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MASKINONGE, EAST HOLLAND AND WEST HOLLAND RIVER SUBWATERSHEDS

ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREA ASSESSMENT

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REPORT

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Table of Contents

1.0 INTRODUCTION AND BACKGROUND 3

1.1 ESGRA Assessment Background and Objectives 3

1.2 Study Area Description 4

1.3 Previous Model- York Tier 3 Assessment 5

2.0 IDENTIFICATION OF ECOLOGICALLY SIGNIFICANT FEATURES 5

2.1 Coldwater Streams 5

2.2 Wetlands 6

2.3 Areas of Natural and Scientific Interest (ANSI) 7

2.4 Identification of Ecologically Sensitive Features for ESGRA Analysis 7

3.0 MODEL UPDATE 7

3.1 Model Conversion/Modifications 8

3.2 Model Boundary Update 9

4.0 ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREA ASSESSMENT 9

4.1 ESGRA Delineation using Backward Particle Tracking 9

4.2 Statistical Analysis of ESGRA Delineations 10

4.3 Forward Tracking Verification 13

4.4 Comparison of ESGRA areas to SGRA areas 13

5.0 SUMMARY AND CONCLUSIONS 13

TABLES

Table 1: Particle Endpoint Summary- Backward Tracking 10

Table 2: Percent of endpoints covered by potential ESGRAs with varying smoothing parameter (h) and delineation threshold (ε) 11

Table 3: Particle density (particles/km^2) within potential ESGRAs with varying smoothing parameter (h) and delineation threshold (ε) 11

Table 4: Total area (km^2) of potential ESGRAs with varying smoothing parameter (h) and delineation threshold (ε) 11

Table 5: Percent area covered by potential ESGRAs with varying smoothing parameter (h) and delineation threshold (ε) 12

Table 6: Percent Area Coverage of ESGRA by Subwatershed 12

Table 7: Statistical Parameters Used in ESGRA Assessments 13

FIGURES

Figure 1 Study Area Subwatersheds

Figure 2: Stream Order Classification

Figure 3: Representation of Streams in Groundwater Model

Figure 4: Stream Thermal Regime and Fish Sampling Sites

Figure 5: Wetlands and ANSIs

Figure 6: Ecologically Sensitive Features

Figure 7: Model Extents

Figure 8: Cross Boundary Flow from Innisfil Creek Subwatershed

Figure 9: Particle Release Points- Backward Tracking

Figure 10: Particle End Points- Backward Tracking

Figure 11: ESGRA Delineation

Figure 12: ESGRA Delineation and All Particle End Points

Figure 13: Confirmation Particle Endpoints from all ESGRA Areas- Forward Tracking

Figure 14: Forward Particle Tracking Pathlines

Figure 15: Significant Groundwater Recharge Areas (SGRAs)

Figure 16: ESGRA comparison to SGRA

APPENDICES

APPENDIX A
Cluster Sensitivity Analysis Mapping

1.0 INTRODUCTION AND BACKGROUND

Golder Associates Ltd. (Golder) was retained to provide consulting services for the Ecologically Significant Groundwater Recharge Area (ESGRA) Assessment for the Maskinonge, East Holland and West Holland River Subwatersheds.

The scope of work for this project included delineation and analysis of ESGRAs, using an updated version of an existing numerical model, to identify the portions of the landscape that contribute discharge to stream reaches and wetlands delineated by Lake Simcoe Region Conservation Authority (LSRCA).

The work is described in this report, which has been structured as follows:

- Section 1.0: Introduction and Background
- Section 2.0 Identification of Ecologically Significant Features
- Section 3.0 Model Updates
- Section 4.0 ESGRA Delineation
- Section 5.0 Summary and Conclusions

Appendix A provides additional mapping prepared as part of the sensitivity analysis and optimization of the ESGRA delineation.

1.1 ESGRA Assessment Background and Objectives

The Lake Simcoe Protection Plan (LSPP) was established in 2009 to protect, improve and restore the ecological integrity of the Lake Simcoe watershed and its key natural heritage features and functions. The LSPP outlines a number of water quantity related policies to be built on the existing studies already completed under the Clean Water Act. Ecologically Significant Groundwater Recharge Areas are required to be identified in accordance with the LSPP. ESGRAs are identified areas of land that are responsible for replenishing groundwater systems (landscape recharge areas), and those that support sensitive areas like coldwater streams and significant wetlands. Landscape recharge areas or Significant Groundwater Recharge Areas (SGRAs) have been previously characterized during the Source Protection Program and the ESGRA assessment process determines which recharge areas support ecological features within the subwatershed.

The overall objective of the ESGRA assessment is to protect sensitive areas like coldwater streams and both Provincially Significant Wetlands and other wetlands by mapping the areas of land that contribute groundwater to these features.

A methodology to delineate ESGRAs was developed (EarthFX, 2012a) that uses numerical models and statistical analysis to map hydrologic connections between recharge areas and ecologically significant features. This previous methodology was followed to delineate the ESGRAs for the Maskinonge, East Holland and West Holland River subwatersheds, as presented in this report. The method uses a particle tracking approach to delineate the groundwater flow paths between the ecological feature and the recharge area.

The particle tracking analysis is completed using a steady-state groundwater flow model to first determine groundwater heads and fluxes between all model cells and a groundwater velocity flow field. Particle tracks are released in the model and tracked (in both forward and reverse directions) through the flow field to delineate three-dimensional pathways and travel time to a model boundary exit or entry point. Particles are tracked backward from ecologically sensitive features and the end points are grouped and analyzed to determine the particle endpoint density. The particle density does not correspond directly to recharge volumes, however, it has been used to establish that a significant amount of the recharge in the area is delivered to the ecological feature (EarthFX, 2012a). Statistical analysis of the particle end point density is then used to delineate the ESGRAs.

1.2 Study Area Description

The Study Area includes the West Holland, East Holland and Maskinonge River subwatersheds, which are shown in Figure 1. These three subwatersheds were identified as having a moderate to significant potential for stress under the Tier 2 Assessment (EarthFX, 2010) and were determined to require a Tier 3 Assessment. The Tier 3 Assessment began in 2009 and is now complete (EarthFX, 2014). The Tier 3 Assessment report provides a detailed characterization of the hydrology and hydrogeology of these subwatersheds.

The Study Area subwatersheds include the municipal water supply systems for Newmarket, Aurora, Queensville, Holland Landing, Ansnorveldt, Schomberg, Ballantrae and Bradford West Gwillimbury. The Town of Bradford West Gwillimbury has decommissioned all of its municipal wells with the exception of the two Church wells, which are located in King Township. Nearby water systems of King City, Mt. Albert and Stouffville were also included in the Tier 3 Assessment footprint as they could influence the sustainability of the other nearby municipal wells.

The East Holland River is one of the Lake Simcoe basin's most populated subwatersheds occupying 247 km^2. Its headwaters are on the Oak Ridges Moraine and it flows to the confluence with the West Holland River and the mouth at Lake Simcoe's Cook's Bay. The West Holland River occupies 354 km^2 of lands to the southwest of Lake Simcoe's Cook's Bay. Also originating on the Oak Ridges Moraine, the headwaters of the West Holland subwatershed flow through primarily forested and agricultural areas before the river enters the Holland Marsh. The West Holland River then flows past the Town of Bradford, and further past forested and agricultural areas before discharging into the lake. The Maskinonge River occupies 63.5 km^2 of lands to the east of Lake Simcoe's Cook's Bay. There are three main branches to the Maskinonge subwatershed, with the southern branch extending past Queensville, and a small portion in the southeast of the subwatershed lying within the Oak Ridges Moraine.

Located to the north of the Oak Ridges Moraine are western portions of the Peterborough Drumlin Field physiographic region, which consists of drumlinized uplands. The Simcoe Lowlands area separates the Peterborough Drumlin Fields and this area is incised by valleys with wide, swampy bottoms where north-flowing streams including the Holland and Maskinonge Rivers are present. Subglacial drainage events are believed to have formed the valleys and their infill through tunnel channel formation. Flat-lying deposits of lacustrine sand, silt and clay were subsequently deposited at the time that Glacial Lake Algonquin was present in the area. Also occupying the tunnel channels and former glacial lake basins are the Schomberg Clay Plains, which are composed of deposits of stratified clay and silt.

1.3 Previous Model- York Tier 3 Assessment

The basis for this ESGRA Assessment is the numerical model developed as part of the York Tier 3 Assessment (EarthFX, 2012b, 2013 and 2014). The York Tier 3 model boundaries extend to the shorelines of Lake Ontario, Lake Simcoe and the topographic divides to the east and west bounding several major watersheds. The York Tier Three model also includes an extension from the earlier Core Model to include the Upper Humber area.

The York Tier 3 project used the United States Geological Survey (USGS) GSFLOW model. GSFLOW (Markstrom, 2008) was developed to simulate coupled groundwater and surface-water flow in an integrated manner. GSFLOW is based on the integration of the PRMS and MODFLOW codes and combines additional model components such as the Streamflow-Routing Package to simulate stream-aquifer interaction (including unsaturated flow beneath perched streams) and the Lake Package to simulate groundwater interactions with lakes and wetlands.

The York Tier 3 model was reviewed and updated for use in the ESGRA delineation as described in Section 3.0.

2.0 IDENTIFICATION OF ECOLOGICALLY SIGNIFICANT FEATURES

The locations of ecologically sensitive features were provided to Golder by Lake Simcoe Region Conservation Authority (LSRCA) in a GIS-compatible format and were reviewed and compiled as described in this section. Consistent with the other ESGRA assessments, the ecologically sensitive features assessed include the following:

- Coldwater fisheries including identified coldwater streams and coldwater fish capture sites. Consistent with other assessments, the ESGRAs were delineated for all stream reaches regardless of coldwater or warmwater designation, as further described below;
- Wetlands including identified Provincially Significant Wetlands and wetlands identified within the LSRCA Ecological Land Classification (ELC) dataset provided; and
- Areas of Natural and Scientific Interest (ANSI).

The ecologically sensitive features located in the subwatersheds are described in the sections that follow.

2.1 Coldwater Streams

An overview of the Study Area watercourses and the identified coldwater streams and coldwater fish capture sites is provided in this section. The Strahler stream order classification for the Study Area watercourses is shown in Figure 2. The streams with Strahler classifications of 1 to 7 were included as boundaries in the existing groundwater model as shown in Figure 3.

The headwaters of the West Holland River originate on the Oak Ridges Moraine and flow through primarily forested and agricultural areas before the river enters the Holland Marsh. The West Holland River then flows past the Town of Bradford and further past forested and agricultural areas before discharging into Lake Simcoe at Cook's Bay. The East Holland River headwaters are also on the Oak Ridges Moraine and it flows to the confluence with the West Holland River. The Maskinonge River is the only named stream in the subwatershed

and has three main branches with a small portion in the southeast of the subwatershed lying within the Oak Ridges Moraine.

The identified coldwater streams and coldwater fish capture sites are shown in Figure 4. The mapped coldwater streams are generally present in the southern upper reaches of the East and West Holland River subwatersheds, in the northwestern part of the West Holland River subwatershed and in the southernmost part of the Maskinonge River subwatershed. A large number of coldwater fish capture sites are mapped corresponding to the coldwater stream features. The coldwater streams are included as ecologically sensitive features for the ESGRA analysis. The warmwater streams are also shown on Figure 4 and for consistency with other assessments, the ESGRAs were also delineated for these watercourses based on model particle tracking suggesting groundwater contribution to these streams.

2.2 Wetlands

The wetlands in the Study Area subwatersheds are shown in Figure 5. Two sources of wetland information are presented including the identified Provincially Significant Wetlands and the wetlands identified in the LSRCA ELC data.

The wetlands in the West Holland River subwatershed are concentrated in two general areas, the Holland Marsh at the northern end of the subwatershed, and the Provincially Significant Pottageville Wetland Complex, which is comprised predominantly of swamp and where the West Holland River has retained its natural meander. The Ansnorveldt Provincially Significant Wetland is another key area of wetland concentration along the eastern canal. On the Oak Ridges Moraine there are scattered wetlands surrounding many of the headwater stream areas. There are several Provincially Significant Wetland complexes located in the East Holland River subwatershed including the Holland Marsh, Bogart Creek, East Aurora, Mussleman Lake and Vandorf Wetland Complexes. A Provincially Significant Wetland complex is present along much of the Maskinonge River.

The wetland types identified in the ELC data are plotted in Figure 5 including the following ELC code designations:

- SW- Swamp
- FE- Fen
- BO- Bog
- MA- Marsh

Also shown on Figure 5 are the Open Water classifications from the ELC data including:

- OA- Open Aquatic
- SA- Shallow Aquatic

The wetland types in the Study Area are primarily swamp with some marsh and fen areas identified in the area of Holland Marsh. In addition to the Provincially Significant Wetlands, a number of additional wetlands are present in the ELC mapping, primarily including smaller wetlands in proximity to the mapped coldwater streams as well as additional wetlands in the Holland Marsh area. The ELC identified wetland areas and Provincially

Significant wetlands are included as ecologically sensitive features for the ESGRA analysis. The open aquatic and shallow aquatic ELC features associated with provincially significant wetlands, coldwater steams and those noted in the ELC data to be associated with wetland complexes are also included as ecologically sensitive features.

2.3 Areas of Natural and Scientific Interest (ANSI)

Areas of Natural and Scientific Interest (ANSI) are areas of land and water containing natural landscapes or features which have been identified as having values related to protection, natural heritage, scientific study or education. The life science ANSI areas are shown in Figure 5. These areas include the Holland River Marsh ANSI and the Pottageville Swamp ANSI. These ANSI areas are included as ecologically sensitive features.

2.4 Identification of Ecologically Sensitive Features for ESGRA Analysis

The compilation of identified ecologically sensitive features that will be included in the ESGRA analysis for Holland River and Maskinonge River subwatersheds is shown in Figure 6. These features include coldwater streams, Provincially Significant Wetlands, ELC identified wetlands and ANSIs as described above. In addition, for consistency with the other ESGRA assessments, the warmwater streams were also included in the analysis. The ecologically sensitive features included in the ESGRA analysis cover approximately 15 % of the Study Area subwatersheds.

3.0 MODEL UPDATE

The relevant information and data on the existing conceptual and numerical models were compiled. This included obtaining the relevant digital model files for the York Tier 3 Model. The York Tier 3 Phase 1 Model Data Release file package consisted of a hard drive containing 510 gigabytes (GB) of model files (PRMS, MODFLOW and GSFLOW models) and 6 GB of Viewlog project files. Also pdf versions of the associated documentation were provided including:

- Phase 1 Model Development Report (EarthFX, 2013); and
- Phase 1 Model Development Report- Digital Appendix (EarthFX, 2012b).

The PRMS, MODFLOW and GSFLOW files were provided in the following two directories:

\Phase 1 Model Data Release - this directory contains an earlier draft version of the model files released in May, 2012 including some needed model file components not included in the final file release.

\Phase 1 Model Data Release Final - this directory contains the final version of the model files released in January, 2013.

A review of the existing models and associated data was conducted. The primary focus of the model review was to evaluate the current model setup for suitability for the specific purpose of ESGRA delineation. The

assessment of ESGRAs is completed using a steady-state groundwater model and particle tracking. The Tier 3 GSFLOW model required conversion/modification to be used for the ESGRA particle tracking assessment.

A description of the model conversion and modifications including discussion of the model output and review of the model calibration is provided in a separate technical memorandum (Golder, 2014) and is summarized in Section 3.1.

The York Tier 3 model extents are shown in Figure 7. A no-flow boundary was applied along the western edge of the West Holland River subwatershed as part of the Tier 3 model. The potential for cross-boundary flow along the western boundary was evaluated for the ESGRA assessment and the boundary assignment was re-assessed. Adjustments were made to this boundary as part of the model update, as described in Section 3.2.

3.1 Model Conversion/Modifications

To facilitate steady-state model analysis and particle tracking, the York Tier 3 GSFLOW model was converted to the commonly used MODFLOW graphical interface software package Groundwater Vistas. The model conversion and associated modifications are described in detail in Golder (2014). The following provides a summary of the modifications:

- The original model included two aquitard units that were represented by “Quasi 3D” units rather than model layers. These layers were implemented as actual model layers in the converted model to avoid issues using the model for particle tracking.
- The York Tier 3 Model code did not output the cell-by-cell flux output files needed for particle tracking. This was resolved through the conversion to Groundwater Vistas.
- Model layer intersection/crossing issues were identified and corrected using a minimum layer thickness.
- Problems with the original constant head boundary assignment were identified and corrected in the converted model.
- The streamflow routing package (SFR2) was incorporated in the converted model.
- An undocumented change in model code was identified in the original Tier 3 steady-state MODFLOW model. The standard MODFLOW NWT code used in the converted Groundwater Vistas model was re-compiled including a hard-coded adjustment of a 1000 times increase in seepage resistance for use by the MODFLOW UZF package in order to be consistent with the original Tier 3 model. This change has a significant effect on the simulated recharge and model calibration.
- Water budget differences between the previous model and the converted model were identified and investigated. The constant head inflow/outflows were different due to the method used to assign constant head boundaries in the previous model, which was corrected in the current model. The simulated well pumping was different between the models. The simulated well pumping difference is minor and is due to less drying out of wells in the converted model compared to the original model.

- The model hydraulic head calibration was checked against the Tier 3 project set of monitoring well water level targets. The converted model is consistent with the previous model in terms of calibration to monitoring well water level data.

The converted/modified model was reviewed and updated to account for potential cross-boundary flows as described in Section 3.2.

3.2 Model Boundary Update

Due to the presence of potential cross-boundary flows across subwatersheds, the LSRCA requested that a review and modification to the western boundary of the model be included in the scope of work for this project to account for any influence that this could have on the local ESGRAs.

In order to assist in defining appropriate revised model boundaries in the western portions of the model, an initial assessment of flow divides was conducted using the Southern Georgian Bay and Lake Simcoe Tier 2 Model (AquaResource and Golder, 2010) and flow direction mapping based on observed water level data. This analysis showed that the approximation of a no-flow boundary was reasonable although some cross-boundary flow may be occurring in the deeper aquifer (Thorncliffe). Recently a MIKE SHE model was developed for the Innisfil Creek subwatershed with an updated conceptual and numerical representation of the groundwater flow system. For consistency, the cross-boundary flow output from the Innisfil creek model was provided for use in this assessment (Matrix, 2014). The cross boundary flow from the Innisfil Creek Model to the West Holland subwatershed is shown on Figure 8.

The modelled cross-boundary flows were primarily in the Thorncliffe aquifer unit. The fluxes for this unit were applied as boundary inflows in the updated ESGRA model. These cross-boundary flows are relatively minor, as further described in Section 4.1, and there remains uncertainty in the flow directions and these flows due to limited deep well data.

4.0 ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREA ASSESSMENT

Identification and delineation of the ESGRAs was completed following the methodology outlined in the ESGRA Assessment Pilot Study completed for Barrie, Lovers and Hewitts Creek Subwatersheds (EarthFX, 2012a).

4.1 ESGRA Delineation using Backward Particle Tracking

Following the selection of the ecologically sensitive features and the model updates (Sections 2.0 and 3.0), delineation of the ESGRAs was completed using the prescribed backward particle tracking and the particle end point technique described in the pilot study and subsequently utilized in other ESGRA assessments. The particles were released at the ecologically significant features in the uppermost active model layer over a grid of 5 by 5 metres resulting in 400 particles released per cell face. This resolution of particle release points is greater than in the pilot study and has been found in previous ESGRA studies (e.g. Oro and Hawkestone Creeks study) to be adequate to identify all relevant recharge pathlines in the model.

The particle release points are shown in Figure 9. Details of the released particles are shown in Table 1. Similar to other studies, approximately 70% of the particles released moved or were released in discharging cells.

Table 1: Particle Endpoint Summary- Backward Tracking

	# of Particles	% of Particles
Total Particles Released	**7,928,000**	
Total "Moved" Particles	5,463,531	70% of total particles
Particles Reporting to Western Boundary	10,572	0.19% of moved particles
Particle Endpoints outside of Watershed Boundaries	779,598	14% of moved particles
Particles that remain in the Watershed	4,698,637	86% of moved particles

Of the particles that moved, 0.19% reached the western boundary. Given the small percent of particles reaching this boundary, it was decided that an extension of the model into the Innisfil Creek subwatershed was not warranted as this area was not a significant contributor of recharge to the ecologically significant features in this study. The majority of the particles reaching this western boundary are in the deep Thorncliffe aquifer and report to the lower reaches of the Holland River designated as warmwater.

