AN ASSESSMENT OF ERROR IN STATE SHORELINE DESIGNATION FOR LAKES OF WASHINGTON

Photo – Washington Department of Ecology

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EXECUTIVE SUMMARY

Lakes that are 20 acres or larger in size meet the criteria for designation and protection under the jurisdiction of Washington's Shoreline Management Act. However, since the original list of designated lakes was established in 1972, biologists have found some lakes that meet the size criteria but were erroneously not designated as Shorelines; probably because mapping methods were generally limited to coarse measurements of open water areas or did not include the area of wetlands within the ordinary high water mark (OHWM) of the lake.

The objectives of this project were to estimate the error rate in current lake designation in the state and develop a reliable and cost-effective method that could be used by local governments to identify lakes that meet the Shoreline criteria. We used GIS data in Phase I of the assessment to classify 8,888 lakes in Washington based on their size and potential to meet Shoreline criteria. Lake size included two components –acres of open water and acres of adjoining wetland. In Phase II we measured lake size using aerial photo interpretation for a random stratified sample of 108 lakes in western Washington. In Phase III, we field verified a random sub-sample of 12 lakes of these lakes.

We found that, the accuracy of the GIS analysis in identifying lakes that meet Shoreline criteria varied among lake classes, partly because the portion of mapped wetlands that was actually within the OHWM was highly variable. Ninety percent of the lakes with mapped open water areas of 20 acres or greater appeared to meet Shoreline criteria upon further investigation, while only about 30 percent of lakes with a open water areas between 10 and 19 acres and adjacent wetlands (for a total combined size of 20 acres or more), were found to meet Shoreline criteria. Lakes with smaller open water areas or limited wetlands were even less likely to meet Shoreline criteria. In summary, we estimate that in addition to the 765 lakes are currently designated as Shorelines in Washington, approximately 253 lakes meet Shoreline criteria but are not designated. In other words, an estimated 25 percent of the lakes that meet Shoreline criteria in Washington State are not designated or protected under the Shoreline Management Act.

We recommend that local governments conduct a survey of lakes within their jurisdiction to identify and designate lakes that meet Shoreline criteria .We have prepared GIS shape files that summarize the Phase I analysis and including a map of each lake in the state greater than 1 acre in open water area, with its classification and other pertinent data . We recommend that these data be used to identify lakes in each local jurisdiction that have a moderate to high probability of meeting Shoreline criteria; namely those lakes classified as "Open Water 10-19 Acres, Possible Shoreline" and "Open Water 20+ Acres, Possible Shoreline". If time and funding permit, lakes within lake classes that are less likely to meet Shoreline criteria should also be included, particularly lakes within "Open Water 1-9 acres, Possible Shoreline". For each lake identified, a biologist trained in OHWM determination by Washington Department of Ecology should first estimate the lake area using aerial photos and a dot matrix grid or GIS tools as was done in Phase II of this project. Because of the potential error in using aerial photo interpretation alone, all lakes should also be field verified unless aerial analysis unequivocally shows that the lake is less than 20 acres in size, including wetlands. Biologists should conduct the field verification using the methods we developed for Phase III.

INTRODUCTION

The Shoreline Management Act and the History of Lake Designation

The Shoreline Management Act (Chapter 90.58 RCW) was enacted in 1971 to manage and protect the shorelines of Washington State by regulating development in shoreline areas. A major goal of the Act is "to prevent the inherent harm in an uncoordinated and piecemeal development of the state's shorelines." (RCW 90.58.020). Its jurisdiction includes the Pacific Ocean shoreline, the shorelines of Puget Sound, the Strait of Juan de Fuca, and rivers, streams and lakes that meet certain physical criteria. It also regulates wetlands associated with these shorelines.

The primary responsibility for administering the Shoreline Management Act regulatory program is assigned to local governments. Local governments have done so through the mechanism of Shoreline Master Programs, adopted under rules established by the Washington Department of Ecology (Ecology), that establish goals and policies that are implemented through land use regulations. No substantial development is permitted on the state's Shoreline unless a permit is obtained from the local jurisdiction. Through the Shoreline Management Act, local governments have implemented regulations that help protect lakes designated as Shorelines, generally including a 200-foot wide “Shoreland” zone that delineates the minimum extent of Shoreline jurisdiction. Within Shorelines jurisdiction, certain types of timber harvest, land clearing, and development are limited to protect fish, wildlife, and other natural resources. Lakes that are not designated as Shorelines receive no protection under the Shoreline Management Act.

Field biologists with Ecology and other organizations have long recognized that some lakes in Washington that meet the criteria for designation as Shorelines are erroneously not designated. The list of Shoreline designated lakes (WAC 173-20) states that the lakes were selected based on data in Volumes I and II of the book Lakes of Washington by Ernest E. Wolcott (1973a, 1973b) and updated information from the United States Geological Survey. Both of these original sources probably under-estimated lake sizes because they were 1) based on small-scale maps less accurate than those presently available, 2) based partly on smaller-scale aerial photos than those presently available, and 3) may have not included contiguous wetlands within the ordinary high water mark (OHWM) of the lake.

In addition, Ecology decided not to include lakes on the Shoreline list that were surrounded by federal ownership, although the rules specifically include such lakes. According to WAC 173-20-820, lakes or portions thereof which are located on nonfederal lands within the exterior boundaries of federal lands and that meet the Shoreline definition are subject to the jurisdiction of the Shoreline Management Act. Because it is already known that such lakes were erroneously not included on the list of designated Shorelines, this report focuses on the status of lakes outside of federal land boundaries.

Since passage of the Shoreline Management Act 35 years ago, Ecology has conducted no formal review and has proposed no update to the original list of designated lakes. Yet, according to Chapter 173-20-044 WAC, Ecology has a responsibility to review the

Shoreline designations at least once ever five years and prepare necessary revisions for approval by the Shorelines Hearings Board -

*The department shall review all the designations made herein at least once in every five year period following the effective date of chapter 90.58 RCW or as frequently before then as is deemed advisable by the department, and prepare the necessary revisions to ensure that the designations conform to the policies of chapter 90.58 RCW and of chapter 173-20 WAC in the manner and form prescribed for adoption and amending rules and regulations in chapter 34.04 RCW (the Administrative Procedure Act) (*WAC 173-20-044).

Ecology adopted new Shoreline Master Program guidelines, Chapter 173-26 WAC, which became effective January 17, 2004. Cities and counties are required to update their Shoreline Master Programs to be consistent with the new guidelines according to a schedule adopted under 2003 legislation (RCW 90.58.080). The schedule extends from December 1, 2005 to December 1, 2014. Under the Shoreline Management Act, local jurisdictions are required to "utilize a systematic interdisciplinary approach which will ensure the integrated use of the natural and social sciences and the environmental design arts" (RCW 90.58.100). Furthermore, according to the guidelines, the updated master programs should use the "the most current, accurate and complete scientific and technical information available" (Chapter 173-26-201 2(a) WAC).

Ecology recently proposed revisions to the Shoreline rules that even more clearly tranfer responsibility for updating the list of designated lakes from Ecology to local government as part of local updates to the Shoreline Master Programs. The proposed June 12, 2006 amendments to WAC 173-18, 20, and 22 would recognize updated Shoreline Master Programs as the source for identifying Shoreline Management Act jurisdiction. The outdated waterbody lists in the WACs would be superseded as Shoreline Master Programs are updated by local governments and officially approved by Ecology. Furthermore, the proposed rule requires local governments to amend the local Master Program to reflect a new lake designation within three years of the discovery of an error. Thus, this project is intended to provide the scientific and technical information to assist local governments in ensuring accurate designation of lakes as Shorelines within their jurisdiction.

Shoreline Designation Criteria for Lakes

To identify lakes that meet the criteria for Shorelines, but have not been designated as such, it is necessary to examine the criteria closely. The size of the lake, in terms of surface area, is the defining characteristic; lakes of 20 acres or larger meet the criteria for Shoreline designation (underline added) -

2 (d) "Shorelines" means all of the water areas of the state, including reservoirs, and their associated shorelands, together with the lands underlying them; <u>except (i)</u> shorelines of statewide significance; (ii) shorelines on segments of streams upstream of a point where the mean annual flow is twenty cubic feet per second or less and the wetlands associated with such upstream segments; and <u>(iii) shorelines on lakes less than twenty acres in size and wetlands associated with such small lakes;</u> (RCW 90.58 (2) (d))

The size of the lake depends upon how the boundaries of the lake are defined. Does the "lake" include a margin of wetlands or does it only extend to the open water edges of the lake next to "associated wetlands"? In the case of the Shoreline Management Act, a lake is defined as "bounded by the ordinary high water mark" -

"Lake" means a body of standing water in a depression of land or expanded part of a river, including reservoirs, of twenty acres or greater in total area. A lake is bounded by the ordinary high water mark or, where a stream enters a lake, the extension of the elevation of the lake's ordinary high water mark within the stream. (WAC 173-22-030(9))

Ecology staff agrees that under this definition, lake boundaries include vegetated shoreline edges, as long as these areas are within the OHWM. In contrast, an "associated wetland" not included in the lake area would be a wetland that is higher in elevation than the lake's OHWM or separated from the OHWM boundary by an area of high ground. As defined in the Shoreline Management Act, it is apparent that accurately delineating the OHWM may require careful field observation -

