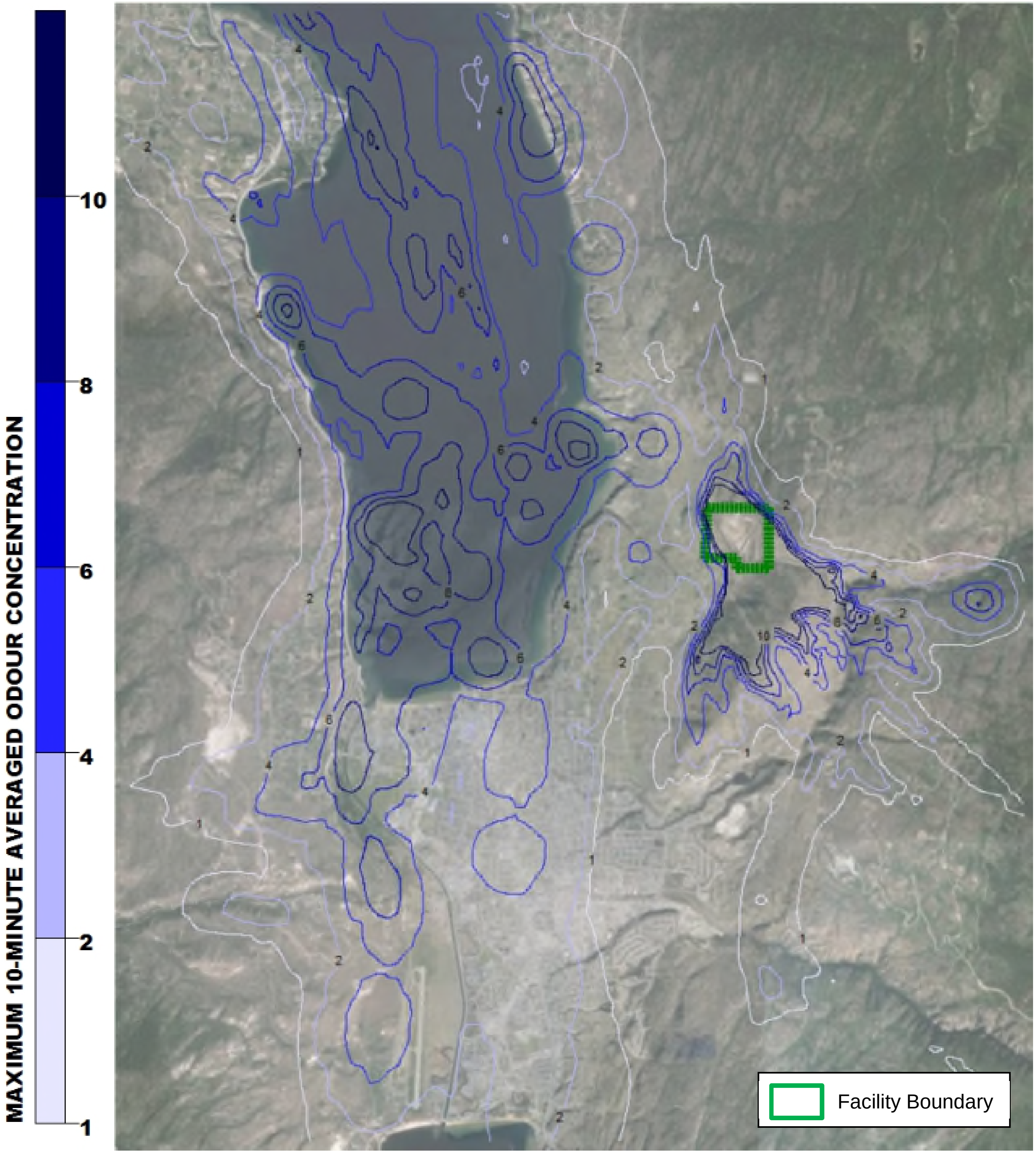


**Figure 10: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (In-Vessel)**

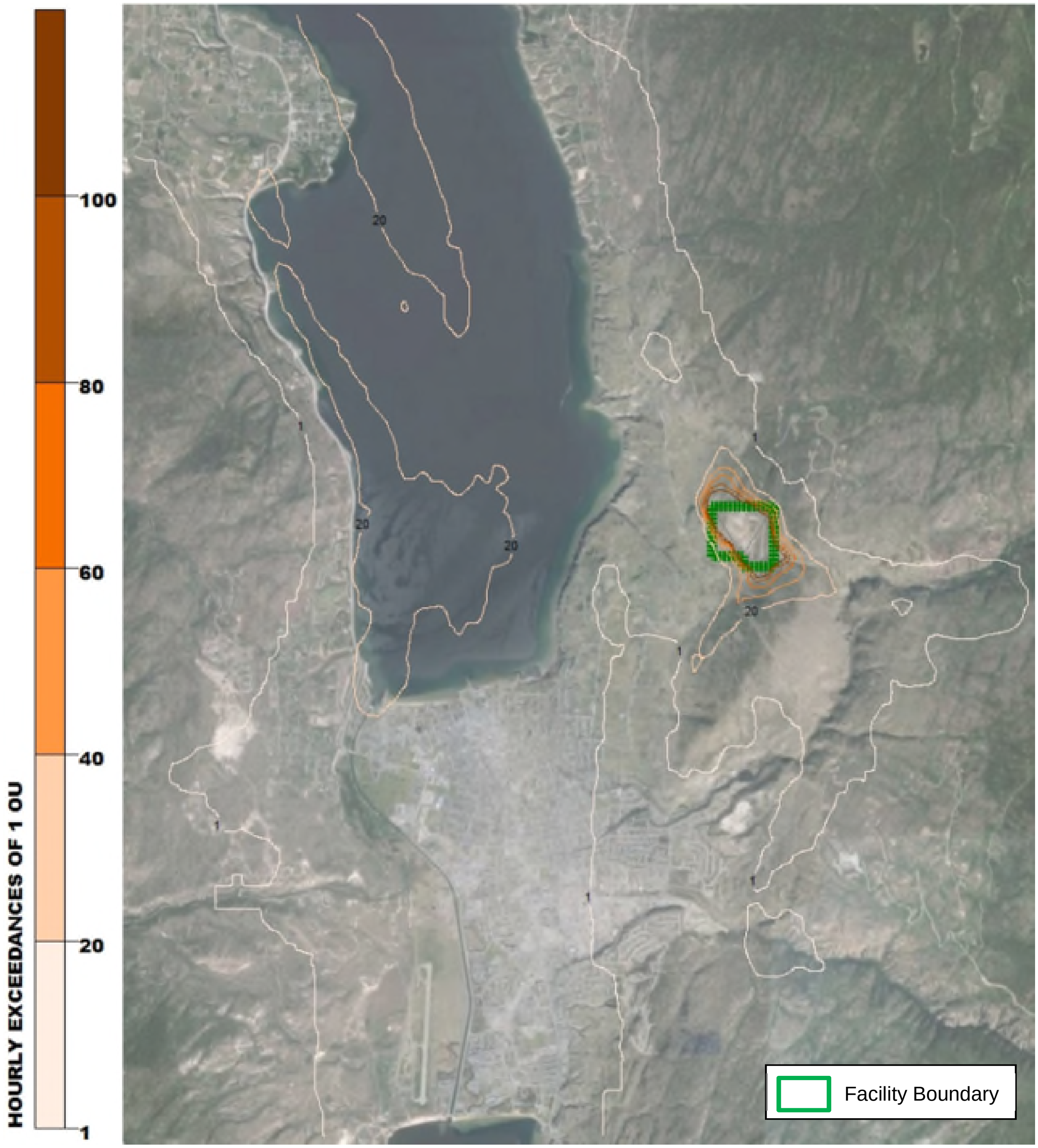


**Figure 11: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (In-Vessel)**

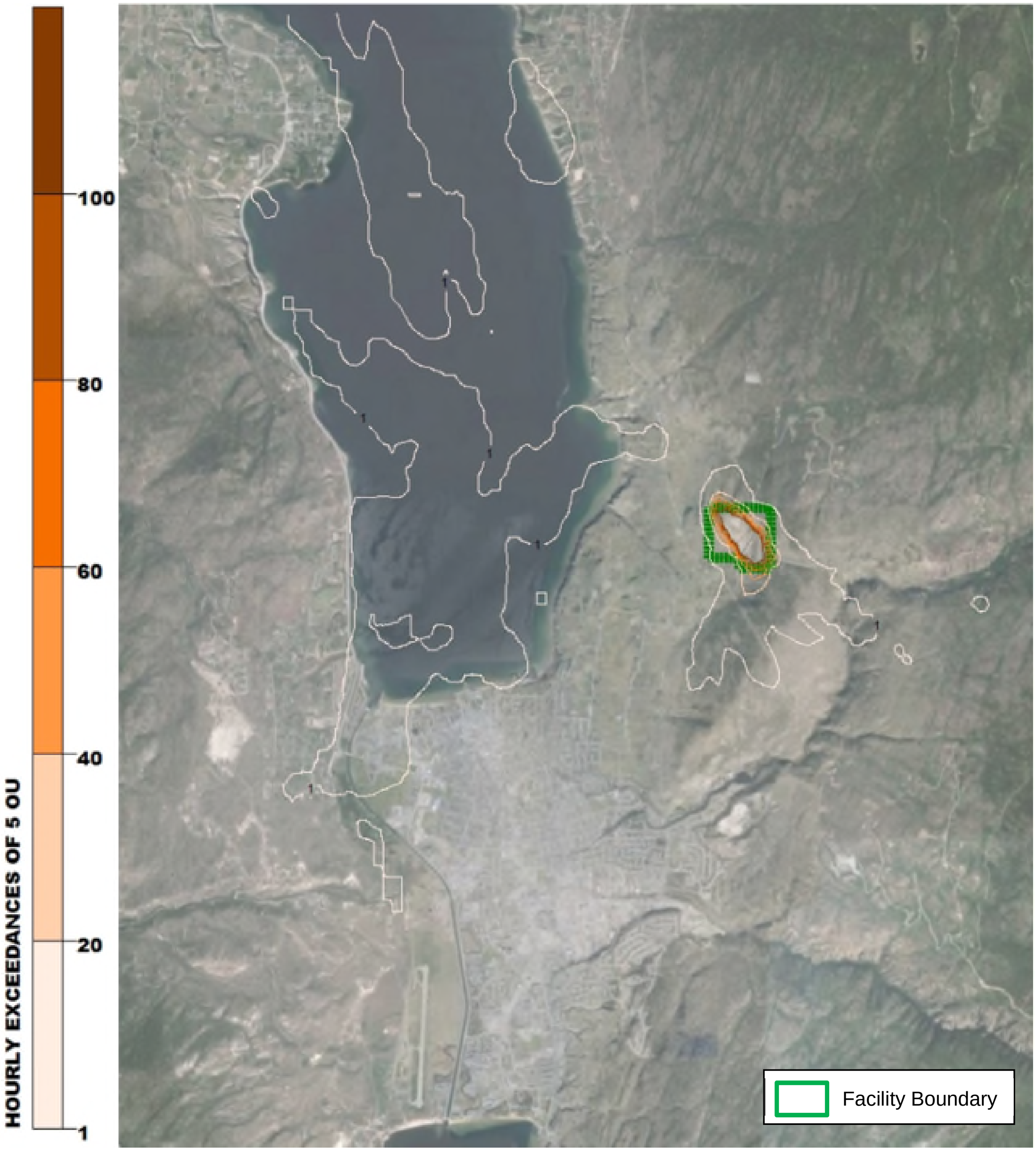


**Figure 12: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (In-Vessel)**

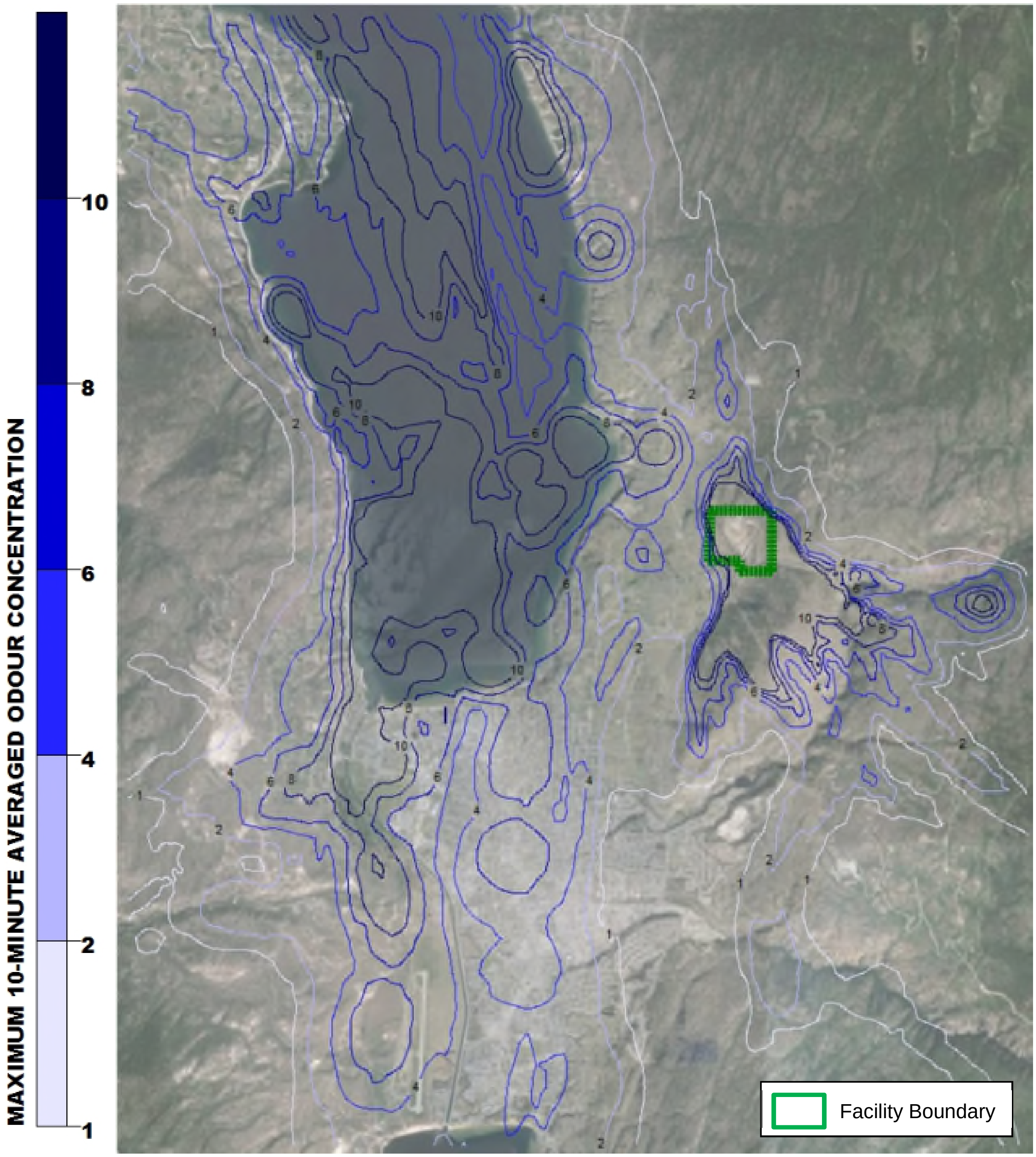


**Figure 13: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (AD)**

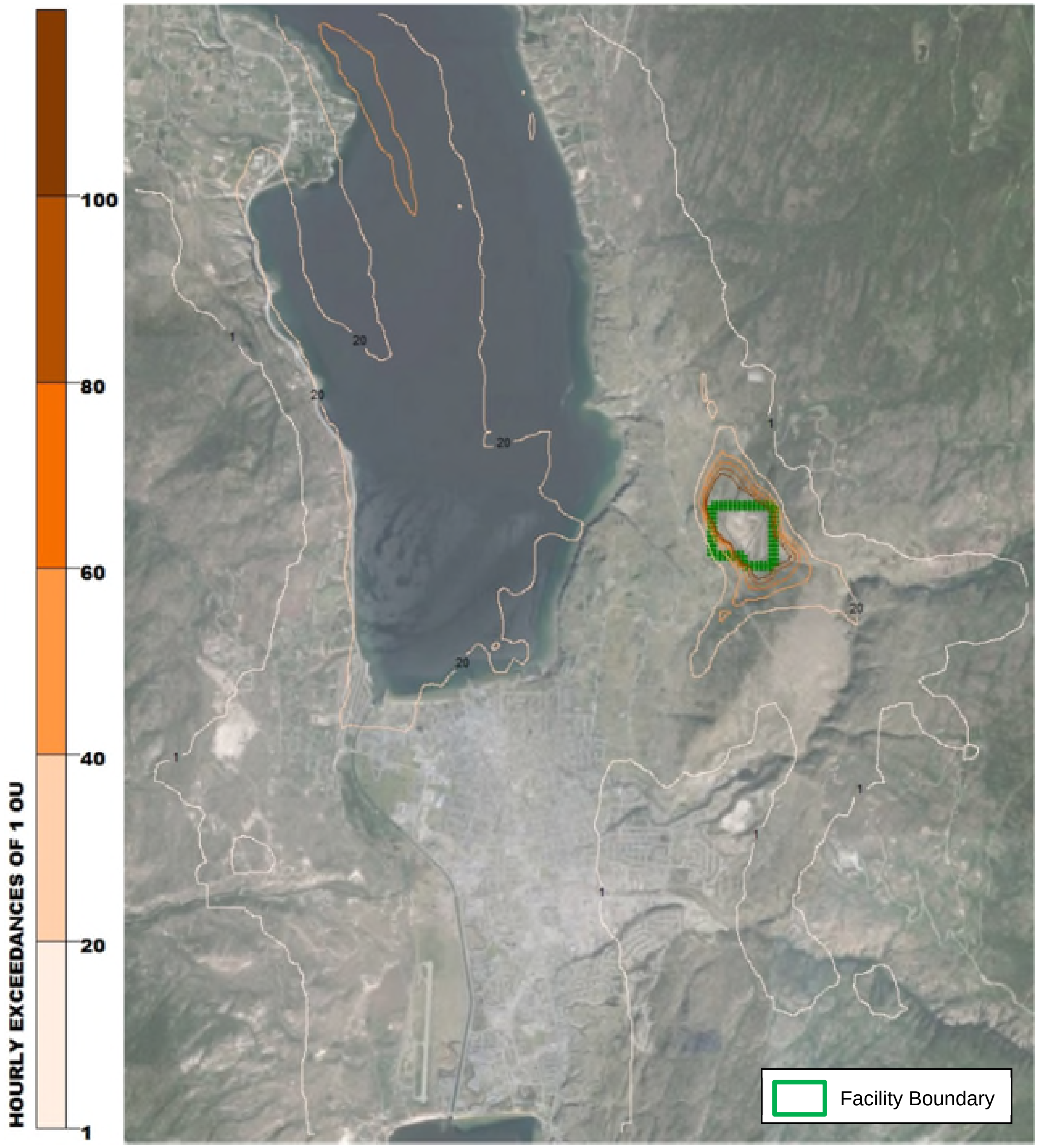


**Figure 14: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (AD)**

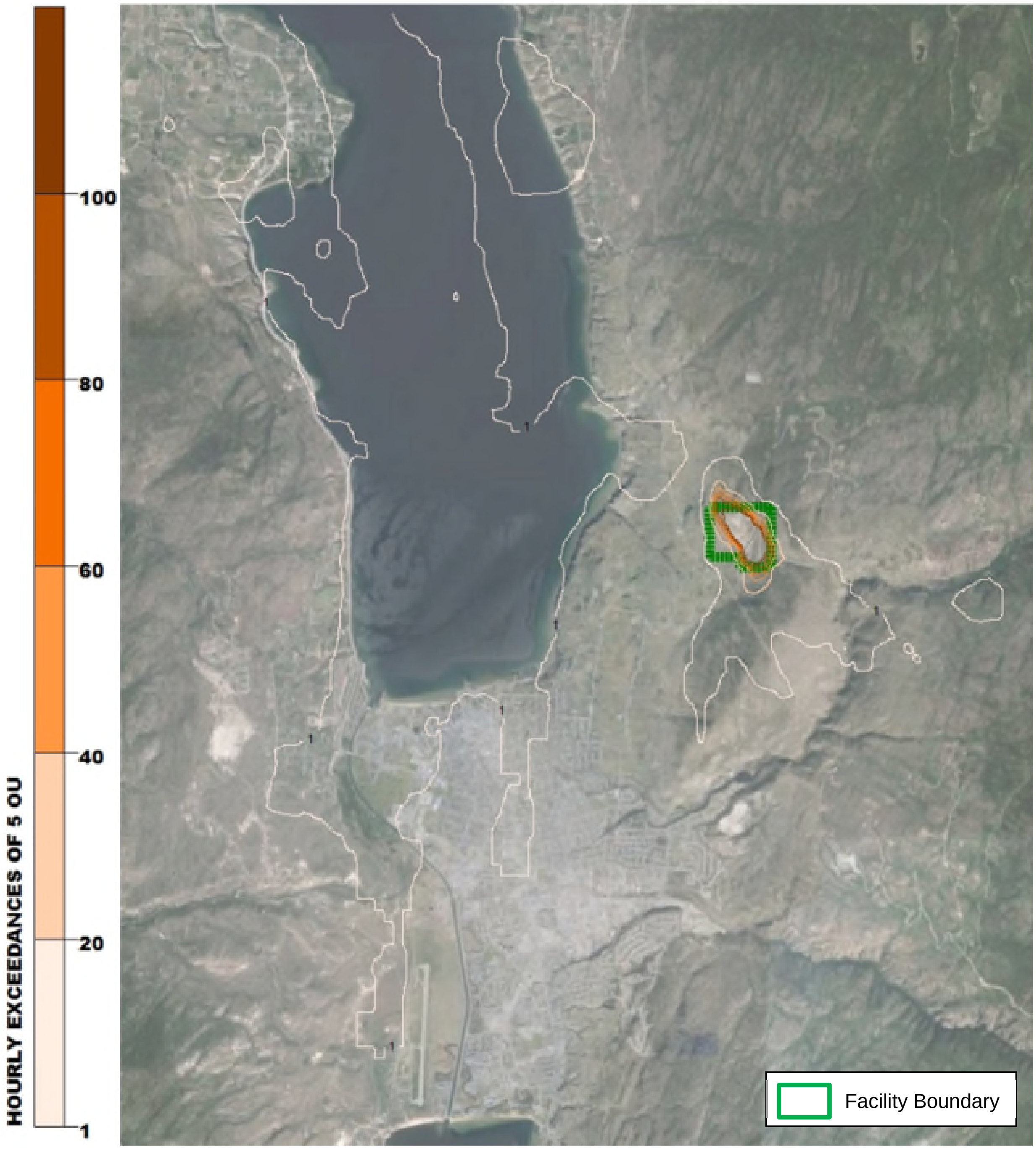


**Figure 15: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (AD)**

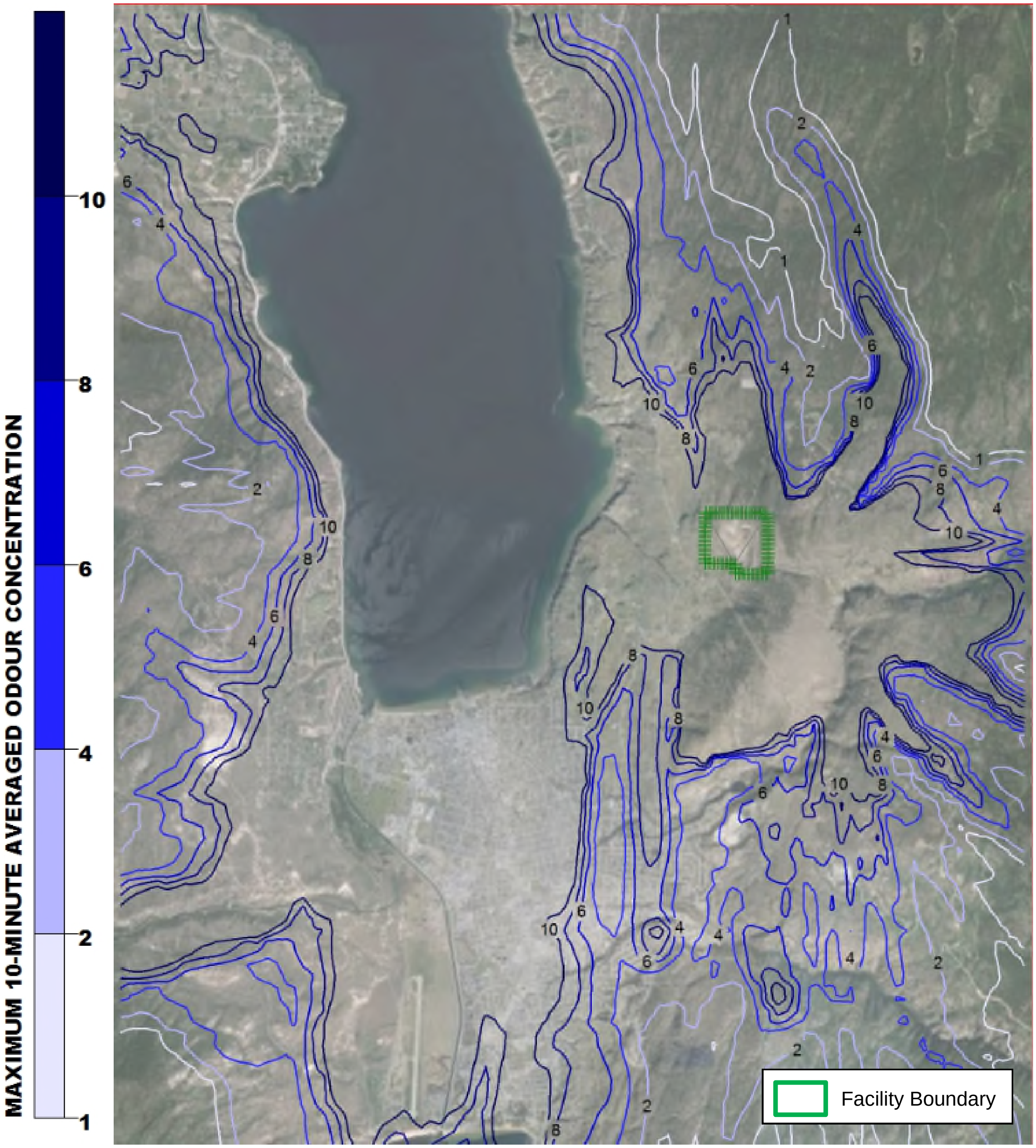


**Figure 16: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (ASP – Regional)**

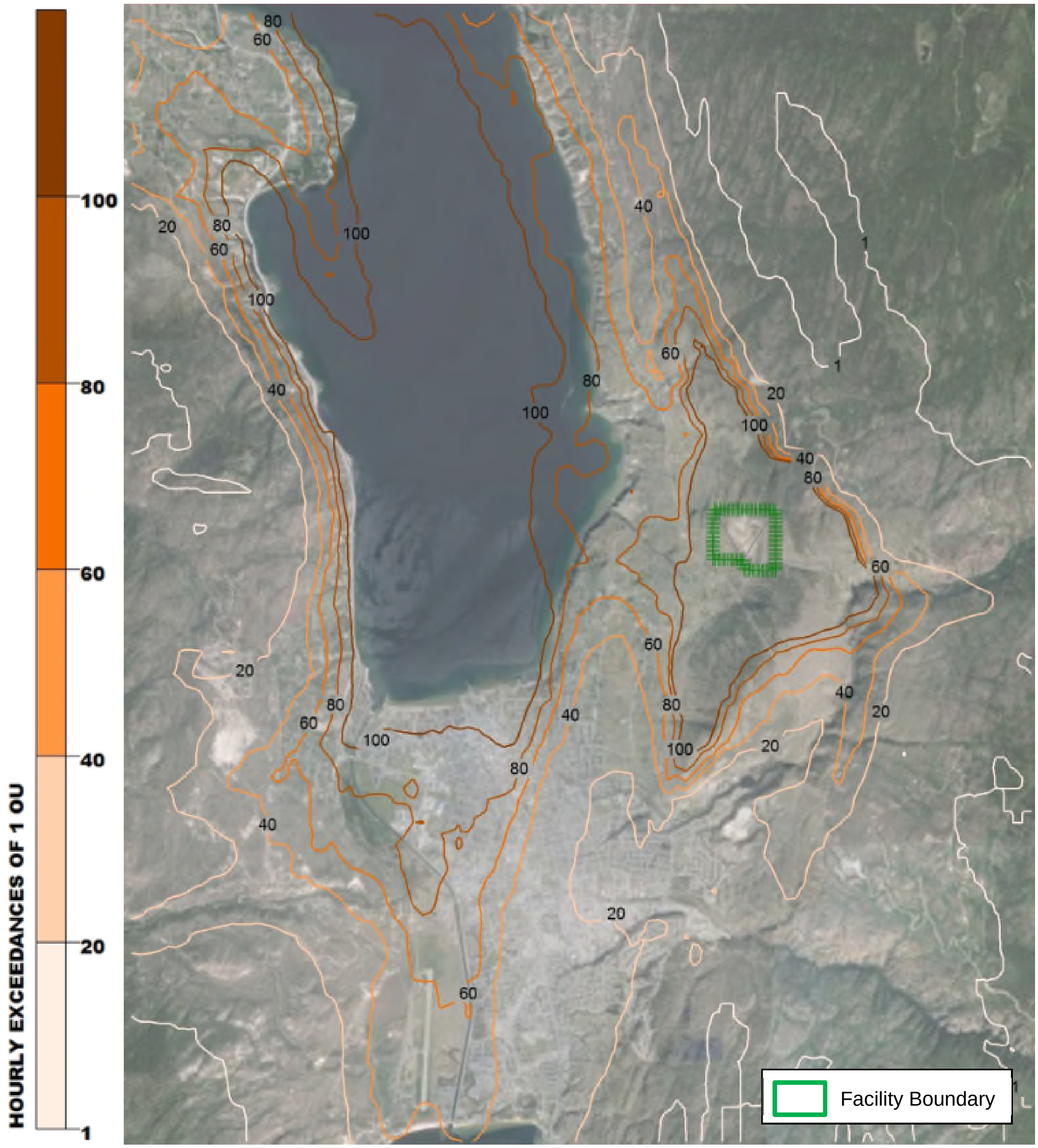


**Figure 17: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (ASP – Regional)**

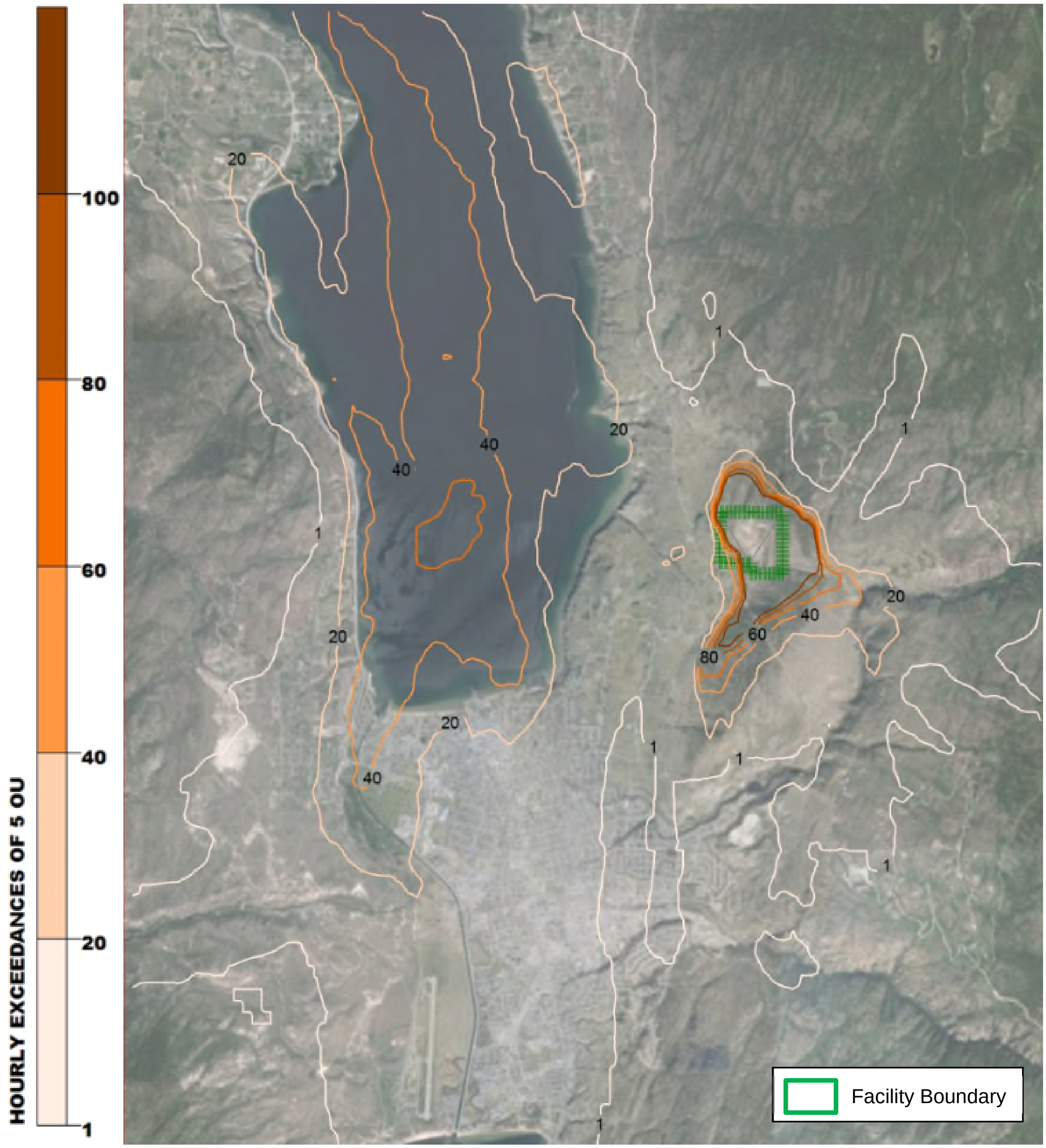


**Figure 18: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (ASP – Regional)**

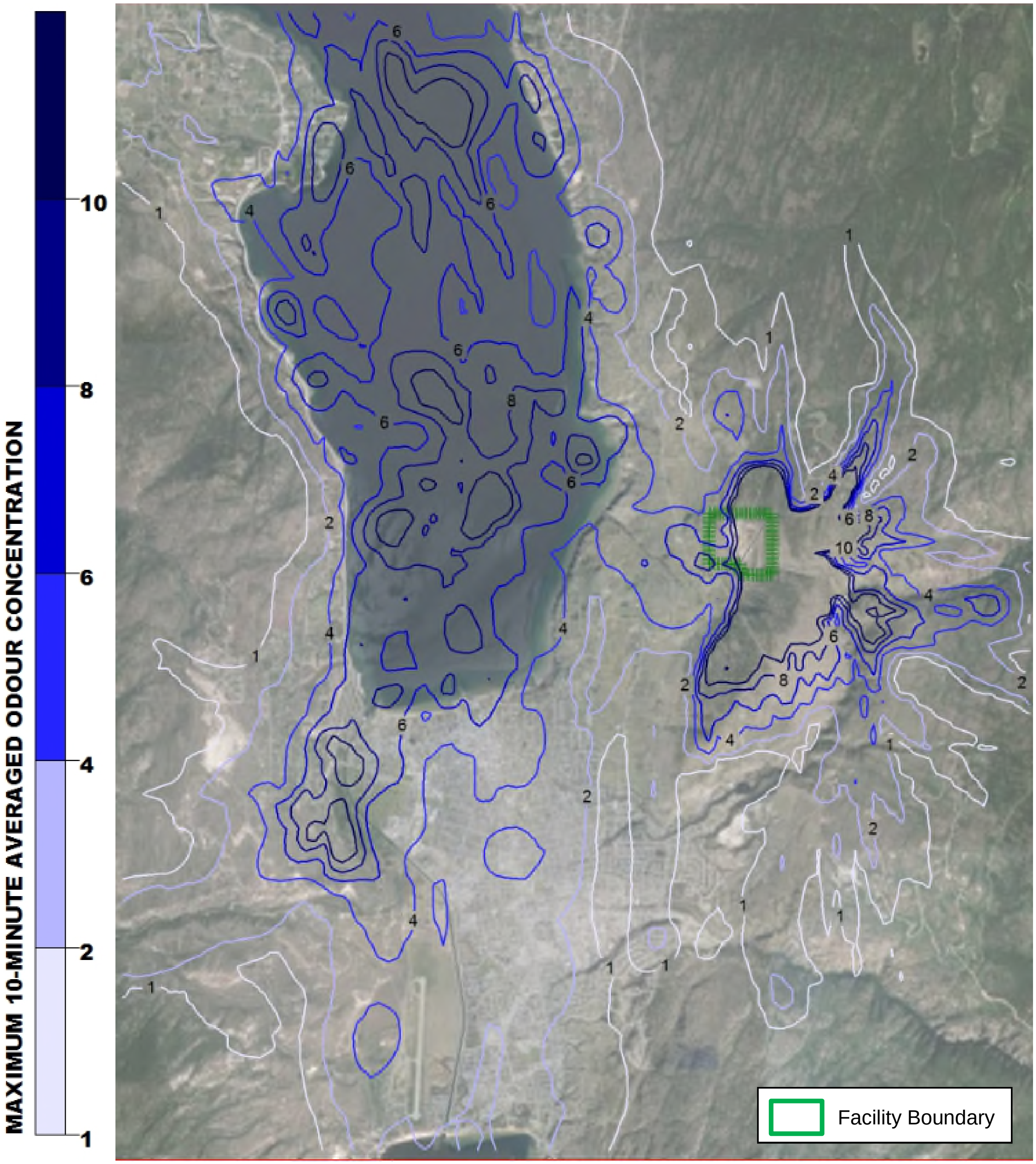


**Figure 19: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Covered ASP – Regional)**

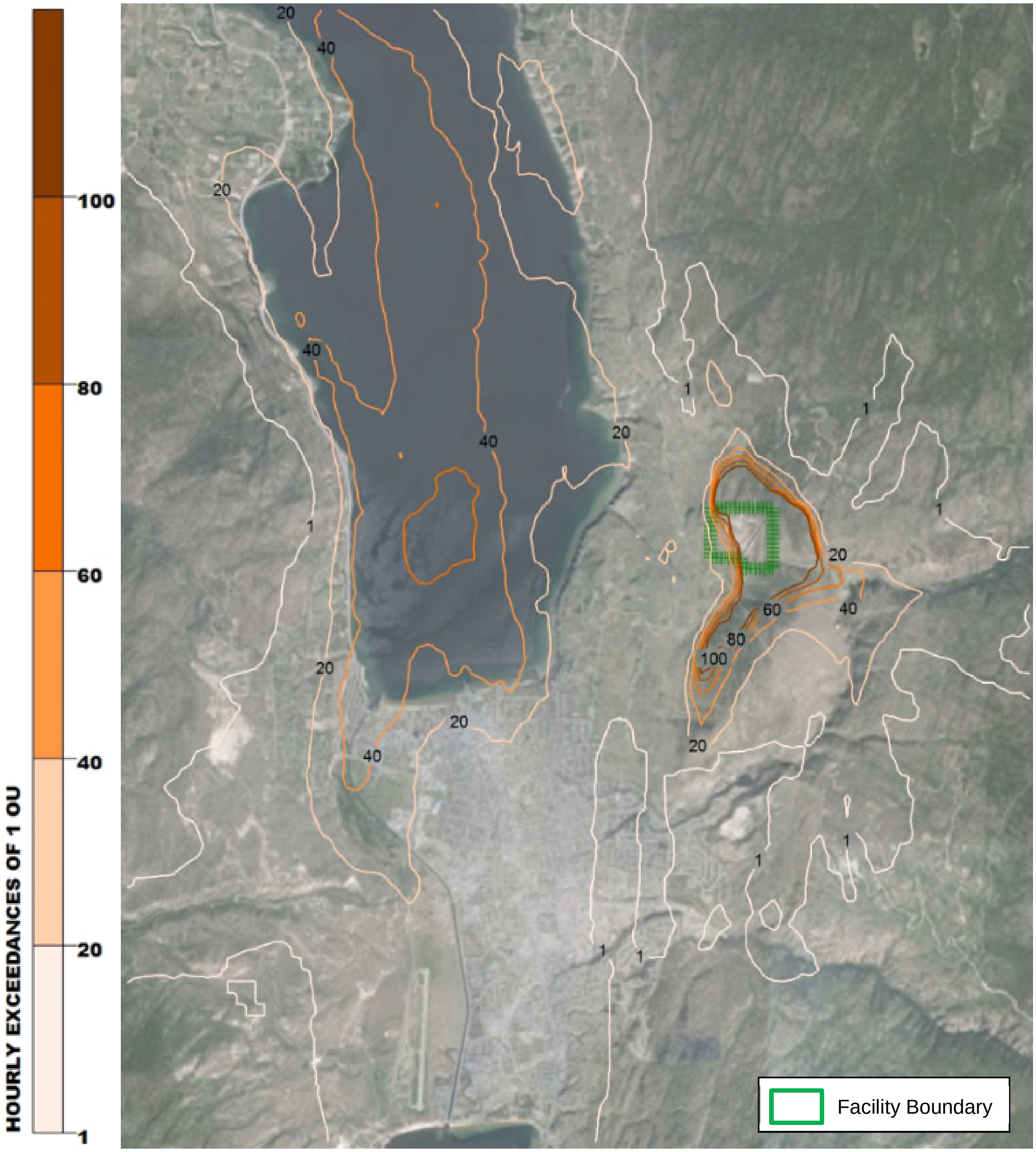


**Figure 20: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Covered ASP – Regional)**

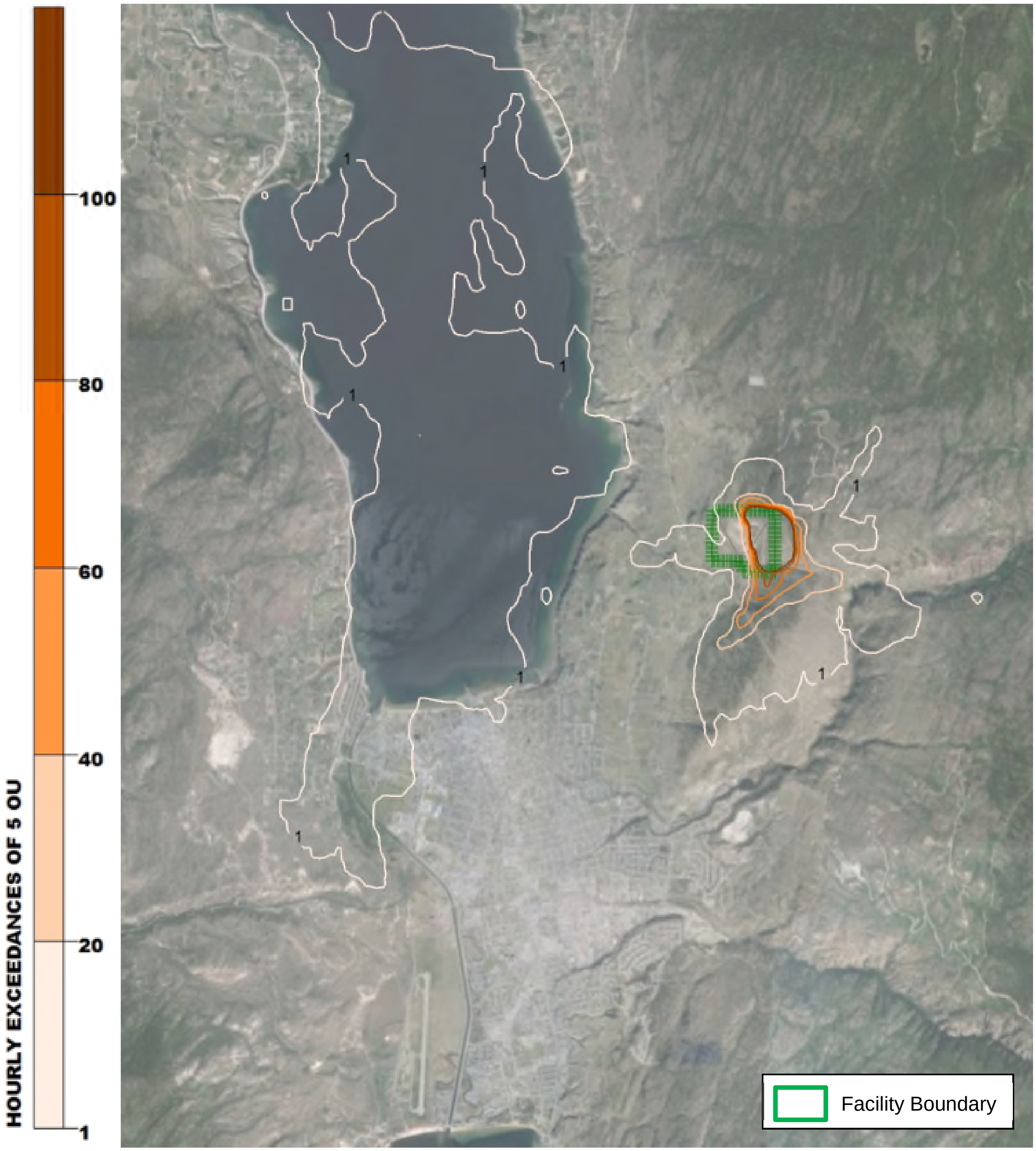


**Figure 21: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (Covered ASP – Regional)**

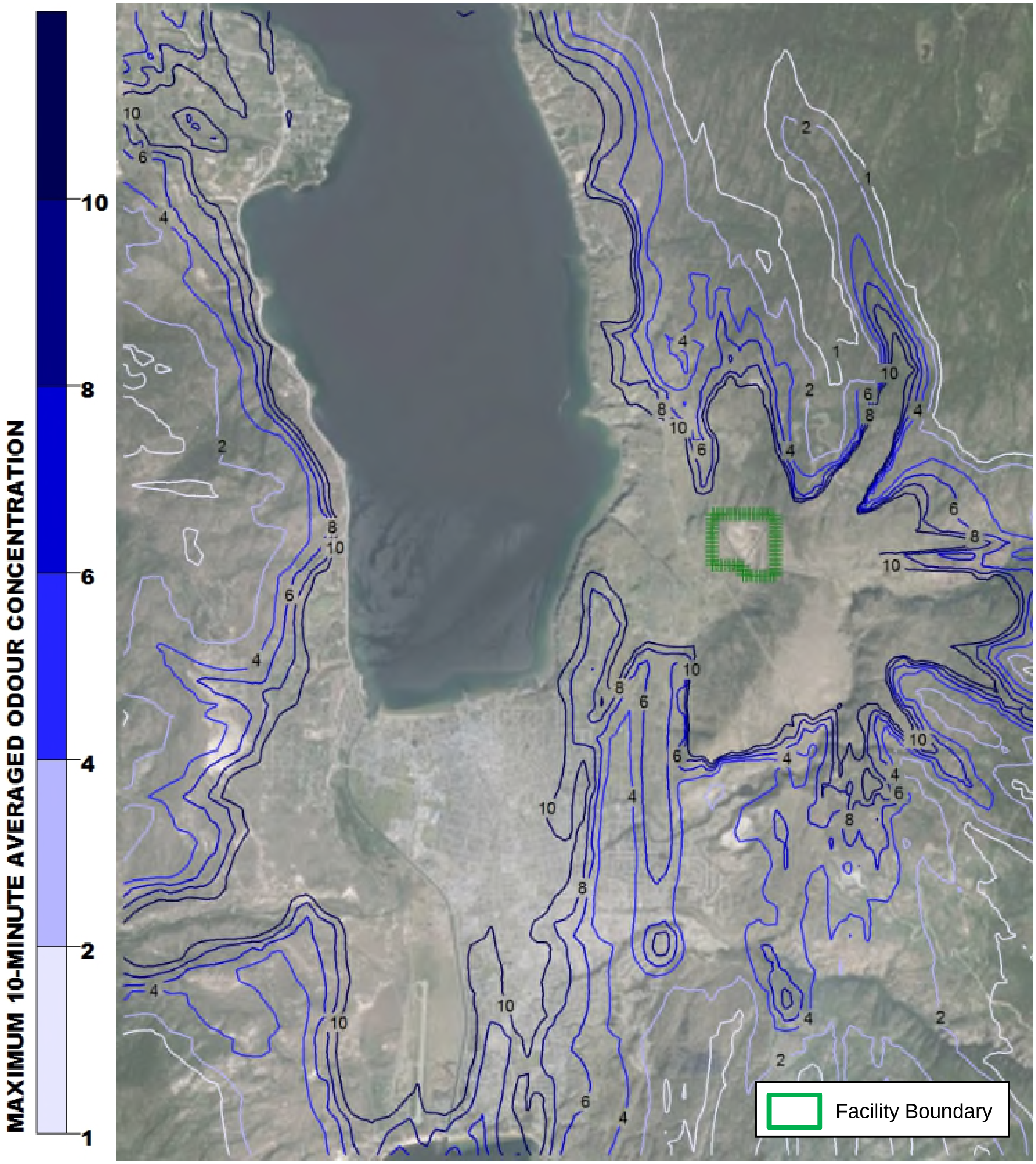


**Figure 22: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (In-Vessel – Regional)**

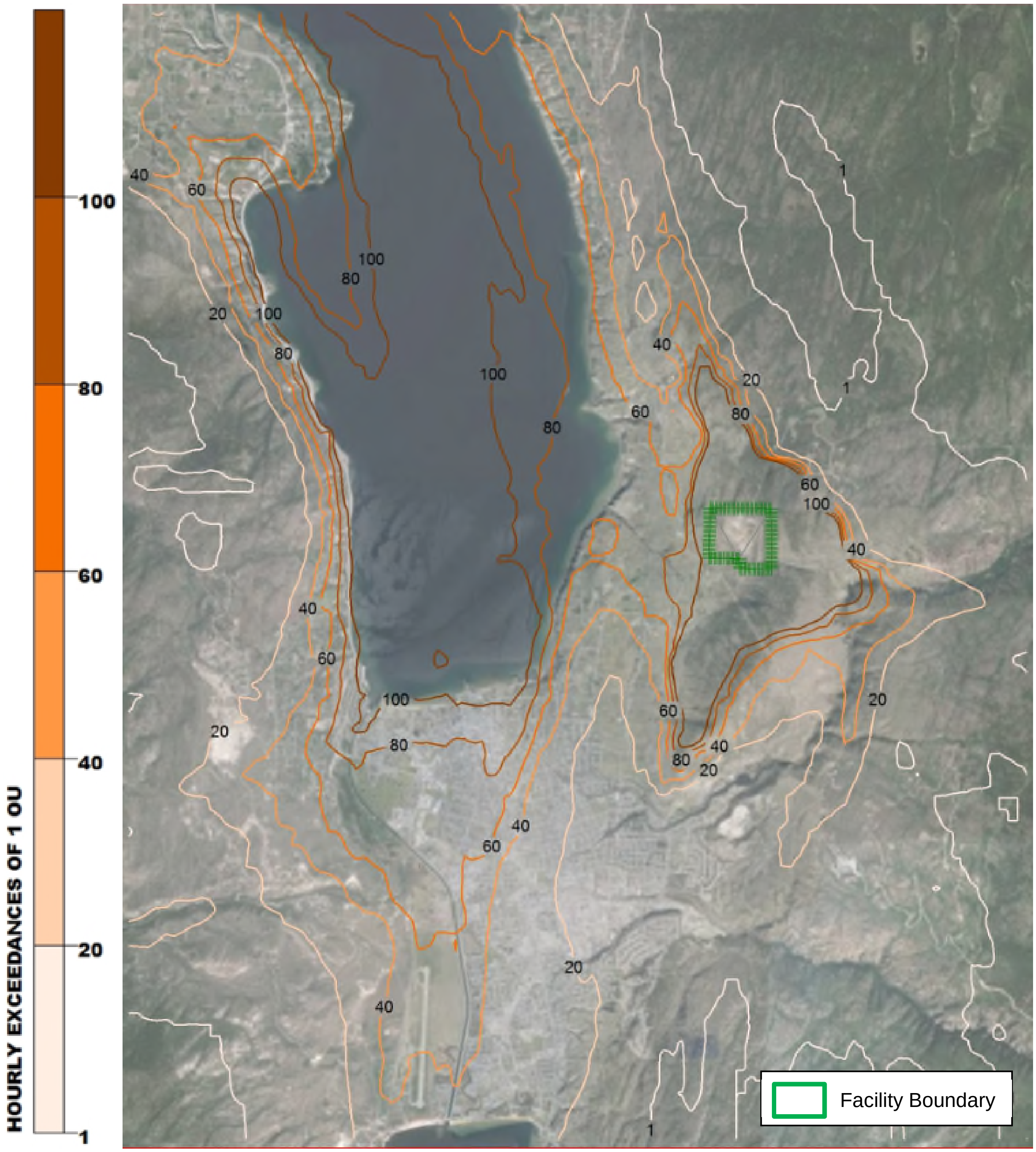


**Figure 23: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (In-Vessel – Regional)**

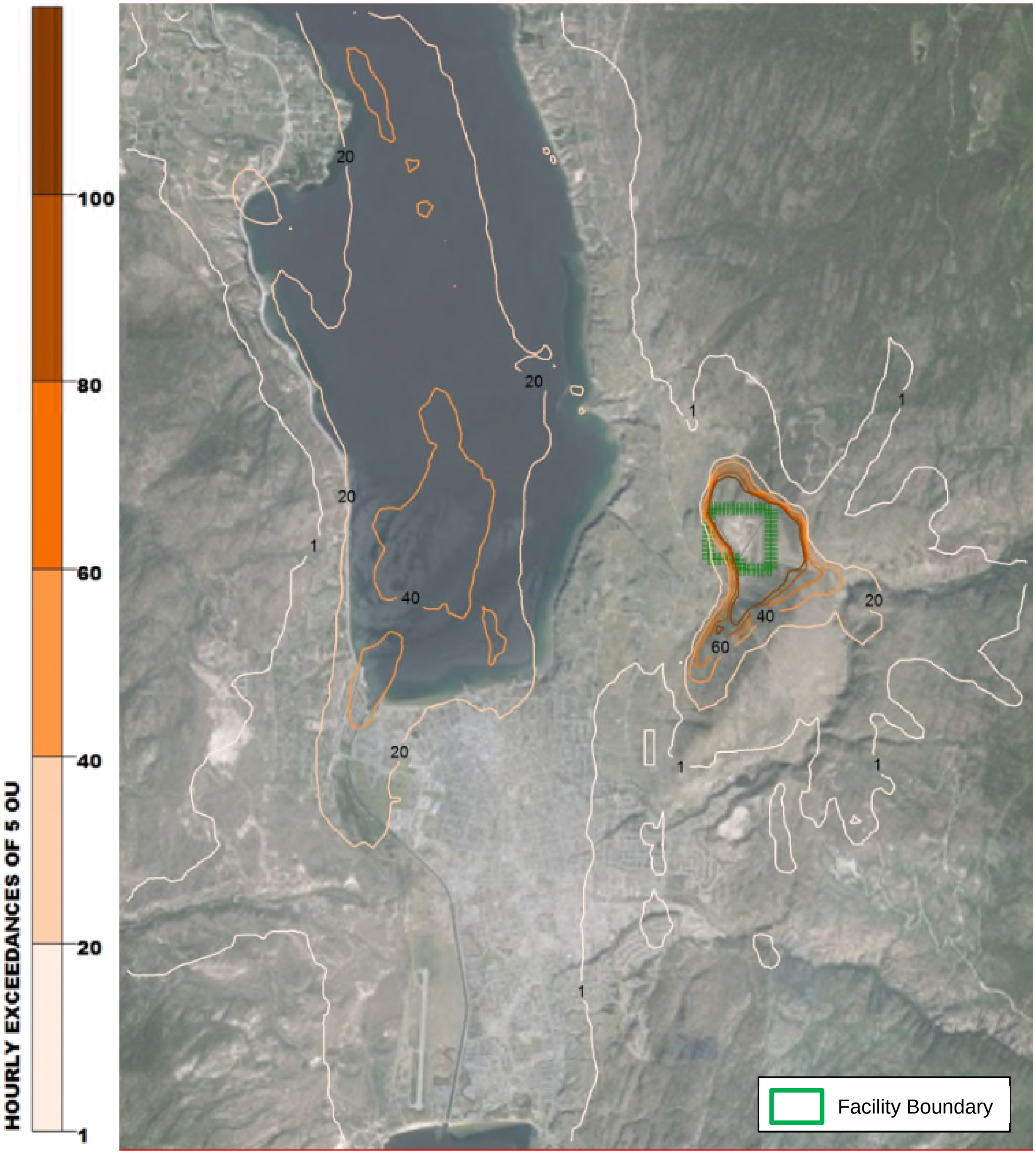


**Figure 24: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (In-Vessel – Regional)**

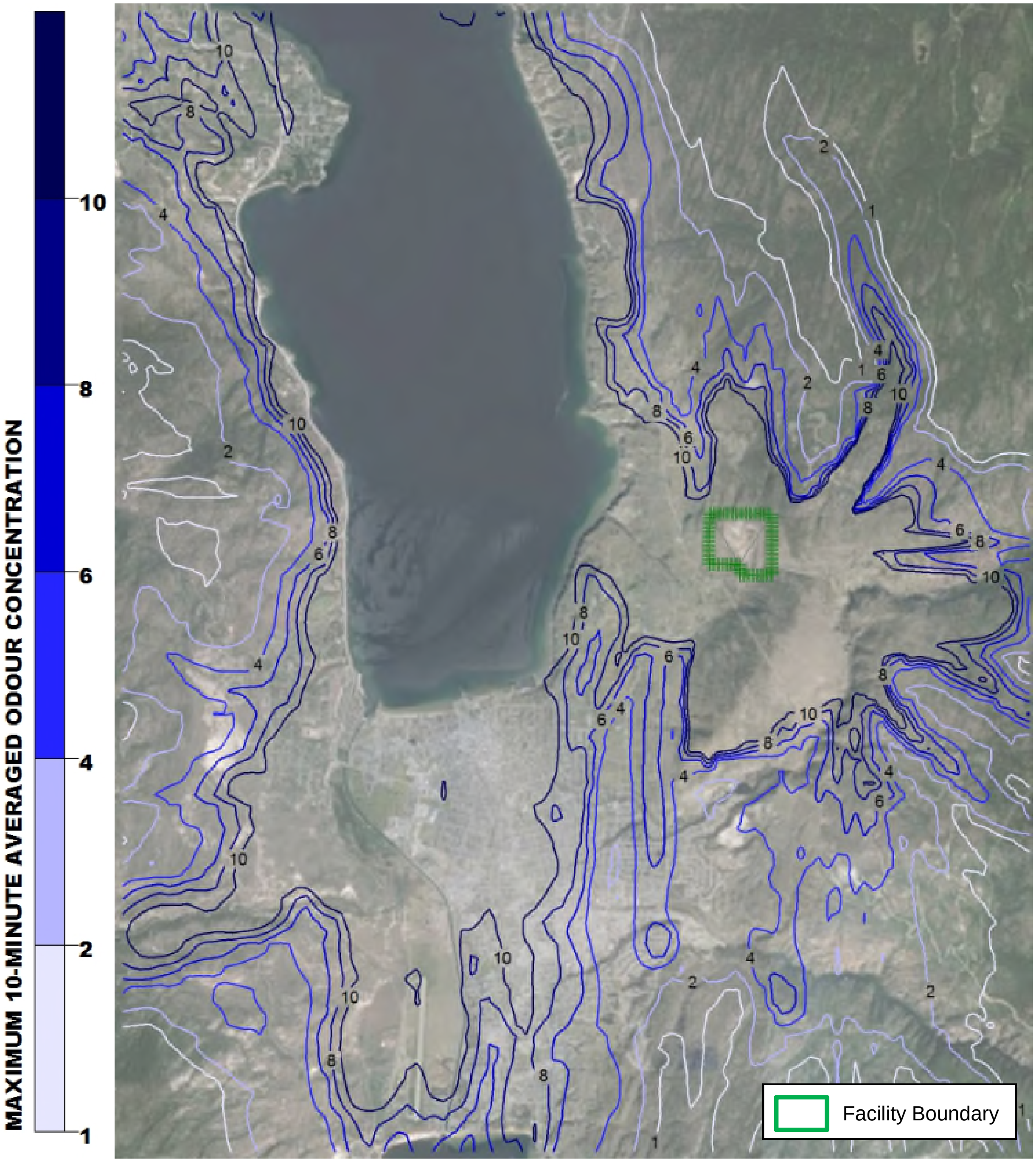


**Figure 25: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (AD – Regional)**

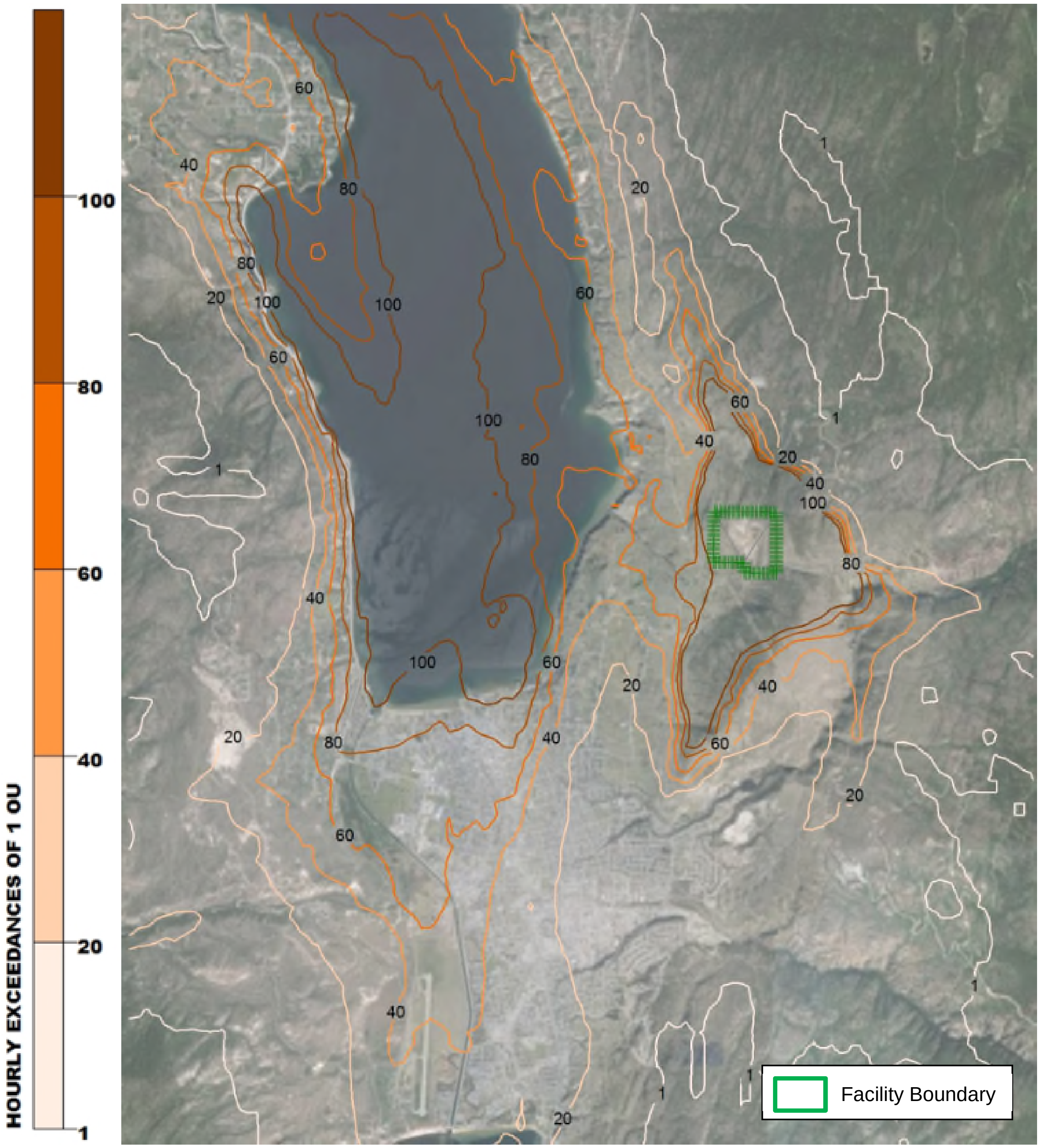


**Figure 26: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (AD – Regional)**

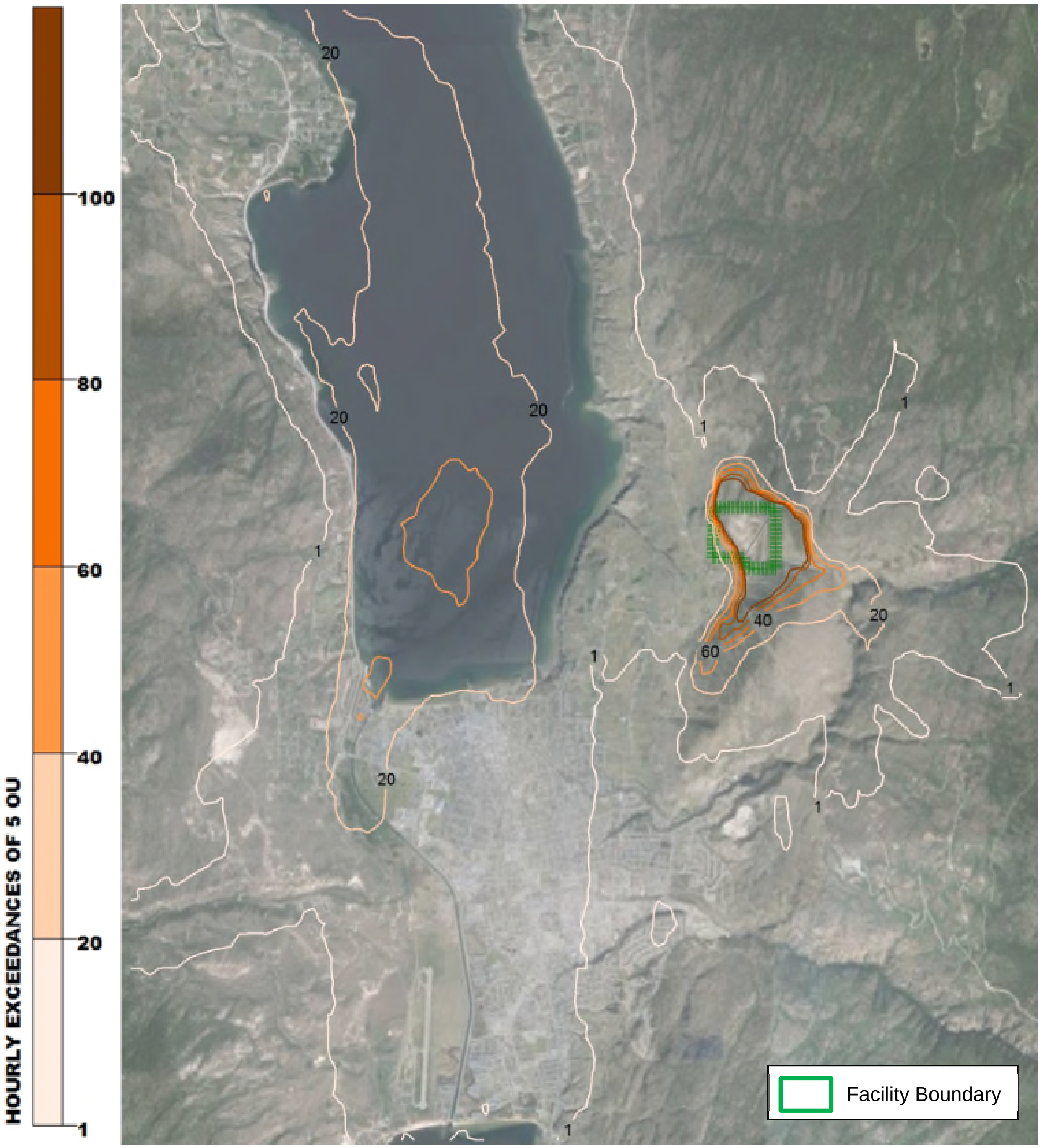


**Figure 27: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (AD – Regional)**

# SUMMERLAND LANDFILL

# 1.0 INTRODUCTION

The following is a summary of model inputs and odour modelling results conducted for the purpose of assessing potential odour impacts from an organics management facility located at Summerland Landfill (hereafter referred to as the "Site"). Odour modelling was conducted using CALPUFF, an advanced air modelling software system recommended by the British Columbia Ministry of Environment (BC MOE).

# 2.0 MODEL INPUTS AND ASSUMPTIONS

## 2.1 Meteorology

The air dispersion model CALPUFF contains a diagnostic meteorological processor, CALMET, which creates a three-dimensional meteorological field over the spatial extent of the model. The data produced by CALMET is used by CALPUFF in its dispersion and plume transport calculations. Inputs to CALMET include the following:

- A geophysical grid, constructed using gridded terrain and land cover data (obtained from GeoGratis – Government of Canada); and
- A combination of prognostic (three-dimensional meso-scale model called MM5) meteorological data and hourly surface observations obtained from Environment Canada and BC MOE meteorological stations.

The Summerland model produced a challenge in that immediately above the facility is Kettle Valley, a conduit for winds running downslope eastward from the plateau to the west. The valley is narrow (approximately 4 km) and valley winds are not resolved in 4 km resolution prognostic data. Capturing the valley winds is important as they will transport odours downslope towards town. Environment Canada Summerland CS Station (49°33'45.2" N, 119°38'55.3" W) observes a large prevalence of westerly winds as a result of Kettle Valley/plateau flows (Figure 2.1).

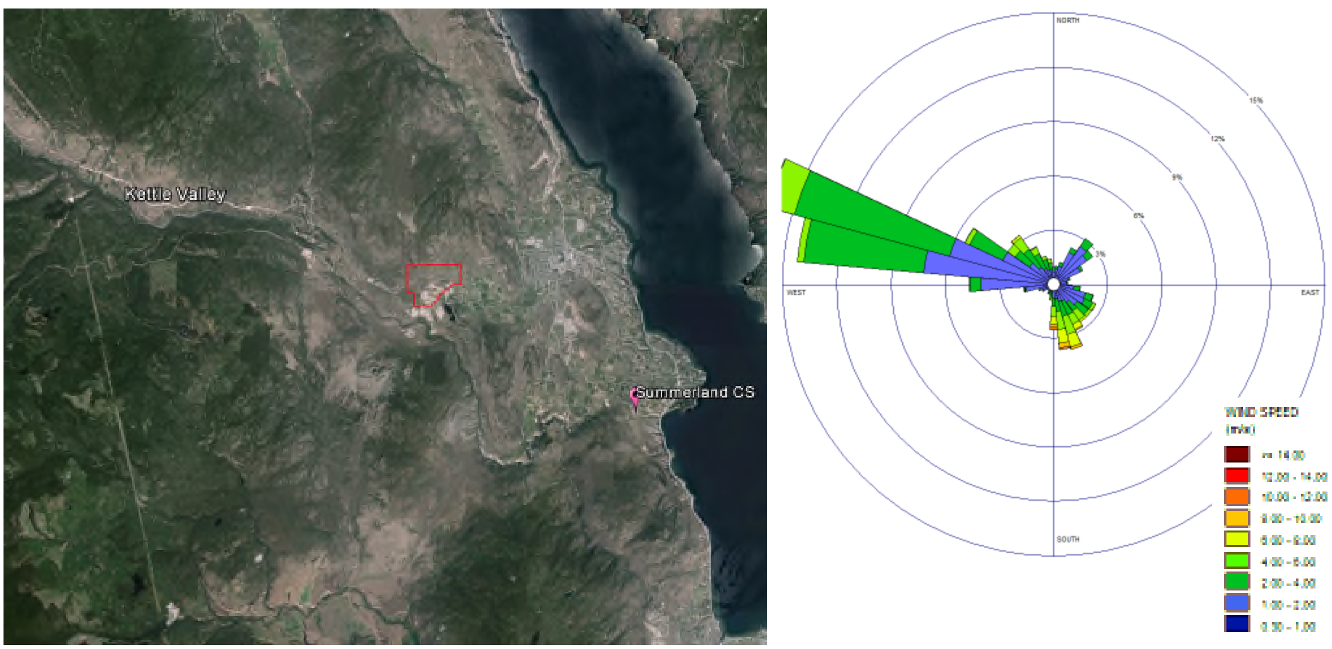


**Figure 2.1: EC Summerland CS Wind Rose (2012)**

In order to provide the valley flow winds in CALMET, a fake observational station was set up in the vicinity of the facility (49°35'33" N, 119°43'53" W) which duplicated all westerly component winds (NW to WSW) observed at Summerland CS. If the wind during any particular hour was from a different direction, the "facility" station provided no data to CALMET.

Running CALMET in "hybrid" mode by combining real hourly wind observations with MM5 can be a challenge in complex terrain. Since CALMET sets the initial guess wind field using the MM5 then adds real observations and blends the wind field, the result can be areas of conflicting wind direction which is unrealistic. To produce a more homogeneous wind field in the complex-terrain Summerland model which also captured the important smaller-scale flow characteristics, the decision was made to eliminate MM5 and use CALMET in "observations-only" mode using regional station observations and twice-daily upper air soundings taken at Kelowna. Observations-only is more data-intensive in that interpolations or substitutions must be made to fill hours with missing data to drive the model. Such substitutions were made in accordance to guidelines described in '*Guidelines for Air Quality Modelling in British Columbia*' (BC MOE 2008). The observational stations used as input to CALMET are shown in Figure 2.2.


**Figure 2.2: Hourly Surface Stations used in CALMET**

To better resolve the complex terrain in the Summerland grid, CALMET was run at a resolution of 100 m over an 18 km x 20 km grid which increased model run times. The grid size was selected in order to allow inclusion of Penticton stations to adequately capture the Okanagan valley flow pattern. The modelled period began January 9, 2012 as Kelowna A upper air sounding data prior to this data were incomplete. Table 2.1 summarizes the meteorological inputs to CALMET used in the Summerland Facility odour modelling and mapping exercise.

### Table 2.1: CALMET Inputs and Metadata

| Parameter | Usage (All Coordinates in UTM Zone 11) |
|---|---|
| Surface Stations | EC Summerland CS (308469 m, 5493366 m)<br>“Facility” (duplicating NW-WSW winds from Summerland CS) (302617 m, 5496896 m)<br>EC Penticton A (311445 m, 5482126 m)<br>BC MOFLNRO Penticton RS (315200 m, 5488208 m)<br>Grower’s Supply Naramata Station (314242 m, 5486044 m) |
| Upper Air Soundings | Kelowna A (329335 m, 5538010 m) |
| Prognostic Data | None |
| Modelled Period | Jan. 9 – Dec. 31, 2012 |
| Meteorological Grid | 18 km (east-west) x 20 km (north-south) at 100 $m^2$ |
| Grid Centrepoint | 309000 m, 5491000 m, UTM Zone 11 |
| Vertical Cells (Cell Face Heights) | 10 (0 m, 20 m, 40 m, 80 m, 160 m, 320 m, 640 m, 1200 m, 2000 m, 3000 m, 4000 m) |
| Terrain Data | CDN DEM 15 min |
| Land Use Data | GeoBase Land Cover circa 2000-Vector |

As land cover characteristics over the modelling domain vary with season (e.g., albedo, Bowen ratio, etc.), seasonal CALMET files were created using the model’s default seasonal geophysical properties for each land cover category contained within the geophysical grid. The date ranges assumed to define each season are listed in Table 2.2. Year-to-year variability will undoubtedly occur, however, this temporal approximation was used to simplify modelling based on Environment Canada 1981 – 2010 climate norms for the Okanagan-Similkameen region. The modelled year was 2012, beginning January 9.

### Table 2.2: Geophysical Property Seasonality

| Season | Date Range |
|---|---|
| Winter | December 1 – February 28 (29) |
| Spring | March 1 – May 31 |
| Summer | June 1 – September 15 |
| Fall | September 15 – November 30 |

## 2.1.1 Meteorological Validations

### 2.1.1.1 Winds

Figure 2.3 are two snapshots of CALMET-modelled surface winds showing examples of the predominant flow conditions through Summerland. The left plot shows CALMET-predicted winds on April 8 at $2^{00}$ hrs during a period of westerly flow from the plateau. The valley flow condition is from the north, which is more typical of spring-summer. The right plot shows CALMET-predicted winds on December 16 at $0^{00}$ hrs during a period of strong southerly valley flow, a condition more typical of winter. The figure also shows the boundary of the site (green border) and the locations of meteorological stations used in CALMET (dark green squares).

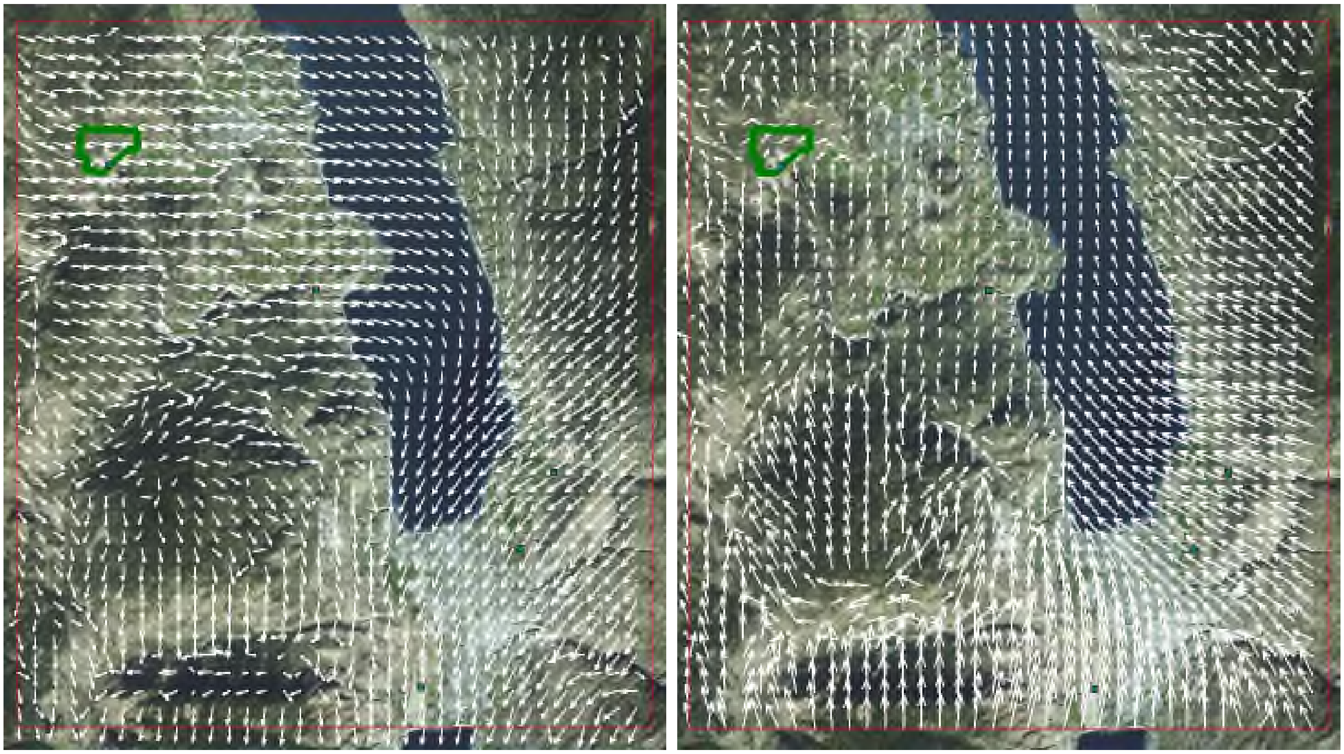

**Figure 2.3: CALMET-Modelled Wind Fields: Apr. 8, 2012, 2$^{00}$ hrs (left), Dec. 16 0$^{00}$hrs (right)**

Figure 2.4 shows graphical plots (wind roses) of CALMET-predicted winds illustrating the spatial pattern of dominant wind flows over Summerland. As CALMET's diagnostic modelling is a terrain-influenced interpolation scheme, the wind field in the vicinity of surface stations (EC Summerland CS Station (49°33'45" N, 119°38'55"W) and the fake facility/Kettle Valley station) is greatly weighted by the observed winds. The wind rose over Okanagan Lake shows the north and south valley flows which are generally stronger than the westerly valley slope flow winds.


**Figure 2.4: CALMET-Predicted Wind Roses – Summerland**

#### 2.1.1.2 Mixing Height

The atmospheric mixing height can be defined as the top of the layer in the lower atmosphere, within which an emitted species, in this case odour, is readily mixed through turbulence and convective processes. Therefore, when the mixing height is low, higher ground-level concentrations will generally be predicted. Figure 2.5 are time series of modelled mixing heights extracted from CALMET over two distinct seasonal periods in 2012 at the location of the closest sensitive receptor to the facility at 16711 Prairie Valley Rd. (303123 m, 5497017 m, Zone 11). The top figure (red) plots a time series of mixing heights in the winter (between February 1 and 8), while the lower figure (blue) plots mixing heights in the summer (between July 1 and 8).

Seasonal contrast is strongly evident since there is reduced solar radiation, lower temperatures and snow cover, among other factors during the winter that results in generally lower mixing heights, and thus resulting in higher concentrations of odour. Both figures show the expected strong diurnal pattern, with mixing heights dropping quite close to the ground surface (~50 m as a default in CALMET) at night. When overnight mixing heights are higher, it is due to turbulence induced by higher wind speeds over uneven terrain.

