Mapping Environmental Indicators in the Puget Sound Region: A Comprehensive Approach to Implementing Cartographic Best Practices

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TABLE OF CONTENTS

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LIST OF FIGURES

ABSTRACT

In the 2007 *State of the Sound* Puget Sound Partnership report, the map graphics fail to communicate their intended purpose for a number of reasons; namely, the lack of a cohesive look, cartographic missteps, and often an unclear message. In the *Analysis* section of this report, we itemize critical map components, and draw on examples from maps containing elements consistent with best cartographic practices. These maps are proposed indicator maps from the University of Washington's GIS & Sustainability Master's Program course "Principles of GIS Mapping". Drawing on the findings from the analysis section, the *Recommendations* section provides a recommended mapping approach, look, and method for evaluating indicator critical points. By adopting these recommendations, subsequent versions of maps in the *State of the Sound* report can avoid inaccurate representation and simple miscommunication.

Cartography, GIS, Puget Sound Partnership, State of the Sound, map

INTRODUCTION

Landowners, biologists, and various elected officials gathered atop a mossy bluff on the west side of San Juan Island. The stakeholders observed as the fleet of boats gathered below, wondering aloud how their presence might affect the whales. Suddenly, the Southern Resident killer whales surfaced, and silence punctuated all conversation. It became apparent that while each stakeholder possessed distinct knowledge and motivations, they agreed that the facts presented before them could no longer be ignored.

Most of the Puget Sound's ecological problems are not as visible as charismatic mega-fauna. Home to 200 species of fish, twenty-six marine mammals, and more than 625 variations of seaweed, the Puget Sound watersheds are a valuable source of food, freshwater, and livelihood to approximately 3.5 million people. By 2025, the region’s population is expected to grow nearly 49 percent to an estimated 5.2 million, all drawing from a limited water supply that takes in an estimated one million pounds of chemicals per year released by permitted discharges. Of the 2,500 miles of shoreline, 800 miles (32 percent) of manmade hard armoring directly impacts the natural shallow water habitat for marine wildlife (“Puget Sound Facts”).

Puget Sound’s degradation occurs at large and small scales, with effects accumulating over time. As the Puget Sound Partnership phrases it, "*Puget Sound is ecologically delicate;* and while its symptoms of trouble are not easily visible, they are undeniable and getting worse,” (Puget Sound Partnership, 2012). In an effort to bring attention to these issues, the Partnership publishes biannual *State of the Sound* reports, tracking environmental indicators that reflect the health of the water quality, habitat, marine life, and climate, which are presented to the governor of Washington State and are available through their website with the hope of educating stakeholders (Puget Sound Partnership, 2012).

The use of enticing maps within the report will help stakeholders visualize the scope of the situation, as they access alternate pathways in the brain (Mayer 2005). The 2007 *State of the Sound* report contains 18 maps (Washington State Sound Action Team and Puget, 2007a), but in our review of the cartography, we conclude that the maps do not follow cartographic best practices and the cartography is not integrated with the rest of the report. The 2009 *State of the Sound* report does not utilize maps as heavily (Puget Sound Partnership, 2010); perhaps because the Puget Sound Partnership is aware of the cartographic issues (Washington State and Puget Sound Action Team, 2007b).

The upcoming publication of the 2011 report and the possible publication of a Puget Sound Encyclopedia are opportunities to improve the quality of the cartography of the maps. In this report, we analyze a series of mock indicator maps created by University of Washington graduate students to find the best treatment of data selection, data classification, scale, extent, labeling, text, legend, color, and the relationship between figure and ground. Our recommendations require explicit organizational planning and consistency to present geographic and temporal thematic data, with the desired result of attractive, readable maps used to supplement the persuasive message of the written publication.

Our primary motivation for the creation of this report is to support the Puget Sound Partnership's work by furthering the conversation about the health and outlook of the Puget Sound Region. The conversation can only move forward when everyone, including the general public, is able to visualize and understand the same accurate summary about key indicators and their status. Policy decisions should be based on reality and undistorted by political biases, inaccurate representation, or by simple miscommunication. We hope that the recommended cartographic approach outlined in this report will aid the Puget Sound Partnership in future mapping projects.

BACKGROUND

The mandate of the Puget Sound Partnership is to coordinate and lead the effort to restore and protect Puget Sound by bringing together affected citizens, governments, tribes, scientists and businesses. Basing decisions on science, the Partnership will focus on initiatives that "bring forth the greatest impact, and ensure that involved parties work cooperatively" (Puget Sound Partnership, 2012). The University of Washington works in cooperation with the Puget Sound Partnership, and the creation of this report carries on that alliance.

As part of a graduate course in the fundamentals of cartography (The Principles of GIS Mapping—GEOG560), taught by Dr. Robert Aguirre, students identified potential conflicts with cartographic best practices for each map in the 2007 *State of the Sound* report. Later, groups of three students produced a map of different indicators that are tracked by the Puget Sound Partnership. This process entailed designing, implementing, and documenting the use of color, symbology, text, and various other map elements. Students endeavored to communicate a message about geographic relationships and the phenomena of interest with a finished map layout suitable for publication on the Web as a full page-sized graphic.

Prior to writing this report, we analyzed the strengths and weaknesses of the final maps produced in the course, and selected maps that emphasized or exemplified certain characteristics. This report can be considered a survey of cartographic best practices, tailored to the needs of the Puget Sound Partnership.

ANALYSIS – Indicator Map Review, Critique and Discussion

This analysis is based on the review of nine indicator maps, with results compiled in a spreadsheet listing the positives, problematic components, and suggestions for each map. From this table, five major discussion points emerged that were deemed critical map components. Sample indicator maps are selected that exemplify the selected trait. The maps used are purely samples that exhibit cartographic elements worthy of discussion, and should not be viewed as final, factually accurate examples ready for publication.

CLARITY AND DATA SELECTION

Clarity is perhaps the most critical characteristic of a map. To achieve it requires that appropriate data is chosen, both in quality and quantity, and then displayed in a visually engaging manner that allows the viewer to quickly derive the intended message of the map. The goal is to hold the reader's attention without overwhelming them with information.

Limiting map data can be a successful way of improving the clarity of the map. More data displayed does not necessarily equate to more knowledge gained. In fact, too much data might detract from the map's message and leave the map reader confused. Figure 1 displays a wealth of information: freshwater quality, human population density, and salmon run length. The combination is based on ecological relationships: dense human population adversely affects water quality, which adversely affects salmon runs. Each is represented by a different geometric shape: point, area and lines, respectively, which distinguishes them visually. Yet, in spite of that, the layers still find a way to compete with each other. The overload of visual data may leave the viewer unsure of the intended message of the map.

Figure 1: Snippet of Map E "Freshwater Quality"

Map A, "Land Development" is successful in delivering one clear message – that a changing population density is occurring in the Puget Sound, increasing the amount of land development. The map splits density up into two areas, inside and outside the urban growth area. The viewer only needs to focus on one phenomenon, so comprehending the densities of two distinct regions is manageable.

This map might benefit from using two distinct color ramps to distinguish between inside and outside the urban growth area. This change would help direct the viewer's attention to areas of most concern, in this case, areas with a high percentage population increase outside of the urban growth area, rather than those inside the urban growth area where population growth is seen as a positive. Figure 2A shows Thurston County experiencing 4.11% growth outside of the urban growth area from 2001-2006, the highest of all Puget Sound counties (peach color). The second map snippet proposes a color adjustment to assist in delivering a clear message – that Thurston County is experiencing a critical rate of growth (bright red). The area inside the urban growth area should be changed, possibly to a grayscale ramp, since growth here is seen as a positive, and should not be viewed as alarming. The importance of color use and its role in delivering a clear message is discussed in depth later in this report.

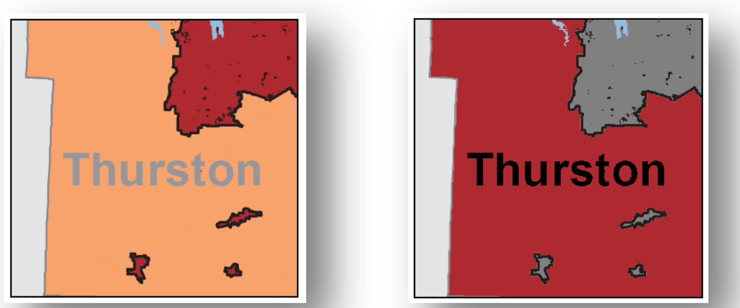


Figure1A **Figure 1B**

Figure 2: Snippet from Map A "Land Development"
A) Color ramped used in original map. B) Suggested alteration to the colors.

EXTENT & SCALE

The Puget Sound Partnership tracks indicators throughout the entire Puget Sound region. County boundaries are sometimes used due to their relationship with population data, but using Water Resource Inventory Areas (WRIA) as natural boundaries is the logical choice for mapping ecological phenomena. The shapes of the WRIAs may not be familiar to many map viewers, thus they should be displayed within the outline of the Puget Sound or perhaps within a separate locator map. There are certain phenomena that need to be mapped illustrating a smaller extent at a larger map scale, contrasting the smaller scale of regional indicator maps. In cartographer's lingo, "small map scale" means zoomed out to a large mapped earth area or large geographic extent usually with less information and more generalized features; whereas "large map scale" means zoomed IN to a small mapped earth area or small geographic extent usually with more information and less generalized features. In the Shoreline Armoring Index Map (Figure 3) it is necessary for map extent to focus on close-up, large map scale areas of coastline to accurately show the current extent of armored shorelines.