"Ordinary high water mark" on all lakes, streams, and tidal water is that mark that will be found by examining the bed and banks and ascertaining where the presence and action of waters are so common and usual, and so long continued in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland, in respect to vegetation as that condition exists on June 1, 1971, as it may naturally change thereafter, or as it may change thereafter in accordance with permits issued by a local government or the department…(RCW 90.58 (2) (b))

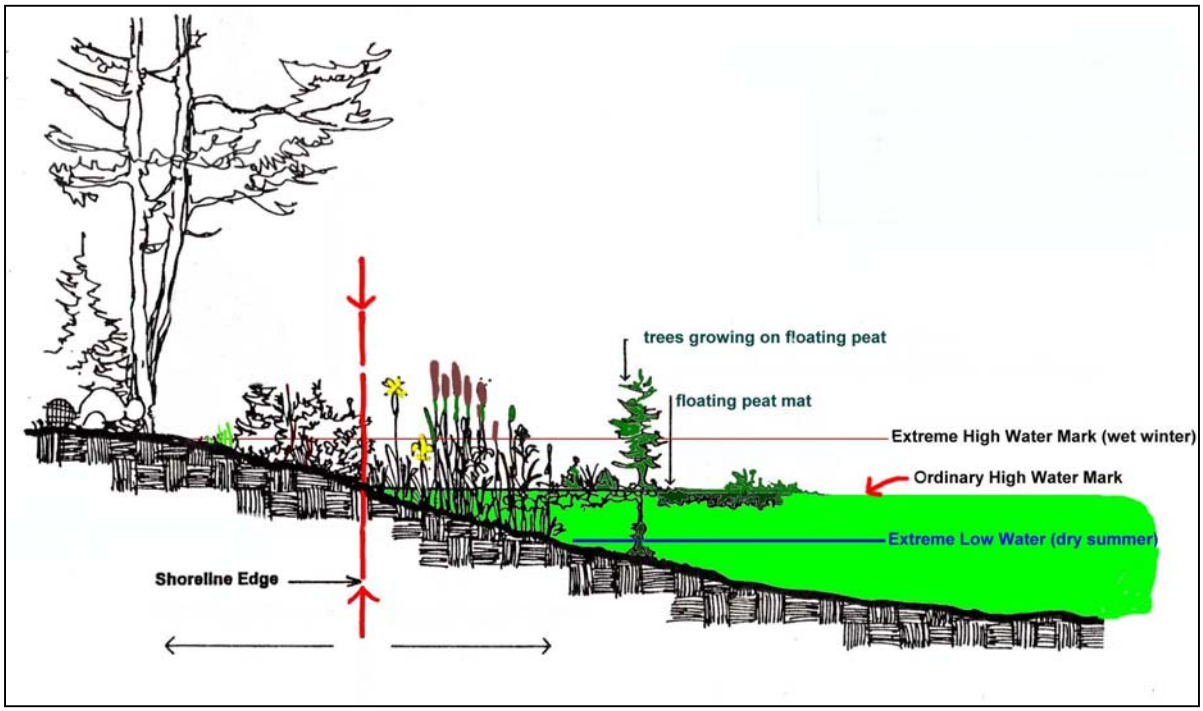


Figure 1. Red arrows denote edge of lake shoreline and ordinary high water mark (Source - Erik Stockdale, Ecology, 2005).

Figure 2. Twenty three acre Thorndyke Lake in Jefferson County, where only 4 acres are open water. (Source – Perry Lund, Ecology, 1998).

Goals and Objectives

The working hypothesis of this pilot project, based on our preliminary field observations and conversations with Ecology staff, is that many lakes that are 20 acres or larger were erroneously not given Shoreline designation because of mapping methods which were generally limited to coarse measurements of open water areas or did not include the area of wetlands within the OHWM of the lake, as discussed above.

Since 1972, when the initial list of lakes was designated by Washington State as Shorelines, advances in technology (global positioning systems (GPS), geographic information systems (GIS), laser rangefinders, geo-rectified orthophotos, satellite imagery, etc.) now allow much more accurate and precise measurements of lake size. The goal of this pilot project is to help state and local governments ensure that all lakes that meet the criteria for protection under the Shoreline Management Act are identified and designated as Shorelines. The objectives of the project are to 1) estimate the error rate in current lake designation in the state, and 2) develop a reliable and cost-effective method that can be used by local jurisdictions to identify lakes that meet the criteria to be designated as Shorelines, but are not now so designated. It is our intention that the results of this project will assist local governments in their efforts to update their Shoreline Master Programs.

METHODS

The assessment involved three phases. In Phase I, we used commonly available GIS coverages to classify 8,888 lakes statewide based on their potential for designation as Shorelines. We then sub-sampled these lakes to assess the accuracy of the Phase I results in identifying lakes that meet Shoreline criteria. In Phase II we measured lake size using aerial photo interpretation for a random stratified sample of 108 lakes in western Washington. In Phase III, we field verified a random sub-sample of 12 lakes.

Phase I - GIS Identification of Shoreline Lakes

In the Phase I GIS analysis, lake size and other data were obtained on every lake in the state, not including lakes within federal lands. The purpose of the analysis was to -

a) Estimate potential error in lake Shoreline designation on a state-wide level;

b) Determine the number of lakes in each ecoregion that should be subsampled as part of Phase II analysis, based on the relative number of lakes in each ecoregion;

c) Determine the best size range of lakes to subsample.

The Washington Department of Natural Resource's (DNR) 1:24,000 "hydro" coverage of lakes, intersected with the Ecology's ecoregions data layer and a federal lands data layer, was used to obtain lake sizes and other data for all lakes in the state outside of federal lands (Figure 3). Wetlands adjacent to lakes were identified using DNR wetland coverage included in their hydro layer and the National Wetlands Inventory (NWI) GIS coverage of three wetland types (aquatic bed, emergent, and scrub/shrub). All of the GIS data layers were converted to the same map projection and coordinate systems. The following data on each lake were collected-

Unique lake identification number.
Geographic coordinates (Centroid of the lake and legal description)
Ecoregion
County
Open water size (acres)
Adjacent wetland size for NWI and DNR wetland coverages (acres)
Possible Lake size (Open water + adjacent NWI or DNR wetland) (acres)
Designated as a Shoreline by Ecology (Yes or No)

Lakes were classified into eight categories for the analysis based on three criteria –

1) "Open water" size of the lake as determined by the DNR GIS coverage of lakes. Open water size categories of 1-9 acres, 10-19 acres, and 20 acres or greater were used. Figure 4 provides an example of the DNR boundary of a lake, which generally denotes the open water surface area of a lake.

2) Total lake area based on the sum of the DNR open water size and adjacent wetland acreage if present. The larger of either the NWI or DNR derived wetland area was used. Three NWI wetland types were included in the analysis - aquatic bed, emergent, and shrub/scrub. To compensate for possible inaccuracies of mapped wetland and lake locations, wetlands within 300 feet of the DNR open water lake edge were included in the wetland acreage. Lakes that were found to

be 20 acres or larger by this method were identified as a “Possible Shoreline”. Lakes that were less than 20 acres were labeled “Not Shoreline”. Figure 5 provides an example of a lake showing the contiguous NWI wetland area.

3) Lakes that were already designated as Shorelines of the State, or “On Ecology List”.

The DNR GIS data for a “lake” was originally derived from USGS maps and aerial photos and generally denotes the open water portion of a lake. Thus, the classification system uses the DNR lake area, in size categories from 1-9 acres, 10-19 acres, and greater than 20 acres, to better understand how changes in open water lake size relate to changes in patterns of Shoreline designation (Table 1). In general, we expect that lakes with an open water area slightly less than 20 acres have the highest probability of meeting Shoreline criteria; a small amount of additional lake area or wetland within OHWM boundary puts the total lake area over the 20 acre threshold. The lake classification system was used stratify lakes for subsampling and for analysis purposes.

The GIS layer for federal lands was coarse and lakes with more than one-half of their area within the federal boundary were not included in the assessment. In addition, lakes with less than one acre of open water surface area, according to the DNR GIS coverage, were not included. Thus, some lakes that may meet Shoreline criteria were probably excluded from the analysis.

