MEMORANDUM

File No.: Long Range Planning
09-6500-20-2021

DATE OF MEETING:	June 6, 2022
TO:	Galiano Island Local Trust Committee
FROM:	William Shulba, P.Geo, Senior Freshwater Specialist Local Planning Services
COPY:	Narissa Chadwick, Island Planner Brad Smith, Galiano Island Planner
SUBJECT:	Methodology Memorandum: Galiano Island Groundwater Recharge Protection Development Permit Area

PURPOSE

The purpose of this memorandum is present to the Galiano Local Trust Committee, a groundwater recharge protection development permit area boundary delineation methodology developed by Islands Trust staff with options to consider.

SUMMARY

At the February 1, 2021 meeting, the LTC endorsed a project charter for the implementation phase of the Groundwater Sustainability Science Program on Galiano Island. Staff have been working on bylaw amendments based on review and analysis of groundwater resource mapping projects. New Development Permit Area (DPA) guidelines and boundaries are proposed to amend existing DPA guidelines for Galiano's Elevated Groundwater Catchment DPA.

At the March 7, 2022 LTC meeting the following resolutions were passed:

That the Galiano Island Local Trust Committee request staff to prepare a draft bylaw to amend the "Galiano Island Official Community Plan Bylaw No. 108, 1995" to include Critical Aquifer Recharge Development Permit Area guidelines, map updates and minor updates to relevant sections as identified in the March 7, 2022 staff report.

The proposed Groundwater Recharge Protection Development Permit Area considers the existing Galiano Island Elevated Groundwater Catchment Development Permit Area developed in 2014 that involved a hydrogeology consultant, Waterline Resources. In 2020, GW Solutions, a groundwater assessment and protection consulting company, in cooperation with Islands Trust staff, developed a GIS-based methodology to estimate the spatial variability of recharge potential on islands in the Islands Trust Area.

Islands Trust Planning staff, Information Services, and the Senior Freshwater Specialist developed a methodology to classify Critical Aquifer Recharge Areas from the raw data of the Islands Trust Area Groundwater Recharge Mapping project. The methodology was used to determine Critical Aquifer Recharge Areas for every parcel on Galiano Island.

METHODOLOGY

Groundwater is subterranean water that flows in a similar way to surface water that is highly influenced topography but also by the forest root zone, soil type, rock composition, structural geology, well extraction, and groundwater recharge potential. Groundwater recharge is the process whereby precipitation replenishes aquifers by percolating through the landscape surface to the subsurface. Groundwater recharge potential is dependent upon several inherent geographical factors such as topographic slope, precipitation interception by plants, evaporation of water bodies on the land surface, the permeability of the soil, and subsurface geologic formations.

Groundwater Recharge Potential Mapping

To determine groundwater recharge potential elements influencing groundwater recharge were weighted based on previous studies and observed data. The methodology addresses diffuse and localized groundwater recharge.

- **Diffuse recharge** is due to the widespread movement of water from land surface to the water table that varies spatially and seasonally. The percentage of precipitation that becomes diffuse recharge is dependent on soil, vegetation, local topography, and depth to the water table.
- **Localized recharge** occurs along discrete, bedrock lineaments including fractures, faults and geologic bedding planes and contacts.

The Islands Trust Area Groundwater Recharge Potential Mapping report describes in detail the methodology to determining groundwater recharge potential on islands in the Islands Trust Area. The methodology was developed over three projects over a 4 year period. The resulting raw data is a *raster* dataset of a spatial resolution of 400 square metres (0.04 Hectares) per pixel. A raster consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information, such as temperature, elevation, or in this case groundwater recharge potential.

The resulting raster data is on a scale from 0.0 to 1.0. Whereby 0.0 is very low recharge and can be determined as a groundwater discharge area where groundwater is exiting from the subsurface to the surface. A groundwater recharge potential of 1.0 is very high recharge where all precipitation will enter the ground although it is unlikely that in any landscape 100% of precipitation enters the groundwater system. Figure 1 shows the methods that contributed to the determination of groundwater recharge potential and are described in the *Islands Trust Area Groundwater Recharge Potential Mapping report* (GW Solutions, 2021).

Classification of Critical Aquifer Recharge Areas

Islands Trust planning staff, Information Services, and the Senior Freshwater Specialist developed a methodology to classify critical aquifer recharge areas from the raw raster data of the Islands Trust Area Groundwater Recharge Mapping project. In the case of Galiano Island, the maximum amount of recharge potential was determined as 0.86 and minimum of 0.04 with an average mean of 0.39 and a standard deviation of 0.13. The divisions of significant recharge potential, herein known ***as Critical Aquifer Recharge Areas***, are based on statistical analysis using standard deviation to determine value breaks. The overall mean average of the recharge potential data is considered ***Moderate*** and is the majority of the potential recharge area. As shown in Figure 2 and illustrated in Figure 4, the average of ***High*** recharge is 1 standard deviation above the overall mean and the average of ***Very High*** recharge is 2 standard deviations above the overall mean. The average of ***Low*** recharge is 1 standard deviation below the overall mean and the average of ***Very Low*** recharge is 2 standard deviations below the overall mean.

Following classification, the raster was processed into a vector polygons to be used to determine ***Critical Aquifer Recharge Areas***. Rather than a raster dataset of pixel values, a vector polygon consists of 3 or more vertices that are connected and "closed", that outlines lakes, oceans, parcels, and in this case classified groundwater recharge areas (Figure 4).