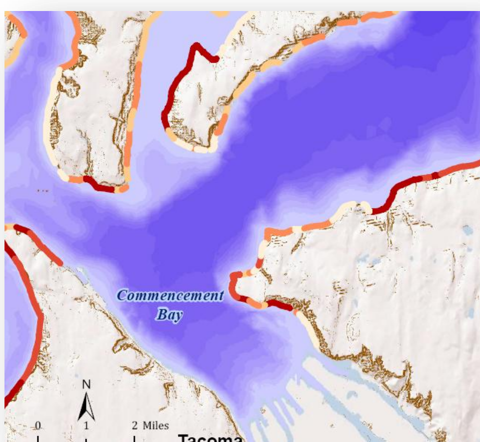


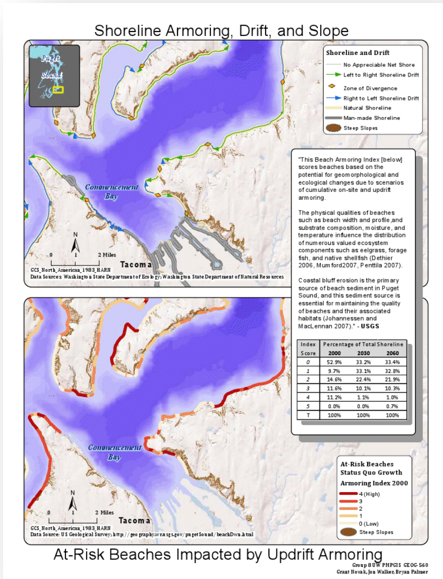
Figure 3: Snippet from Map H
“Shoreline Armoring”

LABELS & ANCILLARY TEXT

Appropriate text and labeling are critical to map legibility. Maps use text in a number of locations, including the title, legend, labels, and ancillary text. Although text can add important details to the map's message, excessive or poorly designed text may detract from the map's clarity. Readability of the text and placement should be the paramount concern when adding text of any kind.

Labeling a map is critical to ensure the viewer understands the location of important features. Labels should be as close as possible to the labeled feature, and placed within polygons or above lines. They should be legible, in a sans serif font, sized according to the visual hierarchy, and colored or haloed according to their background. Labels should be kept consistent whenever possible.

If "a picture is worth a thousand words", ancillary text should be used minimally, and be lower than the map graphics in the visual hierarchy. Placing a text box off to the side (see Figure 4) makes sense because it does not overlap where the data is shown. The content of the text is fairly short and to the point, and directly relates to understanding the map image. Map 4A includes a table as part of the text that adds to map message. The format of the text box creates a defined foreground-background relationship with the outline and shadow, making for easy readability. Figure 4B uses a considerable amount of text, but the text layout is done in a successful way that does not interfere or detract from the map graphics.



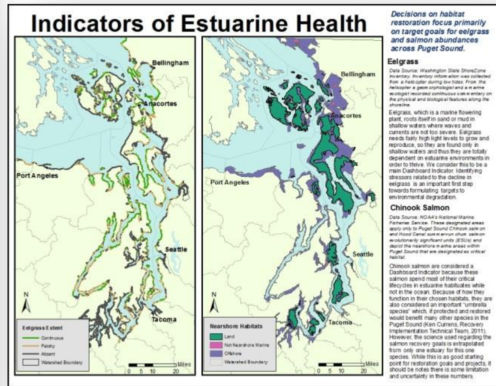


Figure 4B: Map F "Indicators of Estuarine Health"

Figure 4A: Map H "Shoreline Armoring, Drift, and Slope"

LEGENDS

If maps are representations of real world objects and phenomena, the key to these real world representations lie within the map legend. The map legend should contain the most important map elements, and should explain these elements with a sense of clarity. In other words, if there is confusion with the map, the legend should succinctly explain anything that is unclear, and essentially, it can function as a "data dictionary".

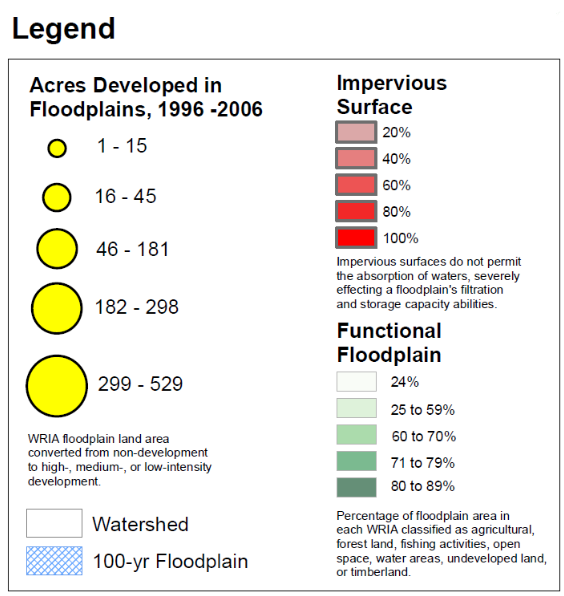


Figure 5: Snippet from Map G "Floodplain Functionality"

The legend symbology isn't the only legend component that must possess clarity. Complex maps sometimes need a very organized and titled legend so that the person viewing the map can quickly understand what exactly is being represented. A well-crafted legend will aid a viewer in their quick comprehension of the map's content, as shown in Figure 5. Generally, using four or five data classes will simplify the map without over-generalizing. Dividing the data into too many classes creates problems with the symbology. The cartographer will likely have trouble finding enough distinct options and the audience may be unable to decipher between them.

The legend is an important part of the map composition in that it needs to be thoughtfully balanced within the map layout. It needs to strike a good visual balance, without being the focus of attention. The reader's eyes normally move from top to bottom and left to right, following a diagonal through the visual center (Surrey 1929). For this reason, the lower left hand corner is routinely utilized as a space reserved for the map legend. In this location, the legend will be visible, but won't dominate the map or upset the balance of the layout. This isn't always practical or possible, but one should keep in mind that all vacant spaces on the map layout aren't created equal.

Ideally, the legend will be labeled as such at the top of the legend box in larger font than any of the text within the legend box. In Cartography: Thematic Map Design, the authors recommend that "legend captions be set at 1 to 1.5 the size of the largest feature in the map," (Dent, Torguson, and Hodler 2009). It is appropriate to apply subtype labels to like groups of data representation within the legend (i.e. boundaries, streets, data classifications, etc.). Additionally, ancillary text can be placed within the legend box if it contributes to the overall story of the map.

COLOR & THE FIGURE-GROUND RELATIONSHIP

A well-constructed figure-ground relationship assists the cartographer in conveying the intended message of the map by communicating the most important information to the audience in a clear fashion. The *figure* data is central within the layout, emphasizing which data is meant for consumption and which data doesn't necessarily deserve equal attention. The layout of *figure* layers succeeds when the eye of the reader is immediately drawn to those layers upon first glance at the map. This can be more easily accomplished by using high values of red, blue, and yellow. The relationship between the figure data and the background can sometimes be a difficult balance to strike. For indicator maps, the following have proven to make solid "ground" layers:

- Digital Elevation Models
- Bathymetry / Water bodies
- Administrative layers (counties, water resource inventory areas, state boundaries)

In Figure 6, light color values are used to set the map foundation. Background information is displayed in a way that doesn't immediately draw the reader's eye. Alternatively, the reader's attention is immediately drawn to the colored areas in the map. The strategic use of color is one way to establish the figure-ground relationship.

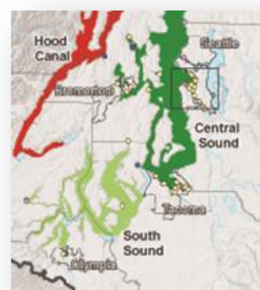


Figure 6: Snippet from Map D "Marine Sediment"

Similarly, Map B (seen in Figure 7) uses color to establish a visual hierarchy which in turn assists the audience in distinguishing between the figure and the ground. Critical map information is centered and displayed in differing variations of hue, whereas non-essential reference data is shown in grayscale The use of color in mapmaking is a subjective process that lends itself greatly to the author's sense of creative license. However, when making decisions about color, one can benefit greatly from the implementation of color contrast, and the use of hue, value and saturation as it pertains to a visual hierarchy and the figure-ground relationship.

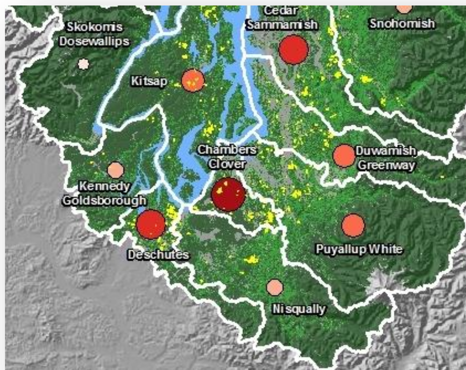


Figure 7: Snippet from Map B "Forest Land Conversion to Developed Land"

RECOMMENDATIONS – A Comprehensive Mapping Approach

The task thus far has been to examine and evaluate indicator maps. The focus now is to provide recommendations for an absolute approach that embodies forethought, organization, and a cohesive look for the creation of all indicator maps. The aim of the following recommended approach is to provide guidelines that enable the successful return of maps into the Puget Sound Partnership's *State of the Sound* reports, by clearly and accurately educating the stakeholder public on the conditions of the problem, as well as any progress made. Based on observations gathered from our analysis, the following are guidelines that can be followed when creating an extensive mapping project, such as the task at hand for the Puget Sound Partnership:

- The creation of a preliminary *organizational table*
- The use of an initial project map that presents the scope and extent of the *project area*
- Practicing *consistency* as a guiding theme throughout the mapping project
- Successfully implementing the dimension of *time* into the project

Each of these points will be discussed at length, with examples provided to assist with implementing the stated recommendation.