The particle end points from the reverse particle tracking are shown in Figure 10.

Some particles (14%) originated in areas outside the study area subwatersheds including portions of the Black River subwatershed to the east and the Humber River subwatershed to the south. The majority of the particles originating outside the study area subwatersheds are modelled to report to the lower reaches of the Holland River designated as warmwater and therefore are not considered to significantly support ecological functions.

4.2 Statistical Analysis of ESGRA Delineations

After the particle endpoints from the backward particle tracking were generated, the bivariate kernel density cluster analysis approach used during the Barrie, Lovers and Hewitts Creek ESGRA pilot study was applied to statistically evaluate the ESGRA delineations.

The initial parameters (smoothing parameter (h) and delineation threshold (ε)) for the cluster analysis were chosen as the values from the pilot study. The parameter values were varied as part of a sensitivity analysis to determine the most appropriate/optimized values. In addition to the bivariate kernel density cluster analysis, small areas of less than 0.045 km^2 were infilled or removed consistent with the approach used in the pilot study. Based on a review of the outcomes of the above analysis, the infilling/removal threshold of 0.045 km^2 was increased to 0.1 km^2 to further reduce small areas of outliers.

A series of combinations of parameters were run to achieve an optimized set of parameters. The results of this sensitivity analysis and optimization are shown in Tables 2, 3, 4 and 5. The calculations take into account the infilling/removal of small areas. The calculations relating to areas and percent coverage apply to within the study area subwatersheds. The mapping of the coverage for each of the sensitivity runs is included in Appendix A.

Table 2: Percent of endpoints covered by potential ESGRAs with varying smoothing parameter (h) and delineation threshold (ε)

ε	h = 10	h = 25	h = 50	h = 100	h = 150	h = 250
20	-	-	-	-	5.7%	6.3%
100	-	1.2%	19.1%	38.3%	46.5%	48.9%
200	-	5.4%	34.4%	63.2%	68.5%	70.0%
1000	5.4%	32.4%	80.6%	90.5%	91.3%	92.0%
2000	11.5%	47.1%	87.3%	**93.0%**	94.0%	94.3%
10000	43.6%	72.0%	94.5%	96.9%	97.0%	97.0%

Table 3: Particle density (particles/km^2) within potential ESGRAs with varying smoothing parameter (h) and delineation threshold (ε)

ε	h = 10	h = 25	h = 50	h = 100	h = 150	h = 250
20	-	-	-	-	284,781	272,238
100	-	519,162	190,878	98,941	84,760	79,798
200	-	273,415	116,118	60,326	53,310	50,290
1000	262,601	91,833	39,941	27,169	25,512	24,973
2000	143,322	56,864	29,017	**22,639**	21,588	21,172
10000	46,912	27,107	20,161	17,788	17,402	17,286

Table 4: Total area (km^2) of potential ESGRAs with varying smoothing parameter (h) and delineation threshold (ε)

Ɛ	h = 10	h = 25	h = 50	h = 100	h = 150	h = 250
20	~~0~~	~~0~~	~~0~~	~~0~~	0.9	1.1
100	~~0~~	0.1	4.7	18.2	25.8	28.8
200	~~0~~	0.9	13.9	49.2	60.4	65.4
1000	1.0	16.6	94.8	156.6	168.2	173.1
2000	3.8	38.9	141.4	**193.0**	204.5	209.2
10000	43.7	124.8	220.2	255.9	261.8	263.6

Table 5: Percent area covered by potential ESGRAs with varying smoothing parameter (h) and delineation threshold (ε)

ε	h = 10	h = 25	h = 50	h = 100	h = 150	h = 250
20	~~0%~~	~~0%~~	~~0%~~	~~0%~~	0%	0%
100	~~0%~~	0%	1%	3%	4%	4%
200	~~0%~~	0%	2%	7%	9%	10%
1000	0%	3%	14%	24%	25%	26%
2000	1%	6%	21%	**29%**	31%	32%
10000	7%	19%	33%	39%	40%	40%

The optimized parameters chosen were h = 100 and ε = 2000 (highlighted in bold in Tables 2, 3, 4 and 5). These parameters were chosen as they maximize the percent of endpoints included while minimizing the area of coverage and excluding areas with a very low density of particles. The resulting ESGRA delineation is shown in Figure 11. Figure 12 shows the delineation ESGRA areas with the particle endpoints overlain.

The percentage of coverage of the ESGRA overall and in each Study Area subwatershed is shown in Table 6 for the optimized final result.

Table 6: Percent Area Coverage of ESGRA by Subwatershed

Subwatershed Areas	Catchment Area (km^2)	ESGRA Coverage (km^2)	Percent Area Coverage of ESGRA
Entire Study Area	663	193	29%
West Holland River	352	142	40%
East Holland River	247	45	18%
Maskinonge River	64	6	9%

The ESGRA coverage ranged from 40% in the West Holland subwatershed to 9% in the Maskinonge subwatershed with an overall average of 29%. The East Holland subwatershed had less ESGRA coverage (18%) than the West Holland primarily due to the larger urbanized area in this subwatershed and the fact that there are fewer sections classified as coldwater and fewer coldwater fish identified in the headwaters of the East Holland subwatershed.

A comparison of the statistical parameters used in this ESGRA assessment to those used in other assessments is shown in Table 7.

Table 7: Statistical Parameters Used in ESGRA Assessments

Project	h	ε	% Endpoints	Total Area (km^2)	% Study Area	Resolution (m)	Particle Density (Endpoints per km^2)
Barrie, Lovers, Hewitts (pilot)	25	100	96.7%	unknown	15.3%	25	unknown
Black, Georgina	100	200	98.3%	135	31.7%	25	unknown
Innisfil Creeks	75	1000	97.0%	unknown	31.0%	Varied	unknown
Oro North, South, Hawkestone	25	200	96.2%	42.9	24.0%	25	21,397
Ramara, Whites Talbot	25	200	98.0%	206	33.9%	50	6,221
Holland River and Maskinonge	100	2000	93.0%	193	29.0%	25	22,639

4.3 Forward Tracking Verification

Secondary confirmation of ESGRA delineations was conducted using forward particle tracking. Particles were released in the ESGRA areas over a 5 x 5 m grid and were forward tracked to determine their end point. The particle endpoints are shown in Figure 13 and were found to generally correspond to the identified ecologically significant features. Forward particle tracking was completed to illustrate the pathlines by releasing particles over a 100 m by 100 m grid (1 particle per cell face) from the delineated ESGRAs. The results of this forward particle tracking are shown in Figure 14. This shows that some particles travelled outside the study area subwatershed boundaries when tracked forward.

4.4 Comparison of ESGRA areas to SGRA areas

The Significant Groundwater Recharge Area (SGRA) method completed as part of the Tier 3 Assessment (EarthFX, 2014) delineates areas where modelled recharge is 15% greater than the average recharge. Unlike the ESGRAs, the identification of SGRAs is independent as to whether or not the recharge supports ecologically significant feature. The SGRAs delineated as part of the Tier 3 Assessment are shown in Figure 15. The SGRAs are not expected to be coincident with ESGRAs. For example, there are ESGRAs that are not part of SGRAs and SGRAs that are not part of ESGRAs. The ESGRAs are shown with the SGRAs overlain in Figure 16.

5.0 SUMMARY AND CONCLUSIONS

The following provides a summary of the work completed and conclusions:

- ESGRA areas were delineated for the West Holland, East Holland and Maskinonge River Subwatersheds using an updated version of the York Tier 3 Model.

- For this study the features identified as ecologically significant included all streams (coldwater and warmwater), ANSIs, wetlands (provincially significant and ELC). These ecologically significant features cover 15% of the Study Area.
- As with the other ESGRA studies, normalized bi-kernel density analysis was used with optimized smoothing parameter (h) and delineation threshold (ε) parameter values to statistically delineate the ESGRA areas. Holes in the ESGRA coverage less than 0.1 km^2 were infilled and small ESGRA areas less than 0.1 km^2 were removed. The optimized parameter values selected were h = 100 and ε = 2000.
- The ESGRA coverage ranged from 40% in the West Holland subwatershed to 9% in the Maskinonge subwatershed with an overall average of 29%. The East Holland subwatershed had less ESGRA coverage (18%) than the West Holland primarily due to the larger urbanized area in this subwatershed.
- Forward particle tracking confirmed that particles released in the ESGRAs reported to the ecologically significant features.
- The amount of backward tracked particles crossing the western boundary to the Innisfil creek subwatershed was 0.19% and therefore was not considered significant to justify expanding the model further west.
- Some areas of recharge outside the subwatersheds were identified in the Black River subwatershed to the east and in the Humber subwatershed to the south. Recharge from these areas were modelled to report to the lower reaches of the Holland River (designated as warmwater) and are therefore not considered to significantly support ecological functions. As a result, they were not included in the identified ESGRA areas.
- The ESGRA areas were plotted in comparison to the SGRA areas. As found with other studies, not all of the SGRAs provide recharge to the ecologically significant features and there are areas outside the SGRAs that provide significant recharge to the features.

Report Signature Page

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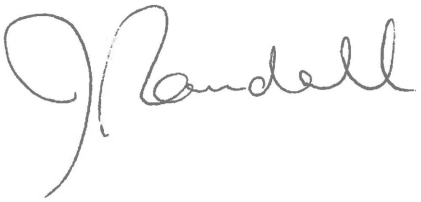


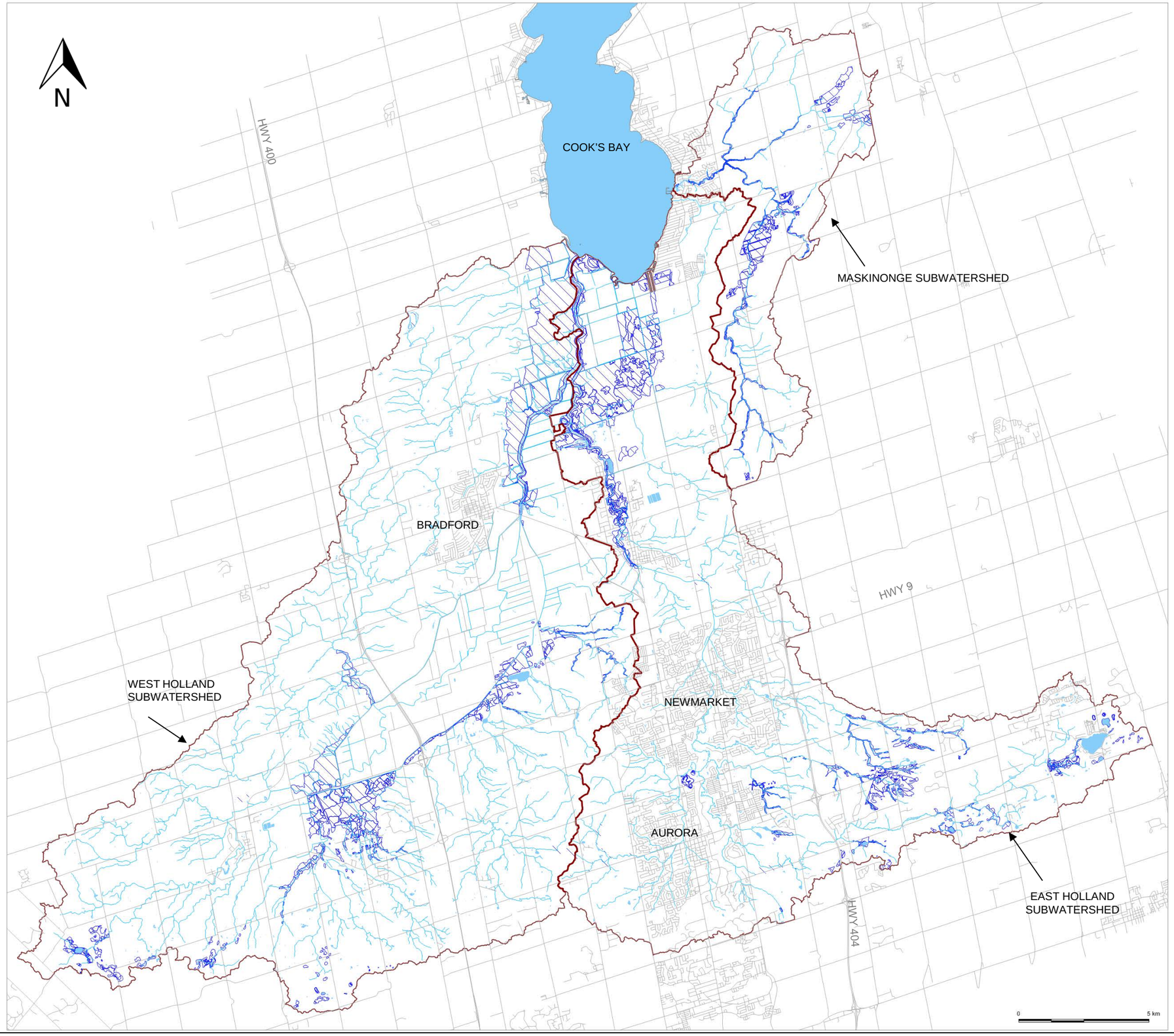
John Piersol, M. Sc., P. Geo.
Associate, Senior Hydrogeologist

Jeff Randall, P.Eng.
Groundwater Modeller

JAP/JR/rh

n:\active\2014\1169\1402007 lscra esgra holland river\reports\final reports\revised final nov 2015\1402007 esgra 23november2015.docx

FIGURES



NOTES:

BASE MAPPING PROVIDED BY LSRCA – APRIL 2014

LEGEND

- STUDY AREA SUBWATERSHEDS
- WETLANDS (PSW)
- WATERBODIES
- WATERCOURSES
- ROADS

PROJECT

LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE

STUDY AREA SUBWATERSHEDS

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)				REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 1	
GIS	AM	27 JULY 2015		
CHECK	JER	27 JULY 2015		
REVIEW	JAP	27 JULY 2015		

N

COOK'S BAY

HWY 400

MASKINONGE SUBWATERSHED

BRADFORD

WEST HOLLAND
SUBWATERSHED

NEWMARKET

AURORA

HWY 9

HWY 404

EAST HOLLAND
SUBWATERSHED

0 5 km

NOTES:

BASE MAPPING PROVIDED BY LSRCA – APRIL 2014

LEGEND

- STUDY AREA SUBWATERSHEDS
- WATERBODIES
- WATERCOURSES
- ROADS
- STREAM ORDER 1
- STREAM ORDER 2
- STREAM ORDER 3
- STREAM ORDER 4
- STREAM ORDER 5
- STREAM ORDER 6
- STREAM ORDER 7

PROJECT

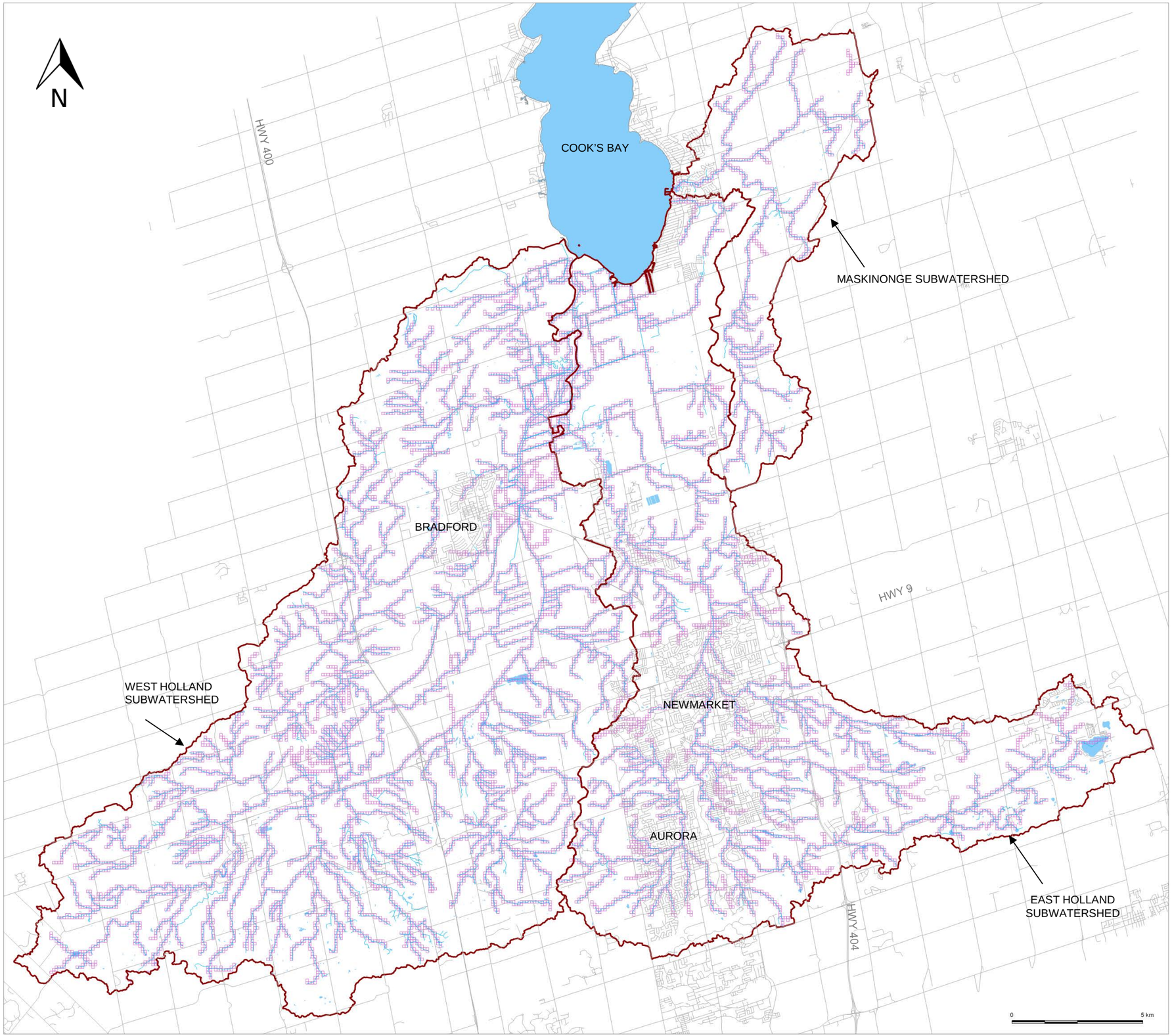
LSRCA HOLLAND AND MASKINONGE RIVER
SUBWATERSHED ESGRA PROJECT

TITLE

STREAM ORDER CLASSIFICATION

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 2
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

BASE MAPPING PROVIDED BY LSRCA – APRIL 2014

LEGEND

- STUDY AREA SUBWATERSHEDS
- WATERBODIES
- WATERCOURSES
- ROADS
- MODFLOW RIVER/STREAM BOUNDARY

PROJECT

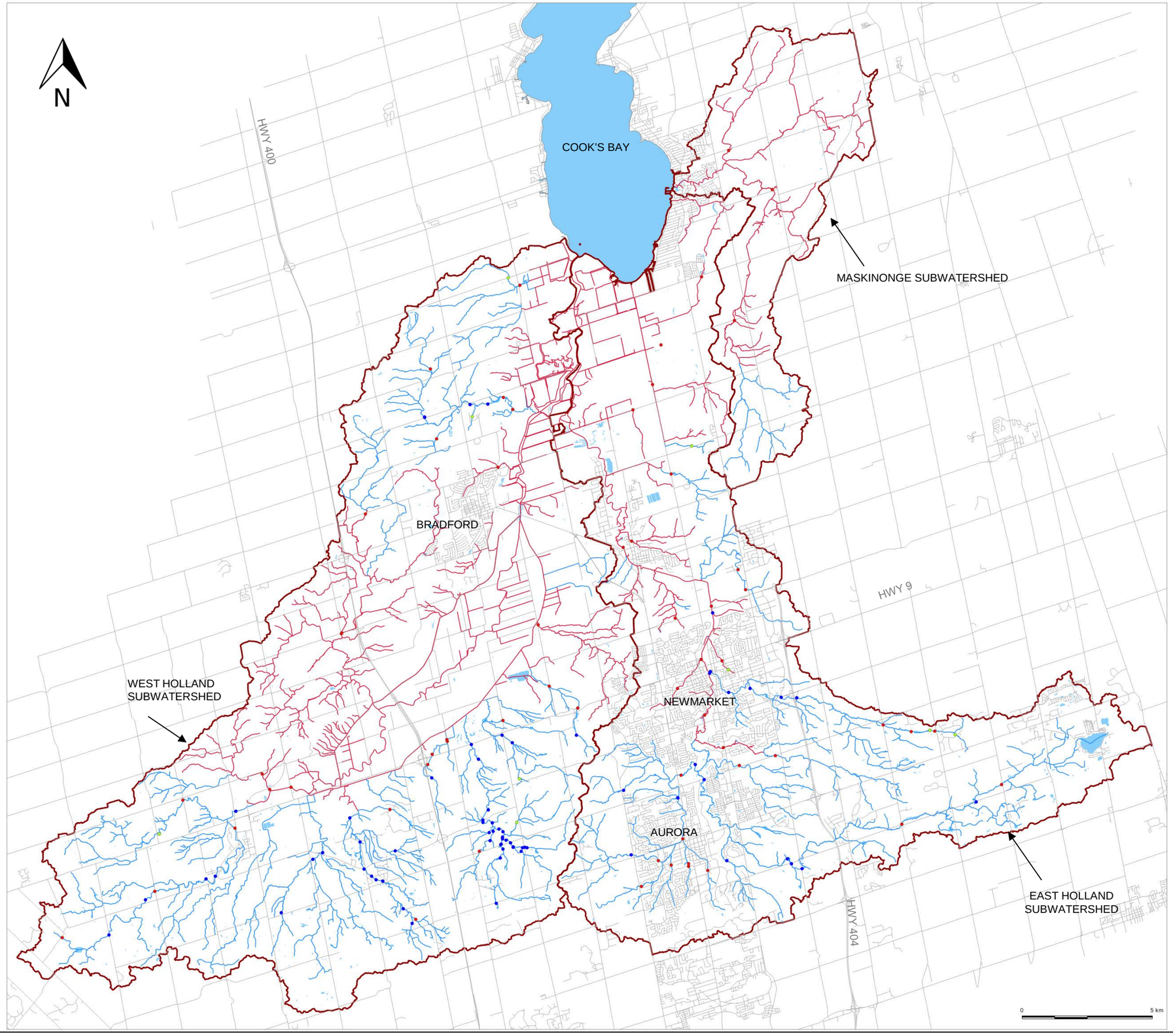
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE