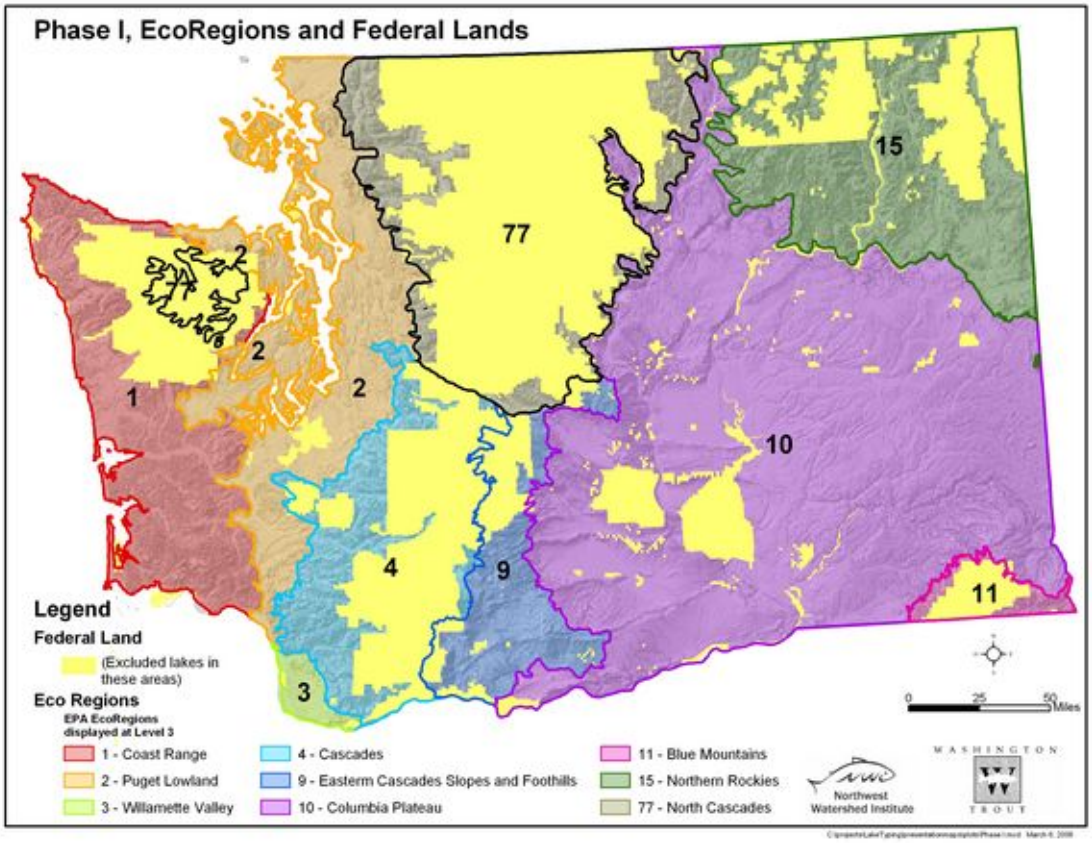


Fig 3. Ecoregions of Washington State. Lakes within federal lands (yellow areas) were excluded from the analysis.

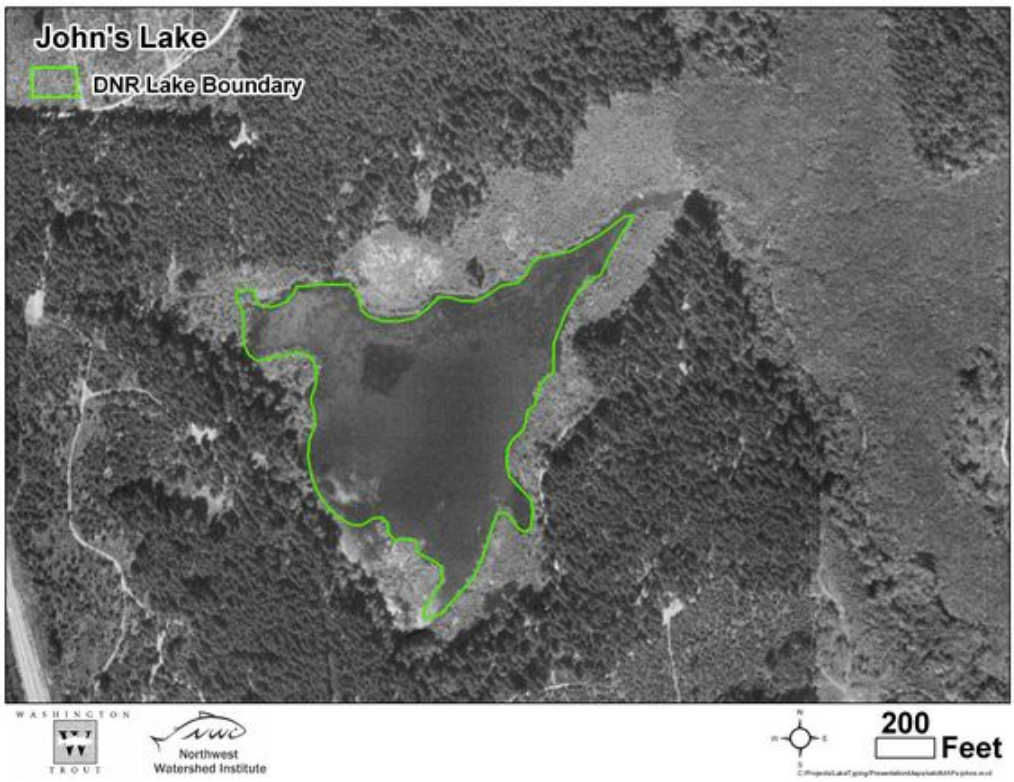


Figure 4. Example of digital ortho-photo with DNR GIS coverage of lake boundary.

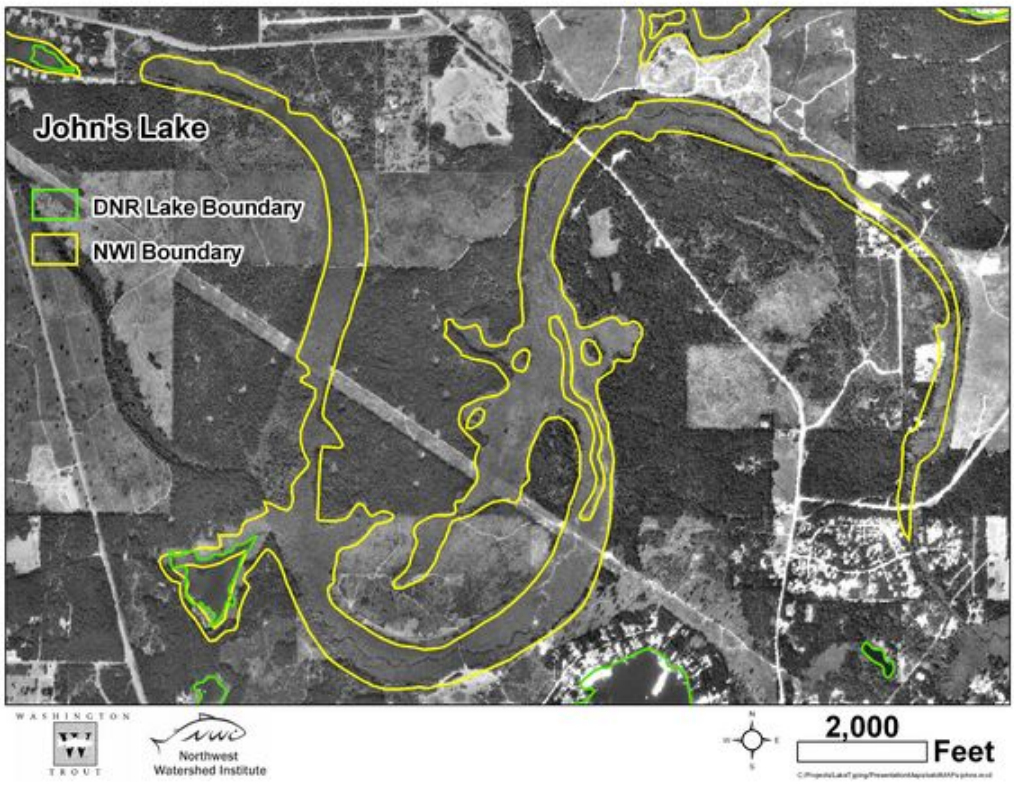


Figure 5. DNR lake boundary and National Wetlands Inventory boundary.

Phase II – Sub-sampling by Hand Digitizing

The purpose of Phase II of the analysis was to estimate the accuracy of the Phase I remote sensing results. A stratified random sample of 108 lake orthophotos was hand-digitized, representing about 5 percent of lakes in each class sampled in the entire state (Table 1). The selection method was based on an original sample size of 306 lakes statewide with a representative proportion of lakes selected from each lake class and eco-region. However, due to budget constraints, mainly "west side" lakes in Ecoregions 1, 2 and 3 were selected for hand digitizing, representing 10 to 20 percent of the lakes in each lake class in these western ecoregions (Figure 6). (One lake in eastern Washington was sampled to test new aerial photos available in that region). Lakes in the DNR size category of 1-9 acres and totaling less than 20 acres with the addition of adjacent wetlands (Not Shoreline) were not sampled due to the large number of these lakes and the inability to obtain a representative sample.

The GIS Specialist, who was not a professional wetland ecologist, hand digitized the OHWM boundary using digital orthophotos, and using the DNR hydro layer and NWI state-wide wetlands layer for guidance (Figure 7). The GIS Specialist was instructed to draw the boundary line of the lake to include both open water and wetland vegetation zones that appeared to be below OHWM, as per the WAC 173-22-030 lake boundary definition. However, we purposely did not provide extensive training or direction in OHWM photo interpretation to the GIS Specialist to simulate the experience level that might be available to local jurisdictions.

Table 1. Number and percent of lakes in each lake class selected for sampling in Phase II, and original sampling goals.

