

THE REGIONAL OPEN SPACE STRATEGY



ROSS, 2014

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Analyzing Actions in the Lower Puyallup Green Heart

Report by Christy Heaton, Sarah Bengtson, and Jake Hearen

Project Sponsors: Nancy Rottle and Jeff Raker, UW Green Futures Lab

RECOMMENDED COURSE OF ACTION

The Regional Open Space Strategy (ROSS) Project is creating a report focusing on strategies for increasing green space in the four-county central Puget Sound region (King, Kitsap, Pierce, and Snohomish counties). Their goal is to coalesce various disparate activities and initiatives related to open space conservation in the Puget Sound region as it faces increasing development pressures. Within this project there is a need to assess value of open space and interventions that can be taken to promote the implementation of conservation practices along with the increasing development. This project focuses on the Lower Puyallup Green Heart located in the Puyallup White Watershed. InVEST models are used to analyse various criteria for different scenarios that are proposed in the area by the ROSS project. The outputs of these models are then presented in an ESRI Story Map application for use on the ROSS project website, which we recommend as a very effective way to communicate project goals and model results. Model outputs can also be used to add value to the proposed actions and make them more appealing to those in a position to implement the proposed actions.

The goal of this project was to use InVEST models to assess quantitative values of the interventions proposed in the ROSS report. The ROSS project can benefit from ecosystem services modeling for their proposed actions in order to influence decision makers. The scenarios developed for this project have been refined and specialized for the purposes of this project and come from the Puyallup-White Watershed Open Space Strategy. Scenarios were thoughtfully created considering the priorities of the ROSS project and available time and data needs.

We recommend utilizing InVEST models such as Nutrient Retention, Carbon Sequestration, and Overlap Analysis, which are the foundation of this report, as well investigating other InVEST Ecosystems Services models such as Sediment Retention and Habitat Quality, with guidance from area technical experts to aid in valuing open space at the watershed level. Additionally, any analysis of floodplain changes resulting from changes in hydraulic structures, such as the proposed levee setbacks along the Lower Puyallup River, should begin with a future scenario (“with project”) hydrologic and hydraulic analysis using appropriate software such as the U.S. Army Corps of Engineer Hydraulic Engineering Center’s HEC-RAS and HEC-HMS. While Esri’s GeoPlanner tool would be a good way to analyze the results of the InVEST models and modify proposed open spaces, it was not used in this project due to time constraints and access to the software. We also did not consider the financial valuation of models, since this is not the focus of the ROSS project, though addition of such valuation could lend to a much more compelling argument in the future.

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The Regional Open Space Strategy

ANALYZING ACTIONS IN THE LOWER PUYALLUP GREEN HEART

INTRODUCTION

The Puget Sound is currently facing intense development pressure, which is altering the natural ecological state of the area. Some of the negative impacts of this development pressure are decreased water quality, decreased sustainability of organic agriculture, and people's access to a healthy environment including nearby green space in the form of parks and trails. The Regional Open Space Strategy (ROSS), a part of the University of Washington Green Futures Lab, is making an effort to address these growing pressures by proposing conservation and enhancement plans such as protecting priority agriculture sites, connecting existing trail networks, and improving access to green space for underserved populations.

The (ROSS) seeks to bring together regional partners and stakeholders in an effort to “conserve and enhance open space systems that contribute to the ecological, economic, recreational, and aesthetic vitality” of the central Puget Sound Region (ROSS, 2012). Open space refers to a wide and diverse spectrum of lands at a variety of scales, from rural to urban at large to small scales, that encompasses not only our traditional understanding of open space as wilderness and parks but also resource lands for agriculture and timber, wetlands and water bodies, recreational trail systems, and urban green spaces. Open spaces provide valuable ecosystem services such as biodiversity and habitat, water quality, flood control, air quality, and carbon sequestration, as well as enhancing public health and well-being through increased recreational opportunities and aesthetic quality. There exist many ongoing open space and environmental protection projects, creating a fragmented landscape of ecological priorities. The ROSS believes these efforts can be greatly enhanced by identifying and making essential connections among projects and systems, prioritizing resources where they are most critically needed, and fostering cooperative approaches to shared challenges through a full and tangible assessment of the true value and services current open space systems provide (ROSS, 2014). Our role in helping the ROSS to achieve this vision is to explore how geospatial tools can articulate the region's ability to optimize the benefits and services provided by open space.

In order to model the results of the proposed conservation or enhancement of open space projects, ecosystem valuation models can be used. Ecosystem services valuation is a way to assess the value, either financial or otherwise of an ecosystem on society. For example, what is the value of having a certain land cover type over another when it comes to the retention of nutrients flowing into local streams? If a stream gets sufficiently polluted, it will be costly to clean, much costlier than maintaining vegetative land cover which will purify the downstream water flow naturally. While this can be a controversial means of assessing the value of nature, it can often be the most effective at influencing the public and decision makers to take action (Ecosystem Valuation, 2014).

This project will use the Natural Capital Project’s Integrated Valuation of Environmental Services and Tradeoffs (InVEST) (The Natural Capital Project, 2014). These models are a free and open source tool that can be used to model ecosystem services such as nutrient retention, carbon sequestration, and overlap analysis among others. The outputs of these models can be used to quantify and visualize the outcomes of different scenarios and describe ecosystem services in an influential way.

DESIGN & METHODS

SOCIAL-ECOLOGICAL SYSTEMS TABLE

We begin our exploration of valuating open space by breaking down the scope of the ROSS into its component parts, defining the state spaces and interrelationships that hold them together to form a social-ecological system. ... The social-ecological systems table breaks down the complexity of the regional open space approach into modules for geospatial application development which can eventually be coalesced into an integrated solution. Here, we describe the state spaces of the system as the intersection of domains (columns) and geographic scales (rows). A state space can typically be thought of as a state of affairs. In the context of this project, we use an individual state space as a statement of goals. Figure 1 below details the social-ecological system at four geographic scales (a fine scale, a focal scale, a scale immediately above, and an even greater focal scale) across three dimensions (biophysical, economic, and social).

The success of the ROSS begins at the watershed level. This Watershed Open Space Strategy (WOSS) comprises seven watersheds in the central Puget Sound region. The Puyallup-White Watershed provides the first test case in articulating, evaluating, promoting, and implementing a comprehensive strategy towards regional open space management (above focal scale). Within this watershed, there are three strategic geographic areas where efforts will be focused: the White River Corridor, the Greater Rainier Conservation and Recreation Initiative, and the Lower Puyallup Green Heart. This last strategic area lies at the focal scale of this report. We have included the City of Puyallup as representing a finer scale of the social-ecological system, but we feel the scale is too fine to conduct any meaningful analysis given the larger scope of the ROSS.

SUSTAINABLE SYSTEMS MAP

The purpose of the Lower Puyallup Green Heart strategy is to undertake a multi-jurisdictional action plan to conserve, enhance and celebrate the shorelines, wetlands and rural lands along the Puyallup River, creating a rural/natural oasis in the heart of urbanized Pierce County. The strategy encompasses the following projects:

EA-1: The designation of the Green Heart itself.

EA-2: Setback levees along the Puyallup and White Rivers to provide flood risk reduction up to the 200-year level of protection.

H-1: Completion of the Seattle-Tacoma-Rainier link of the Cross State Recreational Trail.

RA-1: Initiation of a comprehensive agricultural lands and aquatic systems enhancement program.

We developed a sustainable systems map (Figure 2) to visually represent these projects and the various geospatial phenomena that impact or will be impacted by them. Additionally, location maps are included to illustrate the Green Heart’s geographic position within the larger regional context of the WOSS and ROSS.

Social-Ecological System Table ROSS Puyallup-White Watershed Open Space Strategy Goal: Coalesce various disparate activities and initiatives related to open space conservation in the Puget Sound region; assess the value of open space and interventions that can be taken to promote the implementation of conservation practices. (Adapted from PSRC’s VISION 2040 Regional Design Strategy and the Puyallup-White WOSS Report.)				
Geography		Biophysical	Economic	Social
Greater Scale	Central Puget Sound Region (ROSS)	<ul style="list-style-type: none"> Connect ecologically linked open space systems (especially aquatic systems) for greater resilience. Use ecosystem services analysis to identify key green infrastructure resources. 	<ul style="list-style-type: none"> Identify at-risk resource lands and strategies to sustain them (e.g., purchase development rights, agricultural economy programs, sustainable forestry practices, etc.). 	<ul style="list-style-type: none"> Connect urban neighborhoods to regional open space resources and enhance urban elements that also serve as open space and green infrastructure resources. Support ‘healthy communities’ programs by prioritizing recreation and activity improvements. Integrate PSRC’s transportation oriented trail plan with counties’ recreation trail planning to identify most beneficial improvements. Ensure fair access to resources for all communities and populations.
Above Focal Scale	Puyallup-White Watershed (WOSS)	<ul style="list-style-type: none"> Protection or enhancement of the Puyallup and White River corridors (aquatic ecosystems services). Development of systematic approaches/standards to address urban forestry and protect forest cover. Identification and preservation of 5 Biodiversity Management Areas within the watershed through education and stewardship. 	<ul style="list-style-type: none"> Encourage the long term viability of resource-based activities within the watershed through agricultural land preservation and interagency forest management strategies. Support agri-tourism and ecotourism to boost local economies. 	<ul style="list-style-type: none"> Increase health, active living, and access to recreation through a variety of proposals within the watershed, specifically by completing crucial recreation trail links and addressing deficit of recreational resources in North Puyallup, Pacific, Milton, and Lake Tapps vicinity
Focal Scale	Lower Puyallup Green Heart/Core	<ul style="list-style-type: none"> Construct setback levees along the Puyallup and White Rivers as a critical ecological improvement Constrain urban growth in the central area to protect existing open space and agricultural lands. 	<ul style="list-style-type: none"> Initiate comprehensive agricultural lands and aquatic systems enhancement program to prevent further loss of productive farmland and reduce flood hazards (economic loss). 	<ul style="list-style-type: none"> Complete the Seattle-Tacoma-Rainier link of the Cross State Trail to provide access to and opportunities for recreation and health.
Finer Scale	City of Puyallup			