REPRESENTATION OF STREAMS IN GROUNDWATER MODEL

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 3
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

BASE MAPPING PROVIDED BY LSRCA – APRIL 2014

LEGEND

- STUDY AREA SUBWATERSHEDS
- WATERBODIES
- ROADS
- STREAM THERMAL CLASSIFICATION: COLD
- STREAM THERMAL CLASSIFICATION: WARM
- FISH SAMPLING SITE: COLD
- FISH SAMPLING SITE: NO FISH
- FISH SAMPLING SITE: WARM

PROJECT

LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE

STREAM THERMAL REGIME AND FISH SAMPLING SITES

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
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CHECK	JER	27 JULY 2015	
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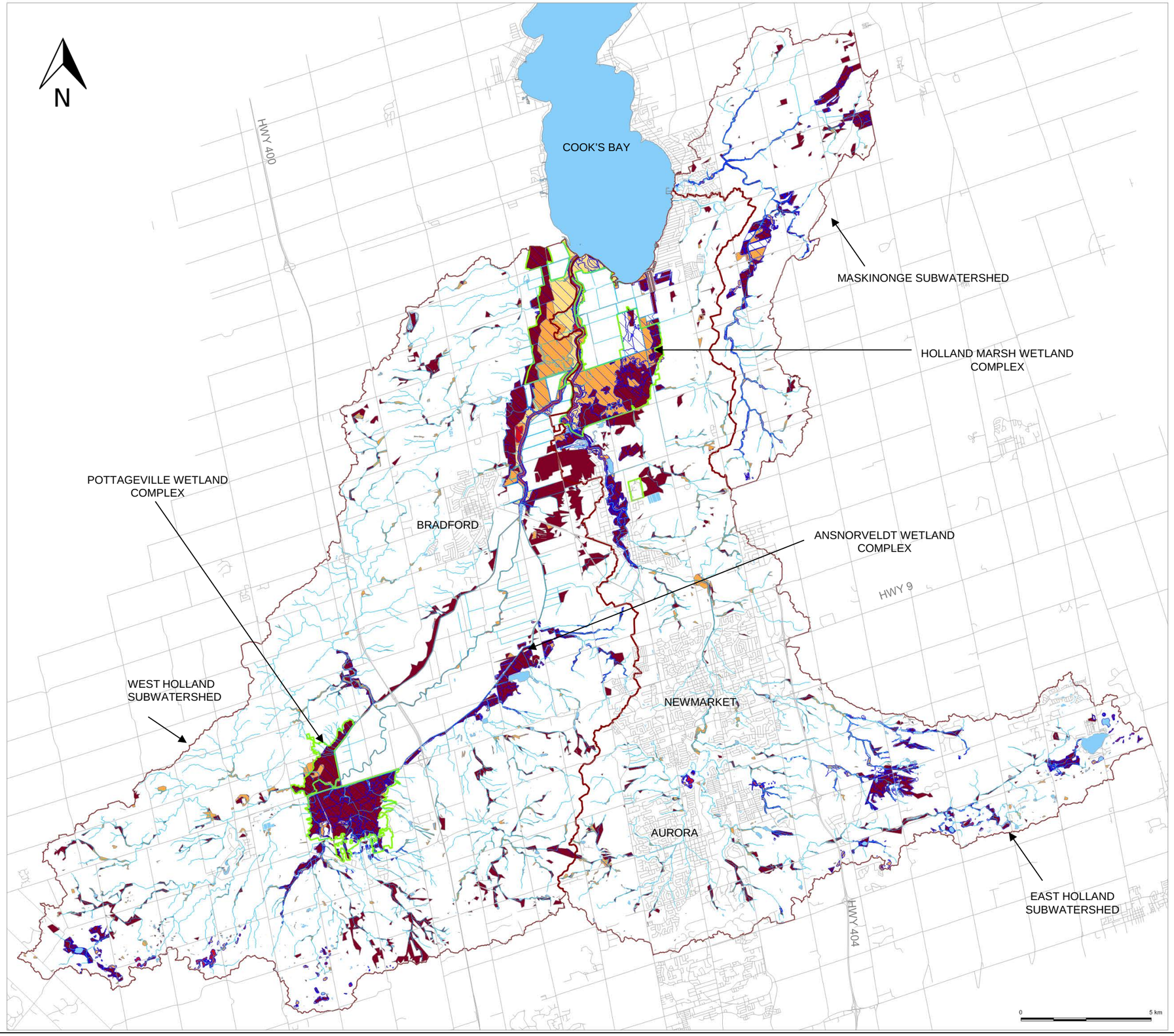


NOTES:

BASE MAPPING PROVIDED BY LSRCA – APRIL 2014

LEGEND

- STUDY AREA SUBWATERSHEDS
- WATERBODIES
- WATERCOURSES
- ROADS
- ANSI, LIFE SCIENCE
- WETLANDS (PSW)
- ELC LAND COVER: BOG
- ELC LAND COVER: FEN
- ELC LAND COVER: MARSH
- ELC LAND COVER: OPEN AQUATIC
- ELC LAND COVER: SHALLOW AQUATIC
- ELC LAND COVER: SWAMP

PROJECT

LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE

WETLANDS AND ANSI

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 5
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	

N

COOK'S BAY

HWY 400

MASKINONGE SUBWATERSHED

HOLLAND MARSH WETLAND COMPLEX

POTTAGEVILLE WETLAND COMPLEX

BRADFORD

ANSNORVELDT WETLAND COMPLEX

HWY 9

WEST HOLLAND SUBWATERSHED

NEWMARKET

AURORA

EAST HOLLAND SUBWATERSHED

HWY 404

0 5 km

NOTES:

BASE MAPPING PROVIDED BY LSRCA – APRIL 2014

LEGEND

- STUDY AREA SUBWATERSHEDS
- WATERBODIES
- WARM WATER STREAMS
- ROADS
- ECOLOGICALLY SENSITIVE FEATURES

PROJECT

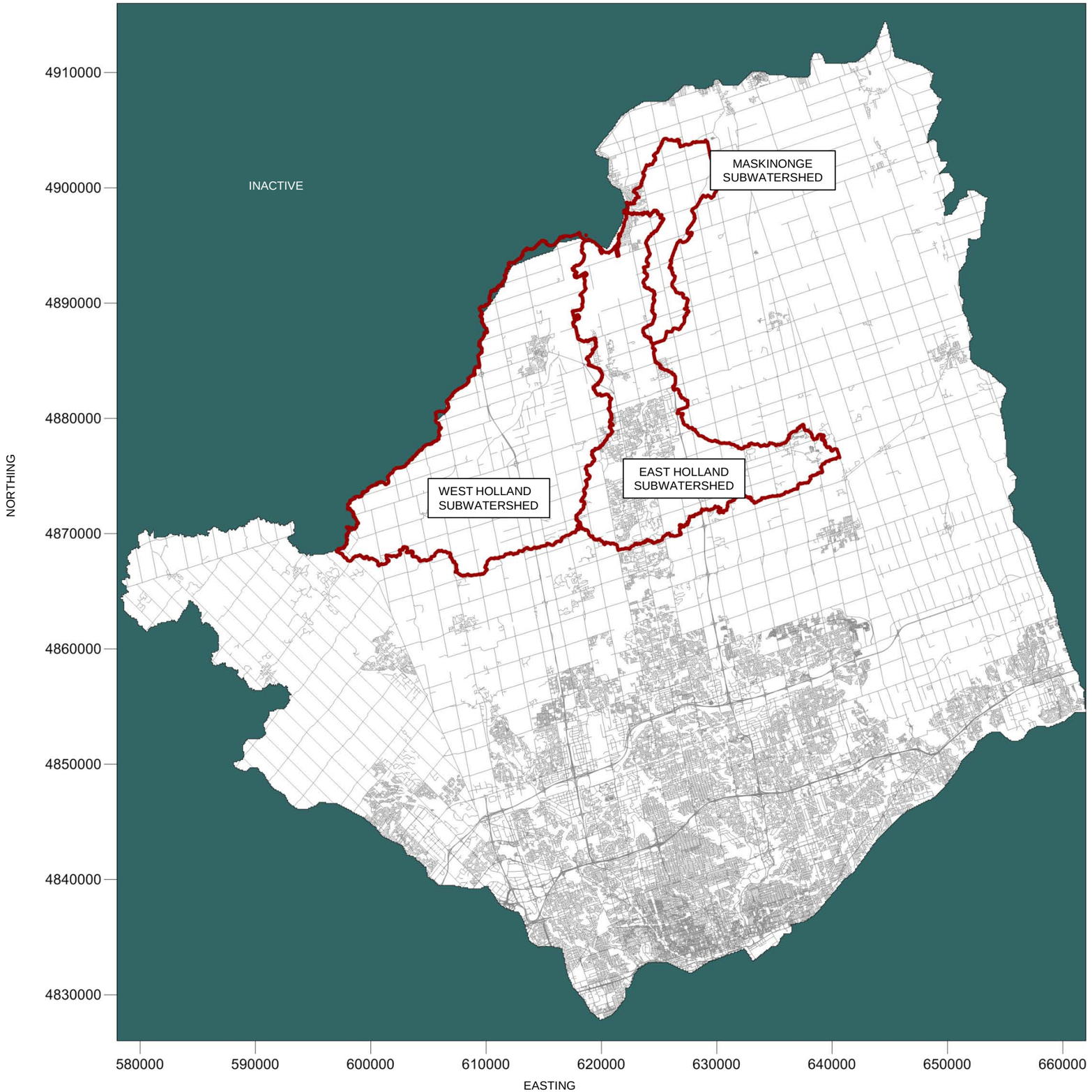
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE

ECOLOGICALLY SENSITIVE FEATURES

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 6
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

BASE MAPPING PROVIDED BY LSRCA – APRIL 2014

LEGEND

STUDY AREA SUBWATERSHEDS

ROADS

PROJECT

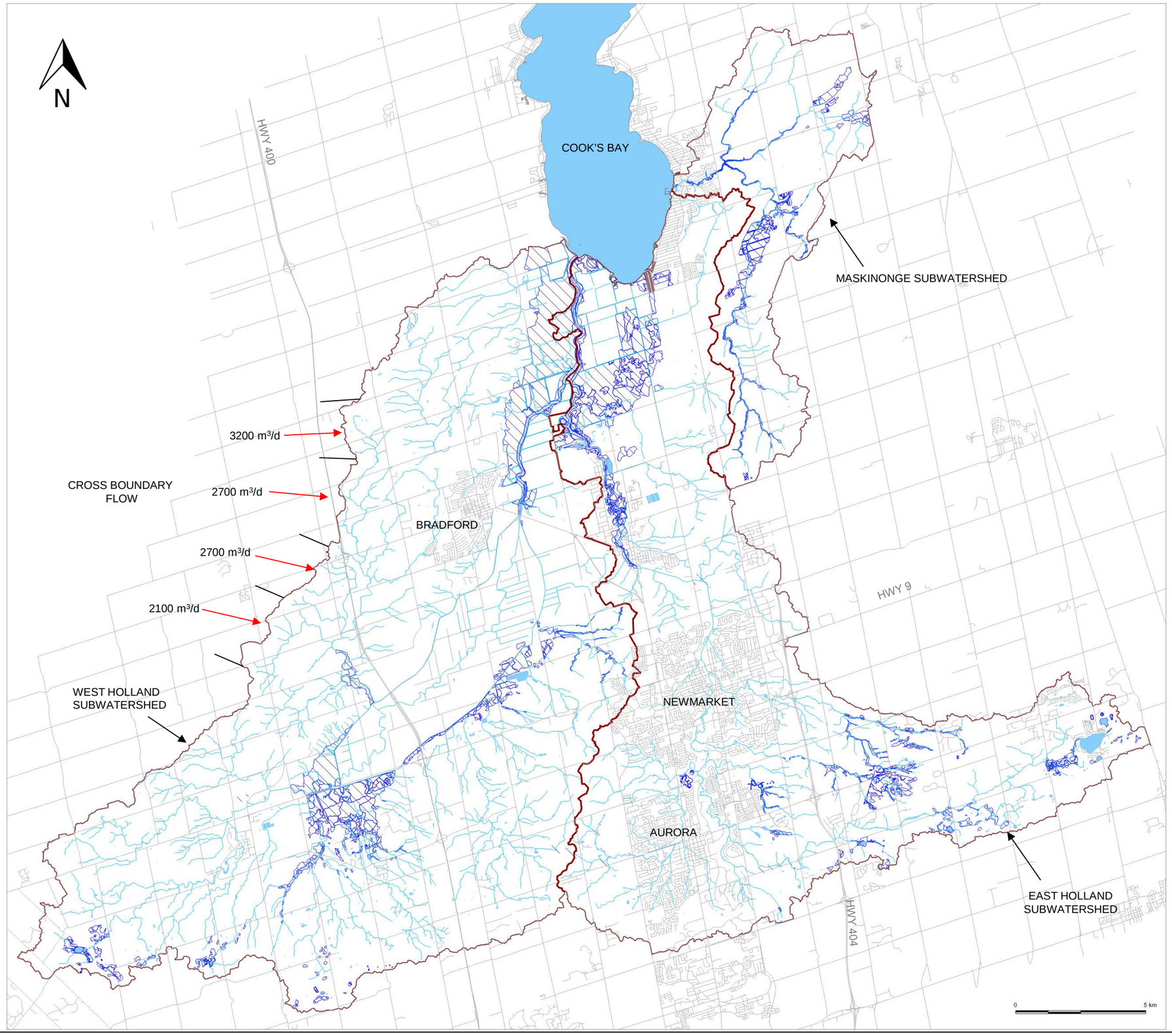
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE

MODEL EXTENTS

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)				REV. 0.0
DESIGN	AM	27 JULY 2015		
GIS	AM	27 JULY 2015		FIGURE: 7
CHECK	JER	27 JULY 2015		
REVIEW	JAP	27 JULY 2015		



NOTES:

BASE MAPPING PROVIDED BY LSRCA – APRIL 2014

LEGEND

- STUDY AREA SUBWATERSHEDS
- WATERBODIES
- WATERCOURSES
- ROADS
- WETLANDS (PSW)

PROJECT

LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE

MODELLED CROSS BOUNDARY FLOW FROM INNISFIL CREEK SUBWATERSHED

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 8
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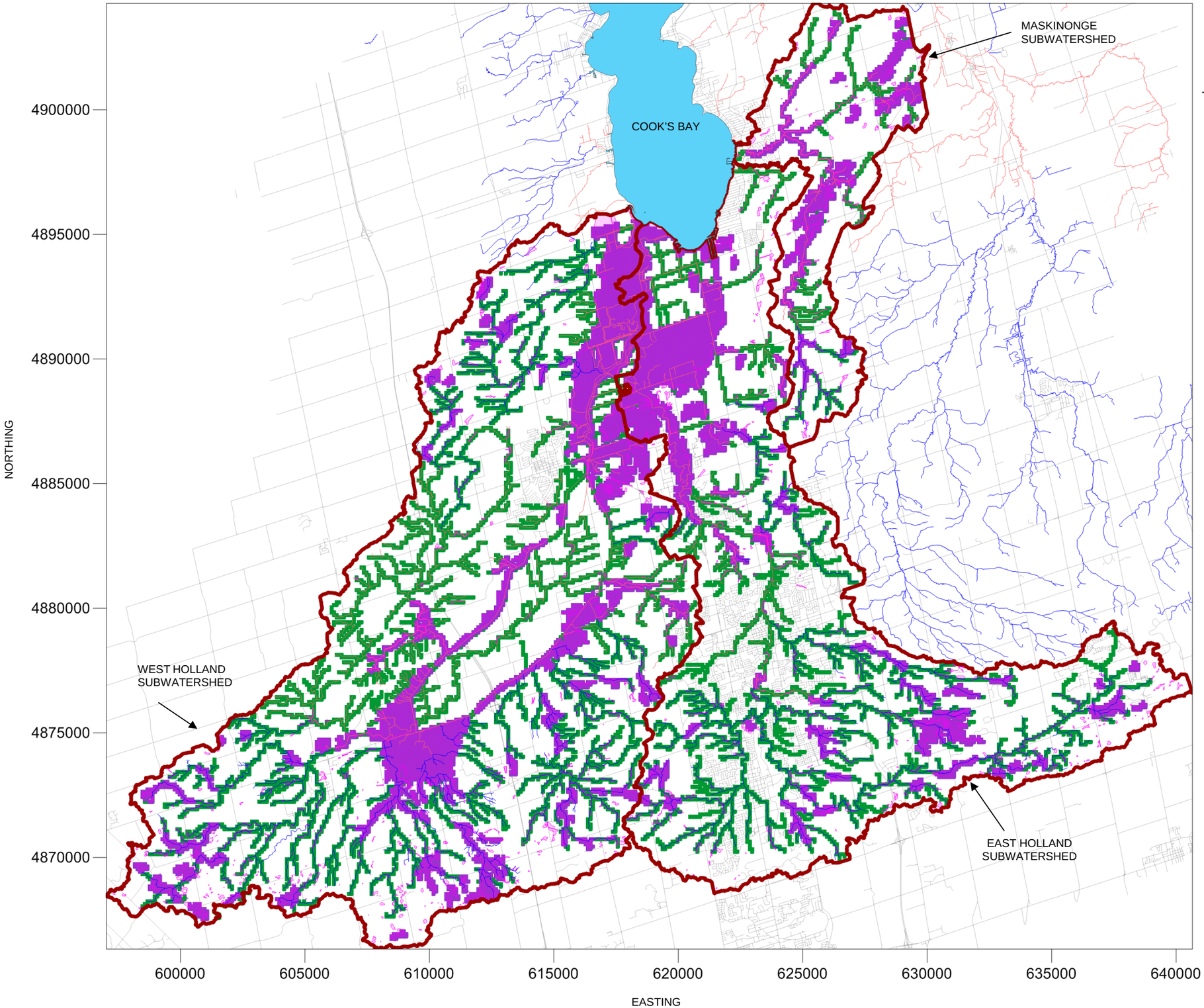
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

BASE MAPPING PROVIDED BY LSRCA – APRIL 2014

LEGEND

- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- STREAM/RIPARIAN ZONE PARTICLE RELEASE POINT
- ECOLOGICALLY SENSITIVE FEATURE PARTICLE RELEASE POINT