Lake Class	Total Number of Lakes	Lakes Selected Statewide (#)	Lakes Selected Statewide (%)	State-wide Sample Goal (#)	Statewide Sample Goal (%)
Open Water 1-9 Acres, Possible Shoreline	684	34	5	103	15
Open Water 1-9 Acres, on Ecology List	41	2	5	8	20
Open Water 1-9 Acres, Not Shoreline	6729	0	0	34	0.5
Open Water 10-19 Acres, Possible Shoreline	170	16	9	34	20
Open Water 10-19 Acres, on Ecology list	60	3	5	12	20
Open Water 10-19 Acres, Not Shoreline	394	15	4	39	10
Open Water 20+ Acres, Possible Shoreline	234	11	5	47	20
Open Water 20+ Acres, on Ecology List	576	27	5	29	5
TOTAL	8,888	108		306	

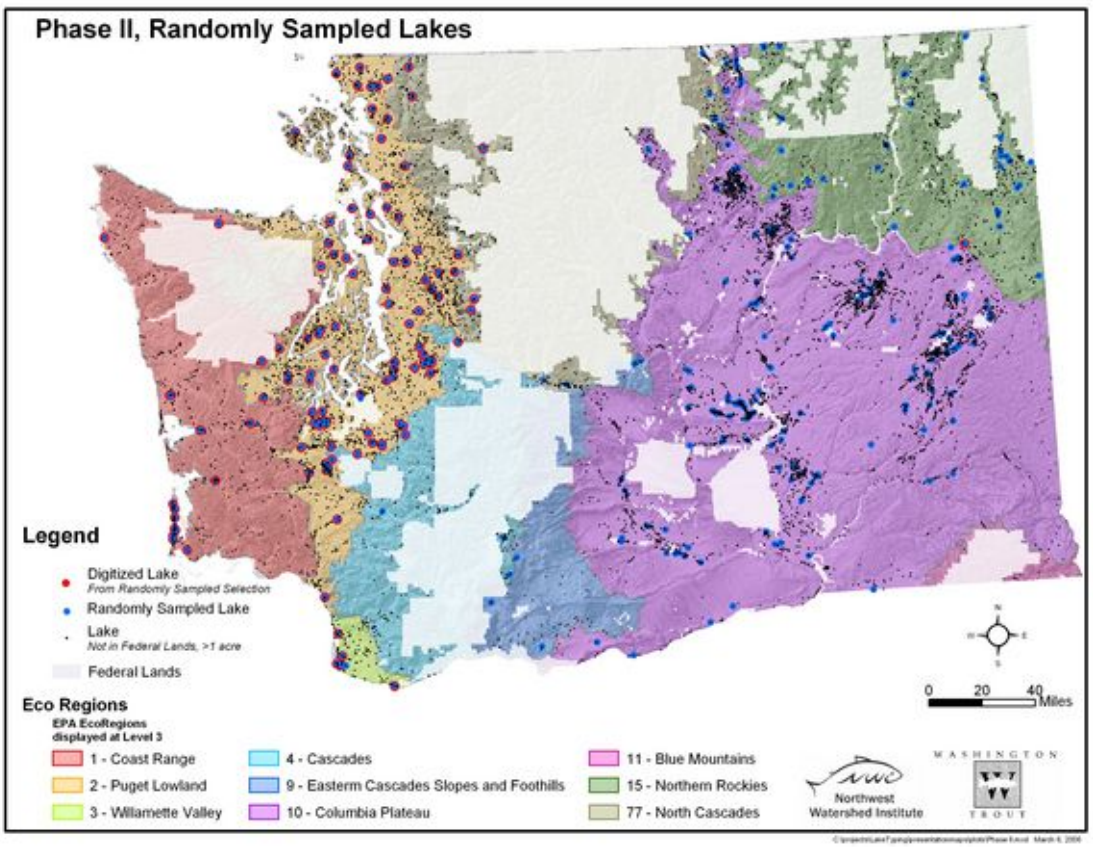


Figure 6. Location of 108 lakes selected for Phase II analysis (red) on the west side of Washington out of a total of 306 lakes originally identified for Phase II analysis (blue).

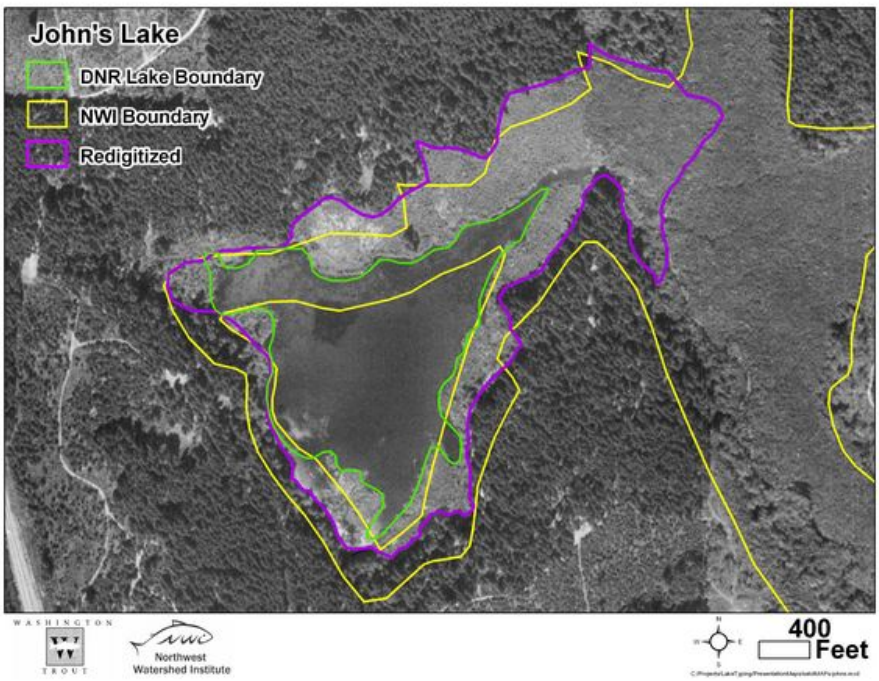


Figure 7. Example of re-digitized lake boundary (estimated OHWM).

Phase III – Field Verification

In Phase III of the analysis, the accuracy of lake sizes obtained from existing GIS coverages and from the GIS specialist's re-digitized subsample of lakes was field-verified. Twelve lakes were randomly selected for field verification, representing 11 percent of the 108 hand digitized lakes in western Washington. Lakes in six of the eight lake classes were sampled, with at least one lake randomly selected from each class. Lakes in the remaining two classes were not sampled – "Open Water 1-9 acres, Not Shoreline" and "Open Water 1-9 acres, On Ecology List".

Prior to the start of the field sampling, wetland scientists from Ecology trained Northwest Watershed Institute and Washington Trout biologists and field technicians in proper methods for determining the OHWM for lakes (Figure 8). Field work occurred between July and September 2005. For each lake selected for field verification, the field crew located the lake edge using field observations at four primary sites, and additional supplemental sites, along the circumference of the lake. The crew recorded the location of the OHWM at each site with a sub-meter accurate Trimble GPS unit from a canoe or on-shore. The crew took photographs and recorded detailed field observations at each of the four primary sites to document their rationale for choosing the OHWM location as related to vegetation and soil conditions. The crew used a field data form based on Ecology's data form for OHWM determination.

The four primary sampling sites provided the rationale and reference for the field crew to locate OHWM at supplemental sites using vegetation, topography, and soil clues as they traveled the circumference of the lake by canoe or foot (Figure 9). Where it was not possible to take a GPS reading at OHWM due to overhanging vegetation, one crew member used a range finder or tape from a boat to measure the distance and bearing from the recorded GPS location at the canoe to the actual OHWM location where the other crew member was standing (Figure 10). The field crew also hand sketched the entire circumference of OHWM on a printed aerial orthophoto, based on their interpretation of OHWM location as it related to observed changes in vegetation type and other features that were also visible on the orthophoto.

The OHWM boundary, recorded during the field verification as a series of GPS points and hand drawn lines, was then entered into a GIS. This layer was then overlaid upon the previously hand digitized boundary, and spatial analyses were performed to compare the difference in lake size between the two layers. The reasons for any observed differences were documented. Figure 11 provides an example of an orthophoto of a lake with Phase I, II, and III lake boundaries displayed.

Figure 8. Perry Lund, Ecology staff, training field crew in OHWM determination.

Figure 9. Field crew using canoe to verify and map OHWM lake edge.

Figure 10. Mary Lou White and Frank Staller record GPS location of lake edge.