Figure 1. Social-Ecological Systems Table

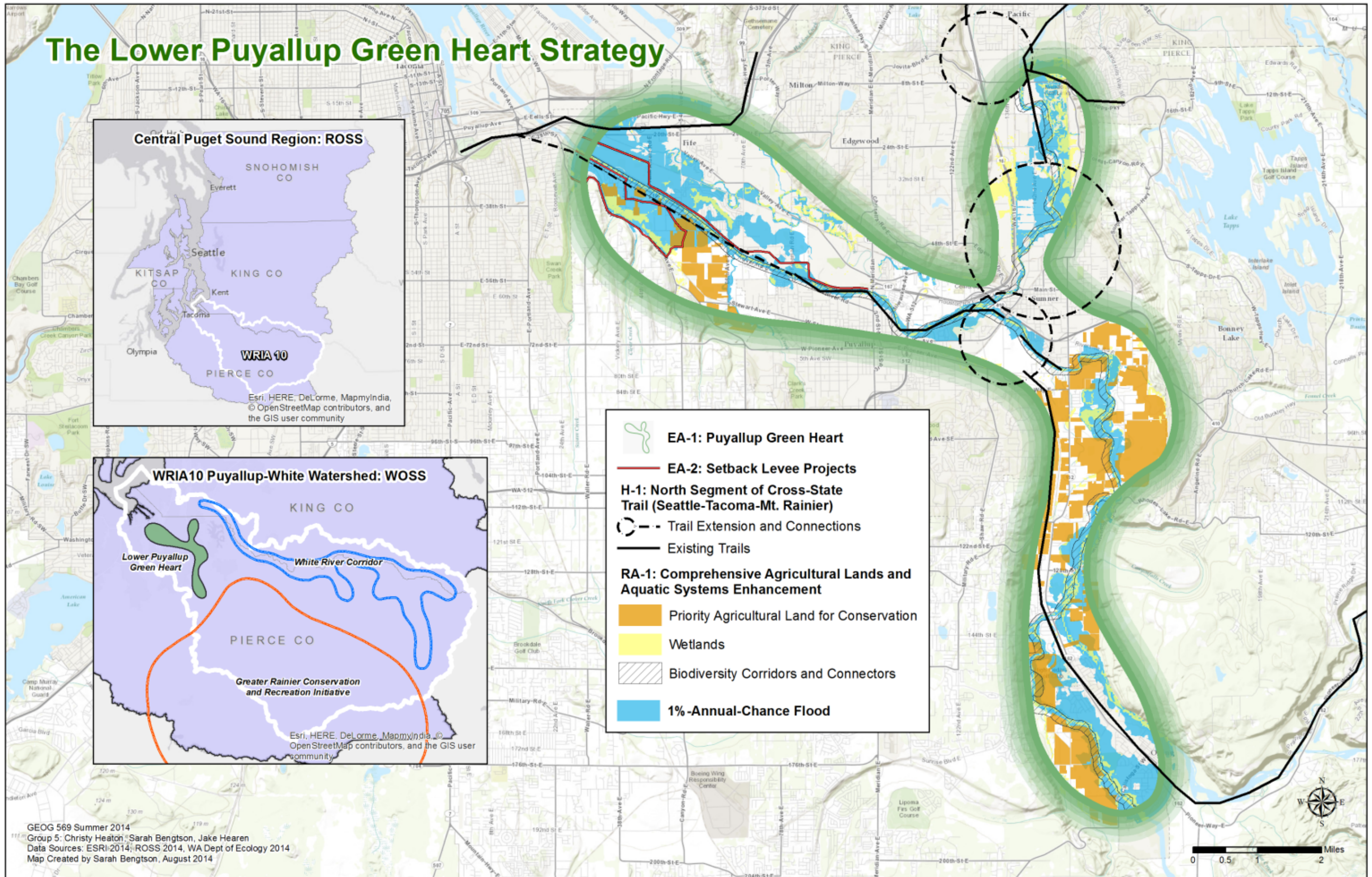


Figure 2. Sustainable Systems Map

THRESHOLDS MATRIX

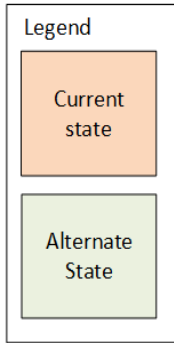
The next step in characterizing our system is to describe the characteristic and (potentially speculated or unknown) alternative states of that system and identify the controlling variables and thresholds that could push the system between states. This is represented in the Thresholds Matrix (Figure 3). The Thresholds Matrix is a chart which summarizes the thresholds of the system at different scales. Once a threshold is crossed, it may be difficult or impossible for the system to recover. If recovery is possible, it will be a difficult process involving large amounts of time and resources. The Thresholds Matrix for this project is specialized for the scales and scenarios of this project.

The cornerstone of the project's Thresholds Matrix (biophysical realm at the scale immediately above the focal scale) corresponds to the main idea of the Puyallup-White Watershed Open Space Strategy's Geographically Linked Strategies. If these strategies are implemented the area could improve its current green space, but if it is allowed to become developed, the very nature of the system may unravel. The Thresholds Matrix also brings into account the governmental aspect of the project, because decision makers are instrumental in the process. The Puyallup-White Watershed Open Space Strategy seeks to gain knowledge about the impacts of these strategies in order to influence those in power to implement said strategies. Finally, the economic component brings in the economic effects of a change in land use from agriculture to development and a possible change in local economies if there is less of an attraction to come to the area and spend money locally.

GEODATABASE SCHEMA

The geodatabase further extends our social-ecological systems table by representing the real world system as a series of features (sentence subjects and objects), attributes (adjectives), and relations (verbs). The ROSS project sponsors provided access to their ArcSDE geodatabase, which contains the vast majority of the data needed to conduct the analyses for this project. Rather than recreate the geodatabase in its entirety, we developed a file geodatabase to store only those layers pertaining to our analyses, the results of those analyses, and other base map features for use in our web map application and other static maps. This geodatabase is meant to be stored locally to facilitate faster geoprocessing and cartographic development. Figure 4 shows the geodatabase schema implemented for this project. Similar to the ROSS geodatabase, we have feature datasets for each of the four action areas – Ecosystem, Recreation and Trails, Rural and Resource Lands, and Urban and Community Development – as well as a Base_Layers feature dataset. Additionally, we have feature datasets to store outputs from the three InVEST models that were used in this project – Carbon Sequestration, Nutrient Retention and Overlap Analysis. These results are initially expressed as rasters, which are stored in the geodatabase, and we have also converted them to polygons and stored them in their respective feature datasets for use in the web map application. Finally, rasters of the land use/land cover for current conditions and scenarios 2-4 are also stored in the geodatabase and provide inputs for the Carbon Sequestration and Nutrient Retention models (discussed in the following sections of this report).

Thresholds Matrix | *The ROSS Project – GEOG 569 Group 5*



- Present results as
- InVEST Model Outputs
 - Story Map

	Map	Biophysical	Economic	Governmental/Social
Scale Further Above: The Puget Sound Region			<p>ROSS project influences decision-makers</p>	<p>ROSS project influences decision-makers</p>
Scale above: The Puyallup-White Watershed		<p>Geographically linked strategies* are implemented</p> <p>*See page 60 of Puyallup-White Watershed Open Space Strategy Report (EA1, EA2, H-1, RA-1)</p>		
Focal Scale: The Lower Puyallup Green Heart		<p>Agricultural land preserved</p> <p>Ag land converted to developed</p>		<p>ROSS Trails Built</p> <p>ROSS Trails Unmaintained</p>
Scale Below: City of Puyallup			<p>ROSS project influences decision-makers</p> <p>ROSS project uninfluential</p>	

Figure 3. Thresholds Matrix

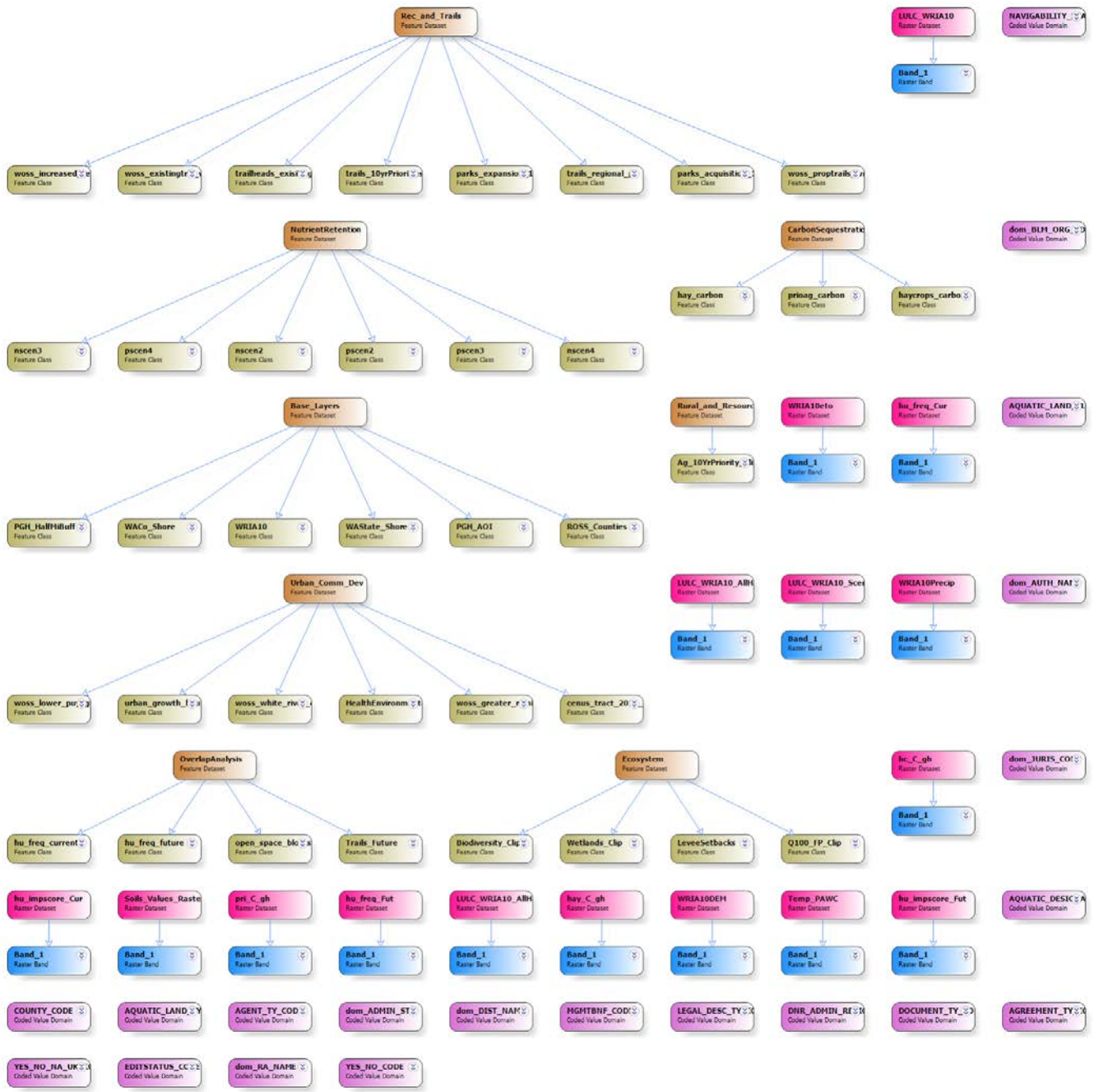


Figure 4. Local File Geodatabase Schema

INVEST OVERLAP ANALYSIS MODEL

It is important to look at the various overlap of different activities that are important to society in the focal scale. The INVEST Overlap Analysis Model is designed to determine the areas within a region that are the most important for human use. The model calculates both frequency and importance of input activities. Weights can be added to each individual activity and this will affect the importance output. However, this was not included in this analysis. In discussions with project partners, we decided to

examine the overlap of five different uses: wetlands, open space, trails, agriculture, and floodplains. Among the ROSS project proposals is the expansion and increased connectivity of the existing trail system. Therefore, this model was used to analyze the difference in the use frequency raster output if the current trail system remains as it is, and if the ROSS proposed trails system is built and connected to the existing trail network.