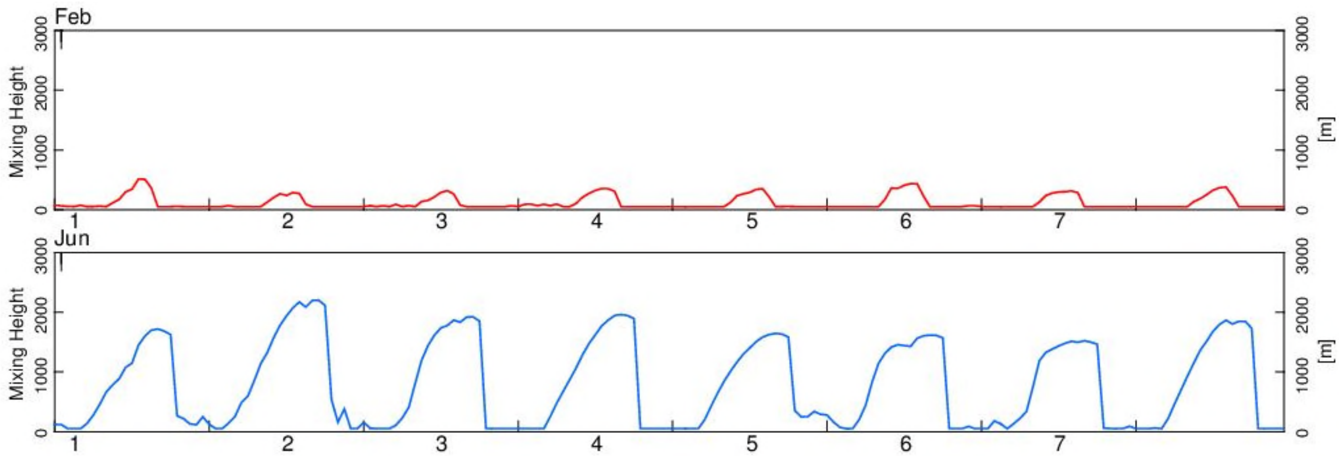


**Figure 2.5: CALMET-Modelled Mixing Heights for Winter (Red) and Summer (Blue)**

## 2.2 Area Sources and Emission Factors

The site layouts from the *Organics Management Consultant Task 2 – Feasibility Assessment* report for Summerland, Summerland Regional Facility, and Summerland Regional Facility with RDCO Biosolids were used to define the boundaries of the odour sources for this modelling analysis. Areas that generate odours were assigned a specific emission factor according to the activity taking place (e.g. composting, curing, pile turning, etc.). In the main report, Table 2.1 provides a description of the emission factors. The scenarios included for odour modelling are presented in Table 2.3.

### Table 2.3: Odour Modelling Scenarios

| Organics Processing Technology | Summerland | Summerland Regional Facility[1] | Summerland Regional Facility with RDCO Biosolids[1,2] |
|---|---|---|---|
| Current Composting Operations | √ | | |
| Aerated Static Pile (ASP) | √ | √ | √ |
| Membrane Covered Aerated Static Pile | √ | √ | √ |
| In-Vessel Composting | √ | √ | √ |
| Anaerobic Digestion (AD) | √ | √ | √ |

[1] Campbell Mountain, Summerland, Oliver, and Osoyoos feedstocks combined.
[2] Includes an additional 5,000 tonnes of biosolids from the Regional District of Central Okanagan.

Emissions were assumed to occur homogeneously over the entirety of the area source. Some odour emissions (e.g. pile turning, pile moving, etc.) were assigned a diurnal variation based on the expected times of day the activity is to be performed (Table 2.1 of the main report). Such activities are expected to occur daily at the Site over a one-to two-hour period, however since the activity may occur at any time during the operational hours of the facility in the morning or in the afternoon, odour emissions were assumed in the model to occur between $10^{00}$ to $12^{00}$ – representing a time of day when vertical mixing is generally highest – and between $15^{00}$ to $17^{00}$ – when, during the winter, the mixing height is approaching its night time minimum, thus resulting in higher concentrations closer to the ground. This is a somewhat conservative approach since the activity may only be occurring over a portion of a single hour rather than four, may not take place every day, and peak odour emission would only occur during and immediately following the activity and decay in the hour following. It should be noted that odour emissions produced from pile building and moving are inconsequential compared to that produced from the biofilters which emit odour continuously.

Emission heights were either assigned a value of 3 m or 1 m depending on the activity occurring within the area source. Specific heights used for the various activity types are listed in Table 2.1 of the main report.

## 2.3 CALPUFF Settings and Assumptions

The CALPUFF model input settings were assigned with consideration to the recommendations in Table 9.7 of '*Recommended CALPUFF Input Group 2 Switch Settings*' in '*Guidelines for Air Quality Dispersion Modelling in British Columbia*'. Generally, default model settings were used. Since the area of interest is in the near-field (within 12 – 15 km of the source), dispersion coefficients were internally calculated using micrometeorological variables (MDISP = 2) based on estimates of the crosswind and vertical components of turbulence based on similarity theory and the land cover type. The probability distribution function (PDF) was used for dispersion under convective conditions (MPDF = 1) which explicitly accounts for the differences in the distribution and strengths of up and down drafts within the convective boundary layer, reporting the average between the two. By using these two settings, AERMOD-type dispersion is simulated (generally accepted as better-predicting in the near-field than CALPUFF), while also providing the benefit of a puff model and allowing for the effects of complex terrain.

The receptor grid spacing was 100 m at ground level over the entire grid. The simulations were to determine the general effects downwind from the facility, on the scale of kilometres, and therefore, did not consider building downwash – the drawdown of the odour plume downwind of facility buildings due to turbulence.

# 3.0 RESULTS

Since the time step of the meteorological data is one-hour, CALPUFF can only output one-hour averaged predictions of odour concentration. However, since odour perception is on a much shorter scale, an averaging time-scalar must be applied to assess shorter-term peak concentrations due to plume meandering within the hourly period. Hourly odour concentrations are scaled to a ten-minute averaging period using Equation 1.

$$Cp = Co * \left(\frac{t_o}{t_p}\right)^{0.28} \qquad (1)$$

Pursuant to Equation 1, $t_o$ is the 60 minute averaging time, $t_p$ is the short-term averaging time (10 minutes) and $C_o$ and $C_p$ are the respective peak concentrations (BC MOE). The scalar when converting from hourly to ten-minute average concentrations equates to 1.65.

## 3.1 Odour Units

An Odour Unit (OU) is a way of quantifying odours through the use of an odour panel that consists of a group of people with 'calibrated noses'. The definition of an OU is based on the proportion of odour panel members that can detect the smell of a substance. One OU represents the concentration of a particular substance when 50% of the odour panel can detect the odour. This is called the perception threshold[1]. At this point, although an odour may be detected, it is not distinct enough to be able to identify the type of odour.

The OU scale is based on dilutions, as shown in the following figure. As the number of OUs increase, more people can detect the odour, and the intensity of the odour increases. Five OU is considered a faint odour and ten OU is considered a distinct odour (the point when some people can identify the type of odour, or its potential source)[2].

[1] http://blog.odotech.com/odor-unit-perception-threshold

[2] Odours and VOCs: Measurement, Regulation and Control Techniques (2009). Kassel University Press.

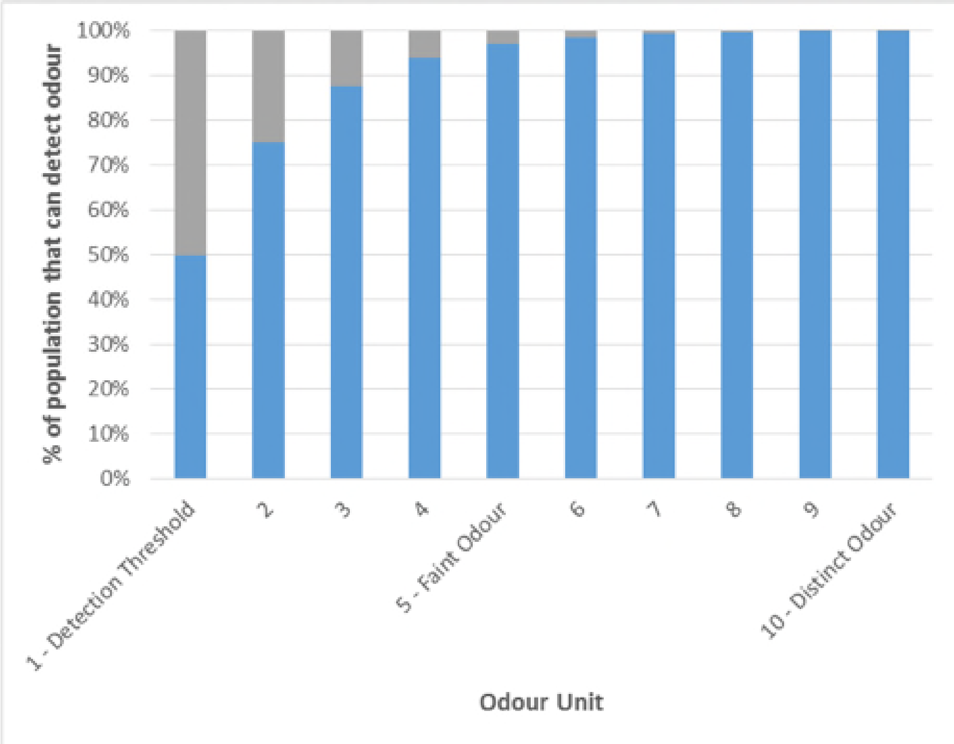


**Figure 3.1: Odour Unit Scale**

There are currently no guidelines for odour limits for composting facilities in British Columbia, however, some wastewater treatment facilities have imposed odour limits. For example, the standard in Metro Vancouver is no more than five OU at the property line. In other jurisdictions, the guideline is to have no detectable odour at the property line. At the Ogogrow facility in Vernon, BC, the limit is 50 OU at the property line.

## 3.2 Odour Maps

Odour maps are included as part of Appendix A. For each organics processing option listed in Section 2.2, odour modelling results are presented as three different plots:

- Maximum Odour Concentrations – The maximum predicted 10-minute odour concentration at each receptor point over the course of the modelled year. This is displayed as a contour plot showing the maximum predicted 10-minute averaged odour concentration at every ground level receptor point over the entire one-year simulation (8784 hours) as a blue gradient (light to dark). The 1 OU contour is white. The highest levels >10 OU are dark blue. The facility boundary is shown as a green outline.
- Hourly Exceedances >1 OU – The number of hours over the course of the modelled year where an odour threshold of 1 OU was exceeded in a ten-minute averaged concentration. This is displayed as a contour plot showing the number of times the predicted 10-minute odour concentration exceeded 1 OU over the modelled year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to 50% of the population being able to detect odour produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.
- Hourly Exceedances >5 OU – The number of hours over the course of the modelled year where an odour threshold of 5 OU was exceeded in a ten minute averaged concentration. This is displayed as a contour plot showing the number of times the predicted 10-minute odour concentration exceeded 5 OU over the modelled

year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to when a faint odour is produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.

## 3.3 Results Summary

The odour maps presented in Appendix A show: (1) the magnitude and spatial extent of maximum ground level odour, and (2) the number of exceedances of odour detection thresholds for the technologies assessed. The membrane covered aerated static pile results had the least odour issues.

The following table summarizes the results of the odour mapping exercise based on the predicted maximum odour and number of hours of odour exceedances at a location 200 m east of the property boundary representing the residence that is closest in proximity to the Site at 16711 Prairie Valley Road (303123 m, 5497017 m, UTM Zone 11), Figure 3.2.

**Table 3.1: Results Summary based on Closest Receptor Point (303123 m, 5497017 m, UTM Zone 11)**

| Scenario | Maximum Predicted 10-min Odour | Odour Exceedance >1 OU (hours per year) | Odour Exceedance >5 OU (hours per year) |
|---|---|---|---|
| **Summerland** | | | |
| Current Composting Operations | 0.3 OU | 0 | 0 |
| Aerated Static Pile | 5 OU | 14 | 1 |
| Membrane Covered Aerated Static Pile | 1 OU | 1 | 0 |
| In-Vessel Composting | 5 OU | 14 | 1 |
| Anaerobic Digestion | 3 OU | 7 | 0 |
| **Summerland Regional Facility** | | | |
| Aerated Static Pile | 22 OU | 274 | 16 |
| Membrane Covered Aerated Static Pile | 5.1 OU | 26 | 1 |
| In-Vessel Composting | 18 OU | 206 | 7 |
| Anaerobic Digestion | 16 OU | 216 | 9 |
| **Summerland Regional Facility with RDCO Biosolids** | | | |
| Aerated Static Pile | 27 OU | 276 | 19 |
| Membrane Covered Aerated Static Pile | 5.3 OU | 22 | 1 |
| In-Vessel Composting | 21 OU | 192 | 12 |
| Anaerobic Digestion | 20 OU | 186 | 5 |

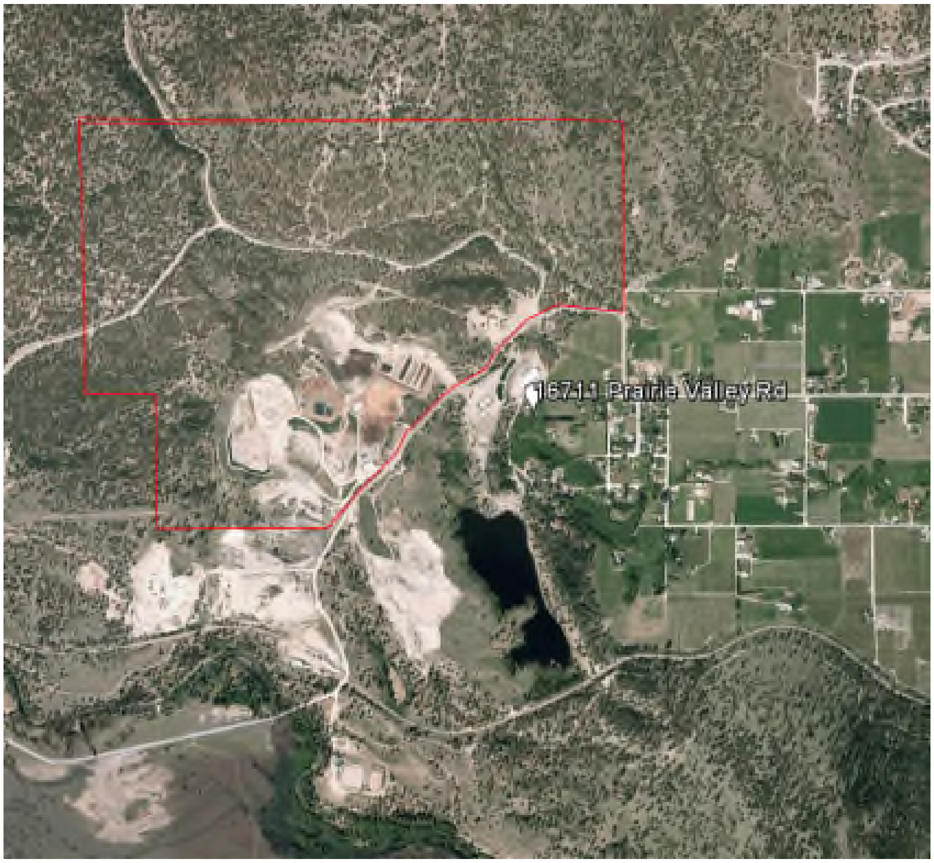


**Figure 3.2: Location of Discrete Receptor (303123 m, 5497017 m, UTM Zone 11)**

### 3.3.1 Biofilter Effect

Similar to the odour maps shown in Appendix A, the Membrane Covered Aerated Static pile has the lowest odour emissions of the technologies as this type of operation does not use a biofilter. The greatest source of odour emissions can be attributed to the biofilters, as seen in Table 3.2.

**Table 3.2: Odour Emissions from Biofilters**

| Scenario | % of Odour from Composting Biofilter |
|---|---|
| **Summerland** | |
| Current Composting Operations | N/A |
| Aerated Static Pile | 77% |
| Membrane Covered Aerated Static Pile | N/A |
| In-Vessel | 72% |
| Anaerobic Digestion | 67% |
| **Summerland Regional Facility** | |
| Aerated Static Pile | 80% |

| Scenario | % of Odour from Composting Biofilter |
|---|---|
| Membrane Covered Aerated Static Pile | N/A |
| In-Vessel Composting | 77% |
| Anaerobic Digestion | 73% |
| **Summerland Regional Facility with RDCO Biosolids** | |
| Aerated Static Pile | 82% |
| Membrane Covered Aerated Static Pile | N/A |
| In-Vessel Composting | 79% |
| Anaerobic Digestion | 75% |

# 4.0 DISCUSSION – METEOROLOGICAL DESCRIPTION OF EXCEEDANCES

## 4.1 Diurnal Variations (Day/Night)

Table 4.1 lists the number of 1 OU exceedances at 6711 Prairie Valley Rd occurring during the night, early in the morning, during the day and during the evening. The diurnal pattern related to mixing height is evident with exceedances occurring overnight or when daytime mixing heights are still low (dawn and dusk). The summary describes the conditions at one location. The temporal distribution could be different at other locations based on the prevalent meteorological conditions, however it can be assumed that the majority of odour issues at any point tend to occur at similar times of day.

### Table 4.1: Diurnal Pattern to Predicted 1 OU Exceedance at 16711 Prairie Valley Road (303123 m, 5497017 m, Zone 11)

| | $22^{00}$ - $7^{00}$ | $8^{00}$ - $10^{00}$ | $11^{00}$ - $16^{00}$ | $17^{00}$ - $21^{00}$ |
|---|---|---|---|---|
| Number of Predicted Exceedances | 8 | 4 | 0 | 2 |