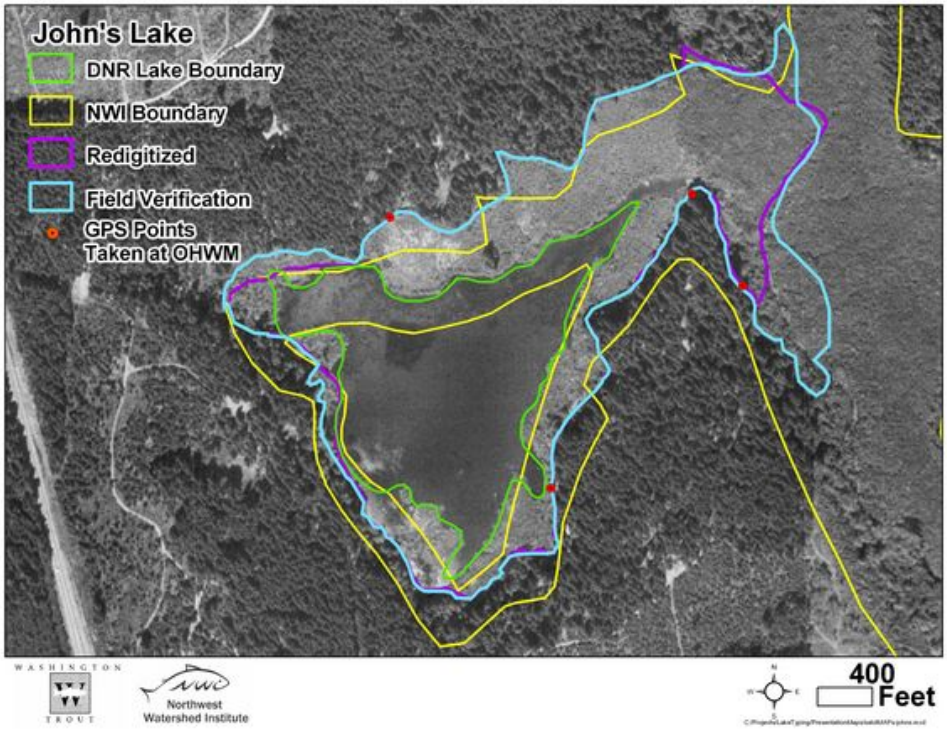


Figure 11. Example of Phase III field verified lake boundary with Phase I and II results.

RESULTS AND DISCUSSION

Phase I - GIS Identification of Possible Shoreline Lakes

The Phase I GIS analysis identified three basic types of lakes – 1) "Possible Shoreline" lakes that are 20 acres or larger, including adjacent wetlands, but are not designated as Shorelines, 2) "Not Shoreline" lakes that appear to be less than 20 acres including adjacent wetlands, and thus are not likely to meet criteria for Shoreline designation, and 3) "On Ecology List" lakes currently designated as Shorelines by the state. Figure 11 shows the distribution of these types of lakes among categories of open water lake size. Most of the lakes in the state are less than 10 acres in open water area. When this size category is removed from Figure 11, it is evident that "Possible Shoreline" lakes were identified in significant numbers in all open water size categories (Figure 12).

Two types of "Possible Shoreline" lakes were found. First, some lakes were identified as 20 acres or larger only when the adjacent wetlands were added to the open water lake area from the DNR GIS lakes coverage (Tables 2 and 3). This method of estimating total lake area likely over-estimated actual lake size in many cases since the entire mapped wetland area may not be included within the OHWM boundary of the lake. However, we assume that in some fraction of these cases, enough of the wetlands are within OHWM that the lake area meets Shoreline criteria of 20 acres or larger.

The second type of "Possible Shoreline" lakes includes lakes that are 20 acres or larger based solely on their "open water" area obtained solely from the DNR GIS lake coverage, but yet are not designated as Shorelines. Two hundred and thirty four lakes, or 29 percent of the total of 811 lakes with an open water lake area of 20 acres or larger are within this category, with the remaining 577 lakes already designated as Shorelines (Tables 2 and 3). Because the DNR GIS lake area data was originally derived from aerial photos and USGS data, we expect that this layer provides a fairly reliable estimate of the open water area of the lake, and thus represents a conservative estimate of lake size. We expect that most lakes identified as "Possible Shoreline" by using only the DNR "open water" data probably meet Shoreline criteria of being 20 acres or larger in size.

Lakes designated by the state as Shorelines were surprisingly difficult to find on the map. The list of Shoreline lakes in the WAC provides only the Section, Township and Range for each lake and Ecology does not have a GIS coverage that identifies Shoreline lakes. We found that some Sections contained more than one lake, some lakes could not be found at all in the GIS, and some lakes were listed more than once since they occurred in more than one county. In addition, we discovered that when DNR produced their hydro layer, they arbitrarily classified lakes of 20 acres or greater as "Shorelines", regardless of whether they are actually designated by Ecology as Shorelines.

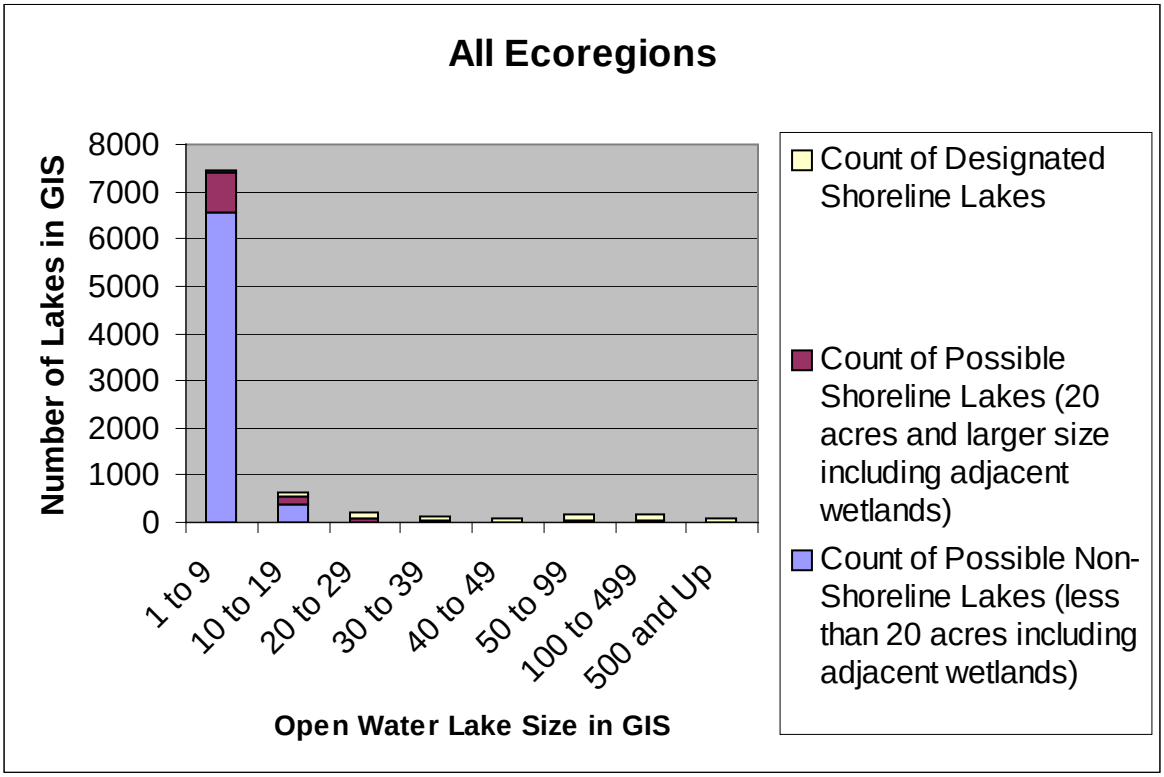


Figure 12. Phase I results for all ecoregions.

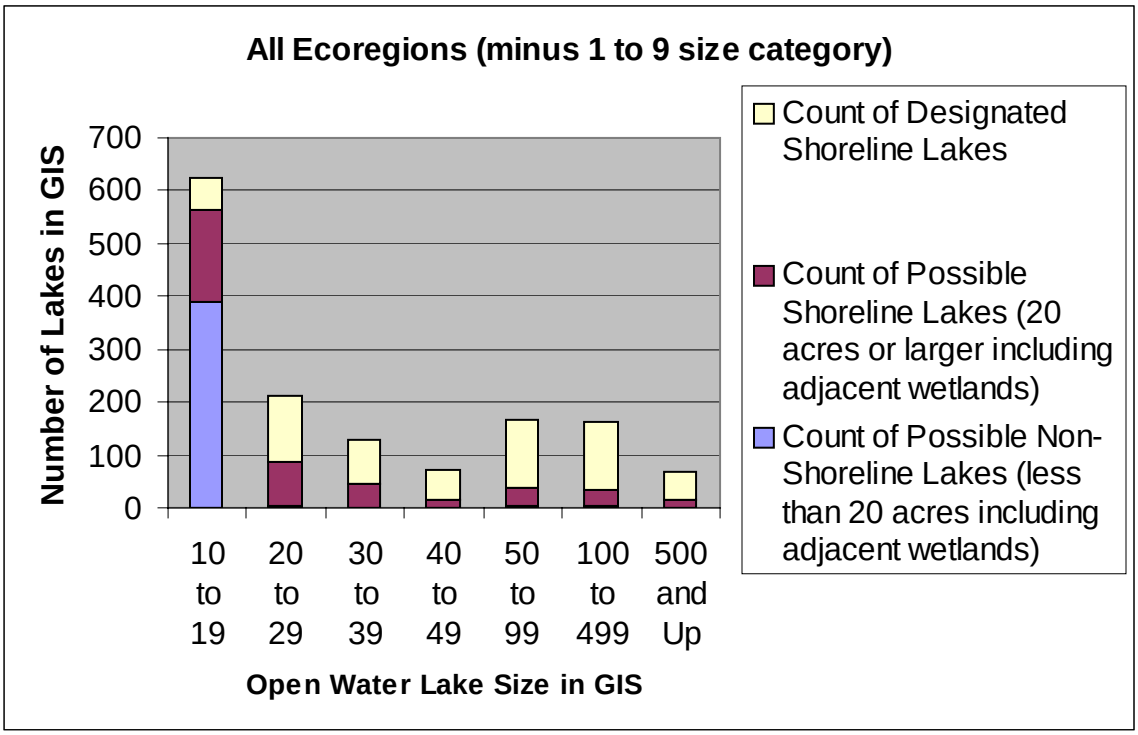


Figure 13. Phase I results, not including lakes with Open Water Lake Size of 1-9 Acres.