To establish ***Critical Aquifer Recharge Areas*** polygons of *high* and *very high* groundwater recharge potential were combined together. Since the conversion from raster data to vector polygons can create unnatural results, a smoothing factor was applied. A polygon smoothing factor method, *multiple ring buffer* tool, was used to address the irregularities from determining polygons from pixels. Additionally, the *dissolve boundaries* tool was used to combine adjacent polygons together to create cohesion of proximal polygons. Further to this, lone pixels and other anomalies from the process were removed manually resulting in a mapping layer that represents ***Critical Aquifer Recharge Areas*** in a scientifically sound and meaningful way (Figure 5). As shown in Figure 6, the smoothing factors generated an area slightly larger than the sum of the high and very high polygons. In addition to solving technical challenges of converting raw groundwater recharge potential raster data to a usable polygon layer, this method also integrates a spatial proximity effect used often in the assessment of changes in ecosystem services for biodiversity conservation (Liu et. al, 2016).

Delineating Boundaries for Groundwater Recharge Protection Development Permit Area

To determine boundaries for the proposed *Groundwater Recharge Protection Development Permit Area* an approach was used that calculated the area of the *Critical Aquifer Recharge Areas* for each individual land parcel on Galiano Island using a geospatial model. The DPA was then established by parcel rather than based on the derived polygons.

Several options are provided for consideration to establish the development permit area. In the case of Galiano Island, the threshold options presented are 2-hectare, 5-hectare, 10-hectare, and 20-hectare of Critical Aquifer Recharge Area on a parcel. Meaning that if the 10-hectare option is selected that any parcel that has 10 or more hectares of Critical Aquifer Recharge Area within the boundaries of that parcel, it will be included in the DPA. Consequently, if the 10-hectare option is chosen, all parcels that are less than 10-hectares are automatically excluded from the DPA regardless if those parcels have *Critical Aquifer Recharge Area* in the parcel.

This method was executed on all parcels of the island that included residential zones, commercial parcels, protected areas, parklands, and forestry lands. For completeness in this methodological memorandum, all parcels that fit the criteria have been included regardless of ownership or zoning. However, the final resulting DPA would likely not include properties that are parks or other protected areas and the LTC has the opportunity to consider excluding other classes of property. The overall methodology is presented in a flow diagram on Figure 7 and the options are presented in Figure 8.