PROJECT

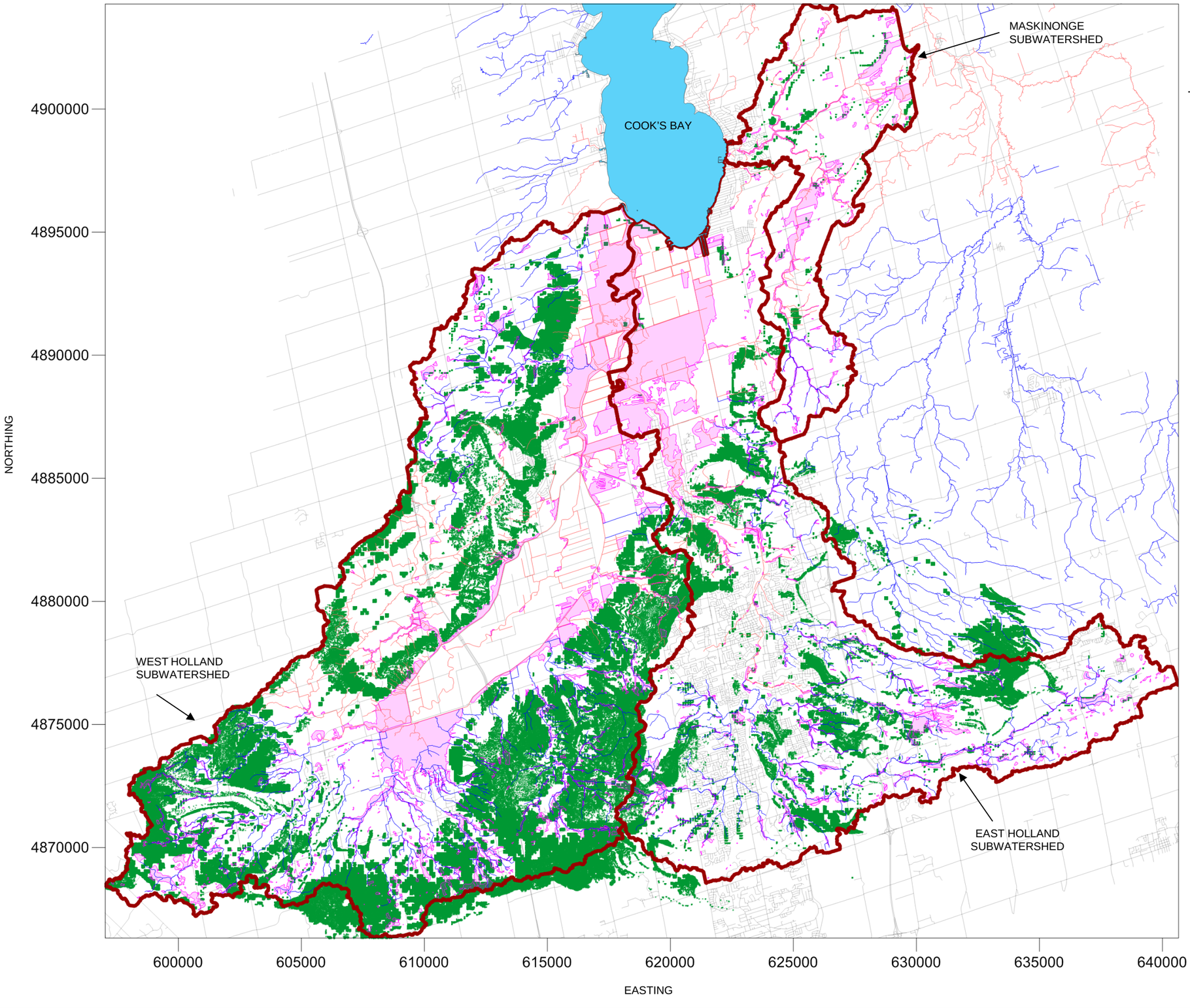
LSRCA HOLLAND AND MASKINONGE RIVER
SUBWATERSHED ESGRA PROJECT

TITLE

PARTICLE RELEASE POINTS
BACKWARD TRACKING

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 9
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

BASE MAPPING PROVIDED BY LSRCA – APRIL 2014

LEGEND

- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- PARTICLE ENDPOINT

PROJECT

LSRCA HOLLAND AND MASKINONGE RIVER
SUBWATERSHED ESGRA PROJECT

TITLE

PARTICLE ENDPOINTS
BACKWARD TRACKING

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
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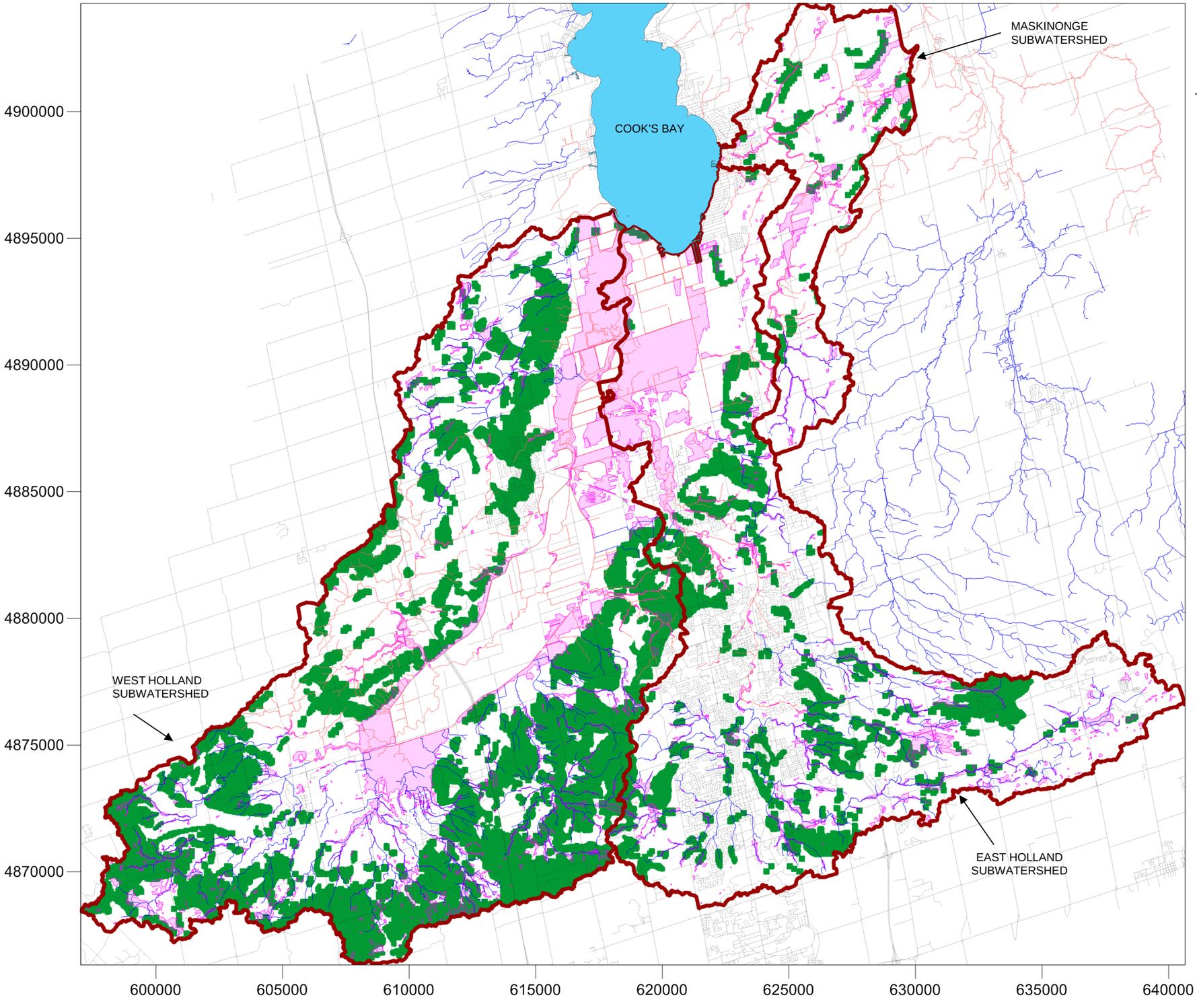
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- FINAL ESGRA DELINEATION h =100 M, ε = 2000

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
FINAL ESGRA DELINEATION RESULTS
h= 100m, ε=2000

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	22 NOV 2015	FIGURE: 11
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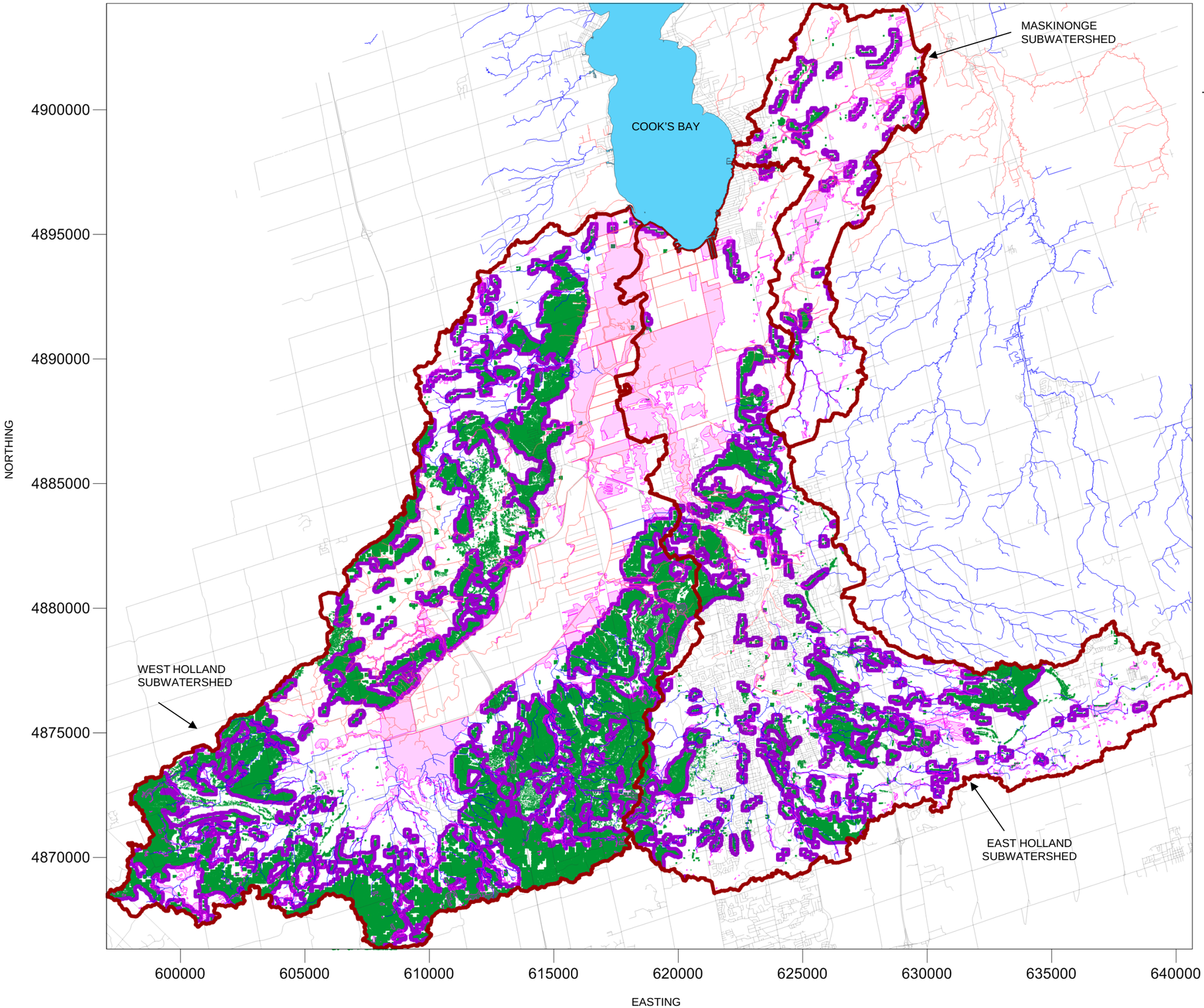

NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- FINAL ESGRA DELINEATION *h* =100 M, ε = 2000
- PARTICLE ENDPOINT

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
FINAL ESGRA DELINEATION AND PARTICLE ENDPOINTS

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
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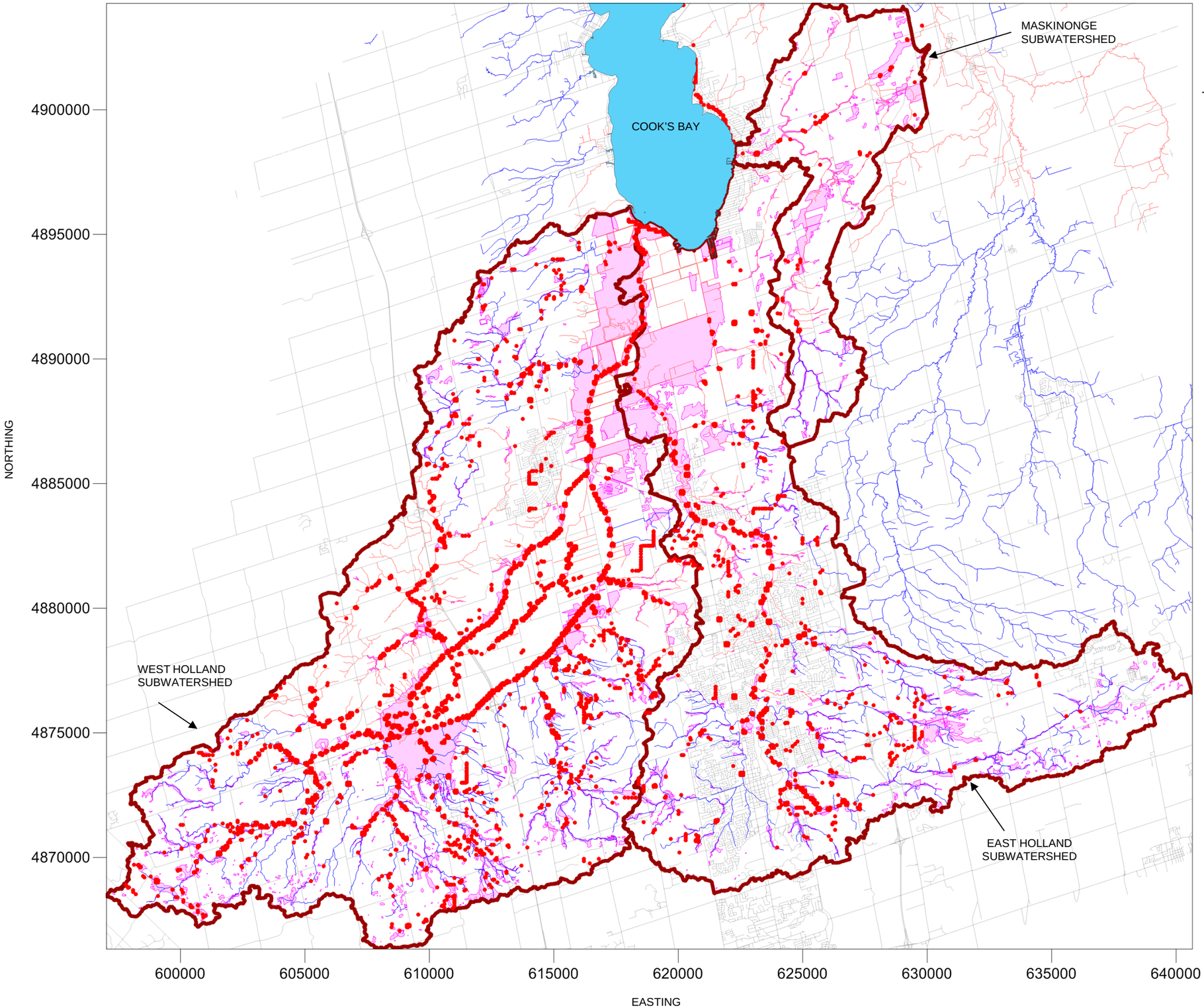
REVIEW	JAP	22 NOV 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014

LEGEND

- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- FORWARD TRACKING ENDPOINT

PROJECT

LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE

FORWARD TRACKING ENDPOINTS FROM ESGRA
h= 100m, ε=2000

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
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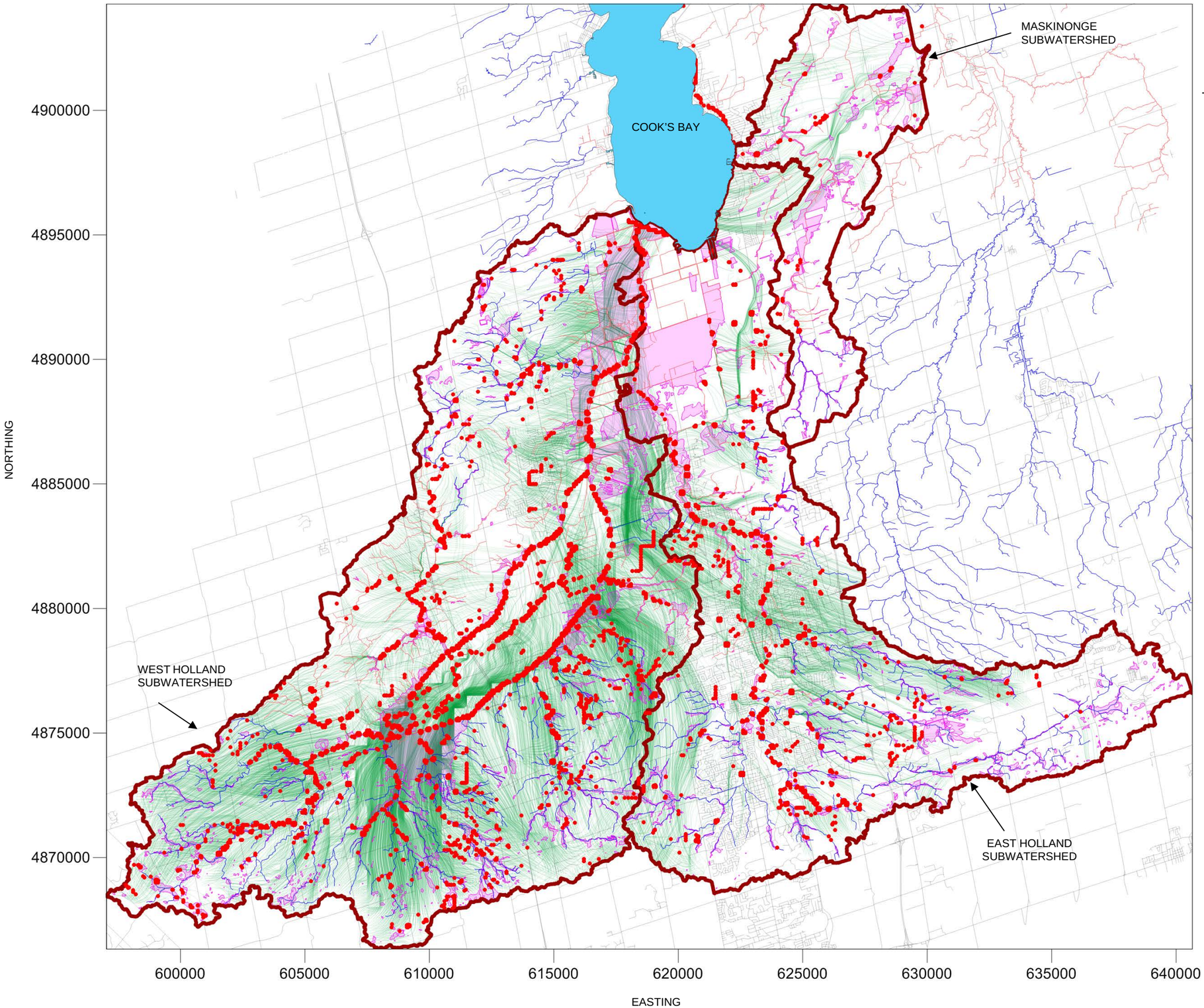
CHECK	JER	22 NOV 2015	
REVIEW	JAP	22 NOV 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED IN FINAL ESGRA AREAS OVER A 100 M X 100 M GRID (1 PARTICLE PER CELL) AND FORWARD TRACKED TO DISCHARGE LOCATION