For this project it was necessary to build a GIS coverage of designated Shoreline lakes using the state list of lakes (WAC 173-20) and associated legal descriptions, cross-referenced using data from lakes of Washington, Volumes I and II (Wolcott 1973a an.1973b) The official list includes 781 lakes, listed by county, as Shorelines or Shorelines of Statewide Significance. We excluded 103 of the 781 listings from the analysis because of one or more of the following reasons - 1) duplicate listings of a lake that occurred in more than one county, 2) the majority of the lake area was within a federal ownership boundary, 3) the listed lake could not be found in the GIS. A total of 678 of the 781 lakes on the Shorelines list were included in the analysis.

Table 2. Phase I results by lake class* and Ecoregion.

	Ecoregion								
Lake Class	**1**	**2**	**3**	**4**	**9**	**10**	**15**	**77**	**Total**
Open Water 1-9 Acres, Possible Shoreline	66	147	16	7	5	343	74	26	684
Open Water 1-9 Acres, on Ecology List	3	5	0	0	1	24	7	1	41
Open Water 10-19 Acres, Possible Shoreline	16	61	4	1	0	64	13	11	170
Open Water 10-19 Acres, on Ecology List	1	10	1	0	1	37	8	2	60
Open Water 10-19 Acres, Not Shoreline	14	140	6	5	4	171	24	30	394
Open Water 20+ Acres, Possible Shoreline	4	44	7	9	1	130	34	5	234
Open Water 20+ Acres, on Ecology List	22	240	6	16	3	201	55	34	577
Total	126	647	40	38	15	970	215	109	2160

* Lake class " Open Water 1-9, Not Shoreline" not included.

Table 3. State-wide summary of Phase I results by lake class*

Lake Class	**Total**	**Percent**
Open Water 1-9 Acres, Possible Shoreline	684	32
Open Water 1-9 Acres, on Ecology List	41	2
Open Water 10-19 Acres, Possible Shoreline	170	8
Open Water 10-19 Acres, on Ecology List	60	3
Open Water 10-19 Acres, Not Shoreline	394	18
Open Water 20+ Acres, Possible Shoreline	234	11
Open Water 20+ Acres, on Ecology List	577	27
Total	2160	100

* Lake class " Open Water 1-9, Not Shoreline" not included.

Phase II – Sub-sampling by Hand Digitizing

Results of hand-digitizing the OHWM boundary of 108 lakes indicate that the error in the Phase I method of identifying "Possible Shorelines" varies greatly depending on the lake class (Table 4). None of the lakes of 1-9 acres in open water size that had adjacent wetlands and were possible Shorelines based on Phase I analysis were confirmed as possible Shorelines in Phase II. However with a sample size of 34 out of 684 lakes in this lake class (Table 1), it is likely that there is a small fraction of lakes in this Class that do qualify as Shorelines but were not selected in the Phase II analysis. Thirty-five percent of the "Possible Shoreline" lakes of 10-19 acres were confirmed as "Possible Shoreline" in Phase II. However, 91 percent of the lakes with an open water area of 20 acres or greater based on the DNR coverage were confirmed as 20 acres or greater by hand digitizing. Thus, Phase I analysis may over-estimate the number of "Possible Shoreline" lakes, but increases in accuracy as DNR open water area approaches and then exceeds 20 acres.

Some lakes designated as Shorelines by Ecology were found to be less than 20 acres in area in the Phase II analysis (Table 4). Phase II results for lakes in the 1-9 acre and 10-19 acre open water categories indicate that these designated lakes may actually be less than 20 acres in size. In addition, nine percent of the designated lakes that were measured as 20 acres or greater in the DNR coverage were found to be less than 20 acres when hand digitized. These apparent errors in original Shoreline designation may be due to one or more causes including a change in the lake environment, such as filling of wetlands after the lake was designated, or an initial error in designation, or errors in the Phase I and II delineation of the OHWM lake boundary.

Table 4. Phase II results by lake class*.

Lake Class Description	Number of Hand Digitized Lakes	Number of Lakes over 20 acres- after digitization	Percent of Hand Digitized over 20 acres
Open Water 1-9 Acres, Possible Shoreline	37	0	0
Open Water 1-9 Acres, on Ecology List	2	0	0
Open Water 10-19 Acres, Possible Shoreline	17	6	35
Open Water 10-19 Acres, on Ecology List	3	0	0
Open Water 10-19 Acres, Not Shoreline	16	1	6
Open Water 20+ Acres, Possible Shoreline	11	10	91
Open Water 20+ Acres, on Ecology List	32	29	91

* Lake class " Open Water 1-9, Not Shoreline" not included.

Within the "Not Shoreline" lake classes, lakes of 1-9 acres were excluded from the analysis due to the large number of these lakes that prevented representative sampling. In the 10-19 acre "Not Shoreline" class, one of 16 hand-digitized lakes (6 %) was identified as a Possible Shoreline indicating a low error rate in this lake class. Within both categories of 1-9 and 10-19 acre "Not Shoreline", we suspect that there is a small percent of lakes that may meet Shoreline Criteria, but due to a variety of mapping errors were not identified as such.

Phase III – Field Verification

The Phase III results of the field verified sizes of 12 lakes versus their original lake classification in Phase I shows the same pattern of increased accuracy in lake classification with an increase in DNR open water lake size (Table 5). Small lakes identified as Shorelines in Phase I are confirmed again as not being Shorelines acres in Phase III. Two of three lakes in the 10-19 acre, "Possible Shoreline" Class were field verified as Shorelines. The one 20+ Possible Shoreline lake that was field sampled was confirmed as meeting Shoreline criteria. For lakes designated as Shorelines, all but the smallest open water size category are field verified as meeting Shoreline criteria. Although these results are from a very small sample size, and one that not include east-side lakes, the results do suggest that the Phase I GIS results are more accurate as the open water lake size approaches 20 acres and larger.

Table 5. Phase III results by lake class.

Lake Classification	Total Lakes Visited	No. of Lakes over 20 acres - Phase lll
Open Water 1-9 Acres, Possible Shoreline	2	0
Open Water 1-9 Acres, on Ecology List	0	0
Open Water 10-19 Acres, Possible Shoreline	3	2
Open Water 10-19 Acres, on Ecology List	1	1
Open Water 10-19 Acres, Not Shoreline	2	0
Open Water 20+ Acres, Possible Shoreline	1	1
Open Water 20+ Acres, on Ecology List	3	3

When the principle author visually checked the hand-digitized OHWM lake boundaries overlain on the ortho-photos, he concluded that the GIS analyst may have been overly conservative in identifying OHWM in some cases. In some cases, the OHWM was fairly obvious (Figures 14 and 15). However, the room for interpretation is much greater for lakes with large amounts of contiguous wetlands. For example, Kellog Lake was hand digitized at only 16.4 acres, but was then field verified at 113.1 acres due to the large

amount of contiguous wetlands that were found to be within OHWM upon field inspection (Figure 16

and Table 6). We suspect that in many cases the boundary between the forest and wetlands that occurs in many cases is a more reliable indicator of the edge of OHWM than a GIS technician's more restrictive interpretation. These observations suggest that a much higher percentage of Phase I potential Shorelines, especially in the DNR size range of 10-19 acres, may be Shorelines than are indicated by the Phase II results.

Table 6 traces the analysis results for the twelve field verified lakes from Phase I through Phase III. Of the 12 lakes sampled in all three Phases, 10 met Shoreline Criteria in Phase I, 7 in Phase II, and 8 in Phase III. The size of open water area appears to be a good indicator of the accuracy of lake classification. All four lakes with an open water area of 20 acres or greater were field verified as such. The two lakes with the smallest open water areas initially appeared to be larger than 20 acres including contiguous wetlands, but were found to be smaller than 20 acres in Phase II and III.

Table 6. Comparison of lake sizes estimated in Phases I, II, and III analyses. Blue indicates lakes that are designated Shorelines, yellow indicates lake sizes of less than 20 acres, green indicates size estimates of 20 acres and larger and meet Shoreline criteria.