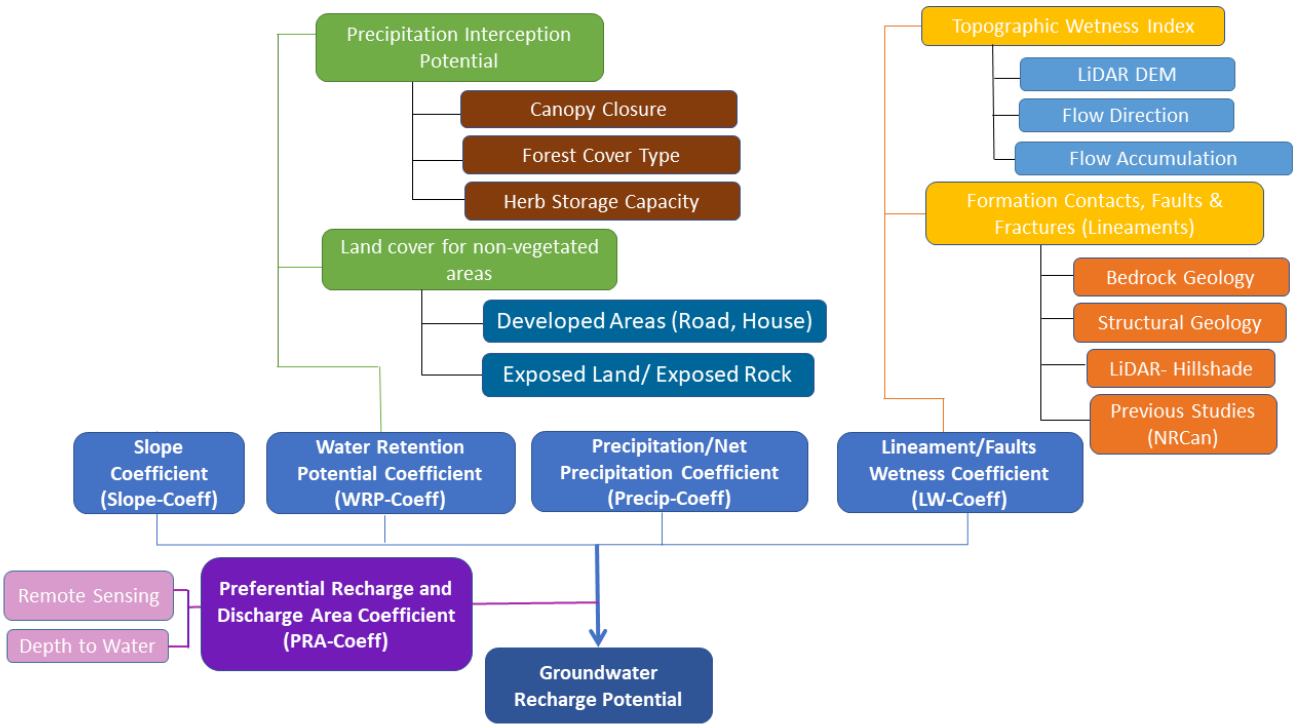

Figure 1: Islands Trust Area Groundwater Recharge Potential Mapping Methodology

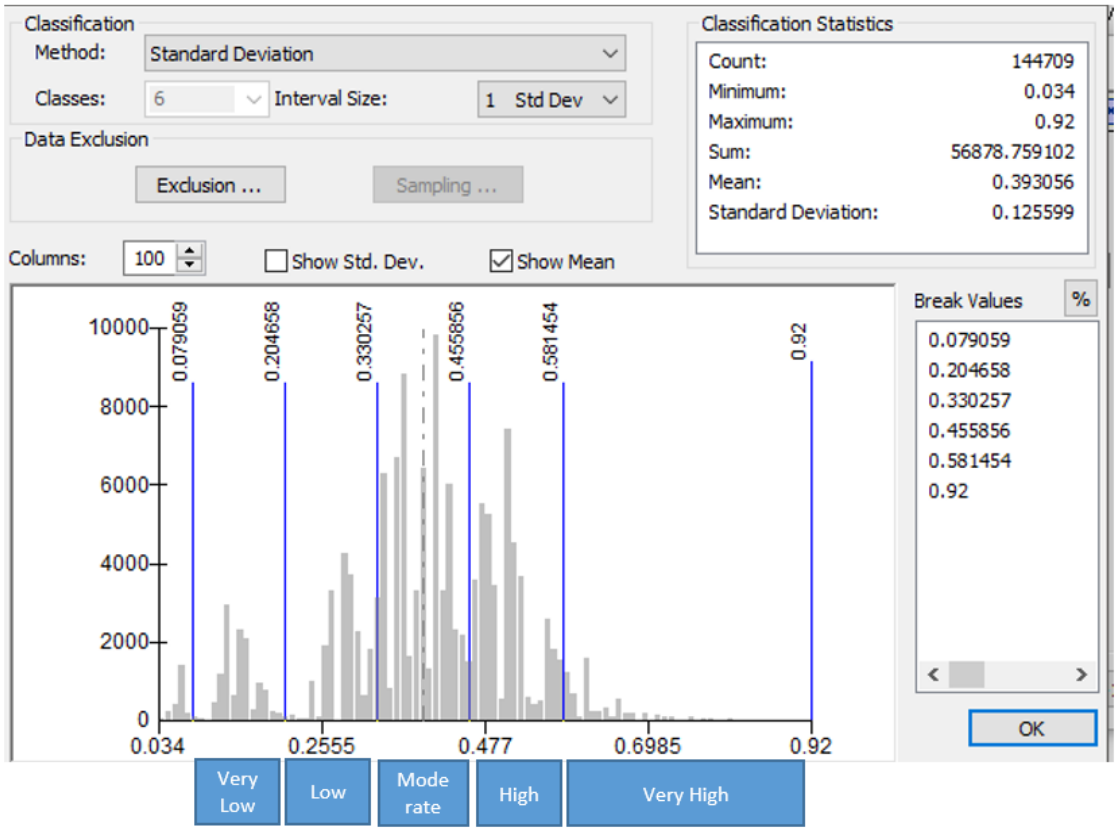

Figure 2: Galiano Islands Trust Groundwater Recharge Potential Classification Distribution