THE ORGANIZATIONAL TABLE

Prior to the creation of the indicator maps, creating a focused *organization table* can greatly assist the cartographer with formulating a clear objective and plan for the map. In addition, such a table will make it simple to compare map plans, so that a similar look can be kept consistent in the design. The organizational table will ensure that the end product displays the intended message of the project. Some recommended columns to include in the table are the following: indicator name, the intended message the map is to communicate, identifying the 'critical points' of the phenomena, and finally the desired look that will successfully display the critical points, and therefore, the story of the map.

The *Intended Message* column should specifically answer the question of why you are including the map in the first place. The statement should state what you want to share with viewers about the selected phenomenon. For example, *freshwater quality has dramatically decreased in these areas between the years of 2006-2011*, or *restoration efforts have shown these positive effects on shoreline habitats from 2001-2011*. The *Intended Message* should be simple, clear and direct, almost like a thesis statement for the map.

If it is of interest to showcase two intended messages on a map, an additional column will need to be added for each message, as well as an additional *Critical Point* column. Considerably more attention will need to be given to the *Desired Look* of the map. It is simple to see that while not unrealistic, adding multiple messages to a single map adds considerable complexity to the organizational table. It logically follows that multiple messages will therefore add to the complexity of the final map product. This marks a good opportunity for the cartographer to decide whether it is important to include multiple messages within one map, or decide to create separate maps for each message. The answer, of course, depends heavily on what the separate messages are. For example displaying “healthy areas” in addition to “unhealthy” areas might be easily combined depending on color choice and the number of classes. If physical space in the report is limited, separate maps might not be an option. As a result, each map might be required to host more information, furthering the necessity of having a well thought out plan.

The *Critical Point* column should then specify what features on the map will be chosen to symbolize the phenomenon. More specifically, what points, lines, or areas are of interest, and what is happening at these locations that absolutely must be displayed on the map. For example, drawing from the "*freshwater quality has dramatically decreased*" example mentioned above, the critical points would then be something along the lines of "*streams with health quality scores of less than 65.0",* or whatever the metric used to assess quality. While the map will likely also display streams with quality scores above this metric, a direct statement such as this will let the cartographer know precisely what needs to stand out on the map.

If these columns are done well, and have a clear focus, filling in the *Map Design* should not require too much thought. Continuing from the example above, simply draw from the critical point and decide on a plan of attack. Since we are focused on "*unhealthy streams"*, the *Map Design* will need a color to represent "unhealthy", and then a plan of how this color will be applied to a particular stream. Table 1.0 looks at a few of the Puget Sound indicators and gives examples of how the cells in this table might be filled in.

Table 1 – Sample Organizational Table

Indicator	**Intended Message**	**Critical Point**	**Map Design**
Land Development	To make it visually apparent where unintended growth is an issue	Areas outside of the urban growth area experiencing a high percentage of growth	Use bright red coloring to highlight the critical areas, making them stand out at as the focus of the map
Shoreline Armoring	To make it visually apparent where shoreline is at risk due to armoring.	At risk shorelines	[Same]
Estuary Health	To make it visually apparent where eelgrass and near-shore habitats are being destroyed	Area of eelgrass depletion and near-shore habitats	[Same]
Land Use/Land Change	To make it visually apparent where forest is being converted to developed surface	Areas with too high of a forestation to developed surface conversion rate	[Same]

The benefit of creating a table like Table 1 is that map creators now have a better understanding of the maps and what they should illustrate and impart to the reader. In addition, common themes will begin to emerge that can be kept consistent throughout the scope of the mapping project. In this case, the desired look of the maps. When it comes time to design the maps, it becomes important to ensure that all additional elements, such as color choice, text, extent, and legends enhance, rather than distract from the intended messages conveyed in the table.

THE STUDY AREA MAP

One way to avoid cluttering up the indicator maps is to include an initial *Study Area Map* early on in the report, defining the extent of the project, the study area, and an index map that provides outsiders with knowledge of the location. The purpose of the *Study Area Map* is twofold: first, it provides an upfront picture of the area of focus and what is being studied, and second, this map alleviates the pressure on further maps of having to continually display repetitive map elements. With the study area established in the beginning, indicator maps can then focus on displaying critical points clearly, without the distraction of unnecessary index maps and excessive labeling.

CONSISTENCY

Consistency is the most important trait that can exist in an extensive mapping project. Design consistency gives the report a polished and professional look, and can result in quicker map comprehension. Viewers do not have the time or patience to relearn color schemes and classifications for each map. Keeping the look and feel of the report consistent will have untold positive effects for conveying information, and more importantly, the intended message of the report and its maps.

The 2007 *State of the Sound* report did not feature a consistent mapping look and feel throughout the document. We highly recommend choosing a consistent color scheme to be employed throughout all indicator maps; one that draws attention to critical points, and is intuitive for the average viewer. Similarly, the number of classes for the data needs to be kept consistent throughout the report.

The website Color Brewer 2.0 takes the guesswork out of choosing an appropriate color scheme, by recommending color selection based on the number of classes used, and the type of data (sequential, diverging, or qualitative). Color Brewer will also recommend which colors are best for printing and photo copying (Colorbrewer, 2012).

Certain hues need to be reserved for certain phenomena, such as a saturated red for areas that need to stand out from the rest of the map (i.e. areas in distress). For ‘healthy’ area, whites or natural greens are appropriate. Using Color Brewer, a sample color scheme is displayed in Figure 8A that would successfully accomplish the intended goals for a mapping project such as this, with the intended message of highlighting the critical points for Puget Sound indicators. We feel the focus of this mapping project is to draw attention to coastlines, water areas, and watersheds in distress and in need of immediate attention and resources. For this reason, red is recommended to draw attention to unhealthy areas due to its alarming intensity, with off-white reserved for healthy areas. This color scheme is sequential, and is viewed as appropriate to represent phenomena ranging from healthy to unhealthy.

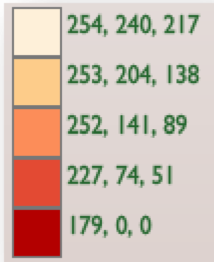


Figure 8A – Sequential color scheme (ColorBrewer 2012)

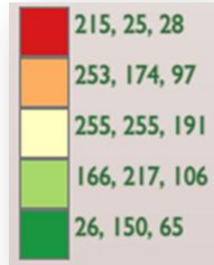


Figure8B – Diverging color scheme (ColorBrewer 2012)

A diverging scheme might also work, with white or yellow representing neutral and green representing healthy due its correlation with nature and contrast with red (Figure 8B). For clarity sake, the sequential scheme is recommended over the diverging, because its single color scheme coordinates with the single focus of identifying areas in distress. A single color scheme makes for more intuitive map, by alleviating the need to constantly reference the map legend to derive the meaning of the color. On a more fundamental note, this keeps green available for use in the ground layers of the maps.

Four different examples are pictured (Figures 9A-9D) to simulate the experience of thumbing through a report with one color scheme and five data classes. Although overly generalized and lacking any real indicator data, the examples give an idea of the effectiveness of sticking with a consistent color scheme throughout the various map types. Despite the absence of title, legends, and context, the eye quickly identifies what is critical in all four maps, in this case, the red "problem" areas. Even though the mind has to relearn a new scale for Figure 9D, the familiar colors make the map message simple to grasp. Keeping the color scheme and number of classes consistent throughout the different indicator maps gives the maps a similar language that, once understood, can quickly be applied throughout the report. Scores and data will change from map to map, but the overall message of *selecting critical areas to target* is visually apparent.