LEGEND

- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- FORWARD TRACKING ENDPOINT
- FORWARD TRACKING PATHLINES

PROJECT

LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE

FORWARD PARTICLE TRACKING PATHLINES

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
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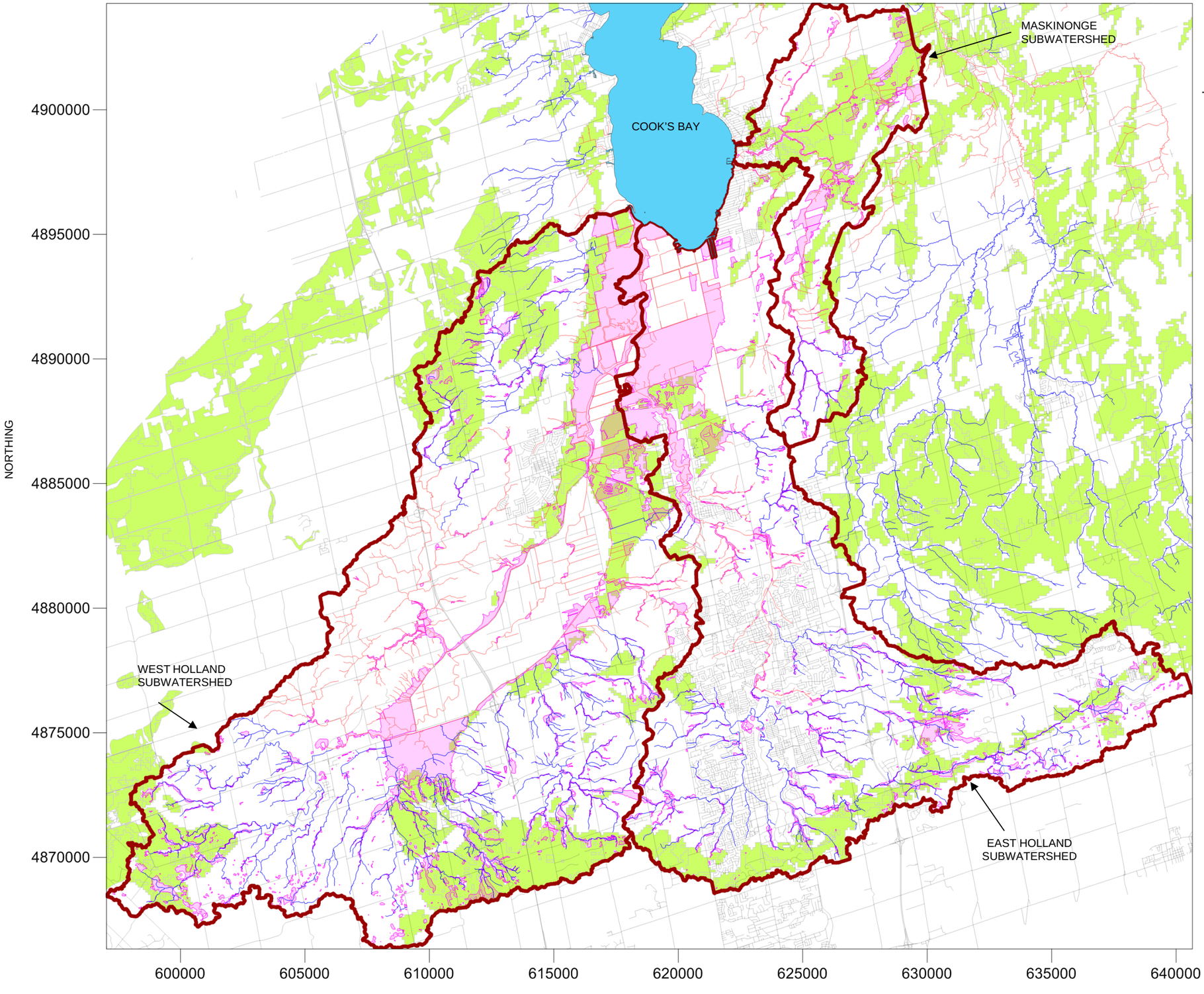
GIS	AM	22 NOV 2015	
CHECK	JER	22 NOV 2015	
REVIEW	JAP	22 NOV 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014

LEGEND

- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- SGRA

PROJECT

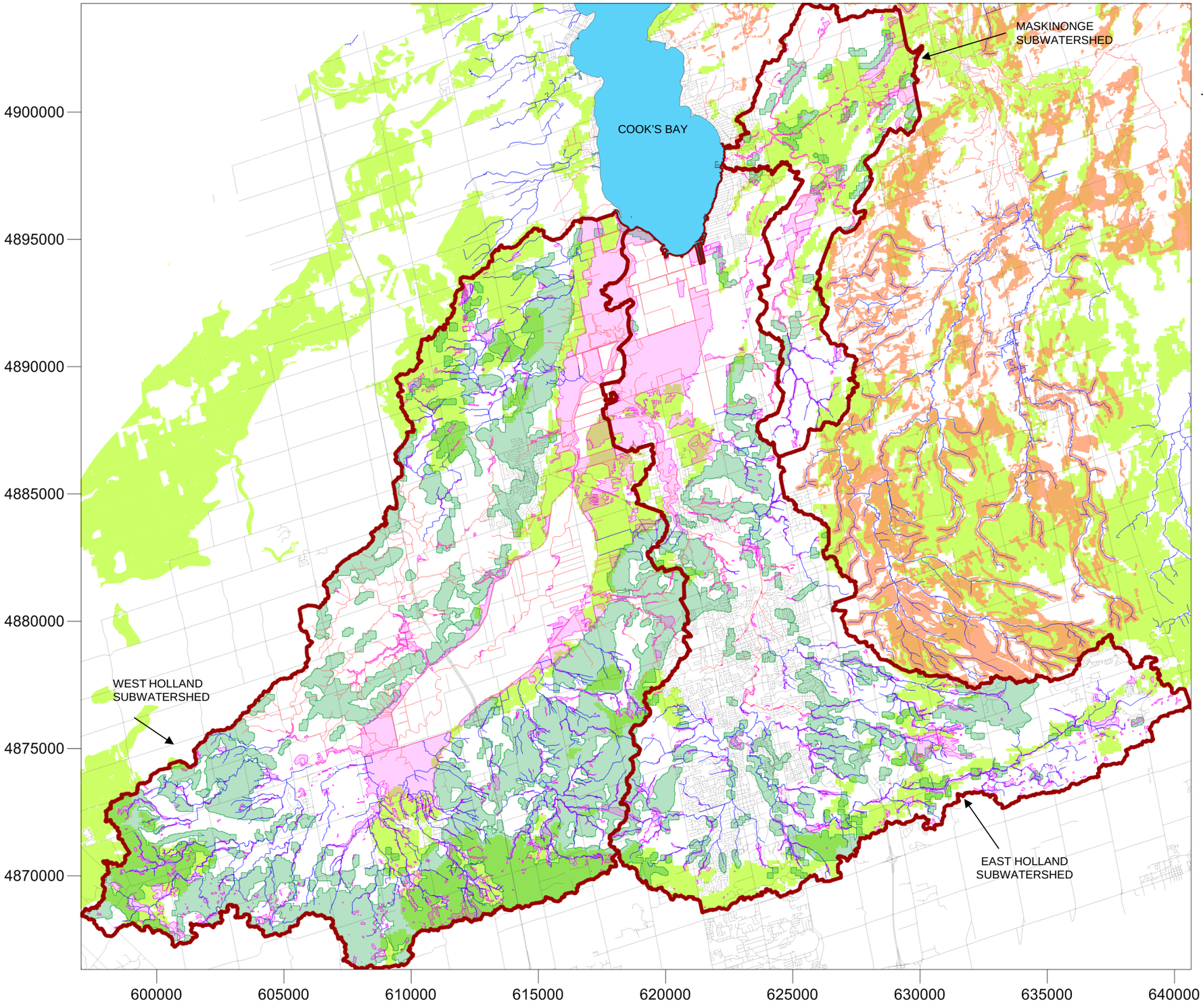
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE

SIGNIFICANT GROUNDWATER RECHARGE AREAS

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 15
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014

LEGEND

- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- SGRA
- BLACK GEORGINA ESGRA
- ESGRA, h=100 m, ℰ=2000

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER
SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA/SGRA COMPARISON

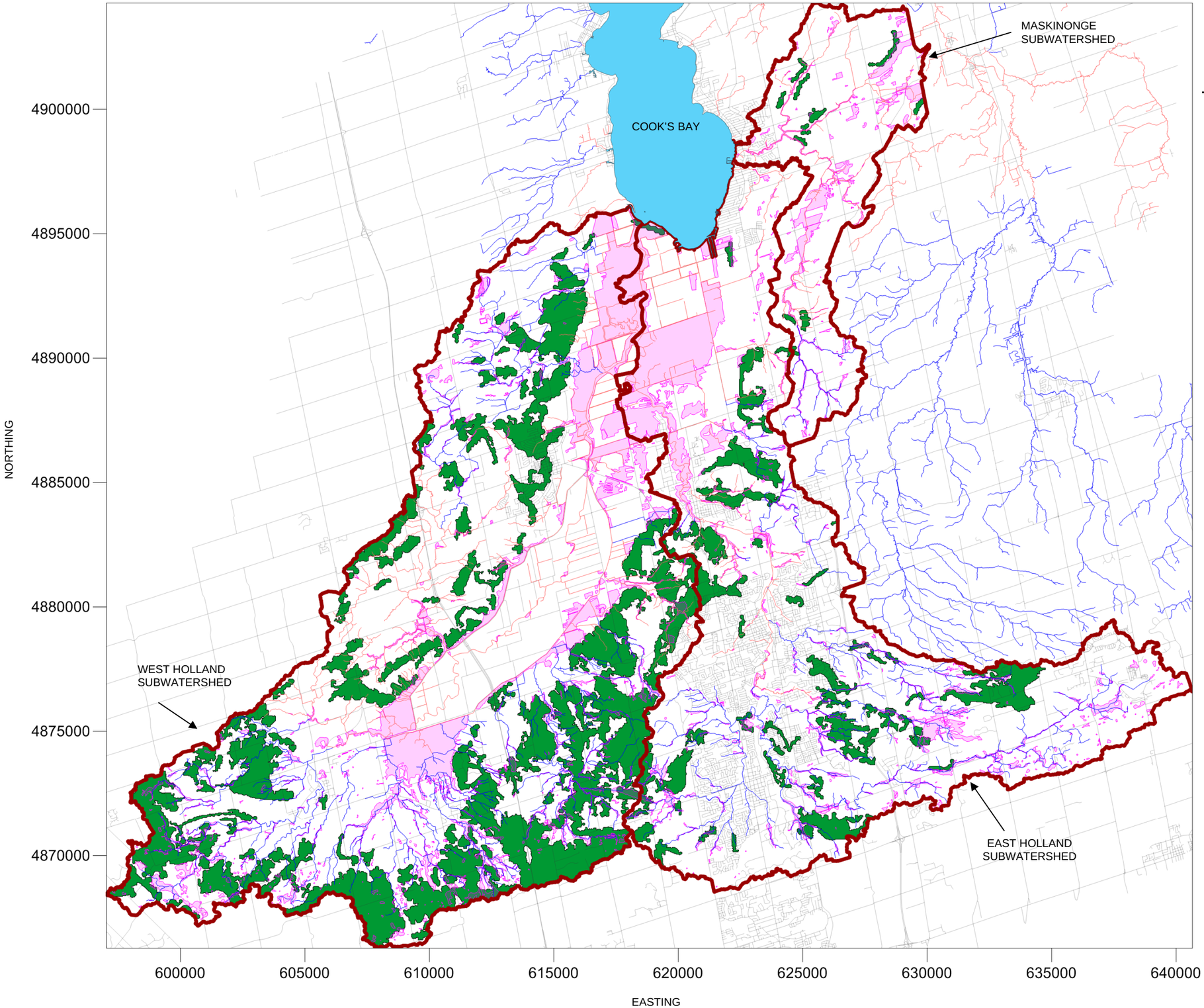
Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	22 NOV 2015	FIGURE: 16
GIS	AM	22 NOV 2015	
CHECK	JER	22 NOV 2015	
REVIEW	JAP	22 NOV 2015	

APPENDIX A

Cluster Sensitivity Analysis Mapping

November 2015
Report No. 1402007



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

PROJECT

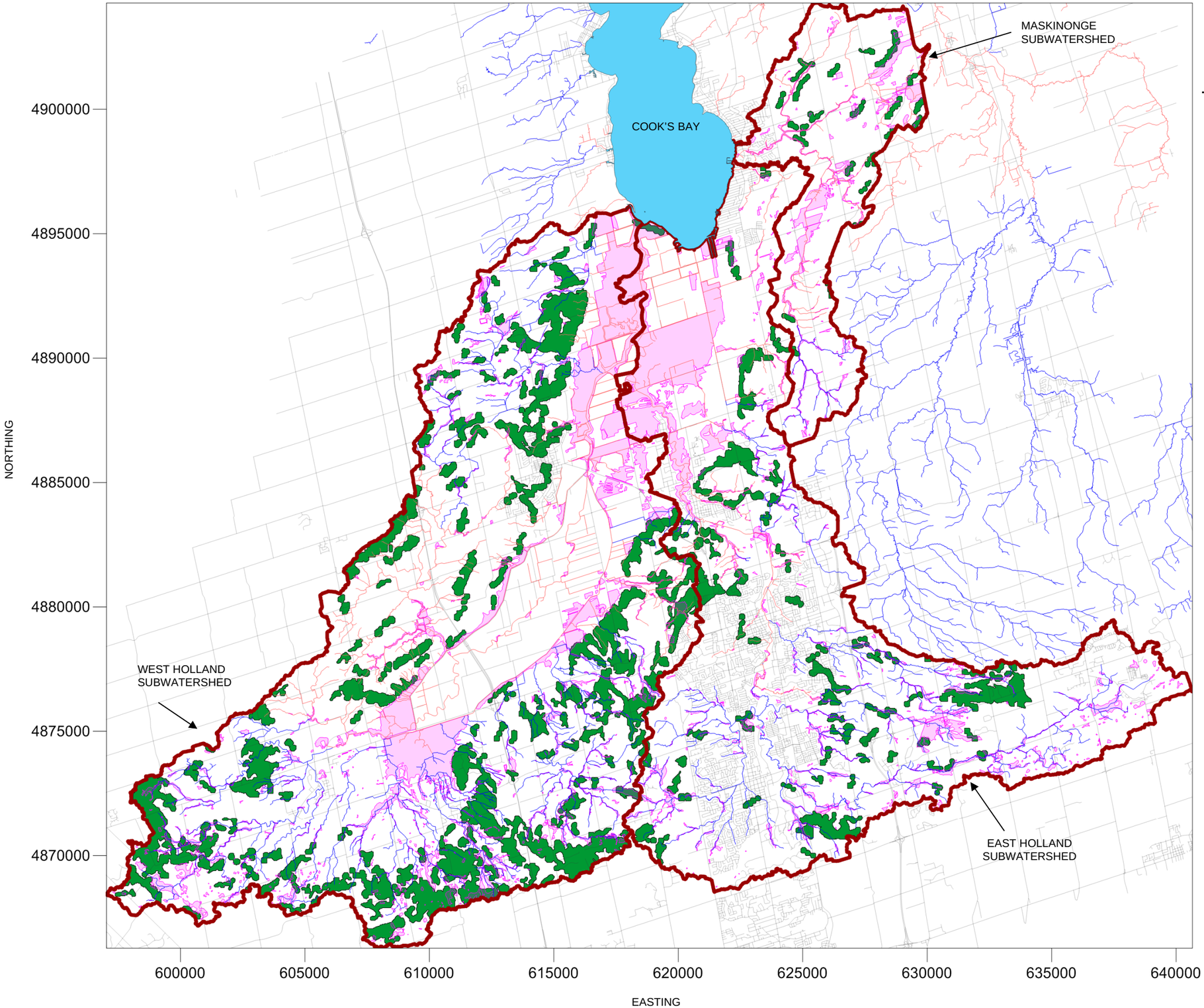
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE

ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 25 m, ε = 10,000

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 1
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

PROJECT

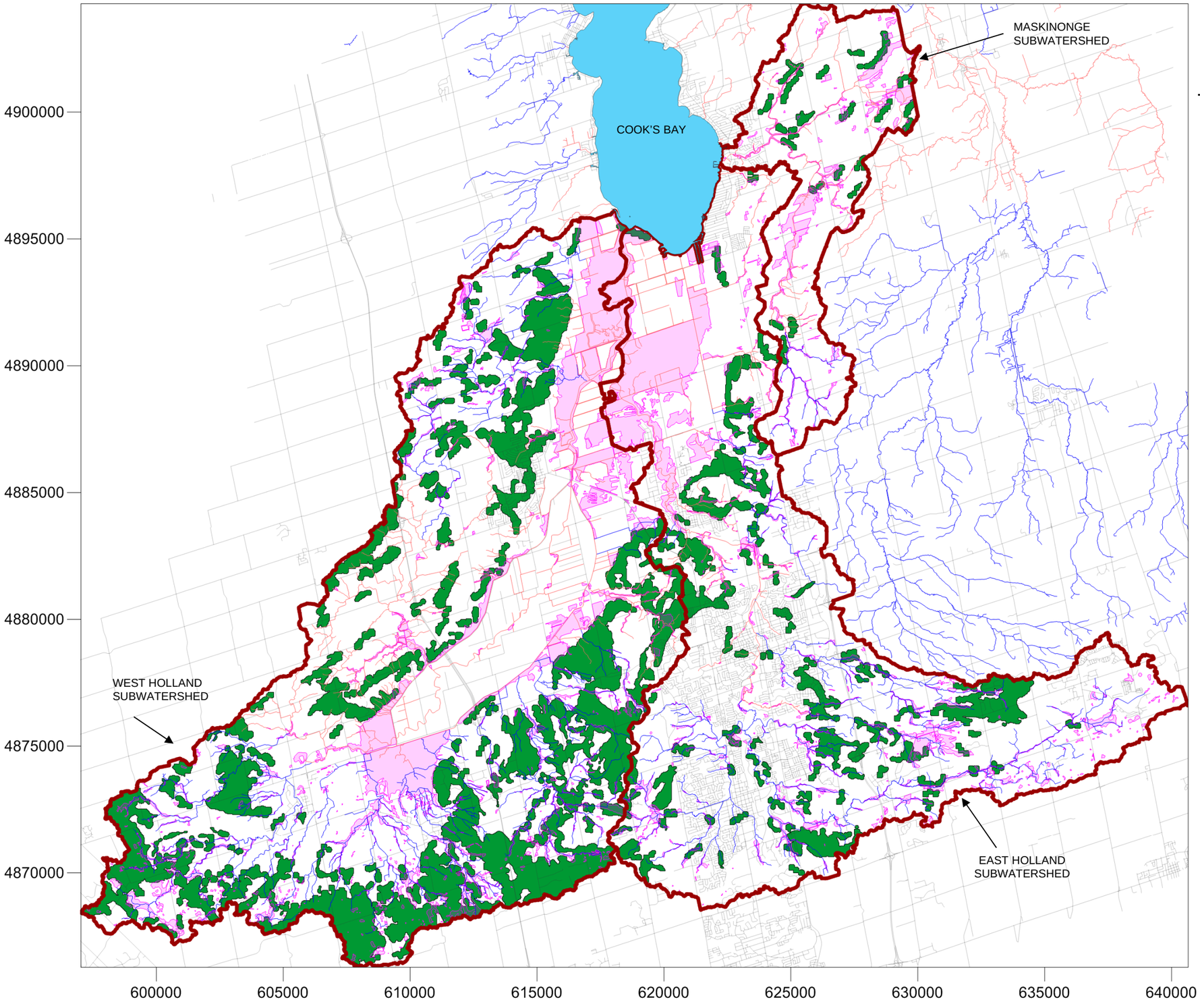
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE

ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 50 m, ε = 1,000

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 2
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