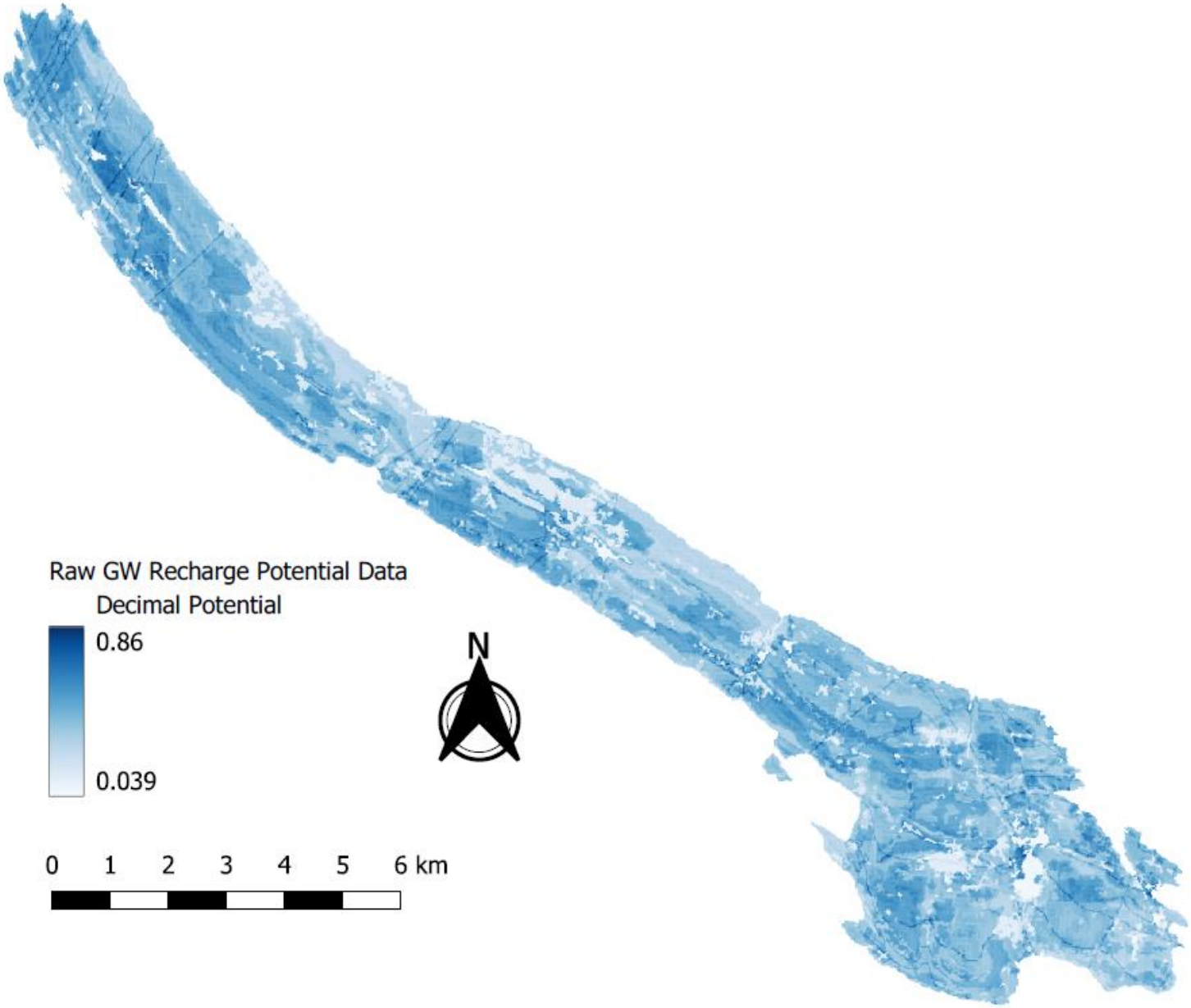

Figure 3: Raw Groundwater Recharge Potential Raster Data on Galiano Island

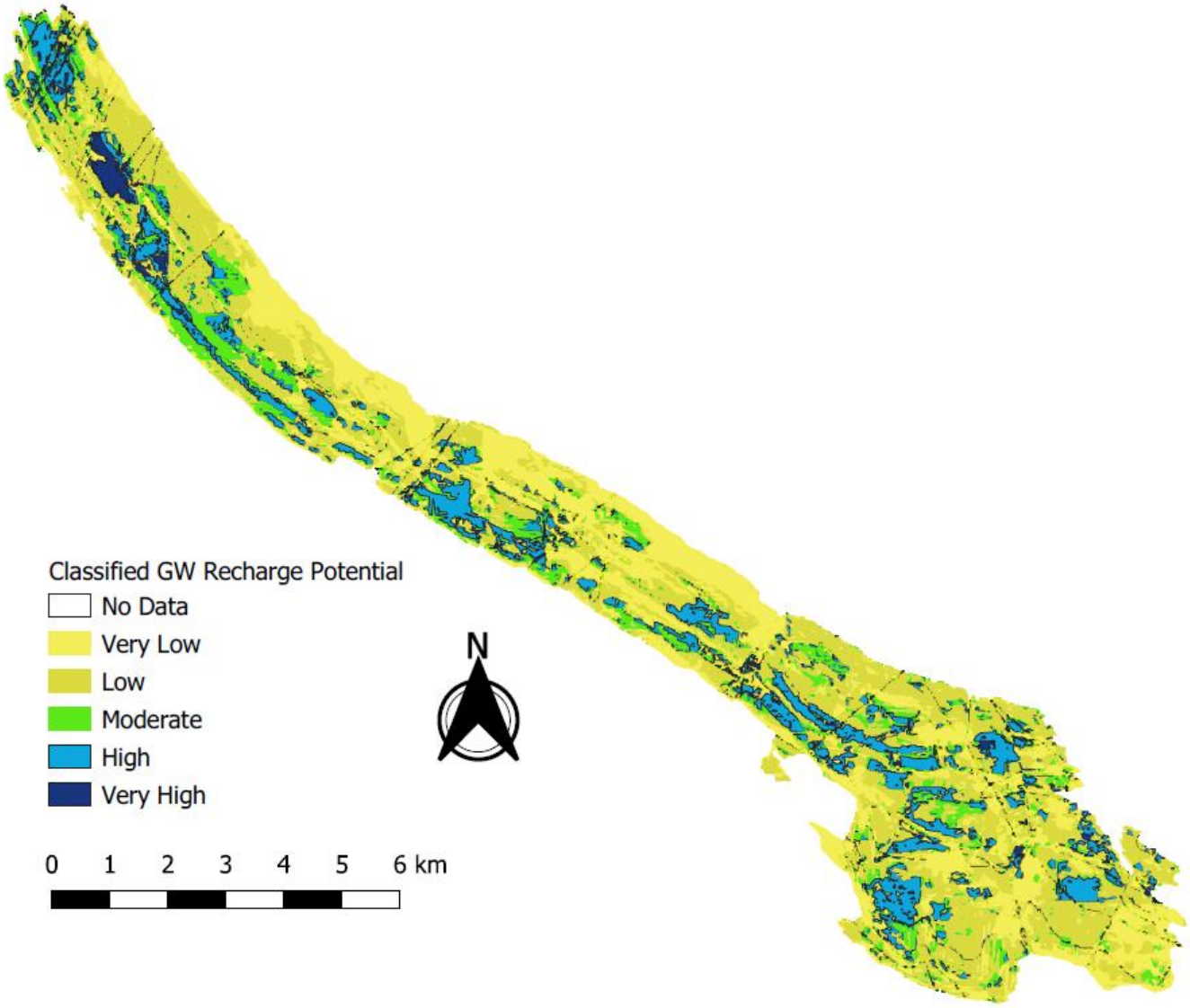