# APPENDIX A

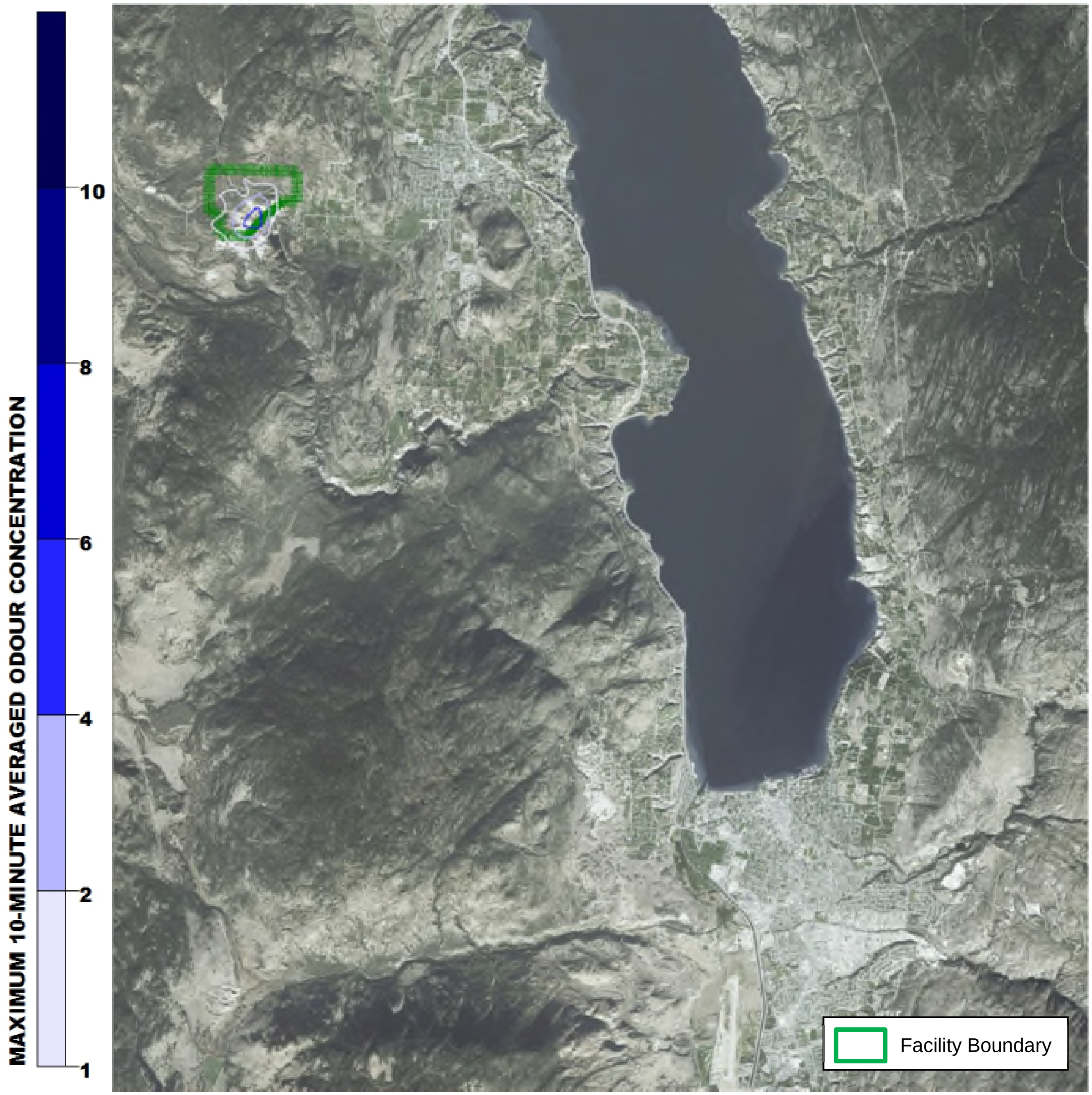


**Figure 1: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Current Composting Operations)**

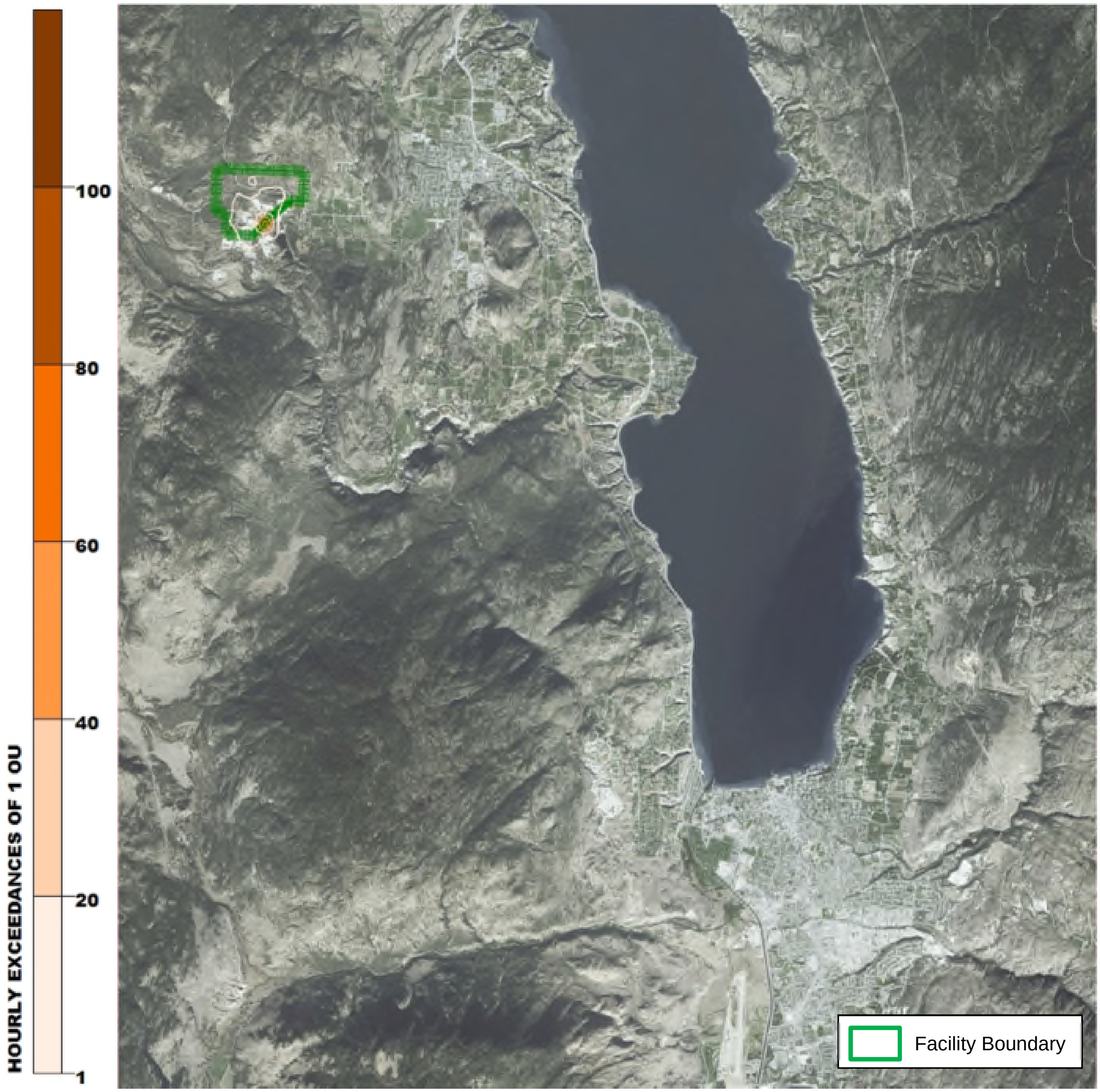


**Figure 2: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Current Composting Operations)**

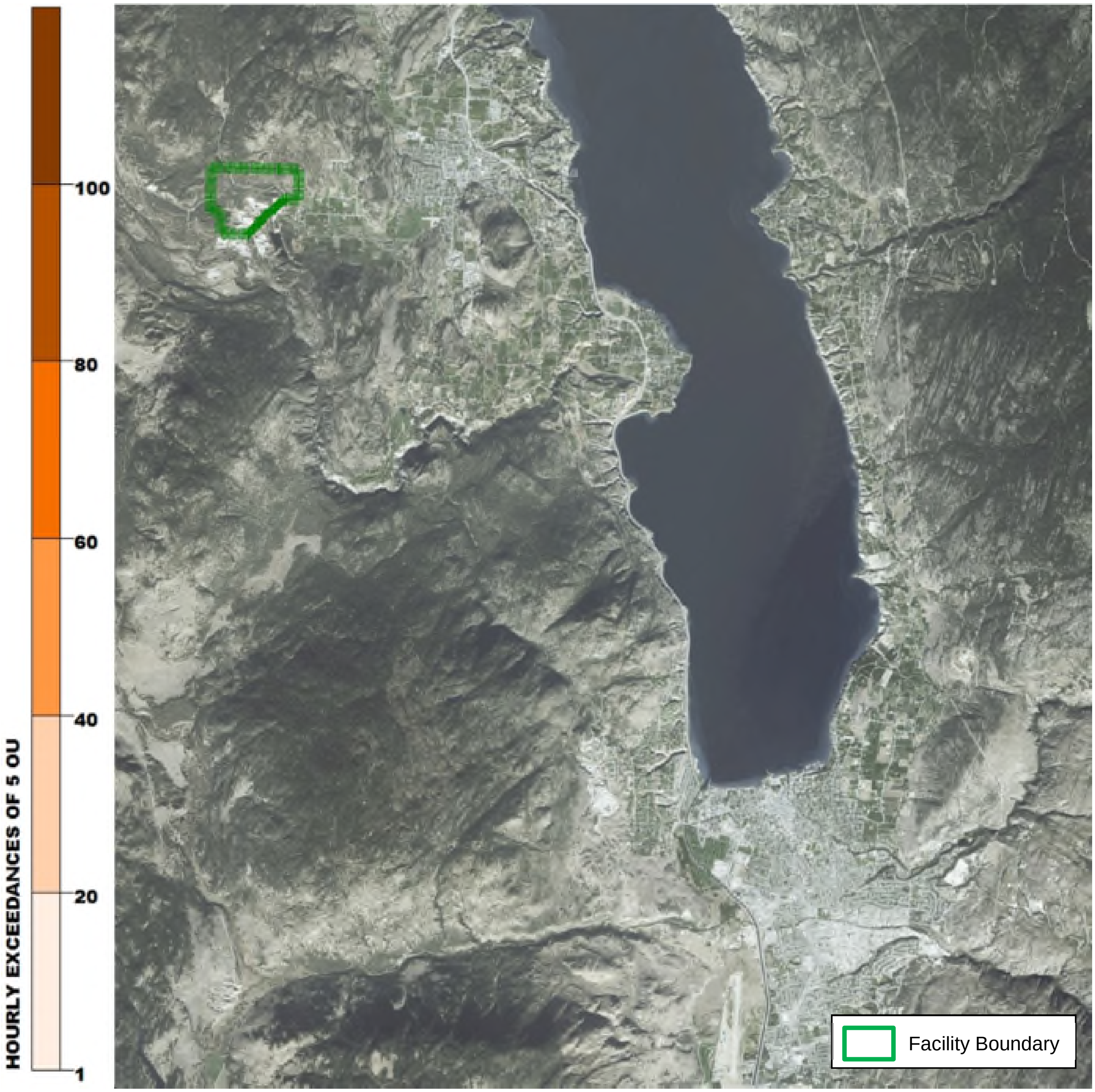


**Figure 3: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (Current Composting Operations)**

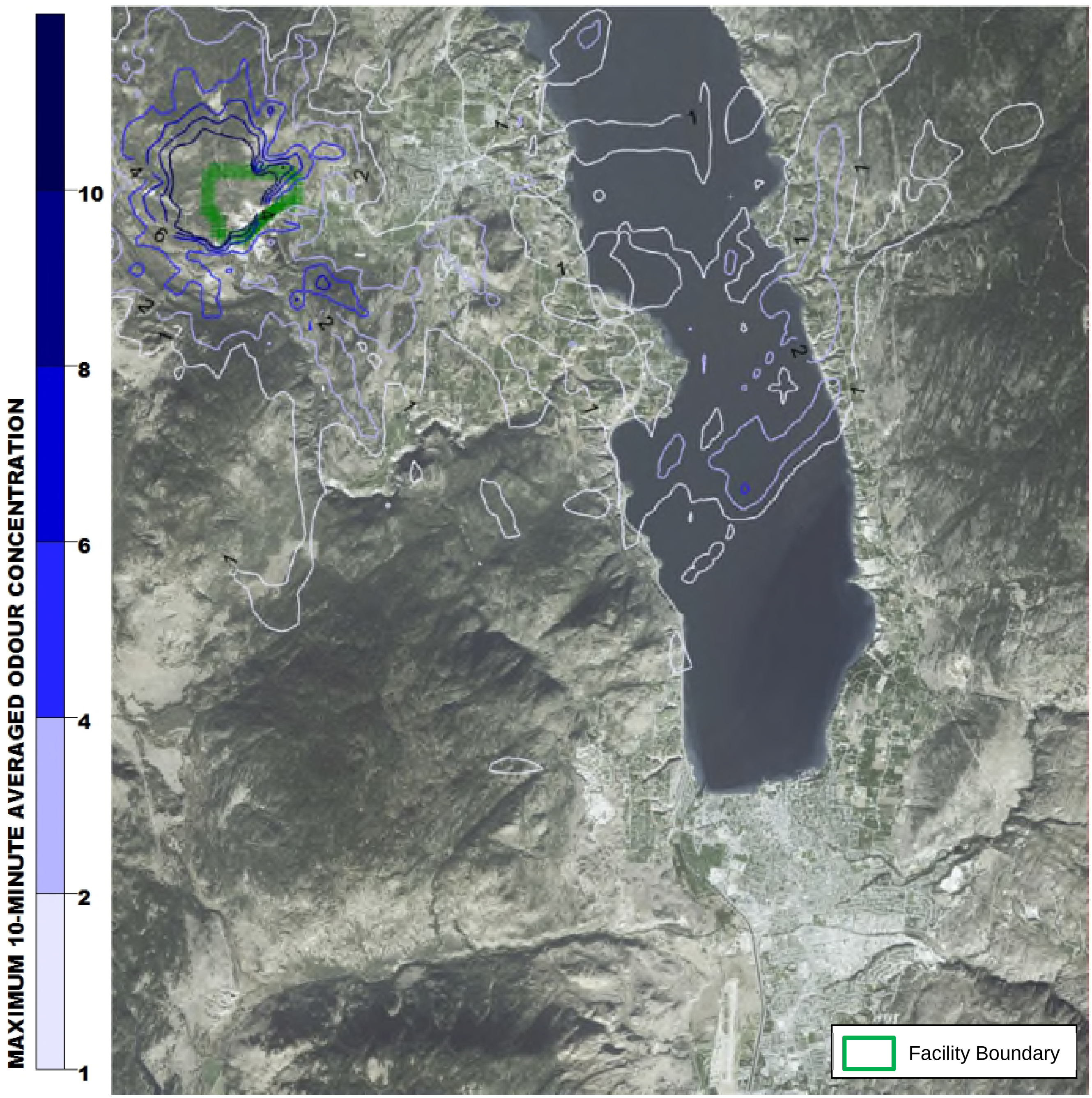


**Figure 4: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (ASP)**

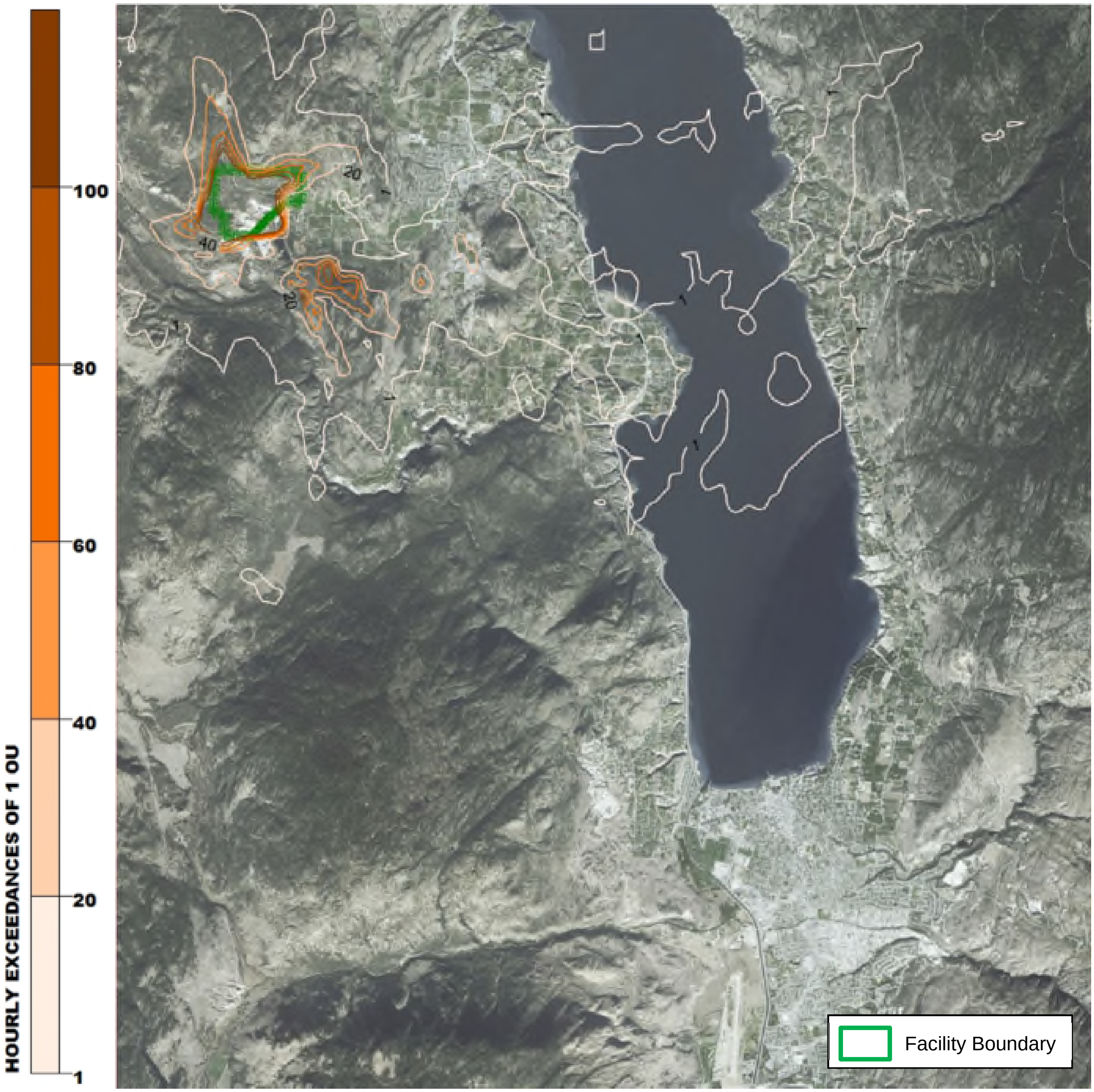


**Figure 5: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (ASP)**

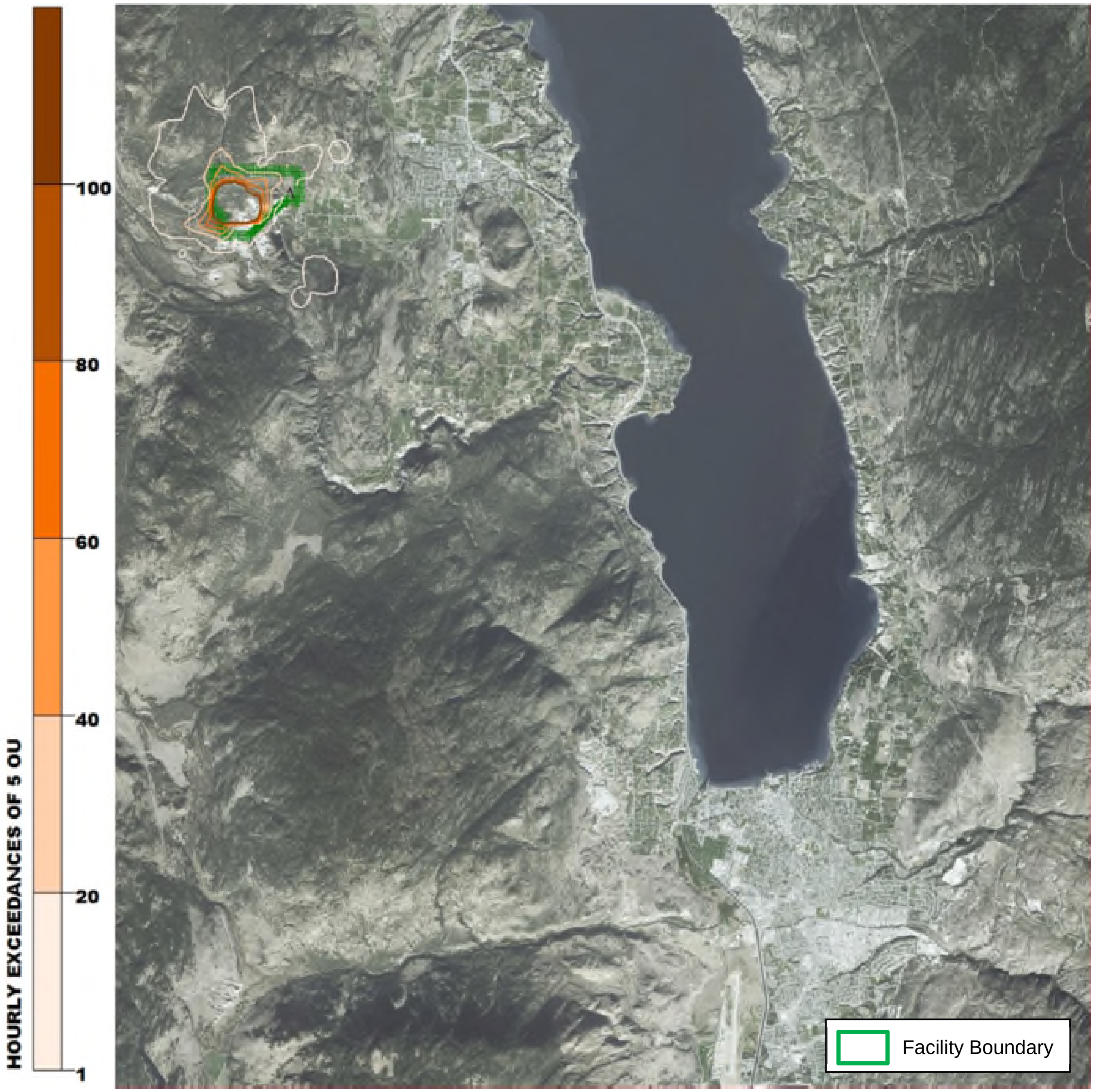


**Figure 6: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (ASP)**

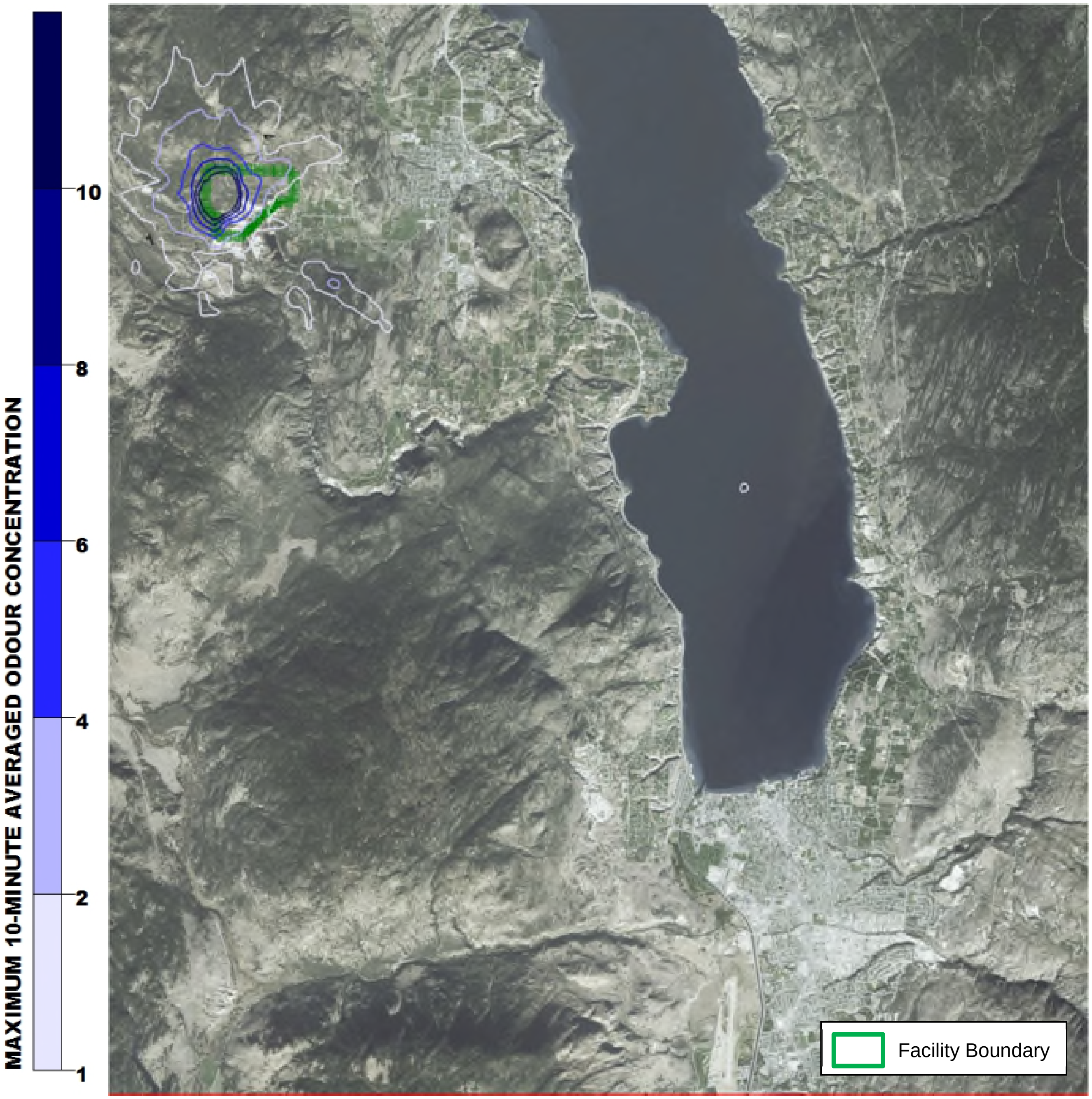


**Figure 7: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Covered ASP)**

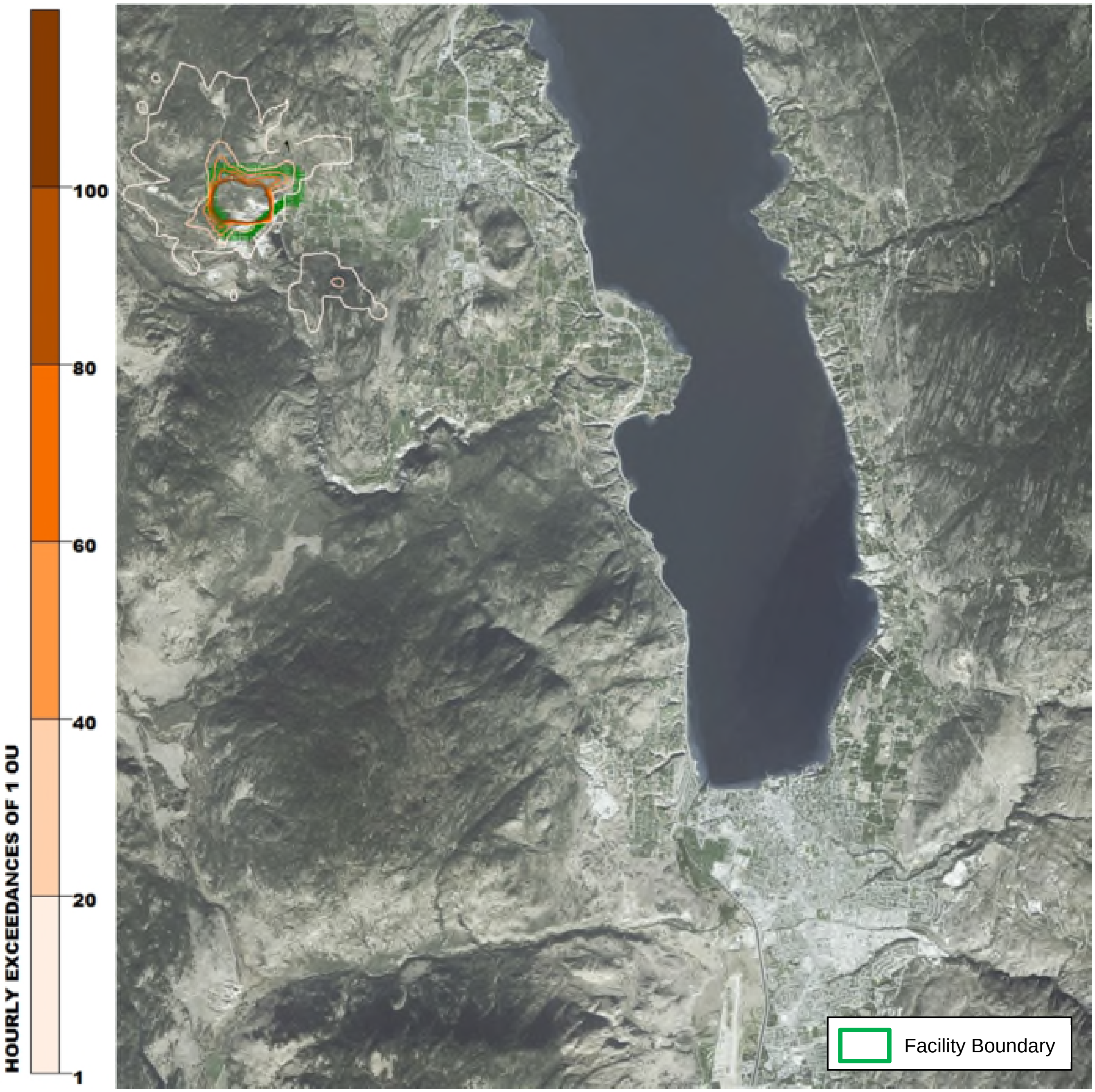


**Figure 8: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Covered ASP)**

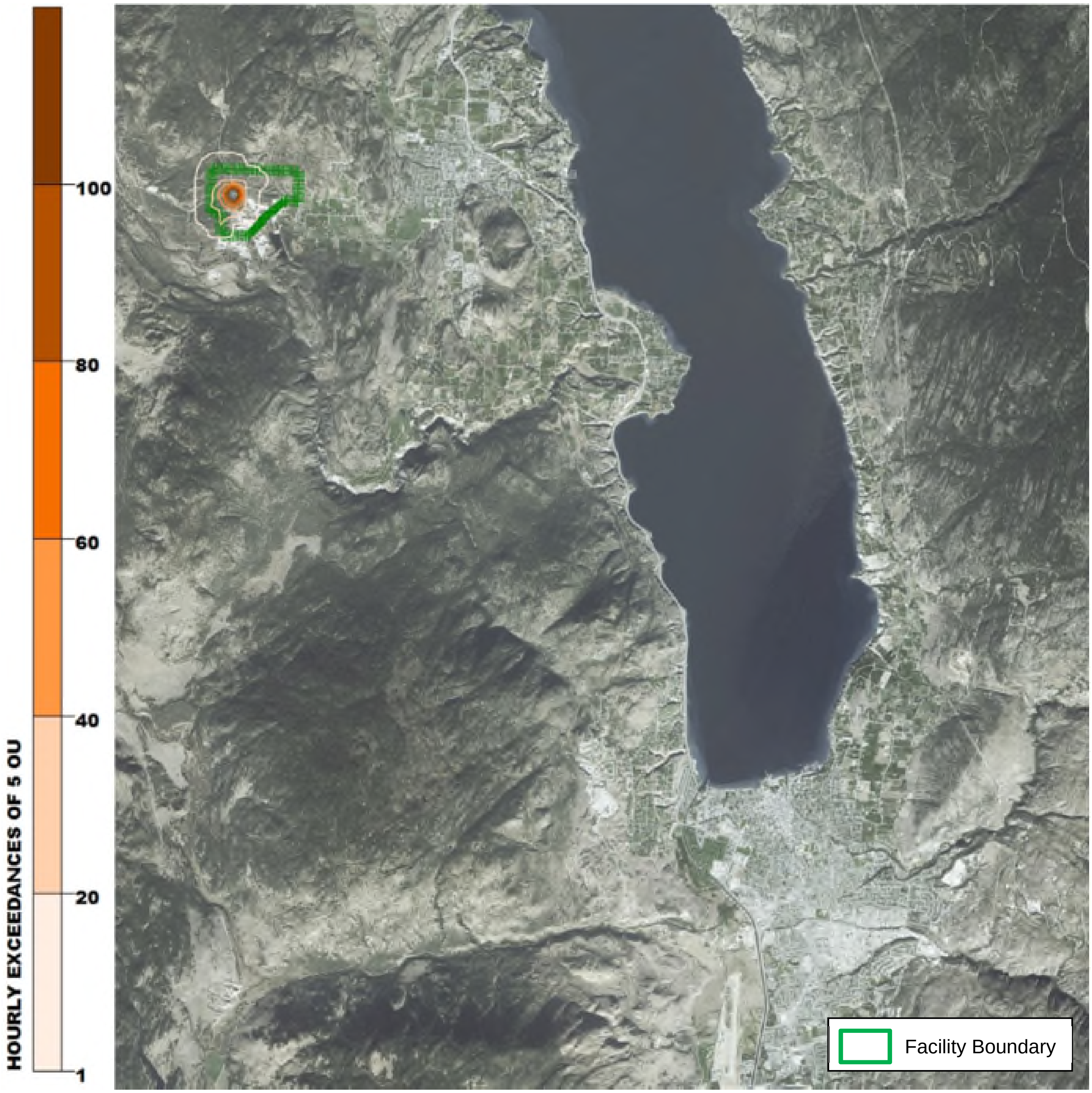


**Figure 9: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (Covered ASP)**

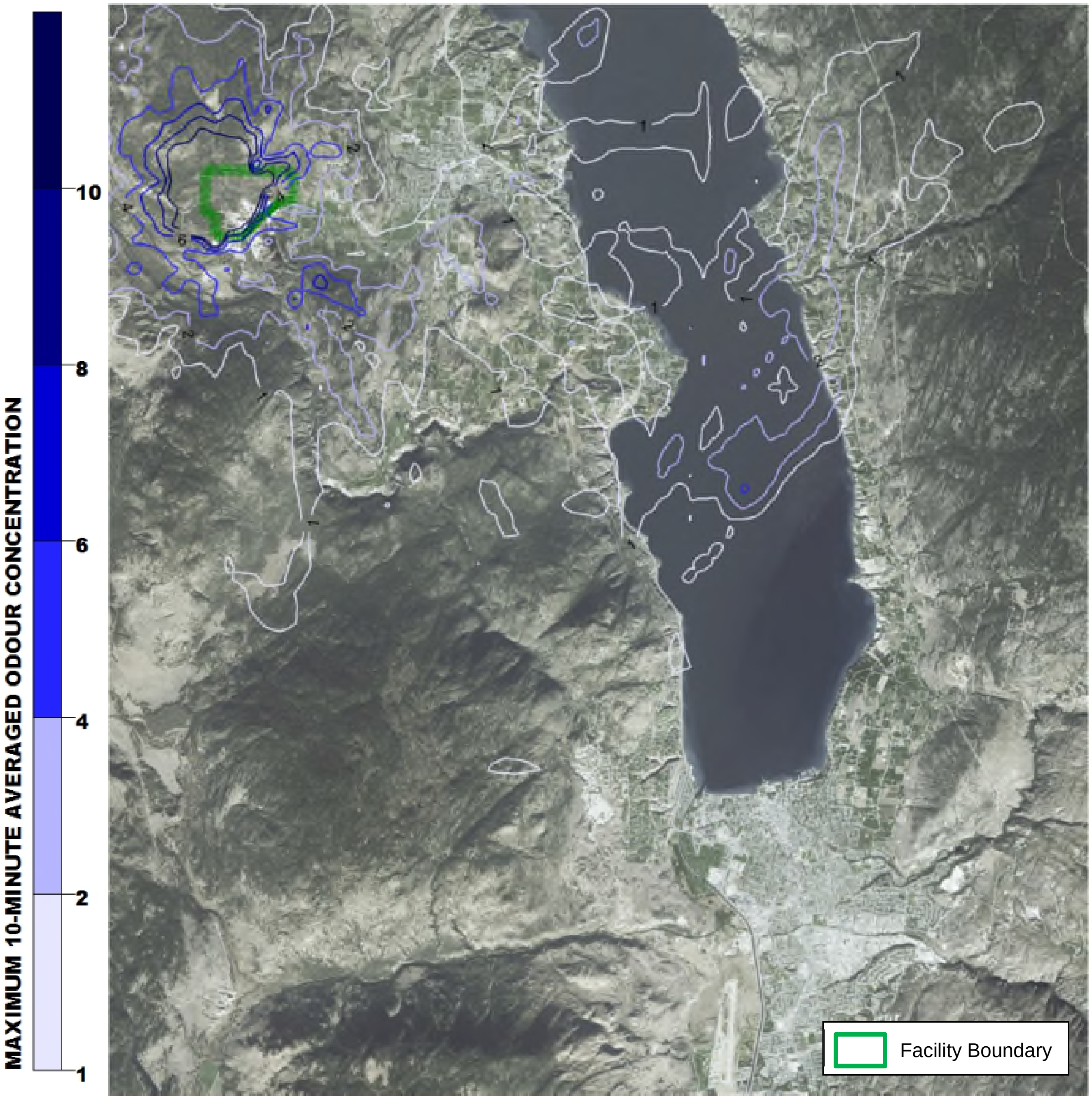


**Figure 10: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (In-Vessel)**

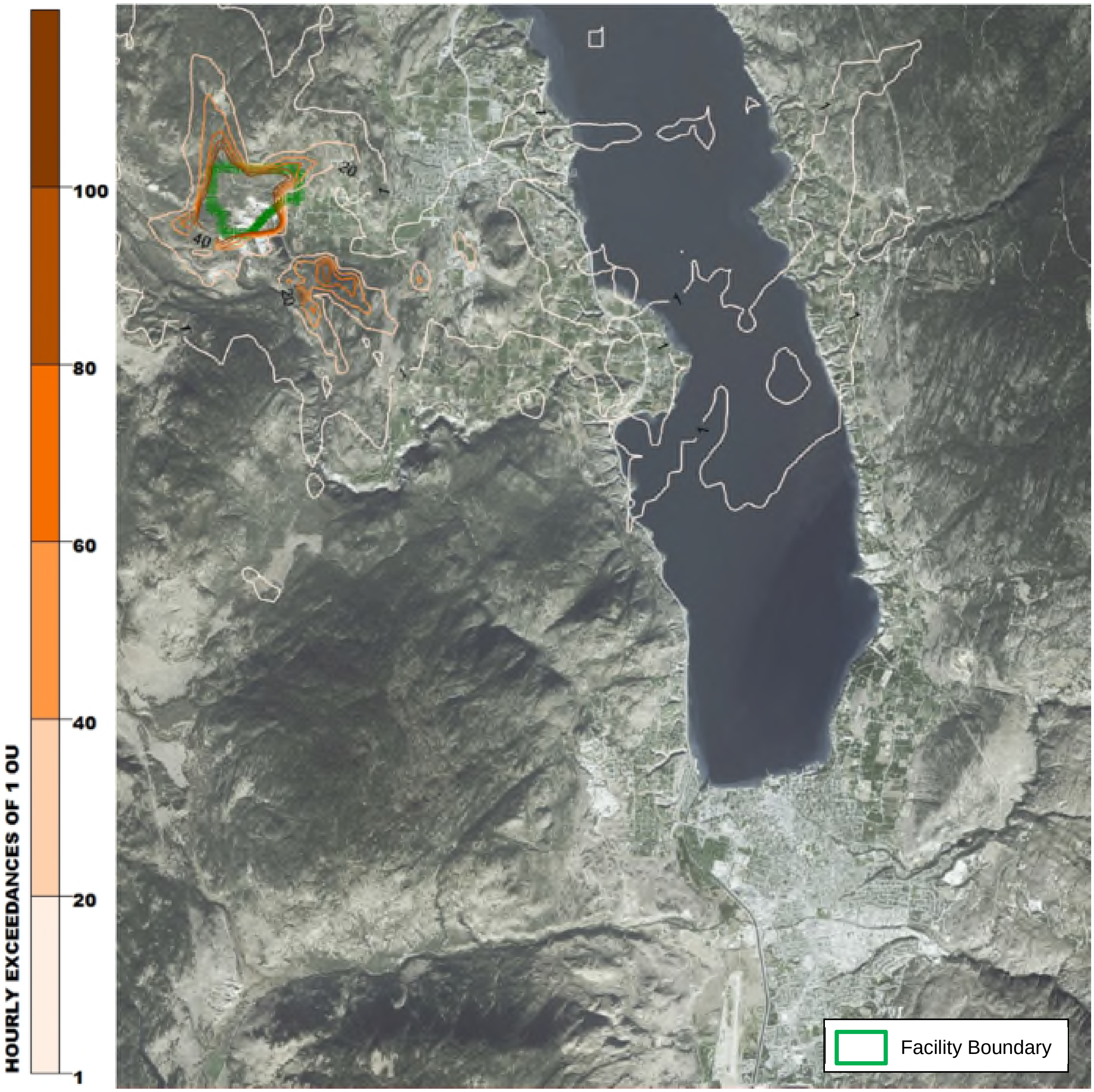


**Figure 11: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (In-Vessel)**

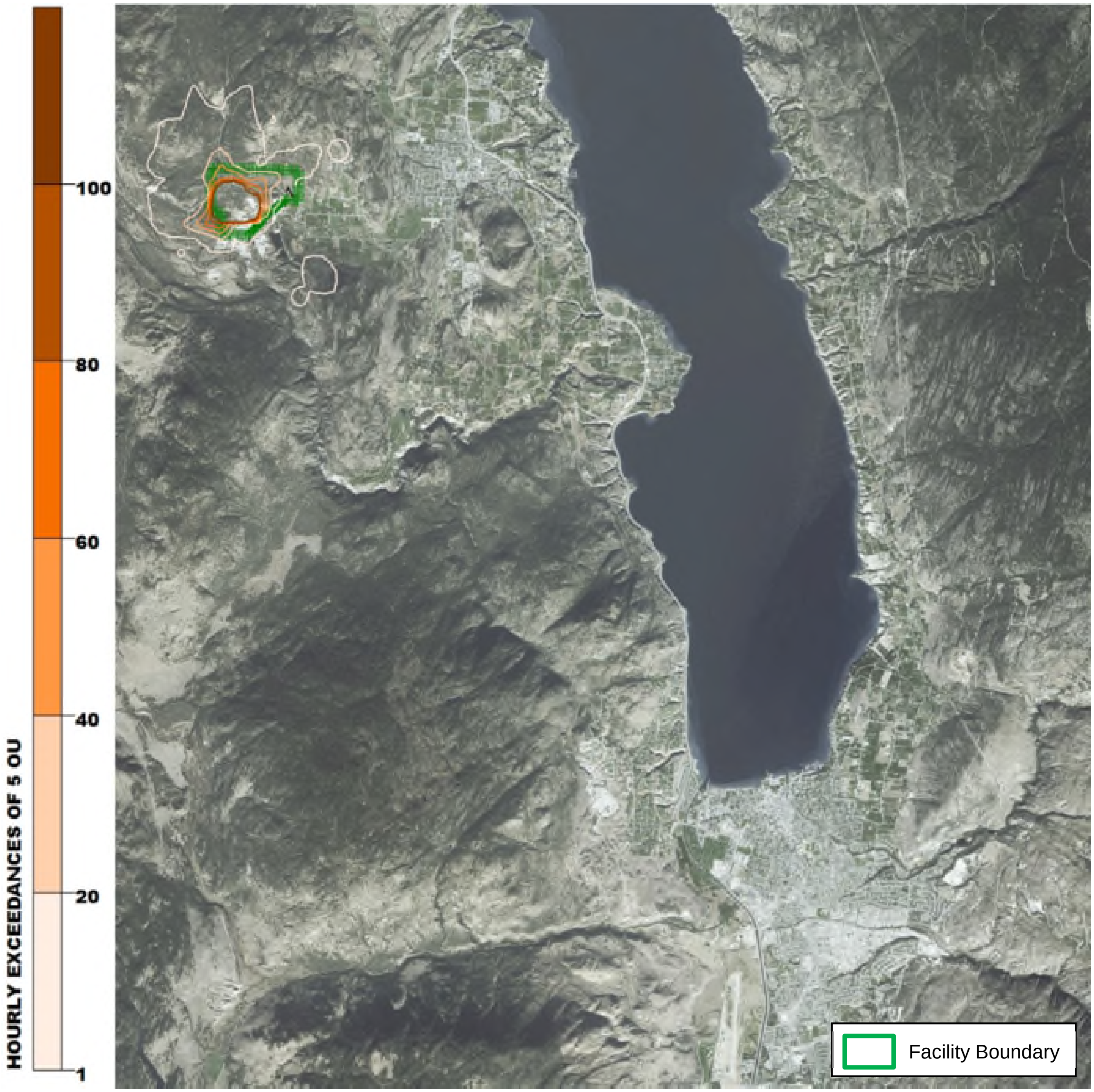


**Figure 12: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (In-Vessel)**

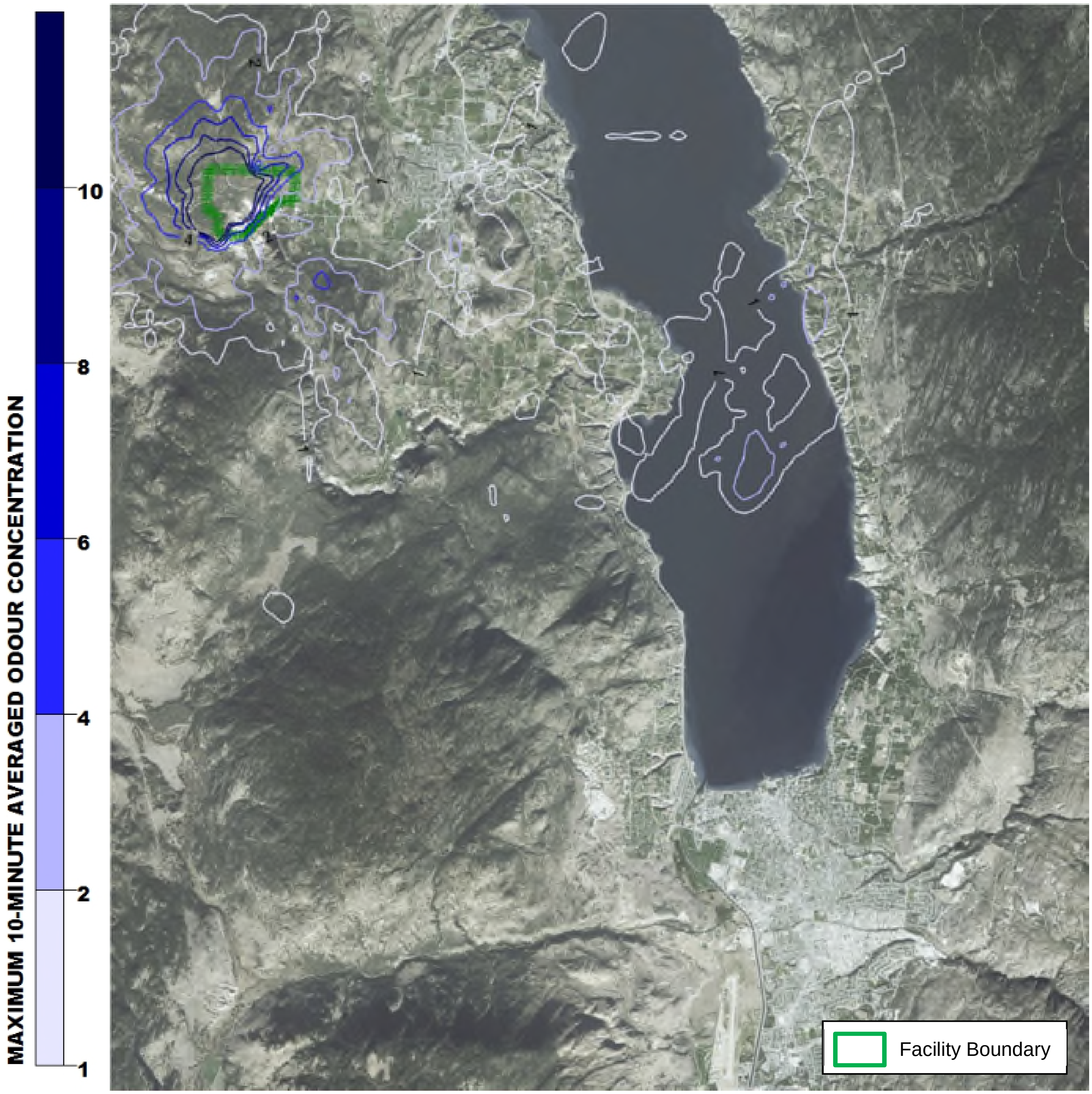


**Figure 13: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (AD)**

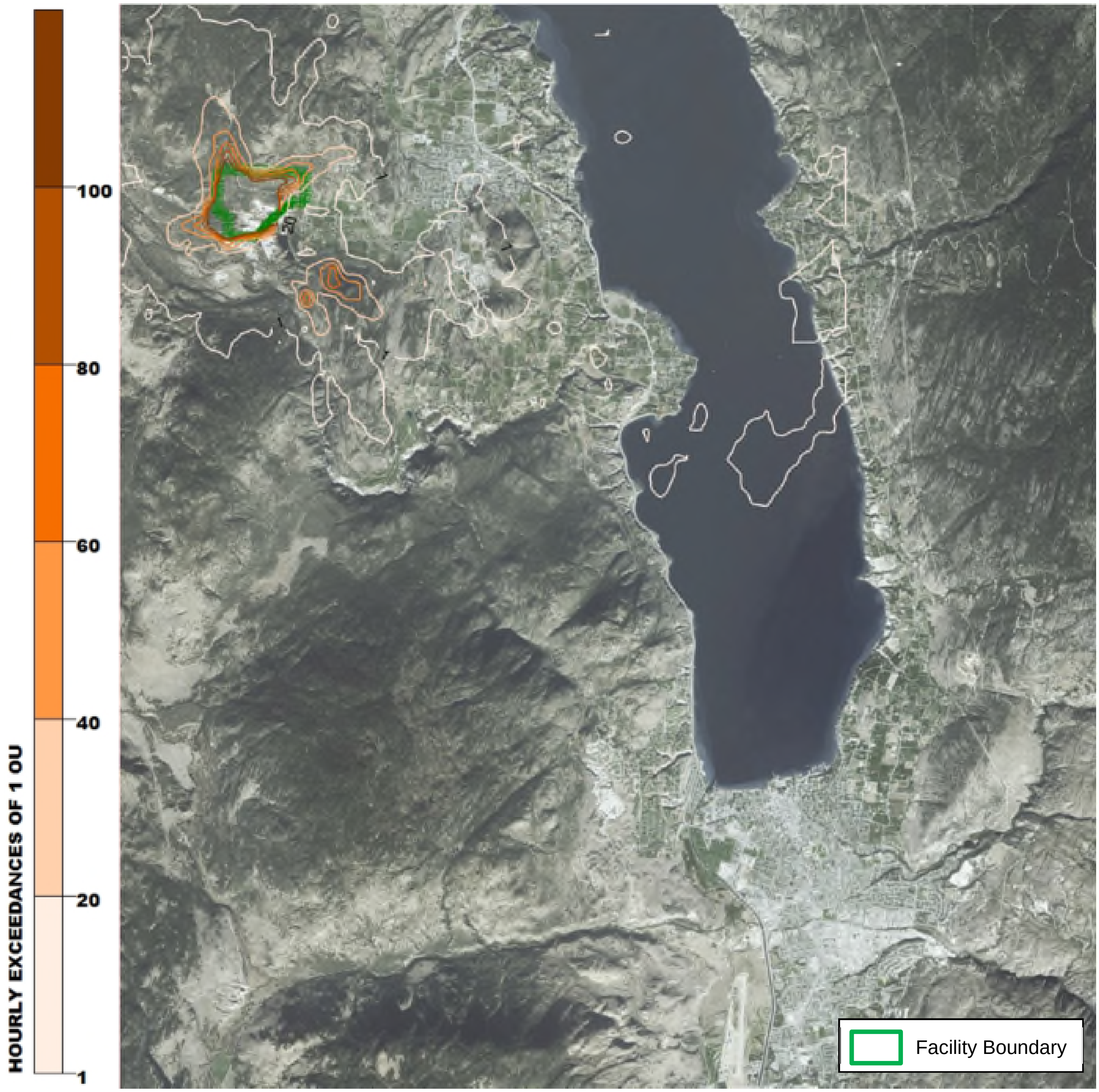


**Figure 14: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (AD)**

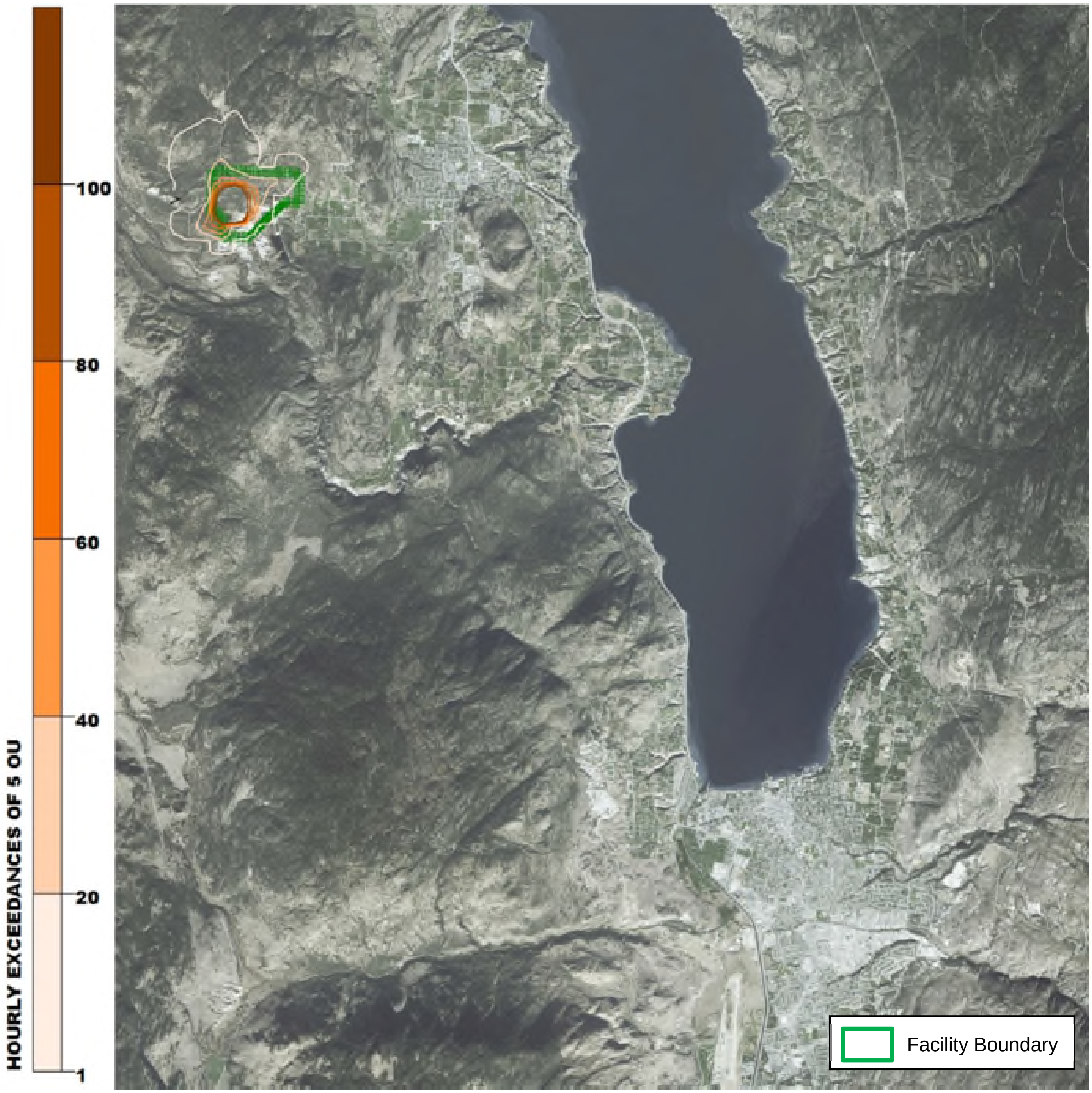


**Figure 15: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (AD)**

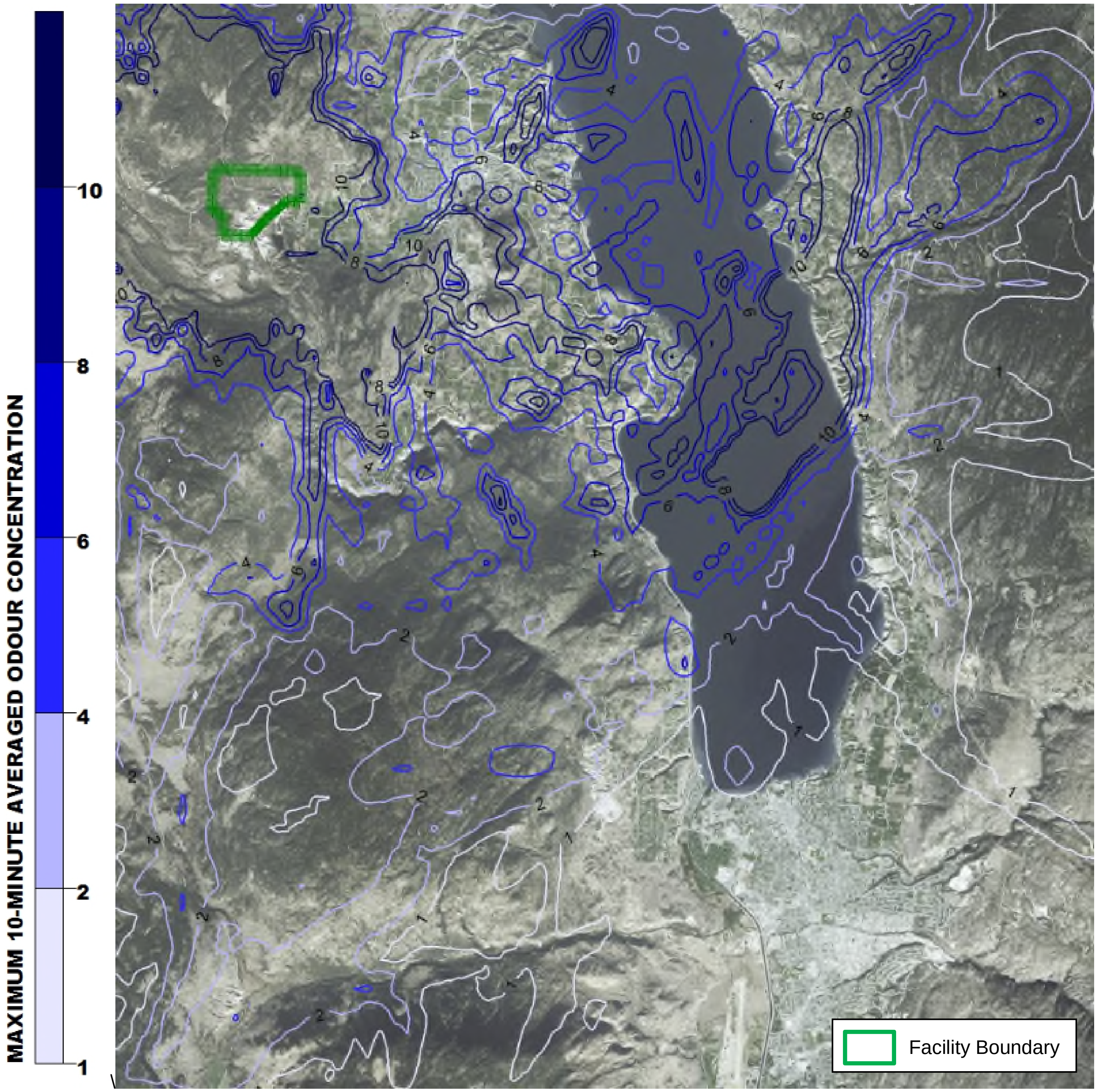


**Figure 16: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (ASP - Regional)**

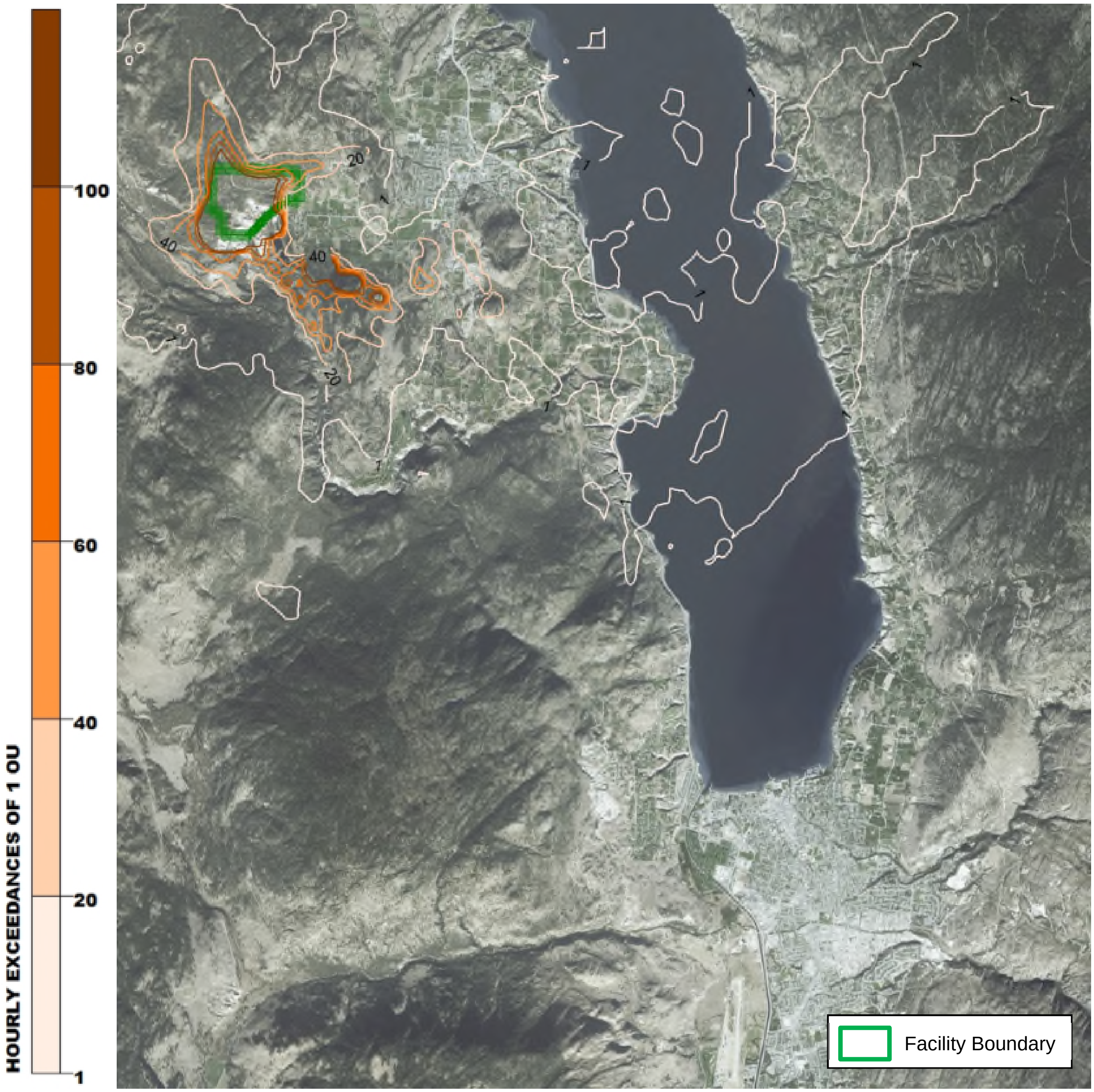


**Figure 17: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (ASP - Regional)**

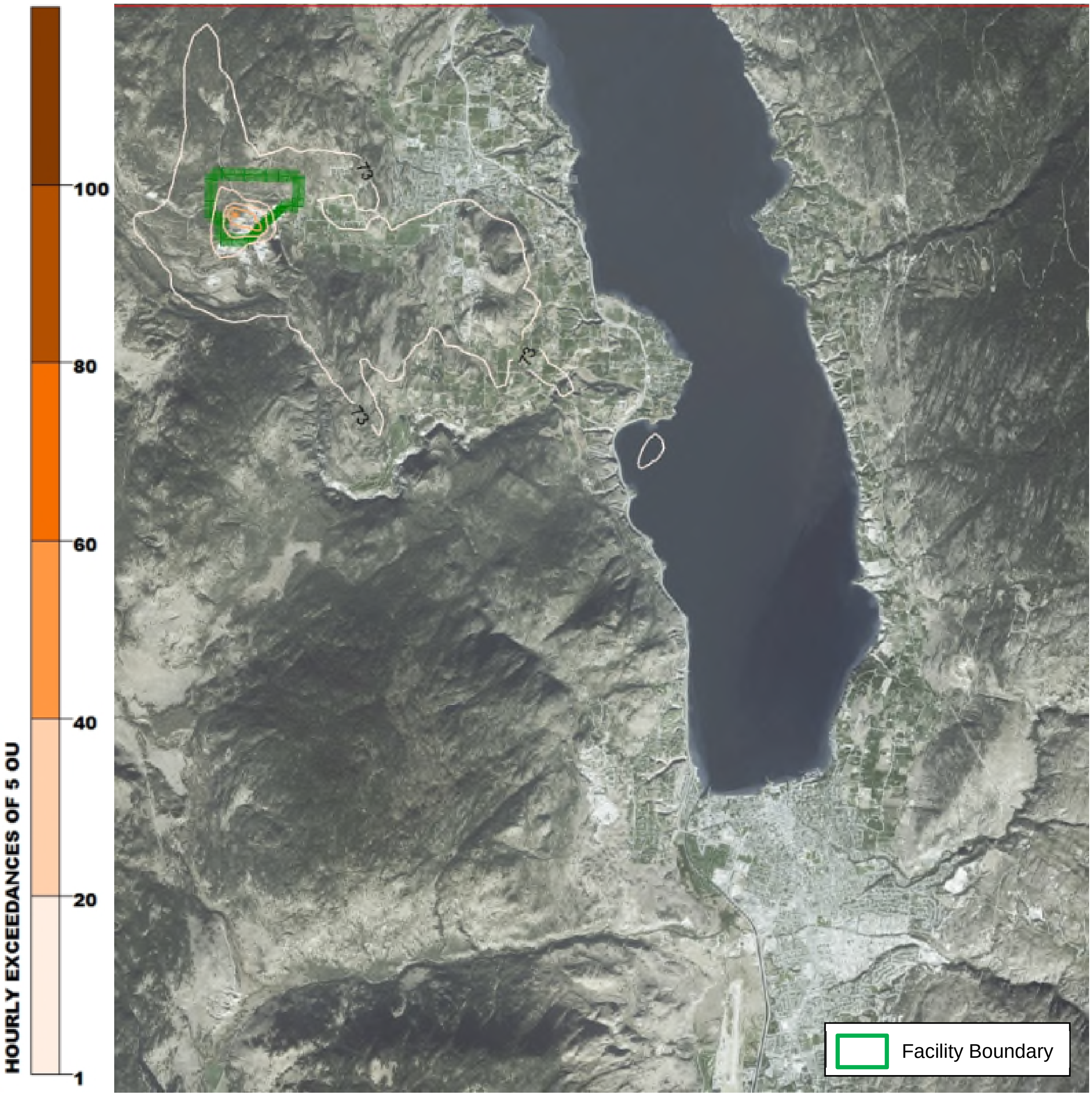


**Figure 18: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (ASP - Regional)**

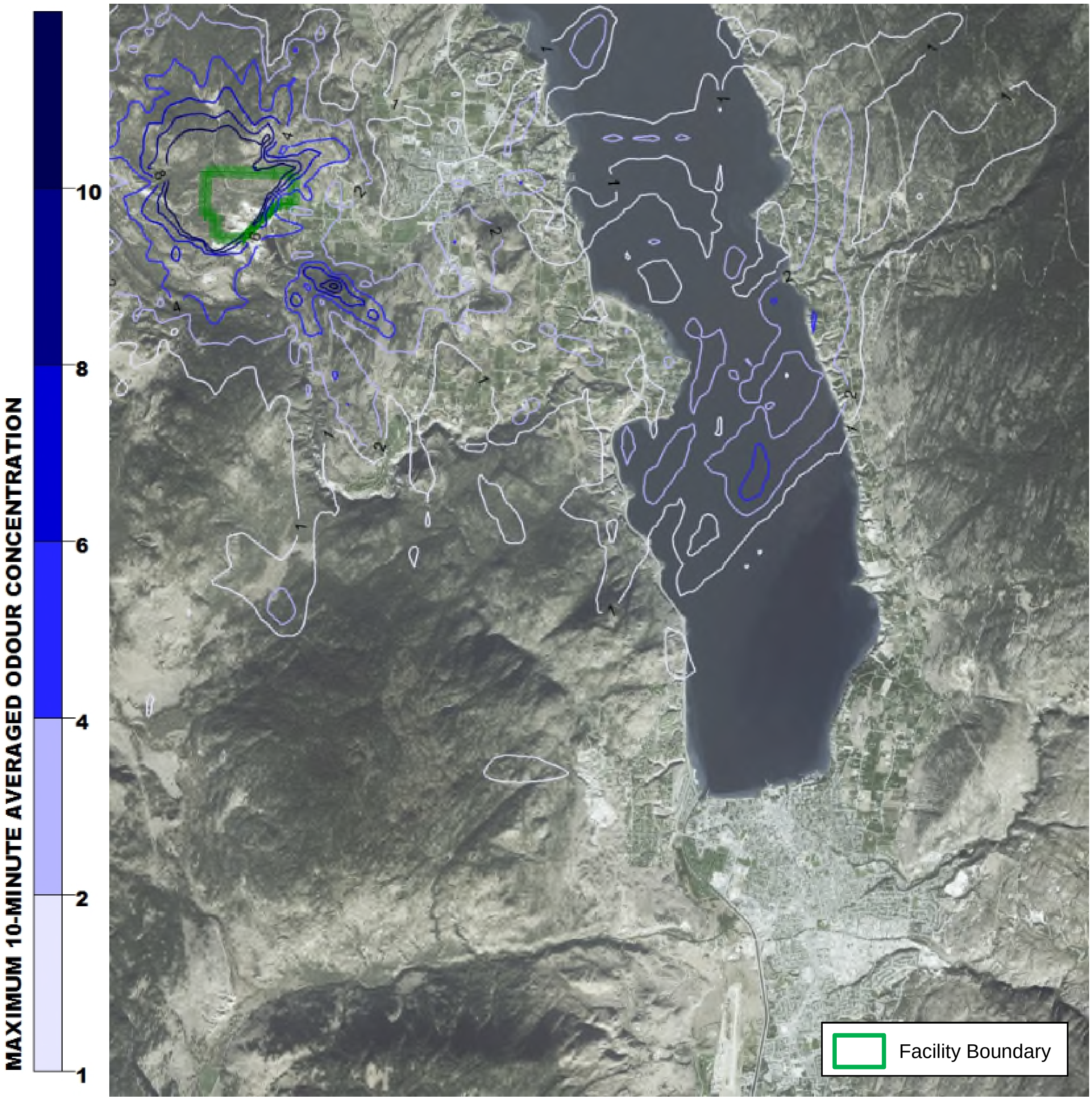


**Figure 19: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Covered ASP - Regional)**

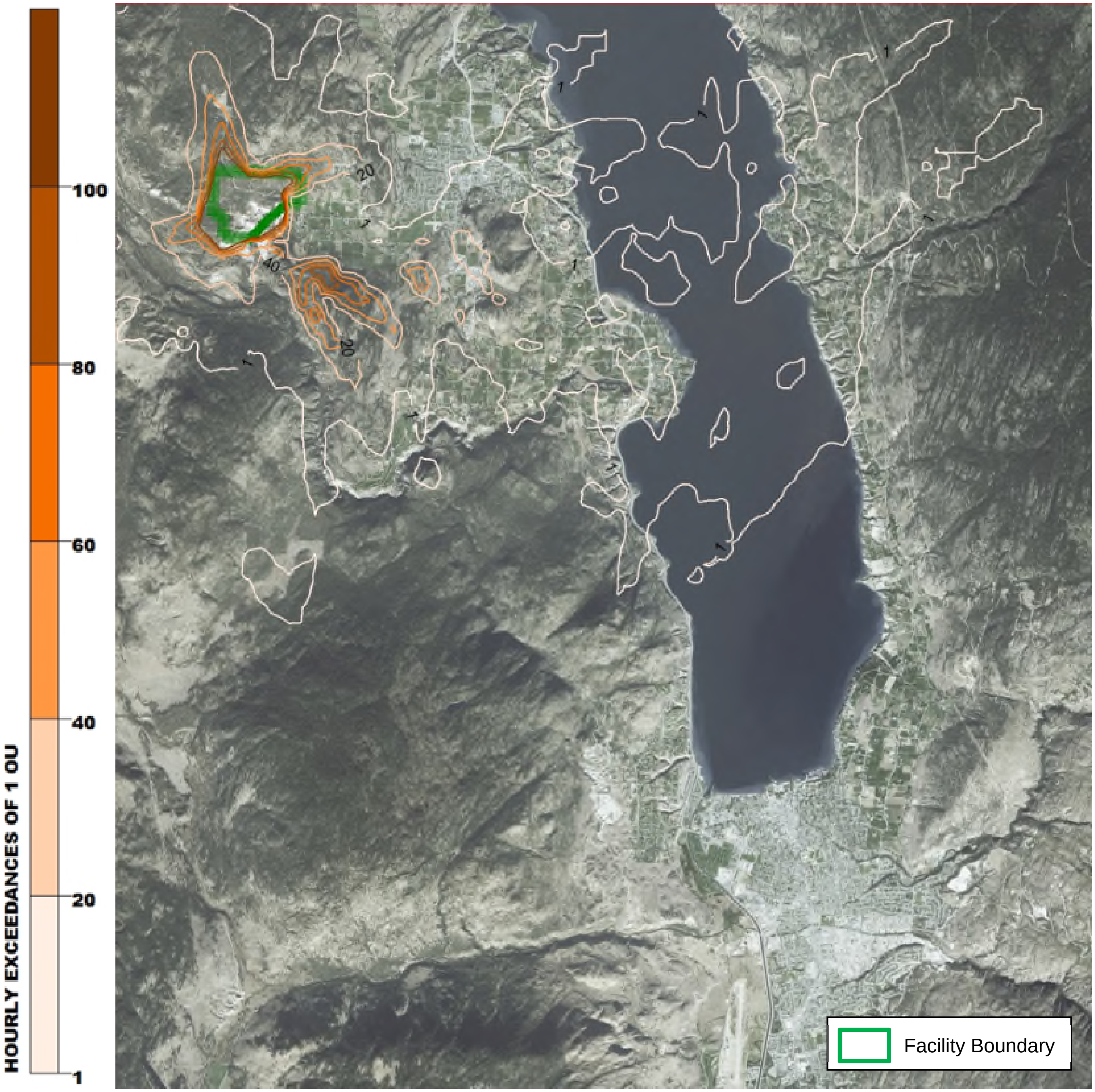


**Figure 20: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Covered ASP - Regional)**

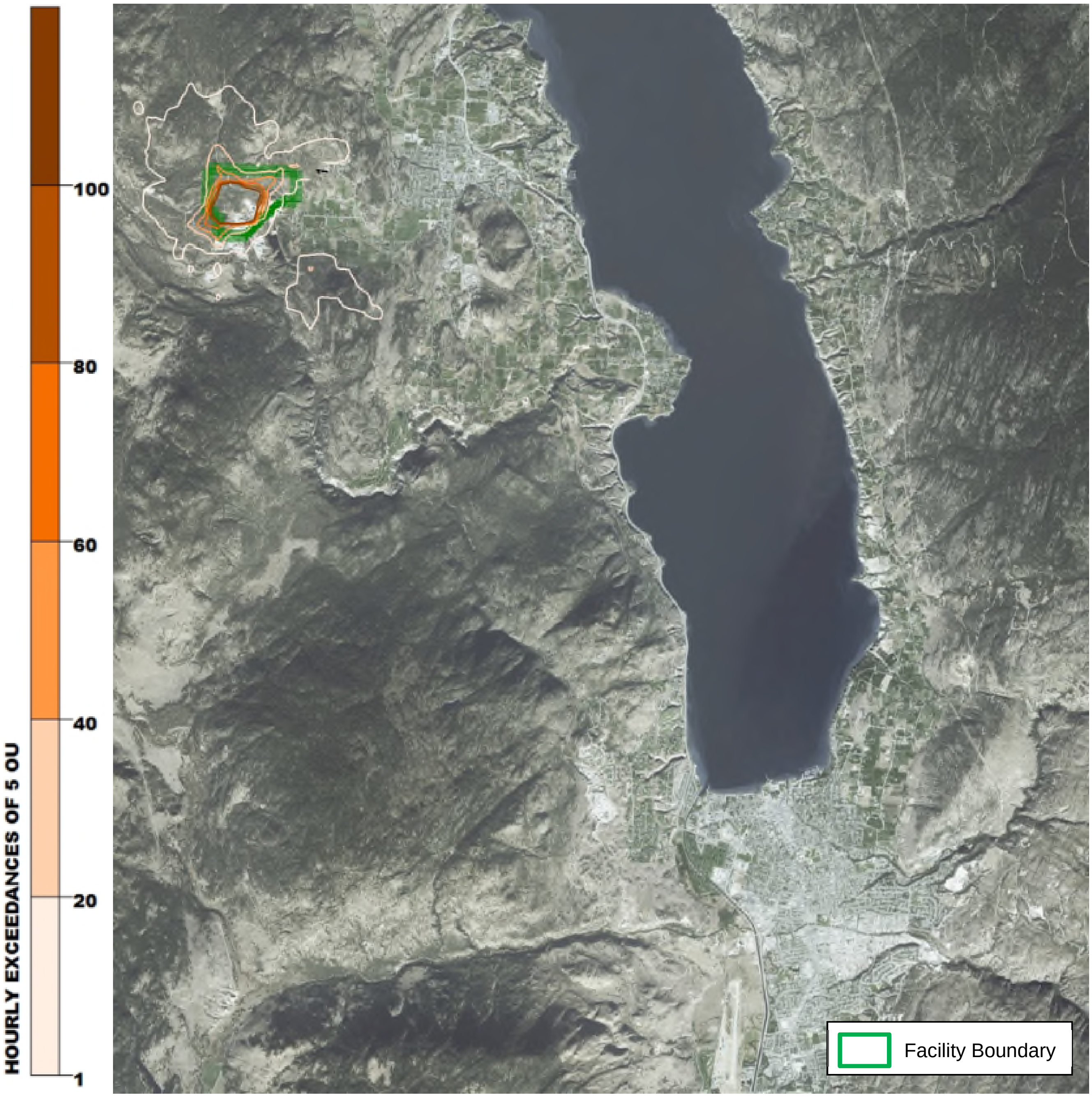


**Figure 21: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (Covered ASP - Regional)**

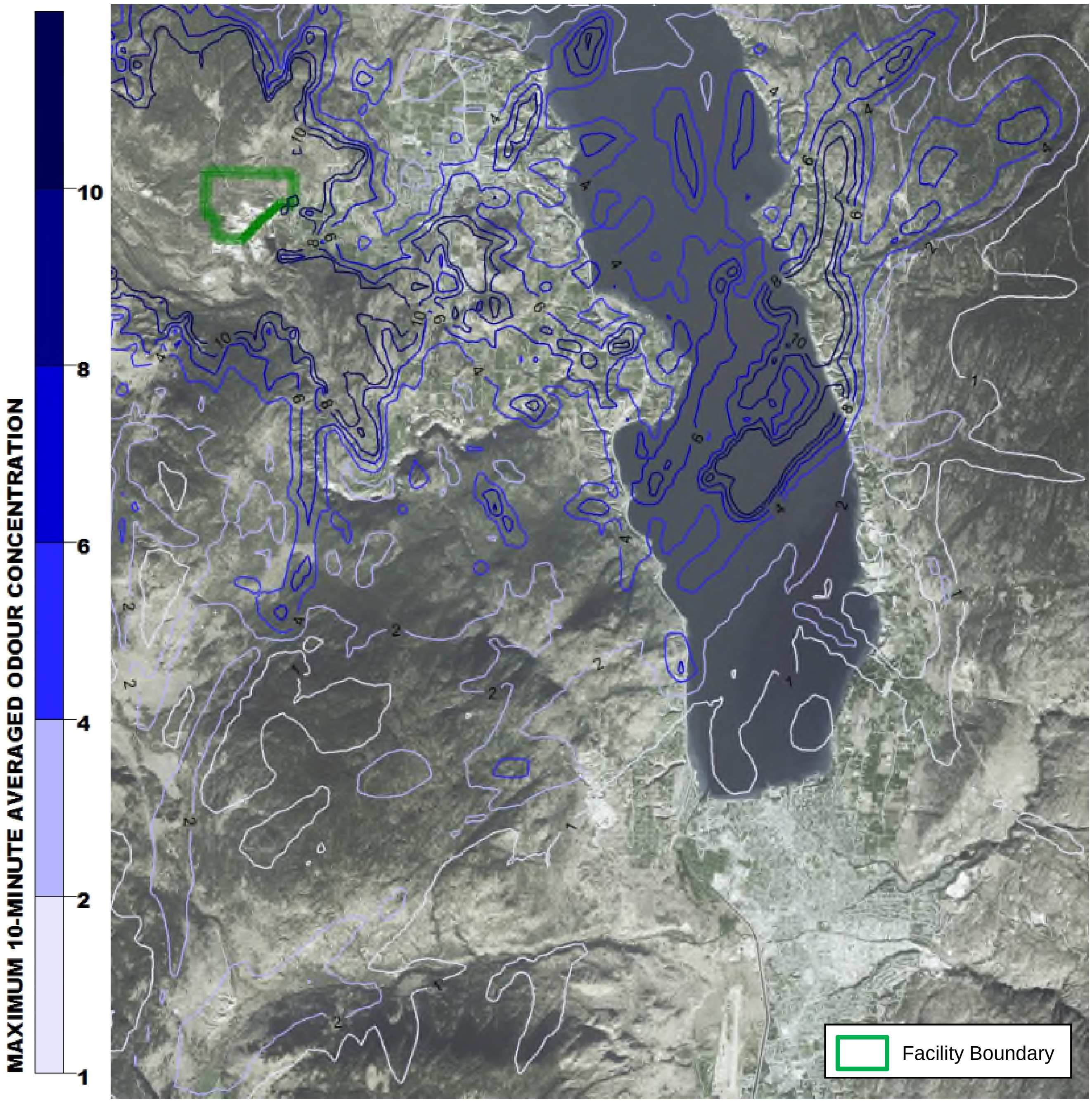


**Figure 22: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (In-Vessel - Regional)**

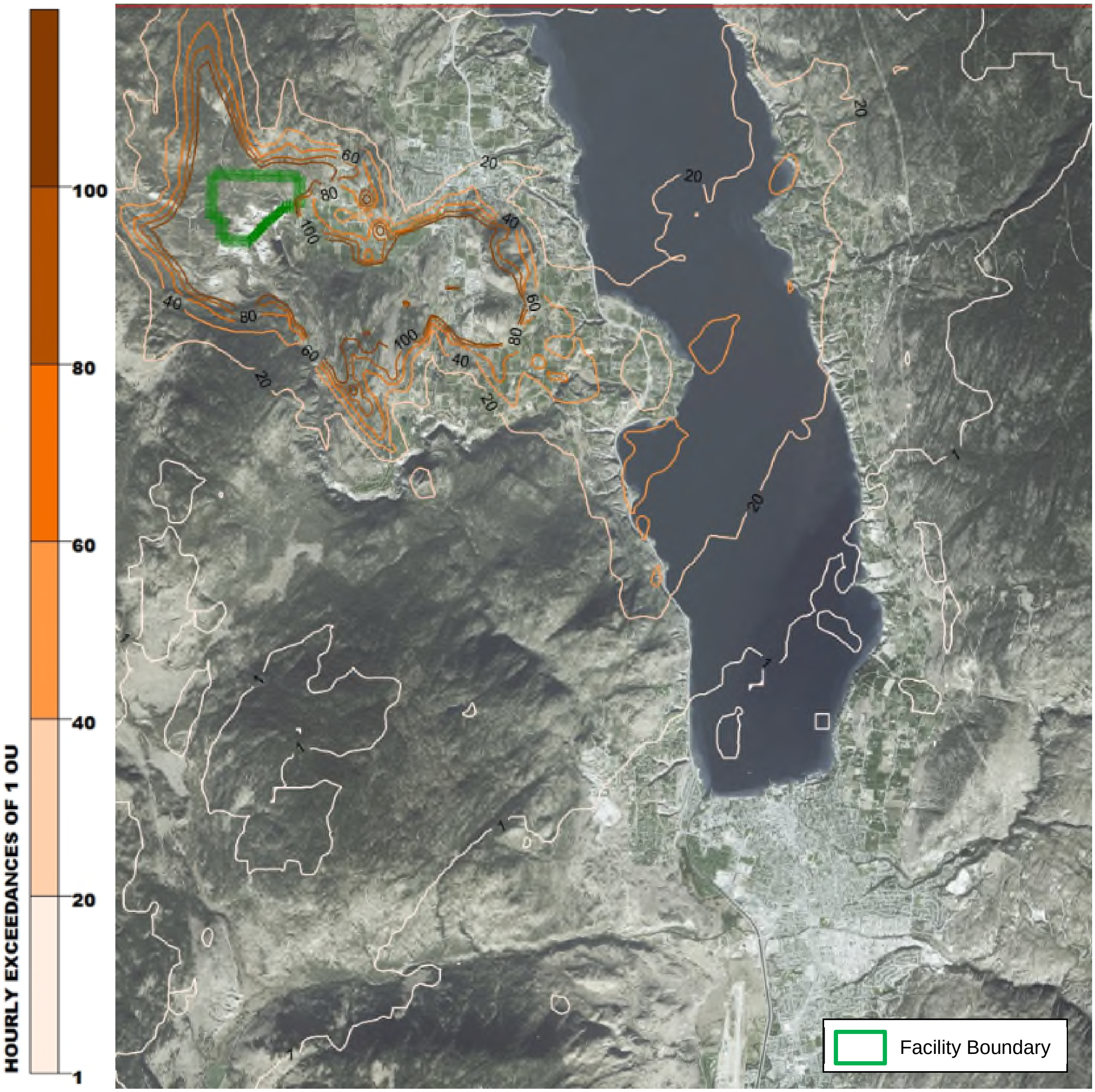


**Figure 23: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (In-Vessel - Regional)**

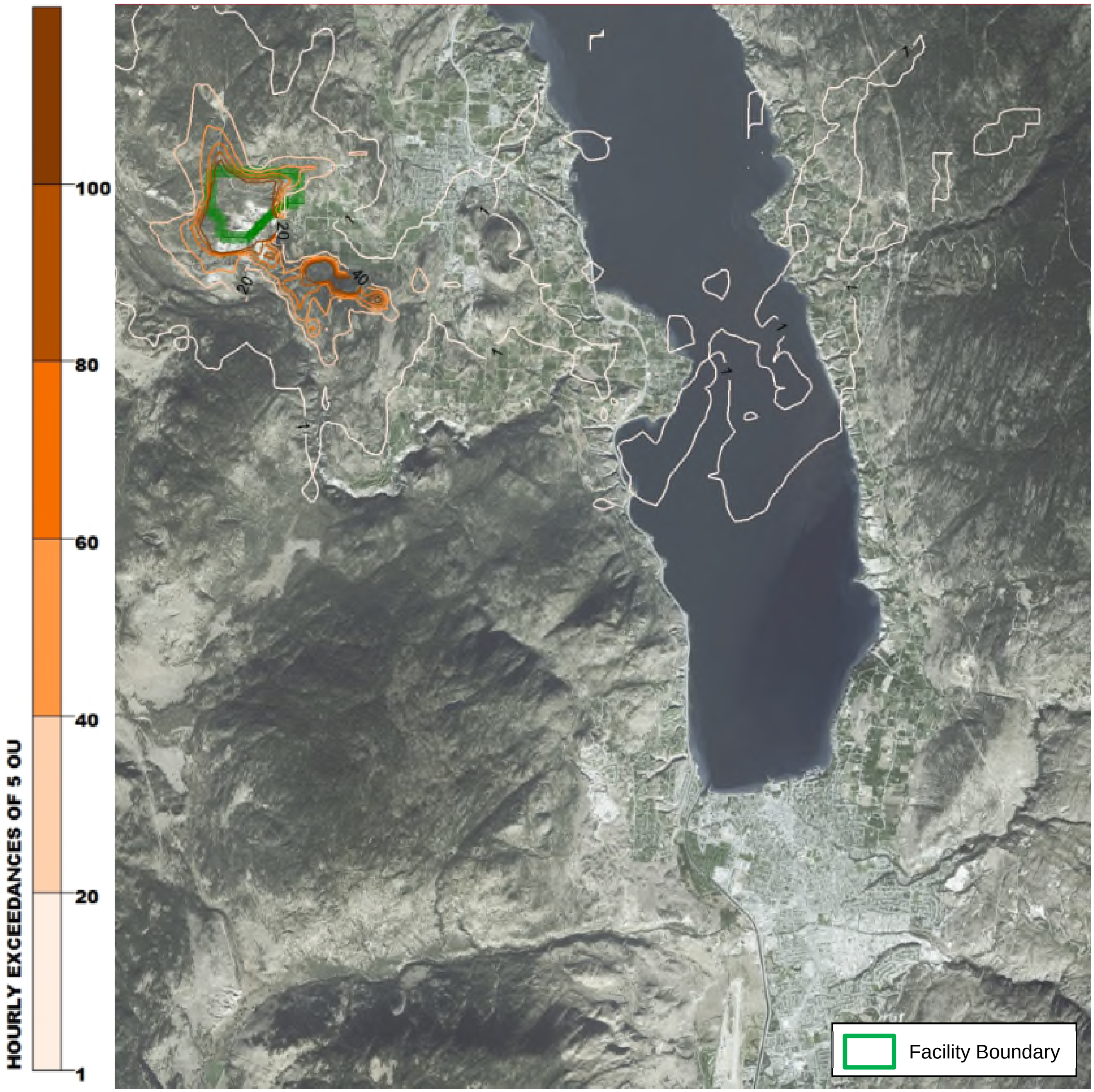


**Figure 24: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (In-Vessel - Regional)**

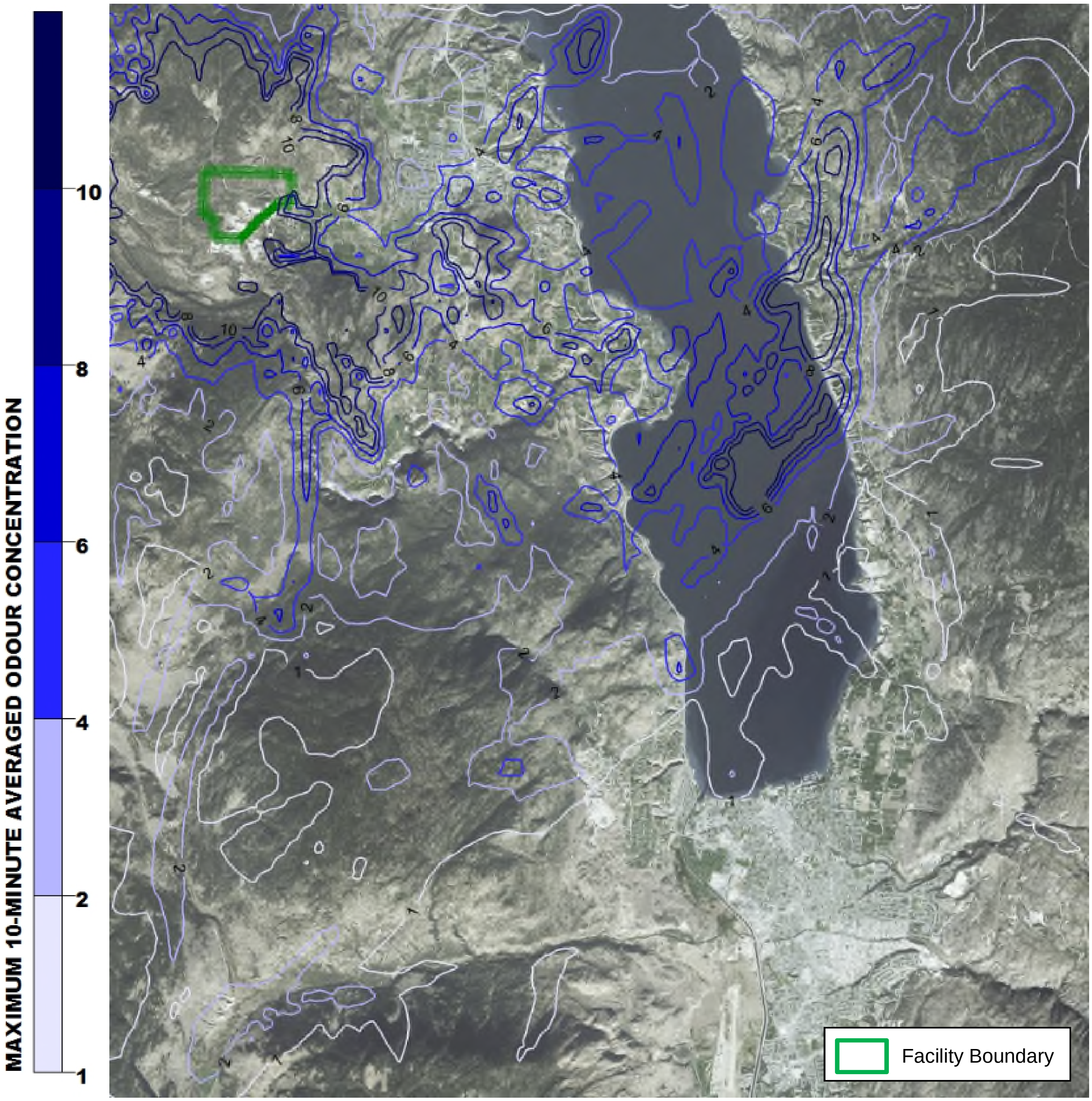


**Figure 25: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (AD - Regional)**

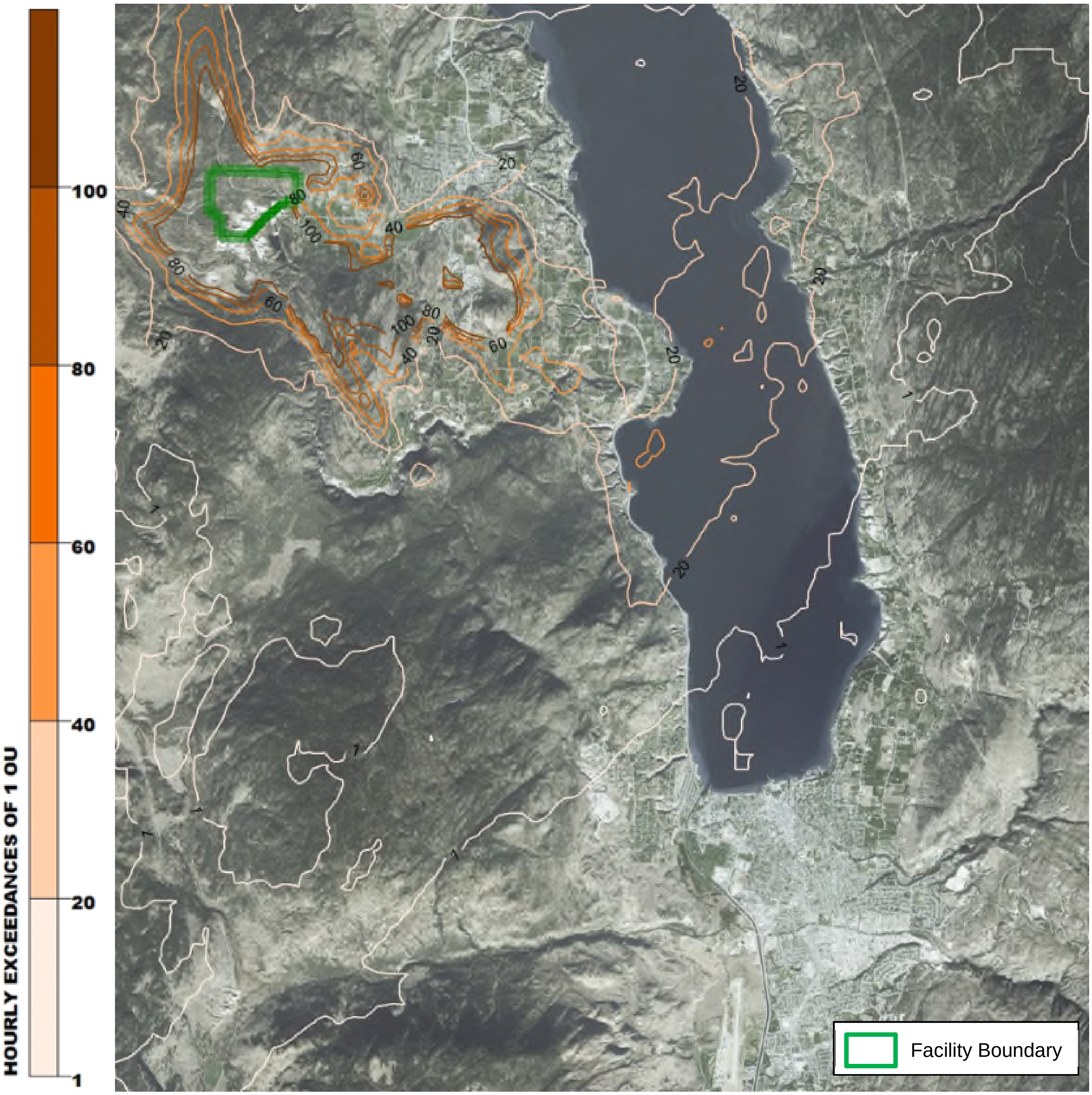


**Figure 26: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (AD - Regional)**

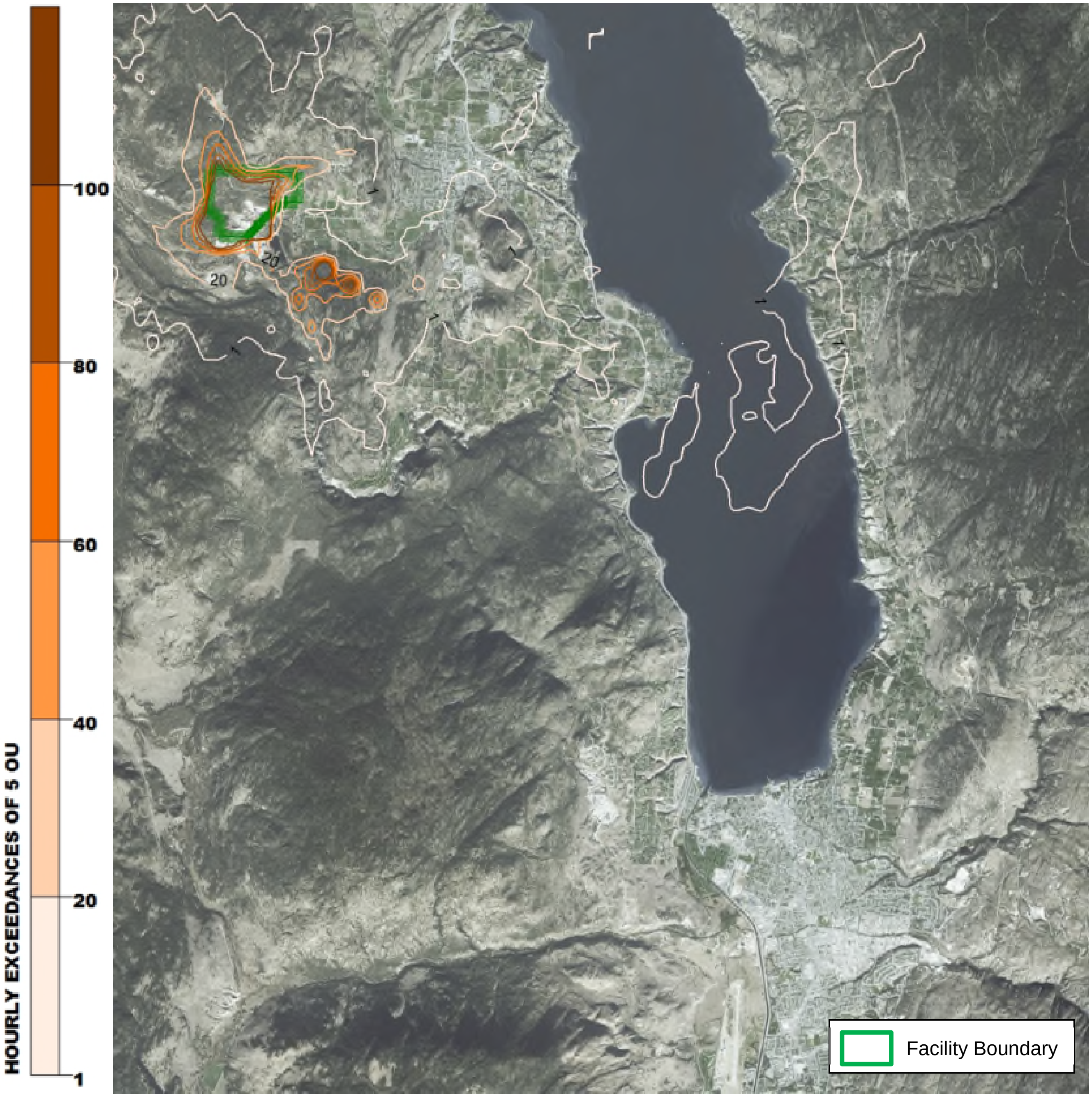


**Figure 27: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (AD - Regional)**

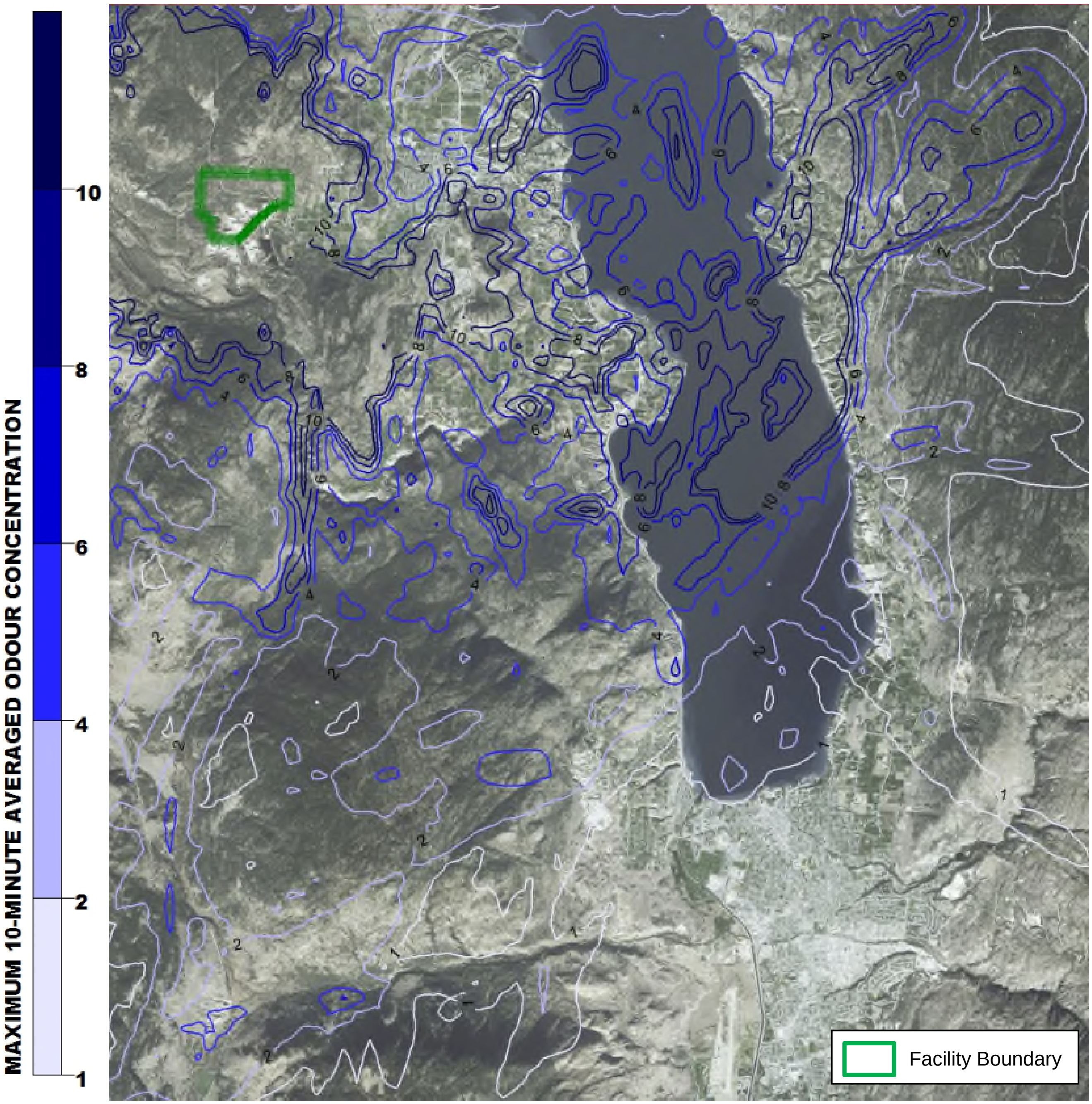


**Figure 28: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (ASP - Regional with RDCO Biosolids)**

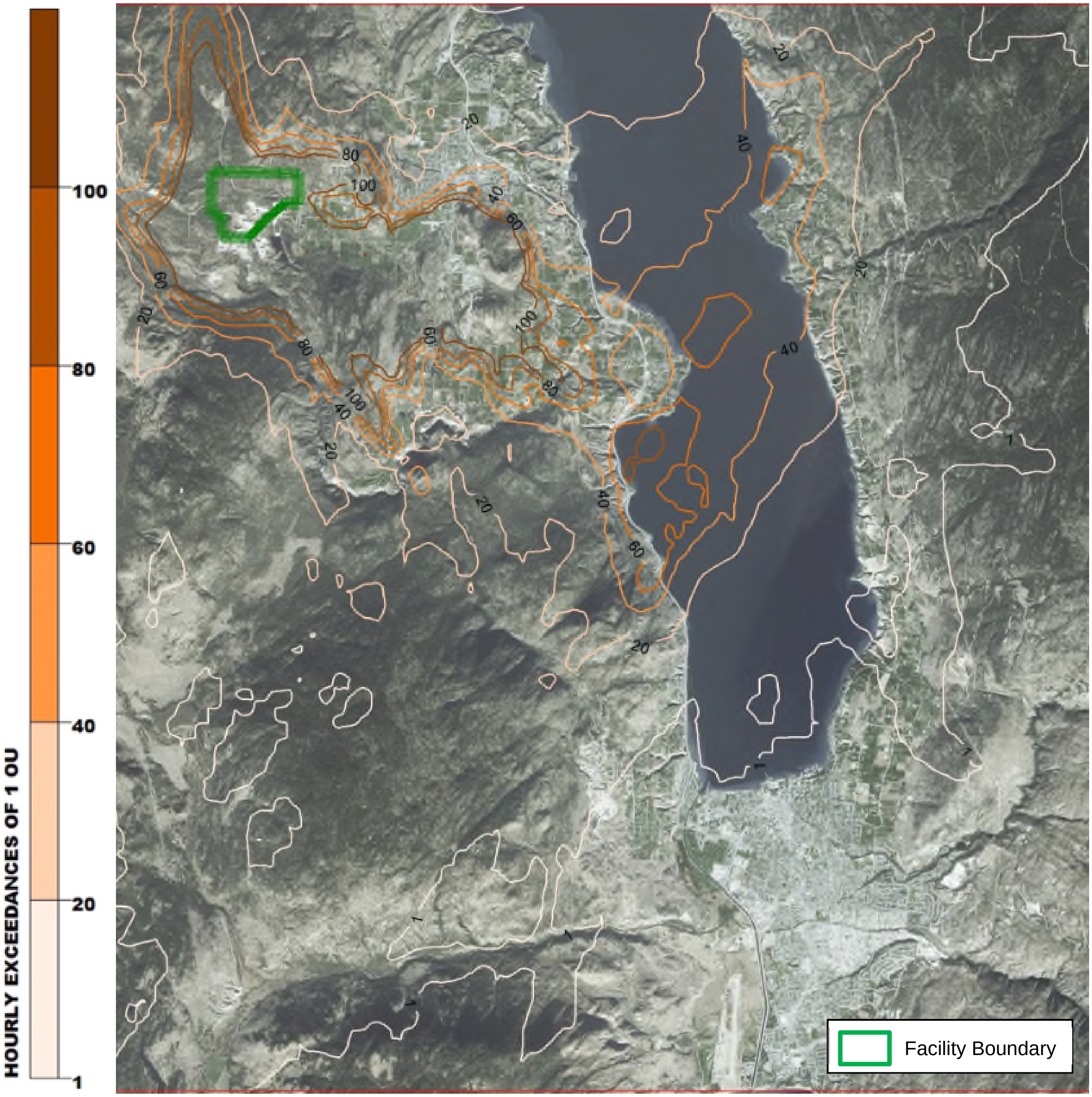


**Figure 29: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (ASP - Regional with RDCO Biosolids)**

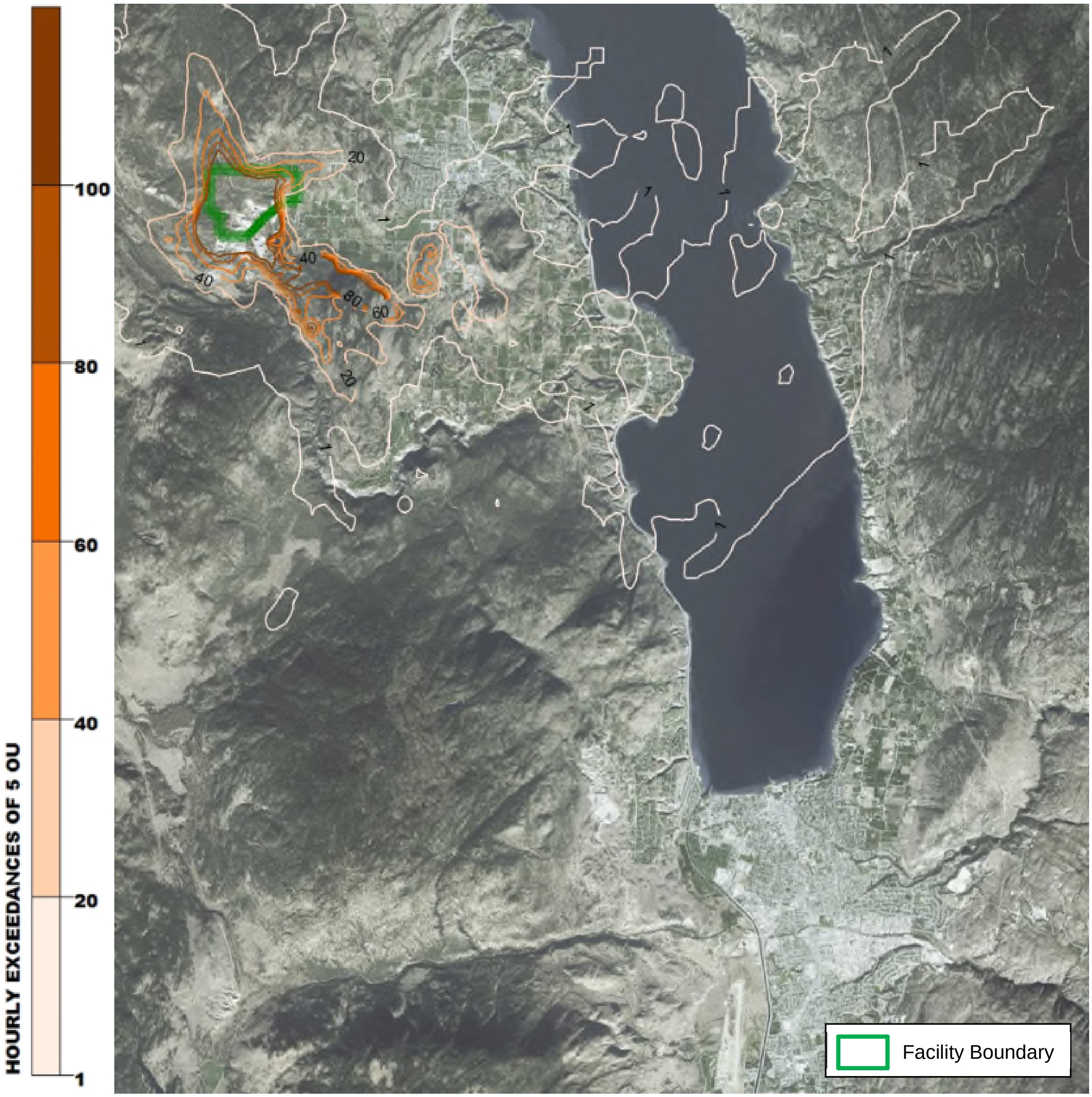


**Figure 30: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (ASP - Regional with RDCO Biosolids)**

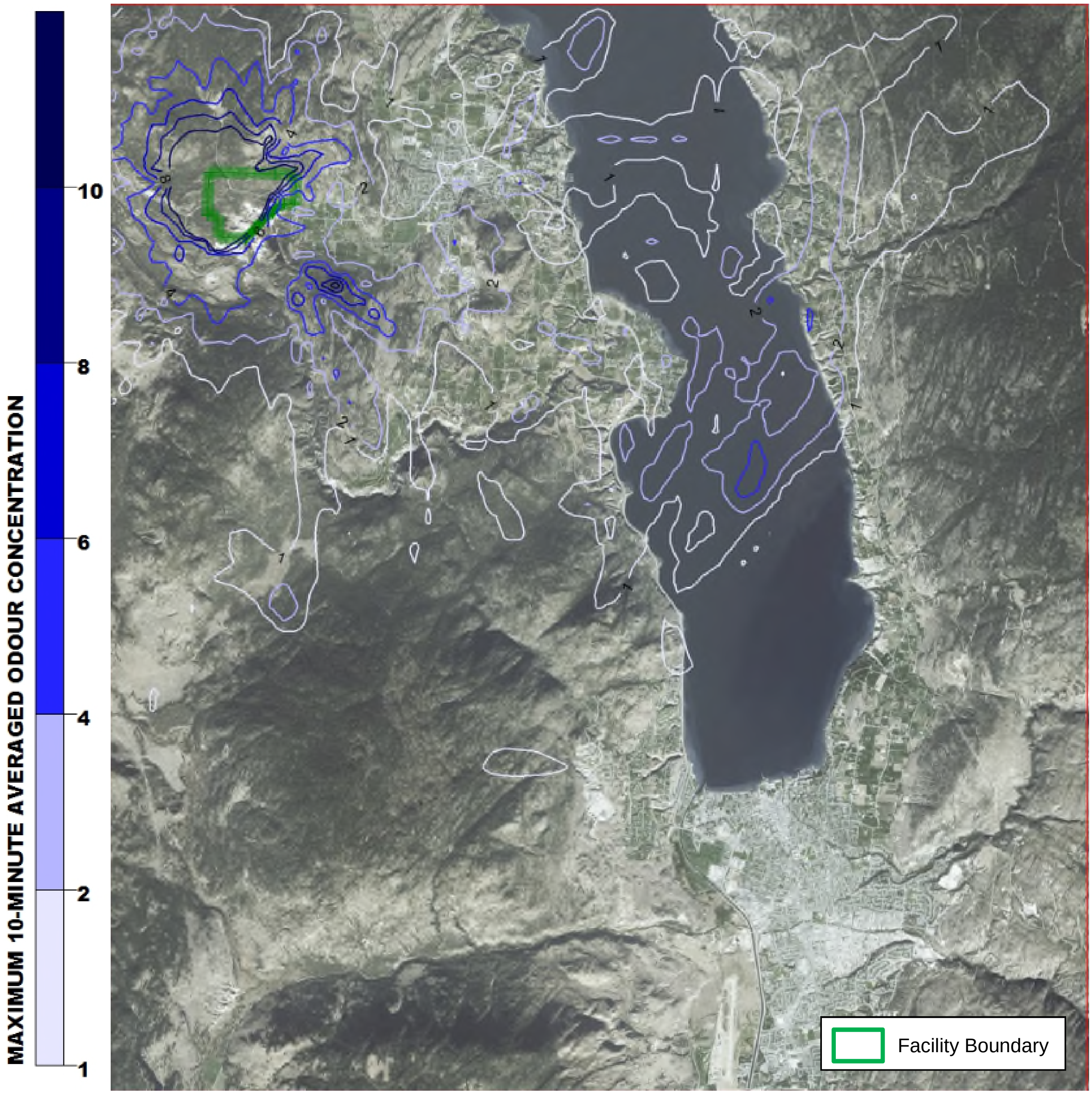


**Figure 31: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Covered ASP - Regional with RDCO Biosolids)**

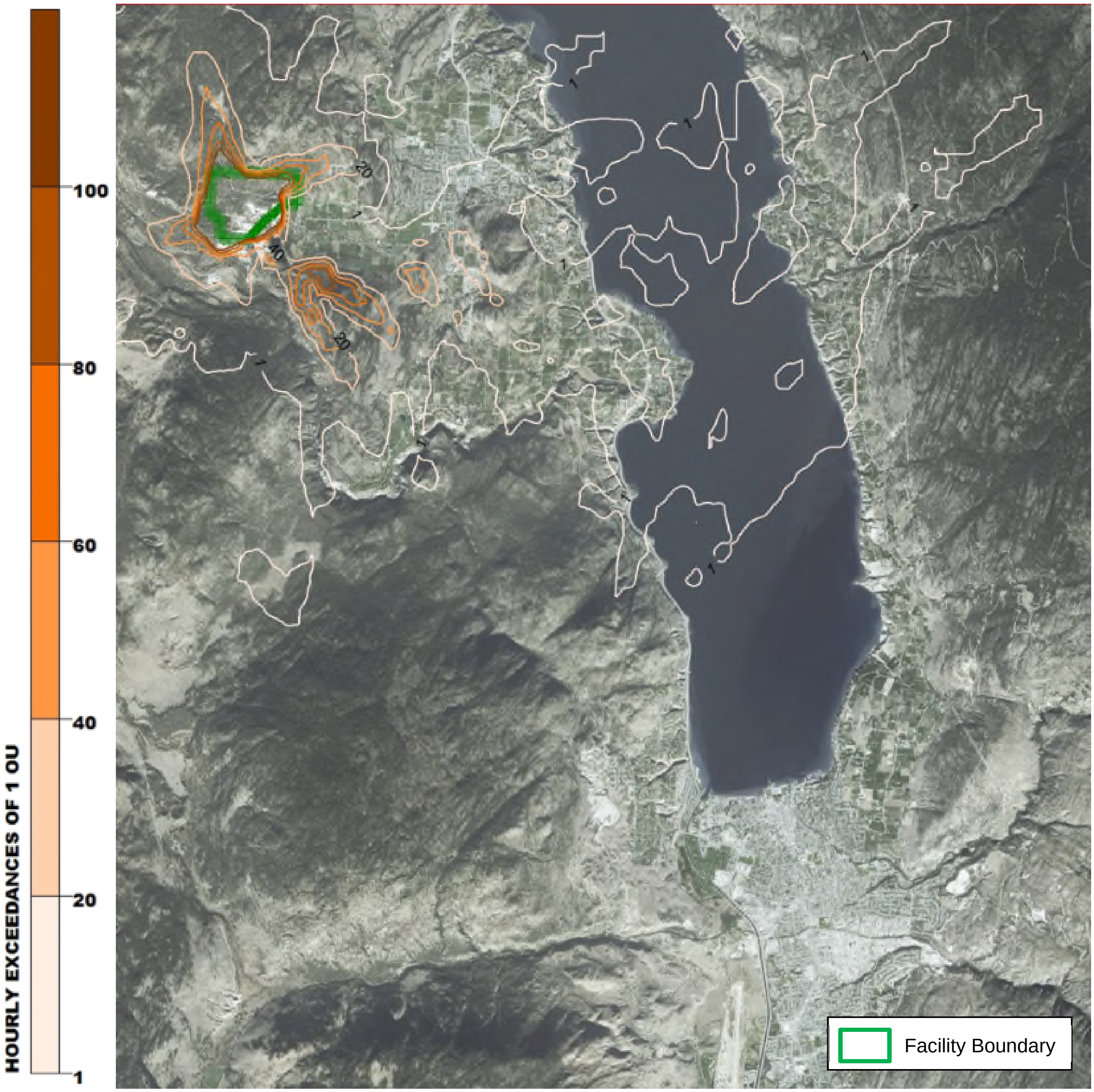


**Figure 32: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Covered ASP - Regional with RDCO Biosolids)**

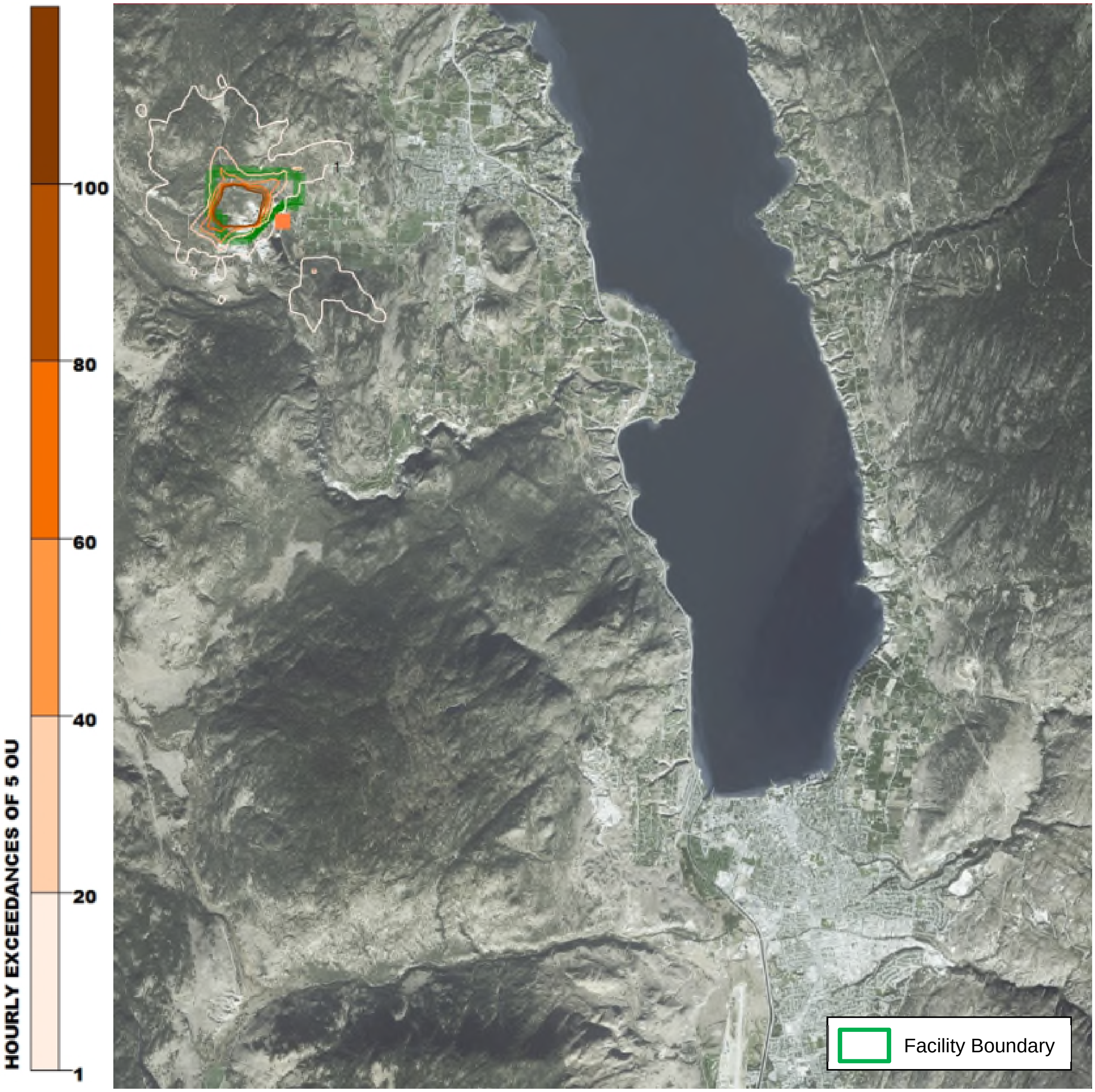


**Figure 33: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (Covered ASP - Regional with RDCO Biosolids)**

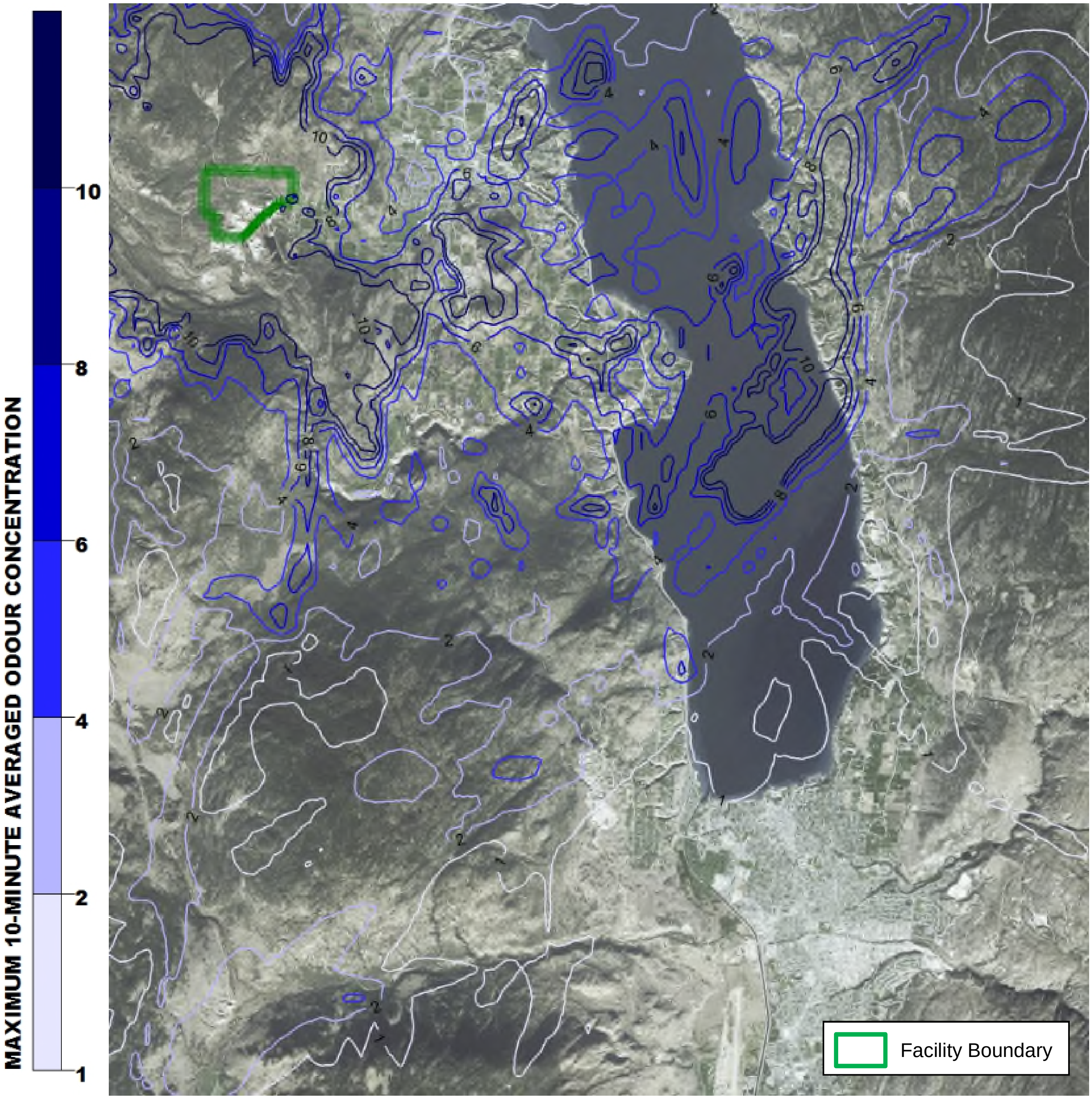


**Figure 34: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (In-Vessel - Regional with RDCO Biosolids)**

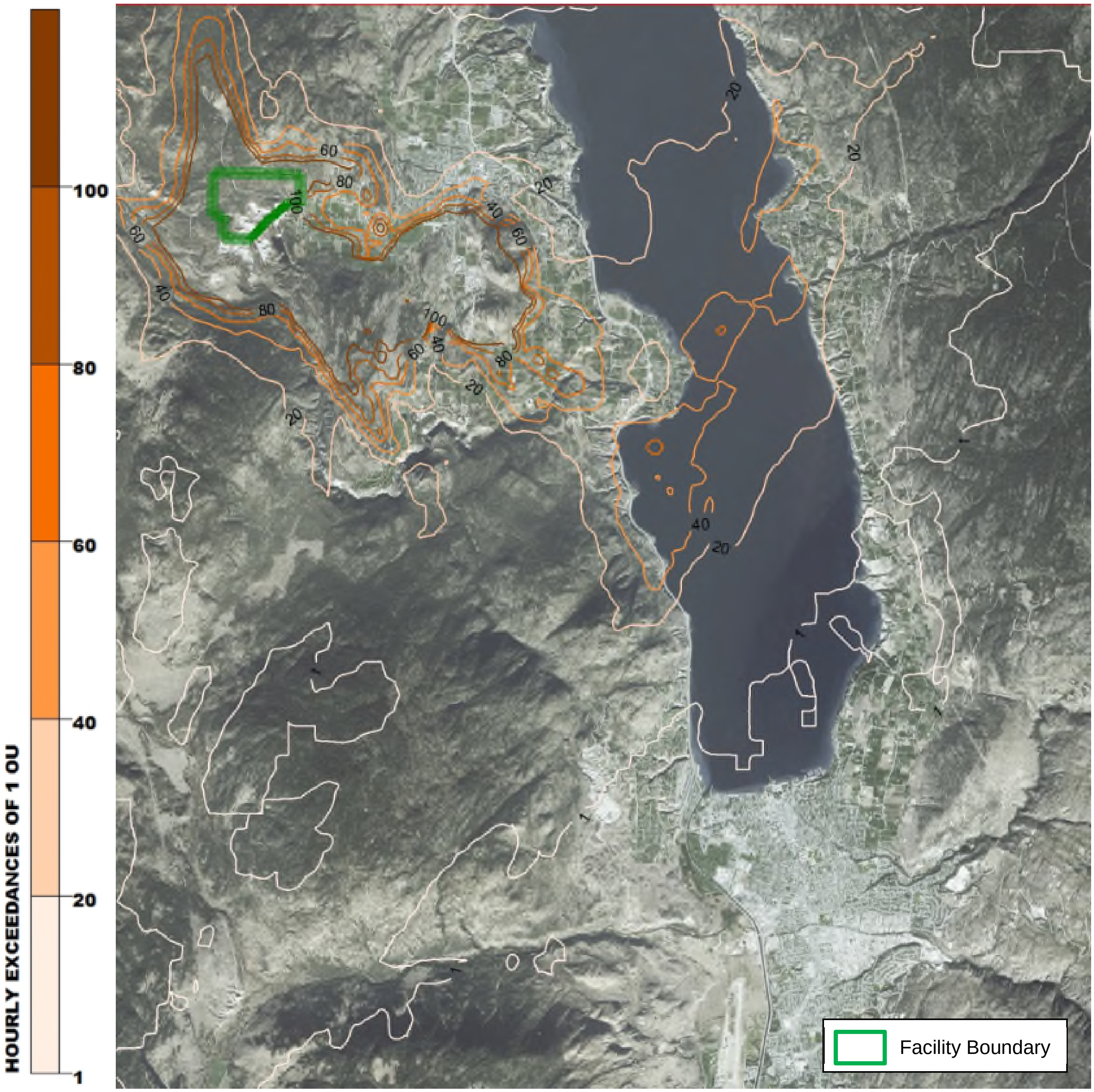


**Figure 35: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (In-Vessel - Regional with RDCO Biosolids)**

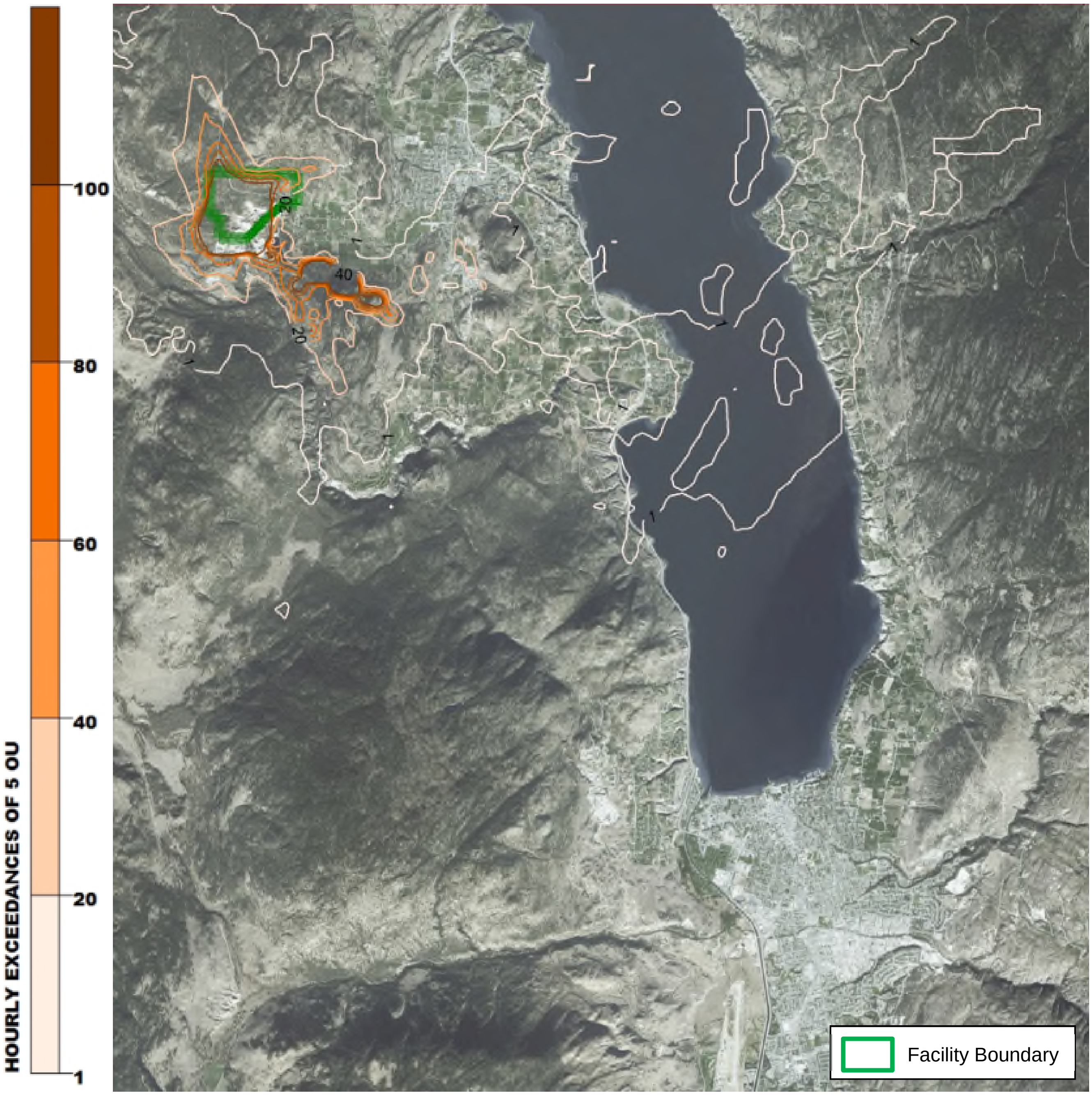


**Figure 36: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (In-Vessel - Regional with RDCO Biosolids)**

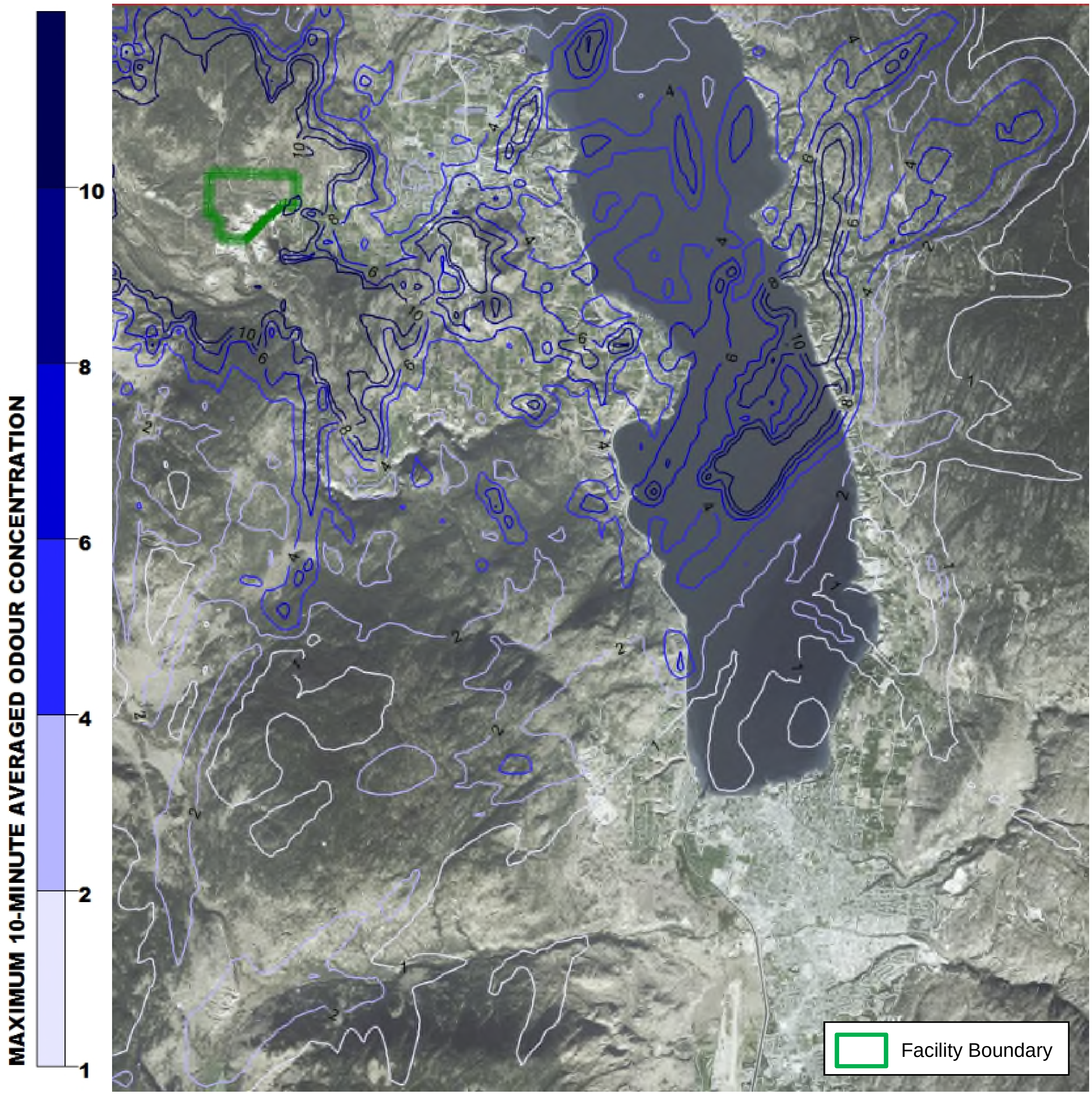


**Figure 37: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (AD - Regional with RDCO Biosolids)**

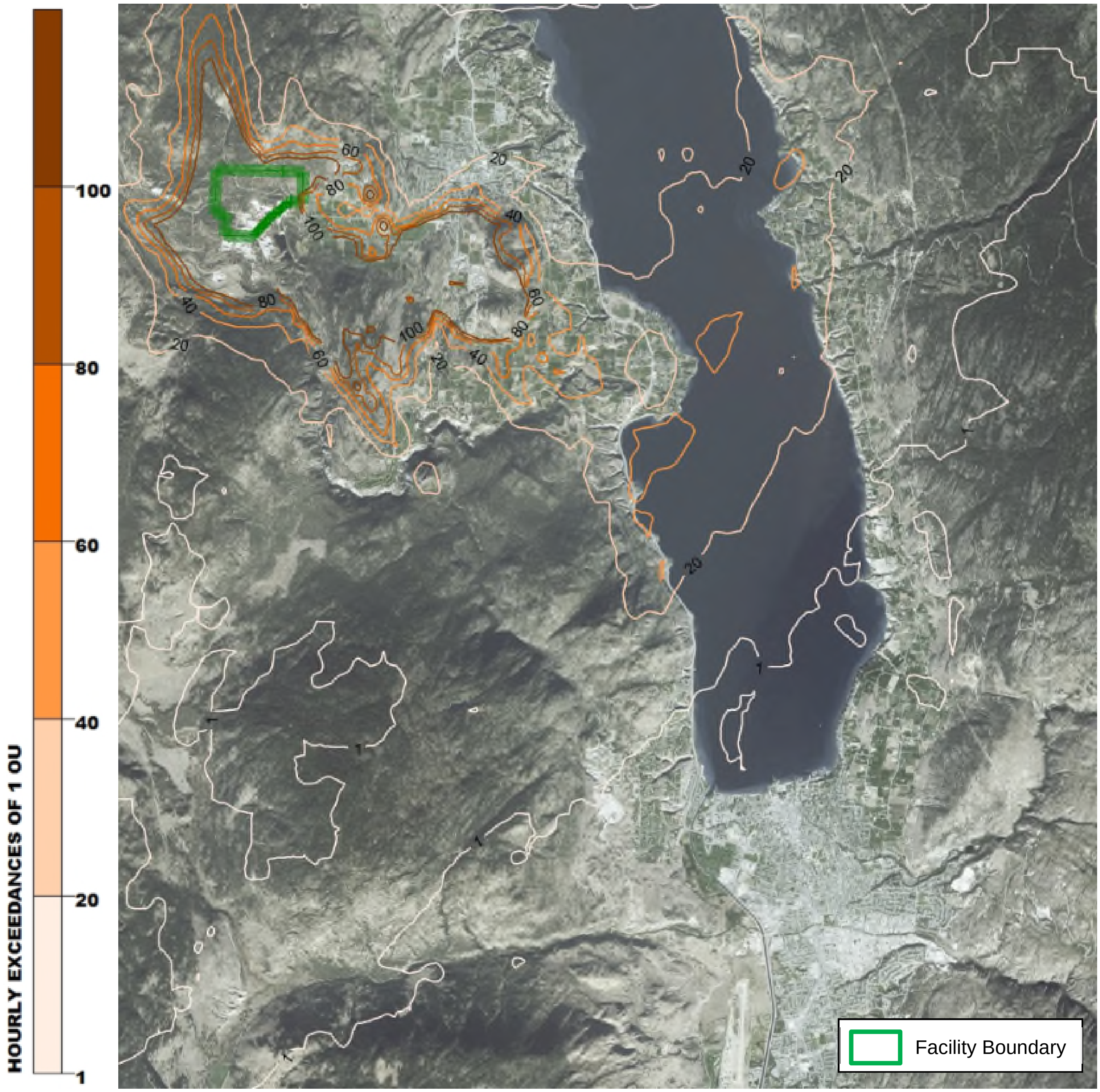


**Figure 38: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (AD - Regional with RDCO Biosolids)**

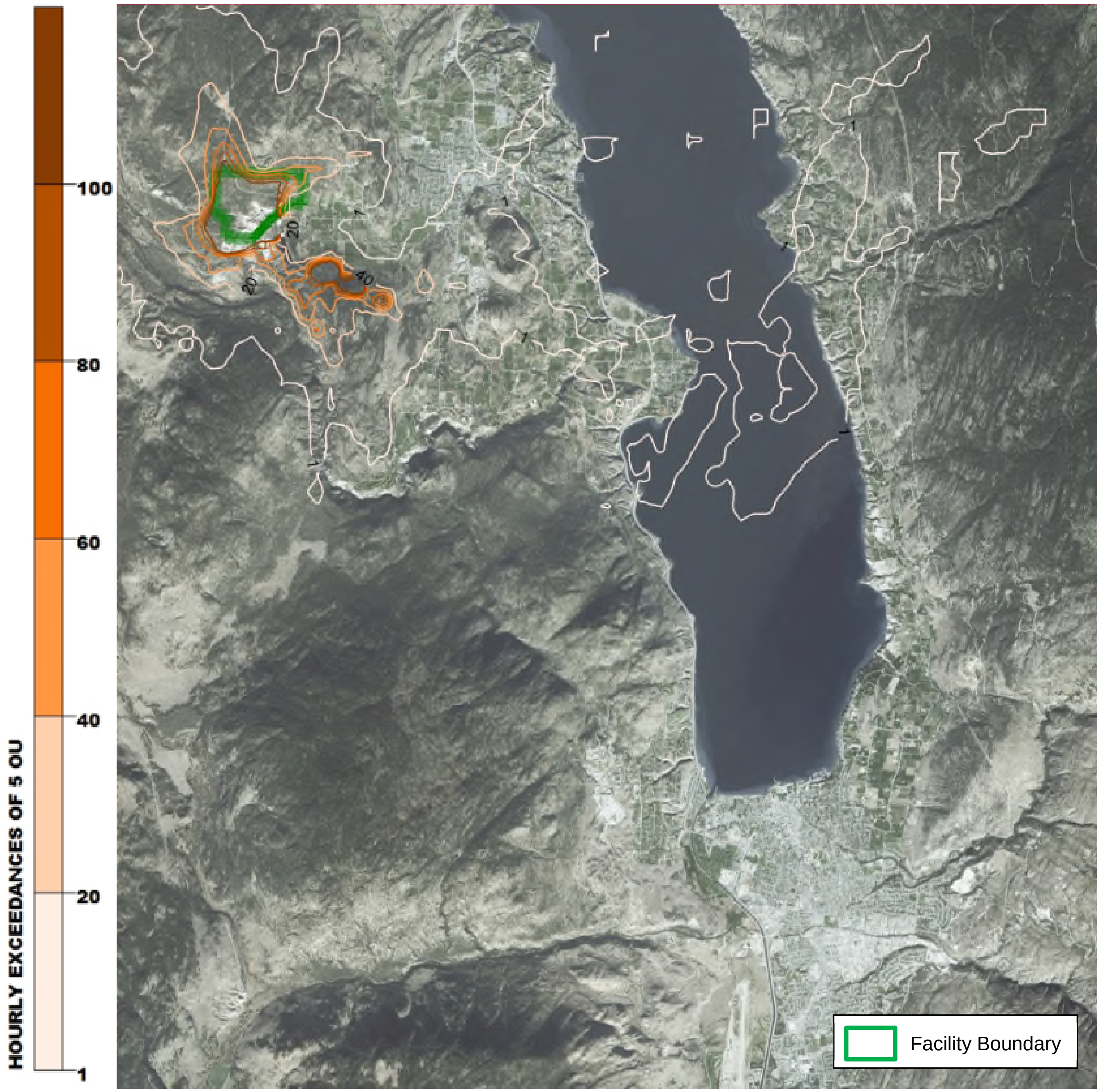


**Figure 39: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (AD - Regional with RDCO Biosolids)**

# OKANAGAN FALLS LANDFILL

# 1.0 INTRODUCTION

The following is a summary of model inputs and odour modelling results conducted for the purpose of assessing potential odour impacts from an organics management facility located at Okanagan Falls Landfill (hereafter referred to as the "Site"). Odour modelling was conducted using CALPUFF, an advanced air modelling software system recommended by the British Columbia Ministry of Environment (BC MOE).