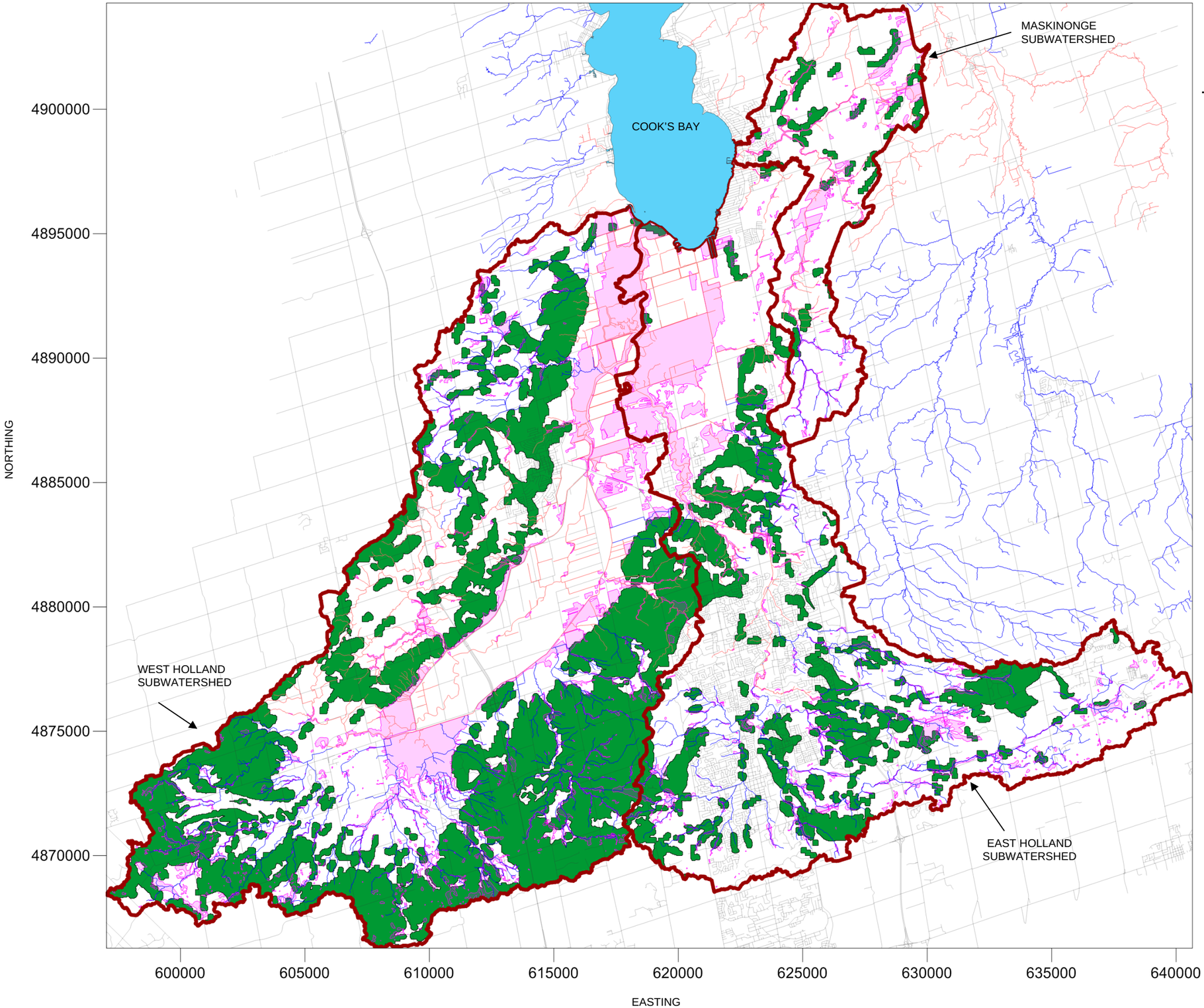
- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 50 m, ε = 2,000

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 3
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 50 m, ε = 10,000

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
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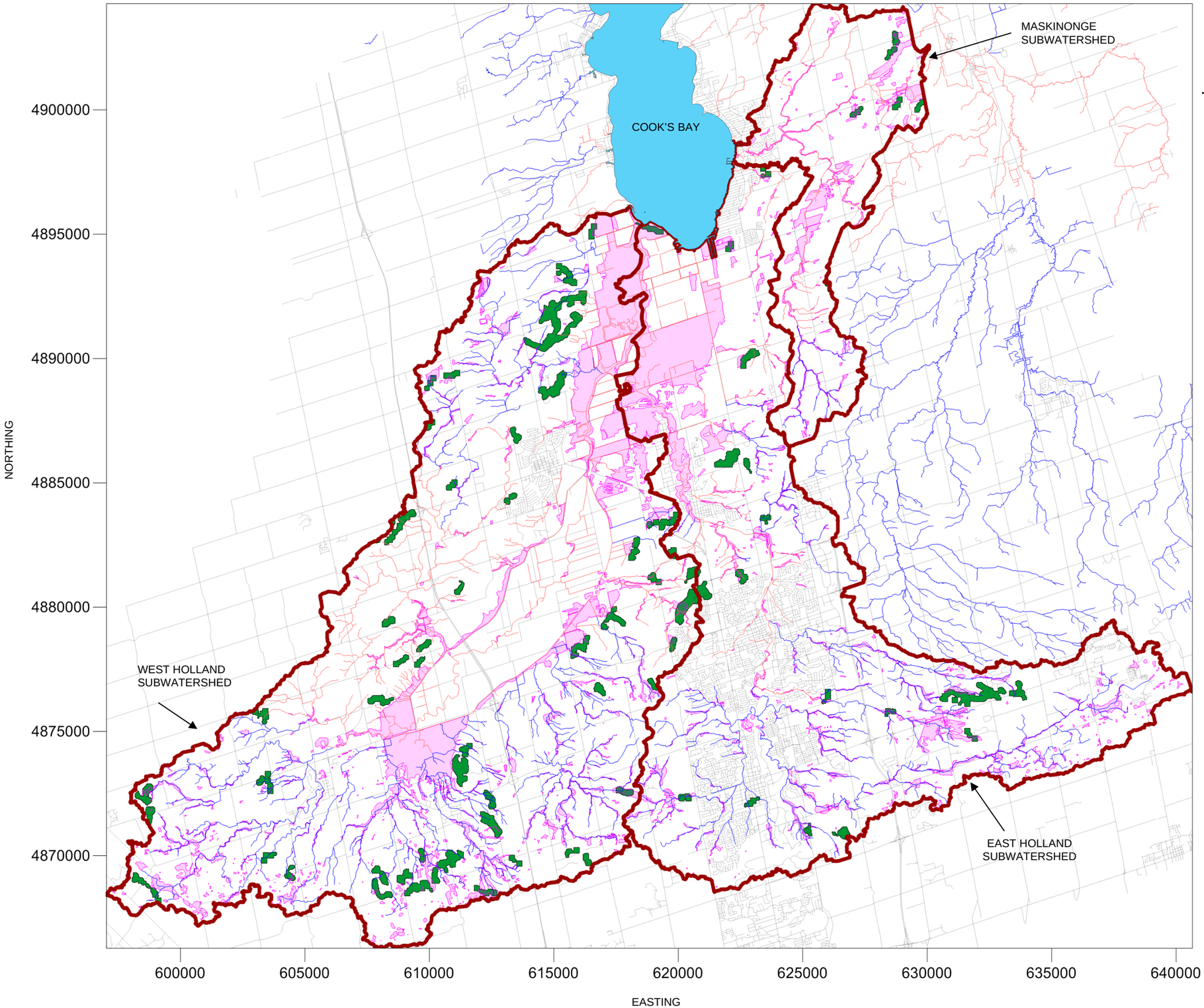
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

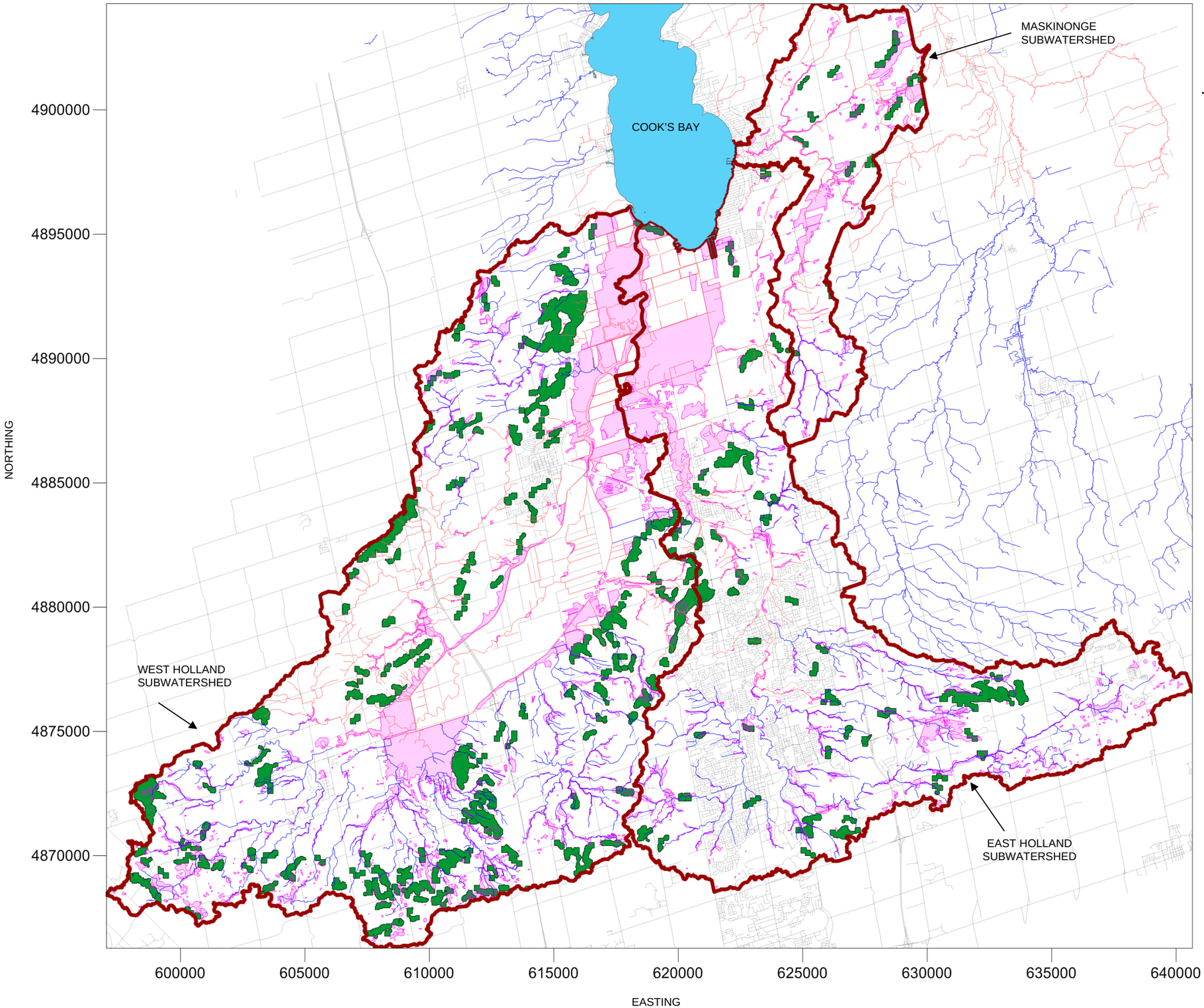
- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 100 m, ε = 100

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 5
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

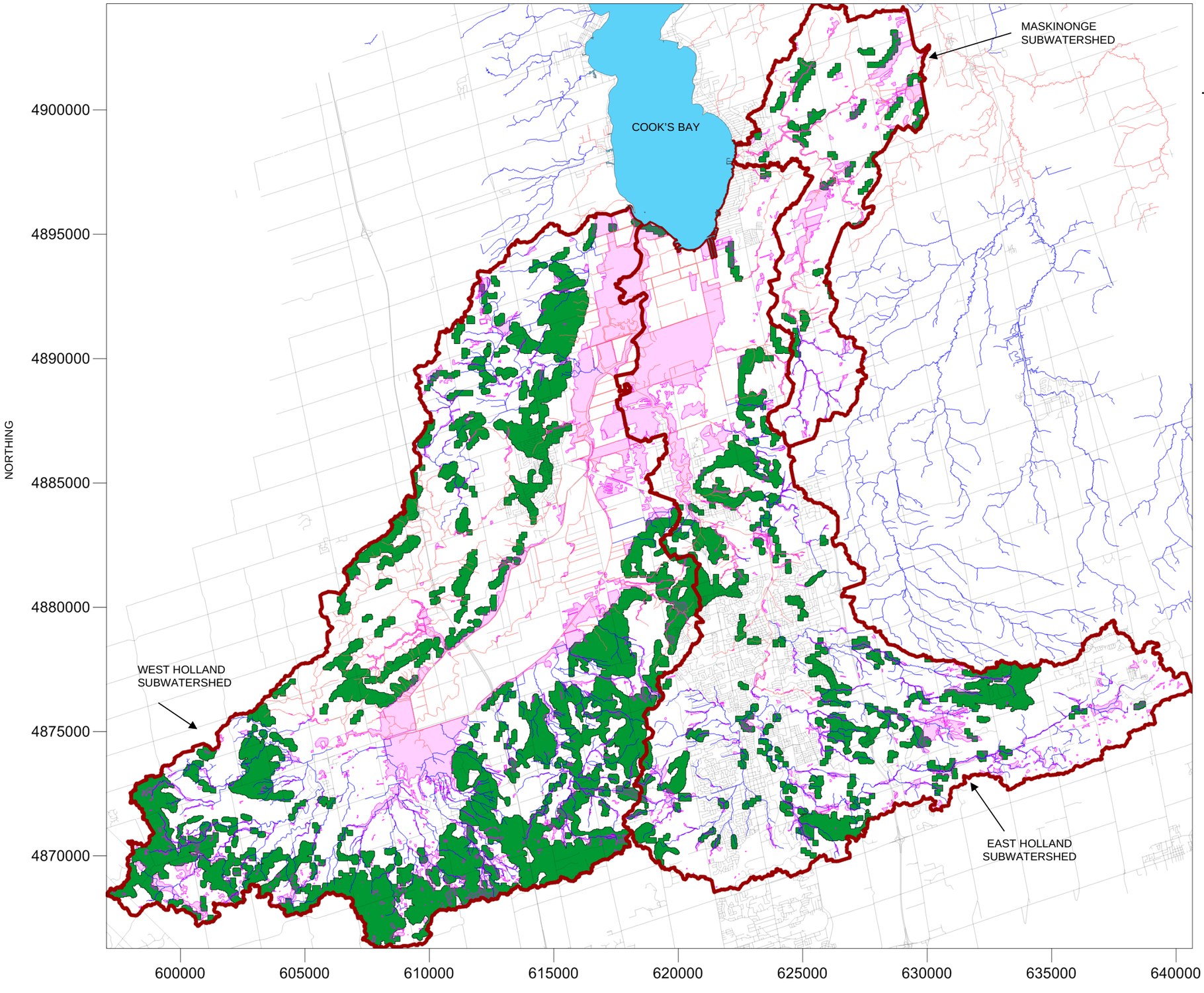
- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 100 m, ε = 200

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 6
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

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- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

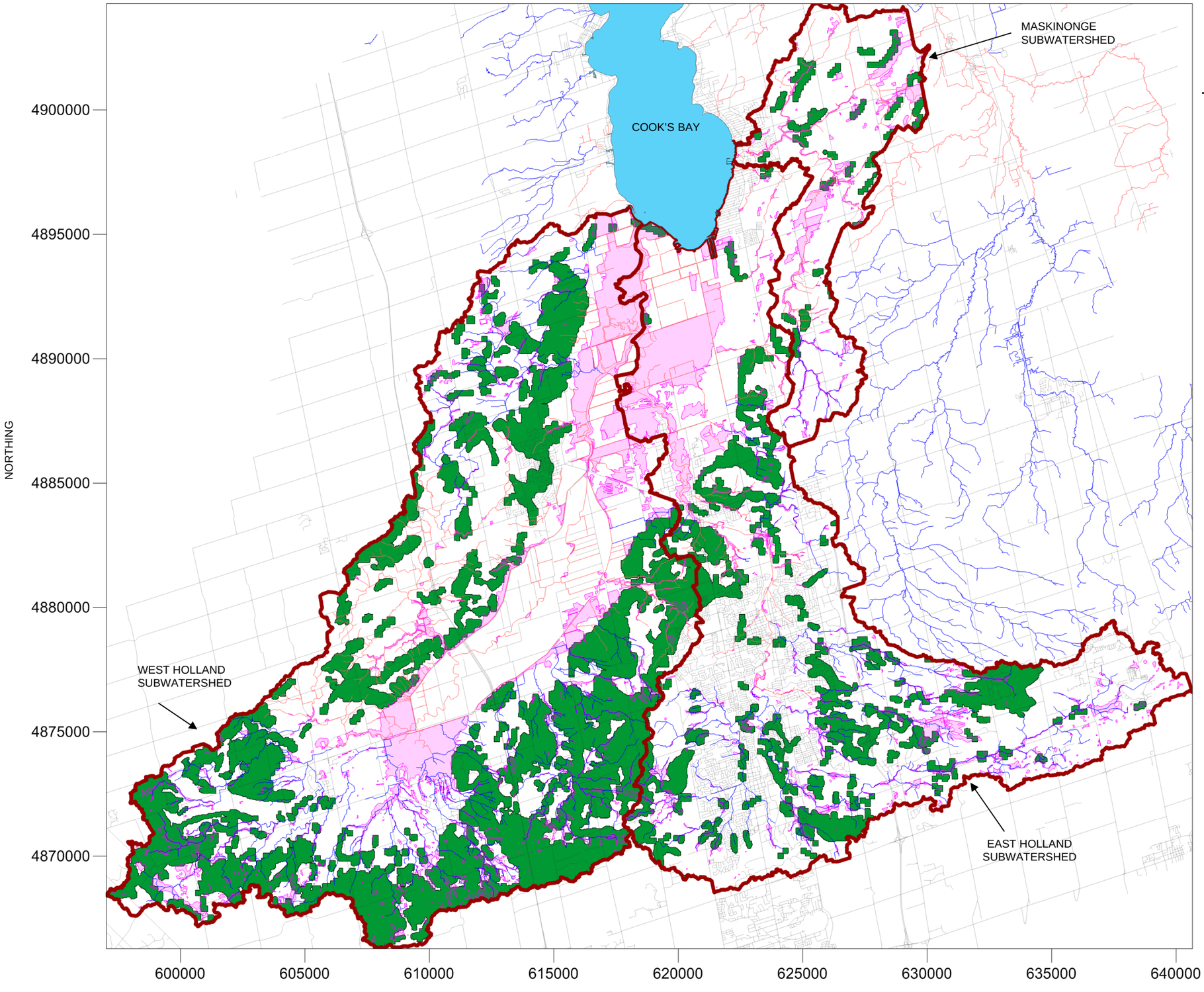
- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 100 m, **ε** = 1,000

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 7
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

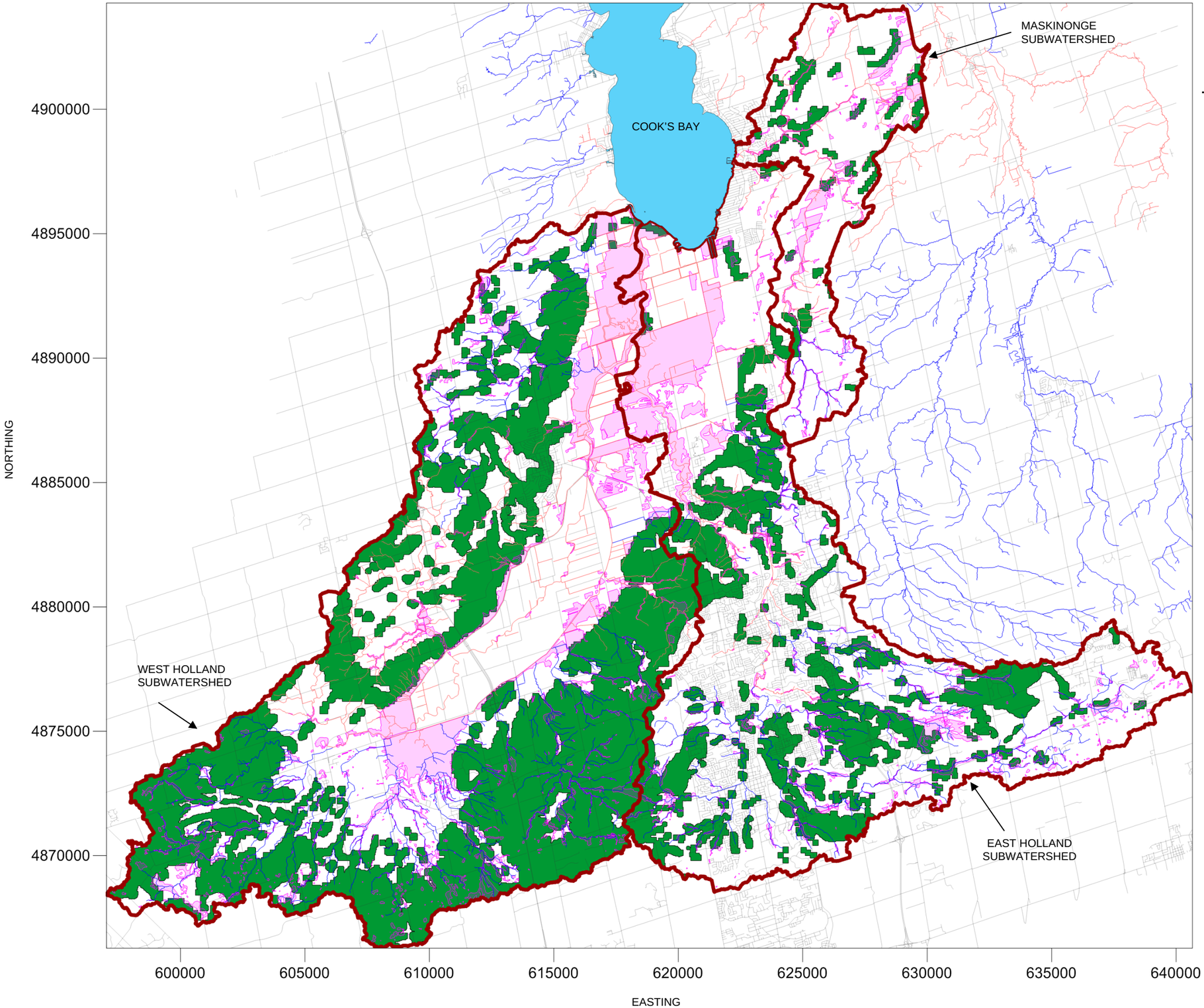
- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 100 m, ε = 2,000