Figure 4: Classified Groundwater Recharge Potential Polygons on Galiano Island

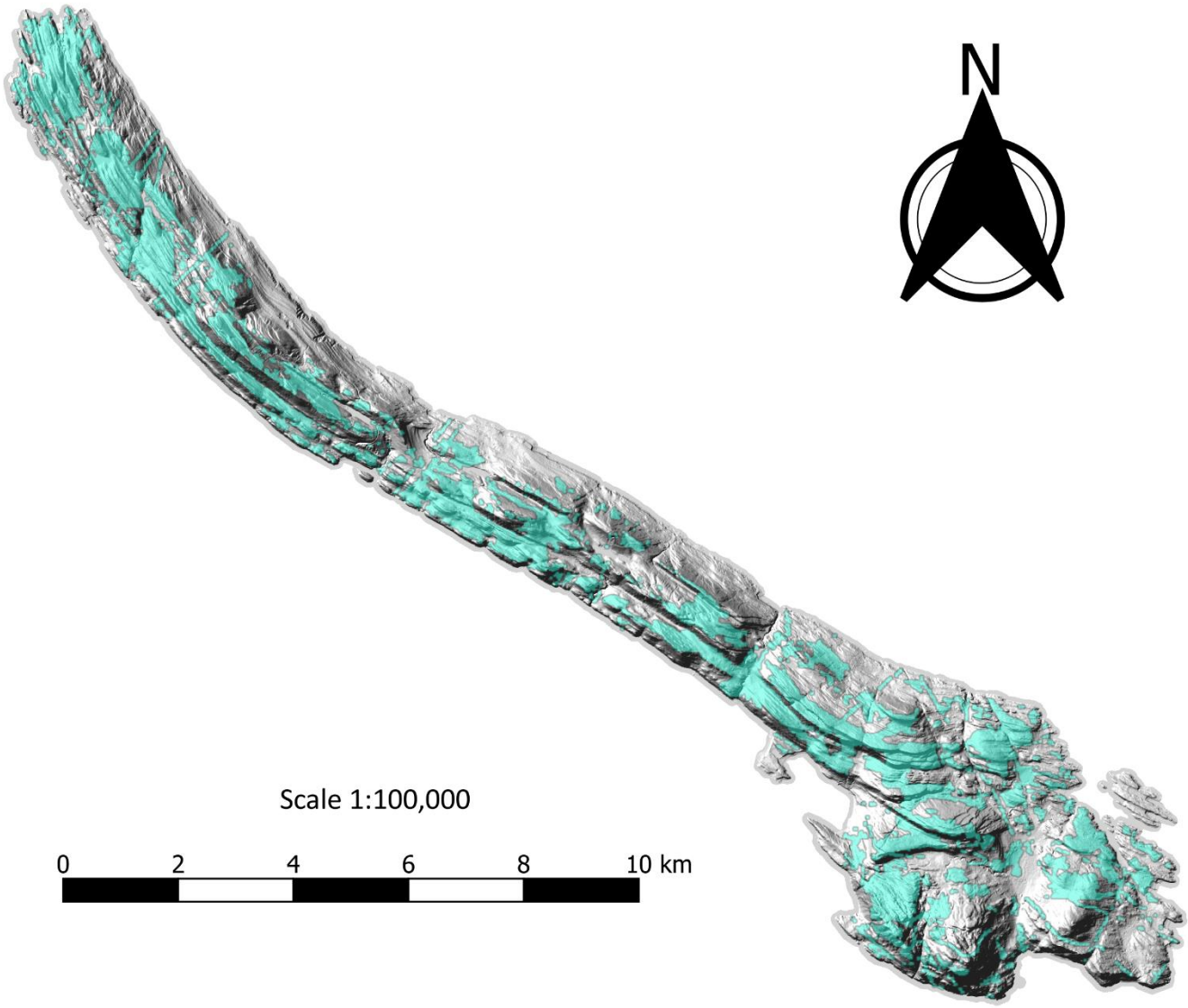

Figure 5: Critical Aquifer Recharge Areas of Galiano Island