General model input parameters consist of:

1. A workspace
2. A directory containing the shapefiles of interest in the study area, representing various human uses, weights of individual areas are an optional parameter
3. Analysis cell size
4. Overlap Analysis Data Directory

Outputs of this model are:

1. Use Frequency raster, depicting the frequency of activities for each cell
2. Importance Score raster, depicting the importance score for each cell

We describe the two trail scenarios (current and future) and their associated data inputs and outputs for each below.

Scenario 1: Current Trail System Persists			
Input (shapefiles of interest):			
High Priority Agriculture	shapefile	AgLand_FromParcels_10yr_WRIA_10_12_1.shp	ROSS Database
Floodplains	shapefile	Floodplain.shp	ROSS Database
Open Space	shapefile	open_space_blocks.shp	ROSS Database
Current Trails	shapefile	Trails_Current.shp	ROSS Database
Wetlands	shapefile	Wetlands.shp	http://www.ecy.wa.gov/services/gis/data/data.htm
Output:			
hu_freq.tif	raster	hu_freq_Current.tif	
huimpscore.tif	raster	hu_freq_Future.tif	

Table 1. Scenario 1 Inputs and Outputs

Scenario 2: Trails Expanded			
Input (shapefiles of interest):			
High Priority Agriculture	shapefile	AgLand_FromParcels_10yr_WRIA_10_12_1.shp	ROSS Database
Floodplains	shapefile	Floodplain.shp	ROSS Database
Open Space	shapefile	open_space_blocks.shp	ROSS Database
Future Trails	shapefile	Trails_Future.shp	ROSS Database
Wetlands	shapefile	Wetlands.shp	http://www.ecy.wa.gov/services/gis/data/data.htm
Output:			
hu_freq.tif	raster	hu_freq_Current.tif	
huimpscore.tif	raster	hu_freq_Future.tif	

Table 2. Scenario 2 Inputs and Outputs

Most data required for modeling uses existing data available online or in the ROSS database, however, some data processing was required in order to modify data for use in different scenarios. Existing trails data from the ROSS project database is sufficient for use in Trails Scenario 1. Current trails in WRIA 10 and proposed trails for WRIA 10 can be found in the ROSS project database. Using ArcGIS geoprocessing tools, both current and planned trails data were merged into one. Some digitization was required to logically connect any missing parts between current and future trails. Communication with project sponsors provided guidance into the manner of connecting the trail system, with the main priority being that they do in fact connect, even if some portions of the trails are not likely accurate of where they would actually be built. The two trail scenarios can be seen in Figure 5.

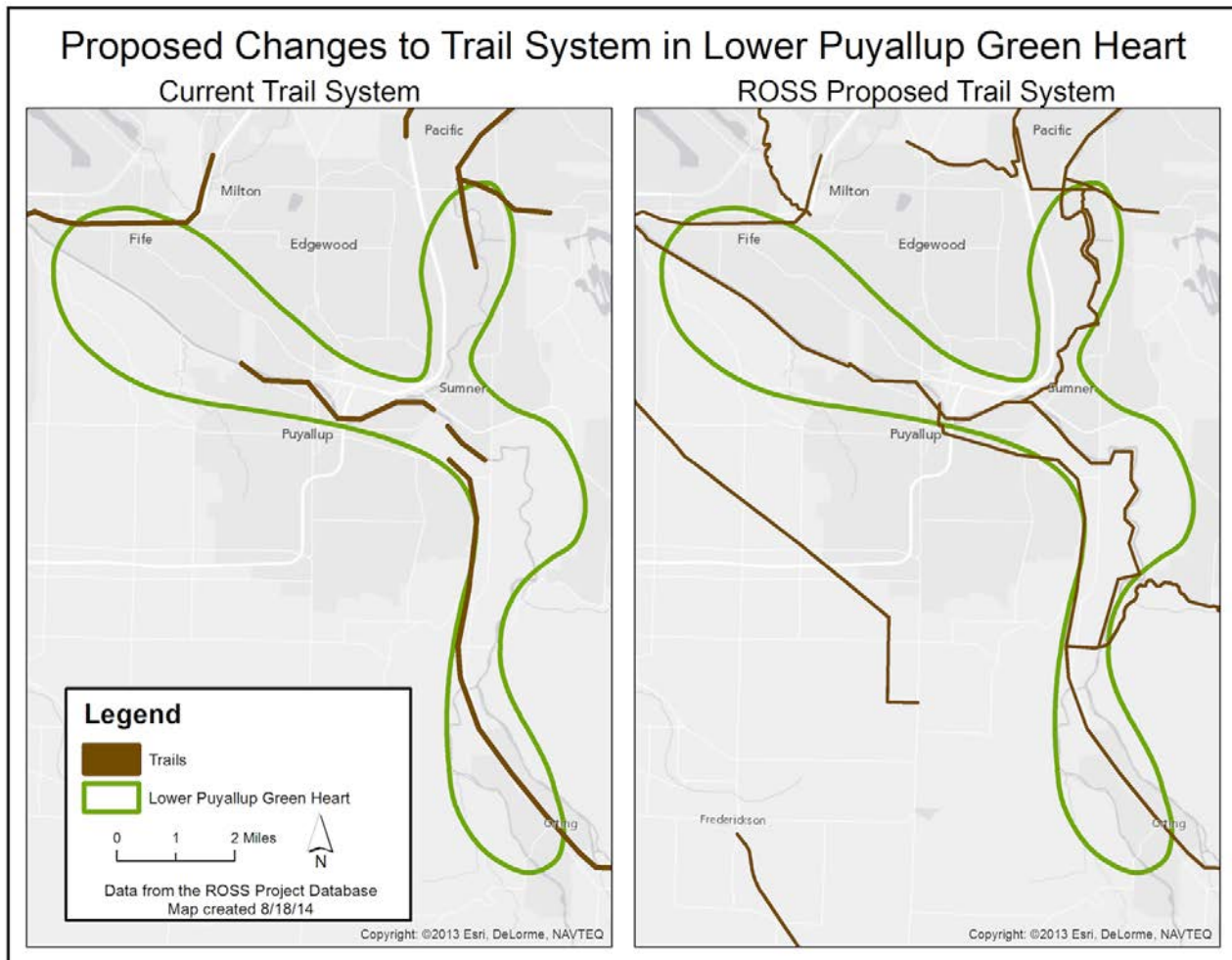


Figure 5. Overlap Analysis, Current and Future Trails Scenarios

All input data needs to be in a folder with no other data for input into the model. A sample run of the future scenario can be seen in Figure 6.

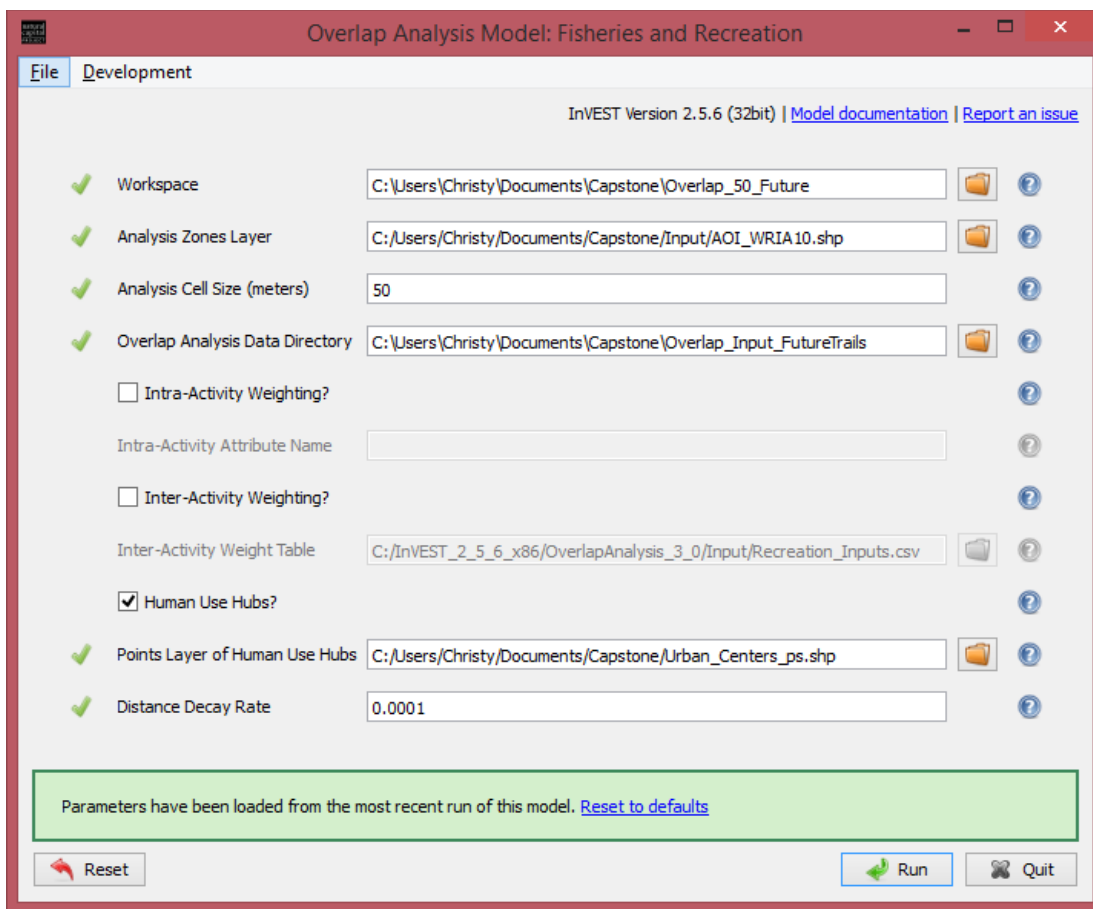


Figure 6. Overlap Analysis Model Interface

Analysis Cell Size was set to 50, as this was determined to be a reasonable size for the scale in question. Intra and Inter activity Weighting was not included in this analysis, as the project sponsors did not feel that the necessary information was available to make this an improvement in the model output. Human Use Hubs were used and defined as the Urban Centers. This data is located in the ROSS database. Distance Decay Rate was set to 0.0001 as this is the default input for the model.

Using these inputs, the model was run successfully for both scenarios.

INVEST NUTRIENT RETENTION MODEL

Nutrient retention is an important ecosystem service and a natural way to keep streams clean. Some vegetative land cover retains more nutrients than others and more than developed land. The InVEST Nutrient Retention model is more complex than the Overlap Analysis model. This model calculates the amount of nitrogen and phosphorous export at the pixel level as well as at the watershed level by looking at land use cover and soil characteristics.

For our test of the Nutrient Retention Model, we designed and modeled the following land use/land cover scenarios:

Scenario 1: Current land use persists.
Scenario 2: High priority agriculture areas as defined by the ROSS project are converted to Developed, Medium Intensity.
Scenario 3: All land cover currently defined as Hay/Pasture is converted to Developed, Medium Intensity.
Scenario 4: All land cover currently defined as Hay/Pasture or Cultivated Crop is converted to Developed, Medium Intensity.

The base Land Use/Land Cover raster is that which was obtained from the GIS Data Gateway (Figure 7).