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 8
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

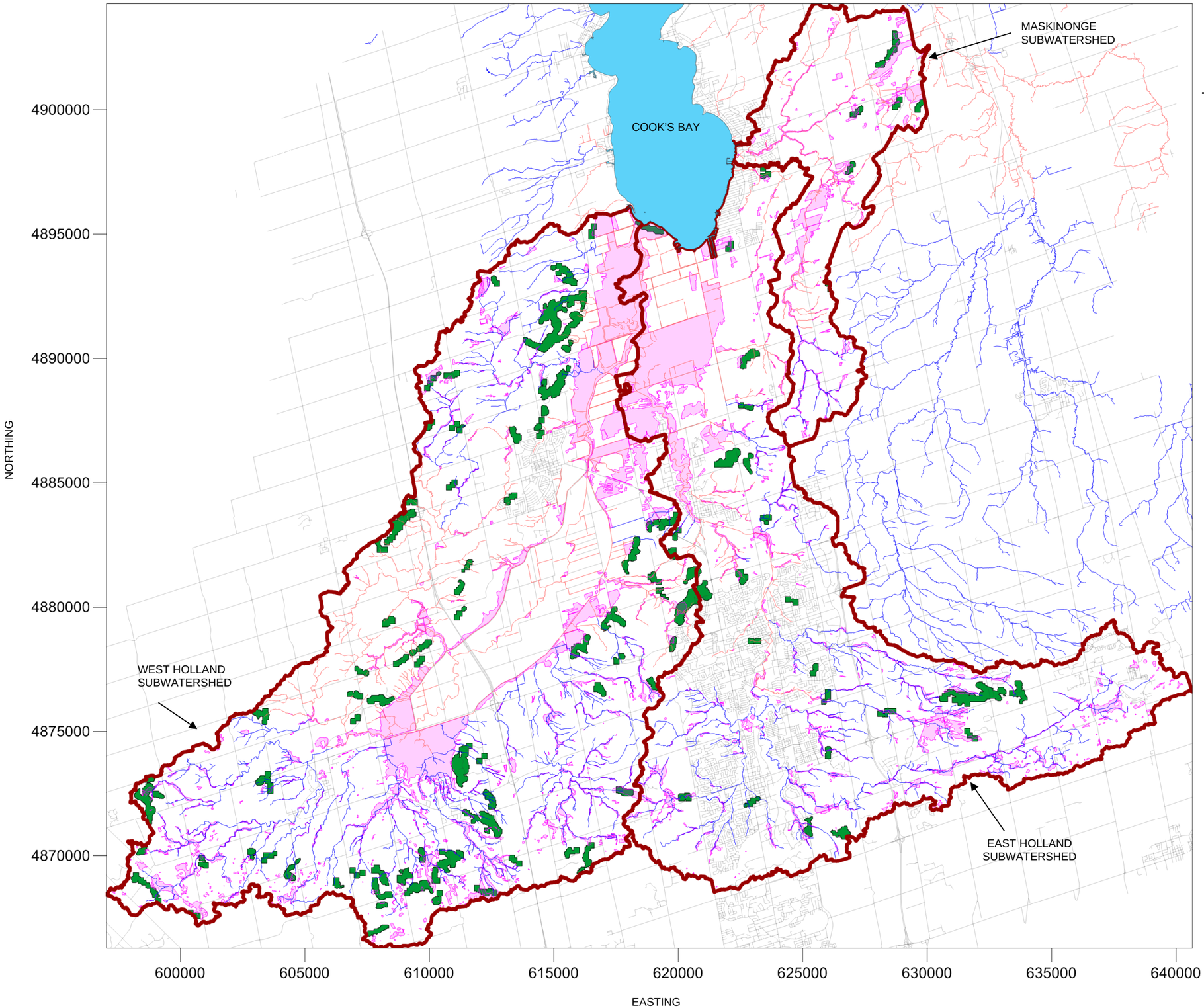
- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 100 m, ε = 10,000

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 9
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
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- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

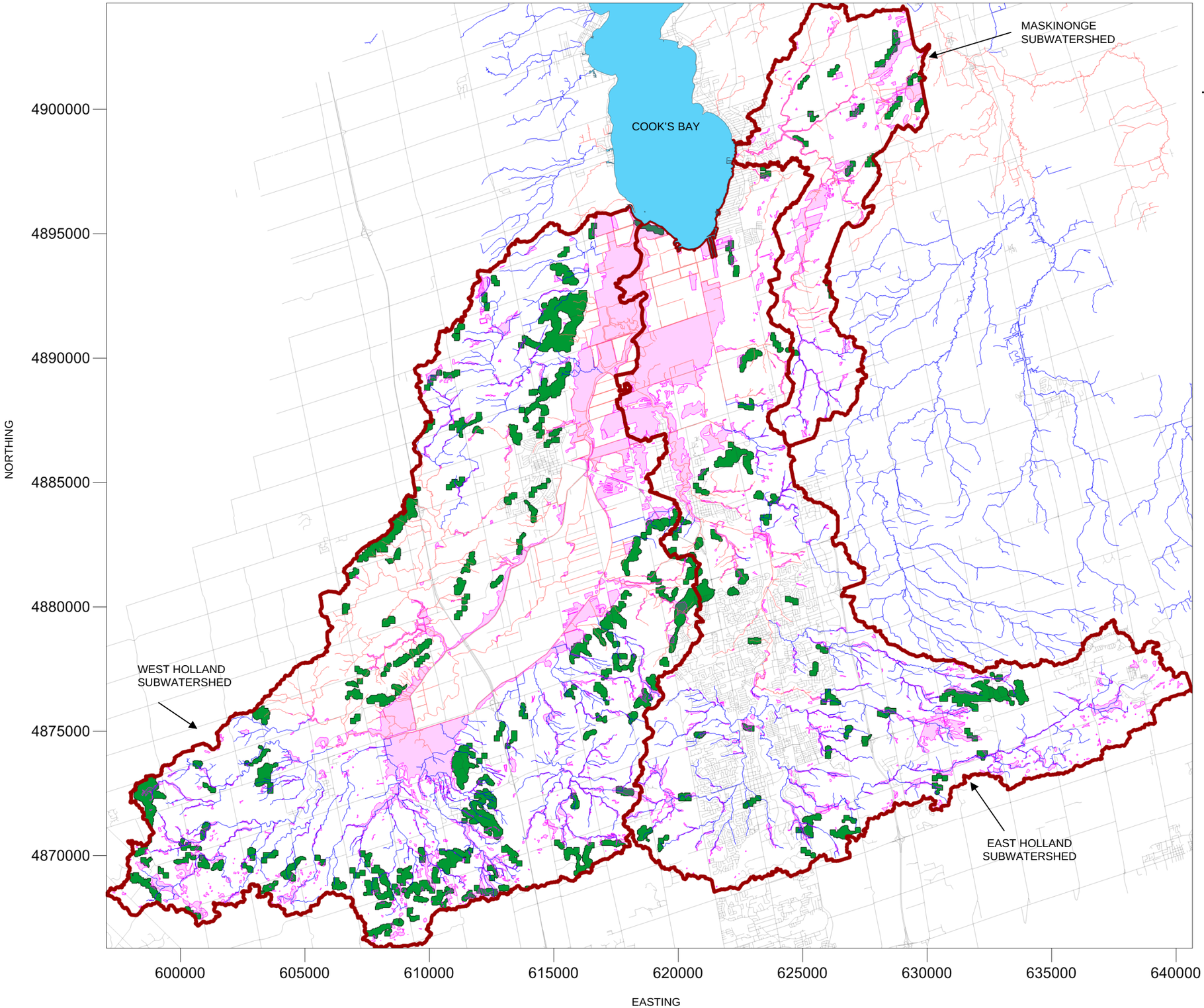
PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 150 m, ε = 100

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	

FIGURE: 10



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

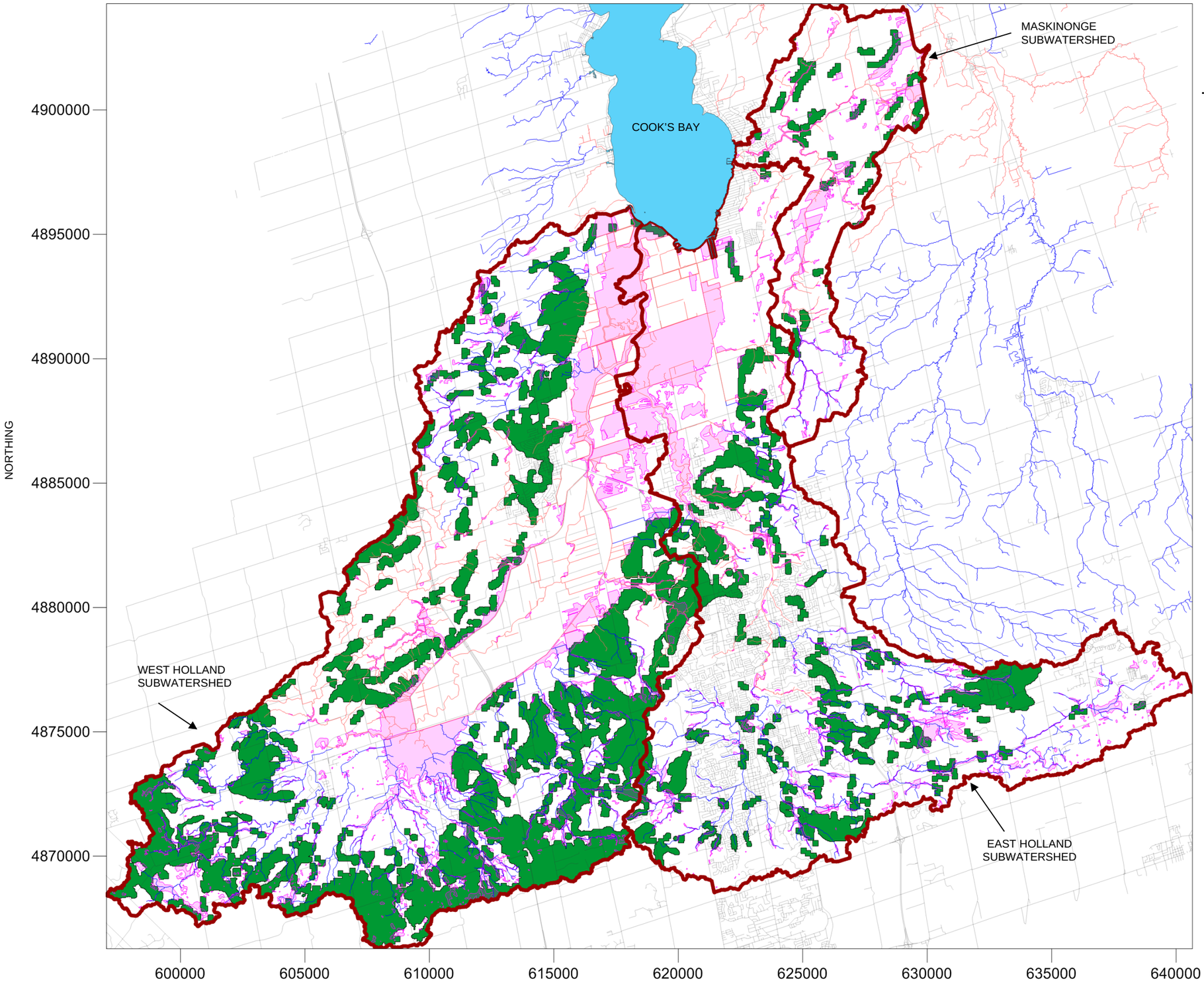
- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 150 m, ε = 200

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 11
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

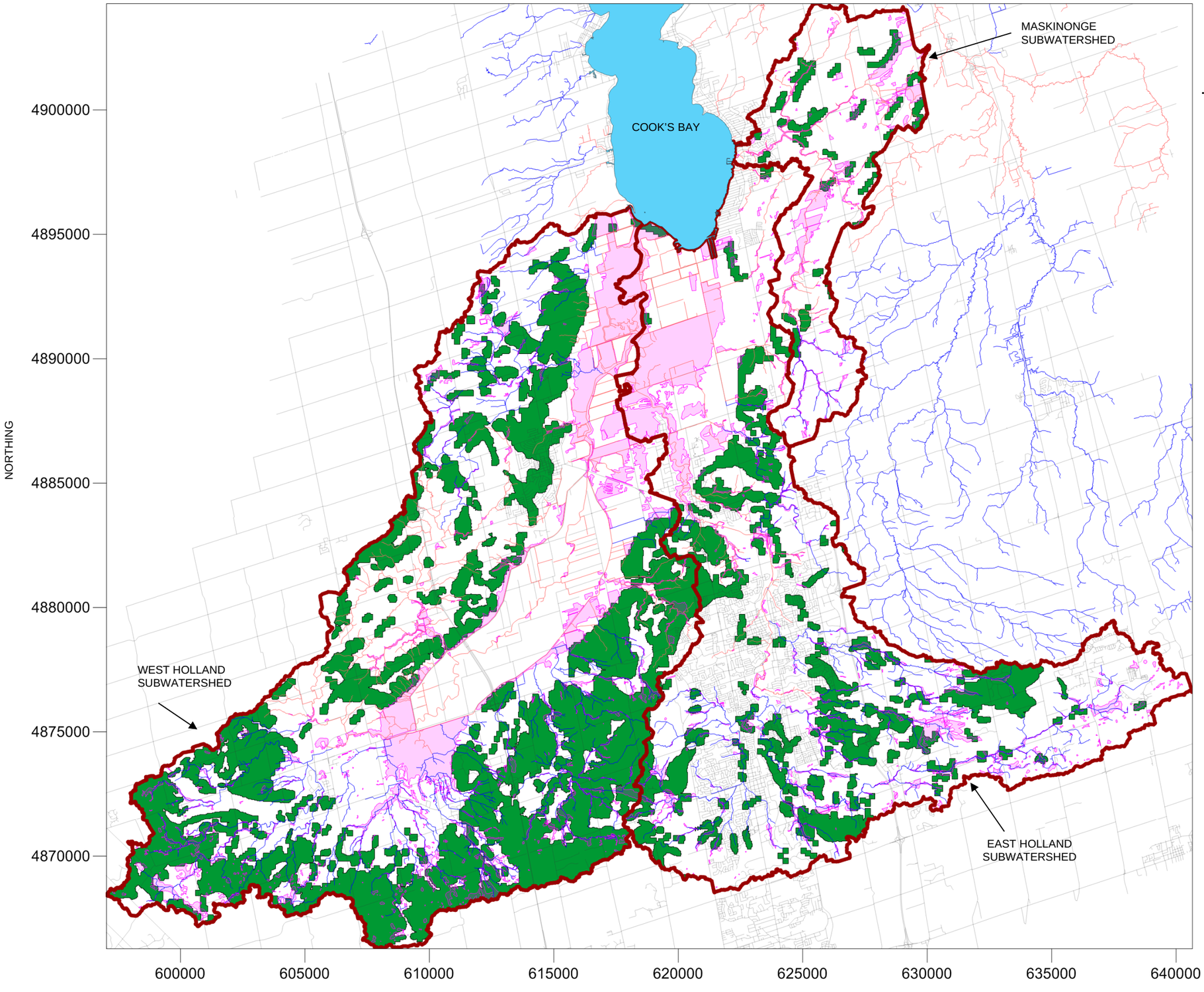
- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 150 m, ε = 1,000

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 12
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

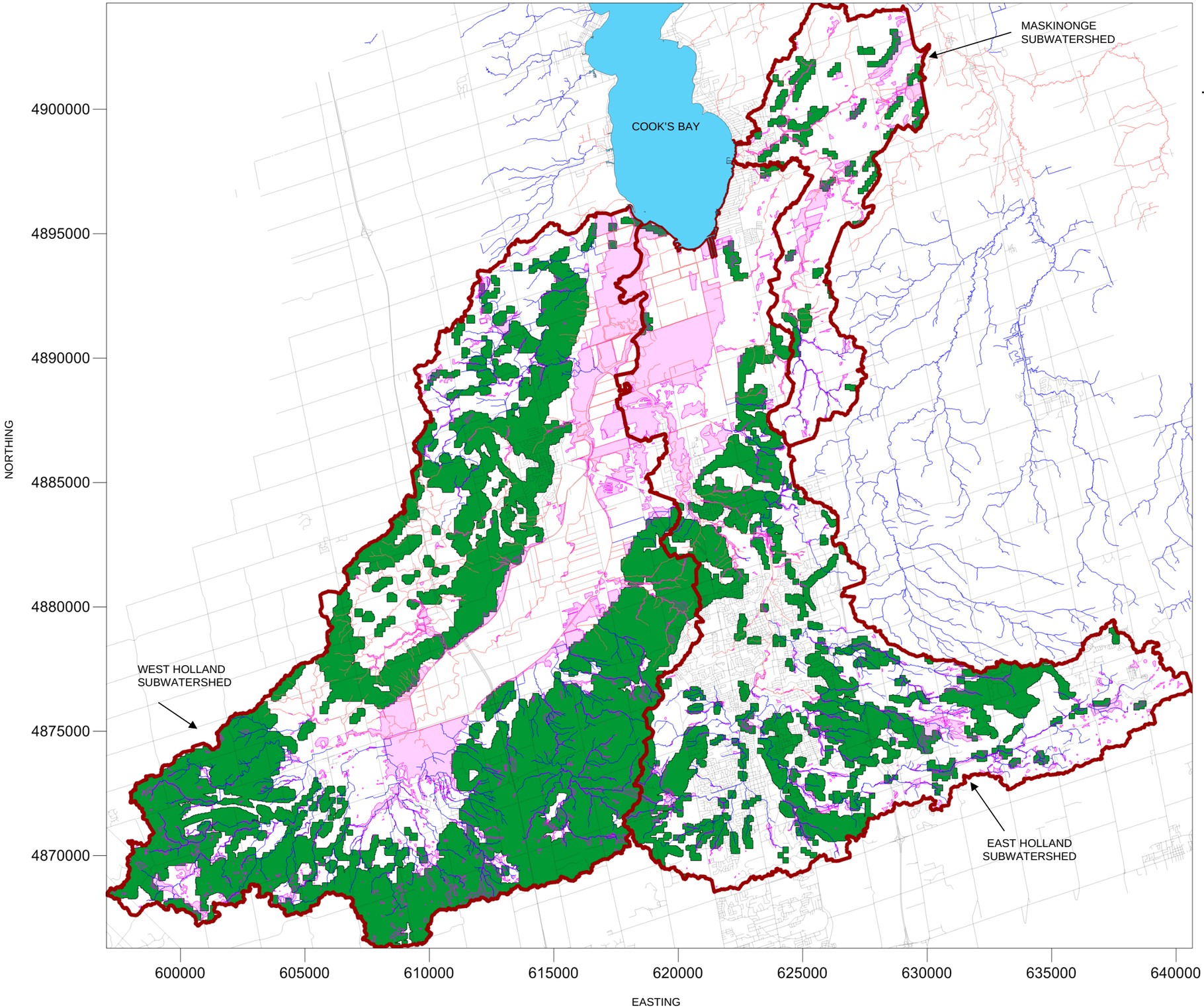
- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 150 m, ε = 2,000