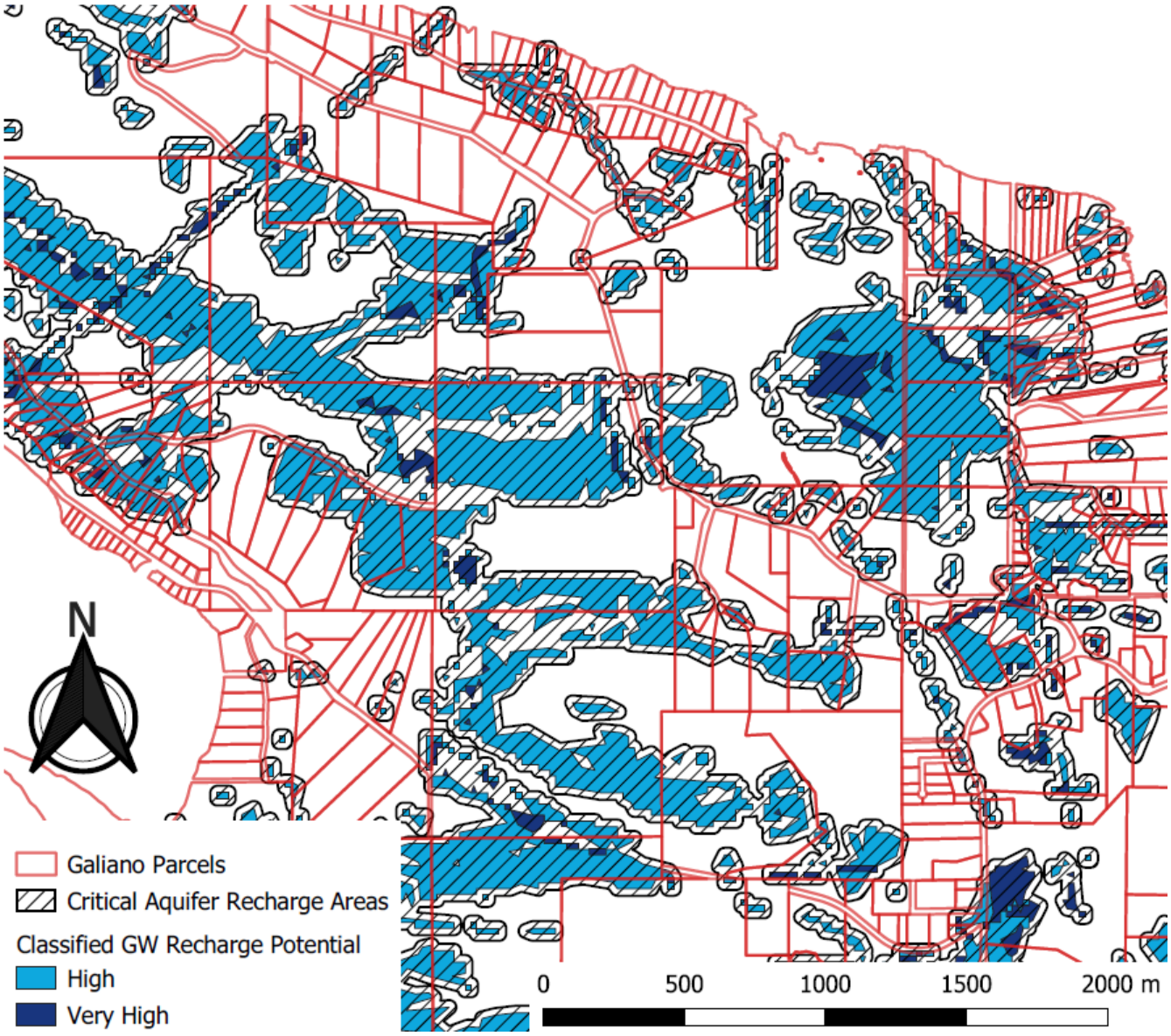

Figure 6: Critical Aquifer Recharge Areas compared to Classified Groundwater Recharge Potential to demonstrate smoothing factor.