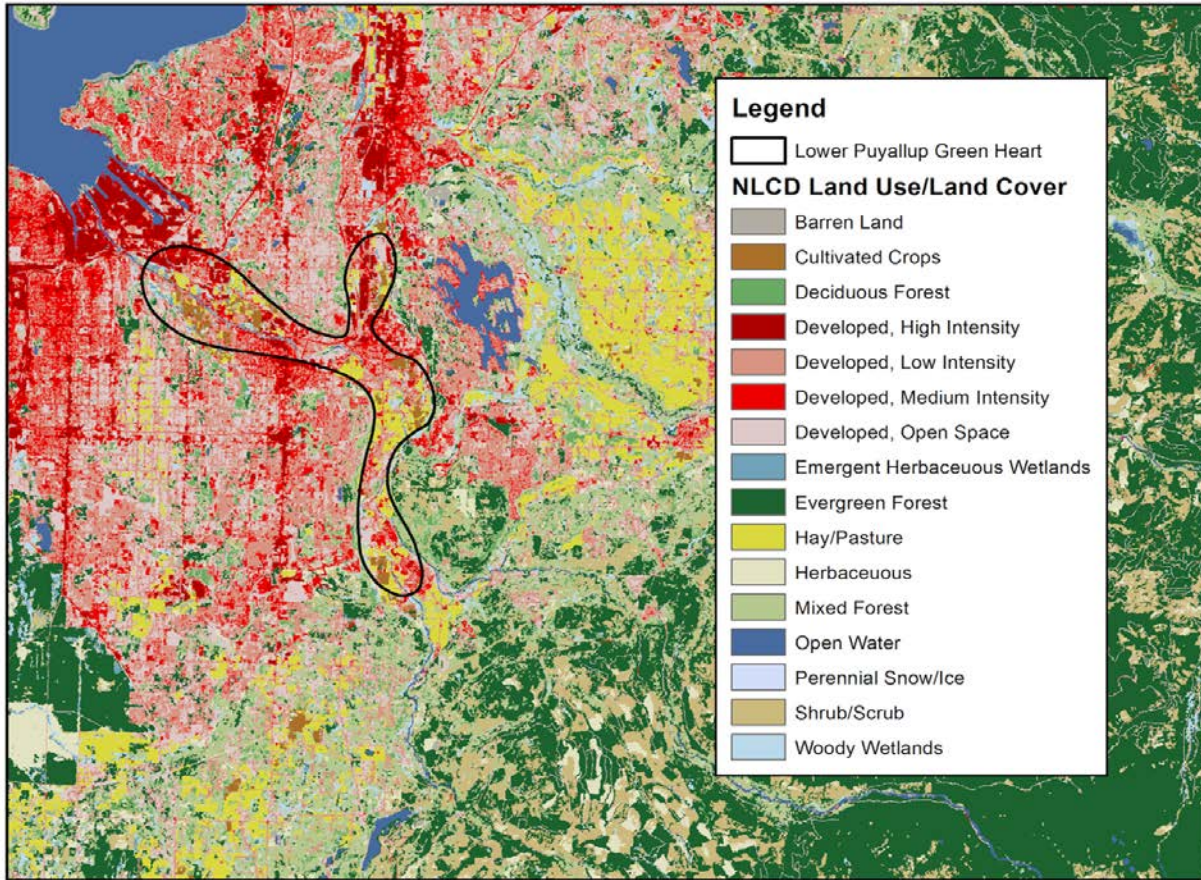


Figure 7. NLCD Land Use/Land Cover, Scenario 1

A model run using current land use characteristics was run using input data as shown in Table 3. Additional model inputs include the Seasonality Constant, the Threshold Flow Accumulation, the Biophysical Table, and the Water Purification Thresholds Table. The values were left as the default and the Biophysical Table was the table included with the model download. The model runs included both nitrogen and phosphorous, but not financial valuation. Using this input data the model was run successfully and outputs were directed to the workspace folder.

A model run of Land Use/Land Cover Scenario 1 can be seen in Figure 8.

Scenario 1: Current			
Data Input	Data Type	Local Name	Source
Land Use Land Cover	raster	LULC_WRIA10.tif	http://datagateway.nrcs.usda.gov
Root to Depth Restricting Layer	raster	Soils_Values_Raster.tif	http://datagateway.nrcs.usda.gov
Subwatershed Polygons	shapefile	Subwatersheds.shp	http://www.ecy.wa.gov/services/gis/data/data.htm#w
Watershed Polygons	shapefile	Watersheds.shp	http://www.ecy.wa.gov/services/gis/data/data.htm#w
DEM Raster	raster	WRIA10DEM.tif	http://gis.ess.washington.edu/data/raster/tenmeter/byquad/index.html
Evapotranspiration	raster	WRIA10eto.tif	http://www.cgiar-csi.org/data/global-aridity-and-pet-database#download
Precipitation	raster	WRIA10Precip.tif	http://www.climatewizard.org/#
Plant Available Water Content	raster	Temp_PAWC.tif	http://datagateway.nrcs.usda.gov
Water Purification Threshold Table	table	water_purification_threshold_test2.csv	http://datagateway.nrcs.usda.gov
Biophysical Table	table	biophysical_table_test.csv	C:\InVEST_2_5_6_x86\Nutrient_Retention\Input

Table 3. Nutrient Retention Scenario 1 Inputs

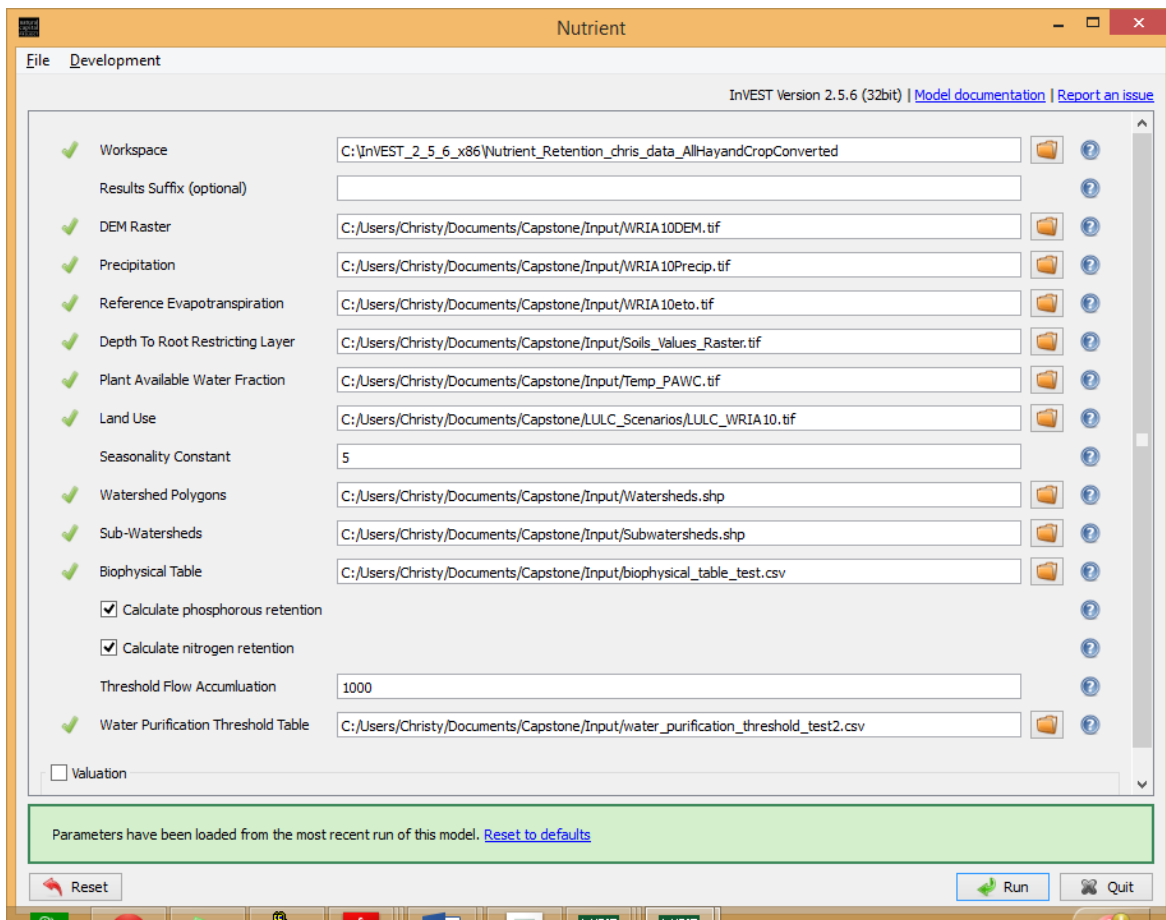


Figure 8. Nutrient Retention Model Interface

Scenario 2 involves changing all Priority Agricultural lands as designated by the ROSS project to Developed, Medium Intensity. Priority Agricultural data in polygon format is located in the ROSS Project database. There are two areas in the database designated as priority agriculture. These represent ROSS proposed priority agricultural lands as designated by parcels and zoning respectively. These two polygons were merged using ArcGIS geoprocessing tools. Using the merged polygons, the Land Use/Land Cover raster was clipped to this area. The extent of these merged areas can be seen in Figure 9.

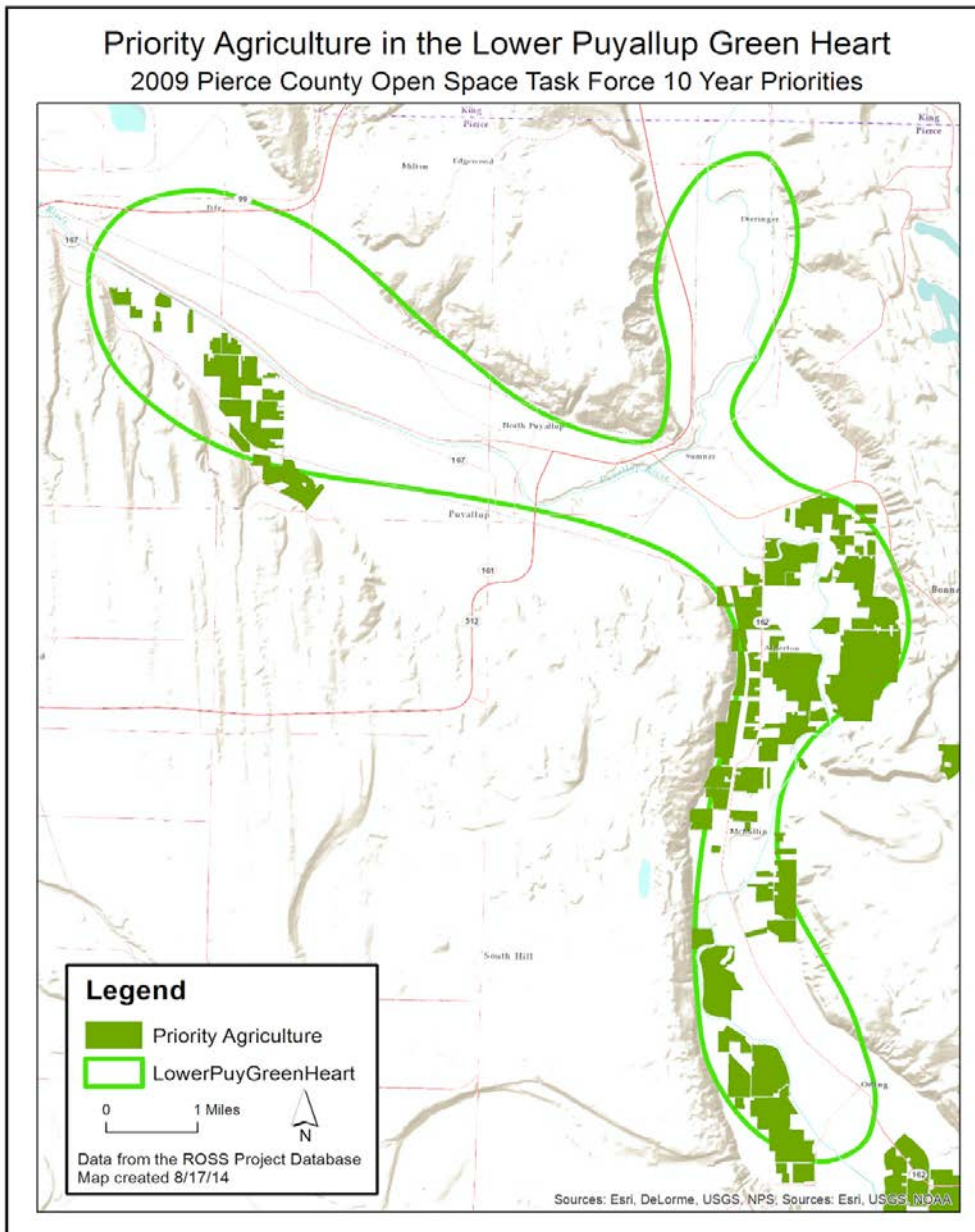


Figure 9. Priority Agricultural Lands (ROSS, 2014)

The Land Use/Land Cover Raster was clipped to the Lower Puyallup Green Heart and then clipped again to the merged Priority Agriculture polygons (Figures 10 and 11, respectively).