# 2.0 MODEL INPUTS AND ASSUMPTIONS

## 2.1 Meteorology

The air dispersion model CALPUFF contains a diagnostic meteorological processor, CALMET, which creates a three-dimensional meteorological field over the spatial extent of the model. The data produced by CALMET is used by CALPUFF in its dispersion and plume transport calculations. Inputs to CALMET include the following:

- a geophysical grid, constructed using gridded terrain and land cover data (obtained from GeoGratis – Government of Canada); and
- a combination of prognostic (three-dimensional meso-scale model called MM5) meteorological data and hourly surface observations obtained from Environment Canada and BC MOE meteorological stations.

When CALMET is run in "no-observations" mode (using only MM5), the surface station observations provide a validation of the CALMET meteorology, in particular winds, to ensure representativeness. As MM5 is a meso-scale regional model, the grid used as input to CALMET is downscaled in three steps from a 32 km resolution grid to a 4 km grid and downscaled again within CALMET to the CALPUFF grid size (250 m). It is not expected that the meteorological time series in CALMET will exactly reproduce observed conditions on an hour by hour basis at any particular grid point, however it is expected to be representative of the general conditions over a given year.

Table 2.1 summarizes the meteorological inputs to CALMET used in the Okanagan Falls Facility odour modelling and mapping exercise.

### Table 2.1: CALMET Inputs and Metadata

| Parameter | Usage |
|---|---|
| Surface Stations | None |
| Upper Air Soundings | None |
| Prognostic Data | 4 km resolution MM5 |
| Meteorological Grid | 10 km (east-west) x 10 km (north-south) at 250 $m^2$ |
| Grid Centrepoint | 315000 m, 5468500 m, UTM Zone 11 |
| Vertical Cells (Cell Face Heights) | 10 (0 m, 20 m, 40 m, 80 m, 160 m, 320 m, 640 m, 1200 m, 2000 m, 3000 m, 4000 m) |
| Terrain Data | CDN DEM 15 min |
| Land Use Data | GeoBase Land Cover circa 2000-Vector |

As land cover characteristics over the modelling domain vary with season (e.g., albedo, Bowen ratio, etc.), seasonal CALMET files were created using the model's default seasonal geophysical properties for each land cover category contained within the geophysical grid. The date ranges assumed to define each season are listed in Table 2.2. Year-to-year variability will undoubtedly occur, however, this temporal approximation was used to simplify modelling based on Environment Canada 1981 – 2010 climate norms for the Okanagan-Similkameen region. The modelled year was 2012.

### Table 2.2: Geophysical Property Seasonality

| Season | Date Range |
|---|---|
| Winter | December 1 – February 28 (29) |
| Spring | March 1 – May 31 |
| Summer | June 1 – September 15 |
| Fall | September 15 – November 30 |

## 2.1.1 Meteorological Validations

### 2.1.1.1 Winds

Figure 2.1 is a snapshot of the CALMET-modelled surface winds on January 1, 2012 at $0^{00}$ hrs. The time and date of the snapshot was selected to show an example of the southerly Okanagan Valley flow condition which is a common occurrence, particularly in the winter. The figure also shows the boundary of the site (green border).

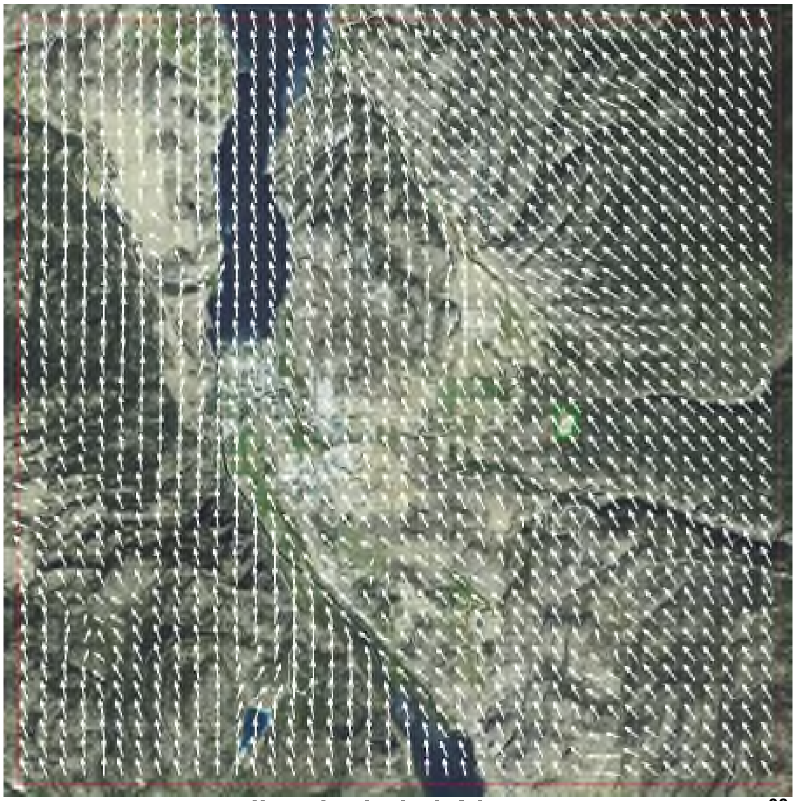

**Figure 2.1: CALMET-Predicted Wind Field – January 1, 2012, $0^{00}$ hrs**

Figure 2.2 shows the seasonal pattern to the CALMET-modelled winds at the facility location for summer (left) and winter (right). During winter, CALMET predicts winds at the facility are most commonly from the southeast as a result of the general southerly flow through the region filtering down into the valley from the Okanagan Highlands. During summer, the general regional flow is from the north, resulting in predominantly northeasterly winds at the facility filtering down into the valley from the Okanagan Highlands.

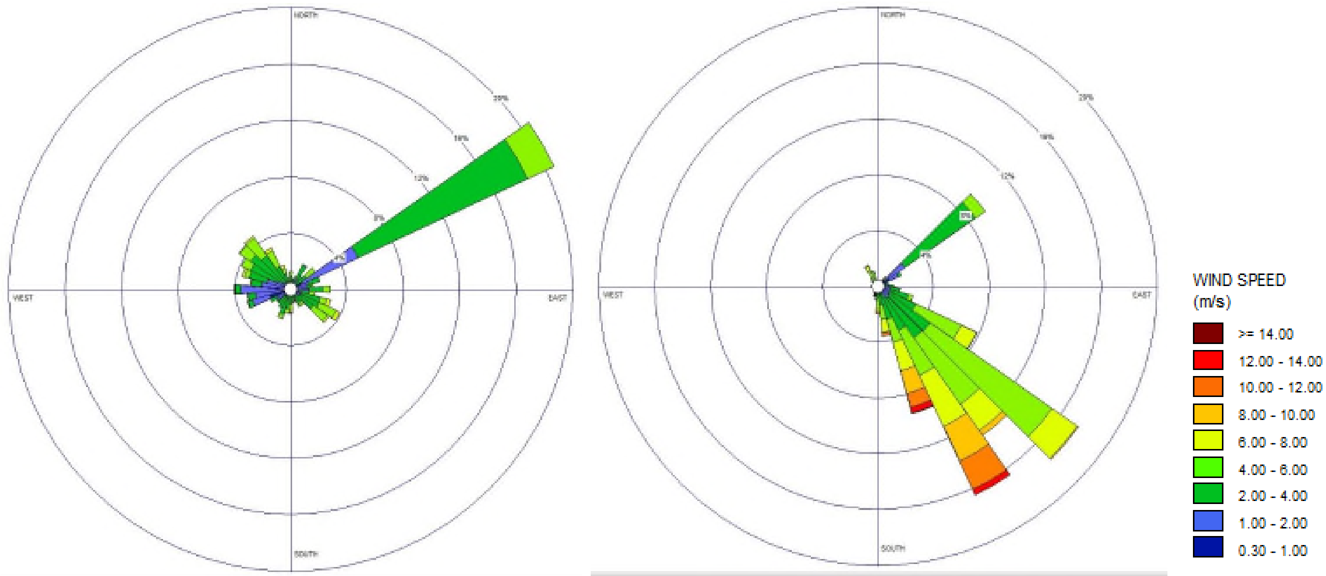


**Figure 2.2: CALMET-Predicted Seasonal Wind Roses at Okanagan Falls Facility: Summer (left) and Winter (right)**

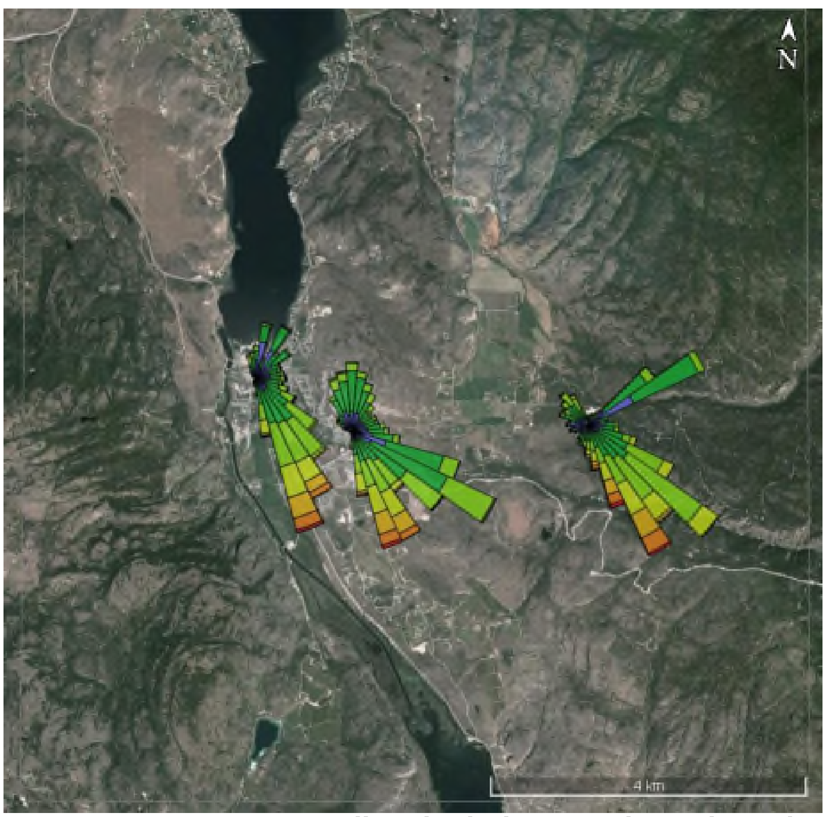


**Figure 2.3: Annual CALMET-Predicted Wind Roses through Model Domain**

Figure 2.3 shows the general spatial pattern to winds over the town of Okanagan Falls as annual wind roses for the CALMET predictions.

#### 2.1.1.2 Mixing Height

The atmospheric mixing height can be defined as the top of the layer in the lower atmosphere, within which an emitted species, in this case odour, is readily mixed through turbulence and convective processes. Therefore, when the mixing height is low, higher ground-level concentrations will generally be predicted. Figure 2.4 are time series of modelled mixing heights extracted from CALMET over two distinct seasonal periods in 2012 over Okanagan Falls. The top figure (red) plots a time series of mixing heights in the winter (between February 1 and 8), while the lower figure (blue) plots mixing heights in the summer (between July 1 and 8).

Seasonal contrast is strongly evident since there is reduced solar radiation, lower temperatures and snow cover, among other factors during the winter that results in generally lower mixing heights, and thus resulting in higher concentrations of odour. Both figures show the expected strong diurnal pattern, with mixing heights dropping quite close to the ground surface (~50 m as a default in CALMET) at night. When overnight mixing heights are higher, it is due to turbulence induced by higher wind speeds over uneven terrain.

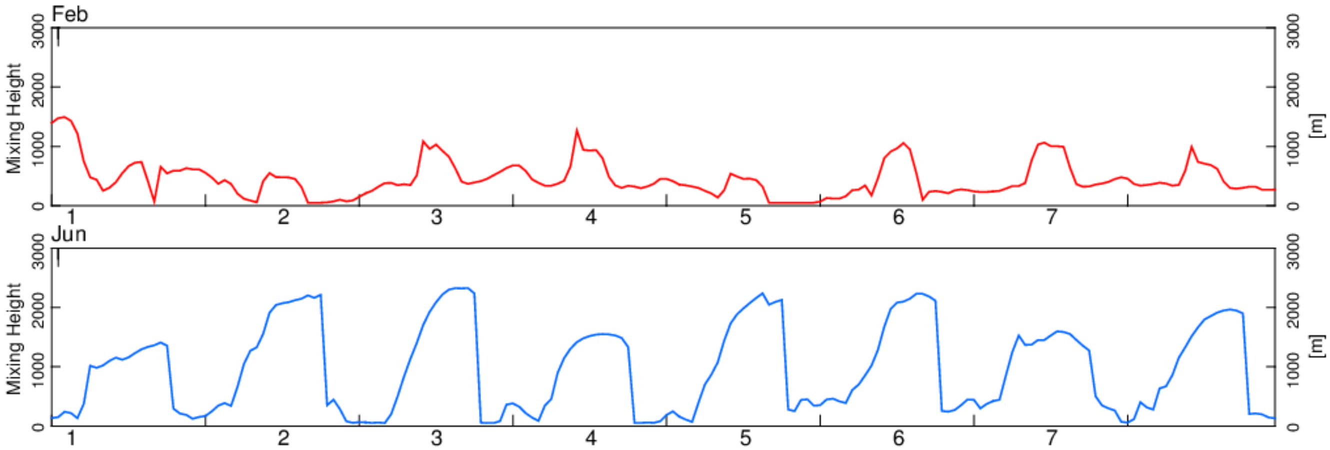


**Figure 2.4: CALMET-Modelled Mixing Heights for Winter (Red) and Summer (Blue)**

### 2.2 Area Sources and Emission Factors

The site layouts from the *Organics Management Consultant Task 2 – Feasibility Assessment* report for Okanagan Falls were used to define the boundaries of the odour sources for this modelling analysis. Areas that generate odours were assigned a specific emission factor according to the activity taking place (e.g. composting, curing, pile turning, etc.). In the main report, Table 2.1 provides a description of the emission factors used for each of the scenarios below:

- Current operations (static piles of yard waste and with small amounts of biosolids);
- Aerated static pile (ASP);
- Membrane covered aerated static pile; and
- In-vessel composting.

Emissions were assumed to occur homogeneously over the entirety of the area source. Some odour emissions (e.g. pile turning, pile moving, etc.) were assigned a diurnal variation based on the expected times of day the activity is to be performed (Table 2.1 of the main report). Such activities are expected to occur daily at the Site over a one- to two-hour period, however since the activity may occur at any time during the operational hours of the facility in the morning or in the afternoon, odour emissions were assumed in the model to occur between $10^{00}$ to $12^{00}$ – representing a time of day when vertical mixing is generally highest – and between $15^{00}$ to $17^{00}$ – when, during the winter, the mixing height is approaching its night time minimum, thus resulting in higher concentrations closer to the ground. This is a somewhat conservative approach since the activity may only be occurring over a portion of a single hour rather than four, may not take place every day, and peak odour emission would only occur during and immediately following the activity and decay in the hour following. It should be noted that odour emissions produced from pile building and moving are inconsequential compared to that produced from the biofilters which emit odour continuously.

Emission heights were either assigned a value of 3 m or 1 m depending on the activity occurring within the area source. Specific heights used for the various activity types are listed in Table 2.1 of the main report.

## 2.3 CALPUFF Settings and Assumptions

The CALPUFF model input settings were assigned with consideration to the recommendations in Table 9.7 of '*Recommended CALPUFF Input Group 2 Switch Settings*' in '*Guidelines for Air Quality Dispersion Modelling in British Columbia*'. Generally, default model settings were used. Since the area of interest is in the near-field (within 12 – 15 km of the source), dispersion coefficients were internally calculated using micrometeorological variables (MDISP = 2) based on estimates of the crosswind and vertical components of turbulence based on similarity theory and the land cover type. The probability distribution function (PDF) was used for dispersion under convective conditions (MPDF = 1) which explicitly accounts for the differences in the distribution and strengths of up and down drafts within the convective boundary layer, reporting the average between the two. By using these two settings, AERMOD-type dispersion is simulated (generally accepted as better-predicting in the near-field than CALPUFF), while also providing the benefit of a puff model and allowing for the effects of complex terrain.

The receptor grid spacing was 250 m at ground level over the entire grid. The simulations were to determine the general effects downwind from the facility, on the scale of kilometres, and therefore did not consider building downwash – the drawdown of the odour plume downwind of facility buildings due to turbulence.

# 3.0 RESULTS

Since the time step of the meteorological data is one-hour, CALPUFF can only output one-hour averaged predictions of odour concentration. However, since odour perception is on a much shorter scale, an averaging time-scalar must be applied to assess shorter-term peak concentrations due to plume meandering within the hourly period. Hourly odour concentrations are scaled to a ten-minute averaging period using Equation 1.

$$Cp = Co * \left(\frac{t_o}{t_p}\right)^{0.28} \qquad (1)$$

Pursuant to Equation 1, $t_o$ is the 60 minute averaging time, $t_p$ is the short-term averaging time (10 minutes) and $C_o$ and $C_p$ are the respective peak concentrations (BC MOE). The scalar when converting from hourly to ten-minute average concentrations equates to 1.65.

## 3.1 Odour Units

An Odour Unit is a way of quantifying odours through the use of an odour panel that consists of a group of people with 'calibrated noses'. The definition of an Odour Unit is based on the proportion of odour panel members that can detect the smell of a substance. One OU represents the concentration of a particular substance when 50% of the odour panel can detect the odour. This is called the perception threshold[1]. At this point, although an odour may be detected, it is not distinct enough to be able to identify the type of odour.

The Odour Unit scale is based on dilutions, as shown in the following figure. As the number of odour units increase, more people can detect the odour, and the intensity of the odour increases. Five OU is considered a faint odour and ten OU is considered a distinct odour (the point when some people can identify the type of odour, or its potential source)[2].

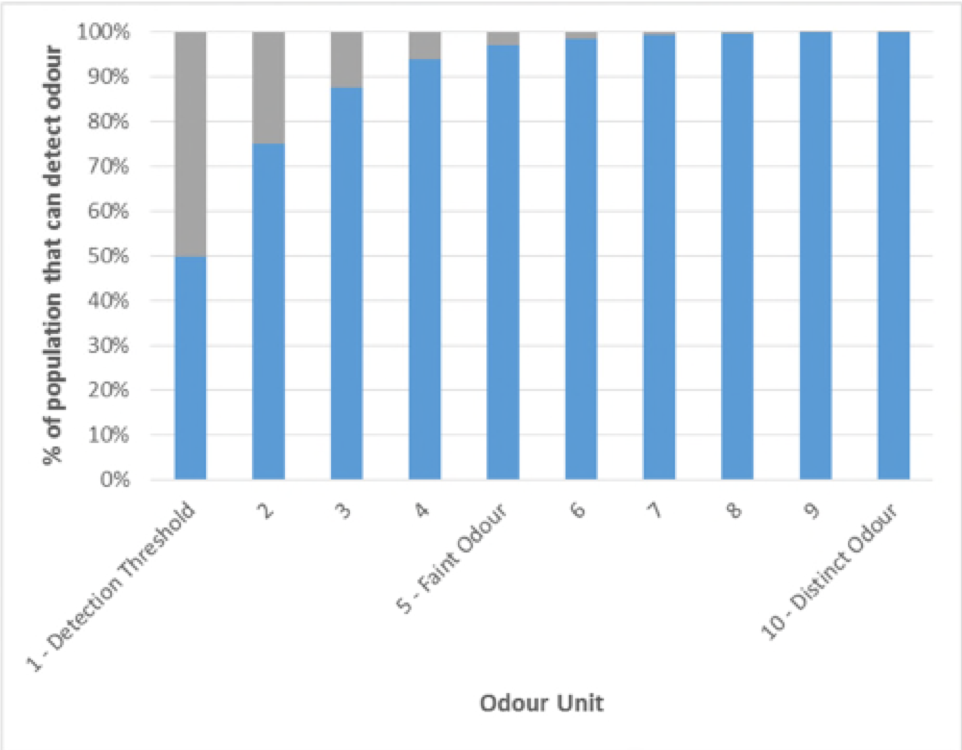


**Figure 3.1: Odour Unit Scale**

There are currently no guidelines for odour limits for composting facilities in British Columbia, however, some wastewater treatment facilities have imposed odour limits. For example, the standard in Metro Vancouver is no more than five OU at the property line. In other jurisdictions, the guideline is to have no detectable odour at the property line. At the Ogogrow facility in Vernon, BC, the limit is 50 OU at the property line.

## 3.2 Odour Maps

Odour maps are included as part of Appendix A. For each organics processing option listed in Section 2.2, odour modelling results are presented as three different plots:

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1 http://blog.odotech.com/odor-unit-perception-threshold

2 Odours and VOCs: Measurement, Regulation and Control Techniques (2009). Kassel University Press.

- Maximum Odour Concentrations – The maximum predicted 10-minute odour concentration at each receptor point over the course of the modelled year. This is displayed as a contour plot showing the maximum predicted 10-minute averaged odour concentration at every ground level receptor point over the entire one-year simulation (8784 hours) as a blue gradient (light to dark). The 1 OU contour is white. The highest levels >10 OU are dark blue. The facility boundary is shown as a green outline.
- Hourly Exceedances >1 Odour Unit (OU) – The number of hours over the course of the modelled year where an odour threshold of 1 OU was exceeded in a ten-minute averaged concentration. This is displayed as a contour plot showing the number of times the predicted 10-minute odour concentration exceeded 1 OU over the modelled year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to 50% of the population being able to detect odour produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.
- Hourly Exceedances >5 OU – The number of hours over the course of the modelled year where an odour threshold of 5 OU was exceeded in a ten minute averaged concentration. This is displayed as a contour plot showing the number of times the predicted 10-minute odour concentration exceeded 5 OU over the modelled year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to when a faint odour is produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.

## 3.3 Results Summary

The odour maps presented in Appendix A show: (1) the magnitude and spatial extent of maximum ground level odour, and (2) the number of exceedances of odour detection thresholds for the technologies assessed. The membrane covered aerated static pile results had the least odour issues.

The following table summarizes the results of the odour mapping exercise based on the predicted maximum odour and number of hours of odour exceedances at a location 480 m northwest of the property boundary representing the resident that is closest in proximity to the Site (49.341783˚, -119.524847˚), Figure 3.2.

### Table 3.1: Results Summary based on Closest Receptor Point

| Scenario | Maximum Predicted 10-min Odour | Odour Exceedance >1 OU (hours per year) | Odour Exceedance >5 OU (hours per year) |
|---|---|---|---|
| Current Operations | 0 OU | 0 | 0 |
| Aerated Static Pile | 0.43 OU | 0 | 0 |
| Membrane Covered Aerated Static Pile | 0.02 OU | 0 | 0 |
| In-Vessel | 0.89 OU | 0 | 0 |


**Figure 3.2: Location of Discrete Receptor (49.341783˚, -119.524847˚)**

### 3.3.1 Biofilter Effect

The Membrane Covered Aerated Static pile has the lowest odour emissions of the technologies as this type of operation does not use a biofilter. The greatest source of odour emissions can be attributed to the biofilters, as seen in Table 3.2.

**Table 3.2: Odour Emissions from Biofilters**

| Scenario | % of Odour from Composting Biofilter |
|---|---|
| Current Operations | N/A |
| Aerated Static Pile | 97% |
| Membrane Covered Aerated Static Pile | N/A |
| In-Vessel | 99% |

# APPENDIX A

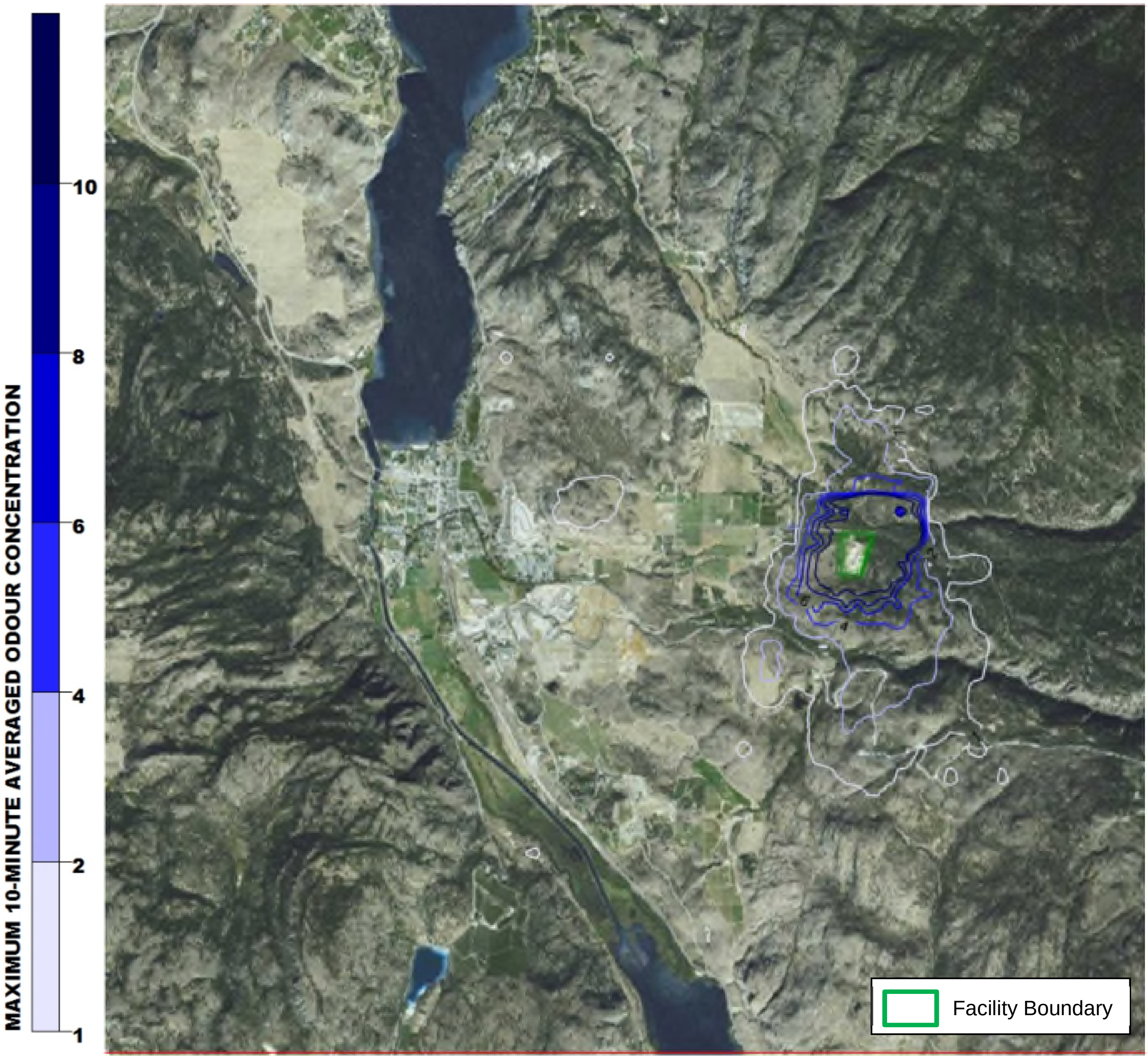


**Figure 1: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (ASP)**

Note: Exceedances of 1 OU for current operations were not observed in the model, therefore figures were not presented.

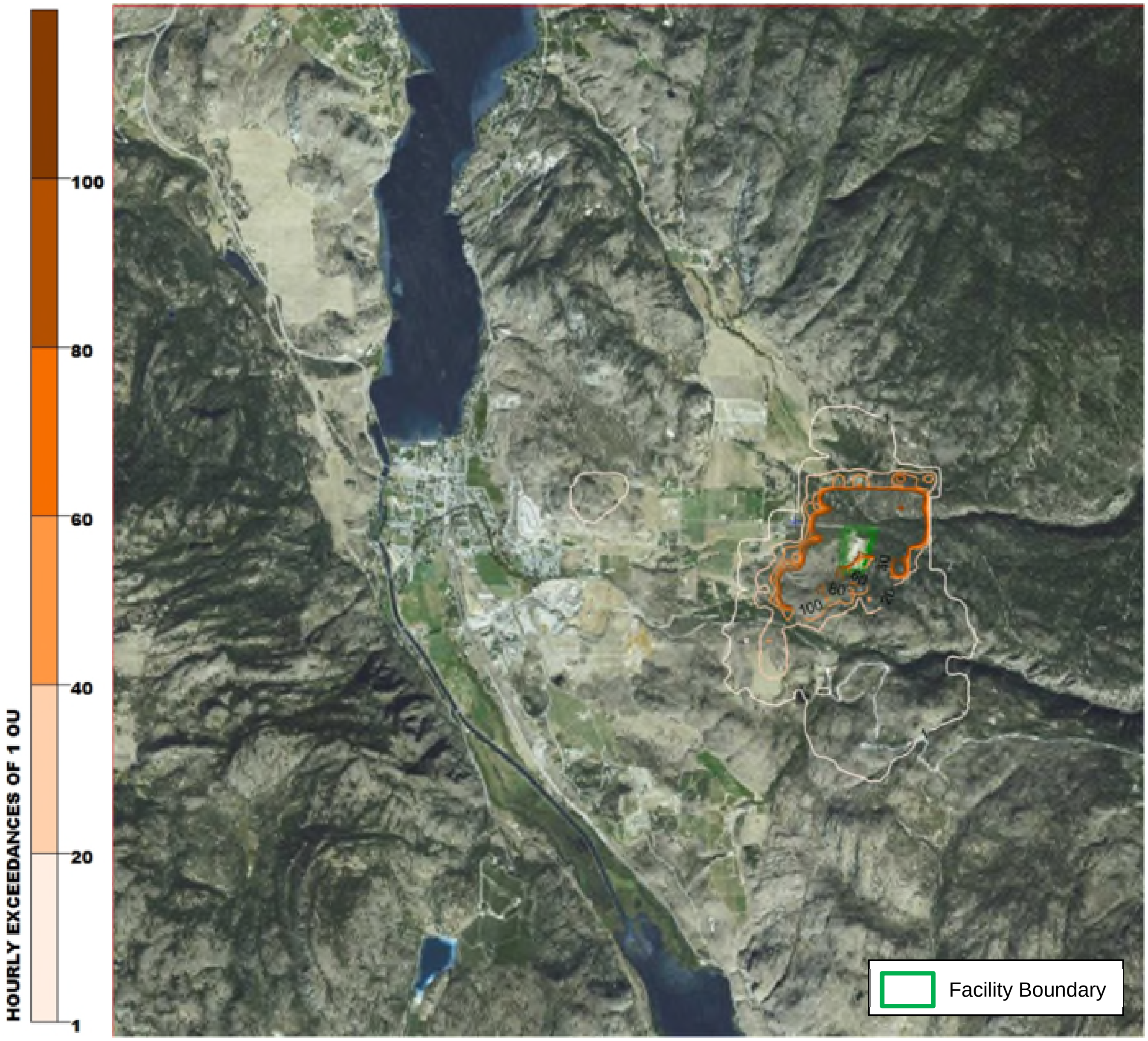


**Figure 2: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (ASP)**

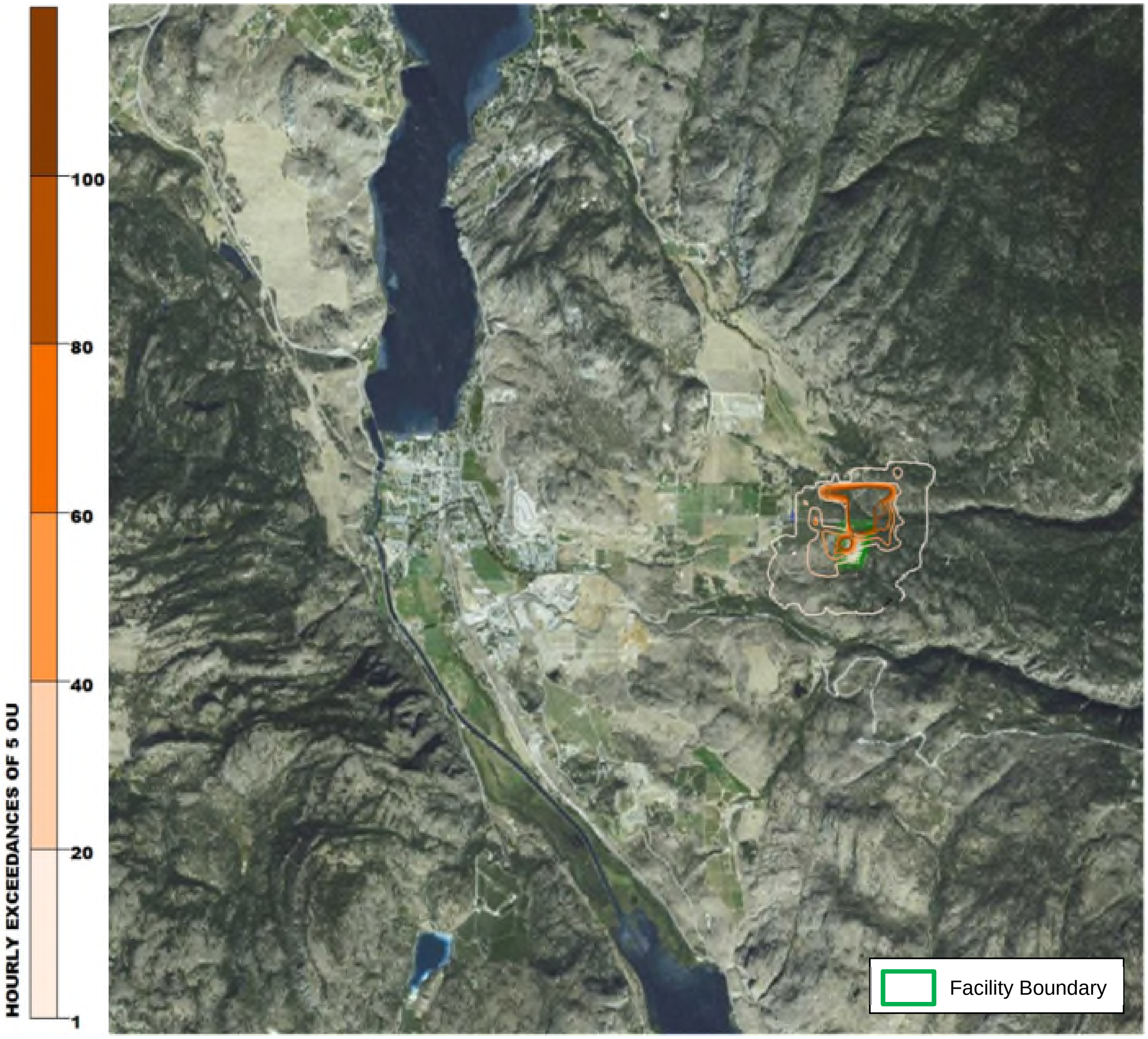


**Figure 3: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (ASP)**

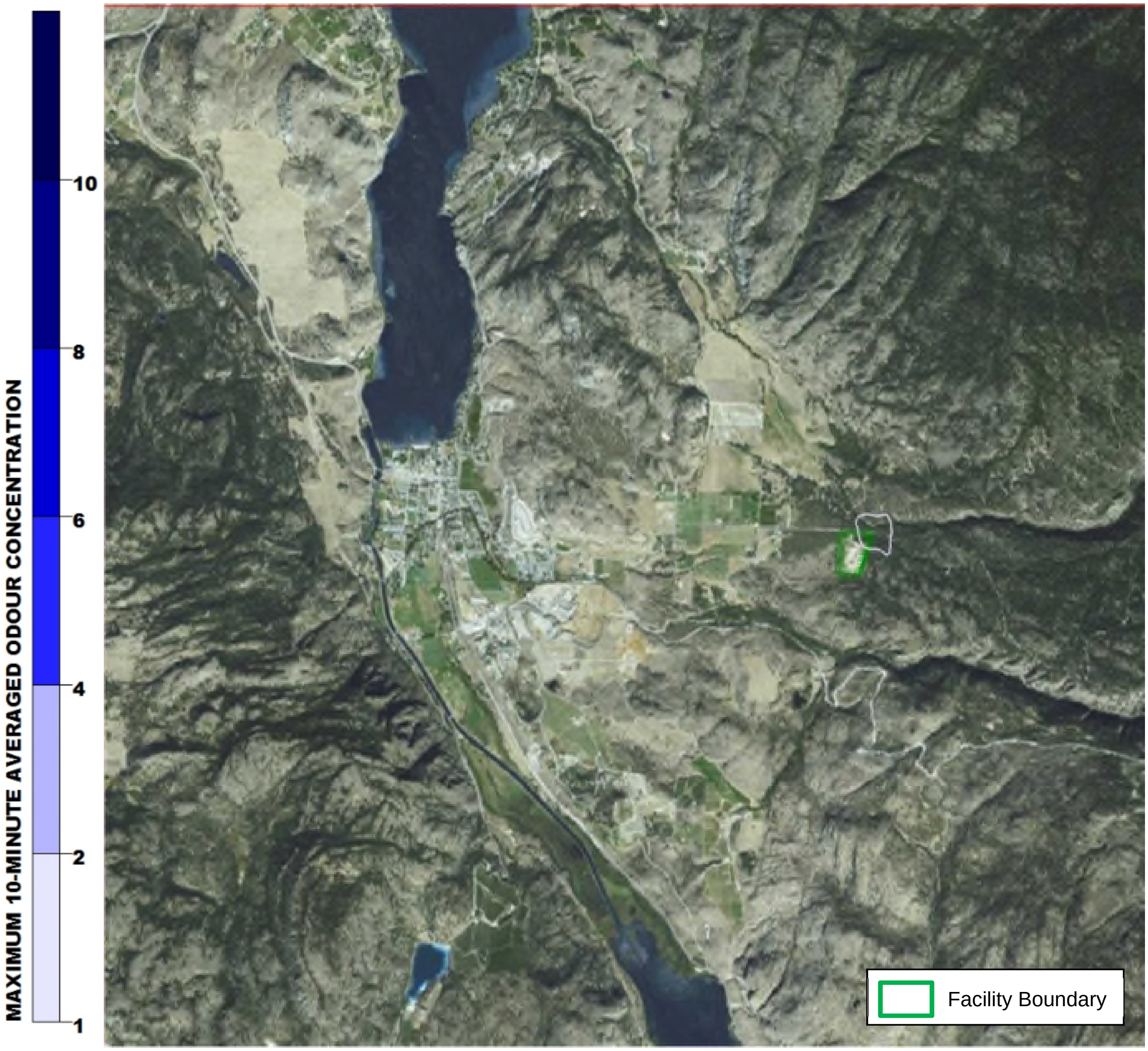


**Figure 4: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Covered ASP)**

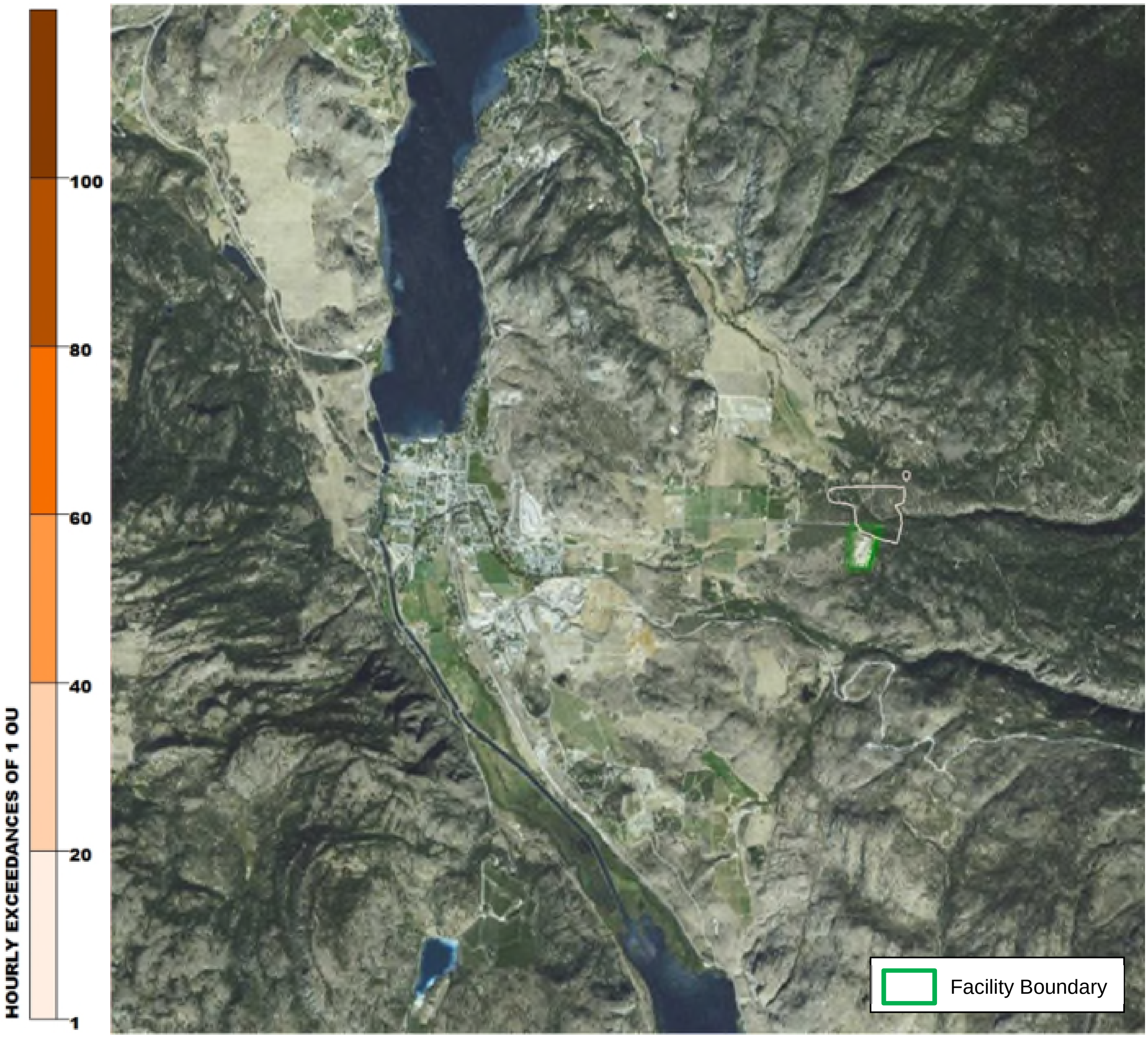


**Figure 5: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Covered ASP)**

Note: Exceedances of 5 OU for covered ASP were not observed in the model, therefore a figure was not presented.

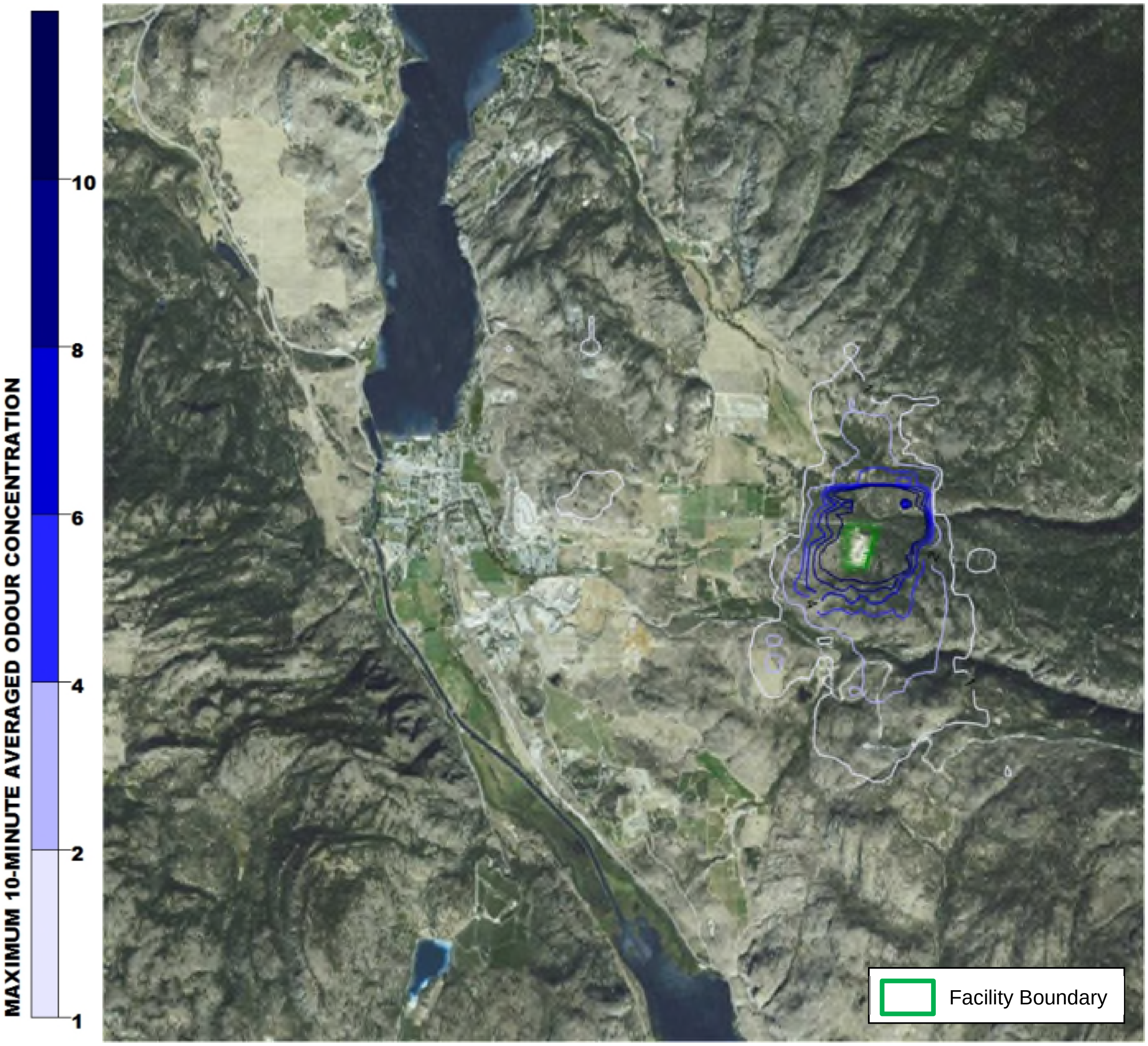


**Figure 6: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (In-Vessel)**

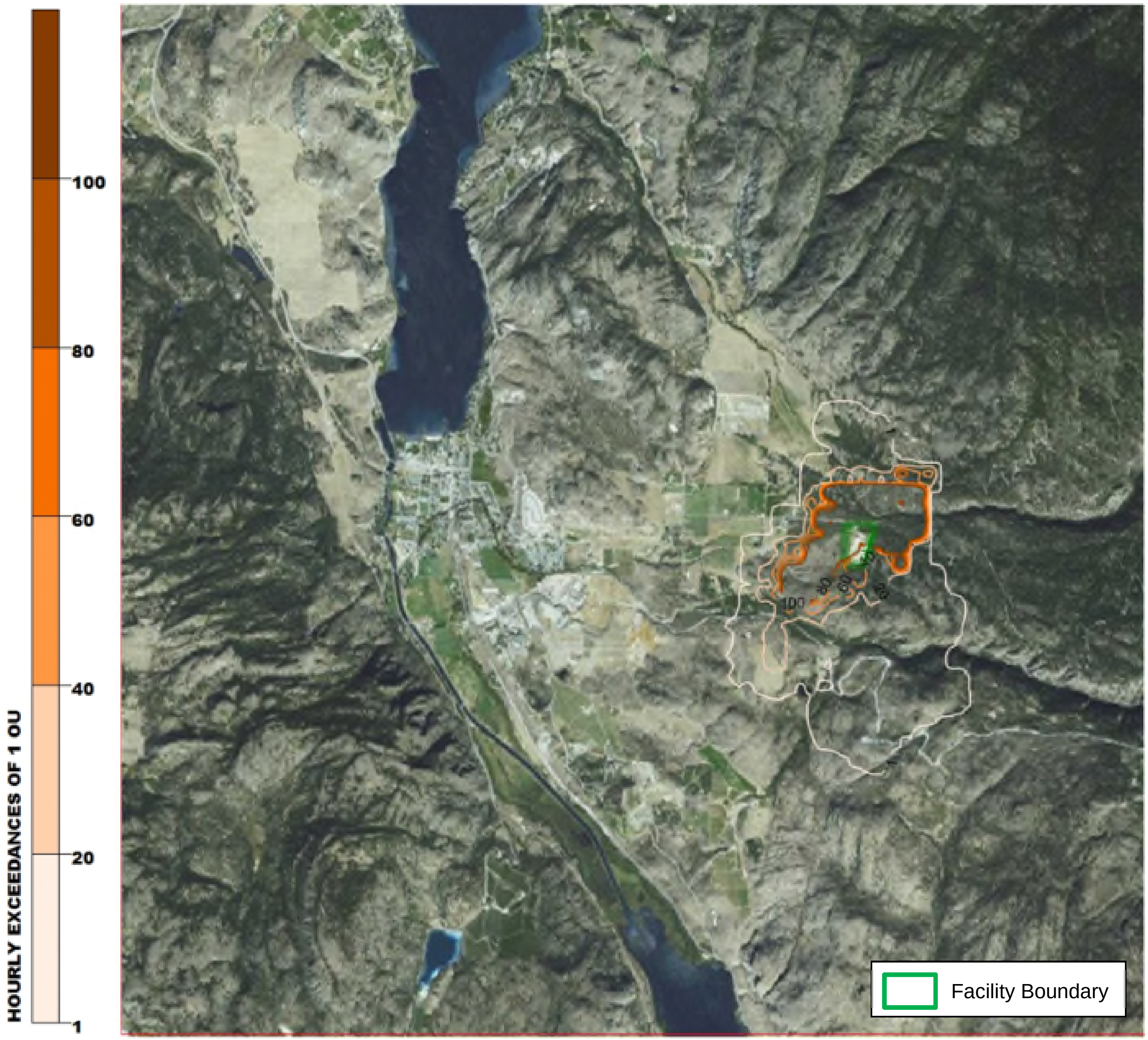


**Figure 7: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (In-Vessel)**

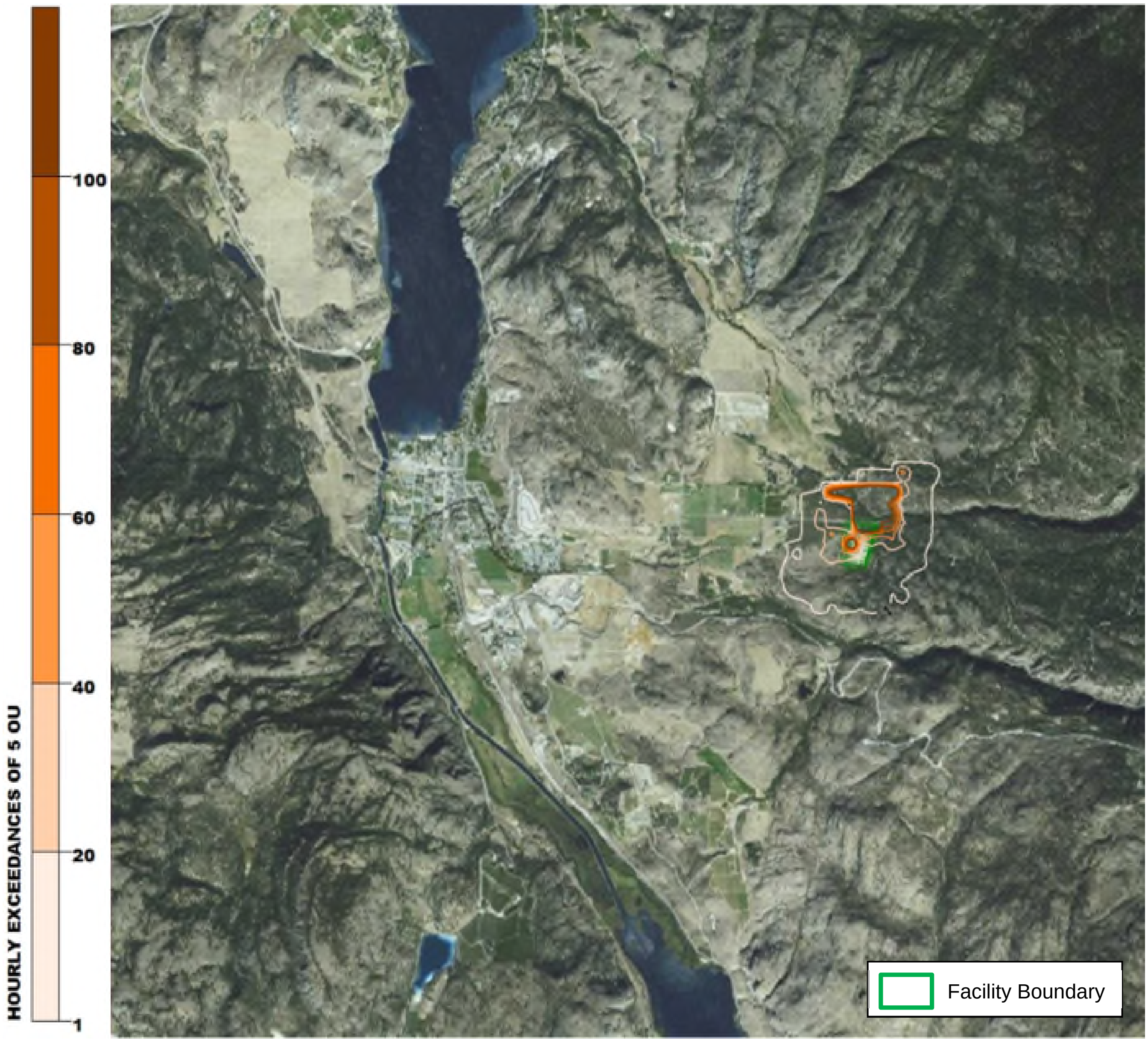


**Figure 8: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (In-Vessel)**

# OLIVER LANDFILL

# 1.0 INTRODUCTION

The following is a summary of model inputs and odour modelling results conducted for the purpose of assessing potential odour impacts from an organics management facility located at Oliver Landfill (hereafter referred to as the "Site"). Odour modelling was conducted using CALPUFF, an advanced air modelling software system recommended by the British Columbia Ministry of Environment (BC MOE).

# 2.0 MODEL INPUTS AND ASSUMPTIONS

## 2.1 Meteorology

The air dispersion model CALPUFF contains a diagnostic meteorological processor, CALMET, which creates a three-dimensional meteorological field over the spatial extent of the model. The data produced by CALMET is used by CALPUFF in its dispersion and plume transport calculations. Inputs to CALMET include the following:

- A geophysical grid, constructed using gridded terrain and land cover data (obtained from GeoGratis – Government of Canada); and
- A combination of prognostic (three-dimensional meso-scale model called MM5) meteorological data and hourly surface observations obtained from Environment Canada and BC MOE meteorological stations.

When CALMET is run in "no-observations" mode (using only MM5), the surface station observations provide a validation of the CALMET meteorology, in particular winds, to ensure representativeness. As MM5 is a meso-scale regional model, the grid used as input to CALMET is downscaled in three steps from a 32 km resolution grid to a 4 km grid and downscaled again within CALMET to the CALPUFF grid size (250 m). It is not expected that the meteorological time series in CALMET will exactly reproduce observed conditions on an hour by hour basis at any particular grid point, however it is expected to be representative of the general conditions over a given year.

Table 2.1 summarizes the meteorological inputs to CALMET used in the Oliver Facility odour modelling and mapping exercise.

### Table 2.1: CALMET Inputs and Metadata

| Parameter | Usage |
|---|---|
| Surface Stations | None |
| Upper Air Soundings | None |
| Prognostic Data | 4 km resolution MM5 |
| Meteorological Grid | 10 km x 10 km at 250 $m^2$ |
| Grid Centrepoint | 313950 m, 5444500 m, UTM Zone 11 |
| Vertical Cells (Cell Face Heights) | 10 (0 m, 20 m, 40 m, 80 m, 160 m, 320 m, 640 m, 1200 m, 2000 m, 3000 m, 4000 m) |
| Terrain Data | CDN DEM 15 min |
| Land Use Data | GeoBase Land Cover circa 2000-Vector |

As land cover characteristics over the modelling domain vary with season (e.g., albedo, Bowen ratio, etc.), seasonal CALMET files were created using the model's default seasonal geophysical properties for each land cover category contained within the geophysical grid. The date ranges assumed to define each season are listed in Table 2.2. Year-to-year variability will undoubtedly occur, however, this temporal approximation was used to simplify modelling based on Environment Canada 1981 – 2010 climate norms for the Okanagan-Similkameen region. The modelled year was 2012.

### Table 2.2: Geophysical Property Seasonality

| Season | Date Range |
|---|---|
| Winter | December 1 – February 29 |
| Spring | March 1 – May 31 |
| Summer | June 1 – September 15 |
| Fall | September 15 – November 30 |

## 2.1.1 Meteorological Validations

### 2.1.1.1 Winds

Figure 2.1 is two snapshots of CALMET-modelled surface winds showing different flow conditions through the valley. The left figure, from January 2 at $0^{00}$ hrs, shows an example of southerly flow through the valley which is a more common occurrence during the winter (Figure 2.2). The right figure, from July 1 at $20^{00}$ hrs shows an example of northerly flow through the valley which is a more common occurrence in the summer (Figure 2.2). The figure also shows the boundary of the site (green border).

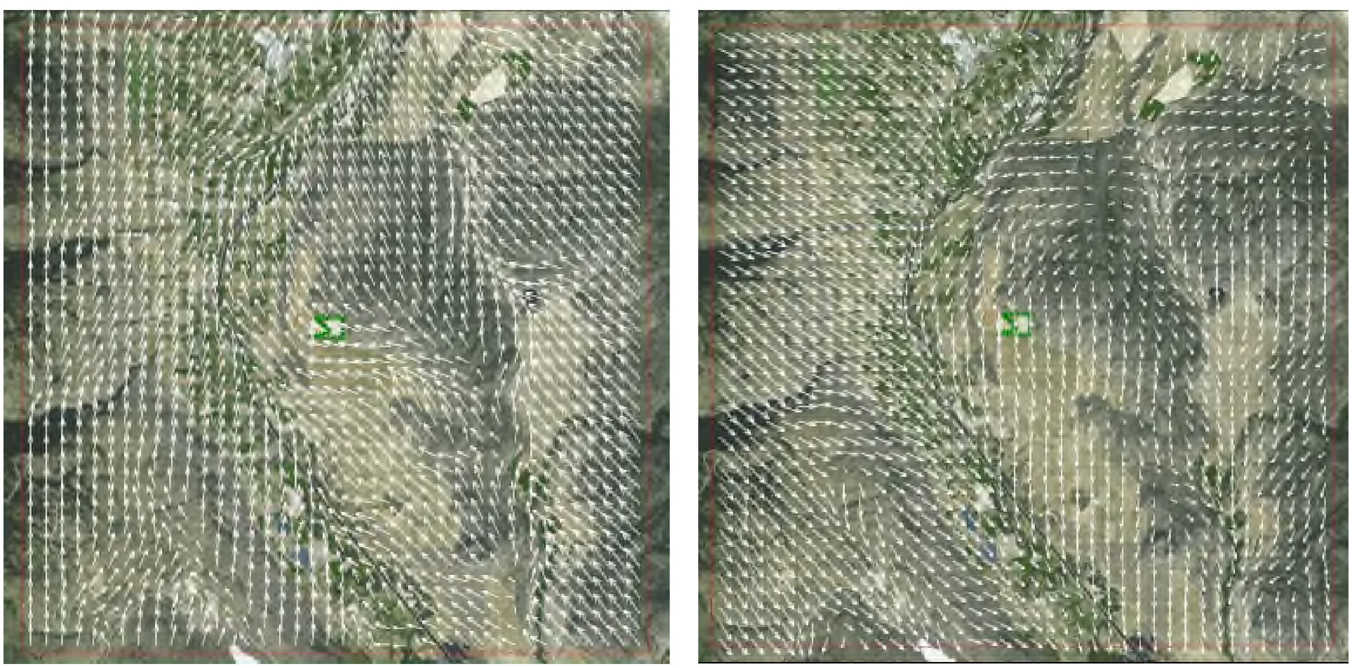

**Figure 2.1: CALMET-Modelled Wind Fields – Southerly Flow (left), Northerly Flow (right)**

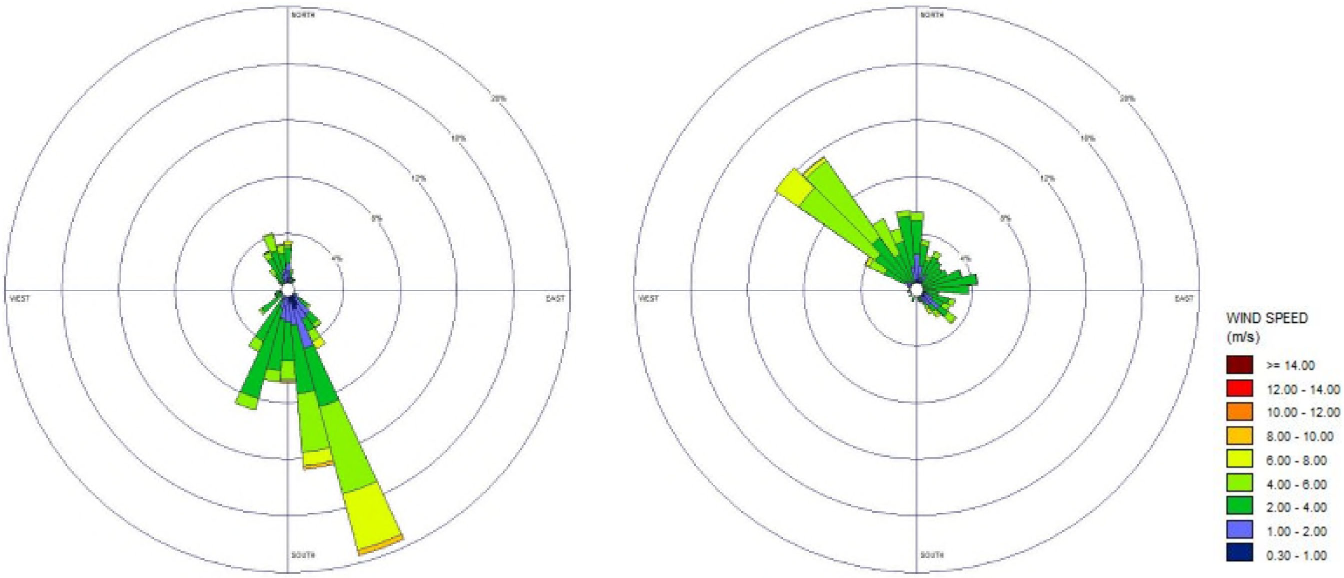


**Figure 2.2: CALMET-Modelled Seasonal Wind Roses: Oliver mid-Valley (312184 m, 5444690 m Z11) Winter (DJF, left), Summer (JJA, right)**

Figure 2.3 shows CALMET-predicted winds at three locations along the valley as annual (2012) wind roses. As would be expected, the wind field generally follows the valley orientation.

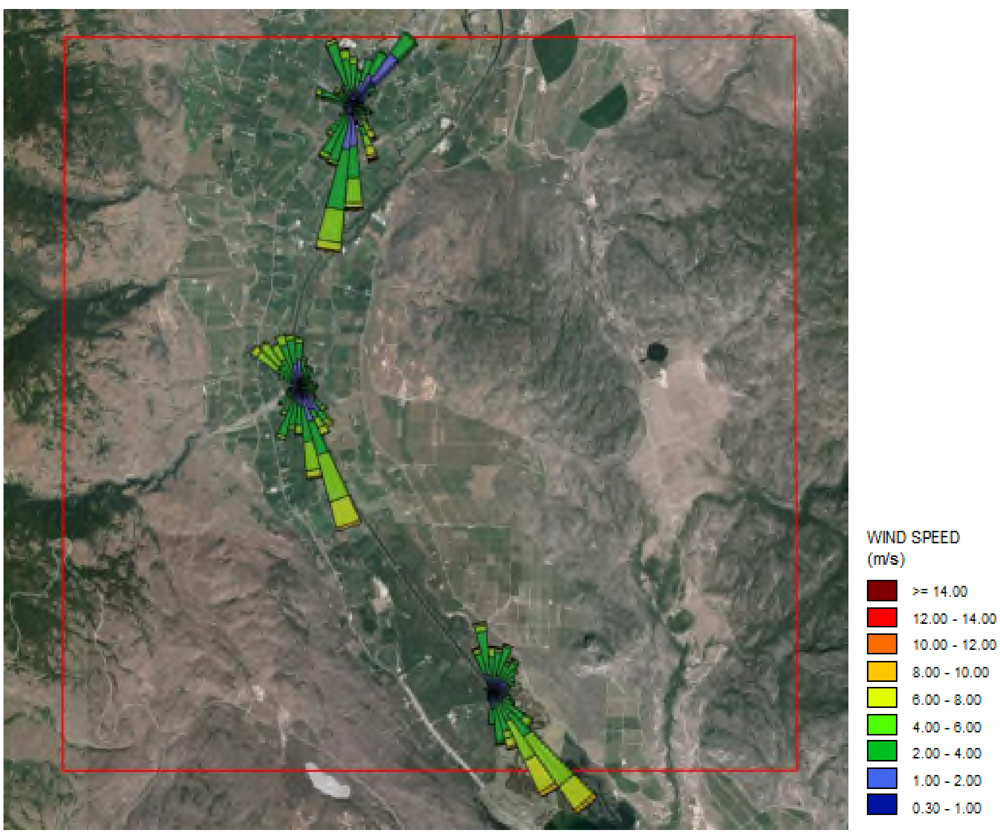


**Figure 2.3: Wind Field Validation – CALMET-Predicted Winds (2012)**

#### 2.1.1.2 Mixing Height

The atmospheric mixing height can be defined as the top of the layer in the lower atmosphere, within which an emitted species, in this case odour, is readily mixed through turbulence and convective processes. Therefore, when the mixing height is low, higher ground-level concentrations will generally be predicted. Figure 2.4 are time series of modelled mixing heights extracted from CALMET over two distinct seasonal periods in 2012 at the mid-valley location (312184 m, 5444690 m Z11) 1.7 km west of the Oliver landfill. The top figure (red) plots a time series of mixing heights in the winter (between February 1 and 8), while the lower figure (blue) plots mixing heights in the summer (between July 1 and 8).

Seasonal contrast is strongly evident since there is reduced solar radiation, lower temperatures and snow cover, among other factors during the winter that results in generally lower mixing heights, and thus resulting in higher concentrations of odour. Both figures show the expected strong diurnal pattern, with mixing heights dropping quite close to the ground surface (~50 m as a default in CALMET) at night. When overnight mixing heights are higher, it is due to turbulence induced by higher wind speeds over uneven terrain.

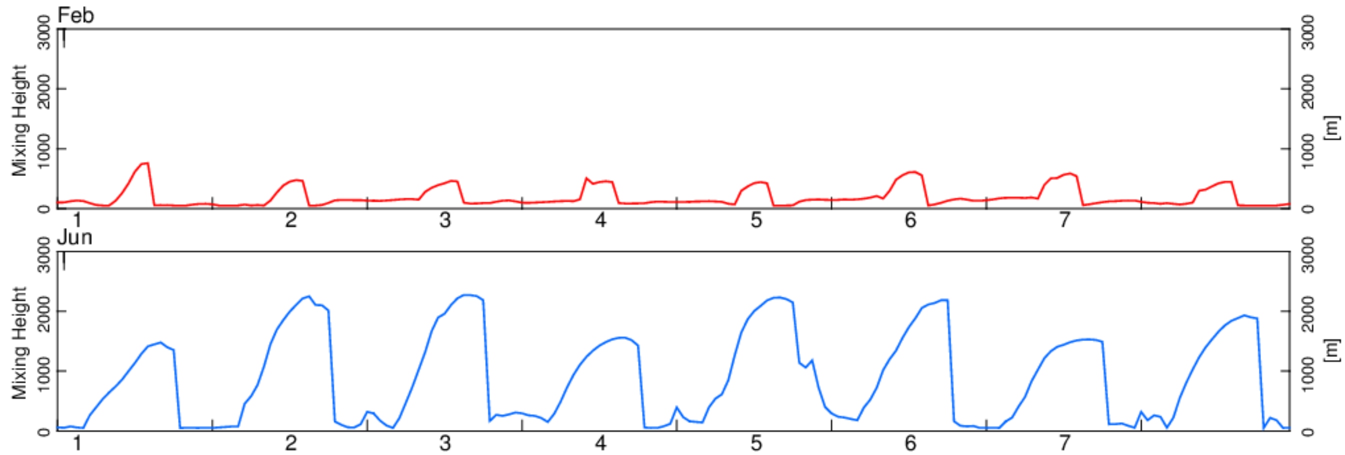


**Figure 2.4: CALMET-Modelled Mixing Heights for Winter (Red) and Summer (Blue)**

## 2.2 Area Sources and Emission Factors

The site layouts from the *Organics Management Consultant Task 2 – Feasibility Assessment* report for Oliver and Oliver Regional Facility were used to define the boundaries of the odour sources for this modelling analysis. Areas that generate odours were assigned a specific emission factor according to the activity taking place (e.g. composting, curing, pile turning, etc.). In the main report, Table 2.1 provides a description of the emission factors. The scenarios included for odour modelling are presented in Table 2.3.

### Table 2.3: Odour Modelling Scenarios

| Organics Processing Technology | Oliver | Oliver Regional Facility[1] |
|---|---|---|
| Current Composting Operations | √ | |
| Aerated Static Pile (ASP) | √ | √ |
| Membrane Covered Aerated Static Pile | √ | √ |
| In-Vessel Composting | √ | √ |
| Anaerobic Digestion (AD) | | √ |

[1] Oliver and Osoyoos feedstocks combined, plus 5,000 tonnes of manure and woodchips from adjacent feedlot

Emissions were assumed to occur homogeneously over the entirety of the area source. Some odour emissions (e.g. pile turning, pile moving, etc.) were assigned a diurnal variation based on the expected times of day the activity is to be performed (Table 2.1 of the main report). Such activities are expected to occur daily at the Site over a one- to two-hour period, however since the activity may occur at any time during the operational hours of the facility in the morning or in the afternoon, odour emissions were assumed in the model to occur between $10^{00}$ to $12^{00}$ – representing a time of day when vertical mixing is generally highest – and between $15^{00}$ to $17^{00}$ – when, during the winter, the mixing height is approaching its night time minimum, thus resulting in higher concentrations closer to the ground. This is a somewhat conservative approach since the activity may only be occurring over a portion of a single hour rather than four, may not take place every day, and peak odour emission would only occur during and immediately following the activity and decay in the hour following. It should be noted that odour emissions produced from pile building and moving are inconsequential compared to that produced from the biofilters which emit odour continuously.

Emission heights were either assigned a value of 3 m or 1 m depending on the activity occurring within the area source. Specific heights used for the various activity types are listed in Table 2.1 of the main report.

## 2.3 CALPUFF Settings and Assumptions

The CALPUFF model input settings were assigned with consideration to the recommendations in Table 9.7 of '*Recommended CALPUFF Input Group 2 Switch Settings*' in '*Guidelines for Air Quality Dispersion Modelling in British Columbia*'. Generally, default model settings were used. Since the area of interest is in the near-field (within 12 – 15 km of the source), dispersion coefficients were internally calculated using micrometeorological variables (MDISP = 2) based on estimates of the crosswind and vertical components of turbulence based on similarity theory and the land cover type. The probability distribution function (PDF) was used for dispersion under convective conditions (MPDF = 1) which explicitly accounts for the differences in the distribution and strengths of up and down drafts within the convective boundary layer, reporting the average between the two. By using these two settings, AERMOD-type dispersion is simulated (generally accepted as better-predicting in the near-field than CALPUFF), while also providing the benefit of a puff model and allowing for the effects of complex terrain.

The receptor grid spacing was 250 m at ground level over the entire grid. The simulations were to determine the general effects downwind from the facility, on the scale of kilometres, and therefore did not consider building downwash – the drawdown of the odour plume downwind of facility buildings due to turbulence.

# 3.0 RESULTS

Since the time step of the meteorological data is one-hour, CALPUFF can only output one-hour averaged predictions of odour concentration. However, since odour perception is on a much shorter scale, an averaging time-scalar must be applied to assess shorter-term peak concentrations due to plume meandering within the hourly period. Hourly odour concentrations are scaled to a ten-minute averaging period using Equation 1.

$$Cp = Co * \left(\frac{t_o}{t_p}\right)^{0.28} \qquad (1)$$

Pursuant to Equation 1, $t_o$ is the 60 minute averaging time, $t_p$ is the short-term averaging time (10 minutes) and $C_o$ and $C_p$ are the respective peak concentrations (BC MOE). The scalar when converting from hourly to ten-minute average concentrations equates to 1.65.

## 3.1 Odour Units

An Odour Unit is a way of quantifying odours through the use of an odour panel that consists of a group of people with 'calibrated noses'. The definition of an Odour Unit is based on the proportion of odour panel members that can detect the smell of a substance. One OU represents the concentration of a particular substance when 50% of the odour panel can detect the odour. This is called the perception threshold[1]. At this point, although an odour may be detected, it is not distinct enough to be able to identify the type of odour.

The Odour Unit scale is based on dilutions, as shown in the following figure. As the number of odour units increase, more people can detect the odour, and the intensity of the odour increases. Five OU is considered a faint odour, and ten OU is considered a distinct odour (the point when some people can identify the type of odour, or its potential source)[2].

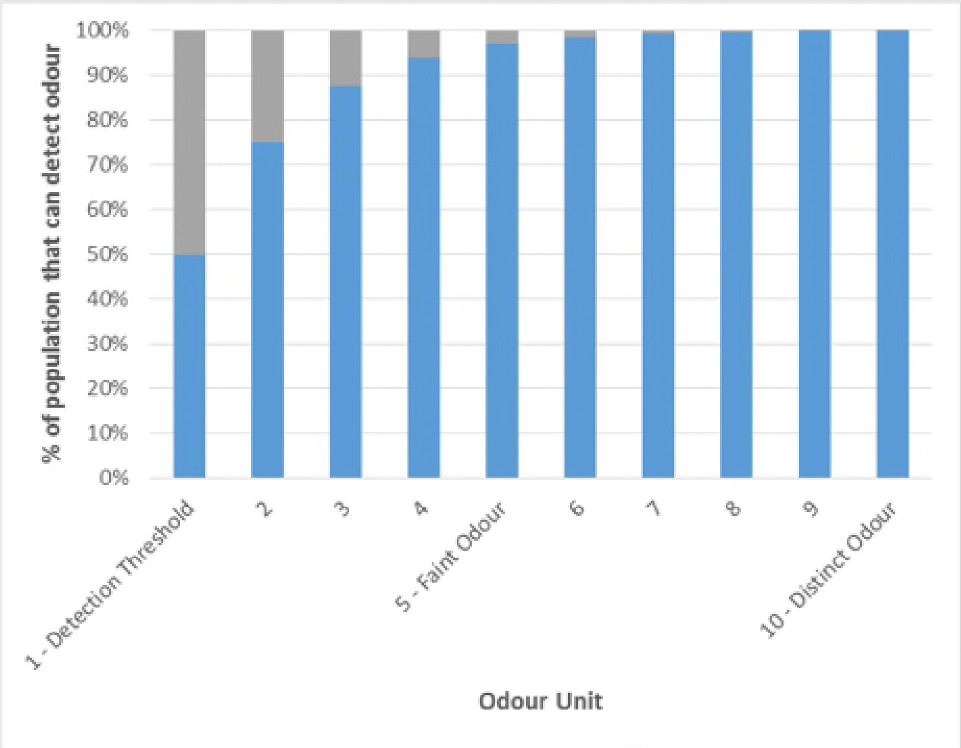


**Figure 3.1: Odour Unit Scale**

There are currently no guidelines for odour limits for composting facilities in British Columbia, however, some wastewater treatment facilities have imposed odour limits. For example, the standard in Metro Vancouver is no more than five OU at the property line. In other jurisdictions, the guideline is to have no detectable odour at the property line. At the Ogogrow facility in Vernon, BC, the limit is 50 OU at the property line.

## 3.2 Odour Maps

Odour maps are included as part of Appendix A. For each organics processing option listed in Section 2.2, odour modelling results are presented as three different plots:

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[1] http://blog.odotech.com/odor-unit-perception-threshold

[2] Odours and VOCs: Measurement, Regulation and Control Techniques (2009). Kassel University Press.

- Maximum Odour Concentrations – The maximum predicted 10-minute odour concentration at each receptor point over the course of the modelled year. This is displayed as a contour plot showing the maximum predicted 10-minute averaged odour concentration at every ground level receptor point over the entire one-year simulation (8784 hours) as a blue gradient (light to dark). The 1 OU contour is white. The highest levels >10 OU are dark blue. The facility boundary is shown as a green outline.
- Hourly Exceedances >1 Odour Unit (OU) – The number of hours over the course of the modelled year where an odour threshold of 1 OU was exceeded in a ten-minute averaged concentration. This is displayed as a contour plot showing the number of times the predicted 10-minute odour concentration exceeded 1 OU over the modelled year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to 50% of the population being able to detect odour produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.
- Hourly Exceedances >5 OU – The number of hours over the course of the modelled year where an odour threshold of 5 OU was exceeded in a ten minute averaged concentration. This is displayed as a contour plot showing the number of times the predicted 10-minute odour concentration exceeded 5 OU over the modelled year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to when a faint odour is produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.

## 3.3 Results Summary

The odour maps presented in Appendix A show: (1) the magnitude and spatial extent of maximum ground level odour, and (2) the number of exceedances of odour detection thresholds for the technologies assessed. The membrane covered aerated static pile results had the least odour issues.

The following table summarizes the results of the odour mapping exercise based on the predicted maximum odour and number of hours of odour exceedances at a location 60 m southwest of the property boundary representing the resident that is closest in proximity to the Site (49.125147, -119.555327), shown in Figure 3.2.

### Table 3.1: Results Summary Based on Closest Discrete Receptor Point

| Scenario | Maximum Predicted 10-min Odour | Odour Exceedance >1 OU (hours per year) | Odour Exceedance >5 OU (hours per year) |
|---|---|---|---|
| **Oliver** | | | |
| Current Composting Operations | 2 OU | 2 | 0 |
| Aerated Static Pile | 94 OU | 216 | 87 |
| Membrane Covered Aerated Static Pile | 21 OU | 105 | 44 |
| In-Vessel Composting | 80 OU | 194 | 78 |
| **Oliver Regional Facility** | | | |
| Aerated Static Pile | 238 OU | 302 | 202 |
| Membrane Covered Aerated Static Pile | 101 OU | 224 | 102 |
| In-Vessel Composting | 190 OU | 301 | 166 |
| Anaerobic Digestion | 225 OU | 298 | 198 |


**Figure 3.2: Location of Closest Discrete Receptor (49.125147, -119.555327)**

### 3.3.1 Biofilter Effect

Similar to the odour maps shown in Appendix A, the Membrane Covered Aerated Static pile has the lowest odour emissions of the technologies as this type of operation does not use a biofilter. The greatest source of odour emissions can be attributed to the biofilters, as seen in Table 3.2.