Figure 9: Various map samples illustrating a consistent color scheme

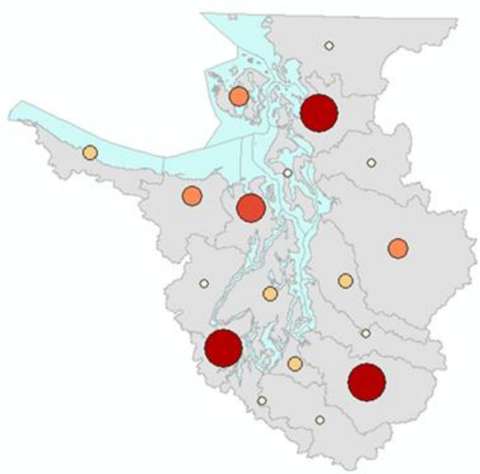


Figure 9A: Sample Graduated Symbol Map

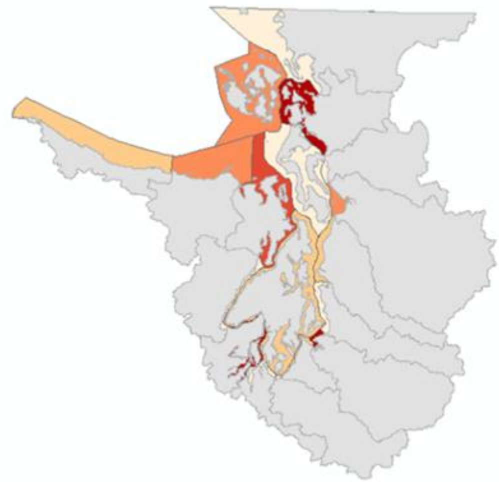


Figure 9B: Sample Choropleth Water Map

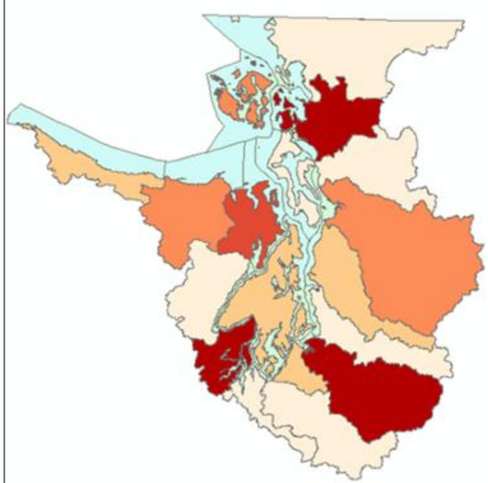


Figure 9C: Sample Choropleth Land Map

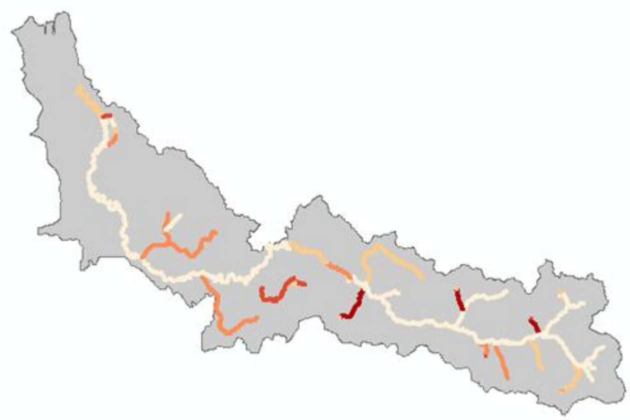


Figure 9D: Sample Choropleth Streams Map

Complex combinations of datasets might benefit from being combined into a single index "score", which can be represented through a single color scheme. This mapping tactic eliminates the challenge of displaying multiple contributing factors all in a single map. An example of this is done in Map H "Shoreline Armoring". The top map displays many of the beach's physical qualities above and below the surface, such as drift, zones of divergence and steep slope. As a visual, this map does not transfer any takeaway information for the viewer. However, when these phenomena are combined into a single weighted scientific formula (U.S. Geological Survey), the viewer can quickly see (in the bottom map) stretches of coastline that are "at risk". Figure 10 gives a visual of the legend schematic demonstrating this change. Using a similar index scoring for other indicators might lead to maps that pack a strong, quick punch, rather than displaying too much and leaving the viewer confused.

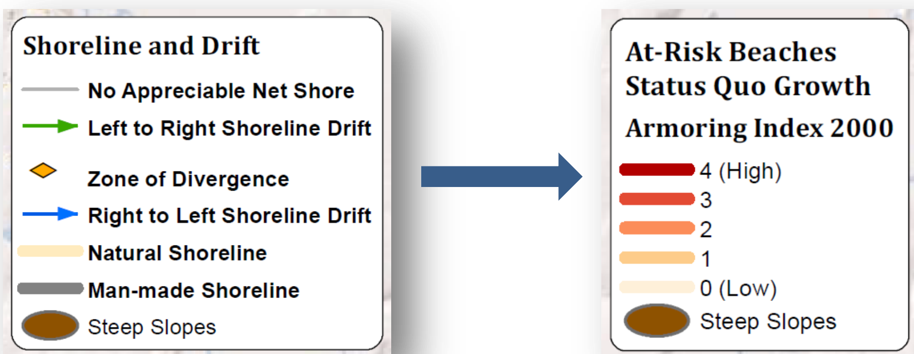


Figure 10: Example of Index Scoring. Legends from Map E "Shoreline Armoring"

In addition to *figure* color selection, the color of the *ground* layer is also important. Light valued colors, such as light gray (see Figure 10), white, and tan are recommended, with the selection kept consistent throughout the report. Although important, the ground layers should not be displayed in a way that distracts the reader from the intended message of the map. In the case of the indicator maps, the reader should easily be able to decipher between the important data represented in the figure of the map, and the ground layer.

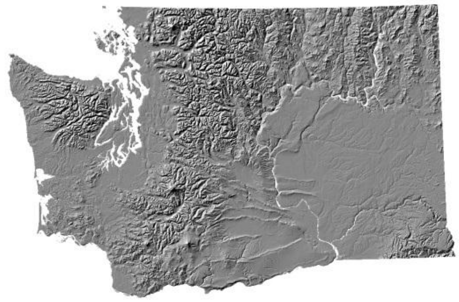
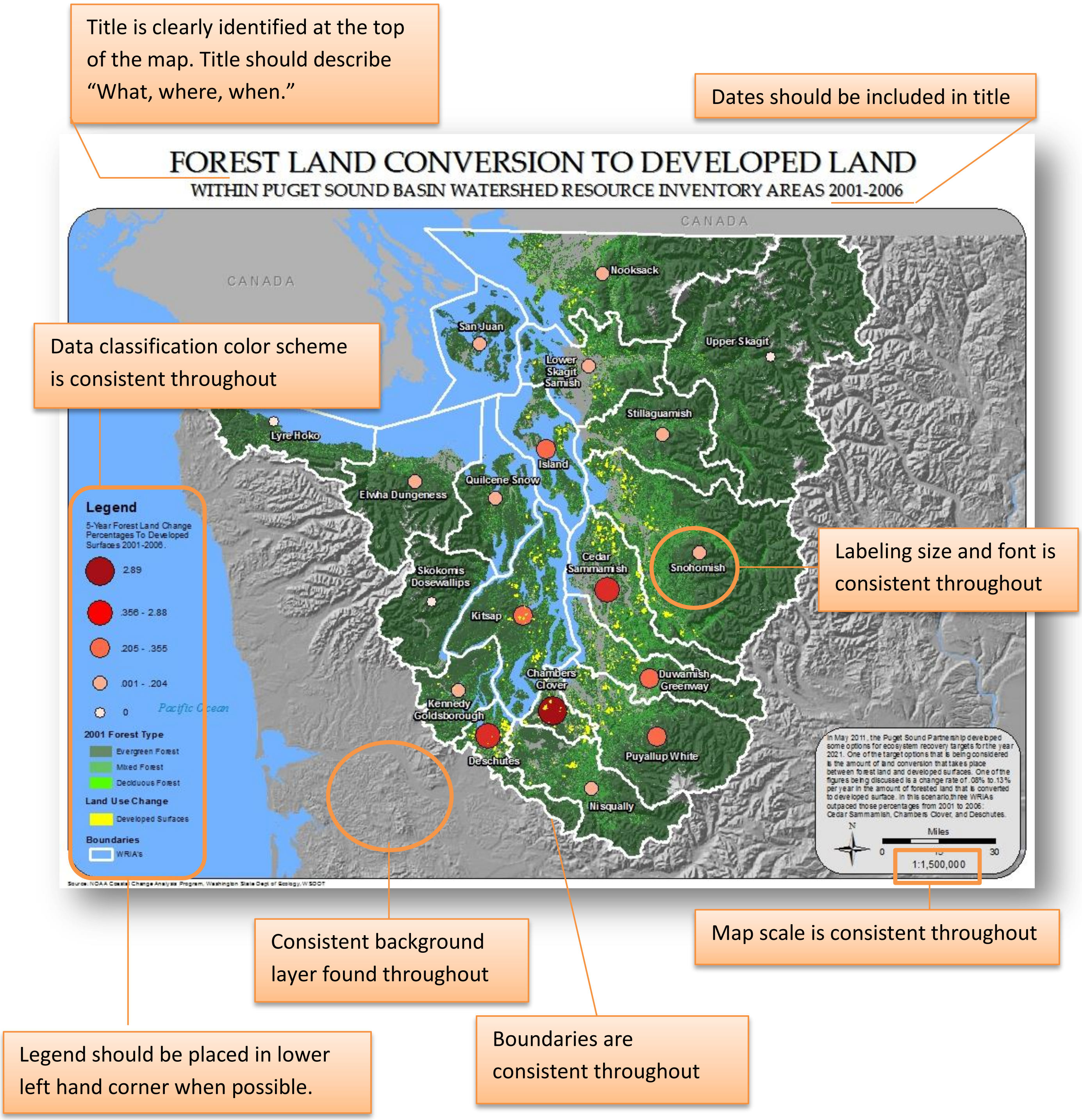


Figure 11: Sample recommended background layer

It is recommended to keep the remaining map elements the same size, style, and placement throughout the report. This includes the title, labels, legend, north arrow and scale bar. One way to accomplish this goal is to create a template that can be used for all maps. In Figure 12, a sample indicator map is displayed showing recommended elements to keep consistent. In the case of the Puget Sound Indicator maps, two templates will be required, one displaying the entire Puget Sound, and one that is used for call out maps that display data at a larger map scale (close up).

Figure 12: Sample Map Template with consistent elements identified



TIME

The element of time is a crucial component to every indicator's story, and considerable attention ought to be given to decide how to implement this dimension uniformly over the course of the mapping report. There are many obstacles that stand in the way of accurately conveying changes over time; primarily, the availability of data from the years desired. To the degree that is possible moving forward, implementing guidelines for each indicator, such as choosing an agreed upon interval for routine data collection, and then mapping the positive and negative changes observed over the course of that time. In Figure 13 we can see an example of how the eelgrass beds have changed over time. Without a visual of this time change, it is often difficult for somebody outside of the situation to know whether the observed data is considered positive or negative.