Lake Name	Phase I – DNR open water acreage only	Phase I - Lake+wetland acreage	Phase II - Re-digitized total acreage	Phase III - Field verified total acreage
Unnamed Lake #40	4.1	22.7	12.4	11.1
Unnamed Lake #10	1.0	42.9	2.6	1.0
Trosper Lake	17.9	45.5	20.6	25.0
Johns Lake	16.4	500.1	38.8	42.7
Unnamed Lake #12	11.4	22.9	11.8	12.9
Kellog (On Ecology list)	13.7	106.5	16.4	113.1
Haven Lake	15.0	15.0	18.2	18.2
Bitter Lake	15.8	19.1	18.7	18.7
Ketchum Lake	24.1	24.1	25.5	26.2
Erie (On Ecology list)	114.1	114.1	117.1	115.8
Padden Lake (On Ecology list)	147.6	162.7	148.2	149.2
Surprise Lake (On Ecology list)	31.0	32.0	32.5	32.5

The accuracy of the Phase I results, in terms of the percent of lakes that are correctly identified as a Possible Shoreline in each lake class can be roughly estimated based on the Phase II and III results (Table 7). As discussed above, this may be an overly conservative measure of accuracy, where hand digitizing completed by a trained biologist might have identified a higher percentage of possible Shoreline lakes. Because lakes in eastern Washington were not included in Phase II and III analysis, it is important to note that statewide error may be substantially lower or higher than shown.

Table 7. Estimated accuracy of Phase I results by lake class.

Lake Class	Accuracy in Phase I GIS Shoreline call
Open Water 1-9 Acres, Possible Shoreline	?low
Open Water 10-19 Acres, Possible Shoreline	20-30%
Open Water 20+ Acres, Possible Shoreline	90%
Open Water 1-9 Acres, on Ecology List	?low
Open Water 10-19 Acres, on Ecology List	?low
Open Water 20+ Acres, on Ecology List	90%
Open Water 10-19 Acres, Not Shoreline	90%

To further check the accuracy of the Phase I results, we investigated the data for Jefferson County, where the principal author had conducted a lake survey in 1998. In this survey, the author inspected maps and aerial photos of eastern Jefferson County. He used aerial photo interpretation to identify OHWM boundaries and a dot matrix grid to estimate lake sizes and identify all lakes on non-federal lands that appeared to meet Shoreline criteria. He identified 9 lakes; three of which were checked in the field with landowners and Ecology staff in 1998 and confirmed by Ecology Shorelines staff as meeting Shoreline criteria. In comparison, in the Phase I GIS analysis, 8 lakes in Jefferson County were identified as Possible Shorelines (Table 8). Six of the same lakes were identified in both surveys as potential Shorelines.

Inconsistent results were found for five lakes. Not surprisingly, these were lakes with small open water areas. In two cases (Chinese Gardens and Thorndyke Lakes) the lakes were not found in the GIS analysis because open water area was mapped as less than 1 acre. In a third case, the GIS analysis may have missed a connection between two seemingly isolated smaller wetlands. These three lakes found in the 1998 survey probably do meet Shoreline criteria and were simply missed in the GIS analysis due to the small or nonexistent mapping of the open water area. In the two remaining cases (Delaney and Embody Lakes), the GIS analysis identified these as possible Shorelines due to the large

amount of wetlands surrounding a relatively small open water area. However, these lakes were not included in the 1998 survey because the wetlands did not appear to be within OHWM and are probably not Shorelines.

In summary, results from Jefferson County suggest that the Phase I GIS methodology is possibly more accurate than predicted by Phase II and III subsampling. Six of 9 lakes identified as Possible Shorelines by the Phase I GIS method were also identified by the 1998 survey (Table 8). All four of the lakes classified by the GIS methodology as having an open water area between 10-19 acres were identified as Shorelines and one lake in the 1-9 acre category was identified. The Phase I survey errors were primarily with lakes with small open water areas. The Phase I survey missed three lakes with small open water areas that are probably Shorelines and included two lakes that are probably not Shorelines. These results indicate that the accuracy of the Phase I GIS to identify Shorelines may be higher than estimated by Phase II and III sampling results, especially for lakes of 10 acres and larger in open water area. More detailed mapping and field verification is needed to verify if these Jefferson County lakes do indeed meet Shoreline criteria. However, if we assume that the six lakes identified by both methods do qualify, this represents a 55 percent increase in designated lakes in Jefferson County beyond the eleven lakes currently designated.

Table 8. Comparison of 1998 survey and Phase I GIS results for Jefferson County. Yellow shows lakes identified by each method that may meet criteria for designation.

Lake Name	**1998 Survey Results**	**GIS Results by Lake Class**
East Wahl	Shoreline	Open Water 1-9 Acres, Possible Shoreline
Beausite	Shoreline	Open Water 10-19 Acres, Possible Shoreline
Horseshoe	Shoreline	Open Water 10-19 Acres, Possible Shoreline
Ludlow	Shoreline	Open Water 10-19 Acres, Possible Shoreline
Teal	Shoreline	Open Water 10-19 Acres, Possible Shoreline
Rice	Shoreline	Open Water 20+ Acres, Possible Shoreline
Browns	Shoreline	Open Water 1-9 Acres, Not Shoreline
Chinese Gardens	Shoreline	Not found -no open water
Thorndyke	Shoreline	Not found - < 1 acre open water
Delaney	Not Shoreline	Open Water 1-9 Acres, Possible Shoreline
Embody	Not Shoreline	Open Water 1-9 Acres, Possible Shoreline

Using the estimate of percent accuracy of the Phase I lake classification, as summarized in Table 7, we can extrapolate the number of lakes in Washington that are 20 acres or larger, but are not designated as Shorelines (Table 9). Approximately 253 lakes may meet Shoreline criteria, but are currently undesignated. Of these lakes, about 213 are from the lake class with 20+ acres of open water. Phase I to III accuracy results indicate that approximately 90 percent of lakes in this class actually do meet Shoreline criteria. Within the “Possible Shoreline” lake class with “Open Water 10-19 Acres” there are probably a minimum of 40 lakes statewide, and possibly a much higher number, that meet Shoreline

designation criteria. Due to the small number of lakes sampled in several additional lake classes, it is difficult to say more than a small percentage of these lakes are probably Shorelines.

Table 9. Estimated number of potential Shoreline lakes statewide.

Lake Class	Phase I - Number of Lakes	Phase I - Error percent	Phase II - Estimated Shoreline lakes	Phase II - Error percent	Phase III - Estimated Number of Shoreline lakes
1-9 Possible Shoreline	684	100	0	100	0
10-19 Possible Shoreline	170	65	60	33	40
20+ Possible Shoreline	234	9	213	0	213
TOTAL	1088		272		253

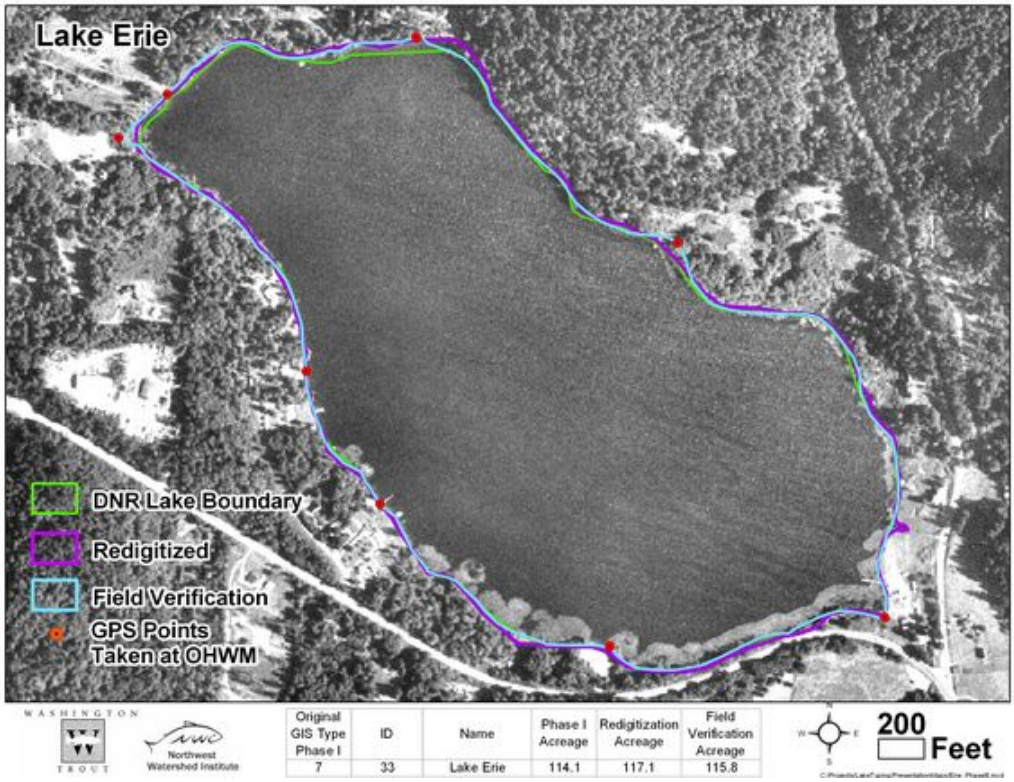
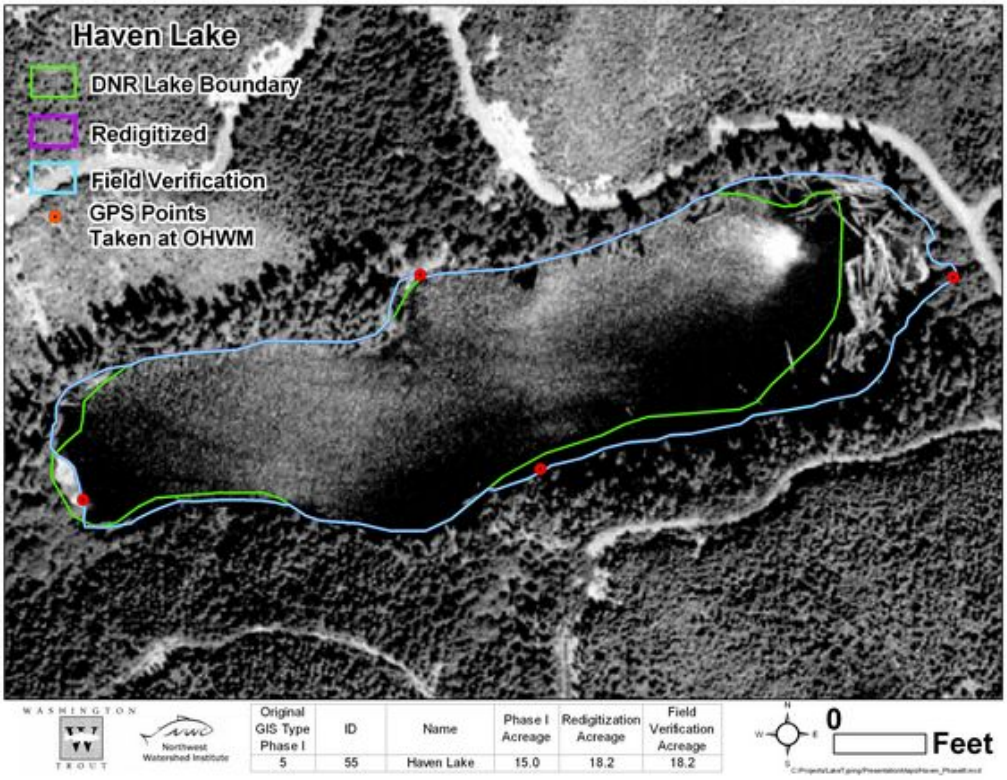