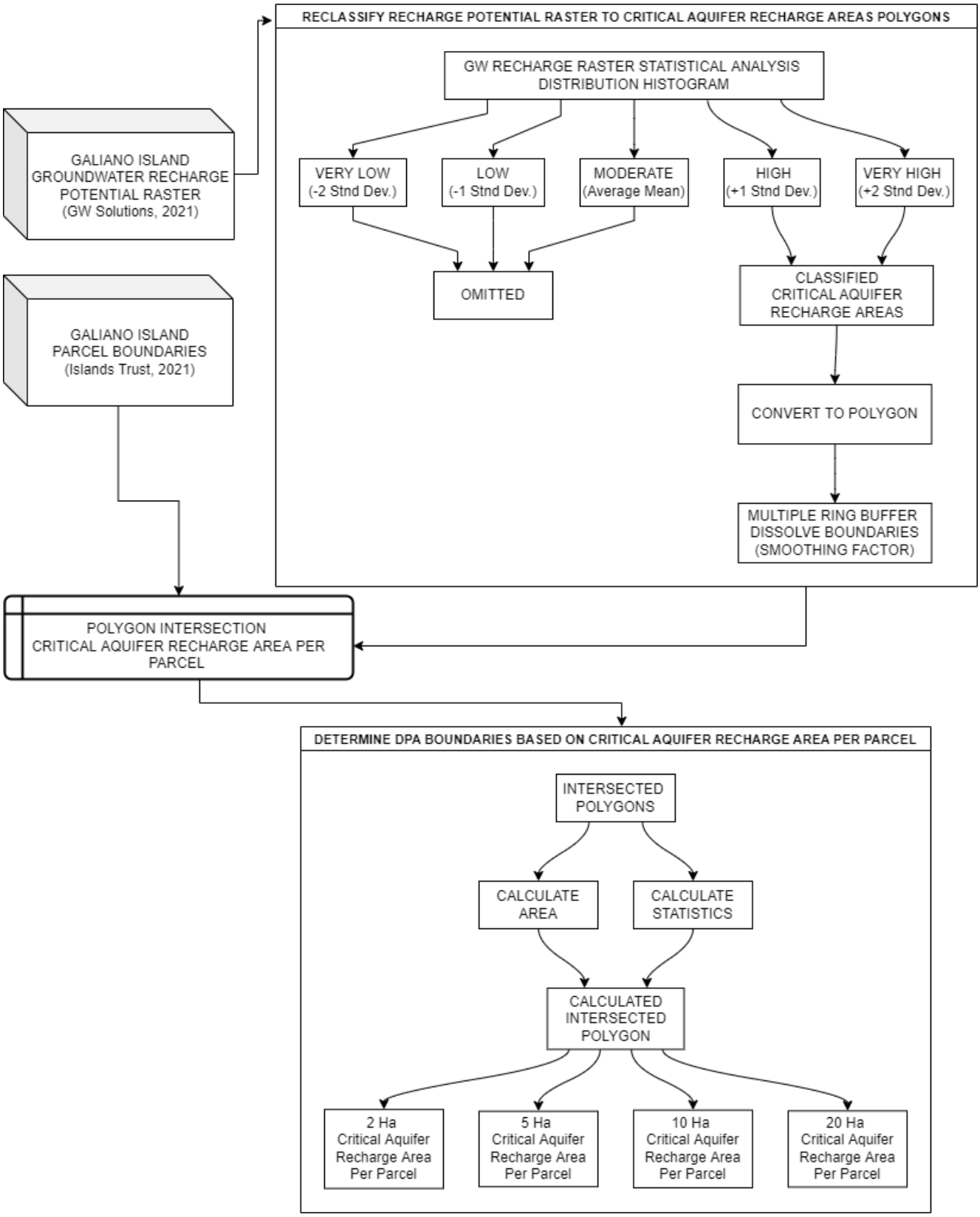

Figure 7: Galiano Island Groundwater Recharge Protection Development Permit Area Boundary Delineation Methodology

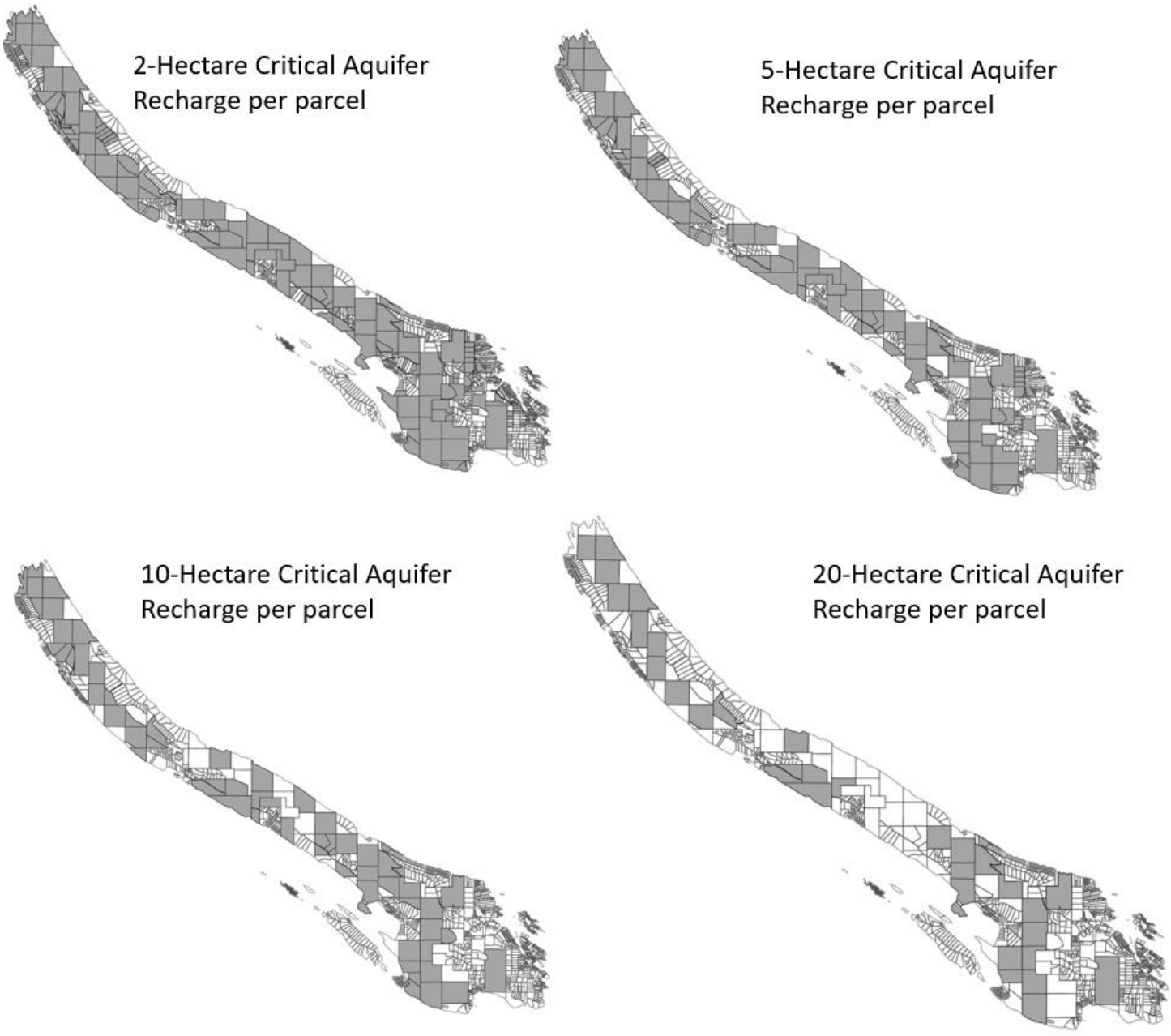

Figure 8: Groundwater Recharge Protection Development Protection Area options

ANALYSIS

The purpose of this groundwater recharge protection development permit area is to protect the ability of aquifers to produce sustainable water resources to the ecosystems and communities of Galiano Island. Islands Trust staff have proposed development permit area boundaries based on:

1. Identifying Critical Aquifer Recharge Areas from raw groundwater recharge potential raster data from the Islands Trust Groundwater Recharge Mapping project totalling 2400 hectares.