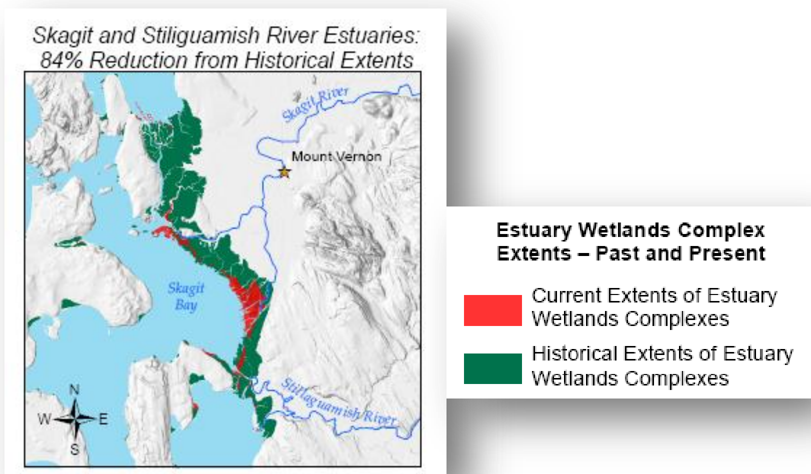


Figure 13: Snippet from Map I "Reduction in eelgrass wetlands complexes over time"

Displaying time changes may prove to be more challenging for certain indicators. If this cannot be done in a single map, another option is to showcase multiple maps for changes over the years. Of course in a printed report, space allotted for maps might limit what is possible in this regard.

As most of us are certainly no strangers to the rapid advancement of internet technology, to ignore this medium and its possibilities for map interactivity would be a mistake. There may never be a replacement to holding a hard copy of a report in your hand, but getting that material to the right people and getting them to read the document are the challenges facing any agency attempting to spread an important message. The capabilities of the web can reach a broader audience and can often communicate more efficiently. Figure 14 demonstrates zooming in to see small scale areas in greater detail, accessing additional information at the click of the button, and seeing a visual of changes over time. These capabilities are necessary map features that just aren't possible with a static printed map.

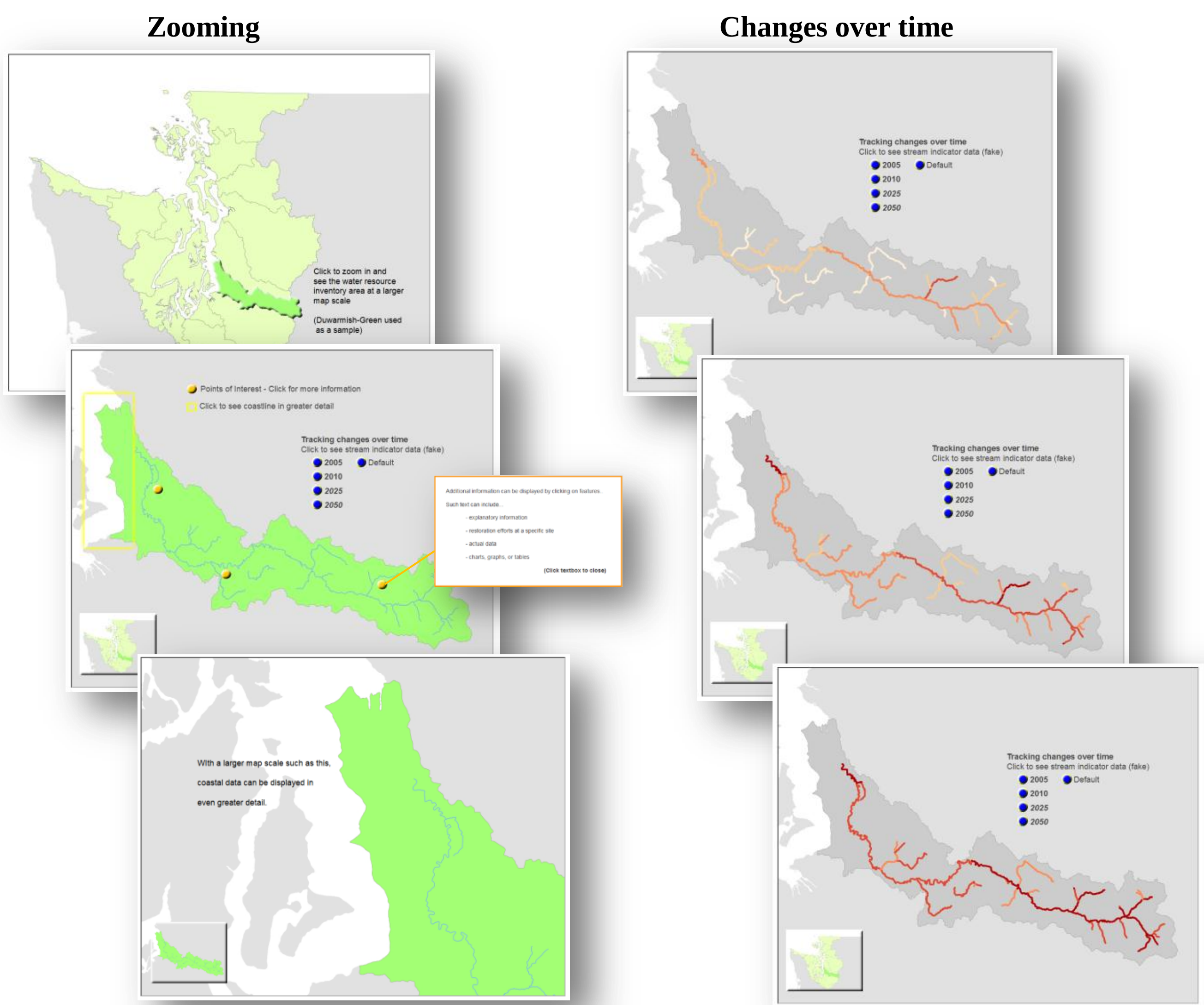


Figure 14: Sample interactive web map found at
jonathanrwalker.com/samplemap.html

CONCLUSION

The Puget Sound region is at a critical juncture, and the decisions made today will decide the health, wealth and lifestyle of generations to come. An accurate portrayal of the facts to stakeholders and the general public is vital to protecting the region. Indicator maps have the potential to do just that, by painting a clear, powerful picture of the status of Puget Sound. Following certain cartographic guidelines can greatly improve map quality, and play a major role in the successful integration of maps into more extensive publications. The cartographic recommendations in this report include the creation of a preliminary organization table, the use of an initial project map that presents the scope and extent of the project area, practicing consistency as a guiding theme throughout the mapping project, and successfully implementing the dimension of time. The need for organization, consistency, and visual clarity to deliver one succinct message is of paramount importance to future *State of the Sound* reports.

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MAP APPENDIX

Maps reviewed, critiqued, and referenced throughout the course of this report:

A. Land Development – Puget Sound Region 2001-2006.

B. Forest Land Conversion to Developed Land within Puget Sound Basin Watershed Resource Inventory Areas 2001-2006

C. Benthic Invertebrates, Stream Health and Dairy Production Runoff in the Puget Sound Region

D. Marine Sediment Quality – Current Status of Monitoring Regions and Cleanup Projects (2014)

E. Puget Sound Freshwater Water Quality – Population Density, Chinook Salmon Runs, and Contaminated Water Sites around Puget Sound Waterways