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 13
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
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LEGEND

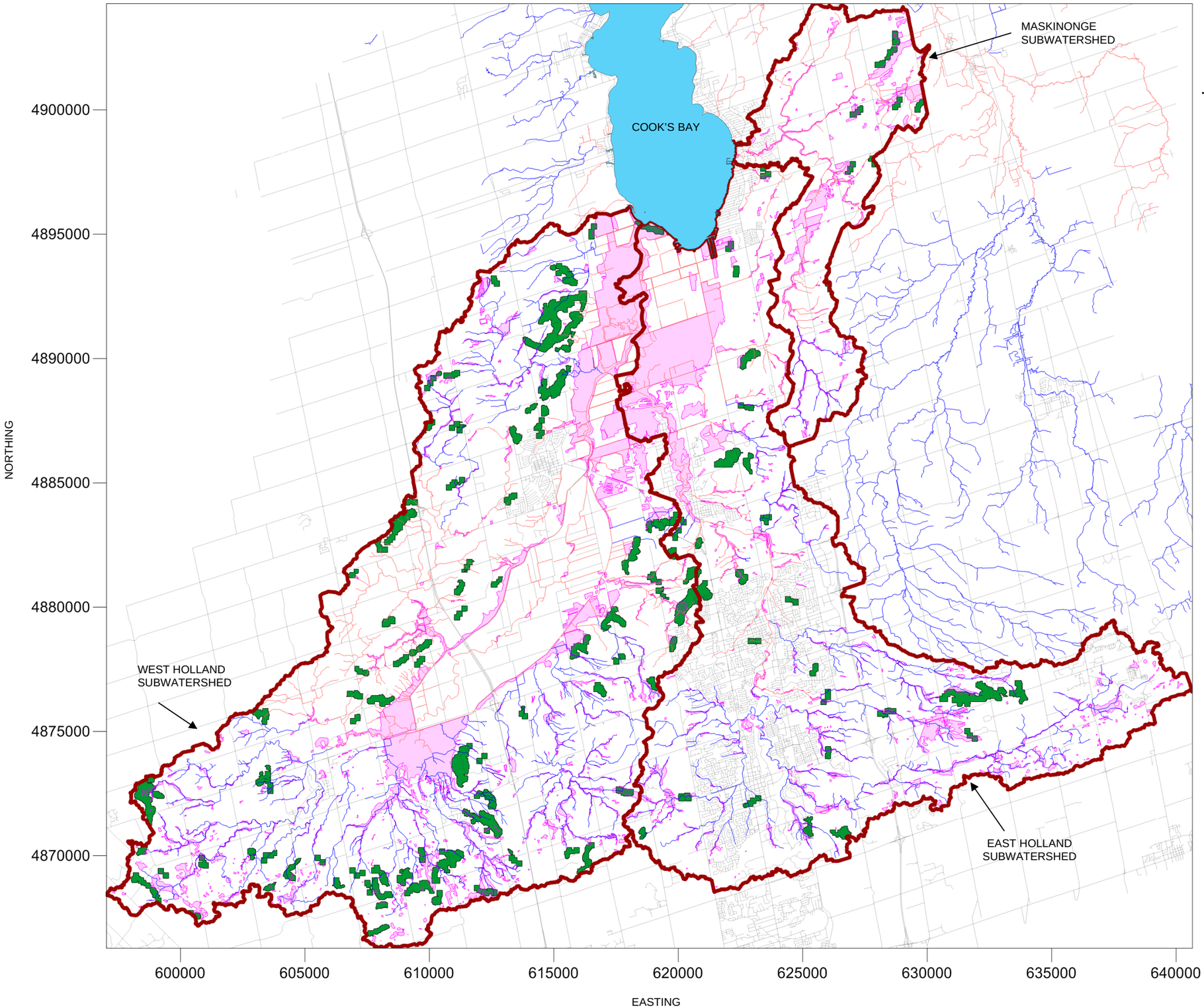
- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 150 m, ε = 10,000

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 14
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

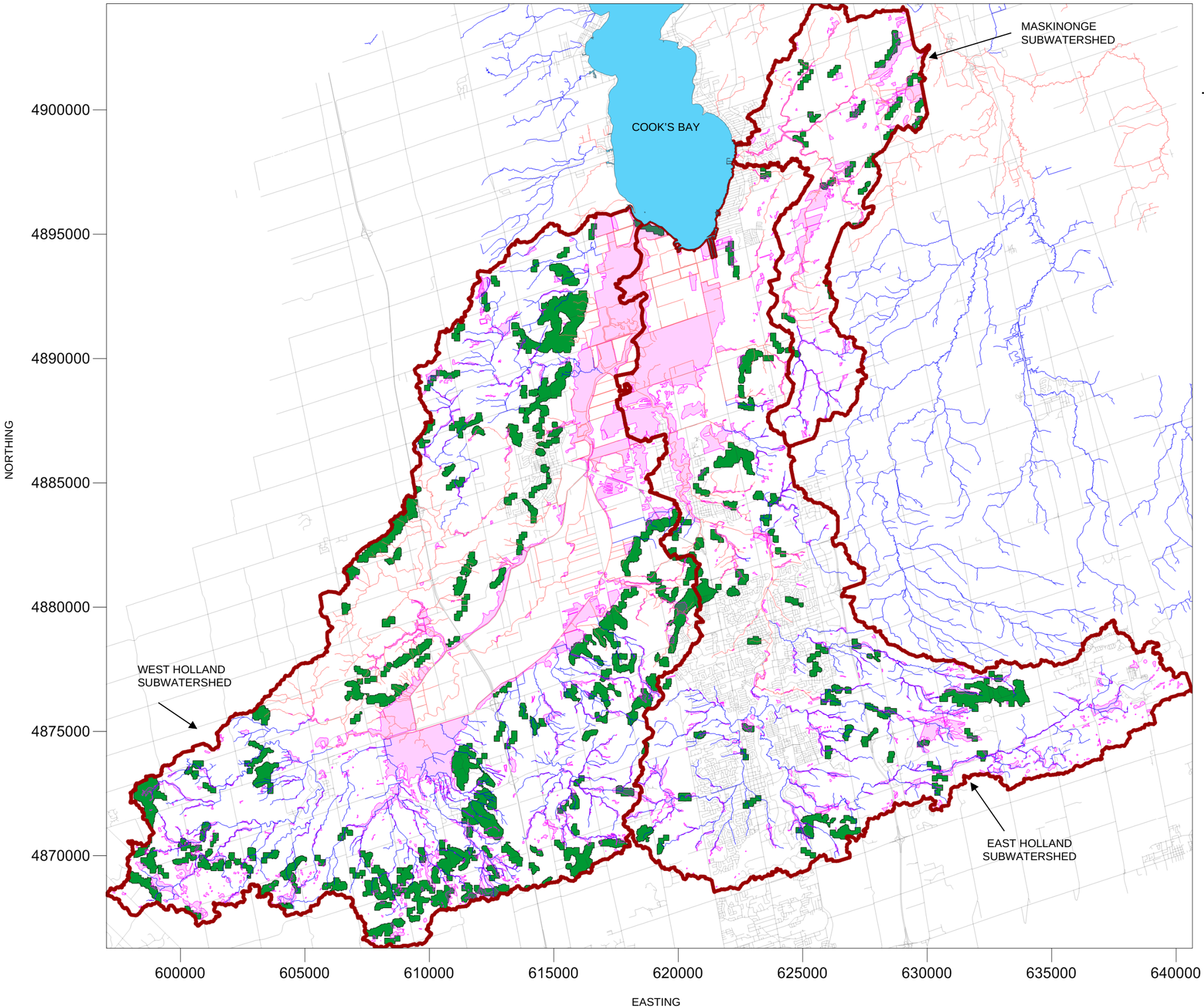
- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 250 m, ε = 100

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 15
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

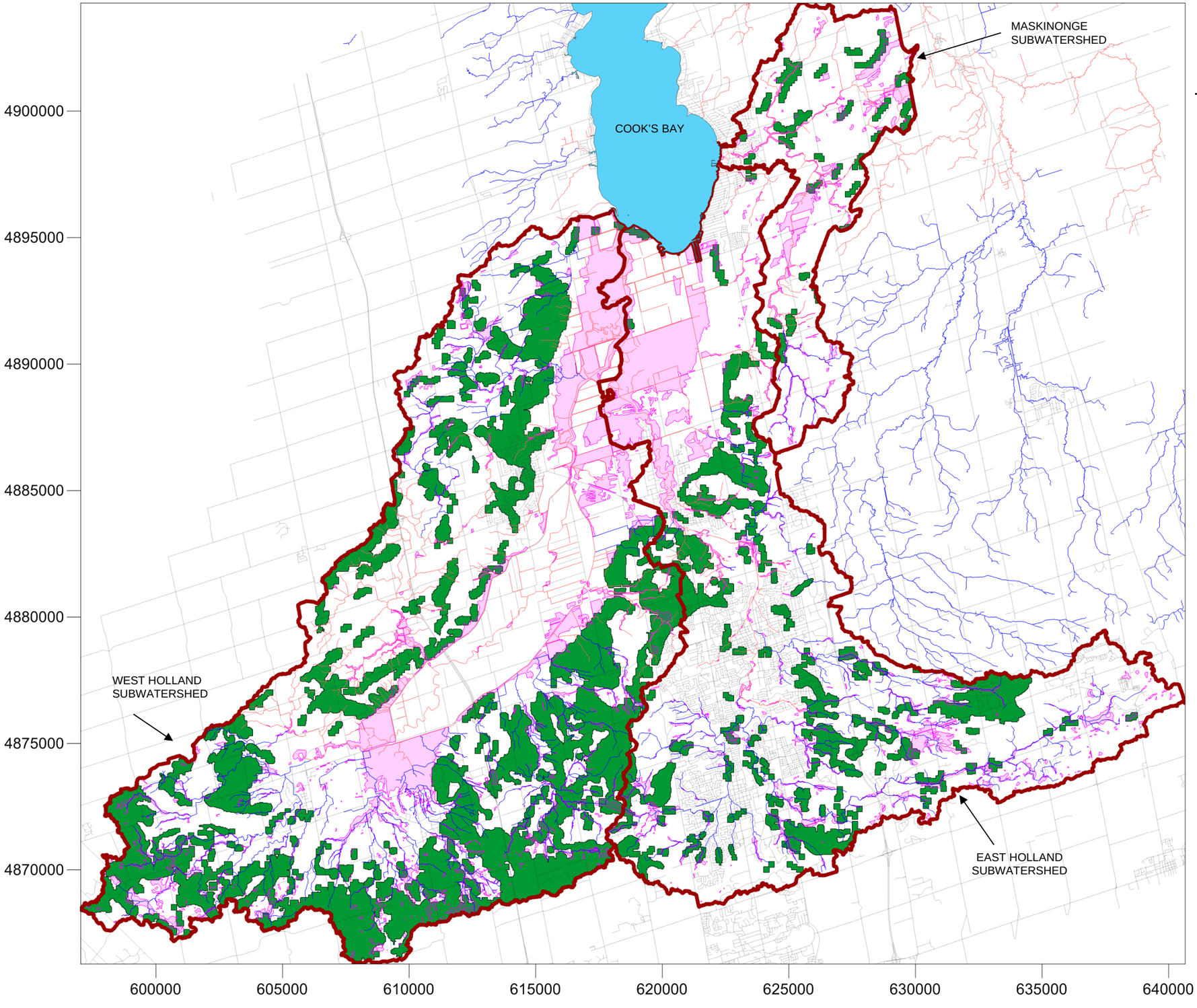
- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
- ECOLOGICALLY SENSITIVE FEATURE
- ESGRA

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 250 m, ε = 200

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 16
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

- BASE MAPPING PROVIDED BY LSRCA – APRIL 2014
- PARTICLES WERE RELEASED FROM FEATURES AND BACKWARD TRACKED TO PARTICLE ENDPOINT
- ESGRAS < 0.1 KM^2 WERE REMOVED
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LEGEND

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- WARM WATER STREAM
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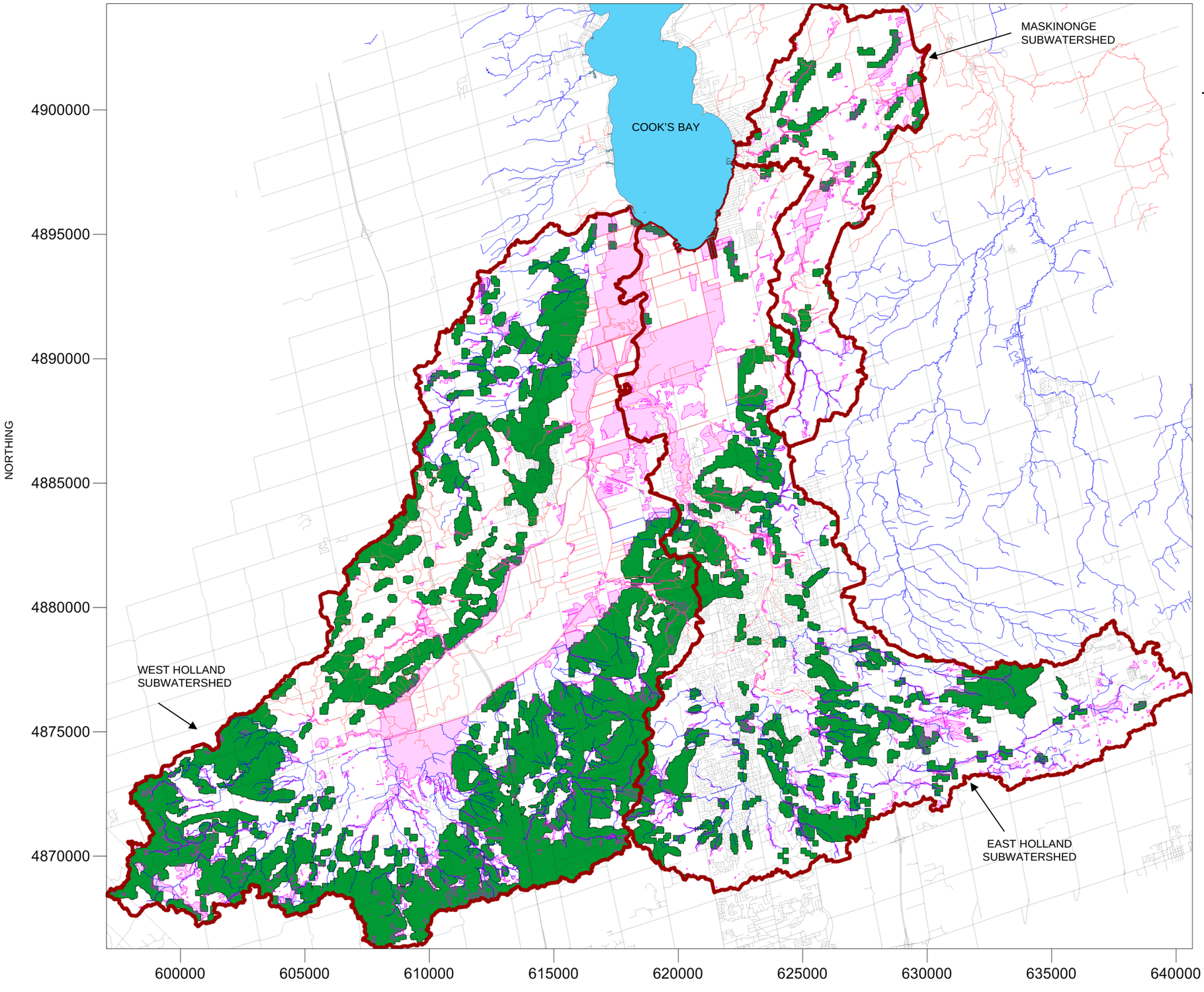
- ESGRA

PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 250 m, ε = 1,000

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 17
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

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LEGEND

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- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
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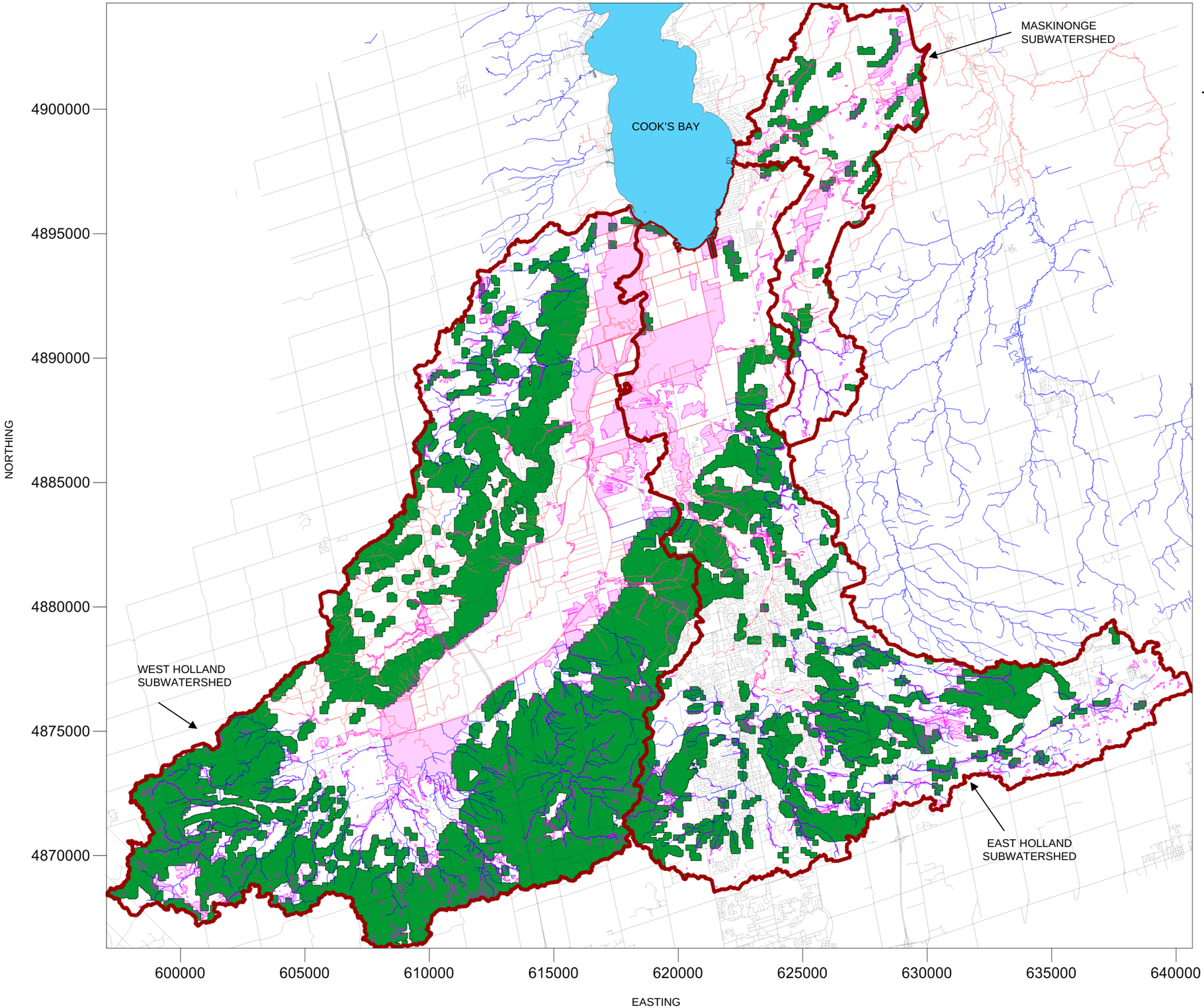
PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 250 m, ε = 2,000

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 18
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	



NOTES:

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- ESGRAS < 0.1 KM^2 WERE REMOVED
- HOLES WITHIN ESGRA ZONES < 0.1 KM^2 WERE IN FILLED

LEGEND

- STUDY AREA SUBWATERSHEDS
- ROADS
- COLD WATER STREAM
- WARM WATER STREAM
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PROJECT
LSRCA HOLLAND AND MASKINONGE RIVER SUBWATERSHED ESGRA PROJECT

TITLE
ESGRA CLUSTER ANALYSIS SENSITIVITY RESULTS
h = 250 m, ε = 10,000

Golder Associates
Mississauga, Ontario

PROJECT No. 1402007 (1000)			REV. 0.0
DESIGN	AM	27 JULY 2015	FIGURE: 19
GIS	AM	27 JULY 2015	
CHECK	JER	27 JULY 2015	
REVIEW	JAP	27 JULY 2015	

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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