**Table 3.2: Odour Emissions from Biofilters**

| Scenario | % of Odour from Composting Biofilter |
|---|---|
| **Oliver** | |
| Current Composting Operations | N/A |
| Aerated Static Pile | 85% |
| Membrane Covered Aerated Static Pile | N/A |
| In-Vessel | 82% |
| **Oliver Regional Facility** | |
| Aerated Static Pile | 75% |
| Membrane Covered Aerated Static Pile | N/A |
| In-Vessel Composting | 71% |
| Anaerobic Digestion | 67% |

# APPENDIX A

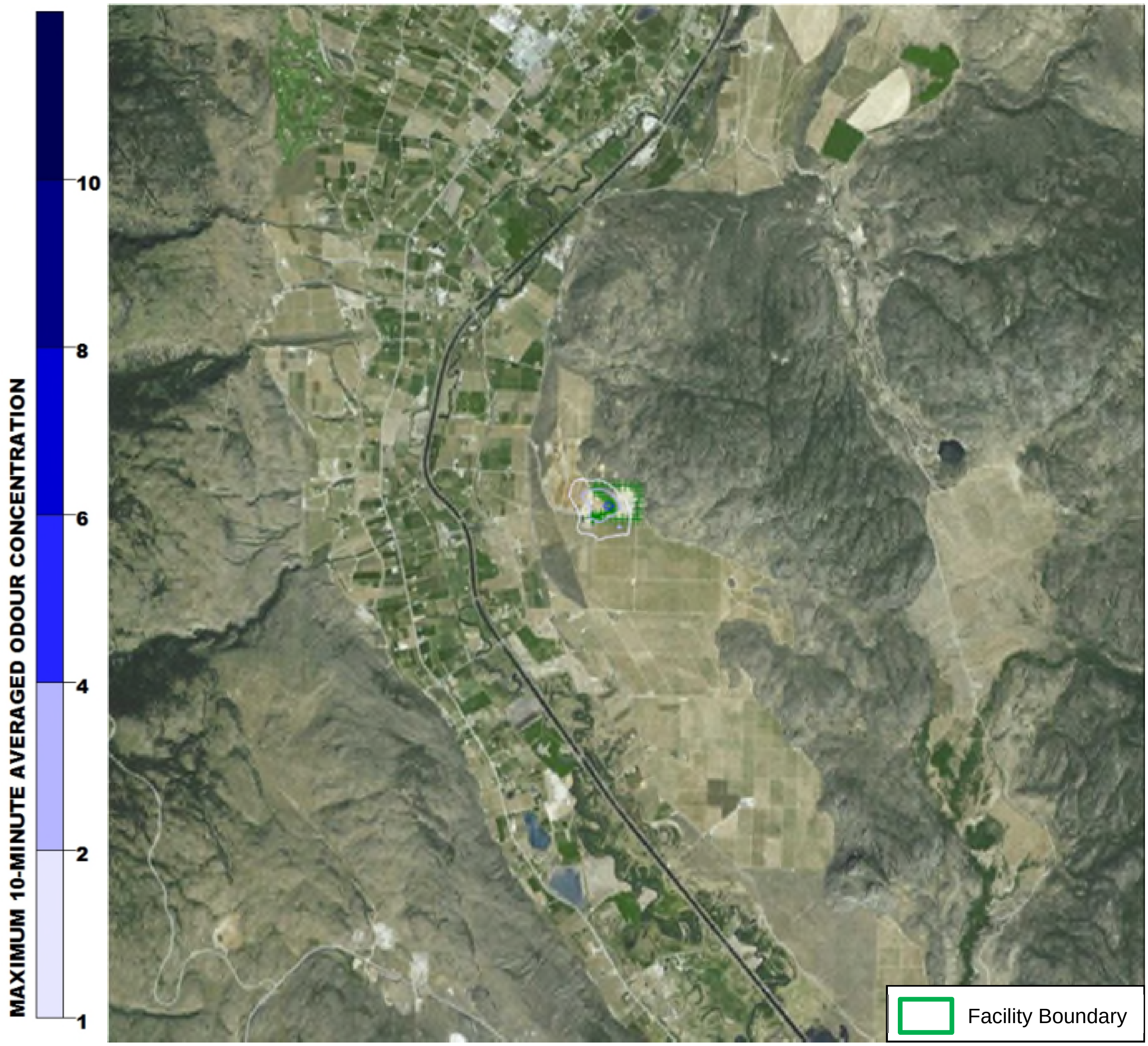


**Figure 1: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Current Composting Operations)**

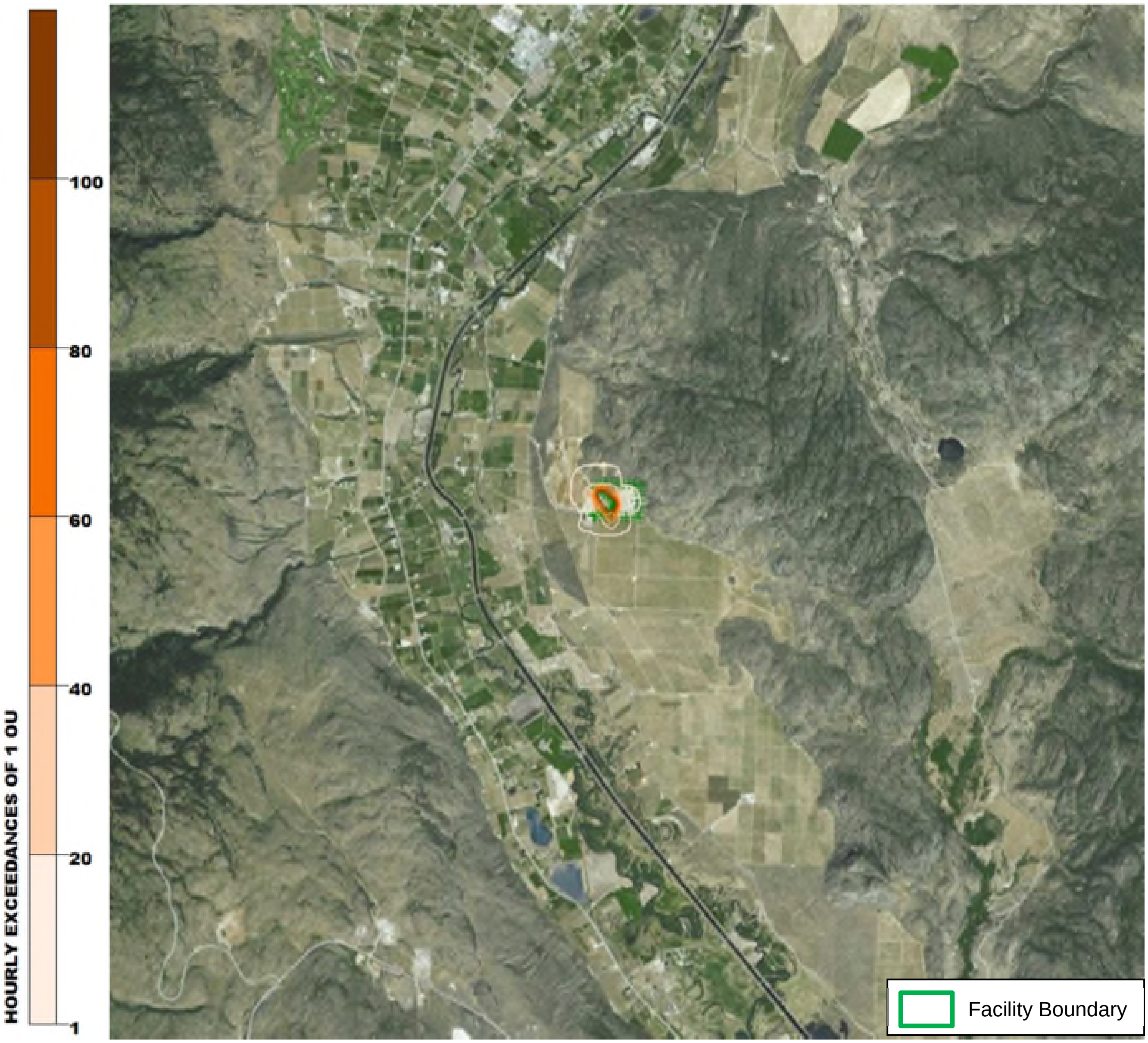


**Figure 2: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Current Composting Operations)**

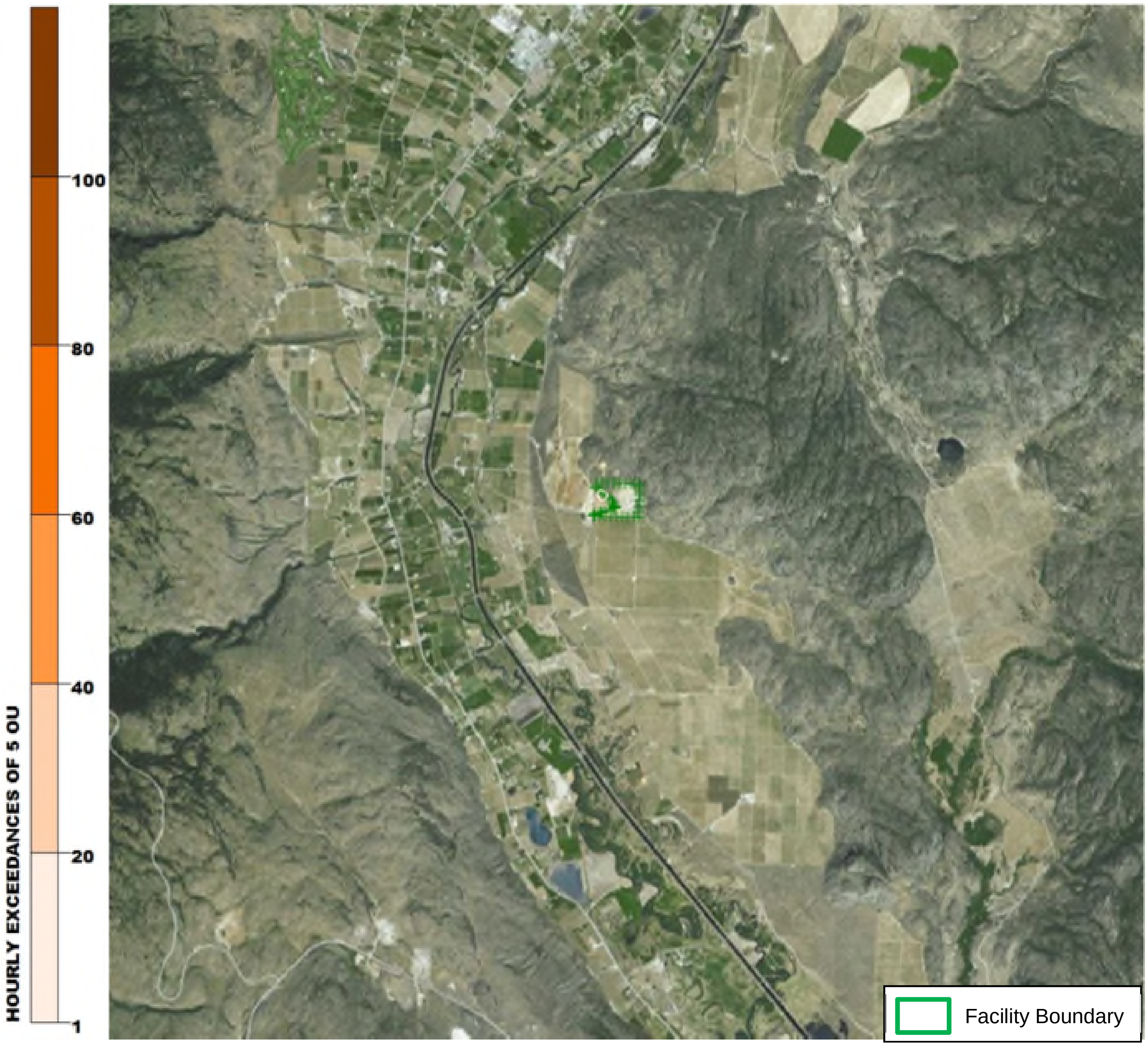


**Figure 3: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (Current Composting Operations)**

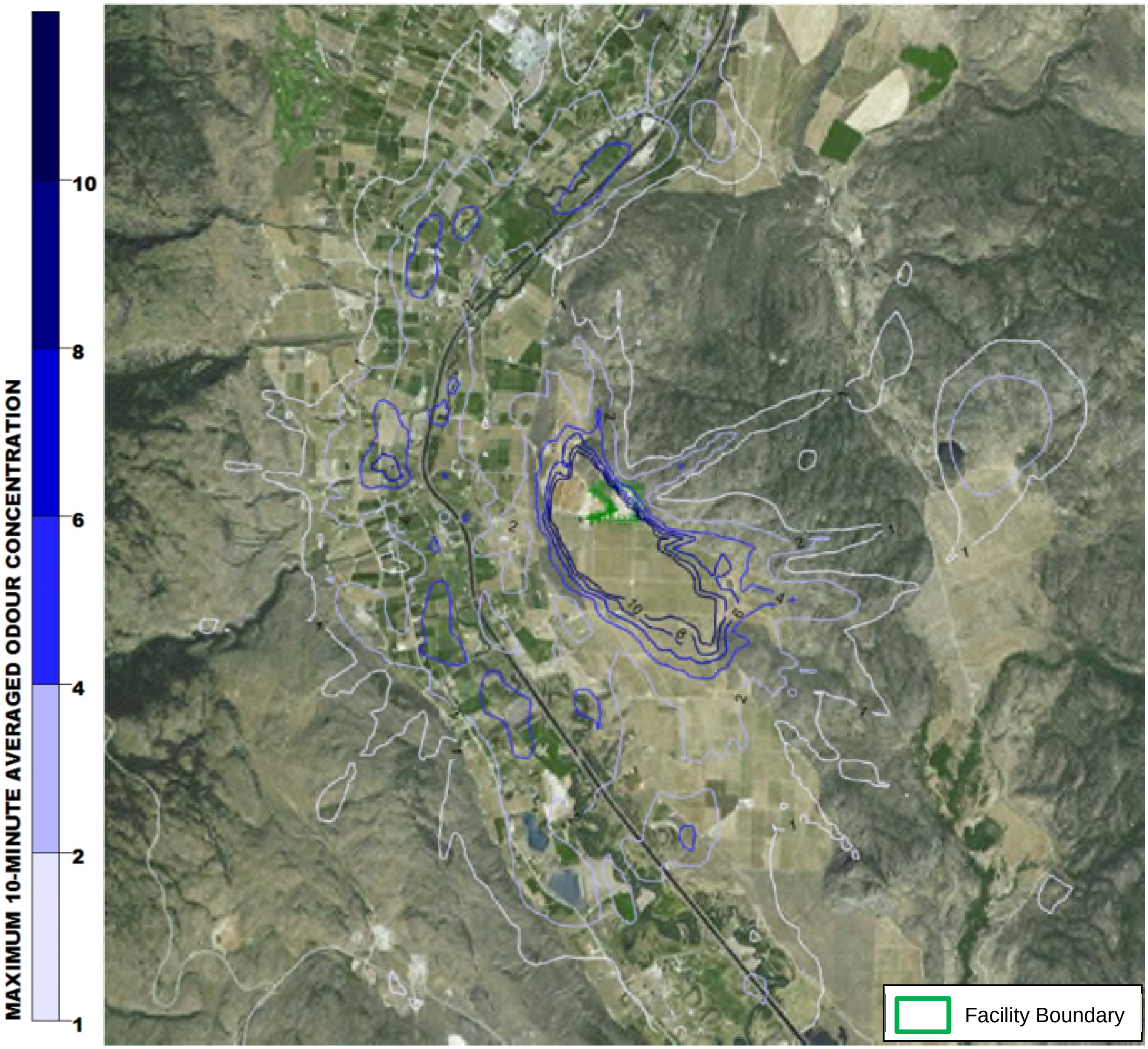


**Figure 4: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (ASP)**

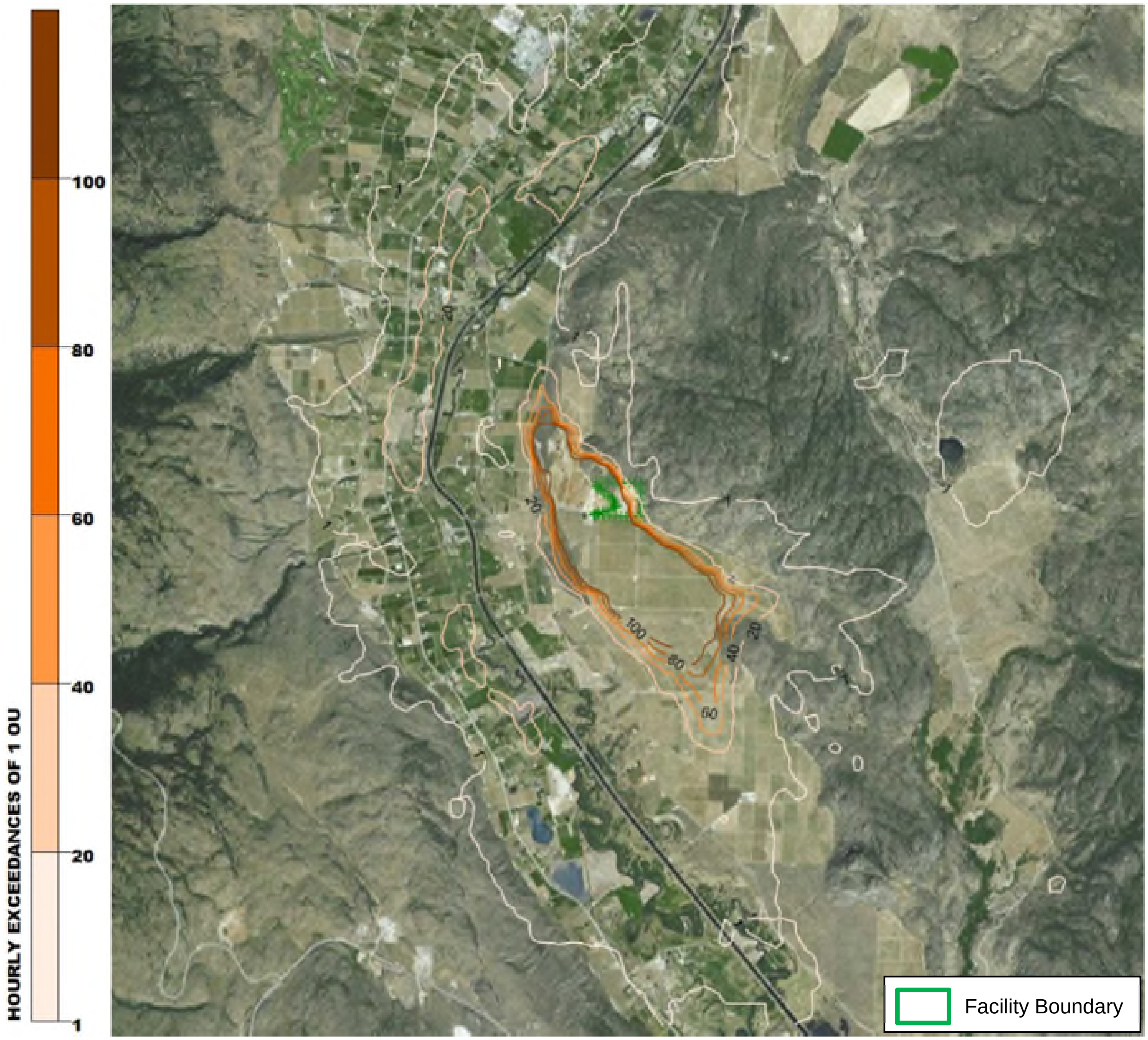


**Figure 5: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (ASP)**

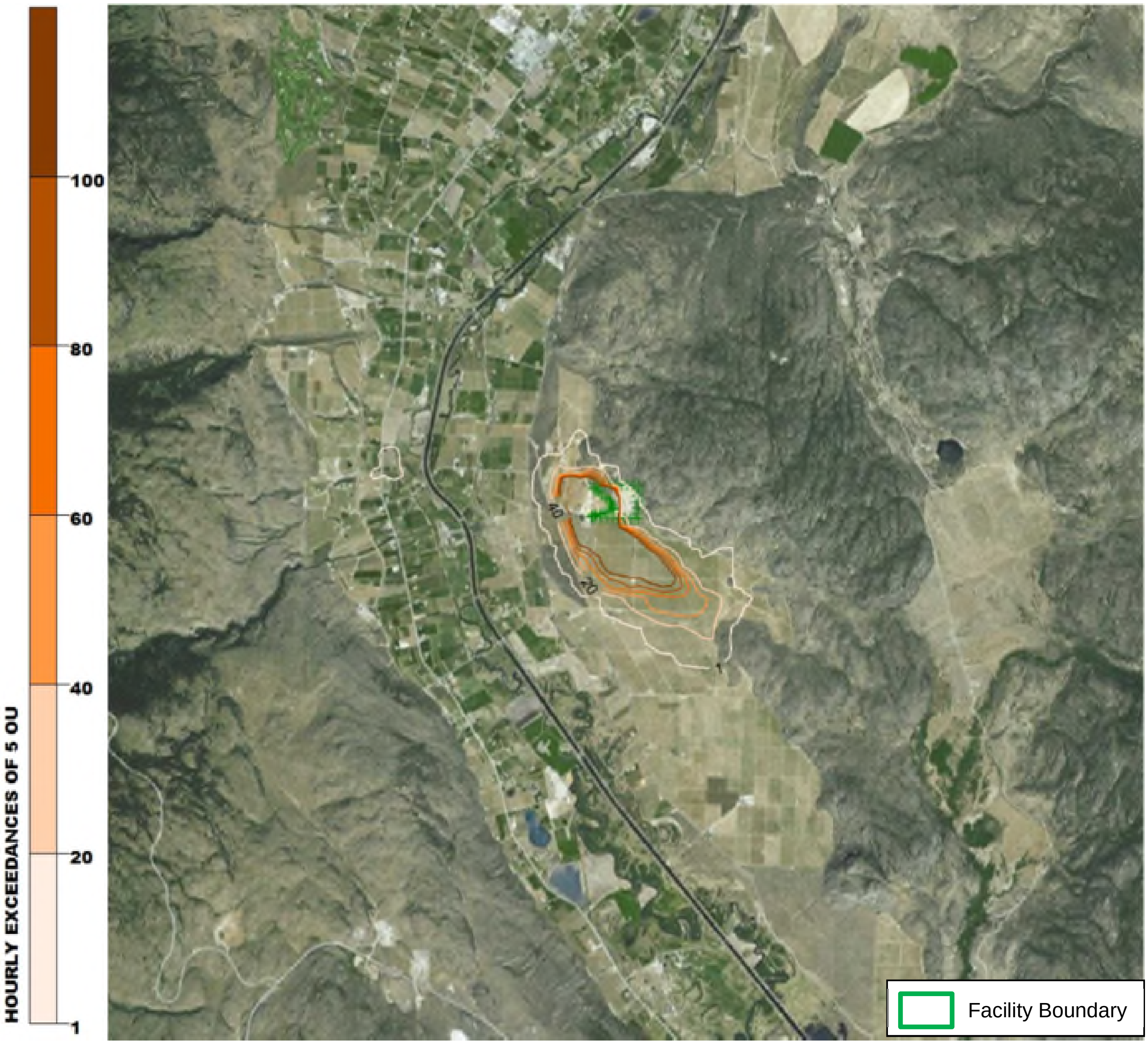


**Figure 6: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (ASP)**

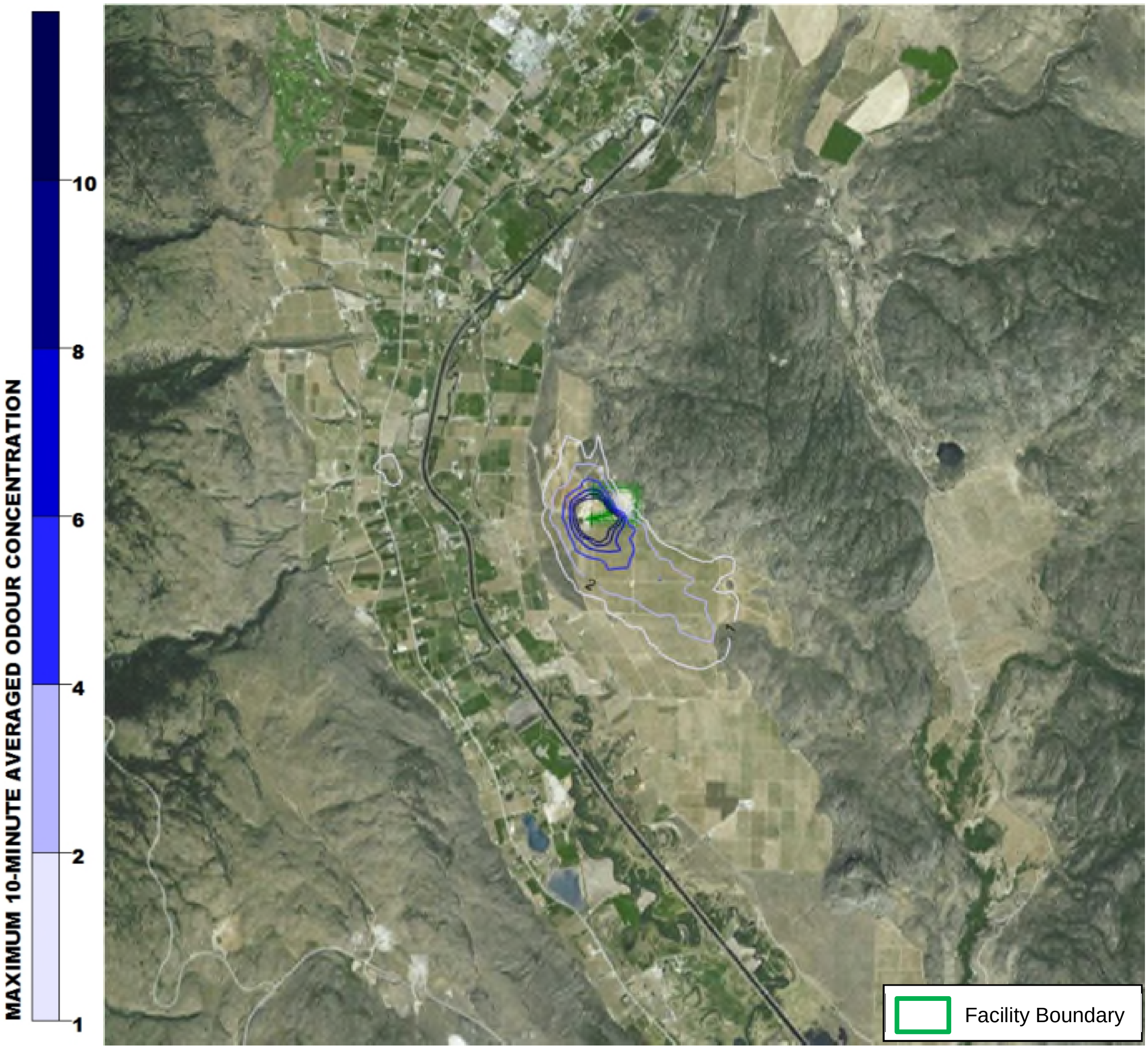


**Figure 7: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Covered ASP)**

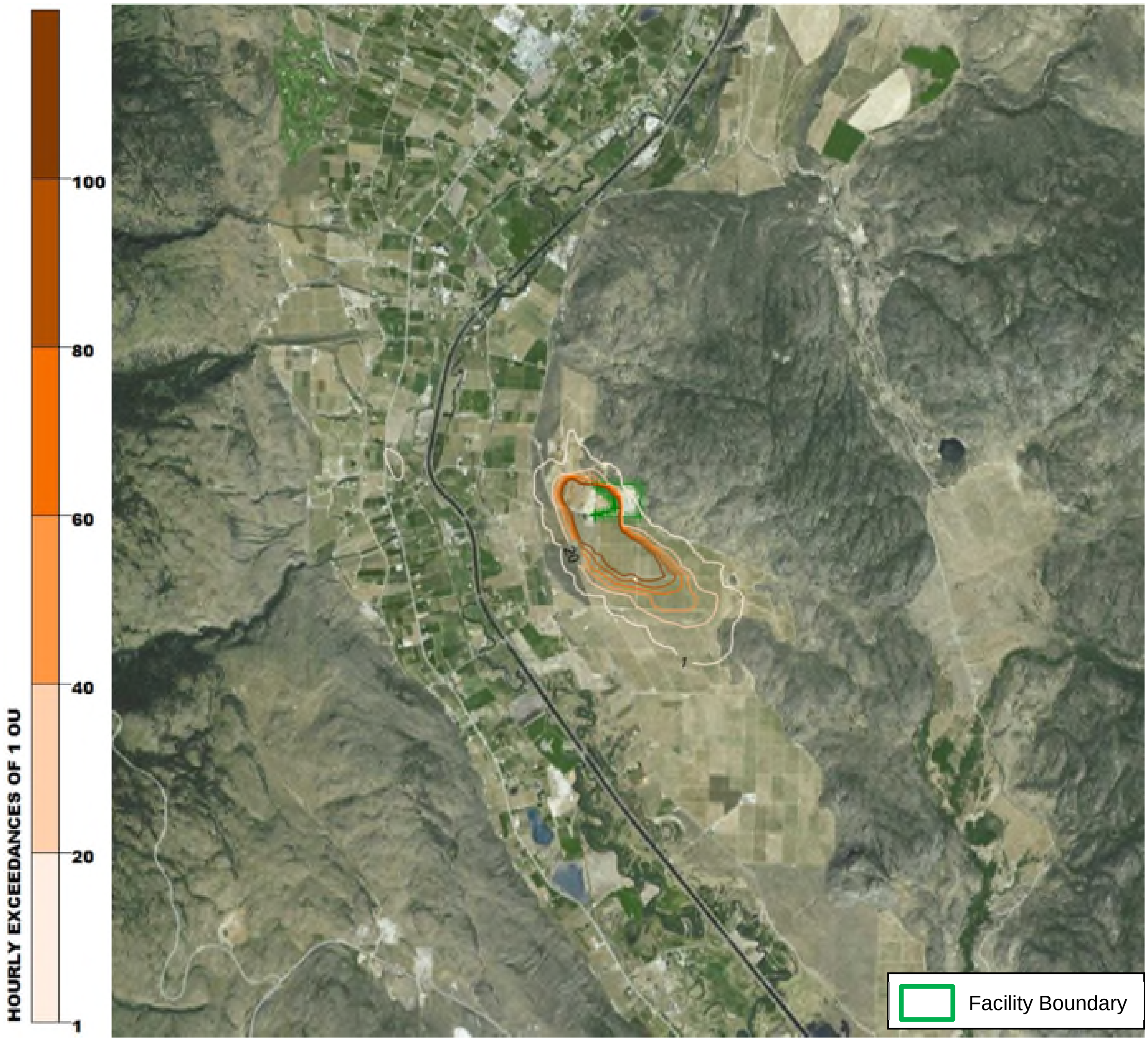


**Figure 8: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Covered ASP)**

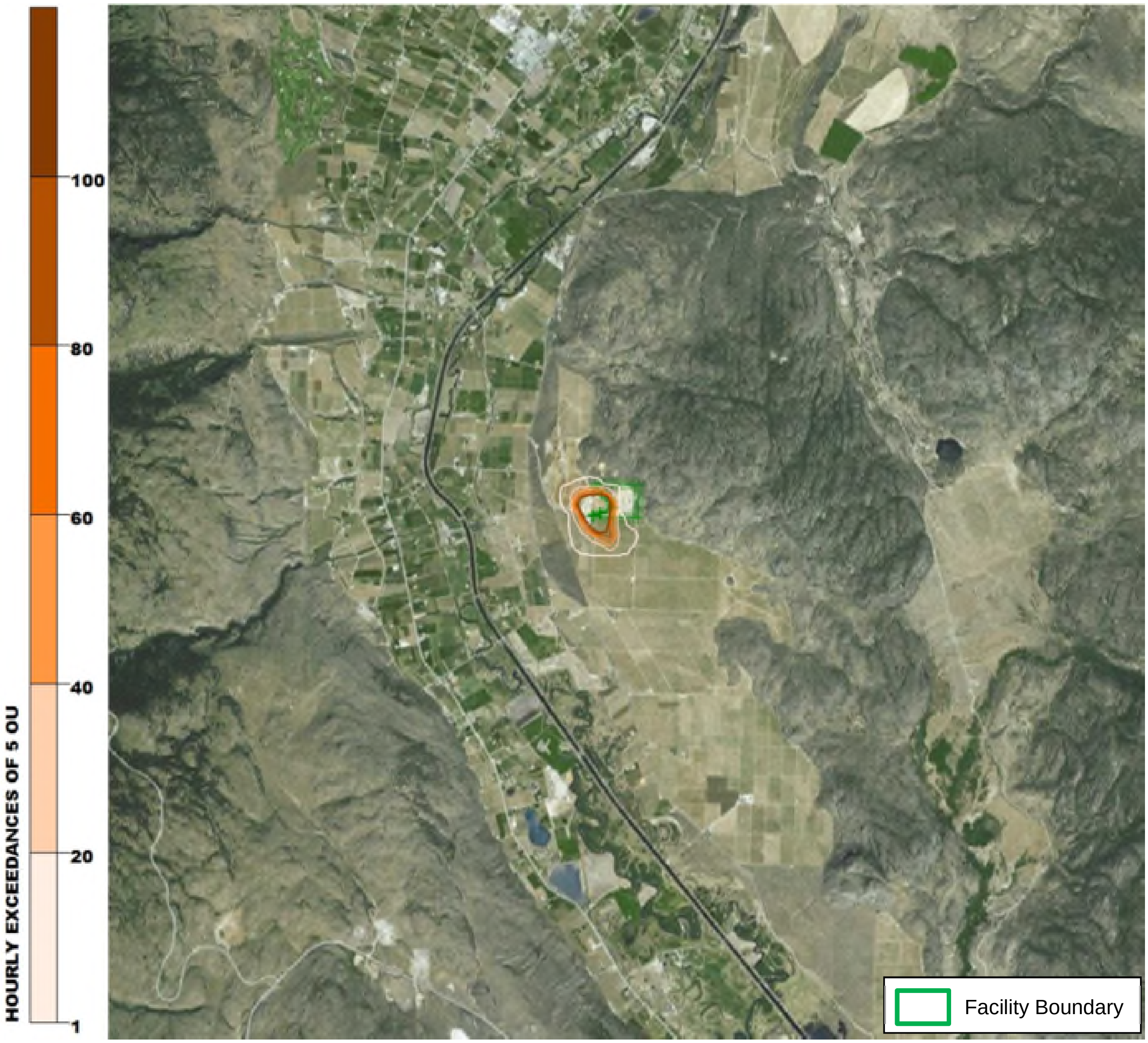


**Figure 9: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (Covered ASP)**

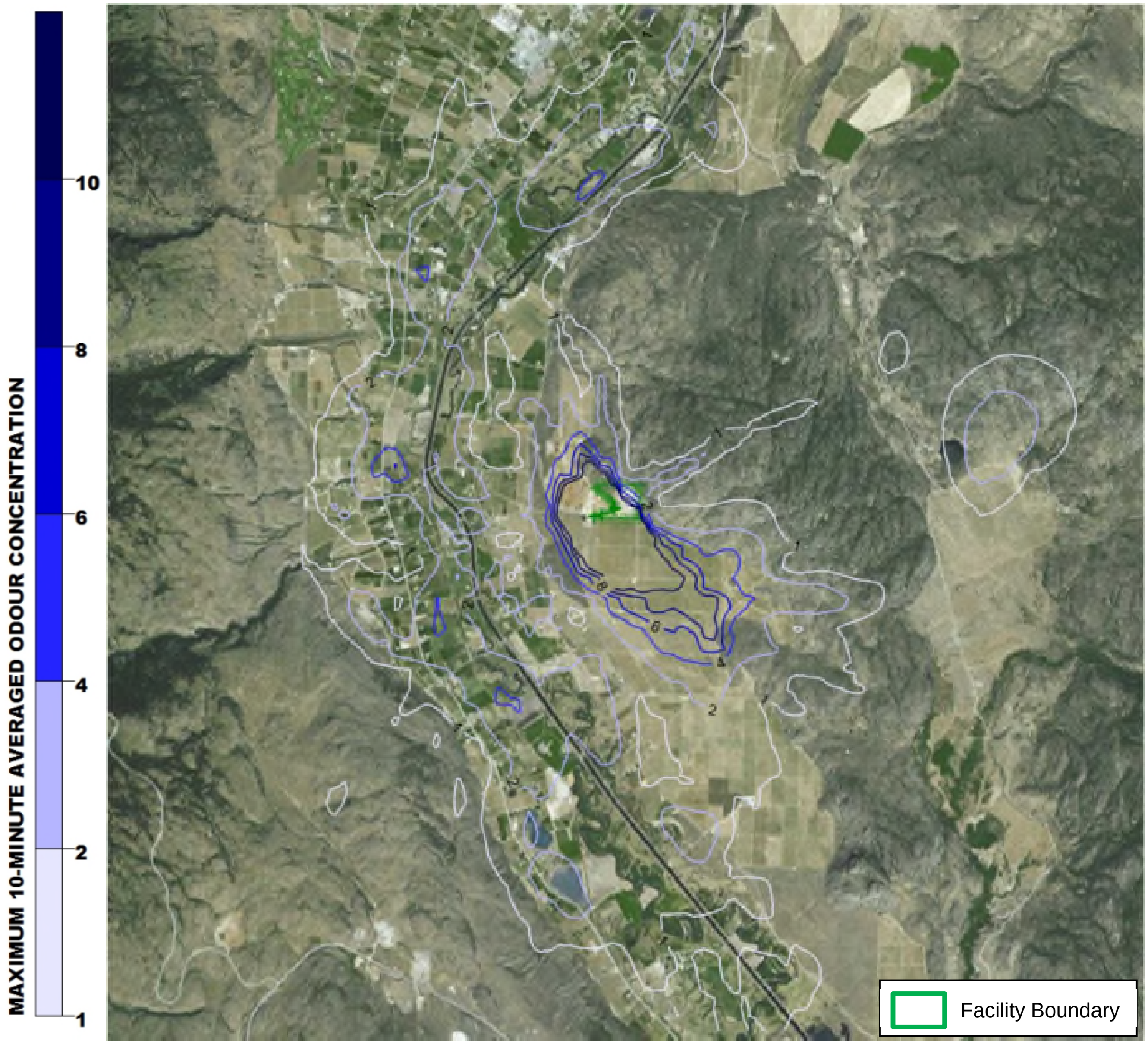


**Figure 10: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (In-Vessel)**

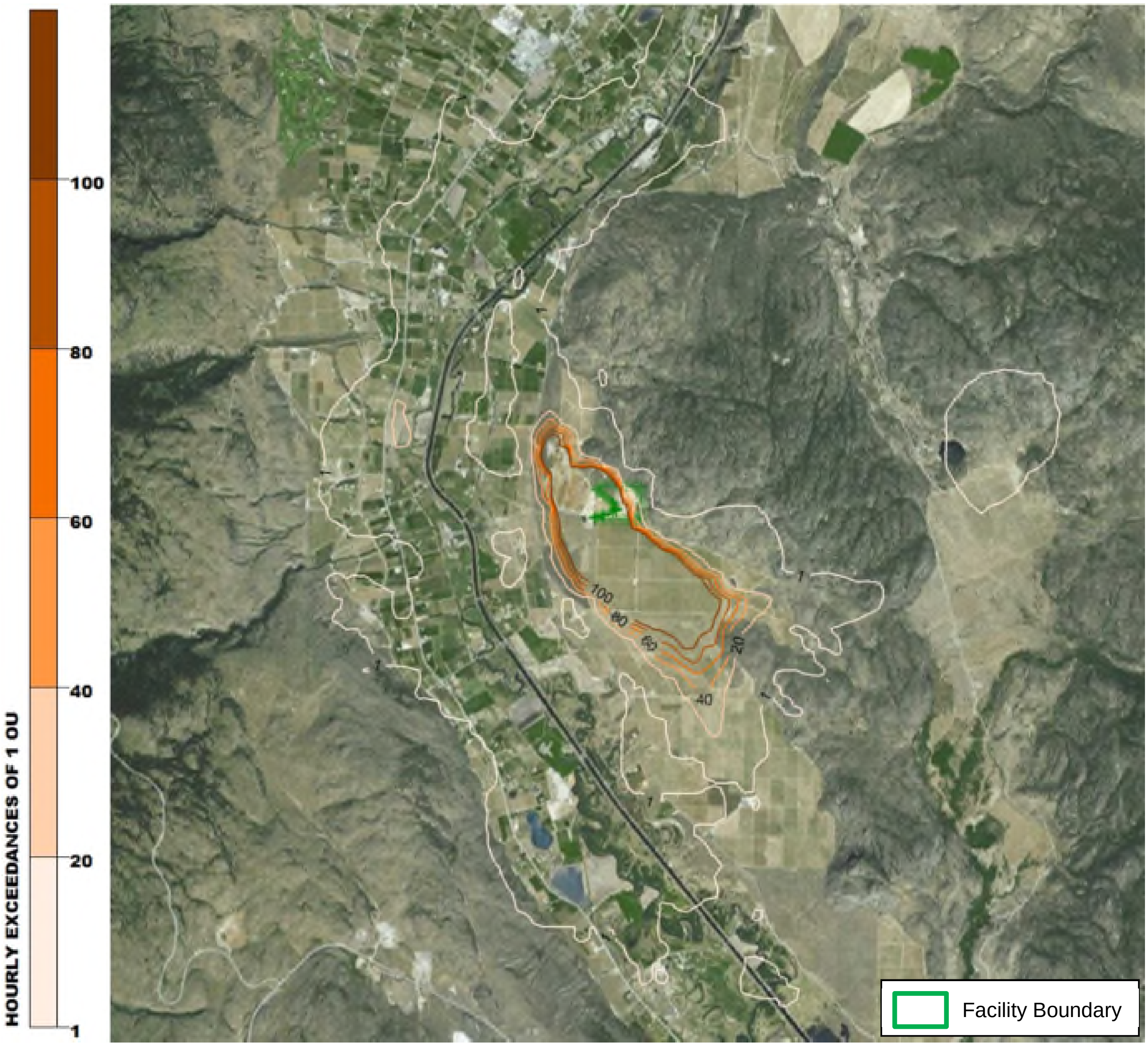


**Figure 11: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (In-Vessel)**

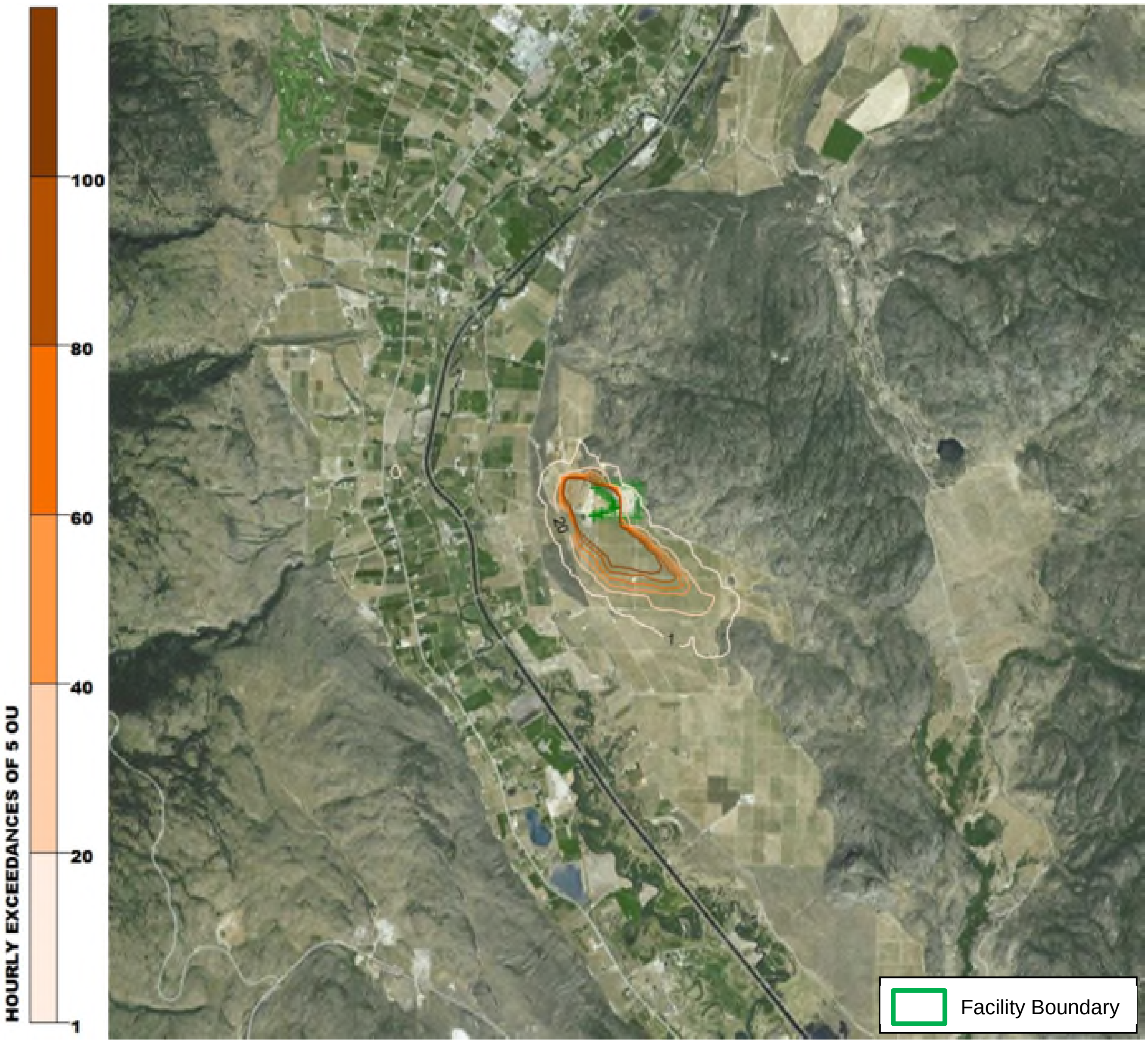


**Figure 12: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (In-Vessel)**

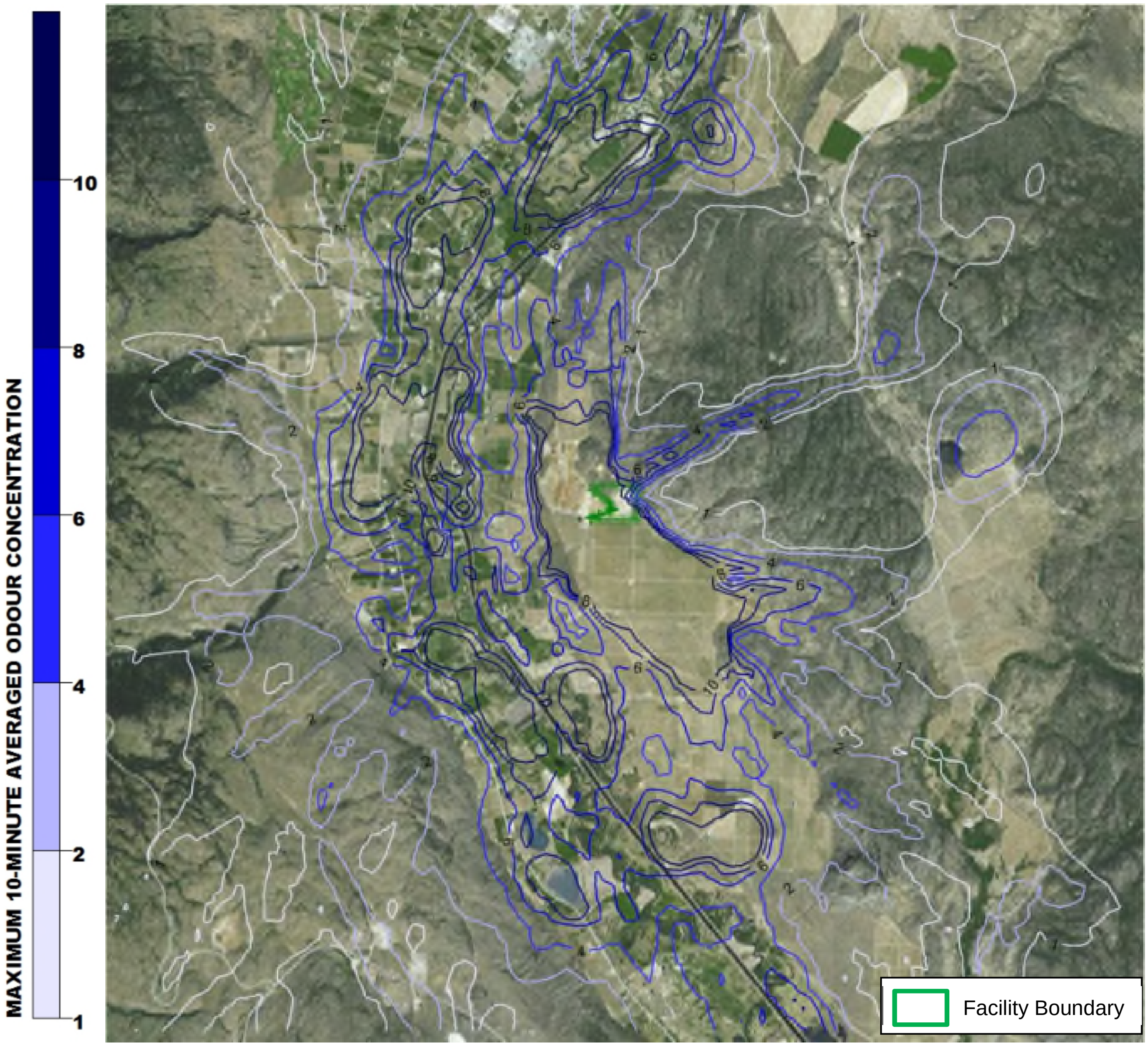


**Figure 13: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (ASP - Regional)**

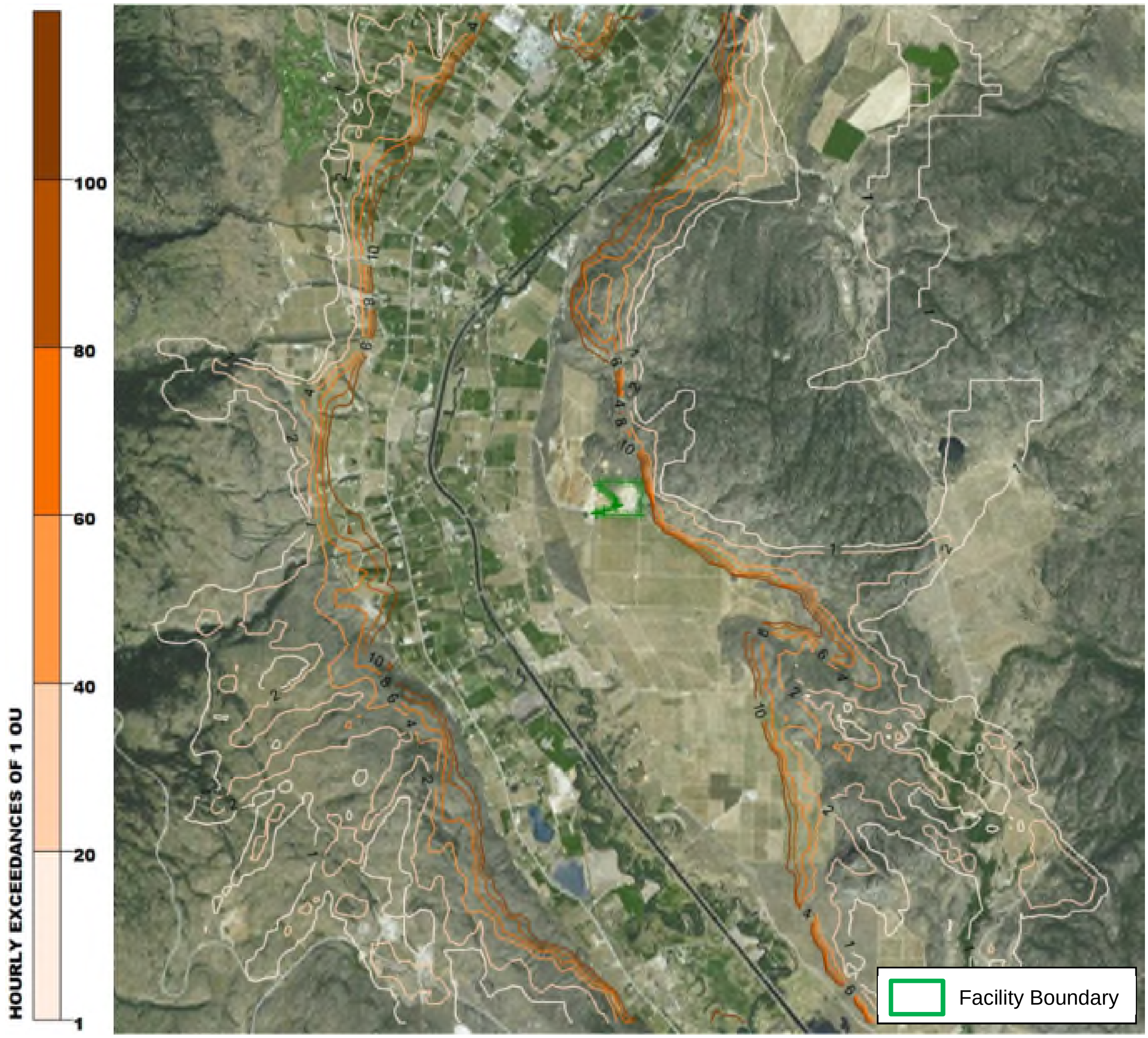


**Figure 14: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (ASP - Regional)**

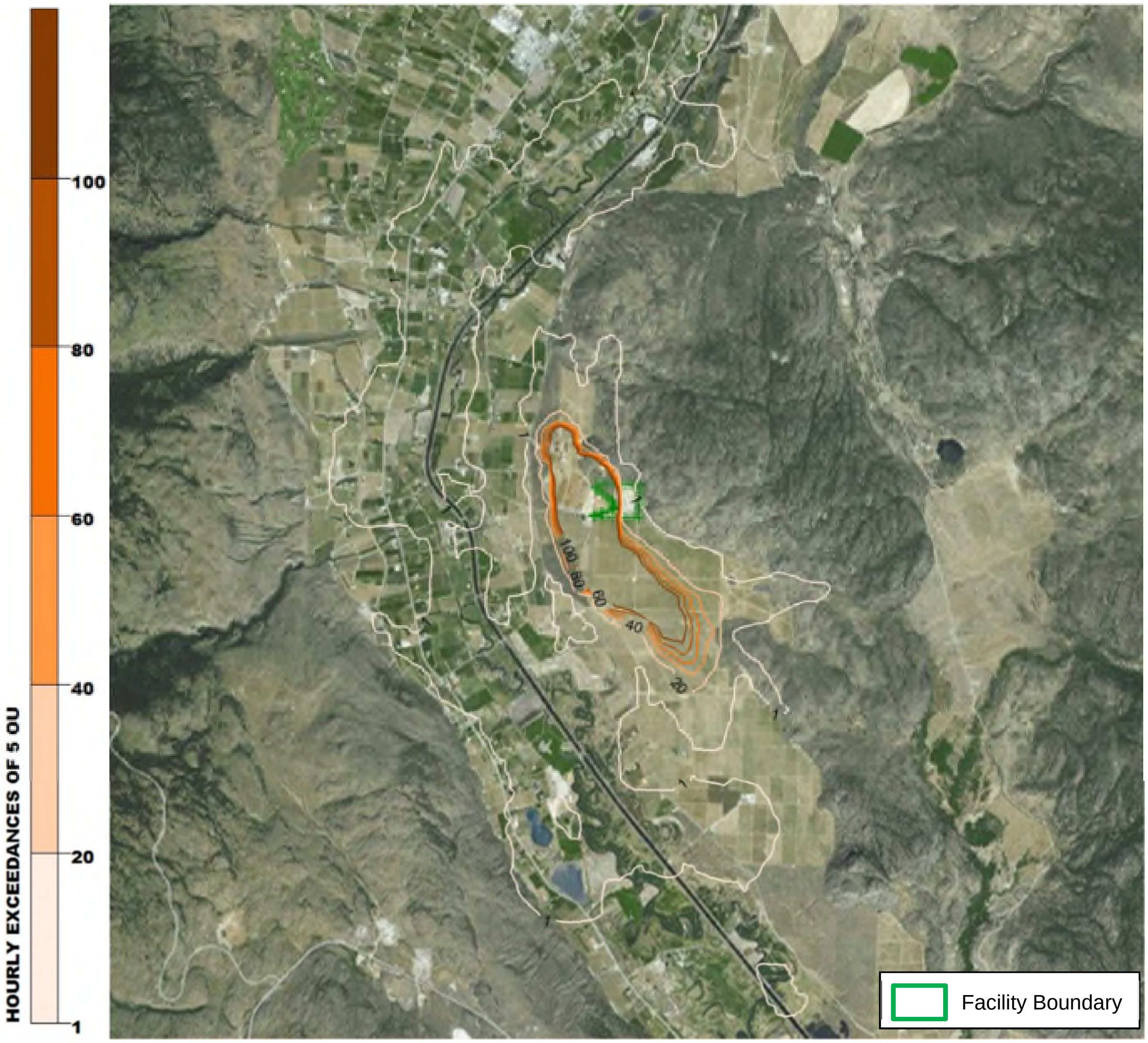


**Figure 15: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (ASP - Regional)**

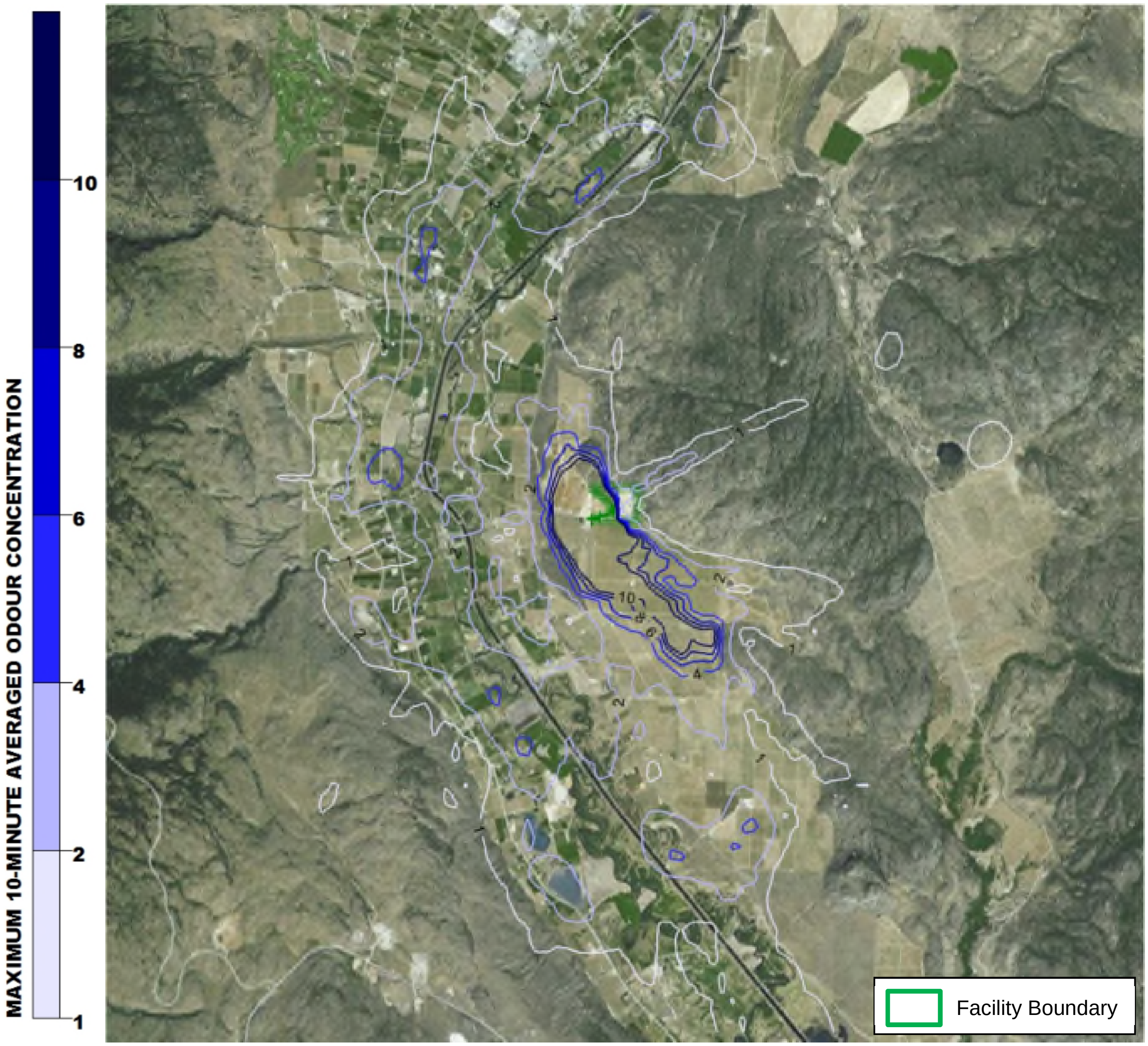


**Figure 16: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Covered ASP - Regional)**

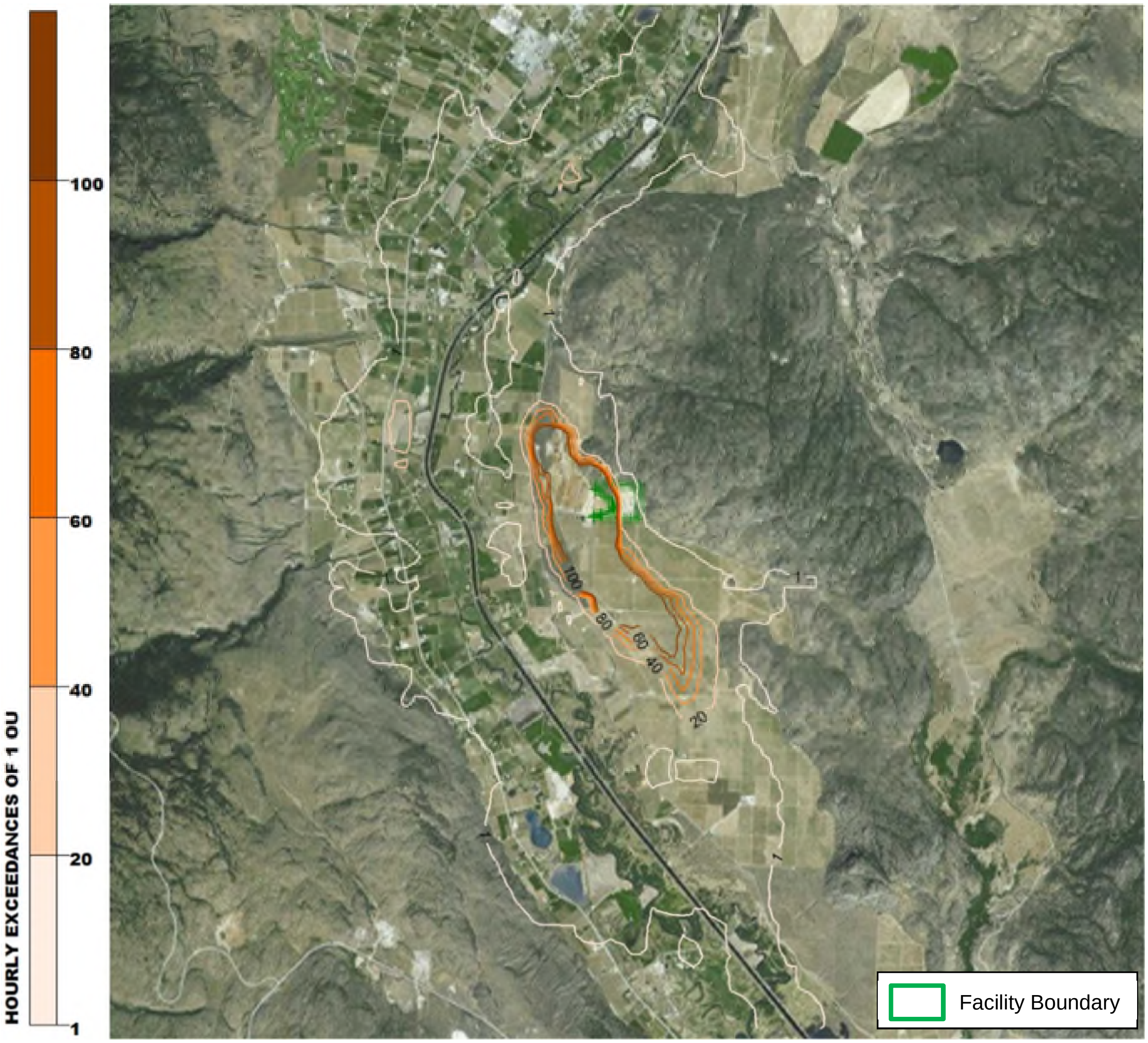


**Figure 17: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Covered ASP - Regional)**

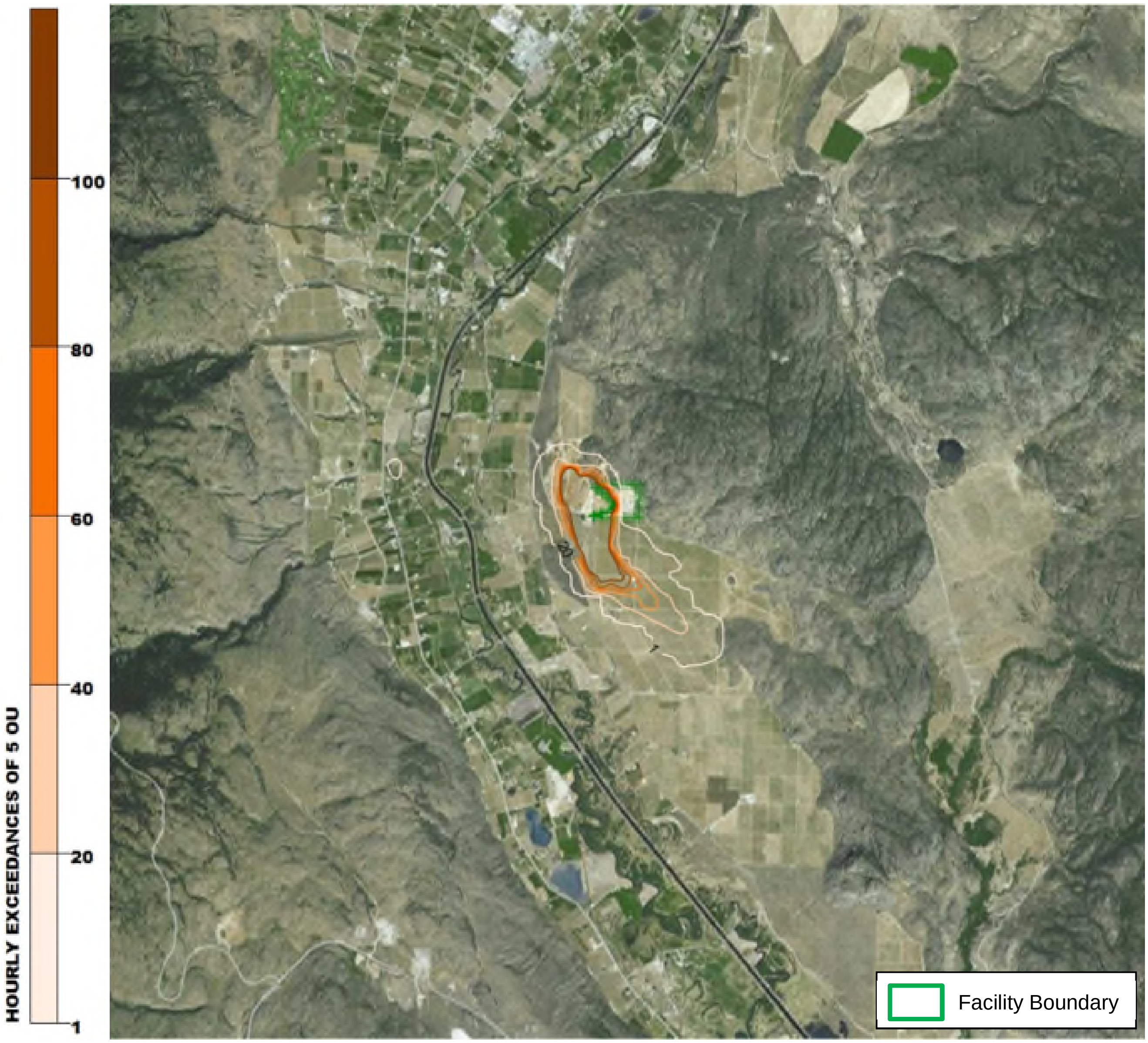


**Figure 18: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (Covered ASP - Regional)**

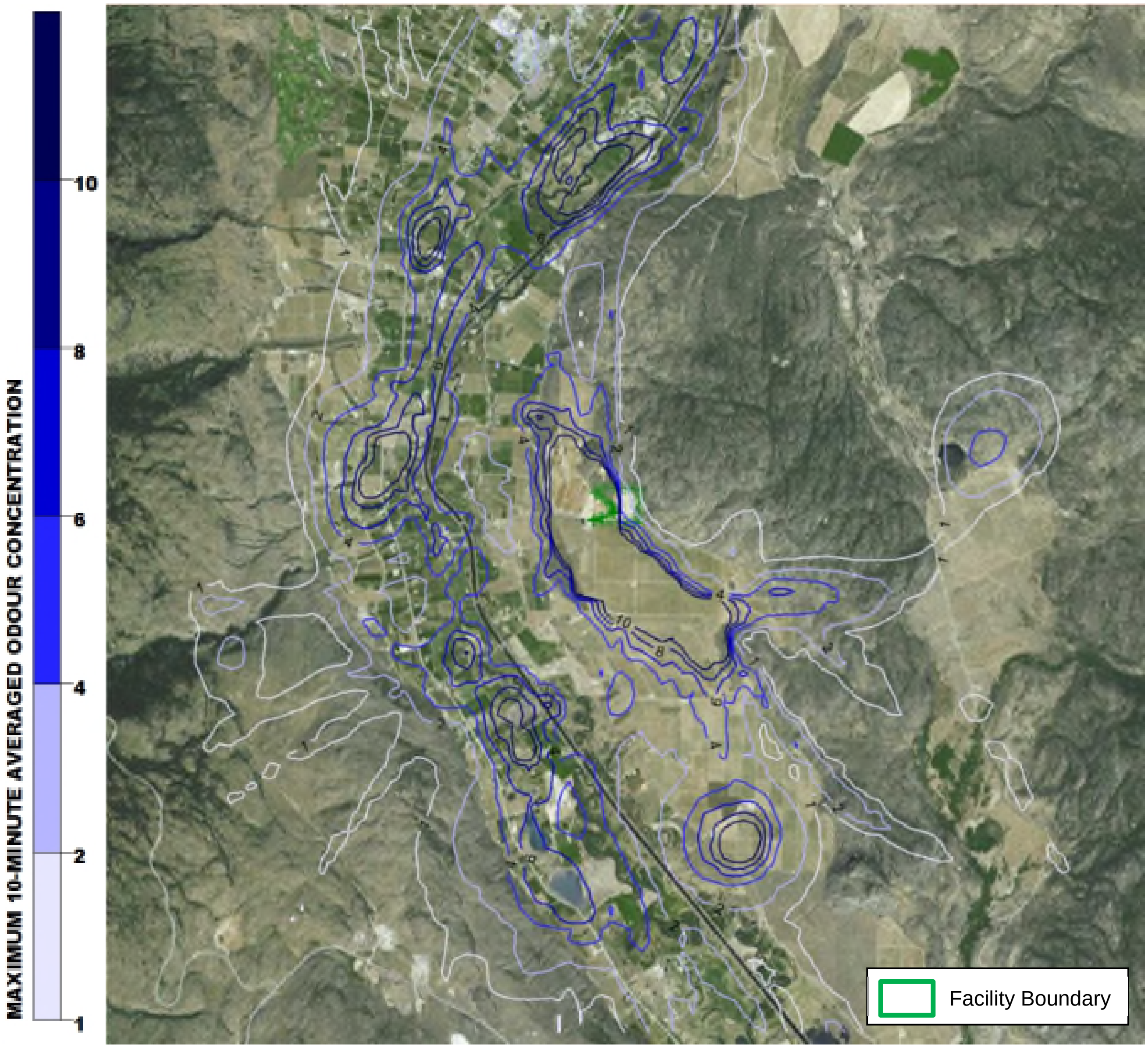


**Figure 19: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (In-Vessel - Regional)**

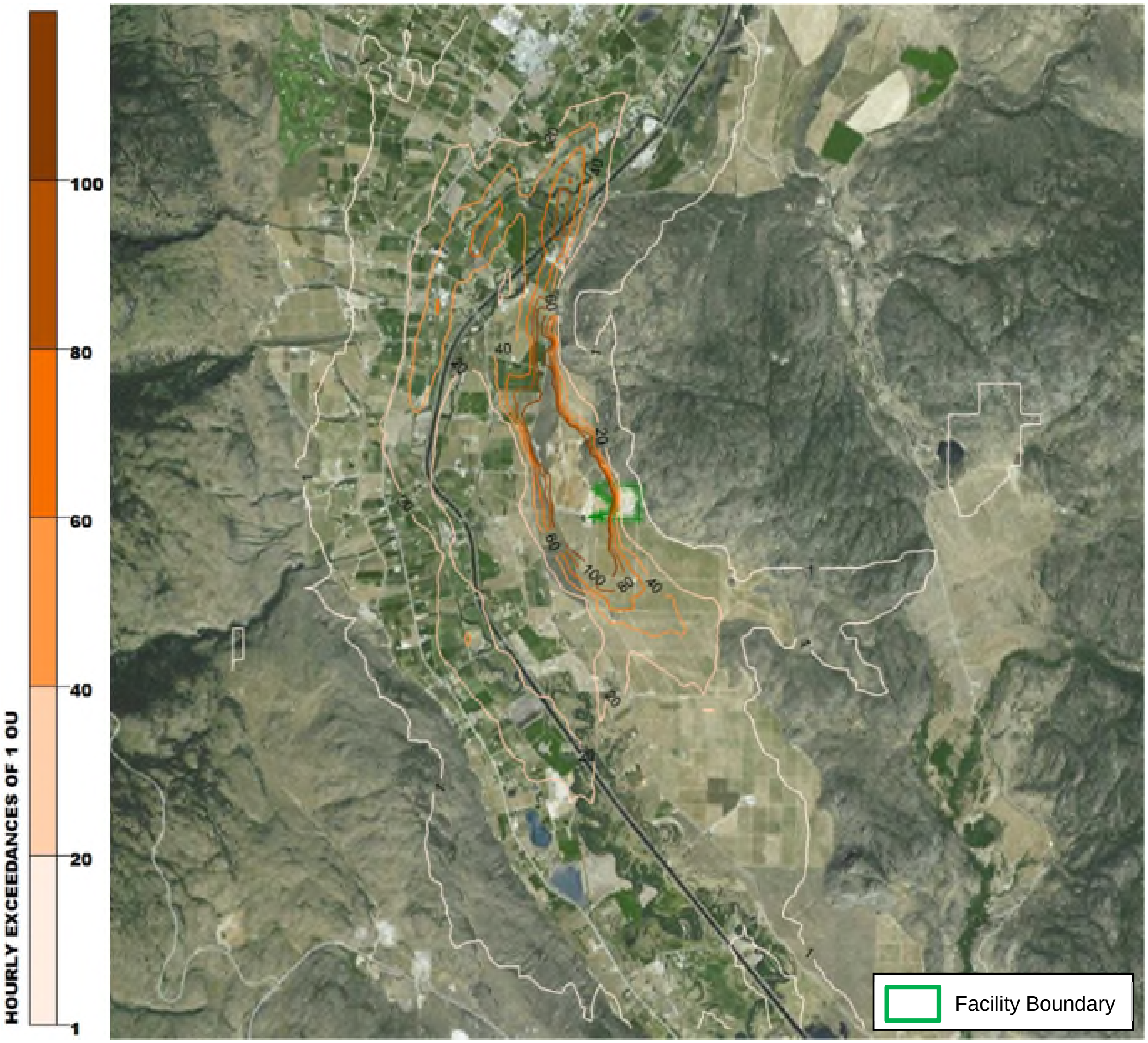


**Figure 20: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (In-Vessel - Regional)**

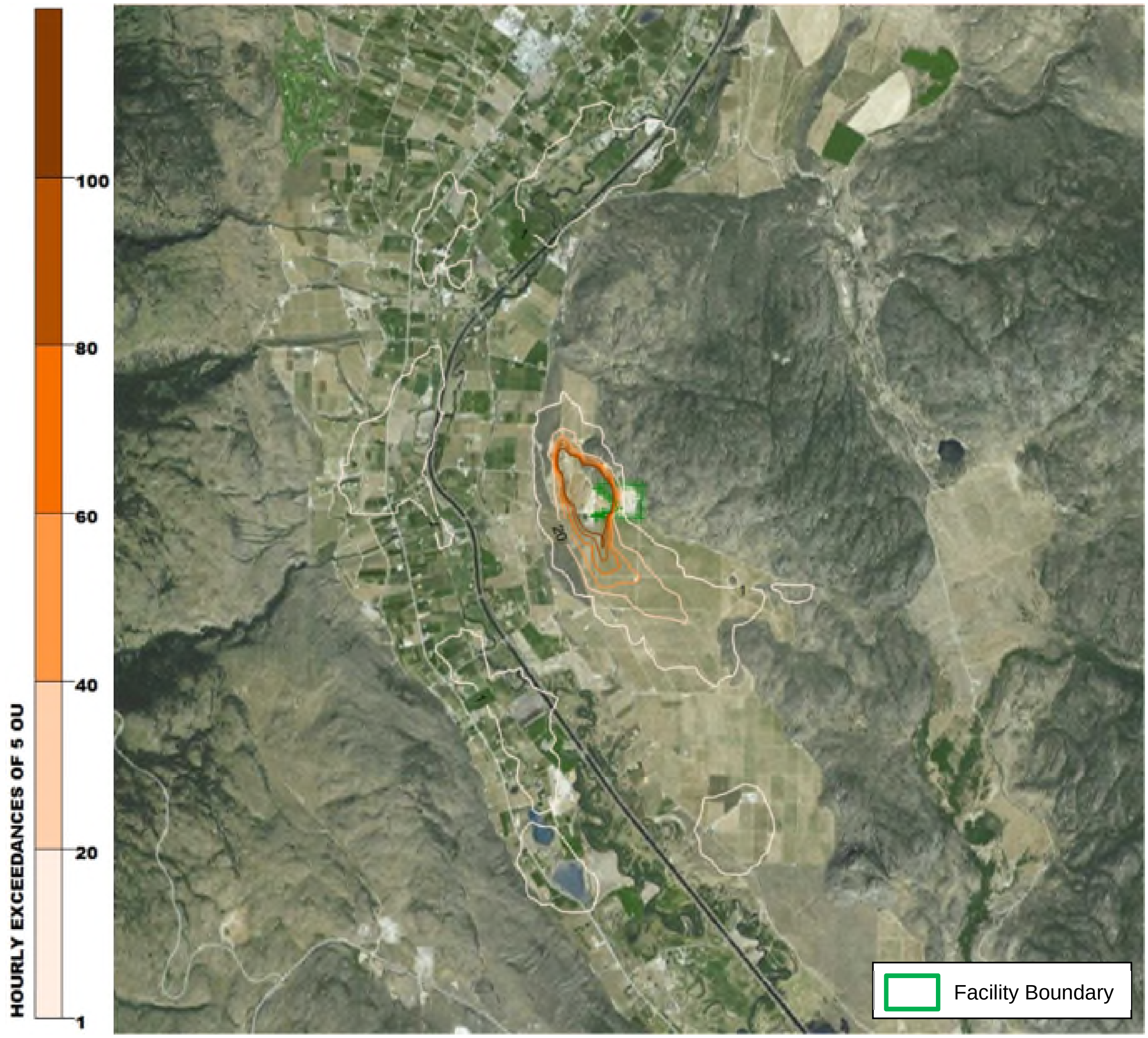


**Figure 21: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (In-Vessel - Regional)**

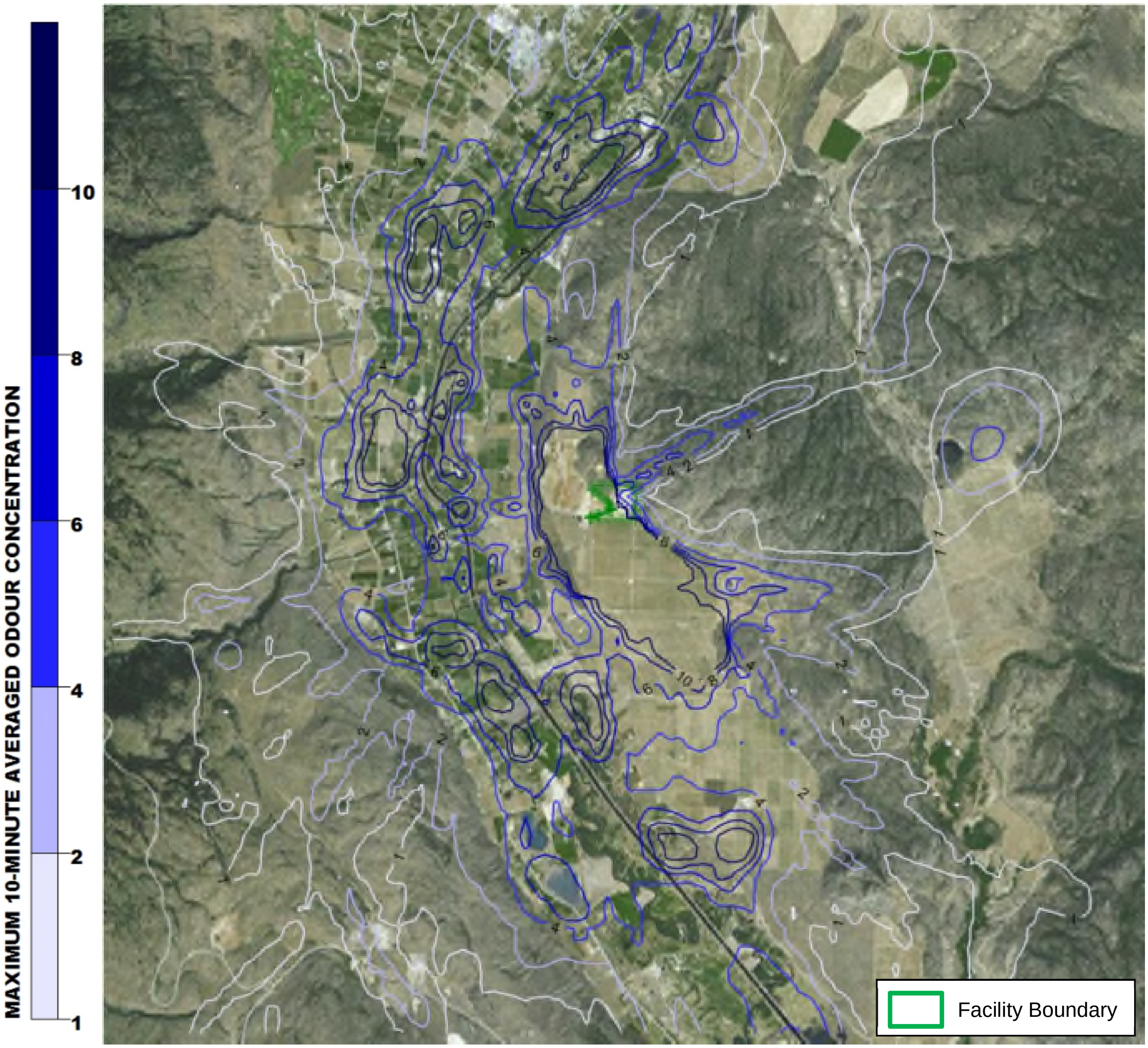


**Figure 22: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (AD - Regional)**

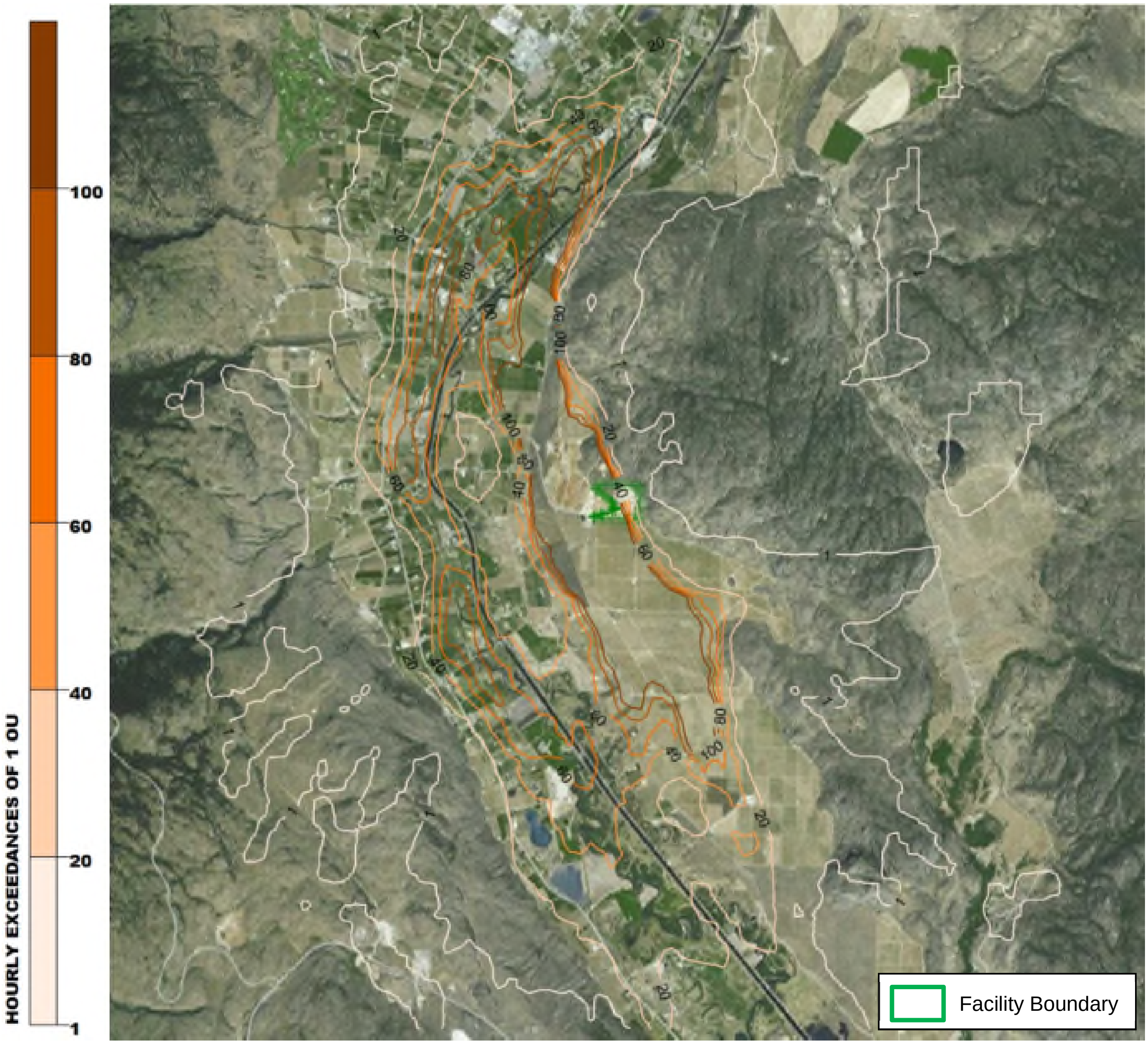


**Figure 23: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (AD - Regional)**

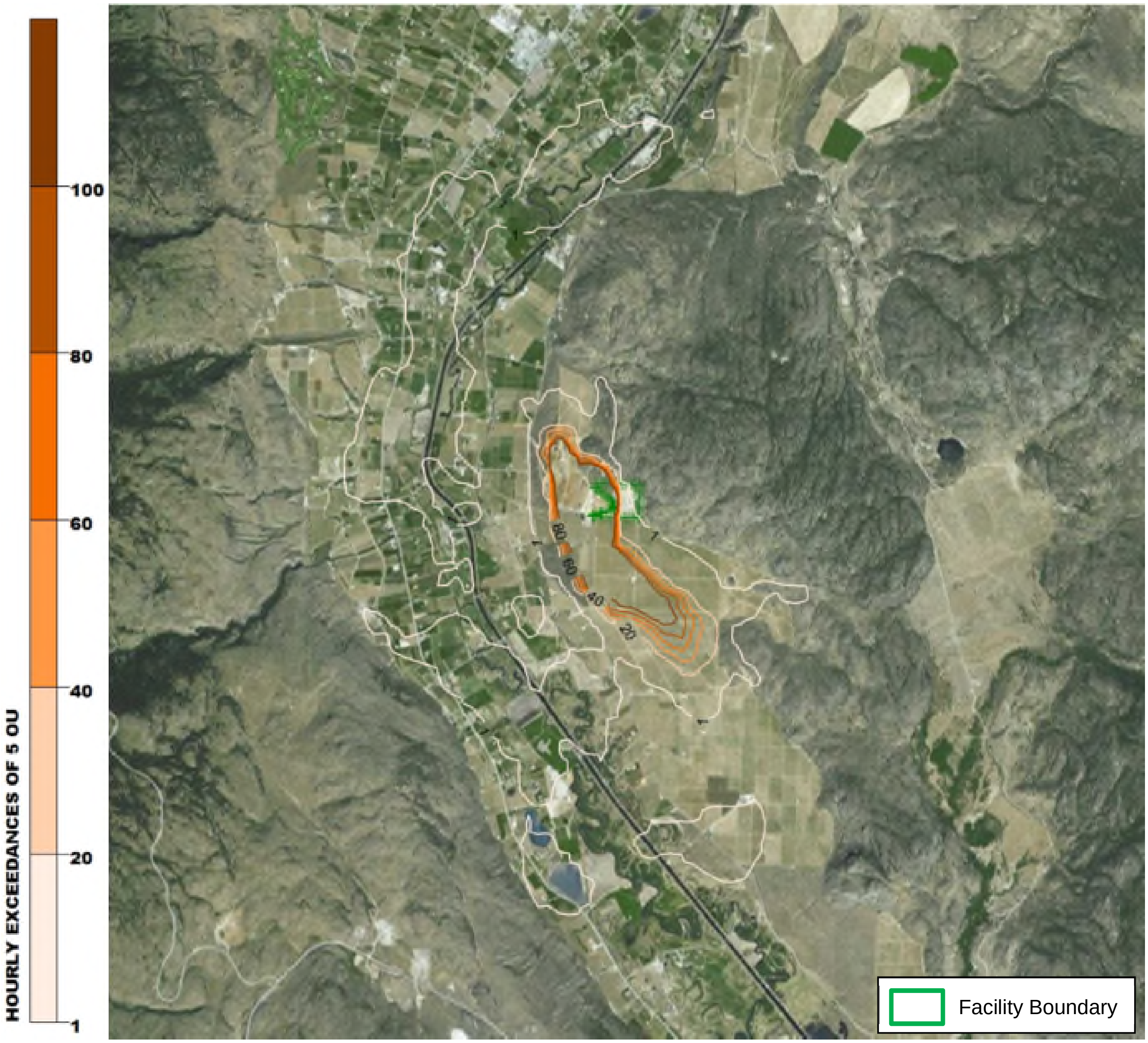


**Figure 24: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (AD - Regional)**

# OSOYOOS LANDFILL

# 1.0 INTRODUCTION

The following is a summary of model inputs and odour modelling results conducted for the purpose of assessing potential odour impacts from an organics management facility located at Osoyoos Landfill (hereafter referred to as the “Site”). Odour modelling was conducted using CALPUFF, an advanced air modelling software system recommended by the British Columbia Ministry of Environment (BC MOE).