Figure 10. LULC of the Lower Puyallup Green Heart

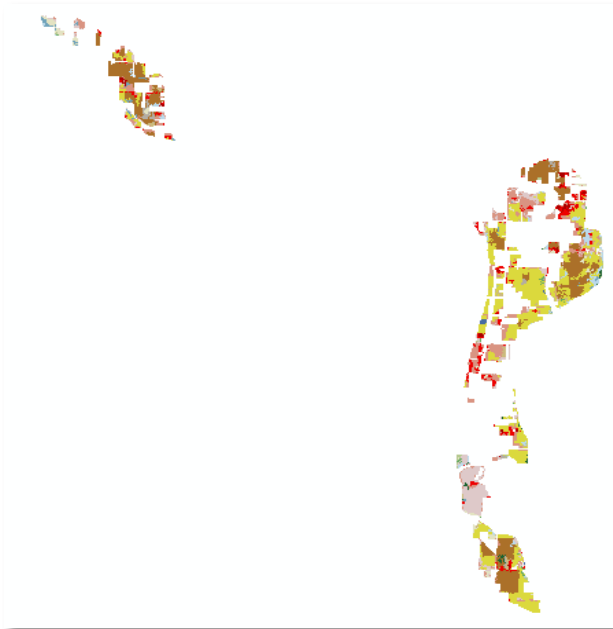


Figure 11. LULC within Priority Agricultural Lands

The clipped Land Use/Land Cover shows the majority of pixels designated as Hay/Pasture and Cultivated Crop. There are also some areas designated as Light or Open Development. This clipped area was then reclassified to be entirely Developed, Medium Intensity (code 23 in the Land Use/Land Cover data)(Figures 12 and 13).

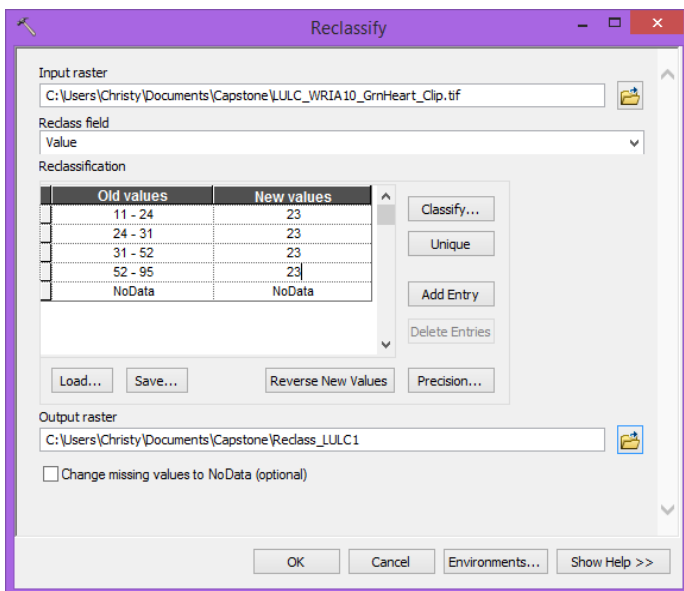


Figure 12. Raster Reclassify Tool



Figure 13. Developed, Medium Intensity

This area now needs to be added back to the original Land Use/Land Cover data, with only these cells remaining classified as Developed, Medium Intensity. The Mosaic to New Raster tool can be used for this task (Figure 14). This tool takes in the original raster and the altered raster. The parameters must be set up to map the appropriate rasters to either the Mosaic Operator (clipped raster) or the Mosaic Colormap Mode (original raster). The output of this tool is the modified Land Use/Land Cover raster to be used in Land Use/Land Cover Scenario 2 (Figure 15).

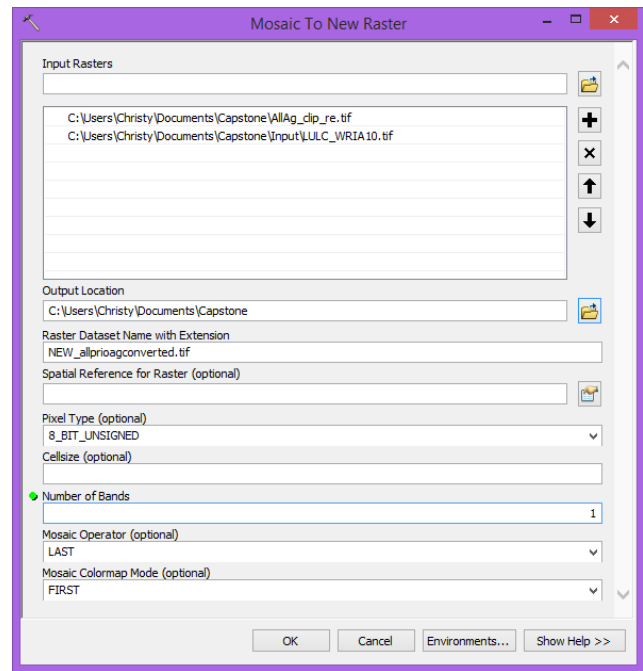


Figure 14. Mosaic to New Raster Tool

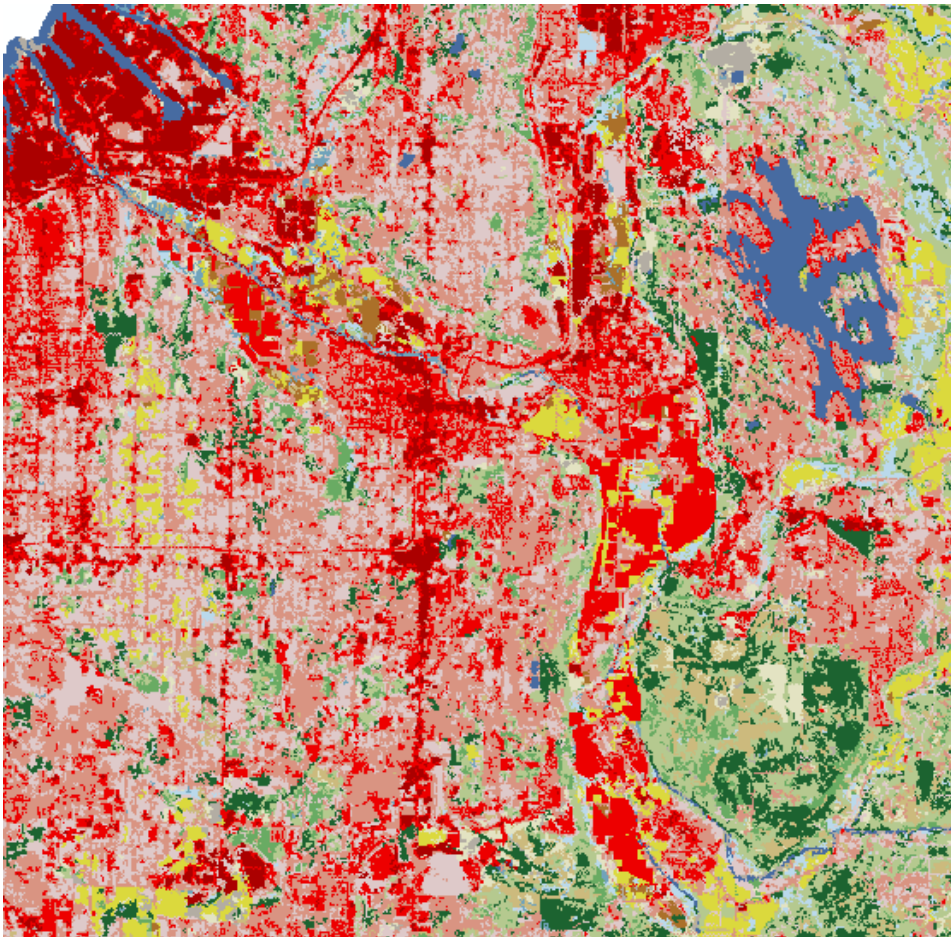


Figure 15. Revised LULC Raster, Scenario 2

The process of creating the Land Use/Land Cover raster for scenario 3 was similar to that used to create Scenario 2. The original Land Use/Land Cover was clipped to the Lower Puyallup Green Heart and then just cells within that clipped raster which were designated as Hay/Pasture (code 81) were reclassified as Developed, medium intensity (code 23).

Then as in Scenario 2, the Mosaic to New Raster was used to join this data back to the original Land Use/Land Cover and this data was ready for use in Scenario 3.

The process of creating the Land Use/Land Cover raster for scenario 4 was the same as that that used to create Scenario 3, except that cells within that clipped raster which were designated as Hay/Pasture (code 81) or Cultivated Crop (code 82) were reclassified as Developed, Medium Intensity (code 23). The Mosaic to New Raster was used to join this data back to the original Land Use/Land Cover and this data was ready for use in Scenario 4.

The same process was used to run the model on Land Use/Land Cover scenarios 2, 3, and 4 simply replacing the Land Use/Land Cover Input with the appropriate data.

The differences in outputs of the different scenarios can be difficult to identify in the raw data. In order to highlight the differences, our team decided to further process outputs to calculate just the differences in scenarios. ArcGIS Raster Calculator was used to subtract Scenario 1 from Scenarios 2, 3, and 4. It was also necessary to calculate the actual difference in nitrogen and phosphorus exported for each scenario. This information was obtained by using the watershed shapefile output of the Nutrient Retention model. This shapefile has an attribute table which has totals of nitrogen and phosphorus export summed at the watershed level. Nitrogen and Phosphorus totals can be found by calculating the statistics on these fields and looking at the Sum.