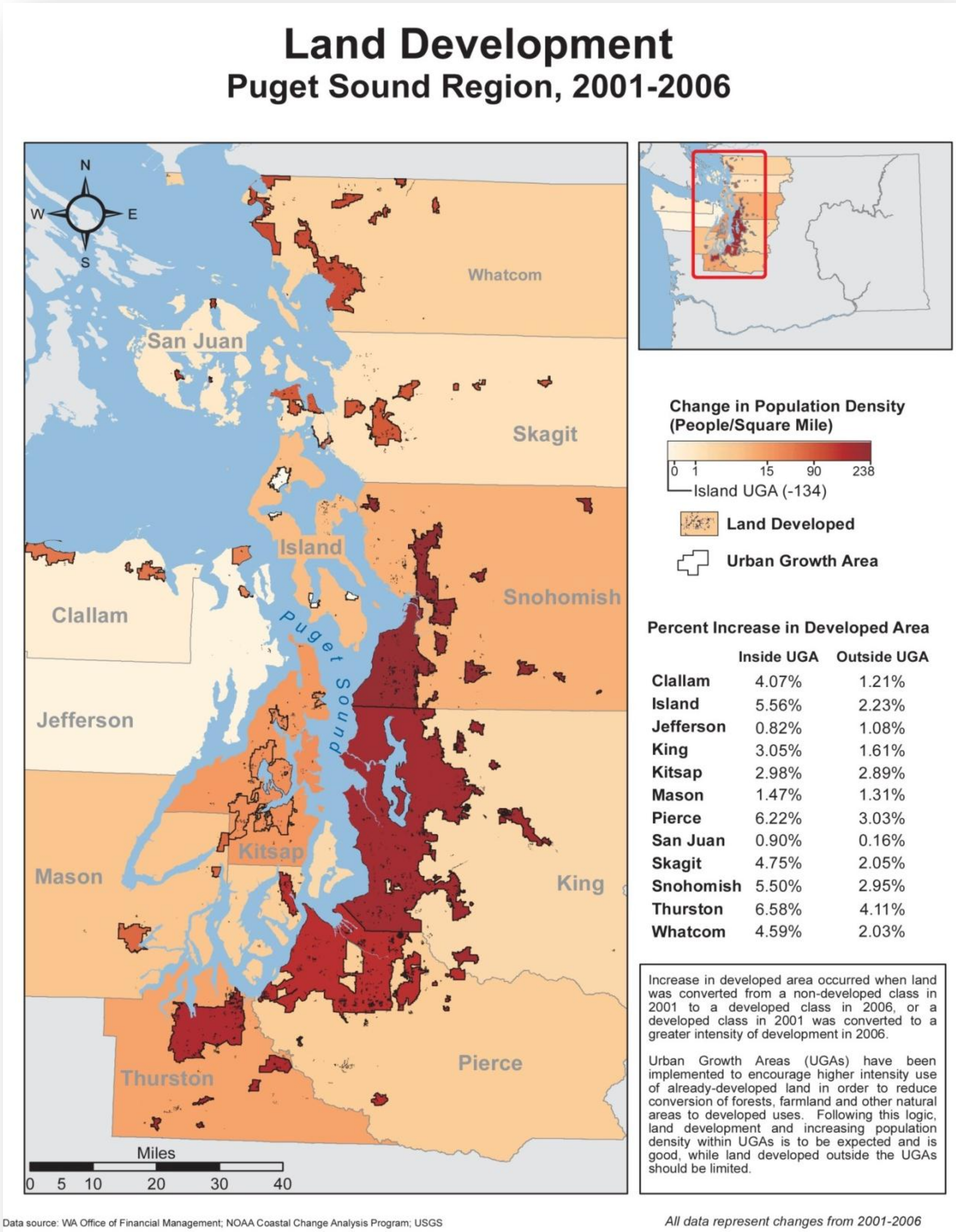
F. Indicators of Estuarine Health

G. Floodplain Functionality

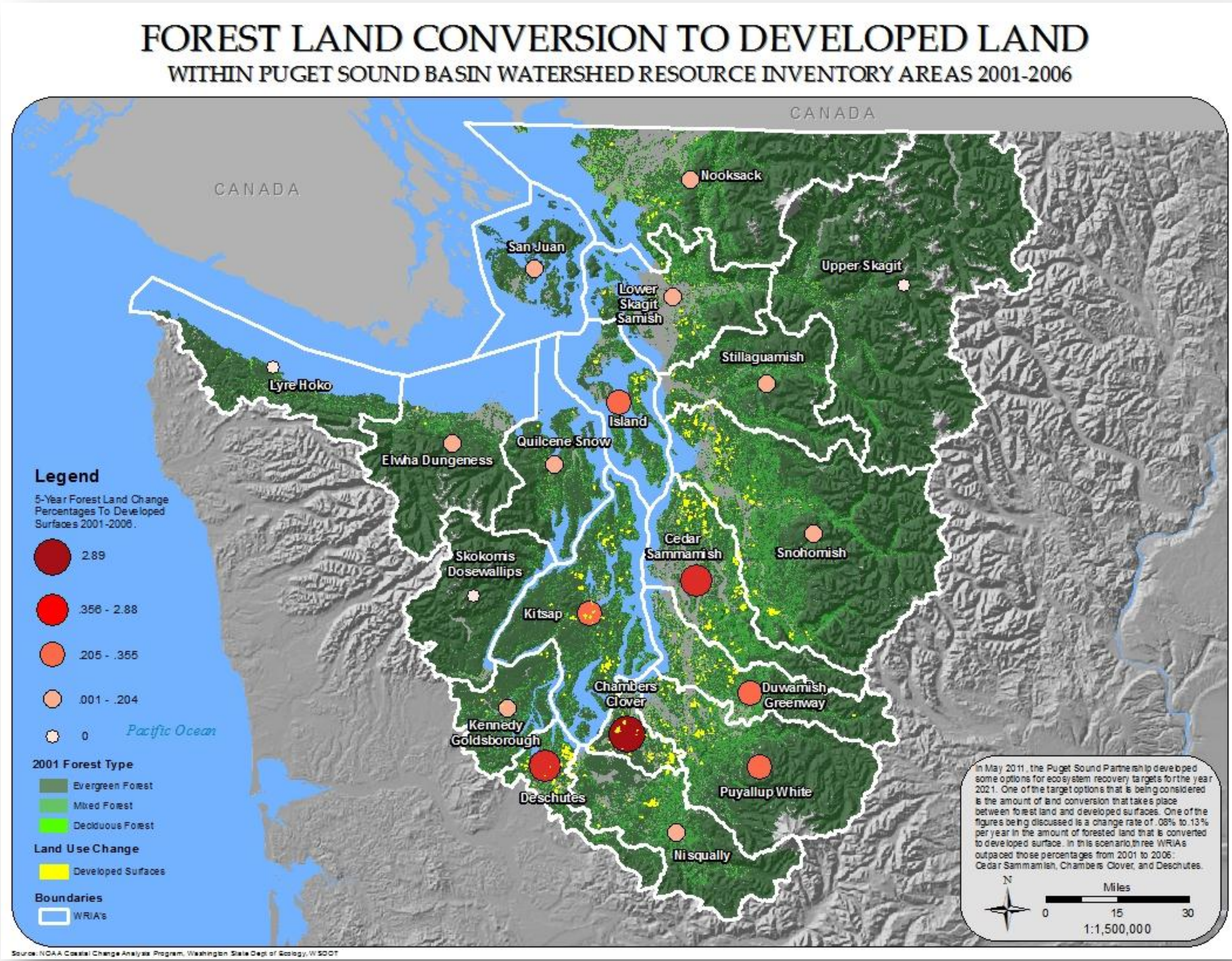
H. Shoreline Armoring, Drift, and Slope

I. Post Settlement Decline in River Mouth Estuary Health in the Puget Sound

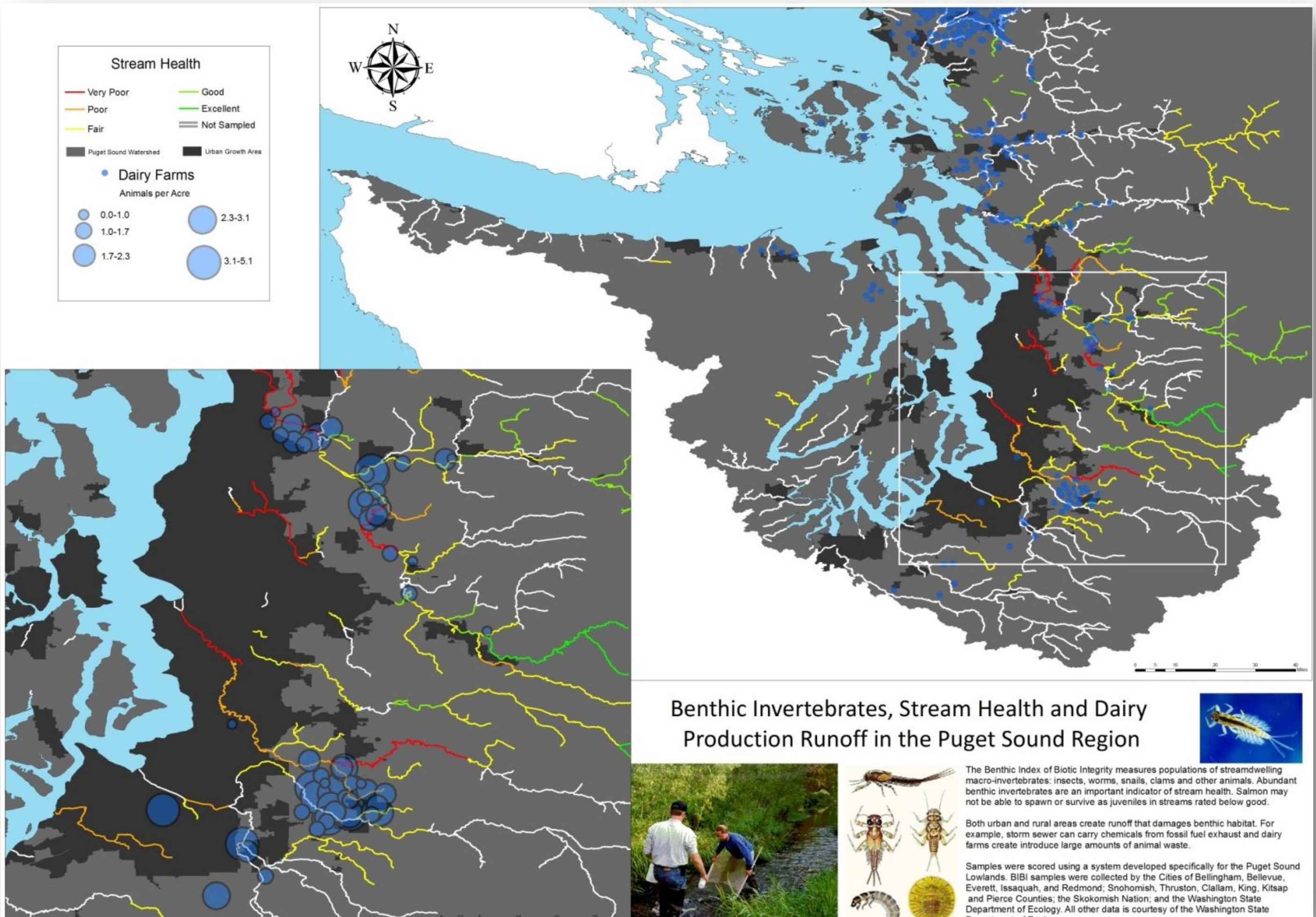
Map A: Land Development – Puget Sound Region 2001-2006.