# 2.0 MODEL INPUTS AND ASSUMPTIONS

## 2.1 Meteorology

The air dispersion model CALPUFF contains a diagnostic meteorological processor, CALMET, which creates a three-dimensional meteorological field over the spatial extent of the model. The data produced by CALMET is used by CALPUFF in its dispersion and plume transport calculations. Inputs to CALMET include the following:

- a geophysical grid, constructed using gridded terrain and land cover data (obtained from GeoGratis – Government of Canada); and
- a combination of prognostic (three-dimensional meso-scale model called MM5) meteorological data and hourly surface observations obtained from Environment Canada and BC MOE meteorological stations.

When CALMET is run in “no-observations” mode (using only MM5), the surface station observations provide a validation of the CALMET meteorology, in particular winds, to ensure representativeness. As MM5 is a meso-scale regional model, the grid used as input to CALMET is downscaled in three steps from a 32 km resolution grid to a 4 km grid and downscaled again within CALMET to the CALPUFF grid size (250 m). It is not expected that the meteorological time series in CALMET will exactly reproduce observed conditions on an hour by hour basis at any particular grid point, however it is expected to be representative of the general conditions over a given year.

Table 2.1 summarizes the meteorological inputs to CALMET used in the Osoyoos Facility odour modelling and mapping exercise.

### Table 2.1: CALMET Inputs and Metadata

| Parameter | Usage |
|---|---|
| Surface Stations | None |
| Upper Air Soundings | None |
| Prognostic Data | 4 km resolution MM5 |
| Meteorological Grid | 20 km (east-west) x 20 km (north-south) at 250 $m^2$ |
| Grid Centrepoint | 317500 m, 5437000 m, UTM Zone 11 |
| Vertical Cells (Cell Face Heights) | 10 (0 m, 20 m, 40 m, 80 m, 160 m, 320 m, 640 m, 1200 m, 2000 m, 3000 m, 4000 m) |
| Terrain Data | CDN DEM 15 min, SRTM1 |
| Land Use Data | GeoBase Land Cover circa 2000-Vector, USGS NLCD92 |

As land cover characteristics over the modelling domain vary with season (e.g., albedo, Bowen ratio, etc.), seasonal CALMET files were created using the model's default seasonal geophysical properties for each land cover category contained within the geophysical grid. The date ranges assumed to define each season are listed in Table 2.2. Year-to-year variability will undoubtedly occur, however, this temporal approximation was used to simplify modelling based on Environment Canada 1981 – 2010 climate norms for the Okanagan-Similkameen region. The modelled year was 2012.

**Table 2.2: Geophysical Property Seasonality**

| Season | Date Range |
|---|---|
| Winter | December 1 – February 29 |
| Spring | March 1 – May 31 |
| Summer | June 1 – September 15 |
| Fall | September 15 – November 30 |

## 2.1.1 Meteorological Validations

### 2.1.1.1 Winds

Figure 2.1 are snapshots of the CALMET-modelled surface winds on January 2, 2012 at $9^{00}$ hrs (left) and on July 1, 2012 at $20^{00}$ hrs (right). The time and date of the snapshots were selected to show the occurrence in the modelled data of the predominant seasonal valley flow conditions: southerly, typical in the winter and northerly typical in the summer. The figure also shows the boundary of both the Osoyoos and Oliver sites (green border) and the location of Environment Canada Osoyoos CS Station, located in East Osoyoos on the eastern side of Osoyoos Lake (green square, 49.028305°, -119.441025°).

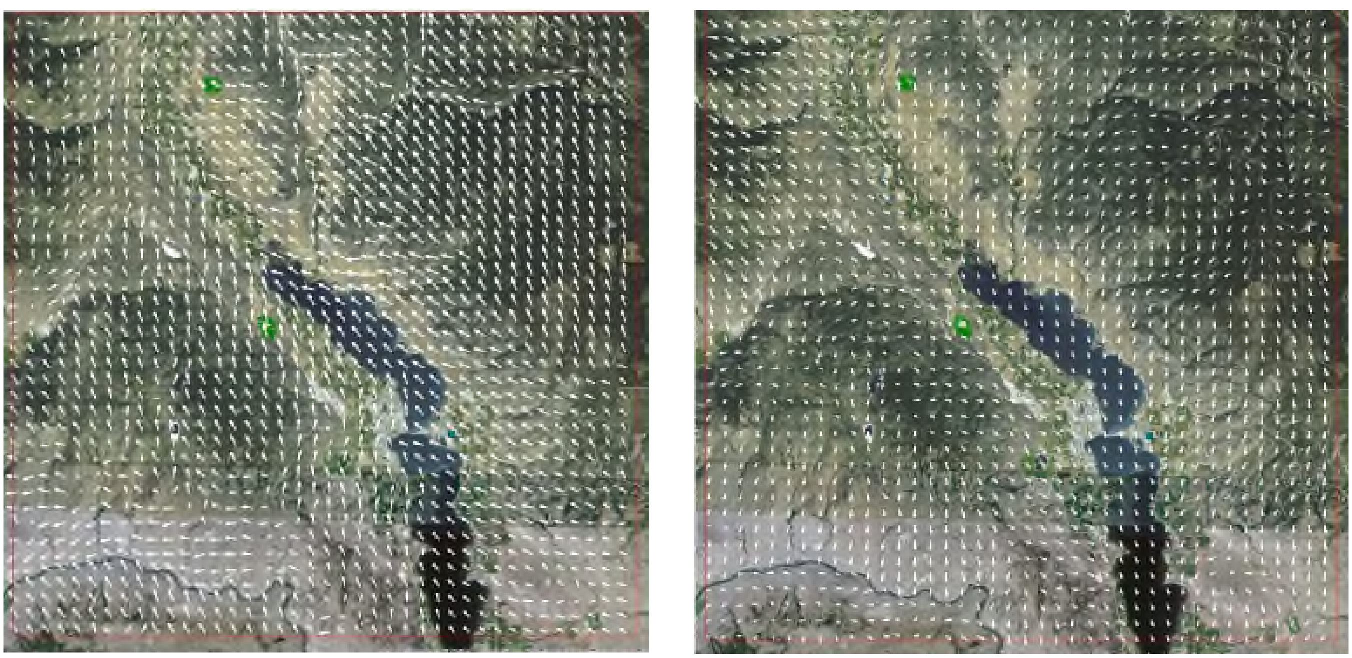

**Figure 2.1: CALMET-Modelled Wind Field – Typical Summer (left) and Winter (right)**

Figure 2.2 is a snapshot of CALMET-predicted winds at January 5, 23[00] hrs, showing a period of relatively calm winds and valley subsidence.

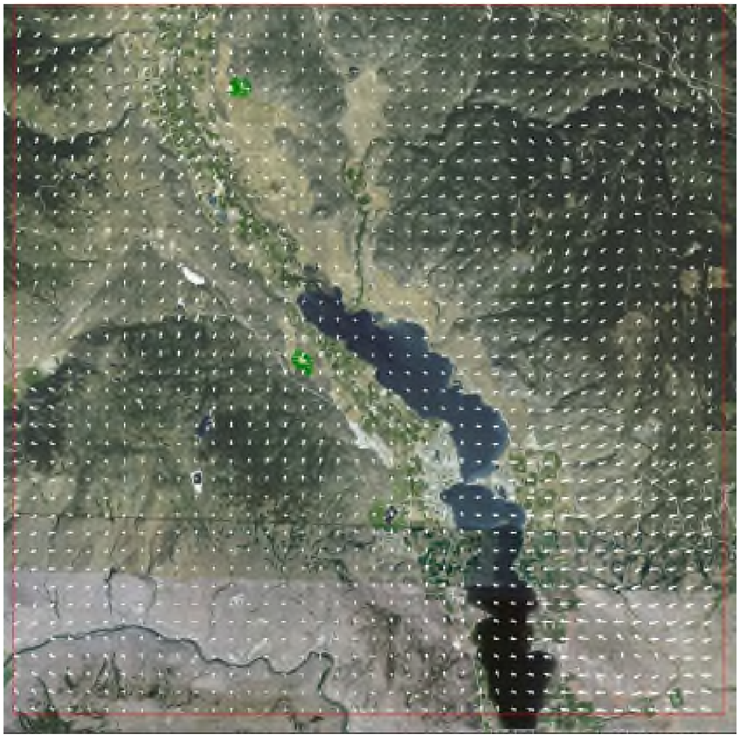

**Figure 2.2: CALMET-Modelled Wind Field – Calm Winds, Valley Subsidence**

Figure 2.3 shows the predicted winds at the location of Osoyoos CS for 2012 (left) and the 2012 observed winds from Environment Canada Osoyoos CS station (right). The directional pattern is captured in CALMET with a slight over-prediction of easterly winds from the Okanagan Highland vs. southerly Okanagan Valley winds in the vicinity of town. MM5/CALMET slightly over-predicts wind speeds in the vicinity of the Osoyoos CS station, however it should be noted that in general, CALMET has been found to slightly under-predict winds at ground level and the observed discrepancy may be the result of siting (located in the residential area of East Osoyoos).

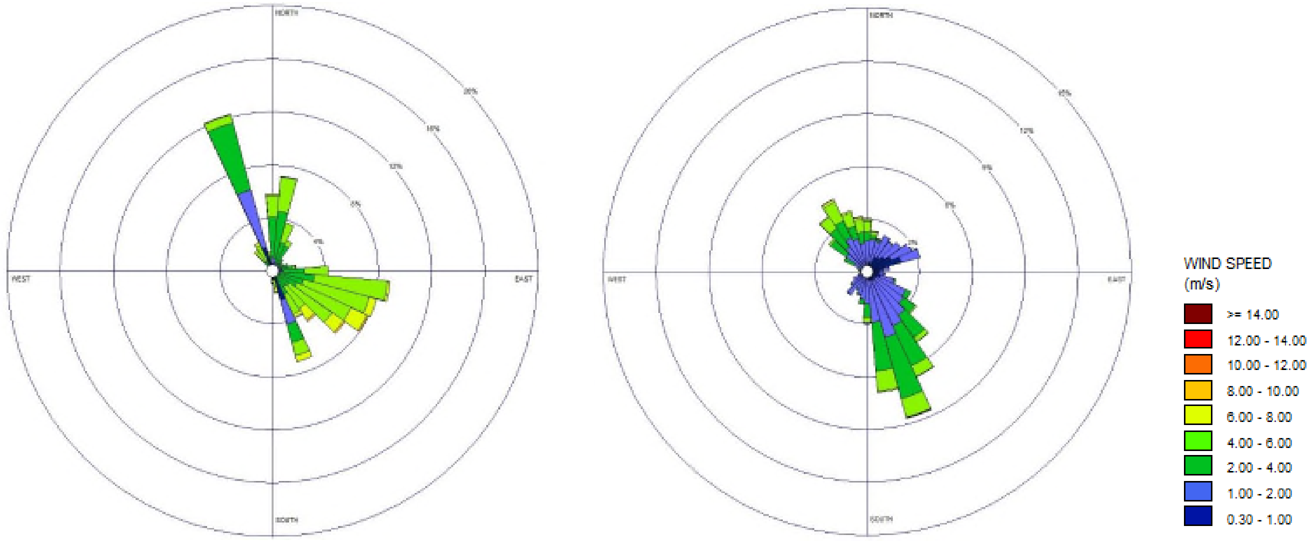


**Figure 2.3: Comparison of CALMET at Osoyoos CS (left) and Observed EC Osoyoos CS Winds (right) (2012)**

Figure 2.4 shows CALMET-predicted winds at four locations along the valley as annual (2012) wind roses. As would be expected, the wind field generally follows the valley orientation.

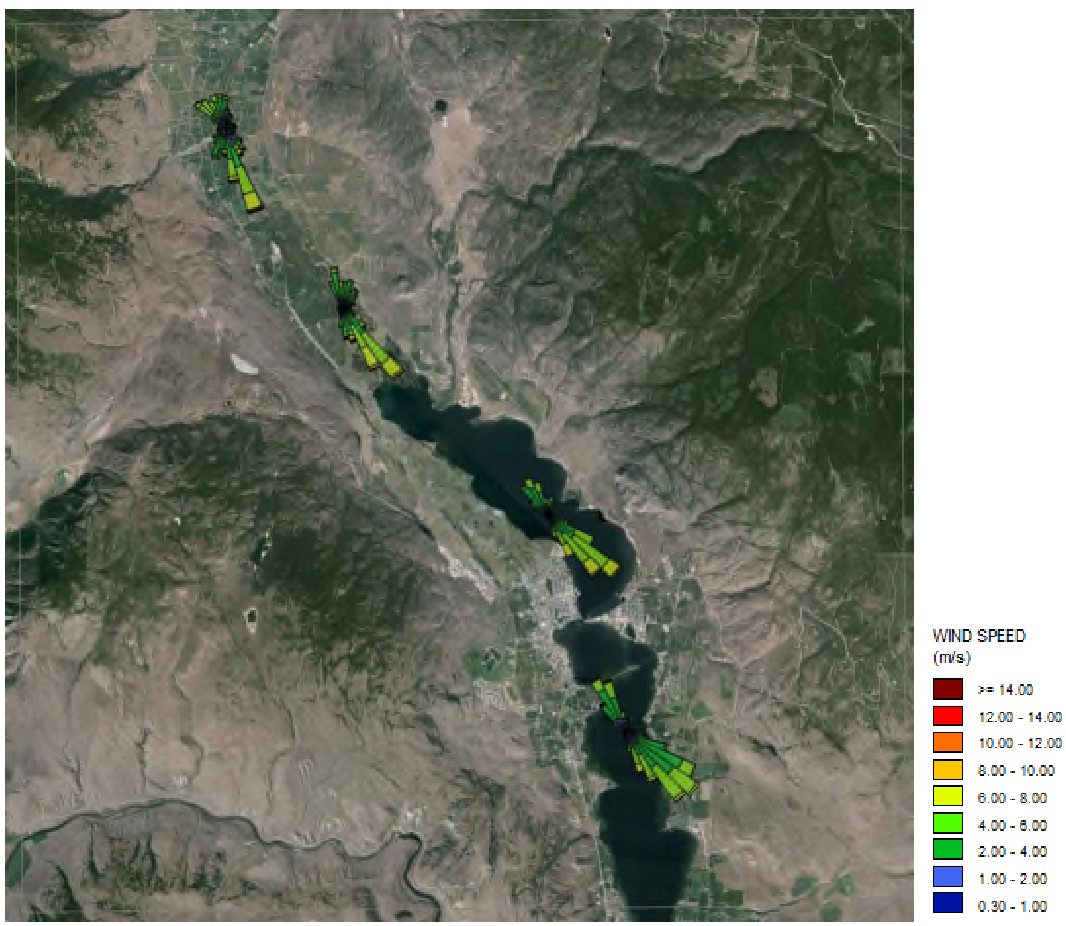


**Figure 2.4: Wind Field Validation – CALMET-Predicted Valley Winds (2012)**

### 2.1.1.2 Mixing Height

The atmospheric mixing height can be defined as the top of the layer in the lower atmosphere, within which an emitted species, in this case odour, is readily mixed through turbulence and convective processes. Therefore, when the mixing height is low, higher ground-level concentrations will generally be predicted. Figures 2.5 and 2.6 are time series of modelled mixing heights extracted from CALMET over two distinct seasonal periods in 2012 over Osoyoos Lake (N 49.049º, -119.471º) and over land, at the location of the residence nearest the Osoyoos Facility (49.059795, -119.518636). Over-water mixing heights during the day are generally lower than that over land. The top figure (red) plots a time series of mixing heights in the winter (between February 1 and 8), while the lower figure (blue) plots mixing heights in the summer (between July 1 and 8).

Seasonal contrast is strongly evident since there is reduced solar radiation, lower temperatures and snow cover, among other factors during the winter that results in generally lower mixing heights, and thus resulting in higher concentrations of odour. Both figures show the expected strong diurnal pattern, with mixing heights dropping quite close to the ground surface (~50 m as a default in CALMET) at night. When overnight mixing heights are higher, it is due to turbulence induced by higher wind speeds over uneven terrain.

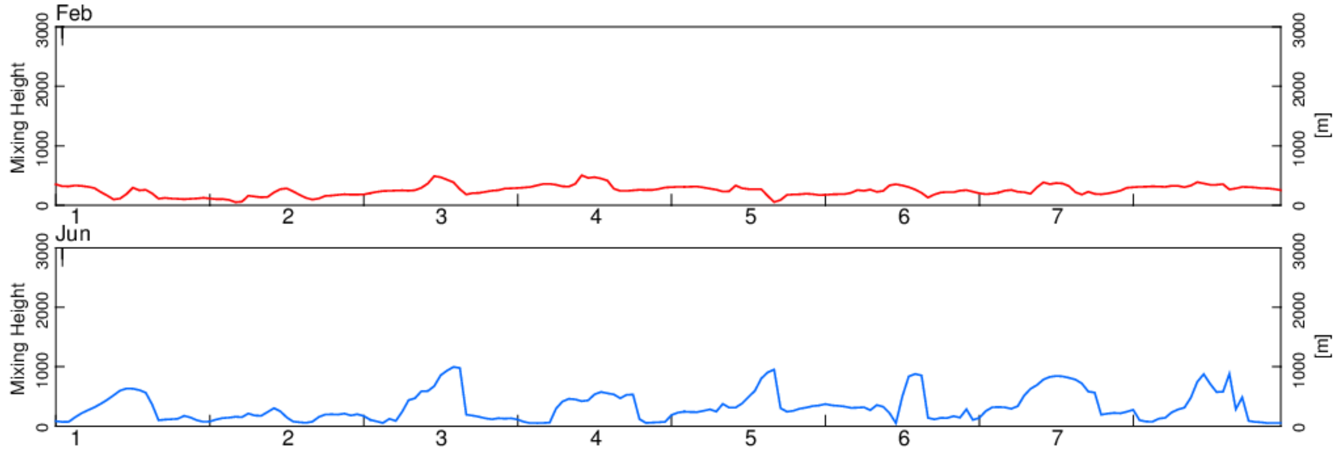


**Figure 2.5: CALMET-Modelled Mixing Heights for Winter (Red) and Summer (Blue) Over Osoyoos Lake**

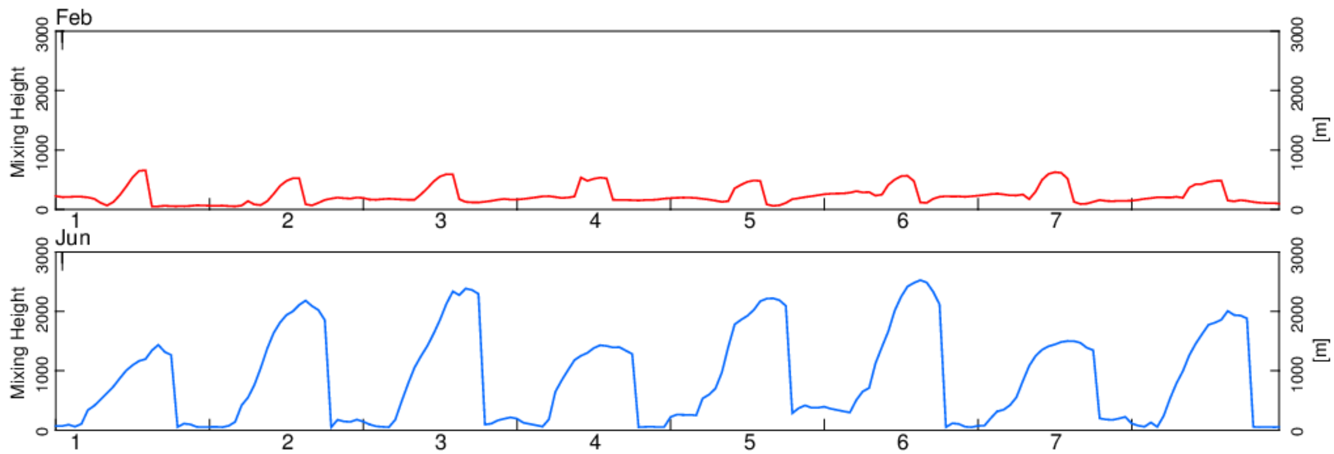


**Figure 2.6: CALMET-Modelled Mixing Heights for Winter (Red) and Summer (Blue) near Osoyoos Facility (49.059795, -119.518636)**

## 2.2 Area Sources and Emission Factors

The site layouts from the *Organics Management Consultant Task 2 – Feasibility Assessment* report for Osoyoos and Osoyoos with SSO (source separated organics from residential food waste) were used to define the boundaries of the odour sources for this modelling analysis. Areas that generate odours were assigned a specific emission factor according to the activity taking place (e.g. composting, curing, pile turning, etc.). In the main report, Table 2.1 provides a description of the emission factors used for each of the scenarios below:

- Current composting operations (windrow composting for yard waste);
- Aerated static pile (ASP);
- Membrane covered aerated static pile;
- In-vessel composting; and
- Windrow composting with SSO from residential collection (as well as current quantities of yard waste).

Emissions were assumed to occur homogeneously over the entirety of the area source. Some odour emissions (e.g. pile turning, pile moving, etc.) were assigned a diurnal variation based on the expected times of day the activity is to be performed (Table 2.1 of the main report). Such activities are expected to occur daily at the Site over a one- to two-hour period, however since the activity may occur at any time during the operational hours of the facility in the morning or in the afternoon, odour emissions were assumed in the model to occur between $10^{00}$ to $12^{00}$ – representing a time of day when vertical mixing is generally highest – and between $15^{00}$ to $17^{00}$ – when, during the winter, the mixing height is approaching its night time minimum, thus resulting in higher concentrations closer to the ground. This is a somewhat conservative approach since the activity may only be occurring over a portion of a single hour rather than four, may not take place every day, and peak odour emission would only occur during and immediately following the activity and decay in the hour following. It should be noted that odour emissions produced from pile building and moving are inconsequential compared to that produced from the biofilters which emit odour continuously.

Emission heights were either assigned a value of 3 m or 1 m depending on the activity occurring within the area source. Specific heights used for the various activity types are listed in Table 2.1 of the main report.

## 2.3 CALPUFF Settings and Assumptions

The CALPUFF model input settings were assigned with consideration to the recommendations in Table 9.7 of '*Recommended CALPUFF Input Group 2 Switch Settings*' in '*Guidelines for Air Quality Dispersion Modelling in British Columbia*'. Generally, default model settings were used. Since the area of interest is in the near-field (within 12 – 15 km of the source), dispersion coefficients were internally calculated using micrometeorological variables (MDISP = 2) based on estimates of the crosswind and vertical components of turbulence based on similarity theory and the land cover type. The probability distribution function (PDF) was used for dispersion under convective conditions (MPDF = 1) which explicitly accounts for the differences in the distribution and strengths of up and down drafts within the convective boundary layer, reporting the average between the two. By using these two settings, AERMOD-type dispersion is simulated (generally accepted as better-predicting in the near-field than CALPUFF), while also providing the benefit of a puff model and allowing for the effects of complex terrain.

The receptor grid spacing was 250 m at ground level over the entire grid. The simulations were to determine the general effects downwind from the facility, on the scale of kilometres, and therefore did not consider building downwash – the drawdown of the odour plume downwind of facility buildings due to turbulence.

# 3.0 RESULTS

Since the time step of the meteorological data is one-hour, CALPUFF can only output one-hour averaged predictions of odour concentration. However, since odour perception is on a much shorter scale, an averaging time-scalar must be applied to assess shorter-term peak concentrations due to plume meandering within the hourly period. Hourly odour concentrations are scaled to a ten-minute averaging period using Equation 1.

$$Cp = Co * \left(\frac{t_o}{t_p}\right)^{0.28} \quad (1)$$

Pursuant to Equation 1, $t_o$ is the 60 minute averaging time, $t_p$ is the short-term averaging time (10 minutes) and $C_o$ and $C_p$ are the respective peak concentrations (BC MOE). The scalar when converting from hourly to ten-minute average concentrations equates to 1.65.

## 3.1 Odour Units

An Odour Unit is a way of quantifying odours through the use of an odour panel that consists of a group of people with 'calibrated noses'. The definition of an Odour Unit is based on the proportion of odour panel members that can detect the smell of a substance. One OU represents the concentration of a particular substance when 50% of the odour panel can detect the odour. This is called the perception threshold[1]. At this point, although an odour may be detected, it is not distinct enough to be able to identify the type of odour.

The Odour Unit scale is based on dilutions, as shown in the following figure. As the number of odour units increase, more people can detect the odour, and the intensity of the odour increases. Five OU is considered a faint odour and ten OU is considered a distinct odour (the point when some people can identify the type of odour, or its potential source)[2].

1 http://blog.odotech.com/odor-unit-perception-threshold
2 Odours and VOCs: Measurement, Regulation and Control Techniques (2009). Kassel University Press.

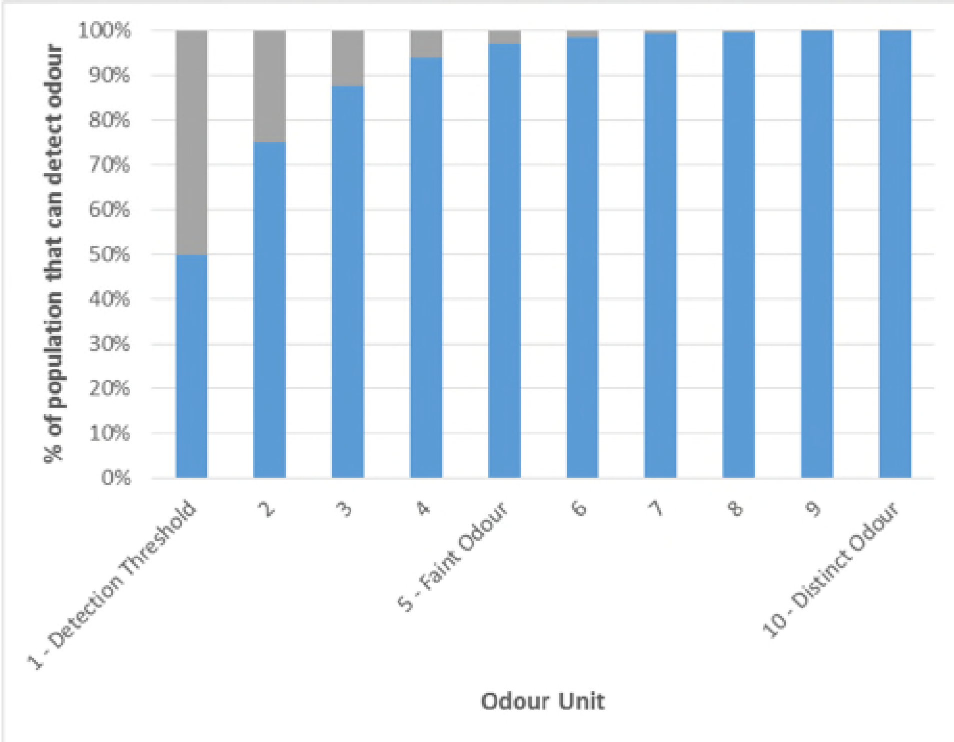


**Figure 3.1: Odour Unit Scale**

There are currently no guidelines for odour limits for composting facilities in British Columbia, however, some wastewater treatment facilities have imposed odour limits. For example, the standard in Metro Vancouver is no more than five OU at the property line. In other jurisdictions, the guideline is to have no detectable odour at the property line. At the Ogogrow facility in Vernon, BC, the limit is 50 OU at the property line.

## 3.2 Odour Maps

Odour maps are included as part of Appendix A. For each organics processing option listed in Section 2.2, odour modelling results are presented as three different plots:

- Maximum Odour Concentrations – The maximum predicted 10-minute odour concentration at each receptor point over the course of the modelled year. This is displayed as a contour plot showing the maximum predicted 10-minute averaged odour concentration at every ground level receptor point over the entire one-year simulation (8784 hours) as a blue gradient (light to dark). The 1 OU contour is white. The highest levels >10 OU are dark blue. The facility boundary is shown as a green outline.

- Hourly Exceedances >1 Odour Unit (OU) – The number of hours over the course of the modelled year where an odour threshold of 1 OU was exceeded in a ten-minute averaged concentration. This is displayed as a contour plot showing the number of times the predicted 10-minute odour concentration exceeded 1 OU over the modelled year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to 50% of the population being able to detect odour produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.

- Hourly Exceedances >5 OU – The number of hours over the course of the modelled year where an odour threshold of 5 OU was exceeded in a ten minute averaged concentration. This is displayed as a contour plot

showing the number of times the predicted 10-minute odour concentration exceeded 5 OU over the modelled year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to when a faint odour is produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.

## 3.3 Results Summary

The odour maps presented in Appendix A show: (1) the magnitude and spatial extent of maximum ground level odour, and (2) the number of exceedances of odour detection thresholds for the technologies assessed. The membrane covered aerated static pile results had the least odour issues.

The scenario Windrow with SSO, where only residential food waste is composted in windrows at the Site, has a similar cumulative odour emission compared to the Membrane Covered Aerated Static Pile, as shown in Appendix A. This scenario could be a lower cost alternative for composting as very little new infrastructure is required, but will still have relatively low odour emissions. In this case, commercial food waste would need to be directed to another composting facility for processing.

The following table summarizes the results of the odour mapping exercise based on the predicted maximum odour and number of hours of odour exceedances at a location 210 m northeast of the property boundary representing the resident that is closest in proximity to the Site (49.059795, -119.518636), Figure 3.2.

### Table 3.1: Results Summary based on Closest Receptor Point

| Scenario | Maximum Predicted 10-min Odour | Odour Exceedance >1 OU (hours per year) | Odour Exceedance >5 OU (hours per year) |
|---|---|---|---|
| Current Composting Operations | 0.2 OU | 0 | 0 |
| Aerated Static Pile | 3.1 OU | 20 | 0 |
| Membrane Covered Aerated Static Pile | 0.7 OU | 0 | 0 |
| In-Vessel | 2.0 OU | 9 | 0 |
| Windrow with SSO | 0.4 OU | 0 | 0 |


**Figure 3.2: Location of Nearest Discrete Receptor (49.059795, -119.518636)**

### 3.3.1 Biofilter Effect

Similar to the odour maps shown in Section 3, the Membrane Covered Aerated Static pile has the lowest odour emissions of the technologies as this type of operation does not use a biofilter. The greatest source of odour emissions can be attributed to the biofilters, as seen in Table 3.2.

### Table 3.2: Odour Emissions from Biofilters

| Scenario | % of Odour from Composting Biofilter |
|---|---|
| Current Composting Operations | N/A |
| Aerated Static Pile | 76% |
| Membrane Covered Aerated Static Pile | N/A |
| In-Vessel | 69% |
| Windrow with SSO[1] | N/A |

[1] Only contains residential food waste; other scenarios include commercial food waste

# APPENDIX A

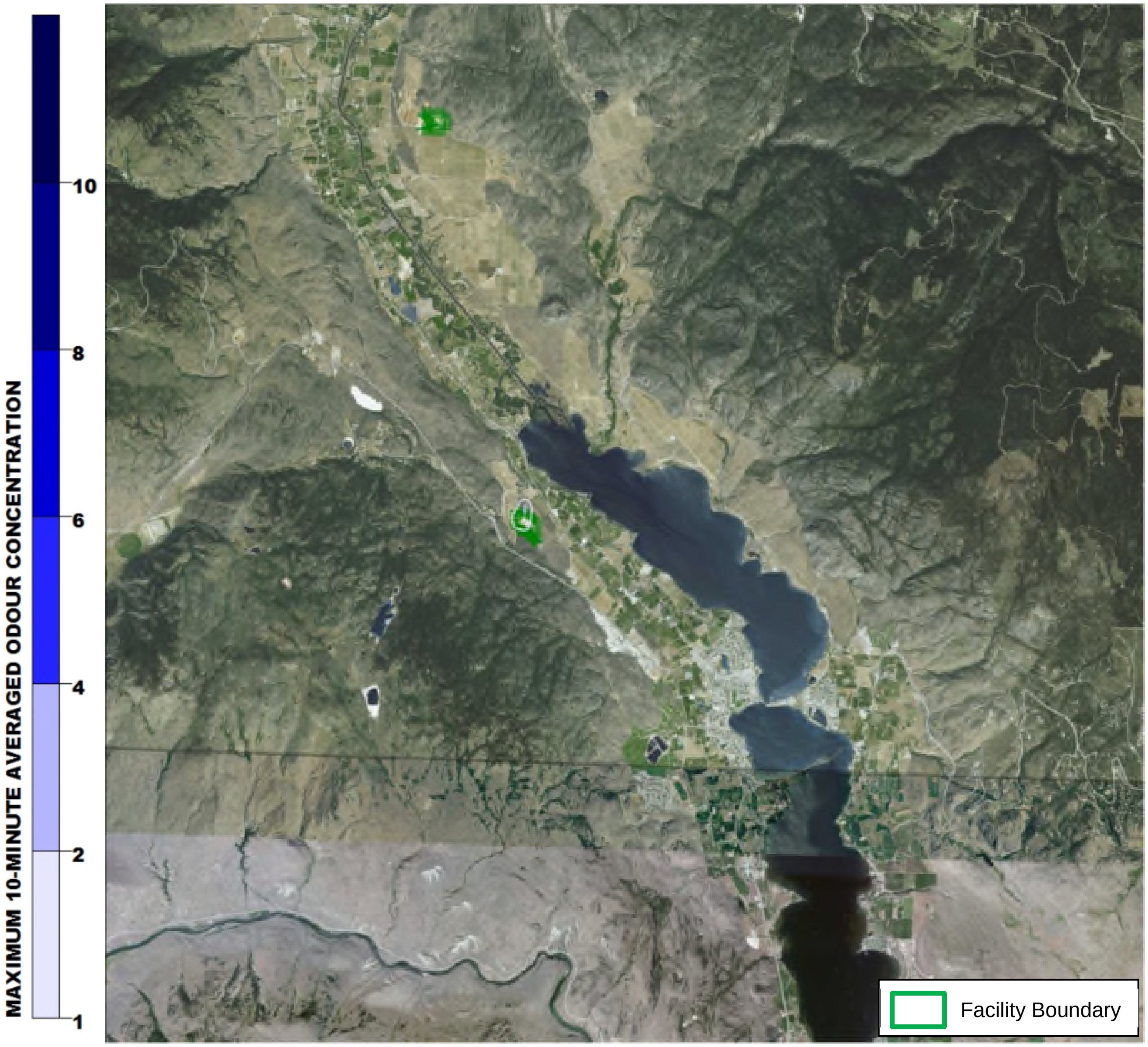


**Figure 1: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Current Composting Operations)**

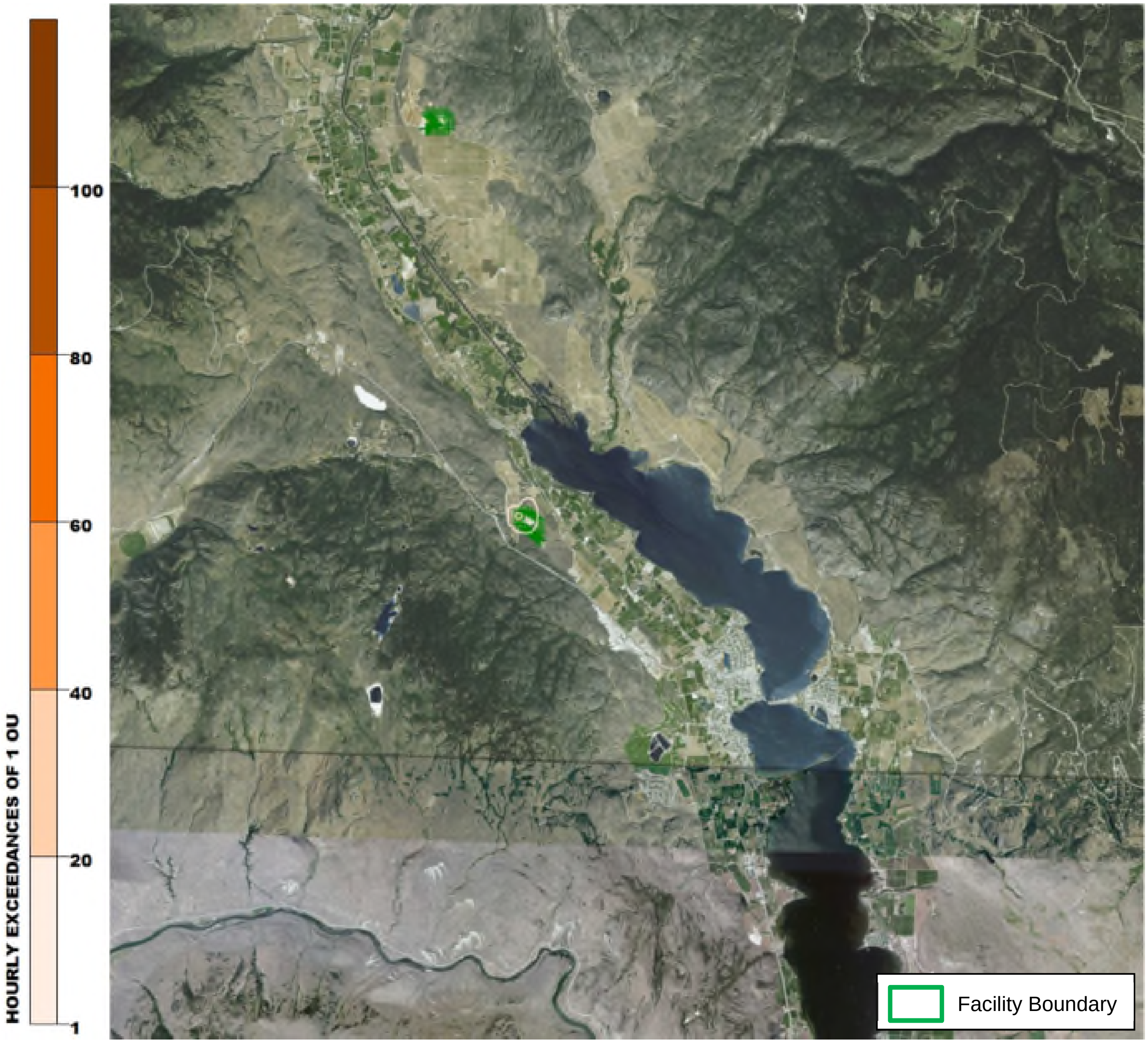


**Figure 2: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Current Composting Operations)**

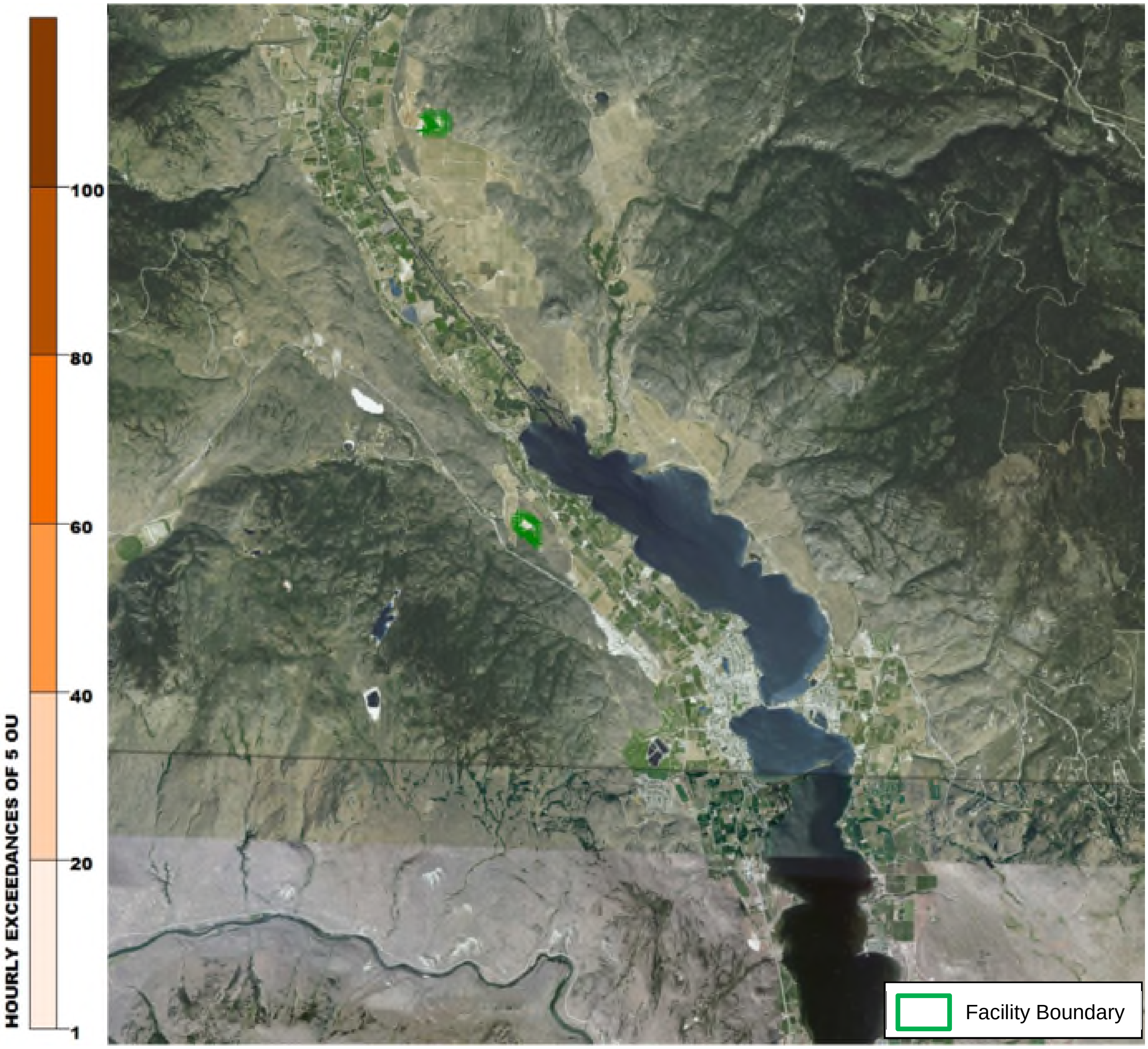


**Figure 3: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (Current Composting Operations)**

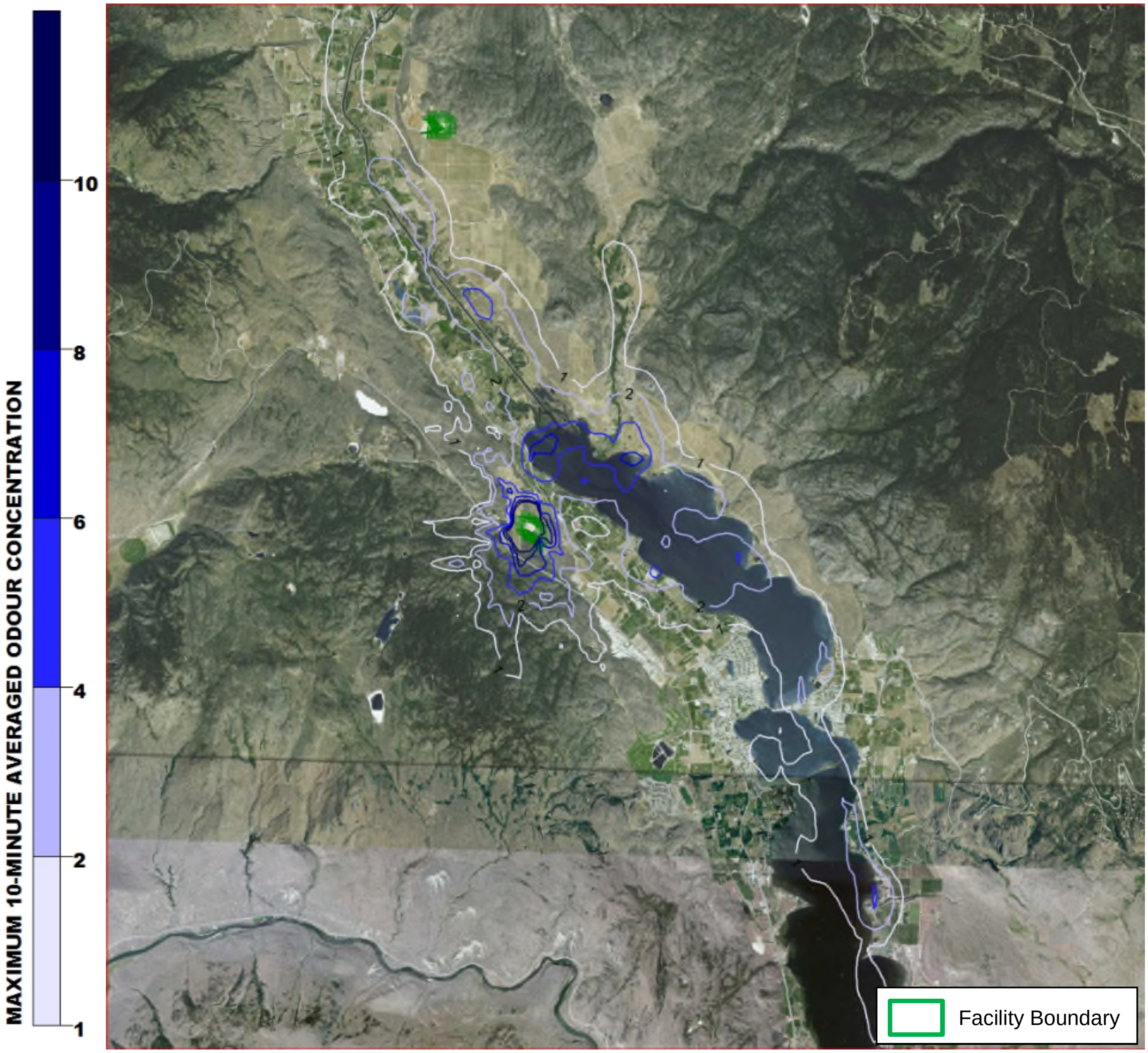


**Figure 4: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (ASP)**

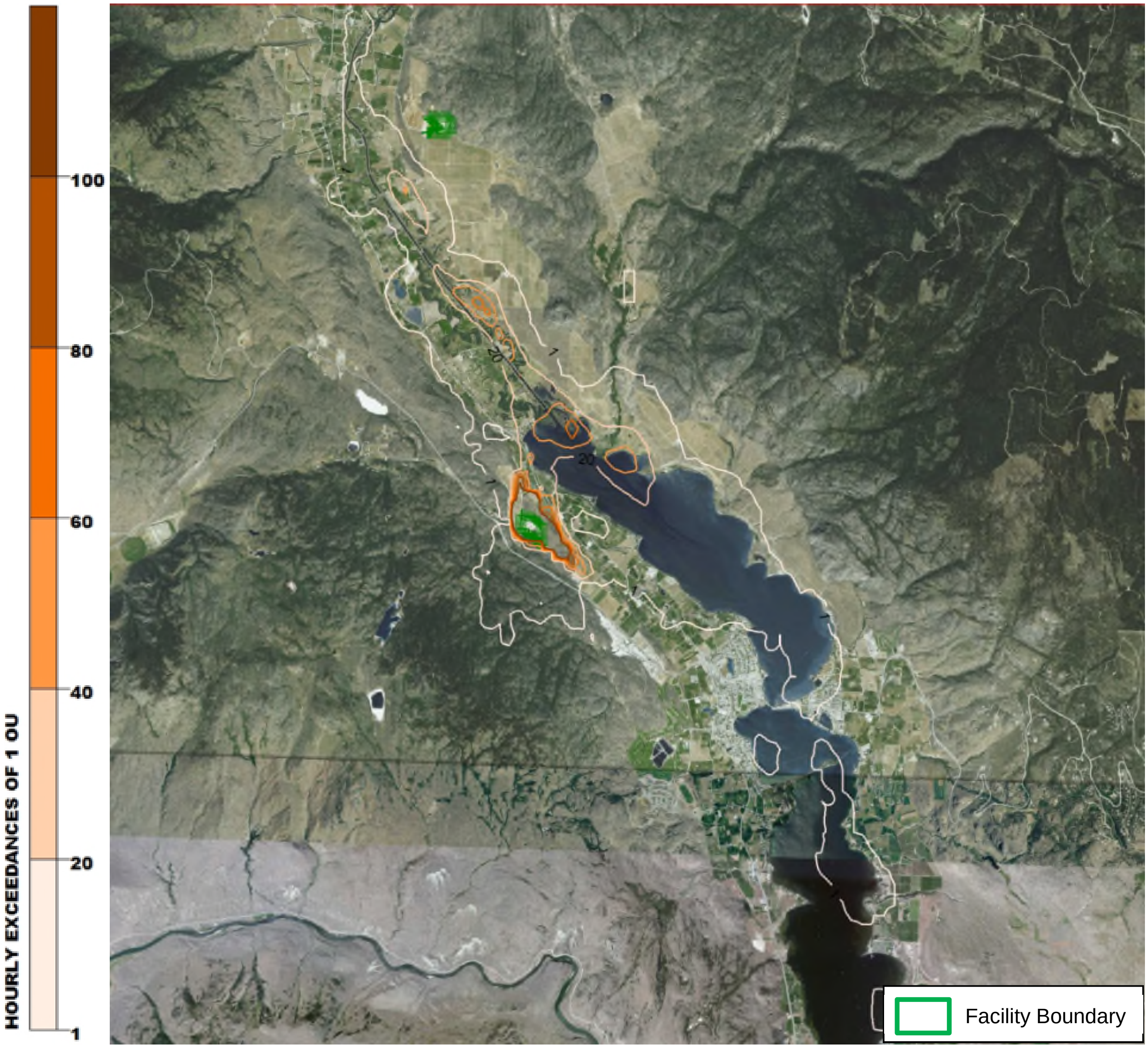


**Figure 5: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (ASP)**

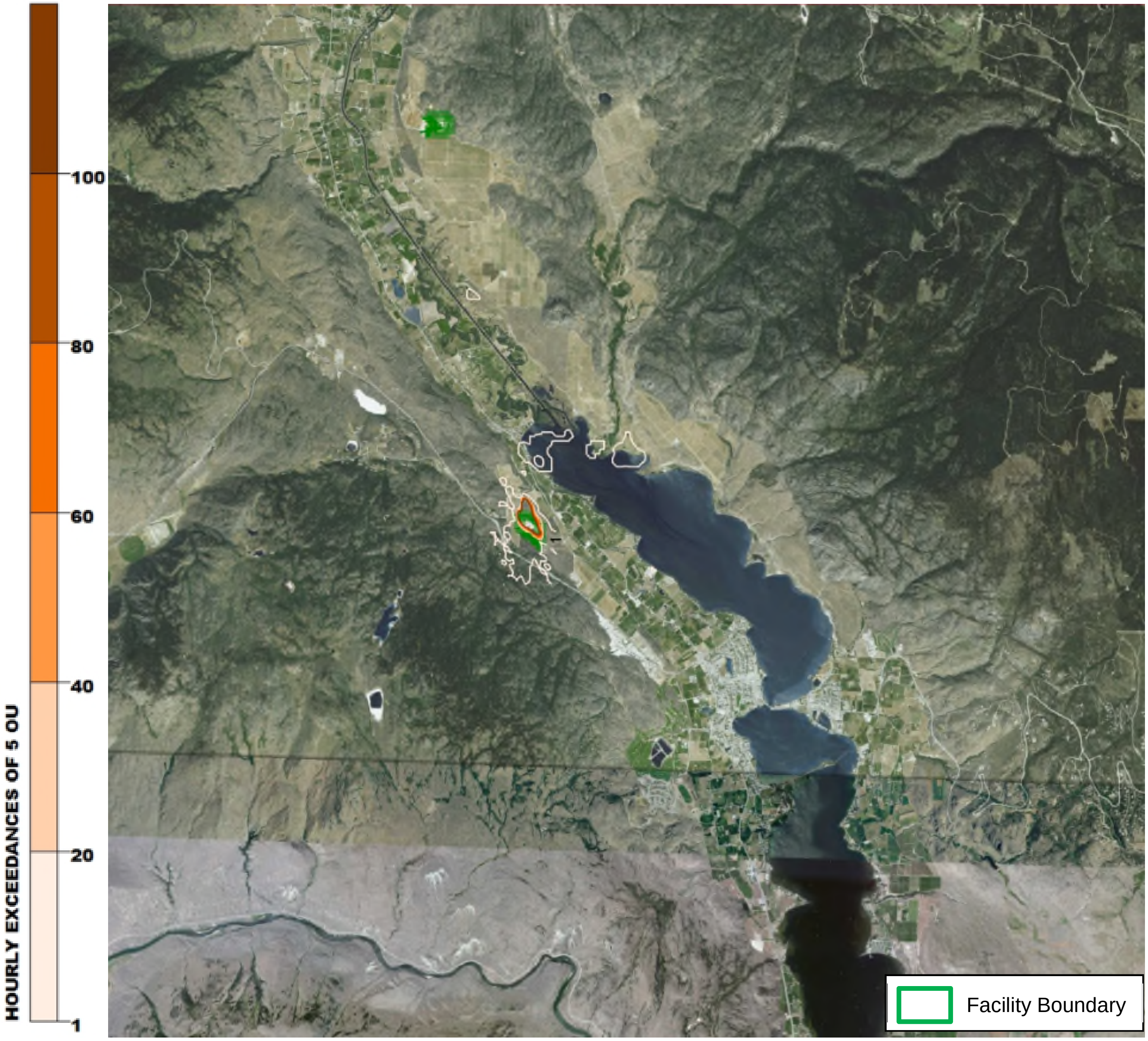


**Figure 6: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (ASP)**

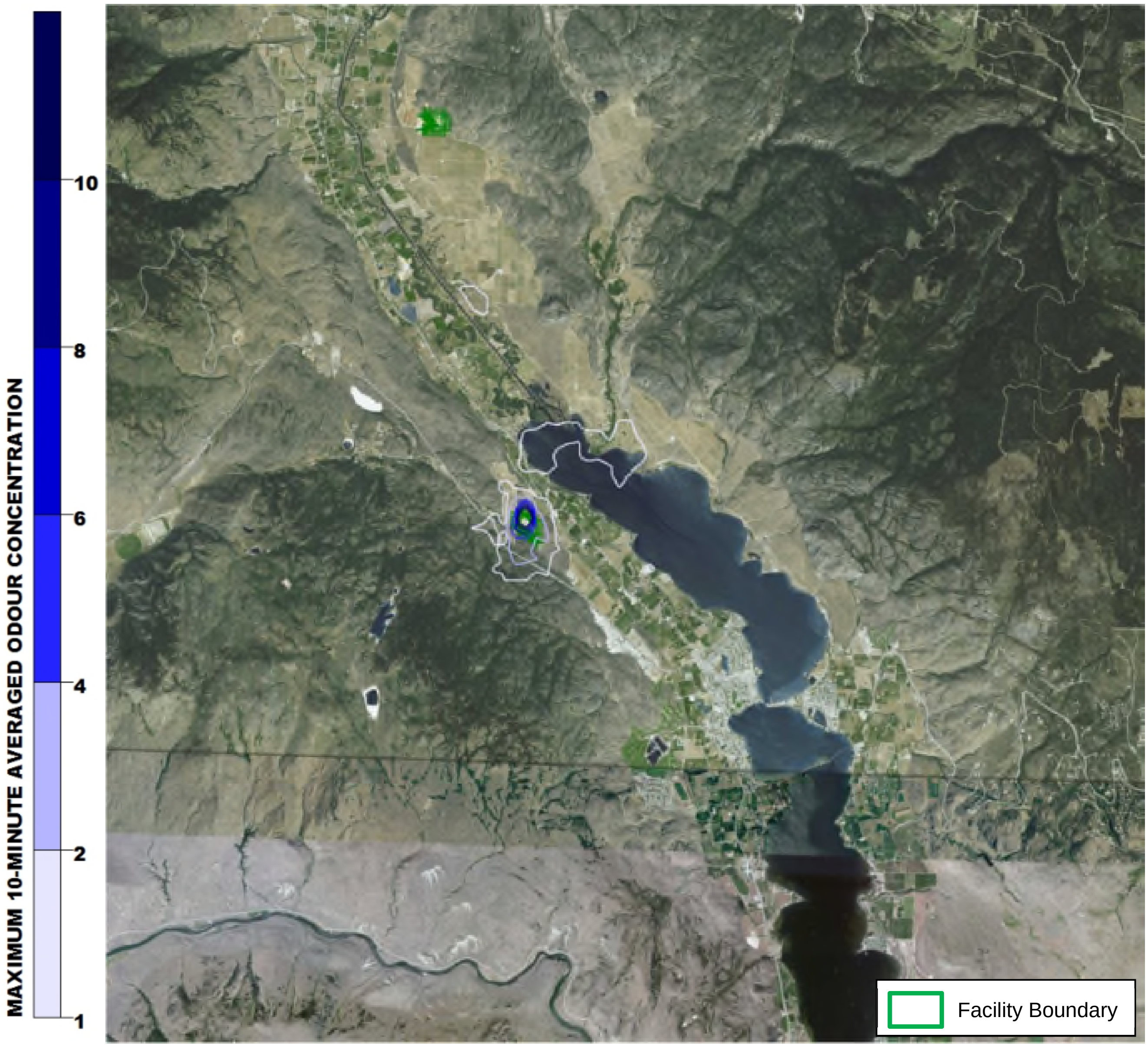


**Figure 7: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Covered ASP)**

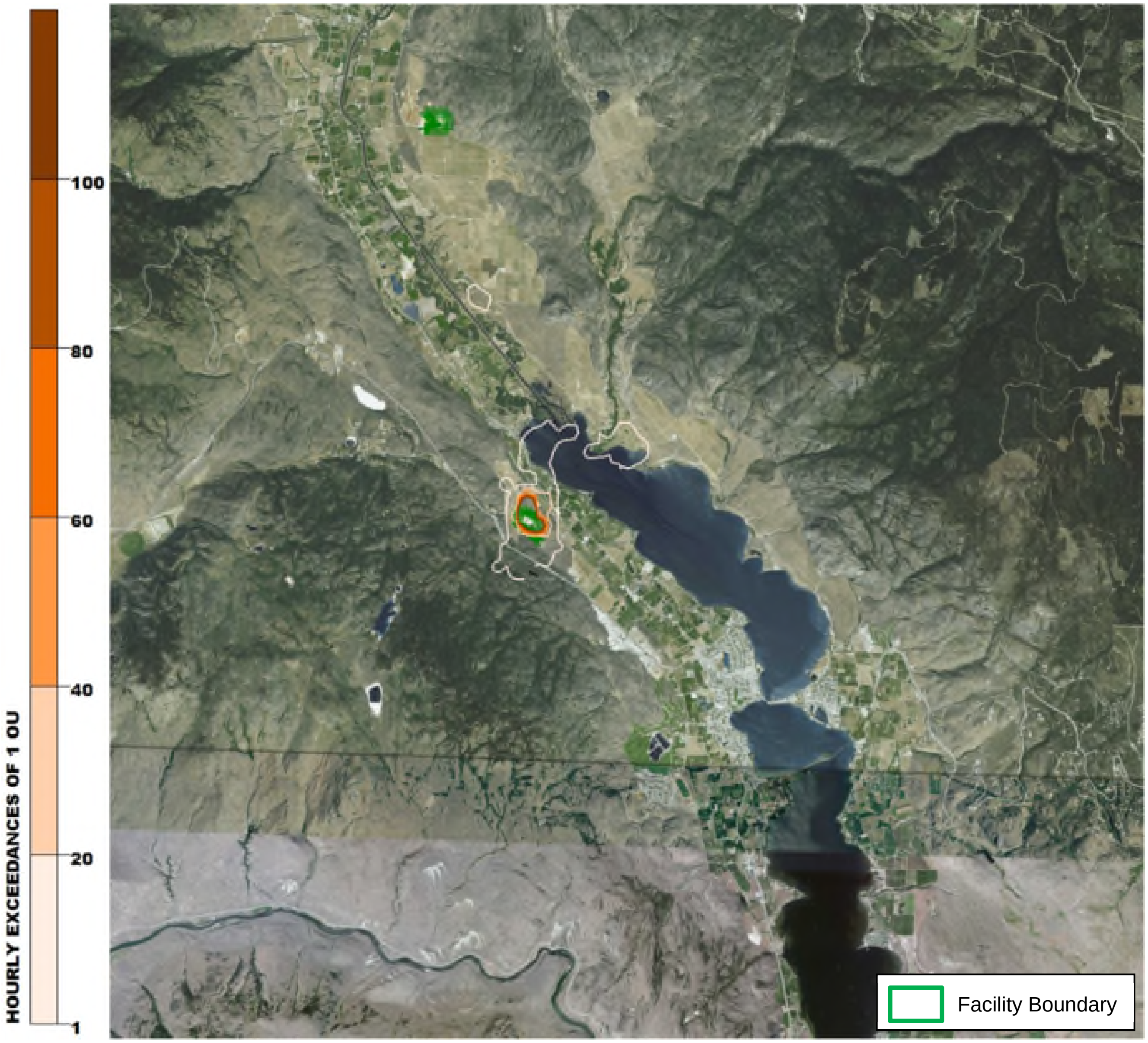


**Figure 8: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Covered ASP)**

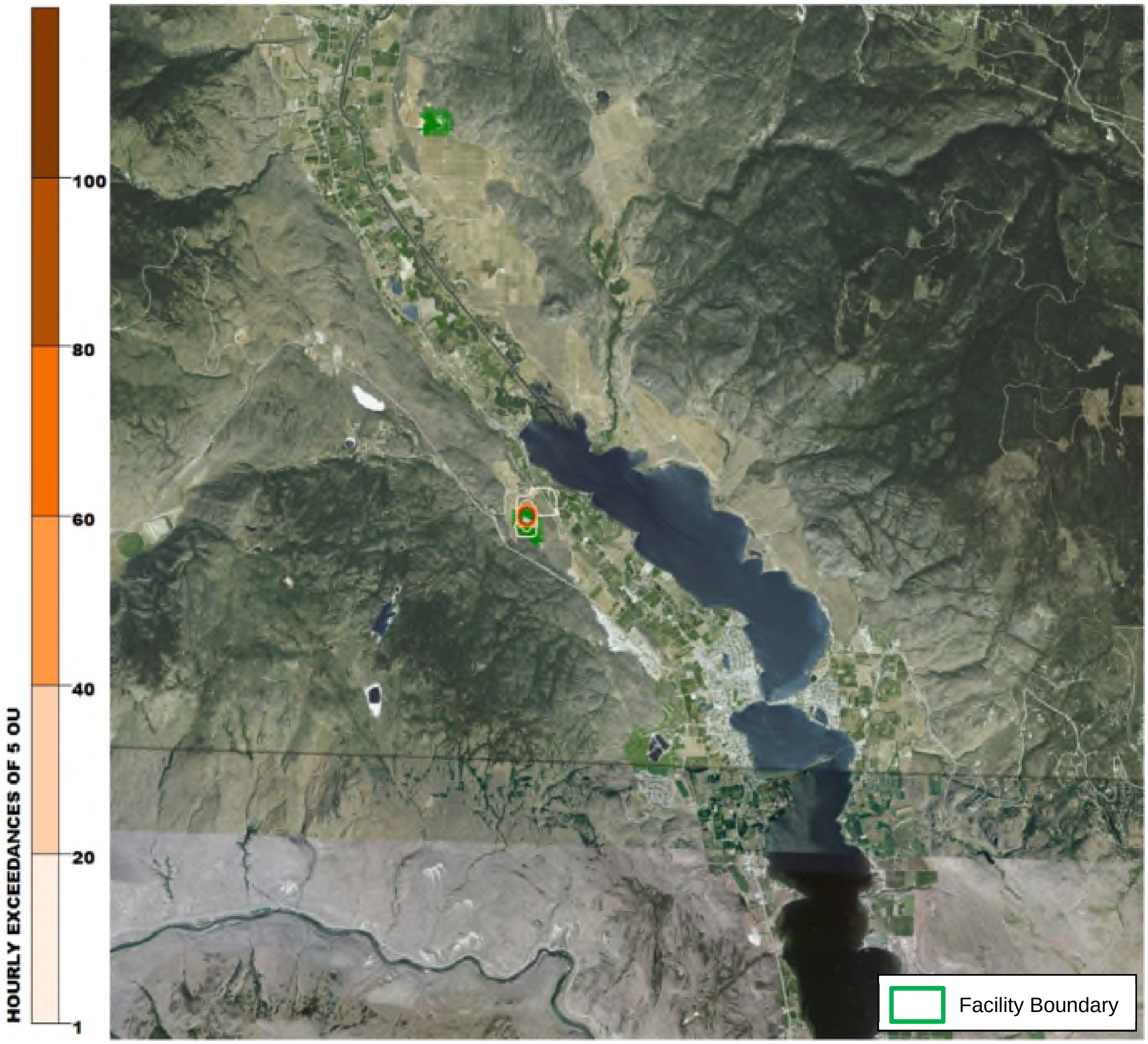


**Figure 9: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (Covered ASP)**

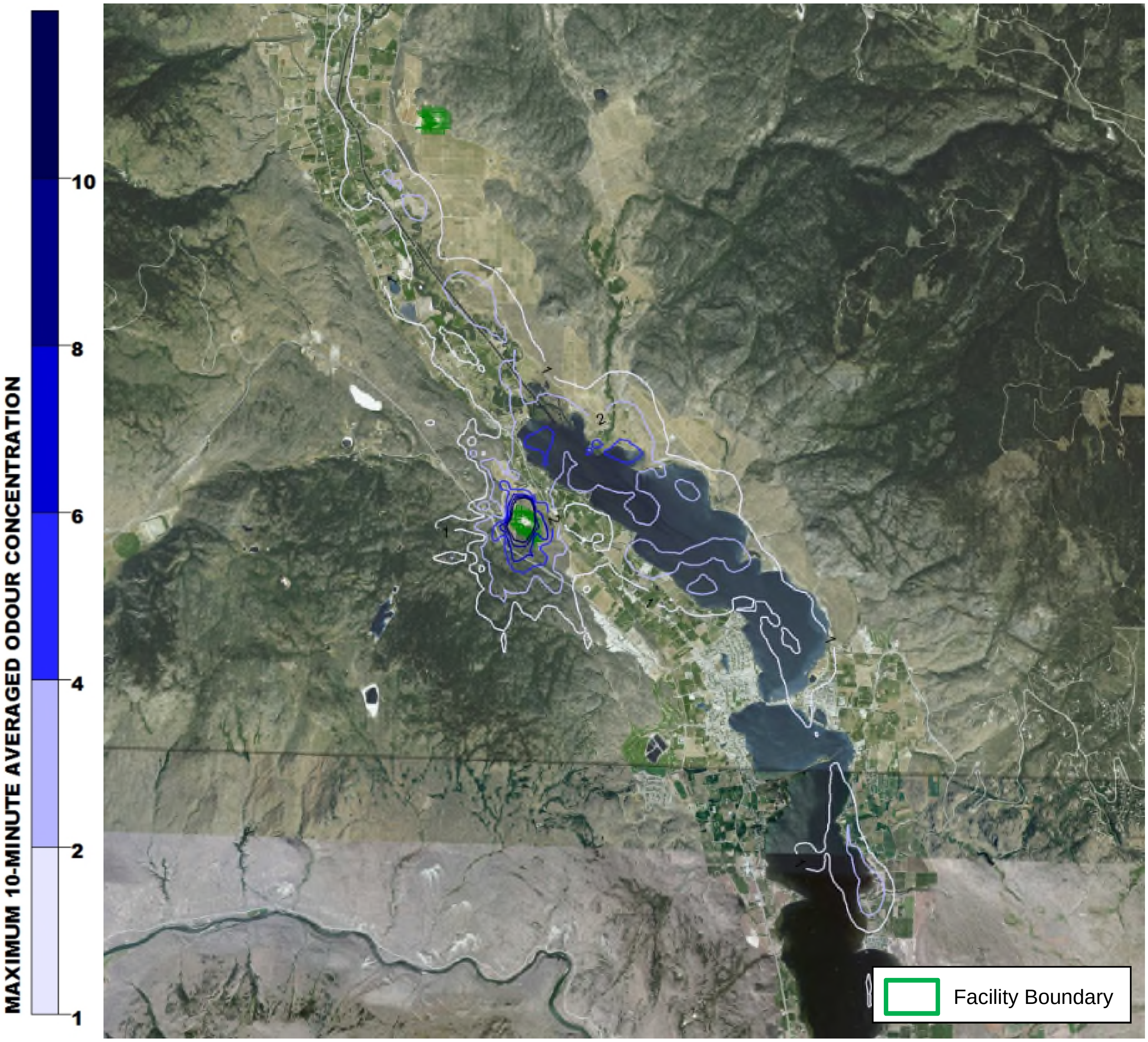


**Figure 10: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (In-Vessel)**

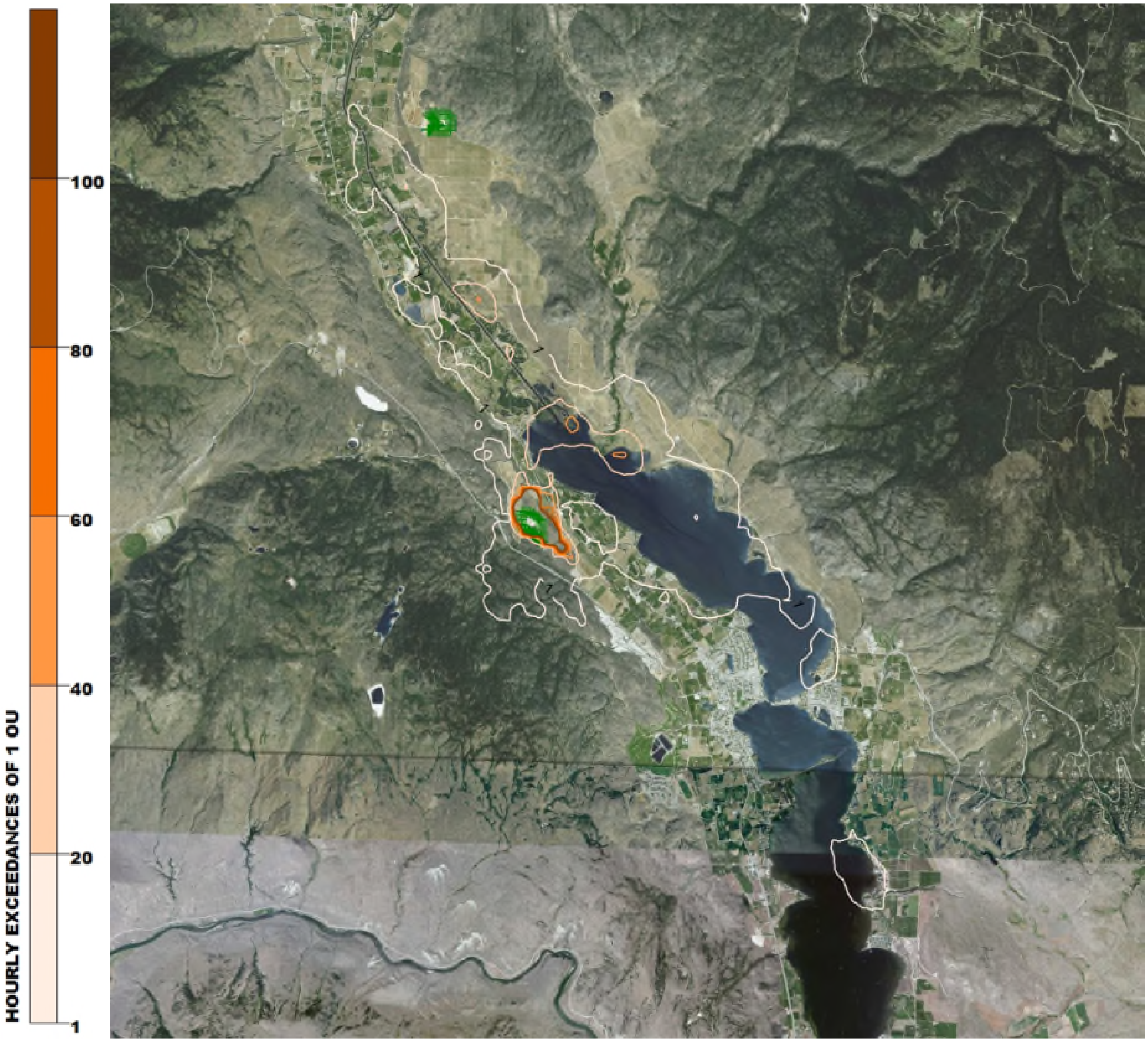


**Figure 11: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (In-Vessel)**

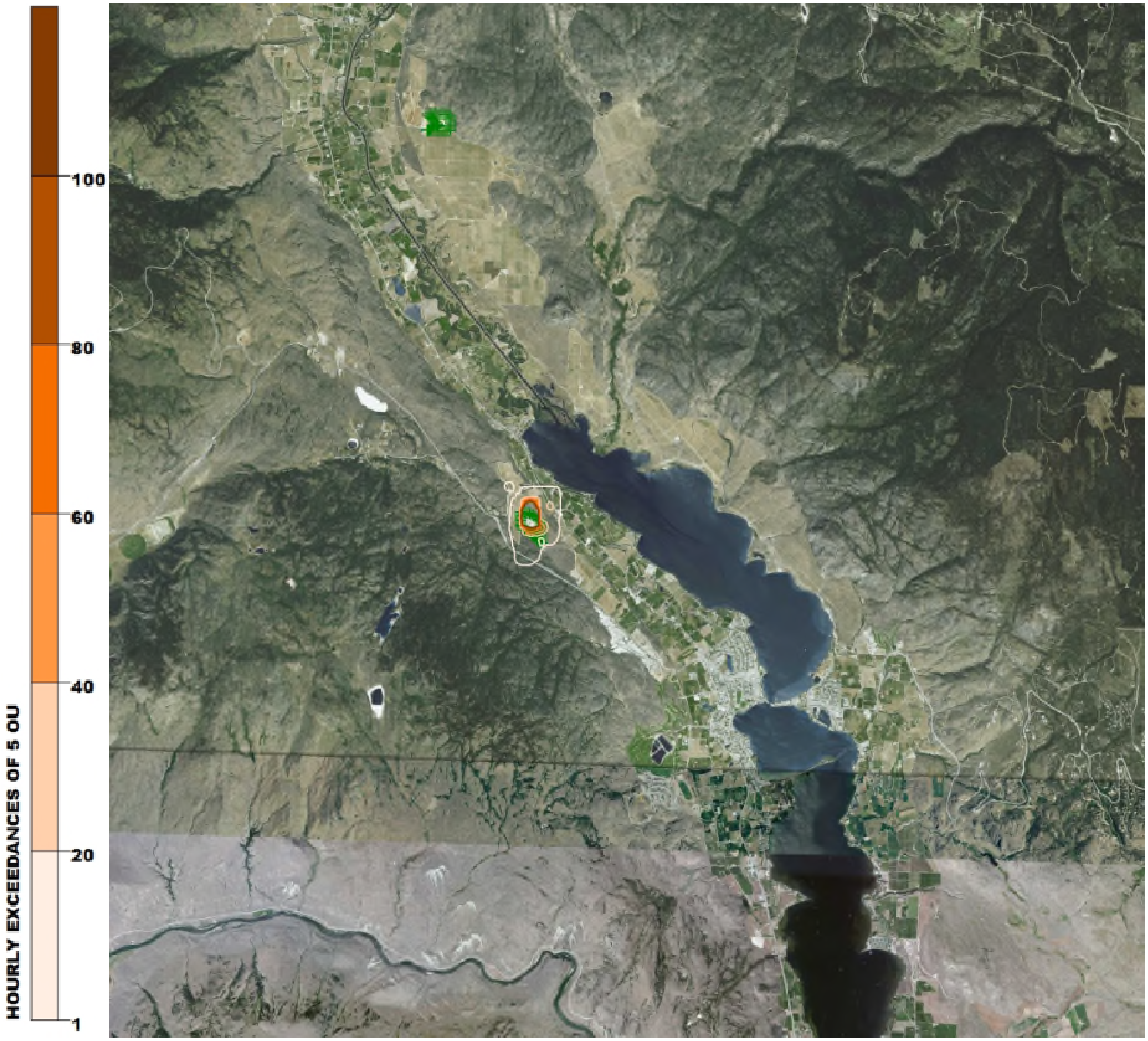


**Figure 12: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (In-Vessel)**

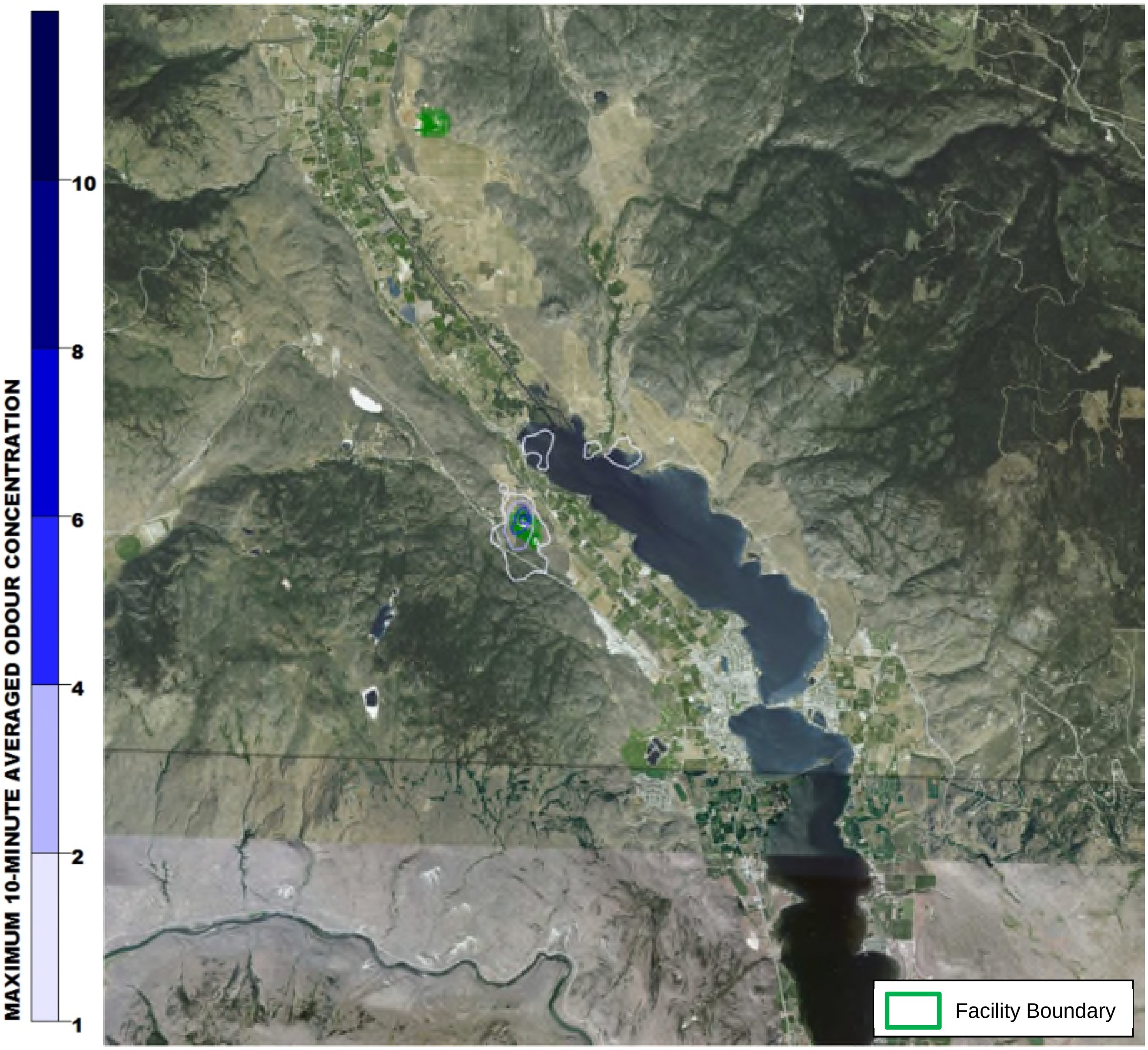


**Figure 13: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Windrow with SSO)**

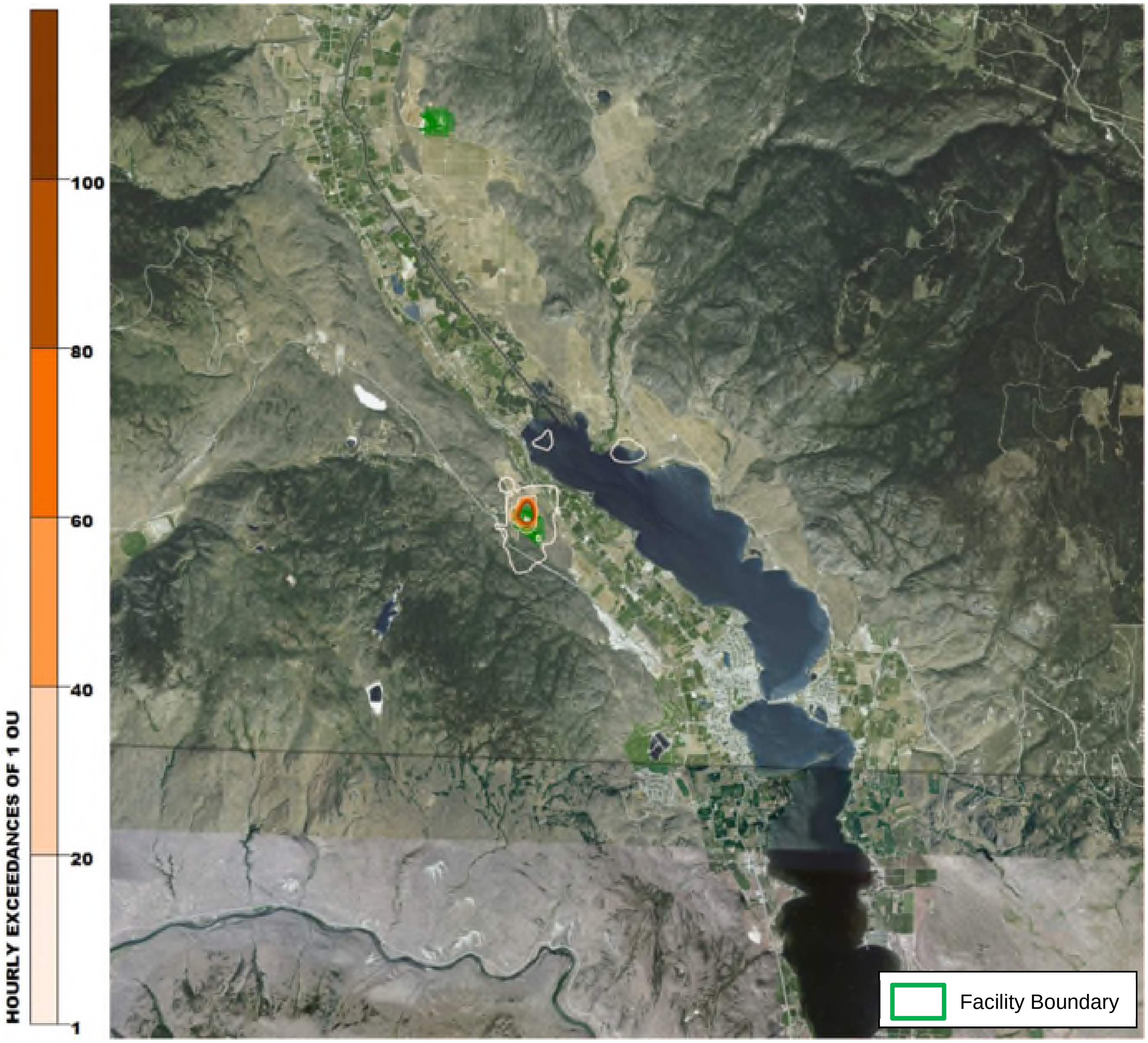


**Figure 14: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Windrow with SSO)**

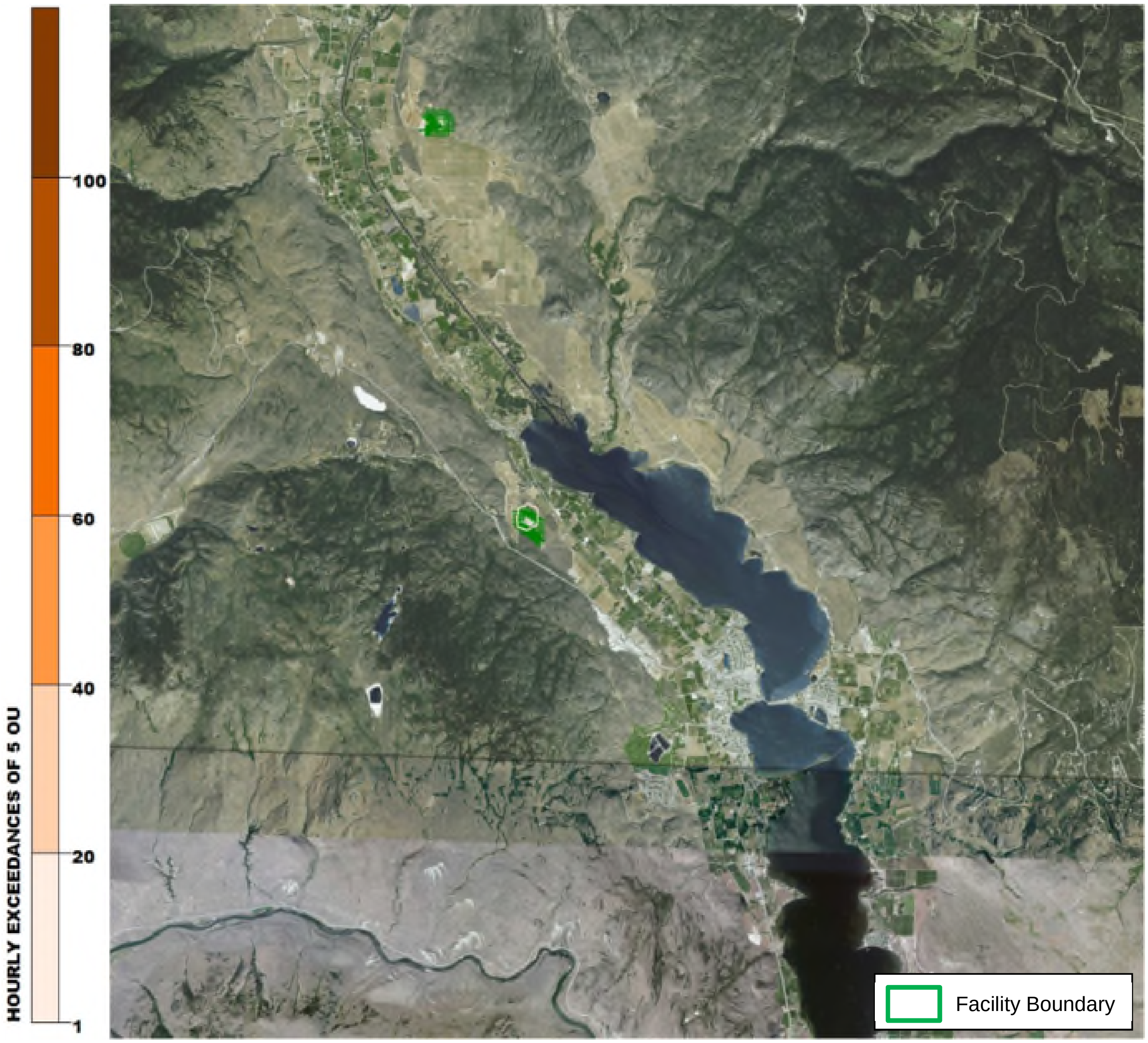


**Figure 15: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (Windrow with SSO)**

# PRINCETON LANDFILL

# 1.0 INTRODUCTION

The following is a summary of model inputs and odour modelling results conducted for the purpose of assessing potential odour impacts from an organics management facility located at Princeton Landfill (hereafter referred to as the "Site"). Odour modelling was conducted using CALPUFF, an advanced air modelling software system recommended by the British Columbia Ministry of Environment (BC MOE).