2. Identified the area of Critical Aquifer Recharge Area for all parcels on Galiano Island.

3. Identified options with respect to hectarage to be considered as a minimum threshold of Critical Aquifer Recharge Area per parcel for consideration as designation as a DPA.

4. Although Development Permit Areas do not typically include crown, federal, provincial, and park lands this methodology memorandum considered all zones and all property ownership for completeness.

Critical Aquifer Recharge Area per Parcel Option	Parcels affected	Total Critical Aquifer Recharge Area Protected (Hectares)	Percentage of Total Critical Aquifer Recharge Area Protected (%)
2-hectare	182	2095	87%
5-hectare	95	1832	76%
10-hectare	62	1591	66%
20-hectare	36	1240	51%

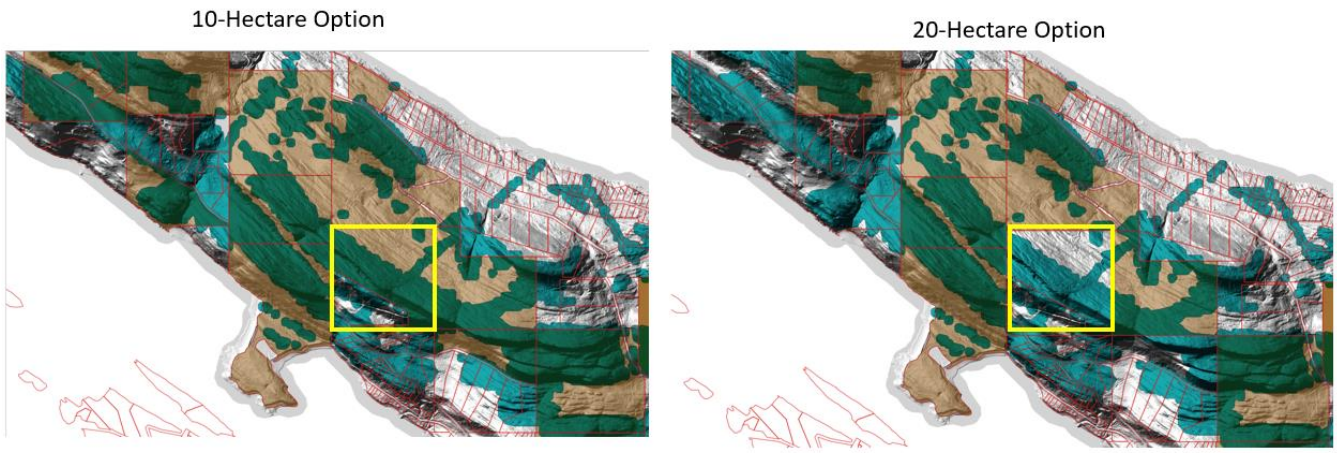

Figure 9: Difference between 10-Hectare and 20-Hectare option in an example area of Galiano Island. Brown coloured parcels indicate those located within the DPA and blue-green colour is the Critical Aquifer Recharge Area.

In Figure 9 an example comparing two options for DPA shows a large parcel with significant area of critical aquifer recharge that in the 10-hectare option is included in the DPA and in the 20-hectare option is not. This parcel is also located on a significant linear geological feature that is characteristic of significant groundwater recharge potential in fractured bedrock aquifers. Further to this, the critical aquifer recharge area located on this parcel is part of a contiguous area that is protected on adjacent parcels. If the LTC chooses the 10-Hectare option, there is an

opportunity to address these specific anomalies. For this particular parcel the area of critical aquifer recharge area is within rounding to 20-hectares (19.95 ha).

The amount of critical aquifer recharge area currently under conservation or parkland is significant. This is a testament to the long history of the Galiano community in coordination with other agencies protecting the most significant natural areas of the island. Indeed, critical groundwater recharge areas are located in forested uplands that hold significant natural amenities that contribute to ecosystem services and healthy watershed hydrology. Although these lands may be protected in some way by the managing agency, coordination with those agencies should be had to ensure best management practices on those lands to protect groundwater recharge.

The majority of critical aquifer recharge areas are located on forestry lands and small residential lots. Although development permit areas are the optimal land-use planning tool available to the Islands Trust to protect groundwater recharge, it is likely that education and advocacy around groundwater recharge protection will be most effective in protecting the resource, indeed it is the most significant tool used to date in groundwater protection.

Nearly every parcel on Galiano Island is related to groundwater resources in some way, either hosting critical aquifer recharge areas, sensitive drainage systems or indeed the use of the groundwater resource. Ultimately protection of the groundwater resources on Galiano Island is the responsibility of every resident.

NEXT STEPS

Next steps are for the Galiano LTC to consider the recommended groundwater recharge protection development permit area boundary delineation methodology.

REFERENCES

GW Solutions, 2021. Islands Trust Area Groundwater Recharge Potential Mapping report

Yanfang Liu, Lei Zhang, Xiaojian Wei, Peng Xie (2016) Integrating the spatial proximity effect into the assessment of changes in ecosystem services for biodiversity conservation, Ecological Indicators, Volume 70, 2016, Pages 382-392, ISSN 1470-160X, https://doi.org/10.1016/j.ecolind.2016.06.019.

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