Map B – Forest Land Conversion to Developed Land within Puget Sound Basin Watershed Resource Inventory Areas 2001-2006

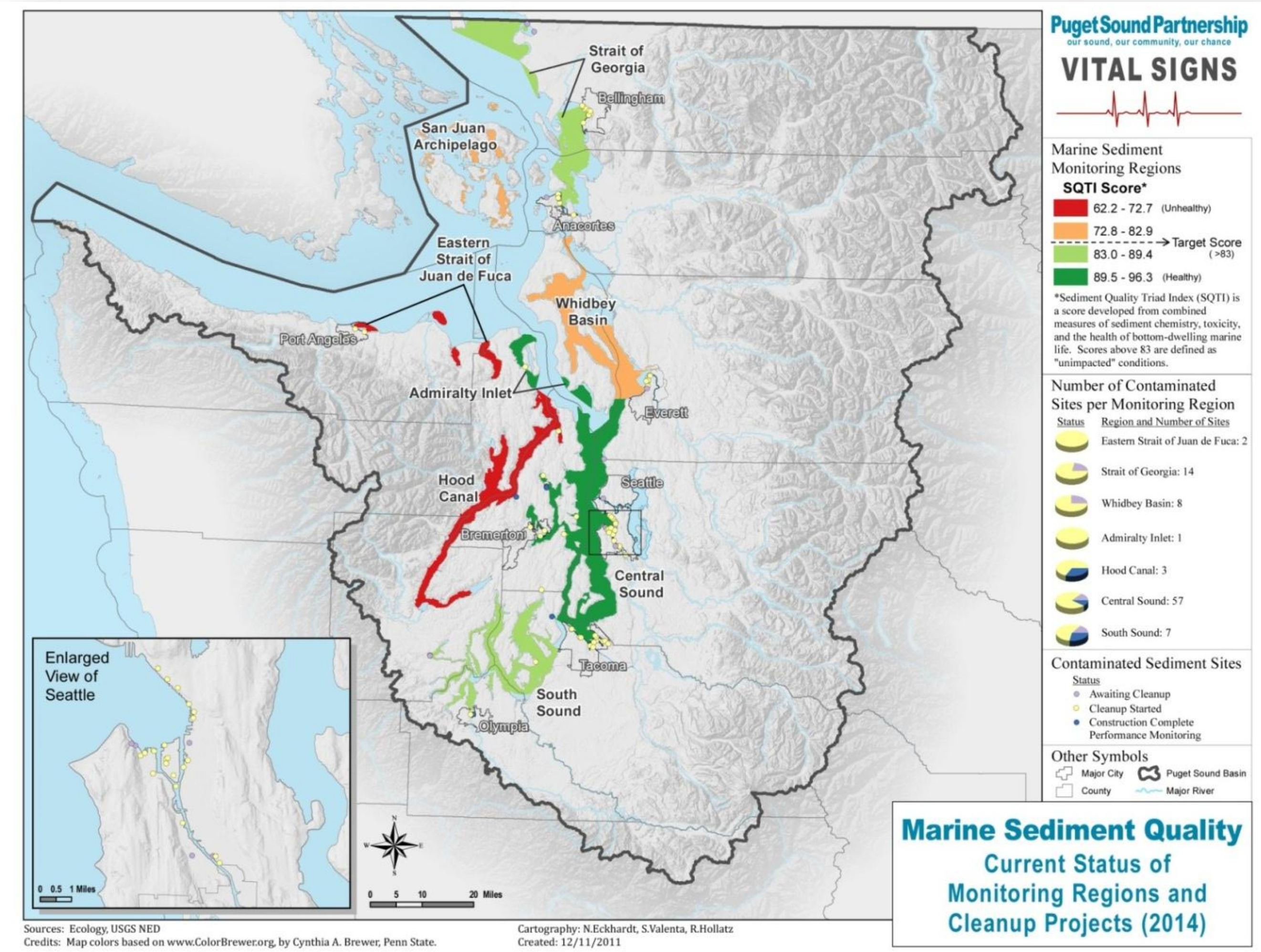


Map C: Benthic Invertebrates, Stream Health and Dairy Production Runoff in the Puget Sound Region

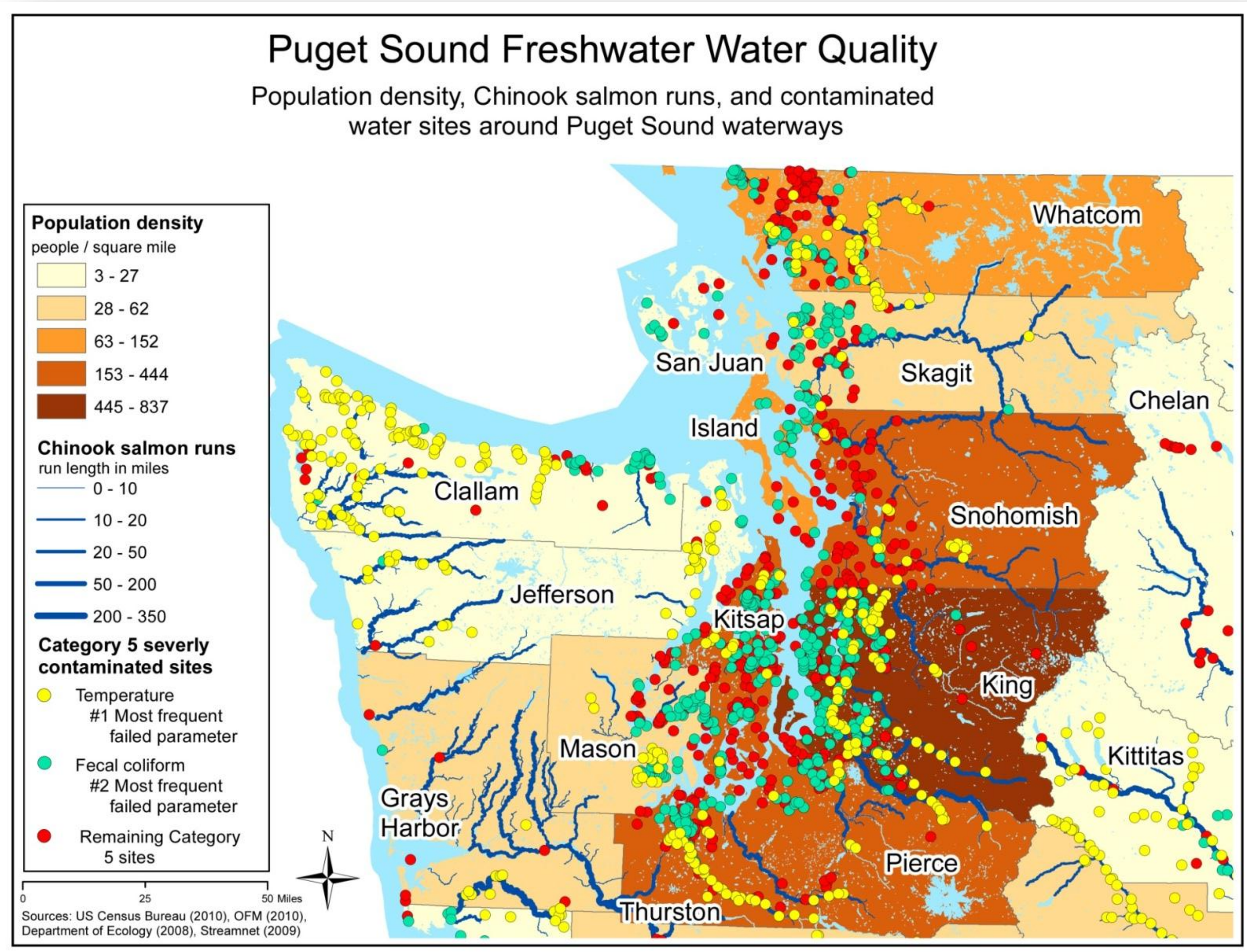


Map D: Marine Sediment Quality –

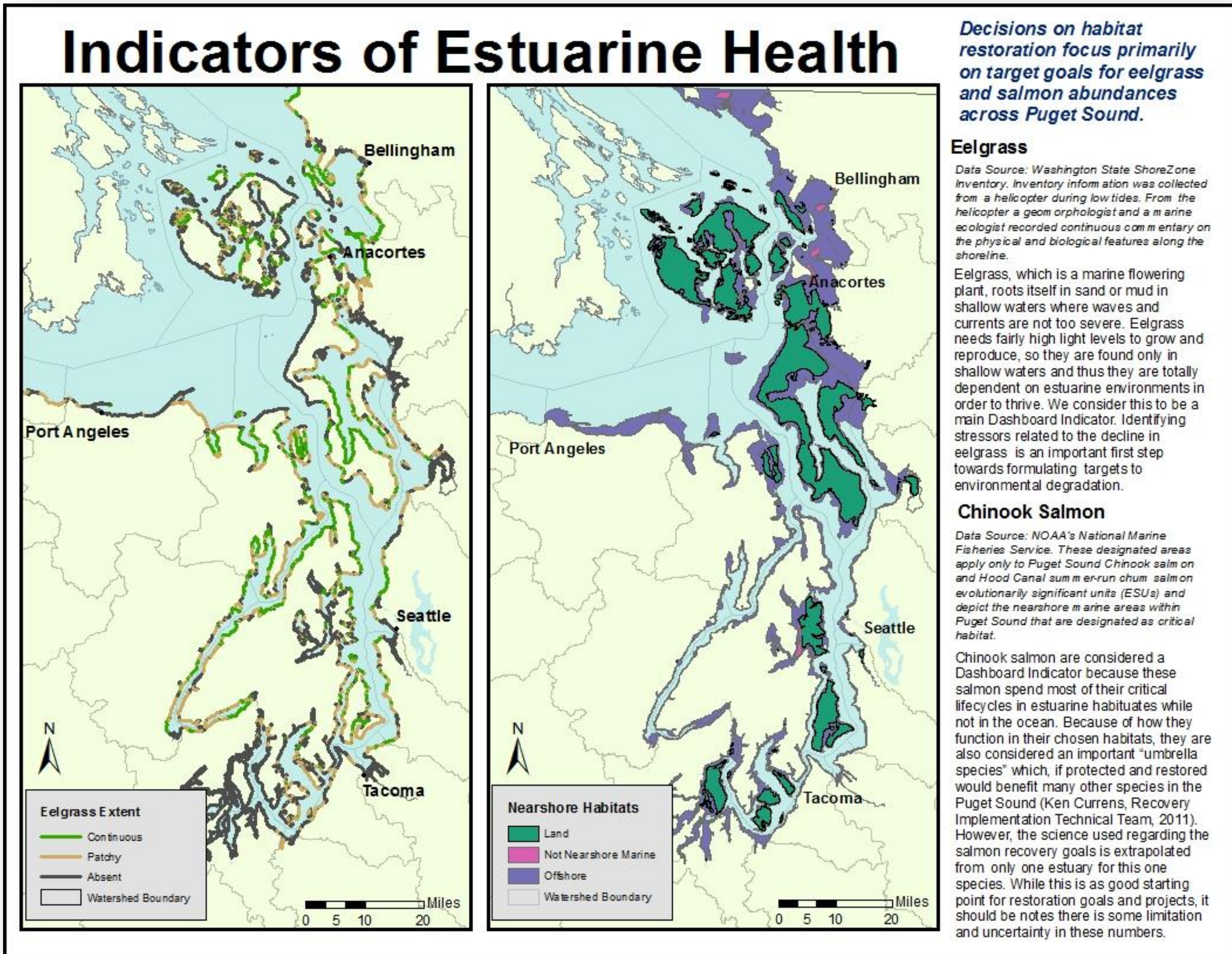
Current Status of Monitoring Regions and Cleanup Projects (2014)