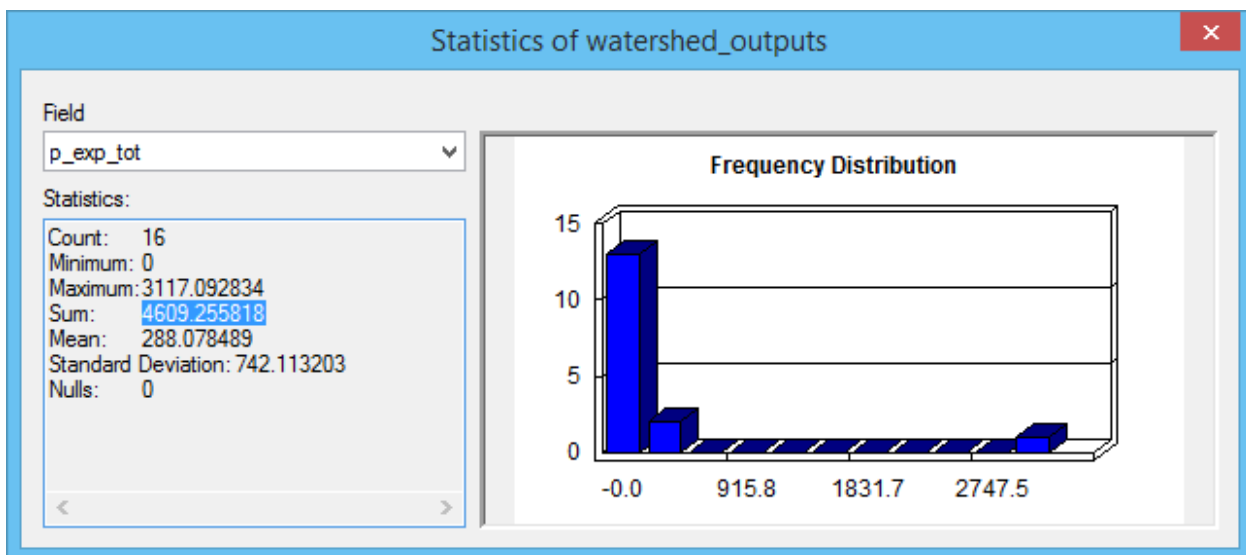


Figure 16. Watershed Outputs Statistics

The sums of nitrogen and phosphorous for Scenario 1 were subtracted from those for Scenarios 2, 3, and 4 in order to get the additional nitrogen and phosphorus exported by scenario.

INVEST CARBON SEQUESTRATION MODEL

The Carbon Sequestration model incorporated in the InVEST model set calculates the amount of carbon that becomes trapped within the environment. This calculation, detailed below, derives principally from a LULC raster by using an associated table (Table 4). The table assigns a value to each class within the raster to visually depict what each environmental factor is capable of sequestering.

Data Input	Data type	Local Name	Source
Workspace	Folder	*/carbon_seq	User Input
Suffix	Text	1) [no suffix] 2) *_pri 3) *_hay 4) *_crop	User Input
Land Use/Land Cover	Raster	1) LULC_WRIA10.tif 2) LULC_WRIA10_pri.tif 3) LULC_WRIA10_hay.tif 4) LULC_WRIA10_crop.tif	Initial LULC raster accessed from http://datagateway.nrcs.usda.gov Subsequent rasters manipulated by group
Uncertain Carbon Pools	CSV Table	uncertainty_carbon_pools.csv	Derived from Natural Capital Project's sample table
Confidence Threshold	Numeric	-----	User Input

Table 4. Carbon Sequestration Inputs

All scenarios are introduced in the order that they were run. Scenario one involves analyzing the current Land Use/Land Cover (LULC), scenario two analyzes the lands deemed as conservation priorities, scenario three analyzes the carbon sequestration if all hay/pasture land were converted to developed land, and scenario four analyzes if all hay/pasture and croplands were developed. These are the same LULC rasters as used in the Nutrient Retention model. Each of these is given the suffix detailed above to differentiate the results within the workspace's output table.

The Uncertainty Carbon Pools table (Table 5) extends the sample table also provided by InVEST for the model's uncertainty analysis. In this analysis, the carbon pools are given an error buffer by including the standard deviation. In doing so, the result depicts a confidence level that can indicate the most likely amount of carbon that can be sunk into a given environment. However as all things are not exact, the table utilizes standard deviation to indicate the progressive likelihood that an environmental feature will continue to take on carbon from the surrounding environment. During our evaluation of the environment, the model was run at 90% confidence. This means that elements within the environment are 90% likely to sequester the calculated amount of carbon.

The table below is based upon the uncertainty carbon pools table provided with the InVEST models at the time of download. However, the sample table is far more in-depth and includes classes such as a breakdown of forests by age and more types of agricultural. For instance, multiple fields in the original

table dealt with the carbon retention of coniferous trees by age while the LULC analyzed made no age distinction of fauna. We have therefore chosen a more conservative route and took the lowest reasonable value for a given field rather than averaging similar fields. This was done to mitigate the potential error of over-averaging for areas such as a partially clearcut field; while the field might be composed of mostly saplings with sparse old growth, averaging the two variables would provide a false variable.

Class Name	Class Code	MEAN				STANDARD DEVIATION			
		ABOVE	BELOW	SOIL	DEAD	ABOVE	BELOW	SOIL	DEAD
Water	11	0	0	0	0	0	0	0	0
Snow/Ice	12	0	0	0	0	0	0	0	0
Developed, Open Space	21	0	0	0	0	0	0	0	0
Developed, Low Intensity	22	0	0	0	0	0	0	0	0
Developed, Medium Intensity	23	0	0	0	0	0	0	0	0
Developed, High Intensity	24	0	0	0	0	0	0	0	0
Barren	31	0	0	0	0	0	0	0	0
Deciduous Forest	41	10	7	76	2.5	2	1.4	15.2	0.5
Evergreen Forest	42	13	28	95	2	2.6	5.6	19	0.4
Mixed Forest	43	10	7	76	2.5	2	1.4	15.2	0.5
Shrubland	52	8	8	25	3	1.6	1.6	5	0.6
Grassland	71	6	6	20	2	1.2	1.2	4	0.4
Hay/Pasture	81	5	4	23	1	1	0.8	4.6	0.2
Agriculture	82	3	2	10	0	0.6	0.4	2	0
Woody Wetland	90	7	3	25	0	1.4	0.6	5	0
Herbaceous Wetland	95	10	5	20	0	2	1	4	0

Table 5. Uncertainty Carbon Pools

RESULTS

OVERLAP ANALYSIS MODEL

There are two outputs of the Overlap Analysis model. The high use frequency output of the Overlap Analysis model runs for Trail Scenarios 1 and 2 can be seen in Figure 17. Additional output from the model depicts the importance score for each of the two scenarios. For the moment, we have chosen not to explore this aspect of the Overlap Analysis Model because we lacked sufficient guidance and time to determine appropriate inputs parameters.

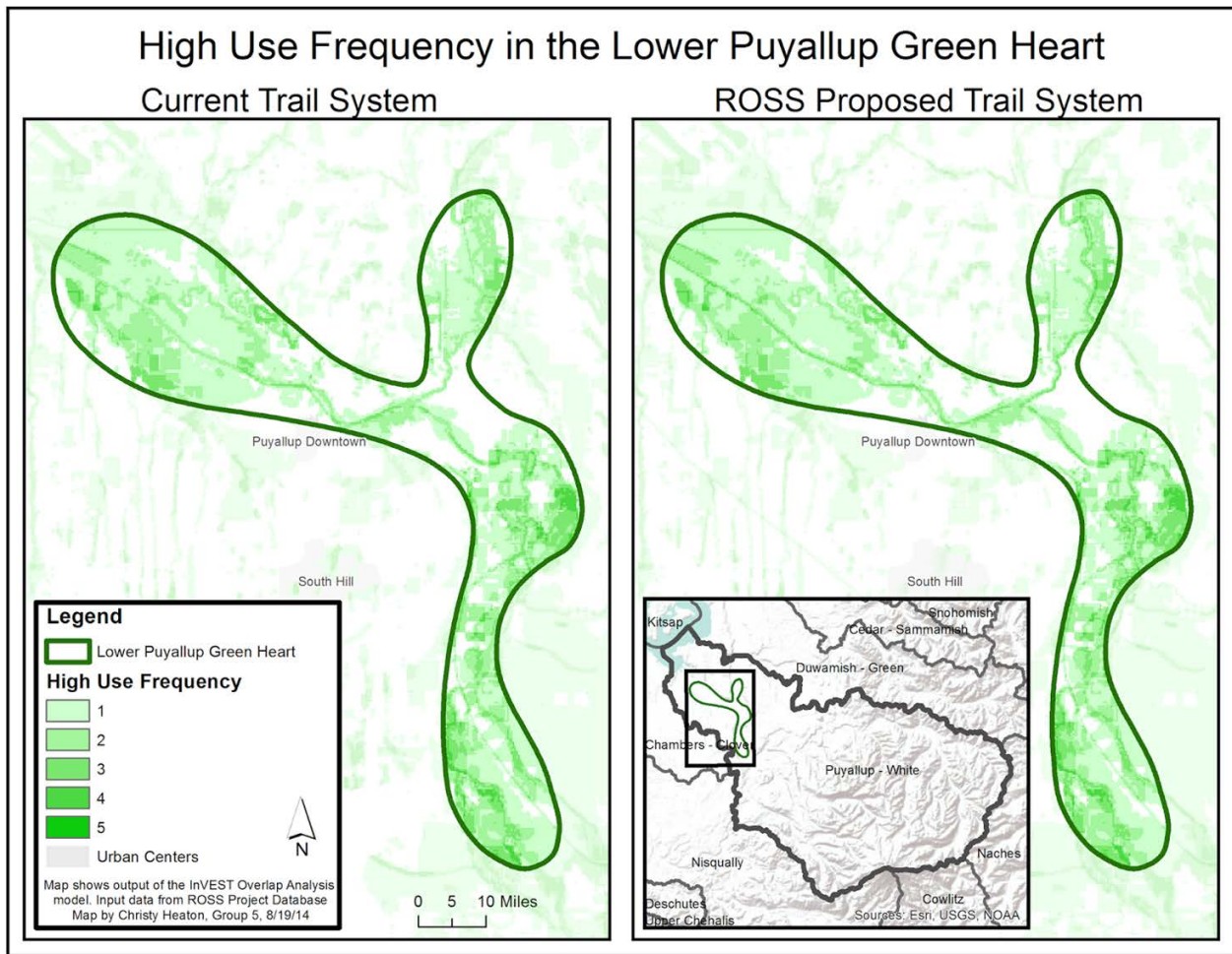


Figure 17. Overlap Analysis Results, High Use Frequency

NUTRIENT RETENTION MODEL

There are three outputs of the Nutrient Retention model, two rasters and one polygon. The two rasters represent nitrogen and phosphorous export at the pixel level. The polygon represents the same watersheds used in the input of the model and has attributes representing nitrogen and phosphorous retention and export.

The nitrogen export at the pixel level output for Land Use/Land Cover scenarios 1, 2, 3, and 4 can be seen in Figure 18. Scenarios 2, 3, and 4 all show an increase in nitrogen from Scenario 1. Scenario 2 shows the greatest increase with 104.11 additional Kg of nitrogen ending up in streams. Scenario 3 follows with 33.56 Kg and the least increase is in Scenario 4 with 18.38 Kg.