# 2.0 MODEL INPUTS AND ASSUMPTIONS

## 2.1 Meteorology

The air dispersion model CALPUFF contains a diagnostic meteorological processor, CALMET, which creates a three-dimensional meteorological field over the spatial extent of the model. The data produced by CALMET is used by CALPUFF in its dispersion and plume transport calculations. Inputs to CALMET include the following:

- a geophysical grid, constructed using gridded terrain and land cover data (obtained from GeoGratis – Government of Canada); and
- a combination of prognostic (three-dimensional meso-scale model called MM5) meteorological data and hourly surface observations obtained from Environment Canada and BC MOE meteorological stations.

When CALMET is run in "no-observations" mode (using only MM5), the surface station observations provide a validation of the CALMET meteorology, in particular winds, to ensure representativeness. As MM5 is a meso-scale regional model, the grid used as input to CALMET is downscaled in three steps from a 32 km resolution grid to a 4 km grid and downscaled again within CALMET to the CALPUFF grid size (250 m). It is not expected that the meteorological time series in CALMET will exactly reproduce observed conditions on an hour by hour basis at any particular grid point, however it is expected to be representative of the general conditions over a given year.

Table 2.1 summarizes the meteorological inputs to CALMET used in the Princeton Landfill Facility odour modelling and mapping exercise.

### Table 2.1: CALMET Inputs and Metadata

| Parameter | Usage |
|---|---|
| Surface Stations | None |
| Upper Air Soundings | None |
| Prognostic Data | 4 km resolution MM5 |
| Meteorological Grid | 10 km (east-west) x 10 km (north-south) at 250 $m^2$ |
| Grid Centrepoint | 681500 m, 5482200 m, UTM Zone 12 |
| Vertical Cells (Cell Face Heights) | 10 (0 m, 20 m, 40 m, 80 m, 160 m, 320 m, 640 m, 1200 m, 2000 m, 3000 m, 4000 m) |
| Terrain Data | CDN DEM 15 min |
| Land Use Data | GeoBase Land Cover circa 2000-Vector |

As land cover characteristics over the modelling domain vary with season (e.g., albedo, Bowen ratio, etc.), seasonal CALMET files were created using the model's default seasonal geophysical properties for each land cover category contained within the geophysical grid. The date ranges assumed to define each season are listed in Table 2.2. Year-to-year variability will undoubtedly occur, however, this temporal approximation was used to simplify modelling based on Environment Canada 1981 – 2010 climate norms for the Okanagan-Similkameen region. The modelled year was 2012.

### Table 2.2: Geophysical Property Seasonality

| Season | Date Range |
|---|---|
| Winter | December 1 – February 29 |
| Spring | March 1 – May 31 |
| Summer | June 1 – September 15 |
| Fall | September 15 – November 30 |

Figure 2.1 is a snapshot of the CALMET-modelled surface winds on January 1, 2012, $20^{00}$ hrs. The figure also shows the boundary of both the Princeton Landfill and Hayfield sites (green border) and the location of Environment Canada (Princeton CS) meteorological station (dark green square).

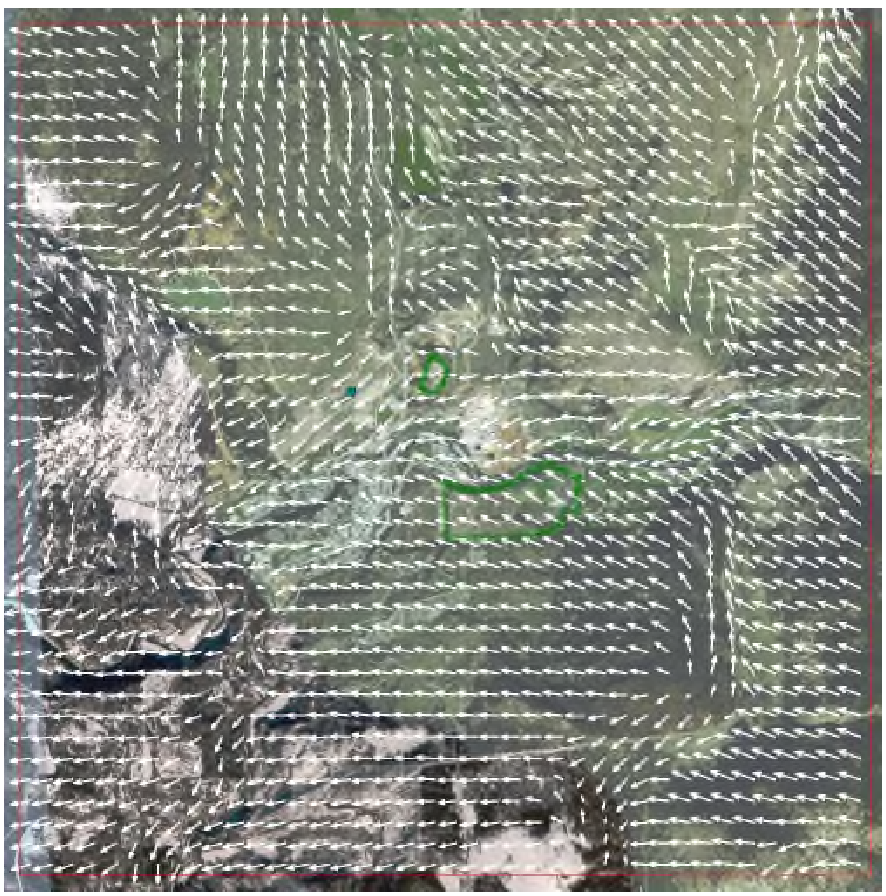

**Figure 2.1: CALMET-Modelled Wind Field (Easterly Flow) – January 1, 2012, $20^{00}$ hrs**

### 2.1.1 Meteorological Validations

#### 2.1.1.1 Winds

Figure 2.2 shows a comparison of the MM5/CALMET-modelled winds (left) and the observed winds recorded at Environment Canada Princeton CS meteorological station, located at Princeton Airport (49.465°, -120.51°, right). MM5/CALMET predicts the predominance of westerly winds seen in the observed data, however observed westerly winds are much more variable in their origin in the western quadrant (WNW-SW). *Note the difference in frequency scale between the two figures (0%-20% on the left and 0%-5% on the right).* Overall though, CALMET predicts nearly the same frequency of occurrence of west-component winds as is observed at Princeton CS.

Compared to Princeton CS station, MM5/CALMET greatly over-predicts the predominance of northeasterly winds, which are easterly valley flow winds which are steered by terrain in the model, at the airport. Easterly winds at Princeton CS are much more variable in their origin in the eastern quadrant (ENE-ESE). However Figure 2.3 shows that the Princeton Airport is aligned NE-SW, suggesting northeast winds are a common occurrence and that Princeton CS may have siting issues.

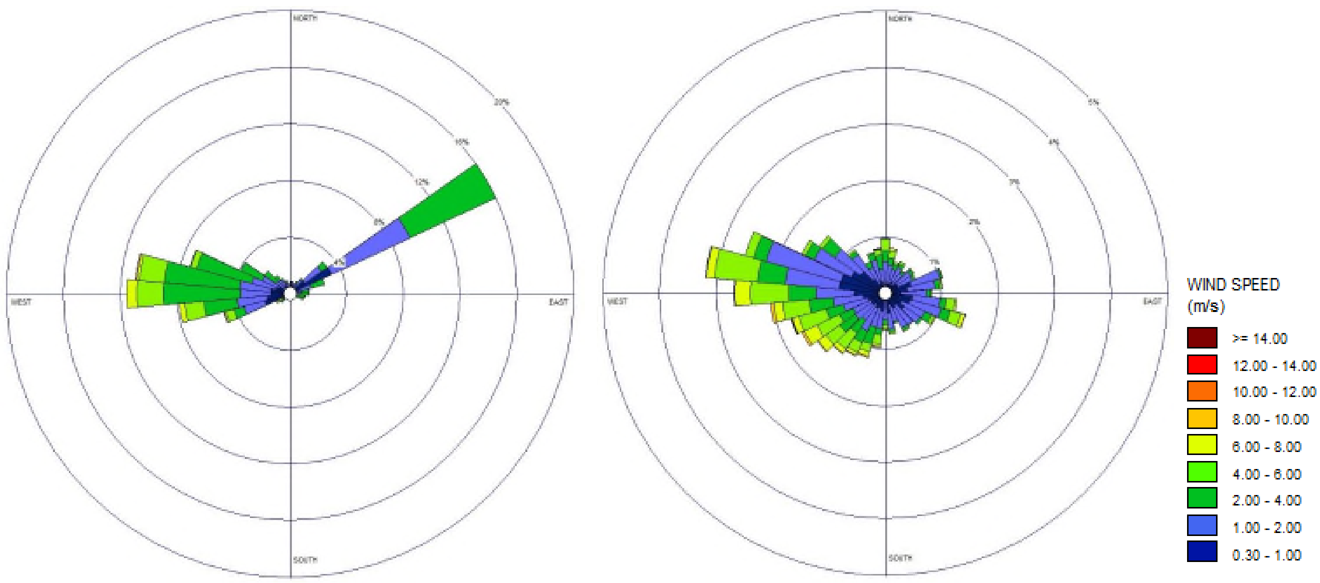


**Figure 2.2: Wind Rose Comparison: Modelled (left) vs. Observed at Princeton CS (right)**

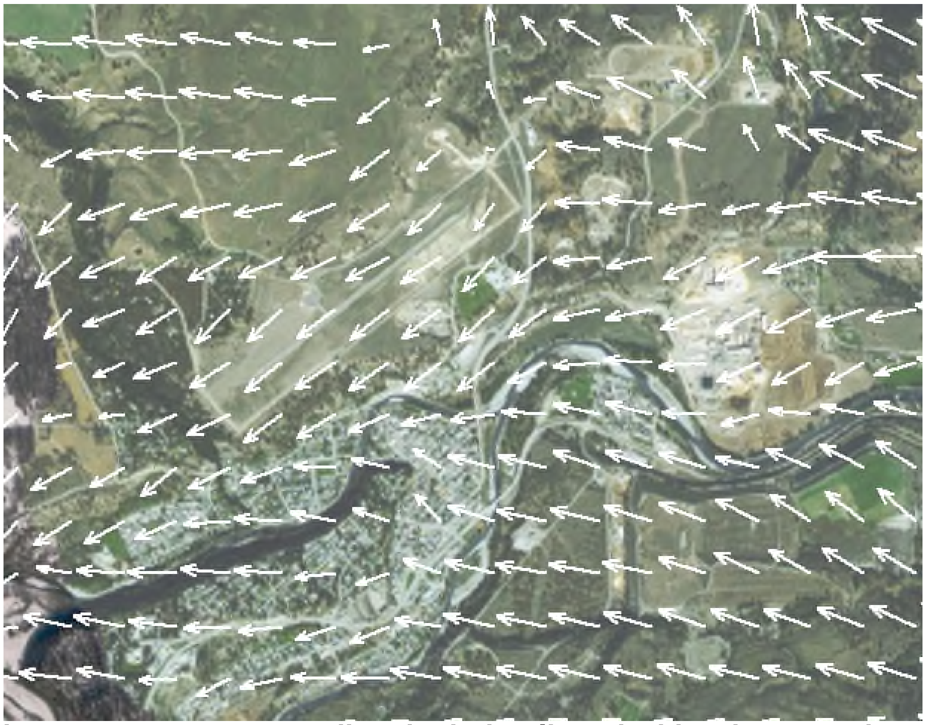

**Figure 2.3: CALMET-predicted Winds Aligned with Princeton Airport**

### 2.1.1.2 Mixing Height

The atmospheric mixing height can be defined as the top of the layer in the lower atmosphere, within which an emitted species, in this case odour, is readily mixed through turbulence and convective processes. Therefore, when the mixing height is low, higher ground-level concentrations will generally be predicted. Figure 2.4 are time series of modelled mixing heights extracted from CALMET over two distinct seasonal periods in 2012 at the location of the Penticton RS station. The top figure (red) plots a time series of mixing heights in the winter (between February 1 and 8), while the lower figure (blue) plots mixing heights in the summer (between July 1 and 8).

Seasonal contrast is strongly evident since there is reduced solar radiation, lower temperatures and snow cover, among other factors during the winter that results in generally lower mixing heights, and thus resulting in higher concentrations of odour. Both figures show the expected strong diurnal pattern, with mixing heights dropping quite close to the ground surface (~50 m as a default in CALMET) at night. When overnight mixing heights are higher, it is due to turbulence induced by higher wind speeds over uneven terrain.

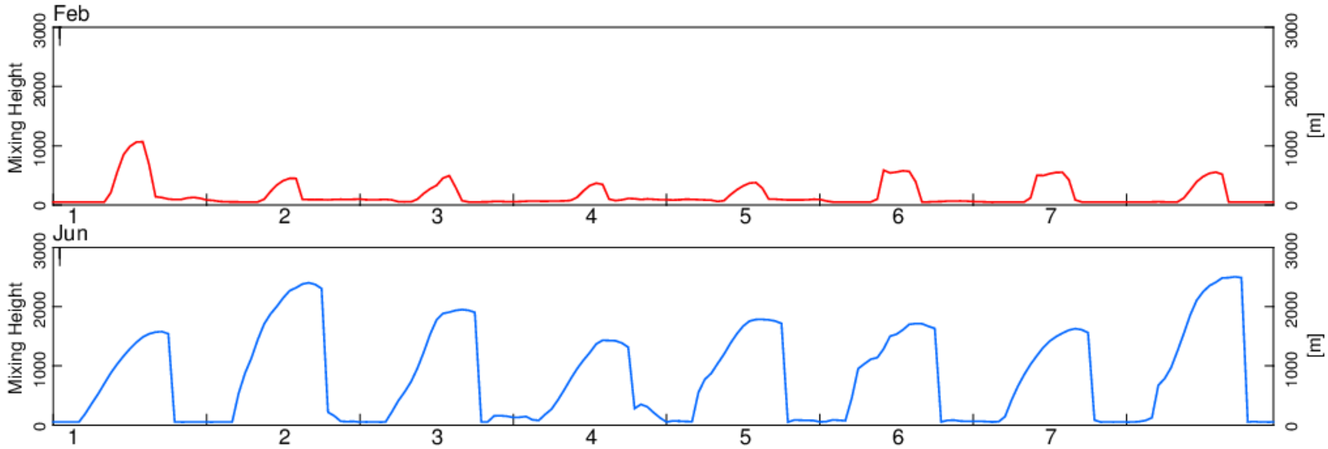


**Figure 2.4: CALMET-Modelled Mixing Heights for Winter (Red) and Summer (Blue)**

## 2.2 Area Sources and Emission Factors

The site layouts from the *Organics Management Consultant Task 2 – Feasibility Assessment* report for Princeton Landfill were used to define the boundaries of the odour sources for this modelling analysis. Areas that generate odours were assigned a specific emission factor according to the activity taking place (e.g. composting, curing, pile turning, etc.). In the main report, Table 2.1 provides a description of the emission factors used for each of the scenarios below:

- Current operations (static piles of yard waste);
- Aerated static pile (ASP);
- Membrane covered aerated static pile; and
- In-vessel composting.

Emissions were assumed to occur homogeneously over the entirety of the area source. Some odour emissions (e.g. pile turning, pile moving, etc.) were assigned a diurnal variation based on the expected times of day the activity is to be performed (Table 2.1 of the main report). Such activities are expected to occur daily at the Site over a one- to two-hour period, however since the activity may occur at any time during the operational hours of the facility in the morning or in the afternoon, odour emissions were assumed in the model to occur between $10^{00}$ to $12^{00}$ – representing a time of day when vertical mixing is generally highest – and between $15^{00}$ to $17^{00}$ – when, during the winter, the mixing height is approaching its night time minimum, thus resulting in higher concentrations closer to the ground. This is a somewhat conservative approach since the activity may only be occurring over a portion of a single hour rather than four, may not take place every day, and peak odour emission would only occur during and immediately following the activity and decay in the hour following. It should be noted that odour emissions produced from pile building and moving are inconsequential compared to that produced from the biofilters which emit odour continuously.

Emission heights were either assigned a value of 3 m or 1 m depending on the activity occurring within the area source. Specific heights used for the various activity types are listed in Table 2.1 of the main report.

## 2.3 CALPUFF Settings and Assumptions

The CALPUFF model input settings were assigned with consideration to the recommendations in Table 9.7 of '*Recommended CALPUFF Input Group 2 Switch Settings*' in '*Guidelines for Air Quality Dispersion Modelling in British Columbia*'. Generally, default model settings were used. Since the area of interest is in the near-field (within 12 – 15 km of the source), dispersion coefficients were internally calculated using micrometeorological variables (MDISP = 2) based on estimates of the crosswind and vertical components of turbulence based on similarity theory and the land cover type. The probability distribution function (PDF) was used for dispersion under convective conditions (MPDF = 1) which explicitly accounts for the differences in the distribution and strengths of up and down drafts within the convective boundary layer, reporting the average between the two. By using these two settings, AERMOD-type dispersion is simulated (generally accepted as better-predicting in the near-field than CALPUFF), while also providing the benefit of a puff model and allowing for the effects of complex terrain.

The receptor grid spacing was 125 m at ground level over the entire grid. The simulations were to determine the general effects downwind from the facility, on the scale of kilometres, and therefore did not consider building downwash – the drawdown of the odour plume downwind of facility buildings due to turbulence.

# 3.0 RESULTS

Since the time step of the meteorological data is one-hour, CALPUFF can only output one-hour averaged predictions of odour concentration. However, since odour perception is on a much shorter scale, an averaging time-scalar must be applied to assess shorter-term peak concentrations due to plume meandering within the hourly period. Hourly odour concentrations are scaled to a ten-minute averaging period using Equation 1.

$$Cp = Co * \left(\frac{t_o}{t_p}\right)^{0.28} \qquad (1)$$

Pursuant to Equation 1, $t_o$ is the 60 minute averaging time, $t_p$ is the short-term averaging time (10 minutes) and $C_o$ and $C_p$ are the respective peak concentrations (BC MOE). The scalar when converting from hourly to ten-minute average concentrations equates to 1.65.

## 3.1 Odour Units

An Odour Unit is a way of quantifying odours through the use of an odour panel that consists of a group of people with 'calibrated noses'. The definition of an Odour Unit is based on the proportion of odour panel members that can detect the smell of a substance. One OU represents the concentration of a particular substance when 50% of the odour panel can detect the odour. This is called the perception threshold[1]. At this point, although an odour may be detected, it is not distinct enough to be able to identify the type of odour.

The Odour Unit scale is based on dilutions, as shown in the following figure. As the number of odour units increase, more people can detect the odour, and the intensity of the odour increases. Five OU is considered a faint odour and ten OU is considered a distinct odour (the point when some people can identify the type of odour, or its potential source)[2].

[1] http://blog.odotech.com/odor-unit-perception-threshold
[2] Odours and VOCs: Measurement, Regulation and Control Techniques (2009). Kassel University Press.

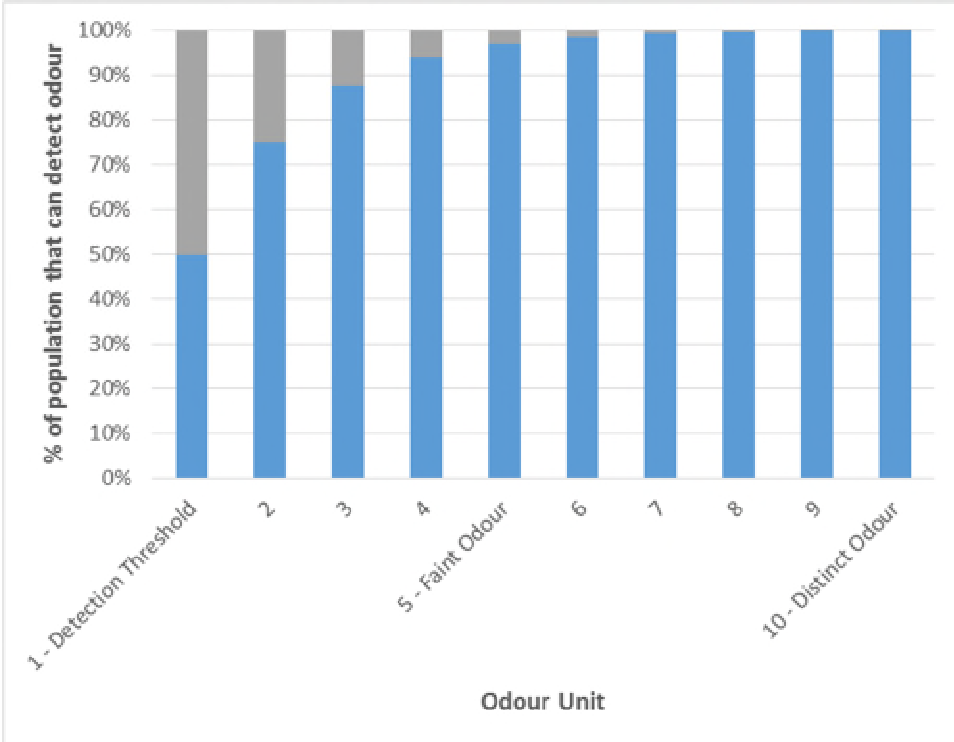


**Figure 3.1: Odour Unit Scale**

There are currently no guidelines for odour limits for composting facilities in British Columbia, however, some wastewater treatment facilities have imposed odour limits. For example, the standard in Metro Vancouver is no more than five OU at the property line. In other jurisdictions, the guideline is to have no detectable odour at the property line. At the Ogogrow facility in Vernon, BC, the limit is 50 OU at the property line.

## 3.2 Odour Maps

Odour maps are included as part of Appendix A. For each organics processing option listed in Section 2.2, odour modelling results are presented as three different plots:

- Maximum Odour Concentrations – The maximum predicted 10-minute odour concentration at each receptor point over the course of the modelled year. This is displayed as a contour plot showing the maximum predicted 10-minute averaged odour concentration at every ground level receptor point over the entire one-year simulation (8784 hours) as a blue gradient (light to dark). The 1 OU contour is white. The highest levels >10 OU are dark blue. The facility boundary is shown as a green outline.
- Hourly Exceedances >1 Odour Unit (OU) – The number of hours over the course of the modelled year where an odour threshold of 1 OU was exceeded in a ten-minute averaged concentration. This is displayed as a contour plot showing the number of times the predicted 10-minute odour concentration exceeded 1 OU over the modelled year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to 50% of the population being able to detect odour produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.
- Hourly Exceedances >5 OU – The number of hours over the course of the modelled year where an odour threshold of 5 OU was exceeded in a ten minute averaged concentration. This is displayed as a contour plot

showing the number of times the predicted 10-minute odour concentration exceeded 5 OU over the modelled year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to when a faint odour is produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.

## 3.3 Results Summary

The odour maps presented in Appendix A show: (1) the magnitude and spatial extent of maximum ground level odour, and (2) the number of exceedances of odour detection thresholds for the technologies assessed. The membrane covered aerated static pile results had the least odour issues.

The following table summarizes the results of the odour mapping exercise based on the predicted maximum odour and number of hours of odour exceedances at a location 335 m southwest of the property boundary representing the resident that is closest in proximity to the Site (49.468446°, -120.502554°), Figure 3.2.

### Table 3.1: Results Summary Based on Closest Receptor Point

| Scenario | Maximum Predicted 10-min Odour | Odour Exceedance >1 OU (hours per year) | Odour Exceedance >5 OU (hours per year) |
|---|---|---|---|
| Current Operations | 0.05 OU | 0 | 0 |
| Aerated Static Pile | 7 OU | 540 | 61 |
| Membrane Covered Aerated Static Pile | 0.2 OU | 0 | 0 |
| In-Vessel | 5.3 OU | 486 | 3 |


**Figure 3.2: Location of Discrete Receptor (49.468446°, -120.502554°)**

### 3.3.1 Biofilter Effect

The Membrane Covered Aerated Static pile has the lowest odour emissions of the technologies as this type of operation does not use a biofilter. The greatest source of odour emissions can be attributed to the biofilters, as seen in Table 3.2.

#### Table 3.2: Odour Emissions from Biofilters

| Scenario | % of Odour from Composting Biofilter |
|---|---|
| Current Operations | N/A |
| Aerated Static Pile | 98% |
| Membrane Covered Aerated Static Pile | N/A |
| In-Vessel | 99% |

# APPENDIX A

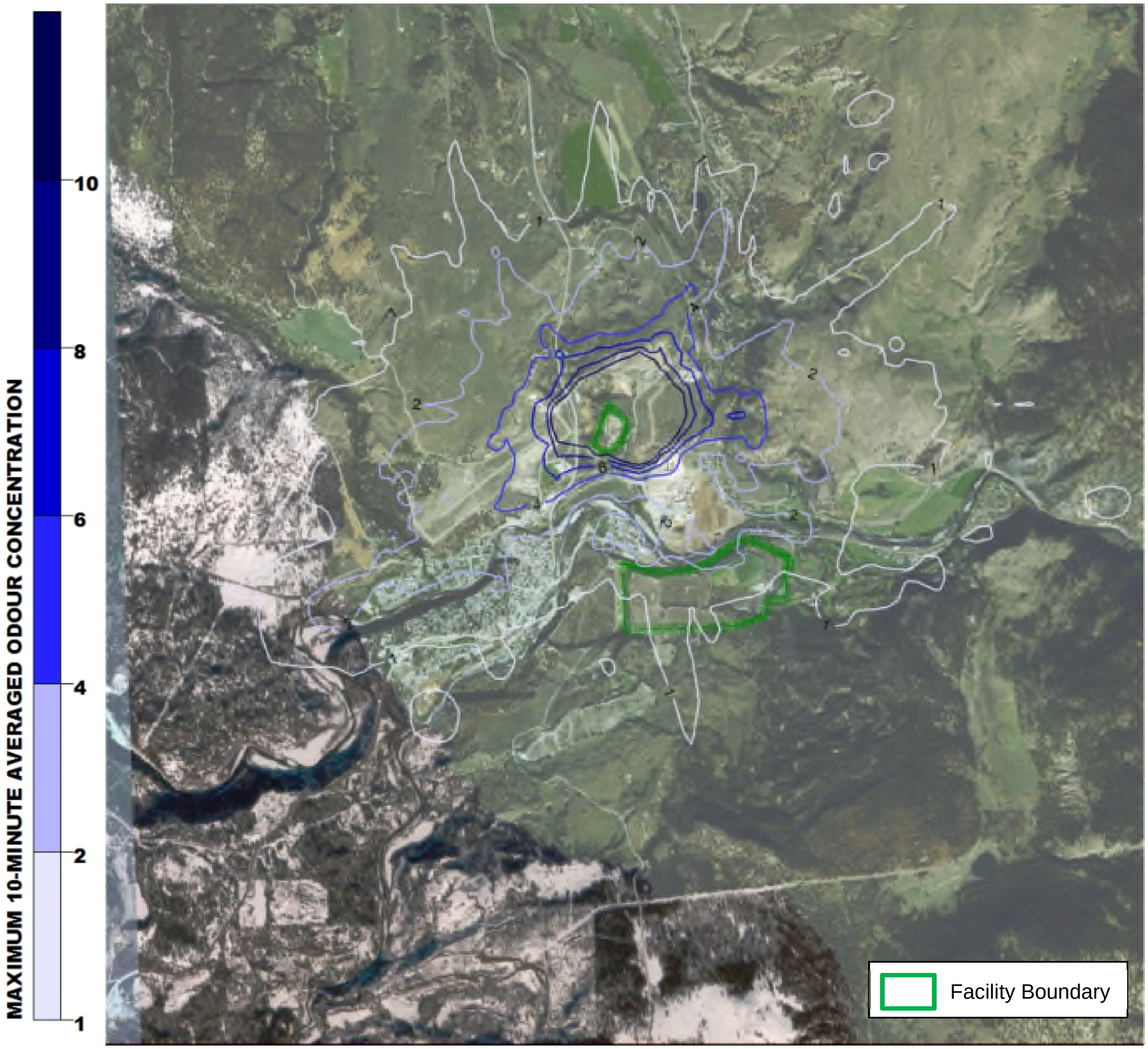


**Figure 1: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (ASP)**

Note: Exceedances of 1 OU were not observed in the model for current operations, therefore figures were not presented.

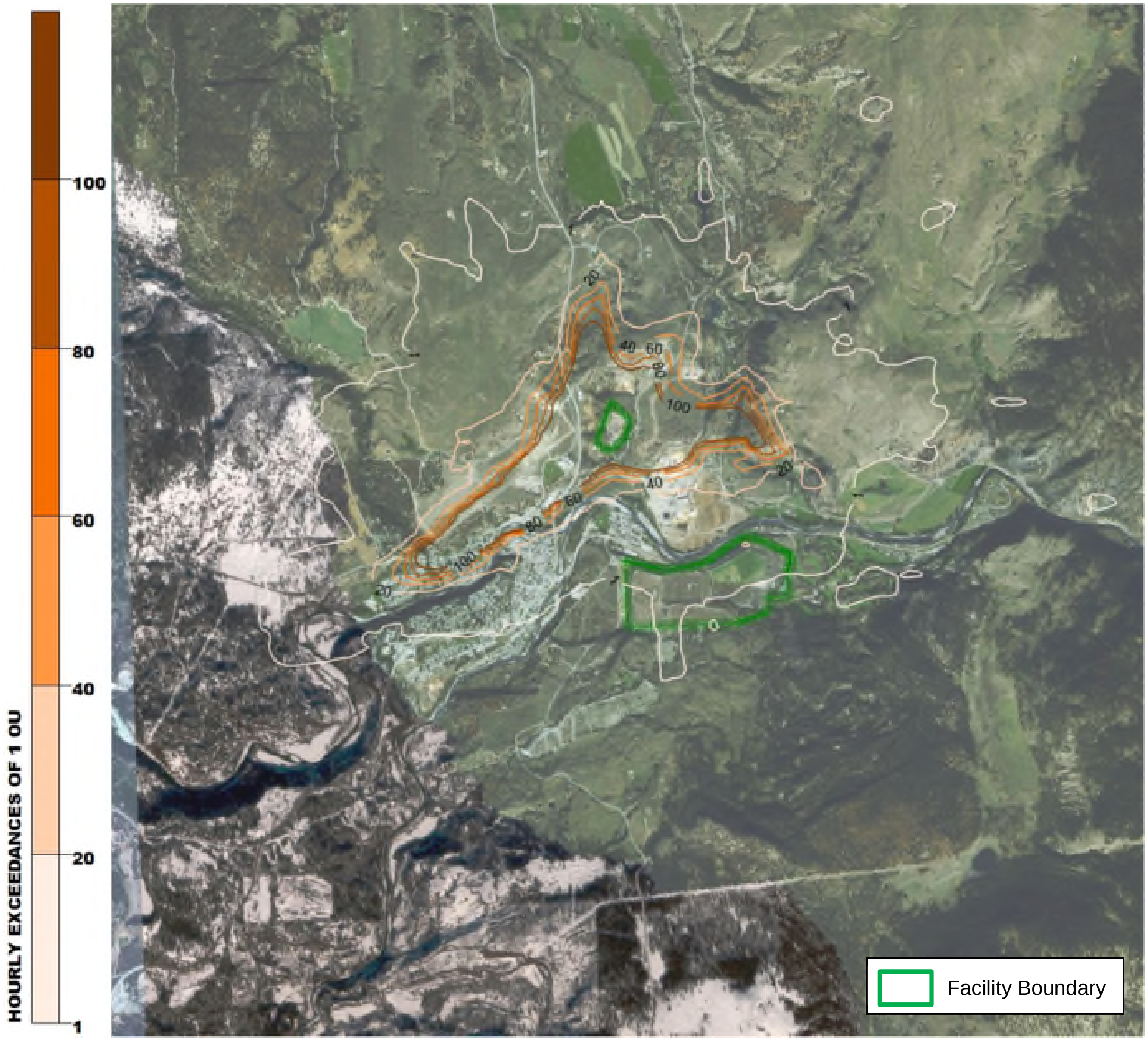


**Figure 2: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (ASP)**

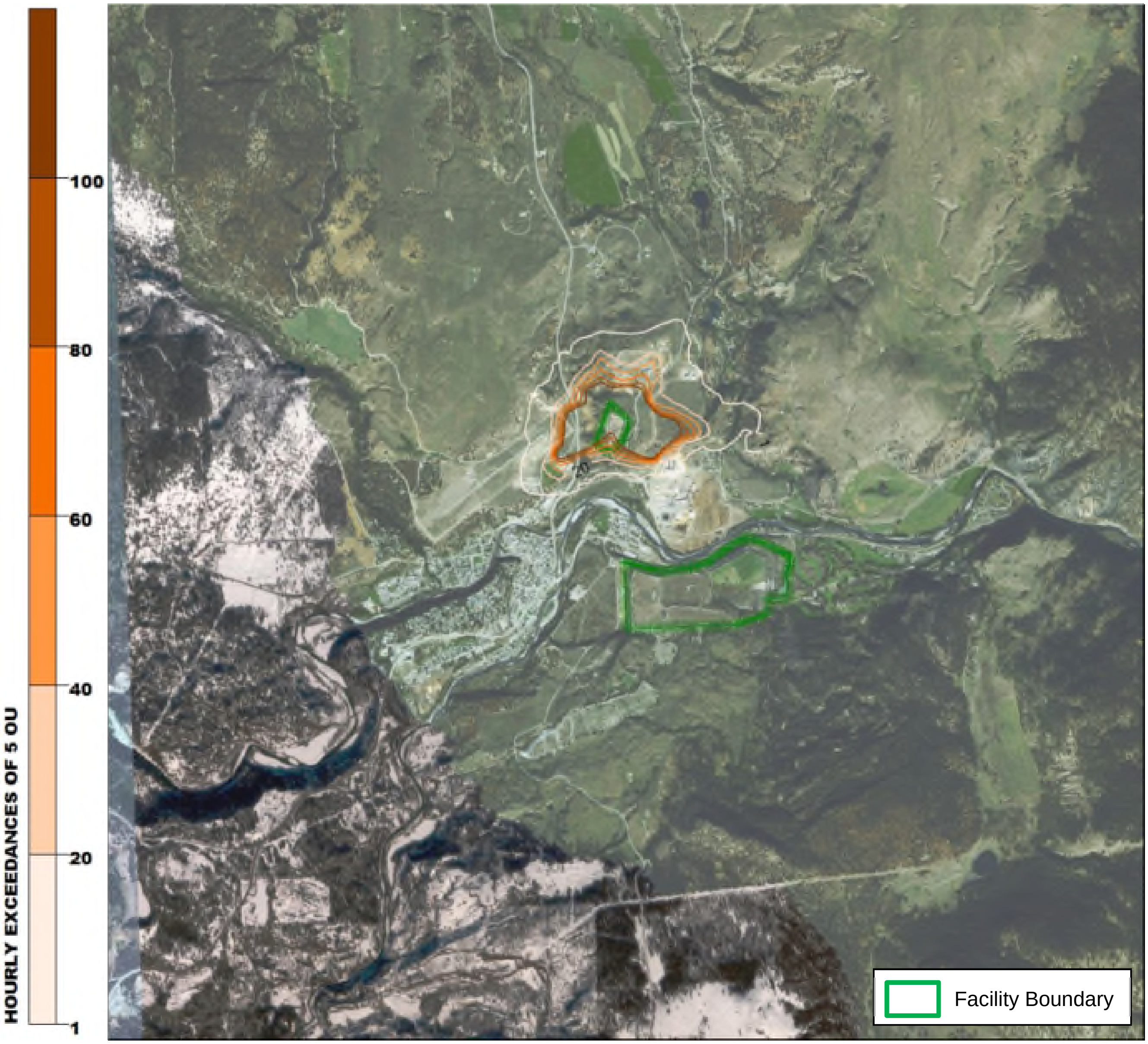


**Figure 3: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (ASP)**

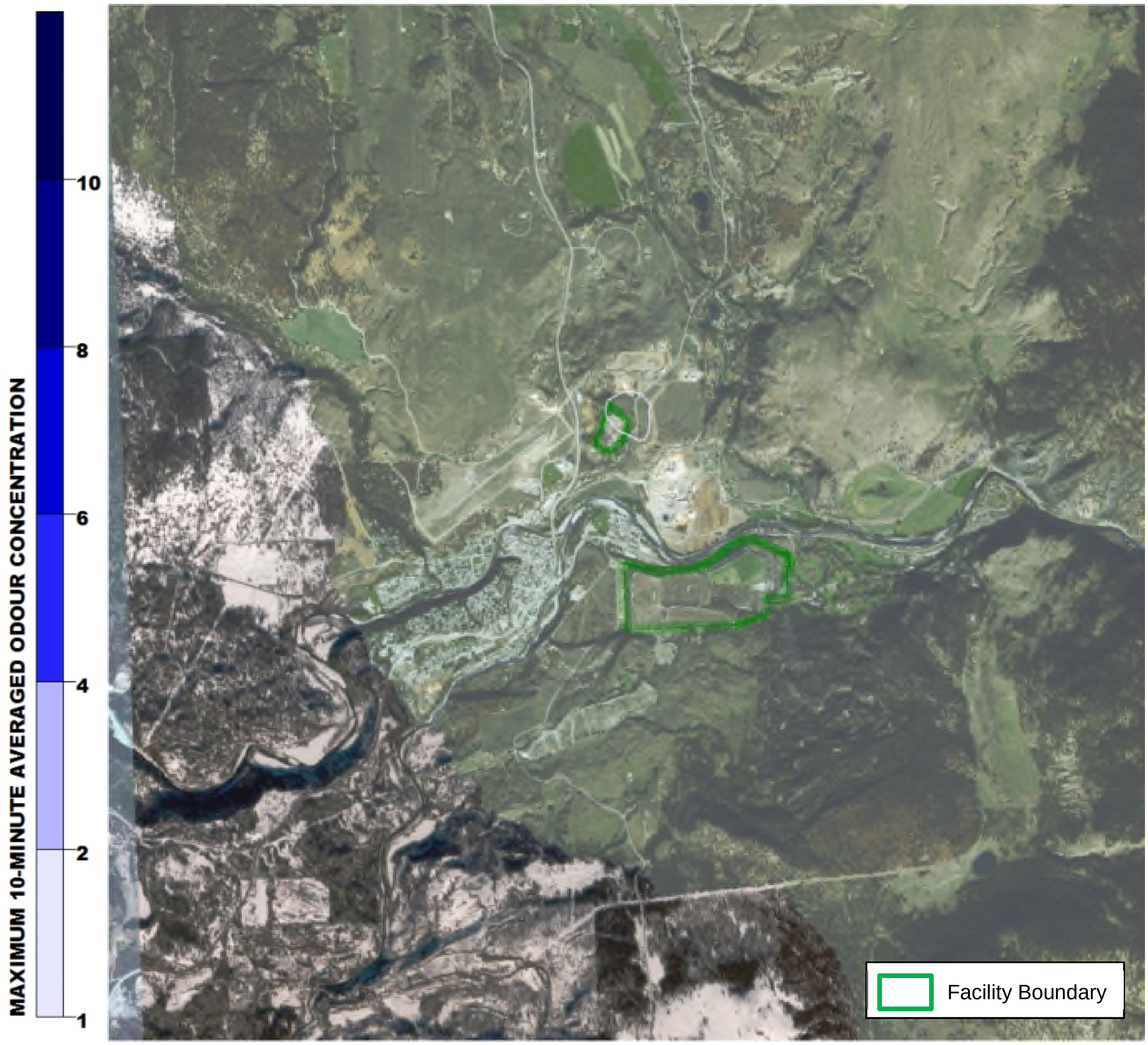


**Figure 4: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Covered ASP)**

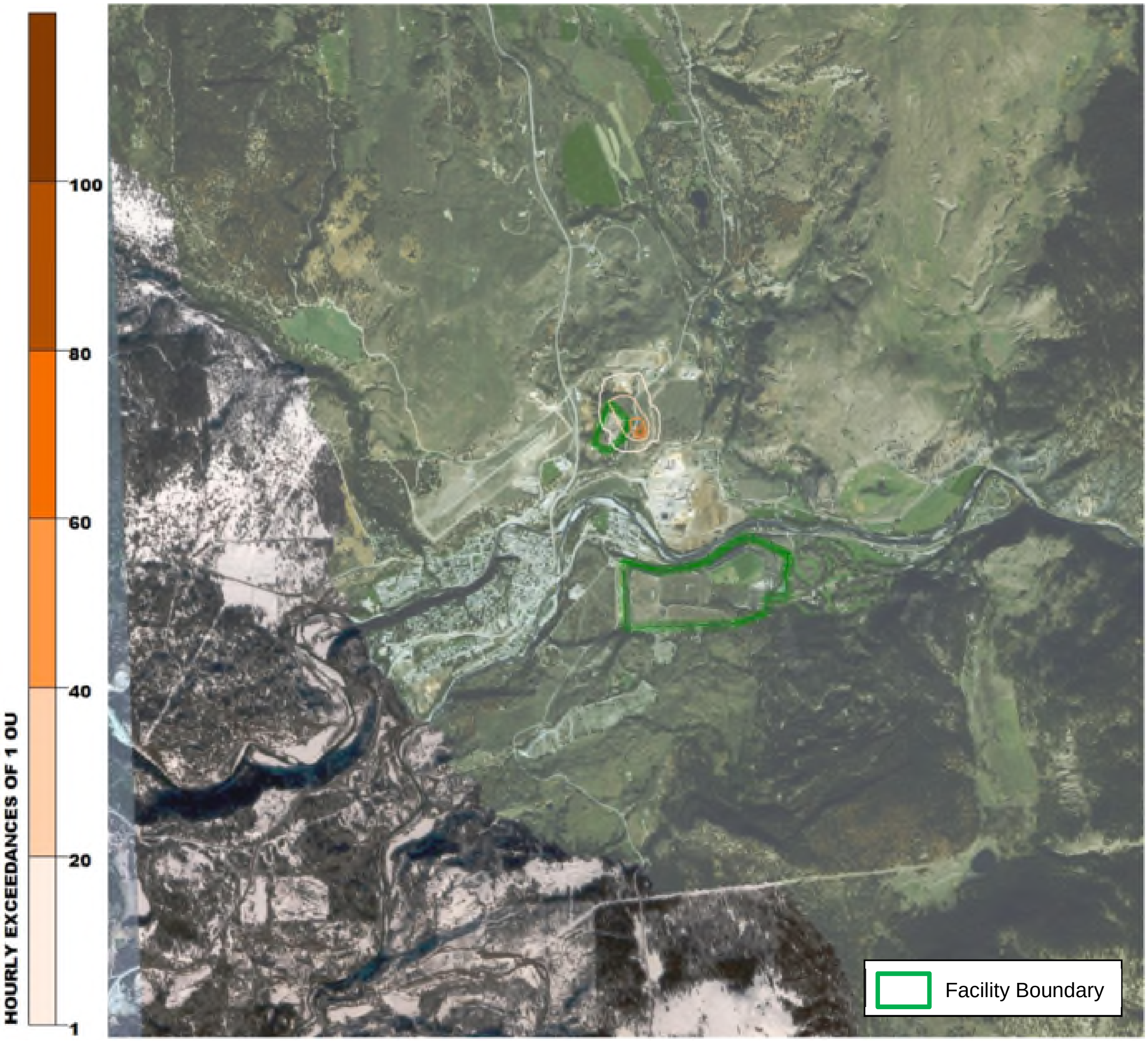


**Figure 5: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Covered ASP)**

Note: Exceedances of 5 OU were not observed in the model, therefore a figure was not presented.

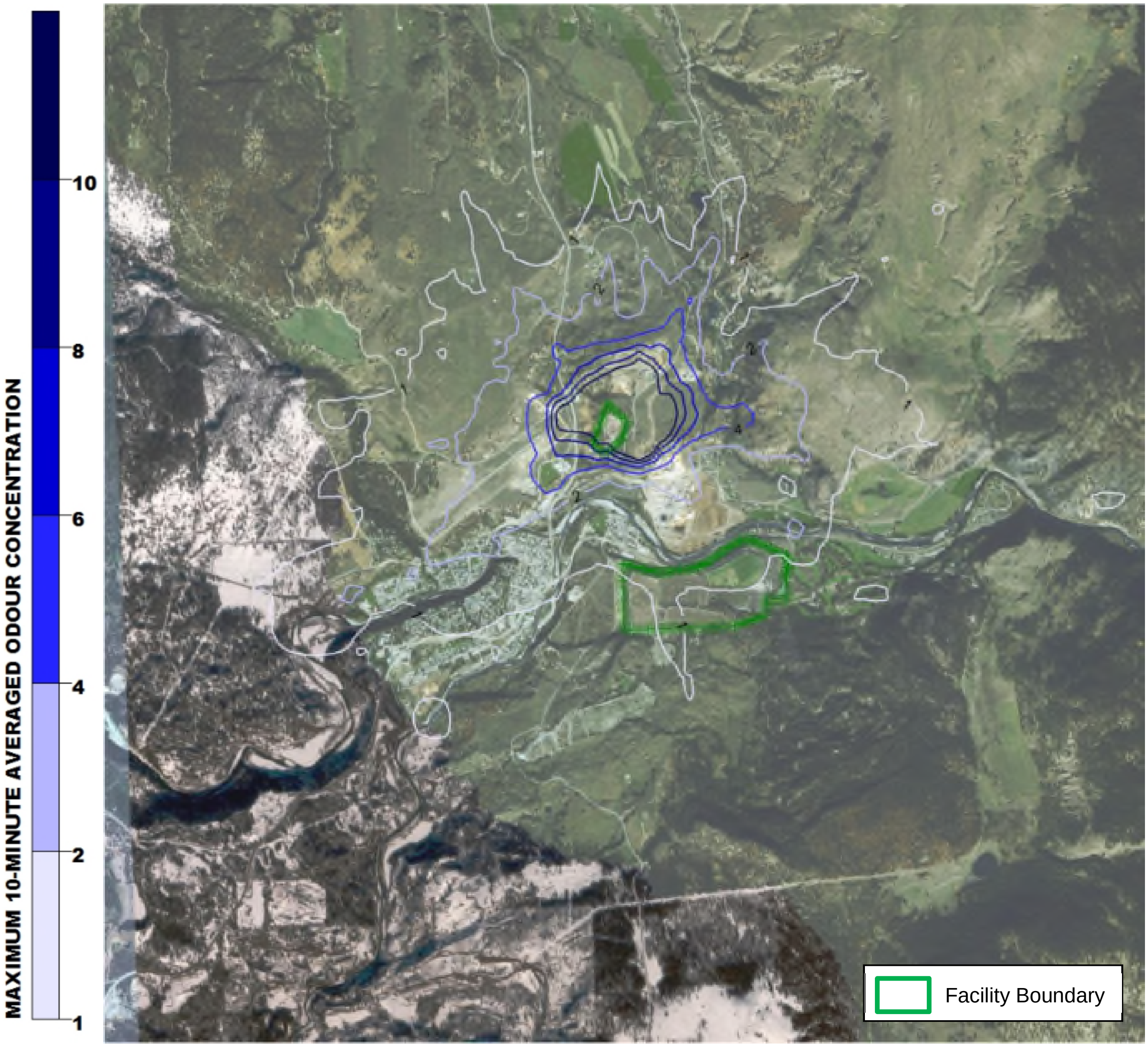


**Figure 6: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (In-Vessel)**

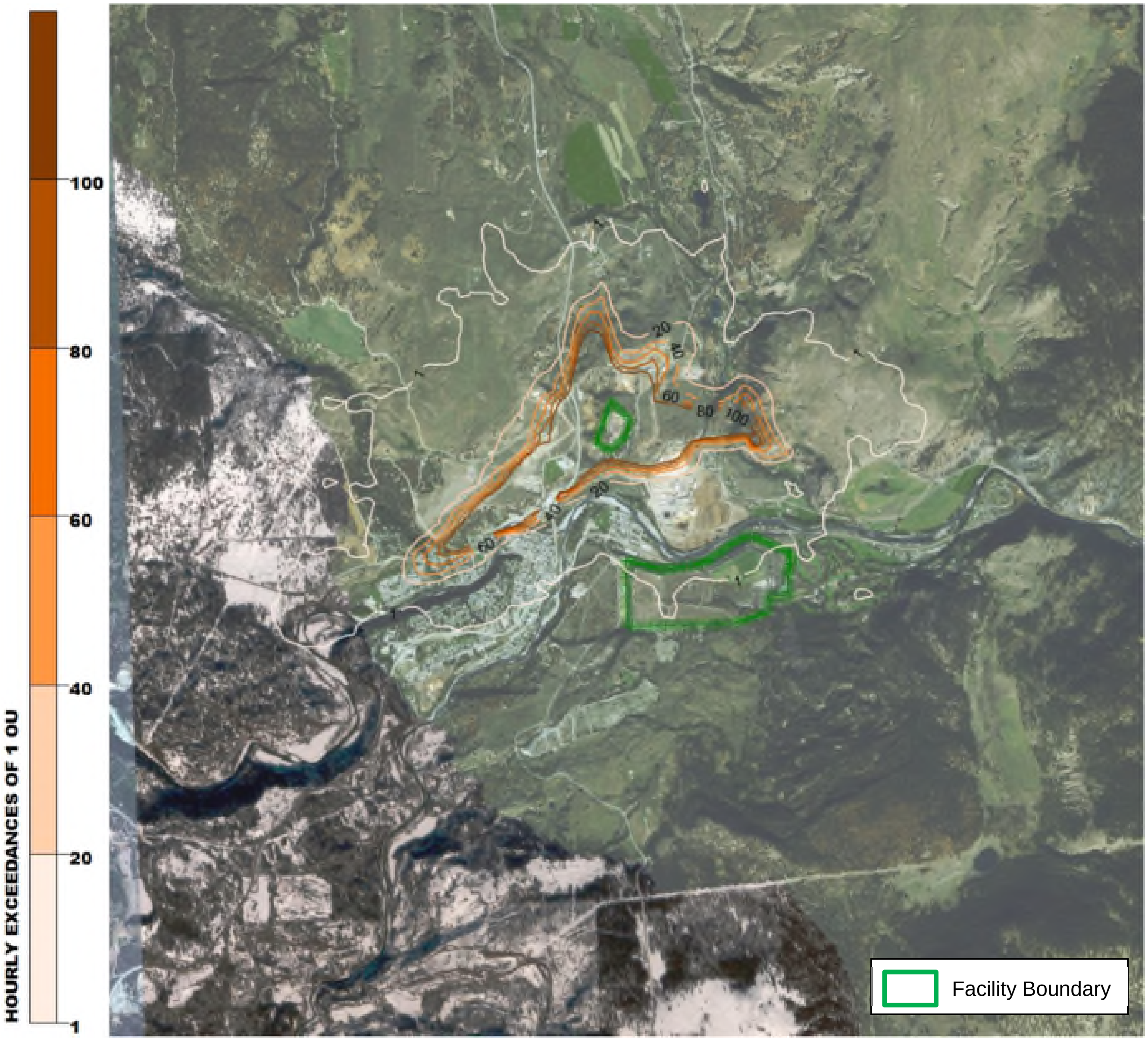


**Figure 7: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (In-Vessel)**

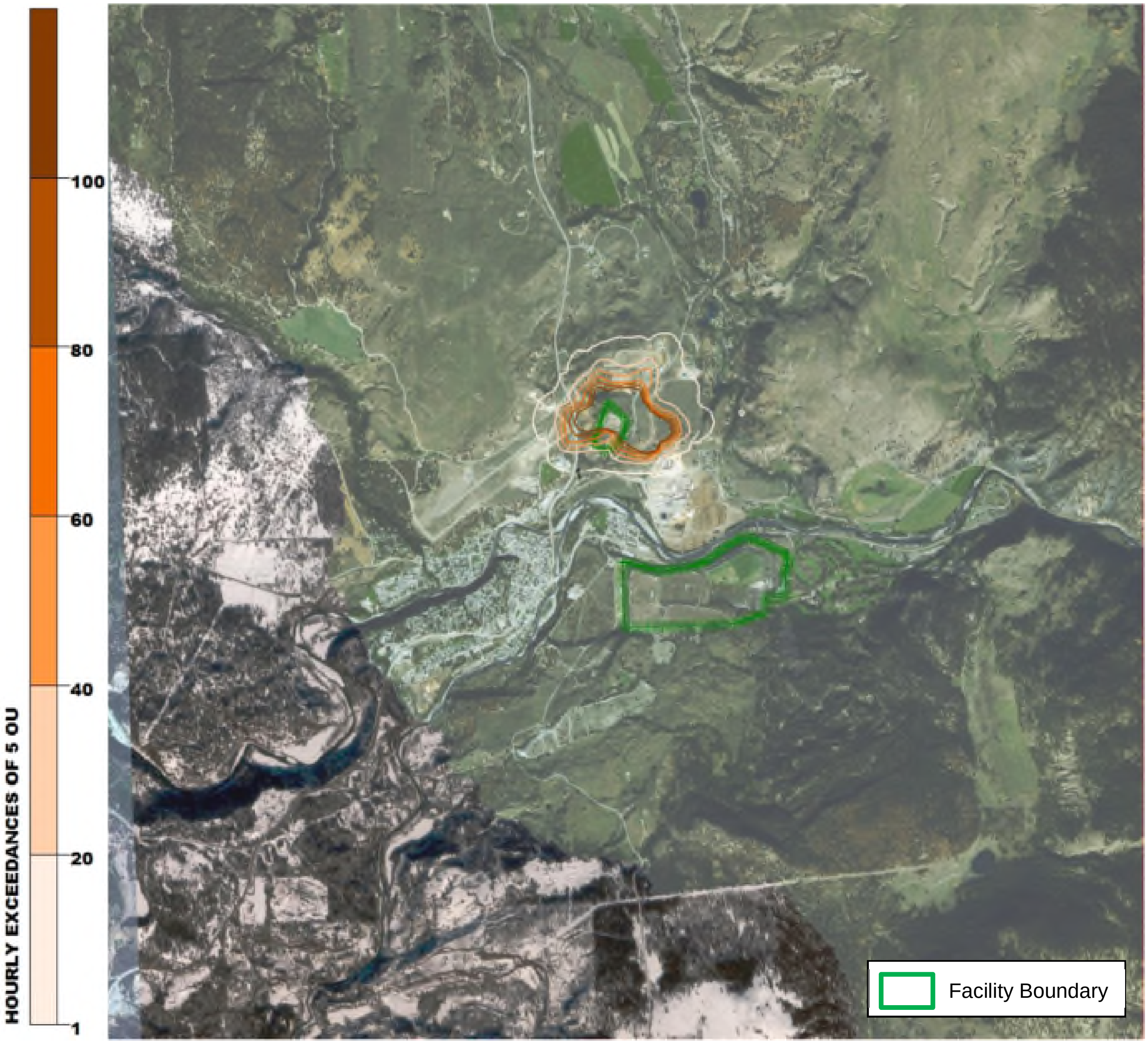


**Figure 8: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (In-Vessel)**

# PRINCETON HAYFIELD

# 1.0 INTRODUCTION

The following is a summary of model inputs and odour modelling results conducted for the purpose of assessing potential odour impacts from an organics management facility located at Princeton Hayfield (hereafter referred to as the “Site”). Odour modelling was conducted using CALPUFF, an advanced air modelling software system recommended by the British Columbia Ministry of Environment (BC MOE).

# 2.0 MODEL INPUTS AND ASSUMPTIONS

## 2.1 Meteorology

The air dispersion model CALPUFF contains a diagnostic meteorological processor, CALMET, which creates a three-dimensional meteorological field over the spatial extent of the model. The data produced by CALMET is used by CALPUFF in its dispersion and plume transport calculations. Inputs to CALMET include the following:

- a geophysical grid, constructed using gridded terrain and land cover data (obtained from GeoGratis – Government of Canada); and
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When CALMET is run in “no-observations” mode (using only MM5), the surface station observations provide a validation of the CALMET meteorology, in particular winds, to ensure representativeness. As MM5 is a meso-scale regional model, the grid used as input to CALMET is downscaled in three steps from a 32 km resolution grid to a 4 km grid and downscaled again within CALMET to the CALPUFF grid size (250 m). It is not expected that the meteorological time series in CALMET will exactly reproduce observed conditions on an hour by hour basis at any particular grid point, however it is expected to be representative of the general conditions over a given year.

Table 2.1 summarizes the meteorological inputs to CALMET used in the Keremeos Transfer Station Facility odour modelling and mapping exercise.

### Table 2.1: CALMET Inputs and Metadata

| Parameter | Usage |
|---|---|
| Surface Stations | None |
| Upper Air Soundings | None |
| Prognostic Data | 4 km resolution MM5 |
| Meteorological Grid | 10 km (east-west) x 10 km (north-south) at 250 $m^2$ |
| Grid Centrepoint | 681500 m, 5482200 m, UTM Zone 12 |
| Vertical Cells (Cell Face Heights) | 10 (0 m, 20 m, 40 m, 80 m, 160 m, 320 m, 640 m, 1200 m, 2000 m, 3000 m, 4000 m) |
| Terrain Data | CDN DEM 15 min |
| Land Use Data | GeoBase Land Cover circa 2000-Vector |

As land cover characteristics over the modelling domain vary with season (e.g., albedo, Bowen ratio, etc.), seasonal CALMET files were created using the model's default seasonal geophysical properties for each land cover category contained within the geophysical grid. The date ranges assumed to define each season are listed in Table 2.2. Year-to-year variability will undoubtedly occur, however, this temporal approximation was used to simplify modelling based on Environment Canada 1981 – 2010 climate norms for the Okanagan-Similkameen region. The modelled year was 2012.

### Table 2.2: Geophysical Property Seasonality

| Season | Date Range |
|---|---|
| Winter | December 1 – February 29 |
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Figure 2.1 is a snapshot of the CALMET-modelled surface winds on January 1, 2012, $20^{00}$ hrs. The figure also shows the boundary of both the Princeton Landfill and Hayfield sites (green border) and the location of Environment Canada (Princeton CS) meteorological station (dark green square).

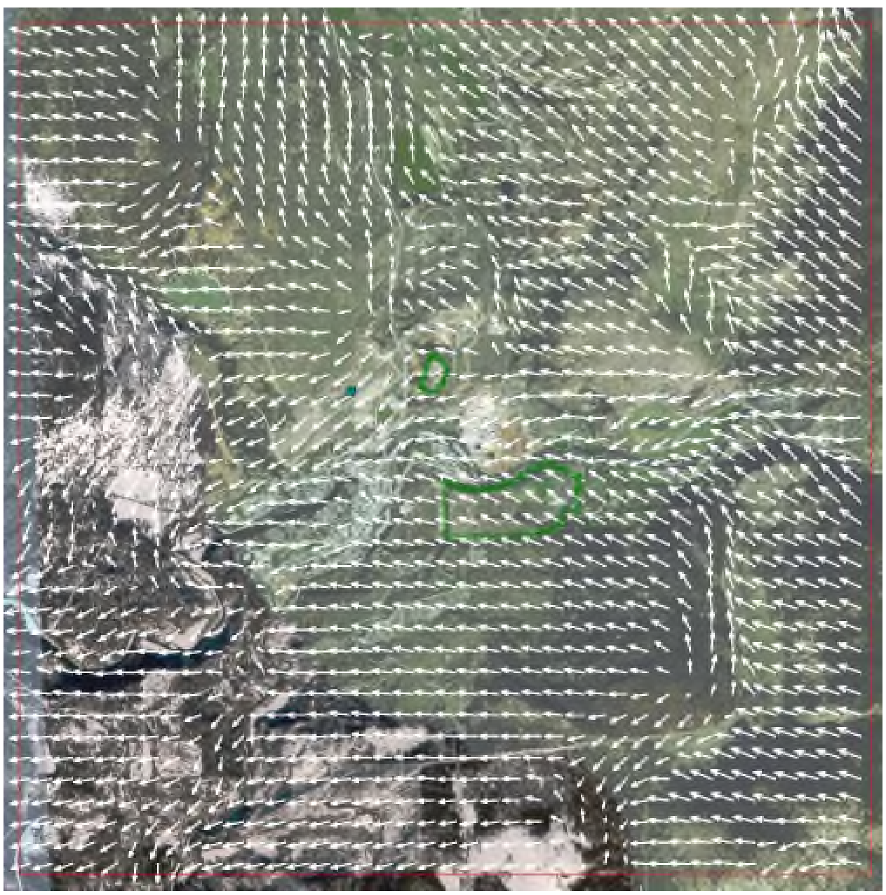

**Figure 2.1: CALMET-Modelled Wind Field (Easterly Flow) – January 1, 2012, $20^{00}$ hrs**

### 2.1.1 Meteorological Validations

#### 2.1.1.1 Winds

Figure 2.2 shows a comparison of the MM5/CALMET-modelled winds (left) and the observed winds recorded at Environment Canada Princeton CS meteorological station, located at Princeton Airport (49.465°, -120.51°, right). MM5/CALMET predicts the predominance of westerly winds seen in the observed data, however observed westerly winds are much more variable in their origin in the western quadrant (WNW-SW). *Note the difference in frequency scale between the two figures (0%-20% on the left and 0%-5% on the right).* Overall though, CALMET predicts nearly the same frequency of occurrence of west-component winds as is observed at Princeton CS.

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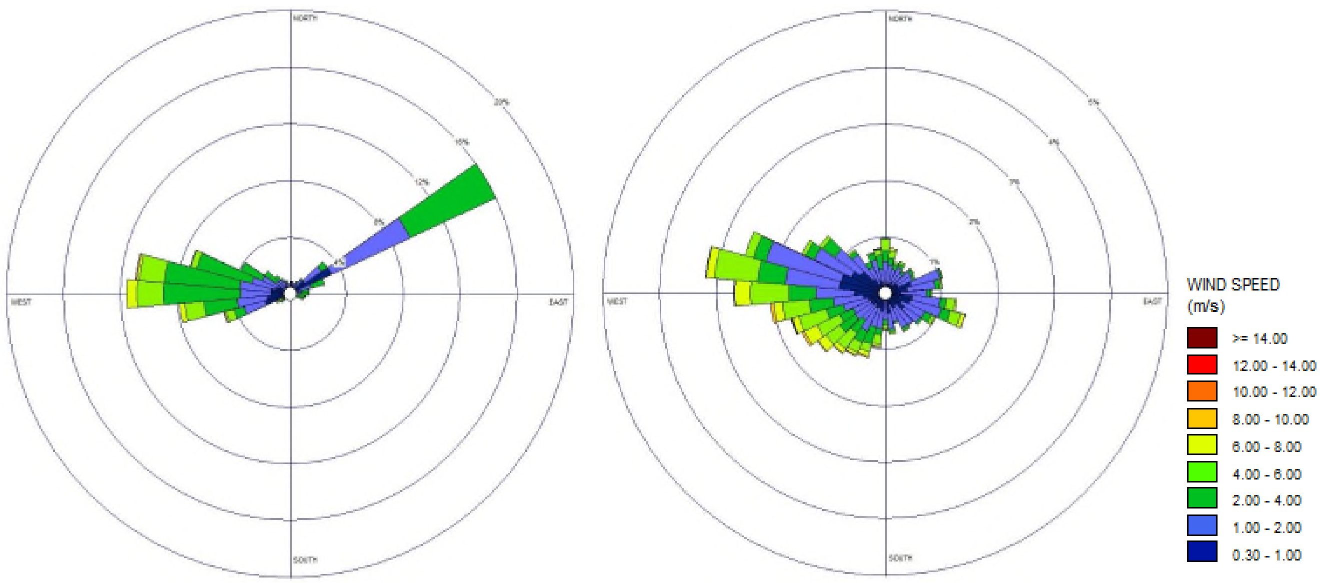


**Figure 2.2: Wind Rose Comparison: Modelled (left) vs. Observed at Princeton CS (right)**

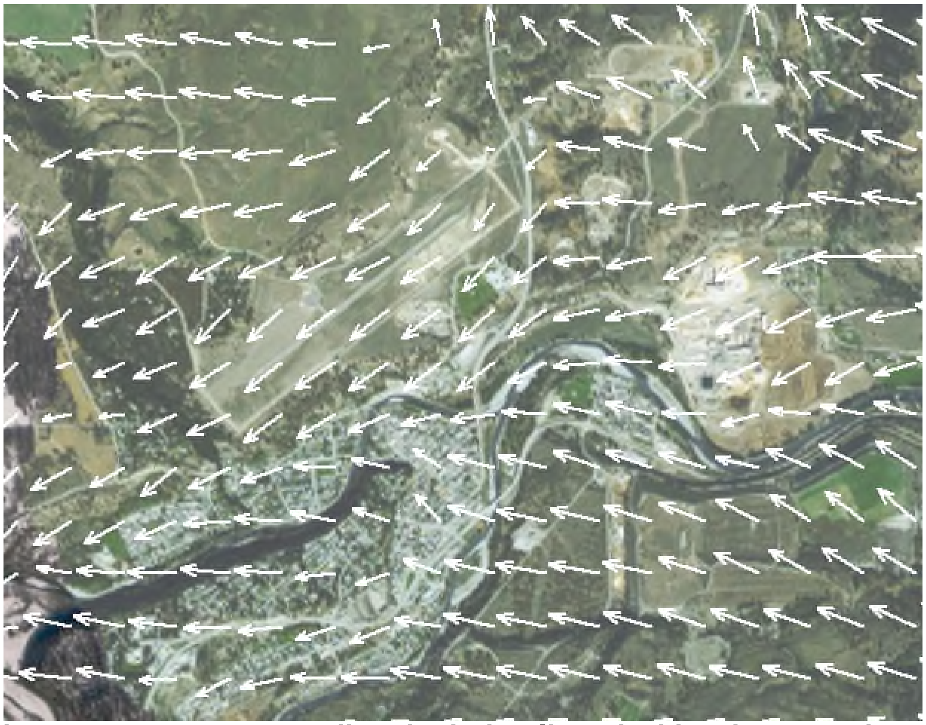

**Figure 2.3: CALMET-predicted Winds Aligned with Princeton Airport**

#### 2.1.1.2 Mixing Height

The atmospheric mixing height can be defined as the top of the layer in the lower atmosphere, within which an emitted species, in this case odour, is readily mixed through turbulence and convective processes. Therefore, when the mixing height is low, higher ground-level concentrations will generally be predicted. Figure 2.4 are time series of modelled mixing heights extracted from CALMET over two distinct seasonal periods in 2012 at the location of the Penticton RS station. The top figure (red) plots a time series of mixing heights in the winter (between February 1 and 8), while the lower figure (blue) plots mixing heights in the summer (between July 1 and 8).

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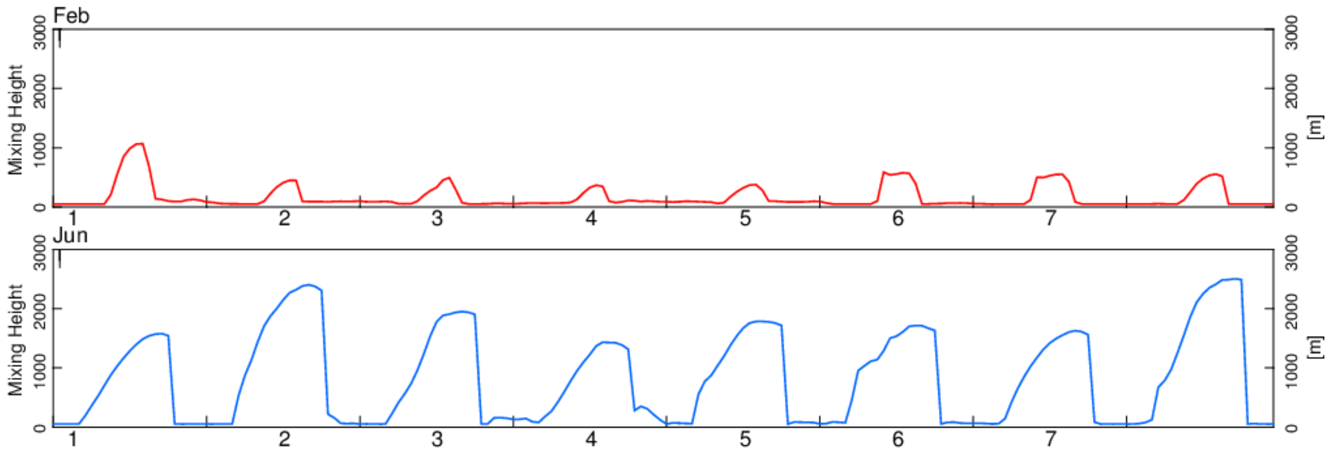


**Figure 2.4: CALMET-Modelled Mixing Heights for Winter (Red) and Summer (Blue)**

## 2.2 Area Sources and Emission Factors

The site layouts from the *Organics Management Consultant Task 2 – Feasibility Assessment* report for Princeton Hayfield were used to define the boundaries of the odour sources for this modelling analysis. Areas that generate odours were assigned a specific emission factor according to the activity taking place (e.g. composting, curing, pile turning, etc.). In the main report, Table 2.1 provides a description of the emission factors used for each of the scenarios below:

- Aerated static pile (ASP);
- Membrane covered aerated static pile; and
- In-vessel composting.

Emissions were assumed to occur homogeneously over the entirety of the area source. Some odour emissions (e.g. pile turning, pile moving, etc.) were assigned a diurnal variation based on the expected times of day the activity is to be performed (Table 2.1 of the main report). Such activities are expected to occur daily at the Site over a one- to two-hour period, however since the activity may occur at any time during the operational hours of the facility in the morning or in the afternoon, odour emissions were assumed in the model to occur between $10^{00}$ to $12^{00}$ – representing a time of day when vertical mixing is generally highest – and between $15^{00}$ to $17^{00}$ – when, during the winter, the mixing height is approaching its night time minimum, thus resulting in higher concentrations closer to the ground. This is a somewhat conservative approach since the activity may only be occurring over a portion of a single hour rather than four, may not take place every day, and peak odour emission would only occur during and immediately following the activity and decay in the hour following. It should be noted that odour emissions produced from pile building and moving are inconsequential compared to that produced from the biofilters which emit odour continuously.

Emission heights were either assigned a value of 3 m or 1 m depending on the activity occurring within the area source. Specific heights used for the various activity types are listed in Table 2.1 of the main report.

## 2.3 CALPUFF Settings and Assumptions

The CALPUFF model input settings were assigned with consideration to the recommendations in Table 9.7 of '*Recommended CALPUFF Input Group 2 Switch Settings*' in '*Guidelines for Air Quality Dispersion Modelling in British Columbia*'. Generally, default model settings were used. Since the area of interest is in the near-field (within

12 – 15 km of the source), dispersion coefficients were internally calculated using micrometeorological variables (MDISP = 2) based on estimates of the crosswind and vertical components of turbulence based on similarity theory and the land cover type. The probability distribution function (PDF) was used for dispersion under convective conditions (MPDF = 1) which explicitly accounts for the differences in the distribution and strengths of up and down drafts within the convective boundary layer, reporting the average between the two. By using these two settings, AERMOD-type dispersion is simulated (generally accepted as better-predicting in the near-field than CALPUFF), while also providing the benefit of a puff model and allowing for the effects of complex terrain.