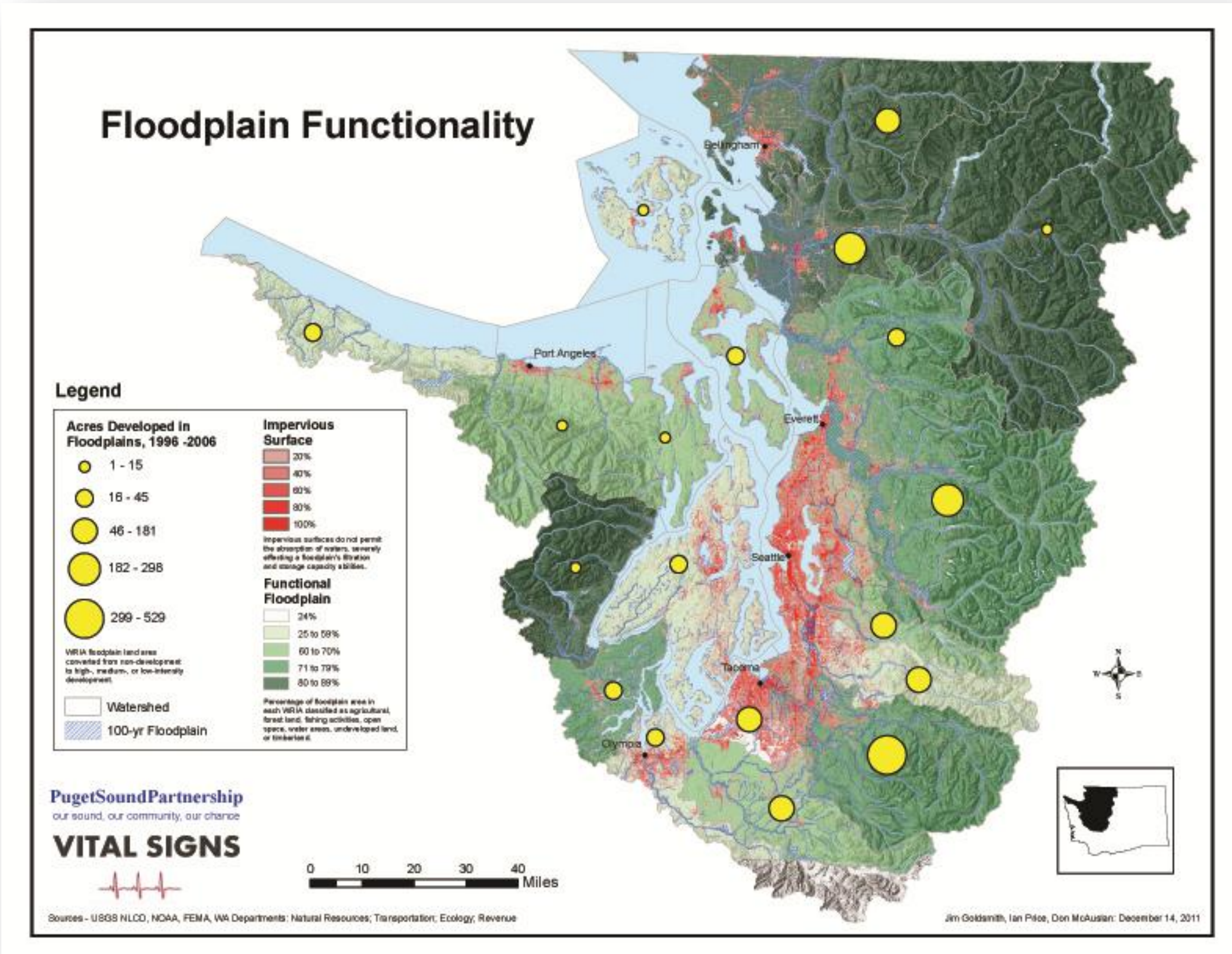
Map E: Puget Sound Freshwater Water Quality – Population Density, Chinook Salmon Runs, and Contaminated Water Sites around Puget Sound Waterways



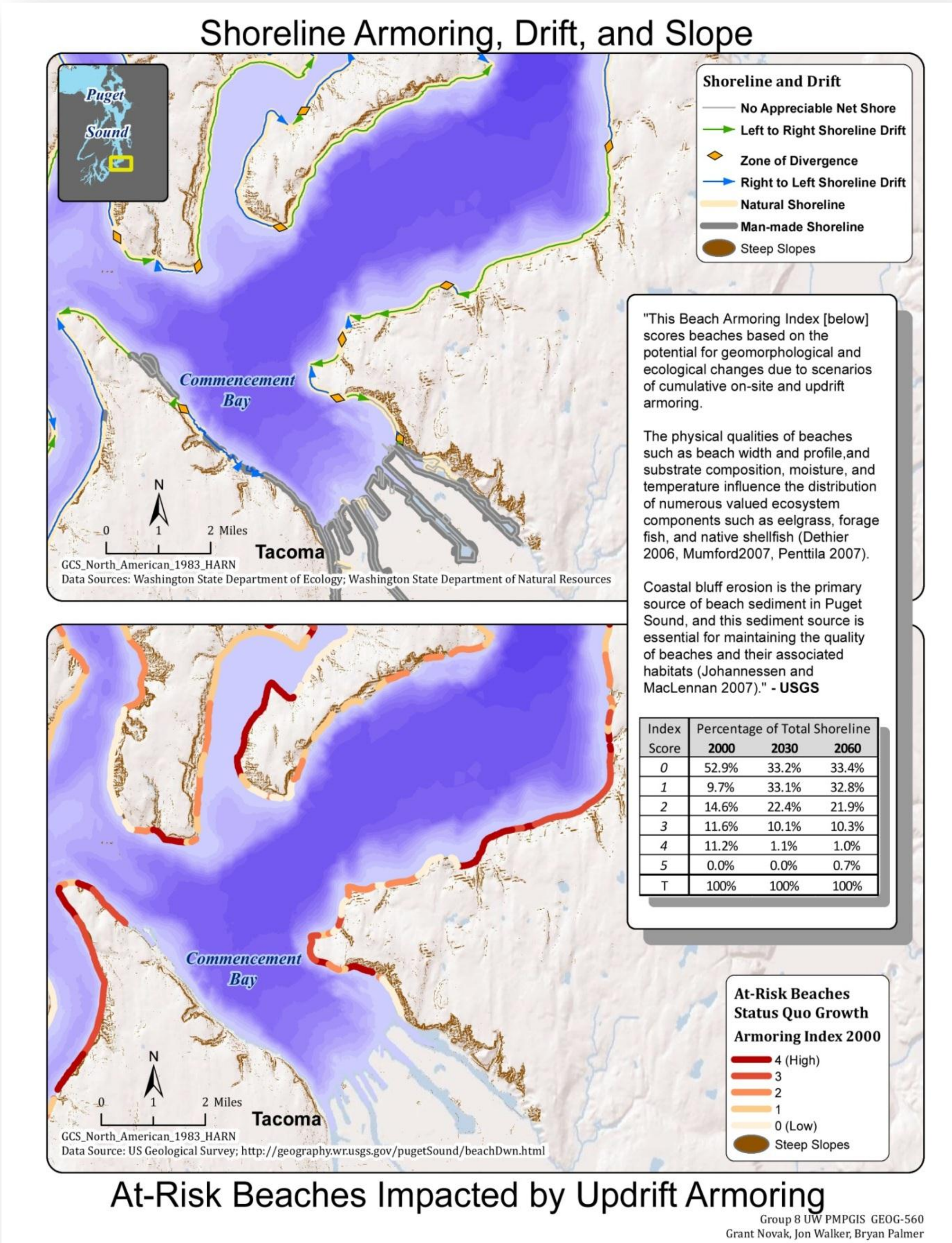
Map F: Indicators of Estuarine Health



Map G: Floodplain Functionality



Map H: Shoreline Armoring, Drift, and Slope



Index	Percentage of Total Shoreline		
Score	2000	2030	2060
0	52.9%	33.2%	33.4%
1	9.7%	33.1%	32.8%
2	14.6%	22.4%	21.9%
3	11.6%	10.1%	10.3%
4	11.2%	1.1%	1.0%
5	0.0%	0.0%	0.7%
T	100%	100%	100%

Map I: Post Settlement Decline in River Mouth Estuary Health in the Puget Sound