The phosphorous export at the pixel level output for Land Use/Land Cover scenarios 1, 2, 3, and 4 can be seen in Figure 19. Scenarios 2, 3, and 4 all show an increase in phosphorous from Scenario 1. Scenario 2 shows the greatest increase with 29.53 additional Kg of phosphorous ending up in streams. Scenario 3 follows with 16.25 Kg and the least increase is in Scenario 4 with 8.99 Kg.

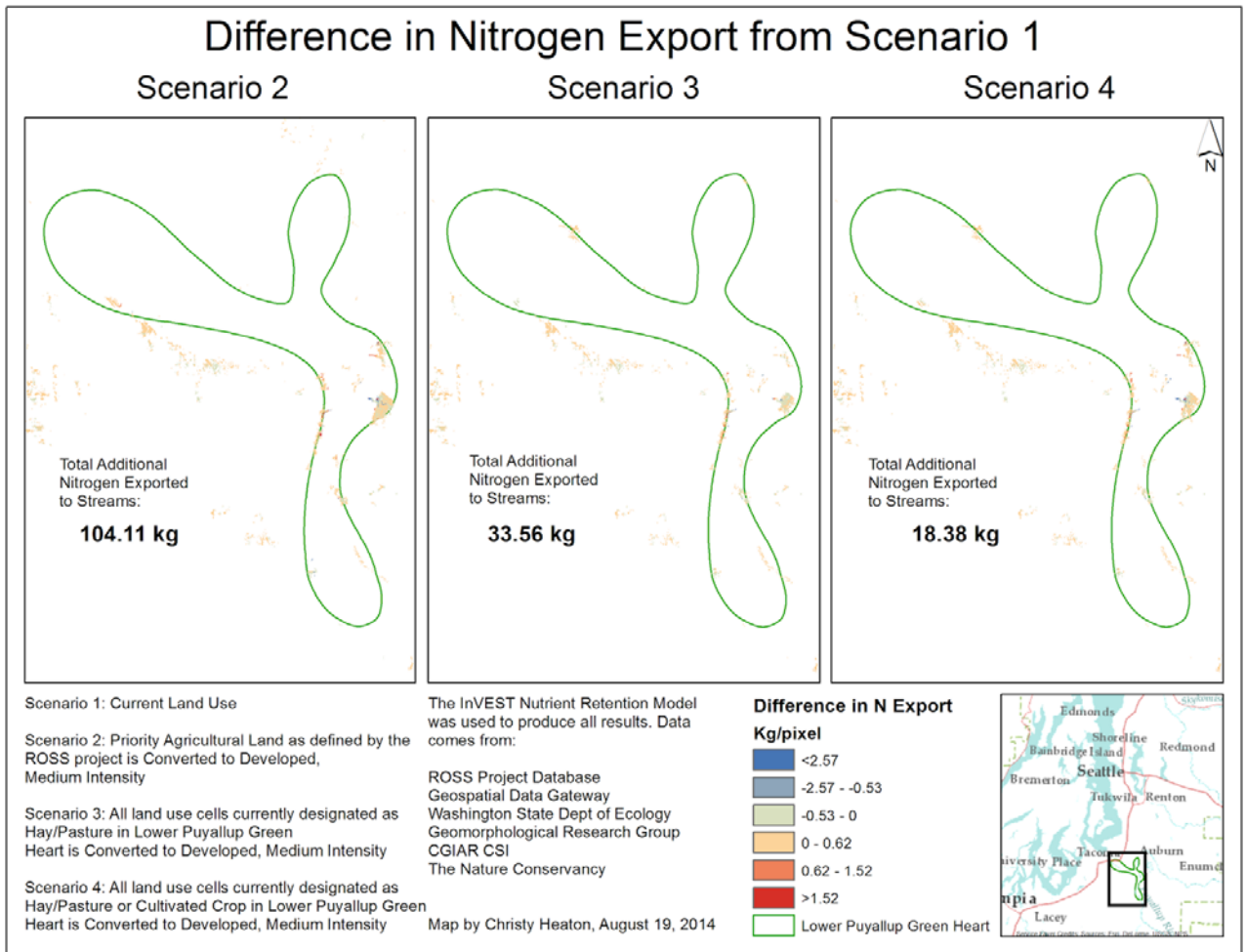


Figure 18. Change in Nitrogen Export

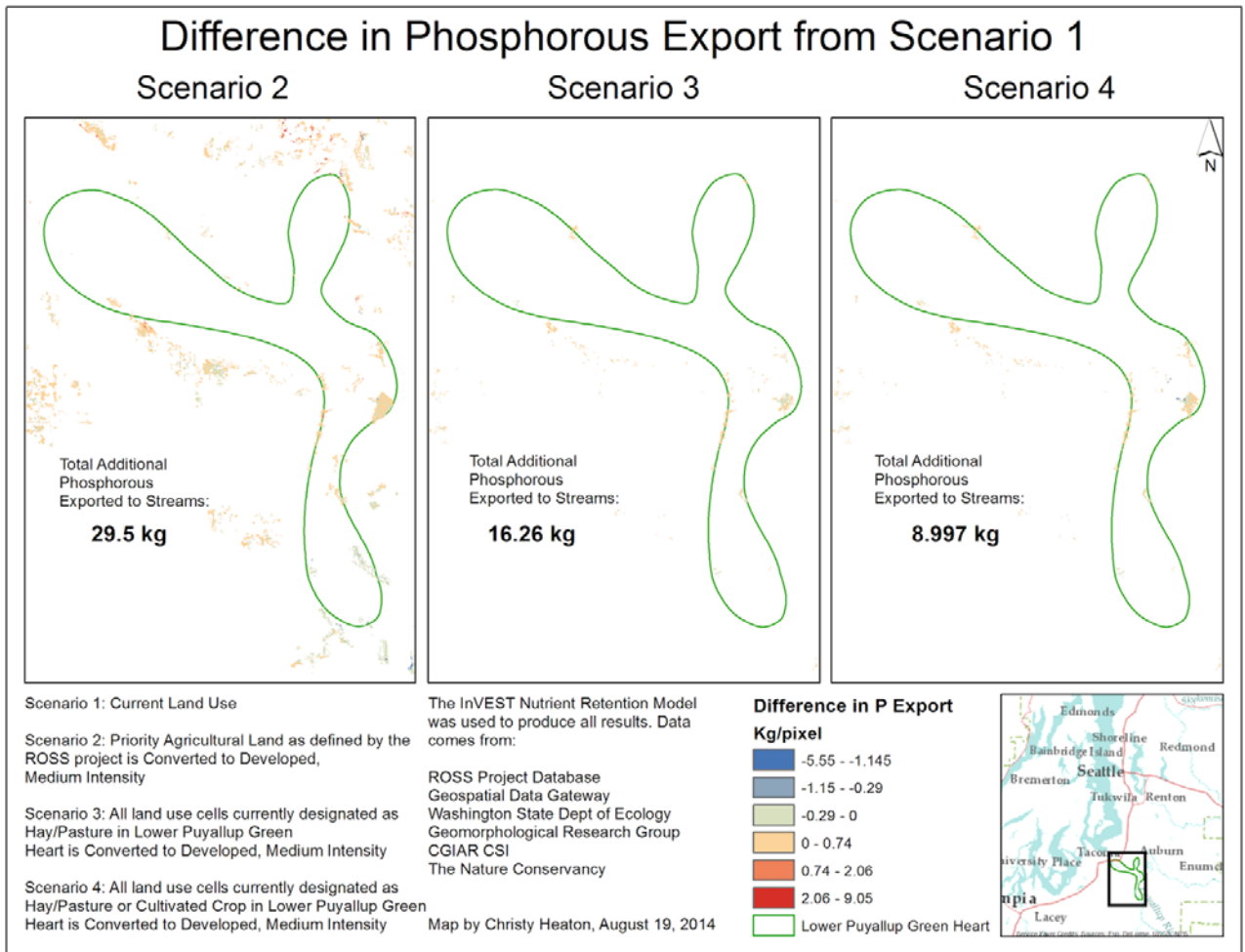


Figure 19. Change in Phosphorus Export

CARBON SEQUESTRATION MODEL

Given the results of the carbon sequestration (Figure 20 below), it is clear that any development that does not result in the creation of new green space results in a sequestration lost. The lands presently categorized by the ROSS Project as priority agricultural lands would result in a higher sequestration loss as the flora elements within this feature are capable of sequestering greater amounts of carbon than the hay and/or pasture fields. Unfortunately, clearer measurements regarding the precise Mg's or tonnes of carbon sequestration loss are not made available by the model until a valuation is run against a future scenario, detailing the amount of loss over time.