The receptor grid spacing was 125 m at ground level over the entire grid. The simulations were to determine the general effects downwind from the facility, on the scale of kilometres, and therefore did not consider building downwash – the drawdown of the odour plume downwind of facility buildings due to turbulence.

# 3.0 RESULTS

Since the time step of the meteorological data is one-hour, CALPUFF can only output one-hour averaged predictions of odour concentration. However, since odour perception is on a much shorter scale, an averaging time-scalar must be applied to assess shorter-term peak concentrations due to plume meandering within the hourly period. Hourly odour concentrations are scaled to a ten-minute averaging period using Equation 1.

$$Cp = Co * \left(\frac{t_o}{t_p}\right)^{0.28} \quad (1)$$

Pursuant to Equation 1, $t_o$ is the 60 minute averaging time, $t_p$ is the short-term averaging time (10 minutes) and $C_o$ and $C_p$ are the respective peak concentrations (BC MOE). The scalar when converting from hourly to ten-minute average concentrations equates to 1.65.

## 3.1 Odour Units

An Odour Unit is a way of quantifying odours through the use of an odour panel that consists of a group of people with ‘calibrated noses’. The definition of an Odour Unit is based on the proportion of odour panel members that can detect the smell of a substance. One OU represents the concentration of a particular substance when 50% of the odour panel can detect the odour. This is called the perception threshold[1]. At this point, although an odour may be detected, it is not distinct enough to be able to identify the type of odour.

The Odour Unit scale is based on dilutions, as shown in the following figure. As the number of odour units increase, more people can detect the odour, and the intensity of the odour increases. Five OU is considered a faint odour and ten OU is considered a distinct odour (the point when some people can identify the type of odour, or its potential source)[2].

[1] http://blog.odotech.com/odor-unit-perception-threshold

[2] Odours and VOCs: Measurement, Regulation and Control Techniques (2009). Kassel University Press.

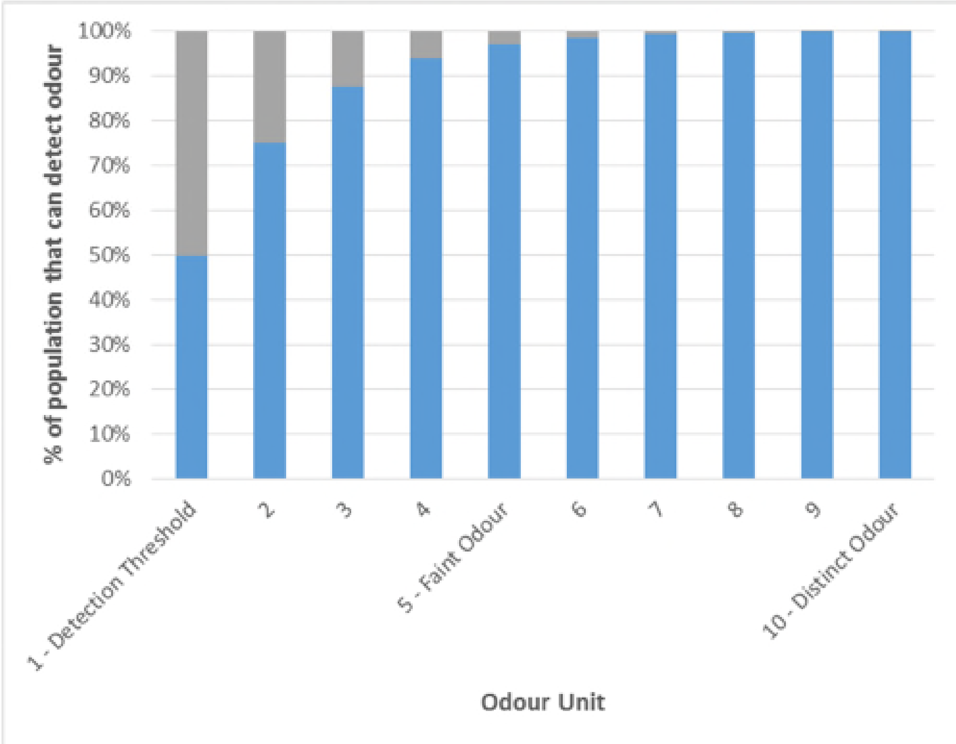


**Figure 3.1: Odour Unit Scale**

There are currently no guidelines for odour limits for composting facilities in British Columbia, however, some wastewater treatment facilities have imposed odour limits. For example, the standard in Metro Vancouver is no more than five OU at the property line. In other jurisdictions, the guideline is to have no detectable odour at the property line. At the Ogogrow facility in Vernon, BC, the limit is 50 OU at the property line.

## 3.2 Odour Maps

Odour maps are included as part of Appendix A. For each organics processing option listed in Section 2.2, odour modelling results are presented as three different plots:

- Maximum Odour Concentrations – The maximum predicted 10-minute odour concentration at each receptor point over the course of the modelled year. This is displayed as a contour plot showing the maximum predicted 10-minute averaged odour concentration at every ground level receptor point over the entire one-year simulation (8784 hours) as a blue gradient (light to dark). The 1 OU contour is white. The highest levels >10 OU are dark blue. The facility boundary is shown as a green outline.
- Hourly Exceedances >1 Odour Unit (OU) – The number of hours over the course of the modelled year where an odour threshold of 1 OU was exceeded in a ten-minute averaged concentration. This is displayed as a contour plot showing the number of times the predicted 10-minute odour concentration exceeded 1 OU over the modelled year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to 50% of the population being able to detect odour produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.
- Hourly Exceedances >5 OU – The number of hours over the course of the modelled year where an odour threshold of 5 OU was exceeded in a ten minute averaged concentration. This is displayed as a contour plot

showing the number of times the predicted 10-minute odour concentration exceeded 5 OU over the modelled year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to when a faint odour is produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.

## 3.3 Results Summary

The odour maps presented in Appendix A show: (1) the magnitude and spatial extent of maximum ground level odour, and (2) the number of exceedances of odour detection thresholds for the technologies assessed. The membrane covered aerated static pile results had the least odour issues.

The following table summarizes the results of the odour mapping exercise based on the predicted maximum odour and number of hours of odour exceedances at a location 100 m south of the property boundary representing the resident that is closest in proximity to the Site (49.462401°, -120.477144°), Figure 3.2.

### Table 3.1: Results Summary based on Closest Receptor Point

| Scenario | Maximum Predicted 10-min Odour | Odour Exceedance >1 OU (hours per year) | Odour Exceedance >5 OU (hours per year) |
|---|---|---|---|
| Aerated Static Pile | 5.2 OU | 159 | 1 |
| Membrane Covered Aerated Static Pile | 0.15 OU | 0 | 0 |
| In-Vessel | 3.9 OU | 132 | 0 |


**Figure 3.2: Location of Discrete Receptor (49.462401°, -120.477144° )**

### 3.3.1 Biofilter Effect

The Membrane Covered Aerated Static pile has the lowest odour emissions of the technologies as this type of operation does not use a biofilter. The greatest source of odour emissions can be attributed to the biofilters, as seen in Table 3.2.

**Table 3.2: Odour Emissions from Biofilters**

| Scenario | % of Odour from Composting Biofilter |
|---|---|
| Aerated Static Pile | 98% |
| Membrane Covered Aerated Static Pile | N/A |
| In-Vessel | 99% |

# APPENDIX A

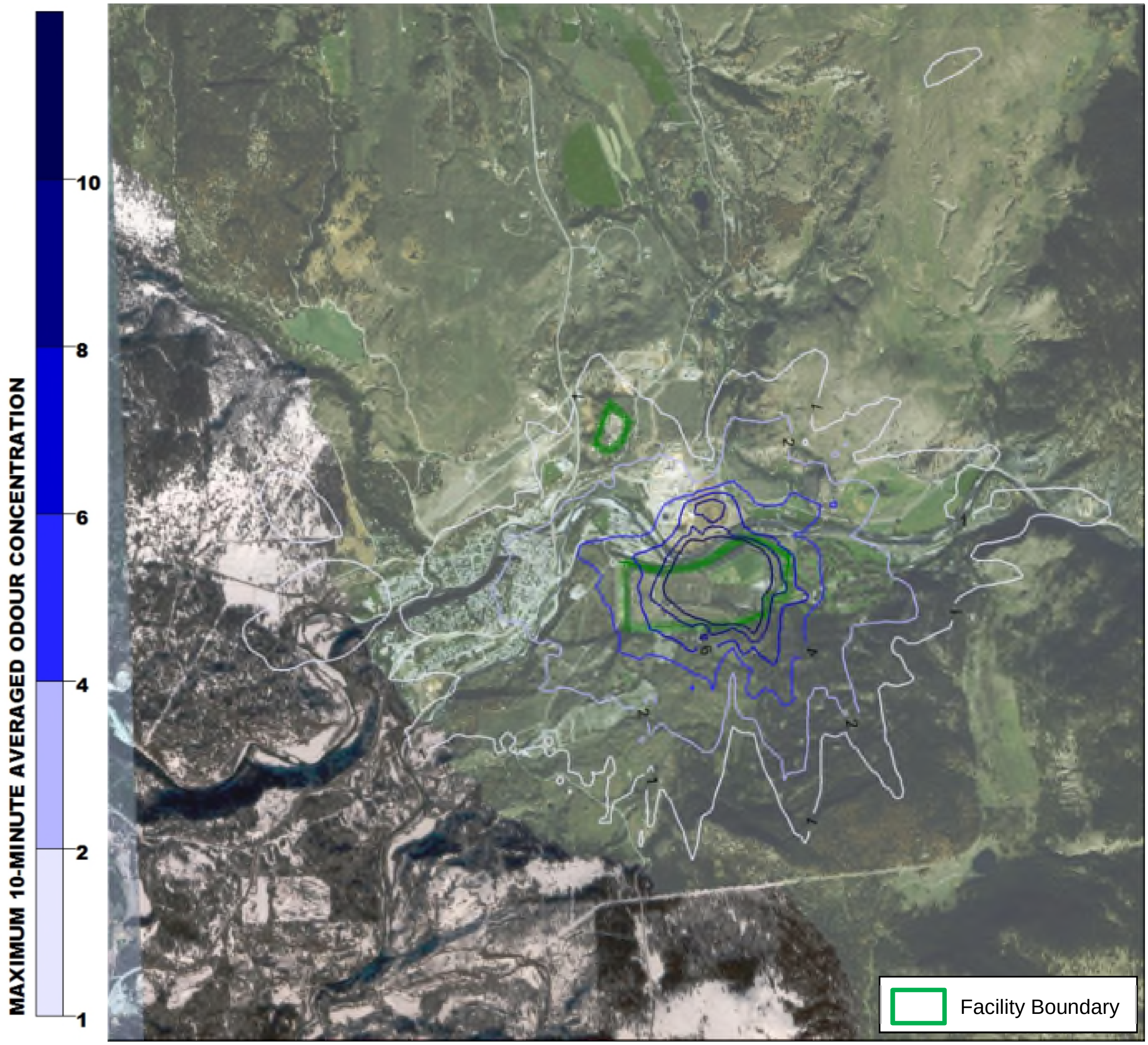


**Figure 1: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (ASP)**

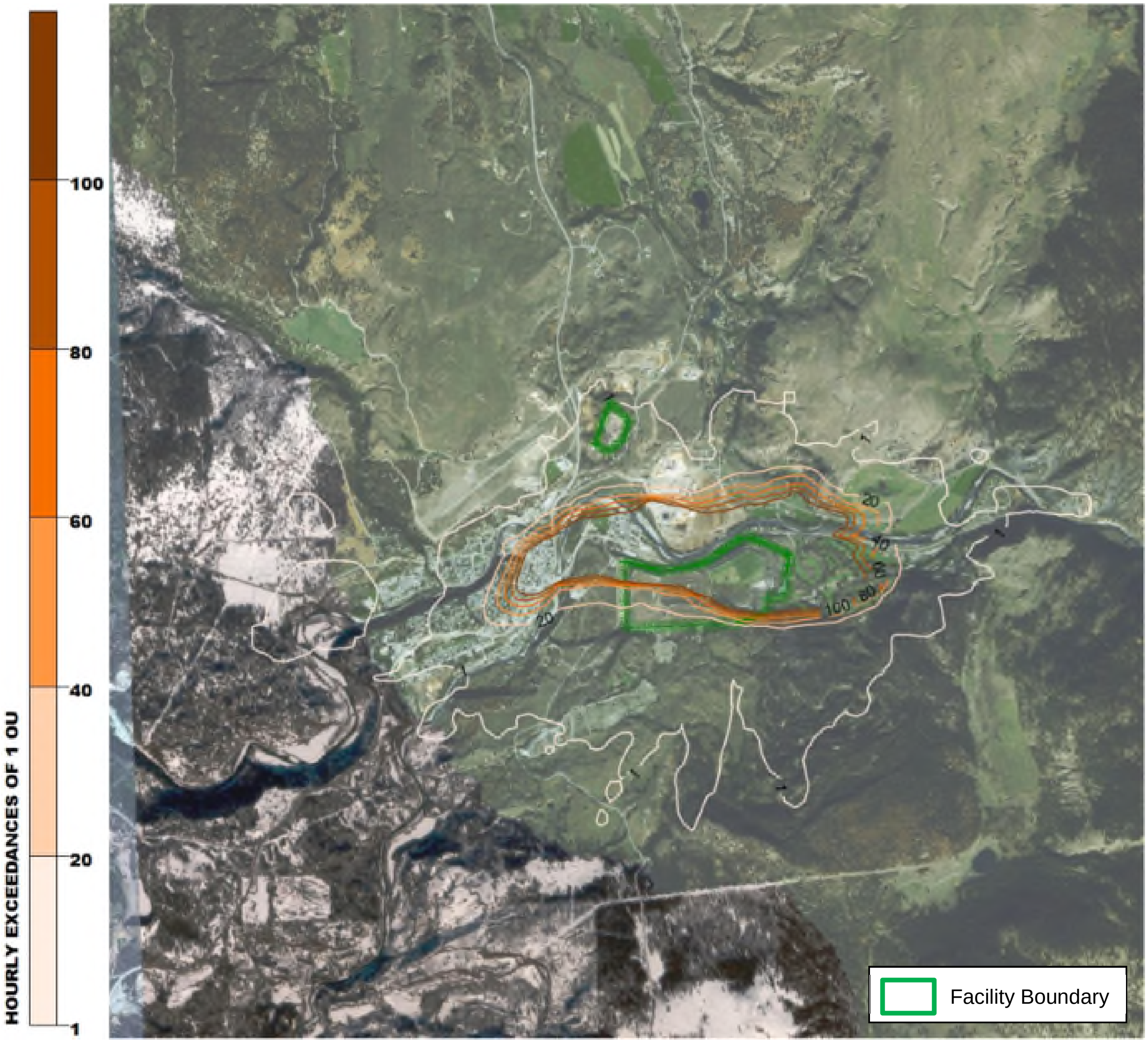


**Figure 2: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (ASP)**

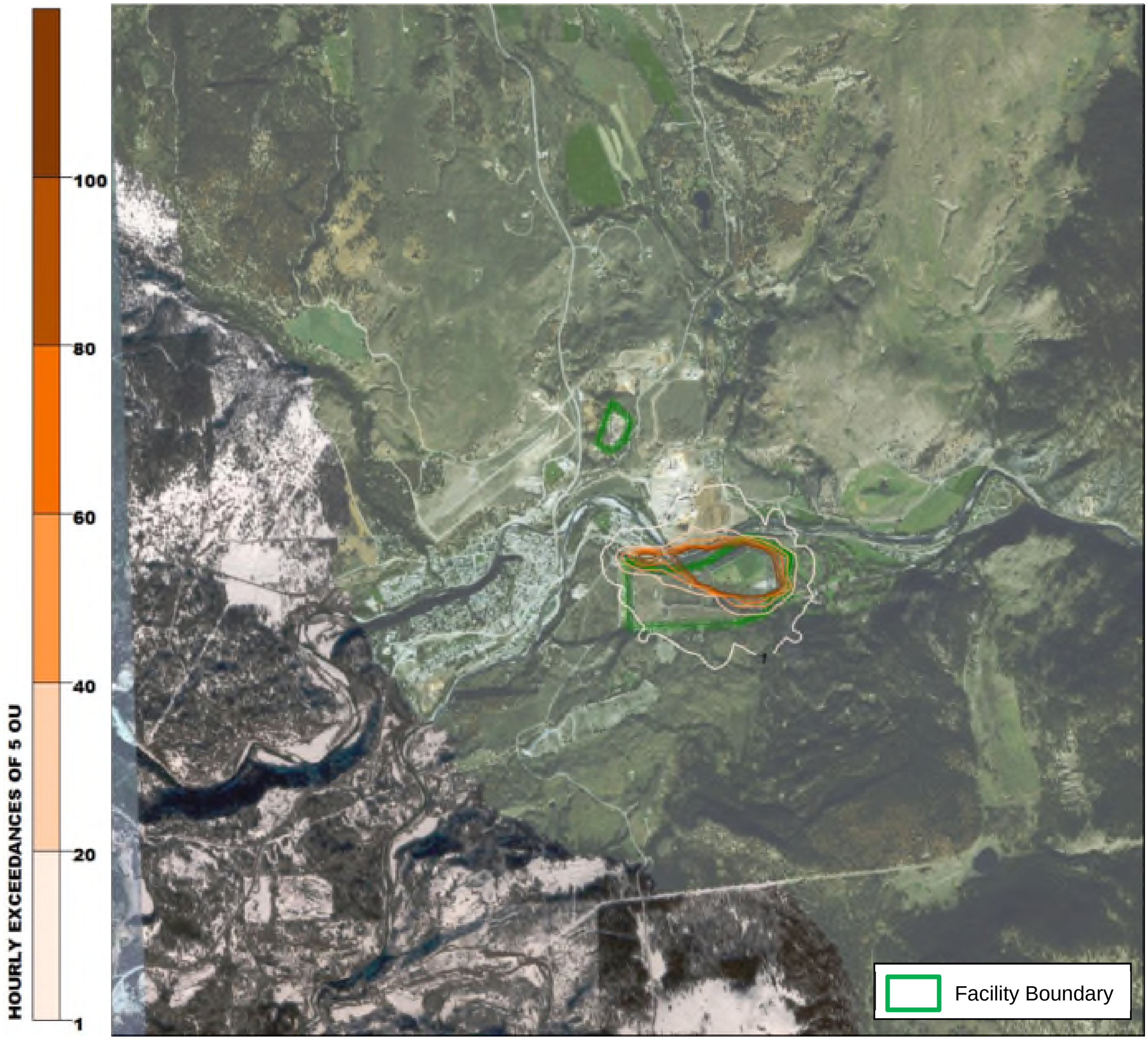


**Figure 3: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (ASP)**

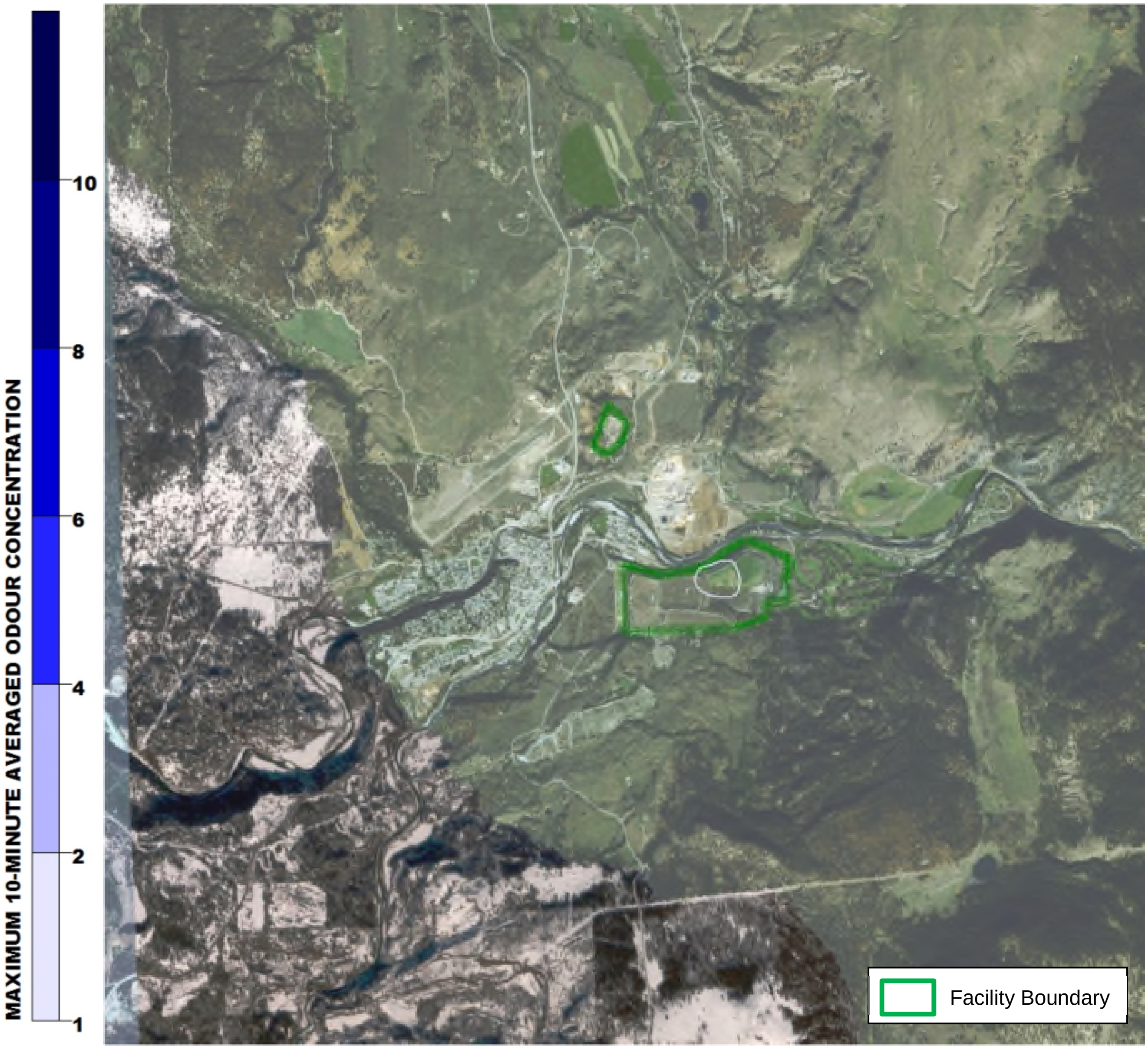


**Figure 4: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (Covered ASP)**

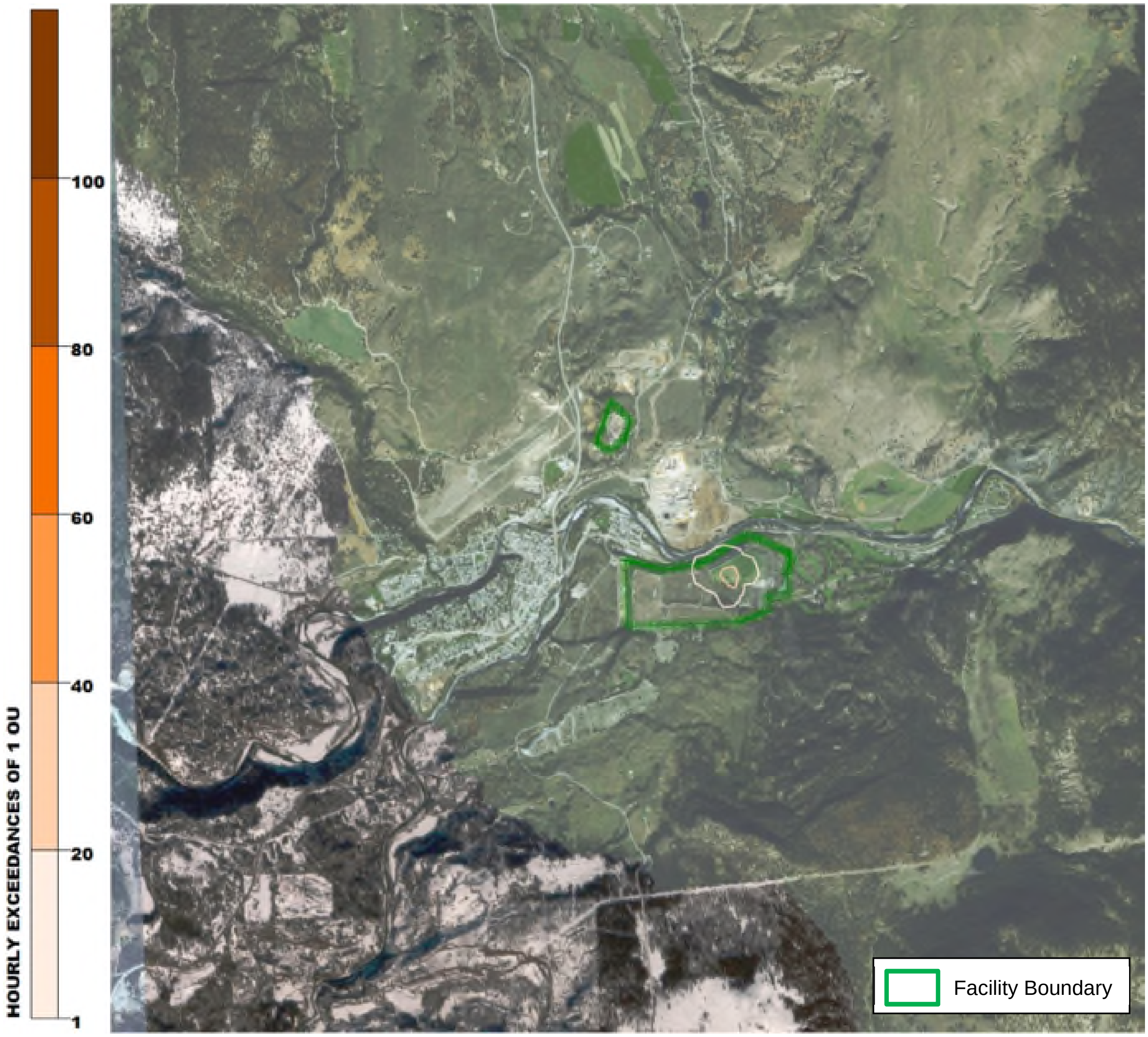


**Figure 5: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (Covered ASP)**

Note: Exceedances of 5 OU were not observed in the model, therefore a figure was not presented.

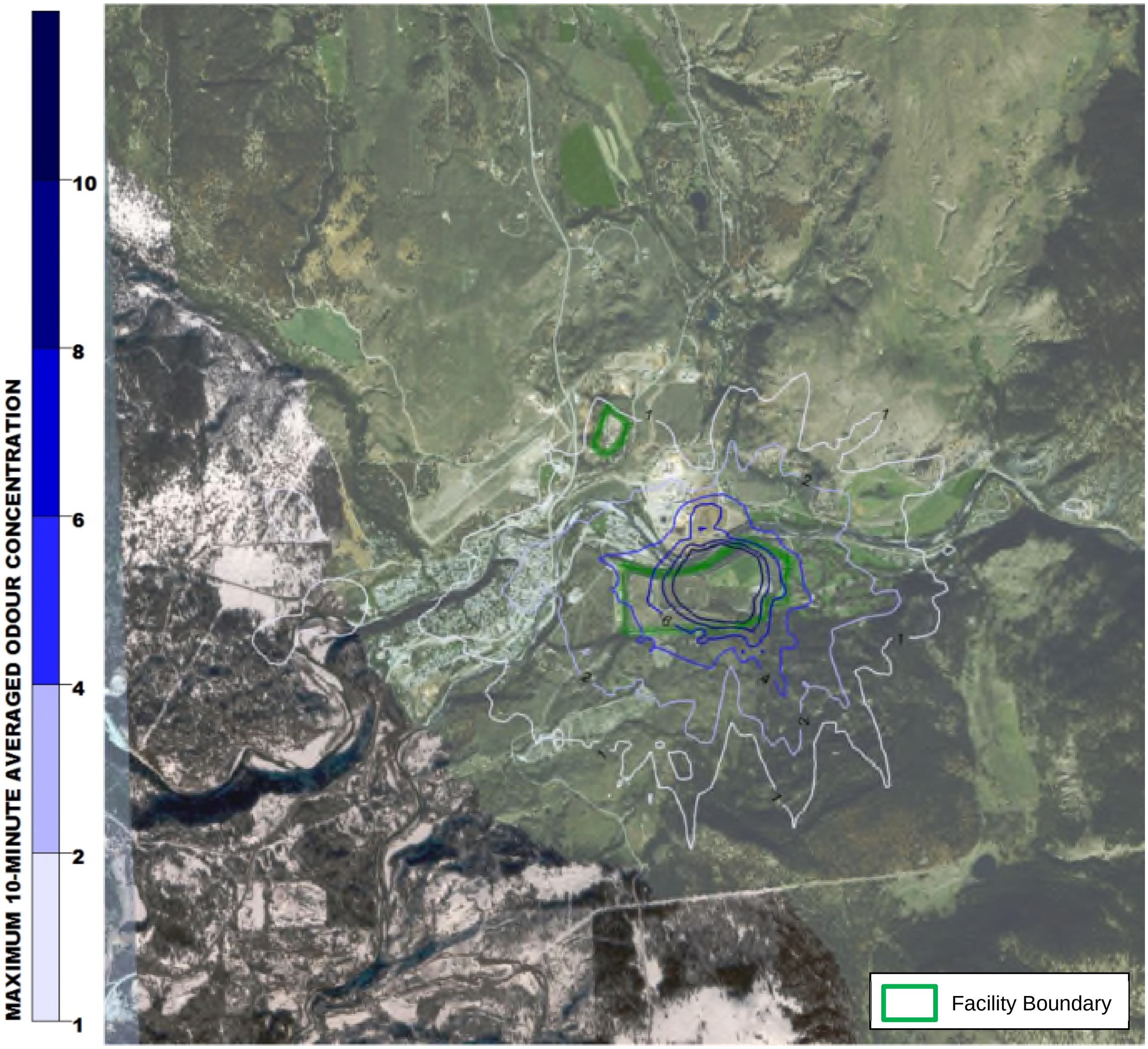


**Figure 6: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (In-Vessel)**

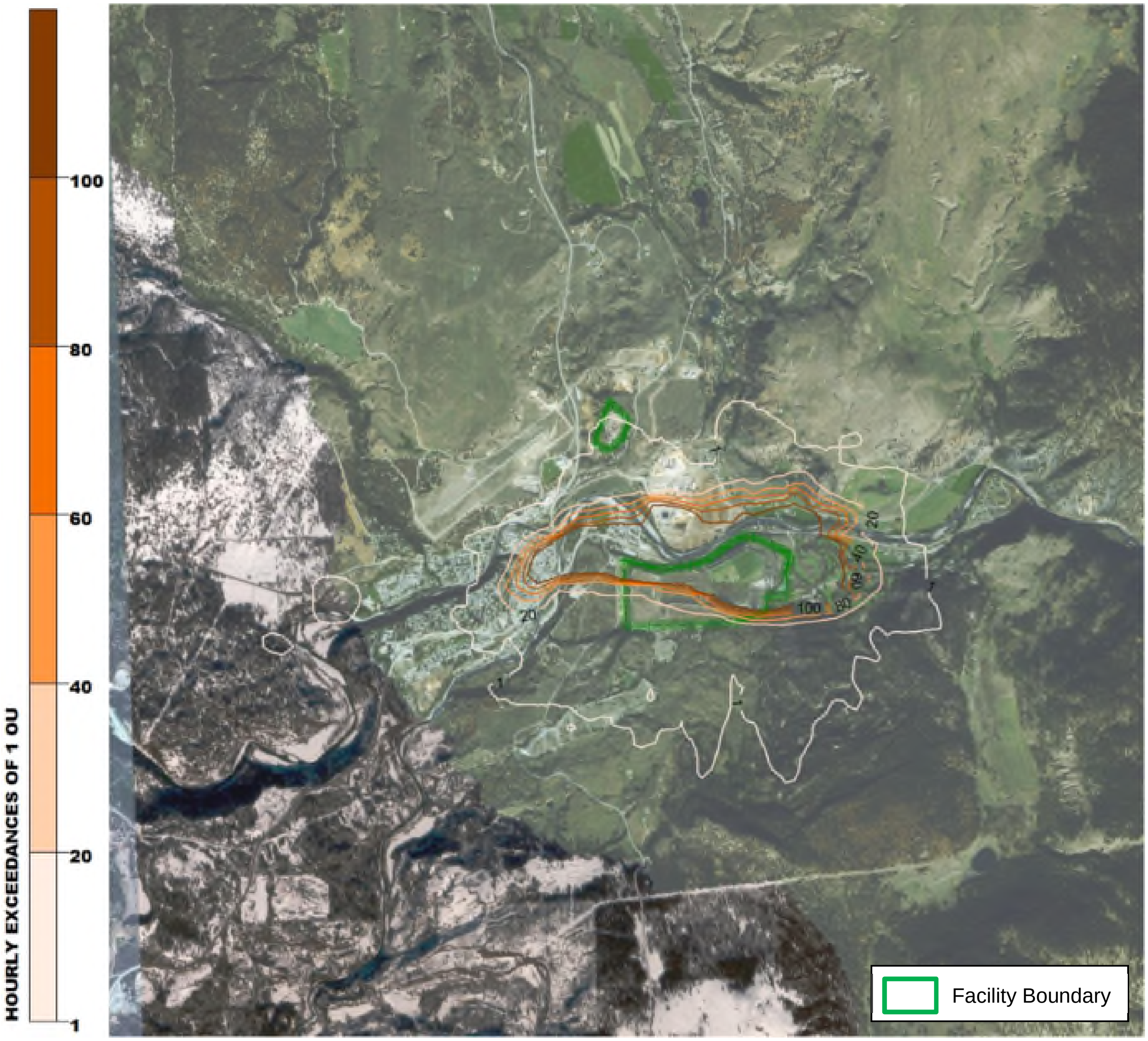


**Figure 7: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (In-Vessel)**

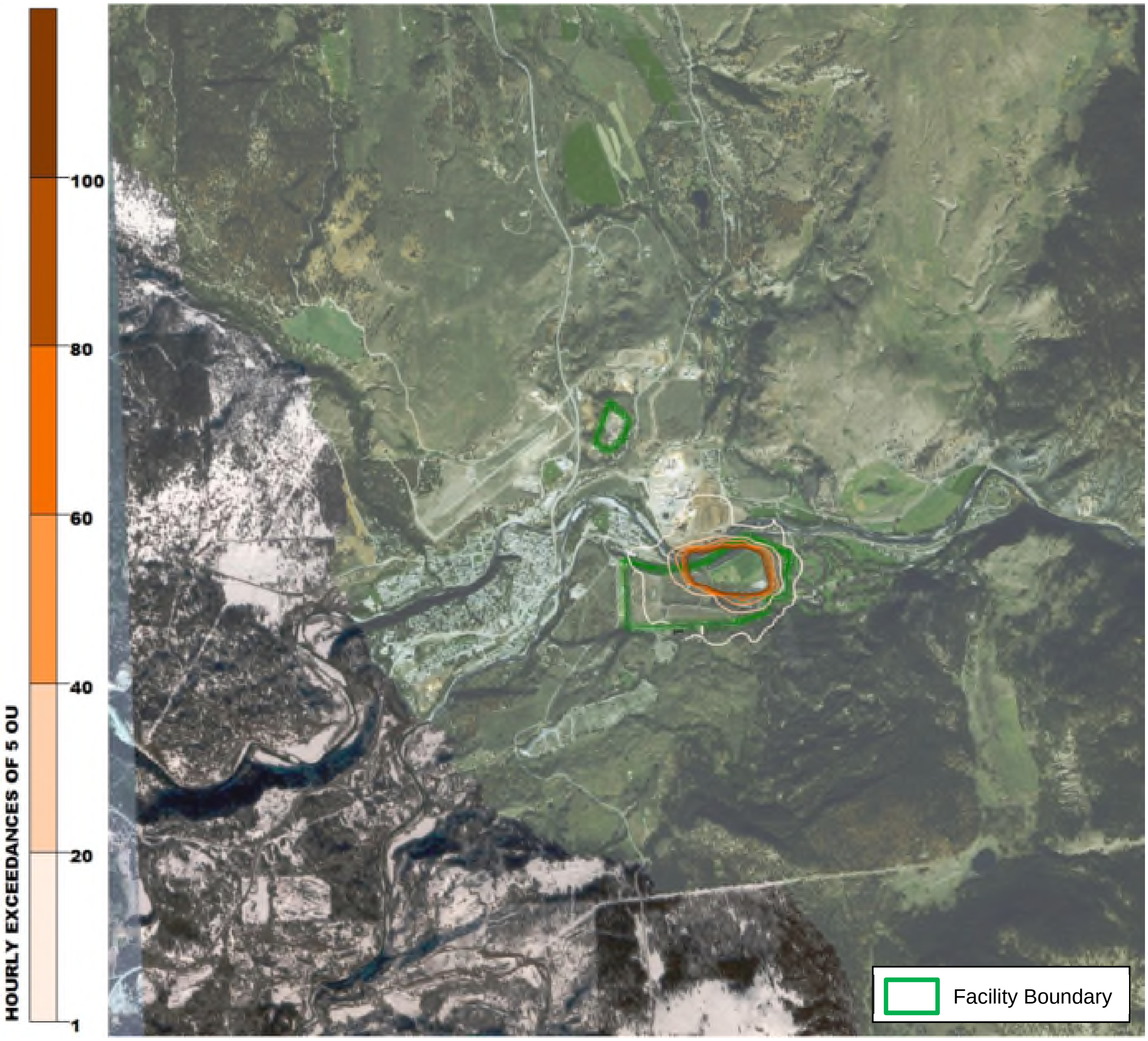


**Figure 8: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (In-Vessel)**

# KEREMEOS TRANSFER STATION

# 1.0 INTRODUCTION

The following is a summary of model inputs and odour modelling results conducted for the purpose of assessing potential odour impacts from an organics management facility located at Keremeos Transfer Station (hereafter referred to as the “Site”). Odour modelling was conducted using CALPUFF, an advanced air modelling software system recommended by the British Columbia Ministry of Environment (BC MOE).

# 2.0 MODEL INPUTS AND ASSUMPTIONS

## 2.1 Meteorology

The air dispersion model CALPUFF contains a diagnostic meteorological processor, CALMET, which creates a three-dimensional meteorological field over the spatial extent of the model. The data produced by CALMET is used by CALPUFF in its dispersion and plume transport calculations. Inputs to CALMET include the following:

- a geophysical grid, constructed using gridded terrain and land cover data (obtained from GeoGratis – Government of Canada); and
- a combination of prognostic (three-dimensional meso-scale model called MM5) meteorological data and hourly surface observations obtained from Environment Canada and BC MOE meteorological stations.

When CALMET is run in “no-observations” mode (using only MM5), the surface station observations provide a validation of the CALMET meteorology, in particular winds, to ensure representativeness. As MM5 is a meso-scale regional model, the grid used as input to CALMET is downscaled in three steps from a 32 km resolution grid to a 4 km grid and downscaled again within CALMET to the CALPUFF grid size (250 m). It is not expected that the meteorological time series in CALMET will exactly reproduce observed conditions on an hour by hour basis at any particular grid point, however it is expected to be representative of the general conditions over a given year.

Table 2.1 summarizes the meteorological inputs to CALMET used in the Keremeos Transfer Station Facility odour modelling and mapping exercise.

### Table 2.1: CALMET Inputs and Metadata

| Parameter | Usage |
|---|---|
| Surface Stations | None |
| Upper Air Soundings | None |
| Prognostic Data | 4 km resolution MM5 |
| Meteorological Grid | 16 km (east-west) x 16 km (north-south) at 250 $m^2$ |
| Grid Centrepoint | 295500 m, 5454000 m, UTM Zone 11 |
| Vertical Cells (Cell Face Heights) | 10 (0 m, 20 m, 40 m, 80 m, 160 m, 320 m, 640 m, 1200 m, 2000 m, 3000 m, 4000 m) |
| Terrain Data | CDN DEM 15 min |
| Land Use Data | GeoBase Land Cover circa 2000-Vector |

As land cover characteristics over the modelling domain vary with season (e.g., albedo, Bowen ratio, etc.), seasonal CALMET files were created using the model's default seasonal geophysical properties for each land cover category contained within the geophysical grid. The date ranges assumed to define each season are listed in Table 2.2. Year-to-year variability will undoubtedly occur, however, this temporal approximation was used to simplify modelling based on Environment Canada 1981 – 2010 climate norms for the Okanagan-Similkameen region. The modelled year was 2012.

### Table 2.2: Geophysical Property Seasonality

| Season | Date Range |
|---|---|
| Winter | December 1 – February 29 |
| Spring | March 1 – May 31 |
| Summer | June 1 – September 15 |
| Fall | September 15 – November 30 |

Figure 2.1 is two snapshots of the CALMET-modelled surface winds showing the two predominant flow conditions through the Similkameen Valley at Keremeos. The left figure shows an example of westerly flow which is much more prominent from spring through fall, occurring on October 16, 2012 at $1^{00}$ hrs. The right figure shows an example of easterly flow which occurs with near equal frequency as westerly winds during winter, occurring on January 22 at $12^{00}$ hrs. The figure also shows the boundary of the site (green border).

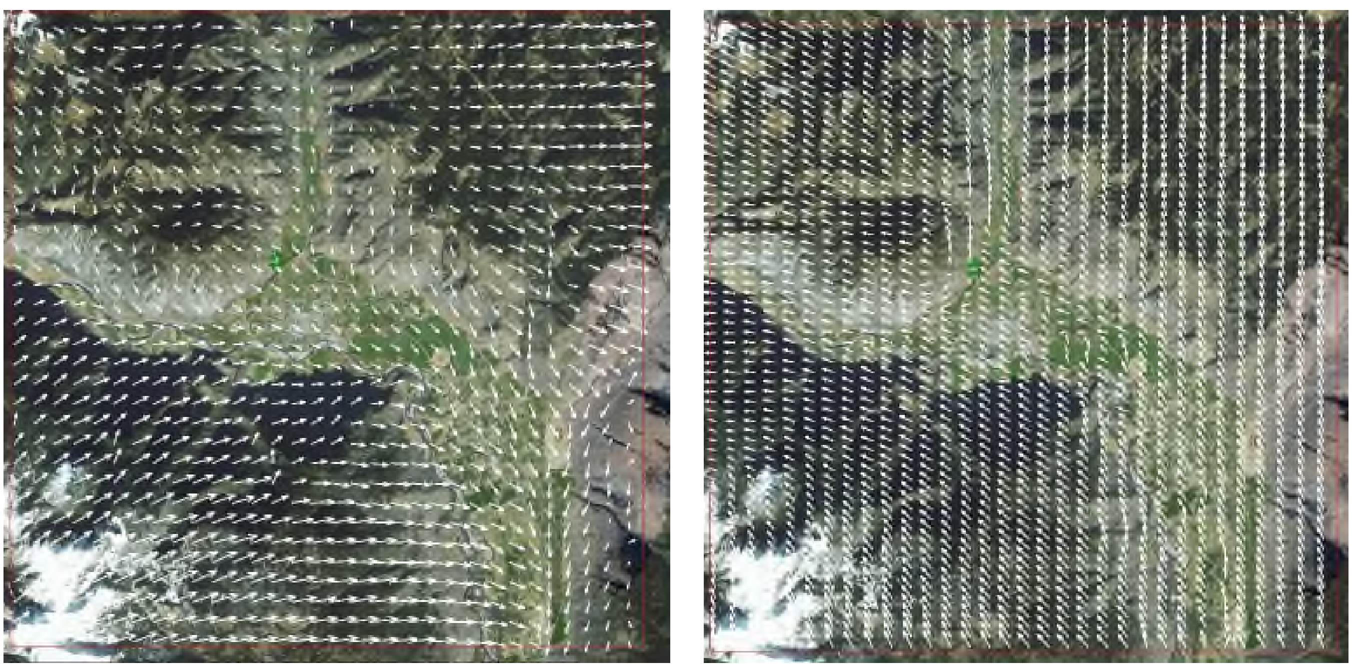

**Figure 2.1: CALMET-Modelled Wind Fields – Westerly and Easterly Flow**

### 2.1.1 Meteorological Validations

#### 2.1.1.1 Winds

Figure 2.2 shows a comparison of the CALMET-modelled winds (left) and the observed winds (right) recorded at B.C. Ministry of Environment Air Quality Station Keremeos Municipal Office (49.205070°, -119.829190°) between August 2008 and December 2009. CALMET produces a very good representation of winds in the center of the valley.

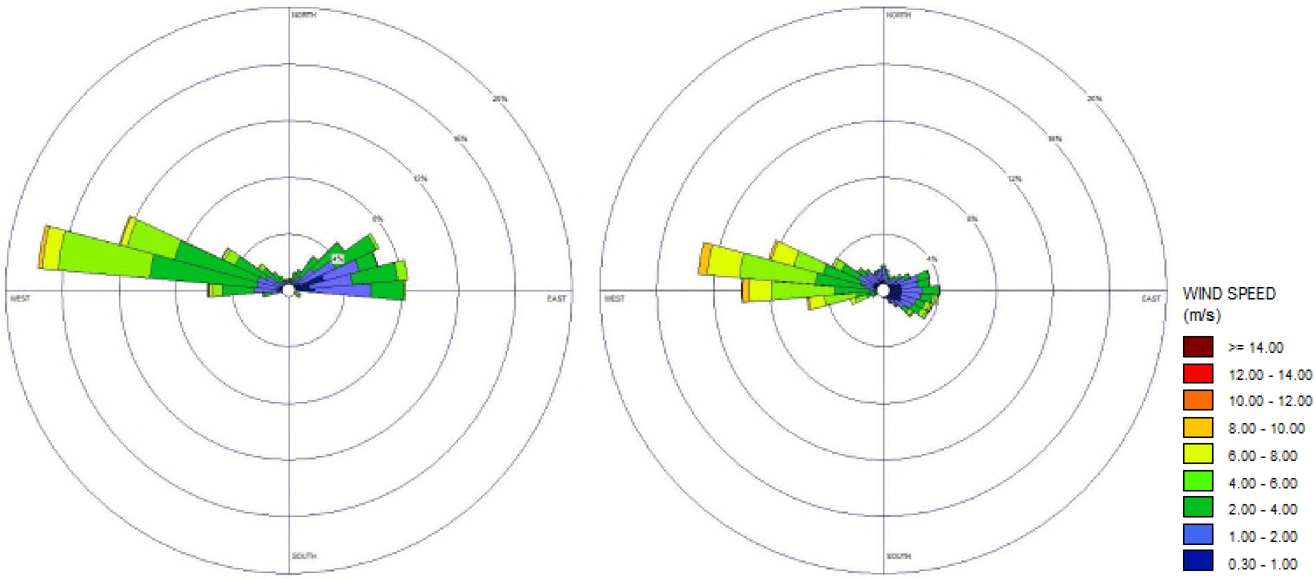


**Figure 2.2: Wind Rose Comparison: Modelled (left) vs. Observed at Keremeos Municipal Office (right)**

#### 2.1.1.2 Mixing Height

The atmospheric mixing height can be defined as the top of the layer in the lower atmosphere, within which an emitted species, in this case odour, is readily mixed through turbulence and convective processes. Therefore, when the mixing height is low, higher ground-level concentrations will generally be predicted. Figure 2.3 are time series of modelled mixing heights extracted from CALMET over two distinct seasonal periods in 2012 at the location of the Keremeos Municipal Office meteorological station. The top figure (red) plots a time series of mixing heights in the winter (between February 1 and 8), while the lower figure (blue) plots mixing heights in the summer (between July 1 and 8).

Seasonal contrast is strongly evident since there is reduced solar radiation, lower temperatures and snow cover, among other factors during the winter that results in generally lower mixing heights, and thus resulting in higher concentrations of odour. Both figures show the expected strong diurnal pattern, with mixing heights dropping quite close to the ground surface (~50 m as a default in CALMET) at night. When overnight mixing heights are higher, it is due to turbulence induced by higher wind speeds over uneven terrain.

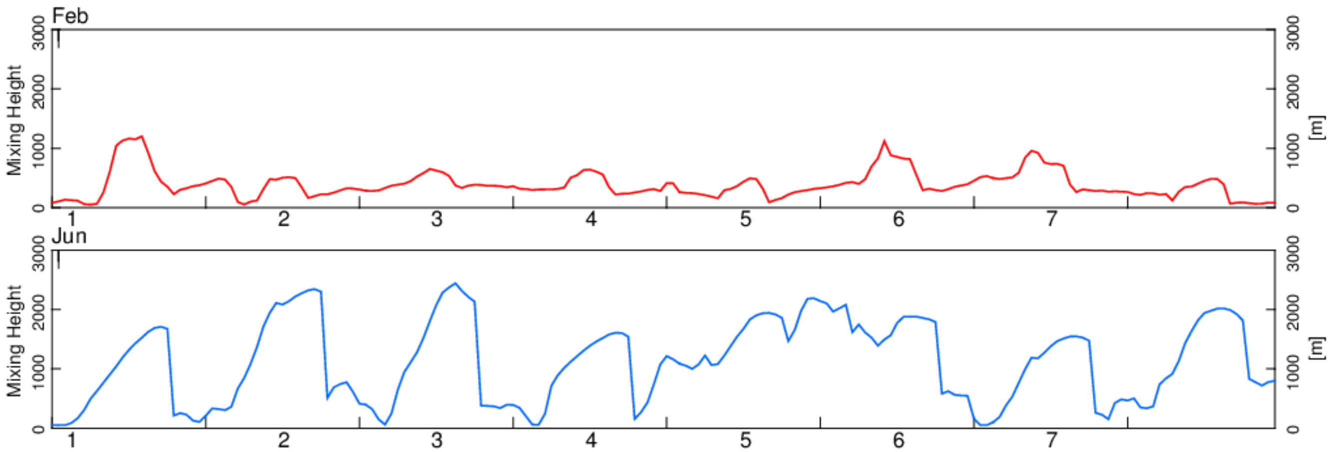


**Figure 2.3: CALMET-Modelled Mixing Heights for Winter (Red) and Summer (Blue)**

## 2.2 Area Sources and Emission Factors

The site layouts from the *Organics Management Consultant Task 2 – Feasibility Assessment* report for Keremeos Transfer Station were used to define the boundaries of the odour sources for this modelling analysis. Areas that generate odours were assigned a specific emission factor according to the activity taking place (e.g. composting, curing, pile turning, etc.). In the main report, Table 2.1 provides a description of the emission factors used for each of the scenarios below:

- Current operations (static piles of yard waste);
- Aerated static pile (ASP);
- Membrane covered aerated static pile; and
- In-vessel composting.

Emissions were assumed to occur homogeneously over the entirety of the area source. Some odour emissions (e.g. pile turning, pile moving, etc.) were assigned a diurnal variation based on the expected times of day the activity is to be performed (Table 2.1 of the main report). Such activities are expected to occur daily at the Site over a one- to two-hour period, however since the activity may occur at any time during the operational hours of the facility in the morning or in the afternoon, odour emissions were assumed in the model to occur between $10^{00}$ to $12^{00}$ – representing a time of day when vertical mixing is generally highest – and between $15^{00}$ to $17^{00}$ – when, during the winter, the mixing height is approaching its night time minimum, thus resulting in higher concentrations closer to the ground. This is a somewhat conservative approach since the activity may only be occurring over a portion of a single hour rather than four, may not take place every day, and peak odour emission would only occur during and immediately following the activity and decay in the hour following. It should be noted that odour emissions produced from pile building and moving are inconsequential compared to that produced from the biofilters which emit odour continuously.

Emission heights were either assigned a value of 3 m or 1 m depending on the activity occurring within the area source. Specific heights used for the various activity types are listed in Table 2.1 of the main report.

## 2.3 CALPUFF Settings and Assumptions

The CALPUFF model input settings were assigned with consideration to the recommendations in Table 9.7 of '*Recommended CALPUFF Input Group 2 Switch Settings*' in '*Guidelines for Air Quality Dispersion Modelling in British Columbia*'. Generally, default model settings were used. Since the area of interest is in the near-field (within 12 – 15 km of the source), dispersion coefficients were internally calculated using micrometeorological variables (MDISP = 2) based on estimates of the crosswind and vertical components of turbulence based on similarity theory and the land cover type. The probability distribution function (PDF) was used for dispersion under convective conditions (MPDF = 1) which explicitly accounts for the differences in the distribution and strengths of up and down drafts within the convective boundary layer, reporting the average between the two. By using these two settings, AERMOD-type dispersion is simulated (generally accepted as better-predicting in the near-field than CALPUFF), while also providing the benefit of a puff model and allowing for the effects of complex terrain.

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# 3.0 RESULTS

Since the time step of the meteorological data is one-hour, CALPUFF can only output one-hour averaged predictions of odour concentration. However, since odour perception is on a much shorter scale, an averaging time-scalar must be applied to assess shorter-term peak concentrations due to plume meandering within the hourly period. Hourly odour concentrations are scaled to a ten-minute averaging period using Equation 1.

$$Cp = Co * \left(\frac{t_o}{t_p}\right)^{0.28} \qquad (1)$$

Pursuant to Equation 1, $t_o$ is the 60 minute averaging time, $t_p$ is the short-term averaging time (10 minutes) and $C_o$ and $C_p$ are the respective peak concentrations (BC MOE). The scalar when converting from hourly to ten-minute average concentrations equates to 1.65.

## 3.1 Odour Units

An Odour Unit is a way of quantifying odours through the use of an odour panel that consists of a group of people with 'calibrated noses'. The definition of an Odour Unit is based on the proportion of odour panel members that can detect the smell of a substance. One OU represents the concentration of a particular substance when 50% of the odour panel can detect the odour. This is called the perception threshold[1]. At this point, although an odour may be detected, it is not distinct enough to be able to identify the type of odour.

The Odour Unit scale is based on dilutions, as shown in the following figure. As the number of odour units increase, more people can detect the odour, and the intensity of the odour increases. Five OU is considered a faint odour and ten OU is considered a distinct odour (the point when some people can identify the type of odour, or its potential source)[2].

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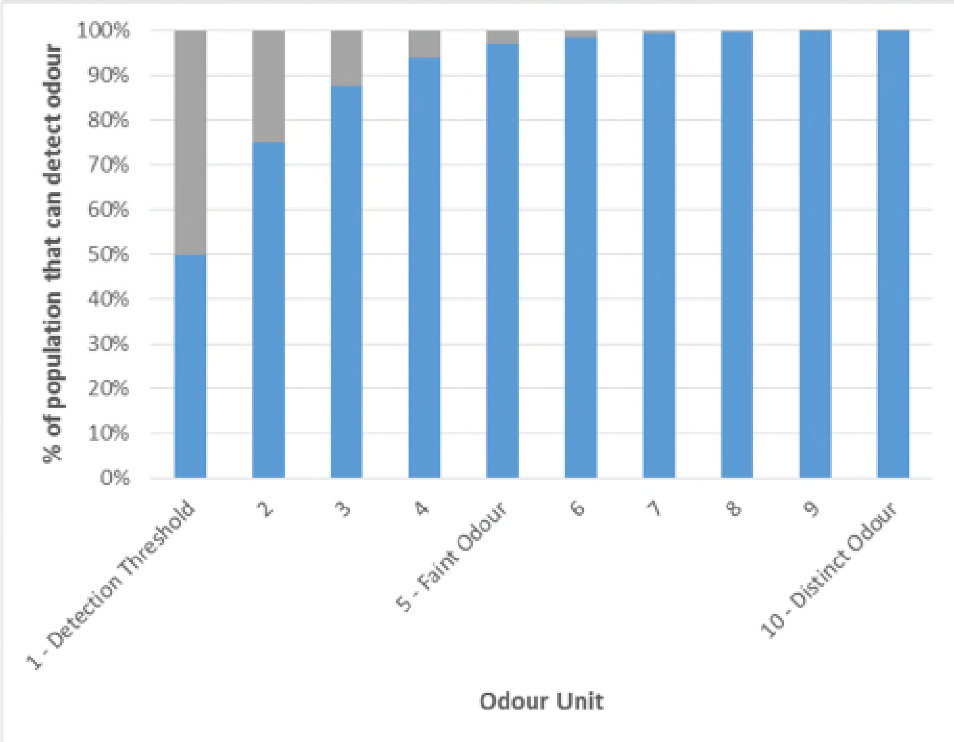


**Figure 3.1: Odour Unit Scale**

There are currently no guidelines for odour limits for composting facilities in British Columbia, however, some wastewater treatment facilities have imposed odour limits. For example, the standard in Metro Vancouver is no more than five OU at the property line. In other jurisdictions, the guideline is to have no detectable odour at the property line. At the Ogogrow facility in Vernon, BC, the limit is 50 OU at the property line.

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Odour maps are included as part of Appendix A. For each organics processing option listed in Section 2.2, odour modelling results are presented as three different plots:

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- Hourly Exceedances >1 Odour Unit (OU) – The number of hours over the course of the modelled year where an odour threshold of 1 OU was exceeded in a ten-minute averaged concentration. This is displayed as a contour plot showing the number of times the predicted 10-minute odour concentration exceeded 1 OU over the modelled year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to 50% of the population being able to detect odour produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.
- Hourly Exceedances >5 OU – The number of hours over the course of the modelled year where an odour threshold of 5 OU was exceeded in a ten minute averaged concentration. This is displayed as a contour plot

showing the number of times the predicted 10-minute odour concentration exceeded 5 OU over the modelled year (2012) as an orange gradient (light to dark). The white contour line represents <20 exceedances per year. This would theoretically equate to when a faint odour is produced by the facility less than 0.2% of the time. The dark orange contour line represents >100 exceedances per year.

## 3.3 Results Summary

The odour maps presented in Appendix A show: (1) the magnitude and spatial extent of maximum ground level odour, and (2) the number of exceedances of odour detection thresholds for the technologies assessed. The membrane covered aerated static pile results had the least odour issues.

The following table summarizes the results of the odour mapping exercise based on the predicted maximum odour and number of hours of odour exceedances at a location 100 m east of the property boundary representing the resident that is closest in proximity to the Site (49.219978º, -119.830363º), Figure 3.2.

**Table 3.1: Results Summary based on Closest Receptor Point (49.219978º, -119.830363º)**

| Scenario | Maximum Predicted 10-min Odour | Odour Exceedance >1 OU (hours per year) | Odour Exceedance >5 OU (hours per year) |
|---|---|---|---|
| Current Operations | 0.01 OU | 0 | 0 |
| Aerated Static Pile | 6.8 OU | 444 | 1 |
| Membrane Covered Aerated Static Pile | 0.13 OU | 0 | 0 |
| In-Vessel | 6.3 OU | 334 | 1 |

**Figure 3.2: Location of Discrete Receptor (49.219978º, -119.830363º)**

### 3.3.1 Biofilter Effect

The Membrane Covered Aerated Static pile has the lowest odour emissions of the technologies as this type of operation does not use a biofilter. The greatest source of odour emissions can be attributed to the biofilters, as seen in Table 3.2.

**Table 3.2: Odour Emissions from Biofilters**

| Scenario | % of Odour from Composting Biofilter |
|---|---|
| Current Operations | N/A |
| Aerated Static Pile | 98% |
| Membrane Covered Aerated Static Pile | N/A |
| In-Vessel | 99% |

# APPENDIX A

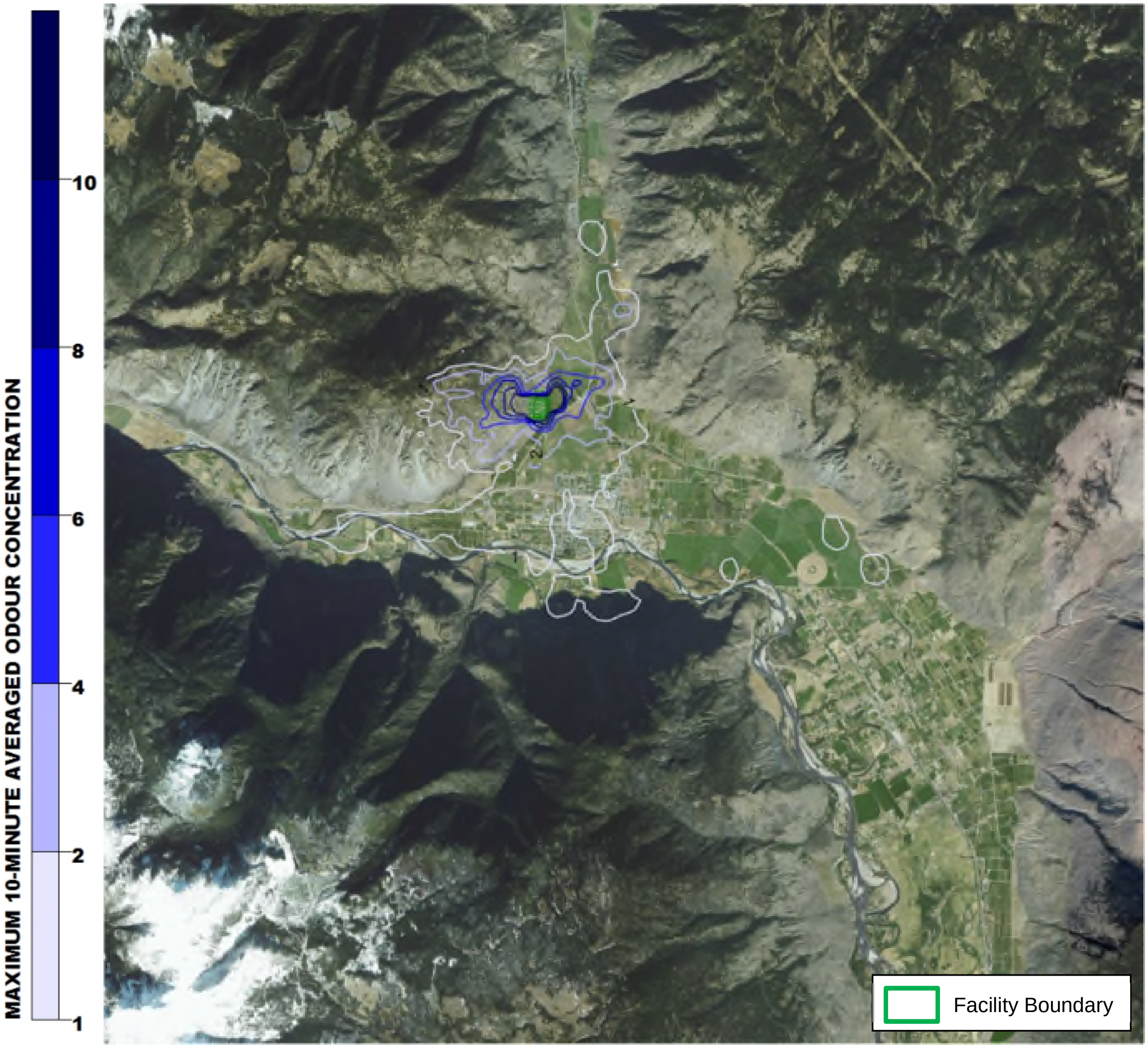


**Figure 1: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (ASP)**

Note: Exceedances of 1 OU for current operations were not observed in the model, therefore figures were not presented.

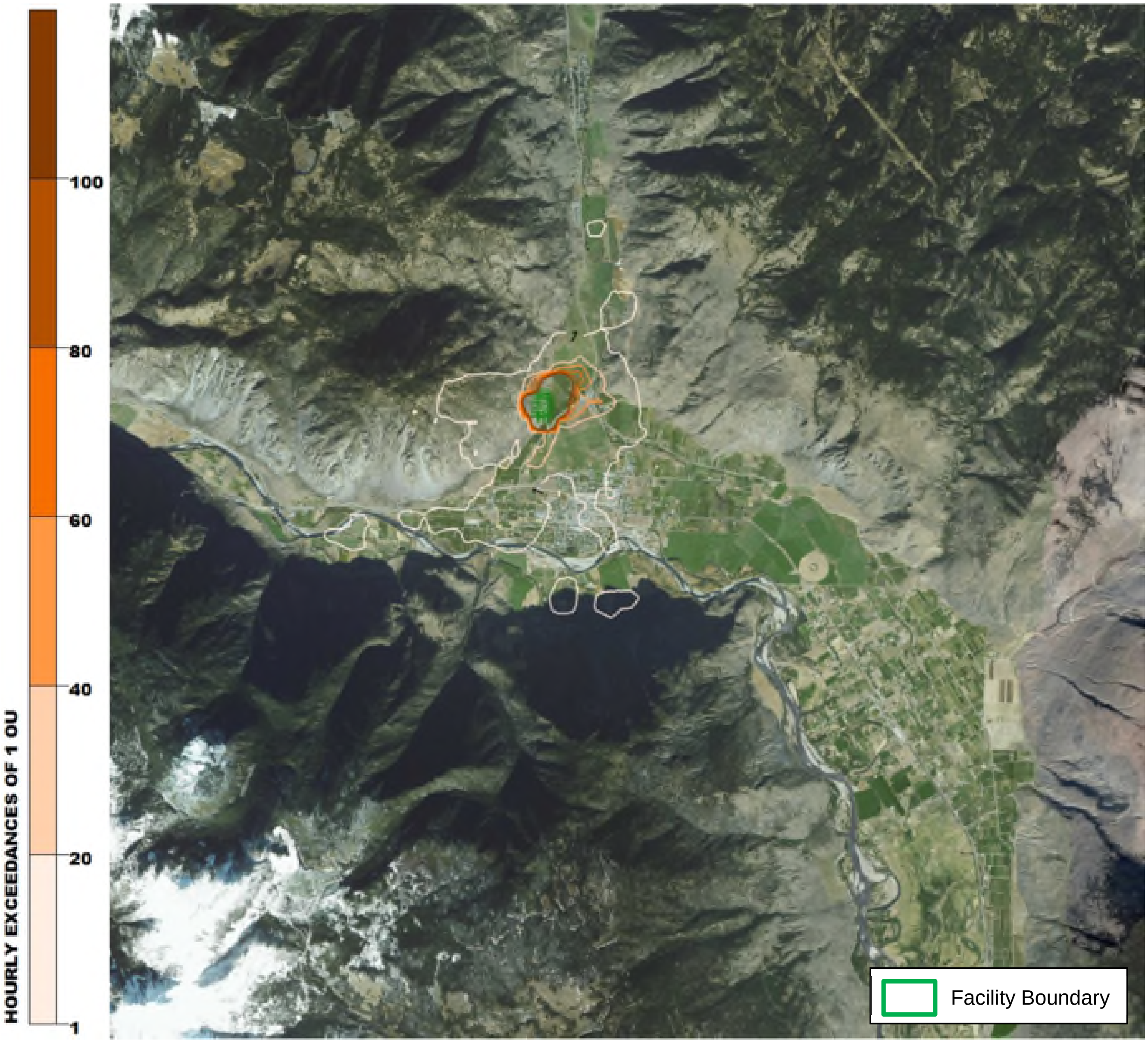


**Figure 2: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (ASP)**

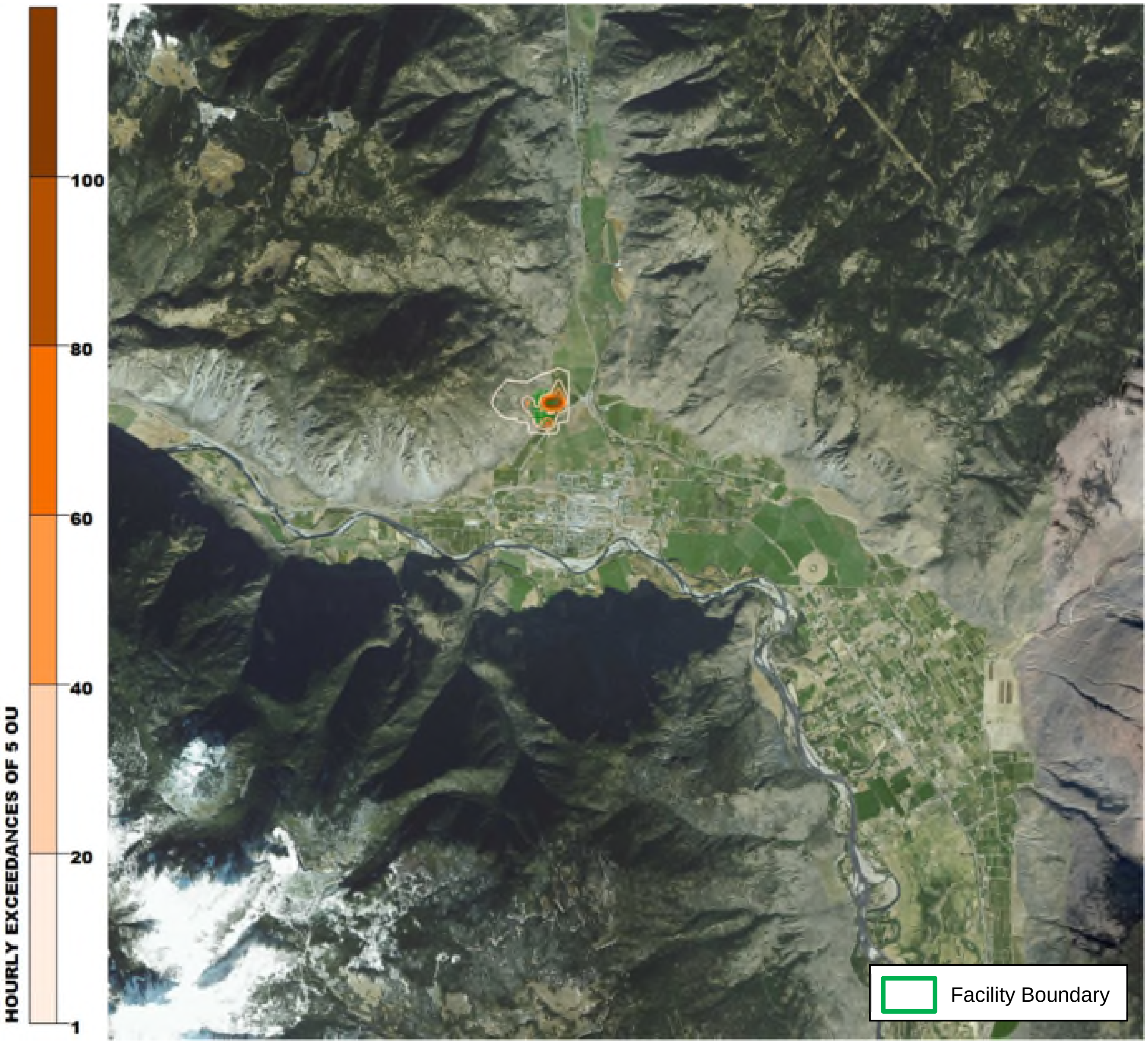


**Figure 3: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (ASP)**

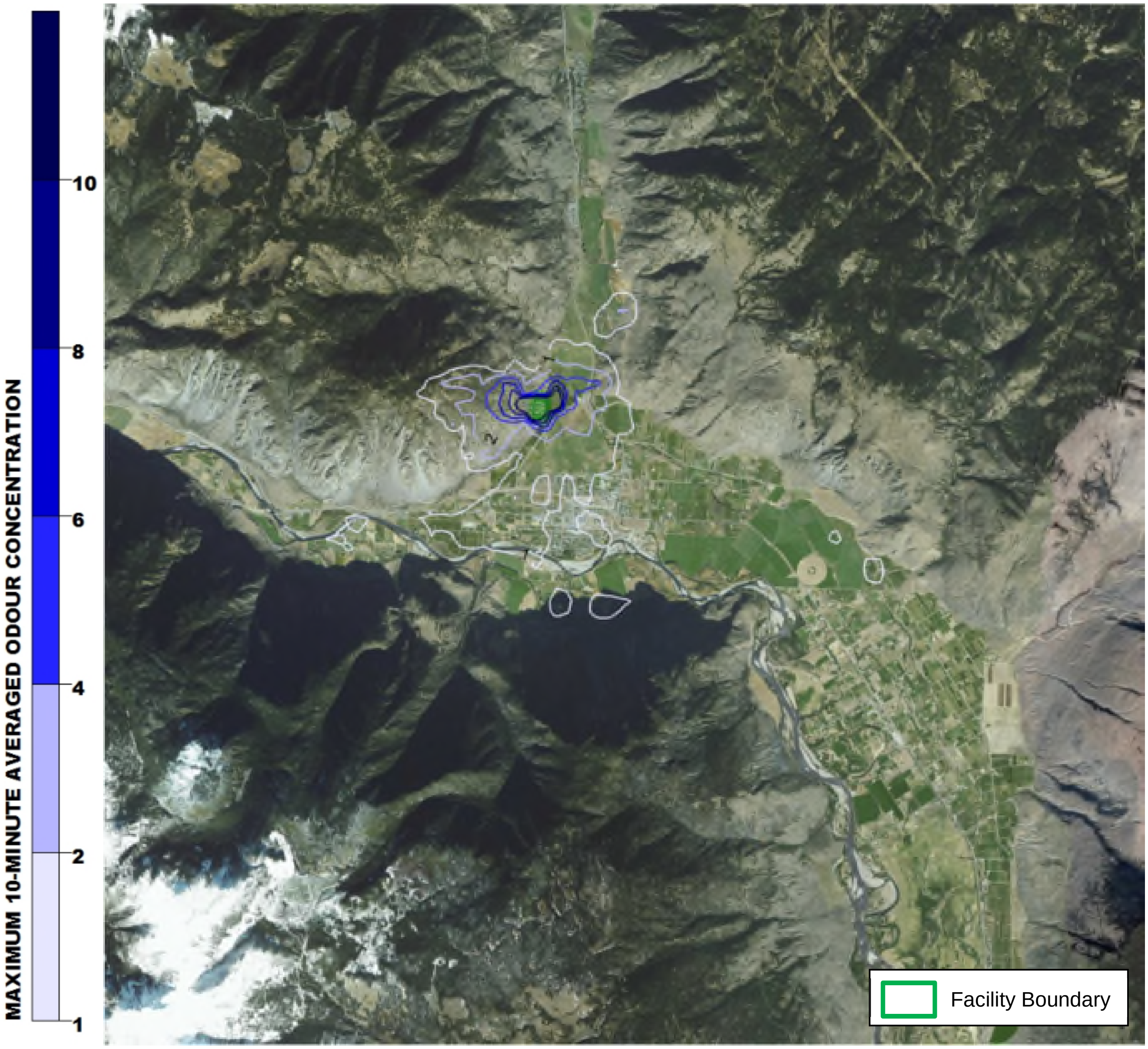


**Figure 4: Maximum Predicted Ground Level Odour Concentration (Over a Sustained 10 Minute Period) within the Course of 1 Year (In-Vessel)**

Note: Exceedances of 1 OU for covered ASP were not observed in the model, therefore figures were not presented.

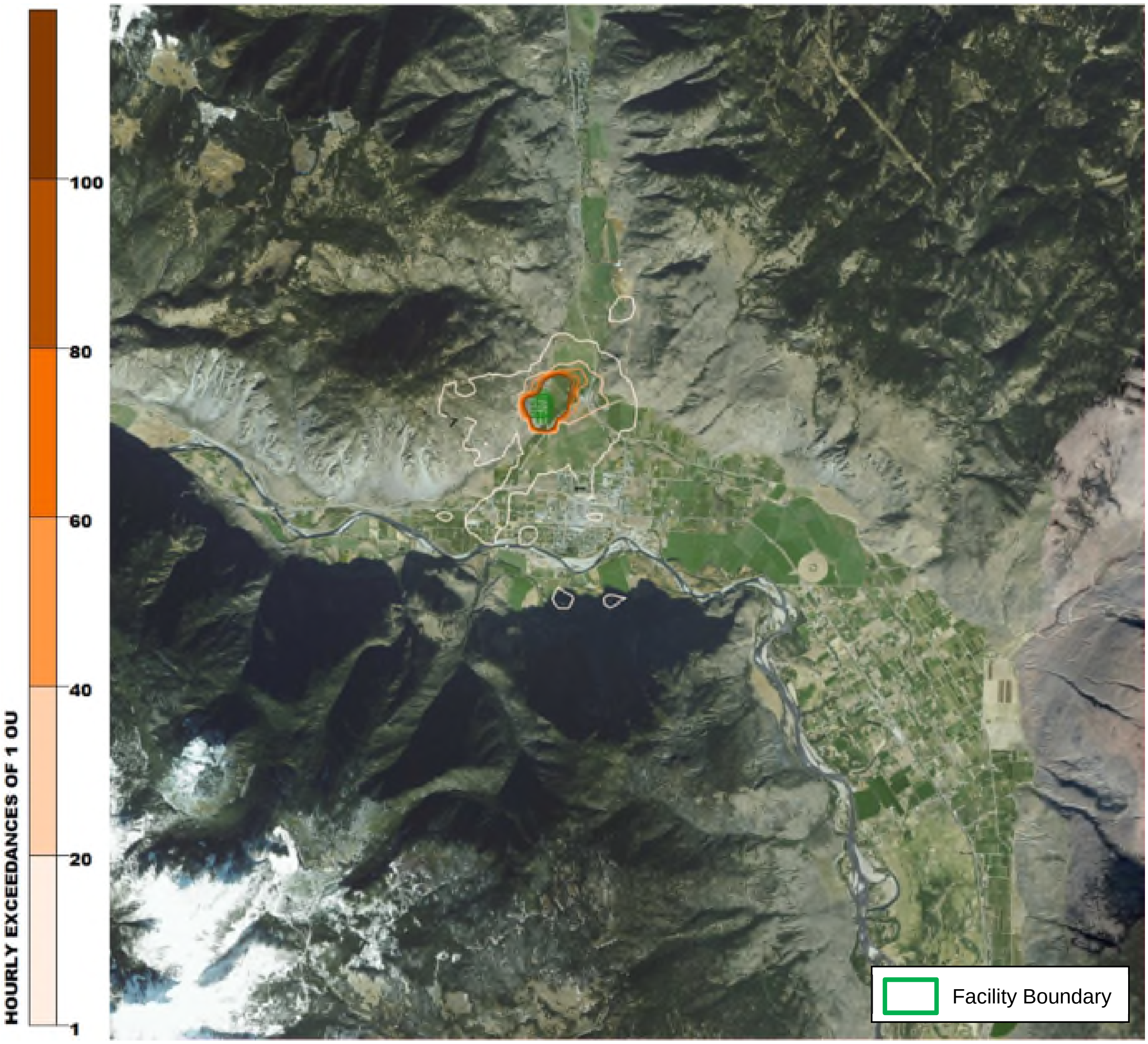


**Figure 5: Number of Hours with Exceedances of 1 OU (Detectable Odour by 50% of the Population) within the Course of 1 Year (In-Vessel)**

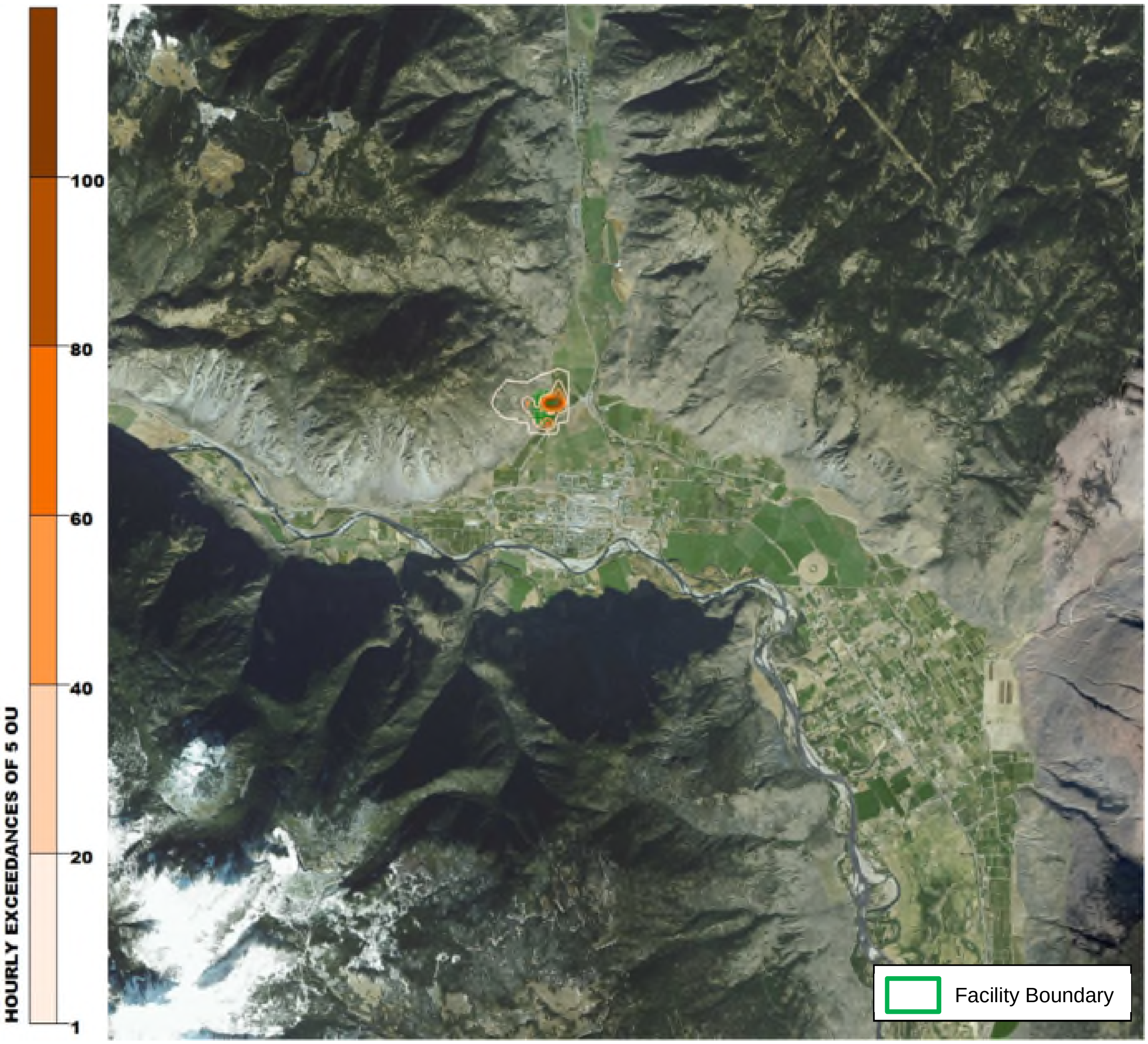


**Figure 6: Number of Hours with Exceedances of 5 OU (Faint Odour) within the Course of 1 Year (In-Vessel)**