Figure 14. Lake Erie showing consistency between measurement methods



Original GIS Type Phase I	ID	Name	Phase I Acreage	Redigitization Acreage	Field Verification Acreage
5	55	Haven Lake	15.0	18.2	18.2

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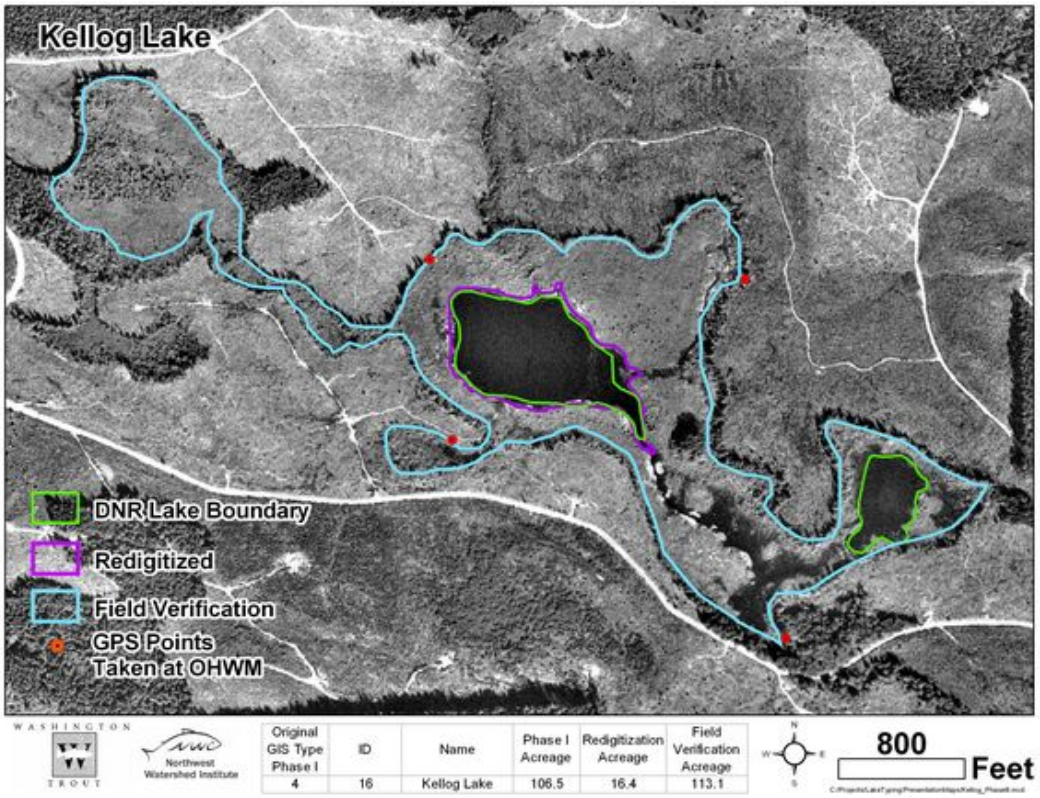
Figure 15. Haven Lake showing field verified OHWM extending into log rafts.



Original GIS Type Phase I	ID	Name	Phase I Acreage	Redigitization Acreage	Field Verification Acreage
4	16	Kellog Lake	106.5	16.4	113.1

Figure 16. Kellog Lake showing initial conservative hand digitizing around open water perimeter and field verified expansion of lake size to include wetlands.

CONCLUSIONS AND RECOMMENDATIONS

Our analysis indicates that a significant number of lakes in Washington that meet the criteria for Shoreline designation are erroneously not designated as Shorelines. From a Statewide GIS lake classification and subsampling of lakes in western Washington we estimated that approximately 253 lakes that meet Shoreline criteria are not designated. Shoreline designation currently extends to 765 lakes, representing only 75 percent of the lakes that are estimated to meet Shoreline criteria. These results are based on a very small sample size of lakes that were assessed in Phase II and III by aerial photo interpretation and field verification. The error rate may be substantially higher or lower than indicated, especially in eastern Washington. We recommend that the Phase II and III subsampling be expanded to eastern Washington, using the original sampling goals of 306 lakes for aerial photo analysis and a total of 30 lakes for field verification.

In addition, it is important to note that lakes that meet the size criteria for Shoreline designation but are located wholly or partly on non-federal lands within federal ownership blocks were generally not designated by Ecology, even though these lakes may be subject to jurisdiction under the Shoreline Management Act. Although federal land areas were excluded from this analysis, it is apparent that additional lakes may merit Shoreline designation within federal ownership areas.

Local governments appear to be in a position to correct the list of designated lakes within their jurisdiction. Ecology has an obligation to update the list of designated lakes every five years. However, they have not done so since the original list was produced in 1973. Local governments are required to use the most current and complete information available in updating their Shoreline Master Programs. To further support action at the local government level, Ecology has recently proposed rules that would require that lake list be revised by local jurisdictions as part of updating their Shoreline Master Plans.

We recommend that local governments conduct a survey of lakes within their jurisdiction to identify lakes that meet Shoreline criteria as part of approval or amendment of their updated Shoreline Master Plans. We have prepared GIS shapefiles that can be used with ArcExplorer or ArcView as a starting point for such a survey. The following shape files, developed as part of Phase I of the analysis, are available for free download from Washington Trout's website –

> **Lakelist1_export** – This file is a map of lakes in the state that have an open water area of 1 acre or larger, as derived from the DNR Hydro layer. Information on each lake includes lake name (if available), open water area (acres), wetlands area (National Wetland Inventory (NWI) or DNR wetlands) and total area (Lake+NWI or DNR wetlands), ecoregion, and lake class.
>
> **WA_County_83HARN** – This file provides county boundaries.
>
> **FederalLands_83HARN** – This file shows the federal lands excluded from the analysis.

We recommend that these data be used to identify lakes that have a high probability of meeting Shoreline criteria; namely those lakes classified as "Open Water 10-19 Acres,

Possible Shoreline" and "Open Water 20+ Acres, Possible Shoreline". If time and funding permit, lake classes that are less likely to contain lakes that meet Shoreline criteria should also be included, particularly "Open Water 1-9 acres, Possible Shoreline". For each lake identified, a biologist trained in OHWM determination by Ecology should estimate the lake area at OHWM using aerial photos and a dot matrix grid or GIS tools as was done in Phase II of this project. Because of the potential error in using aerial photo interpretation alone, all lakes should then be field verified unless aerial analysis unequivocally shows that they are less than 20 acres in size, including wetlands. Biologists should conduct the field verification using the methods we discuss - marking the location of the OHWM with GPS and then checking against the estimated OHWM boundary marked on the aerial orthophotos. In some cases, use of high quality aerial photos alone may be sufficient for use in field verification.

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