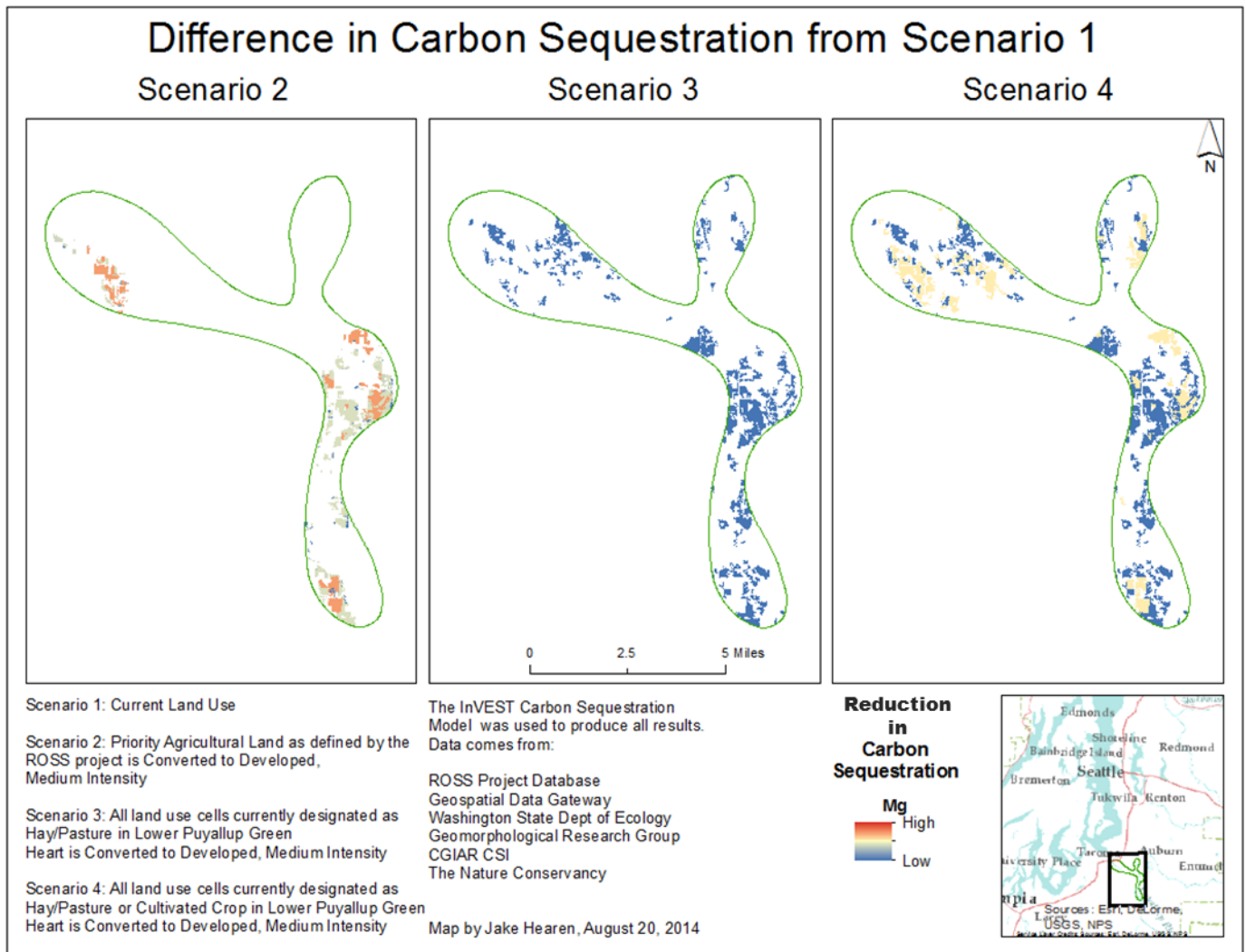


Figure 20. Reduction in Carbon Sequestration

VISUALIZATION & COMMUNICATION

Synthesizing, visualizing, and communicating the results of these analyses is a crucial element of the ROSS Project and its goals to influence decision-makers and encourage stewardship. The traditional media of print and digital (static) maps, tables, charts, and other infographics are useful communication tools. Indeed, the ROSS Project has assembled a number of very rich comprehensive plan and actions reports which contain several illustrative maps. However, we feel using a more interactive approach would have a greater impact. Using ESRI's ArcGIS Online Story Map platform, we chose to present the system, highlighted projects, and initial model results in a Tabbed Viewer application, also known as Text and Legend (see Figure 21).

One major advantage of using a Tabbed Viewer application is that you are able to present several maps side-by-side which can be spatially-linked, meaning as you pan or zoom around one map, maps on other tabs in the application essentially "follow." It makes it easy to compare results at large and small scales. The ability to add pop-up information to specific features in the display provides another avenue for

information dissemination that static maps just do not provide. Access to measuring tools is also a helpful feature of web mapping as is the flexibility in choice of basemaps.

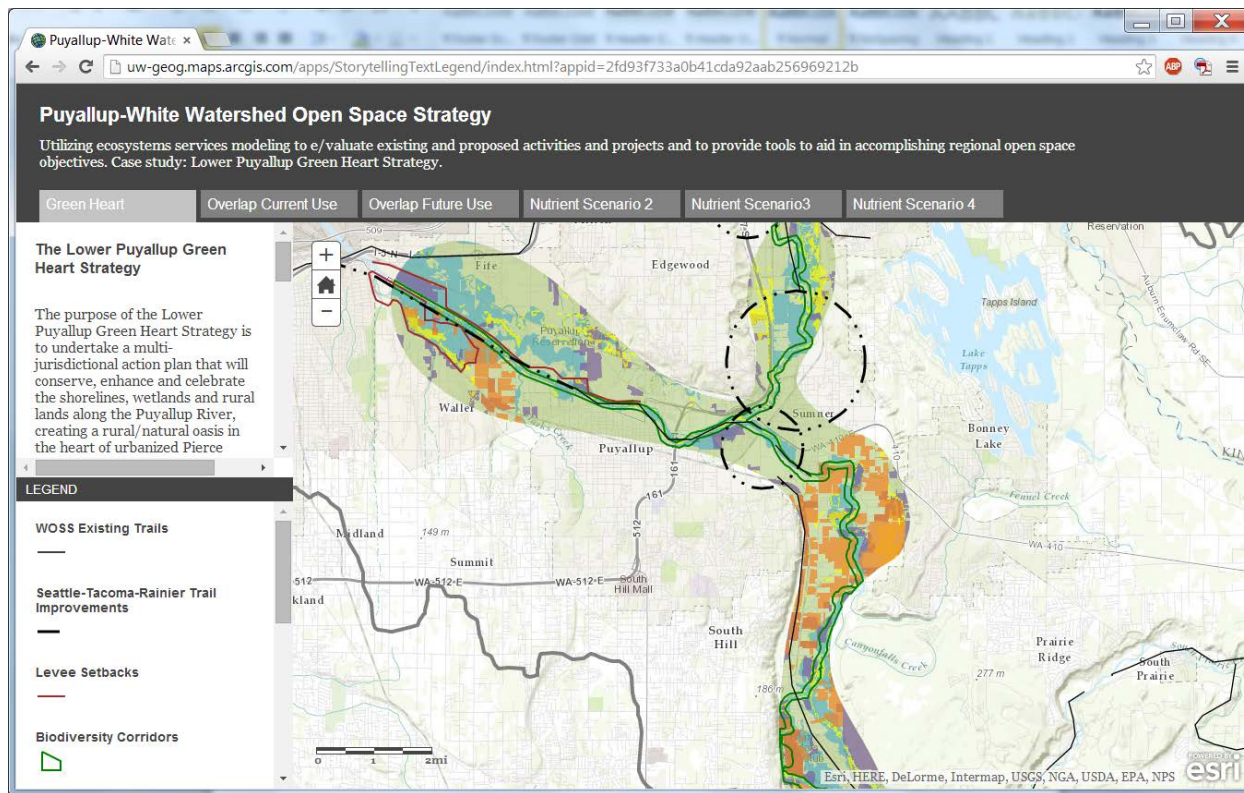


Figure 21. ESRI ArcGIS Online Story Map Application

Setting up the Story Map application is relatively easy and does not require someone with a lot of GIS skill to accomplish. However, this particular application does one very crucial limitation. The end-user is unable to control layer visibility, i.e., turning layer display on or off. In this regard, the guidance of a GIS user or cartographer would be helpful in ensuring that maps are constructed in a meaningful way using best cartographic practices.

DISCUSSION & SIMPLIFYING ASSUMPTIONS

OVERLAP ANALYSIS MODEL

While interesting to view the overlap of current land uses and how this compares to a potential expanded trail network, the outputs of this model do not provide much additional insight into how the implementation of the new expanded and connected trail system would benefit society. Differences in the two scenarios are subtle and predictable.

This model is inherently simple and does not provide much insight into human behavior of the different scenarios. Given the particular interests of this project it is interesting to see where several activities overlap, even if this does not provide hard evidence that an expanded and connected trail network should be built.

NUTRIENT RETENTION

The results of this model were unexpected. This may be due more to the way the model runs and the particular nutrients in question than what would occur in reality in the study area. Discussions with project sponsors suggested that nutrient export would increase, with Scenario 2 producing the least difference, increasing for Scenario 3 and being highest in Scenario 4. The issue may be in that the model considers Cultivated Crops to add a significant amount of nitrogen and phosphorous to the environment in the form of pesticides. Converting this value to Developed, medium intensity therefore does not demonstrate a large difference in nutrient export. The model does not consider the fact that many farms in the area may be of a sustainable and/or organic nature and produce much less pollution than a more typical factory farm. There may be other nutrients that would be better suited to this analysis as well other than nitrogen and phosphorous. Perhaps a different type of nutrient would increase as expected given these scenarios.

All models make assumptions and cannot take into account the complexity of reality. It should be noted also that this model was used by project managers and GIS analysts, not area experts, chemists, or environmental scientists. This model is complex and therefore would have produced better results with the consultation of someone with a background on the area of interest as well as the process of what is being modeled. Therefore, many assumptions were made in the inputs, and each time there is an assumption made additional uncertainty is added.

Additionally, there are several limitations to this model in the documentation. This model was developed for use in landscapes with predominantly a saturation excess runoff hydrology and may be less applicable to locations where the hydrology is determined by rainfall intensity such as areas with flash flooding. The model could be modified for use with a different hydrology, but that was not the focus of this report. The focal scale of this project does have the recommended hydrology for this model.

This model was not designed to address chemical or biological interactions that may occur from the point of loading to the point of interest besides filtration by terrestrial vegetation. Nitrogen and phosphorous inherently degrade over time and distance through interactions with the air, water, other pollutants. This is just one example of the ways in which this model simplifies reality and therefore adds uncertainty to the output.

The model assumes that there is continuous water flow through the landscape and does not account for drainage, ditches, or shortcuts in the flow of nutrients and pollutants to streams.

CARBON SEQUESTRATION

All other factors being equal, the increase in development associated with a change in land use to Developed, Medium Intensity will result in an increase of carbon dioxide within the surrounding environment. However, it stands to reason that an increase in development also results in a corresponding

increase in human activity. Therefore the amount of carbon loss is compounded by not only the amount of carbon naturally lost from the environmental change. To reduce this potential threat, an increase of unprocessed environmental factors, i.e. agriculture, flora, etc. must be introduced back into the system.

Everything within an ecosystem has some level of intake for carbon dioxide and carbon monoxide at varying rates, but any LULC will consolidate these elements for ease of use. This can be problematic when utilizing the sample tables provided with the model, resulting in a loss in translation where some elements become lost while other areas become misrepresented by being consolidated with other elements. In our translation of the table to function with our input LULC, we decided to take a conservative approach with the carbon levels and chose the lowest possible values that might be sequestered. In doing so, we prevented the possibility of averages misrepresentation, i.e. an equal average is assumed despite the reality being extremely one-sided. A majority of the Carbon Sequestration model's capabilities rely on its ability to conduct a future scenario and will garner more results. However, while alternative scenarios were utilized throughout this project, they are not considered future scenarios; the model is stringent about the temporal scale given to each scenario and there was no specific timeline provided.

BUSINESS CASE & IMPLEMENTATION PLAN

For this project, we have not developed a business case per se. Instead, we again emphasize our recommendations moving forward with evaluating and communicating the value of open space and ecosystems services to stakeholders, decision makers, and the public as a whole. We recommend utilizing InVEST models such as Nutrient Retention, Carbon Sequestration, and Overlap Analysis, which are the foundation of this report, as well investigating other InVEST Ecosystems Services models such as Sediment Retention and Habitat Quality, with guidance from area technical experts to aid in valuing open space at the watershed level. Additionally, any analysis of floodplain changes resulting from changes in hydraulic structures, such as the proposed levee setbacks along the Lower Puyallup River, should begin with a future scenario ("with project") hydrologic and hydraulic analysis using appropriate software such as the U.S. Army Corps of Engineer Hydraulic Engineering Center's HEC-RAS and HEC-HMS. While Esri's GeoPlanner tool would be a good way to analyze the results of the InVEST models and modify proposed open spaces, it was not used in this project due to time constraints and access to the software. We also did not consider the financial valuation of models, since this is not the focus of the ROSS project, though inclusion of financial valuation in the future may be useful and compelling. Finally, we advocate using web mapping - particularly the Story Map application - to disseminate results. Story Maps are relatively easy to prepare and do not require someone with a lot of GIS skill to make. However, we would advocate that someone with cartographic knowledge at least work in an advisory capacity to ensure best practices are employed in creating these interactive displays.

This project merely scratches the surface of what is possible with ecosystems services modeling, valuation of open space, and visualization. A great deal of work remains to turn these test case scenarios into truer-to-life scenarios with actionable results. However, we were able to demonstrate that these models can be run with the data the ROSS has available and can be of value as they promote initiatives to preserve and enhance open space in the Central Puget Sound Region.

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